WOLVERINE MINE
RECLAMATION AND CLOSURE PLAN
2016-07 – REVISED V.3

Prepared for:

Yukon Government Department of Energy, Mines and Resources

Yukon Water Board

Prepared by:

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In conjunction with

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Vancouver, British Columbia

December 18, 2017

Date	December 2017			
Revision Tracking				
Date	**Submitted by**	**Submitted to**	**Version**	**Reason for Update**
December 30, 2016	Yukon Zinc Corporation	Yukon Government, Department of Energy, Mines and Resources	1	Submitted under QML Section 8.8 to update the RCP every two years
September 29, 2017	Yukon Zinc Corporation	Yukon Government, Department of Energy, Mines and Resources	2	Updated to reflect request to extend the temporary closure period by two years
December 18, 2017	Yukon Zinc Corporation	Yukon Government, Department of Energy, Mines and Resources	3	Updated to include comments from YG-ENV on Version 2 and undated costing

Executive Summary

On December 30, 2016 Yukon Zinc Corporation (YZC) submitted an updated Reclamation and Closure Plan to reflect updates to the temporary and ultimate closure of the Wolverine Mine, following re-assessment of site conditions after two years of temporary closure (RCP 2016-07). On June 14, 2017, YZC submitted an request to Yukon Government, Department of Energy, Mines and Resources (EMR) to extend the temporary closure period from the currently permitted three years to five years in order for the company to pursue options to re-open the Wolverine Mine. Subsequently, a request was received from EMR on August 8, 2017 to submit an amended version of RCP 2016-07 to reflect the extended five year temporary closure period. RCP 2016-07.V.2 was an amended version of RCP 2016-07 to include an extension of the temporary closure period from three years to five years, and resultant changes to the ultimate closure plan consistent with the temporary closure amendments.

Also received on August 8 were comments from the following Yukon Government reviewers:

- Mineral Resources Branch – Yukon Government;
- Environment – Yukon Government;
- Compliance Monitoring and Inspections – Yukon Government;
- Yukon Workers Compensation Health and Safety Board;
- Kaska Dena Council; and
- Lorax Environmental.

This Plan, version 3, has been prepared to include the above comments, as well as comments subsequently received on November 3, 2017 from Yukon Government, Department of Environment and also the results of costing discussions held on November 20, 2017.

A summary of the sections that have been amended in this plan is provided in the table below from both versions 1 and 2. All other sections remain unchanged.

Should conditions remain unchanged, YZC will submit an update to the RCP in two years, in September 2019. Should mining resume or closure condition change, YZC will submit an updated RCP.

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
1 Introduction	1 Introduction	Updated to reflect temporary closure period extension	Updated Project Timetable to reflect 5-year temporary closure period.	
1.2 Purpose of the Plan and Changes to Previous Versions	1.2 Purpose of the Plan and Changes to Previous Versions	Updated to reflect temporary closure period extension	• Updated rationale and timeline for submitted and approved Reclamation and Closure Plans. • Updated material changes from RCP 2015-06 and 2016-07.	
2.1 Planning Considerations	2.1 Planning Considerations	Updated to reflect activities conducted since submission of RCP 2016-07	• Added list of correspondences with requirements for amended RCP 2016-07. • Updated Table 2-1.	
3.1 Climate	3.1 Climate	Updated climate data	Updated temperature and precipitation data with most recent weather station data.	
3.2.1 Hydrology	3.2.1 Hydrology	Updated hydrology data	Updated hydrological graphs for stations W9 and W82.	
3.3.1 Hydrogeology	3.3.1 Hydrogeology	Updated groundwater level data	As requested in April 17, 2017 letter from Lorax Environmental: • Updated potentiometric elevations to mid-2017 • Added monitoring well water level date from 2009 – 2017 in wells downgradient from the mine	
3.3.2 Groundwater Quality	3.3.2 Groundwater Quality	Updated groundwater quality data	• Updated groundwater quality data to reflect downstream distance to help identify trends. • Update groundwater quality with most recent water quality values.	
4.1 Mine Features, Facilities and Equipment	4.1 Mine Features, Facilities and Equipment	Updated text to reflect flooded underground workings	Text now reflects pumping from the underground mine to the TSF during temporary closure period	
5. Temporary Closure	5. Temporary Closure	Extension of temporary closure period from January 2018 to January 2020	• Yukon Zinc has taken steps to evaluate the feasibility of re-opening the Wolverine Mine under current mineral market conditions. This process continues and includes requesting an extension of the temporary closure period from three years, to five years, which would delay permanent closure of the Wolverine Mine from January 2018 to	

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
			January 2020. • The site will be maintained in a state that will allow for re-start during this extended temporary closure period.	
5.1.1 Site Security	5.1.1 Site Security	Update chemical storage status	• There are 18 bags of copper concentrate and 13 bags of lead concentrate remaining to be shipped off site by the purchaser. • Only 95 tonnes of lime remain on site and will be used in the treatment of the TSF.	
5.1.2 Monitoring Activities	5.1.2 Monitoring Activities	Update surface water and groundwater monitoring as per WUL QZ04-065	Environmental monitoring frequency and sites had been reduced following a letter from CMI; however, YZC will return to the sampling frequency and sites outlined in QZ04-065 for the temporary closure period, including monthly surface water sampling, and quarterly groundwater sampling.	
		Continued bioreactor monitoring	The bioreactor constructed between Waste Rock Pad #2 and the TSF will continue to be monitored throughout the extended closure period. Results from the test work will inform the permanent closure solution.	
		MMER EEM sampling	• Effluent characterization studies under MMER EEM will be required when discharging to Go Creek. • Cycle 4 EEM study will be required to be conducted in late August 2019.	
		Vegetation monitoring	Add requirement to conduct vegetation monitoring for metals prior to closure. Small mammal sampling will be conducted if vegetation sampling indicates statistically significant metals contamination.	
5.1.3 Maintenance Activities	5.1.3 Maintenance Activities	Increase period for maintenance	Ongoing maintenance of site will be required for the extended temporary closure period and must be considered in the cost accounting.	
5.1.3.1 Underground Workings and Openings to Surface	5.1.3.1 Underground Workings and Openings to Surface	Defer bulkhead installation	Bulkhead installation had previously been required by October 2017. As the mine will potentially be re-started, access to the underground must be	

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
	5.2.1 Underground Mine Interim Water Management Plan		maintained. On June 7, 2017, underground discharge reached the surface of the underground mine adit. Dewatering pumps have been installed, and water levels are maintained by pumping the excess water to the TSF. This system will be maintained throughout the temporary closure period.	
5.1.3.2 Tailings Storage Facility (TSF) Area and Water Management Structures	5.1.3.2 Tailings Storage Facility (TSF) Area and Water Management Structures	Add wildlife monitoring	Monitoring for wildlife is also conducted at the TSF pond regularly during the ice-free period.	
5.1.3.4 Mine Infrastructure	5.1.3.4 Mine Infrastructure	LTF not decommissioned	The mine infrastructure will be monitored and maintained as per current conditions. The LTF will not be decommissioned until permanent closure is initialized, as it may be required during re-start and subsequent operation of the mine. Decommissioning will be conducted in accordance with an approved plan from Yukon Environment.	
5.2 Interim Water and Solution Management Plan	5.2 Interim Water and Solution Management Plan	Update to reflect changes in bulkhead design and underground discharge	• Remove underground mine portal bioreactor. • Direct all contaminated water to the TSF. • Evaluate potential to treat underground discharge directly. • Evaluate in-situ treatment of the TSF pond. • Install a water treatment plant in summer 2018. • Discharge to Go Creek May – October as required.	
-	5.2.1 Water Balance	Updated water balance	Data collected over the temporary closure period has informed an updated water balance for the temporary closure period.	Updated to reflect UG flow measurements from August – October. Added high flow sensitivity analysis.
5.2.1 Underground Mine Workings	5.2.2 Underground Mine Workings 5.2.2.1 Adaptive Management Plan Appendix C: Portal	Updated bulkhead design. Bioreactor installation dependent on water chemistry.	• An update to the bulkhead design was completed in July 2017 and is provided in Appendix C. Mine water will be dewatered to below the bulkhead installation. • If a decision to re-start the mine has not been	Update to mine inflow volumes. Provides results of October test work and preliminary plan to discharge underground

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
	Plug Design Report		made by early 2019, the bulkheads will be installed in summer 2019, in preparation for final closure in January 2020. • The updated design is water tight, and as such a bioreactor at the adit will not be required. • The installation of a bioreactor in Wolverine Creek to mitigate potentially contaminated mine water will be dependent on the water chemistry of groundwater and surface water in Wolverine Creek. The installation will be required if the water chemistry meets certain defined trigger levels.	mine water.
5.2.2 TSF Area	5.2.3 TSF Area 5.2.3.1 Water Treatment	TSF pond water treatment	• TSF supernatant will be treated using an active treatment system. • Appendix D: Assessment and Bench Scale Testing of Water Treatment Options	
6. Final Reclamation and Closure Measures	6. Final Reclamation and Closure Measures	Update to reflect changed timelines and changes to temporary closure plan	This section will now include the following, which were deferred from the temporary closure section: • LTF decommissioning • Temporary active water treatment • Increased decommissioning and post-closure environmental sampling • Wolverine Creek monitoring and adaptive management with potential bioreactor installation	Inconsistency with Section 6.5.5 fixed
6.2.1 TSF Water Treatment	6.2.1 TSF Water Treatment	Add water treatment plant	• As a water treatment plant will be installed during the temporary closure period, it will continue to be used during the permanent closure period until all water is removed from the facility. • Deleted Sections 6.2.1.1 & 6.2.1.2.	
6.4 Water Management Structures and Systems	6.4 Water Management Structures and Systems	Change disposal of pipelines	Pipelines and liners will be disposed of in the landfill, not in the TSF.	
6.5.4 Landfill and Waste Storage Areas	6.5.4 Landfill and Waste Storage Areas	Removal of reference to disposal of special and solid waste in TSF	In response to the comment from Yukon Environment, no special or solid waste will be disposed of in the TSF	Includes reference to Commercial Dump permit and facility closure requirements

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
6.5.5 Material and Equipment Salvage	6.5.5 LTF 6.5.6 Material and Equipment Salvage	LTF will remain operational	LTF will not be decommissioned during temporary closure, but will remain operational for the duration of the permanent closure phase to allow for disposal and treatment of contaminated soils.	
6.7 Roads and Other Access	6.7 Roads and Other Access	Added reclamation of quarries	In response to a comment from CMI, stabilization and revegetation of quarries was added.	
6.9.2 Environmental Monitoring	6.9.2 Environmental Monitoring	-	-	Removed sampling at station T1 post-closure. This was already considered in the closure costs.
6.10.1 Risk Assessment	6.10 Risk Assessment	Updated to reflect changes in temporary closure and permanent closure	• Risks include: • TSF failure • Overtopping of dam • Discharge of untreated water	
6.10.2 Post-Reclamation Adaptive Management Plan	-	Deleted this section	• Adaptive management is discussed in Section 5.2.2.1. • All other activities will be conducted as planned and approved by this RCP and by EMR.	
8 Reclamation and Closure Liability	8 Reclamation and Closure Liability	Update unit rates	• Unit rates have been updated in the temporary and final closure cost estimates to reflect • Costs have been updated to reflect the changes outlined in the above rows of this table	Unit rates have been updated to include: • higher cost for power • higher unit rates for activities that use heavy equipment • 10% increase in costs for water quality analysis to account for QA/QC samples
8.1 Temporary Closure Cost Estimate	8.1 Temporary Closure Cost Estimate	-	-	This section has been deleted, and the costs moved to Section 8.1 Final Reclamation and Closure Cost Estimate. Changes to the costing include: • Assumes installation of

RCP 2016-07	RCP 2016-07.V.2	Amendment	Summary	RCP 2016-07.V.3
				WTP in 2018, therefore not required in permanent closure. • Assumes operation of WTP May – October at 1200 m^3/day to dewater the TSF post-closure • Fuel costs were increased from $0.05/kWh to $0.40/kWh • Added a new liner for the decommissioning of the TSF • Detailed waste pad decommissioning based on distance from the TSF • Added a temporary mobile camp to complete decommissioning of the access road • Added weekly flights during water release • Corrected some spreadsheet errors • Added contingency costs

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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
BQE	BQE Water
CCME	Canadian Water Quality Guidelines for the Protection of Aquatic Life
CLO	Concentrate Load Out Facility
CMI	Yukon Government Compliance Monitoring and Inspections
CPUE	Catch per unit effort
EEM	Environmental Effects Monitoring
EMR	Yukon Government Department of Energy, Mines and Resources
ERC	Electrocell treatment
IX	Ion exchange
LOM	Life-Of-Mine
LTF	Land Treatment Facility
MMER	Metal Mine Effluent Regulations
OMS	Operation, Maintenance and Surveillance Manual
QML	Yukon Government Energy, Mines and Resources Quartz Mining Licence QML-0006
RCP	Reclamation and Closure Plan
RO	Reverse Osmosis
RRDC	Ross River Dena Council
TCP	Temporary Closure Plan
TSF	Tailings Storage Facility
TSS	Total Suspended Solids
WPP	Wildlife Protection Plan
WTP	Water treatment plant
WUL	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
$	Canadian dollars
gpm	gallons per minute
ha	hectare
km	kilometres
km/h	kilometres per hour
kW	kilowatts
L	litres
m	metres
m^3	cubic meters
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 2-and-2 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. The current scenario has been updated to reflect a five year temporary closure phase, with permanent closure initiated in January 2020.

Table 1-1: Project Timetable

Year	Original Plan	2016-07 Plan	Current Plan
2009 to 2010	Construction Phase	Construction Phase	Construction Phase
2011	Production Ramp-Up	Production Ramp-Up	Production Ramp-Up
2012	Year 1	Year 1	Year 1
2013	Year 2	Year 2	Year 2
2014	Year 3	Year 3	Year 3
2015	Year 4	Mining Halted: Temporary Closure	Mining Halted: Temporary Closure
2016	Year 5	Temporary Closure	Temporary Closure
2017	Year 6	Temporary Closure	Temporary Closure
2018	Year 7	Permanent Closure: Decommissioning begins	Temporary Closure
2019	Year 8	Decommissioning	Temporary Closure
2020	Year 9	Decommissioning complete	Permanent Closure: Decommissioning begins
2021	Permanent Closure	Post-Closure Phase begins	Decommissioning
2022	Decommissioning	Post-Closure Phase	Decommissioning
2023-2029	Post-Closure Phase	Post-Closure Phase	Decommissioning
2029-2038	Post-Closure Phase	Closure complete	Post-Closure Monitoring
2039+	Post-Closure Phase		Closure complete

1.2 Purpose of the Plan and Changes to Previous Versions

The most recent approved Reclamation and Closure Plan (RCP) for the Wolverine Mine was submitted July 2015 (Version 2015-06). On December 30, 2016 Yukon Zinc Corporation (YZC) submitted an updated Reclamation and Closure Plan to reflect updates to the temporary and ultimate closure of the Wolverine Mine, following re-assessment of site conditions after two years of temporary closure (RCP 2016-07). On June 14, 2017, YZC submitted an request to Yukon Government, Department of Energy, Mines and Resources (EMR) to extend the temporary closure period from the currently permitted three years to five years in order for the company to pursue options to re-open the Wolverine Mine. Subsequently, a request was received from EMR on August 8, 2017 to submit an amended version of RCP 2016-07 to reflect the extended five year temporary closure period. This plan (RCP 2016-07.V.3) presents an amended version of RCP 2016-07 to include an extension of the temporary closure period from three years to five years, and resultant changes to the ultimate closure plan consistent with the temporary closure amendments.

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 2020 following five years of temporary closure.

While this RCP (Version 2016-07.V.3) is a comprehensive and inclusive report that 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, some changes have been made to the previous version to reflect the temporary closure period extension. These changes are summarized above in the Executive Summary for reference.

Material changes in RCP 2016-07 (versions 1 & 2) from the previous RCP (Version 2015-06) include 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. Impermeable HDPE cover will prevent generating and subsequent leaching of acid mine drainage.
- 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.

Material changes in this RCP from RCP 2016-07 include:

- Updated bulkhead design. The updated design is water tight, and therefore does not require a bioreactor to treat water exiting the underground mine. The contingency biopass installed in Wolverine Creek will be installed if trigger concentrations in Wolverine Creek are met.

- Underground groundwater discharge has progressed at a higher rate that previously predicted. As such, an active water treatment plant will be required to treat water accumulating in the TSF from surface runoff and from the underground mine. This RCP has been updated to include the preliminary test work to assess treatability as well as the costs to design, build and operate an active water treatment plant (WTP) during the temporary closure period. The WTP will also be used during the permanent closure period to dewater water collected in the TSF prior to closure of the facility.
- Increased monitoring of surface water sites, piezometric hydrological conditions and EEM requirements to reflect requirements in the WUL and following comments received from regulators following submission of RCP 2016-07.
- Updated unit rates following publication of those rates in February 2017.

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.

Should conditions remain unchanged, in accordance with the *Mine Site Reclamation and Closure Policy*, and with the *Reclamation and Closure Planning for Quartz Mining Projects – Plan requirements and closure costing guidance* (Government of Yukon, 2013), YZC will submit an update to the RCP in two years, in September 2019.

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.

The extended temporary closure period will provide an opportunity for Yukon Zinc to further refine its closure strategy, while at the same time allowing Yukon Zinc to evaluate the possibility of mine re-start, in recognition of the value of both the minerals remaining at the Wolverine deposit and of the infrastructure at the Wolverine Mine.

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;
- Conditions listed in the "Update to Reclamation and Closure Plan 2015-06" letter from EMR to YZC, dated June 21, 2016;
- Comments received May 25 via email from Andrea Kenward regarding further clarification and information on the biopass design and construction information; tailings facility; and monitoring data and activities;
- Comments received during the July 19 conference call with EMR, Water Resources, and Compliance, Monitoring and Inspections; and
- Requirements and comments outlined in the "Proposed Amendments to Wolverine Mine Reclamation and Closure Plan Version 2016-07", including comments from Yukon Government, Yukon Workers Compensation Health and Safety Board and the Kaska Dena Council.

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.V.3.

From QML-0006, Section 8.6:		Section in 2016.V.2 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	6.2 Tailings Storage Facility (TSF) Area

	stabilization and closure of the TSF	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 6.9.2 Environmental Monitoring
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	5.2.2 Underground Mine Workings
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 Appendix E: Wolverine Mine Dam Safety Review Tailing Storage Facility and Earth Structures, Klohn Crippen Berger, August 2017
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 at the site and other matters as appropriate)	5.1.2.1 Surface Water and Groundwater Monitoring *3-D modelling will be conducted as part of the hydrogeological assessment conducted in 2018 to assess the requirement for groundwater monitoring.*
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	5.2.2 Underground Mine Workings
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	5.2.2.1 Adaptive Management Plan
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	5.2.2.1 Adaptive Management Plan
r	Design, maintenance, long-term monitoring and management plans, and implementation schedules for the bioreactor system and creek diversion	5.2.2.1 Adaptive Management Plan

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	5.2.2.1 Adaptive Management Plan
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	Complete
2	Written work plan for the installation of hydraulic plugs (bulkheads)	Complete – Submitted to YG on July 28, 2017
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	Completed - Submitted August 17, 2017
6	Update environmental monitoring program sampling regime	Completed
Conditions outlined in YG letter - dated June 21, 2016		**Location in 2016.V.2 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	5.2.3 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 consideration of both wet (utilizing inert cover material for solids and an overlying wet cover) and dry (landform with encapsulated saturated tailings) closure options	6.2 Tailings Storage Facility (TSF) Area **NOTE: wet cover request no longer required as per May 25, 2017 email from Andrea Kenward**
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	8 Reclamation and Closure Liability

	measures including additional research and/or design work required before implementation of the permanent closure plan would be feasible	
Conditions outlined in YG letter - dated September 11, 2017		**Location in 2016.V.2 RCP**
1.	Describe how the predicted annual average inflow rate for the underground workings compares to the previously predicted inflow rates (Woo Shin, April 2015)	5.2.1 Water Balance
2.	Calculate the actual underground inflow rates using the volume of the underground workings and compare to the predicted inflow rates used in the water balance. a. Reconcile predicted inflow rates and project predicted actual pond elevation through January 2020 using the reconciled water balance.	5.2.1 Water Balance
3.	Provide clear recommendation from the Engineer of Record on the maximum safe water level in the TSF for the following scenarios: a. Liner is repaired at the North End Slump area b. Liner is not repaired.	Appendix A, Appendix B
4.	Provide clear recommendations from the EOR on the instrumentation and monitoring requirements for the TSF during the current state of temporary closure and if temporary closure is granted an extension. a. Do higher water levels in the TSF trigger more rigorous monitoring as the water level approaches the spillway freeboard?	Appendix B
5.	Provide an updated Operating, Maintenance and Surveillance Manual (OMS) as part of the updated Reclamation and Closure Plan for review and approval by September 30, 2017. a. The EOR recommendation for December 2017 does not allow adequate time for review before the current temporary closure expires in January 2018.	Updated *Tailings Facility Operation, Maintenance and Surveillance Manual* to be submitted by October 31, 2017.

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 infrastructure inspections;
  - 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.
- Consideration of conclusions in the August 2017 *Dam Safety Review: Tailing Storage Facility and Earth Structures* by Klohn Crippen Berger.

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 systems and on comparing various seed mixes for the most effective re-vegetation and sediment and erosion control techniques. The results of this test work 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 trials have been underway since 2010, and are being incorporated into the adaptive management plan outlined in Section 5.2.2.1. Details of the ongoing treatment trials are also described in Section 5.2.2.1.

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 2-1, taken in August 2011, shows vegetation establishment in Ditch B.

Photo 2-2, taken in July 2012, demonstrate the success of re-vegetation efforts along the access road corridor, two years after seeding. Photo 2-2, taken in July 2012, shows grass cover establishment on the TSF dam face. Photo 2-4, taken in July 2013, show re-vegetation success around the TSF from seeding completed in 2012. Photo 2-5 to Photo 2-8, 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 2-1: Looking North at Established Vegetation in Coarser Material Along Ditch B (August 2011)

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

Photo 2-3: 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 2-4: Looking South at Established Vegetation on Disturbed Ground Around the TSF Following Fall 2012 Seeding (July 2013)

Photo 2-5: Revegetation Slong the TSF (September 2014)

Photo 2-6: Revegetation Along the Road to Wolverine Lake (September 2014)

Photo 2-7: Revegetation at the Overburden Stockpile Below the TSF (September 2014)

Photo 2-8: 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

5.2.3 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 -4°C, a mean daily summer temperature of 16°C and a mean daily winter temperature of -25°C. Minimum temperatures can reach -37°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 235 mm per year. Maximum wind speeds are less than 40 km/h and the annual average is 15 km/h.

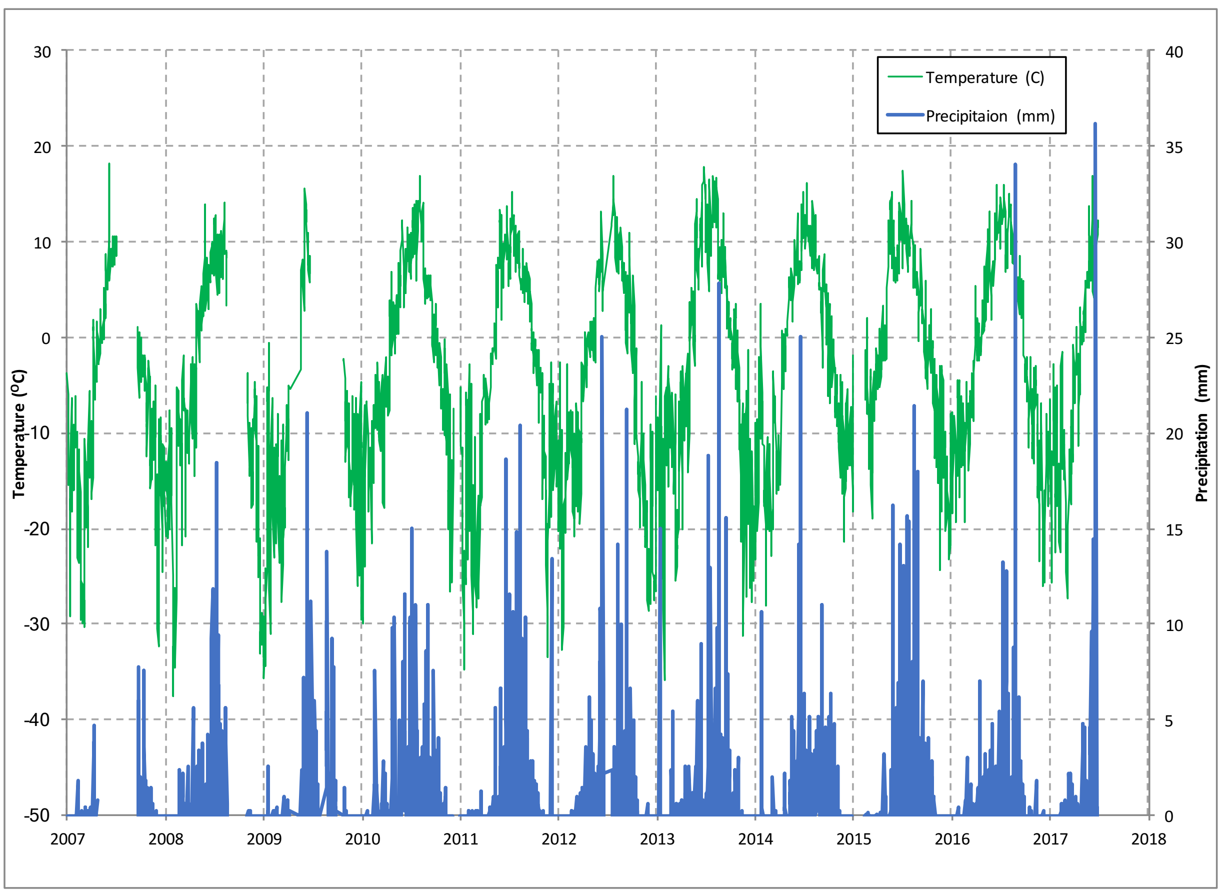


Figure 3-1: Wolverine Mine Daily Precipitation and Average Daily Temperature 2007-2017

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 decommissioned. 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.

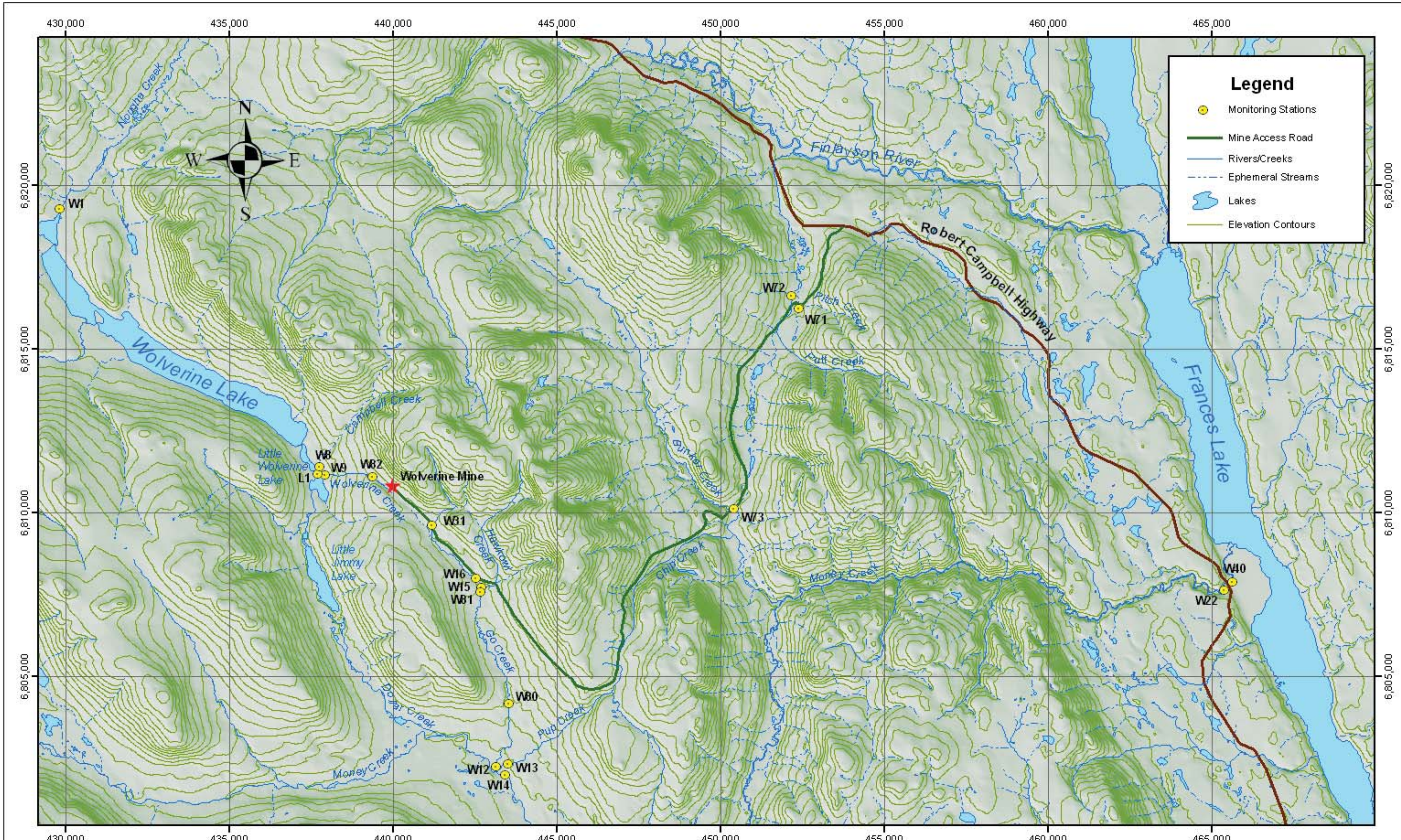
A surface water monitoring program has been established for the Wolverine Mine that provides continuous streamflow data for watercourses in the immediate vicinity of mine site operations as well as more regional coverage (Figure 3-2). Regular monitoring for water quality is also conducted at the sites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

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 m^3/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 m^3/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 m^3/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).



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.

