YukonZinc CORP

WOLVERINE MINE
RECLAMATION AND CLOSURE PLAN
VERSION 2016-07

Prepared for:

Yukon Government Department of Energy, Mines and Resources

Yukon Water Board

Prepared by:

Yukon Zinc Corporation

In conjunction with

Shuksan Environmental Services Ltd.

Adrienne Turcotte Consulting

Vancouver, British Columbia

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Glossary of Terms

For consistency in interpretation of the contents contained herein, the following terms are used, as originally defined by the *Reclamation and Closure Planning for Quartz Mining Projects* (Government of Yukon, 2013), Yukon Government Energy, Mines and Resources Quartz Mining Licence QML-0006 and/or Yukon Water Board Type A Water Use Licence QZ0-4065:

- **Temporary Closure** - Unless otherwise agreed to in writing by the Chief, Department of Energy, Mines and Resources:
  - The cessation of development or production that extends for more than a continuous two week period; or
  - Any closure after the start-up date where no ore is mined, or ore or tailings milled for a period exceeding two consecutive months.
- **Permanent Closure (Decommissioning)** – Closure in which there is no intent to resume mining activities at the site, and the mine project proceeds to the reclamation and closure phase. Further defined as:
  - The period in which decommissioning and reclamation activities are completed for the purpose of returning the mine site to pre-mining conditions; or
  - Where Temporary Closure exceeds three continuous years in duration.
- **Post-Closure** - The period following Permanent Closure where all reclamation activities are complete and the site is subject to ongoing operations, maintenance and monitoring.

Acronyms

AMP	Adaptive Management Plan
CCME	Canadian Water Quality Guidelines for the Protection of Aquatic Life
CLO	Concentrate Load Out Facility
EEM	Environmental Effects Monitoring
EMR	Yukon Government Department of Energy, Mines and Resources
LOM	Life-Of-Mine
LTF	Land Treatment Facility
MMER	Metal Mine Effluent Regulations
QML or QML-0006	Yukon Government Energy, Mines and Resources Quartz Mining Licence QML-0006
RCP	Reclamation and Closure Plan
RRDC	Ross River Dena Council
TCP	Temporary Closure Plan
TSF	Tailings Storage Facility
TSS	Total Suspended Solids
WUL or WUL QZ04-065	Yukon Water Board Type A Water Use Licence QZ04-065
YWB	Yukon Water Board
YZC	Yukon Zinc Corporation
ZVI	Zero Valent Iron

Units

°C	degrees Celsius
gpm	gallons per minute
km	kilometres
km/h	kilometres per hour
kW	kilowatts
L	litres
m	metres
m^3/d	cubic metres per day
masl	metres above sea level or elevation, measured in metres above sea level
mg/L	milligrams per litre
mm	millimetres
Mt	million metric tonnes
t	metric tonnes
tpd	metric tonnes per day

Note: All units in this report are assumed to be metric unless specifically stated otherwise.

1 Introduction

1.1 Project Summary

The Wolverine Mine, owned and operated by Yukon Zinc Corporation (YZC), is a zinc-silver-copper-lead-gold underground mine, with on-site milling capabilities of 1,700 tpd to produce copper, lead, and zinc concentrates. The Wolverine Mine is located in the southeastern Yukon near the headwaters of the Wolverine Lake watershed within the Kaska Nation Traditional Territory (Figure 1-1). The original estimated life-of-mine (LOM) was nine years, based on a 5.2 Mt mineable reserve. The site is accessed by aircraft or by vehicle on a 24 km long access road, which connects with the Robert Campbell Highway at km 190.

Figure 1-1: Location of the Wolverine Mine Within the Yukon and Kaska Nation Traditional Territory

Components of the Wolverine Mine include:

- Underground mine;
- Tailings Storage Facility (TSF);
- Seepage collection pond;
- Waste rock storage piles;
- Industrial complex, mill, and accommodations camp;
- Landfill;
- Airstrip; and
- Site access road.

YZC completed major site construction throughout 2009 and 2010. Mill commissioning commenced in 2011 and commercial production of 1,020 tpd or 60% of rate mill capacity over a 30-day period was achieved on

March 1, 2012. Production first achieved 1,700 tpd in January 2013. In January 2015 YZC announced that it was temporarily shutting down operations at the Wolverine Mine due to unfavourable market conditions, putting the site in “Temporary Closure”. Most employees and contractors were laid off at this time and the mine was put into care and maintenance. Presently, all industrial activity has ceased at the site and the following care and maintenance conditions exist:

- The underground mine is closed and gated;
- The site access road is maintained only during the snow-free period;
- The airstrip is maintained to ensure year-round access;
- There are no industrial activities or processes occurring in the mill;
- No tailings are being produced;
- No waste or ore is being produced or added to existing waste storage areas or stockpiles;
- Energy consumption has been minimized through isolation of essential buildings and machinery and all buildings not in use have been locked off;
- Supply stockpiles, including reagents, have been consolidated, sold, and shipped off-site where possible; and
- Two crews of 3 people each are maintaining the site on 3-and-3 week rotations.

The project timeline from construction through to post-closure is provided in Table 1-1, with the original mine plan compared to the current scenario. There is currently 5+ years of minable reserves identified at the Wolverine Mine.

Table 1-1: Project Timetable

Year(s)	Original Plan	Current Plan
2009 to 2010	Construction Phase	Construction Phase
2011	Production Ramp-Up	Production Ramp-Up
2012 - 2020	Operations Phase	Operations Phase
2012	Year 1	Year 1
2013	Year 2	Year 2
2014	Year 3	Year 3
2015	Year 4	Mining Halted: Temporary Closure
2016	Year 5	Temporary Closure
2017	Year 6	Temporary Closure
2018	Year 7	Permanent Closure: Decommissioning begins
2019	Year 8	Decommissioning
2020	Year 9	Decommissioning complete
2021	Permanent Closure	Post-Closure Phase begins
2021 - 2023	Decommissioning	Post-Closure Phase
2023+	Post-Closure Phase	Post-Closure Phase

1.2 Purpose of the Plan and Changes to Previous Versions

This document presents the Reclamation and Closure Plan (RCP) for the Wolverine Mine, replacing all preceding versions, including the most recent in July 2015 (Version 2015-06). This RCP incorporates requirements of Yukon Government Energy, Mines and Resources (EMR) Quartz Mining Licence QML-0006 (QML) and Yukon Water Board (YWB) Type A Water Use Licence QZ04-065 (WUL) for the Wolverine Mine.

As per QML-0006 Section 8.0 and WUL QZ04-065 Part E, the RCP recognizes the current condition of the mine, which is non-operational and in a state of temporary closure. As such, the RCP addresses care and maintenance of the mine site during temporary closure and provides an update to the decommissioning and reclamation upon final closure. The decommissioning process outlined in the RCP assumes that the mine has not been operated since January 2015 and that a mechanical water treatment plant does not exist on the site. Final closure, as defined in this RCP, is presumed to commence in January 2018 following three years of temporary closure.

This RCP (Version 2016-07) outlines several material changes from the previous RCP (Version 2015-06), including the following:

- Material from Waste Rock Pad #1 and #2 will be placed in the TSF for final closure. This will limit long-term environmental risk of seepage from these areas and reduce the overall land area that requires long-term monitoring and maintenance.
- The TSF will be closed as a dry facility. Free water in the TSF will be treated in situ and dewatered seasonally to Go Creek, in compliance with WUL allowable discharge limits. The TSF will then be covered and capped.
- The underground mine was not completely mined or paste-backfilled as described in previous RCPs, due to the temporary closure status of the mine. Concrete bulkheads will be constructed in the underground mine adit and in the vent raise to impede water egress. Any water discharging from the underground mine will be treated in a passive bioreactor system prior to being discharged to the environment.

In accordance with the *Reclamation and Closure Planning for Quartz Mining Projects* (Government of Yukon, 2013), this RCP summarizes reclamation and closure planning and objectives in Sections 1 and 2; a description of the project area environmental conditions in Section 3; detailed project background information in Section 4; details of the ongoing temporary closure activities in Section 5; final reclamation and closure measures in Section 6; the reclamation and closure execution strategy in Section 7; and reclamation and closure liability in Section 8.

1.3 Closure Philosophy and Objectives

This RCP incorporates the following overarching objectives for reclamation and closure of the Wolverine Mine site:

- Ensuring the physical and chemical stability of the area;
- Minimizing or eliminating any hazards to human health and safety;
- Protecting the environment from mine-related degradation;
- Restoring any degradation from mine-related activities; and
- Optimizing productive long-term use of the land.

These objectives are to be achieved through the implementation of the following guiding principles:

- The RCP is environmentally sound and technically feasible;

- The mine has been developed such that eventual passive closure of the site is achievable;
- Progressive reclamation measures have been implemented during operations;
- Post-closure land use will be commensurate with surrounding areas;
- Closure will include environmental protection measures that prevent adverse environmental impacts;
- Closure of the operation will include the protection of public health and safety; and
- Closure planning will incorporate and commit to a comprehensive site monitoring program to assess effectiveness of closure monitoring for the long term.

Further, "Fundamental Mine Reclamation and Closure Objectives" are described in the *Reclamation and Closure Planning for Quartz Mining Projects – Plan requirements and closure costing guidance* (Government of Yukon, 2013), with specific objectives for each area detailed in the 'Terrestrial Performance Standards' listed in Schedule D of QML-0006. Schedule D also outlines 'General Standards'. These fundamental objectives and specific objectives are summarized in Table 1-2. The strategy for reclamation and closure presented in this RCP aims to meet these fundamental objectives. Specific design criteria that describe how YZC can meet these objectives is described in Section 1.4.

Since the approval of the original RCP (Version 2006-01), the closure approach has developed from conceptual to more detailed in nature with each version. Due to the premature cessation of operations in January 2015, the reduced volume of material in the TSF has led to the development of an alternate closure strategy. This new strategy maintains a focus on long-term protection of the environment and human health, while limiting liabilities and meeting legislative requirements. The strategy also targets a passive closure scenario with land uses that are commensurate with surrounding areas. This philosophy is in line with the guiding principles outlined above.

Table 1-2: Wolverine Mine Reclamation and Closure Objectives

Fundamental Value	Fundamental Objective	Area	Specific Objective
Physical Stability	All mine-related structures and facilities are physically stable and performing in accordance with designs.	Buildings and Infrastructure	Removal or stabilization of any structures remaining after closure to ensure physical stability and to remove any threat to public health and safety, re-establishment of vegetative mat over the disturbed areas of the mine site, and removal of all hazardous substances
		Rock Dumps	Reclaimed rock dumps are to be physically and chemically stable in the long term
		Underground Openings	Prevent long-term inadvertent access to underground mine openings from the surface
		Stability of Underground Workings	Prevent the development of hazardous conditions due to the subsidence of surface materials into underground workings and to restore the site to an approved final land use
	All mine-related structures, facilities and processes can withstand severe climatic and seismic events.	Tailings Impoundment	All tailings impoundments and associated components are to be reclaimed to a condition that ensures physical and chemical stability for the long term
		Water Control Structures	Stable for the long term
Chemical Stability	Release of contaminants from mine related waste materials occurs at rates that do not cause unacceptable exposure in the receiving environment.	General	Prevention of significant exposure to or release of substances that could damage the receiving environment
		Contaminated Soils	Prevent significant release of substances that could damage the receiving environment
		Acid Mine Drainage Concerns	Prevent significant impacts to downstream terrestrial and aquatic resources
		Tailings Impoundment	All tailings impoundments and associated components are to be reclaimed to a condition that ensures physical and chemical stability for the long term
		Rock Dumps	Reclaimed rock dumps are to be physically and chemically stable in the long term
Health and Safety	Reclamation eliminates or minimizes existing hazards to the health and safety of the public, workers and area wildlife by achieving conditions similar to local area features.	General	The protection of health and safety of the public and area wildlife by the elimination of unacceptable health hazards
	Reclamation and closure implementation avoids or minimizes adverse health and safety effects on the public, workers and area wildlife.	Terrain Hazards	The protection of wildlife and public health and safety through measures to prevent and protect wildlife and persons from the terrain hazards such as excavations and surface openings
Ecological Conditions and Sustainability	Reclamation and closure activities protect the aquatic, terrestrial and atmospheric environments from mine-related degradation and restore environments that have been degraded by mine-related activities.	General	Reclamation for productive future use of the land where infrastructure (buildings, chemical and fuel storage, roads, sediment ponds, tailings facilities, waste rock storage areas, open pits, etc.) is or will be located
		General	Prevention of significant exposure to or release of substances that could damage the receiving environment
		General	Minimization of the footprint of mine site development
		Erosion Control	Prevent erosion that significantly impacts drainage quality or impedes re-vegetation of reclaimed site
		Re-vegetation	To restore wildlife habitat through the re-establishment of a vegetative mat (food source, cover, hide, etc.) and self-sustaining native vegetation
		Watercourses	Restore watercourses to required standards
		Contaminated Soils	Prevent significant release of substances that could damage the receiving environment
	The mine site supports a self-sustaining biological community that achieves land use objectives.	Re-vegetation	To restore wildlife habitat through the re-establishment of a vegetative mat (food source, cover, hide, etc.) and self-sustaining native vegetation
Land Use	Lands affected by mine-related activities (e.g., building sites, chemical and fuel storage sites, roads, sediment ponds, tailings storage facilities, waste rock storage areas, underground workings, etc.) are restored to conditions that enable and optimize productive long-term use of land. Conditions are typical of surrounding areas or provide for other land uses that meet community expectations.	General	Reclamation for productive future use of the land where infrastructure (buildings, chemical and fuel storage, roads, sediment ponds, tailings facilities, waste rock storage areas, open pits, etc.) is or will be located
		Roads and Trails	Decommissioning of access corridors when they are no longer required
		Buildings and Infrastructure	Removal or stabilization of any structures remaining after closure to ensure physical stability and to remove any threat to public health and safety, re-establishment of vegetative mat over the disturbed areas of the mine site, and removal of all hazardous substance
	Site access is consistent with community land use expectations.	General	Restoration of the site to a condition that is visually acceptable to the community
Aesthetics	Restoration outcomes are visually acceptable.	General	Restoration of the site to a condition that is visually acceptable to the community
Socio-economic Expectations	Reclamation and closure implementation avoids or minimizes adverse socio-economic effects on local and Yukon communities, while maximizing socio-economic benefits.	General	Reclamation for productive future use of the land where infrastructure (buildings, chemical and fuel storage, roads, sediment ponds, tailings facilities, waste rock storage areas, open pits, etc.) is or will be located
		General	Restoration of the site to a condition that is visually acceptable to the community
	Reclamation and closure activities achieve outcomes that meet community and regulatory expectations.	General	Reclamation for productive future use of the land where infrastructure (buildings, chemical and fuel storage, roads, sediment ponds, tailings facilities, waste rock storage areas, open pits, etc.) is or will be located
Long-term Certainty	Minimize the need for long-term operations, maintenance and monitoring after reclamation activities are complete.	General	Minimization or elimination of the need for maintenance and monitoring in the long term
Financial Considerations	Minimize outstanding liability and risks after reclamation activities are complete.	General	Minimization of liability and environmental risk

1.4 Design Criteria

Design criteria for reclamation and closure activities at the Wolverine Mine were primarily informed by the 'General Standards' outlined in Schedule D of QML-0006. These standards detail practices and targets for undertaking reclamation and closure activities. In addition, several other design criteria were used to guide reclamation and closure planning, to ensure that all the components of the Wolverine Mine were encompassed:

- Practices outlined in the *Yukon Revegetation Manual: Practical Approaches and Methods* (Mining and Petroleum Environment Research Group, 2012), in relation to revegetation efforts;
- The following water quality considerations:
    - Historical (pre-mine) water quality norms in surface water and groundwater at the Wolverine Mine site;
    - Trigger levels set out in the *Wolverine Creek Adaptive Management Plan*;
    - Allowable discharge limits, as set out in the WUL; and
    - The *Canadian Water Quality Guidelines for the Protection of Aquatic Life (freshwater)*.
- *Mined Rock and Overburden Piles, Investigation and Design Manual* (Piteau Associates, 1991);
- *Guidelines for Metal Leaching and Acid Rock Drainage at mine sites in British Columbia* (Price and Errington, 1998); and
- *CDA Dam Safety Guidelines* (CDA, 2007) and the complimentary *Application of Dam Safety Guidelines to Mining Dams* (CDA, 2014).

Other references sourced in this document are provided in Section 9.

2 Reclamation and Closure Planning

2.1 Planning Considerations

This RCP has been written to reflect current conditions and liabilities at the Wolverine Mine. The RCP assumes that temporary closure activities (Section 5) will continue to minimize on-site liabilities and that permanent closure (Section 6) will follow the temporary closure phase. This RCP does not assume resumption of mining activities or propose closure activities following those mining activities. Should the status of mining activities at the Wolverine Mine change, the RCP will be updated to reflect those conditions.

In addition to the philosophy and principles previously described, this RCP was written to meet EMR and YWB requirements, as outlined in the following documents:

- *Reclamation and Closure Planning for Quartz Mining Projects – Plan requirements and closure costing guidance* (August 2013);
- QML-0006;
- WUL QZ04-065;
- Conditions listed in Appendix 1 of the "Response to EMR Wolverine Project Reclamation and Closure Plan Approval letter" letter from EMR to YZC, dated December 23, 2015; and
- Conditions listed in the "Update to Reclamation and Closure Plan 2015-06" letter from EMR to YZC, dated June 21, 2016.

Specific regulatory requirements for the RCP are outlined in Table 2-1 below, with the corresponding locations in the RCP included.

Table 2-1: Regulatory Requirements for RCP Version 2016-07

From QML-0006, Section 8.6:		Section in 2016 RCP
a	An analysis of the measures required to be implemented to ensure the ongoing physical and chemical stability at the site	2.1 Planning Considerations
b	A description of how the Licensee will meet the performance standards identified in Schedule D of the Licence, unless other standards are agreed to in writing by the Chief in advance of submission of the document	1.3 Closure Philosophy and Objectives
c	Designs for the closure of all structures, works and installations associated with the Undertaking, including dams, impoundment structures, spillways, diversion ditches, waste rock and overburden dumps, the access road and any other roads at the site, and ore stockpiles	6 Final Reclamation and Closure Measures
d	A description of the methodology for the removal of all infrastructure at the site, including the mill, camp, and access road	6 Final Reclamation and Closure Measures
e	A plan and implementation schedule for ensuring the long-term stabilization and closure of the TSF	6.2 Tailings Storage Facility (TSF) Area 7.1 Reclamation and Closure Schedule
f	A plan and implementation schedule for a reclamation research program focusing on characterization of soils in the area, establishing test plots, and documenting re-vegetation to support reclamation and closure of the Undertaking	2.2.2 Re-vegetation Trials
g	Results of ongoing humidity cell testing to monitor any ARD/ML potential of waste rock dumps and paste backfill and any changes to mitigation required to accommodate the results of testing	This test work ceased in 2012. No further test work has been conducted. Results have been presented in previous Annual Reports.
h	A water quality model for flooded mine workings, including a consideration of water samples taken from paste backfill leachate during mining operations	6.1.2 Underground Mine Water Quality
i	A program and related implementation schedule for progressive reclamation to be carried out while production and development is ongoing at the site	2.2 Reclamation Research
j	A monitoring and maintenance program and implementation schedule to obtain surface and hydrogeological information, and related implementation schedule adequate to verify that performance objectives and discharge requirements applicable for all structures, works and installation are met at closure and post-closure	5.1.2 Monitoring Activities 6.9 Monitoring and Maintenance
k	A cost estimate prepared by an engineer to implement the plan, including a cost estimate for post-closure monitoring, inspections, and interim care and maintenance	8 Reclamation and Closure Liability
l	Details respecting maintenance of site security, including any requirements for continuous care by an on-site care-taker	5.1 Site Security, Monitoring and Maintenance 6.9 Monitoring and Maintenance
m	Updates on the collection and further interpretation of hydrogeological information, related geochemical effects and underground discharge rates from mine workings, and effects on receiving environment during closure and post-closure, including a 3-dimensional numerical hydrogeological model for the underground workings must be provided (details or monitoring of geochemical and physical stability of all facilities	6.1 Underground Workings and Openings to Surface

	at the site and other matters as appropriate)	
n	Designs for the construction of engineered hydraulic bulkheads, with an analysis of bulkhead surrounding material competence and grouting requirements, incorporating hydrogeological model and details of how the hydraulic bulkhead may affect groundwater flow	6.1 Underground Workings and Openings to Surface
o	Details of material stockpiles and on site equipment required to ensure that the Licensee can provide adequate response to an unexpected water management event or spill or release of a hazardous substance	5.1.1 Site Security
p	A contingency plan to ensure that mine discharge from backfilled mine workings does not affect the environmental integrity of Wolverine Creek and Little Wolverine Lake	2.2 Reclamation Research 6.1 Underground Workings and Openings to Surface
q	Results of efforts undertaken to test the bioreactor system under site conditions, including any modifications required to be made to the bioreactor proposal to accommodate results of the field trials and any enhanced knowledge of the relevant biological processes under site conditions	2.2 Reclamation Research 5.2 Interim Water and Solution Management Plan
r	Design, maintenance, long-term monitoring and management plans, and implementation schedules for the bioreactor system and creek diversion	6.1 Underground Workings and Openings to Surface 7.1 Reclamation and Closure Schedule
s	Any enhanced understanding of relevant hydrogeological conditions to ensure the bioreactor system is placed to capture groundwater that has encountered the backfilled mine workings	2.2 Reclamation Research 5.2 Interim Water and Solution Management Plan 6.1 Underground Workings and Openings to Surface
t	Details of incorporation of technological developments in best management practices	1.4 Design Criteria
u	Details respecting management of a temporary closure as described in paragraph 8.3	5 Temporary Closure
Conditions outlined in Appendix 1 of YG letter - dated December 23, 2015		**Status**
1	Disposal of reagents and other hazardous materials on site	In progress
2	Written work plan for the installation of hydraulic plugs (bulkheads)	In progress
3	Written plan for environmental monitoring of underground workings AMP for environmental monitoring of underground workings	Completed - Submitted to YG in May 2016
4	Written plan for experimental water treatment systems	Completed - Submitted to YG in May 2016
5	Written plan for water treatment of tailings management facility effluent: Plan	Due July 17, 2017
6	Update environmental monitoring program sampling regime	Completed
Conditions outlined in YG letter - dated June 21, 2016		**Location in 2016 RCP**
a	A description of existing conditions	3 Environment Description 4 Project Description 5 Temporary Closure
b	A description of the status of the underground cemented plugs, including as-built drawings	5.1.3.1 Underground Workings and Openings to Surface
c	Surveyed volumes of all waste rock on surface	5.1.3.3 Waste Rock and Overburden Dumps
d	Surveyed volumes of tailings and water stored in the tailings management facility	5.2.2 Tailings Storage Facility (TSF) Area
e	Closure methodologies for waste rock management facilities, stockpile pads, and any locations where ore and/or concentrate were stored during operations	6.3 Waste Rock and Overburden Dumps
f	Closure methodologies for the tailings management facility including	6.2 Tailings Storage Facility (TSF) Area

	consideration of both wet (utilizing inert cover material for solids and an overlying wet cover) and dry (landform with encapsulated saturated tailings) closure options	
g	A water treatment and management plan for the underground workings and tailings management facility	6.1 Underground Workings and Openings to Surface 6.2 Tailings Storage Facility (TSF) Area
h	Issued-for-use design drawings, for the current mine configuration, stamped by a Professional Engineer licenced to practice in the Yukon for the following facilities:	-
	i. Waste rock management facilities, including cover designs	6.3 Waste Rock and Overburden Dumps
	ii. Tailings management facility, including wet or dry cover designs	6.2 Tailings Storage Facility (TSF) Area
	iii. Mechanical water treatment facilities	6.2 Tailings Storage Facility (TSF) Area
	iv. Any other engineered facility	6 Final Reclamation and Closure Measures
i	Description of all activities during Temporary Closure required ensuring the site is capable of transitioning to Permanent Closure, if necessary. This includes a description of any tailings water sampling and treatment that will occur during the Temporary Closure period in order to advance a "dry" closure option should that option proceed	5 Temporary Closure
j	A detailed costing for the implementation of permanent closure measures including additional research and/or design work required before implementation of the permanent closure plan would be feasible	8 Reclamation and Closure Liability

In addition to the regulatory requirements that were considered in the development of this RCP, the following research and information sources were also central in writing this RCP:

- The results of reclamation research described in Section 2.2:
    - Wolverine Creek bioreactor laboratory studies;
    - Waste Rock Pad #2 bioreactor installation; and
    - Re-vegetation trials and site implementation.
- Consultation with water quality experts to determine the best approach for treating free water in the TSF, prior to any dewatering. The assessment to determine the best approach included reviewing site data such as:
    - Selenium speciation results of the free water in the TSF;
    - Results of ongoing environmental monitoring on site;
    - Historical environmental monitoring data;
    - Results of the Fall 2016 site surveys conducted by Knight Piésold Inc.;
    - TSF bathymetric survey; and
    - Surveys of waste rock stockpiles.
- Consideration of concepts presented in *Closure Assessment Yukon Zinc Corporation Wolverine Mine* (September 11, 2015) by Lorax Environmental Services Ltd. and Ecowest Consultants Inc. for EMR.

- Consideration of concepts presented in *Environmental Risk Assessment Yukon Zinc Corporation Wolverine Mine* (March 26, 2015) by Lorax Environmental Services Ltd. and Ecowest Consultants Inc. for EMR.
- Consideration of professional opinions presented in *Review of YZC's Wolverine Mine Reclamation and Closure Plan 2015-06 Document and Preparation of an Independent Closure Cost Estimate* (November 17, 2015) by SteveJan Consultants Inc. for EMR.

2.2 Reclamation Research

Reclamation research was conducted during the operational period and has continued in the temporary closure period to further evaluate the reclamation techniques proposed in earlier versions of the RCP. Reclamation research focuses on refining the components of the proposed bioreactor at the outlet of underground mine and on comparing various seed mixes for the most effective re-vegetation and sediment and erosion control techniques. The results of this testwork are summarized below and have been used to inform the techniques used in this RCP for closure of the Wolverine Mine.

2.2.1 Bioreactor Water Treatment Trials

Surface water and groundwater in the Wolverine Mine area is naturally high in certain metals. One of the main closure issues facing the Wolverine Mine site is the presence of contaminants of concern (copper, selenium, and zinc) in water leaving the mine site. However, the Wolverine Mine is situated in an environment that is conducive to utilizing passive water treatment systems to treat mine water.

Bioreactor treatment system is the term used to describe a passive treatment channel, typically containing organic based biological material, which promotes the development of microbes that fix and/or precipitate metals in the water passing through the bioreactor system. Bioreactor systems can also contain chemical treatment materials, such as limestone, activated carbon, or other absorptive materials. Chemical treatment passive systems may also be called "permeable reactive barriers". Due to the high incidence of metals in the Wolverine Mine area, the microbes found in the area are naturally predisposed to utilize these metals in their cellular processes. The bioreactor process proposed for the Wolverine Mine aims to provide the conditions necessary for these microbes to replicate and thus more readily remove contaminants from the contact water. Bioreactor treatment research has been ongoing since early 2012 and has consisted of two laboratory studies and a pilot scale study.

The 2012 laboratory study evaluated five columns filled with varying compositions of gravel and Wolverine Creek substrate organics, and were un-amended (control column) or amended with manure, sewage sludge, zero valent iron (ZVI), or wood chips and alfalfa. Results of this testwork showed selenium, sulphate, and the other deleterious elements were significantly lowered within the control column and by the columns amended with sewage sludge. Sewage sludge greatly increased the rate at which the columns became reducing, thereby increasing sulphide precipitation and cadmium and zinc co-precipitation. The addition of ZVI increased the sulphate and selenium removal to almost 100%. The addition of wood chips and alfalfa did not appear to greatly influence the removal mechanisms in the columns, but could affect the long-term success of a treatment system.

Subsequently, laboratory studies were conducted at the Yukon College, initiated as part of the work conducted by the Industrial Research Chair. Four bioreactors were prepared using sediment from Wolverine Creek, incubated and then fed continuously with dewatering effluent from the Wolverine Mine. Different solid supports were compared (gravel/sand, gravel/sand/wood/lime, and gravel/sand/biochar), as well as ethanol addition to assess the role of ethanol in supporting microbe growth. The columns were run for a total period of approximately 320 days.

Results of the testwork indicated that while ethanol addition may enhance microbial activity (and hence metal co-precipitation), it is not necessary to meet the discharge objectives. Additionally, the inclusion of carbon amendments (wood) and sources of alkalinity (limestone) did not significantly change the quality of the effluent over the duration of the experiment (~320 days). All four columns were effective at achieving the discharge limits for cadmium, selenium, and zinc.

The results of the laboratory testwork were incorporated into the design of a field scale bioreactor constructed at the mine site in summer 2016. The bioreactor was constructed to test the effectiveness in treating runoff from waste rock and ore stockpiles between Waste Rock Pad #2 and the north end of the TSF. Prior to the construction of the field scale bioreactor, runoff from Waste Rock Pad #2 was previously collected at the south end and discharged via a pipe and hose to the north end of the TSF. Water from Waste Rock Pad #2 is typically high in metals and sulphate and requires treatment prior to discharging to the environment to meet requirements of the WUL QZ04-065.

The field scale bioreactor is 100 m long, 2.5 m deep, and 3 m across (Photo 2-1). The gravel, wood chip, and organic substrate mixture placed in the bioreactor is shown in Photo 2-2 and the final bioreactor configuration is shown in Photo 2-3.

Photo 2-1: Bioreactor Trench (July 12, 2016)

Photo 2-2: Bioreactor Substrate Material (May 31, 2016)

Photo 2-3: Bioreactor Filled with Substrate Material (July 16, 2016)

Water quality results from the field scale bioreactor have been positive thus far. The bioreactor has been effective at removing metals to orders of magnitude below the inlet concentrations, with all parameters in the outlet below the WUL discharge limit, except for concentrations of iron and TSS. Reductions in sulphate, cadmium, and zinc indicate that sulphate-reducing conditions have been achieved in the bioreactor. Selenium concentrations were lowered by 98% to below the discharge limit. Manganese and aluminum concentrations increased, which along with the increases in iron, is typical for reducing, anoxic systems. These increases may be a relic of the acclimation period, but if they are sustained, can be mitigated by allowing the water to be aerated prior to discharge. This is typically achieved by allowing the effluent to flow over rocky channels or through the use of limestone channels, if required. Total Suspended Solids (TSS) concentration increases are also likely a relic of solids settling, which will likely decrease as the bioreactor system reaches a steady state.

The field scale bioreactor will continue to be monitored for metal and sulphate removal effectiveness and will provide comprehensive, site specific results that can be used to directly predict applicability in mine closure scenarios.

2.2.2 Re-vegetation Trials

Re-vegetation trials have been ongoing at the Wolverine Mine since construction was completed in 2009. At the end of the summer construction seasons in 2009 and 2010 several exposed areas were seeded and re-vegetation has been successful.

To date, in areas of disturbance, stockpile areas, and along the site access road, YZC has used a 'Roadside Reclamation' seed mix originating from western Canada, the Yukon and/or Alaska containing 40% Violet wheat grass (*Agropyron violaceum*), 25% Arctic Red Fescue (*Festuca saximontana*), 20% Sheep Fescue (*Festuca ovina*), 10% Slender wheat grass (*Agoropyron paucifloru*), and 5% Tickle Grass (*Agrostis scabra*). The mix was specified to meet the following purity and germination requirements:

- Species must not exceed the following limits for noxious weeds per 25 grams: 0 primary, 5 secondary, 25 total, and 0 sweet clover; and
- Minimum percent of pure living seed must be 70%.

Photo 2-4, taken in August 2011, shows vegetation establishment in Ditch B.

Photo 2-5, taken in July 2012, demonstrate the success of re-vegetation efforts along the access road corridor, two years after seeding. Photo 2-5, taken in July 2012, shows grass cover establishment on the TSF dam face. Photo 2-7, taken in July 2013, show re-vegetation success around the TSF from seeding completed in 2012. Photo 2-8 to Photo 2-11, taken in September 2014, demonstrate the success of progressive reclamation and re-vegetation efforts around site. Given the success of this re-vegetation strategy, the same seed mix will be used during final closure.

Photo 2-4: Looking North at Established Vegetation in Coarser Material Along Ditch B (August 2011)

Photo 2-5: Revegetation Along the Site Access Road Corridor Near km 16 (July 2012)

Photo 2-6: Construction of the Ultimate TSF dam; Note Seeding on the Starter Dam Face has Resulted in ~50% Grass Cover Between the Crest and Construction Zone (July 2012)

Photo 2-7: Looking South at Established Vegetation on Disturbed Ground Around the TSF Following Fall 2012 Seeding (July 2013)

Photo 2-8: Revegetation Slong the TSF (September 2014)

Photo 2-9: Revegetation Along the Road to Wolverine Lake (September 2014)

Photo 2-10: Revegetation at the Overburden Stockpile Below the TSF (September 2014)

Photo 2-11: Revegetation Along the Downstream Face of the TSF Dam (September 2014)

2.2.3 Future Reclamation Research

Any future reclamation research will be carried out as part of the during the temporary closure phase (Section 5). Work described above for the Waste Rock Pad #2 bioreactor is ongoing and results are regularly reported to EMR and YWB.

2.3 Community Engagement

The Wolverine Lake area is sparsely populated and is used occasionally for harvesting, gathering, and trapping by the Kaska First Nation bands from the Yukon, the Ross River Dena Council (RRDC), and the Liard First Nation. In July 2005, YZC signed a *Socio-Economic Participation Agreement* with the RRDC on behalf of the Kaska Nation that provides a basis for participation by all Kaska Nation members in project exploration and mine development and operations activities. This has and will include the review of environmental, social, and economic matters related to activities that support mine development, operation, and closure. The Wolverine Mine has been operated and will be reclaimed in accordance with the *Kaska Socioeconomic Participation Agreement* and the *RRDC Traditional Knowledge Protocol Agreement*.

2.4 Closure Option Selection

The main objectives for closure planning are to minimize environmental concerns and to maximize geotechnical stability. Previous iterations of the RCP envisioned a wet closure of the TSF due to the potentially acid generating nature of the tailings. However, with the initiation of temporary closure and the potential for an early closure scenario, alternative closure scenarios were considered.

Many factors were considered in selecting the best closure option for the Wolverine Mine. As described in Section 2.1, an assessment of the treatability of the water in the TSF was undertaken in Fall 2016 (see Sections 5.2.2 and 6.2.1). The results of this assessment were instrumental in determining which closure option for the TSF (dry closure or wet closure) would best achieve the closure objectives for the site (see Section 1.3).

The closure scenarios described herein apply the best available technology in terms of environmental protection and geotechnical stability, in order to create a closure landscape for the Wolverine Mine that is most conservative.

3 Environment Description

The following section summarizes environmental conditions for the Wolverine Mine and associated infrastructure, including climate, surface water, groundwater, vegetation and wildlife, soil and bedrock, and seismicity.

3.1 Climate

Weather monitoring at the Wolverine Mine consists of temperatures, pressure, precipitation, radiation, wind speed and direction, and relative humidity data collected from an on-site weather station installed at the south end of the airstrip. As shown in Figure 3-1, weather has been relatively comparable at the Wolverine Mine since consistent recording started in 2007. Note that the HOBO weather station does not record precipitation that falls as snow, consequently only precipitation as rain is provided in Figure 3-1.

The project site elevation is approximately 1,350 masl and the area is cold, with a mean temperature of -5°C, a mean daily summer temperature of 15°C and a mean daily winter temperature of -25°C. Minimum temperatures can reach -32°C and maximum temperatures can reach around 25°C. Precipitation falls fairly evenly throughout the year, predominantly as rain from May to September and snow for the balance of the year. The mean annual precipitation is 570 mm, with total snowfall of less than 2 m. Average rainfall is approximately 240 mm per year. Maximum wind speeds are less than 40 km/h and the annual average is 15 km/h.

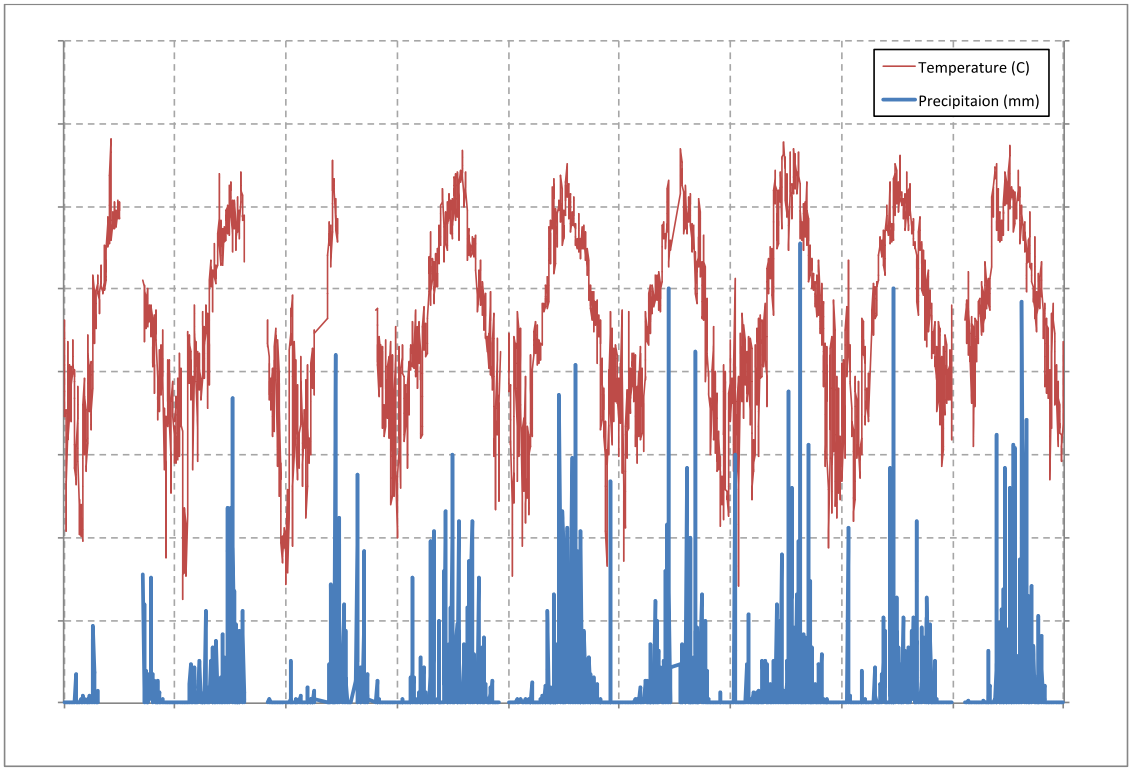


Figure 3-1: Wolverine Mine Daily Precipitation and Average Daily Temperature 2007-2015

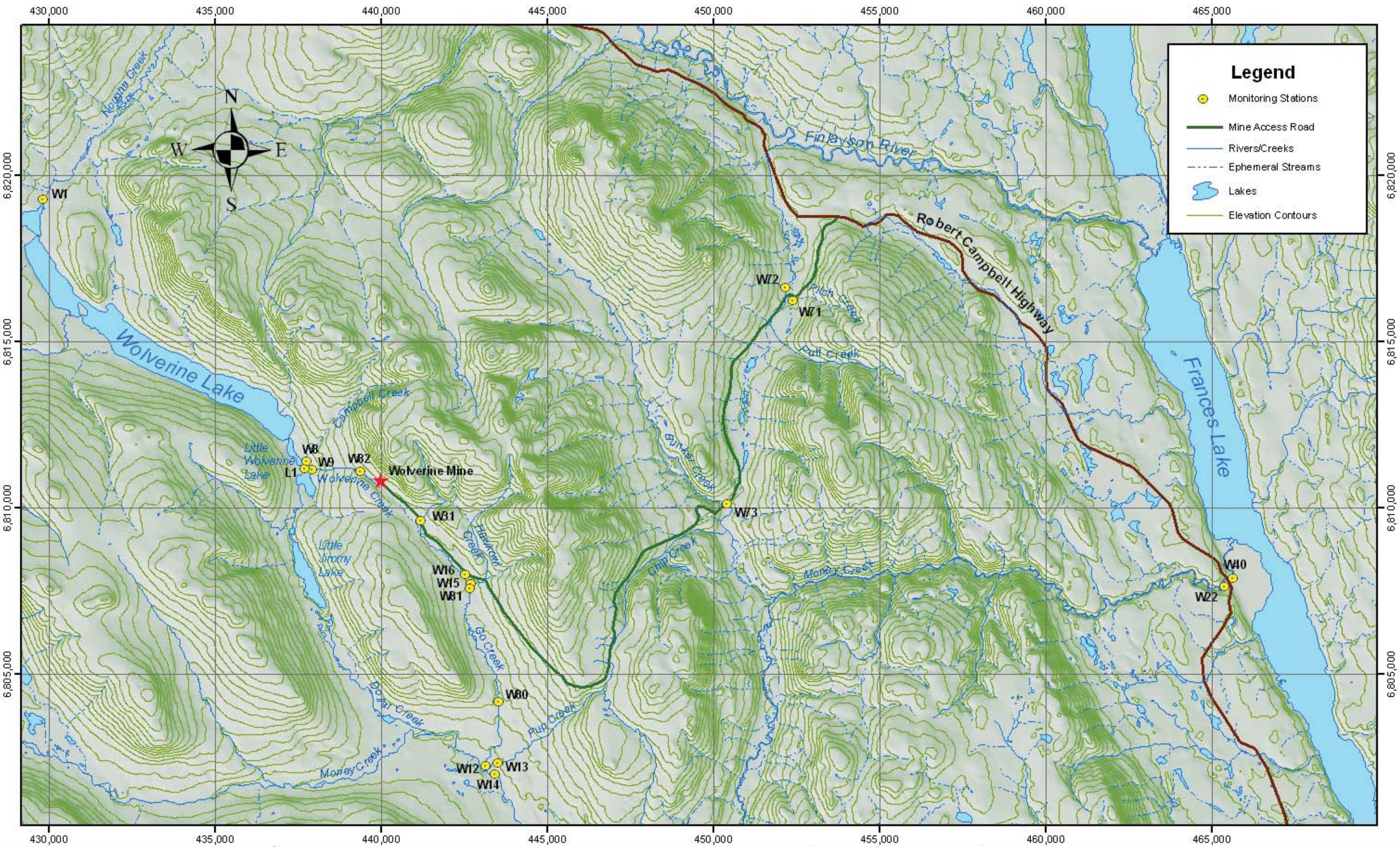
3.1.1 Climate Scenarios Considered for Closure

The potential effects of climate change have been evaluated and duly considered in the design and closure management of the TSF. Wide-ranging precipitation conditions (e.g. 100-year dry and 100-year wet) were evaluated in water balance modeling for the TSF in support of this RCP. With the shift to a dry closure, ongoing monitoring and maintenance of the TSF embankment will not be required, as the embankment will be decomissioned. Therefore, the climate change effects will not impact the closure techniques or activities. However, continued monitoring of site meteorological conditions (e.g. precipitation and evaporation) will continue, as will monitoring of runoff from the long-term structures until stable conditions are met.

3.2 Surface Water

The Wolverine Mine is located at the headwaters of the Wolverine Lake watershed and the Go Creek watershed. Go and Bunker Creeks flow into Money Creek, which flows east to Frances Lake in the Liard River drainage. Wolverine Creek flows north to Little Wolverine Lake, which in turn drains to Wolverine Lake and via Nougha Creek, discharges to the Finlayson River. The aquatic ecosystems in the area are generally typified by cold and clean water. Waters in the upper drainage areas around the mine (i.e, Go Creek, Wolverine Creek, small tributaries of Money Creek, Bunker Creek, and Putt Creek) all have limited to no fisheries potential.

A surface water monitoring program has been established for the Wolverine Mine that provides continuous streamflow data for watercourses in the immediate vicinity of mine site operations as well as more regional coverage (Figure 3-2). Regular monitoring for water quality is also conducted at the sites outlined in Figure 3-2. The hydrological and water chemistry conditions around the mine site are summarized below.



0 1,000 2,000 4,000 6,000 Meters

Projection: UTM Zone 9, NAD 83

LORAX ENVIRONMENTAL

YukonZinc CORP

DESIGNED BY		
DWG. CHECK		
DRAWN BY	SSS	April 7, 2010
SCALE	1:110,000	
PROJECT NO.	474-3	

Baseline Characterization Report

Surface Water Quality Monitoring Stations

Figure 3-2

REV.

3.2.1 Hydrology

Stations W9 and W82, respectively, have been established on Wolverine Creek at the mouth and in the upper reaches immediately adjacent to the underground operations, respectively. These stations monitor the influence of underground dewatering on flow conditions in Wolverine Creek. Upper Wolverine Creek (station W82) is a narrow creek that freezes to ground in the winter. Flows at this station average 0.005 m3/s, as shown in Figure 3-3. As Wolverine Creek descends towards Little Wolverine Lake, volumetric flows increase, with average flows just above the confluence of 0.01 m3/s, on average, shown in Figure 3-5. Typically, the flows in Wolverine Creek are highest during spring freshet, level off during the late summer, and peak again in late fall during rain on snow events.

Monitoring of flow conditions in Go Creek occurs at station W80. Flows have averaged 0.47 m3/s over the monitoring period. W80 also represents the compliance monitoring point for effluent discharges. Hydrology in Go Creek (Figure 3-5) is characterized by high flows in May and June with decreasing flows throughout the summer. Spikes in flow rate are evident again in October due to rain on snow events. Flows are lowest in the late winter months: February, March, and April.

Regional hydrology is monitored via station W22 on Money Creek. Hydrology in Money Creek is relatively consistent, with measured flows ranging from ~4 m^3/s to ~20 m^3/s; although the data logger recorded some peak flows up to 148 m^3/s (Figure 3-6). On average flow rates are ~8 m^3/s. Similar to other creeks in the area, Money Creek is characterized by high flows in May and June, with decreasing flows throughout the summer, and spikes again in late fall, with the lowest flows in late winter (February through April).

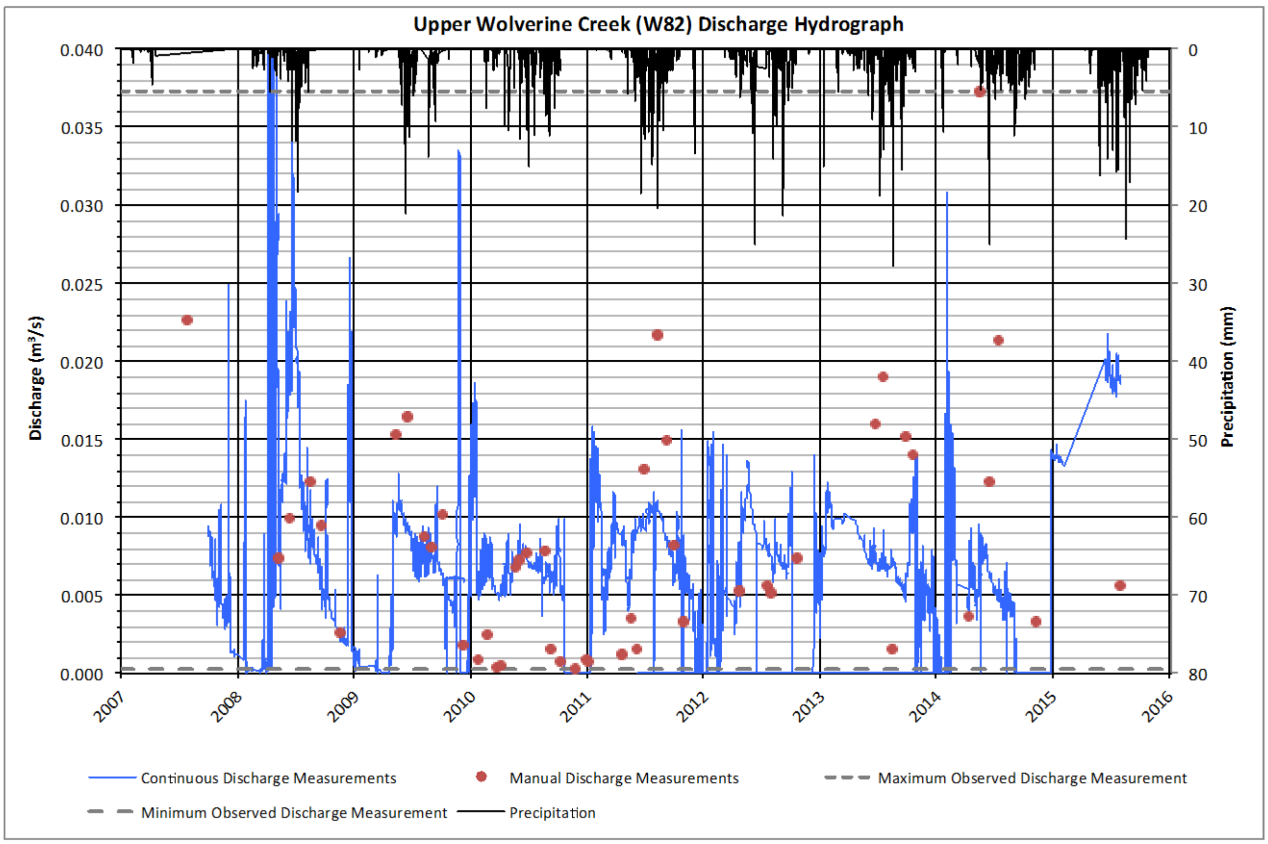


Figure 3-3: W82 Discharge Hydrograph

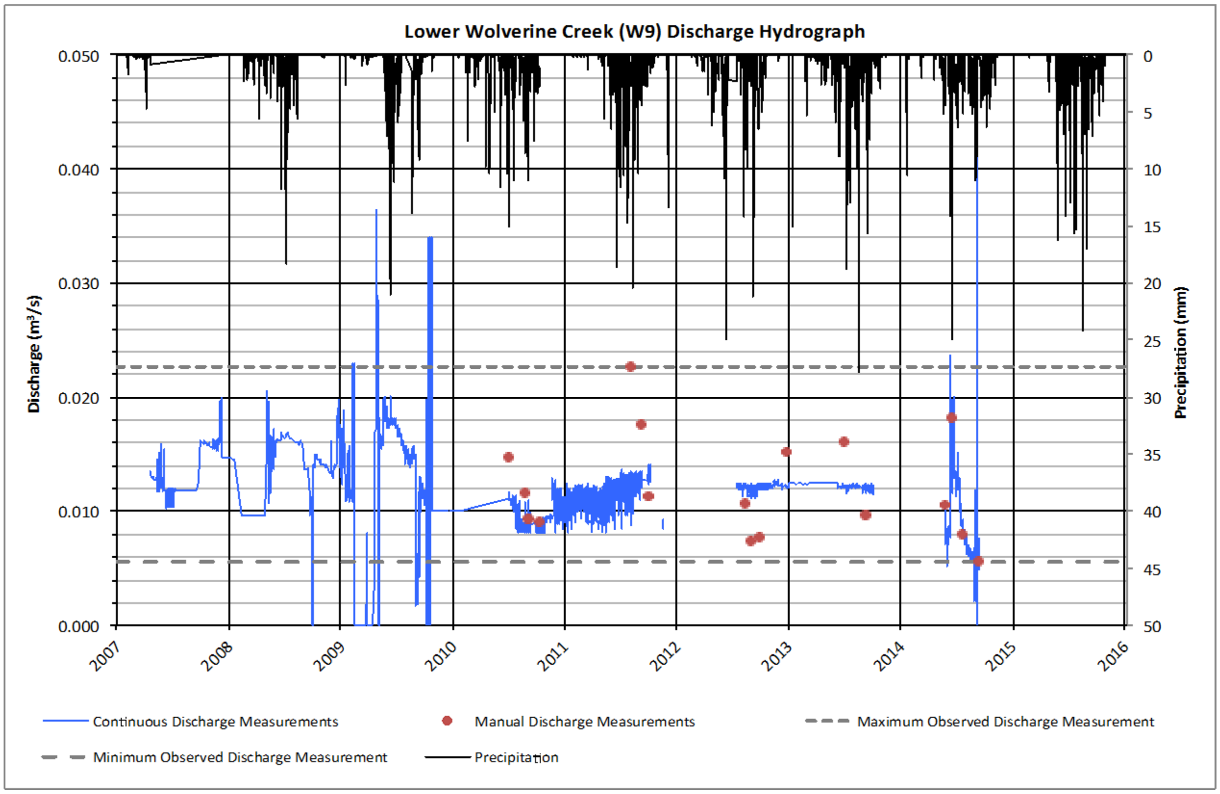


Figure 3-4: W9 Discharge Hydrograph

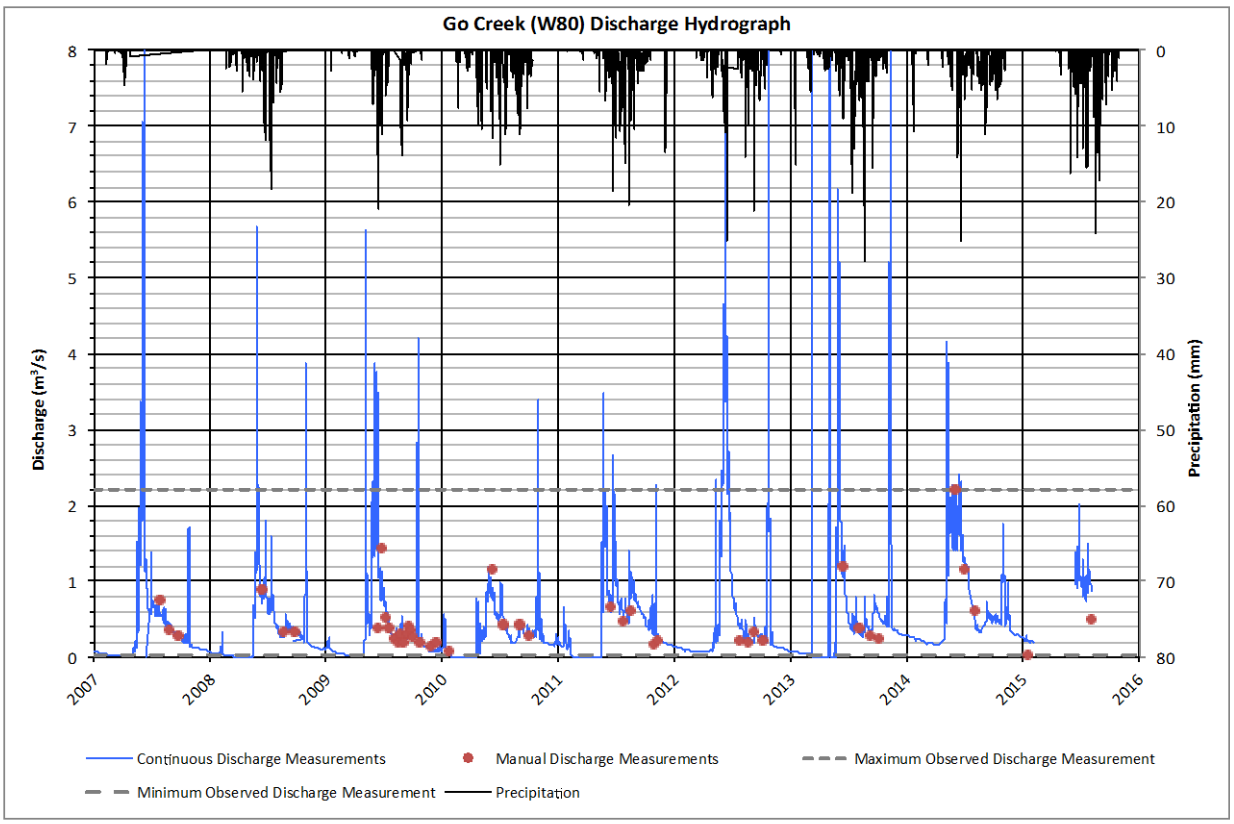


Figure 3-5: W80 Discharge Hydrograph

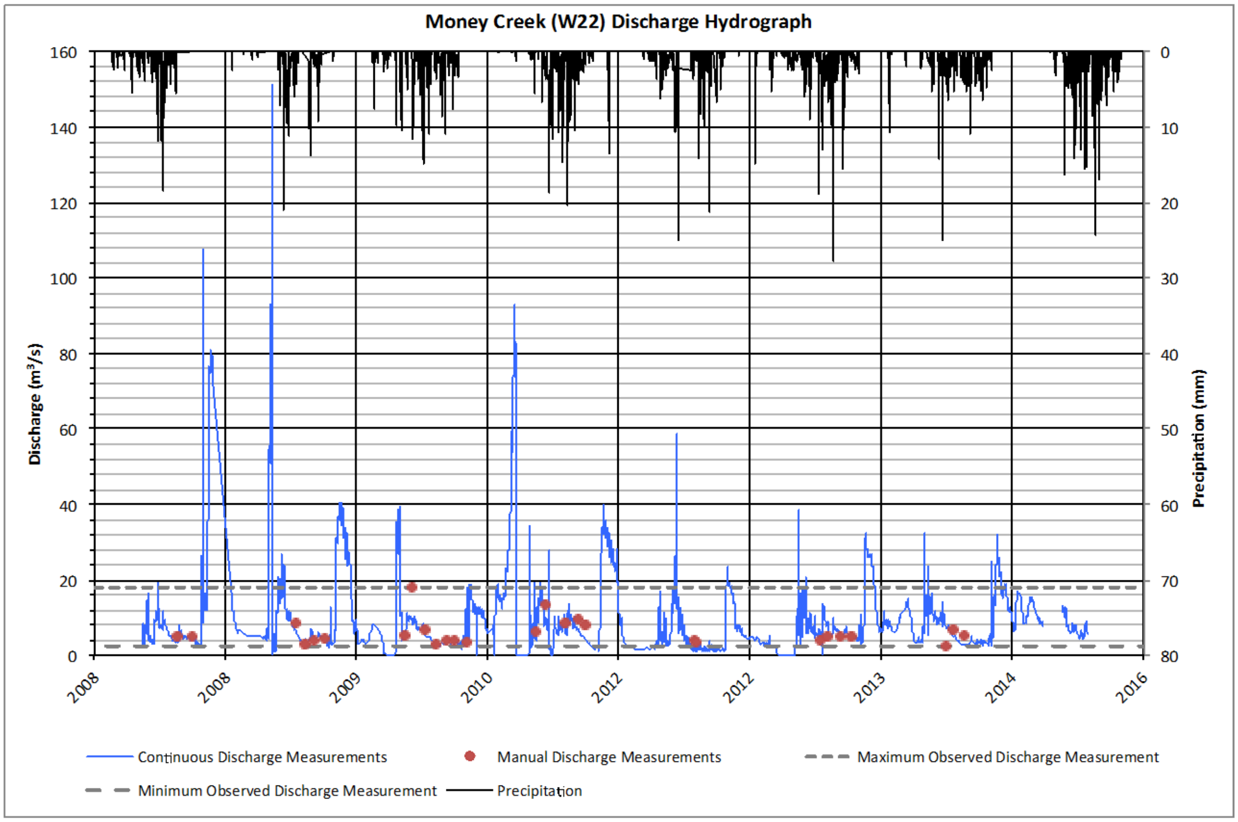


Figure 3-6: W22 Discharge Hydrograph

3.2.2 Surface Water Quality

Surface water quality in the area proximate to the Wolverine Mine is relatively pristine, with high metal concentrations directly adjacent to the ore body in Wolverine Creek. Water chemistry statistics for samples taken 2009-2016 inclusively are shown in Figure 3-7 through Figure 3-17, with water quality sites listed in order moving downstream from the mine. Values that were reported as being less than the reportable detection limit were taken to be half the detection limit when calculating the median, 25th and 75th percentile values. Parameter concentrations are compared to the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME), or the ambient water quality guideline from the Ministry of Environment of British Columbia for sulphate, where applicable. Median hardness was used to calculate hardness dependent guideline concentrations (i.e., cadmium and sulphate).

Wolverine Creek naturally receives drainage from the mineralized area of the Wolverine deposit. As such, concentrations of cadmium, copper, selenium, and zinc in Upper Wolverine Creek (W82) are typically above the CCME guidelines and generally decrease with downstream distance (i.e., W82 is in upper Wolverine Creek and W9 is in lower Wolverine Creek). Metal concentrations above CCME guidelines were also evident at stations along the road route, which is likely tied to the high TSS values experienced in the spring (Figure 3-10). Metal concentrations in the Go Creek and Money Creek watersheds are statistically comparable and show very little fluctuations. These values and trends are consistent with baseline values (Lorax, 2010).

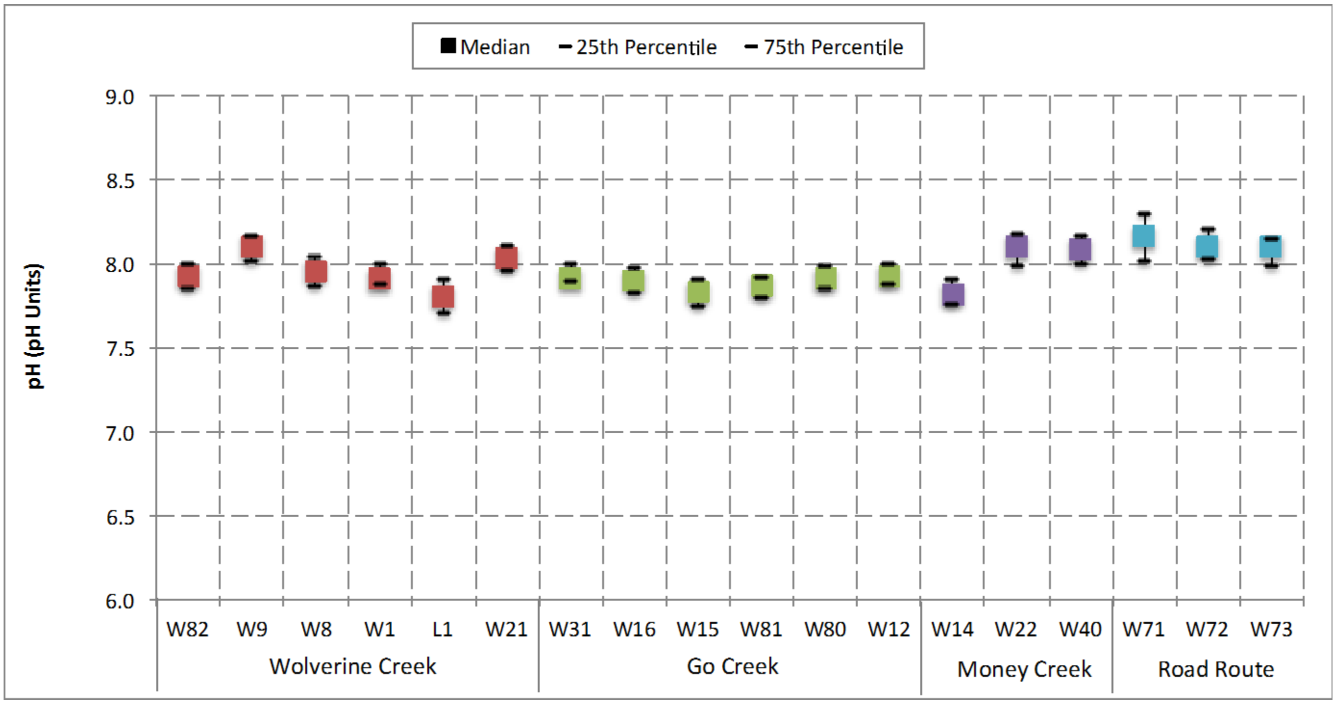


Figure 3-7: Surface Water Chemistry – pH (2009-2016 data)

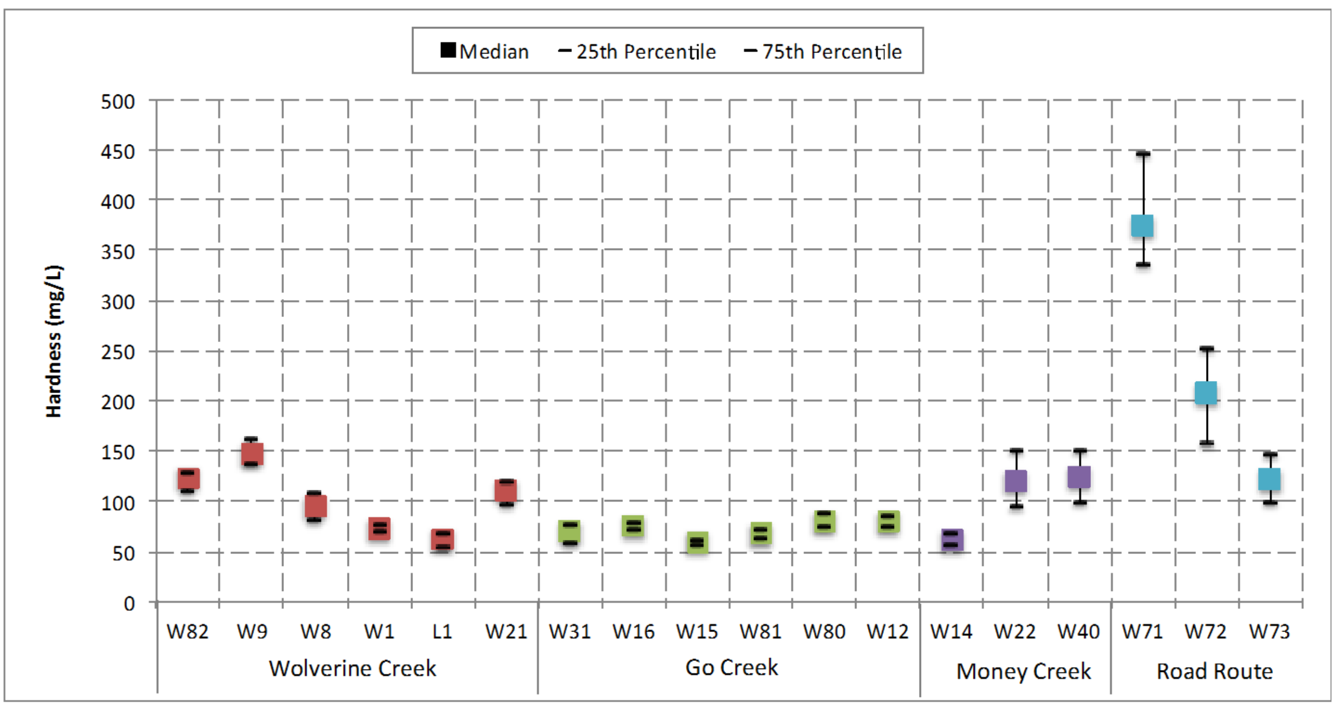


Figure 3-8: Surface Water Chemistry – Hardness (2009-2016 data)

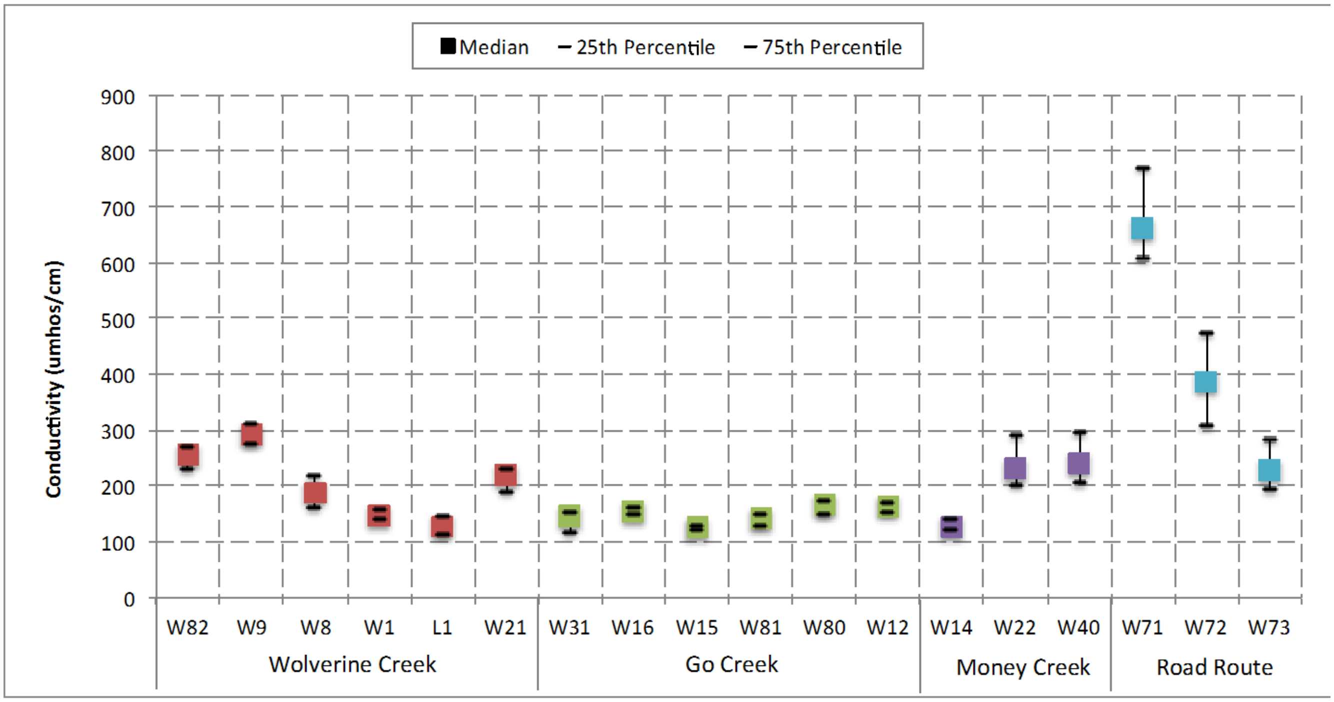


Figure 3-9: Surface Water Chemistry – Conductivity (2009-2016 data)

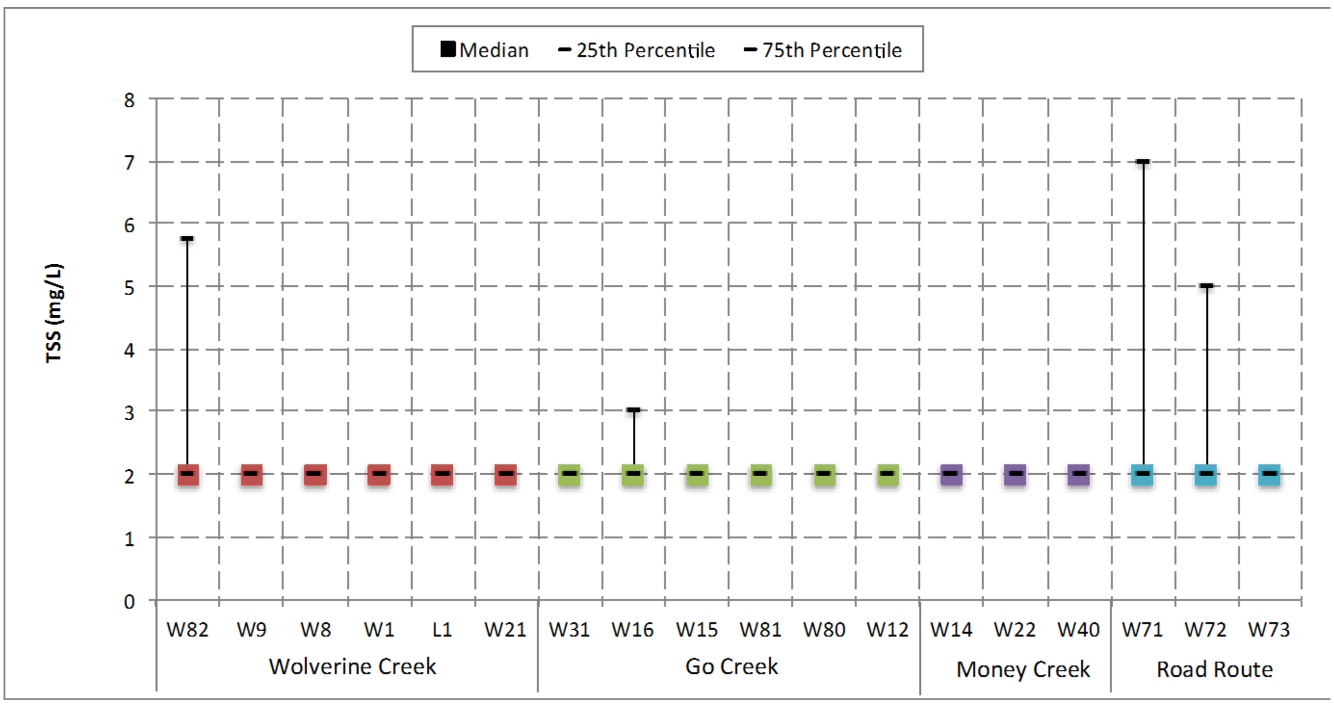


Figure 3-10: Surface Water Chemistry – Total Suspended Solids (2009-2016 data)

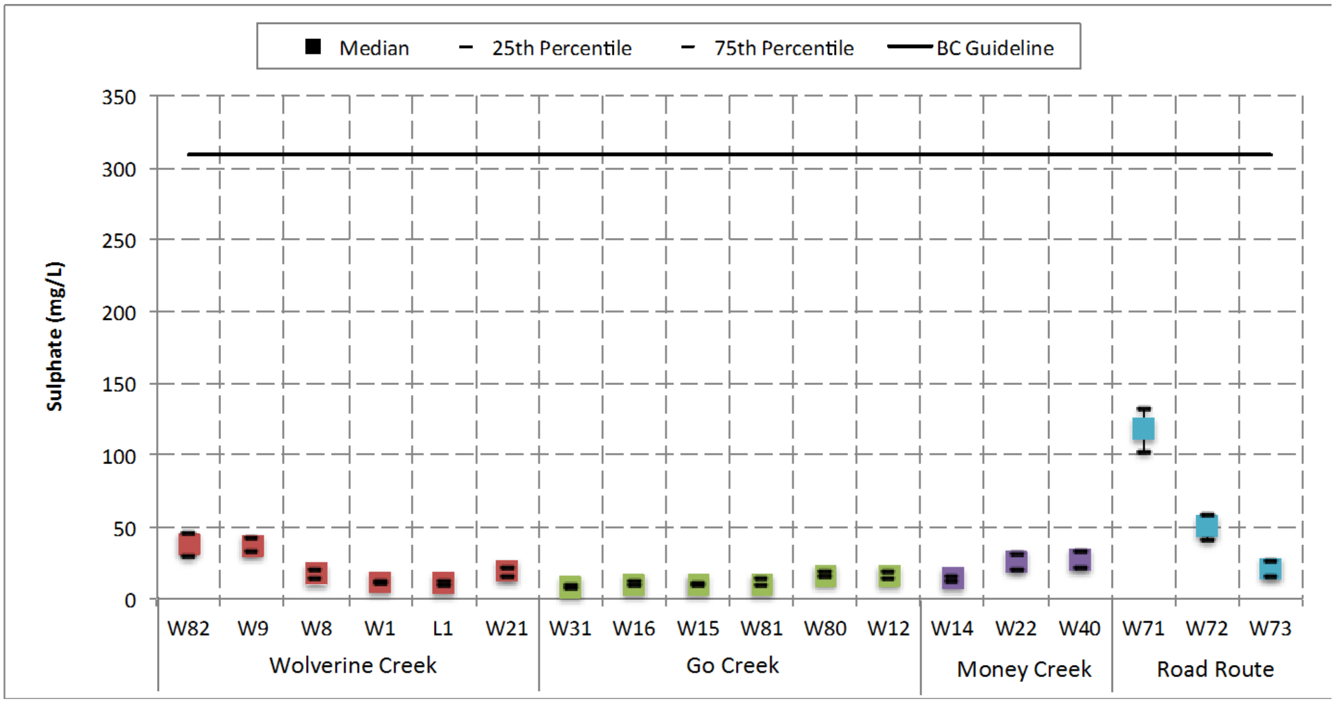


Figure 3-11: Surface Water Chemistry – Sulphate (2009-2016 data)

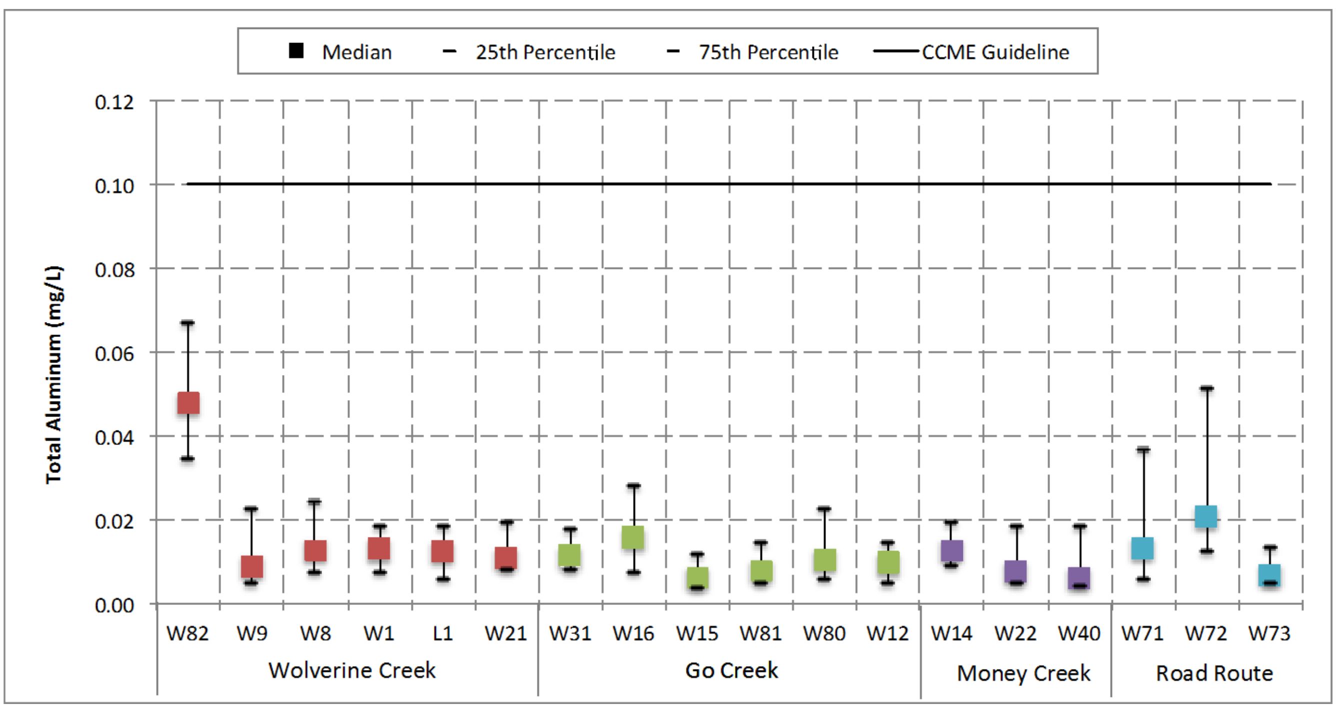


Figure 3-12: Surface Water Chemistry – Total Aluminum (2009-2016 data)

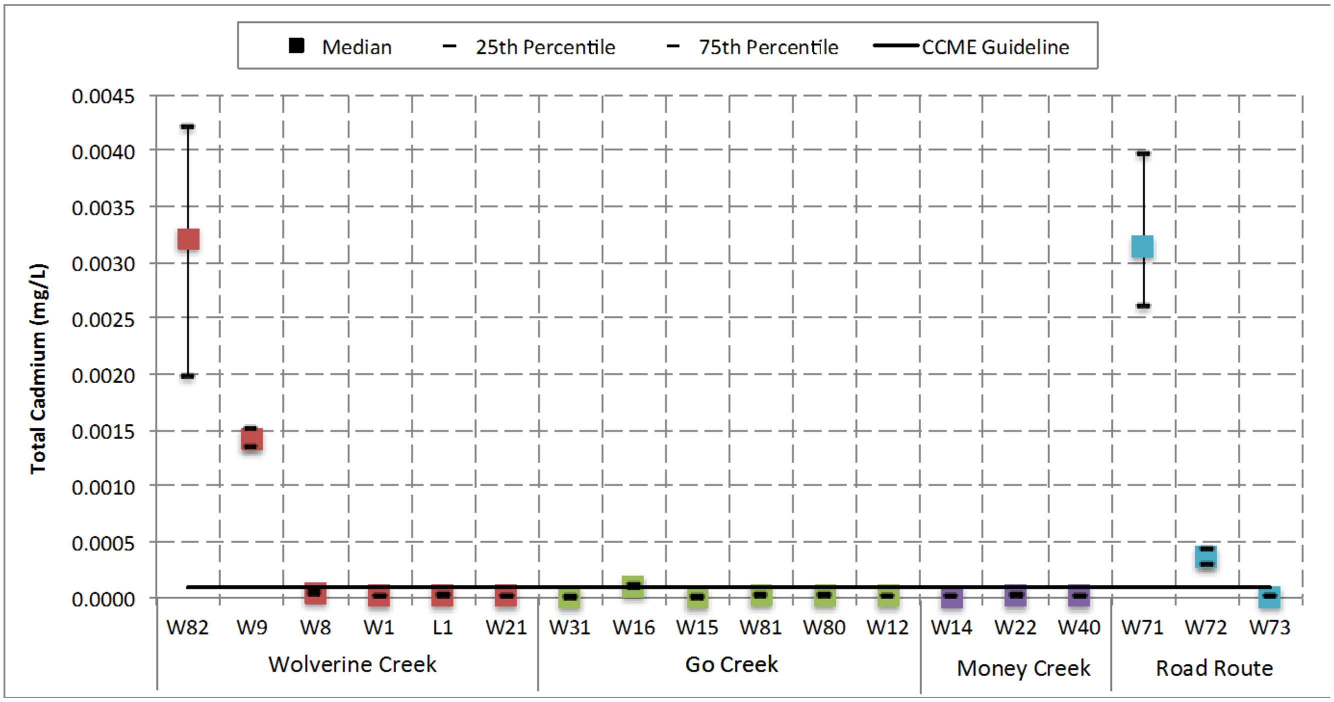


Figure 3-13: Surface Water Chemistry – Total Cadmium (2009-2016 data)

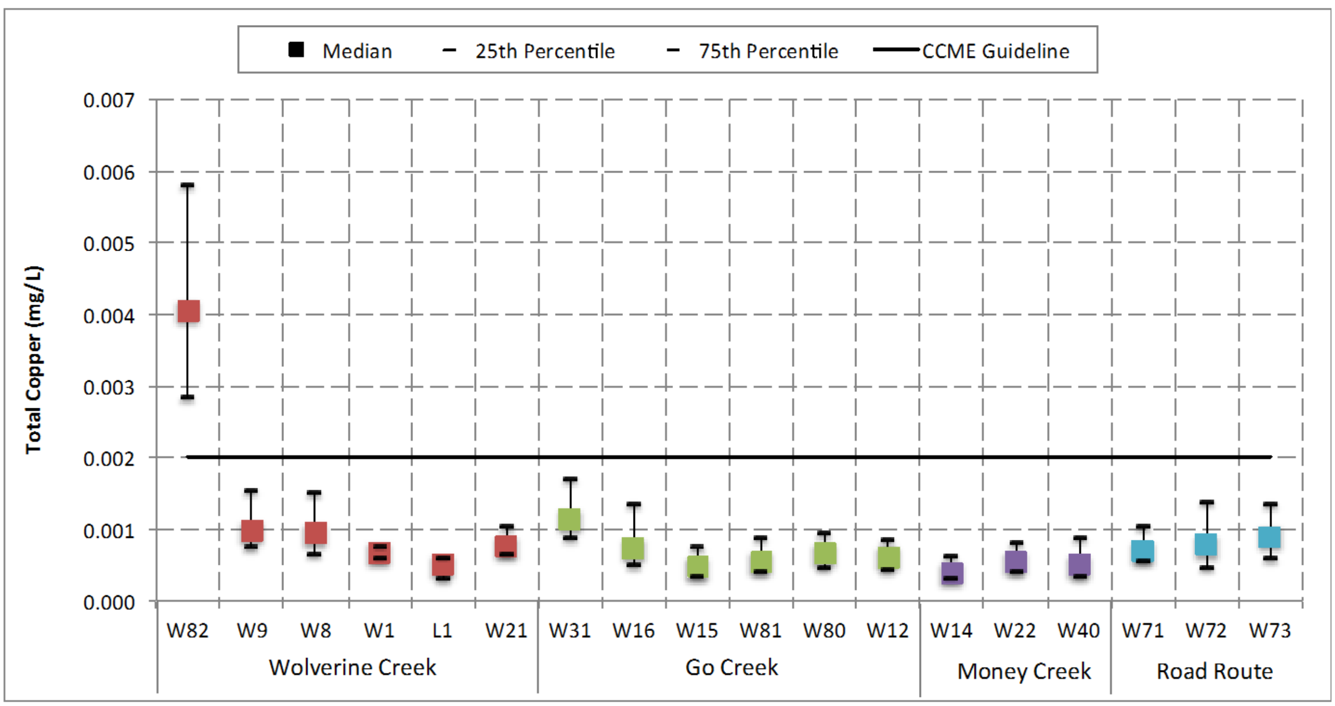


Figure 3-14: Surface Water Chemistry – Total Copper (2009-2016 data)

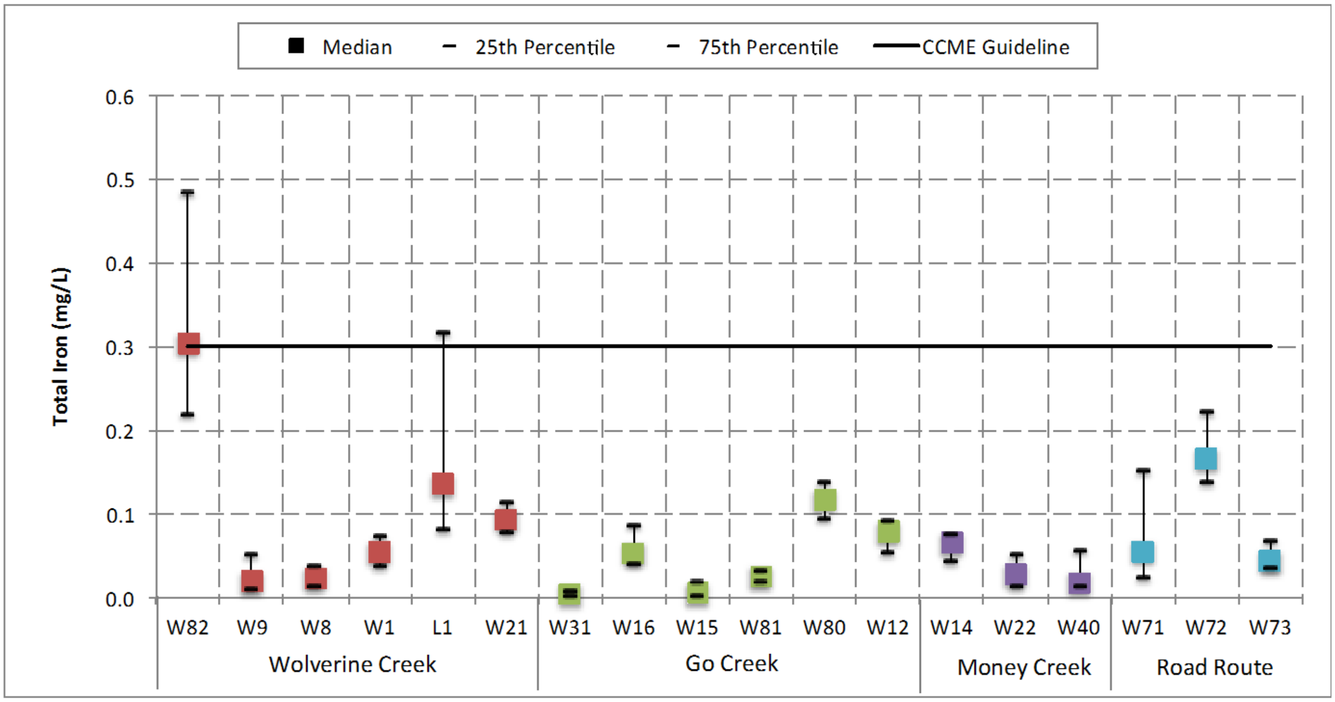


Figure 3-15: Surface Water Chemistry – Total Iron (2009-2016 data)

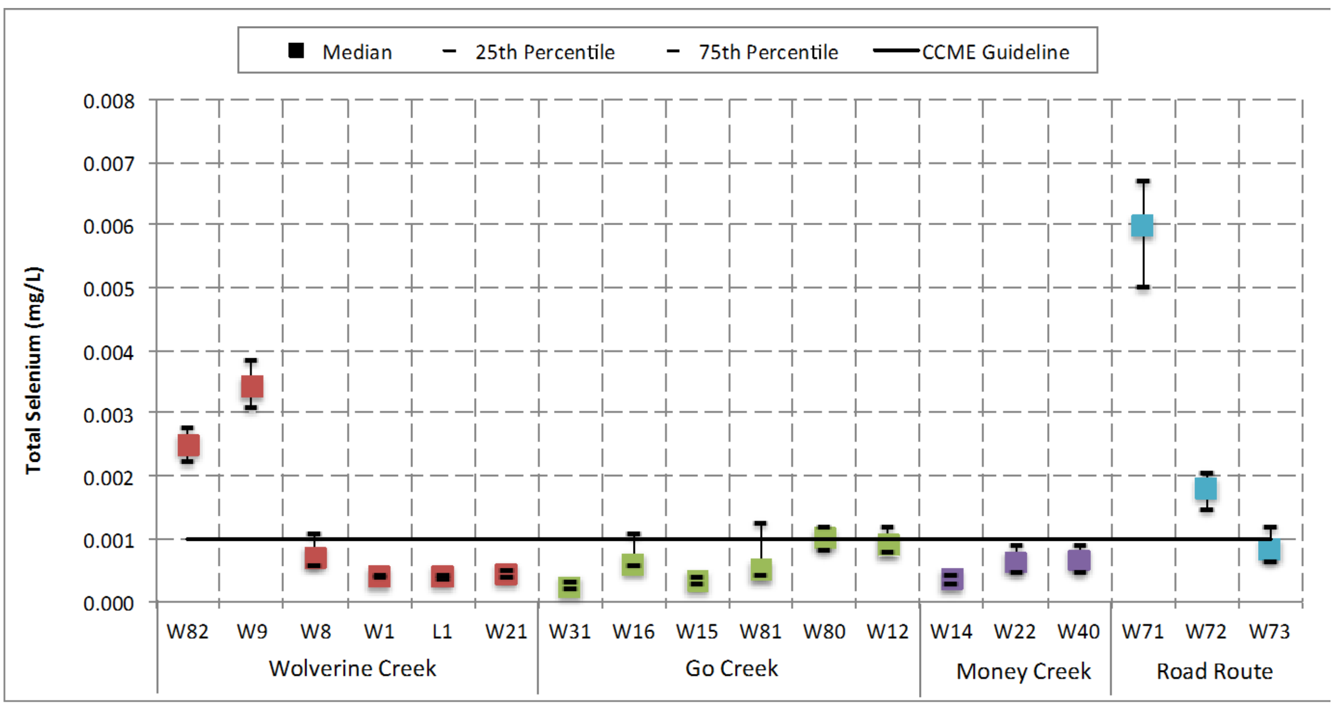


Figure 3-16: Surface Water Chemistry – Total Selenium (2009-2016 data)

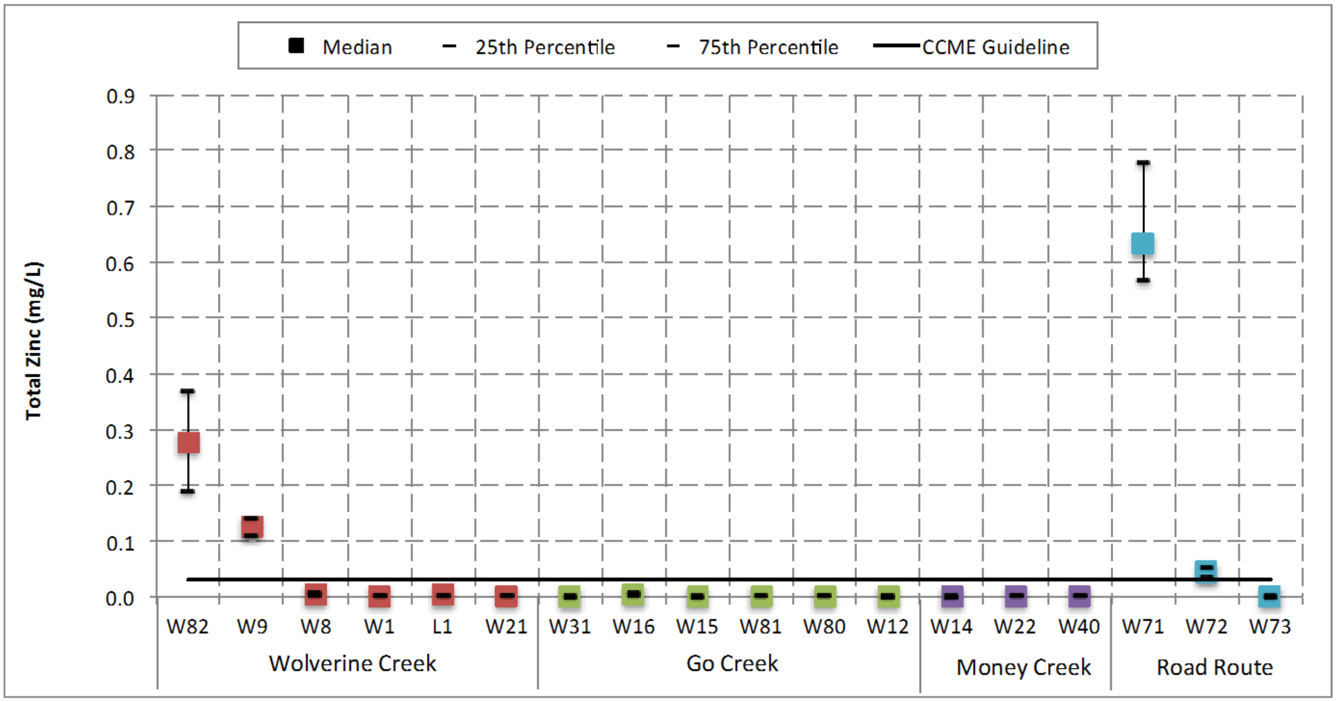


Figure 3-17: Surface Water Chemistry – Total Zinc (2009-2016 data)

3.3 Groundwater

3.3.1 Hydrogeology

Comprehensive analysis of the hydrogeology in the mine site area was developed for the Environmental Assessment (YZC, 2005) to predict the impacts of the underground mine on the Wolverine Creek watershed. Ongoing monitoring is conducted at groundwater monitoring wells throughout the Wolverine Creek and Go Creek basin (Figure 3-19). The conceptual hydrogeologic model plan and cross-sections, and predicted dewatered zones, are shown in Figure 3-20 through Figure 3-24.

Two bedrock aquifers are present in the vicinity of the mine including a shallow unconfined aquifer above the iron formations and a deeper, semi-confined aquifer below the iron formations. The upper and lower iron formation as well as the mineralized zone behave as aquitards and may slow the flow of groundwater. There is a homogeneous and isotropic aquifer inferred to be 150 m in thickness. Water table depths and flow divides were inferred based on ground surface topography, surface water bodies and known water table elevations in close proximity to the mine area. Groundwater is inferred to flow from northeast to southwest near the mine. Precipitation on the ground surface above the mine infiltrates into the ground and recharges the groundwater flow system. Groundwater flows southwestward to discharge locations along Wolverine Creek.

Potentiometric elevations are measured at four vibrating wire piezometers installed in two exploration boreholes (PZ-A and PZ-B) in the Lynx and Wolverine mineralized zones, respectively. Results from ongoing monitoring following mine development are shown in Figure 3-18. Battery failure of the piezometers in 2009 resulted in gaps in the data. A malfunction was discovered with the PZA Deep sensor and data is corrupted after June 26th, 2014, therefore data is not presented.

The shallow PZA and PZB wells showed a slight decrease in elevation between 2007-2013. However, the deep PZA and PZB wells showed a marked decrease from 2009, which may be attributed to an intersection of the mining operations with the well, as noted by the mining personnel. PZB Deep showed a steady decline from 2008 to 2013, markedly decreasing in 2009 and 2013. PZA Deep shows the most significant decline of the four piezometers since 2008. The majority of this decline occurred during 2010 and 2011. Water level increases are seen shortly after summer rain events, even in the deep well installations.

Overall the underground development (started in September 2009) seems to have had a significant overall effect on the lower (or deep) aquifers, with little to no effect on the upper (or shallow) aquifers.

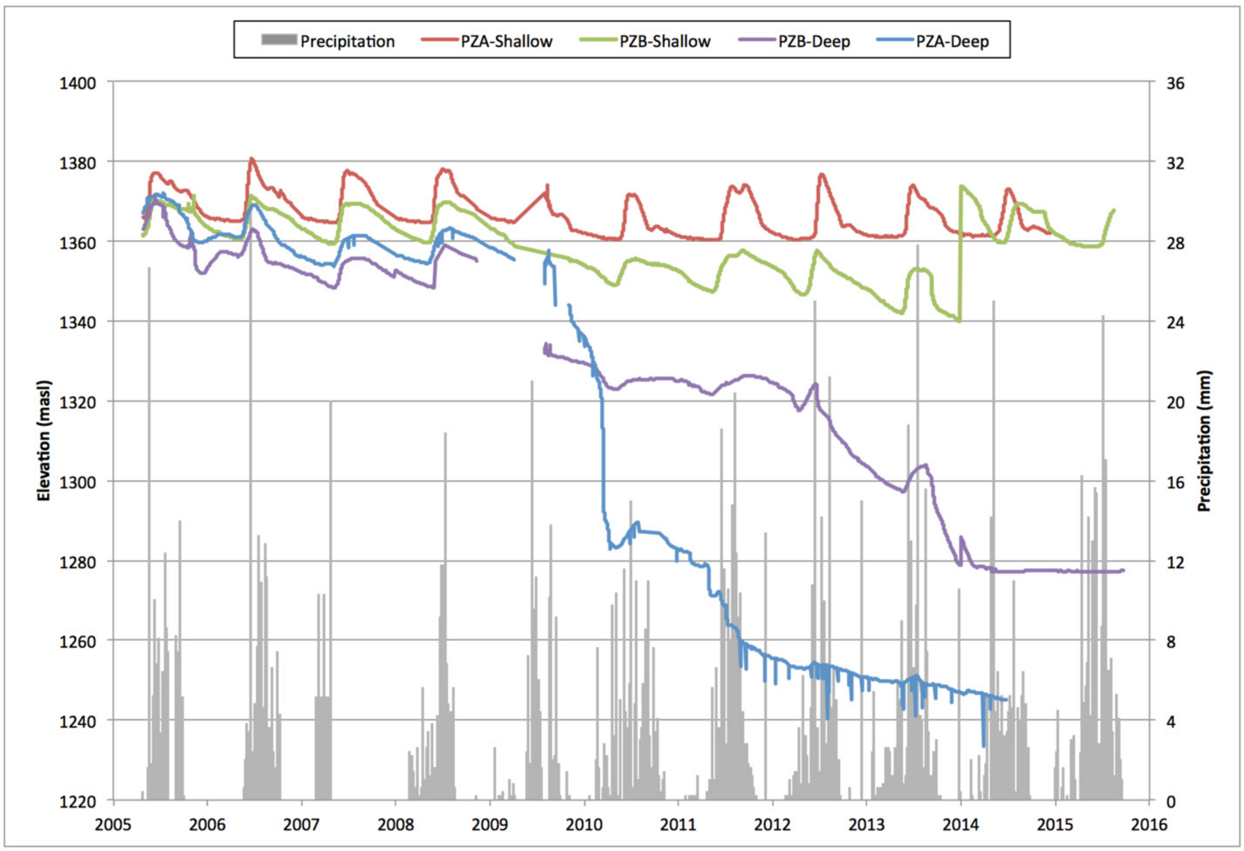
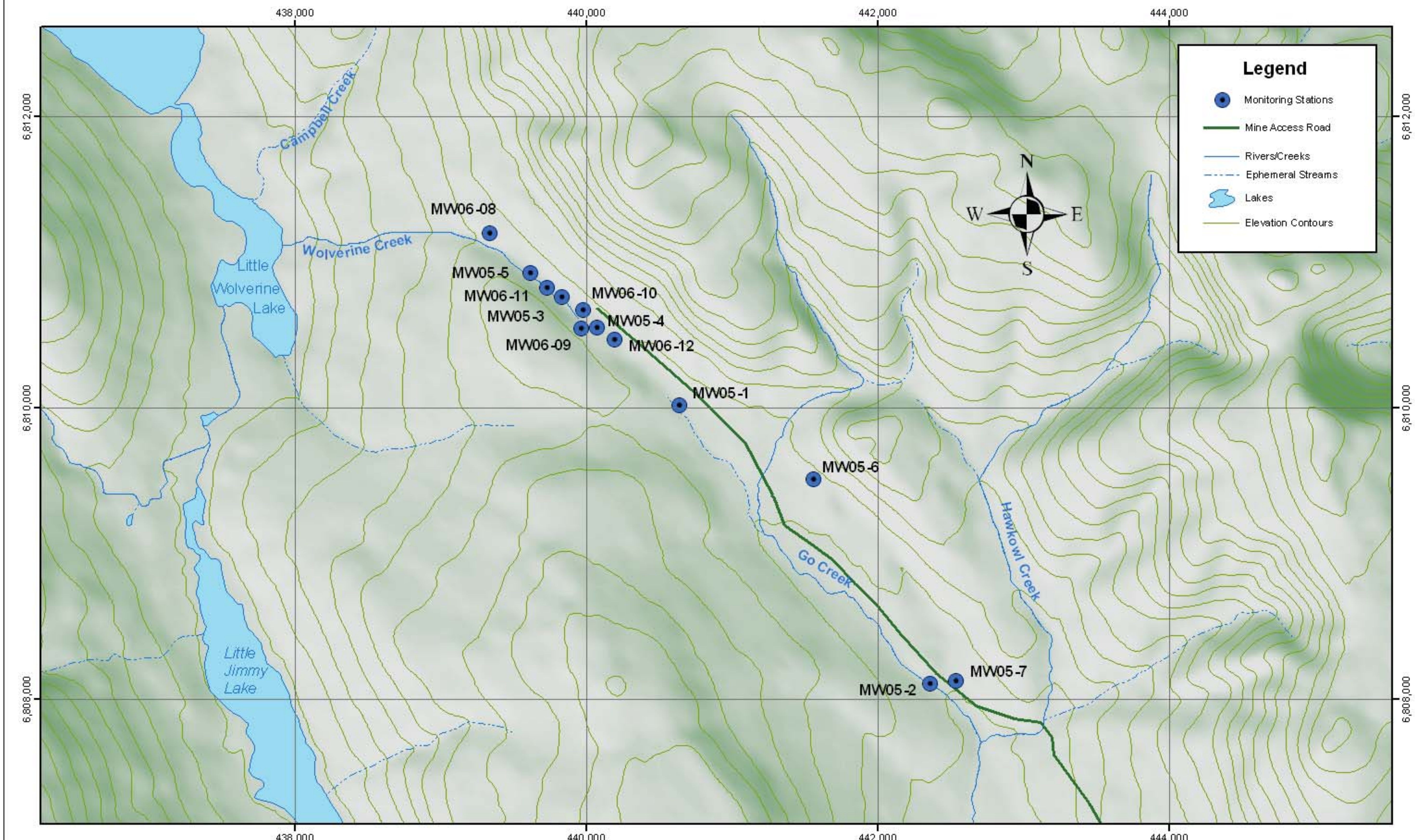


Figure 3-18: 2005-2015 Pieziometric and Precipitation Data

In the vicinity of TSF area, the groundwater table is generally sloping southwest following the trend of the topography. Near the downstream end of the impoundment basin at MW05-7 (Figure 3-19), the piezometric pressure in the bedrock is slightly artesian (few meters above ground) and the water table rises, with the topography, towards the dam abutments. In general, the groundwater table in the overburden is slightly lower than that in the bedrock. The groundwater table exhibits seasonal variation, reaching highest elevation after spring runoff season.

The main groundwater aquifer is the 10 m to 20 m thick overburden overlying bedrock within the Go Creek Valley. Downstream of Go Creek valley, which appears to be a hanging valley, the morphology changes to a broader terraced valley where much thicker deposits of post glacial outwash soils provide a larger groundwater flow regime.