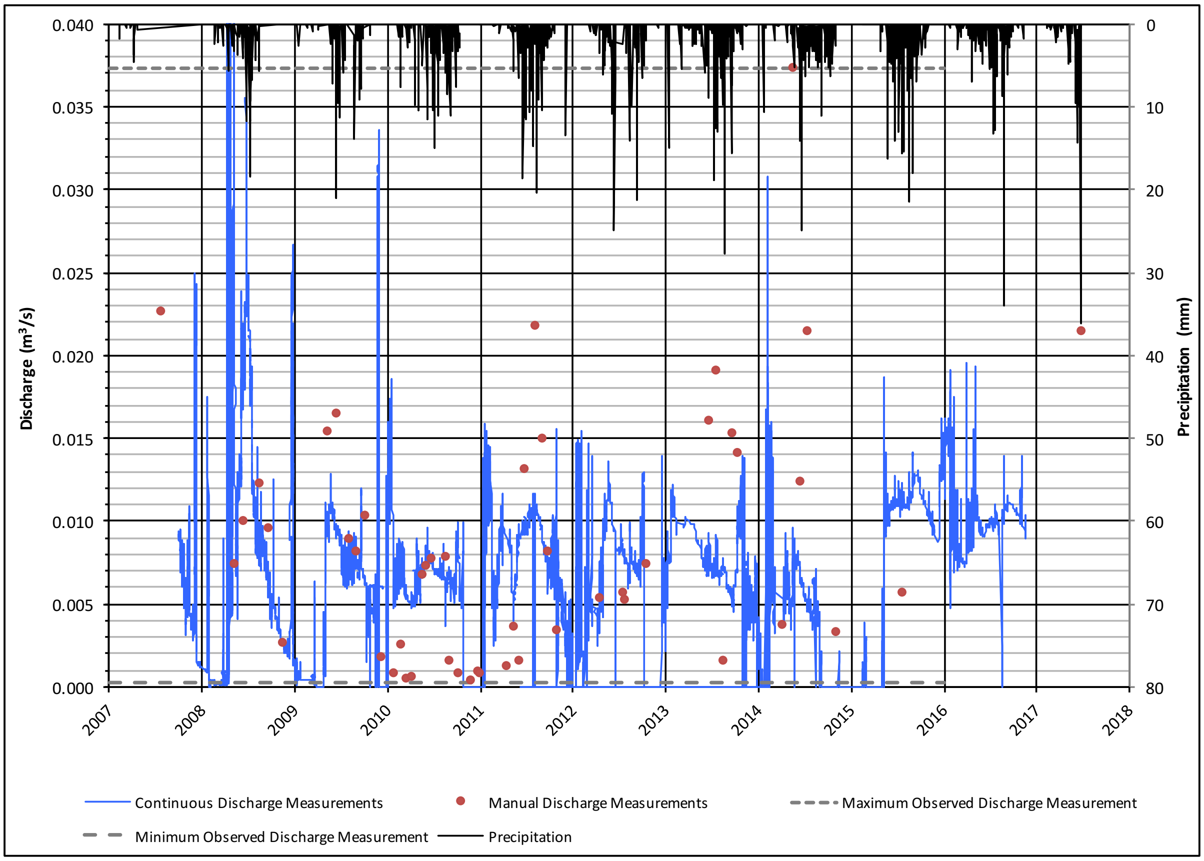


Figure 3-3: W82 Discharge Hydrograph

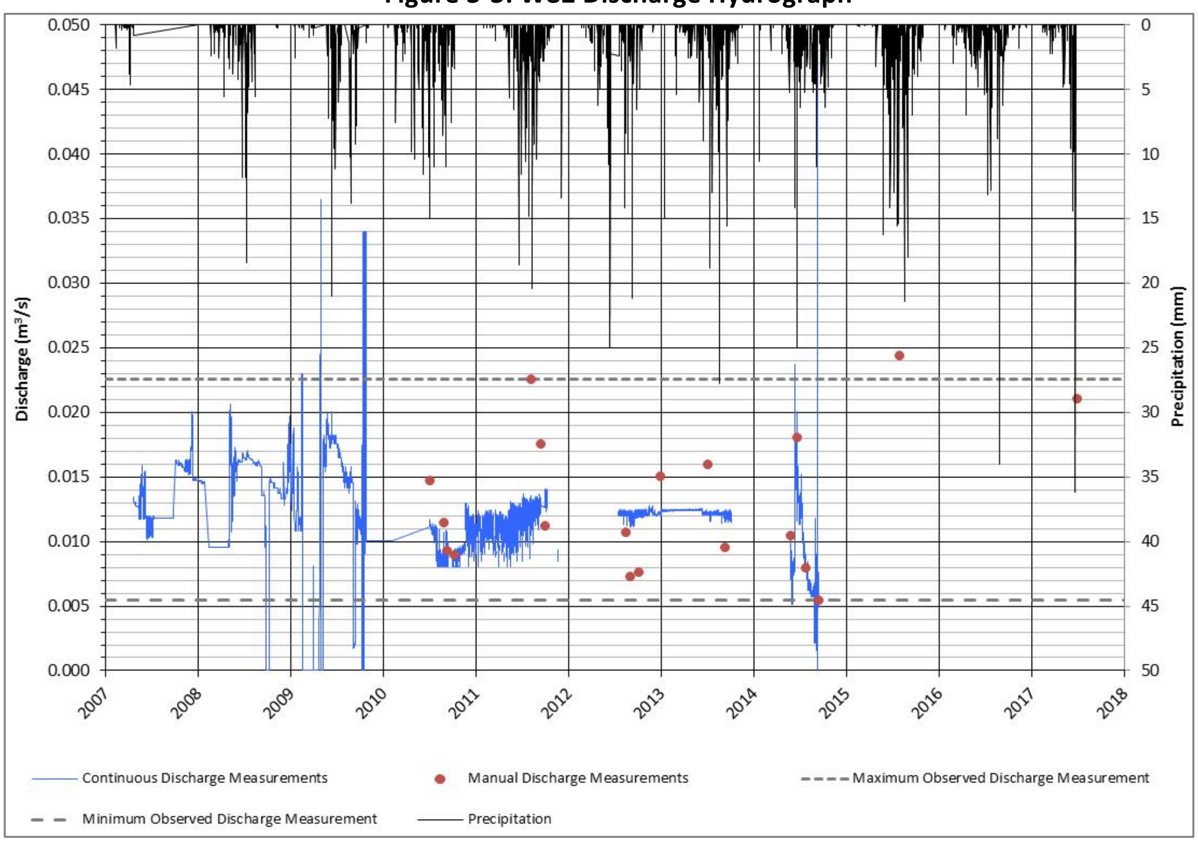


Figure 3-4: W9 Discharge Hydrograph

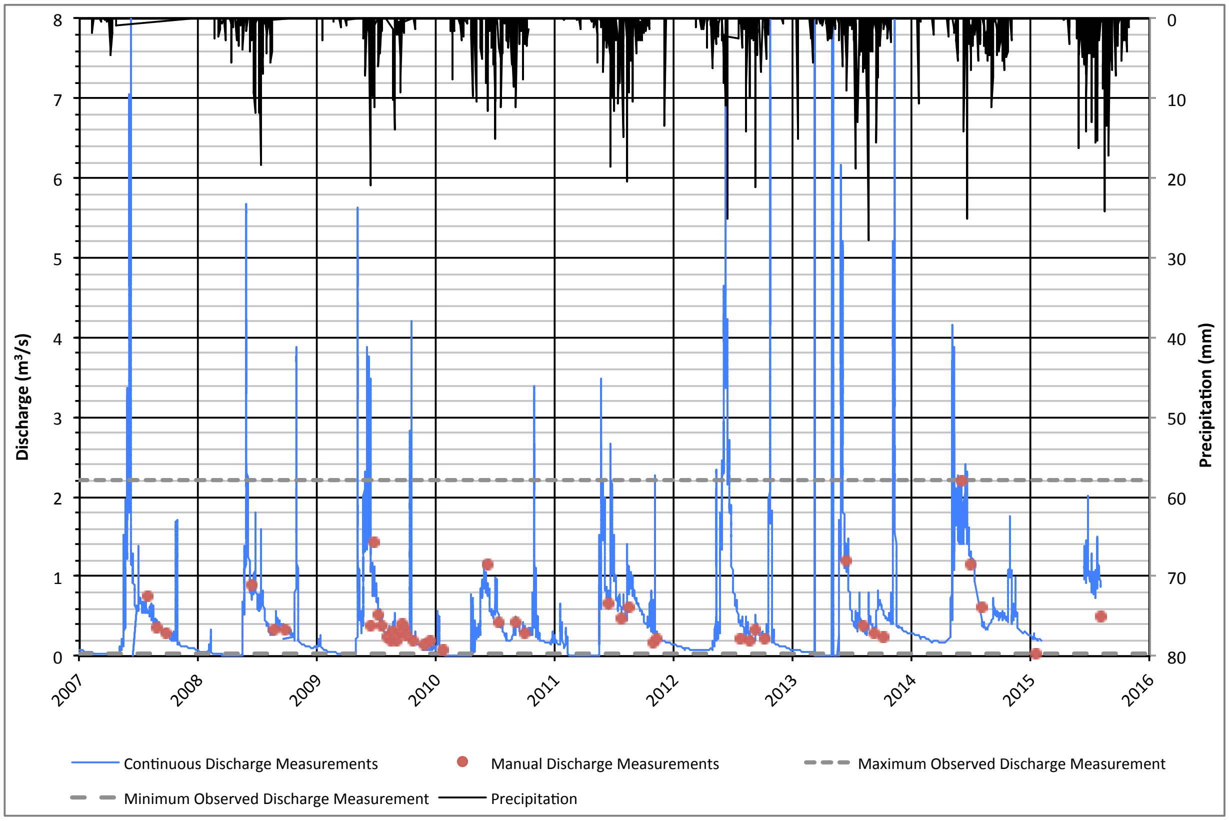


Figure 3-5: W80 Discharge Hydrograph

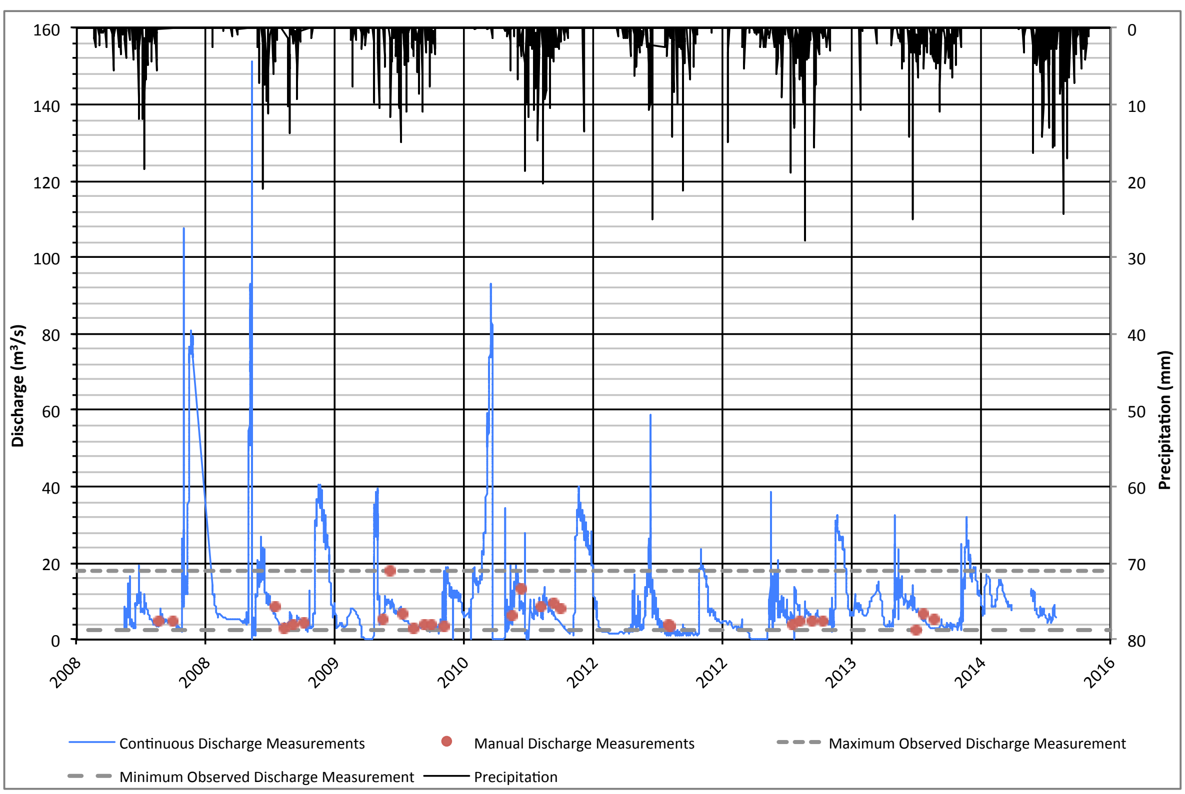


Figure 3-6: W22 Discharge Hydrograph

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).

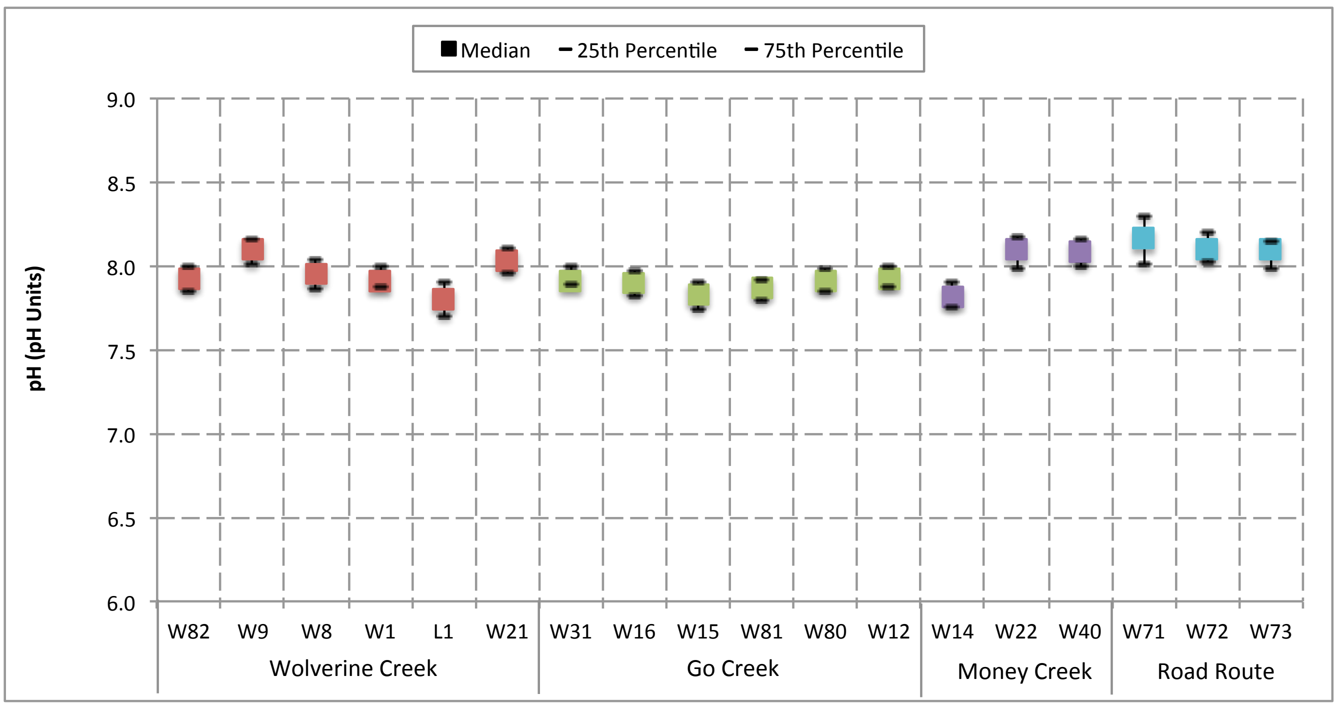


Figure 3-7: Surface Water Chemistry – pH (2009-2016 data)

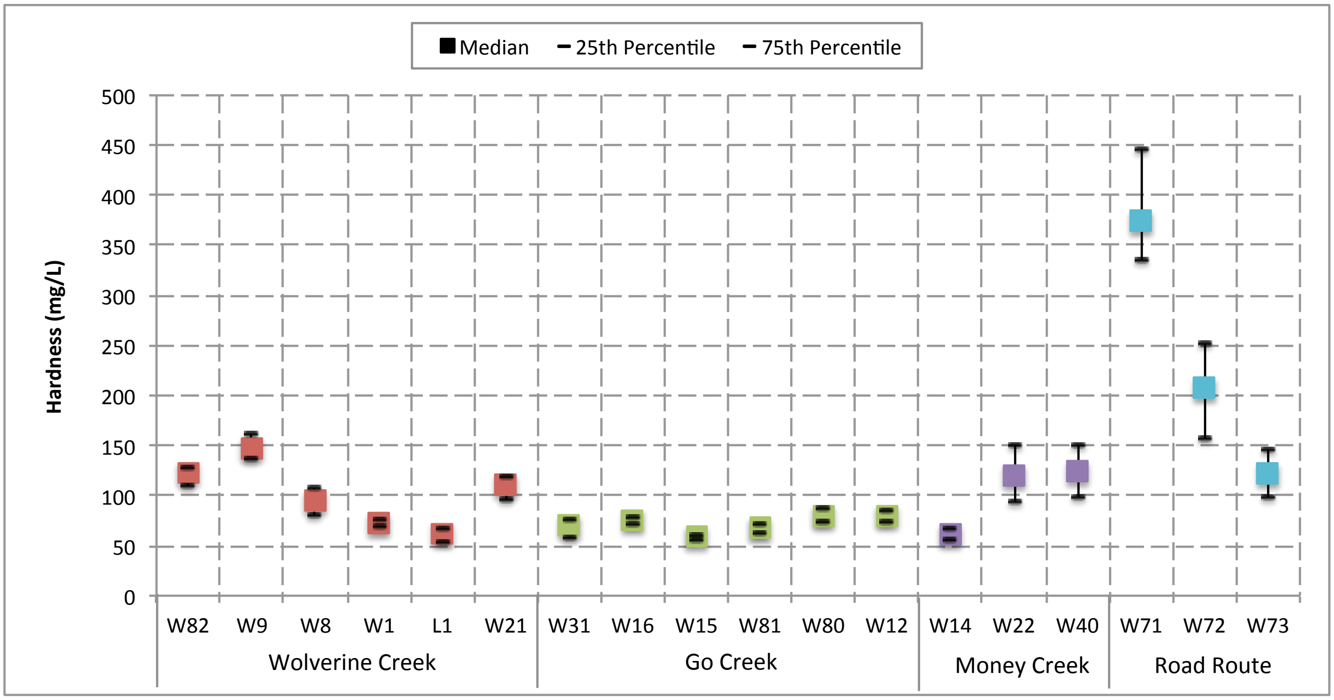


Figure 3-8: Surface Water Chemistry – Hardness (2009-2016 data)

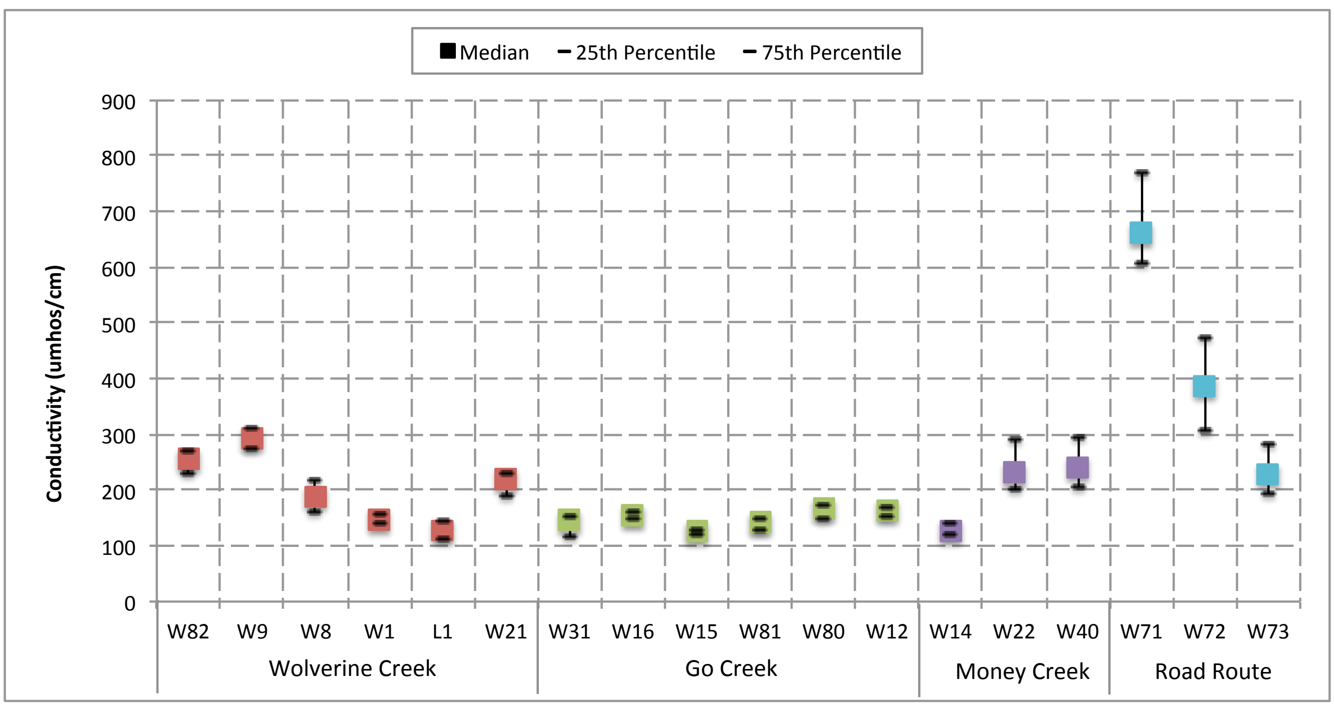


Figure 3-9: Surface Water Chemistry – Conductivity (2009-2016 data)

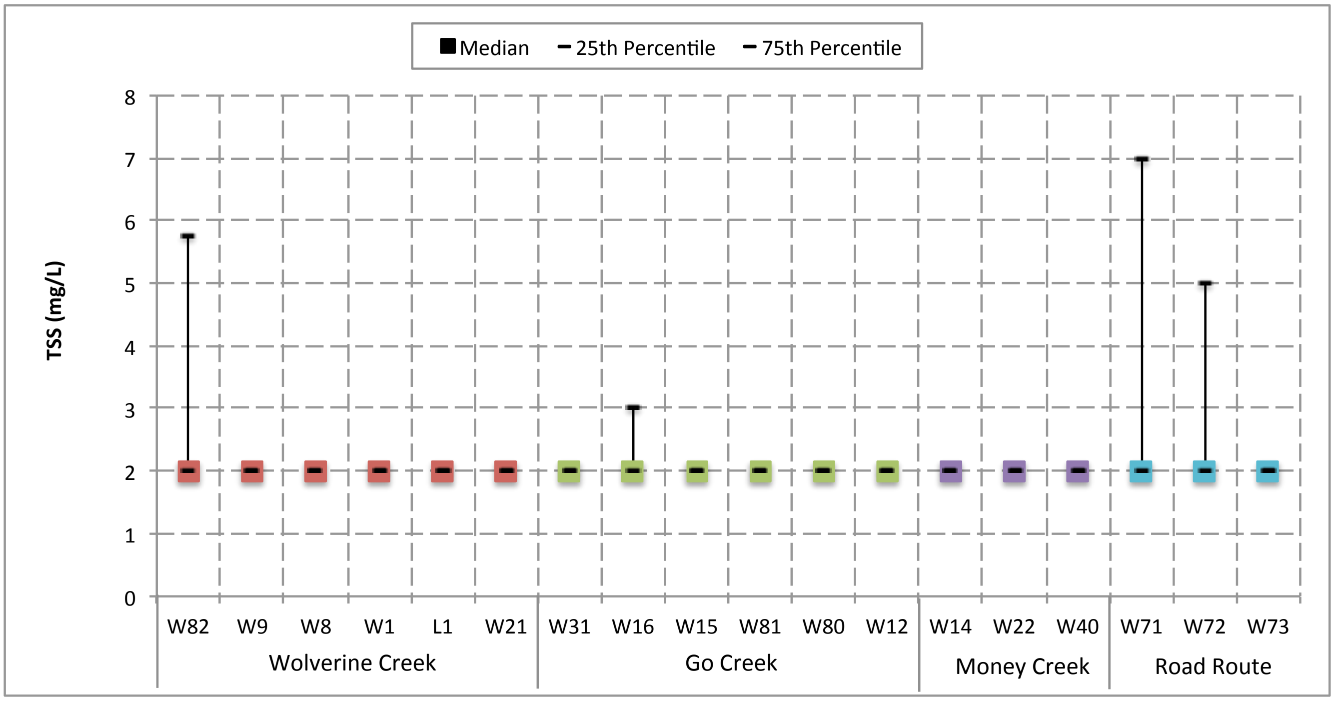


Figure 3-10: Surface Water Chemistry – Total Suspended Solids (2009-2016 data)

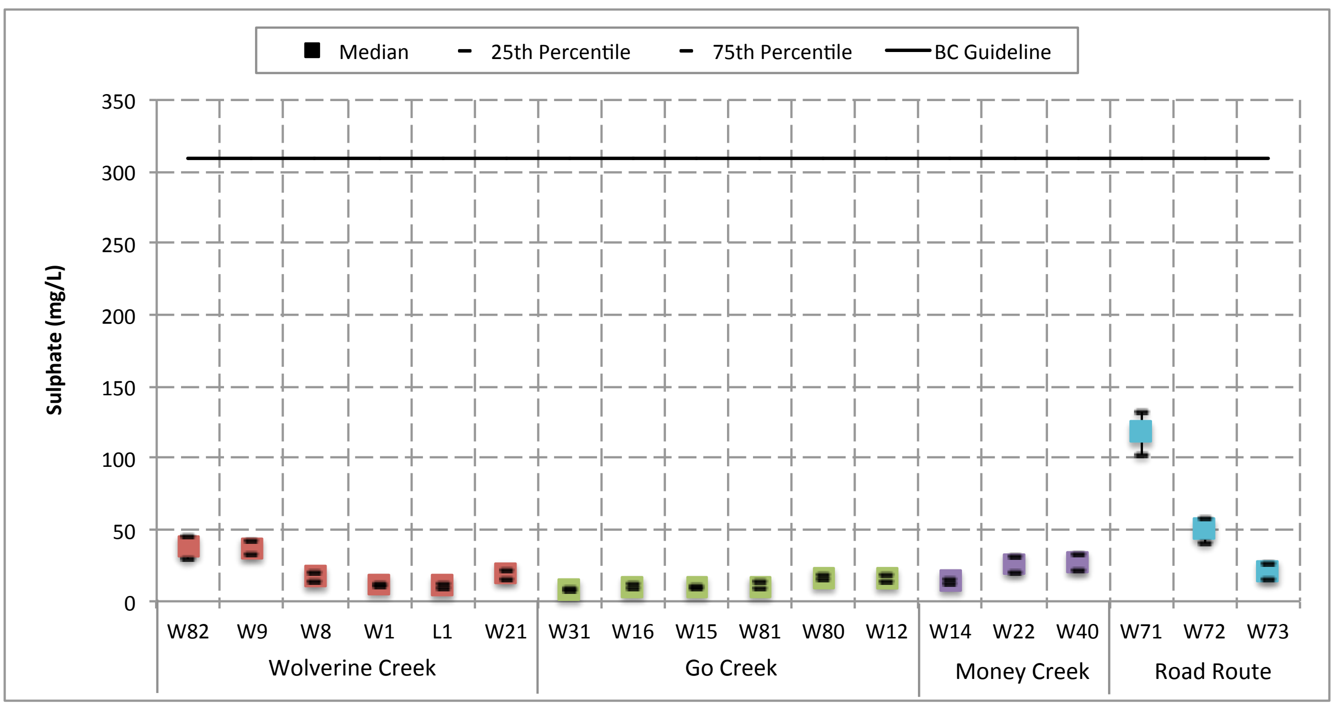


Figure 3-11: Surface Water Chemistry – Sulphate (2009-2016 data)

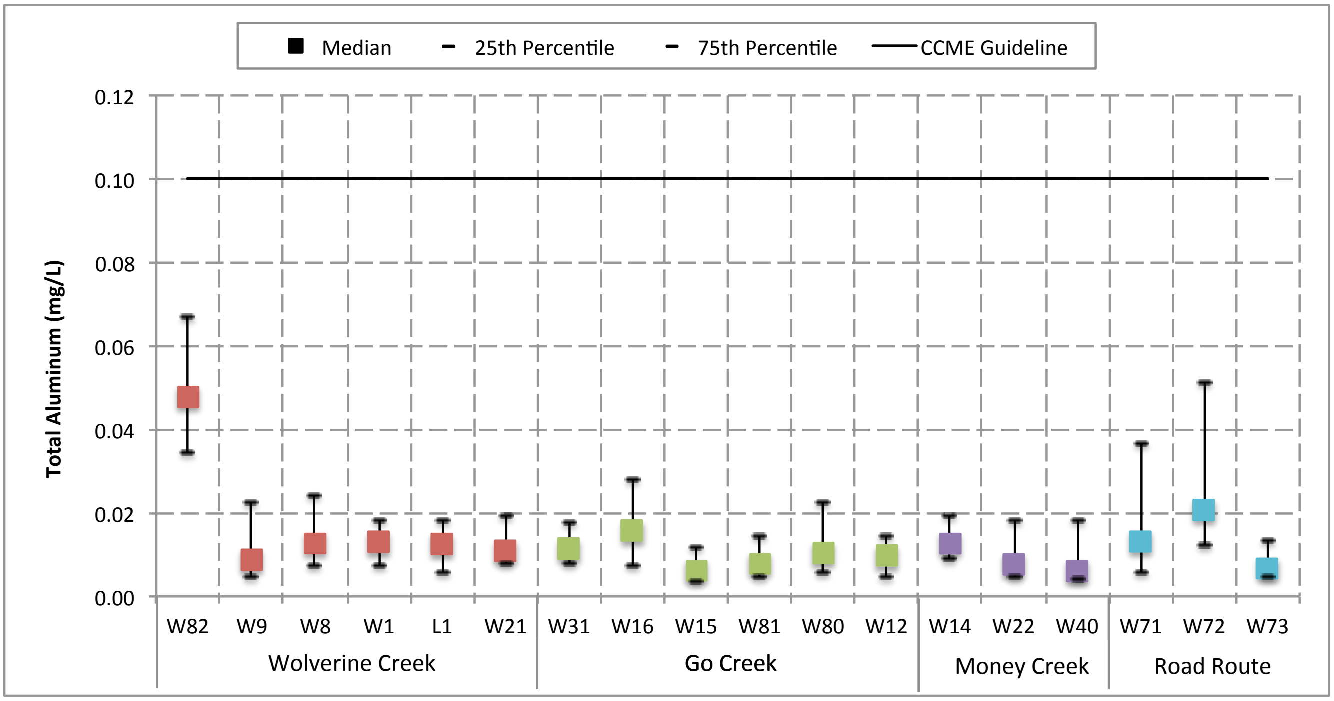


Figure 3-12: Surface Water Chemistry – Total Aluminum (2009-2016 data)

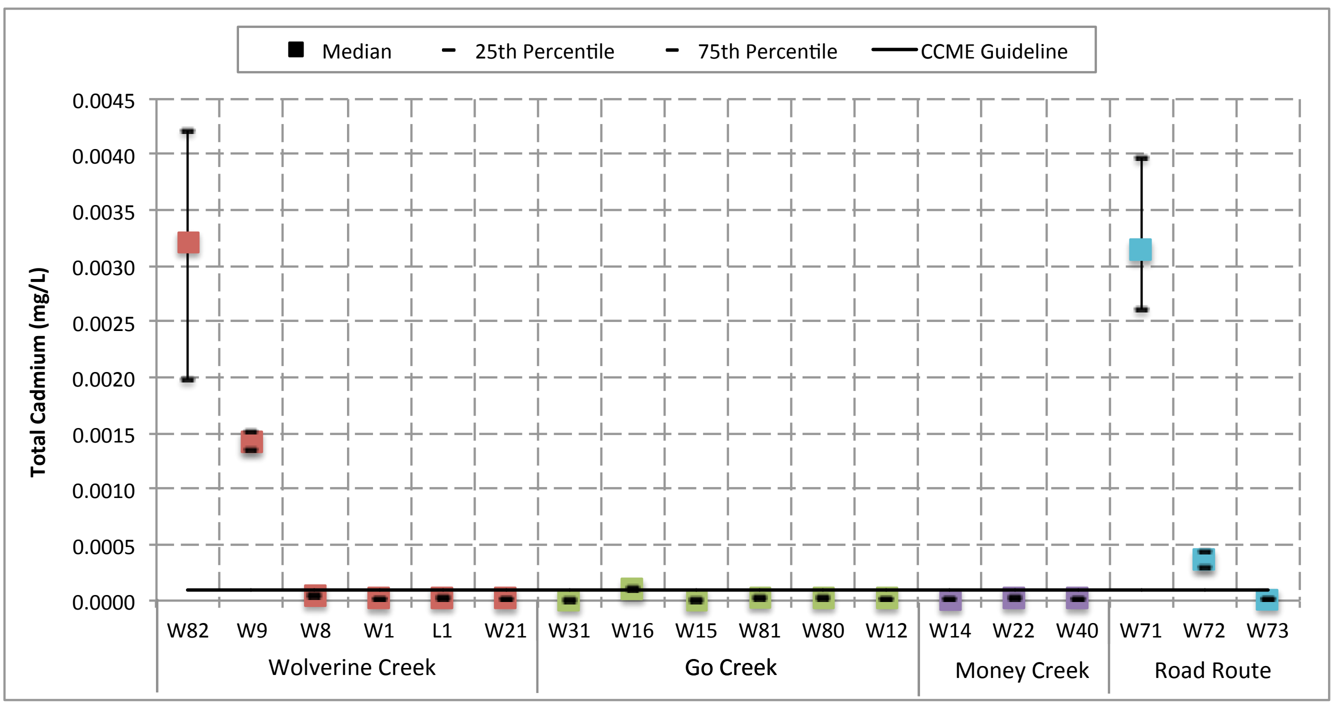


Figure 3-13: Surface Water Chemistry – Total Cadmium (2009-2016 data)

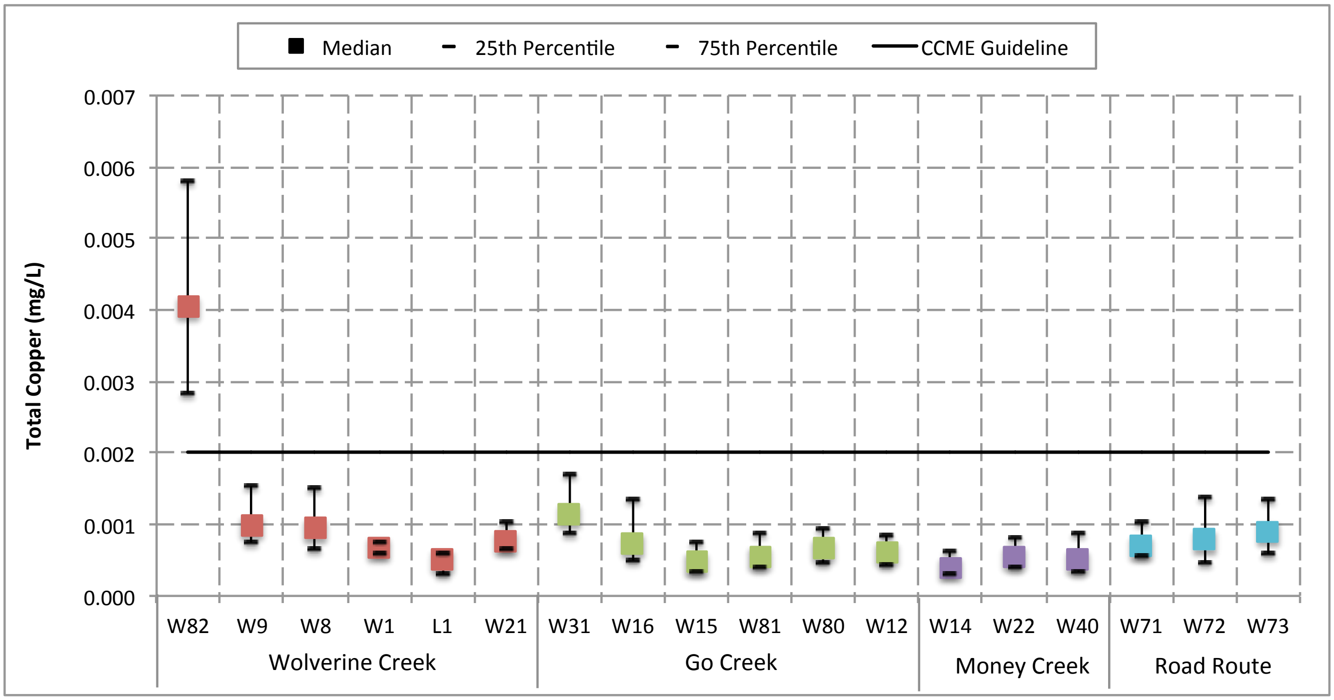


Figure 3-14: Surface Water Chemistry – Total Copper (2009-2016 data)