0 250 500 1,000 1,500 Meters

Projection: UTM Zone 9, NAD 83

LORAX ENVIRONMENTAL

YukonZinc CORP

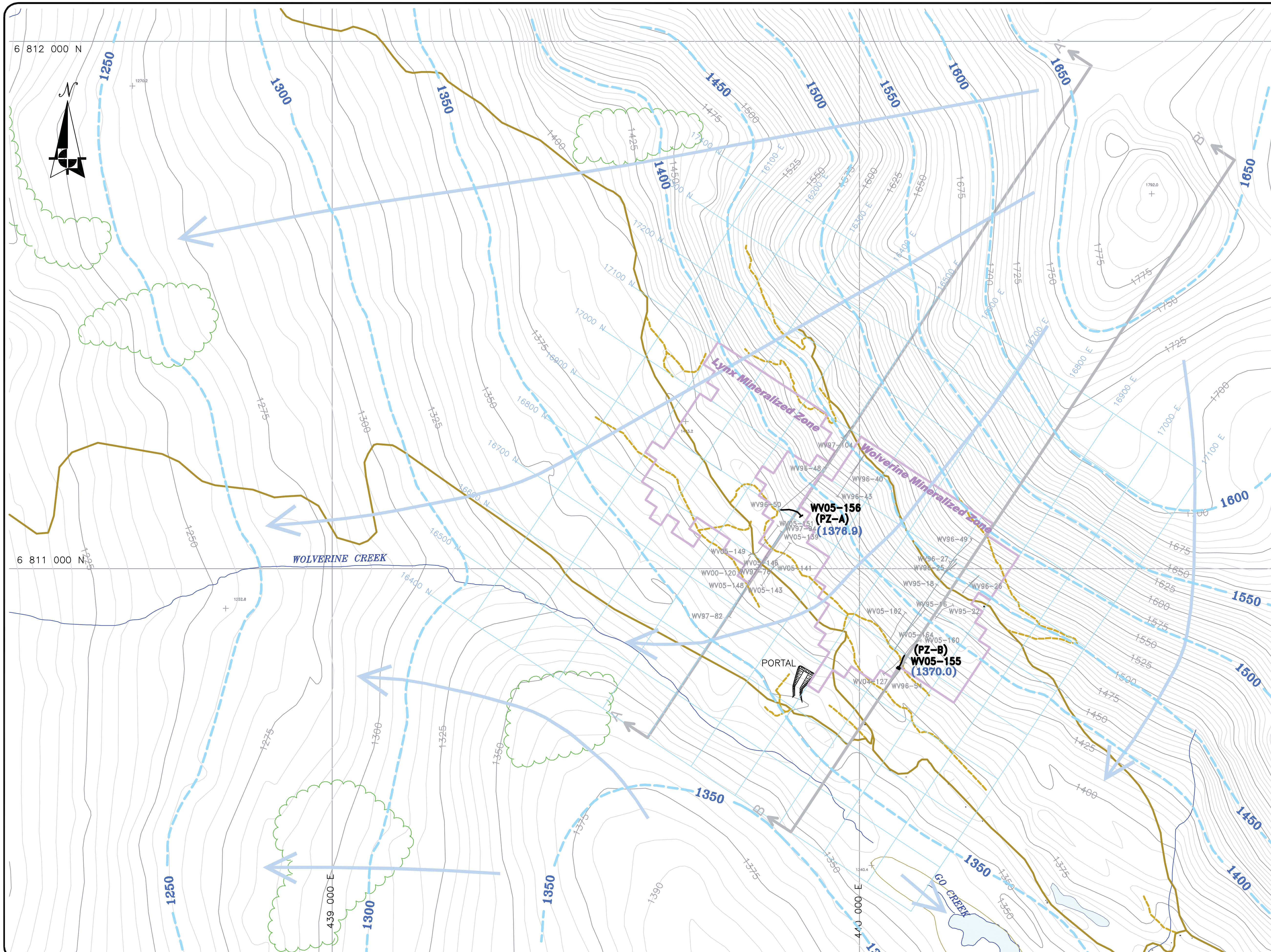
DESIGNED BY		
DWG. CHECK		
DRAWN BY	SSS	April 7, 2010
SCALE	1:25,000	
PROJECT NO.	474-3	

Baseline Characterization Report

Groundwater Monitoring Wells

Figure 3-19

REV.



LEGEND:

- GROUND SURFACE CONTOUR (M ASL) – 5m INTERVAL
- DRAINAGE
- ROAD – MAIN
- ROAD – DRILL ACCESS
- INFERRED GROUNDWATER EQUIPOTENTIAL LINE (M ASL)
- MINERALIZED ZONE
- INFERRED GROUNDWATER FLOW DIRECTION (JULY 1, 2005)
- A A' CROSS SECTION LINES
- WV05-155 PIEZOMETER INSTALLED BY GARTNER LEE IN APRIL 2005 (PROJECTED TO SURFACE)
- (1370.0) GROUNDWATER ELEVATION MEASURED ON JULY 1, 2005 (M ASL)
- WV97-100 ON-SECTION DIAMOND DRILL HOLE (PROJECTED TO SURFACE)

Data Sources:

1. Proposed Roads, contour and drainage data provided by Expatriate Resources on September 22, 2004
2. Claims and mineralized zones from drawings provided by Yukon Zinc Corporation
3. Wolverine Creek watershed boundary provided by Madrone Environmental Services Ltd.

REVIEWED BY : DJ/RF/RM
PREPARED BY : PW
DATE ISSUED : OCTOBER, 2005
PROJECT NO. : 50-288
FILE NAME : 50288-4D-01.dwg
REVISION : 1

YukonZinc CORP

Wolverine Project

Figure 3-20

CONCEPTUAL HYDROGEOLOGIC MODEL PLAN

Date: OCTOBER, 2005

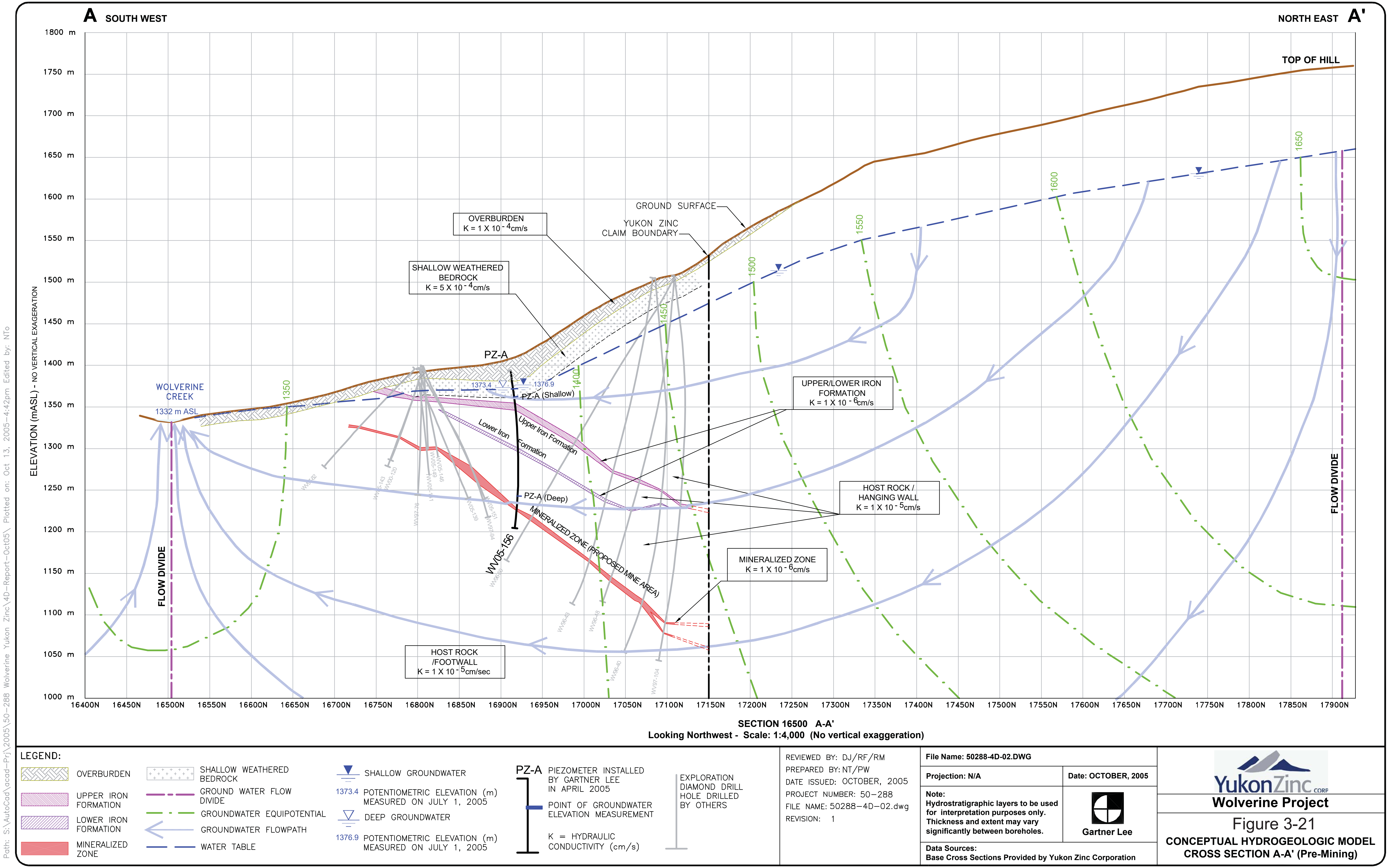
Projection: UTM Zone 9, NAD 27 | **File Name: 50288-4D-01.DWG**

0 50 100 200 300m

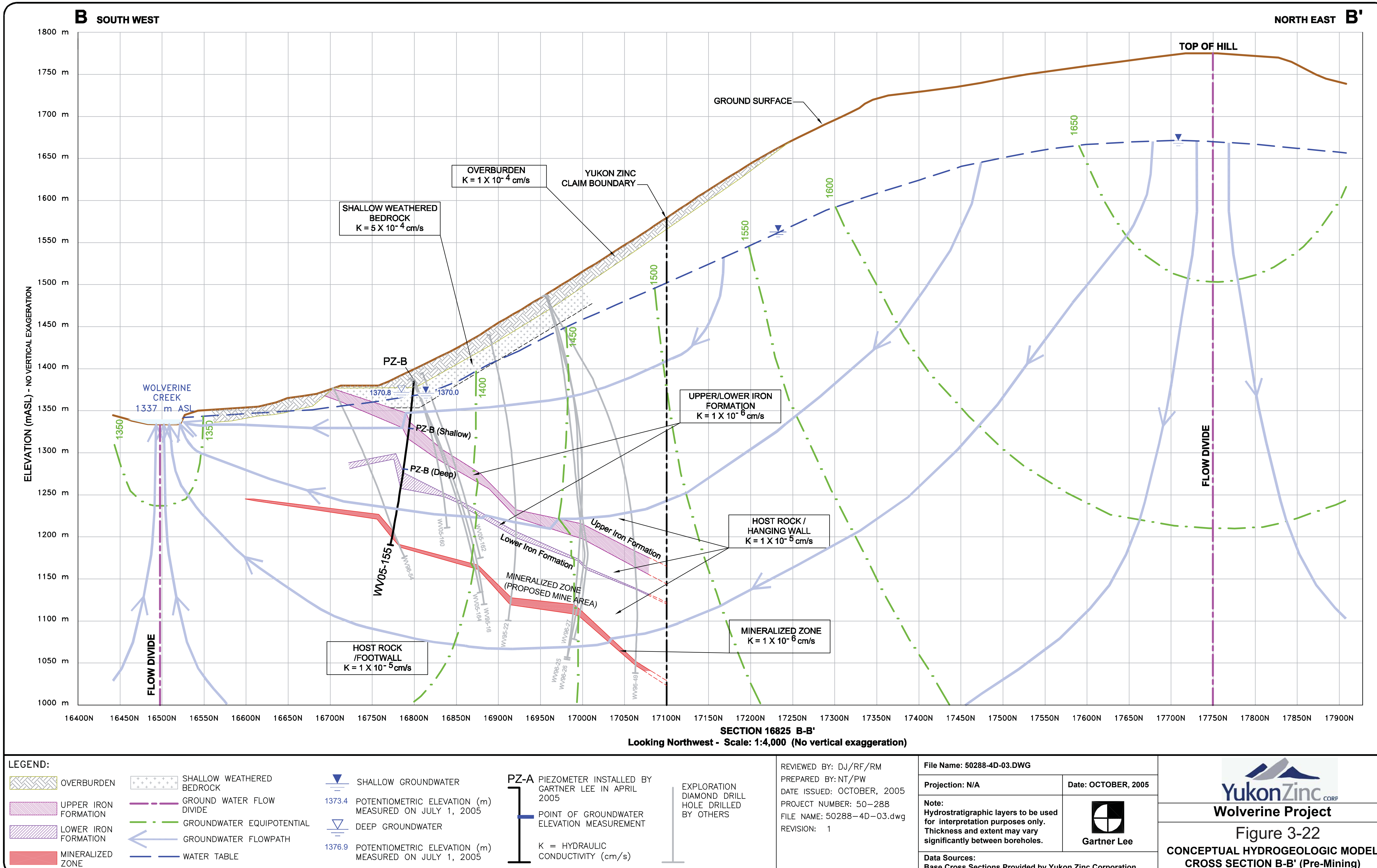
Scale 1:7,000

Gartner Lee

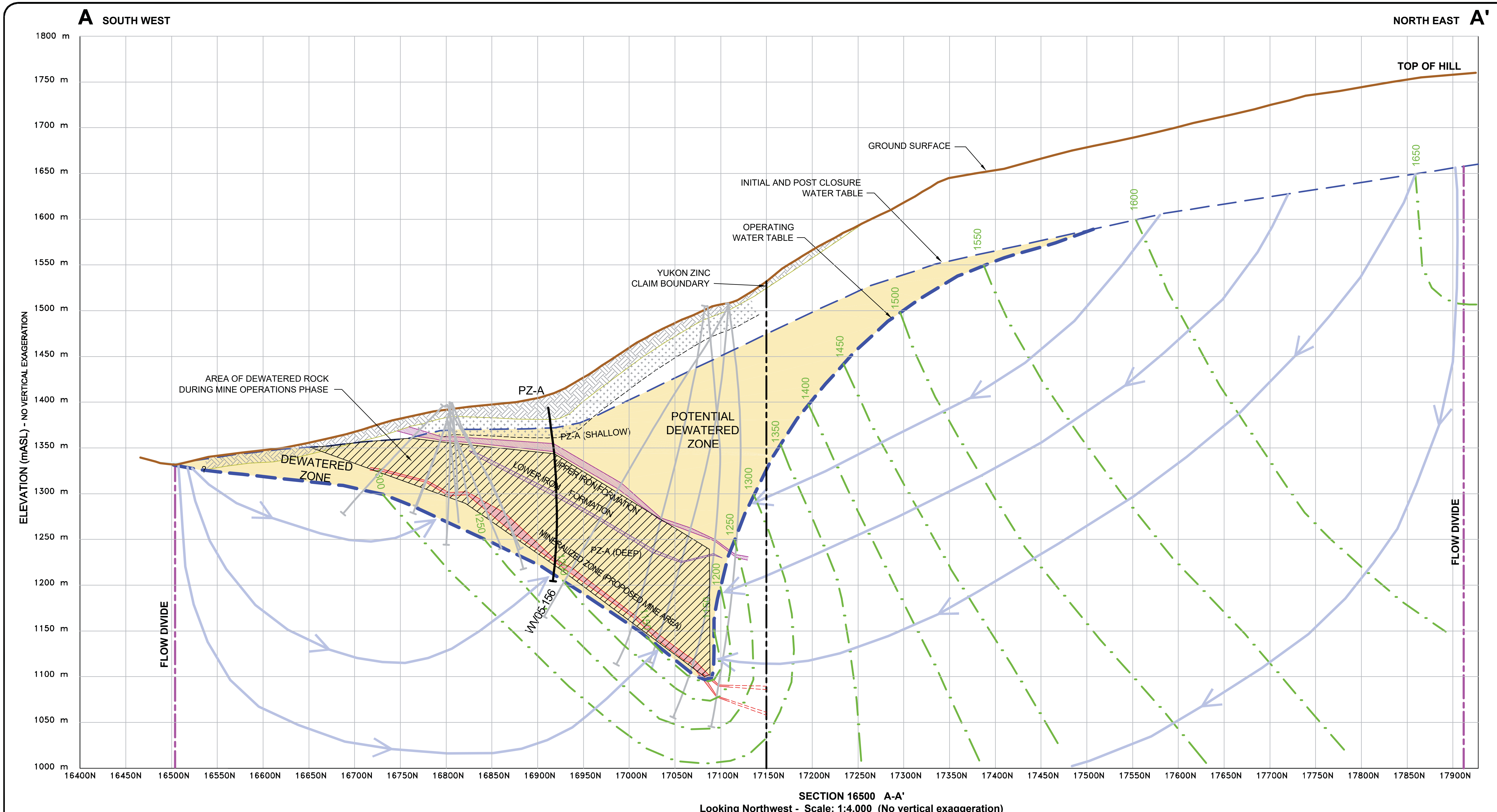
Path: S:\AutoCad\acad-Prj\2005\50-288 Wolverine Yukon Zinc\4D-Report-Oct05\ Plotted on: Oct 13, 2005-4:36pm Edited by: NTo



A SOUTH WEST
NORTH EAST A'
TOP OF HILL
GROUND SURFACE
YUKON ZINC CLAIM BOUNDARY
OVERBURDEN K = 1 X 10^-4 cm/s
SHALLOW WEATHERED BEDROCK K = 5 X 10^-4 cm/s
PZ-A
1373.4
1376.9
PZ-A (Shallow)
PZ-A (Deep)
WOLVERINE CREEK
1332 m ASL
Upper Iron Formation
Lower Iron Formation
MINERALIZED ZONE (PROPOSED MINE AREA)
WV05-156
UPPER/LOWER IRON FORMATION K = 1 X 10^-6 cm/s
HOST ROCK / HANGING WALL K = 1 X 10^-5 cm/s
MINERALIZED ZONE K = 1 X 10^-6 cm/s
HOST ROCK /FOOTWALL K = 1 X 10^-5 cm/sec
FLOW DIVIDE
FLOW DIVIDE
1350
1400
1450
1500
1550
1600
1650
ELEVATION (mASL) - NO VERTICAL EXAGERATION
1800 m
1750 m
1700 m
1650 m
1600 m
1550 m
1500 m
1450 m
1400 m
1350 m
1300 m
1250 m
1200 m
1150 m
1100 m
1050 m
1000 m
16400N 16450N 16500N 16550N 16600N 16650N 16700N 16750N 16800N 16850N 16900N 16950N 17000N 17050N 17100N 17150N 17200N 17250N 17300N 17350N 17400N 17450N 17500N 17550N 17600N 17650N 17700N 17750N 17800N 17850N 17900N
SECTION 16500 A-A'
Looking Northwest - Scale: 1:4,000 (No vertical exaggeration)
LEGEND:
OVERBURDEN
UPPER IRON FORMATION
LOWER IRON FORMATION
MINERALIZED ZONE
SHALLOW WEATHERED BEDROCK
GROUND WATER FLOW DIVIDE
GROUNDWATER EQUIPOTENTIAL
GROUNDWATER FLOWPATH
WATER TABLE
SHALLOW GROUNDWATER
1373.4 POTENTIOMETRIC ELEVATION (m) MEASURED ON JULY 1, 2005
DEEP GROUNDWATER
1376.9 POTENTIOMETRIC ELEVATION (m) MEASURED ON JULY 1, 2005
PZ-A PIEZOMETER INSTALLED BY GARTNER LEE IN APRIL 2005
POINT OF GROUNDWATER ELEVATION MEASUREMENT
K = HYDRAULIC CONDUCTIVITY (cm/s)
EXPLORATION DIAMOND DRILL HOLE DRILLED BY OTHERS
REVIEWED BY: DJ/RF/RM
PREPARED BY: NT/PW
DATE ISSUED: OCTOBER, 2005
PROJECT NUMBER: 50-288
FILE NAME: 50288-4D-02.dwg
REVISION: 1
File Name: 50288-4D-02.DWG
Projection: N/A
Date: OCTOBER, 2005
Note: Hydrostratigraphic layers to be used for interpretation purposes only. Thickness and extent may vary significantly between boreholes.
Gartner Lee
Data Sources: Base Cross Sections Provided by Yukon Zinc Corporation
YukonZinc CORP
Wolverine Project
Figure 3-21
CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION A-A' (Pre-Mining)
Path: S:\AutoCad\acad-Prj\2005\50-288 Wolverine Yukon Zinc\4D-Report-Oct05\ Plotted on: Oct 13, 2005-4:42pm Edited by: NTo



B SOUTH WEST
NORTH EAST B'
TOP OF HILL
GROUND SURFACE
OVERBURDEN K = 1 X 10-4 cm/s
YUKON ZINC CLAIM BOUNDARY
SHALLOW WEATHERED BEDROCK K = 5 X 10-4 cm/s
PZ-B
WOLVERINE CREEK 1337 m ASL
1370.8
1370.0
PZ-B (Shallow)
PZ-B (Deep)
UPPER/LOWER IRON FORMATION K = 1 X 10-6 cm/s
Upper Iron Formation
Lower Iron Formation
HOST ROCK / HANGING WALL K = 1 X 10-5 cm/s
MINERALIZED ZONE (PROPOSED MINE AREA)
MINERALIZED ZONE K = 1 X 10-6 cm/s
HOST ROCK /FOOTWALL K = 1 X 10-5 cm/s
WV05-155
FLOW DIVIDE
FLOW DIVIDE
ELEVATION (mASL) - NO VERTICAL EXAGERATION
1800 m
1750 m
1700 m
1650 m
1600 m
1550 m
1500 m
1450 m
1400 m
1350 m
1300 m
1250 m
1200 m
1150 m
1100 m
1050 m
1000 m
1350
1350
1400
1450
1500
1550
1600
1650
16400N
16450N
16500N
16550N
16600N
16650N
16700N
16750N
16800N
16850N
16900N
16950N
17000N
17050N
17100N
17150N
17200N
17250N
17300N
17350N
17400N
17450N
17500N
17550N
17600N
17650N
17700N
17750N
17800N
17850N
17900N
SECTION 16825 B-B'
Looking Northwest - Scale: 1:4,000 (No vertical exaggeration)
LEGEND:
OVERBURDEN
UPPER IRON FORMATION
LOWER IRON FORMATION
MINERALIZED ZONE
SHALLOW WEATHERED BEDROCK
GROUND WATER FLOW DIVIDE
GROUNDWATER EQUIPOTENTIAL
GROUNDWATER FLOWPATH
WATER TABLE
SHALLOW GROUNDWATER
1373.4 POTENTIOMETRIC ELEVATION (m) MEASURED ON JULY 1, 2005
DEEP GROUNDWATER
1376.9 POTENTIOMETRIC ELEVATION (m) MEASURED ON JULY 1, 2005
PZ-A PIEZOMETER INSTALLED BY GARTNER LEE IN APRIL 2005
POINT OF GROUNDWATER ELEVATION MEASUREMENT
K = HYDRAULIC CONDUCTIVITY (cm/s)
EXPLORATION DIAMOND DRILL HOLE DRILLED BY OTHERS
REVIEWED BY: DJ/RF/RM
PREPARED BY: NT/PW
DATE ISSUED: OCTOBER, 2005
PROJECT NUMBER: 50-288
FILE NAME: 50288-4D-03.dwg
REVISION: 1
File Name: 50288-4D-03.DWG
Projection: N/A
Date: OCTOBER, 2005
Note: Hydrostratigraphic layers to be used for interpretation purposes only. Thickness and extent may vary significantly between boreholes.
Gartner Lee
Data Sources: Base Cross Sections Provided by Yukon Zinc Corporation
YukonZinc CORP
Wolverine Project
Figure 3-22
CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION B-B' (Pre-Mining)



SECTION 16500 A-A'

Looking Northwest - Scale: 1:4,000 (No vertical exaggeration)

LEGEND:

- OVERBURDEN
- UPPER IRON FORMATION
- LOWER IRON FORMATION
- MINERALIZED ZONE
- SHALLOW WEATHERED BEDROCK
- GROUND WATER FLOW DIVIDE
- INFERRED GROUNDWATER EQUIPOTENTIAL LINE
- INFERRED GROUNDWATER FLOW DIRECTION
- MINE DEWATERED ZONE
- INFERRED POTENTIALLY DEWATERED ZONE
- INFERRED WATER TABLE DURING MINE OPERATION
- WATER TABLE – SUMMER 2005
- PZ-A PIEZOMETER INSTALLED BY GARTNER LEE IN APRIL 2005
- POINT OF GROUNDWATER ELEVATION MEASUREMENT
- K = HYDRAULIC CONDUCTIVITY (cm/s)
- EXPLORATION DIAMOND DRILL HOLE DRILLED BY OTHERS

REVIEWED BY: DJ/RF/RM
PREPARED BY: NT/PW
DATE ISSUED: OCTOBER, 2005
PROJECT NUMBER: 50–288
FILE NAME: 50288–4D–06.dwg
REVISION: 1

File Name: 50288-4D-06.DWG

Date: OCTOBER, 2005

Projection: N/A

Notes:

1. Hydrostratigraphic layers to be used for interpretation purposes only. Thickness and extent may vary significantly between boreholes.
2. Inferred groundwater equipotential and flow directions based on limited data and analytical equations.

Data Sources:
Base Cross Sections Provided by Yukon Zinc Corporation

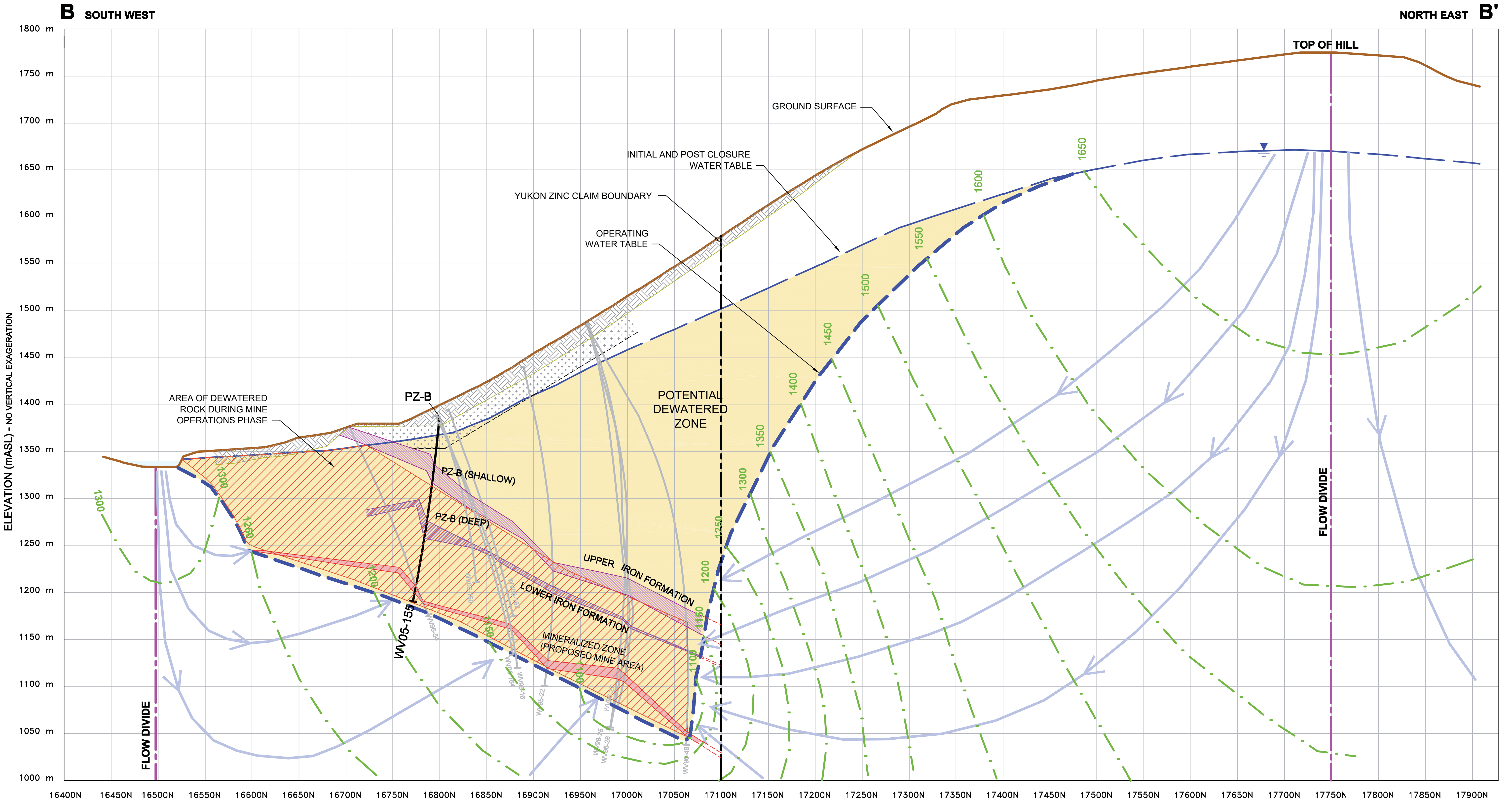
Gartner Lee

YukonZinc CORP

Wolverine Project

Figure 3-23

CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION A-A' (Operating)



SECTION 16825 B-B'
Looking Northwest - Scale: 1:4,000 (No vertical exaggeration)

LEGEND:

- OVERBURDEN
- SHALLOW WEATHERED BEDROCK
- UPPER IRON FORMATION
- GROUND WATER FLOW DIVIDE
- LOWER IRON FORMATION
- INFERRED GROUNDWATER EQUIPOTENTIAL LINE
- MINERALIZED ZONE
- INFERRED GROUNDWATER FLOW DIRECTION
- MINE DEWATERED ZONE
- INFERRED POTENTIALLY DEWATERED ZONE
- INFERRED WATER TABLE DURING MINE OPERATION
- WATER TABLE – SUMMER 2005
- PZ-A PIEZOMETER INSTALLED BY GARTNER LEE IN APRIL 2005
- POINT OF GROUNDWATER ELEVATION MEASUREMENT
- K = HYDRAULIC CONDUCTIVITY (cm/s)
- EXPLORATION DIAMOND DRILL HOLE DRILLED BY OTHERS

REVIEWED BY: DJ/RF/RM
PREPARED BY: NT/PW
DATE ISSUED: OCTOBER, 2005
PROJECT NUMBER: 50–288
FILE NAME: 50288–4D–05.dwg
REVISION: 1

File Name: 50288-4D-05.DWG
Date: OCTOBER, 2005
Projection: N/A

Notes:
1. Hydrostratigraphic layers to be used for interpretation purposes only. Thickness and extent may vary significantly between boreholes.
2. Inferred groundwater equipotential and flow directions based on limited data and analytical equations.

Gartner Lee

Data Sources:
Base Cross Sections Provided by Yukon Zinc Corporation

YukonZinc CORP

Wolverine Project

Figure 3-24

CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION B-B' (Operating)

Path: S:\AutoCad\acad—Prj\2005\50-288 Wolverine Yukon Zinc\4D—Report—Oct05\ Plotted on: Oct 31, 2005—10:56am Edited by: pwhiting

3.3.2 Groundwater Quality

Groundwater monitoring wells for characterizing baseline groundwater conditions were installed in strategic locations at the mine site during 2005 and 2006. Consistent monitoring of these wells has been ongoing since 2006. The majority of groundwater monitoring wells are located downgradient of the mine area within the upper Wolverine Creek basin (Figure 3-19). Sixteen groundwater monitoring wells have been installed at eight nested locations in the Wolverine Creek basin and monitor the shallow alluvial groundwater system, the shallow bedrock and deeper bedrock aquifers. Groundwater monitoring wells are also installed in the upper Go Creek basin and immediately downgradient of the TSF area. The wells in the Go Creek basin monitor the shallow alluvial and shallow bedrock aquifers.

The statistical results for select parameters in the groundwater systems are provided in Figure 3-25 through Figure 3-34. Values that were reported as being less than the reportable detection limit were taken to be half the detection limit when calculating the median, 25th and 75th percentile values.

Groundwater quality varies significantly in the Wolverine Creek alluvial system over relatively short distances. Groundwater quality at station MW05-3B is naturally elevated in cadmium, copper, selenium, and zinc. Zinc concentrations are very elevated and on the order of 1.8 mg/L. Cadmium and selenium concentrations are also very elevated for alluvial groundwater systems at approximately 0.021 mg/L and 0.008 mg/L, respectively. Groundwater quality at MW05-4B is also characterized by naturally elevated concentrations of cadmium and zinc, although each parameter is present at concentrations approximately an order of magnitude lower than observed at MW05-3B. Selenium concentrations do not appear to be naturally elevated in this portion of the alluvial aquifer. Further downgradient at station MW05-5B, groundwater contains much lower concentrations of cadmium, selenium, and zinc. This suggests a localized natural source of elevated metals in the upper Wolverine Creek basin alluvial aquifer in the vicinity of MW05-3B (Figure 3-19).

Water chemistry in the Wolverine Creek shallow bedrock system, monitoring well MW05-3A exhibits naturally elevated cadmium, selenium, and zinc concentrations, similar in magnitude to the concentrations observed for these parameters in the overlying alluvial aquifer. Conversely, elevated concentrations of cadmium and zinc were not observed in MW05-4A. Naturally elevated zinc concentrations are however, observed in well MW06-8S (~1.3 mg/L) and suggest that localized sources are responsible for the widely variable groundwater quality in the alluvial and shallow bedrock aquifers. This tenet is also supported by the locally elevated sulphate concentrations measured in MW06-12S (~250 mg/L), which is not observed elsewhere in the shallow bedrock aquifer.

In the Wolverine Creek deep bedrock aquifer, unlike the alluvial and shallow bedrock systems, baseline groundwater quality is less variable between wells and no parameters are considered to be naturally elevated in the background.

In the Go Creek basin, which has been divided into the Go Creek basin and TSF area, no deep bedrock monitoring wells have been installed and only the shallow aquifer systems are monitored. Most trace metals are present at very low concentrations in both the alluvial and shallow groundwater systems in upper Go Creek, except for dissolved iron concentrations in upper Go Creek alluvial groundwater (~4 mg/L) in well MW05-1B.

Metal concentrations in wells MW05-7B and MW05-2A are present at very low concentrations. Iron concentrations at well MW05-2B are naturally elevated (~10 mg/L). The elevated iron concentrations were not observed in the shallow bedrock well MW05-2A, suggesting that alluvial and shallow bedrock aquifer does not appear to be hydraulically connected.

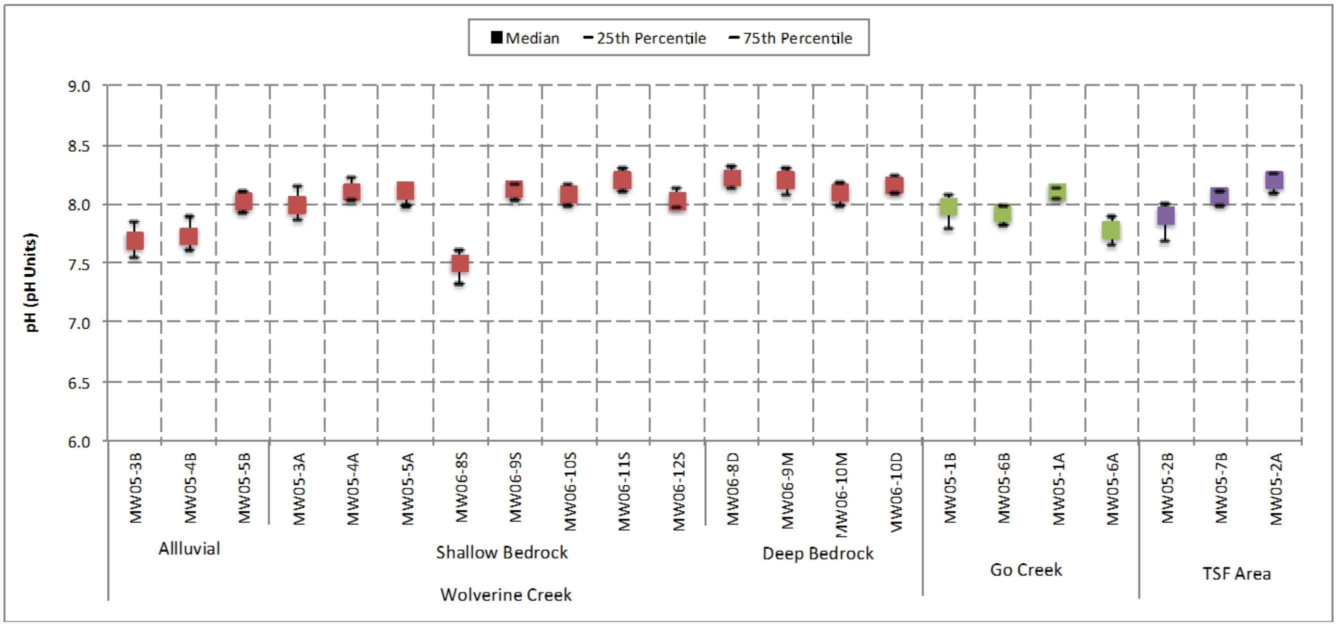


Figure 3-25: Groundwater Chemistry – pH (2009-2016)

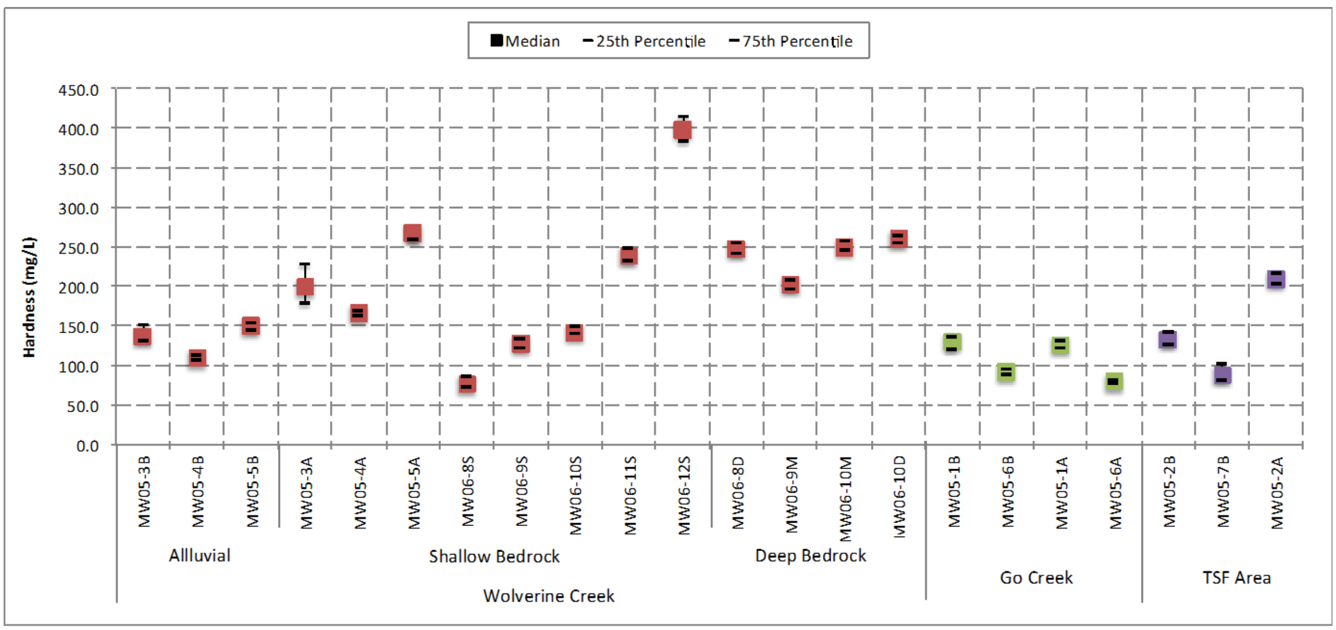


Figure 3-26: Groundwater Chemistry – Hardness (2009-2016)

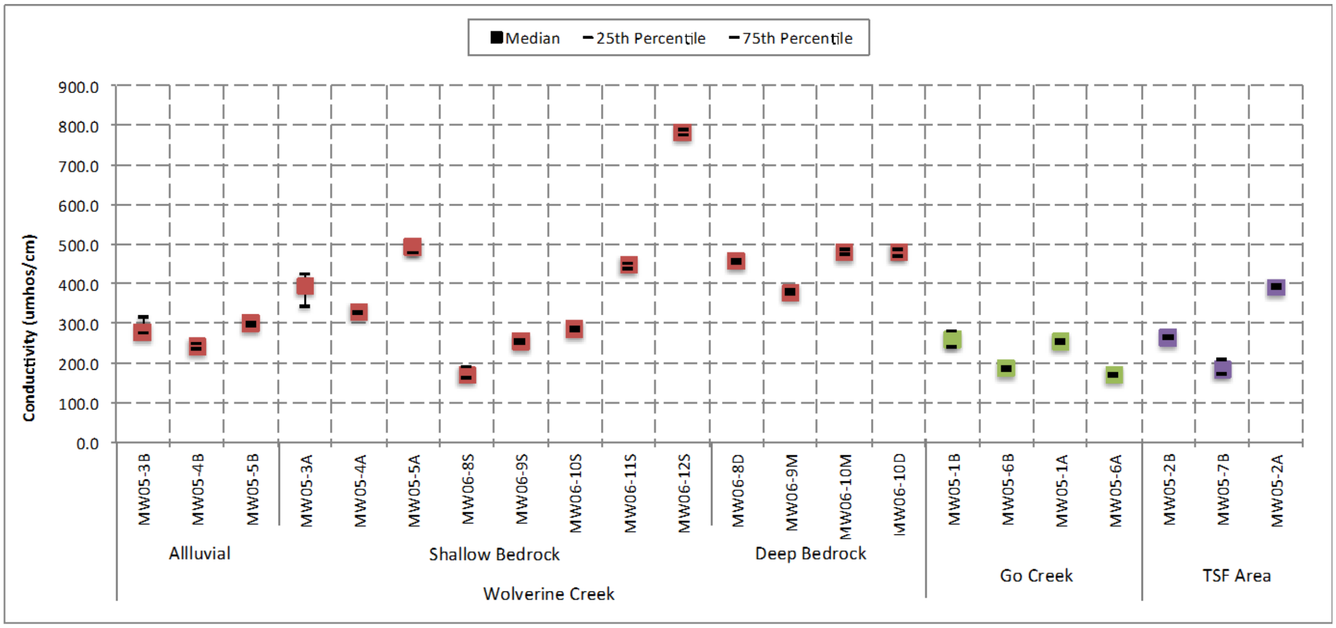


Figure 3-27: Groundwater Chemistry – Conductivity (2009-2016)

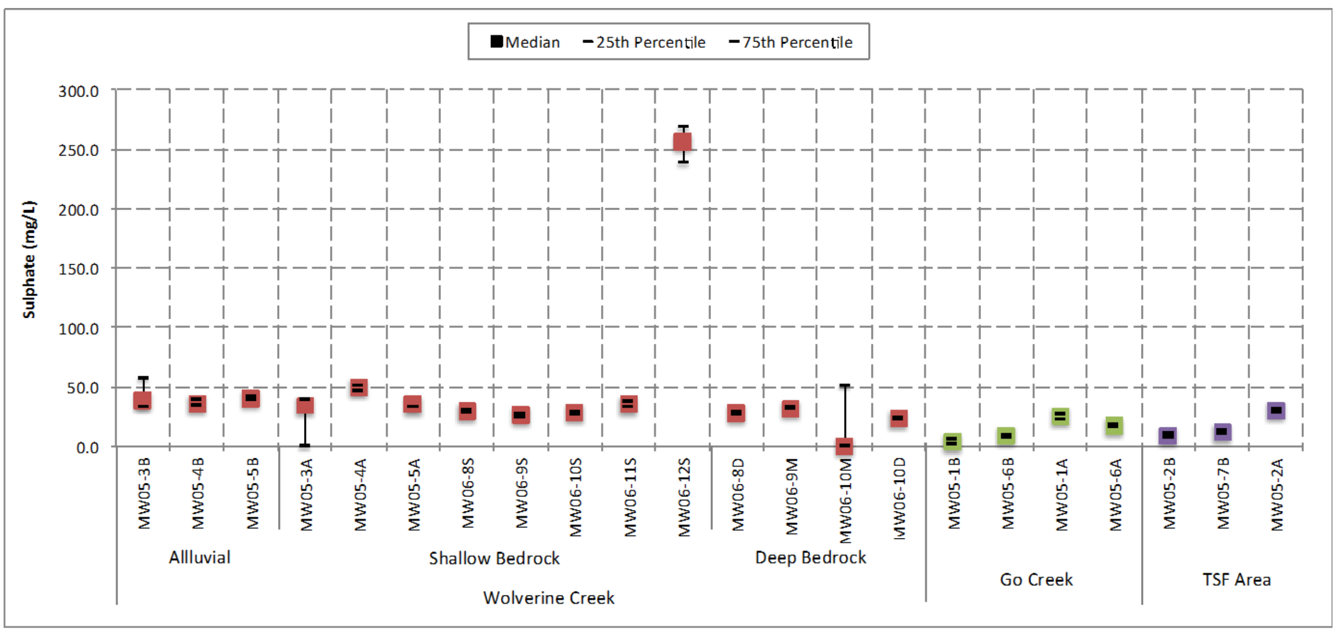


Figure 3-28: Groundwater Chemistry – Sulphate (2009-2016)

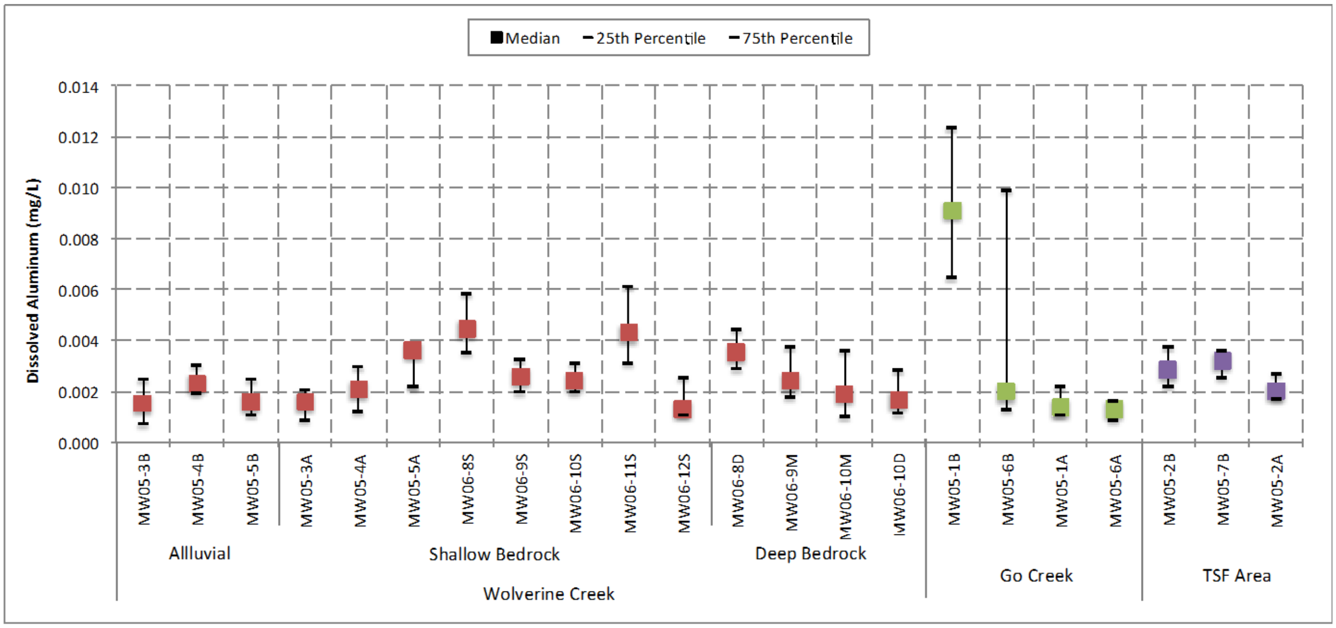


Figure 3-29: Groundwater Chemistry – Dissolved Aluminum (2009-2016)

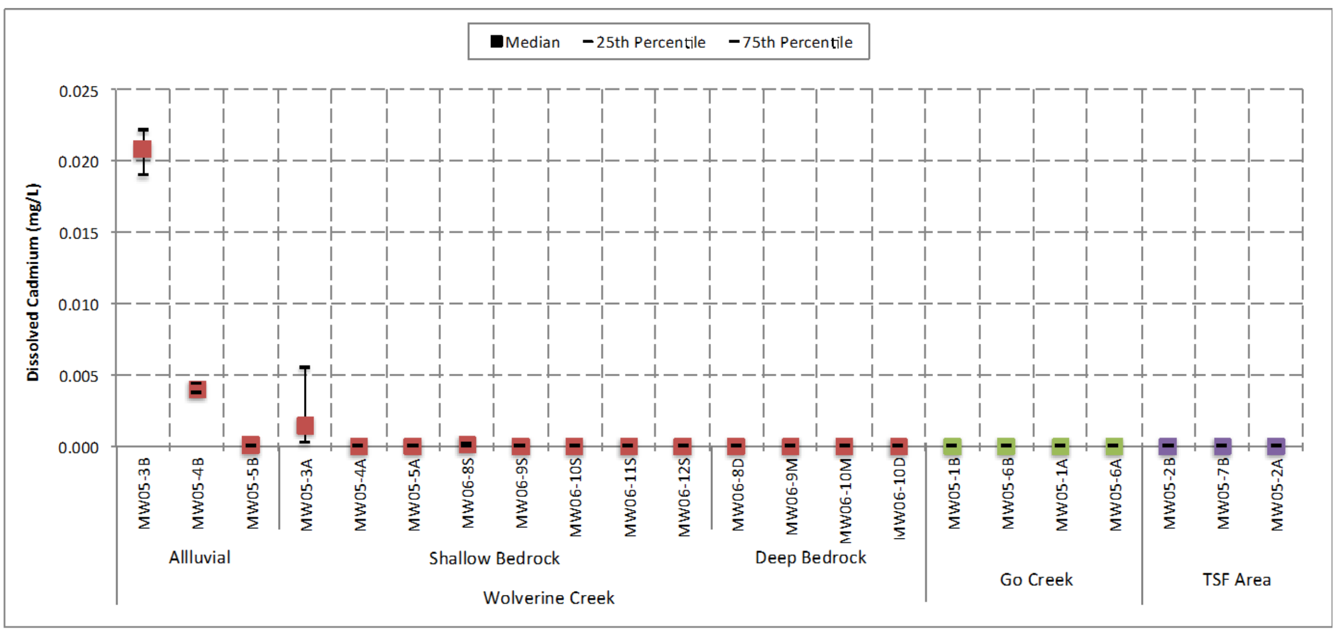


Figure 3-30: Groundwater Chemistry – Dissolved Cadmium (2009-2016)

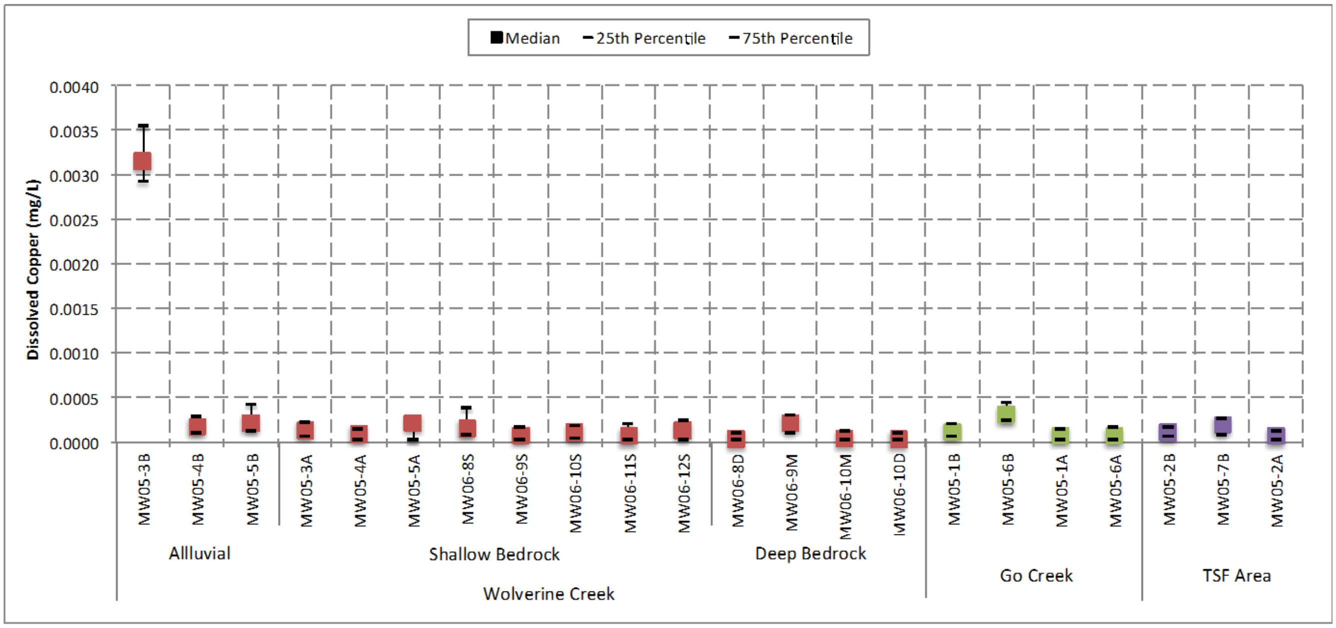


Figure 3-31: Groundwater Chemistry – Dissolved Copper (2009-2016)