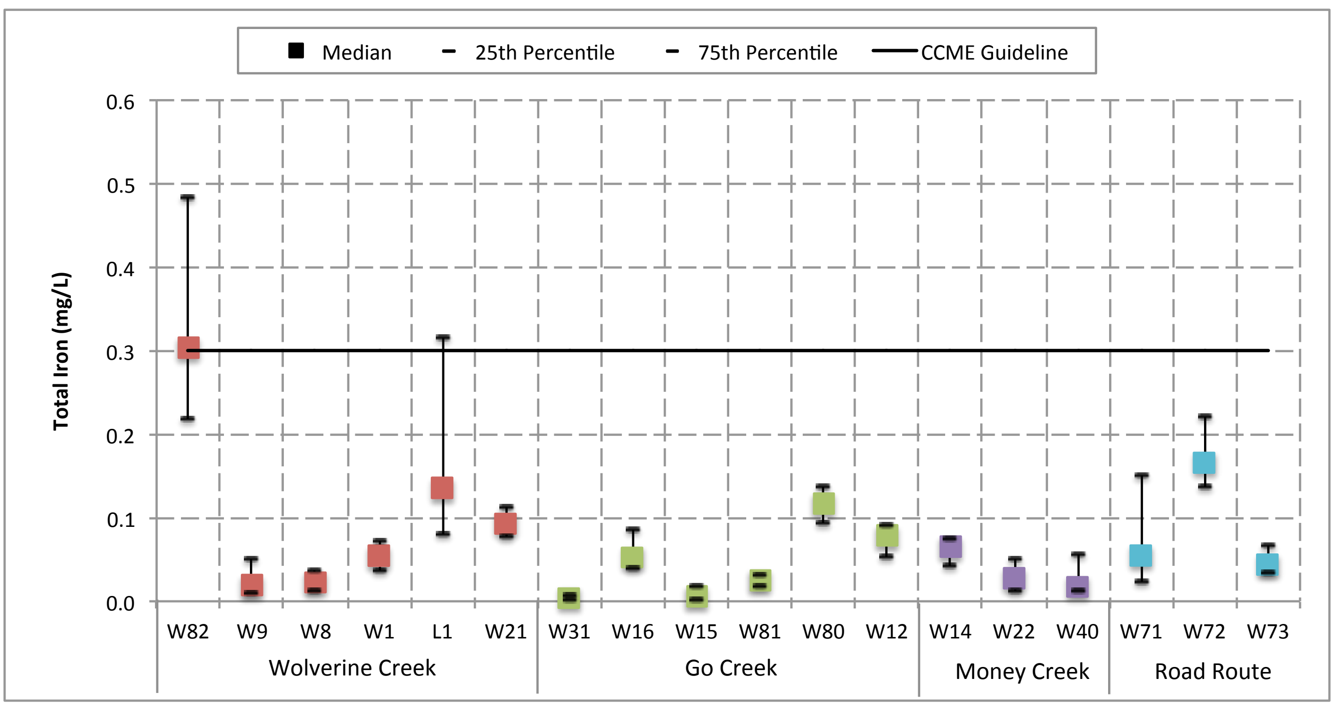


Figure 3-15: Surface Water Chemistry – Total Iron (2009-2016 data)

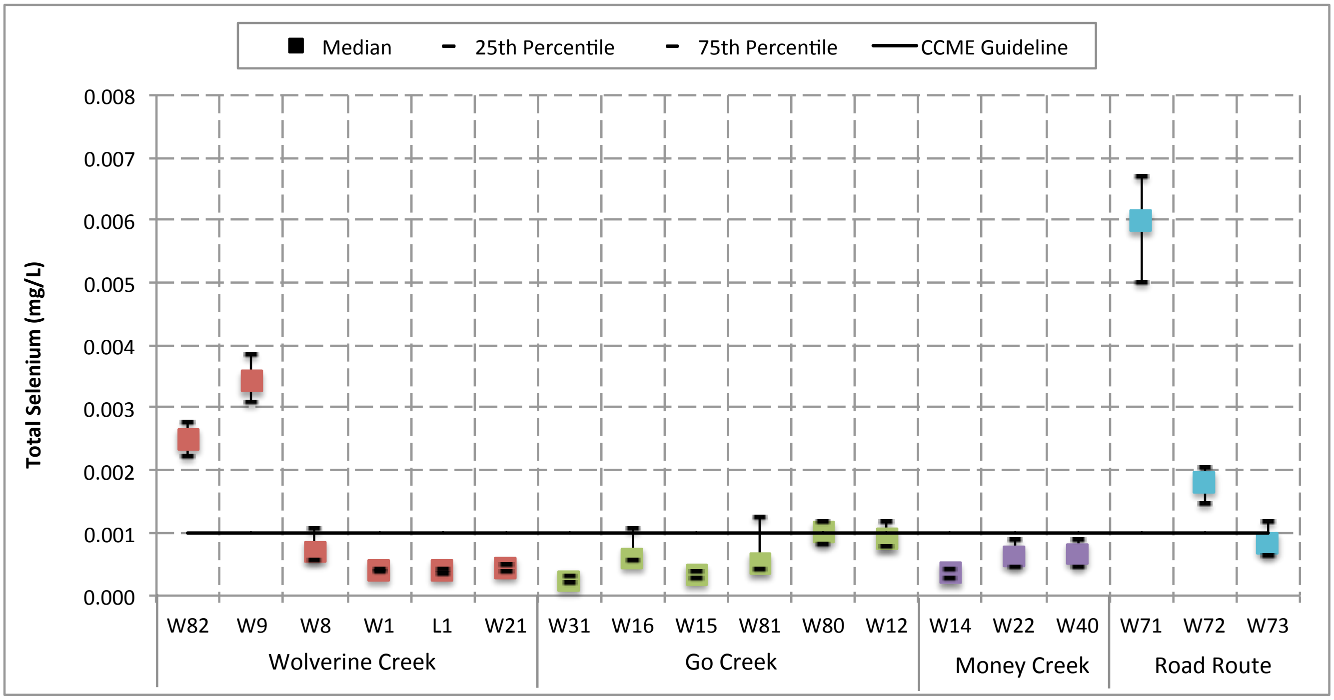


Figure 3-16: Surface Water Chemistry – Total Selenium (2009-2016 data)

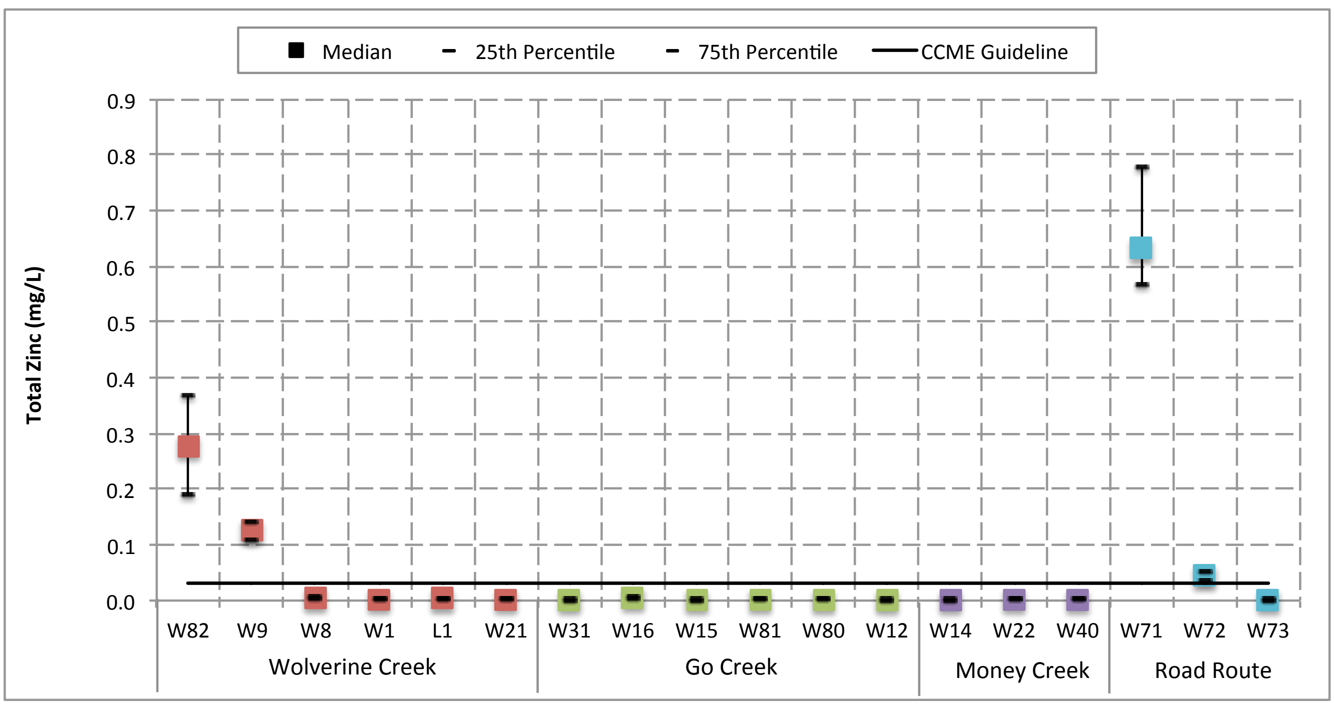


Figure 3-17: Surface Water Chemistry – Total Zinc (2009-2016 data)

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 3-21). The conceptual hydrogeologic model plan and cross-sections, and predicted dewatered zones, are shown in Figure 3-22 through Figure 3-26.

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 in June 2014 and in the PZA Shallow sensor in December 2015, therefore data is not presented after those dates.

The shallow piezometers remained relatively constant throughout pre-production and operations, although the PZB shallow piezometer indicates an increase in the water table since mid-2016 in parallel to the PZB deep piezometer. The deep piezometers showed a marked decrease from 2009 to the cessation of operations, which, while originally attributed to an intersection of the mining operations with the well, the PZB Deep piezometer has recovered back to pre-production levels as of mid-2017.

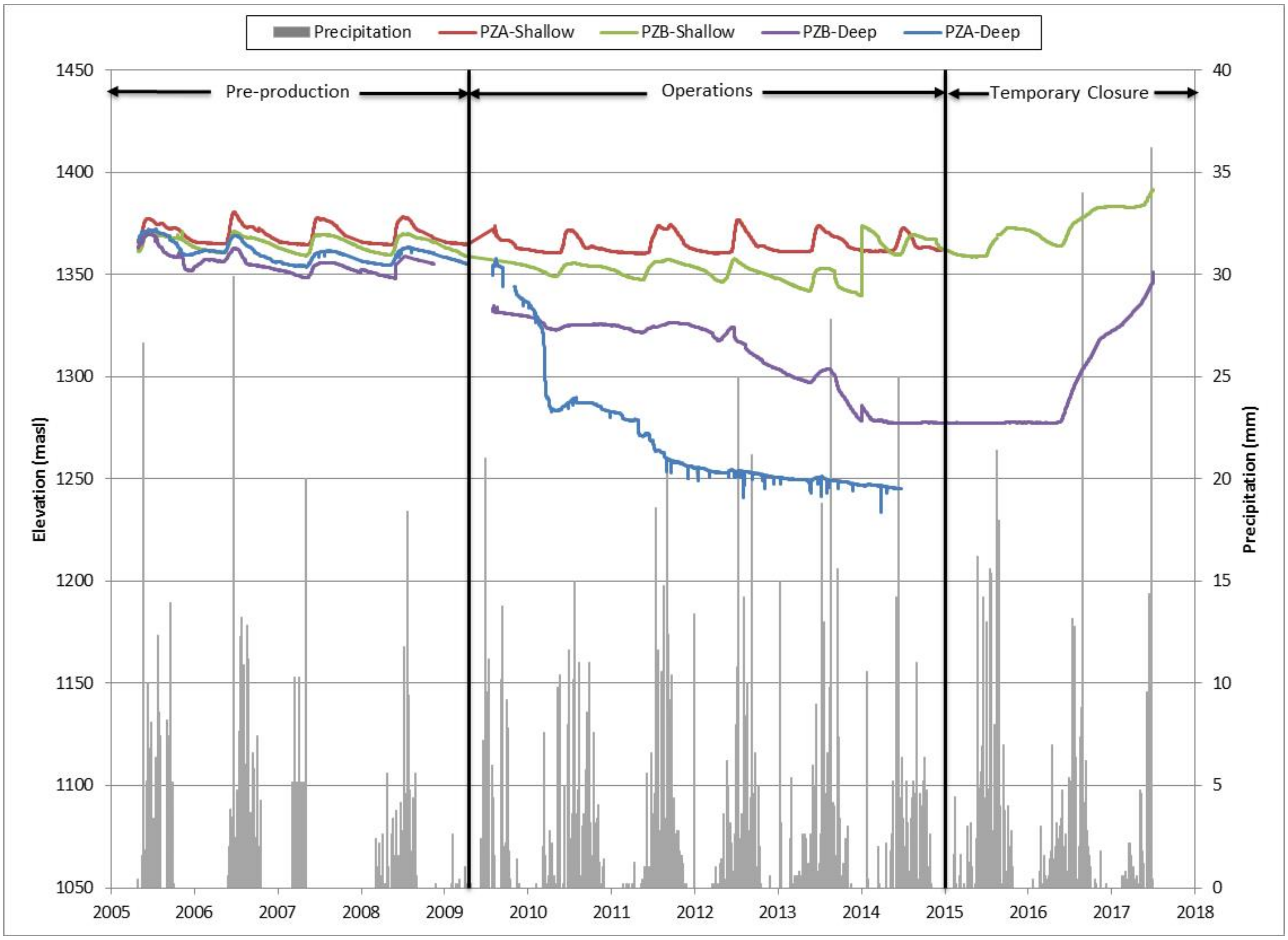


Figure 3-18: 2005-2017 Pieziometric and Precipitation Data

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 3-21), 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. Water levels in groundwater wells downstream of the mine (MW05-5 and MW06-11 - Figure 3-19 and Figure 3-20) have been relatively consistent, although water levels in MW06-11 dropped in mid-2011, and values have been relatively constant since. The increase in water level in mind 2007 and mid 2010 in MW05-5A and MW05-5B, respectively, are due to re-installation of the loggers, and not representative of actual water level shifts. The groundwater table exhibits seasonal variation, reaching highest elevation after spring runoff season (Figure 3-19 and Figure 3-20).

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.

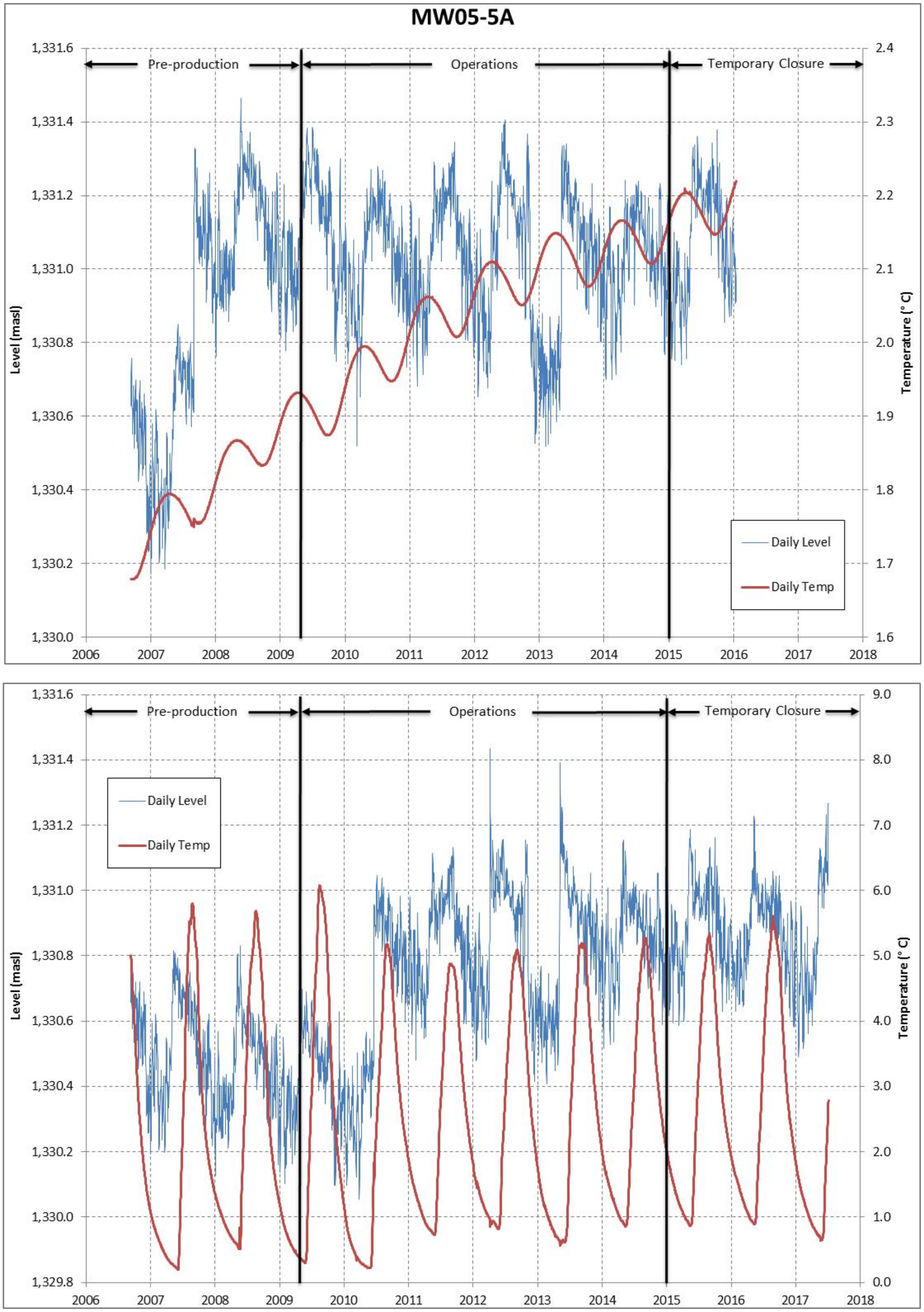


Figure 3-19: Groundwater Well MW05-5 Water Level and Temperature

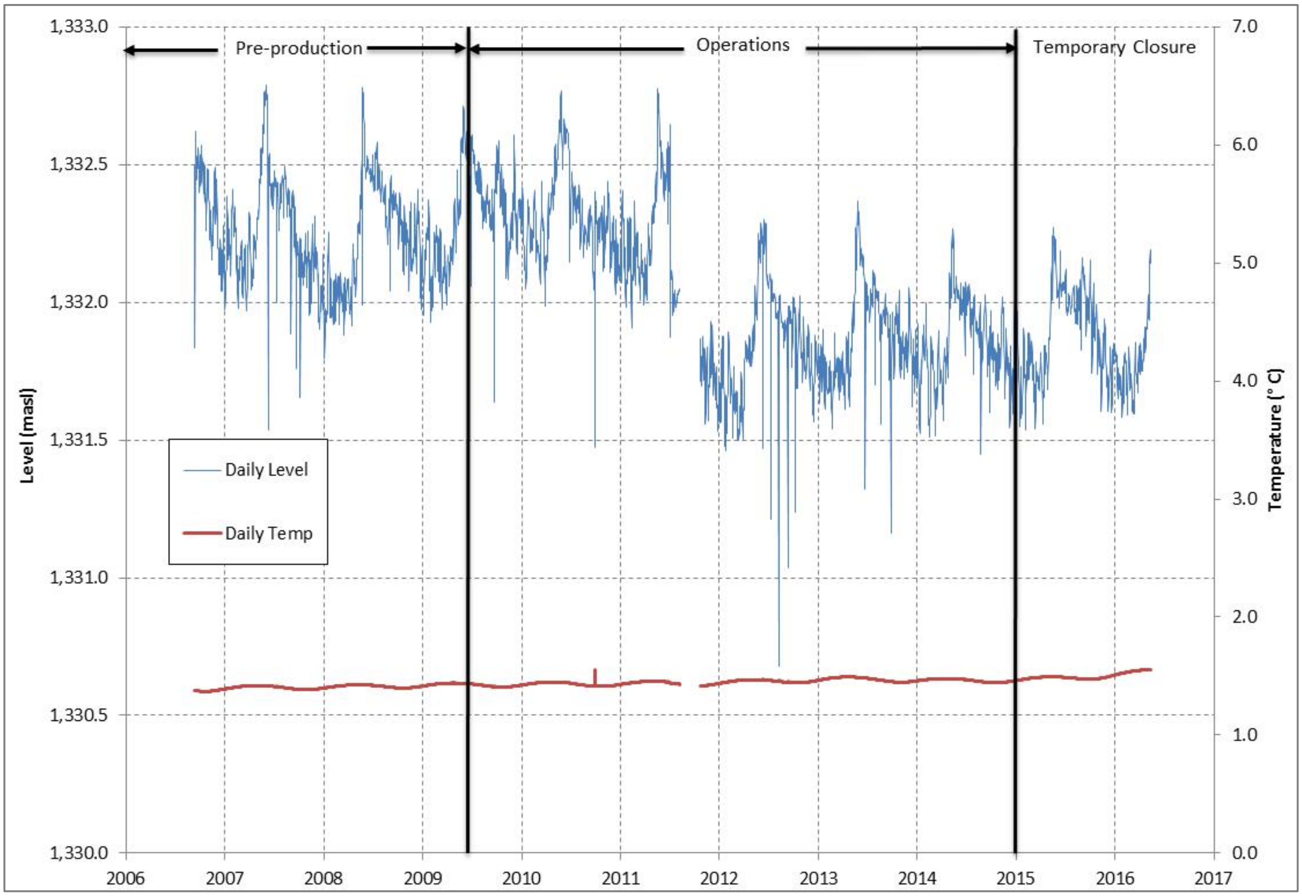
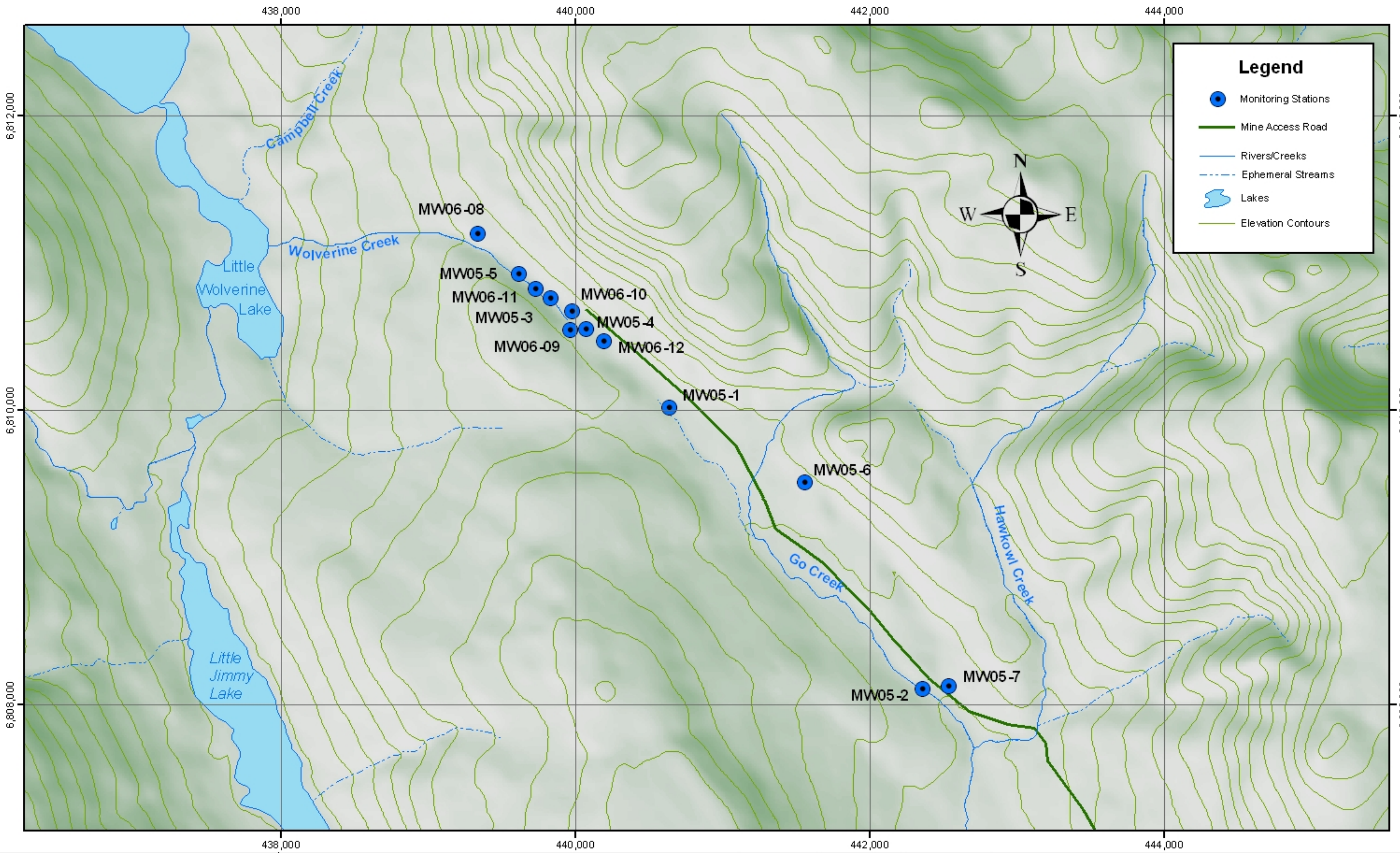


Figure 3-20: Groundwater Well MW06-11S Water Level and Temperature



Projection: UTM Zone 9, NAD 83

LORAX ENVIRONMENTAL

YukonZinc CORP

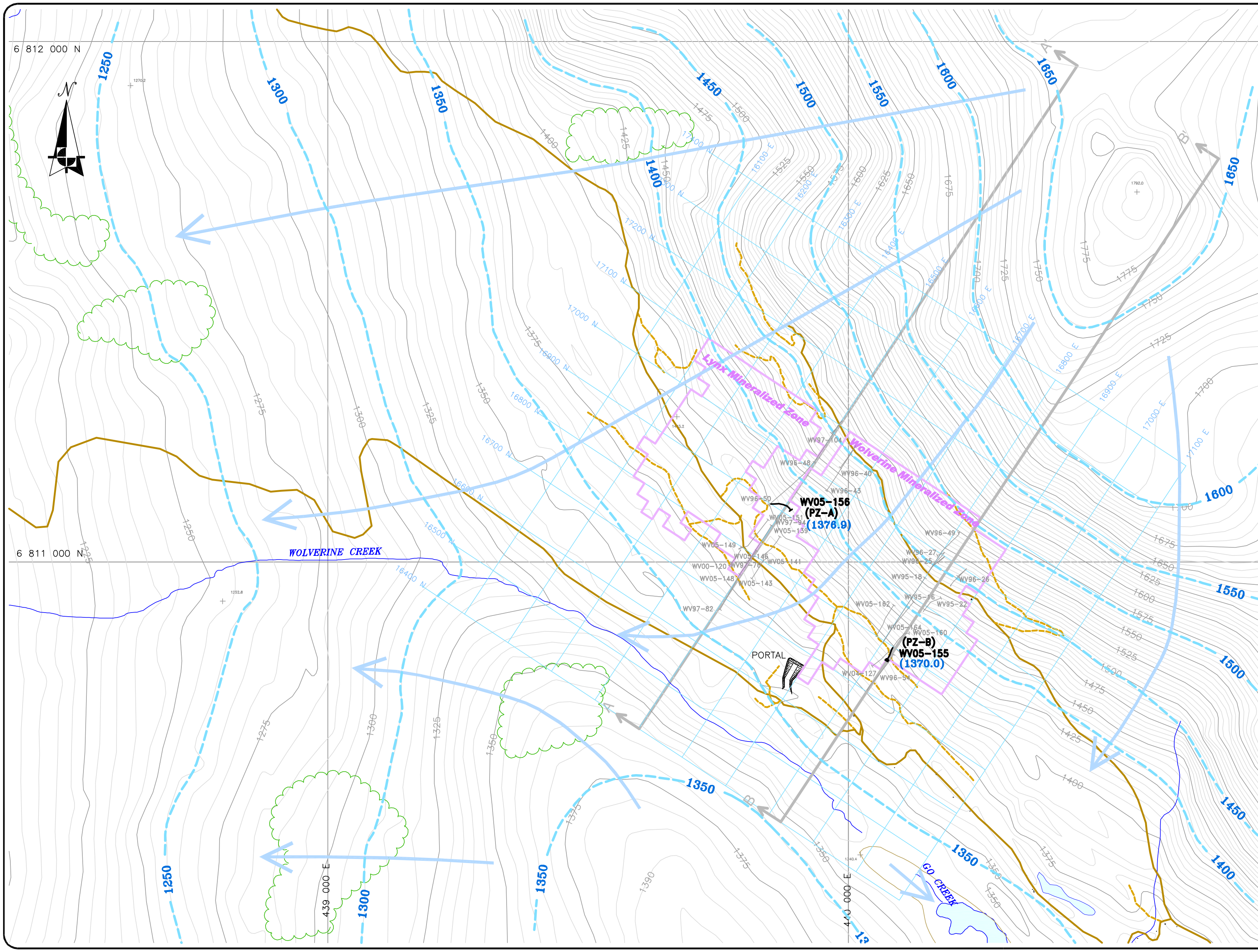
DESIGNED BY		
DWG. CHECK		
DRAWN BY	SSS	April 7, 2010
SCALE	1:25,000	
PROJECT NO.	474-3	

Baseline Characterization Report

Groundwater Monitoring Wells

Figure 3-21

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

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Figure 3-22

CONCEPTUAL HYDROGEOLOGIC MODEL PLAN

Date: OCTOBER, 2005

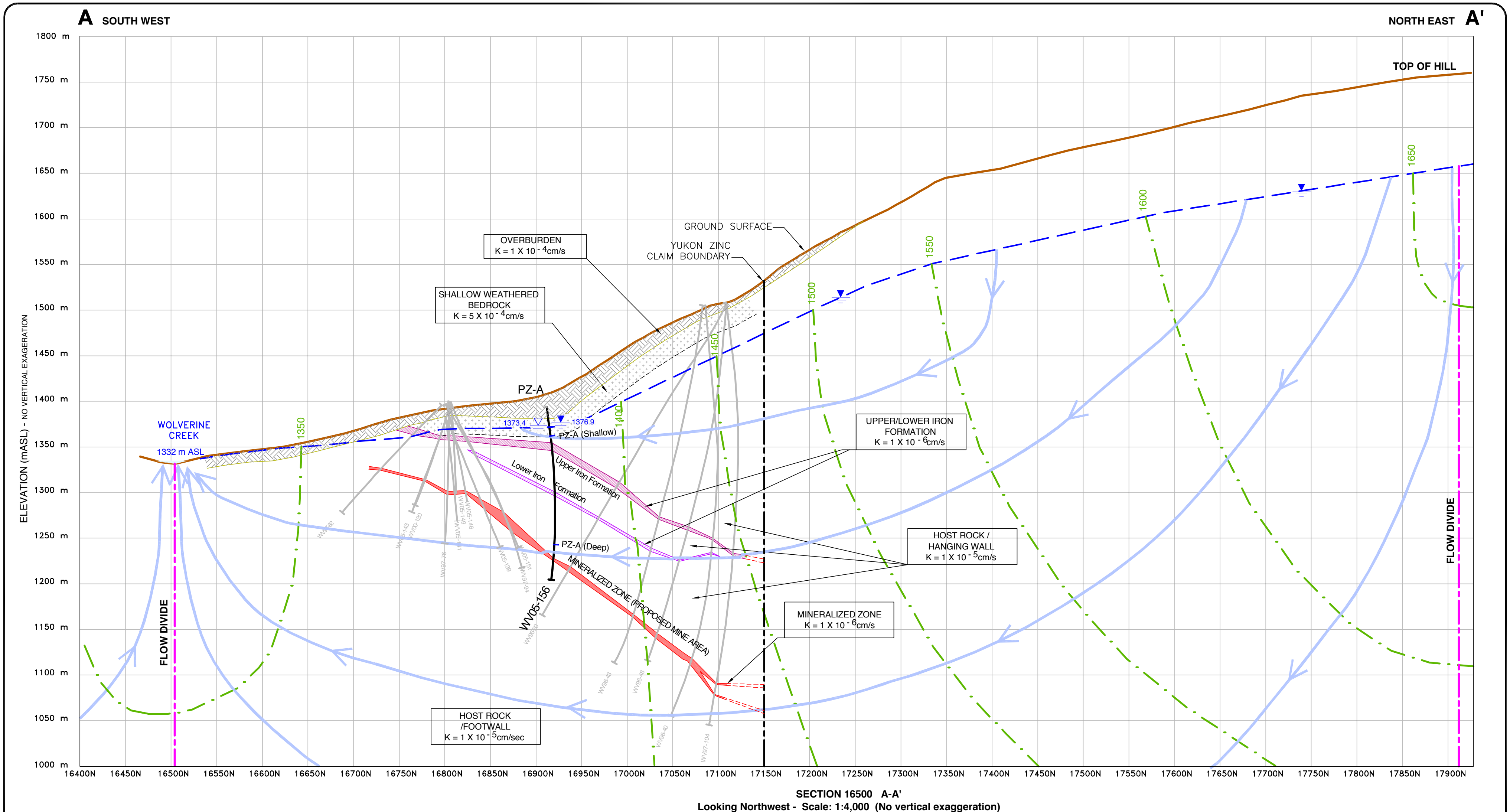
Projection: UTM Zone 9, NAD 27 | **File Name: 50288-4D-01.DWG**

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



LEGEND:

- OVERBURDEN
- SHALLOW WEATHERED BEDROCK
- UPPER IRON FORMATION
- LOWER IRON FORMATION
- MINERALIZED ZONE
- 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

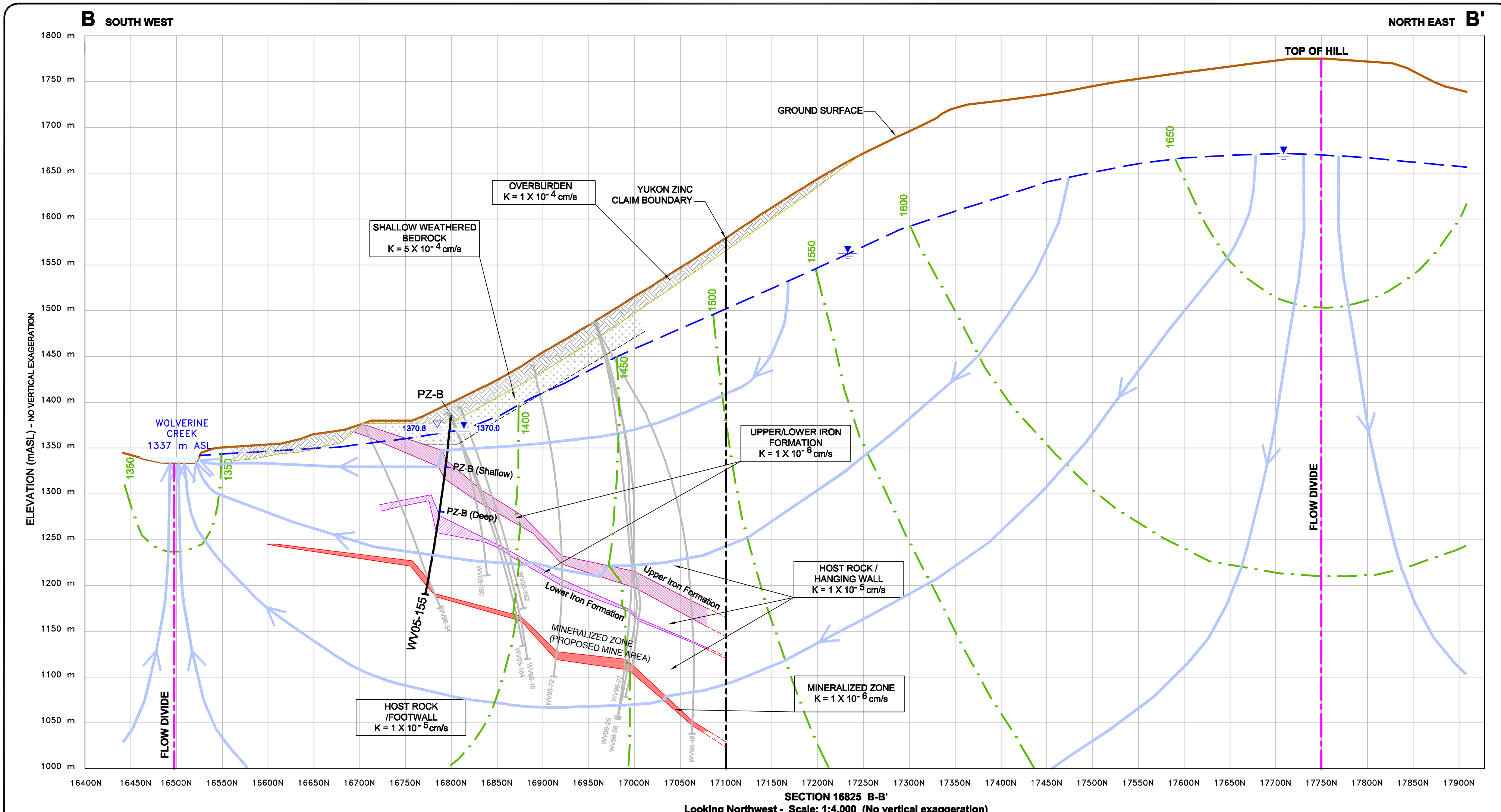
Data Sources:
Base Cross Sections Provided by Yukon Zinc Corporation

Yukon Zinc CORP

Wolverine Project

Figure 3-23:

CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION A-A' (Pre-Mining)



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

LEGEND:

- OVERBURDEN
- SHALLOW WEATHERED BEDROCK
- UPPER IRON FORMATION
- LOWER IRON FORMATION
- MINERALIZED ZONE
- 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

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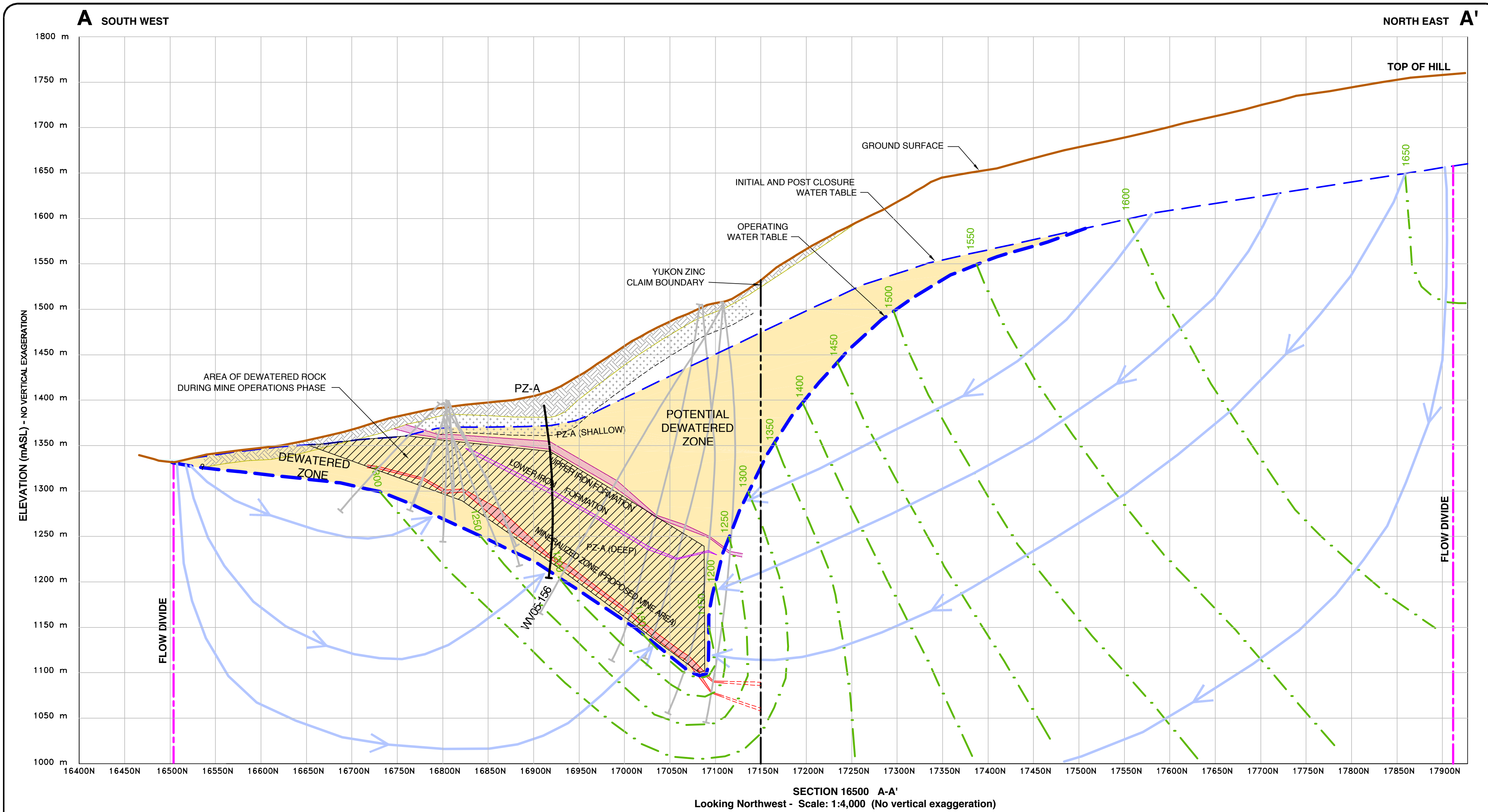
Figure 3-24

CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION B-B' (Pre-Mining)

Path: S:\AutoCad\acad-Prj\2005\50-288 Wolverine Yukon Zinc\4D-Report-Oct05\ Plotted on: Oct 13, 2005-4:43pm Edited by: NTo



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.

Gartner Lee

Data Sources:
Base Cross Sections Provided by Yukon Zinc Corporation

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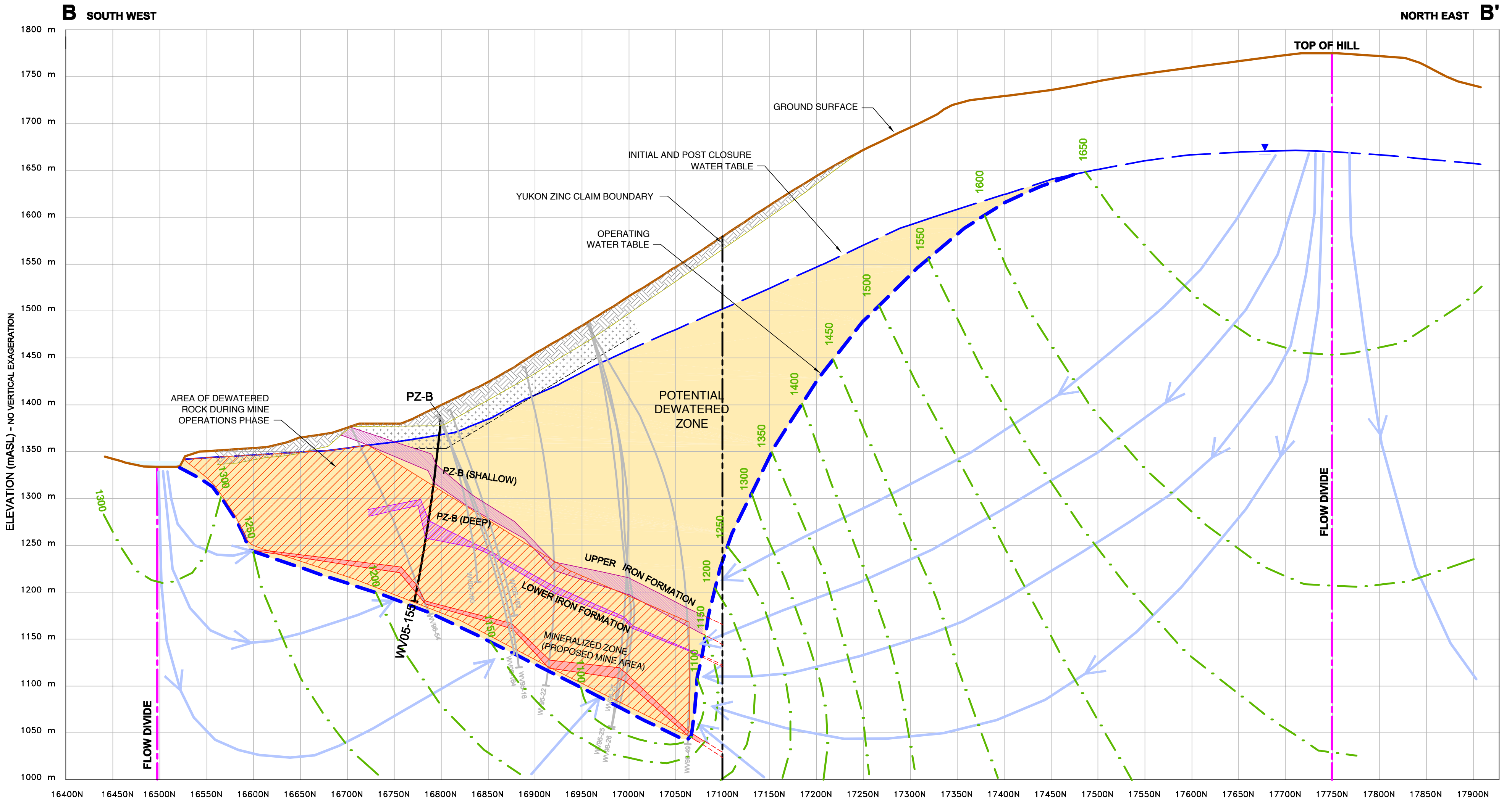
Figure 3-25
CONCEPTUAL HYDROGEOLOGIC MODEL CROSS SECTION A-A' (Operating)



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
- 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–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 3-26:
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 3-21). 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.

Water chemistry statistics for samples taken 2009-2017 inclusively are shown in Figure 3-27 through Figure 3-36, 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.

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 3-21).

Water chemistry in the Wolverine Creek shallow bedrock system, sampled at 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.

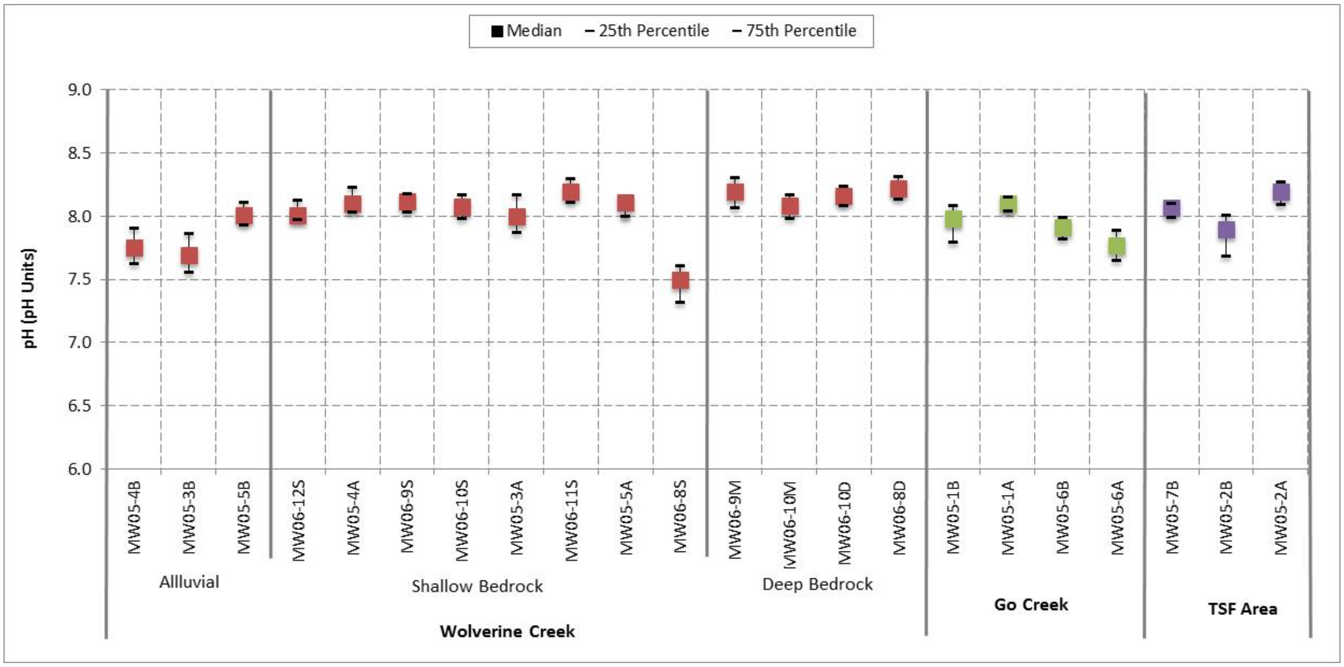


Figure 3-27: Groundwater Chemistry – pH (2009-2017)

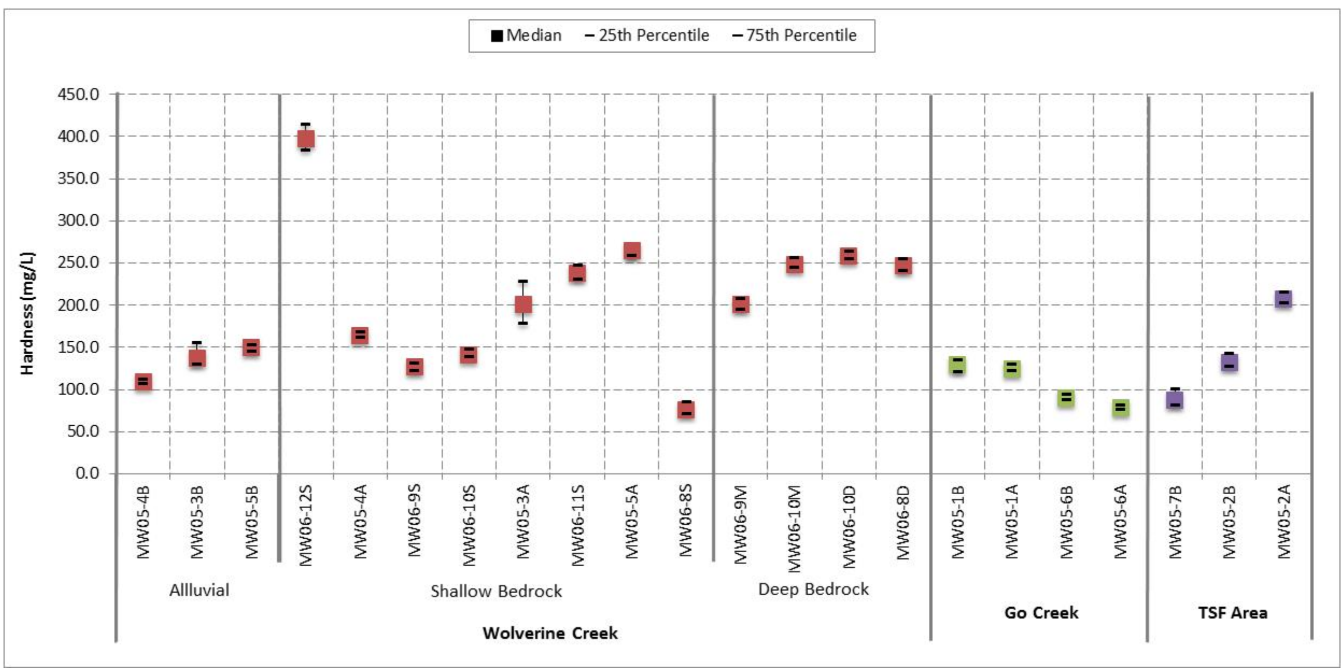


Figure 3-28: Groundwater Chemistry – Hardness (2009-2017)

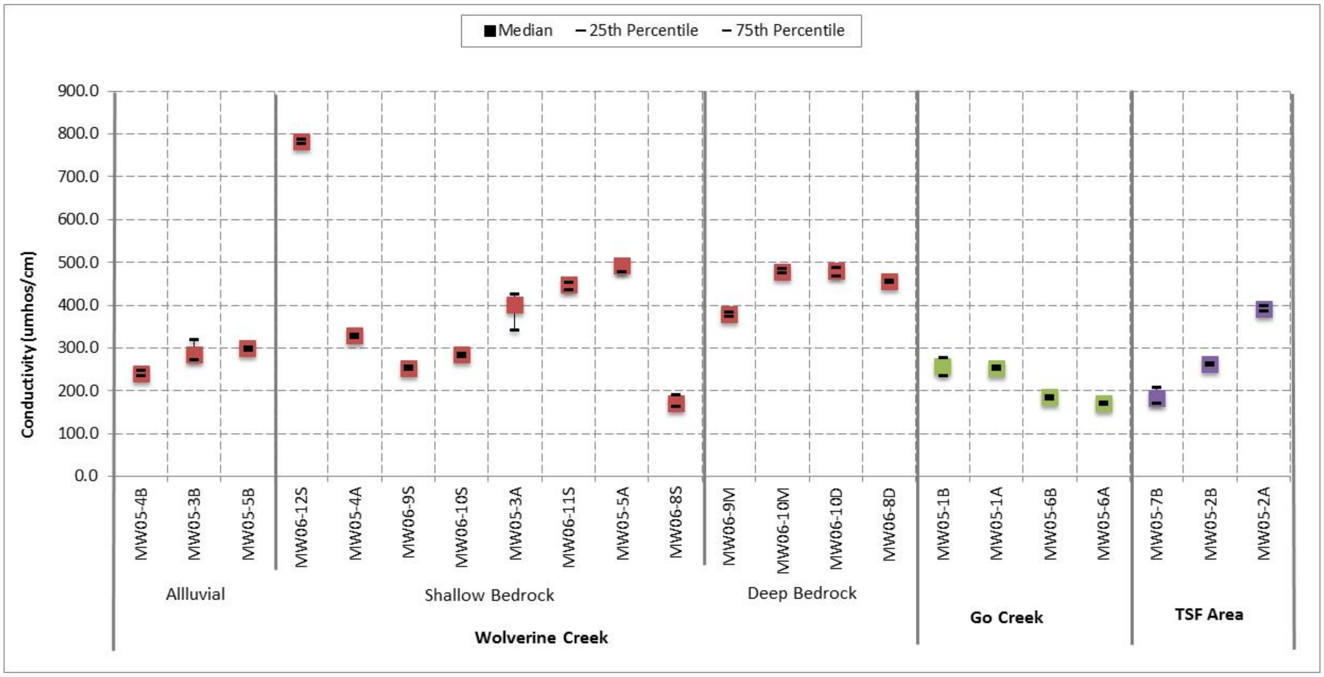


Figure 3-29: Groundwater Chemistry – Conductivity (2009-2017)

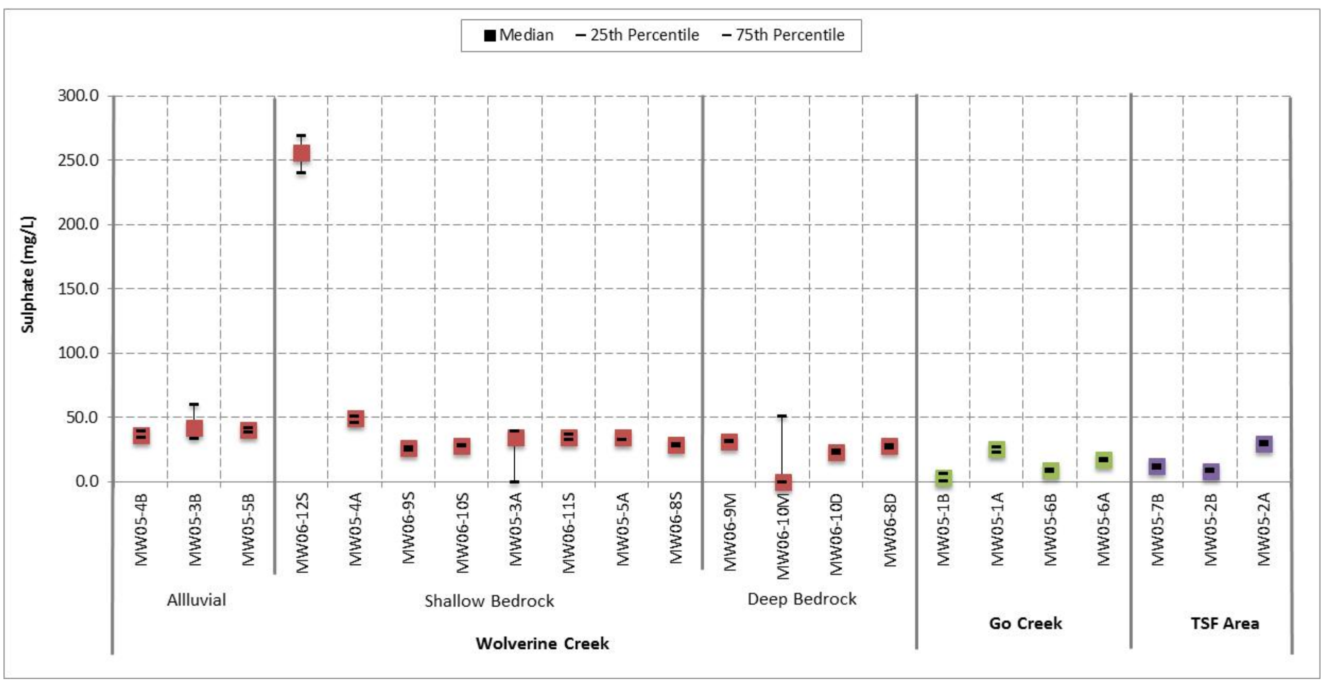


Figure 3-30: Groundwater Chemistry – Sulphate (2009-2017)

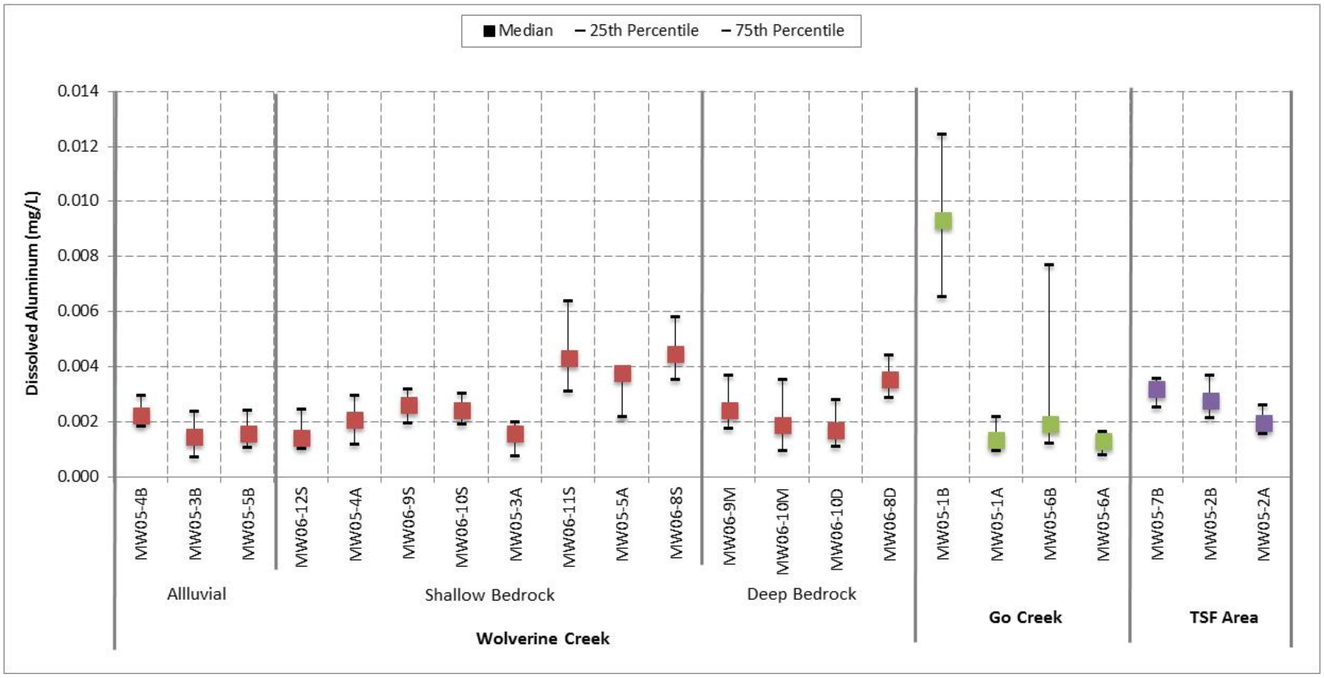


Figure 3-31: Groundwater Chemistry – Dissolved Aluminum (2009-2017)

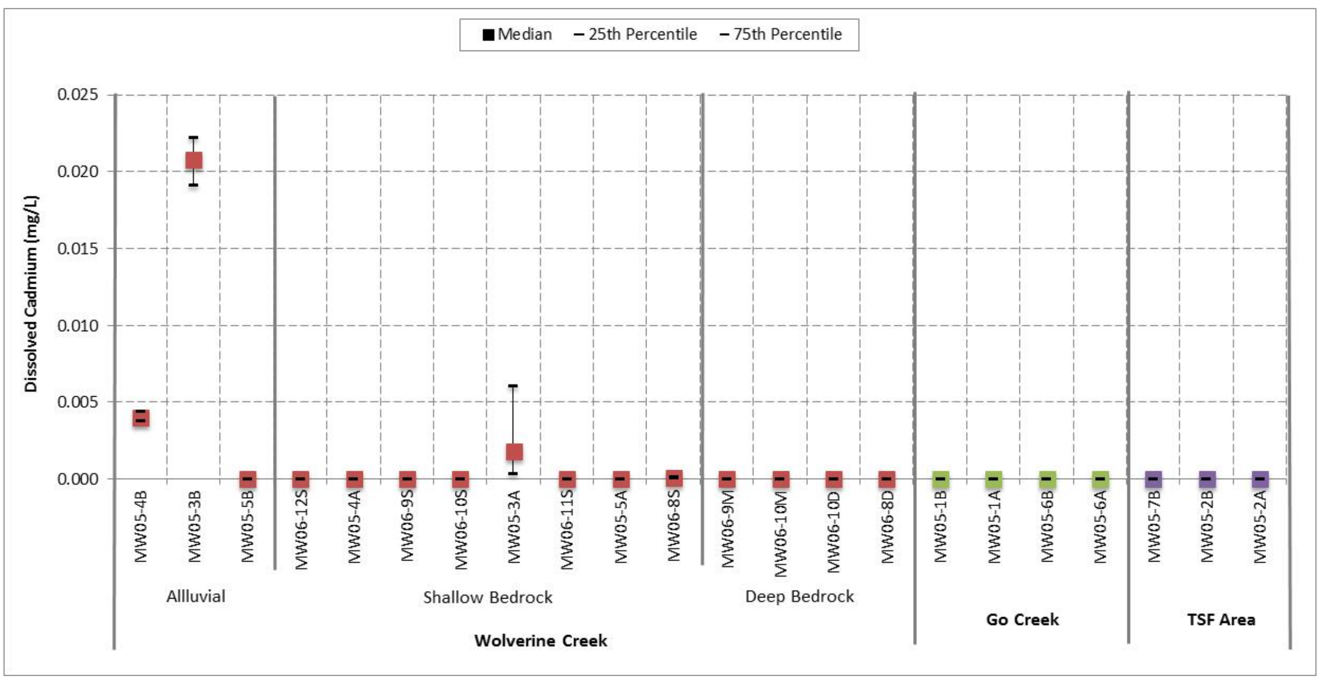


Figure 3-32: Groundwater Chemistry – Dissolved Cadmium (2009-2017)

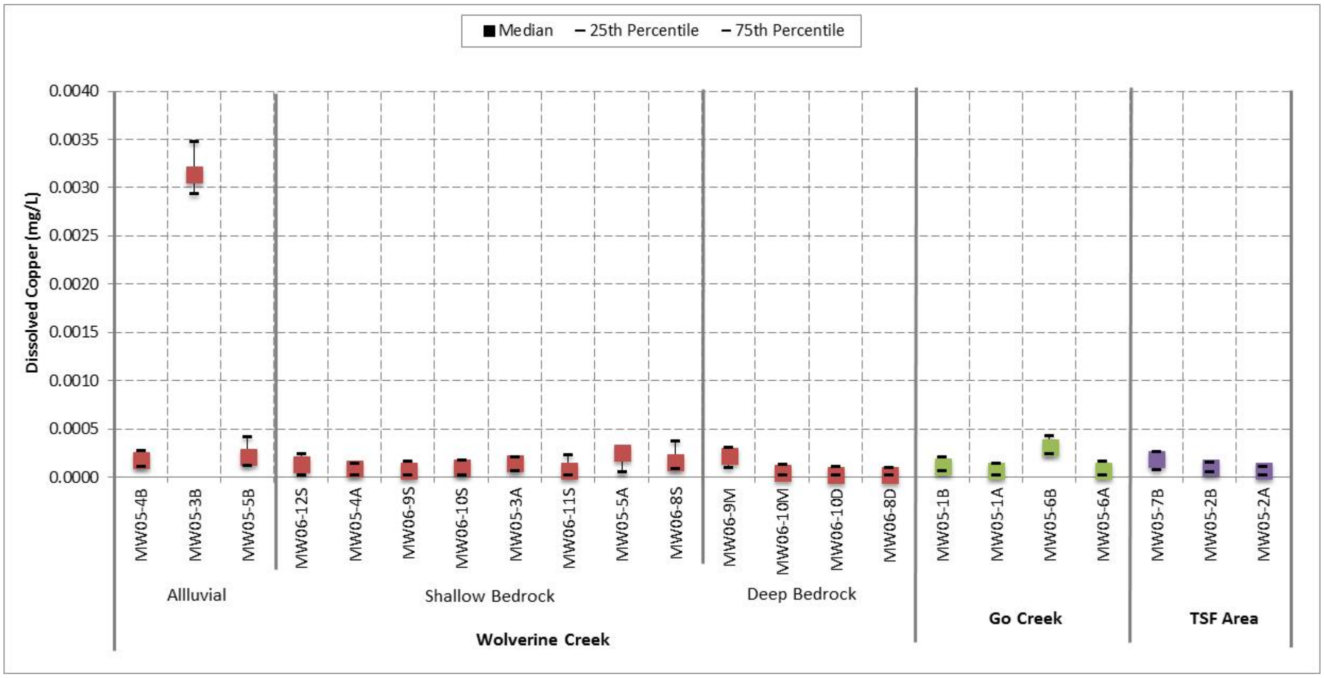


Figure 3-33: Groundwater Chemistry – Dissolved Copper (2009-2017)