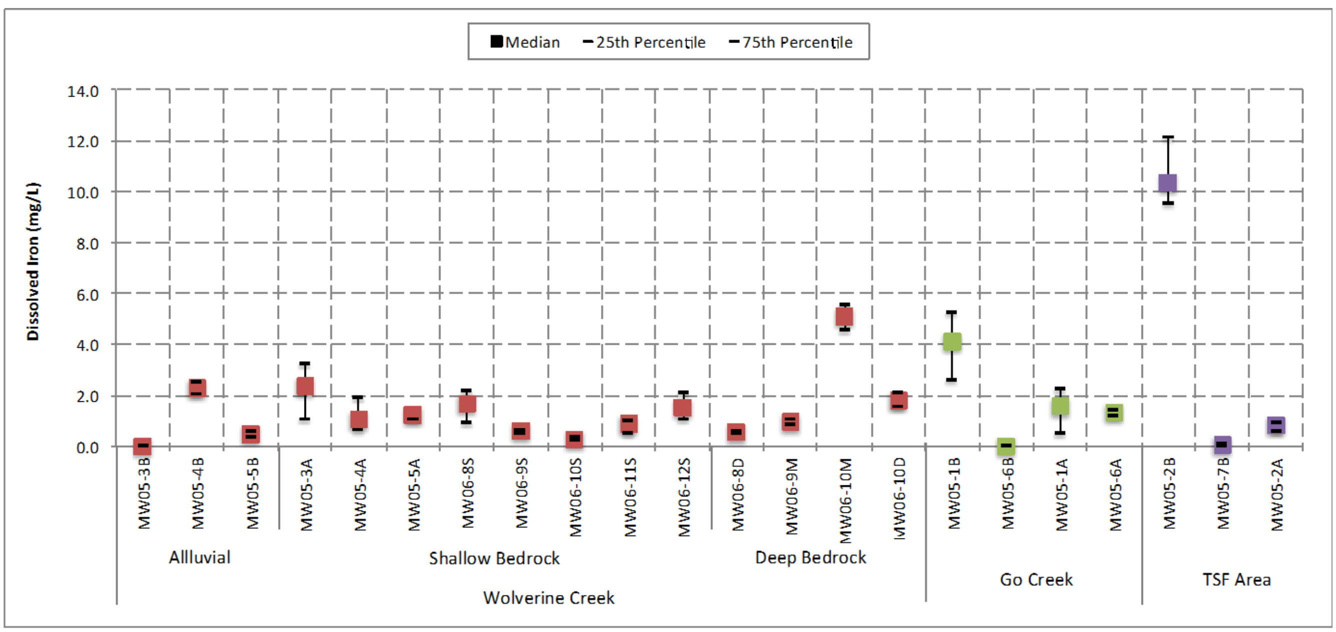


Figure 3-32: Groundwater Chemistry – Dissolved Iron (2009-2016)

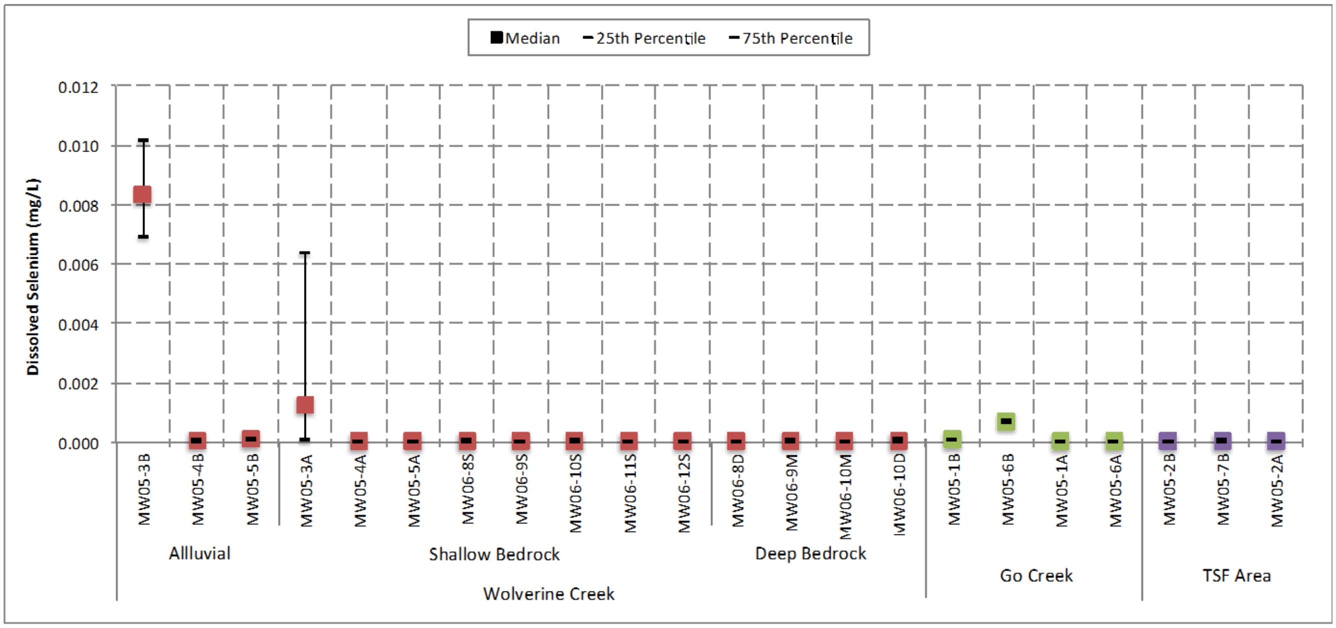


Figure 3-33: Groundwater Chemistry – Dissolved Selenium (2009-2016)

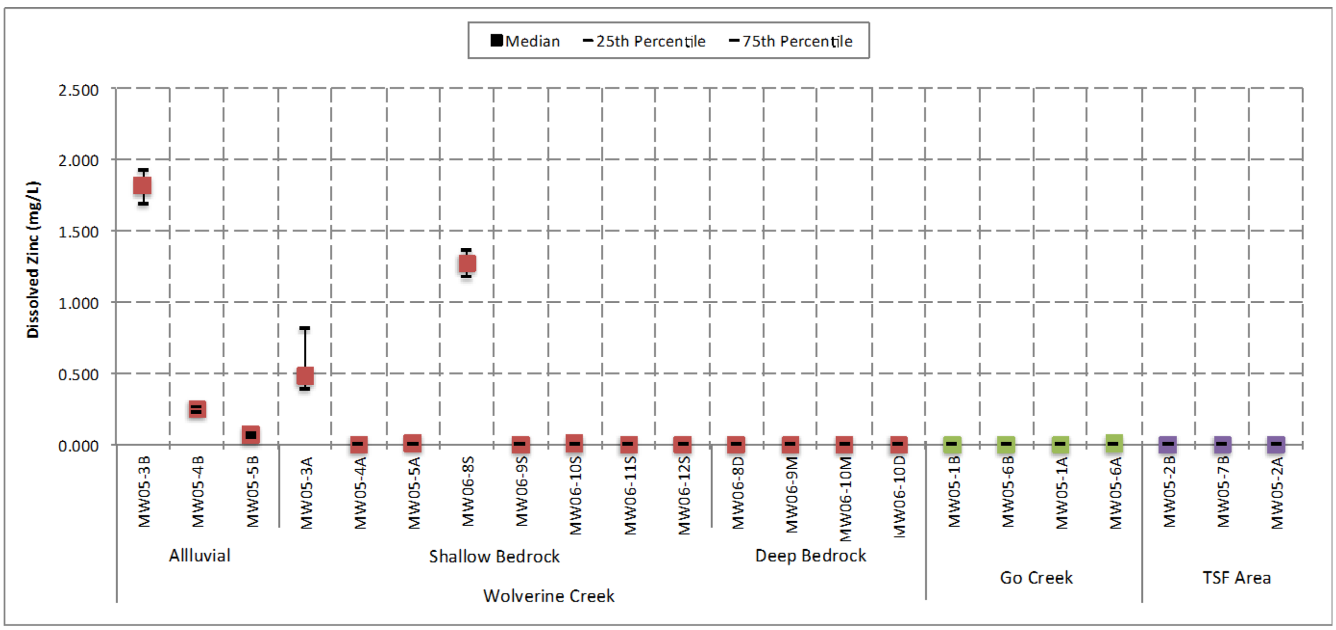


Figure 3-34: Groundwater Chemistry – Dissolved Zinc (2009-2016)

3.4 Vegetation and Wildlife

3.4.1 Aquatic Life

Aquatic life is monitored for the purposes of Metal Mine Effluent Regulations (MMER) Environmental Effects Monitoring (EEM), as per the *Fisheries Act*, at the locations shown in Figure 3-35.

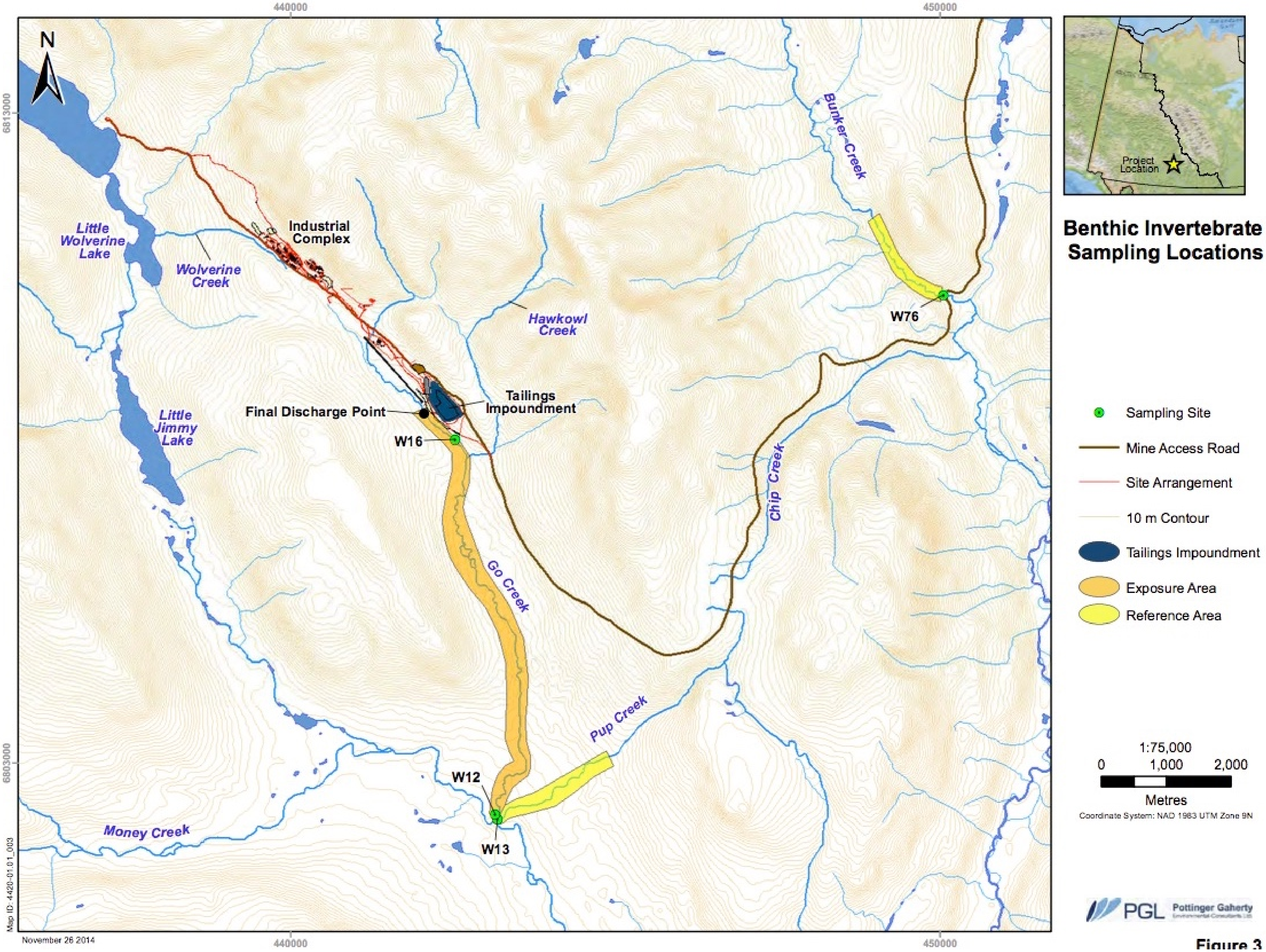


Figure 3-35: MMER EEM Monitoring Locations

Baseline fish surveys were carried out in 1996, 1997, 2004, 2005, and 2014. Results indicated "fish habitat in Money Creek is generally good, with varied in-stream features providing suitable habitat for most life stages of fish species expected to inhabit the area. Many of the first order tributaries to Money Creek (including Go, Pup, and Bunker Creeks) have fast flows and limited habitat diversity that likely limit spawning, rearing, and overwintering potential of these streams." (Lorax, 2014). Results of baseline electrofishing surveys in the exposure and reference areas are summarized in Table 3-1. The number of fish captured in each survey was low in all streams and slimy sculpin was the most abundant species at all sites. Other species encountered during baseline surveys included arctic grayling and bull trout. Snorkel surveys and minnow traps were used in 2014 in addition to electrofishing, but did not yield higher catch numbers.

Table 3-1: Results of Baseline Electrofishing Surveys in Go Creek, Pup Creek and Bunker Creek

Sampling Event	Location		Effort (s)	Species*	Number	CPUE** (#/min)
July 1996	Go Creek	Upper	299	n/a	0	0
		Mid	232	n/a	0	0
		Lower	1366	GR	4	0.176
				CCG	21	0.922
				BT	5	0.220
	Pup Creek	Lower	175	CCG	6	2.057
Sept. 1996	Go Creek	Lower	89	n/a	0	0
Oct. 2004	Pup Creek	Mid	487	n/a	0	0
	Bunker Creek	u/s of road	858	n/a	0	0
		Below road btw beaver dams	972	BT	2	0.123
		Below road d/s of beaver dam	1267	n/a	0	0
Aug. 2005	Go Creek	Upper	300	n/a	0	0
		Mid	1070	n/a	0	0
		Lower	2640	GR	4	0.091
				BT	4	0.091
				CCG	1	0.023
	Pup Creek	Lower	300	n/a	0	0
	Bunker Creek	u/s of road	1770	n/a	0	0
		Below road btw beaver dams	840	n/a	0	0
Sept. 2014	Go Creek	Mid/Upper	4198	BT	1	0.014
		Lower	3527	CCG	1	0.017
				BT	2	0.034
	Pup Creek	Near confluence with Go Creek	not specified	BT	16	n/a
	Bunker Creek	Mid (near bridge)	not specified	n/a	0	0

** GR = Arctic grayling (Thymallus arcticus)*
CCG = Slimy sculpin (Cottus cognatus)
BT = Bull trout (Salvelinus confluentus)
*** CPUE = Catch per Unit Effort*

3.4.2 Benthic Invertebrates and Periphyton

Benthic invertebrate and periphyton monitoring in the mine area was conducted in 1997, 2005, and 2007 in Wolverine Creek, Nougha Creek, Money Creek, Go Creek, Putt Creek, Bunker Creek, and a tributary to little

Jimmy Lake. Additional benthic invertebrate sampling was conducted in 2011 and 2014 as part of the EEM cycle 1 and cycle 2 programs.

Benthic invertebrate monitoring was conducted at two sites in Go Creek; a near field site (W16) close to where effluent discharge will eventually occur in upper Go Creek and a far field site (W12) in lower Go Creek just upstream of the confluence with Money Creek. Two reference sites were also monitored, one at the mouth of Pup Creek near Go Creek (W13), the other on Bunker Creek upstream of the road crossing (W76). Stream morphology was most similar between W16 and W13. Site W76 had substantially higher discharge rate than at W16 and W13, and embeddedness was lower at W76 (Lorax Environmental, 2011).

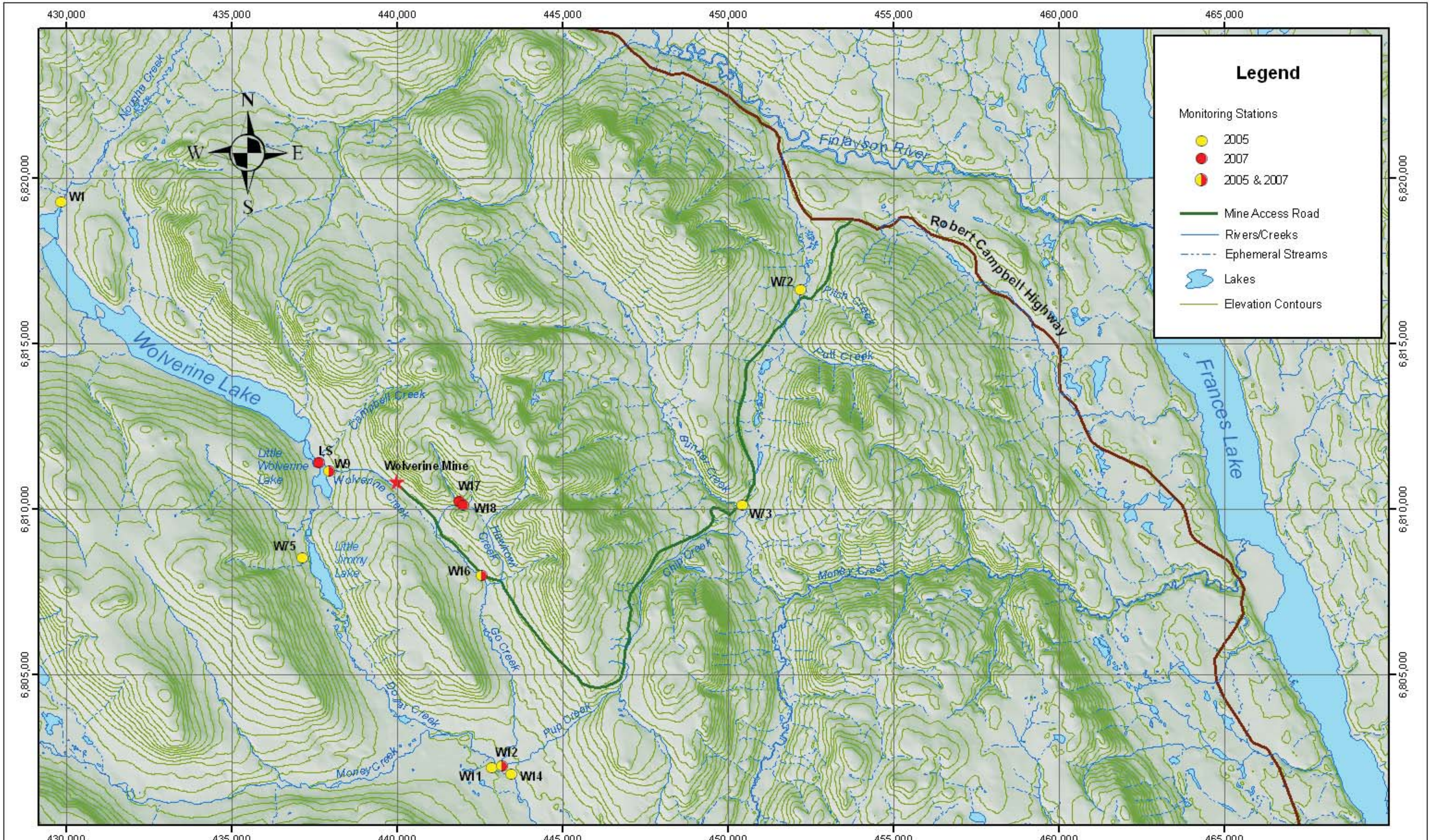
Five replicates of benthic invertebrate samples were collected at each site. Descriptive statistics and statistical endpoints were calculated at the family taxonomic level and the analysis of results is summarized in Table 3-2. Overall, differences were found to be fairly small when taken in an ecological context and not unusual for highly dynamic benthic invertebrate populations.

Table 3-2: Results of Benthic Surveys in Go Creek, Pup Creek and Bunker Creek

Community Indicators	September 2011 Study	September 2014 Study
Total invertebrate density	W12 < W16 = W13 = W76	W12 = W16 = W13 = W76
Mean family richness	W12 > W16 = W13 = W76	W12 = W76 > W16 = W13
Mean Simpson's evenness	W16 < W12 = W13 = W76	W12 < W16 = W13 + W76
Bray Curtis dissimilarity	W16 = W12 > W13 = W76	W12 > W16 = W13 > W76

Periphyton were sampled from riffle habitats in 2005 and 2007 at sites shown on Figure 3-36 (9 sites in 2005, 5 sites in 2007, 3 samples measured in both years). Samples were analyzed for chlorophyll *a* as a measure of biomass, and for taxonomic composition. There was high variability among the 3 replicates taken from each station, high variability among stations sampled in the same year, and high interannual variability at the same station.

Upper Go Creek had the highest average biomass of all the stations. Predominant periphyton and the filamentous red alga *Audouinella violacea* was present, as was moss. Taxonomic composition in Wolverine Creek had relatively low abundance of diatoms; predominant taxa were the colonial chrysophyte *Hydrurus foetidus* and crustose blue-green alga *Chamaesiphon* cf. *incrustans*.



0 1,000 2,000 4,000 6,000 Meters

Projection: UTM Zone 9, NAD 83

LORAX ENVIRONMENTAL

YukonZinc CORP

DESIGNED BY		
DWG. CHECK		
DRAWN BY	SSS	April 7, 2010
SCALE	1:110,000	
PROJECT NO.	474-3	

Baseline Characterization Report

Benthic Invertebrate and Periphyton Monitoring Stations

Figure 3-36

REV.

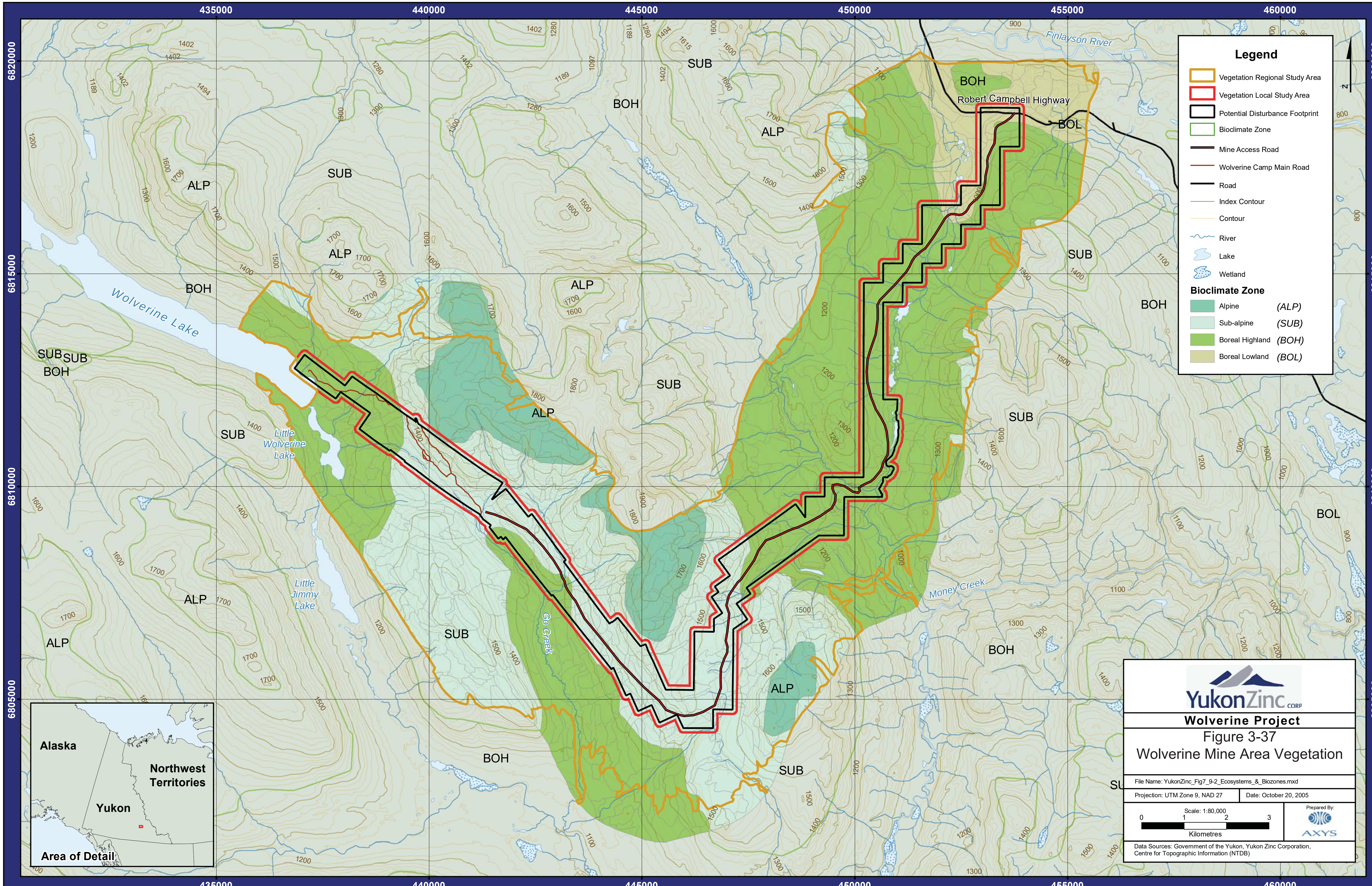
3.4.3 Vegetation

The Wolverine Mine lies within the Liard Basin and Pelly Mountains Ecoregions of the Boreal Cordillera Ecozone and abuts the Yukon Plateau-North Ecoregion (YZC, 2005). The area ranges from approximately 920-1900 masl and covers four elevation bioclimate zones: 'Boreal Lowland', 'Boreal Highland', 'Subalpine', and 'Alpine' (Figure 3-37). Much of the area around the mine is above the altitudinal treeline, which occurs between 1250 m and 1500 masl depending on exposure and cold air drainage and ponding. Discontinuous but widespread permafrost occurs throughout the area, particularly on north-facing slopes, under thick organic soil layers, and in bog complexes. Alpine soils are generally acidic and often show signs of cryoturbation (YZC, 2005).

Mixed stands of subalpine fir (*Abies lasiocarpa*) and white spruce (*Picea glauca*) dominate the landscape of the mine area. These tree species typically occur in open stands with varying understory characteristics depending on soil texture and microclimatic factors. Feathermosses are common understory components in mesic areas with fruiticose lichens becoming the dominant cryptograms in drier sites. Dense trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera ssp. balsamifera*) stands also occur; such stands are usually disturbance initiated and early successional. Black spruce (*Picea mariana*) is the dominant tree species of bogs and bog complexes and occurs primarily in open stands on thick organic soils. Some black spruce stands also occur in upland sites on mineral or thin organic soils and with subalpine fir stands in the project area. Open subalpine fir stands are predominant at and immediately below treeline with individuals becoming krummholz or decumbent at the treeline. Dwarf birch (*Betula glandulosa*)-dominated communities become dominant immediately above the treeline and commonly co-occur with willows and/or ericaceous shrubs. At higher elevations, these communities gradually give way to alpine dwarf-shrub heath and herb communities with various species compositions that are influenced by soil texture (granitic vs. sedimentary). Extreme elevations and aspects are vegetated primarily by lichen or lichen-dwarf shrub communities (YZC, 2005).

3.4.4 Wildlife

Habitats in the vicinity of the Wolverine Mine support a number of wildlife species including woodland caribou, moose, black bear, grizzly bear, wolf, fox, coyote, wolverine, marten, mink, lynx, river otter, beaver, small mammals, raptors, ptarmigan, waterfowl, shorebirds, and a variety of forest songbirds. The Finlayson Lake/River area and the east slope of the Pelly Mountains are part of the Tintina Trench migration corridor and are used extensively by waterfowl and shorebirds including trumpeter swan and sand hill crane on their north-south migration (Sinclair *et al*., 2003). The lakes and small pond-wetland complexes in the region provide breeding and migratory habitat for waterfowl, shorebirds, and other species. The mine site is situated in the southeast portion of the Finlayson Caribou Herd range (YZC, 2009).



Legend
Vegetation Regional Study Area
Vegetation Local Study Area
Potential Disturbance Footprint
Bioclimate Zone
Mine Access Road
Wolverine Camp Main Road
Road
Index Contour
Contour
River
Lake
Wetland
Bioclimate Zone
Alpine (ALP)
Sub-alpine (SUB)
Boreal Highland (BOH)
Boreal Lowland (BOL)
Wolverine Lake
Little Wolverine Lake
Little Jimmy Lake
Go Creek
Money Creek
Finlayson River
Robert Campbell Highway
Alaska
Northwest Territories
Yukon
Area of Detail
YukonZinc CORP
Wolverine Project
Figure 3-37
Wolverine Mine Area Vegetation
File Name: YukonZinc_Fig7_9-2_Ecosystems_&_Biozones.mxd
Projection: UTM Zone 9, NAD 27
Date: October 20, 2005
Scale: 1:80,000
0 1 2 3
Kilometres
Prepared By:
AXYS
Data Sources: Government of the Yukon, Yukon Zinc Corporation, Centre for Topographic Information (NTDB)
435000
440000
445000
450000
455000
460000
6820000
6815000
6810000
6805000

3.5 Soil and Bedrock

The Wolverine Mine is located in the Campbell Range, at the easternmost limit of the Pelly Mountains and abuts the broad Yukon Plateau to the north and east. The area consists of rolling, glacially scoured mountains with no significant peaks. Elevations on the property range approximately between 1200 and 1400 masl. The main valleys are wide and U-shaped. Glacial till covers the majority of the lower lying valleys and there is significant infilling by post-glacial sediments.

The Wolverine Lake area lies within the limits of the McConnell Glaciation (youngest of the four glaciations in Yukon Territory) and most of the geomorphic features in the area are related to this glaciation. McConnell glacial ice covered this area between 14,000 and 35,000 years ago. As the McConnell ice retreated and down-wasted, a complex network of ice tongues developed in valley bottoms. Morainal deposits are found at lower to mid-elevation and valley floors and may contain a more complex assemblage of glacio-fluvial, colluvial, and fluvial sediments (Mougeot, 1996).

Regional geology is provided in Figure 3-38. The soil map (along with legend) for the mine area is provided in Figure 3-39. The main glacial soils in the vicinity of the tailings impoundment consist of up to 20 m of silty, sand and gravel, with cobbles. The area is underlain by bedrock strata generally paralleling the valley trend, i.e., striking in the direction of the valley. The bedrock consists of an interlayered sequence of volcanoclastic (rhyolite and quartz feldspar) and carbonaceous/argillic sediments, overlain with basalt. The iron formation, which hosts the ore zone, trends northwest-southeast throughout the Wolverine Mine area.

3.5.1 Permafrost

The Wolverine Mine is located within a zone of discontinuous permafrost (Burn, 2002). Cryoturbated soils are evident in the floodplain immediately east of the airstrip and in all alpine areas (Axys Environmental Consulting Ltd., 2005). Periglacial processes were found in the alpine areas of this study, including solifluction lobes, blockfields, sorted polygons, stripes and pushed up stones. Ground ice was also found overlain by organic materials in one of the high elevation soil profiles sampled. A thermokarst feature (Figure 3-39) was found in the glaciolacustrine materials of Putt Creek. In general, permafrost is more or less continuous in the alpine areas (mountain tops) and discontinuous in the upper elevational valleys and the headwaters of Go Creek. Permafrost was not encountered in the TSF area during construction in 2009; further, borrow from the impoundment area did not encounter any frost (Klohn Crippen Berger, 2010).

Along the road, the intersection with the Campbell Highway was relocated to km 190.0 of the Campbell Highway in order to avoid permafrost. Ice content within the discontinuous permafrost in the area towards Putt Creek (from km 0.7 to km 2.9) was found to be generally less than 10% in granular soils. Frozen soil (permafrost) conditions were associated with thick organic cover, most of which are characterized as open, shallow gradient sideslope bog areas with black spruce/moss/larch vegetation.

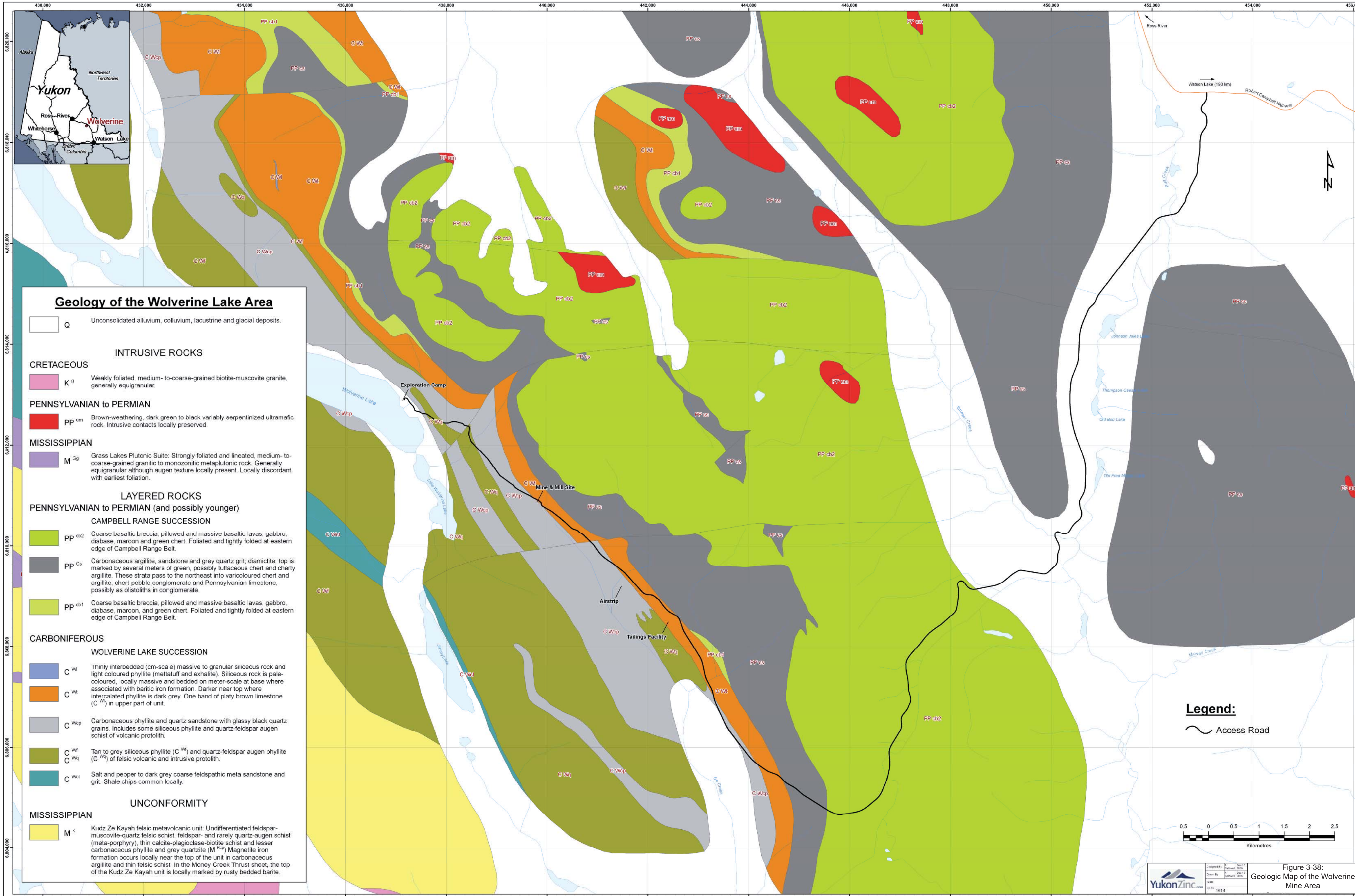


Figure 3-38: Geologic Map of the Wolverine Mine Area

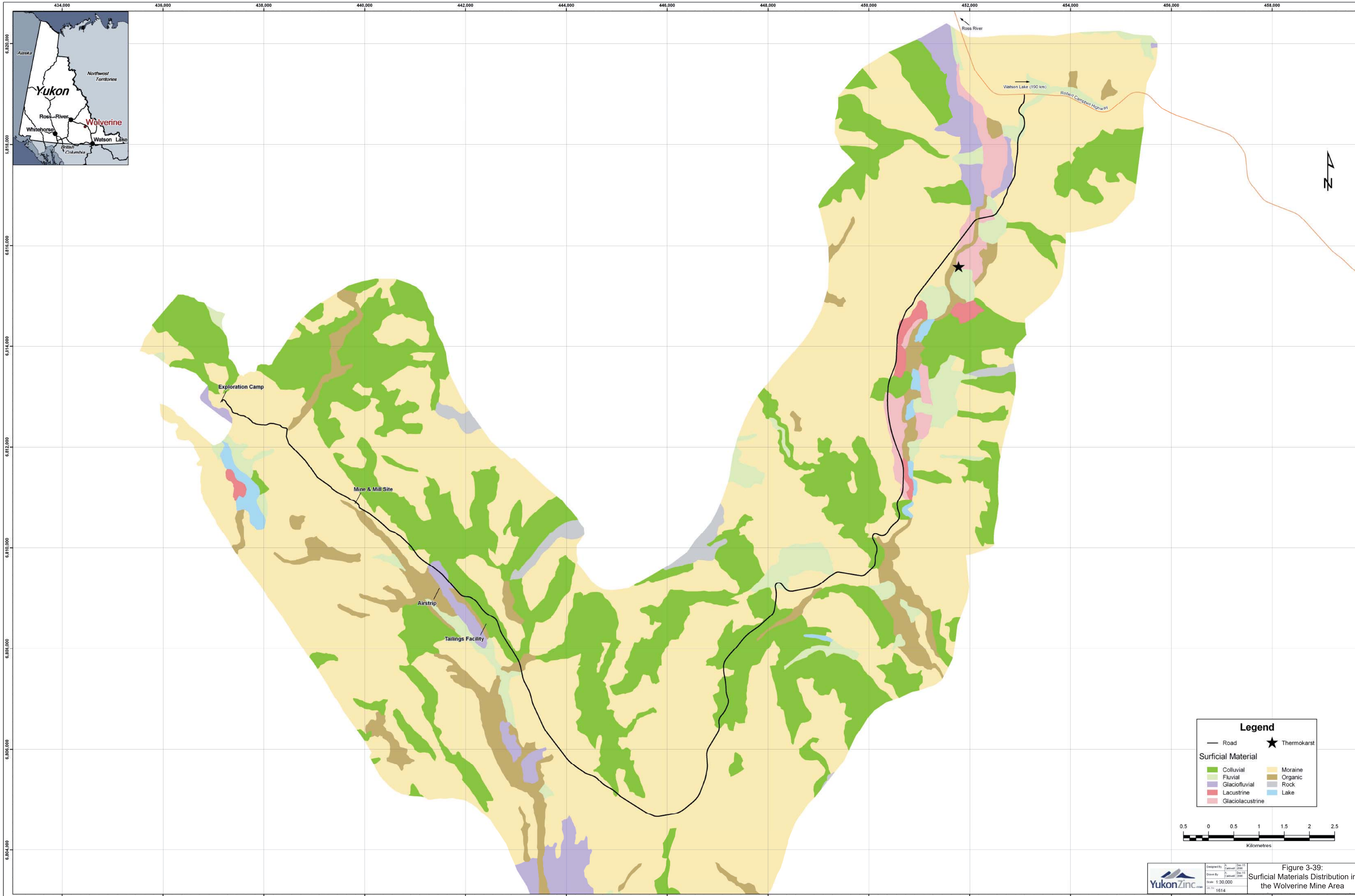
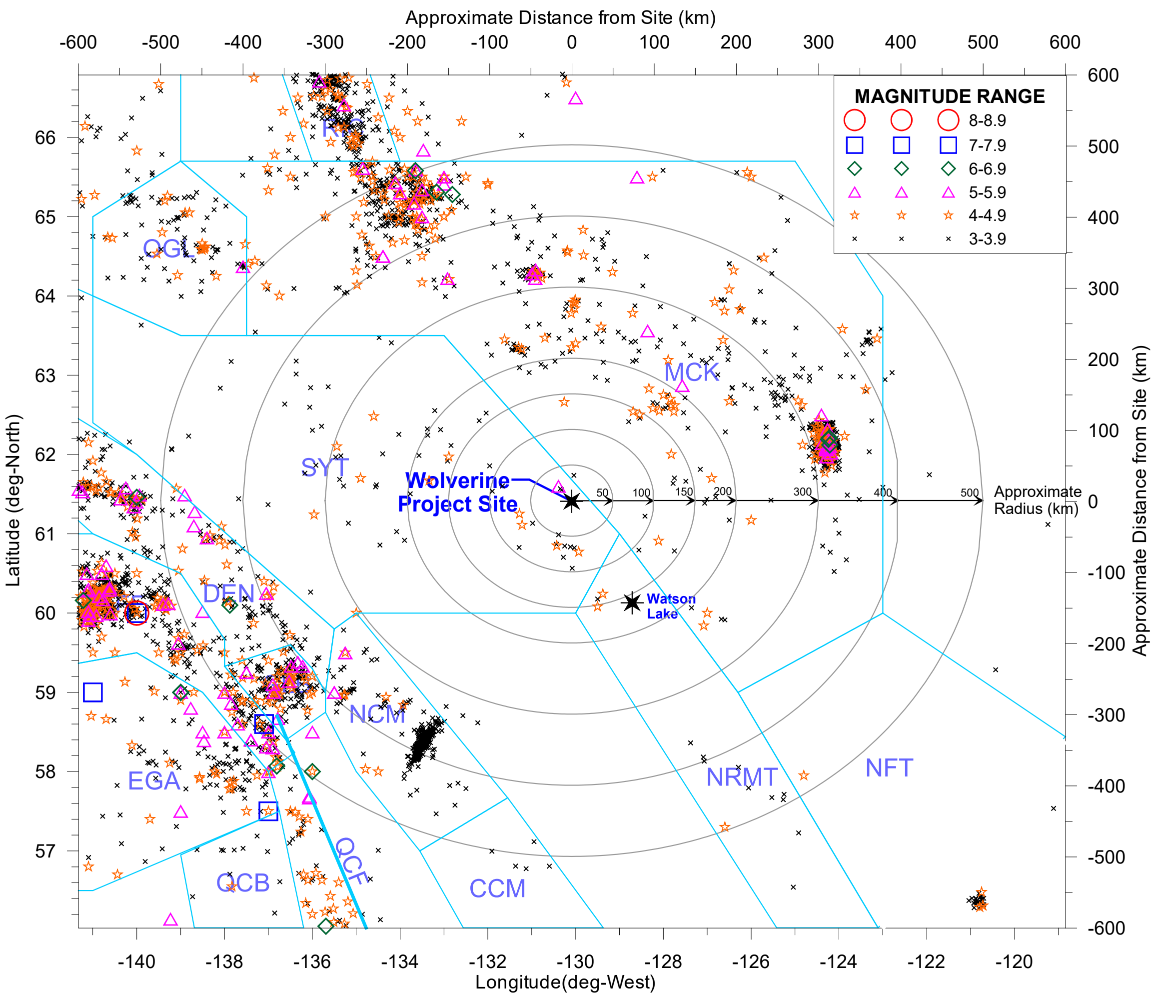


Figure 3-39: Surficial Materials Distribution in the Wolverine Mine Area

3.6 Seismicity

The most seismically active region near the Wolverine Mine area is along the plate boundaries in the coastal and offshore area. The most significant inland seismicity occurs along segments of the Denali fault zone system, where the seismicity rate is an order of magnitude lower than that in the coastal region. The region between the Denali and Tintina systems is relatively a seismic, with relatively few and small earthquakes.

Data on recent earthquakes that occurred within about 600 km from the mine site (61.41°N and 130.09°W) from September 1899 to December 2005 was extracted from the Canadian Earth Physics Branch/Geological Survey of Canada/Western Canada-Pacific Geoscience Centre database and are shown on Figure 3-40. No earthquakes with magnitude greater than 5 have occurred within 200 km from the site. However, a magnitude 5 event did occur about 28 km northwest of the mine site with a focal depth of 5 km on May 12, 1999.



Notes:
1. Only earthquakes with magnitude M > 3 within a grid of 56.03° N-66.79° N and 118.84° W-141.33° W and from September 1899 to December 2005 are shown.
2. Epicentre data taken from Canadian EPB/GSC/PGC database and
3. Distances from project site are approximate, assuming one degree of latitude and longitude as 111.43 km and 53.37 km, respectively.

GSC-H Model Seismic Souce Zone Boundary
SYT GSC-H Model Seismic Source Zones

Figure 3-40: Map of Recent Regional Epicentres Near the Wolverine Mine

4 Project Description

4.1 Mine Features, Facilities and Equipment

The location of the Wolverine Mine in Yukon is shown in Figure 1-1. Arial views of the TSF area and industrial complex are shown in Figure 4-1 and Figure 4-2, respectively; while the general mine site layout of is illustrated in Figure 4-3. Figure 4-4 and Figure 4-5 provide the layouts for the industrial complex and TSF areas, respectively. Mine infrastructure remains in place during temporary closure and is described further below. Temporary closure conditions are described further in Section 5. The surface facilities and infrastructure at the Wolverine Mine include the following:

- TSF;
- Seepage collection pond;
- Waste rock storage piles;
- Industrial complex and camp;
- Land Treatment Facility (LTF);
- Landfill;
- Mine roads;
- Airstrip; and
- Site access road.