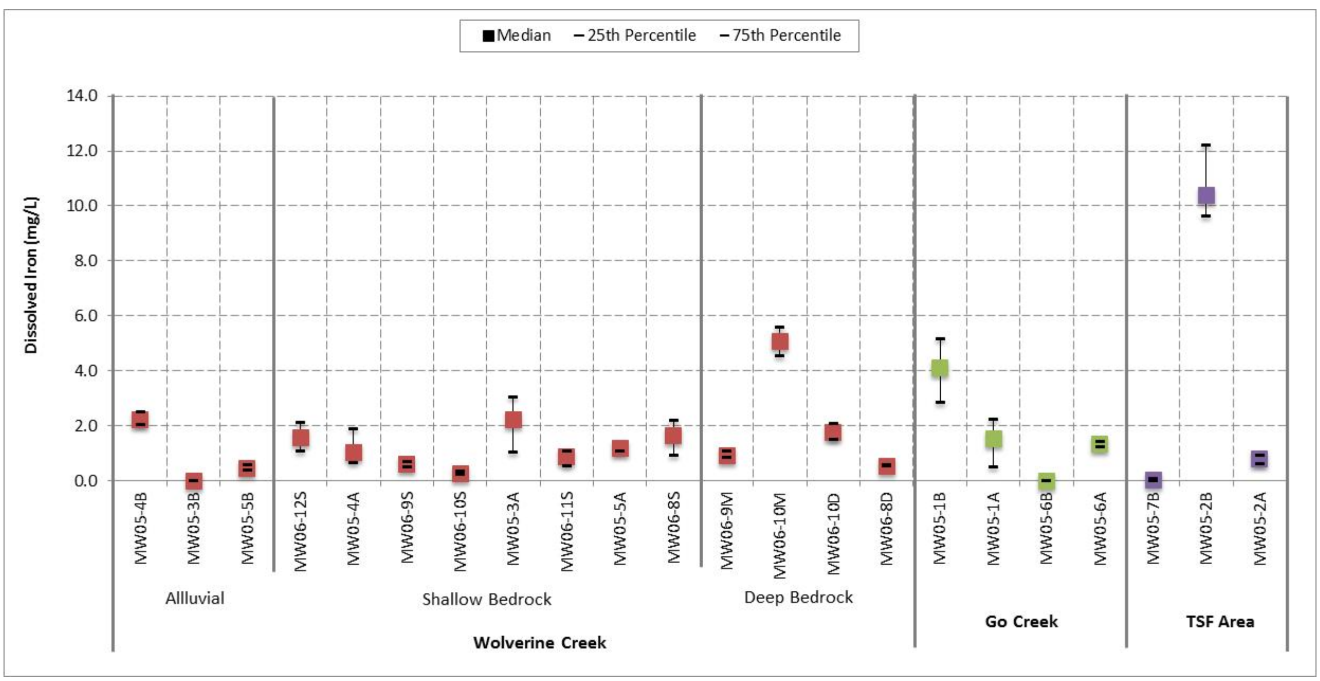


Figure 3-34: Groundwater Chemistry – Dissolved Iron (2009-2017)

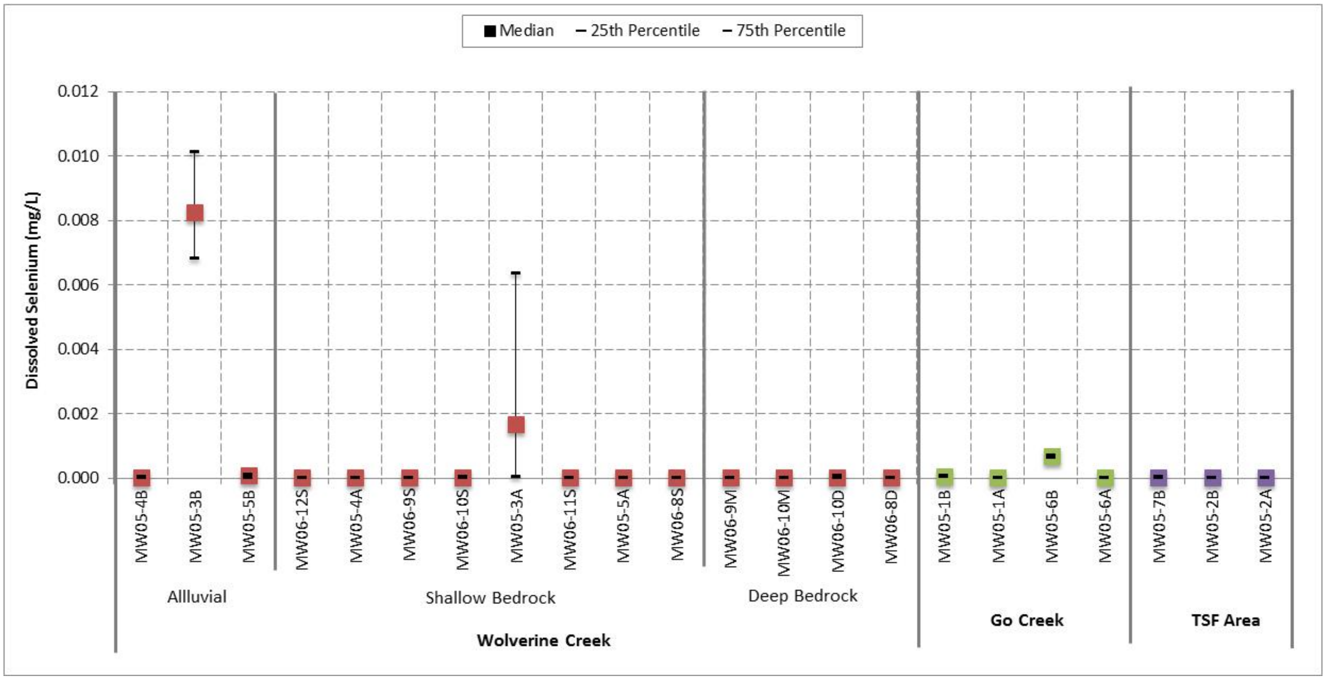


Figure 3-35: Groundwater Chemistry – Dissolved Selenium (2009-2017)

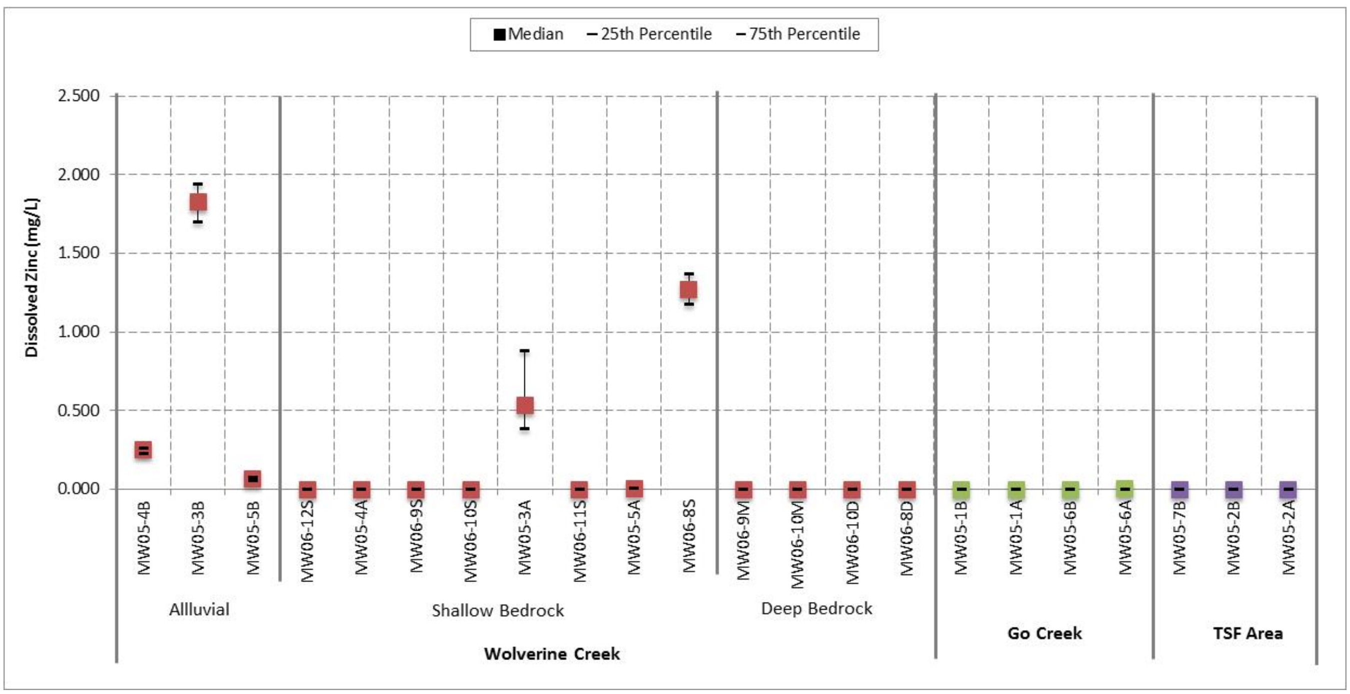


Figure 3-36: Groundwater Chemistry – Dissolved Zinc (2009-2017)

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 3-37.

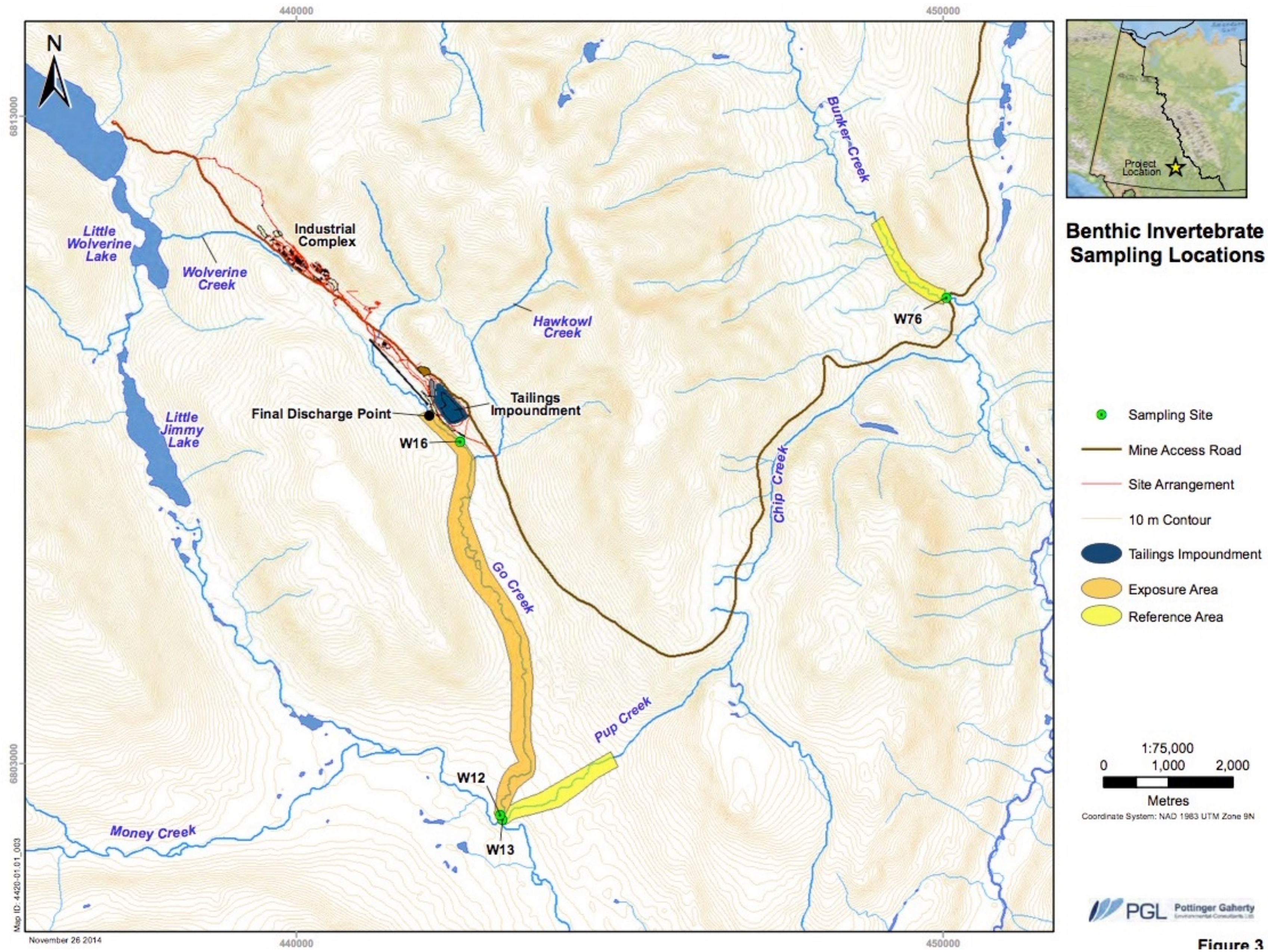


Figure 3-37: MMER EEM Monitoring Locations

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

<table>
<tr><th>Sampling Event</th><th colspan="2">Location</th><th>Effort (s)</th><th>Species*</th><th>Number</th><th>CPUE** (#/min)</th></tr>
<tr><td rowspan="6">July 1996</td><td rowspan="5">Go Creek</td><td>Upper</td><td>299</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td>Mid</td><td>232</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="3">Lower</td><td rowspan="3">1366</td><td>GR</td><td>4</td><td>0.176</td></tr>
<tr><td>CCG</td><td>21</td><td>0.922</td></tr>
<tr><td>BT</td><td>5</td><td>0.220</td></tr>
<tr><td>Pup Creek</td><td>Lower</td><td>175</td><td>CCG</td><td>6</td><td>2.057</td></tr>
<tr><td>Sept. 1996</td><td>Go Creek</td><td>Lower</td><td>89</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="4">Oct. 2004</td><td>Pup Creek</td><td>Mid</td><td>487</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="3">Bunker Creek</td><td>u/s of road</td><td>858</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td>Below road btw beaver dams</td><td>972</td><td>BT</td><td>2</td><td>0.123</td></tr>
<tr><td>Below road d/s of beaver dam</td><td>1267</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="8">Aug. 2005</td><td rowspan="5">Go Creek</td><td>Upper</td><td>300</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td>Mid</td><td>1070</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="3">Lower</td><td rowspan="3">2640</td><td>GR</td><td>4</td><td>0.091</td></tr>
<tr><td>BT</td><td>4</td><td>0.091</td></tr>
<tr><td>CCG</td><td>1</td><td>0.023</td></tr>
<tr><td>Pup Creek</td><td>Lower</td><td>300</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">Bunker Creek</td><td>u/s of road</td><td>1770</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td>Below road btw beaver dams</td><td>840</td><td>n/a</td><td>0</td><td>0</td></tr>
<tr><td rowspan="5">Sept. 2014</td><td rowspan="3">Go Creek</td><td>Mid/Upper</td><td>4198</td><td>BT</td><td>1</td><td>0.014</td></tr>
<tr><td rowspan="2">Lower</td><td rowspan="2">3527</td><td>CCG</td><td>1</td><td>0.017</td></tr>
<tr><td>BT</td><td>2</td><td>0.034</td></tr>
<tr><td>Pup Creek</td><td>Near confluence with Go Creek</td><td>not specified</td><td>BT</td><td>16</td><td>n/a</td></tr>
<tr><td>Bunker Creek</td><td>Mid (near bridge)</td><td>not specified</td><td>n/a</td><td>0</td><td>0</td></tr>
</table>

** 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).

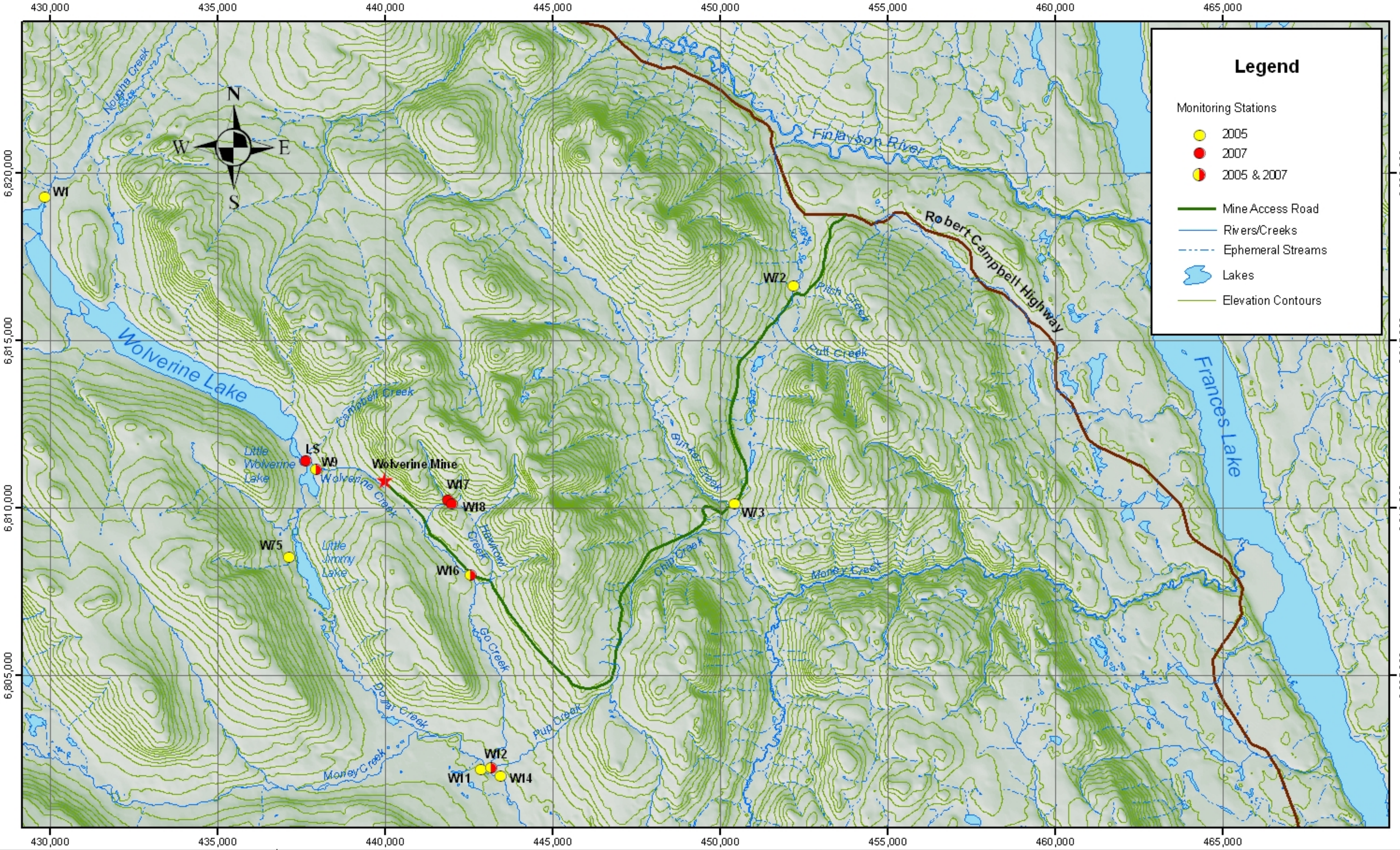
Five replicates of benthic invertebrate samples were collected at each site. Descriptive statistics and statistical endpoints were calculated at the family taxonomic level and the analysis of results is summarized in Table 3-2. Overall, differences were found to be fairly small when taken in an ecological 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 3-38 (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*.



Projection: UTM Zone 9, NAD 83

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 3-38

REV.

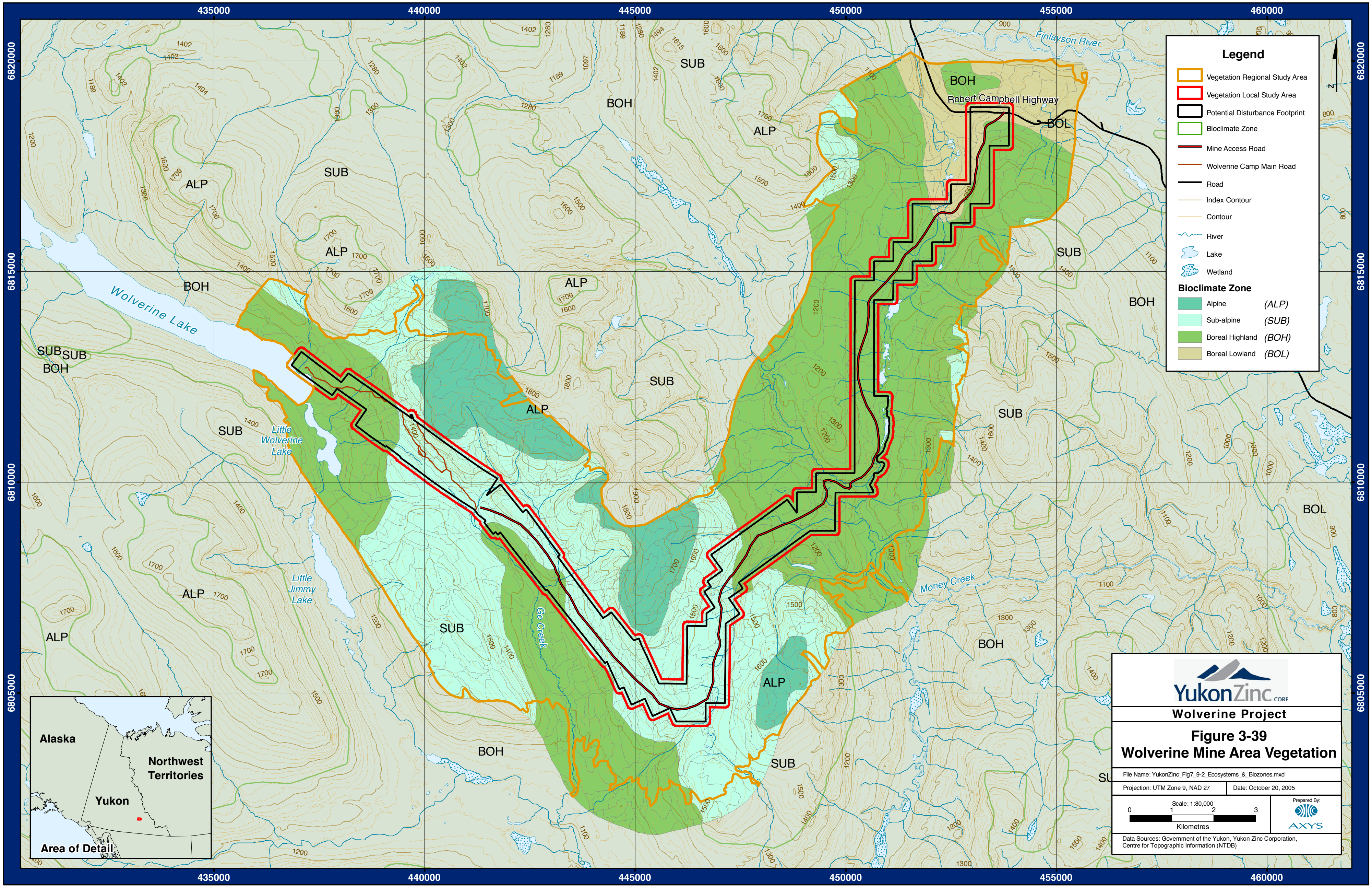
3.4.3 Vegetation

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 3-39). 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 3-39
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 3-40. The soil map (along with legend) for the mine area is provided in Figure 3-41. 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 3-41) 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.

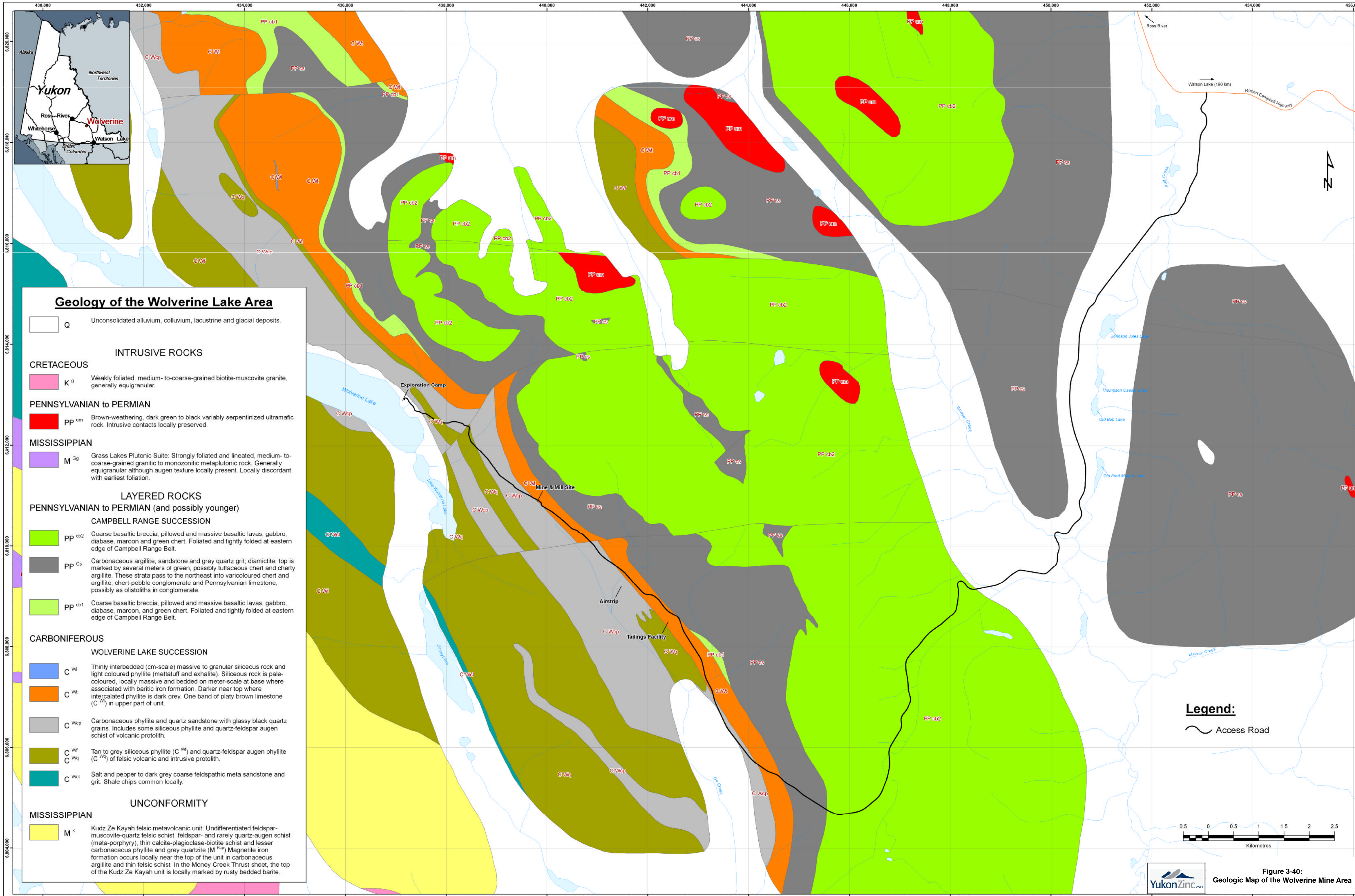


Figure 3-40:
Geologic Map of the Wolverine Mine Area

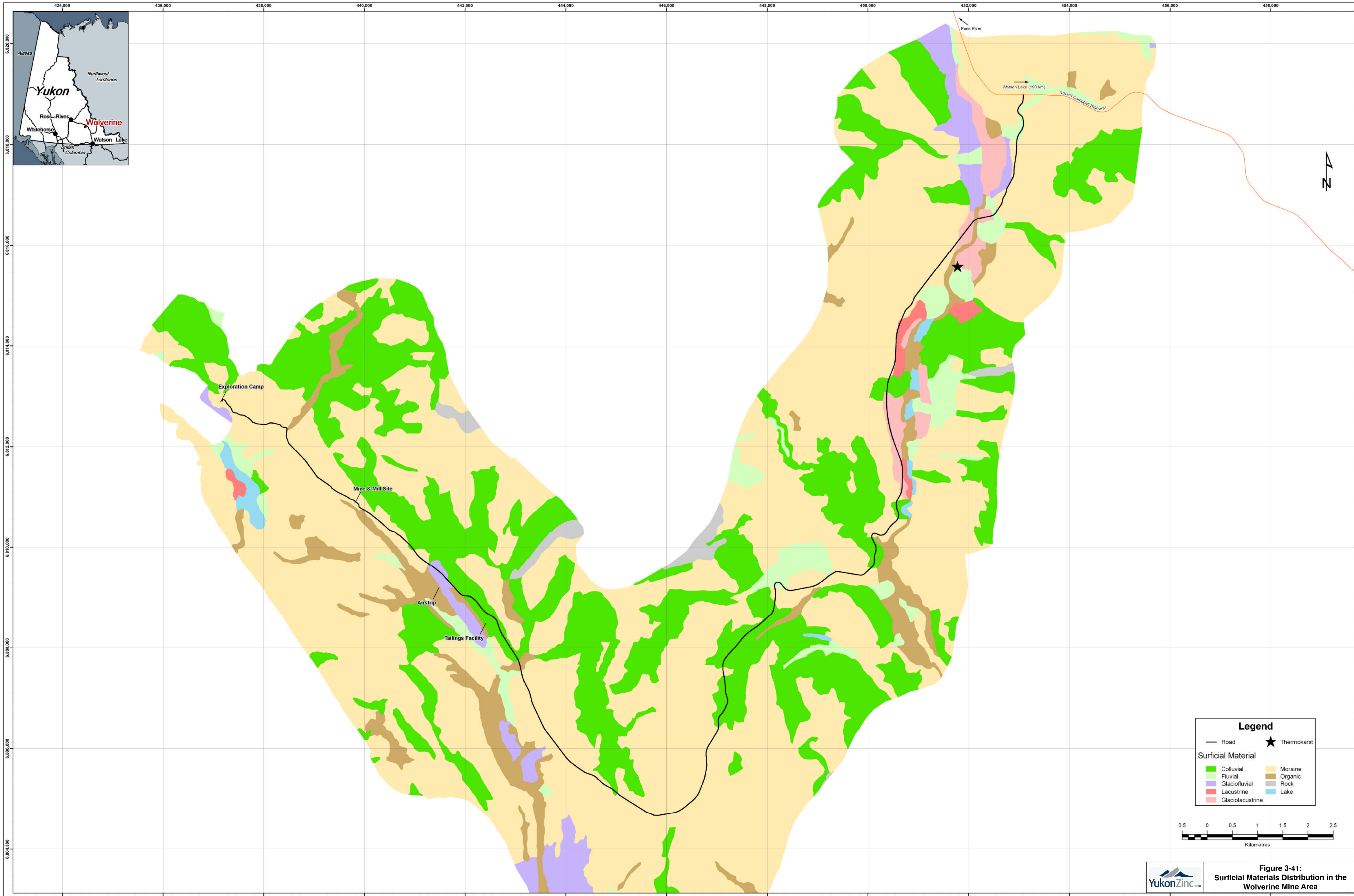
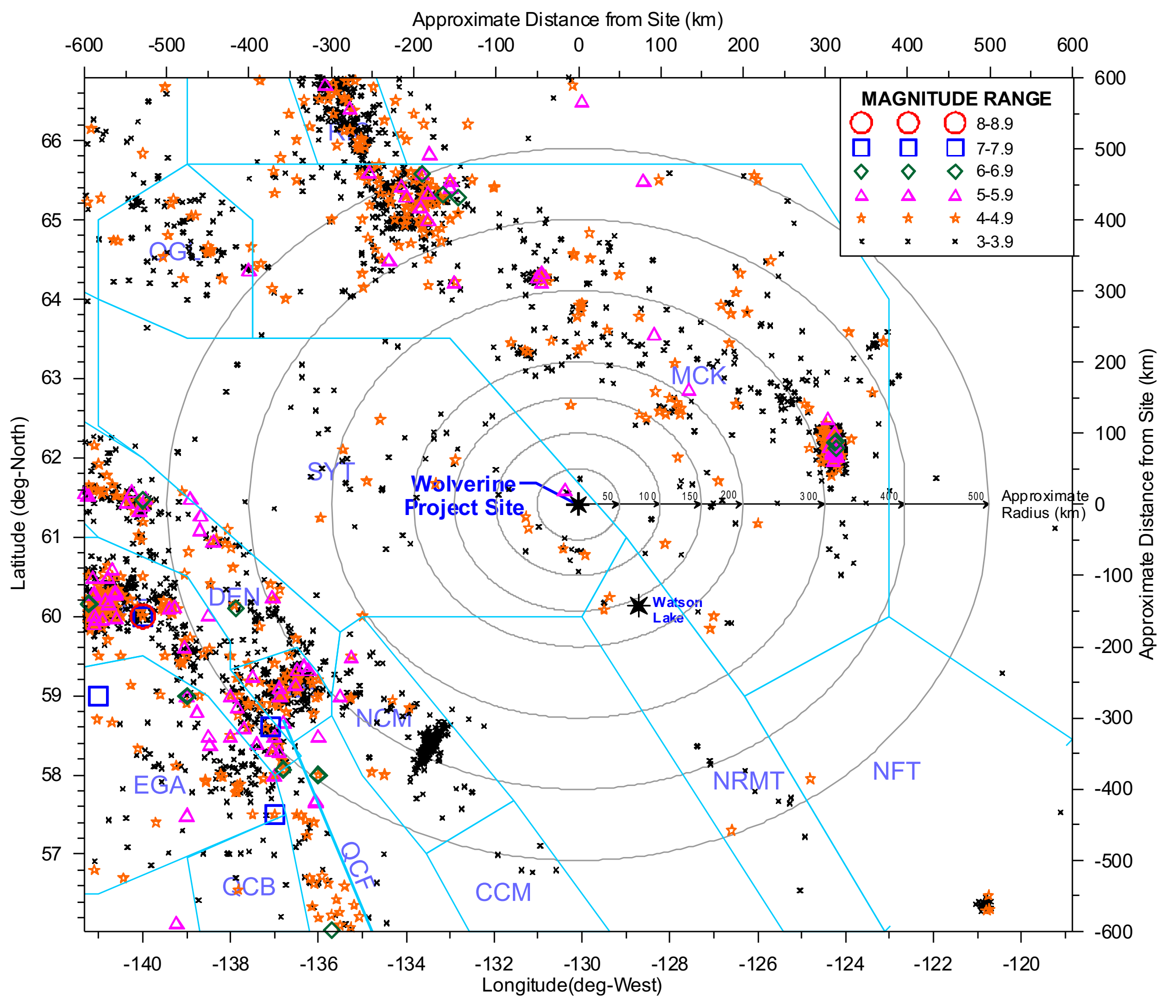


Figure 3-41: Surficial Materials Distribution in the Wolverine Mine Area

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 3-42. 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 3-42: 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:

- Tailings Storage Facility (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 Layout

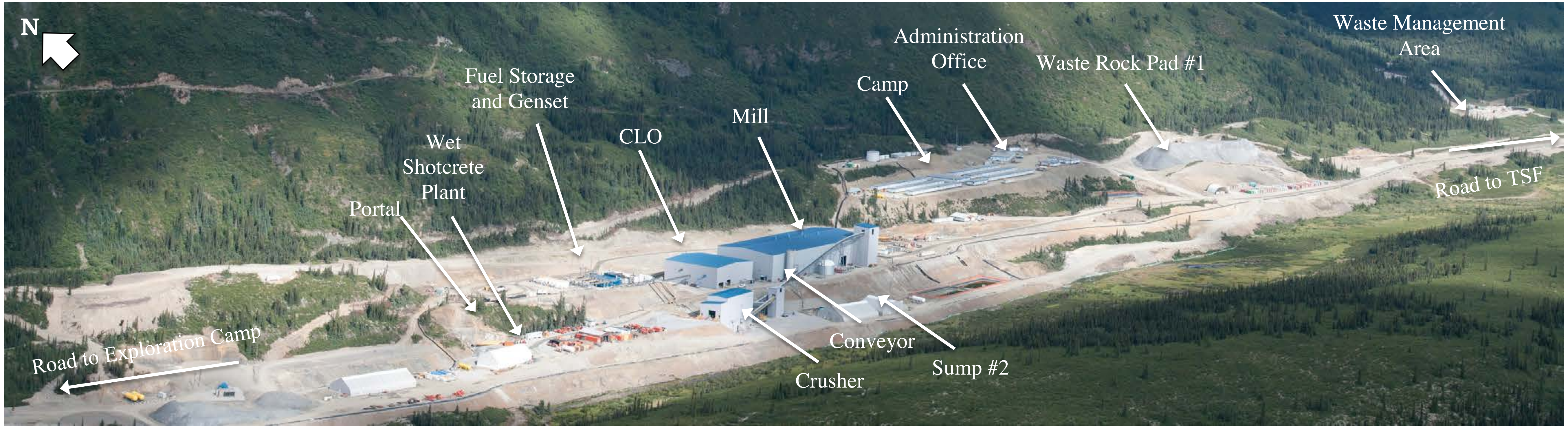
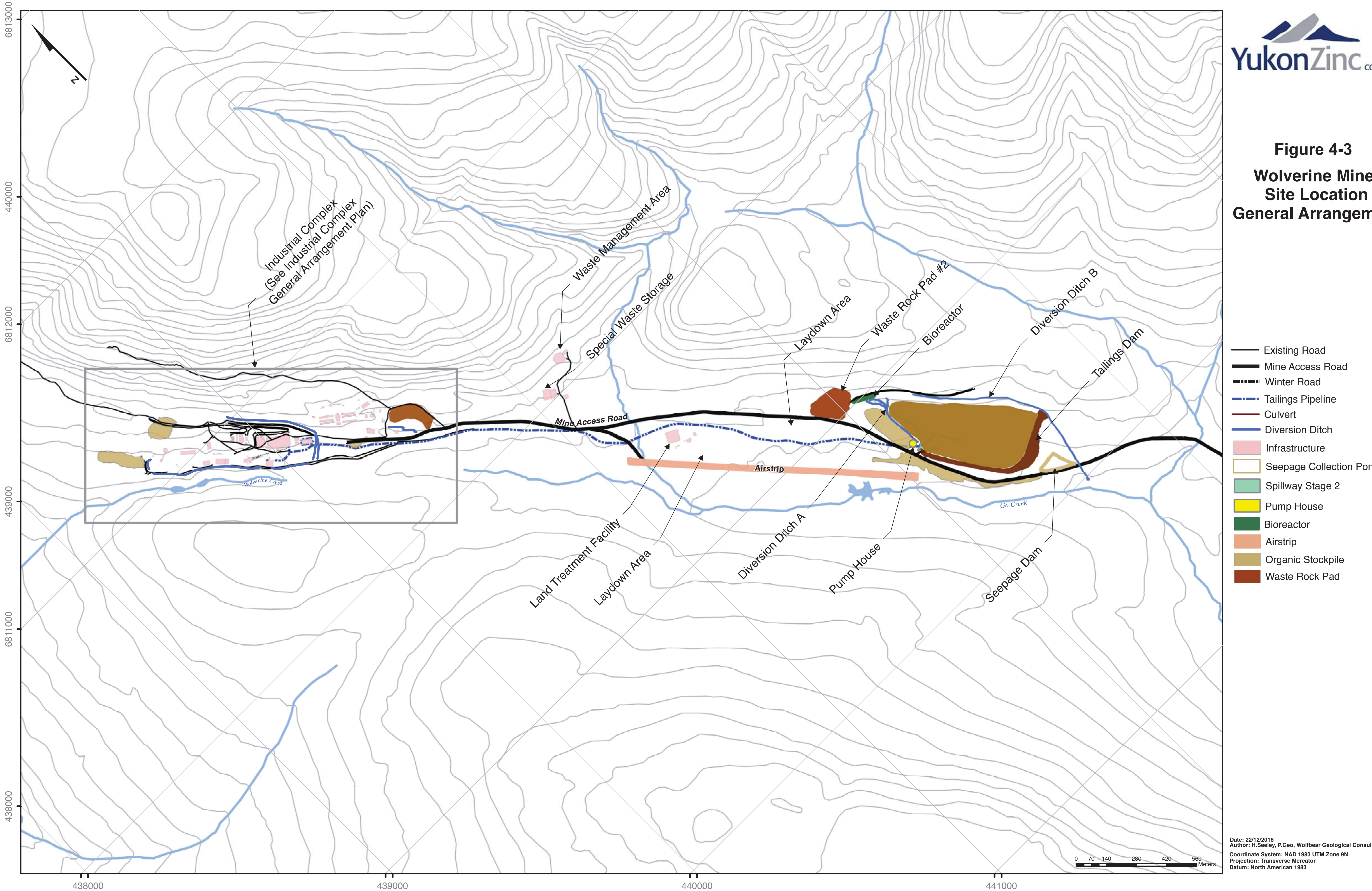


Figure 4-2: Industrial Complex Layout



YukonZinc CORP

Figure 4-3

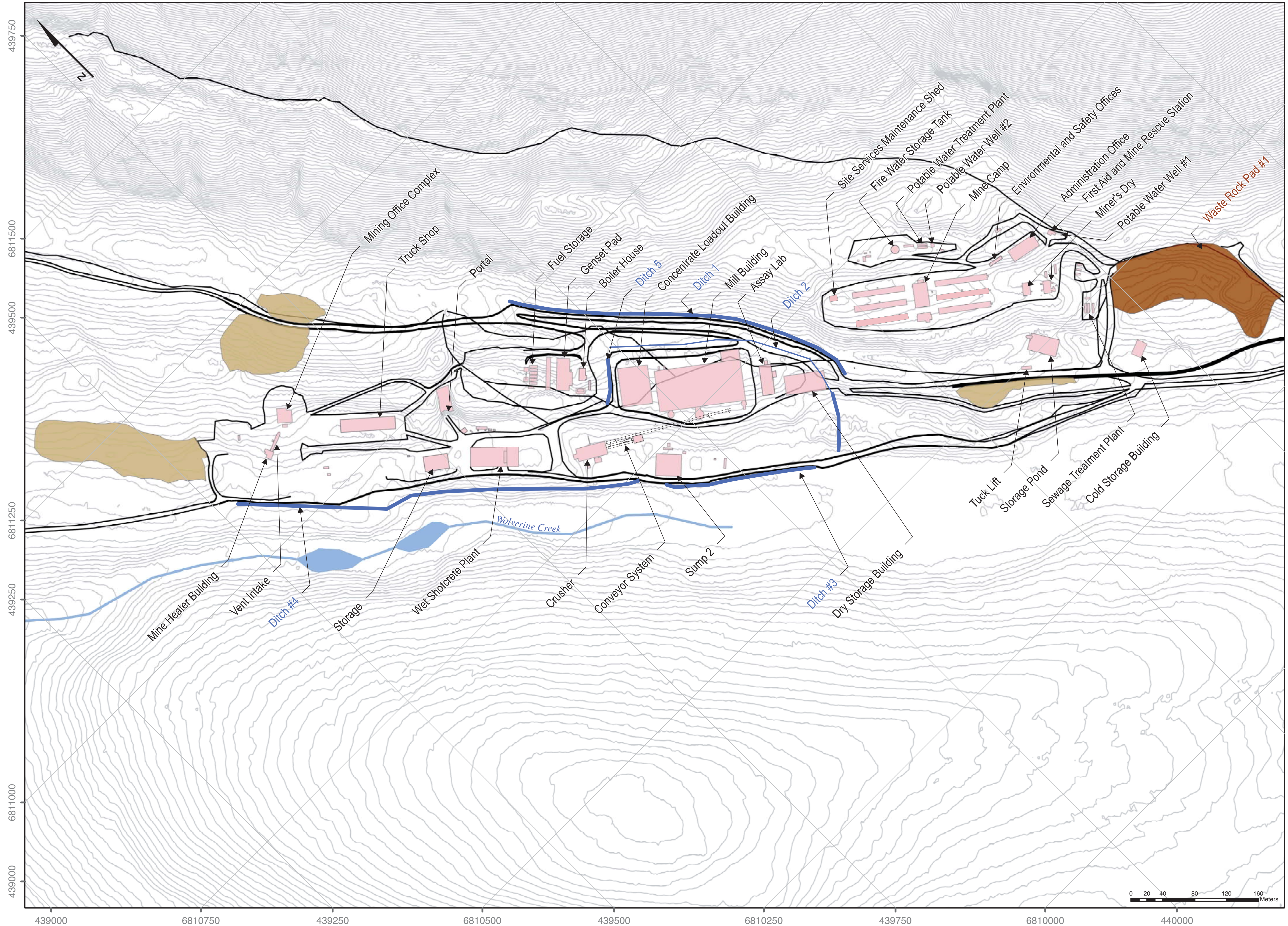
Wolverine Mine: Site Location General Arrangement

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

YukonZinc CORP

Figure 4-4
Wolverine Mine: Industrial Complex General Arrangement



- Ditch
- Existing Road
- Mine Access Road
- Infrastructure
- Organic Stockpile
- Waste Rock Pad

Topography

- Contour
- Watercourse
- Waterbody

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

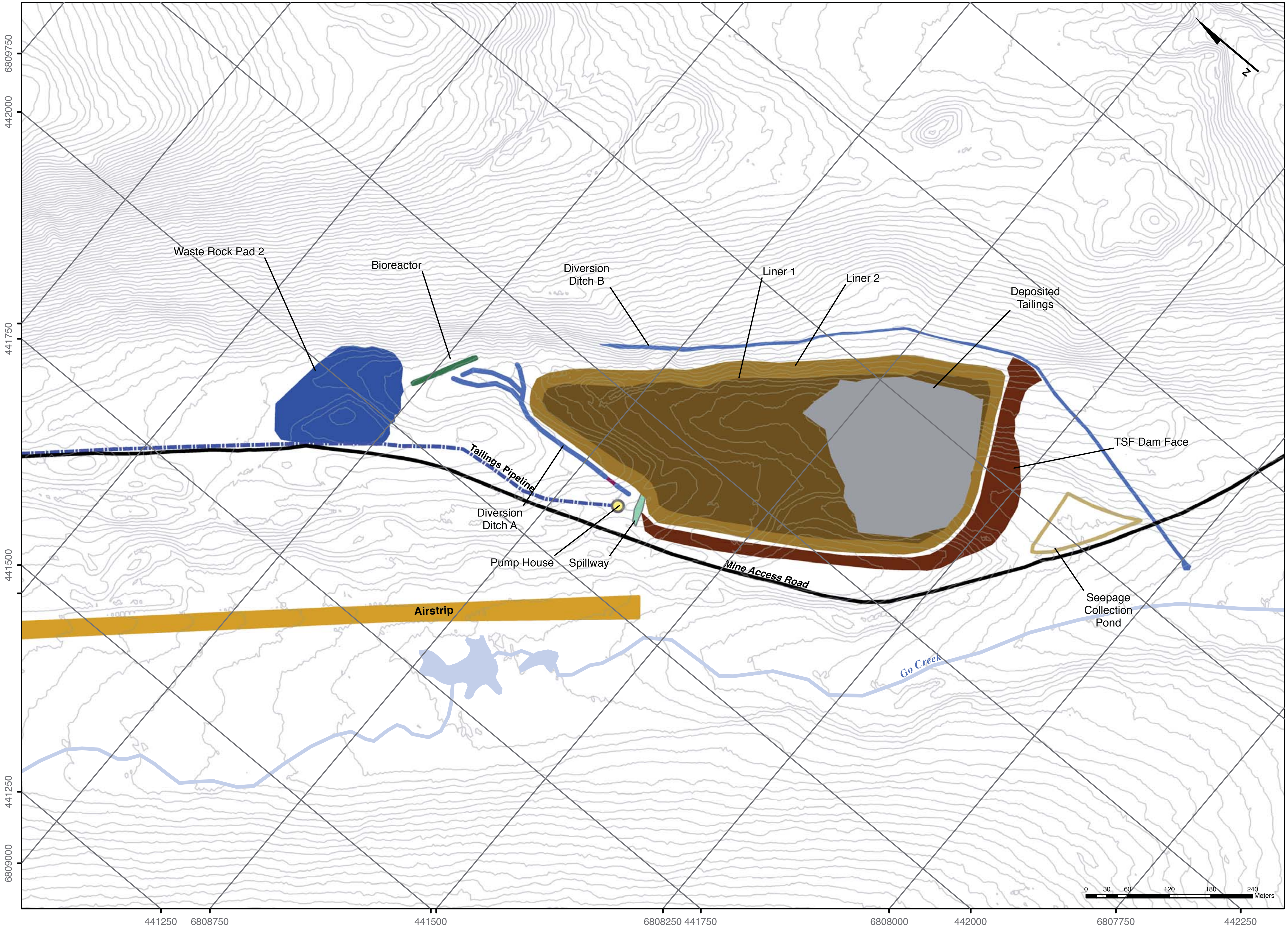


Figure 4-5

Wolverine Mine: Tailings Storage Facility

Mine Access Road	
Tailings Pipeline	
Culvert	
Diversion Ditch	
Pump House	
Bioreactor	
Liner	
Seepage Collection Pond	
Airstrip	
Waste Rock Pad 2	
Spillway Stage 2	
Deposited Tailings	
TSF Dam Face	

Date: 07/12/2016
Author: H.Seeley, P.Geo, Wolfbear Geological Consulting
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

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, however, excess groundwater discharge from the underground mine is pumped to the TSF via the mill pumpbox to utilize the pumping and pipeline infrastructure in the mill. Inputs to the TSF during temporary closure 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 and excess groundwater discharge from the underground mine.

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 shutdown 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 2020. This section has been updated from the previously submitted RCP 2016-07 to reflect an extension of the temporary closure period from three years to five years. The focus of the TCP continues to be 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, 2016, and 2017 (COMPLETED);
- Conduct Dam Safety Review of the TSF (COMPLETED IN 2017);
- Managing excess groundwater discharge from the underground mine workings (ONGOING);
- Transporting all reagents off site (COMPLETE);
- 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 currently no zinc concentrate remaining on site and there are 18 bags of copper concentrate and 13 bags of lead concentrate remaining to be shipped off site by the purchaser. The CLO has been swept and cleaned out; all reagents have been removed from site except for ~95 tonnes of lime. The remaining lime is securely packaged and stored in sealed freight containers on the site. This lime will be used to treat the depressed pH in the TSF.

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 in accordance with requirements outlined in Type A Water Use Licence QZ04-065 (WUL), and the *Wolverine Mine Monitoring and Surveillance Plan V2011-03*. 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 the YWB. Water quality results are also compared to triggers outlined in the *Wolverine Creek Adaptive Management Plan*, to ensure the protection of the downstream 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. During the temporary closure period, many sampling sites have limited accessibility due to freezing conditions, low flow, or inaccessibility by boat during lake freezing or by road when the road is closed in winter. A summary of actual sampling frequencies based on the monitoring programs conducted 2005 – 2017 is provided in Table 5-2. These frequencies are used in sample cost estimates provided in Section 8.

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

Station Number	Station Location	Watershed	Sampling Frequency
T1	Tailings Barge	TSF	Monthly
W82	Upper Wolverine Creek	Wolverine Creek	Monthly
W9	Wolverine Creek at Little Wolverine Lake		Monthly
W1	Wolverine Lake outlet		Monthly
L1	Little Wolverine Lake		Monthly
W21	Nougha Creek at Campbell Highway		Monthly
W8	Campbell Creek		Monthly
W15	Hawkowl Creek above Go Creek	Go Creek	Monthly
W16	Go Creek below tailings facility		Monthly
W81	Go Creek below Hawkowl Creek		Monthly
W31	Go Creek above TSF		Monthly
W80	Go Creek		Monthly (daily during discharging)
W12	Go Creek above Money Creek		Monthly
W14	Upper Money Creek	Money Creek	Monthly
W22	Money Creek above Campbell Highway		Monthly
W40	Money Creek below Campbell Highway		Monthly
W71	Pitch Creek below road crossing	Site Access Road	Monthly
W72	Light Creek		Monthly
W73	Bunker Creek at road crossing		Monthly

Table 5-2: Surface Water Sampling Frequency

	Jam	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
T1	1	1	1	1	1	1	1	1	1	1	1	1	**12**
W82	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W9	0	0	0	0	0	1	1	1	1	0	0	0	**4**
W1	0	0	0	0	0	1	1	1	1	0	0	0	**4**
L1	0	0	0	0	0	1	1	1	1	0	0	0	**4**
W21	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W8	0	0	0	0	0	1	1	1	1	0	0	0	**4**
W15	1	1	1	1	1	1	1	1	1	1	1	1	**12**
W16	1	1	1	1	1	1	1	1	1	1	1	1	**12**
W81	1	1	1	1	1	1	1	1	1	1	1	1	**12**
W31	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W80	0	0	0	0	31	30	31	31	30	31	0	0	**184**
W12	0	0	0	0	0	1	1	1	1	0	0	0	**4**
W14	0	0	0	0	0	1	1	1	1	0	0	0	**4**
W22	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W40	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W71	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W72	0	0	0	0	1	1	1	1	1	1	0	0	**6**
W73	0	0	0	0	1	1	1	1	1	1	0	0	**6**
Total	**4**	**4**	**4**	**4**	**43**	**43**	**43**	**43**	**43**	**43**	**4**	**4**	**304**

Bioreactor Water Quality Monitoring

There is one active bioreactor on site between Waste Rock Pad #2 and the TSF (see Section 5.2.3). 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. Results of this monitoring is presented for every four month period starting May 31, 2016 and submitted every four months following to EMR.

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 3-21). Groundwater monitoring is conducted at stations and frequencies outlined in Table 5-3. Quarterly sampling for most sites are conducted in accordance with the WUL. However, as described in the *Wolverine Mine Environmental Monitoring of Underground Workings Plan* (May, 2016), monthly sampling at stations MW05-5 and MW06-11 are conducted to evaluate the effect of the underground mine filling on Wolverine Creek.

An assessment of groundwater stations was conducted in 2017, and revealed that many of the stations were compromised due to old tubing having fallen down the wells or frost jacking or well contamination. Therefore, many of the stations cannot be sampled, as summarized in Table 5-4. The temporary closure program includes a hydrogeological assessment to be conducted in 2018 to assess the requirements for continued sampling at the stations, and provide recommendations for repairs/re-establishment of these wells. The assessment will also include the preparation of the 3-D numerical hydrogeological model using MODFLOW or an equivalent software, as required in Section 8.6(m) of the QML. The stations able to be sampled, as summarized in Table 5-4 are used in the costing provided in Section 8.

Table 5-3: 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

Table 5-4: Groundwater Sampling Program Frequencies

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
MW05-1A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-1B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-2A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-2B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-3A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-3B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-4A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-4B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-5A	1	1	1	1	1	1	1	1	1	1	1	1	**12**
MW05-5B	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW05-6A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-6B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-7B	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW056-8S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-8M	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-8D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-9S	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-9D	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW06-10S	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW06-10M	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-10D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-11S	1	1	1	1	1	1	1	1	1	1	1	1	**12**
MW06-12S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW08-13	0	0	1	0	0	1	0	0	1	1	0	0	**4**
Total	**2**	**2**	**16**	**2**	**2**	**16**	**2**	**2**	**16**	**16**	**2**	**2**	**80**

Underground Mine

Four vibrating wire piezometers are installed at two locations (PZ-A and PZ-B) 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. Station PZ-A deep was compromised in 2014 when underground development intersected the logger. Station PZ-A shallow was also compromised in December 2014, and hence is no longer reported. Water levels from logger PZ-B are reported in annual reports to EMR.

As groundwater discharge has reached the mine adit, as of June 2017, groundwater discharge rates are monitored via pumping rates as groundwater excess is pumped to the TSF. Groundwater discharge rates are estimated weekly and will continue to be monitored throughout the temporary closure period. Flow rates are provided in the monthly reports submitted to the YWB and EMR.

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 biological studies are conducted every 3 years. The *Third Interpretive Report* was submitted December 3, 2017. The studies include benthic invertebrate monitoring and sediment sampling, as per MMER requirements. Subsequent studies will be conducted by September 2020 to meet the requirement to submit the Cycle 4 EEM biological survey report 36 months after the day on which the most recent interpretative report was required to be submitted (i.e., December 5, 2017).

Should effluent discharge commence, subsequent EEM studies will require a fish population survey in addition to the benthic invertebrate studies. Effluent characterization sampling (water chemistry, sub-lethal and acute toxicity testing) will also be carried out once discharge to Go Creek begins. Routine water quality monitoring in the exposure and reference areas, which is not required as per QML-0006 under temporary closure conditions, will resume when discharge to Go Creek begins in order to meet the 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. While monitoring of small mammals and vegetation is required by the *Wolverine Mine Wildlife Protection Plan V2009-01* (WPP), due to minimal site activities, this monitoring has not been conducted in 2017, as was required in the WPP. Due to the invasive nature of the small mammal sampling program, YZC will conduct vegetation sampling as per the WPP in spring 2019, prior to permanent closure. If statistical metal contamination is detected in the vegetation, a small mammal trapping program will also be conducted. Should the mine re-start, vegetation sampling will be conducted in the spring season following mine re-start.

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. An early morning inspection on June 7, 2017 indicated that groundwater discharge had reached the mine adit collar. Since then, daily pumping has occurred to pump excess groundwater discharge to the TSF for storage to prevent unintended discharge to the environment. Pumping will continue throughout the temporary closure period, as required. Water management at the underground mine is detailed in Section 5.2.2, including an updated bulkhead design.

Monitoring of the underground mine is conducted daily to ensure structural stability of the collar, functionality of the pumping and piping system and status of the groundwater recharge.

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.

An updated OM&S is to be provided by October 31, 2017. Letters regarding the capacity of for water storage in the TSF and confirmation of the instrumentation and monitoring during the temporary closure period are provided in Appendix A and Appendix B.

See Section 5.2.3 for details on water management relating to the TSF area.

Monitoring for wildlife is also conducted at the TSF pond regularly during the ice free period. Should wildlife be detected (i.e., migratory birds landing in the pond) they are deterred. Mechanisms previously used to deter wildlife has included driving around the pond, or, if required, shooting bear bangers off above the pond to encourage the birds to move on.

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 activities 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 decommissioned 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. A small area of the plant is accessed to facilitate pumping water through the mill pumpbox from the underground mine pump to the TSF via the tailings pipeline.

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.

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 two 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 helicopter 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. This section has been materially changed to reflect the request for extension of the temporary closure period, the current mine flooding conditions and the comments received on RCP 2016-07. Updated bulkhead designs and a comprehensive dam safety review completed in 2017 have informed this updated water management plan for the temporary closure period. As the mine discharge rates are now known, an updated water balance is provided below, and directly dictates the requirements for water management during the extended temporary closure period and into the permanent closure period. Updated water management plans for the underground mine and the TSF follow.

5.2.1 Water Balance

Water around the project site is managed to prevent contaminated discharge to the environment, and avoid collecting clean water. Clean water is diverted around mine infrastructure, and all potentially contaminated water is pumped or trucked to the TSF. Loads and discharges to Go Creek from around the Wolverine Mine are shown in Figure 5-2 and average monthly flow rates are provided in Table 5-5 and in Figure 5-1 based on measurements taken over the temporary closure period (January 2015 to present).

Surface runoff is collected from the industrial complex, the waste rock storage pads, the land treatment facility and in the catchment around the TSF. Runoff and seepage is also collected in the TSF seepage pond, which is pumped back to the TSF as required. As there are only 3-4 people on-site for the majority of the year, use of groundwater for potable water is minimal, but increases in the summer with slightly more on-site activity (i.e., environmental monitoring, site inspections, etc.).

On June 7, 2017 groundwater discharge collecting in the underground mine reached the adit collar and has since been pumped to the TSF via the mill pump box. On average, there is approximately 308 m^3/day of water pumped to the TSF and approximately 142 m^3/day is collected in the TSF as precipitation or as runoff from the TSF catchment.

Table 5-5: Predicted Monthly Flow Rate and Annual Average Flow Rates for the Temporary Closure Period

Flow Rates (m^3/day)	Underground	Sewage Treatment Plant	Various Surface Runoff	Sump #2	Seepage Pond	Net Precipitation	Water to Tailings (m^3/day)
January	260	0.2	0.2	0.0	0	0	260
February	260	0.2	0.3	0.0	0	0	261
March	260	0.2	0.4	0.5	0	31	292
April	260	0.2	0.6	0.0	0	62	323
May	260	0.2	23.0	57.3	0	372	713
June	260	1.0	11.0	111.4	73	404	860
July	260	1.0	113.0	83.0	0	310	767
August	260	1.0	4.0	12.8	0	279	557
September	260	0.5	6.0	64.8	0	186	518
October	260	0.2	0.8	5.2	0	62	328
November	260	0.2	0.0	0.0	0	0	260
December	260	0.2	0.0	0.0	0	0	260
Annual Average	**260**	**0.4**	**13**	**28**	**6**	**142**	**450**

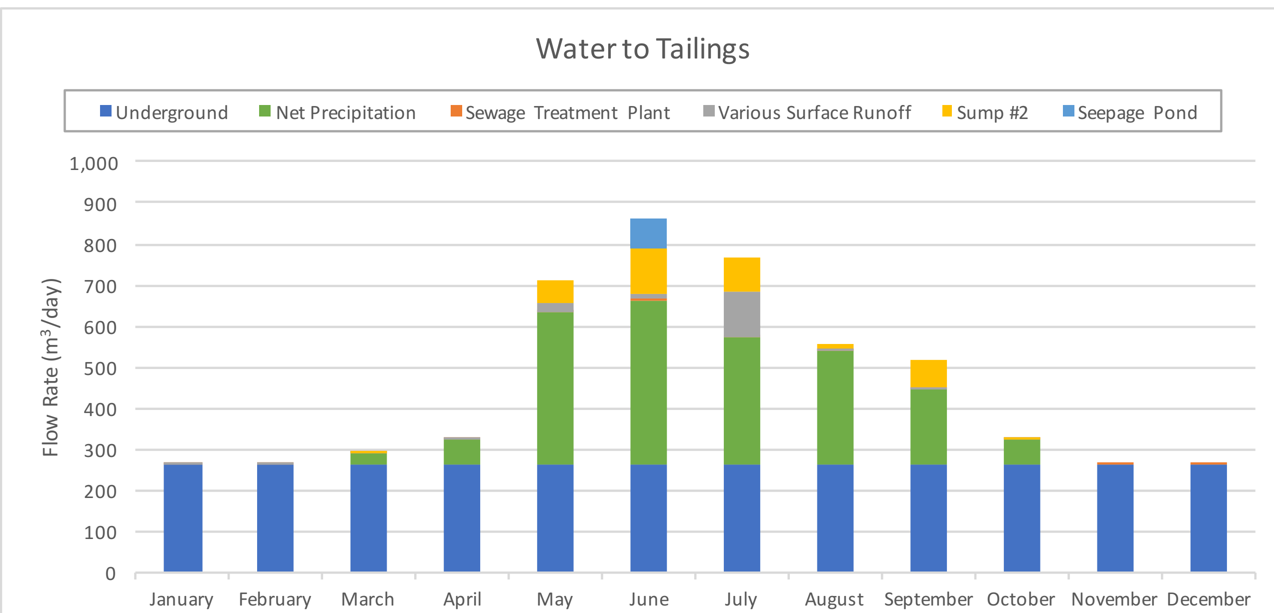


Figure 5-1: Predicted Monthly Discharge to TSF During the Temporary Closure Period

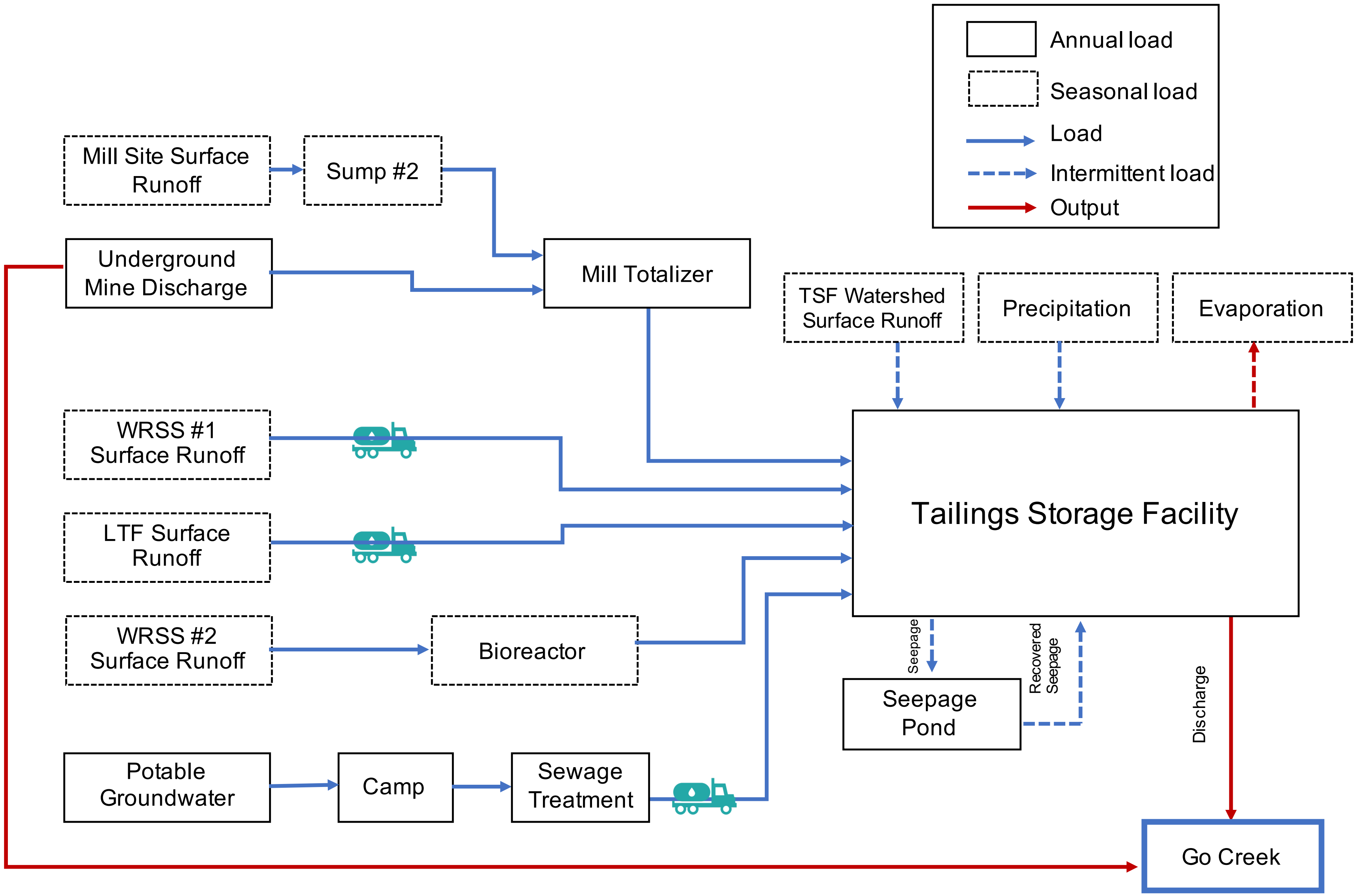


Figure 5-2: Temporary Closure Water Balance Model

As water is accumulating in the TSF, monitoring of the water level in the TSF is conducted weekly to add to the water level monitoring conducted during operations (Figure 5-3). Since December 2014, the elevation in the TSF has increased from 1307.1 m to 1309.0 m (Figure 5-5). This indicates an increase in volume of ~233,099 m^3. Since the underground groundwater has been discharged to the TSF, the cumulative flow discharged to the TSF has been ~713 m^3/day. However, these high flows are likely due to the high rainfall in June and July (Figure 3-18), which resulted in meteoric water collecting in the mine adit, in addition to the groundwater discharge. Recent measurements (August – October 2017) indicate daily flow rates of ~260 m^3/day, and flows in December 2017 have been ~160 m^3/day. These values are consistent with historic inflow rates, which averaged 300 m^3/day in 2012 through 2014 (Figure 5-4) and varied seasonally.

A recent evaluation conducted by the Engineer of Record, provided in Appendix A, requires that to maintain sufficient freeboard in the tailings below the spillway, the water level cannot exceed 1310.0 m. The current water level is 1309.05 m (October 31, 2017). At a rate of filling of 450 m^3/day (Table 5-5), the pond will reach the 1310 m elevation in June 2018 and will overtop the spillway in October 2019 (Figure 5-5). As such, both an active water treatment plant (WTP) is required to facilitate treatment and discharge of water accumulated in the TSF, and diversion of underground water from entering the TSF by treatment and discharge to Go Creek, is required. Details of the WTP are provided in Section 5.2.3. Treatment of the underground mine water is described in Section 5.2.2.