Figure 4-1: Tailings Storage Facility (TSF) Layout

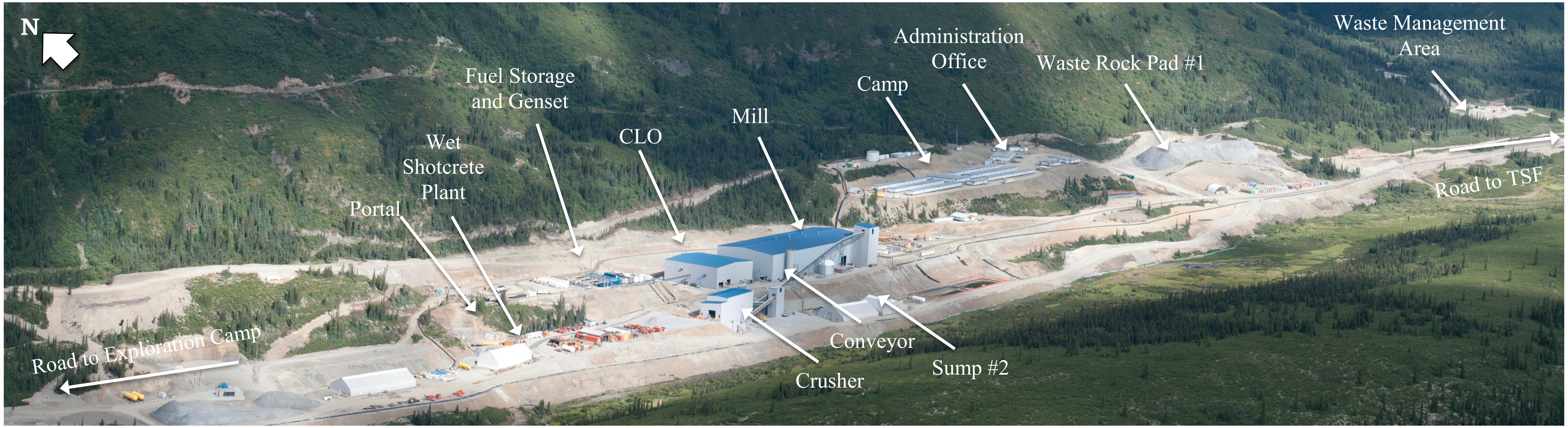


Figure 4-2: Industrial Complex Layout

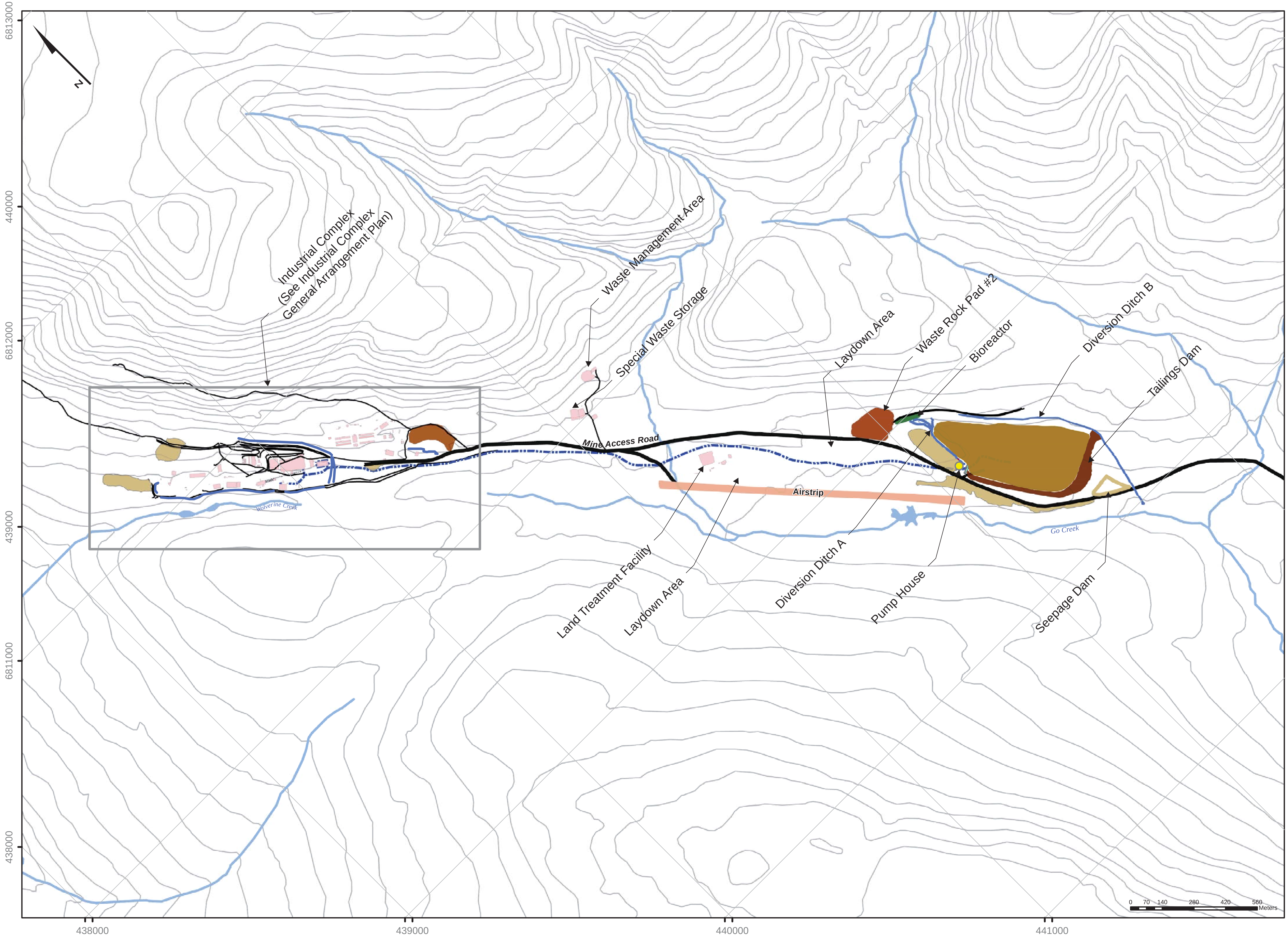


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Figure 4-3

Wolverine Mine:
Site Location
General Arrangement

- Existing Road
- Mine Access Road
- Winter Road
- Tailings Pipeline
- Culvert
- Diversion Ditch
- Infrastructure
- Seepage Collection Pond
- Spillway Stage 2
- Pump House
- Bioreactor
- Airstrip
- Organic Stockpile
- Waste Rock Pad

Date: 22/12/2016
Author: H.Seeley, P.Geo, Wolfbear Geological Consulting

Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

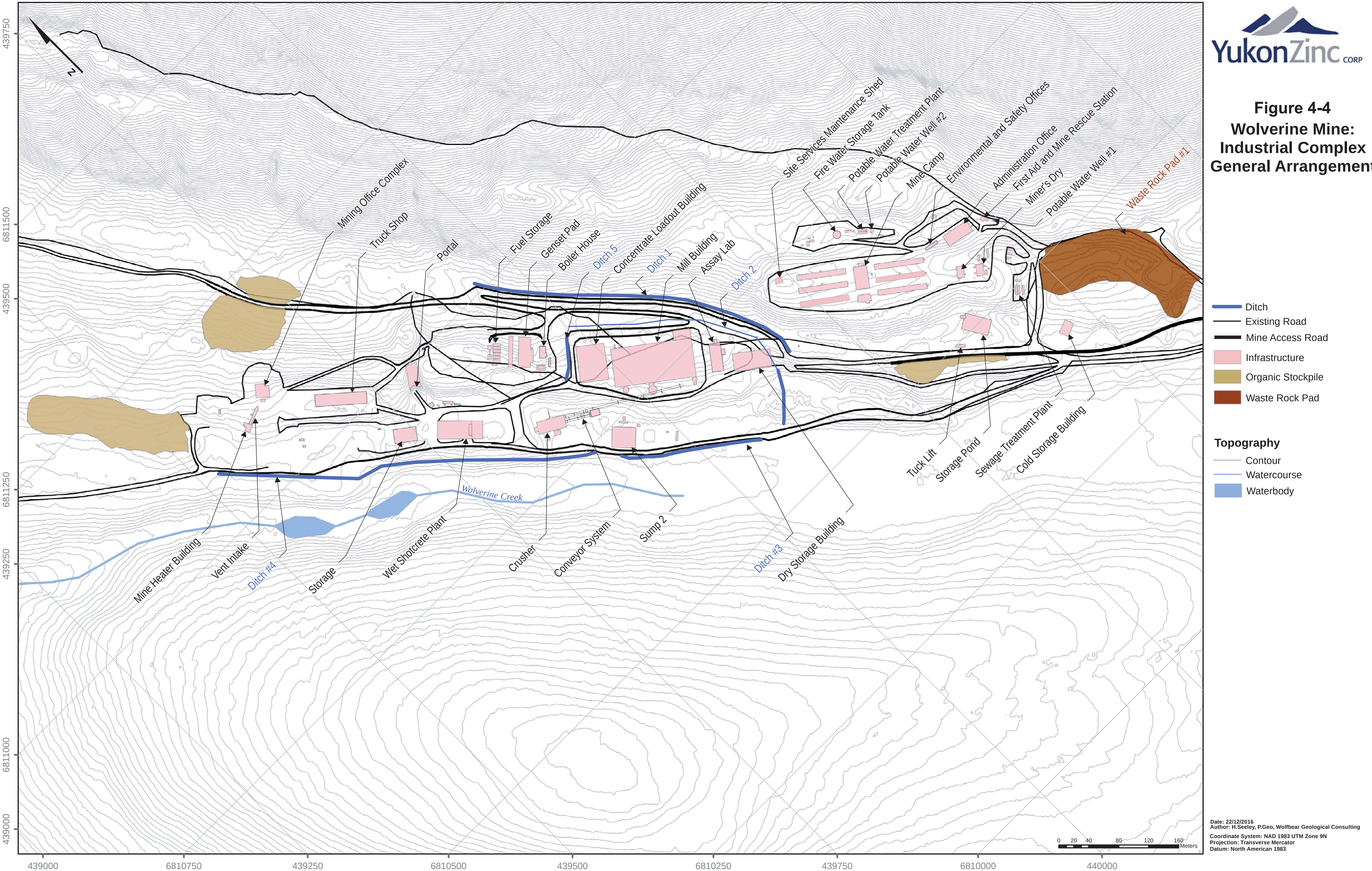


Figure 4-4
Wolverine Mine: Industrial Complex General Arrangement

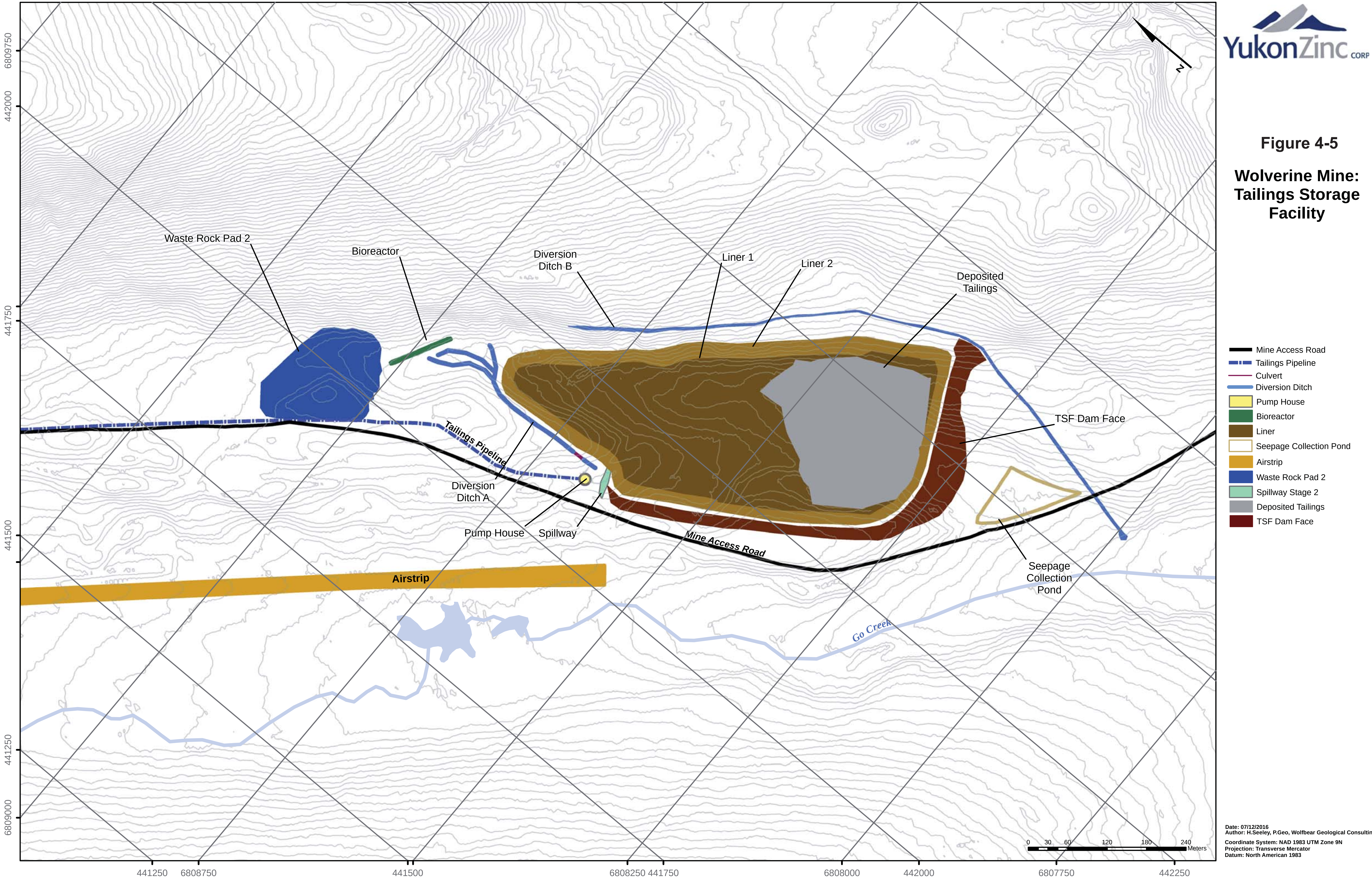


Figure 4-5

Wolverine Mine: Tailings Storage Facility

The Wolverine Mine is accessed by a private, 24 km single-lane gravel road with passing bays, connected to the Robert Campbell Highway at km 190. The site access road is restricted by a gate and the road is operated under radio control. The road can be used year-round, subject to snow clearing activities, with minimal load restrictions. Alternate access to the mine site is via a gravel airstrip on site. The airstrip is 1,340 m long, which enables a twin engine aircraft to land on the airstrip with a full passenger load. The airstrip is intended for restricted use only under Visual Flight Rules and is maintained and used year-round.

Diesel fuel for the site power generators and associated operating equipment is supplied from six diesel fuel storage tanks (75,000 L capacity each) and an 8,500 L gasoline tank. Storage is based on two weeks of reserve during normal operations in the event of road problems and/or use restrictions. A fuel truck transports diesel fuel and lubricants to mobile equipment as required.

On-site power generation is provided by eight diesel generator sets, each rated 1,200 rpm, 1.26 MW continuous, 1.45 MW prime power generating at 4,160 V for a total installed generating capacity of 10.08 MW continuous, 11.60 MW prime power. In addition, a number of standby generators are present on site in varying capacities. Fuel requirements during temporary closure have been minimized to reduce fuel consumption.

The underground mine is accessed by a surface ramp that extends from approximately 1,345 masl (the portal entrance) to 1,115 masl (the current lowest elevation). Additional access is through a ventilation raise that has an evacuation route. The underground mine is currently flooding passively with groundwater recharge and is inaccessible. A 2015 geotechnical survey of the main access ramp revealed a number of potential ramp support failures that need to be addressed before the ramp can be safely used. The only pieces of equipment remaining in the underground mine are the electrical transformers, switch gear and communications equipment, a single refuge station, and some pumps and fans.

The process facilities consist of a crusher building, mill building, and concentrate load out facility (CLO). Feed conveyors connect the crusher building to the mill and transport crushed ore to the rod and ball mills. Ancillary facilities include a wet shotcrete plant, assay laboratory, mining office complex, truck shop and camp. Camp infrastructure at the Wolverine Mine consists of six 41-man dormitories, a kitchen, recreation hall, administration office, first aid office, mine rescue station, and dry facilities. Additional support infrastructure includes a maintenance workshop, training room, firewater tank, potable water treatment plant, communication station, and sewage treatment plant.

During mining operations, water from the underground workings and the tailings slurry from the milling process is pumped to the TSF and reclaimed water from the TSF is pumped back to the mill for process water use The TSF is a compacted homogeneous earthfill dam with an impervious geosynthetic liner, built in two stages. The liner covers the base of the TSF impoundment and the upstream face of the dam to the crest. A seepage collection dam downstream of the main dam collects seepage water to be returned to the TSF, or settled prior to discharge into the Go Creek drainage. During temporary closure, the mill is not operational and groundwater discharge is stored in the underground mine. Therefore, the only inputs to the TSF are precipitation and surface runoff collected in sumps at the industrial complex, Waste Rock Pad #1, Waste Rock Pad #2 and at the seepage pond.

Waste rock from the mine is stored on two designated waste rock pads (Waste Rock Pad #1 and #2). Waste Rock Pad #1, located southeast of the camp, was constructed in 2005 to hold development waste prior to operations. Waste Rock Pad #2, located north of the TSF, was constructed in 2011 and holds development waste rock and ore that was not processed prior to the shut down of the mining operations.

4.2 History of Mining Operations

Exploration of the Wolverine Mine area commenced in the early 1970s. In early 2005 a Type B Water Use Licence (QZ01-051) and a Mining Land Use Permit (LQ00140) were issued for advanced exploration activities. Under these approvals, YZC completed test mining and detailed infill diamond drilling programs. QML-0006 and WUL QZ04-065 were issued in December 2006 and October 2007, respectively, for the development and operation of the mine.

The Wolverine Mine was designed to operate 365 days per year, 24 hours per day at 1700 tpd of mill feed ore. Project manpower during normal operations requires approximately 370 workers, working on a two-shift basis, with approximately 190 people on site at any one time. The total tonnage mined to date is shown in Table 4-1. The “paste” column indicates tailings returned to the underground mine as paste backfill.

Table 4-1: Mining and Milling Activities Summary

Year	Mined Ore (t)	Milled Ore (t)	Concentrate (t)	Paste (t)	Tailings (t)
2010	26,826	0	0	0	0
2011	142,315	153,352	26,723	0	126,629
2012	441,095	428,955	82,486	86,506	259,963
2013	505,942	419,625	112,629	146,903	260,093
2014	443,867	413,879	100,952	134,502	196,425
2015	35,207	19,594	6,095	2,927	10,572
2016	0	0	0	0	0
Total	**1,595,253**	**1,553,405**	**328,885**	**370,838**	**853,682**

During operations, metal concentrates produced by the milling process were trucked south on the Robert Campbell Highway. Concentrate trucks travelled via Watson Lake to the Stewart Bulk Terminal in Stewart, BC for transportation via ocean freighter to various smelters in Asia.

5 Temporary Closure

This section presents the Temporary Closure Plan (TCP) for the Wolverine Mine and represents the current program of work being carried out by YZC until January 2018. The focus of the TCP is to maintain the physical and chemical stability of the Wolverine Mine site, limit liability, and minimize water inputs to the TSF in order to maintain storage capacity and ultimately limit the volume of water requiring treatment in the TSF.

Given that the Wolverine Mine is currently in the temporary closure phase, this TCP details activities that have been completed or are ongoing as part of temporary closure and activities that are planned for the duration of the temporary closure phase, in place of a theoretical plan. A significant amount of clean up and closure work has been completed since operations were halted in January 2015.

Temporary closure activities that have been undertaken to date include:

- Decommissioning and reclaiming the exploration camp area and roads (COMPLETED);
- Consolidating all temporary ore and waste stockpiles to Waste Rock Pad #2 (COMPLETED);

- Constructing a bioreactor water treatment system between Waste Rock Pad #2 and the TSF (COMPLETED);
- Conducting bathymetric surveys of the TSF in 2015 and 2016 (COMPLETED);
- Characterizing of the free water in the TSF (COMPLETED);
- Conducting annual engineering inspections in 2015 and 2016 (COMPLETED);
- Monitoring water level in the underground mine workings (ONGOING);
- Transporting all reagents off site (ONGOING);
- Reclamation land preparation and seeding of areas in the project footprint (ONGOING);
- Maintaining the airstrip and mine roads (ONGOING); and
- Conducting environmental monitoring, including surface water, groundwater, and wildlife (ONGOING).

Proposed and ongoing temporary closure measures are described further below.

5.1 Site Security, Monitoring and Maintenance

5.1.1 Site Security

Since the cessation of mining activities in January 2015, the care and maintenance crew has consolidated mine supplies, including chemicals and equipment to ensure the safety and security of the site. The site is operated by a 3-person care and maintenance crew and access to the site is controlled by a gate on the site access road at the intersection with the Robert Campbell Highway.

There is currenlty no zinc concentrate remaining on site and there are less than 20 bags of lead and copper concentrate remaining to be shipped off site by the purchaser. The CLO has been swept and cleaned out; while the majority of reagents have been removed from site, some are awaiting transportation and are securetly stored in the CLO. The remaining lime is also securely packaged and stored in sealed freight containers on the site. This lime is intended to be used to advance reclamation and closure efforts, over the next 5 years.

No explosives remain on site. The explosives magazines have been emptied, the explosives burned, and the licences returned to Yukon Worker's Compensation Health and Safety Board to be held for YZC.

The existing fuel storage facilities are used in temporary closure and are comprised of six 75,000 L tanks (450,000 L total storage). This is sufficient to supply the smaller gensets as well as the mobile equipment through the 6-month winter period. With sufficient on-site fuel storage capacity for the winter period it is not necessary to keep the site access road open and maintained, which further reduces the site maintenance requirements during temporary closure.

In the event of hazardous substance spill, spill response follows the approved *Spill Contingency Plan* (V2010-03). The Wolverine Mine is equipped with spill response kits at various locations around the site:

- Industrial complex;
- Fuel storage tanks;
- Camp; and
- Airstrip.

5.1.2 Monitoring Activities

Environmental monitoring is conducted to reflect the lower risk of the limited temporary closure activities. Ongoing monitoring consists of monthly and quarterly surface and ground water monitoring, vegetation and wildlife monitoring, and climate monitoring. Periodic monitoring includes monitoring of the TSF and annual geotechnical inspections.

5.1.2.1 Surface Water and Groundwater Monitoring

Water quality monitoring is conducted at surface water stations, groundwater stations, and via piezometric installations above the underground mine. Water chemistry and hydrological results from this monitoring are compared to historical data and the allowable discharge limits outlined in the WUL, and findings are presented in monthly and annual reports to EMR and YWB. Water quality results are also compared to triggers outlined in the *Wolverine Creek Adaptive Management Plan*, to ensure the protection of the environment. Monitoring of experimental test systems is also conducted to establish treatment effectiveness. These water monitoring programs are described below.

Surface Water Quality Monitoring

Surface water monitoring during temporary closure includes surface water quality and hydrological monitoring in the Wolverine and Go Creek watersheds. The surface water quality sampling program is outlined in Table 5-1 at stations shown on Figure 3-2. Quarterly surface water sampling is undertaken for those sites easily accessed year round and seasonal sampling is undertaken for those sites only accessible via the site access road, which is closed in winter.

Table 5-1: Surface Water Sampling Program During Temporary Closure

Station Number	Station Location	Watershed	Sampling Frequency
T1	Tailings Barge	TSF	Quarterly
W82*	Upper Wolverine Creek	Wolverine Creek	Quarterly
W9*	Wolverine Creek at Little Wolverine Lake		Quarterly
L1	Little Wolverine Lake	Little Wolverine Lake	Quarterly
W15	Hawkowl Creek above Go Creek	Go Creek	Quarterly
W81*	Go Creek below Hawkowl Creek		Quarterly
W31	Go Creek above TSF		Quarterly
W80*	Go Creek		Quarterly
W22	Money Creek above Robert Campbell Highway	Money Creek	Seasonally
W71	Pitch Creek below road crossing	Site Access Road	Seasonally
W72	Light Creek		Seasonally
W73	Bunker Creek at road crossing		Seasonally

*Weekly samples are collected when discharging any water into Go Creek or Wolverine Creek

Bioreactor Water Quality Monitoring

At the time of writing, there was one active bioreactor on site: between Waste Rock Pad #2 and the TSF (see Section 5.2.2). Another bioreactor is planned to be constructed during temporary closure at the outlet of the underground mine workings, discharging to sump #2 (see Section 5.2.1). Water quality at the inlets and outlets of these bioreactors will be monitored during snow free conditions. This will ensure that they are functioning as designed and ensure suitable water quality at the outlets.

Groundwater Monitoring

The groundwater monitoring program during temporary closure includes monitoring water level, temperature, and water quality at 24 locations in alluvial, shallow, and deep bedrock in the Wolverine Lake and Go Creek watersheds (Figure 3-19). Groundwater monitoring is conducted at stations and frequencies outlined in Table 5-2.

Table 5-2: Groundwater Sampling Program During Temporary Closure

Groundwater Station	Location	Watershed	Sampling Frequency
MW05-1A, 1B	Airstrip North	Go Creek	Quarterly
MW05-2A, 2B	TSF – Southwest	TSF	Quarterly
MW05-3A, 3B	Mine	Wolverine Creek	Quarterly
MW05-4A, 4B	Mine		Quarterly
MW05-5A, 5B	Mine		Monthly
MW05-6A, 6B	Airstrip East	Go Creek	Quarterly
MW05-7B	Mine	TSF	Quarterly
MW06-8S, 8M, 8D	Mine	Wolverine Creek	Quarterly
MW06-9S, 9M	Mine		Quarterly
MW06-10S, 10M, 10D	Mine		Quarterly
MW06-11S	Mine		Monthly
MW06-12S	Mine		Quarterly
MW08-13	TSF - West	TSF	Quarterly

Underground Mine

Four vibrating wire piezometers are installed at two locations (PZA and PZB) above the underground mine. Both locations have one shallow and one deep piezometer. These piezometers measure the water table above the mine and results delineate any effects from underground mining on the water table. Water levels at these locations are reported in annual reports to EMR.

Pumping of groundwater discharge in the underground mine has ceased; therefore, the rising water level in the underground mine is monitored on an ongoing basis. Access to the underground mine is prohibited, so the water level is verified by pumping air down the adit and detecting the flow of air via the fresh air raise, which indicates whether the water has reached the 1300 level. An estimate of actual inflow rate may be made based on the time since flooding commenced and the date when the 1300 level is flooded.

5.1.2.2 Vegetation, Aquatic Organisms, and Wildlife

Revegetation efforts are monitored at sites that have been seeded. Photographs are taken to document revegetation success from year to year. As detailed in Section 2.2.2, a preferred reclamation seed mix has been determined through vegetation monitoring of seeded areas. Monitoring of these areas will continue throughout the temporary closure period and they will be re-seeded if required.

While aquatic organism monitoring is not required under the monthly monitoring program, as part of the requirements under the *Fisheries Act* MMER a Cycle 3 biological study will be completed in late summer 2017, as per the *MMER EEM Cycle 3 Study Design* submitted September 19, 2016. A *Third Interpretive Report* will be subsequently completed and submitted by December 3, 2017. The study will include benthic inveterbrate monitoring and sediment sampling, as per MMER requirements.

Wildlife monitoring consists of incidental wildlife encounters on site and documentation of all wildlife-related incidents. These events are reported in annual reports to EMR and YWB.

5.1.2.3 Climate and Water Balance

Climate is monitored during temporary closure by the weather station on the Wolverine Mine site. The weather station is located at the south end of the airstrip and records the following data:

- Temperature;
- Pressure;
- Precipitation;
- Radiation in and out;
- Wind speed and direction; and
- Relative humidity.

Data from the weather station is collected by the care and maintenance crew. Mean monthly temperatures, minimum temperatures, maximum temperatures, average daily temperatures, daily precipitation (as rain), and annual cumulative precipitation are reported in annual reports to EMR.

Inputs to the TSF are also monitored through tracking of water pumped or trucked to the TSF throughout the year. This enables better prediction of inflow rates into the TSF to aid in long-term planning for discharge activities.

5.1.3 Maintenance Activities

The care and maintenance crew on site undertakes all routine maintenance work during temporary closure. Any work outside normal care and maintenance duties is contracted out. The maintenance work is verified annually, as per the requirements outlined in Section 10 of QML-0006. The annual physical inspection for all structures, works and installations must be conducted by an engineer. This inspection includes:

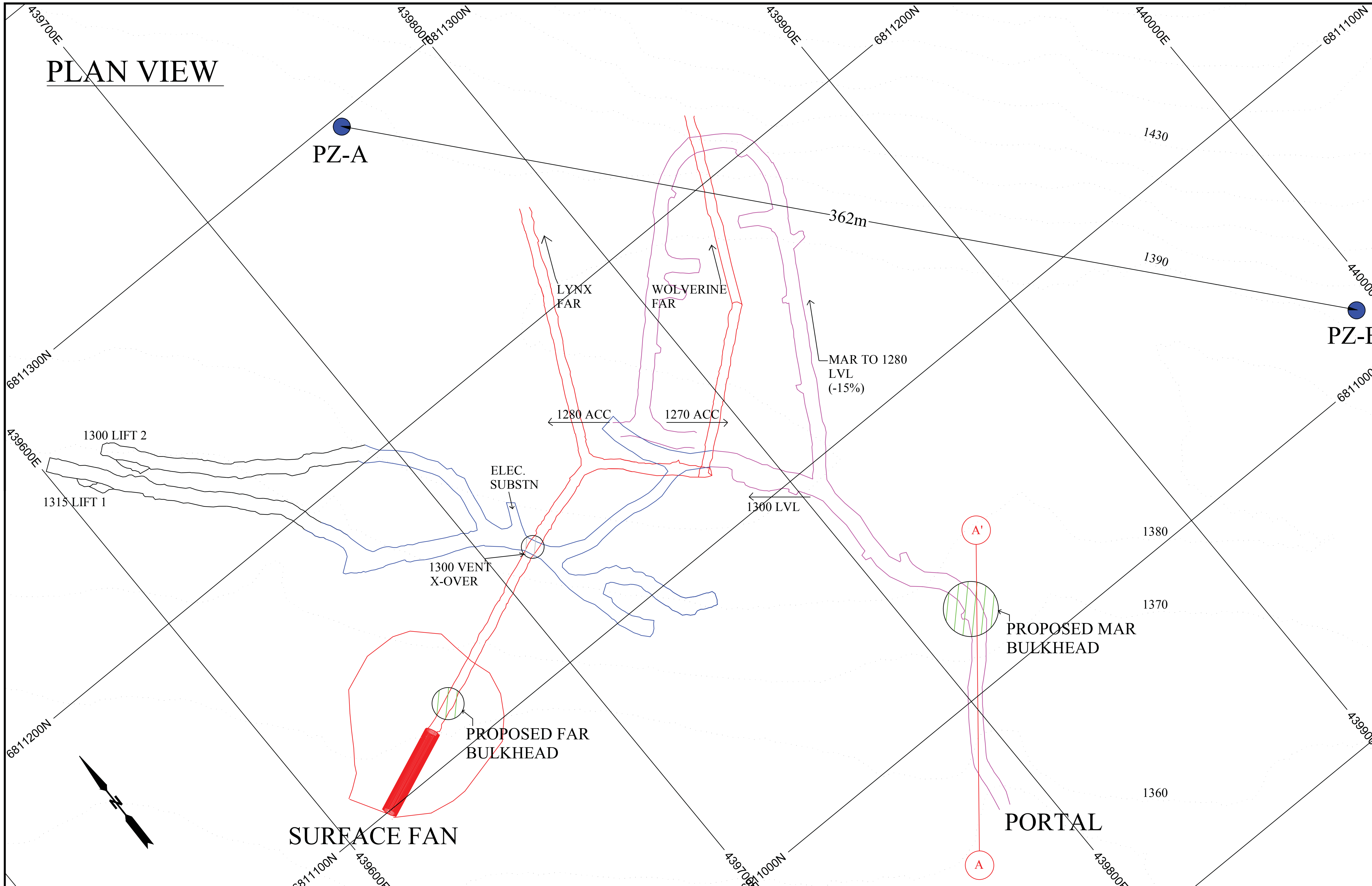
- Seepage collection dams;
- Tailings impoundment structures;
- Waste rock dumps;
- Diversion structures (channels and dams);
- Mill;
- Underground mine;
- Camp infrastructure; and
- Any other engineered structures, works or installations associated with the Wolverine Mine site.

5.1.3.1 Underground Workings and Openings to Surface

The underground mine is currently gated and locked, as the mine is flooding. Hydraulic bulkheads for the main portal and ventilation raise will be constructed during Summer 2017. Closure of the surface openings will be conducted in accordance with the Yukon Occupational Health and Safety Regulations and under the direction of a qualified engineer to ensure physical and chemical stability. The installation of these watertight bulkheads will prevent access to the underground mine workings in order to protect human health and safety, and limit conflicts with wildlife.

The designs for the hydraulic bulkheads are currently being finalized and will be submitted to EMR for approval prior to construction. The current design is provided in the *Watertight Bulkhead Design & Calculation* document (Shin, 2016). The bulkhead location, main ramp bulkhead design, and raise watertight bulkhead design are provided in Figure 5-1, Figure 5-2 and Figure 5-3, respectively.

Although the bulkheads are designed to be watertight, some groundwater may discharge from the host rock or from the bulkhead, depending on the water pressure. As such, a bioreactor will be constructed during temporary closure at the outlet of the underground mine workings, discharging to sump #2. Bioreactor maintenance will be minimal; crews will add material to the bioreactor if required, maintain the standpipes, make sure the bioreactor has no blockages, and make sure the bioreactor is functioning as intended. See Section 5.2.1 for details on water management relating to the underground mine.



GENERAL NOTES

1) PZ-A & PZ-B COORDINATES (GARTNER LEE LTD., 2006) WERE CONVERTED FROM UTM NAD27 TO UTM NAD83 DATUM APPLYING NTv2 (NATURAL RESOURCES CANADA) APPLICATION WITH A RESULTING ERROR OF +/-0.3m AFTER CONVERSION.

2) UNDERGROUND MINE AS-BUILT SURVEY WERE REFERENCED TO MOST UP TO DATE SURVEY DATA AVAILABLE FROM MINECAD PLOT SERVER.

3) APPROXIMATE PROPOSED BULKHEAD LOCATIONS WERE REFERENCED TO 'WATERTIGHT BULKHEAD DESIGN & CALCULATION' DRAFT (SHIN, 2016).

REFERENCE

DWG. No.	DESCRIPTION
1	YZC BULKHEAD SECTION A-A'

REVISIONS

No.	DATE	DESCRIPTION	DRAWN	CHK	GR CTRL	GEOL	TS SUP	MANAG

SCALE :	1:1500	
DRAWN:	IH	160825
CHECKED:		
GRND CTRL:		
GEOLOGY:		
TS SUPER:		
MANAGER:		

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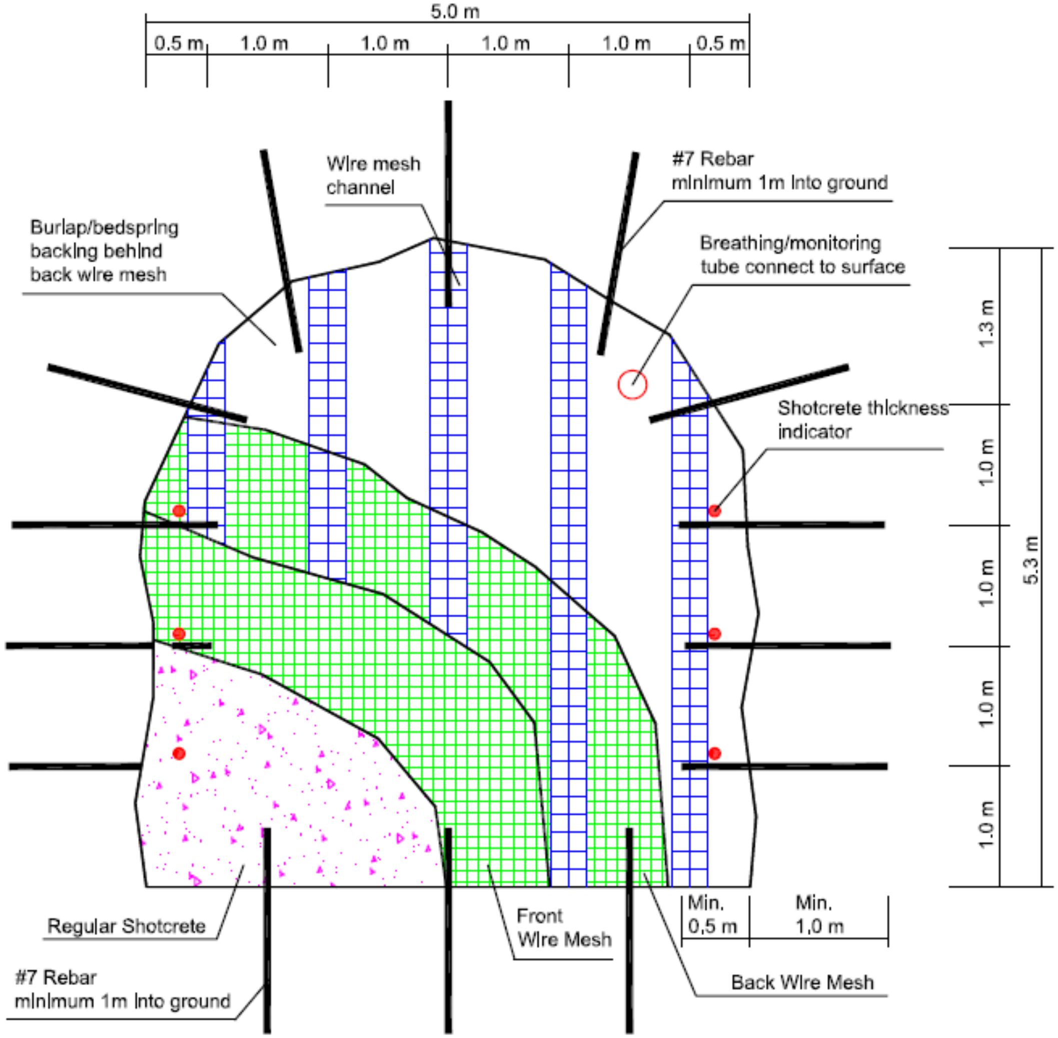
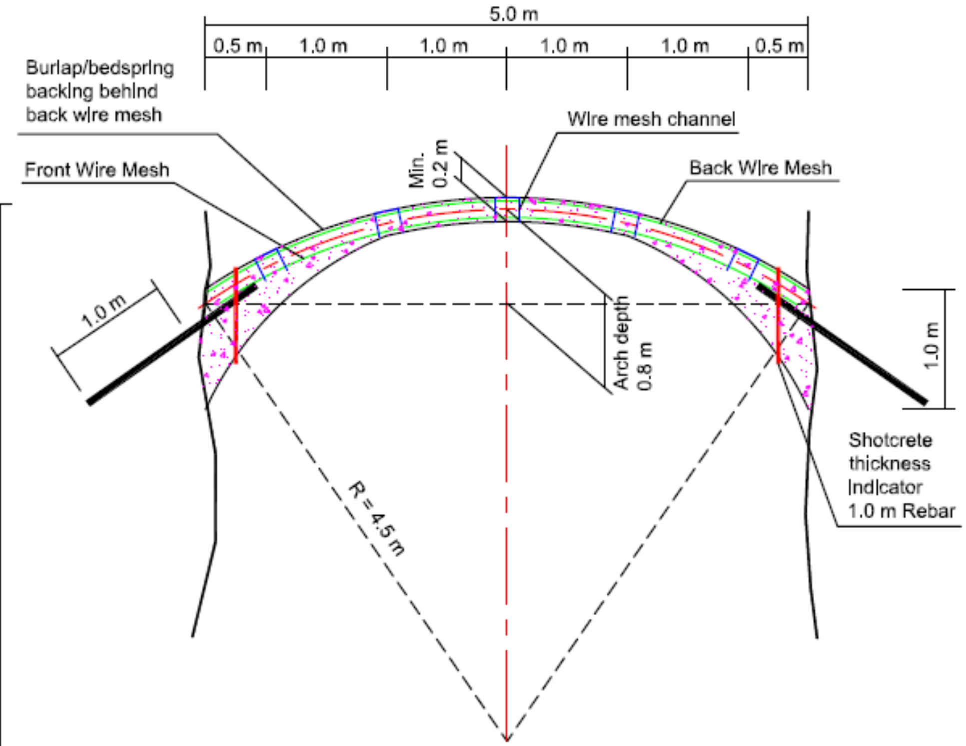
Figure 5-1: Proposed Bulkhead - Plan View

FRONT VIEW



PLAN VIEW



- Thickness of shotcrete should be minimum 0,2 m (8 inches). Shotcrete thickness contact to ground must be larger than 1.0m and sealed off tightly.
- Shotcreted bulkhead need to be supported by #7 fully grouted rebar in 1.0 m spacing. Rebar should be inserted into ground more than 1.0m and minimum 0.5 m of rebar head in place to shotcrete bulkhead.
- Breathing/monitoring pipe must be connected to surface. Water release valve and piezometer tube need to be installed at the end of the pipe.

YukonZinc CORP

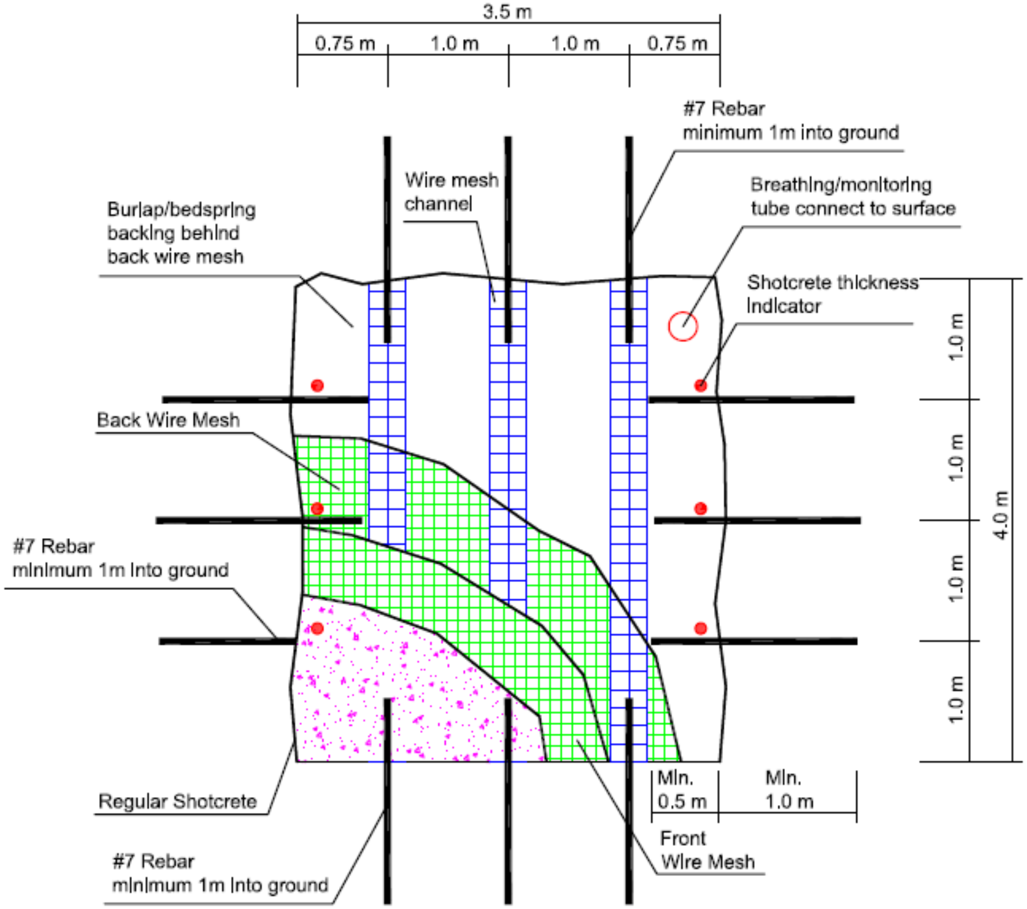
Designed By:	WS	05/10/2018
Checked By:		
Drawn By:	WS	
SCALE: N.T.S.		

Main Ramp Watertight Bulkhead

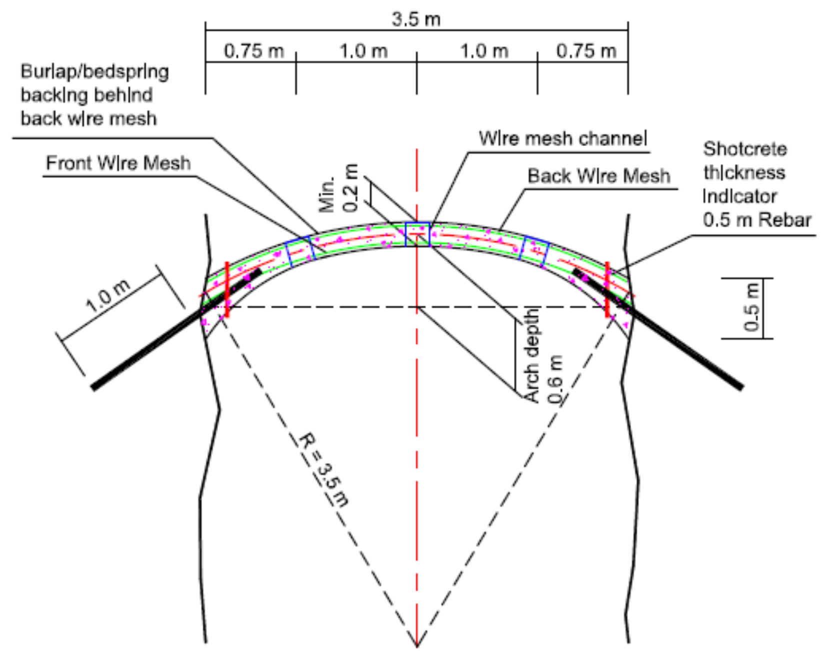
FILE NAME: WATERTIGHTBULKHEAD.DWG

Rev. 1

FRONT VIEW



PLAN VIEW



- Thickness of shotcrete should be minimum 0.2 m (8 inches). Shotcrete thickness contact to ground must be larger than 0.5 m and sealed off tightly.
- Shotcreted bulkhead need to be supported by #7 fully grouted rebar in 1.0 m spacing. Rebar should be inserted into ground more than 1.0m and minimum 0.5 m of rebar head in place to shotcrete bulkhead.
- Breathing/monitoring pipe must be connected to surface. Water release valve and piezometer tube need to be installed at the end of the pipe.

Designed By:	WS	05/10/2016	Raise Watertight Bulkhead
Checked By:			
Drawn By:	WS		
SCALE N.T.S.			FILE NAME: WATERTIGHTBULKHEAD.DWG — Rev. 1

5.1.3.2 Tailings Storage Facility (TSF) Area and Water Management Structures

Temporary closure maintenance activities relating to the TSF primarily involve ensuring the long-term physical stability and integrity of the structure and associated components. The TSF undergoes an annual dam safety inspection by a professional engineer, as per the *Canadian Dam Association Dam Safety Guidelines* (CDA, 2013) and QML-0006. QML-0006 also directs that all diversion structures undergo an annual physical inspection by an engineer. In accordance with the *Wolverine Mine Tailings Facility Operation, Maintenance and Surveillance Manual V2010-01*, maintenance and surveillance activities include:

- Regularly checking diversion ditches, spillways and culverts for accumulation of debris or sediment, or any other form of blockage, and removing blockages as required;
- Visually inspecting diversions, spillways, seepage collection dam and all ditches for cracking, bulging, slumping, or any other indications of slope movement;
- Performing regular performance tests on seepage pond pump;
- Re-grading the dam crest, as required, to prevent local ponding and direct surface runoff towards the seepage pond;
- Repairing erosion gullies, local slumps or slides in the dam face, diversion ditches or spillway channels;
- Repairing damaged liner sections (the geomembrane liner could be damaged by wildlife or ice movement during spring break-up; and
- Monitoring for changes in seepage conditions on the downstream slope or at the toe of the dam.

Routine and/or regular visual inspections of the dam, liner, diversion ditches, seepage collection dam, spillways, pipelines, and pumping infrastructure are carried out on an on-going basis as required. The visual inspections comprise all components of the dam, including the crest, upstream and downstream slopes, abutments, the liner, the water reclaim system, pipelines and pipeline crossings, diversion ditches, and spillways. Event-driven maintenance is conducted in the event of a pipeline leak or break, earthquake, avalanche, or a flood.

See Section 5.2.2 for details on water management relating to the TSF area.

5.1.3.3 Waste Rock and Overburden Dumps

Currently there are two waste rock pads at the Wolverine Mine site. Waste Rock Pad #1 (Photo 5-1) is located south of the camp and Waste Rock Pad #2 (Photo 5-2) is located north of the TSF. All temporary ore and waste stockpiles were moved to Waste Rock Pad #2 in July and August 2015. Waste Pad #2 was surveyed in August 2016, and the volume of waste and ore on the pad is 10,439 m^3 and 29, 890 m^3, respectively. Waste Pad #1 has not had material placed on it since 2012, and the volume at that time was 91,000 m^3.

Temporary closure maintenance activitites relating to the waste rock pads consist of ensuring physical stability, which is accomplished by conducting annual physical inspections, as per QML-006. Care and maintenance crews also monitor the waste rock pads for shifting or slumping on an ongoing basis and after storms.

Waste Rock Pad #1 has a lined sump at the toe that is monitored for liner integrity. Crews check that there are no holes in the liner and that no material around the sump is slumping. Runoff from Waste Rock Pad #2 is currently routed through a bioreactor before entering the TSF, with the option to bypass the bioreactor and discharge directly to the TSF. Bioreactor maintenance is minimal; crews add material to the bioreactor as required, maintain the standpipes, make sure the bioreactor has no blockages, and make sure the bioreactor is functioning as intended.

Photo 5-1: Waste Rock Pad #1, East of the Camp (July 2013)

Photo 5-2: Waste Rock Pad #2, North of the TSF (July 2013)

5.1.3.4 Mine Infrastructure

Exploration Camp and Roads

Closure activities at the exploration camp have been completed. The camp has been decomissioned and the footprint has been seeded. Revegetation in seeded areas has been successful and no other reclamation work is scheduled for the exploration camp. Exploration camp roads will not be maintained during temporary closure, although they will be driveable with an ATV for the purposes of accessing environmental monitoring sites.

Camp

Only a portion of the camp is operated during temporary closure, as the care and maintenance crew does not require the full camp. Parts of the main kitchen and mess hall have been converted into office space and the office building has been shut down. Living accommodation is provided in one half of Bunkhouse #3; all remaining bunkhouses and buildings have been winterised and shut down.

Processing Plant and Other Buildings

A metallurgical and processing crew of ten mill workers and a metallurgical engineer was brought to site in May 2015 to secure the processing plant and remaining site reagents left on site. The completed work included:

- Clean up of the mill area and other safety-related jobs;
- Wash down of all areas and sumps;
- Emptying the ball mill and rod mill of charge and jacking them onto their cradles and off their pinions;
- Emptying of all flotation cells;
- All pumps were split and left open as appropriate;
- All equipment that requires warm storage was identified and segregated for potential removal from site, or warm storage;
- Filled all gear boxes with oil for long-term preservation;
- Emptied all reagent tanks, flushed any chemicals remaining in the reagent holding tanks to the TSF;
- Ensured that all stored reagents on site are appropriately identified and labelled, repackaged as required, and stored in a secure area (such as the CLO, or prepared lined storage areas); and
- Disposed of any other small amounts of reagents that could be effectively washed to the TSF.

There is no other work planned for the processing plant and mill during temporary closure and the facility is locked.

Power Generation Infrastructure

The eight primary generators were secured in 2015 and the glycol loop has been emptied into on site storage tanks. The empty glycol line was isolated into short loops, wherever possible, by closing all the system valves.

The current power system and many of the mill pumps and processes are controlled by a DeltaV programmable control system. All powered facilities required for temporary closure have been converted to manual operations with all necessary interlocks. Power during the temporary closure period is provided by a 350 kW Caterpillar genset, along with a smaller 115 kW standby set. These two generators service the camp and other facilities, with an average consumption of 768 L of diesel fuel per day during winter months.

Landfill and Waste Storage Areas

Maintenance for the landfill is in accordance with the Commercial Dump Permit 81-014. The landfill will remain operational throughout temporary closure.

The Special Waste Pad on site has been cleaned up and organised and dirty totes have been washed out and sent to the scrap pile. All other old barrels and scrap material are being collected around site and sorted appropriately.

Land Treatment Facility (LTF)

The LTF was constructed in 2008 to treat contaminated soil produced through advanced exploration, construction and operational activities at the Wolverine Mine. The material stored in the LTF is segregated into oil-contaminated, diesel-contaminated, gas-contaminated, and glycol-contaminated soil. The LTF was also intended to accept any contaminated material excavated during decommissioning and reclamation of the industrial complex footprint.

However, to attain the objective of minimized site disturbance and reducing site liability during temporary closure, the LTF will be decommissioned during the temporary closure period. Following approvals from the Yukon Governmen Environmental Programs Branch, all material stored in the LTF will be disposed of in the TSF. The liner and geotextile use to line the LTF will also be disposed of in the TSF. The area will then be re-contoured and seeded with the approved grass seed mixture. This work is currently planned for summer 2017.

During reclamation and closure activities, any contaminated soil required to be excavated will be co-disposed of in the TSF with the tailings and waste rock material.

5.1.3.5 Roads and Other Access

The care and maintenance crew maintains the site access road, except during winter months when the site becomes a fly-in/fly-out operation with regular flights every three weeks to change crews and bring supplies in or out. The mine site roads are maintained as needed and are cleared of snow in the winter. The airstrip and heli landing pad are maintained year-round to ensure there is always access to the site.

5.2 Interim Water and Solution Management Plan

This section describes the plans for the management of clean water and contaminated water during the temporary closure phase at the Wolverine Mine site. There are no process solutions generated during the temporary closure period, as all milling and mining activities have ceased.

The following strategy is proposed to manage water in temporary closure:

- Limit clean or treatable water entering the TSF to maintain storage capacity in the TSF.
- Treat contaminated water via bioreactors where possible, prior to discharging into the Go Creek drainage (while meeting WUL conditions), where possible:
    - Construct a bioreactor at the outlet of the underground mine portal that drains via ditch to sump #2. If water quality limits are met, discharge sump #2 to the upper Go Creek watershed.

  - Treat water from Waste Rock Pad #2 through the existing bioreactor and discharge to the seepage pond. Once water quality limits are met, discharge seepage pond via overflow culvert to Ditch B spillway in Go Creek.
- Remove LTF to eliminate collection of snowmelt and rain in the LTF sump.
- Continue to pump and/or truck all mine-contaminated water to the TSF, including from Waste Rock Pad #1, the sewage treatment plant, and sump #2, if water quality limits are not met.
- Treat water stored in the TSF to improve water chemistry.

Water egress into the underground mine and water accumulation and treatment at the TSF are further described below.

5.2.1 Underground Mine Workings

The underground mine workings are currently flooding and have been since the cessation of operations in January 2015. In August 2016 an updated volumetric survey of underground workings was conducted to predict flooding rates and key dates. Where possible, validated solids were used from the previously constructed mine plan. 3D as-builts were constructed using GEOVIA Surpac 6.7 and used to calculate volumes. A 150 m^3/d rate of flooding was used based on the inspection conducted in April 2015 (Shin, 2015). With a total underground volume calculated at 168,611 m^3 and a flooded volume as of September 1, 2016 of 73,350 m^3, the mine is expected to be completely flooded to portal elevation by late May 2018.

As described above, bulkheads will be installed in both the main ramp and fresh air raise to mitigate water egress from the underground mine. The bulkheads will be installed by the end of September 2017, well in advance of the flooding prediction date of late May 2018. The bulkheads should prevent water from discharging from the underground mine; however, if water does discharge from the underground mine or from fractures in the host rock, it will be collected and treated via a bioreactor.

The mine adit bioreactor is proposed to be constructed during summer 2017 at the outlet of the underground mine portal (Figure 5-4). Water exiting the bioreactor will be piped to sump #2 and sampled prior to discharge into Go Creek, to ensure that any discharge meets the conditions outlined in the WUL. This would enable a large volume of water to be treated, in place of being stored in the TSF. Results from Waste Rock Pad #2 bioreactor water treatment trials have shown this to be a feasible and effective way to treat water at the Wolverine Mine site. The results will continue to inform the design of the underground mine bioreactor. A cross-section of the proposed underground mine bioreactor is provided in

Figure 5-5. Geochemical predictions for the underground mine workings are provided in Section 6.1.2.