As requested by Yukon Environment, a sensitivity analysis was applied to the filling rate of the TSF. Assuming the average inflow rate of 190 m^3/day was equivalent to the average precipitation, increased precipitation for the 1:10 year wet (230 m^3/day) and the 1:100 wet year (260 m^3/day) were applied to the rate of filling, for both the rate of precipitation and for the underground inflow rate. The impact of these increased rates on the TSF filling is shown in Figure 5-6 and Figure 5-7 and indicate overtopping of the dam in June and March 2019, respectively.

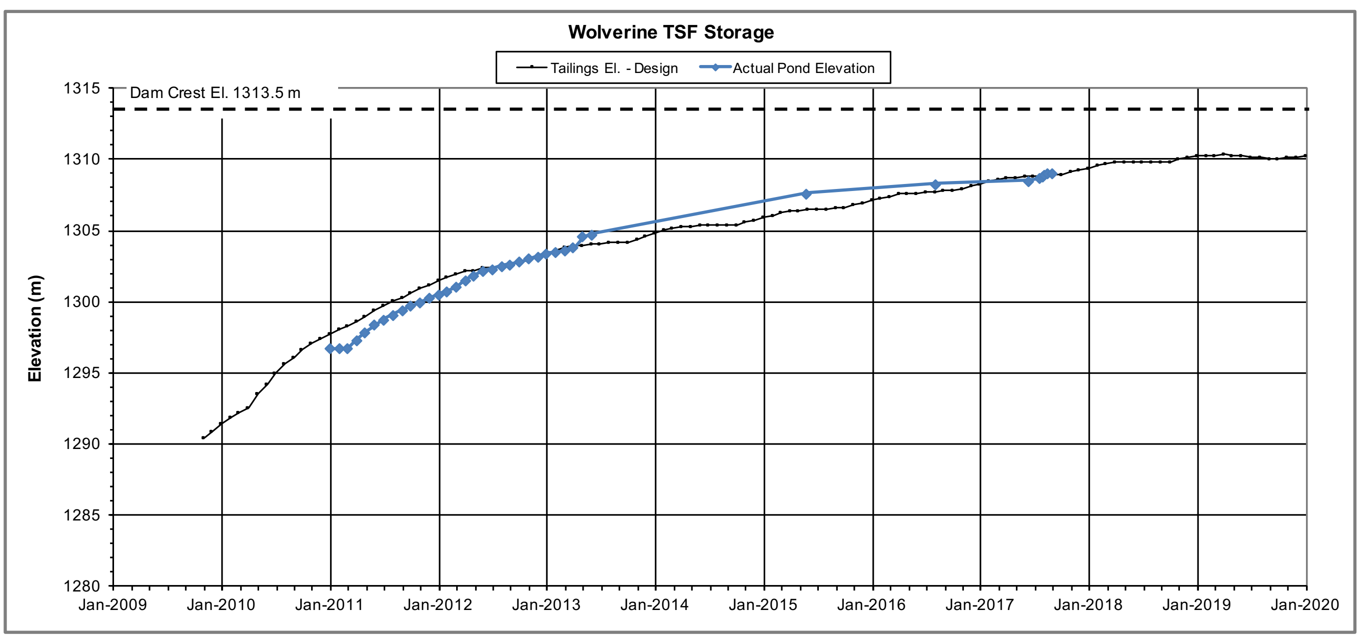


Figure 5-3: TSF Storage Curve, January 2009 to January 2020

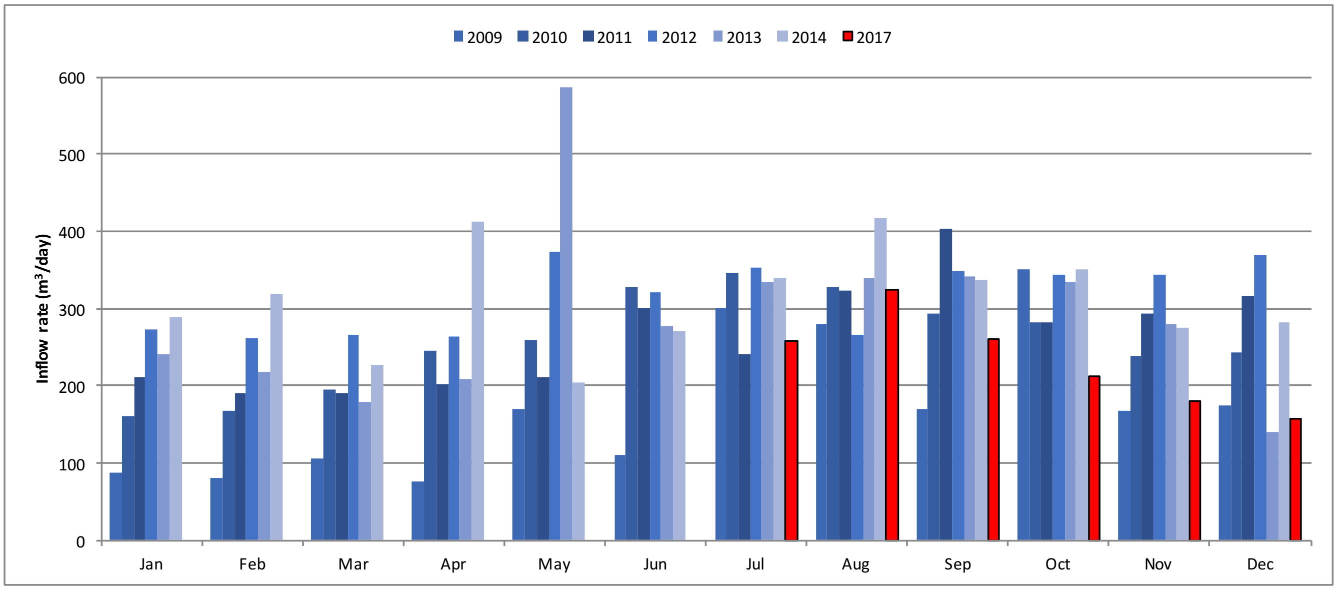


Figure 5-4: 2017 Underground Discharge rates compared to historic measurements

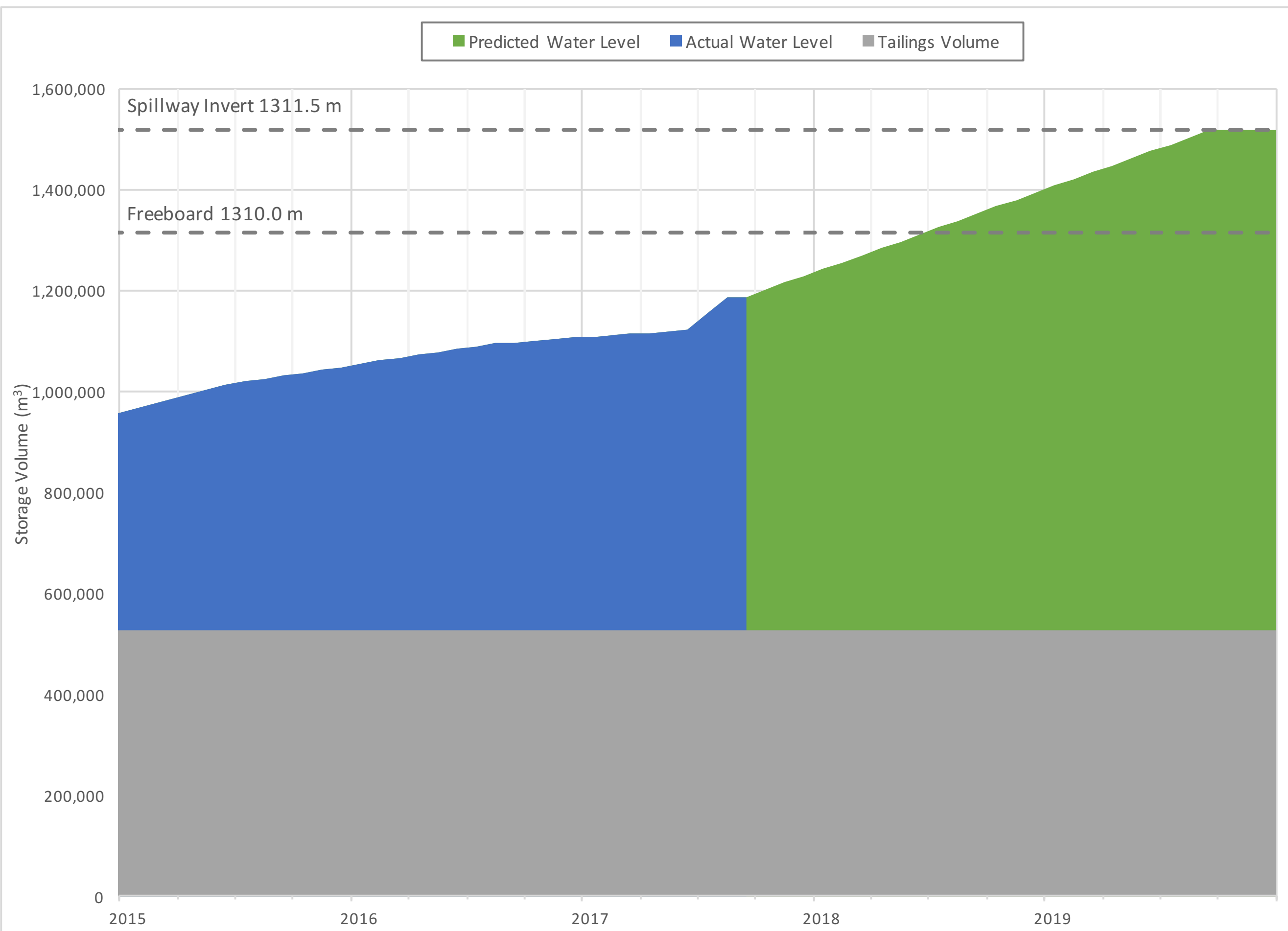


Figure 5-5: TSF Storage Curve, Temporary Closure Period with no water treatment

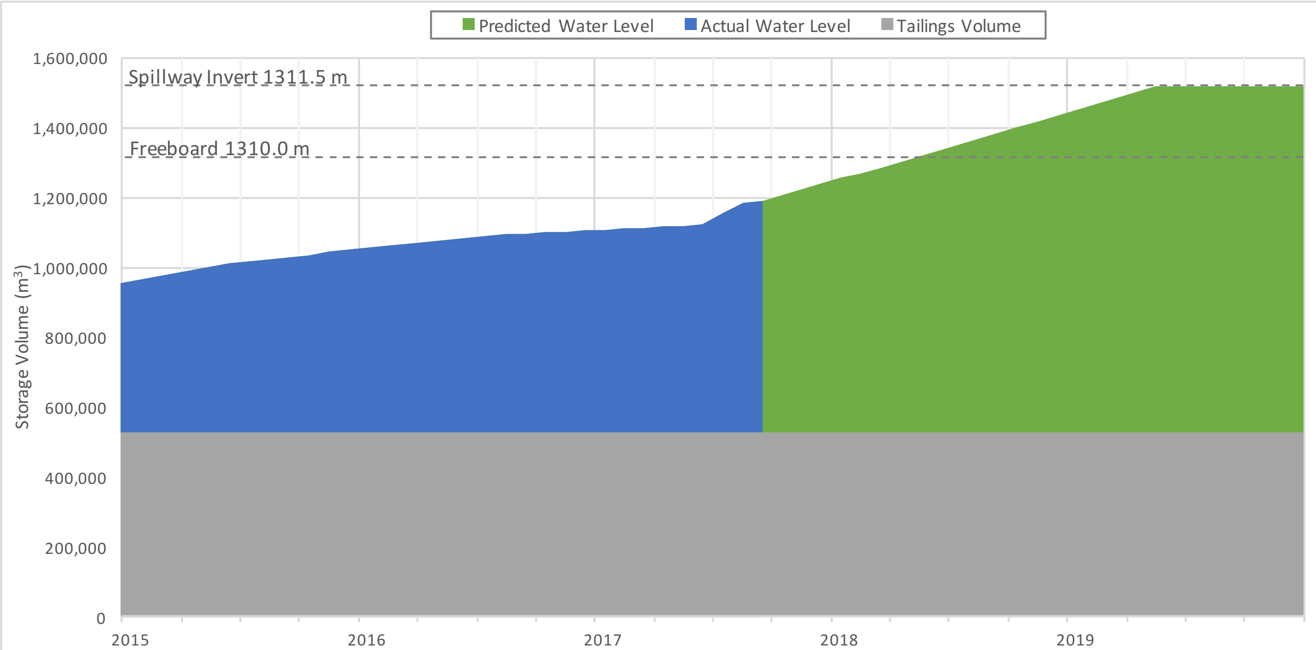


Figure 5-6: TSF Storage Curve, Temporary Closure Period with no water treatment, 1:10 Year Wet Year

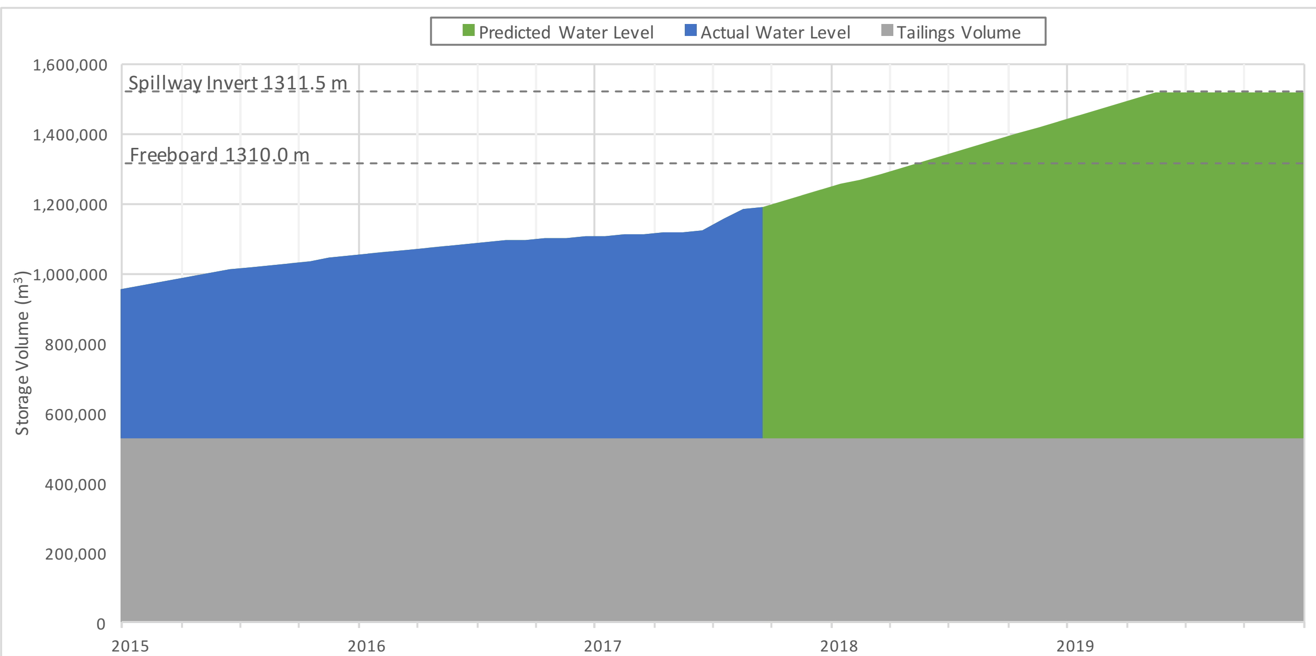


Figure 5-7: TSF Storage Curve, Temporary Closure Period with no water treatment, 1:100 Year Wet Year

5.2.2 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. 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, the mine was expected to be completely flooded to portal elevation by late May 2018. However, as discussed above, the underground mine water reached the adit collar on June 7, 2017. Using the updated known discharge rate, and an updated estimate of mine voids (Table 5-6), an updated estimate of mine water inflow indicates a rate over the January

2015 – June 2017 of 249 m^3/day. As summer rates have been measured since the groundwater reached the adit collar in June, a conservative rate of 260 m^3/day on average has been used to estimate underground discharge rates during the temporary closure period (Figure 5-4).

Table 5-6: Underground Mine Inflow Calculations

	2016 Estimate	2017 Actuals
Underground Volume	168,611 m^3	169,573 m^3
Mine shut down date	January 13, 2015	January 13, 2015
Flooding date	May 2018	June 8, 2017
Inflow Estimate	150 m^3/day	260 m^3/day

A pump and piping system has been installed at the adit of the underground mine (Photo 5-3) to pump excess groundwater recharge from the adit to the TSF. This system is installed above the gated entrance to the mine in the mine collar, as access below the collar is prohibited. The pump is run for a few hours per day as needed to maintain a consistent water level that prevents discharge to the mill pad. Water is pumped from the adit to the pumpbox in the mill, where it is then pumped to the TSF. Water quality has been monitored in the water pumped to the TSF since June, as summarized in Table 5-7, and compared to water quality measured during the 2006 – 2009 dewatering period.

On average, the water in the underground mine when there are no mining operations exceed discharge limits for most metal parameters, with exceedances of cadmium, copper, lead, selenium, and zinc. Groundwater recharge tends to have low concentrations of nitrogen species (i.e., ammonia, nitrate and nitrite) as these are directly tied to mine operations, due to explosives residues. Cyanide is also relatively non-present, with concentrations below the detection limit.

Photo 5-3: Wolverine Mine Adit Groundwater Pump System (July 13, 2017)

Table 5-7: Underground Mine Water Quality Statistics and 2017 Chemistry Results

Parameter (mg/L)	A License QZ04-065 ADL*	Dewatering Period Water Quality 2006 - 2009 (n=123)			2017 Portal Samples				
		Min	Avg	Max	07-Jun	28-Jun	10-Jul	18-Aug	23-Oct
TSS	**15**	1.5	**102.2**	**3630**	**18**	**22.8**	**41.5**	**16**	**60.7**
Ammonial Nitrogen	**5**	0.0025	0.069	0.3115	1.4	1.5	1.1	1.5	
Total Arsenic	**0.05**	0.00046	0.0109	**0.451**	0.0052	0.0043	0.0069	0.0054	0.0137
Total Cadmium	**0.002**	0.00002	**0.0089**	**0.433**	0.0005	0.0011	**0.013**	0.0030	**0.018**
Total Copper	**0.015**	0.00074	**0.1284**	**4.6**	0.0054	0.0063	**0.0419**	0.0042	0.0064
Total Lead	**0.02**	0.0006	**0.189**	**7.91**	0.0049	0.016	**0.198**	0.0041	**0.248**
Total Nickel	**0.5**	0.0003	0.0066	0.108	0.0099	0.017	0.0185	0.0286	0.065
Total Selenium	**0.02**	0.0034	**0.0281**	**0.252**	0.0015	0.0044	**0.0459**	0.0032	0.0084
Total Zinc	**0.5**	0.003	**0.924**	**45.4**	0.339	**0.516**	**0.981**	**0.624**	**1.19**

*ADL = Allowable discharge limits from Type A Water Use Licence QZ04-065; Bold values indicate exceedances of the ADL

The 2017 samples (Table 5-7) were mostly below discharge limits, except for iron (not shown), cadmium, lead, zinc and total suspended solids in most samples. However, generally the water is of relatively good quality, and indicates it may be amenable to treatment and discharge without being pumped to the TSF. Test work was conducted in October to evaluate whether the underground mine water is amenable to direct treatment using ferric sulphate, similar to the system that was used in 2006-2009, but with an additional lime treatment step (Figure 5-8). Initial results indicate that because the dissolved concentrations of Cd, Cu, Pb, Se and Zn concentrations were already below discharge limits in the feed water, the ferric sulphate treatment had no visible effect on metal removal. However, lime treatment was very effective at further reducing cadmium, iron and zinc and was very effective at lowering total metal concentrations well below discharge limits (Figure 5-9).

Therefore, direct treatment of underground mine water is proposed to prevent unnecessary discharge to the TSF. Underground mine water may be treated directly in 2018 for direct discharge to Go Creek. All water discharged to Go Creek will meet discharge limits outlined in the WUL and will only be discharged during times permitted under the WUL.

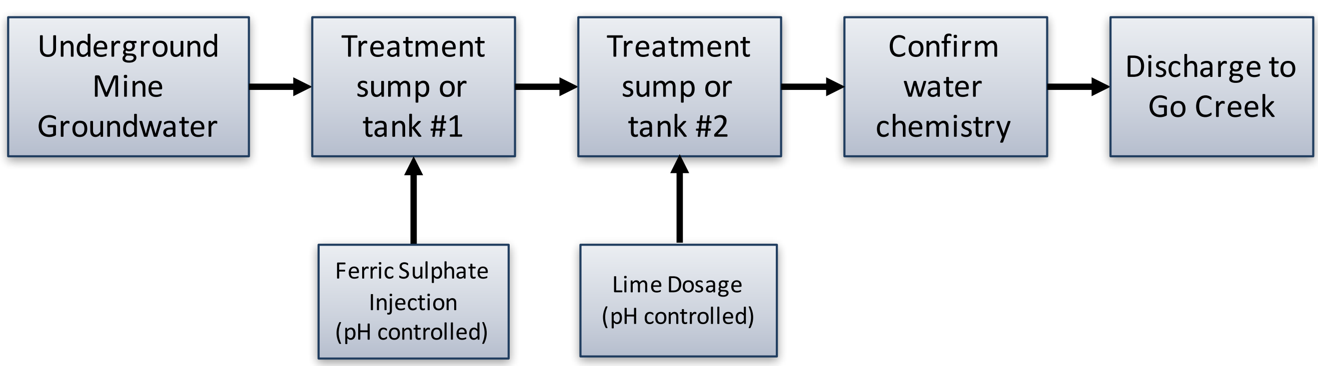


Figure 5-8: Underground Mine Treatment Flowchart

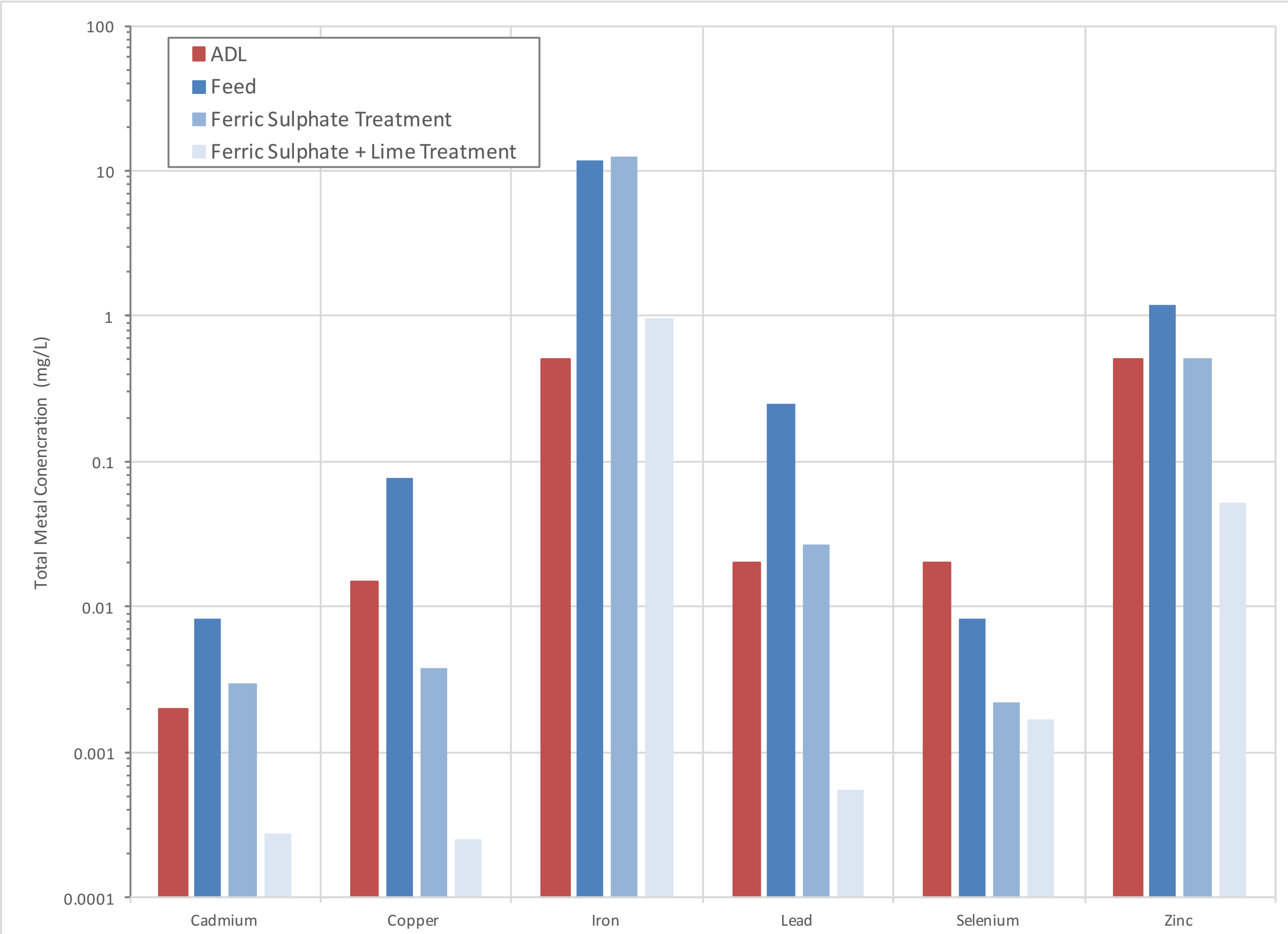


Figure 5-9: Preliminary Results of Underground Mine Water Treatment Tests

In advance of permanent closure, two hydrostatic bulkheads (or plugs) will be installed in the underground mine in summer 2019: one in the decline and one in the vent raise, shown in Figure 5-10. The details of the plug designs are provided in Appendix C. Prior to initiating construction, water levels within the mine must be maintained at a level below the Decline Plug, and for an additional 28 days after pouring of the concrete plug or until the design strengths have been achieved. To maintain adequate water levels, it may be necessary to pump the water level down sufficiently before building the form walls, or install a drain pipe through the decline plug to maintain correct water levels. Options to dewater the mine to maintain the 28 days of dry conditions necessary for plug installation, including installing dewatering wells from surface, or pumping directly from within the mine, are currently being evaluated. All necessary safety considerations will be implemented, and approval for work from Yukon Workers Compensation Health and Safety Board will be acquired before starting any work to access the underground mine.

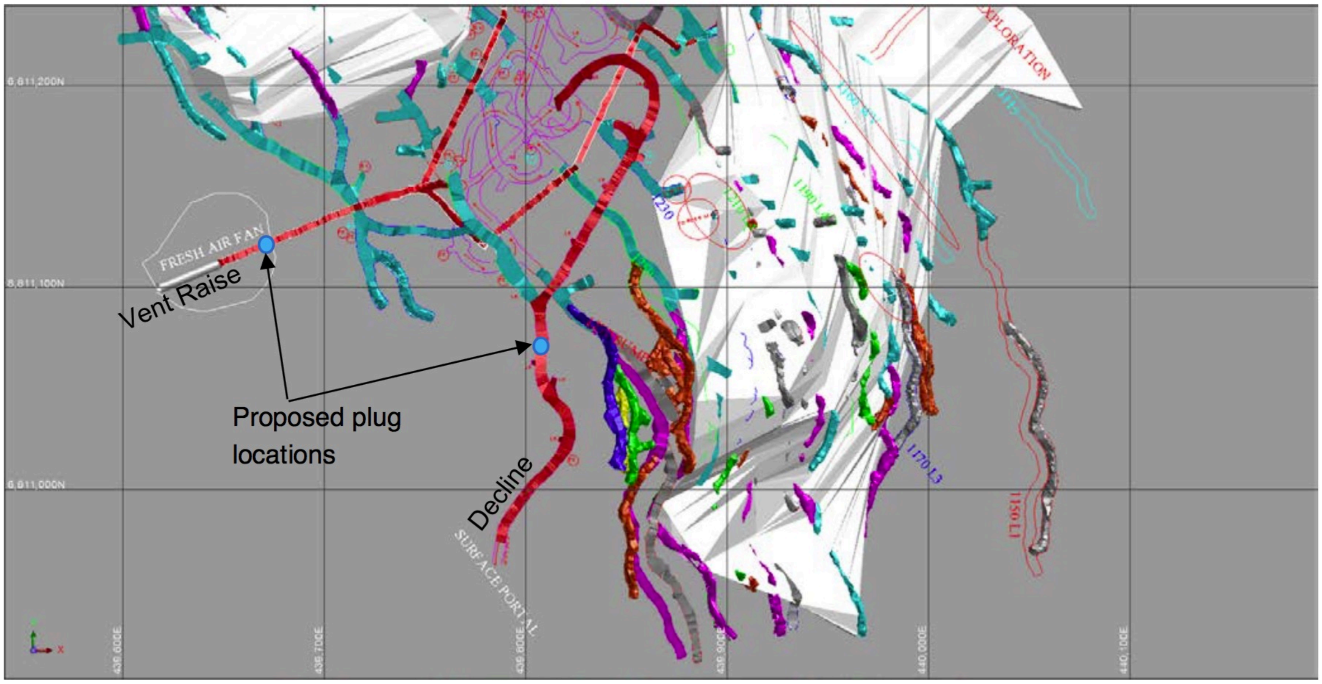


Figure 5-10: Proposed Decline and Vent Rains Plug Locations

The updated plug design is a water-tight design, and therefore, does not require seepage treatment as previously proposed in RCP 2016-07. However, adaptive management of potentially contaminated water in Wolverine Creek is proposed, and is summarized below.

Freezing of the underground adit is also proposed for the winter of 2018 and 2018/2019 in order to further minimize the volumes pumped to the TSF. The impacts on the TSF water balance are detailed in Section 5.2.3.

5.2.2.1 Adaptive Management Plan

As described in Section 3.2.2 and 3.3, groundwater that intercepts the underground mine daylights in Wolverine Creek, and is evident by increases in metal concentrations sampled in the alluvial groundwater system and the surface water samples downstream of the mine. An adaptive management plan has been submitted to EMR to identify trends in Wolverine Creek water chemistry and set trigger levels for the requirement to build a biopass system in Wolverine Creek to remediate contaminated groundwater prior to discharge to Wolverine Creek. This adaptive management plan was originally submitted in May 2016, and is summarized below as it pertains to the temporary closure activities.

Quarterly groundwater quality samples are taken at all sites at the Wolverine Mine as required by the WUL. Monthly samples are taken at stations MW05-5 and MW06-11 to identify trends in underground mine affected groundwater systems. Results of surface and groundwater monitoring are summarized monthly and annually in reports to the Yukon Water Board, and Yukon Government Department of Energy, Mines and Resources. These reports provide graphical analyses of surface and groundwater quality monitoring, specifically for copper, selenium and zinc, as these parameters are generally elevated in the area of the Wolverine Mine, and indicate overall metal concentration trends.

For the purposes of the adaptive management plan for Wolverine Creek, copper, selenium and zinc will continue to be used as indicator parameters, with trigger levels attributed to these parameters. However, all contaminants of potential concern (i.e., those limited by the WUL) are considered during evaluation of the monthly monitoring results.

Table 5-8 summarizes the baseline and operational average concentrations for copper, selenium and zinc for the surface and groundwater quality monitoring sites in Wolverine Creek. Concentrations of the main parameters of concern are generally comparable between baseline (1995 – 2008) and during operations (2009 – 2014) for groundwater quality monitoring stations, however, at surface water quality monitoring station W82, the operational average value is consistently greater than the baseline average value by between 40% - 75%.

The trigger concentrations for the surface and groundwater quality stations has been set to 20% times the 95th percentile value from either station MW05-3B or W82 for copper, selenium and zinc, whichever is highest (Table 5-8), in keeping with the guidance from the BC Ministry of Environment for the derivation of water quality objectives (BC MOE, 2013). This is because the concentrations measured at stations MW05-3 and W82 1995 – 2014 exceed the allowable discharge concentrations throughout the monitoring period, evidence of impact from the ore body on groundwater and surface water quality (Figure 5-11 through Figure 5-16).

Table 5-8: Wolverine Creek Trigger Values

Parameter	W82 Concentrations					MW05-3B Concentrations					Trigger Value (mg/L)
	P25	Median	P75	P95	*WQO*	P25	Median	P75	P95	*WQO*	
Copper	0.0027	0.0038	0.0057	0.0126	*0.0151*	0.0029	0.0031	0.0035	0.0045	*0.0054*	**0.0151**
Selenium	0.0022	0.0025	0.0028	0.0045	*0.0053*	0.0069	0.0083	0.0101	0.0115	*0.0138*	**0.0138**
Zinc	0.181	0.272	0.365	0.473	*0.568*	1.700	1.830	1.940	2.558	*3.070*	**3.07**

The concentrations outlined in the licence for discharge to Wolverine Creek are not applicable, as baseline chemistry for many limited parameters in surface water station W82 and in some groundwater stations, exceed those discharge concentrations (Figure 5-11 through Figure 5-16).

When the concentration for copper, selenium or zinc in any groundwater or surface water monitoring station approaches the trigger value, the biopass passive treatment system will be constructed in Wolverine Creek. Copper, selenium and zinc have been chosen as key indicators for the ore body, and will be indicative of contamination of the groundwater system by water that has contacted the mined areas.