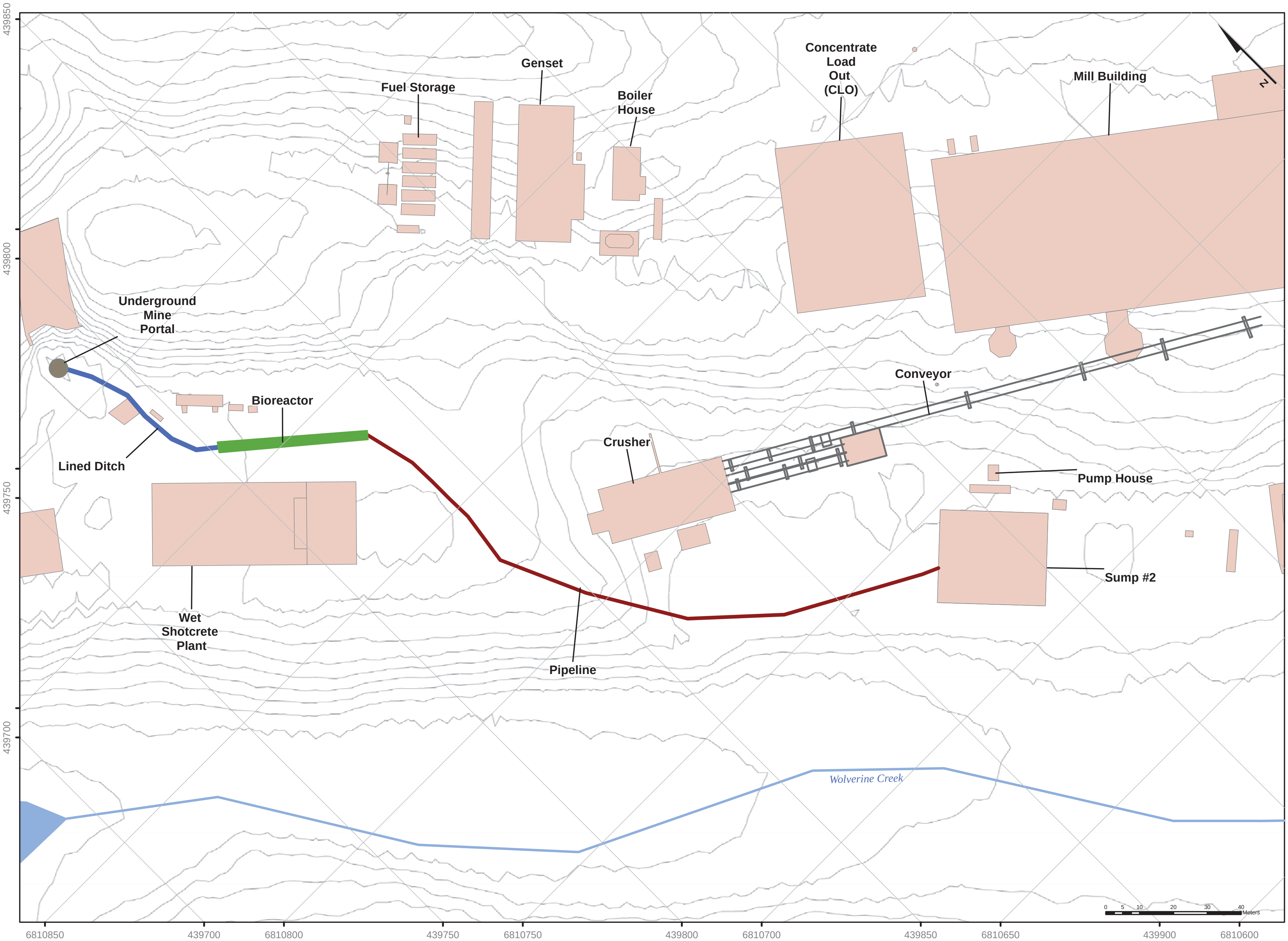


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Figure 5-4

Wolverine Mine: Proposed Underground Mine Portal Bioreactor

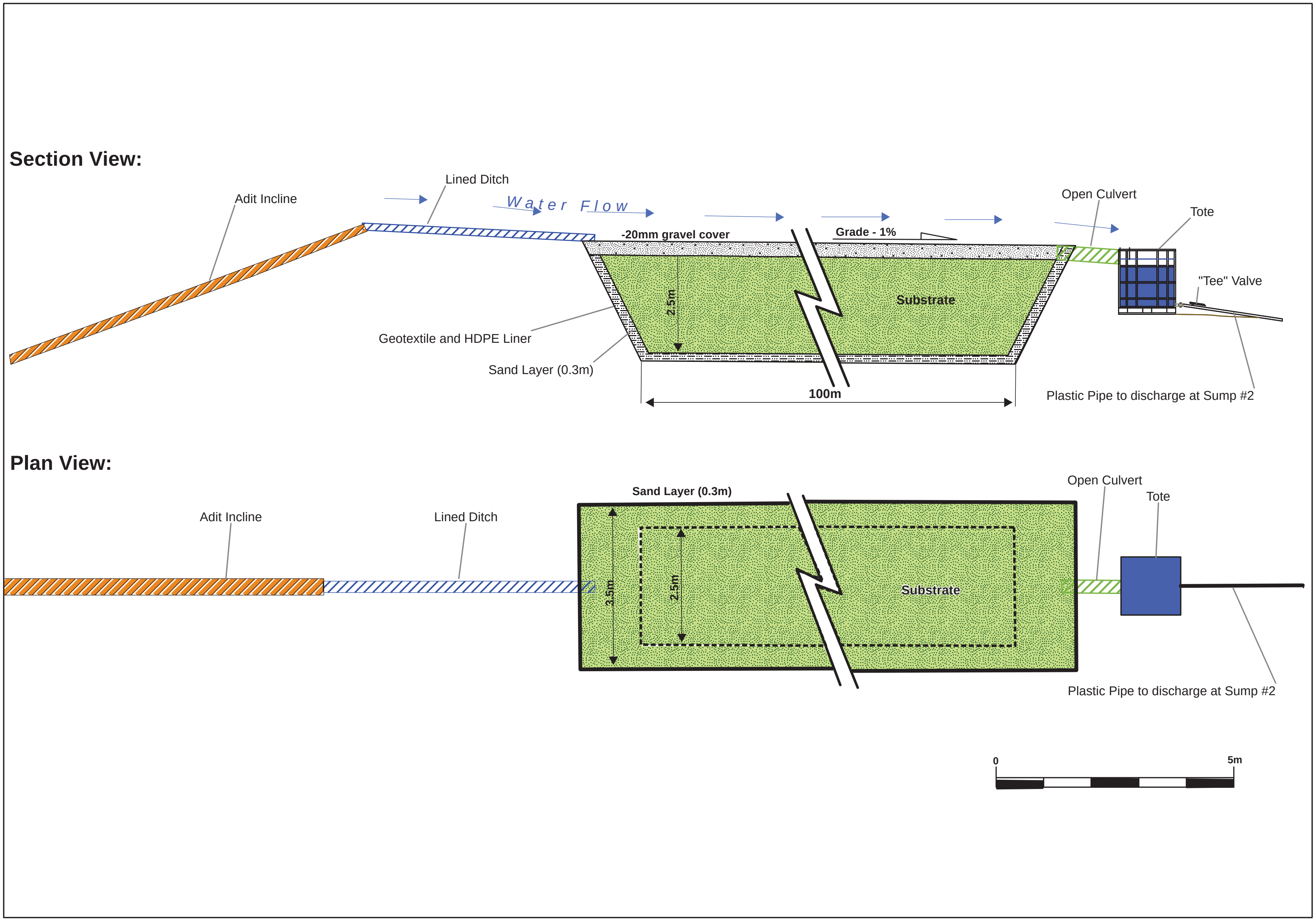
- Lined Ditch
- Conveyor System
- Pipeline
- Underground Mine Portal
- Bioreactor
- Site Infrastructure

Topography

- Contour
- Watercourse
- Waterbody

Date: 14/12/2016
Author: hbrown

Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983



YukonZinc

Figure 5-5

Wolverine Mine: Plan and Section of Proposed Underground Mine Portal Bioreactor

Date: 22/12/2016
Author: H.Seeley, P.Geo, Wolfbear Geological Consulting

Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

5.2.2 Tailings Storage Facility (TSF) Area

The TSF is currently used as the main water management infrastructure for the Wolverine Mine. In August 2016, the total volume of the TSF was estimated at 1,095,000 m^3 by bathymetric survey. Approximately 570,000 m^3 was occupied by saturated tailings while the volume of free water above the tailings was roughly 525,000 m^3. According to the site water balance, the inventory increases by approximately 50,000 m^3/year in years with average precipitation. Therefore, by 2017 the inventory is expected to be approximately 575,000 m^3 and 675,000 m^3 by 2019.

The total storage capacity of the TSF to the spillway elevation is 1,553,000 m^3 (1311.5 m elevation) (Figure 5-6). Assuming that the annual inflow amount to the average of 50,000 m^3, it will take approximately 8 years to fill the TSF. Assuming that 1 m freeboard is required below the below the dam spillway (at 1310.5 m), the total storage capacity is 1,378,000 m^3. It will take approximately 5 years for the TSF inventory to reach this volume, assuming average annual precipitation.

In Fall 2016 a TSF water treatability assessment was completed by SRK for YZC (Appendix A), to aid in closure planning and assist in identifying a preferred approach to closing the TSF. The TSF water treatment methods were evaluated based on the following design basis:

- Effluent quality: WUL discharge limits.
- Treatment season: the treatment season is assumed to last from June 1 to September 30, or approximately 120 days. The treatment season must include time for mobilization to site, construction and commissioning of treatment equipment, treatment campaign and demobilization of equipment. For the purpose of this assessment, it is assumed that the 120 day season includes 90 equivalent days of full capacity treatment to account for commissioning, mobilization and mechanical downtime.
- Treatment capacity, assuming:
  - One operating season (2019): 675,000 m^3 within one open water season (90 treatment days) corresponds to an average treatment capacity of 7,500 m^3/d or 1,400 gpm.
  - Two operating seasons (2018/2019): 340,000 m^3 within two open water seasons (90 treatment days per season) corresponds to an average treatment capacity of approximately 700 m^3/d or 700 gpm.
- Treatment residuals: residuals from the treatment process must be disposed of in a stable form on site.
- Complexity: suitable for implementation at a remote site with limited infrastructure.

The assessment identified several main parameters that will require treatment during the temporary closure phase before the TSF can be dewatered during the permanent closure phase (Section 6.2). These parameters and treatment options for each are summarized in Table 5-3 below.

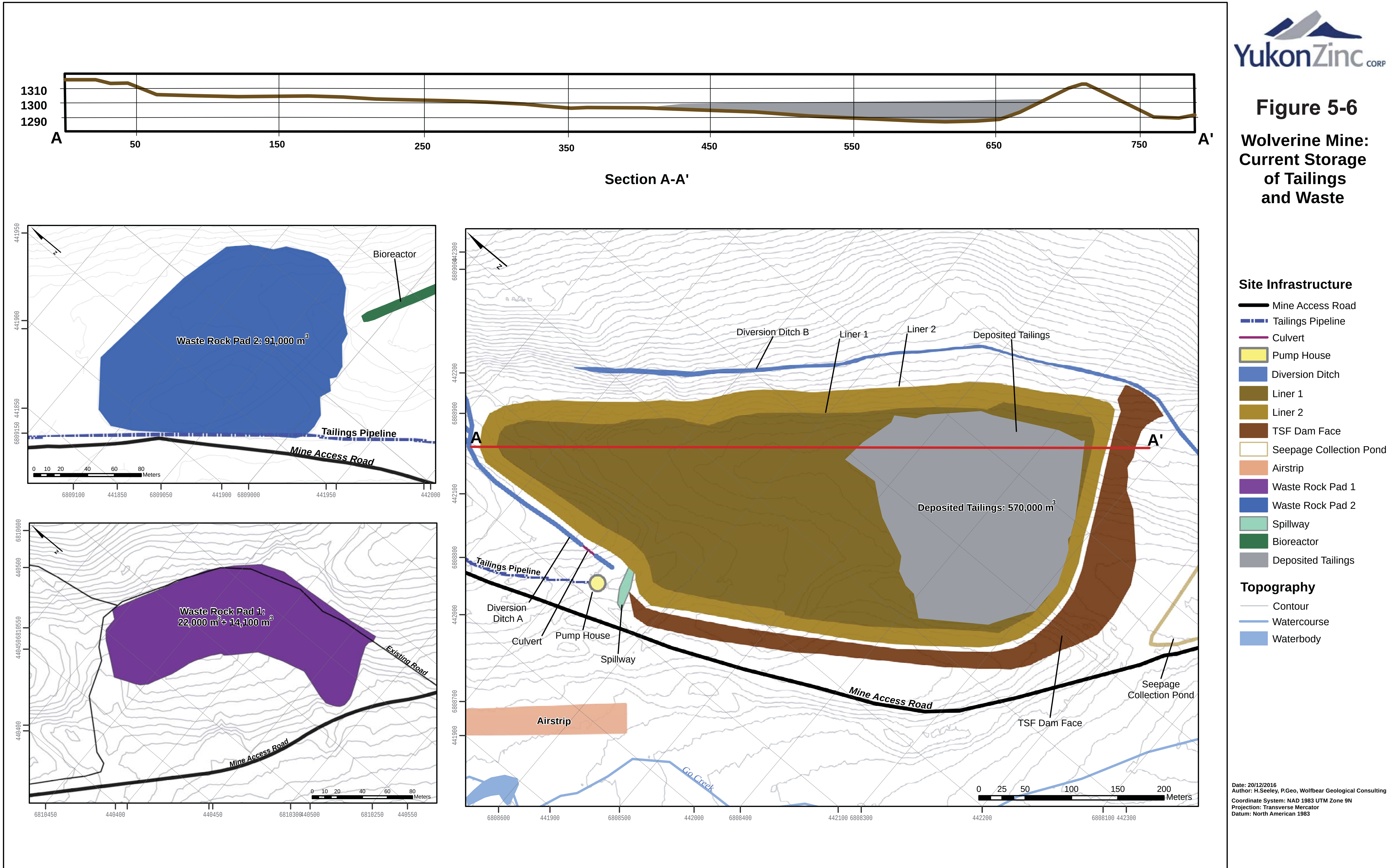


Figure 5-6

Wolverine Mine: Current Storage of Tailings and Waste

Table 5-3: TSF Water Quality Issues and Treatment Options

TSF Water Quality Parameter	Treatment Action
Low pH	Add 40 tonnes of quicklime to the TSF during the next open water season (2017). This will prevent the TSF from becoming acidic, which would solubilize metals and sulphate, and would generally deteriorate water quality.
Elevated Dissolved Metals (Cd, Cu, Fe, Pb, Ag, Zn)	Treatment Options (discussed in Section 6.2): Lime (CaO) or caustic (NaOH) water treatment, with or without ferric coagulation Ferric co-precipitation Lime or caustic added to mine water raises the pH, which causes metals to precipitate as metal hydroxides. The metal hydroxide precipitates can then be collected and disposed of. All species of dissolved metals to be removed at Wolverine are amenable to lime and ferric water treatment. Treatment residuals, lime or ferric sludge, can safely be disposed of in the TSF following dewatering during the decommissioning phase. To determine the ideal option, field-scale tests will be conducted on site in 2017.
Elevated Selenium	Preferred options (discussed in Section 6.2): In-situ biological treatment combined with ferric co-precipitation and lime/caustic treatment ZVI treatment combined with lime/caustic treatment. Field-scale pilot studies will be conducted during the 2017 open water season to determine site-specific advantages and disadvantages of each option, to better inform the final treatment option selection.
Sulphate	To date, sulphate concentrations in the tailings supernatant have generally been below the WUL limit of 1,800 mg/L. However, new sulphate loadings or careless efforts to concentrate the tailings water could potentially cause sulphate concentrations to increase above the effluent concentration limit. Sulphate water treatment is onerous and costly. Every effort should be made to avoid implementing treatment methods that could, be design or inadvertently, increase the concentration of sulphate in the tailings supernatant. Sulphate will be monitored during the course of the field-scale tests on site in 2017.

6 Final Reclamation and Closure Measures

This section presents the final reclamation and closure plan for all components of the Wolverine Mine site. Final closure activities are expected to commence following 3 years of temporary closure. As such, final closure activities would commence in January 2018, unless approval from the Chief is received to extend the temporary closure period. The activities outlined below are designed to meet or exceed the objectives outlined in Table 1-2.

Decommissioning and reclamation will be conducted during a 2-3 year period; the timing of facility closures is dependent on the purpose of the facility and its future use and environmental considerations. For example, mine site roads will need to be left usable until the end of the closure period, as they will be used to truck decomissioned infrastructure from site.

The experimental textwork conducted during the temporary closure period will continue to inform the treatment of effluent from the underground mine and TSF into the decommissioning phase. The conceptual closure plan for the TSF will also be finalized by the engineer of record to meet the *Canadian Dam Association Dam Safety Guidelines*, prior to final decomissioning of the TSF.

During decommissioning and the early closure period, soils will be tested for contaminants in all areas where ore, concentrate, waste rock, solid wastes, special wastes, fuel, and chemicals were stored or handled at the site. If contamination is found, the contaminated soil will be removed from the area and disposed of in the TSF.

Once infrastructure is removed, slopes will be stabilized by contouring and leveling to provide land forms that conform to the surrounding terrain and provide suitable seedbeds. Erosion features will be minimized on re-sloped surfaces, runoff will be diverted away from steep slopes, and settling ponds and diversion ditches will be used as necessary.

The total area of disturbance at the Wolverine Mine site is summarized in Table 6-1 and shown in

Figure 6-1. A total of 88 ha is required to be reclaimed. These areas will be revegetated based on the reclamation research that has been conducted on the Wolverine Mine site to date (Section 2.2.2).

Details of the reclamation and closure activities for the mine, TSF, waste rock dumps, mine infrastructure, and associated monitoring and maintenance is described below.

Table 6-1: Mine Components and Area of Disturbance

Component	Quantity (ha)
Industrial Complex Area	**21.7**
Mill Buildings, Truck Shop, Offices	14.5
Diversion Ditches	0.5
Organic Stockpiles	2.4
Camp and Support Facilities	2.8
Landfill	1.5
TSF Area	**28.1**
Impoundment	16.6

Component	Quantity (ha)
Dam Face	2.4
Diversions	0.5
Seepage Recovery Pond	0.8
Tailings Lines Corridor	1.8
Organic Stockpiles and Borrow Areas	6.0
Site Access Road	**31.2**
Mine Site Roads	**7.0**
TOTAL	**88**

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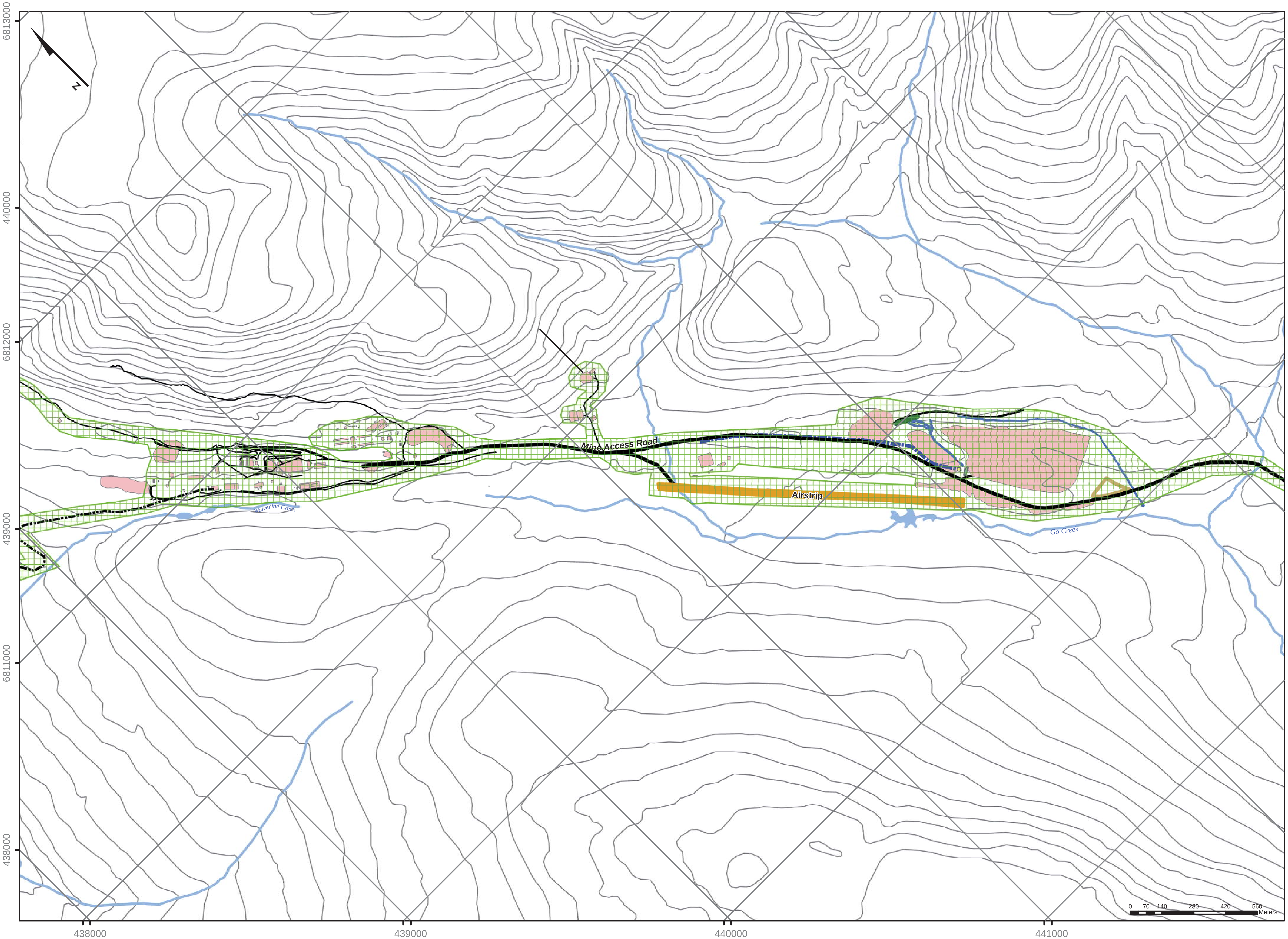

Figure 6-1

Wolverine Mine: Site Disturbance

6.1 Underground Workings and Openings to Surface

The two surface openings (main portal and ventilation raise) will have been sealed with hydraulic bulkheads during the temporary closure phase (see Section 5.1.3.1). The installation of these watertight bulkheads will prevent access to the underground mine workings in order to protect human health and safety, and limit conflicts with wildlife. Hydraulic pressure buildup behind the bulkheads is not expected to pose a risk, as once the underground mine has finished flooding the water table is not expected to surpass the levels of the main portal and ventilation raise where the bulkheads are located.

The nature of surface disturbance from the underground mine workings is limited to the mine access points: the portal area and ventilation raise area. Land preparation and revegetation of these areas will be undertaken in conjunction with the reclamation of the industrial complex area during the decommissioning phase. Revegetation methodology will be based on reclamation research conducted to date at the mine site (see Section 2.2.2).

6.1.1 Underground Mine Water Level

In August 2016 an updated volumetric survey of underground workings was conducted to predict flooding rates and key dates. Where possible, validated solids were used from the previously constructed mine plan. 3D as-builts were constructed using GEOVIA Surpac 6.7 and used to calculate volumes. A 150 m^3/d rate of flooding was used based on the inspection conducted in April 2015 (Shin, 2015), which is comparable to rates seen in the advaced exploration phase from 2006-2009. With no active mining and increased hydraulic pressure, a daily inflow rate of 150 m^3 is reasonable. With a total underground volume calculated at 168,611 m^3 and a flooded volume as of September 1, 2016 of 73,350 m^3, the mine is expected to be completely flooded to portal elevation by late May 2018.

6.1.2 Underground Mine Water Quality

The water quality in the underground mine for copper, selenium, and zinc is summarized in Figure 6-2 for samples collected from 2006 to 2014, inclusively. There was a marked increase in metal concentrations during pre-production development and during mine production. These periods are characterized by high suspended solids due to activities in the underground mine and the use of shotcrete to reinforce the walls of the underground mine. Metals content in the water is generally a composite of dissolved metals and suspended solids in the water. With no underground activities and the ingress of groundwater into the underground mine, the suspended solids fraction of metals concentrations should reduce to zero and no longer drive the concentration of contaminants in the underground recharge water. Therefore, water chemistry during the dewatering period (May 2006 to April 2009) is considered to be more representative of predicted underground mine water quality during closure, than water quality results following the commencement of preproduction development (April 2009 to May 2010).

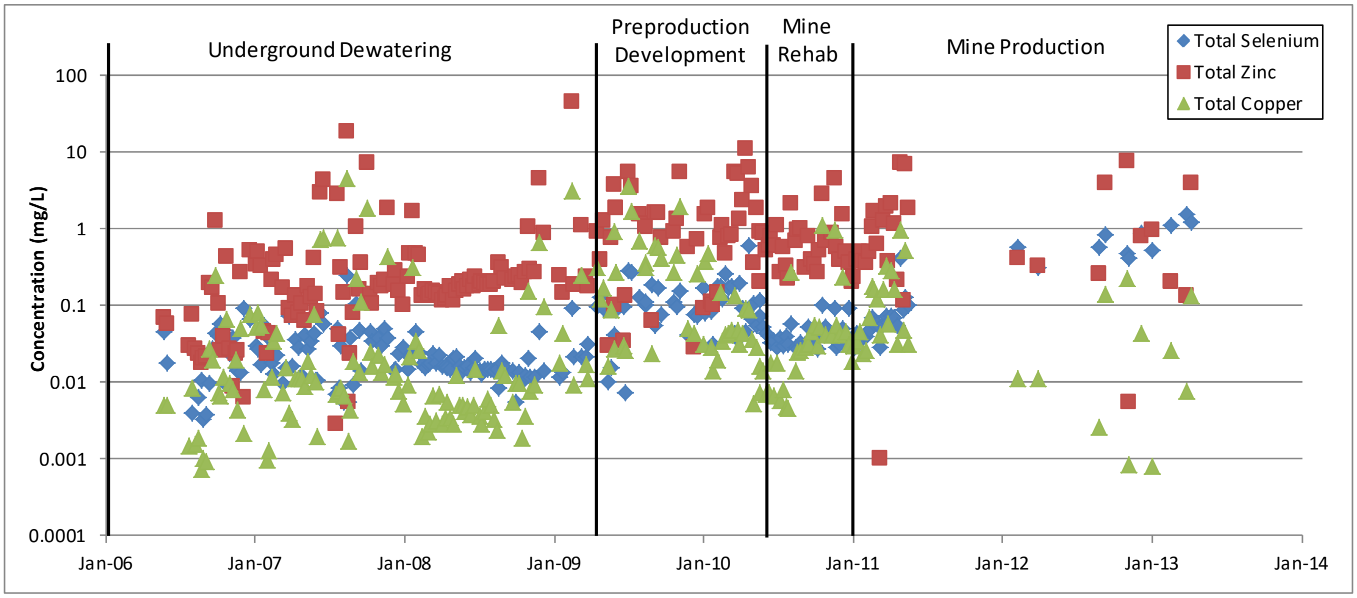

Figure 6-2: Underground Mine Total Copper, Selenium and Zinc Concentrations from 2006 to 2014 (exponential scale)

To identify potential exceedences of water quality objectives, summary statistics for the underground dewatering period (May 2006 to April 2009) are provided in Table 6-2. The mean results for underground mine water during the dewatering period were in exceedance of discharge standards for TSS, cadmium, copper, lead, selenium and zinc.

Table 6-2: Underground Mine Water Quality Statistics (2006 – 2008; n=123)

Parameter (mg/L)	WUL QZ04-065 ADL*	MIN	MEAN	MEDIAN	MAX
Total Suspended Solids	15	1.5	**102.2**	**17.3**	**3630.0**
Ammonial Nitrogen	5	0.0025	0.0692	0.0336	0.3115
Total Arsenic	0.05	0.00046	0.01093	0.00238	**0.45100**
Total Cadmium	0.002	0.00002	**0.00893**	0.00140	**0.43300**
Total Copper	0.015	0.001	**0.128**	0.009	**4.600**
Total Lead	0.02	0.0006	**0.1890**	**0.0339**	**7.9100**
Total Nickel	0.5	0.00025	0.00657	0.00228	0.10800
Total Selenium	0.02	0.0034	**0.0281**	0.0180	**0.2520**
Total Zinc	0.5	0.003	**0.924**	**0.176**	**45.400**

*ADL – Allowable discharge limits for discharge to Go Creek

Total metal concentrations are frequently tied to TSS concentrations, as shown in Figure 6-3, and mine dewatering activities may have artificially increased metal concentrations, which would not be evident during closure. Therefore, metal concentrations in the underground mine during closure, when there is no underground activity, may be lower again than those presented in Table 6-2.

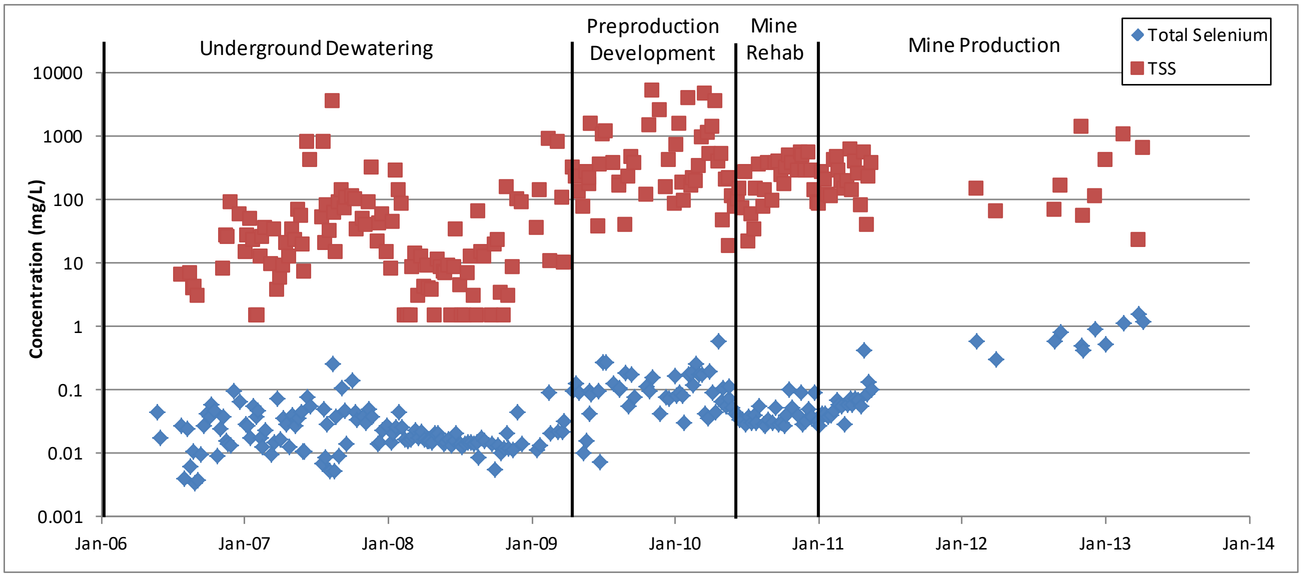

Figure 6-3: Underground Mine TSS and Total Selenium Concentrations from 2006 to 2014 (exponential scale)

6.1.3 Underground Mine Portal Bioreactor

Although the bulkheads are designed to be watertight, some groundwater may discharge from the host rock or from the bulkhead, depending on the water pressure. As such, a bioreactor will be constructed during temporary closure at the outlet of the underground mine workings to collect and treat potential underground discharge water. Any water discharging from the bioreactor during the post-closure phase is anticipated to be suitable for discharge into Wolverine Creek. This bioreactor will have been constructed during summer 2017 of the temporary closure phase (see Section 5.2.1) and will drain into sump #2, prior to discharge to the Go Creek drainage. Once the performance of the bioreactor is proven, the outlet of the bioreactor will be re-routed to Wolverine Creek for ongoing discharge.

6.2 Tailings Storage Facility (TSF) Area

Ultimately, the TSF will be dewatered and closed as a dry facility with an impermeable cover. This approach will limit risks to human health and safety and the environment, and will maintain physical and chemical stability via the final TSF landform. In its final landform, surface water will be diverted off of, or around the TSF to the Go Creek drainage.

During the decommissioning phase, materials from Waste Rock Pad #1 and #2 (including the liners) will be deposited into the TSF during the decommissioning phase. The dam and the Stage 2 area will be modified to reduce the overall area of the TSF and subsequently reduce the overall size of the TSF landform. As part of the decommissioning phase, the Stage 2 area will be deconstructed and the footprint of the TSF will be confined to the Stage 1 area. The tailings discharge pipeline will be disposed of in the TSF. Dam material above the tailings level will be removed and will be used as non-acid generating cover material for the final TSF landform. This modification will enable the declassification of the dam. The seepage recovery dam will be decommissioned in conjunction with the site access road, as the dam is formed by a section of mine road.

Conceptual schematics are provided in Figure 6-4 and the ultimate design will be verified by the engineer of record prior to final construction.

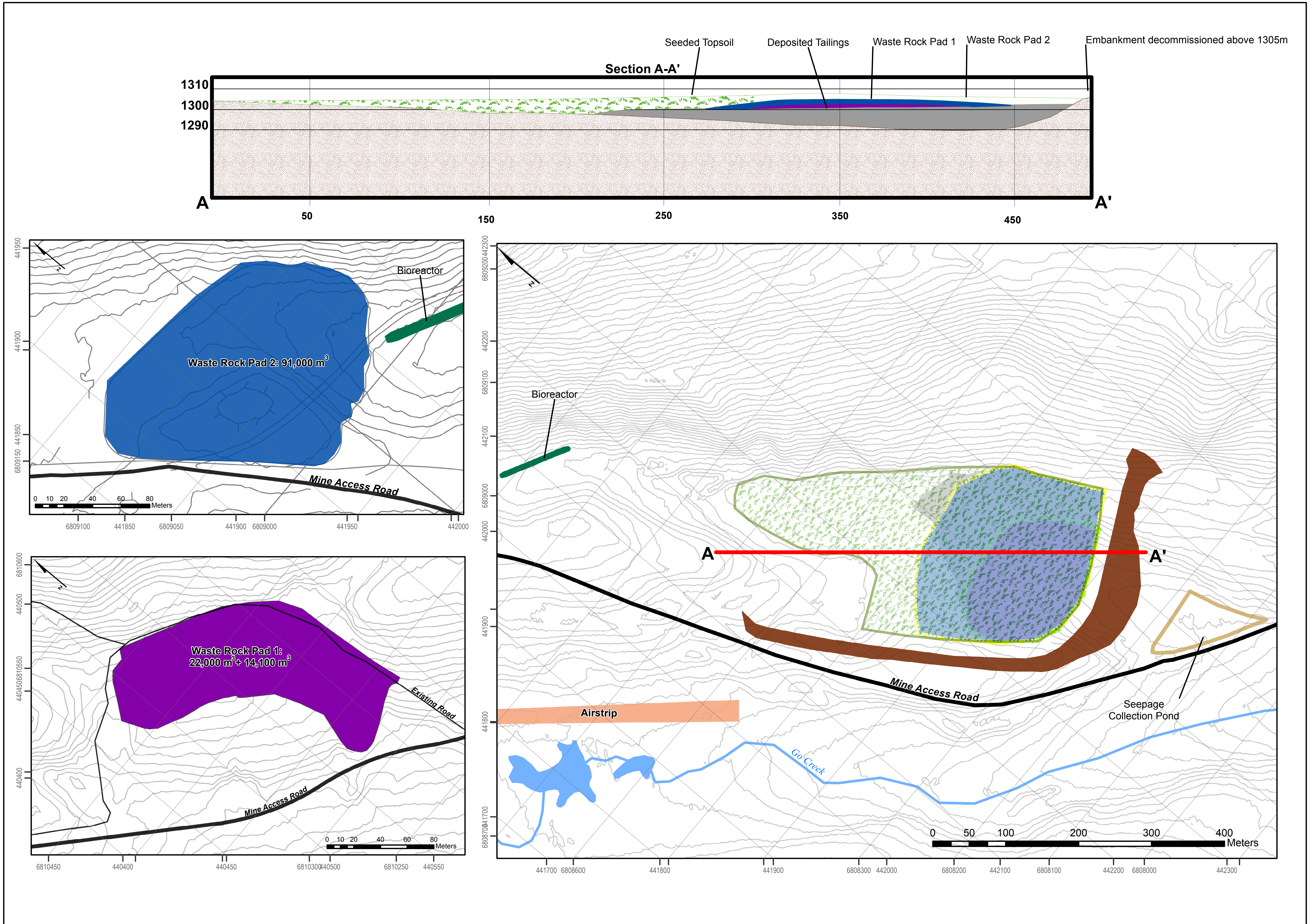

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Figure 6-4

Wolverine Mine: Conceptual TSF Closure Plan

Site Infrastructure

- Mine Access Road
- TSF Dam Face
- Seepage Collection Pond
- Airstrip
- Waste Rock Pad 1
- Waste Rock Pad 2
- Bioreactor
- Deposited Tailings
- TSF Footprint

Topography

- Contour
- Watercourse
- Waterbody

Date: 27/12/2016
Author: H.Seeley, P.Geo, Wolfbear Geological Consulting
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

CONCEPTUAL
NOT FOR
CONSTRUCTION

The solids portion of the tailings material (a sand-silt mixture with relatively low permeability) is considered to be potentially acid generating, based on static and kinetic testing of composite tailings samples. Static testing indicated that tailings material contains significant quantities of sulphide-sulphur and lesser quantities of neutralization potential. Kinetic testing of two tailings samples in laboratory humidity cells, overseen by Marsland Environmental Associates, ceased in February 2012 after operating for over 340 weeks each. Humidity cell tests indicated that the onset of acid generation under laboratory conditions could take five years for the diluted ore tailings sample, the most representative sample of actual Wolverine tailings. By maintaining the TSF material in a saturated state in a lined and covered facility, the potential effects of any potential acid generation are mitigated.

The TSF landform will be seeded based on the reclamation research that has been conducted on the Wolverine Mine site to date (Section 2.2.2). Landform design will aim to reclaim the land to restore wildlife habitat through the re-establishment of a self-sustaining vegetative mat. Detailed design of the TSF landform will be completed prior to construction. Physical and chemical stability of the TSF landform will be monitored during the decommissioning and post-closure phases. No long-term maintenance is expected once the landform is established. Water treatment of any seepage is not anticipated to be required, as the TSF landform is lined to prevent against seepage and the cover will be impermeable, thus there should be no seepage from the capped TSF. Any surface water runoff in the TSF landform area should not be affected by the chemistry of the tailings and waste embalmed in the TSF landform.

6.2.1 Tailings Storage Facility (TSF) Water Treatment

During the decommissioning phase, the TSF water will be treated in situ and subsequently dewatered. Water treatment must remove approximately 99% of selenium, 96% of copper, and 60% to 85% of other metals to comply with WUL discharge limits. In fall 2016 a treatability assessment was completed by SRK and two selenium treatment options were favoured and are discussed below (full report in Appendix A). The final treatment method will be determined by the success of field-scale trials conducted during the temporary closure phase.

6.2.1.1 Selenium Removal Option 1: In-Situ Biological Treatment, Ferric Co-Precipitation and Lime Treatment

One option to treat the elevated selenium in the TSF is to implement in situ biological treatment combined with ferric co-precipitation and lime treatment. The in-situ biological treatment process is similar to the treatment concept proposed in RCP 2015-06. The concept is illustrated in Figure 6-5.

Carbon and nutrients would be added to the TSF supernatant in July or August 2018. The relatively warm water at that time will promote growth of microorganisms and reducing conditions will begin to develop. Diffusion of atmospheric oxygen into the TSF water may initially hinder or limit the formation of reducing conditions. However, the formation of an ice cover on the TSF in late fall is expected to significantly reduce diffusion of oxygen into the water column thereby enhancing the development of reducing conditions. Depending on the consumption of carbon and nutrients through the summer months, it may be necessary to add a second dose in the fall.

In the spring of 2019, it is anticipated that the majority of selenate in the TSF will have been reduced to elemental selenium or selenite. Elemental selenium and selenite are then removed by ferric co-precipitation, flocculation and sedimentation. The alkalinity concentration of the TSF water is very low. Therefore, it will likely be necessary to add lime or caustic to maintain neutral pH after the addition of ferric.

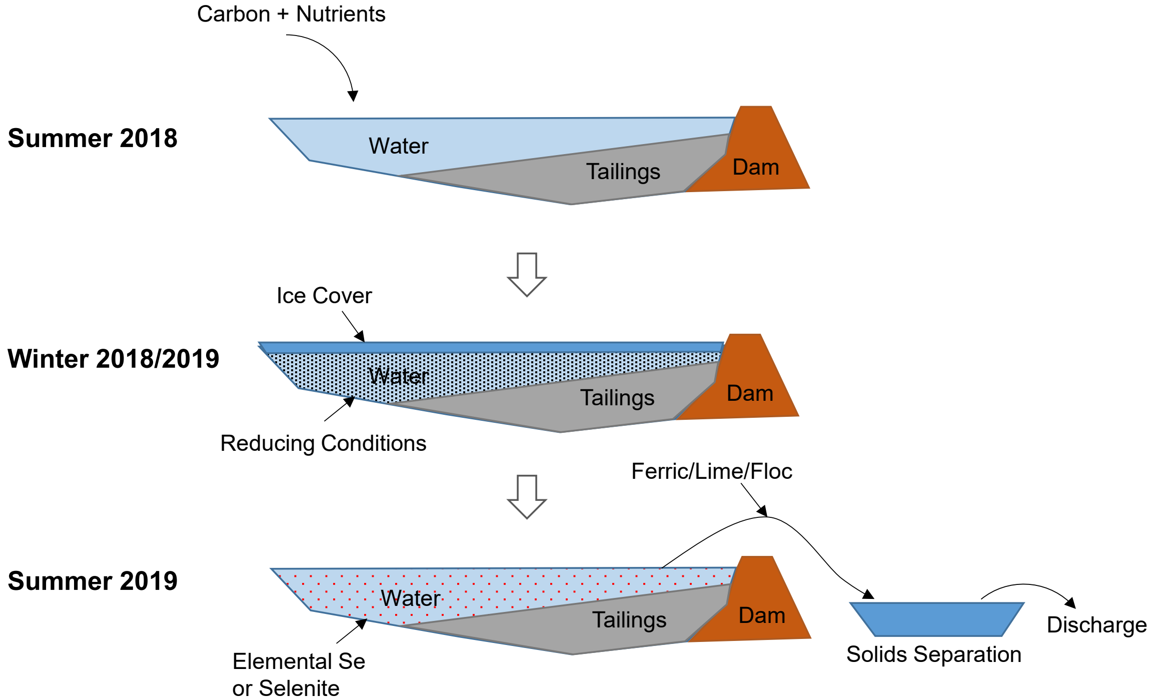

Figure 6-5: Schematic of In-situ Biological Treatment Process

The ferric co-precipitation stage proposed here differs slightly from the concept suggested in RCP 2015-06, as water would be pumped from the TSF to a settling basin or solids separation area and ferric and flocculant and lime or caustic would be added inline. Separating the solid-liquid separation step of the ferric treatment process allows for better control of dosing and mixing. It also permits the addition of other post-treatment steps such as detoxification (i.e. oxidation) of free sulphide and oxidation of ferrous iron and manganese, if required. Finally, it reduces the risks of re-suspending or oxidizing selenite through whole-pod mixing of the TSF.

A settling pond would need an effective settling area of approximately 3,200 m^2 for ferric co-precipitation. A settling pond of this size is not available on site. As an alternative, solids separation can be achieved using large geotextile bags such as Geotubes (Photo 6-1).

Photo 6-1: Example of a Geotube in Operation

In-situ biological treatment considerations include:

- Reducing conditions can lead to dissolution of certain metals such as arsenic, ferrous iron and manganese. It is likely necessary to implement an oxidation step to remove these metals if they persist in reduced form after the over-winter biological reduction treatment.
- Excessive reducing conditions can lead to formation of hydrogen sulphide gas, which can be hazardous to wildlife and human health. A plan for managing excessive reducing conditions must be developed.
- The propagation and subsequent die-off of anaerobic microorganisms could release organic molecules that can chelate dissolved metals such as copper, zinc, and cadmium. Chelated metals can be much more difficult to treat than free cationic metals.

A field trial will have been conducted in 2017/2018 to evaluate the above considerations. Full-scale treatment would then occur in 2018/2019. A field-scale trial would consists of a limno-corral installed in the TSF. A limno-corral is a cylindrical, impermeable baffle curtain that floats in the TSF and thereby encloses a volume of water (large plastic bag). The corral can have a closed bottom or can have an open bottom that is anchored to the bottom of the TSF by chains. The field-scale trial would replicate the treatment conditions intended for the whole TSF in terms of carbon and nutrient dose, mixing and subsequent ferric/lime/floc treatment. Implementation of full scale treatment would be informed by the results of the field-scale trial, including determination of reagent doses and operational parameters for the ferric treatment.

Residuals from the in-situ biological treatment and ferric co-precipitation include ferric hydroxide sludge containing elemental selenium, selenite, and metal hydroxides. In addition, some elemental selenium solids may settle directly in the TSF. If the ferric sludge is collected in geotextile bags, the sludge could be hauled for disposal in the TSF, at the end of the treatment campaign. The sludge is likely to be relative stable as long as it is not exposed to highly acidic conditions. Keeping the sludge saturated should prevent oxidation and dissolution of the selenium contained in the ferric hydroxide matrix.

6.2.1.2 Selenium Removal Option 2: Zero Valent Iron (ZVI) and Lime Treatment

A second option to treat the elevated metals in the TSF is by using ZVI treatment in combination with ferric/lime treatment.

ZVI treatment consists of passing feed water through a media of powdered ZVI followed by oxidation and removal of ferric iron (Figure 6-6). The configuration of the flow and media is not important, as long as good contact between water and the surface of the iron particles are achieved.

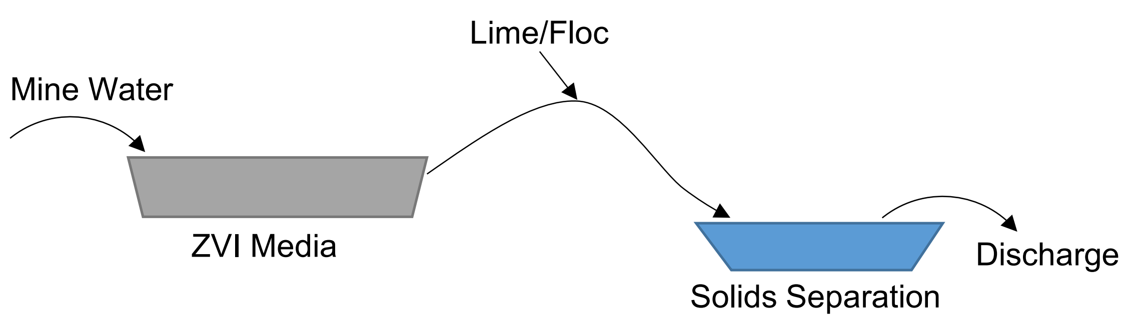

Figure 6-6: Schematic of ZVI Water Treatment Process

As oxidized species in the water are reduced, iron is oxidised to ferrous or ferric iron. Ferric iron precipitate as iron hydroxide solids, which adsorb a wide range of dissolved ions including selenite. The ferrous iron produced ferrous primarily report with the ZVI media effluent along with manganese and other constituents that may have been mobilized by the reducing action of the iron. The dissolved iron and other reduced species must be removed in a post-treatment step. Post-treatment includes an oxidation step followed by settling or filtration of the precipitated ferric hydroxide. The post-treatment concept also proposes the use of a geotextile bag for filtration and sludge accumulation (Photo 6-1).

ZVI is a strong reductant. As long as good contact between the surface of the iron particles and water is ensured, ZVI will reduce selenate to a form that can be precipitated. The greatest performance risk is likely associated with the potential for plugging the media with suspended solids and for inability to attain uniform flow through the media. However, both of these issues can be addressed through careful detailed design of the treatment system.

The main challenge associated with ZVI treatment is to prevent coating or blinding of the iron particles by layers of oxidation products. This includes ensuring that feed water is free of suspended particles. If the iron particles become coated, the dissolved constituents in the water are not able to contact the iron surface and will therefore not become reduced. Blinding of the iron media can be mitigated in two ways:

- Using a large volume of ZVI media such that the potential load of oxidation products are insufficient to completely coat the iron particles; or
- Implement engineering measures to reactivate blinded iron particles (chemical or mechanical).

Residuals from the treatment process consists of the spent iron powder, which can be disposed of in the TSF at the end of the treatment campaign.

On-site pilot- or field-scale tests are required to inform design and operation of a full-scale system. A pilot or field trial will have been completed in 2017.

ZVI treatment could be implemented by trucking the media to site when site becomes accessible in 2019. Construction of a reservoir and installation of piping would commence in late May or early June 2019 and treatment would be completed in July, August, and September. Demobilization would be complete by late September or early October.

6.3 Waste Rock and Overburden Dumps

There are two lined waste rock pads on site containing waste rock generated from underground mining:

- Waste Rock Pad #1, located south of the camp; and
- Waste Rock Pad #2 located north of the TSF.

These waste rock pads and their liners will be deposited into the TSF during the decommissioning phase. Following this work, the footprints of the waste rock pads will be reclaimed in conjunciton with the industrial complex area reclamation. This will eliminate any requirement for long-term seepage quality monitoring and possible treatment. It will also eliminate any requirement to monitor physical stability of the waste rock pads.

All temporary ore piles were moved to Waste Rock Pad #2 during temporary closure. Reclamation of the footprint areas will be carried out in conjuction with the reclamation of the industrial complex area.

6.4 Water Management Structures and Systems

Drainage structures within the industrial complex area (collection ditches 2, 3, and 5 - Figure 4-4) consist of geomembrane-lined open channels to transport storm water to a collection pond (sump #2) prior to being pumped to the TSF. The collection ditches and sump #2 will be decommissioned following the removal of all industrial complex structures. Liners will be removed and landfilled, and the ditches and sump backfilled with coarse material. Drainage will be allowed to flow naturally back to the receiving environment.

Ditch 1 which is located upslope of the industrial complex and is used to divert non-contact surface runoff around the area, will be decommissioned once infrastructure footprints and collection ditches have been reclaimed. Diversion ditches A and B (Figure 4-5) and upgradient underdrains will be decommissioned. Ditches will be re-contoured consistent with the original topography. Disturbed areas along the ditch alignments will be re-vegetated.

The tailings and water reclaim pipelines will be dismantled and disposed of in the TSF. The pipeline corridor will be seeded as barren ground is exposed with pipeline removal.

6.5 Mine Infrastructure

6.5.1 Camp

The camp facilities will be progressively removed and sold as onsite personnel requirements decrease. Facilities will remain in place for care and maintenance staff until the end of the decommissioning phase. Sewage treatment facilities will also be decommissioned and salvageable material removed from site. The water supply wells will be decommissioned once the potable water treatment and camp facilities are no longer required. The pump houses and the buried distribution system will be removed for salvage or, if deemed appropriate, the distribution system will remain buried in situ to minimize subsequent surface disturbance associated with removal. Water wells will be backfilled throughout their entire length with a combination of concrete and grout and the top 5 m will be completely cemented. Following decommissioning, the camp area will be re-contoured, soil growth medium will be added, and the area will be revegetated.

6.5.2 Industrial Complex

All materials from the industrial complex buildings will be completely dismantled and removed, with the exception of concrete foundations, which will be buried in situ. Equipment with marketable value will be sold and the remaining assets will be disposed of through demolition and salvage contracts. In the event that it is uneconomical to remove non-hazardous materials from the site, such material will be buried in the landfill. Following demolition and dismantling of the industrial complex area, approximately 22 ha of area will require soil placement and reseeding.

6.5.3 Power Generation Infrastructure

All gensets will be de-activated, packaged, and transported off the mine site to be sold. Distribution power lines will be re-spooled and sold as scrap. Power poles and distribution lines to other facilities will be salvaged or buried in the landfill. For any poles that are treated with a preservative such as creosote, the contaminated portion of the poles will be disposed of in accordance with Yukon Special Waste Regulations. The glycol loop has been emptied and the used glycol is stored in tanks. The used glycol will be transported offsite for permanent disposal or recycling.

6.5.4 Landfill and Waste Storage Areas

Decommissioning and demolition activities will generate some non-hazardous waste material that will be disposed of in the landfill area. Waste that cannot be buried in the landfill will be disposed of in the TSF. At the end of the decommissioning phase, the landfill and storage areas will be covered with a 250 mm thick compacted layer of glacial till and graded to encourage the shedding of water. The sites will then be revegetated.

6.5.5 Material and Equipment Salvage

All salvageable material will be sold and removed from the site. Material that has no scrap value will be disposed of in the landfill. Materials will be examined to ensure that all hazardous materials have been removed for proper disposal. All fixed and mobile equipment with marketable value will be removed and sold. All fixed materials currently underground inside the mine will be left in place, as the mine will have flooded during temporary closure. Equipment that cannot be sold or is deemed to be hazardous will be disposed of in a proper manner.

6.6 Hazardous Materials

Fuels and lubricants required during the decommissioning phase will be ordered on an as-needed basis with the objective of reducing the inventory of remaining fuels during decommissioning. Fuels remaining at the end of the decommissioning phase will be returned to the original supplier or sold. All tanks will be emptied of their contents in accordance with the *Yukon Environment Act*. Excess fuel storage tanks will be hauled away for resale or salvage.

Any reagents or chemicals remaining on site that are not required for closure will be disposed of in an appropriate manner. Explosives magazines have been removed during the temporary closure phase.

6.7 Roads and Other Access

The site access road will be decommissioned at the end of the decommissioning phase, which will require the following activities:

- Remove all culverts and drainage structures offsite for permanent disposal at an appropriate location.
- Trenches resulting from the removal of culverts will be swaled or contoured to match the surrounding topography. Erosion protection will be installed where required within the remaining swales, to a point where the reclaimed watercourse intersects its original course.
- The Bunker Creek Bridge at km 10 will be removed and the abutments will be excavated to the level of the rip-rap placed during construction.
- In smaller cuts and fills ditches will be filled in and the soils contoured to match the surrounding topography. Where ditches are planned to be left intact in some steeper sections, existing ditch erosion protection may be left in place.

- In large cuts and fills the embankment or excavation footprint will be contoured to a lesser extent, but all slopes will be altered to better match the surrounding topography.
- Organic stripping materials placed at the toe of fills during the original construction phase will be contoured along the downhill side to act as a sediment filter and to re-establish vegetation.
- Surfaces with less than 25% slope will be scarified to better receive seeding.
- Staging areas and roadside stockpiles will be contoured.
- All remaining borrow sources will be stabilized and contoured to prevent surface erosion and seeded.

Once all decommissioning activities have been completed and use of the site access road is no longer required, a permanent rock barricade will be installed near km 14. This location has been selected on a 10% ascending gradient, some 3 km north of the glacio-fluvial plateau that separates the upper Money Creek and Go Creek drainages. The location will deny access to highway vehicles, all-terrain vehicles and snowmobiles, should they proceed along the reclaimed road corridor from the highway. The site access road will also be barricaded at the juction with the Robert Campbell Highway.

6.8 Borrow Materials Planning

Glacial till for reclaiming disturbed areas will be supplied from borrow source areas around the mine site and from stockpiled areas at the industrial complex and adjacent to the TSF area (Figure 4-2 and Figure 4-3). Potential additional locations include areas adjacent to TSF and along the site access road (km 11, 17, 27).

6.9 Monitoring and Maintenance

6.9.1 Tailings Storage Facility (TSF) Dam

During the decommissioning phase (2018-2020), the TSF dam will be maintained in accordance with the *Wolverine Mine Tailings Facility Operation, Maintenance and Surveillance Manual V2011-03*. The physical and seepage conditions in the dam and area directly downstream of the dam will be monitored as follows:

- Quarterly: visual monitoring by mine personnel, along with the water sampling program, until safe long-term trends are indicated;
- Intermediate: annual review of monitoring data and performance of the TSF by a designated independent TSF engineer;
- Comprehensive: dam safety review by dam engineer prior to decommissioning; and
- Special Reviews: site visit and review of monitoring data are required after the occurrence of any potentially damaging events (e.g., floods, earthquakes) or unusual observations (e.g., cracks, sinkhole formation).

During the construction of the TSF landform, the crest of the dam will be used as NAG fill for the landform cover. As a result, the dam will be declassified and long-term post-closure dam safety monitoring and inspections will not be required. However, the landform will be monitored for surficial erosion, stability, vegetation establishment, and overall performance.

6.9.2 Environmental Monitoring

During the first three years of permanent closure (2018-2020), 6 surface water sites in the mine area will be monitored monthly or seasonally during open water conditions and 24 groundwater wells will be monitored annually. The proposed monitoring programs are summarized in Table 6-3 and Table 6-4. Bioreactor water quality and performance monitoring of the underground mine bioractor is included in the monitoring program. This will ensure the bioreactor is performing as designed and that water quality is meeting WUL conditions. The monitoring programs should be evaluated annually to determine if steady state conditions have been reached. Once steady state conditions have been reached, the sampling sites and frequencies should be re-evaluated.

Table 6-3: Surface Water Quality Sampling Program During Closure

Sampling Location		Sampling Frequency	
		Decommissioning Phase (2018-2020)	Post-closure Phase (2021+)
TBD	Underground Mine Portal Discharge	Monthly*	Annually
TBD	Underground Mine Portal Bioreactor Outlet	Monthly*	Annually
W82	Upper Wolverine Creek	Seasonally*	Annually
W9	Wolverine Creek at Little Wolverine Lake	Seasonally*	Annually
W16	Go Creek below TSF	Seasonally*	Annually
W80	Go Creek	Seasonally*	Annually

*During open water conditions

Table 6-4: Groundwater Quality Sampling Program During Closure

Groundwater Well	Watershed	Decommissioning Phase (2018-2020)	Post-closure Phase (2021+)
MW05-1A, 1B	Go Creek	Annually	Annually
MW05-2A, 2B	TSF	Annually	Annually
MW05-3A, 3B	Wolverine Creek	Annually	Annually
MW05-4A, 4B		Annually	Annually
MW05-5A, 5B		Annually	Annually
MW05-6A, 6B	Go Creek	Annually	Annually
MW05-7B	TSF	Annually	Annually
MW06-8S, 8M, 8D	Wolverine Creek	Annually	Annually
MW06-9S, 9M		Annually	Annually
MW06-10S, 10M, 10D		Annually	Annually
MW06-11S		Annually	Annually
MW06-12S		Annually	Annually
MW08-13	TSF	Annually	Annually

Reclamation monitoring will be completed annually during the first three years of permanent closure (2018-2020). Monitoring will include areas of disturbance that have been reclaimed including: waste rock pad areas, industrial complex area, the LTF area, landfill, exploration camp area, and mine roads. Vegetation establishment and self-sufficiency will be monitored, as well as whether fertilization is required to help vegetation communities achieve self-sufficiency. Metal uptake in vegetation will also be monitored to ensure that no uptake of metals is occuring in the vegetation. Monitoring will continue on an annual basis during the post-closure phase, until all areas have been successfully revegetated and meet the terrestrial performance standards outlined in QML-0006, including:

- Vegetation must be self-sustaining 3 to 5 years after the last application of re-seeding, maintenance, or fertilization.
- The vegetative cover must be capable of self-regeneration without continued dependence of fertilizer or re-seeding.
- Establishment of a vegetative cover with sufficient density and species diversity to stabilize the surface against the effects of long-term erosion.
- No uptake of metals by vegetation.

The site access road barriers will also be monitored annually to ensure that the mine site remains inaccessible to the public.

6.10 Performance Uncertainty and Risk Management

6.10.1 Risk Assessment

Prior to the construction and operation of the Wolverine Mine, the TSF was to be closed as a ‘wet facility’. Owing to the premature cessation of operations, the closure concept was re-evaluated to determine the best option to preserve human health and safety, and the environment. In this RCP, the final closure concept was selected to mitigate long-term risks and to best meet the reclamation and closure objectives for the Wolverine Mine (outlined in Table 1-2).

The most consequential risk to the environment and human health would be as a result of the failure of the TSF dam prior to complete decommissioning. To mitigate this risk, TSF dam monitoring will be carried out as per the *Tailings Facility Operation, Maintenance and Surveillance Manual (V2010-01)* during the decommissioning phase. Following the construction of the final TSF landform, the dam will be declassified, which will significantly reduce risks associated with the TSF dam. Not only will the physical structure pose less risk of failure, in dewatering the TSF and closing it as a dry, covered facility, the risk of a release or breach event to the Go Creek drainage is eliminated.

Other risks include discharge of contaminated water to the environment. This is mitigated through consolidation of all waste into a single facility and therefore the only potential discharge will be the negligible flow from the closed underground mine. Any discharge will be treated in a passive bioreactor treatment system, which requires minimal maintenance and monitoring. Any long-term discharge from the underground mine will likely achieve acceptable discharge standards.

6.10.2 Post-Reclamation Adaptive Management Plan

In May 2016 YZC submitted a plan to EMR regarding the environmental monitoring of underground mine workings. An Adaptive Management Plan (AMP) is included within this plan, in relation to the water quality in Wolverine Creek and discharge from the underground mine workings. Copper, selenium, and zinc have been selected as indicator parameters for overall metal concentration trends. Trigger levels for these parameters were developed from the discharge limits outlined in the WUL and Yukon Ministry of Environment guidance for developing water quality objectives.

A post-reclamation AMP will be developed during temporary closure for the Wolverine mine site. The AMP will contain details regarding:

- Triggers and thresholds for water quality indicators and adaptive management;
- Triggers for constructed/engineered structures and adaptive management; and
- Triggers for decommissioning the site access road.

This will provide a more comprehensive approach to managing the uncertainty associated with the post-closure phase.

7 Reclamation and Closure Execution Strategy and Schedule

7.1 Reclamation and Closure Schedule

This section describes the timing, sequencing, and duration of all reclamation and closure activities. Table 7-1 details the closure activities for each mine component, by phase (temporary closure, decommissioning, and post-closure). Progressive reclamation activities will continue throughout the temporary closure phase; specific activities and undertakings are described in Section 5. Reclamation research remaining to be completed during temporary closure is included in Table 7-1. Overall monitoring and maintenance applicable to all mining components for the decommissioning and post-closure phases is described in Section 6.9.

Table 7-1: Wolverine Mine Reclamation and Closure Schedule

Component	Temporary Closure Present to January 2018	Decommissioning January 2018 to December 2020	Post-Closure January 2021 to 2027
Underground Mine	• The underground mine will continue to flood. • A bioreactor will be constructed during Summer 2017 at the entrance of the underground mine to capture discharge. Water treatment trials will commence once the bioreactor is constructed. • The hydraulic bulkheads for the portal and ventilation raise will be installed during Summer 2017.	• Water quality from the underground mine portal will be monitored on an ongoing basis. Discharge will be treated through the bioreactor, if required to meet allowable discharge limits. Triggers outlined in the AMP will determine when treatment is required. • The portal apron will be reclaimed.	• Water quality is anticipated to be suitable for direct discharge to Wolverine Creek. Discharge will be treated through the bioreactor, if required to meet allowable discharge limits. Triggers outlined in the AMP will determine when treatment is required.
TSF	• The TSF will continue to receive water from site. • TSF in situ water treatment field trials will be initiated in Summer 2017 for biological in situ treatment and ZVI treatment. • In situ treatment will take place during each open water season prior to dewatering the TSF. • The contents of the LTF will be deposited into the TSF during Summer 2017.	• The free water in the TSF will be treated prior to dewatering and discharging to Go Creek. • Waste Rock Pads #1 and #2 (including liners) will be deposited into the TSF. • The TSF dam material above the tailings level will be removed. This material will be used as NAG cover material for the final TSF landform. • The Stage 2 area will be deconstructed and the footprint of the TSF will be confined to the Stage 1 area. • The TSF will be closed as a dry facility with an impermeable cover. Surface water will be diverted off of, or around the final TSF landform.	• Monitoring of the final TSF landform will be ongoing during post-closure. Landform stability will be monitored to ensure the final TSF landform is performing as designed.
Seepage collection pond	• The seepage collection pond will operate throughout temporary closure.	• The seepage collection pond will be decommissioned with road.	• Reclamation monitoring will be ongoing during post-closure.
Waste rock and overburden dumps	• Waste Rock Pad #1 and Waste Rock Pad #2 will remain in place during temporary closure. • Waste Rock Pad #2 bioreactor trials will continue through the temporary closure phase.	• Waste Rock Pad #1 and Waste Rock Pad #2 (including liners) will be deposited into the TSF. • The footprints of Waste Rock Pad #1 and #2 will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Ore stockpiles and pads	• The temporary ore stockpiles have been consolidated into Waste Rock Pad #2.	• The footprints of any ore stockpiles will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Industrial complex	• The industrial complex has been cleaned up to meet health and safety and temporary closure requirements. Materials are being salvaged and assets are being sold.	• The industrial complex will be decommissioned and the footprint will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Camp and Administration Complex	• The camp and administration buildings will remain in operation in a limited capacity throughout temporary closure.	• The camp and administration buildings will be decommissioned and the footprint will be reclaimed. • Any facilities required for decommissioning crews will be	• Reclamation monitoring will be ongoing during post-closure.

Component	Temporary Closure Present to January 2018	Decommissioning January 2018 to December 2020	Post-Closure January 2021 to 2027
		the responsibility of the decommissioning contractor.	
Land treatment facility (LTF)	• The LTF will be decommissioned during Summer 2017 and the footprint will be reclaimed. • The contents of the LTF will be deposited into the TSF during Summer 2017.	• Reclamation monitoring will be ongoing during decommissioning.	• Reclamation monitoring will be ongoing during post-closure.
Landfill	• The landfill will remain operational throughout temporary closure.	• The landfill will be closed at the end of decommissioning phase.	• Reclamation monitoring will be ongoing during post-closure.
Exploration camp and roads	• The exploration camp has been decommissioned and the footprint has been reclaimed. • Critical roads will be drivable by ATV, for the purpose of accessing environmental monitoring sites.	• Critical roads will remain drivable by ATV until the end of the decommissioning phase. • The road footprints will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Mine roads	• The mine roads will continue to be maintained year-round.	• Critical mine roads will remain open until the end of the decommissioning phase. • The mine roads footprints will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Airstrip	• The airstrip will continue to be maintained year-round.	• The airstrip will remain operational until the end of the decommissioning phase. • The airstrip footprint will be reclaimed.	• Reclamation monitoring will be ongoing during post-closure.
Site access road	• The site access road will continue to be maintained during snow-free months.	• The site access road will remain operational for the decommissioning phase. The road will be deactivated and reclaimed at the end of the decommissioning phase.	• Reclamation monitoring will be ongoing during post-closure.

7.2 Execution Strategy

This section describes the human resource requirements for the execution of the RCP. Human resource requirements for each mine component are summarized in Table 7-2 by phase. Contractors will be retained to carry out most closure activities, as YZC has only a small number of full-time site staff. Environmental monitoring during the decommissioning and post-closure phases will be undertaken by YZC employees, or contractors (see Section 6.9).

Table 7-2: Human Resource Requirements for Closure

Closure Component		Personnel Required		
		Temporary Closure Present to January 2018	Decommissioning January 2018 to December 2020	Post-Closure January 2021 to 2027
Underground mine	Installation of hydraulic bulkheads and closure of underground mine portals	• Lead engineer • Senior environmental consultant • Site staff • Installation contractor	N/A	N/A
	Underground mine portal bioreactor construction and operation	• Site Supervisor • Senior environmental consultant • Site staff	• Site Supervisor • Senior environmental consultant • Site staff	• Reclamation monitor
TSF	Water treatment field-scale studies: • In situ TSF water treatment • Waste Rock Pad #2 Bioreactor ongoing trials	• Site Supervisor • Senior environmental consultant • Site staff	N/A	N/A
	Water treatment and dewatering	N/A	• Site Supervisor • Senior environmental consultant • Site staff • Water treatment workers	N/A
	Final landform	N/A	• Site Supervisor • Senior environmental consultant • Site staff • Construction workers	• Reclamation monitor
Land Reclamation and Revegetation: • Industrial complex, including underground mine portal • Waste rock / stockpile footprints • Camp • Mine roads • Seepage collection pond • Airstrip • Landfill • LTF • Exploration camp and roads • Site access road		N/A	• Site Supervisor • Senior environmental consultant • Site staff • Construction workers	• Reclamation monitor

8 Reclamation and Closure Liability

The temporary closure cost estimate (Section 8.1) encompasses two of the conditions specified in the *Reclamation and Closure Planning for Quartz Mining Projects – Plan requirements and closure costing guidance* (August 2013) document:

1. Current status, and
2. Peak liability (e.g. prior to the permanent closure of the TSF and the underground mine).

The third condition, end-of-mine life, is considered in the final reclamation and closure cost estimate (Section 8.2).

Each reclamation and closure liability cost estimate considers local conditions and costs, and the current state of the Wolverine Mine. These cost estimates assume that work will be undertaken by a third party contractor and use best available costing information. Although the cost estimates rely on rates for contractors, as directed by the *Reclamation and Closure Planning for Quartz Mining Projects – Plan requirements and closure costing guidance* document, it should be noted that YZC has the majority of required equipment on site, which will save a considerable amount of actual cost.

The unit rates applied in the temporary closure cost estimate and the permanent closure cost estimate are the same, given that the temporary closure phase will be complete 1 year after the submission of this RCP, and the permanent closure phase will start just over 1 year after the submission of this RCP.

Unit rates for equipment for dry conditions were obtained from Government of Yukon Third Party Equipment Rental Rates (2011/2012) and focused on contractors and rates published out of Whitehorse, Ross River, and Watson Lake.

The unit rates used in these cost estimates are summarized in Table 8-1.

Table 8-1: Unit Rates Used to Calculate the Temporary Closure and Permanent Closure Cost Estimates

Equipment	Hourly Rate	Monthly Rate
Cat D8N Dozer (1991)	$245	
Volvo A30D Rock Truck (2006)	$197	
Compactor - Cat CS563 84" (2006)	$140	
Cat 320CL Excavator (2004)	$125	
Cat 320 Excavator + Hammer (2004)	$170	
Cat 14G grader (2000)	$160	
Cat 950H Loader (2009)	$150	
Drill Rig	$190	
Crane 30 ton	$160	
Light-duty vehicle		$2,500
Labourer	$50	
Tradesman	$80	
Site Supervisor	$95	
Design Engineer	$130	
Project Engineer	$140	
Project Manager		$10,500
Site Caretaker		$8,800
Environmental Technician		$6,000
Contractor Unit Rates; Misc. Costs	**Units**	**Cost**
Excavation of Soil in Stockpile	m^3	$5
Supply and place geotextile	m^2	$12
Load, haul and place topsoil	m^3	$5
Load, haul and place tailings cover (CIM)	m^3	$7
Load, haul and place rock cover, organics, granular till and clay	m^3	$8
Drill, Blast and Haul Rip Rap	m^3	$22
Place Rip Rap	m^3	$14
Camp Costs	day/person	$85
Surface water quality analyses	sample set	$420
Groundwater quality analyses	sample set	$290
Water Treatment Cost	m^3	$0.40
Revegetation Seed Mix	kg	$13
Fertilizer	kg	$1
Seed and Fertilizer Application	ha	$1,500
Concrete	m^3	$85
Culvert Removal (<1200mm)	each	$1,500
Culvert Removal (>1200mm or multiple/location)	each	$5,000
Flights (Whitehorse-Wolverine + commercial connections)	each	$3,000
Erosion barrier	per linear km	$3,000

8.1 Temporary Closure Cost Estimate

QML-0006 allows for a temporary closure phase of 3 years, prior to initiating permanent closure activities. The The Wolverine Mine will have been in temporary closure for almost 2 years by the time this RCP is submitted to EMR; therefore, the temporary closure cost estimate reflects the period from January 2017 to January 2018.

Table 8-2 provides a summary of reclamation and closure costs for the temporary closure phase.

Table 8-2: Summary of Temporary Closure Costs (current status & peak liability)

Work Item Description	Sub Total Costs	Total Costs
Mine Workings		**$378,433**
Underground Mine Hydraulic Bulkhead Installations	$318,300	
1345 Portal & Vent Raise Closures	$18,520	
Underground Mine Portal Bioreactor Construction	$7,210	
10% Contingency	$34,403	
Tailings Area		**$30,800**
Assess Water Treatment Options	$28,000	
10% Contingency	$2,800	
Infrastructure		**$6,732**
Move LTF to TSF	$6,120	
10% Contingency	$612	
Site Management and Monitoring		**$912,709**
Organization, Security and Overhead	$509,675	
Compliance Monitoring and Reporting	$320,060	
10% Contingency	$82,974	
Estimated Total Temporary Closure Cost		**$1,328,674**

The total estimated cost for the temporary closure phase is approximately $1.33 M dollars.

8.1.1 Basis of Costing

The following sections describe the assumptions used to estimate costs for manpower, equipment, and supplies for each of the options considered.

The temporary closure cost estimate includes the following assumptions:

- A minimum crew is maintained at site, with additional training as required to fulfill all functions, such as first aid and environmental monitoring. Rotations are assumed to be 21 days in and 21 days out.
- Minimal power requirements, allowing for the use of smaller gensets and a corresponding significant reduction in diesel consumption which is currently being applied at the site.
- The site access road is operated six months per year, from May to October. The project is operated on a “fly in-fly out” basis from November to April.
- The airstrip and local site roads will be maintained year-round.

8.1.1.1 Manpower

The proposed TCP assumes a full time staff of six workers in total, on two three-person rotating crews working three weeks “on” followed by three weeks “off”. As such, there are only three full-time workers on site at any given time. Occasionally a work plan will require additional temporary assistance, primarily for equipment maintenance and operation. In this case, additional specialist operators and mechanics have been assumed depending on the optional programs enacted.

Support costs for all YZC personnel have been estimated at approximately $116 per worker day. This is based on the cost of commercial travel, charter flights, grocery flights, and allows a camp support cost of $85 per worker day.

8.1.1.2 Equipment Operation

Hourly operating costs were derived by determining the rated hourly fuel consumption of the relevant equipment; additional charges were then estimated by scaling for parts and maintenance costs based on data from another operation.

Rates for contractor equipment were derived from an independent quotation from a contractor to a regular favourable client in BC; these rates include the equipment and its operator. As these were preferred rates, a premium of 30% was added to reflect the mine’s remote location in Yukon.

Fuel for the TCP is planned to be stockpiled on site in the fuel tank farm during the six months of road operations for subsequent consumption through the winter months. This results in a “seasonal fuel adjustment” in the cost estimate.

8.2 Final Reclamation and Closure Cost Estimate

The final reclamation and closure cost estimate is reflective of activities taking place from January 2018 onwards. The decommissioning phase is assumed to be from January 2018 to December 2020 (3 years), and the post-closure phase is assumed to be from 2021 to 2027 (7 years).

The estimation of reclamation and closure costs from the RCP V2013-05 and RCP V2015-06 was used as the starting point for the estimate of closure costs for this RCP. Although the unit costs used in RCP V2013-05 and RCP V2015-06 are three and one years old respectively, they are still considered to be valid for application to this RCP. This is owing to the reductions in Northern wages and current reduced chargeout rates for construction equipment in the current mining downturn. As a consequence, no inflation has been added to these rates. In fact, due to the retraction of the mining and energy industries, an argument could be advanced that construction deflation has occurred, particularly to wages in the North, given the high rates of unemployment in the energy and mining sectors. These rates should therefore be considered valid and conservative for use in 2016.

Table 8-3: Summary of Final Reclamation and Closure Costs (end-of-mine life)

Work Item Description	Sub Total Costs	Total Costs
Tailings Area		**$3,144,356**
Decommission Diversion Ditches	$24,955	
Remove Tailings Pipeline - Place in TSF	$65,325	
Remove Reclaim Pipeline - Place in TSF	$65,325	
Treat and Discharge TSF Free Water (ONE OPTION)	$2,232,000	
Construct Final TSF Landform	$470,900	
10% Contingency	**$285,851**	
Infrastructure		**$2,355,944**
Industrial Complex + Office Buildings	$582,676	
Power Supply - Gensets	$54,700	
Reclaim Site Diversions	$31,875	
Water Supply Wells	$10,421	
Reclaim Explosive Magazines	$225	
Miscellaneous Buildings and Structures	$110,910	
Industrial Reagents Fuels and Waste	$210,000	
Spill Cleanup	$30,000	
Demolition Overhead	$110,000	
Waste Rock Pads	$893,200	
LTF Area Reclamation Maintenance	$300	
Close Landfill	$4,500	
Reclaim Stockpile Footprints	$3,600	
Decommission and Reclaim Mine Site Roads	$95,760	
10% Contingency	**$213,817**	
Access Road		**$529,612**
Decommission and Reclaim Access Road	$481,466	
Reclaim Seepage Recovery Dam	$15,720	
10% Contingency	**$48,147**	
Site Management and Monitoring		**$2,318,734**
Organization, Security and Overhead	$1,216,290	
Compliance Monitoring and Reporting	$800,000	
15% Contingency	**$302,444**	
Estimated Total Closure Costs		**$8,348,645**

The total estimated cost for the permanent closure phase is approximately $8.35 M dollars. In combination with the estimated temporary closure costs, it will cost an estimated $9.67 M dollars to reclaim and close the Wolverine Mine.

Details for each cost calculation are included in Appendix B for each the following mine components:

- Tailings Area
- Infrastructure
- Site Access road; and
- Site Management and Monitoring.

8.2.1 Basis of Costing

The final closure cost estimate is based on the following assumptions and rationale:

- No salvage value is included in the estimate.
- No discounting has been included in the estimate.
- Reclamation and decommissioning costs are based on the cost to have the work completed by a third party contractor.
- The excess liner from the TSF will be able to be used as an impermeable cover in the final TSF landform construction.
- Any discharge from the underground mine portal will be able to be treated by a bioreactor at its outlet.
- Costs associated with closure monitoring, and in particular surface water quality and groundwater quality analytical, are based on current costs incurred by YZC. The number of samples for analysis over the total closure period is significantly reduced from monitoring requirements set forth in WUL QZ04-065.
- Non-acid generating fill and rock and glacial till will be available within the project area for closure activities.
- Decommissioning and post-closure phases are assumed to be complete 10 years after the commencement of permanent closure.
- Contingencies, ranging from 10% to 15%, have been included in the cost estimate for each closure component based on the level of uncertainty in the assessment and the degree of risk associated with each component.

A number of personnel will be required onsite to implement the various decommissioning, closure and reclamation activities. The majority of these activities will be undertaken during the snow-free period (May to October) and directed by an onsite supervisor.

To accurately represent the costs to YZC going forward, premiums have been applied to most cost elements as follows:

- Manpower: A premium of +30% has been applied to all contractor rates. An annual retention bonus of one month's salary is assumed for all staff, applied to the month of October.
- Supplies: A premium of +30% is applied to most supplies costs, +10% for fuel
- Equipment: A premium of +30% has been applied to all equipment rental and parts replacement costs.
- Added to these premiums, a contingency of 30% has been applied to all costs.

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Appendix A: Wolverine Mine Water Treatment Assessment, SRK Consulting, December 2016

Wolverine Mine
Water Treatment Assessment

Prepared for

Yukon Zinc

Prepared by

SRK Consulting (Canada) Inc.
1CY004.000
December 2016

Wolverine Mine
Water Treatment Assessment

December 2016

Prepared for

Yukon Zinc
705 – 1030 West Georgia St
Vancouver, BC V6E 2Y3

Tel: 604 682 5474
Web: www.yukonzinc.com

Prepared by

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2
Canada

Tel: +1 604 681 4196
Web: www.srk.com

Project No: 1CY004.000

File Name: Wolverine Mine Water Treatment Assessment 1CY004.000 20161209_SRJ_FNL.docx

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1 Introduction

This report documents a water treatment assessment by SRK Consulting (SRK) for the Wolverine Mine owned and operated by Yukon Zinc Corporation (YZC). The purpose of the assessment is to evaluate options for treating and releasing approximately 650,000 m^3 of free pond water (supernatant) stored in the Tailings Storage Facility (TSF) at the mine.

In the 2015 Reclamation and Closure Plan for the Wolverine Mine, YZC envisioned that the TSF would be closed as a water retaining facility, which would maintain a water cover over the predominantly acid generating tailings (YZC, 2015). When the closure plan was issued in June 2015, the tailings occupied approximately 40% of the design capacity (about 0.85 million tonnes (Mt) of the design capacity of 2.1 Mt).

The prospect of closing the mine prior to complete build-out of the TSF prompted YZC to re-evaluate the closure concept for the facility. Specifically, YZC wanted to look at options for closing the TSF as a dry facility by dewatering the supernatant pond and covering the tailings with a synthetic liner and waste rock. The construction of a cover with a synthetic liner is thought to eliminate or reduce the need for ongoing water treatment. In addition, a dry tailings facility would potentially allow for declassification of the dam structure, which would minimize ongoing maintenance and geotechnical inspection requirements. This assessment assumes that the Wolverine Mine would be permanently closed in January 2018, following the current period of Temporary Closure, with no additional milling or mining activities conducted in the interim.

This report summarizes the water treatment assessment conducted by SRK, and presents options for effectively treating the supernatant to meet regulatory discharge requirements prior to dry closure of the TSF. The report also summarizes recommendations to improve water chemistry in the TSF during the temporary closure period, and next steps in the treatment evaluation.

2 Water Treatment Requirements

2.1 Treatment Concept

This water treatment assessment was focused on evaluating options for treating and discharging approximately 650,000 m^3 of free water from the tailings pond at Wolverine, in order to close the TSF with little or no pond in the tailings area. The proposed concept would include a treatment campaign and partial dewatering of the facility in the open water season of 2018 or 2019. Relocation of tailings and placement of a cover could be completed concurrently or after the conclusion of the treatment campaign.

The campaign nature of the proposed concept and the short open water season is a key consideration for the treatment assessment. Treatment campaigns typically rely on mobile equipment, which favor low-complexity treatment methods such as simple reactors (column or mix tanks) followed by solids separation (sedimentation and filtration). Treatment methods that require long residence times or complex infrastructure are more difficult or impractical to implement on a campaign basis, particularly at a remote site. The suitability of different treatment methods will be discussed further in Section 3.

2.2 Water Quality and Free Water Inventory

Discharge of water from the Wolverine Mine is governed by the Type A Water Use Licence (WUL) QZ04-065. The WUL stipulates maximum water quality parameter concentrations permitted in effluent from the mine to Go Creek, which is located downstream of the TSF. Table 1 shows summaries of the two most recent quarterly water quality samples collected from the TSF pond (Station T1) along with the WUL discharge limits.

Table 1 Tailings Pond (T1) Surface Water Quality and WUL Discharge Limits

	T1 Surface		WUL QZ04-065
	7 June 2016	**20 Sept 2016**	**Go Creek Discharge Quality Limits**
pH	7.29	6.82	6.5-9.0
Total Suspended Solids	2	5	15
Sulphate	1340	1700	1800
Ammonia-N	0.62	0.44	5
Nitrate-N	0.10	0.21	10
Nitrite-N	0.10	<0.20	0.6
Cyanide -total	n/a	0.0115	0.05
Cyanide-weak acid dissoc.	n/a	n/a	0.02
Total Metals			
Aluminum (Al)	0.0571	0.0240	0.8
Antimony (Sb)	0.0450	0.0437	0.08
Arsenic (As)	0.0074	0.0074	0.05
Cadmium (Cd)	0.013	0.012	0.002
Copper (Cu)	0.426	0.364	0.015
Iron (Fe)	0.595	0.218	0.5
Lead (Pb)	0.173	0.080	0.02
Molybdenum (Mo)	0.070	0.094	0.73
Nickel (Ni)	0.0069	0.0072	0.5
Selenium (Se)	1.58	1.49	0.02
Silver (Ag)	0.0052	0.0045	0.001
Zinc (Zn)	1.32	1.36	0.5
Dissolved Metals			
Aluminum (Al)	0.015	0.0094	**Dissolved Parameters not Regulated**
Antimony (Sb)	0.040	0.046	
Arsenic (As)	0.006	0.0066	
Cadmium (Cd)	0.012	0.012	
Copper (Cu)	0.403	0.337	
Iron (Fe)	0.126	0.054	
Lead (Pb)	0.110	0.041	
Molybdenum (Mo)	0.059	0.089	
Nickel (Ni)	0.0065	0.0072	
Selenium (Se)	1.55	1.68	
Silver (Ag)	0.0024	0.0031	
Zinc (Zn)	1.26	1.33	

Notes: **Highlighted** values indicate exceedances of licenced discharge water quality limits

Currently, the TSF pond water would have to be treated for selenium, copper, lead, cadmium, silver and zinc in order to comply with the WUL discharge limits. Both total and dissolved parameter concentrations exceed the WUL limits, which indicates that the elevated concentrations are not associated with suspended solids (i.e. simple filtration of suspended solids will not work as a treatment method). Selenium concentrations exceed the applicable discharge limit by about 76 times, copper by 26 times and lead, cadmium, silver and zinc by 2 to 6 times. This means that treatment must remove approximately 99% of selenium, 96% of copper and 60% to 85% of the other metals.

Since 2014, the alkalinity and pH of the TSF water has gradually decreased with an accompanying increase in certain parameters such as sulphate and dissolved zinc. The consequences of the decreasing alkalinity are discussed in Section 3.1.

In August 2016, the total TSF volume of the TSF was estimated at 1,095,000 m^3 by bathymetric survey. Approximately 570,000 m^3 was occupied by saturated tailings while the volume of free water above the tailings was roughly 525,000 m^3. According to the site water balance, the inventory increases by approximately 50,000 m^3/year in years with average precipitation. Therefore, by 2017 the inventory is expected to be approximately 575,000 m^3 and 675,000 m^3 by 2019 (YZC 2015). For this assessment, a free water volume of 650,000 m^3 was assumed.

The total storage capacity of the TSF to the spill-level elevation is 1,553,000 m^3 (1311.5 m elevation). Assuming that the annual inflow amount to the average of 50,000 m^3, it will take approximately 8 years to fill the TSF. Assuming that a 1 m freeboard is required below the below the dam spillway (at 1310.5 m), the total storage capacity is 1,378,000 m^3. It will take about 5 years for the TSF inventory to reach this volume assuming average annual precipitation.

2.3 Design Basis

Water treatment methods for the Wolverine Mine was evaluated based on the design basis listed below.

- Effluent quality: WUL discharge limits as listed in Table 1.
- Treatment season: the treatment season is assumed to last from June 1 to September 30, or approximately 120 days. The treatment season must include time for mobilization to site, construction and commissioning of treatment equipment, treatment campaign and demobilization of equipment. For the purpose of this assessment, it is assumed that the 120 day season includes 90 equivalent days of full capacity treatment to account for commissioning, mobilization and mechanical downtime.
- Treatment capacity, assuming:
  - One operating season (2019): 650,000 m^3 within one open water season (90 treatment days) corresponds to an average treatment capacity of 7,200 m^3/day or 1,300 gpm.

  - Two operating seasons (2018/2019): 340,000 m^3 within two open water seasons (90 treatment days) corresponds to an average treatment capacity of approximately 700 m^3/day or 700 gpm.

- Treatment residuals: residuals from the treatment process must be disposed of in a stable form on site.
- Complexity: suitable for implementation at a remote site with limited infrastructure.

3 Screening Assessment of Water Treatment Methods

3.1 TSF Pond Alkalinity

As discussed in Section 2.2, the alkalinity concentrations and pH of the TSF pond water has been decreasing since the commencement of temporary closure in February 2015 (Figure 1). At the same time, dissolved zinc and iron concentrations have increased (Figure 2 and Figure 3), while selenium concentrations have decreased (Figure 4). The reduction in selenium is likely a result of the increased iron concentrations/loadings, which can co-precipitate selenite as iron precipitates as ferric hydroxide.

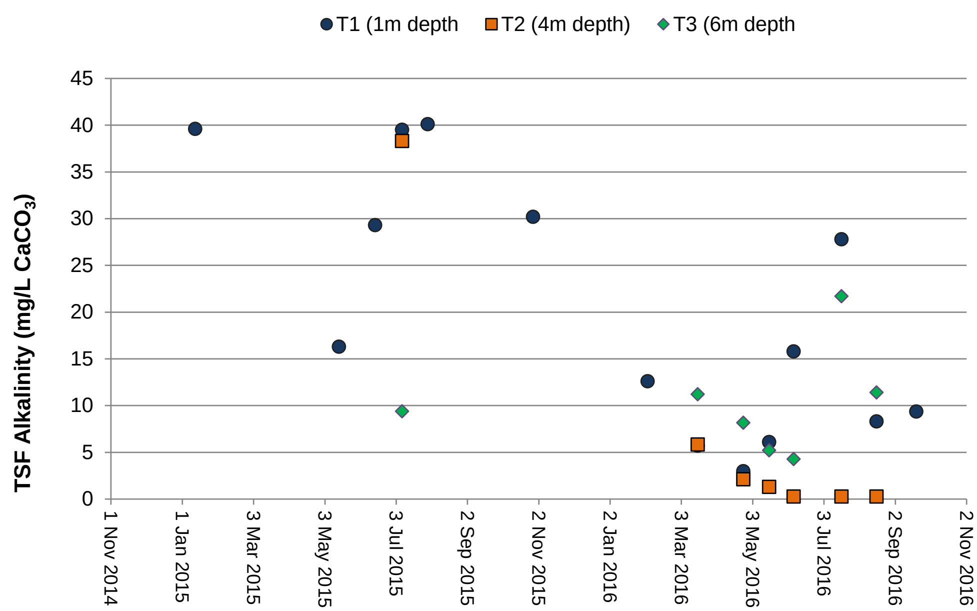

Figure 1 Alkalinity Concentrations in the Wolverine TSF

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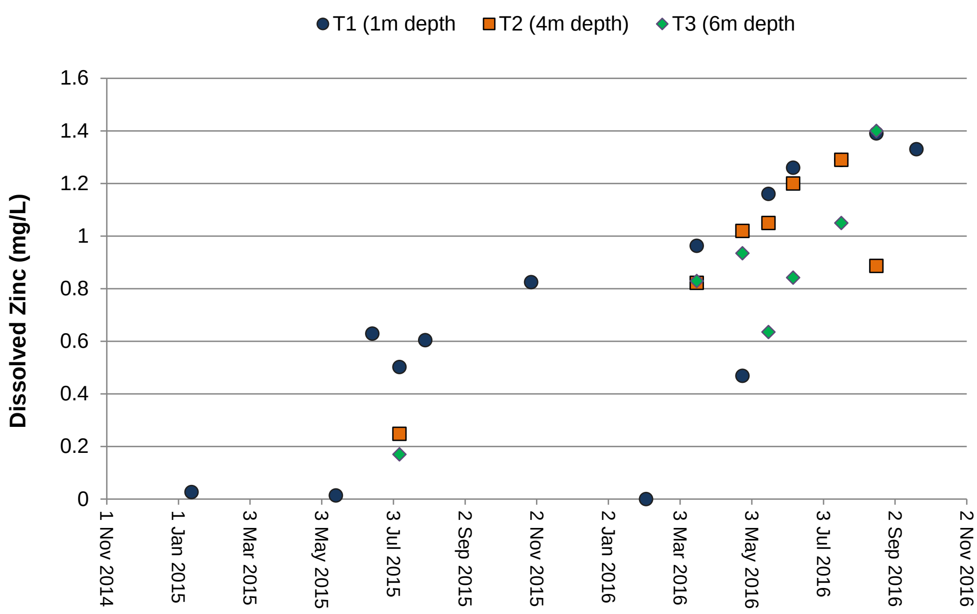

Figure 2 Dissolved Zinc Concentrations in the Wolverine TSF

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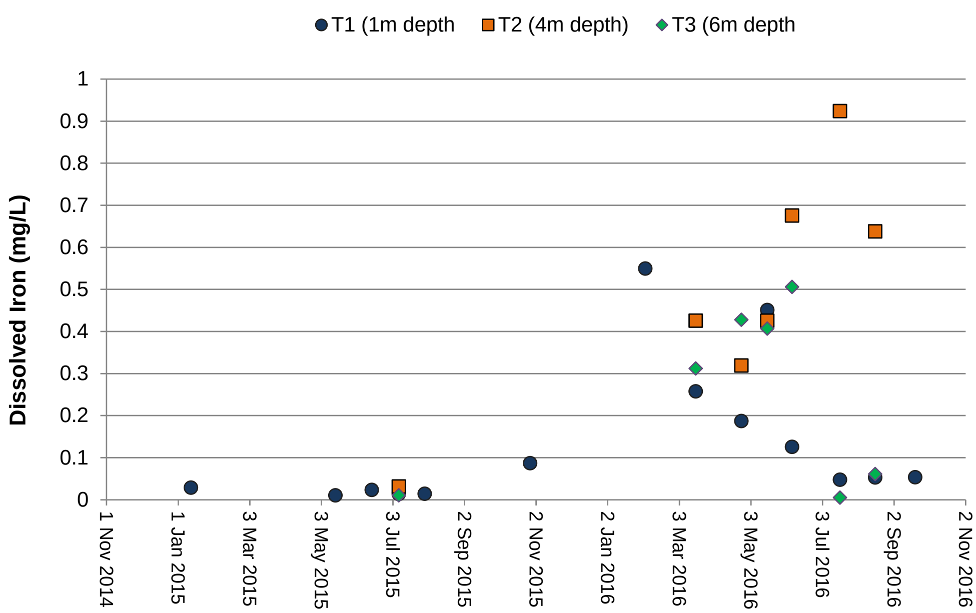

Figure 3 Dissolved Iron Concentrations in the Wolverine TSF

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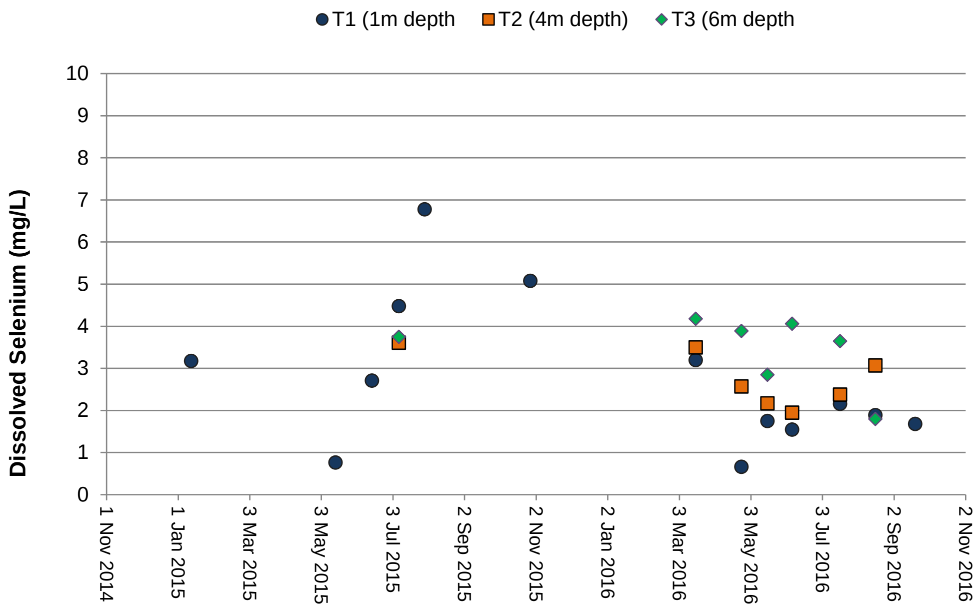

Figure 4 Dissolved Selenium Concentrations in the Wolverine TSF

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The specific sources of acidity have not been characterized. Assuming that the reduction in alkalinity between July 2015 and July 2016 was approximately 35 mg/L (as $CaCO_3$), the total acidity load added in that year was about 18 tonnes (as $CaCO_3$).

The near depletion of alkalinity in the TSF means that the pond is likely to become acidic (i.e. pH less than 5) sometime within the next 6 to 12 months. Acidic pond water will solubilize metals and sulphate and generally deteriorate the pond water quality. This can be mitigated by adding a source of alkalinity to the pond, such as lime. Assuming that YZC aims to maintain the pond water at near-neutral pH until a treatment campaign can be launched in 2018 or 2019, then approximately 60 tonnes of alkalinity would be required, which is equivalent to approximately 40 tonnes of quicklime. Such a dose will add approximately 100 mg/L of alkalinity to the pond water.

3.2 Selenium Treatment

Selenium has long been identified as the primary water quality parameter of concern for the Wolverine Mine. Unlike most dissolved metals, selenium cannot be removed using conventional water treatment methods such as lime or ferric treatment, but requires treatment methods that are more challenging to implement. Selenium treatment technologies for mine operations are generally in the 'development' or 'early adoption' phase. Only a hand-full of Canadian mines have implemented selenium water treatment and performance and operational information or data from full scale operations are limited.

YZC has previously invested in development and advancement of selenium treatment through a number of bench-, pilot- and field-scale studies (YZC 2015; YZC 2016). The water treatment studies have focused on semi-passive in-situ water treatment systems that involves anaerobic biological reduction and sequestration of selenium. In addition, YZC developed a treatment concept for the 2015 closure and reclamation plan, which involved biological treatment and ferric co-precipitation implemented in-situ in the TSF (YZC 2015).

General methods for removing selenium from mine water have been documented in numerous publications and proceedings (NAMC 2010; Sandy 2010; Sobolewski 2006; US EPA 2001). This assessment focussed on evaluation of conventional and proven selenium treatment methods and on the in-situ biological treatment concept previously developed by YZC. The following general methods were considered:

A. In-situ biological reduction + ferric co-precipitation

B. Chemical or electrochemical reduction

C. Ion exchange + electrochemical reduction

D. Membrane concentration (reverse osmosis or nano-filtration + A or B).

E. Barium sulphate co-precipitation.

3.2.1 In-Situ Biological Reduction + Ferric Co-Precipitation

In recent years, some coal mines in British Columbia have constructed selenium treatment plants that use biological reduction process and ferric co-precipitation for selenium removal. Examples include the mine water treatment plant installed by Teck at the West Line Creek Operation in the Elk Valley[1]. Such biological reduction plants are highly engineered, costly and complex and are therefore not suitable for use in campaign-based treatment.

However, the in-situ biological reduction coupled with ferric co-precipitation may be a viable options for the Wolverine site. Although not a common treatment method, in-situ biological reduction has been implemented at full scale at mine sites (Harrington 2013; Paulson 2004; Park 2006; Martin 2009).

As described in the Reclamation and Closure Plan (YZC 2015), the treatment method works by converting selenate (SeO_4^{2-}), the oxidized unreactive form of selenium, to the more reduced selenite (SeO_3^{2-}) form or to elemental selenium (S^0). Selenite is more reactive than selenate and can be removed by ferric co-precipitation. Elemental selenium is a solid, which can be removed by settling or filtration (Figure 5).

[1] Described in http://www.teck.com/media/2015-Water-elk_valley_water_quality_plan_T3.2.3.2.pdf

Harrington 2013

Figure 5 Elemental Selenium in Open Pit Following Whole-Pit In-Situ Biological Treatment

Reducing conditions are generated by adding nutrients and a source of easily degradable organic carbon such as molasses or methanol to the TSF pond. Microorganisms that are naturally present in the TSF will metabolize the carbon and thereby consume oxygen and produce anoxic/reducing conditions. The intensity of the reducing conditions is governed by the dose of carbon (higher dose = more reducing) and by the presence and transfer of oxidants to the water, including diffusion of atmospheric oxygen.

When conditions are sufficiently reducing, selenium present as in the oxidized selenate form (SeO_4^{2-}) will become reduced. If conditions become further reduced, sulphate (SO_4^{2-}) may become reduced to hydrogen sulphide (H_2S), which is a highly reactive, noxious gas. Hydrogen sulphide reacts with dissolved metals, including those targeted for treatment at the Wolverine Mine TSF (Cd, Cu, Fe, Pb, Ag and Zn) to form insoluble metal sulphide precipitates. However, care must be taken to control the extent of the reducing conditions as excessive hydrogen sulphide can off-gas to the atmosphere and become hazardous to human health and wildlife (inhalation and ingestion).

Reducing conditions promote the dissolution of certain constituents such as manganese, iron and arsenic if minerals containing such metals are present. Therefore, concentrations of these constituents may be elevated after the mine water has been exposed to reducing conditions. However, it is anticipated that metals that undergo reductive dissolution will be removed in the subsequent metal treatment process (see Section 3.2).

In-situ biological reduction and ferric co-precipitation is a potential option for the Wolverine site and is discussed further in Section 4.

3.2.2 Chemical or Electrochemical Reduction

It is possible to reduce selenate to selenite or elemental selenium using an inorganic reductant, such as zero-valent iron (ZVI). As zero valent iron reduces selenate, oxygen and other oxidized species dissolved in the feed water, the iron is oxidized to ferrous and ferric iron, which precipitates as hydroxides. In turn, these hydroxides facilitate removal of reduced selenium species.

For water treatment applications, ZVI is sold as a powder that can be used as packing for column or in other liquid/solid contact unit operations (Figure 6). ZVI has been used as a media in permeable reactive barriers for removal of selenium from groundwater (ESL 2005).

http://hepure.com/products/ferox-zero-valent-iron-powders/ferox-target/

Figure 6 Zero Valent Iron Powder

The use of zero-valent iron for selenium reduction is potentially a viable option for treating the TSF water at Wolverine and is therefore included in the scoping level assessment in Section 4.

Electrochemical reduction methods that use iron electrodes, which produce ferrous iron have also been developed (Baek 2013). It is unlikely that electrochemical reduction is able to remove selenium to concentrations less than 0.020 mg/L, which is the WUL discharge limit. Therefore, electrochemical reduction was not considered as a stand-alone treatment method.

3.2.3 Ion Exchange + Electrochemical Reduction

The use of ion exchange for removal of selenium from mine water has been developed by Bioteq Environmental Technologies (Bioteq 2013). Ion exchange works by selectively adsorbing selenate ions in the mine water onto active sites on an anionic ion exchange resin. Once all active sites are occupied by selenate, the resin is regenerated by flushing it with a saline solution containing high concentrations of sulphate. The result is mine water with low concentrations of selenium and a brine solution with high selenium concentrations.

In the initial development of the ion exchange treatment technology, the brine solution with selenium was treated using a biological reduction process. However, Bioteq subsequently modified the process to rely on electrochemical reduction of the brine solution. In August 2015, Seabridge and Bioteq announced that a pilot trial of the ion-exchange/electrochemical precipitation process had been successfully concluded[2].

In spite of encouraging results using ion exchange, the treatment method is unlikely to be viable for treating TSF supernatant at Wolverine. Treating between 700 and 1,400 gpm of mine water requires installation of a large and complex water treatment plant, complete with ion exchange columns and circuits for feed water, regenerant and rinse water as well as electrochemical precipitation vessels and post-treatment unit operations. Although the capital cost potentially is lower than that associated with biological reduction plants, the operational complexity is similar. Campaign treatment may be possible using mobile treatment units but only at a smaller scale. Therefore, the ion exchange treatment method was not evaluated in Section 4.

3.2.4 Membrane Concentration (Reverse Osmosis or Nano-Filtration + A or B)

The option of using of membrane concentration such as Reverse Osmosis (RO) or nano-filtration as a pre-treatment step is a variation on the options discussed in Section 3.2.1 and 3.2.2.

Membrane technologies such as RO work by forcing feed water through a membrane under high pressure. The membrane allows passage of uncharged water molecules, but resists passage of ions and charged molecules. RO units typically recover 60% to 80% of feed water as clean membrane permeate, while the remaining 20% to 40% of the feed water is rejected by the membrane as RO brine. The RO brine contains 95% to >99% of the dissolved constituents in the feed water.

The option of using membrane filtration ahead of selenium treatment is discussed here because RO is often mistakenly thought of as a stand-alone treatment process that is able to effectively remove nearly all contaminants from water. However, because of the residual brine, the process is more correctly characterized as a pre-treatment or pre-concentration step ahead of primary treatment.

The use of RO at Wolverine is unlikely to be a suitable option. The calcium and sulphate concentrations in the TSF are near the levels of gypsum ($CaSO_4$) saturation, which can lead to scaling of the RO membranes. Although RO system can operate at concentrations above saturation limits by adding antiscalant reagents, the recoveries would likely suffer and the antiscalant reagents in the brine may cause problems in the brine treatment step.

Furthermore, discharge of permeate without concurrent discharge of treated brine could cause sulphate concentrations in the TSF to exceed the WUL effluent limit of 1,800 mg/L due to internal loading of sulphate (assuming brine is returned to the TSF). Finally, the cost of renting mobile RO treatment units are high and commissioning can be difficult and lengthy process. Therefore, a RO concentration step was not considered in this assessment.

[2] http://seabridgegold.net/pdf/2015Q2SR.pdf

3.2.5 Barium Sulphate Co-Precipitation

In water treatment applications, barium salts such as $BaCl_3$ or $Ba(OH)_3$ can be used to precipitate sulphate by formation of the insoluble barium sulphate. Because of the chemical similarities between selenate (SeO_4^{2-}) and sulphate (SO_4^{2-}), selenate tends to co-precipitate with barium sulphate. A study be Lalvani (2004) demonstrated that selenium concentrations of approximately 1,000 ug/L could be reduced to approximately 20 ug/L by addition of barium chloride and precipitation of barium sulphate. The study suggested that low level selenium removal was contingent on near-complete removal of sulphate.

The TSF water at Wolverine contains approximately 1,500 mg/L of sulphate. Complete sulphate precipitation would require a barium chloride dose of approximately 3,800 mg/L (stoichiometric) or a barium hydroxide dose of approximately 3,000 mg/L. This translates to a barium chloride demand of approximately 2,000 tonnes or a barium hydroxide demand of about 1,700 tonnes, assuming 100% utilization. At costs greater than $1,000/tonne, the reagent costs would exceed $2M.

In addition, large-scale water treatment equipment would be required. According to the study, the process also requires a solids loading of about 15 g/L. This means that the process would require reactors and a clarifier capable of recirculating precipitated solids to the reactors. Also, if barium chloride is used, the chloride concentration of the mine water would increase by approximately 1,300 mg/L, which may cause secondary toxicity issues. Because of the high reagent costs and potential challenges dealing with the large reagent dose, barium treatment was not evaluated further at this stage.

3.3 Metals Treatment

Methods for removing dissolved metals (Cd, Cu, Fe, Pb, Ag and Zn) considered in this assessment include:

- Lime (CaO) or caustic (NaOH) water treatment, with or without ferric coagulation, and
- Ferric co-precipitation.

Lime (or caustic) and ferric treatment are by far the most common water treatment methods used in the mining industry for removal of dissolved metals. Lime or caustic added to mine water raises the pH, which causes metals to precipitate as metal hydroxides. The metal hydroxide precipitates are then collected and disposed of. The treatment methods are relatively simple and proven in countless applications. All species of dissolved metals to be removed at Wolverine are amenable to lime and ferric water treatment, except selenium. Treatment residuals, lime or ferric sludge, can safely be disposed of in the TSF. Due to the wide-spread use and proven track record of these treatment methods, other treatment methods were not considered in the assessment, and both lime and ferric treatment are carried through into the scoping level water treatment assessment (Section 4).

3.4 Sulphate Treatment

To date, sulphate concentrations in the tailings supernatant have generally been below the WUL limit of 1,800 mg/L. However, new sulphate loadings or careless efforts to concentrate the tailings water could cause potentially sulphate concentrations to increase above the effluent concentration limit.

Sulphate water treatment is onerous and costly. Although in-situ biological treatment *could* be used as a treatment method, it would be challenging to implement it safely because of the generation of hydrogen sulphide. In general, every effort should be made to avoid implementing treatment methods that could, be design or inadvertently, increase the concentration of sulphate in the tailings supernatant. For example, it may be necessary to use ferric chloride rather than ferric sulphate if ferric co-precipitation is required.

3.5 Screening Assessment Summary

Table 2 summarizes the screening assessment. Addition of lime to mitigate the development of acidic conditions in the TSF water is the method of choice for neutralizing excess acidity. In addition, currently stored on site is approximately 90 tonnes of quicklime, which can be used for the purpose.

Table 2 Screening Assessment Summary

Objective	Method	Suitable (Y/N)	Carried through to Scoping Level Assessment (Y/N)
Neutralization of Acidity in TSF	Lime Addition	Y	Y
Metals Treatment	Lime (CaO) or caustic (NaOH) with or without ferric coagulation	Y	Y
	Ferric co-precipitation	Y	Y
Selenium Treatment	In-situ biological reduction + ferric co-precipitation	Y	Y
	Chemical reduction	Y	Y
	Electrochemical reduction	N	N
	Ion exchange + electrochemical reduction	Y	N
	Membrane concentration (reverse osmosis or nano-filtration + A or B).	N	N
	Barium sulphate co-precipitation.	Y	N
Sulphate Treatment	Not currently required – however, need to ensure sulphate concentrations do not increase over current levels.	Not applicable	Not applicable

Similarly, lime and ferric treatment is the best suited and most reliable method for removing dissolved metals from mine water. Although alternative methods are available, lime and ferric are used in the vast majority of metals treatment applications.

In-situ biological treatment + ferric co-precipitation and chemical reduction could both be suitable to implement as part of a treatment campaign at the Wolverine Mine. Other, more equipment intensive methods such as ion exchange and barium co-precipitation would likely produce discharge-compliant effluent, but equipment, unit operations and infrastructure required to operate such processes are better suited for more permanent installations.

Electrochemical reduction as a stand-alone technology is unlikely to meet the WUL effluent limit of 0.020 mg/L. Membrane pre-treatment is not useful for treating the TSF water because of the elevated sulphate concentrations and because of the cost and effort required to operate a membrane treatment plant.

4 Scoping Level Water Treatment Assessment

The following treatment methods were identified as potentially viable based on the abbreviated screening of treatment methods in Section 3, and are detailed below:

1. In-situ biological treatment combined with ferric co-precipitation and lime/caustic treatment, and
2. Zero valent iron treatment combined with lime/caustic treatment.

Each option assumes that the alkalinity in the TSF pond has been increased back to ~100 mg/L following the addition of 40 tonnes of quicklime in 2017.

4.1 Option 1: In-Situ Biological Treatment, Ferric Co-Precipitation and Lime Treatment

4.1.1 Process Overview and Flowsheet

The in-situ biological treatment process proposed here is similar to the treatment concept proposed in the 2015 Reclamation and Closure Plan. The concept is illustrated in the example in Figure 7. Carbon and nutrients would be added to the TSF supernatant in summer 2018. The relatively warm water at that time will promote growth of microorganisms and reducing conditions will begin to develop. Diffusion of atmospheric oxygen into the TSF water may initially hinder or limit the formation of reducing conditions. However, the formation of an ice cover on the TSF in late fall is expected to significantly reduce diffusion of oxygen into the water column thereby enhancing the development of reducing conditions. Depending on the consumption of carbon and nutrients through the summer months, it may be necessary to add a second dose in the fall.

In the spring of 2019, it is anticipated that the majority of selenate in the TSF has been reduced to elemental selenium or selenite which are both amenable to removal by ferric co-precipitation, flocculation and sedimentation. Addition of lime or caustic addition will likely also be required, as ferric treatment lowers the pH of the effluent.

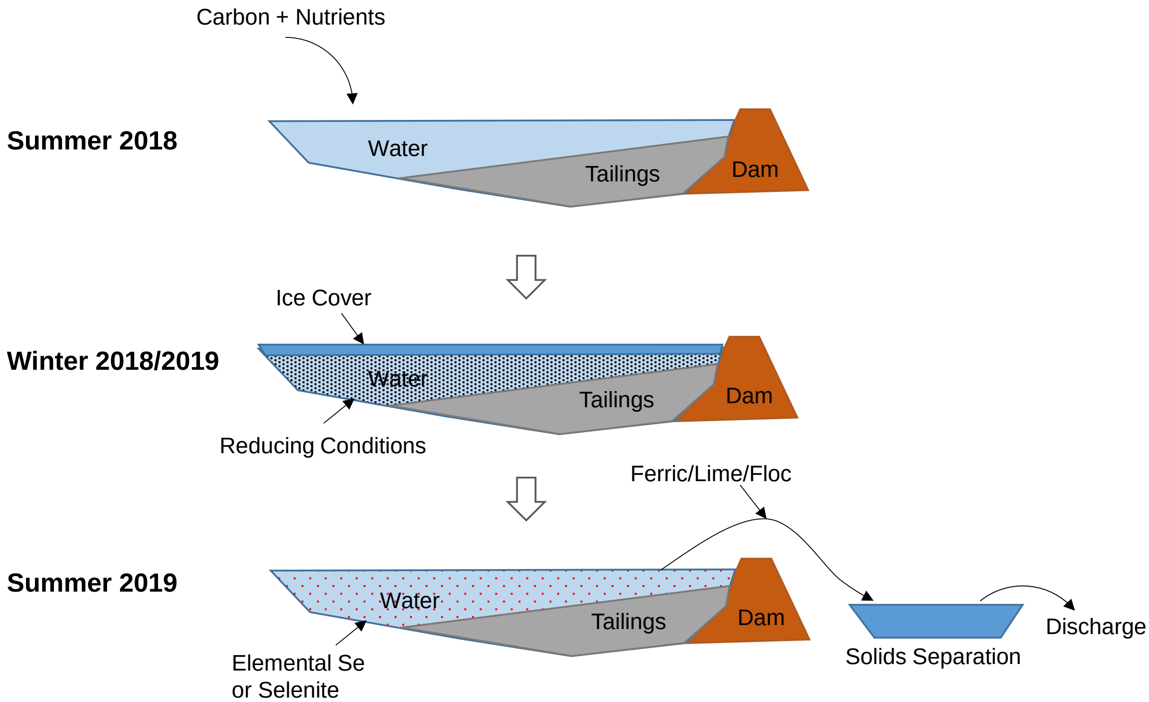

Figure 7 Schematic of In-Situ Biological Treatment Process

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The implementation of the ferric co-precipitation stage proposed here differs slightly from the concept suggested in the 2015 Reclamation and Closure Plan. Instead of in-situ mixing and settling of ferric hydroxide in the TSF, SRK proposes to pump water from the TSF to a settling basin or solids separation area, and add ferric and flocculant and lime or caustic in-line. Separating the solid-liquid separation step of the ferric treatment process allows for better control of dosing and mixing. It also permits the addition of other post-treatment steps such as detoxification (i.e. oxidation) of free sulphide and oxidation of ferrous iron and manganese, if required. Finally, it reduced the risks of re-suspending or oxidizing selenite through whole-lake mixing of the TSF.

4.1.2 Equipment and Infrastructure

The following equipment and infrastructure would be required to implement in-situ biological treatment:

TSF carbon and nutrient amendment:

- Tanker truck with liquid organic carbon for dosing TSF water.
- Mixing tote for make-up of nutrient solution such as mono-potassium phosphate (MKP).
- Small boat with outboard motor for distributing nutrient solution and for monitoring TSF water.

Ferric co-precipitation:

- Solids Separation: assuming that 675,000 m^3 of water would be discharged in 2019, over a period of 90 days the average rate of discharge would be approximately 7,500 m^3/day or about 320 m^3/hr. As a rough rule of thumb, reasonable settling can be achieved in a pond using a rise rate of 0.10 m/hr. This means that a settling pond would need an effective settling area of approximately 3,200 m^2. A settling pond of this size is not currently available on site. As an alternative, solids separation can be achieved using large geotextile bags such as Geotubes (Figure 8). In 2011, Wesatech used two GT500 Geotubes (200 ft by 120 ft circumference) for solids separation for the ferric treatment campaign at the Tundra Mine in NWT (Wesatech 2011). Approximately 530,000 m^3 was treated in 92 days. The ferric dose was between 75 mg/L and 150 mg/L, which is a higher dose than the one anticipated for Wolverine. The concept is illustrated in Figure 9.
- Pump for pumping water TSF to settling system.
- Discharge and recycle pump.
- Ferric totes and dosing pumps.
- Flocculant make-up tank and dosing pumps.
- Hydrated lime make-up tanks and dosing pumps.
- Shelter for reagent skids.
- Power at TSF.
- Camp facilities for on-site operational personnel (2019 season only).

Figure 8 Example of a Geotube in Operation

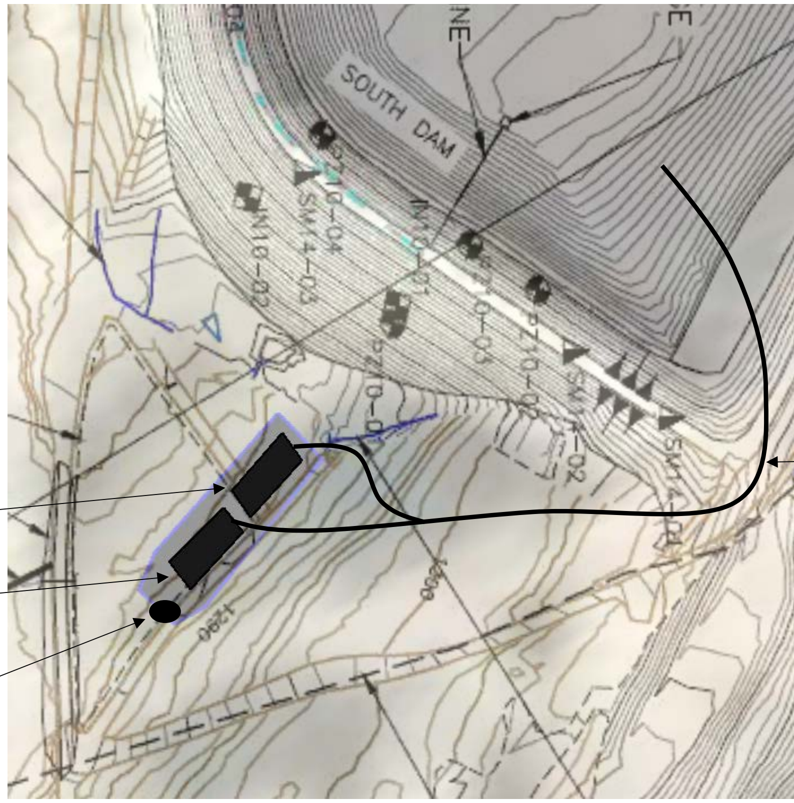

Figure 9 Potential Layout of two GT500 Geotubes Downstream of the South Dam

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It is possible that equipment on site and in the mill can be used for the water treatment campaign, in particular pumps, tanks, mixers and reagent dosing pumps. A detailed review of the equipment inventory is required to determine if this is an option.

4.1.3 Performance and Risks

The performance of in-situ biological treatment is, by its nature, uncertain. However, the process has been implemented successfully for treatment of mine water at full scale in the past. One of the best documented examples of in-situ biological reduction and removal of selenium is the 1999 to 2002 treatment of the Sweetwater Pit Lake in Wyoming (Paulson 2004; Harrington 2013). Approximately 3 months after addition of molasses and methanol to the pit lake, reducing conditions were established and selenium concentrations were reduced from approximately 0.450 mg/L to less than 0.010 mg/L. The reduced selenium concentrations persisted for the following two years.

However, conditions at the Wolverine TSF are different from a relatively deep pit lake. Therefore, the treatment performance at the Sweetwater Pit should not be taken as an indication that the same performance will necessarily result at Wolverine.

In-situ biological treatment comes with risks that must be carefully considered:

- A reduction of selenium concentration to levels below the WUL effluent quality limit of 0.020 mg/L may not be achieved. A contingency plan for addressing this possibility must be developed as part of the water treatment plan. Options include a second treatment campaign or a switch to another treatment technology.
- Reducing conditions can lead to dissolution of certain metals such as arsenic, ferrous iron and manganese. It is likely necessary to implement an oxidation step to remove these metals if they persist in reduced form after the over-winter biological reduction treatment.
- Excessive reducing conditions can lead to formation of hydrogen sulphide gas, which can be hazardous to wildlife and human health. A plan for managing excessive reducing conditions must be developed.
- The propagation and subsequent die-off of anaerobic microorganisms could release organic molecules that can chelate dissolved metals such as copper, zinc and cadmium. Chelated metals can be much more difficult to treat than free cationic metals.

One option for mitigating the performance and operational risks is to conduct a field trial in 2017/2018 and then plan to implement full-scale treatment in 2018/2019. A field-scale trial would consist of a limno-corral installed in the TSF. A limno-corral is a cylindrical, impermeable baffle curtain that floats in the TSF and thereby encloses a volume of water (large plastic bag). The corral can have a closed bottom or can have an open bottom that is anchored to the bottom of the TSF by chains. The field-scale trial would replicate the treatment conditions intended for the whole TSF in terms of carbon and nutrient dose, mixing and subsequent ferric/lime/floc treatment. Implementation of full scale treatment would be informed by the results of the field scale trial, including determination of reagent doses and operational parameters for the ferric treatment.

The equipment and materials required for a trial costs approximately $15,000: $10,000 for three limnocorrals and $5,000 for water quality analysis, nutrients and other consumables. This cost estimate does not include the cost of personnel time and reporting.

4.1.4 Operational complexity

The operational complexity is relatively low and suitable for implementation at the Wolverine Mine.

4.1.5 Residual Management

Residuals from the in-situ biological treatment and ferric co-precipitation include ferric hydroxide sludge containing elemental selenium, selenite and metal hydroxides. In addition, some elemental selenium solids may settle directly in the TSF. Assuming that the ferric sludge is collected in geotextile bags, the sludge could likely be hauled for disposal in the saturated part of the TSF. The sludge is likely to be relative stable as long as it is not exposed to highly acidic conditions. Keeping the sludge saturated should prevent oxidation and dissolution of the selenium contained in the ferric hydroxide matrix.

A detailed disposal plan would be developed prior to implementation of treatment.

4.1.6 Capital and Operating Costs

Table 2 shows an scoping-level estimate of capital and operating costs associated with implementation of in-situ biological treatment of TSF water at the Wolverine Mine. The estimated costs do not include power and camp costs or travel to and from camp. Estimated costs are -35%/+50%. Costs associated with closure or care and maintenance activities besides water treatment are also not included.

Table 3 Capital and Operating Cost Estimate for In-Situ Biological Water Treatment (-35%/+50%)

Equipment and Reagents	Estimated Cost
Carbon Source and Nutrients, Delivered	$150,000
Pumps and Piping[A]	$50,000
Preparation of Filtration Area	$20,000
Geotextile Bags (3)	$150,000
Liner (6,000 m^2)	$75,000
Reagent circuit equipment	$100,000
Quicklime	***On site***
Ferric	$50,000
Floc and Consumables	$15,000
Analytical Laboratory	$60,000
Contingency (20%)	$133,000
Sub-Total	*$803,000*
Personnel and Admin	
2018 Personnel, 30 days, 4 full time on site	$150,000
2019 Personnel, 120 days, 4 full time on site	$600,000
Trades and Consultants	$150,000
Admin and overhead (20%)	$170,000
Contingency (20%)	$234,000
Sub-Total	*$1,304,000*
Total Estimate	$2,107,000

Notes: A – assumes partial use of pumps and pipes on site. Source: \\VAN-SVR0\Projects\01_SITES\Wolverine\1CY004.000_Water_Treatment_Assessment\Treatment Assessment\Tretment Assessment Wolverine REV00 SRJ.xlsx

4.2 Option 2: Zero Valent Iron and Lime Treatment

4.2.1 Process Overview and Flowsheet

Zero valent iron (ZVI) treatment consists of passing feed water through a media of powdered zero-valent iron followed by oxidation and removal of ferric iron (Figure 10). The configuration of the flow and media is not important as long as good contact between water and the surface of the iron particles are achieved.

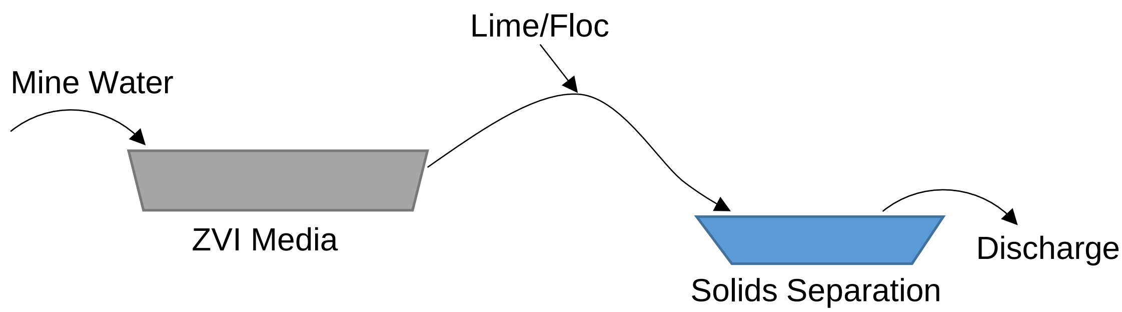

Figure 10 Schematic of ZVI Water Treatment

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The main challenge associated with ZVI treatment is to prevent coating, or blinding, of the iron particles by layers of oxidation products. This includes ensuring that feed water is free of suspended particles. If the iron particles become coated, the dissolved constituents in the water are not able to contact the iron surface and will therefore not become reduced. Blinding of the iron media can be mitigated in two ways:

- Using a large volume of zero-valent iron media such that the potential load of oxidation products are insufficient to completely coat the iron particles; or
- Implement engineering measures to reactivate blinded iron particles (chemical or mechanical).

For this assessment, the approach was to include a generous estimate of the ZVI volume required as reactivation of media requires equipment and operational effort not warranted for campaign-based treatment.

As oxidized species in the water are reduced, iron is oxidized to ferrous or ferric iron. Ferric iron precipitates as iron hydroxide solids, which adsorb a wide range of dissolved ions including selenite. The ferrous iron end up in the treated effluent along with manganese and other constituents that may have been mobilized by the reducing action of the iron. The dissolved iron and other reduced species must be removed in a post-treatment step. Post-treatment includes an oxidation step followed by settling or filtration of the precipitated ferric hydroxide. The post-treatment concept proposed here is the same as the method described in Section 4.1 – i.e. the use of a geotextile bag for filtration and sludge accumulation.

ZVI treatment could be implemented by trucking the media to site when site becomes accessible in 2019. Construction of a reservoir and installation of piping would commence in late May or early June 2019 and treatment would be completed by September, and demobilization would be complete by late September or early October.

4.2.2 Equipment and Infrastructure Required

ZVI treatment of 675,000 m^3 of TSF water requires:

- Between 200 and 300 tonnes of iron powder (scoping-level estimate).
- Vessel or reservoir for holding the iron powder and facilitate flow of water through the media.
- Pre-filtration units or engineering controls to prevent water with high suspended solids concentrations entering and fouling the iron media bed.
- Lime or caustic mix tank and dosing pump for post-treatment.
- Blowers or hydrogen peroxide for post-treatment oxidation step.
- Flocculant make-up tank and dosing system.
- Geotextile bag and liner.
- Feed and effluent pumps.

4.2.3 Performance and Risks

ZVI is a strong reductant. As long as good contact between the surface of the iron particles and water is ensured ZVI will reduce selenate to a form that can be precipitated. Malcolm Pirnie (2012) reported successful removal of approximately 0.100 mg/L selenium to less than 0.006 mg/L. A full scale system was able to consistently produce effluent with less than 0.005 mg/L selenium although the feed selenium concentrations were relatively low (less than 0.020 mg/L). However, the full-scale system was reported to remain effective after passing 5,400 bed volumes of feed water without replacing the ZVI media (Bouse 2013).

The greatest performance risk is likely associated with the potential for plugging the media with suspended solids and potential non-uniform flow through the media. However, both of these issues can be addressed through careful detailed design of the treatment system.

Bench-scale tests can be carried out ahead of the treatment season. However, results from such test are only useful as rough indications of the potential performance of a full-scale treatment system. On-site pilot- or field-scale tests are required to inform design and operation of a full-scale system. A pilot or field trial could be completed in 2017 or in 2018 if the full-scale treatment campaign is deferred until 2019.

Depending on the scale of the trial, the equipment and materials required can likely be procured for less than $10,000. Equipment would include a batch of zero valent iron, tanks, drums or exfiltration basis for holding the ZVI, feed pumps and metering equipment. The cost estimate includes shipping but does not include personnel time or reporting.

4.2.4 Operational Complexity

The operational complexity is low and suitable for implementation at Wolverine.

4.2.5 Residual Management

Residuals from the treatment process consists of the spent iron powder, which can be disposed of in the TSF at the end of the treatment campaign.

4.2.6 Capital and operating costs

Table 3 shows a scoping-level estimate of capital and operating costs for a ZVI water treatment campaign at the Wolverine mine. Estimated costs are -35%/+50%. The cost estimate does not include power, camp costs or the cost of travel to and from site. Costs associated with closure or care and maintenance activities besides water treatment are also not included.

Table 4 Capital and Operating Cost Estimate for ZVI Water Treatment (-35%/+50%)

Equipment and Reagents	**Estimated Cost**
ZVI Media (250 tonnes assumed)	$600,000
Pumps and Piping[A]	$50,000
Preparation of Filtration Area	$20,000
Geotextile Bags (2)	$100,000
Liner (6,000 m^2)	$75,000
Reagent circuit equipment	$100,000
Lime	***On site***
Floc and Consumables	$15,000
Oxidant or blower	$50,000
Analytical Laboratory	$60,000
Contingency (20%)	$224,000
Sub-Total	***$1,294,000***
Personnel and Admin	
2019 Personnel, 120 days, 4 full time on site	$600,000
Trades and Consultants	$150,000
Admin and overhead (20%)	$170,000
Contingency (20%)	$204,000
Sub-Total	***$1,224,000***
Total Estimate	**$2,418,000**

Notes: A – assumes partial use of pumps and pipes on site. Source: \\VAN-SVR0\Projects\01_SITES\Wolverine\1CY004.000_Water_Treatment_Assessment\Treatment Assessment\Tretment Assessment Wolverine REV00 SRJ.xlsx

5 Conclusions and Recommendations

The following was concluded based on the water treatment assessment for the Wolverine TSF:

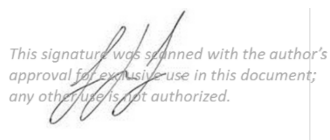
- Two treatment methods for removal of selenium and dissolved metals from TSF water at the Wolverine mine were evaluated at a scoping level:
  - In-situ biological reduction combined with ferric/lime treatment, and
  - Zero-valent iron treatment combined with ferric/lime treatment.

  Other available treatment methods were deemed to be unsuitable for use in campaign-based treatment.
- The scoping level costs for the two treatment methods were similar at approximately $2.5M.
- Implementation of in-situ biological treatment would require at least two treatment seasons, while ZVI treatment likely could be completed within a single season. Pilot- or field-scale tests would add one season in each case.
- The operational and performance risk profiles are different for the two approaches:
  - For In-situ biological treatment, the dominant risk is insufficient selenium removal. Evolution of excessive hydrogen sulphide and complexation or chelation of metals by organic molecules as well as residual organic carbon in the effluent are risks that must also be considered.
  - The primary operation risk for ZVI treatment include blinding or plugging of the ZVI media and non-uniform flow through the media (channelling).
- It is anticipated that residuals for both treatment options (ferric hydroxide slurry or spent ZVI media) can be disposed of in the TSF without causing long term water quality issues.

Based on the water treatment assessment, SRK recommends that:

- Lime solution be added to TSF in 2017. The addition of 40 tonnes of quicklime will likely prevent the TSF pond from becoming acidic for up to 3 years based on the current rate of acidity influx to the pond.
- YZC complete pilot or field-scale tests for any treatment option intended for full-scale implementation.

This report, Wolverine Mine Water Treatment Assessment, was prepared by



Soren Jensen, P.Eng.

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendix B: Detailed Closure Cost Estimates

Table B-1: Temporary Closure Detailed Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Organization, Security and Overhead					
Site Supervisor	Management	month	12	$10,500	$126,000
Site Caretaker	Management	month	12	$8,800	$105,600
Corporate	Management and oversight	L.S.			$20,000
Camp Cost	per person day (assuming 3 staff on site at all times)	day	1095	$85	$93,075
Vehicle for security and technician	light-duty vehicle	month	12	$2,500	$30,000
Flights	2 flight/month for shift rotations, specialist visits, supplies	flights	24	$3,000	$72,000
Site maintenance costs Summer	maintenance, fuel (350 L per day), supplies	month	6	$10,500	$63,000
Site maintenance costs Winter	maintenance, fue (500 L per day)l, supplies	month	6	$20,000	$120,000
				Sub Total	**$509,675**
Compliance Monitoring and Reporting					
Environmental Technician	Sampling and monitoring	month	12	$6,000	$72,000
Water Quality Analytical	Surface water (when not frozen)	each	100	$420	$42,000
Water Quality Analytical	Groundwater (when not frozen)	each	120	$290	$34,800
External Consulting Services	2 rounds of surface water, groundwater (not incl. laboratory analyses), hydrology, climate, benthic sampling (incl. laboratory analyses)	L.S.			$126,260
EEM reporting	Contract	L.S.			$10,000
Geotechnical Inspections	Contract	L.S.			$35,000
				Sub Total	**$320,060**
Assess Water Treatment Options					
TSF in situ lime application	Treatment during open water season with lime from site	tonnes	40	$-	$-
In situ biological reduction water treatment trial - equipment & operation	operating and equipment costs, laboratory analyses	L.S.		$17,000	$17,000
In situ ZVI water treatment trial - equipment & operation	operating and equipment costs, laboratory analyses	L.S.		$11,000	$11,000
				Sub Total	**$28,000**
Underground Mine Hydraulic Bulkhead Installations					
Install hydraulic pressure bulkhead - access ramp		L.S.			$186,700
Install hydraulic pressure bulkhead - ventilation raise		L.S.			$131,600
				Sub Total	**$318,300**

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
1345 Portal & Vent Raise Closures					
Plug portal and ventilation raise with tires	Cat 320CL Hoe	hrs	10	$125	$1,250
Place waste rock cap over tires	Cat 320CL Hoe	hrs	15	$125	$1,875
Place waste rock cap over tires	A30D Rock truck	hrs	15	$197	$2,955
Supply broken rock at base of plug and discharge channel riprap	Cat 320CL Hoe	hrs	10	$125	$1,250
Supply broken rock at base of plug and discharge channel riprap	A30D Rock truck	hrs	10	$197	$1,970
Construct rock drain at base of plug	Cat 320CL Hoe	hrs	10	$125	$1,250
Supply fill to seal discharge channel	Cat 320CL Hoe	hrs	10	$125	$1,250
Supply fill to seal discharge channel	A30D Rock truck	hrs	10	$197	$1,970
Supervision to design & install tires and cap	Site Supervisor	hrs	50	$95	$4,750
				Sub Total	**$18,520**
Underground Mine Portal Bioreactor Construction					
Construct lined open channel for discharge from portal to Bioreactor system; 100 m length	Cat 320CL Hoe	hrs	15	$125	$1,875
Construct lined open channel for discharge from portal to Bioreactor system; 100 m length	Compactor	hrs	10	$140	$1,400
Stabilize and vegetate area around channel	Seed and Fertilize	ha	0.09	$1,500	$135
Labour for channel construction	General labour	hrs	30	$50	$1,500
Labour to assist with placing tires & cap	General labour	hrs	20	$50	$1,000
Design of rock drain and channel (Engineering)	Design Engineer	hrs	10	$130	$1,300
				Sub Total	**$7,210**
Move LTF to TSF					
LTF decommissioning	General labour	hrs	20	$50	$1,000
Move contents to TSF	load and haul to TSF	hrs	10	$5	$50
Move contents to TSF	A30D Rock truck	hrs	10	$197	$1,970
Move contents to TSF	Cat 320CL Hoe	hrs	20	$125	$2,500
Reclaim footprint	Seed and Fertilize	ha	0.4	$1,500	$600
				Sub Total	**$6,120**
Total					**$1,207,885**
10% Contingency					**$120,789**
Grand TOTAL					**$1,328,674**

Table B-2: Temporary Closure Environmental Sampling

SURFACE WATER QUALITY SAMPLING				
Station Number	**Station Location**	**Watershed**	**Sampling Frequency**	**Number of Samples**
T1	Tailings Barge	TSF	Quarterly	4
W82	Upper Wolverine Creek	Wolverine Creek	Quarterly	4
W9	Wolverine Creek at Little Wolverine Lake		Quarterly	4
L1	Little Wolverine Lake	Little Wolverine Lake	Quarterly	4
W15	Hawkowl Creek above Go Creek	Go Creek	Quarterly	4
W81	Go Creek below Hawkowl Creek		Quarterly	4
W31	Go Creek above Tailings Facility		Quarterly	4
W80	Go Creek		Quarterly	4
W22	Money Creek above Robert Campbell Highway	Money Creek	Seasonally	3
W71	Pitch Creek below road crossing	Access Road Route	Seasonally	3
W72	Light Creek		Seasonally	3
W73	Bunker Creek at road crossing		Seasonally	3
Bioreactors				
WRD #2 inlet			Monthly	12
WRD #2 outlet			Monthly	12
Underground Mine Portal bioreactor inlet			Bi-monthly*	16
Underground Mine Portal bioreactor outlet			Bi-monthly*	16
TOTAL				**100**
GROUNDWATER QUALITY SAMPLING				
Groundwater Station	**Location**	**Watershed**	**Sampling Frequency**	**Number of Samples**
MW05-1A, 1B	Airstrip North	Go Creek	Quarterly	8
MW05-2A, 2B	Tailings Facility – Southwest	Tailings Facility	Quarterly	8
MW05-3A, 3B	Mine	Wolverine Creek	Quarterly	8
MW05-4A, 4B	Mine		Quarterly	8
MW05-5A, 5B	Mine		Monthly	24
MW05-6A, 6B	Airstrip East	Go Creek	Quarterly	8
MW05-7B	Mine	Tailings Facility	Quarterly	4
MW06-8S, 8M, 8D	Mine	Wolverine Creek	Quarterly	12

GROUNDWATER QUALITY SAMPLING				
MW06-9S, 9M	Mine		Quarterly	8
MW06-10S, 10M, 10D	Mine		Quarterly	12
MW06-11S	Mine		Monthly	12
MW06-12S	Mine		Quarterly	4
MW08-13	Tailings Facility - West	Tailings Facility	Quarterly	4
TOTAL				**120**

*once constructed (assumed 8 months of the year)

Table B-3: Tailings Area Detailed Closure Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Decommission Diversion Ditches					
Decommission Diversion Ditches A & B	Cat D8N Dozer - regrade and contour	hrs	60	$ 245	$ 14,700
Decommission Diversion Ditch B	Cat 320CL Excavator for steep slopes	hrs	20	$ 125	$ 2,500
Revegetate and Stabilize	Seed and Fertilize area 1.56 km x 5 m	ha	0.78	$ 1,500	$ 1,170
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.39	$ 1,500	$ 585
Culvert removal (800 mm)	Uncovering and removal	each	4	$ 1,500	$ 6,000
				Sub Total	**$ 24,955**
Remove Tailings Pipeline - Place in TSF					
Remove Pipeline	Cat 320CL Excavator	hrs	150	$ 125	$ 18,750
Remove Pipeline	A30D Rock Truck	hrs	150	$ 197	$ 29,550
Remove Pipeline	General labour	hrs	300	$ 50	$ 15,000
Reclaim area	Seed, fertilize - 3km length x 3 m corridor	ha	0.9	$ 1,500	$ 1,350
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.45	$ 1,500	$ 675
				Sub Total	**$ 65,325**
Remove Reclaim Pipeline - Place in TSF					
Remove Pipeline	Cat 320CL Excavator	hrs	150	$ 125	$ 18,750
Remove Pipeline	A30D Rock Truck	hrs	150	$ 197	$ 29,550
Remove Pipeline	General labour	hrs	300	$ 50	$ 15,000
Reclaim area	Seed, fertilize - 3km length x 3 m corridor	ha	0.9	$ 1,500	$ 1,350
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.45	$ 1,500	$ 675
				Sub Total	**$ 65,325**
Treat and Discharge TSF Free Water (ONE OPTION)					
In situ biological water treatment		L.S.			$ 2,100,000
In situ ZVI water treatment		L.S.			$ 2,364,000
				Sub Total	**$ 2,232,000**
Construct Final TSF Landform					
Landform engineering + design	detailed design	L.S			$ 50,000
Push Stage 2 material to Stage 1	Cat D8N Dozer	hrs	400	$245	$ 98,000
Remove TSF dam above 1305 level	Cat D8N Dozer	hrs	400	$245	$ 98,000
Impermeable cover installation	Use existing liner from TSF area to wrap overtop of TSF landform				$ -
Spread dam material over TSF landform	Cat D8N Dozer	hrs	300	$245	$ 73,500
Spread dam material over TSF landform	Compactor		200	$140	$ 28,000
Load, haul and place topsoil		m^2	16,400	$ 5	$ 82,000

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Seed and fertilize TSF landform and Stage 2 area	Seed and Fertilize	ha	16.4	$ 1,500	$ 24,600
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	8.2	$ 1,500	$ 12,300
Reclaim borrow areas	Seed and Fertilize	ha	2	$ 1,500	$ 3,000
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	1	$ 1,500	$ 1,500
				Sub Total	**$ 470,900**
				Total	**$ 2,858,505**
				10% Contingency	**$ 285,851**
				Grand TOTAL	**$ 3,144,356**

Table B-4: TSF Water Treatment Detailed Costs – In situ Biological Treatment

Equipment and Reagents	Estimated Cost
Carbon Source and Nutrients, Delivered	$ 150,000
Pumps and Piping	$ 50,000
Preparation of Filtration Area	$ 20,000
Geotextile Bags (3)	$ 150,000
Liner (6,000 m^2)	$ 75,000
Reagent circuit equipment	$ 100,000
Quicklime	*On site*
Ferric	$ 50,000
Floc and Consumables	$ 15,000
Analytical Laboratory	$ 60,000
Sub Total	**$ 670,000**
Personnel and Admin	
2018 Personnel, 30 days, 4 full time on site	$ 150,000
2019 Personnel, 120 days, 4 full time on site	$ 600,000
Trades and Consultants	$ 150,000
Admin and overhead (20%)	$ 180,000
Sub Total	**$ 1,080,000**
Total	**$ 1,750,000**
Contingency (20%)	**$ 350,000**
Grand TOTAL	**$ 2,100,000**

Table B-5: TSF Water Treatment Detailed Costs – ZVI Treatment

Equipment and Reagents	Estimated Cost
ZVI Media (250 tonnes assumed)	$ 600,000
Pumps and Piping	$ 50,000
Preparation of Filtration Area	$ 20,000
Geotextile Bags (2)	$ 100,000
Liner (6,000 m^2)	$ 75,000
Reagent circuit equipment	$ 100,000
Lime	*On site*
Floc and Consumables	$ 15,000
Oxidant or blower	$ 50,000
Analytical Laboratory	$ 60,000
Sub Total	**$ 1,070,000**
Personnel and Admin	
2019 Personnel, 120 days, 4 full time on site	$ 600,000
Trades and Consultants	$ 150,000
Admin and overhead (20%)	$ 150,000
Sub Total	**$ 900,000**
Total	**$ 1,970,000**
Contingency (20%)	**$ 394,000**
Grand TOTAL	**$ 2,364,000**

Table B-6: Infrastructure Detailed Closure Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Industrial Complex + Office Buildings					
Remove salvageable equipment	General Labour	hrs	1152	$ 50	$ 57,600
Remove salvageable equipment	Trades Labour	hrs	1128	$ 80	$ 90,240
Dismantle Building - Manpower	General Labour	hrs	1152	$ 50	$ 57,600
Dismantle Building - Manpower	Trades Labour	hrs	576	$ 80	$ 46,080
Dismantle Building - Equipment and Loading	Cat 320CL Excavator	hrs	160	$ 125	$ 20,000
Dismantle Building - Equipment and Loading	Crane	hrs	80	$ 160	$ 12,800
Concrete Demolition	Cat 320CL Excavator with Hammer	hrs	80	$ 170	$ 13,600
Misc. Supplies & Tools	Misc.	L.S.			$ 10,000
Scrap haul to landfill	A30D Rock Truck	hrs	208	$ 197	$ 40,976
Reslope and contour and bury	Cat D8N Dozer	hrs	80	$ 245	$ 19,600
Load, Haul and place topsoil	Area of 145244 m^2 x 0.25 m depth	m^3	36311	$ 5	$ 181,555
Reclaim area	Seed and Fertilize	ha	14.5	$ 1,500	$ 21,750
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	7.25	$ 1,500	$ 10,875
				Sub Total	**$ 582,676**
Power Supply - Gensets					
Remove salvageable equipment	General Labour	hrs	180	$ 50	$ 9,000
Remove salvageable equipment	Trades Labour	hrs	108	$ 80	$ 8,640
Salvage and remove power line and poles		L.S.			$ 25,000
Dismantle Building - Manpower	General Labour	hrs	96	$ 50	$ 4,800
Dismantle Building - Manpower	Trades Labour	hrs	48	$ 80	$ 3,840
Dismantle Building - Equipment	Cat 320CL Excavator	hrs	12	$ 125	$ 1,500
Dismantle Building - Equipment	Crane	hrs	12	$ 160	$ 1,920
				Sub Total	**$ 54,700**
Reclaim Site Diversions					
Decommission 1500 m of diversion ditches	Cat 320 CL Excavator	hrs	150	$ 125	$ 18,750
Remove culverts (<1200 mm)		L.S.	8	$ 1,500	$ 12,000
Reclaim area	1.5 km x 3 m	ha	0.5	$ 1,500	$ 750
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.25	$ 1,500	$ 375
				Sub Total	**$ 31,875**
Water Supply Wells					
Remove salvageable equipment - pipeline/pumps and tank	General Labour	hrs	24	$ 50	$ 1,200

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Remove salvageable equipment - pipeline/pumps and tank	Trades Labour	hrs	24	$ 80	$ 1,920
Remove pipeline and haul to TSF	A30D Rock Truck	hrs	8	$ 197	$ 1,576
Remove pipeline and haul to TSF	Cat 320CL Excavator	hrs	8	$ 125	$ 1,000
Decommission water supply wells	fill with concrete	each	2	$ 2,000	$ 4,000
Misc. Supplies & Tools	Misc.	L.S.			$ 500
Reclaim area	Seed and Fertilize	ha	0.1	$ 1,500	$ 150
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.05	$ 1,500	$ 75
				Sub Total	**$ 10,421**
Reclaim Explosive Magazines					
Reclaim area	Seed and Fertilize	ha	0.1	$ 1,500	$ 150
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.05	$ 1,500	$ 75
				Sub Total	**$ 225**
Miscellaneous Buildings and Structures					
Remove salvageable equipment	General Labour	hrs	216	$ 50	$ 10,800
Remove salvageable equipment	Trades Labour	hrs	216	$ 80	$ 17,280
Remove salvageable equipment	Cat 950H loader	hrs	150	$ 150	$ 22,500
Dismantle Building - Manpower	General Labour	hrs	216	$ 50	$ 10,800
Dismantle Building - Manpower	Trades Labour	hrs	216	$ 80	$ 17,280
Dismantle Building - Equipment and Loading	Cat 320CL Excavator	hrs	40	$ 125	$ 5,000
Dismantle Building - Equipment and Loading	Crane	hrs	8	$ 160	$ 1,280
Concrete Demolition	Cat 320CL Excavator with Hammer	hrs	40	$ 170	$ 6,800
Reslope, contour & bury	Cat D8N Dozer	hrs	60	$ 245	$ 14,700
Misc. Supplies & Tools	Misc.	L.S.			$ 2,500
Scrap haul to landfill	A30D Articulated haul truck	hrs	10	$ 197	$ 1,970
				Sub Total	**$ 110,910**
Industrial Reagents Fuels and Waste					
Industrial Reagents - truck to Swan Hills, AB	remove from site	tonnes	50	$ 100	$ 5,000
Industrial reagents - incineration cost	remove from site	tonnes	50	$ 3,000	$ 150,000
Remove Glycol from site	remove from site	trips	6	$ 5,000	$ 30,000
Fuels	remove from site	L.S.			$ 5,000
Wastes	remove from site	L.S.			$ 20,000
				Sub Total	**$ 210,000**
Spill Cleanup					
Concentrate load out area		L.S.			$ 15,000

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Other building site contamination clean up		L.S.			$ 15,000
				Sub Total	**$ 30,000**
Waste Rock Pads					
Move WRD #1 to TSF		m^3	34100	$ 7	$ 238,700
Reclaim WRD #1 footprint	Seed and Fertilize	ha	0.6	$ 1,500	$ 900
Move WRD #2 to TSF		m^3	91000	$ 7	$ 637,000
Reclaim WRD #2 footprint	Seed and Fertilize	ha	1.8	$ 1,500	$ 2,700
Remove liners and deposit in TSF	2 liners	L.S.	2	$ 8,000	$ 16,000
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	1.0	$ 1,500	$ 1,500
				Sub Total	**$ 896,800**
Reclaim Stockpile Footprints					
Reclaim temporary stockpile areas	Seed and Fertilize	ha	2.4	$ 1,500	$ 3,600
				Sub Total	**$ 3,600**
LTF Area Reclamation Maintenance					
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.2	$ 1,500	$ 300
				Sub Total	**$ 300**
Close Landfill					
Reclaim Landfill area	Seed and Fertilize	ha	2	$ 1,500	$ 3,000
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	1	$ 1,500	$ 1,500
				Sub Total	**$ 4,500**
Decommission and Reclaim Mine Site Roads					
Lower road grade	Cat 14G Grader	hrs	60	$ 160	$ 9,600
Lower road grade	Cat 320CL Excavator	hrs	80	$ 125	$ 10,000
Lower road grade	A30D Rock Truck	hrs	80	$ 197	$ 15,760
Stabilize slopes	Cat 320CL Excavator	hrs	40	$ 125	$ 5,000
Culvert Removal (<1000m)	uncover, remove and stabilize	each	15	$ 1,500	$ 22,500
Scarify	Cat D8N Dozer	hrs	70	$ 245	$ 17,150
Reclaim mine road footprints	Seed and Fertilize	ha	7	$ 1,500	$ 10,500
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	3.5	$ 1,500	$ 5,250
				Sub Total	**$ 95,760**
Demolition Overhead					
Supervision	Site Supervisor	hrs	1,000	$ 95	$ 95,000
Office/Admin Costs	Contracts oversight	year	3	$ 5,000	$ 15,000
				Sub Total	**$ 110,000**

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
				Total	**$ 2,141,767**
				10% Contingency	**$ 214,177**
				Grand TOTAL	**$ 2,355,944**

Table B-7: Access Road Detailed Closure Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Decommission and Reclaim Access Road					
Lower road grade	Cat 14G Grader	hrs	100	$ 160	$ 16,000
Lower road grade	Cat 320CL Excavator	hrs	140	$ 125	$ 17,500
Lower road grade	A30D Rock Truck	hrs	140	$ 197	$ 27,580
Stabilize cut/fill slopes	Cat 320CL Excavator	hrs	80	$ 125	$ 10,000
Culvert Removal (<1200mm)	Removal to offsite for re-use, resloping banks and armoring wetted section	each	69	$ 1,500	$103,500
Culvert Removal >1200mm or multiple at 1 location	Removal to offsite for re-use, resloping banks and armoring wetted section	each	3	$ 1,500	$ 4,500
Culvert Crossing restoration work	Installation of environmental protection measures	L.S.		$ 20,000	$ 20,000
Bunker Creek Bridge Removal	Removal of bridge complete with bin-wall, resloping of banks	L.S.		$ 75,000	$ 75,000
Bunker Creek habitat restoration	Restoration in riparian zone and re-seeding	L.S.		$ 2,000	$ 2,000
Scarify road surface to encourage re-vegetation (24 km x 13 m)	Cat D8N Dozer	ha	31.2	$ 500	$ 15,600
Permanent barrier at highway	Install trench and barricades	L.S.		$ 3,500	$ 3,500
Permanent barrier at Km 14	Install barricade to prevent interior access	L.S.		$ 1,500	$ 1,500
Recontour staging and roadside stockpile areas	Cat 320CL Excavator, Cat 14G Grader	L.S.		$ 20,000	$ 20,000
Borrow Sources-stabilize slopes	Stabilize the slopes of the excavations - Cat D8N Dozer	hrs	30	$ 245	$ 7,350
Borrow Sources- revegetate	Using ATV mounted applicator for seed and fertilizer	ha	10	$ 1,500	$ 15,000
Revegetation of road surface + disturbed areas	Using ATV mounted applicator for seed and fertilizer	ha	37.5	$ 1,500	$ 56,250
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	18.75	$ 1,500	$ 28,125
Engineering 5%	For major components, particularly removal of bridge		0.05	$423,405	$ 21,170
Surveying 5%	For final as-builts of new contours and stream crossings		0.05	$423,405	$ 21,170
				Sub Total	**$465,746**
Reclaim Seepage Recovery Dam					
Seepage Dam Regrade	Cat D8N Dozer - regrade and contour	hrs	16	$ 245	$ 3,920
Load Haul and Place topsoil	Area of 8000 m^2 with 0.25 m depth	m^3	2000	$ 5	$ 10,000
Reclaim area	Seed and Fertilize	ha	0.8	$ 1,500	$ 1,200
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	ha	0.4	$ 1,500	$ 600
				Sub Total	**$ 15,720**
				Total	**$481,466**
				10% Contingency	**$ 48,147**
				Grand TOTAL	**$529,612**

Table B-8: Site Management and Monitoring Detailed Closure Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Organization, Security and Overhead					
Site Manager - 6 months per year for 2 years, 3 months for 3rd year	Project Manager	month	15	$10,500	$ 157,500
Camp Costs[1]	per day per person	day[1]	4854	$ 85	$ 412,590
Site caretaker	Security, camp operation, general maintenance (8 months per year for 3 years)	month	24	$ 8,800	$ 211,200
vehicles for security and manager	light-duty vehicle	month	72	$ 2,500	$ 180,000
site maintenance costs	general maintenance	year	3	$10,000	$ 30,000
Flights - Whitehorse charter and commercial connections	flight every 3 weeks for 3 years	flights	25	$ 3,000	$ 75,000
miscellaneous office/supply/costs	miscellaneous	year	10	$15,000	$ 150,000
				Sub Total	**$1,216,290**
Compliance Monitoring and Reporting					
External Consulting Services	Annual water sampling (surface water, groundwater, hydrology) and monitoring	year	10	$50,000	$ 500,000
Water Quality Analytical (Closure Phase Year 1 to Year 3)	Surface water quality analytical (20 sites, incl. T1 & R1)	each	78	$ 420	$ 32,760
Water Quality Analytical (Closure Phase Year 1 to Year 3)	Groundwater quality analytical (24 sites)	each	72	$ 290	$ 20,880
Water Quality Analytical (Post-Closure Phase Year 4 to Year 10)	Surface water quality analytical (19 sites, incl. T1)	each	42	$ 420	$ 17,640
Water Quality Analytical (Post-Closure Phase Year 4 to Year 10)	Groundwater quality analytical (24 sites)	each	168	$ 290	$ 48,720
Geotechnical Inspections Closure Phase		year	3	$25,000	$ 75,000
Geotechnical Inspections Post-Closure Phase		year	7	$15,000	$ 105,000
				Sub Total	**$ 800,000**
				Total	**$2,016,290**
				15% Contingency	**$ 302,444**
				Grand TOTAL	**$2,318,734**

1: Camp-person days: assumed 12 persons for 6 months (183 days) in Year 1 (2196 days); 6 persons for 6 months in Year 2 (1098 days); 4 persons for 6 months in Year 3 (732 days) and 1 Caretaker for 6 months for 3 years (548 days), and for Years 4 to 10 - 2 persons for 20 days per year during sampling and monitoring (280 days)

Table B-9: Decommissioning and Post-closure Environmental Sampling

SURFACE WATER QUALITY SAMPLING									
		Sampling Frequency							
		Decommissioning Phase				Post-closure Phase			
Sampling Location		**(2018-2020)**	**Years**	**Samples/Year**	**Number of Samples**	**(2021-2027)**	**Years**	**Samples/Year**	**Number of Samples**
TBD	Underground Mine Portal Discharge	Monthly*	3	7	21	Annually	7	1	7
TBD	Underground Mine Portal Bioreactor Outlet	Monthly*	3	7	21	Annually	7	1	7
W82	Upper Wolverine Creek	Seasonally*	3	3	9	Annually	7	1	7
W9	Wolverine Creek at Little Wolverine Lake	Seasonally*	3	3	9	Annually	7	1	7
W16	Go Creek below TSF	Seasonally*	3	3	9	Annually	7	1	7
W80	Go Creek	Seasonally*	3	3	9	Annually	7	1	7
TOTAL					**78**				**42**

GROUNDWATER QUALITY SAMPLING									
		Sampling Frequency							
		Decommissioning Phase				Post-closure Phase			
Groundwater Well	**Watershed**	**(2018-2020)**	**Years**	**Samples/Year**	**Number of Samples**	**(2021-2027)**	**Years**	**Samples/Year**	**Number of Samples**
MW05-1A, 1B	Go Creek	Annually	3	2	6	Annually	7	2	14
MW05-2A, 2B	Tailings Facility	Annually	3	2	6	Annually	7	2	14
MW05-3A, 3B	Wolverine Creek	Annually	3	2	6	Annually	7	2	14
MW05-4A, 4B		Annually	3	2	6	Annually	7	2	14
MW05-5A, 5B		Annually	3	2	6	Annually	7	2	14
MW05-6A, 6B	Go Creek	Annually	3	2	6	Annually	7	2	14
MW05-7B	Tailings Facility	Annually	3	1	3	Annually	7	1	7
MW06-8S, 8M, 8D	Wolverine Creek	Annually	3	3	9	Annually	7	3	21
MW06-9S, 9M		Annually	3	2	6	Annually	7	2	14
MW06-10S, 10M, 10D		Annually	3	3	9	Annually	7	3	21
MW06-11S		Annually	3	1	3	Annually	7	1	7
MW06-12S		Annually	3	1	3	Annually	7	1	7
MW08-13	Tailings Facility	Annually	3	1	3	Annually	7	1	7
TOTAL					**72**				**168**

*During open water conditions