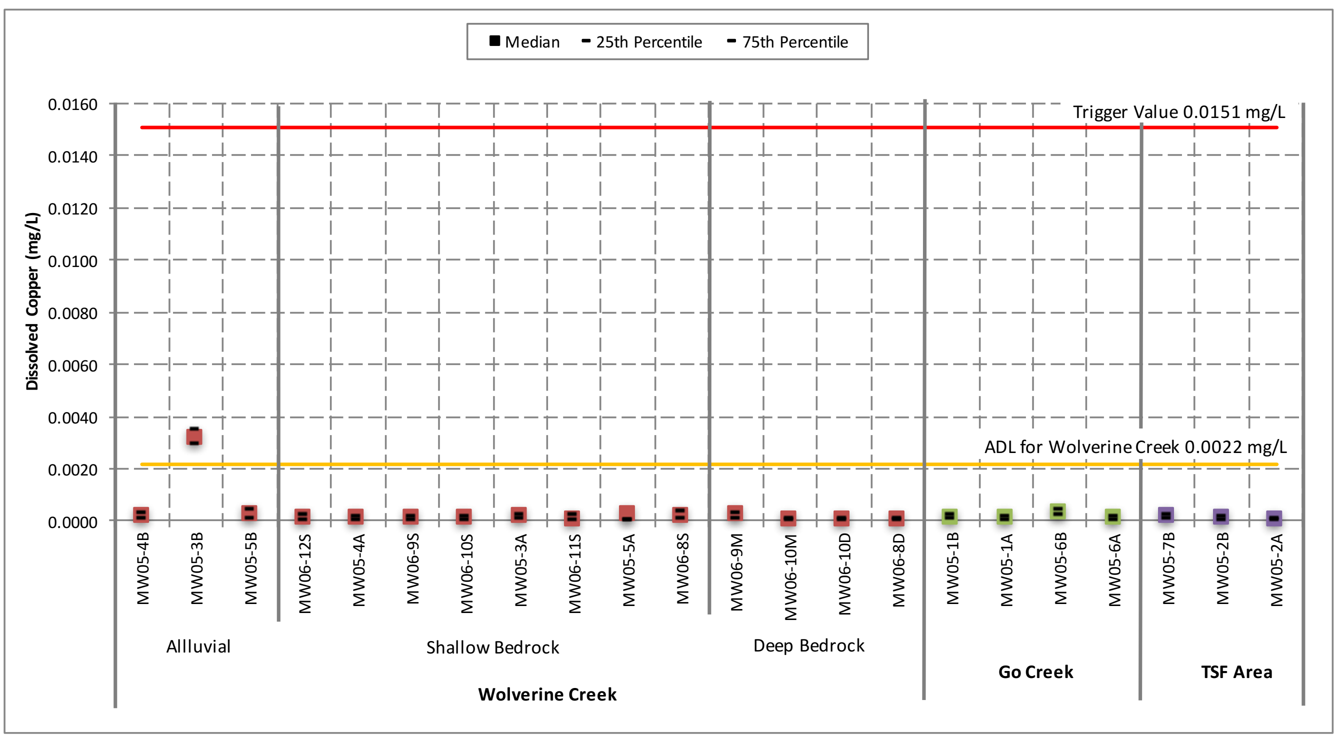


Figure 5-11: Groundwater Copper Concentrations and and Trigger Values

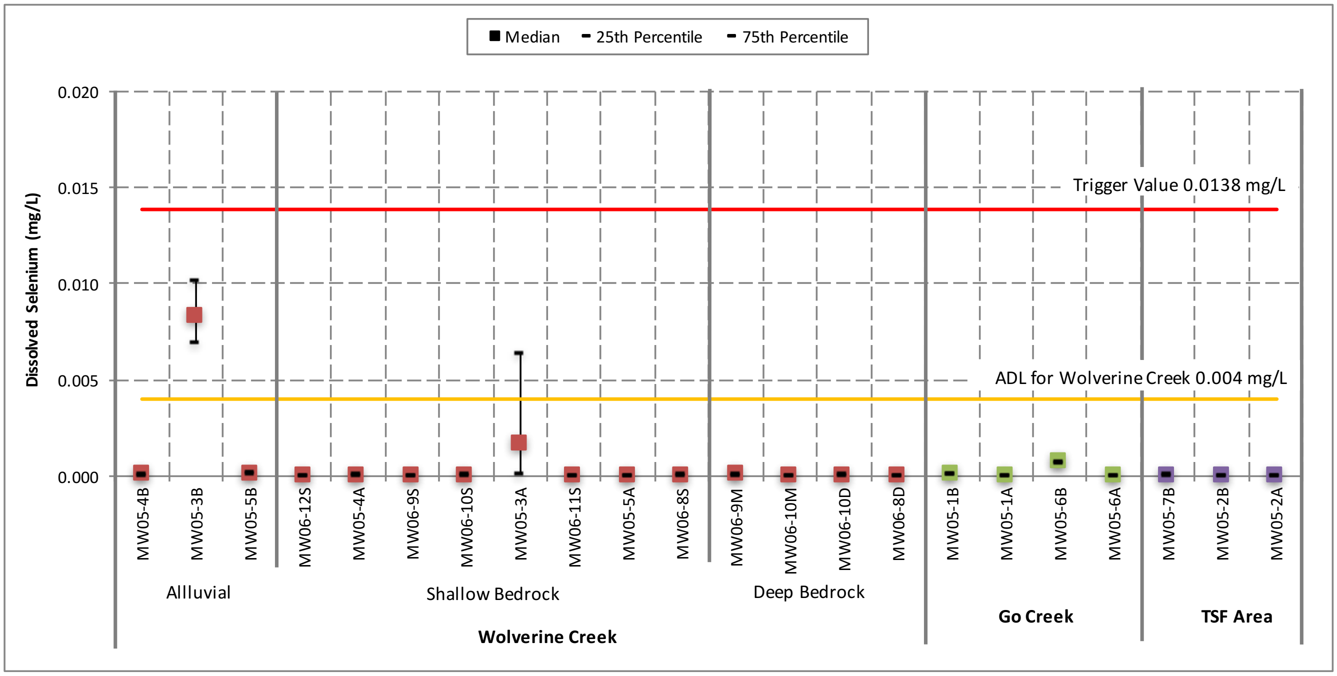


Figure 5-12: Groundwater Selenium Concentrations and and Trigger Values

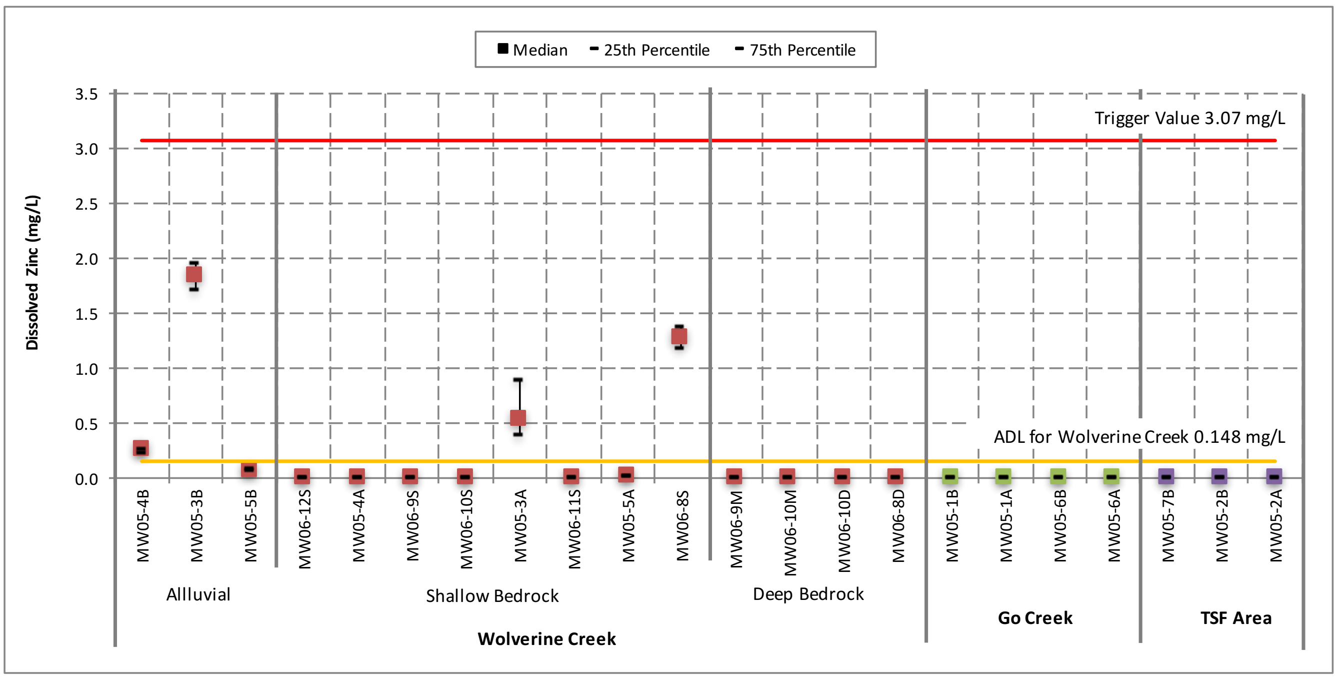


Figure 5-13: Groundwater Zinc Concentrations and and Trigger Values

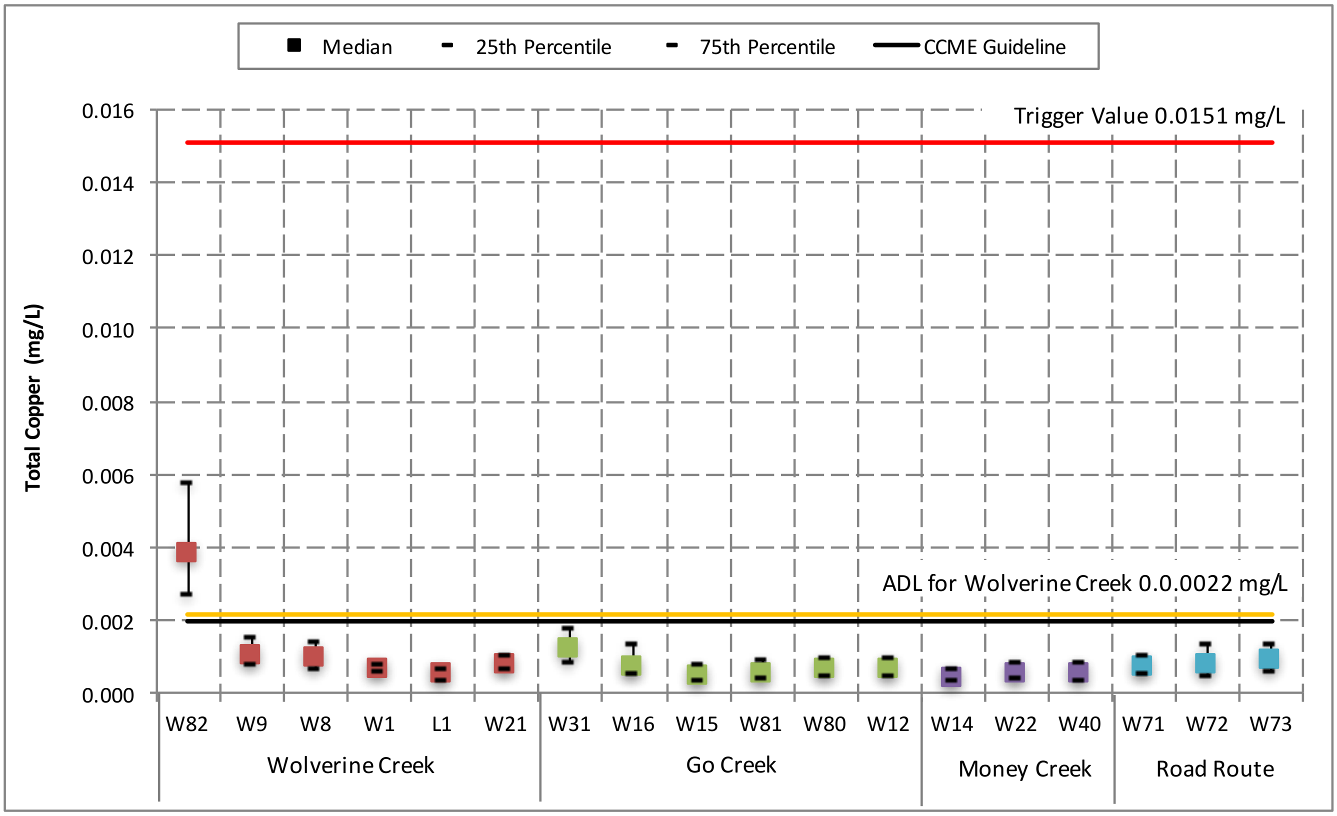


Figure 5-14: Surface Water Copper Concentrations and and Trigger Values

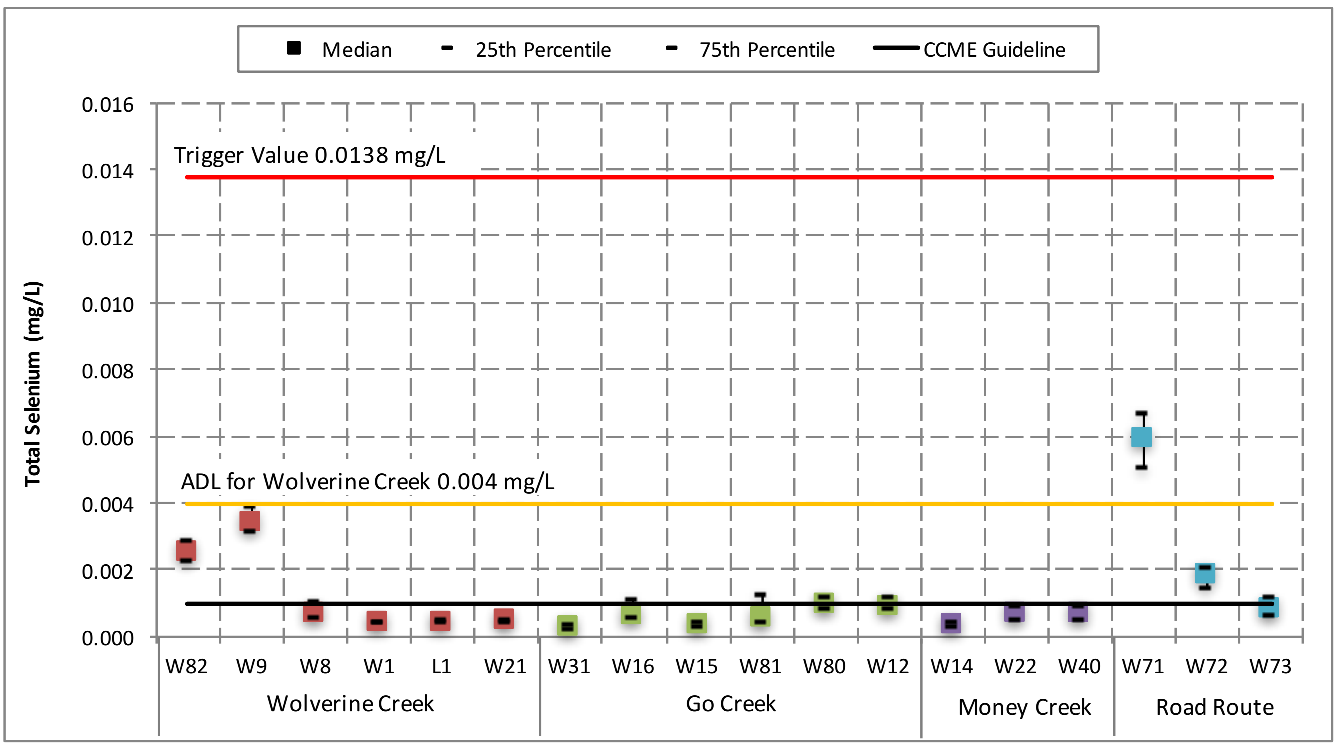


Figure 5-15: Surface Water Selenium Concentrations and and Trigger Values

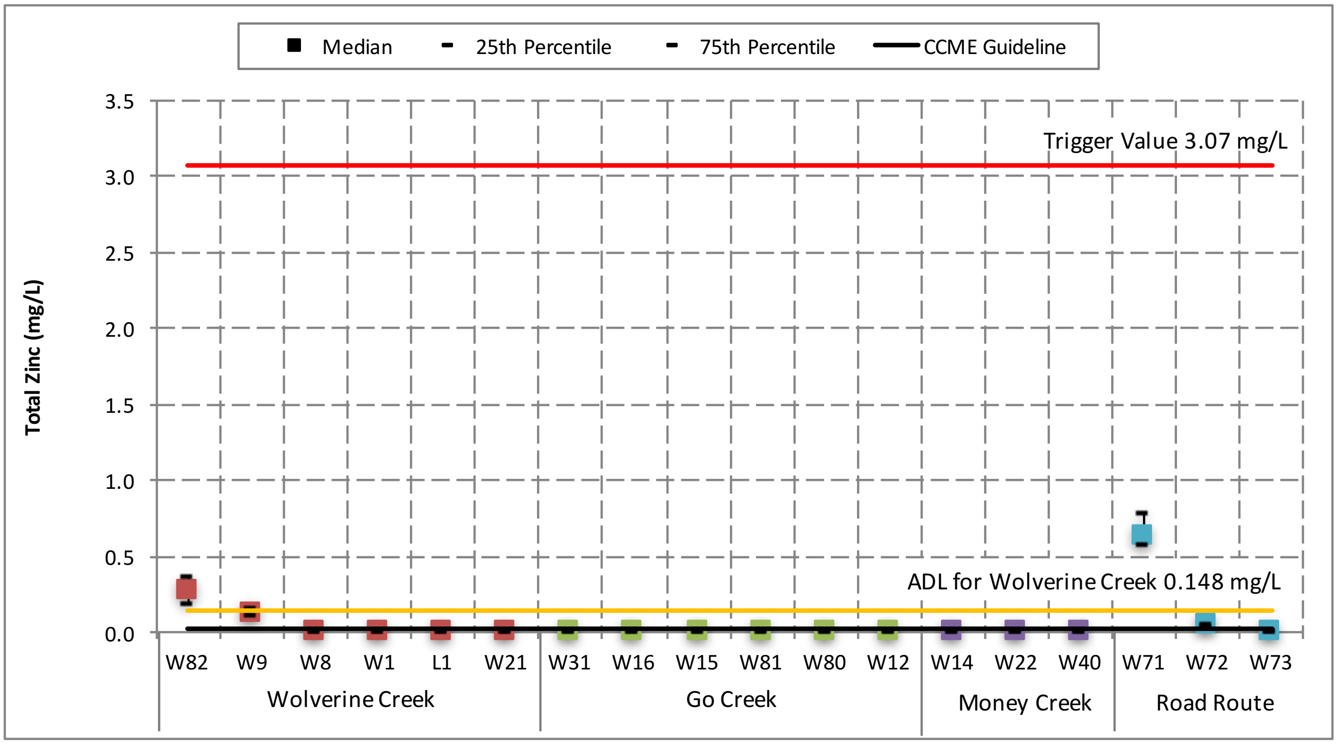


Figure 5-16: Surface Water Zinc Concentrations and and Trigger Values

Biopass Design

Biopass treatment systems are the term used to describe a passive treatment channel, typically containing organic based biological material, which promotes the development of microbes that fix and precipitate the metals in the water passing through the system. Biopass systems can also contain chemical treatment materials, such as limestone, activated carbon or other absorptive materials. Chemical systems utilize lime to neutralize acidity and treat mine water drainage, while activated carbon is an absorptive mechanism to remove contaminants suspended in the effluent. Biological treatment systems generally utilize naturally occurring microbes to precipitate metals as metal sulphides or biologically reduce dissolved metals to solid phase elements.

The proposed biopass system is a biological treatment system, in which the main reaction mechanisms operating include biologically mediated transformations, metal sulphide precipitation, adsorption and co-precipitation (Neculita et al., 2007; Blowes et al., 2000). The mechanisms often change over the life of the bioreactor are more readily available carbon sources are consumed and more complex carbon sources degrade. At the beginning, metals may be removed primarily through adsorption to organic matter, and in an oxidized or slightly reducing environment, can precipitate as hydroxides and carbonates. When a reducing environment has been achieved sulphide co-precipitation dominates, and under very reducing conditions iron sulphides and the associated co-precipitates form (Neculita et al., 2007).

Bioreactors have been used successfully at other mines in the Yukon, both at small scale barrel studies (Minto Mine, Janin, Herbert and Gjertsen, 2015) and at much larger pilot scales (United Keno Hill Mines, Alexco, 2011).

The initial part of development and testing of the Wolverine Creek Biopass system was completed as part of a Royal Roads University Master of Science thesis in early 2012 (Mioska, 2012). In the experimental test work, five columns were 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, or wood chips and alfalfa. Selenium, sulphate and the other parameters of concern were lowered most effectively by 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; however, sewage sludge is a concern for human health reasons, and is therefore not suggested to be used in future design. The addition of zero-valent iron 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, in December 2013, test work was initiated at the Yukon College, as part of the work by the Industrial Research Chair, to further the design of the Biopass (Janin, 2014). The 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 with and without ethanol addition to assess the role of ethanol in supporting microbe growth. Residence time was set at 69 days to mimic residence time expected in the proposed Biopass system proposed (assuming underground water flow of 0.5 L/s). The reactors were setup in December 19, 2013 with incubation (no flow) until January 23, 2014.

The columns were run through December 2014. Due to the variability in the influent concentrations, the cadmium, copper and zinc concentrations were also highly variable. Concentrations in the column effluents were comparable between the five treatments, indicating relatively little impact on removal from column amendments. All four columns were effective at achieving the discharge limits for cadmium, selenium and zinc and while none of the columns achieved the discharge limit for arsenic, the ethanol-biochar column (C8) was most effective. The ethanol-biochar column was also most effective at removing selenium, with concentrations less than the detectable limit (0.7 µg/L) in many instances.

These results indicate 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). The addition of zero-valent iron however, drastically improved the removal of selenium and sulphate, and while the wood chip/alfalfa amendments didn't appear to change the results, they are likely to provide long-term carbon sources.

2016 Pilot Bioreactor

In late May 2016 YZC commenced construction of a field scale bioreactor to test the effectiveness of in treating runoff from waste rock and ore stockpiles. The bioreactor was constructed in between waste pad #2 and the north end of the TSF. Following temporary closure of the mine in 2015, waste rock and ore temporarily stored near the mine portal was consolidated at the lined area and the facility remains in operation. Runoff from Waste Pad #2 collects at the south end, and discharges via a pipe and hose to the north end of the TSF.

Construction of the field scale bioreactor began in late May 2016. Construction activities consisted of cut and fill activities to create a stable 2% grade that the bioreactor could be excavated within. Once level, a trench for the bioreactor was dug (Photo 5-4), lined with geotextile fabric (Photo 5-5) and impermeable liner. The substrate material for the bioreactor was a mixture of locally sourced gravel, wood chips, and peat material excavated from the upper Go Creek area (Photo 5-6). It was mixed on surface with a back-hoe, then placed in the lined bioreactor trench (Photo 5-7). Influent to the bioreactor was from the original pipeline from Waste Pad #2, into a plastic tote, then distributed into the bioreactor at the upper end through a gravel pad (Photo 5-8). The final system also included two slotted pipe structures to enable sampling at two points within the bioreactor.

A final survey of the bioreactor mid-way through filling of the substrate was conducted on August 6, 2016, and is provided in Figure 5-17.

Photo 5-4: Bioreactor Trench (July 11, 2016)

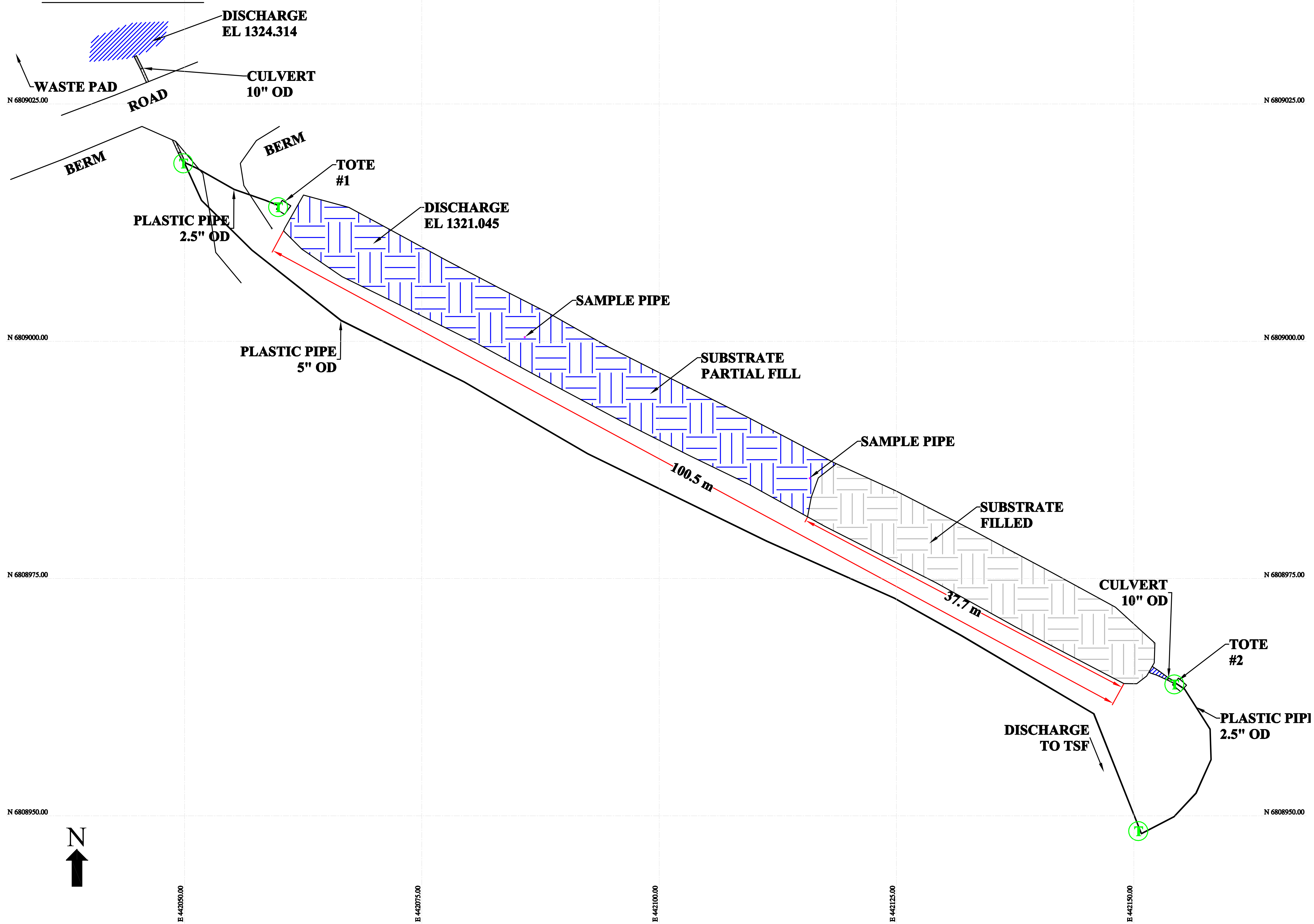
Photo 5-5: Bioreactor Trench Lined with Geotextile Fabric (July 12, 2016)

Photo 5-6: Bioreactor Substrate Material (May 31, 2016)

Photo 5-7: Bioreactor Filled with Substrate Material (July 16, 2016)

Photo 5-8: Bioreactor Influent System (July 16, 2016)

PLAN VIEW



NOTES

1. SURVEY DATE - AUGUST 06, 2016
2. SURVEY ELEVATIONS BASED ON TOP OF SURFACE
3. SUBSTRATE PARTIALLY FILLED IN BLUE HATCH AND SUBSTRATE COMPLETELY FILLED IN GRAY HATCH
4. CULVERT ANGLE (FROM WASTE PAD) = 2.7°

PROJECT

YUKON ZINC CORP.
WOLVERINE MINE

TITLE

WOLVERINE MINE
BIOPASS
SURVEY ASBUILT

DRAWING	
DATE:	AUGUST 06, 2016
SCALE:	1:400
SIZE:	ANSI B
DWG No.:	2016_YZC_BP
REV.:	0

YUKON ZINC CORP.

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Vancouver, BC V6C 2B3
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FIGURE 1

Water quality and flow rates are measured in the inlet and outlet totes located at either end of the bioreactor. Flow rates are measured at a v-notch weir in the totes. Flows measured in August and September ranged from 7 L/hour to 20 L/hour. Water quality samples were taken in August, September and October 2016, and in June and July 2017, and results for cadmium, copper, selenium and zinc are provided below. The bioreactor was initially very effective at removing metals to orders of magnitude below the inlet concentrations, with all parameters in the outlet below the Type A WUL discharge limit, except for concentrations of iron and TSS, in the 2016 and June 2017 samples. 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 also increased, which is typical for reducing, anoxic systems. These increases can be mitigated by allowing the water to be aerated prior to discharge, typically by allowing the effluent to flow over rocky channels, or through the use of limestone channels, if required. TSS concentration increases are also likely just a relic of solids settling, which will likely decrease as the bioreactor system reaches steady state.

Increases in metal concentrations in the July samples were due to the pumping of Sump #2 sludge to the Waste Pad #2 in early July, which resulted in sedimentation of the discharge pipe into the bioreactor, and water from Waste Pad #2 no longer discharging to the bioreactor. The pipe screen was cleaned out in late August, and results indicate chemistry was improved and again met discharge limits.

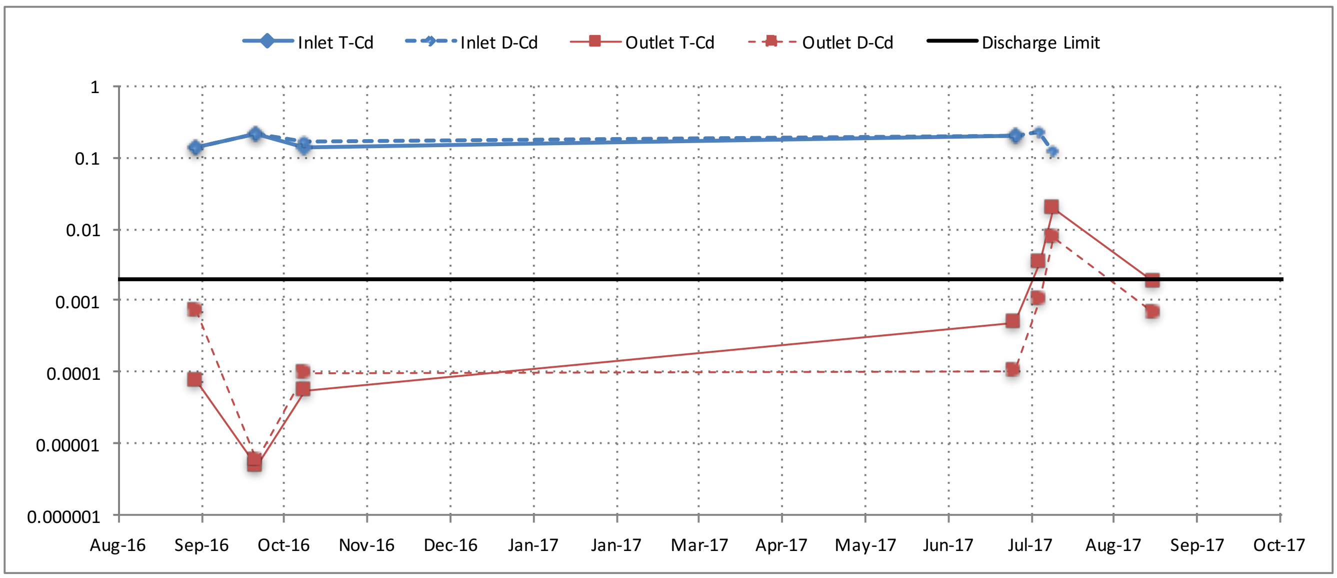

Figure 5-18: Waste Pad #2 Bioreactor Water Quality Results - Cadmium

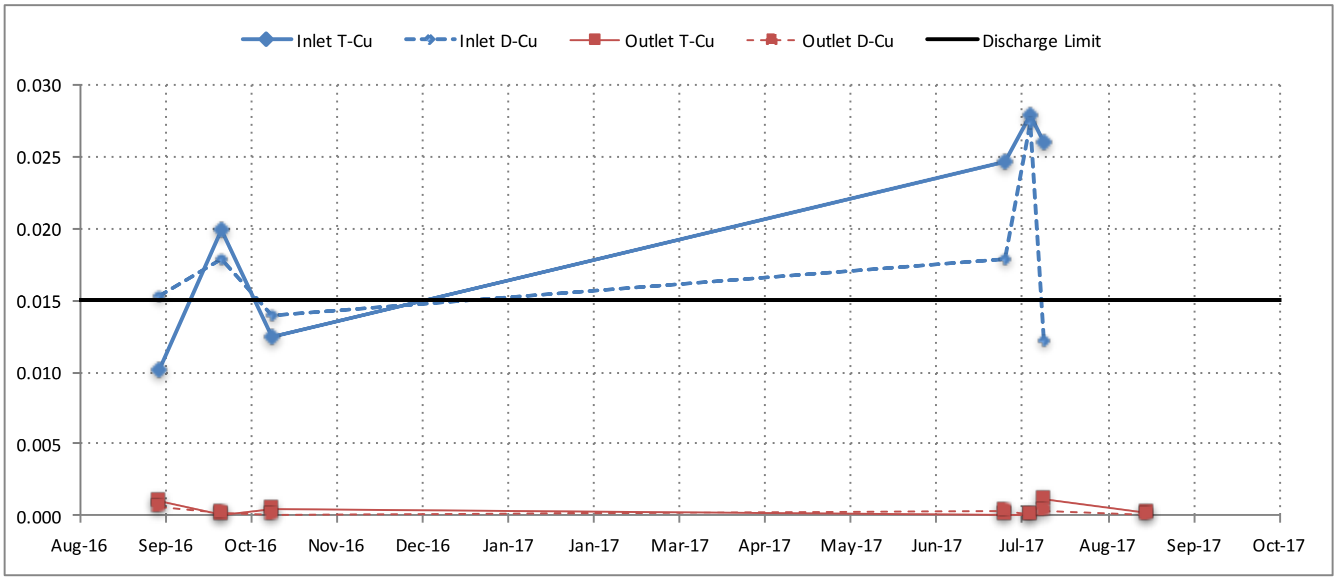

Figure 5-19: Waste Pad #2 Bioreactor Water Quality Results - Copper

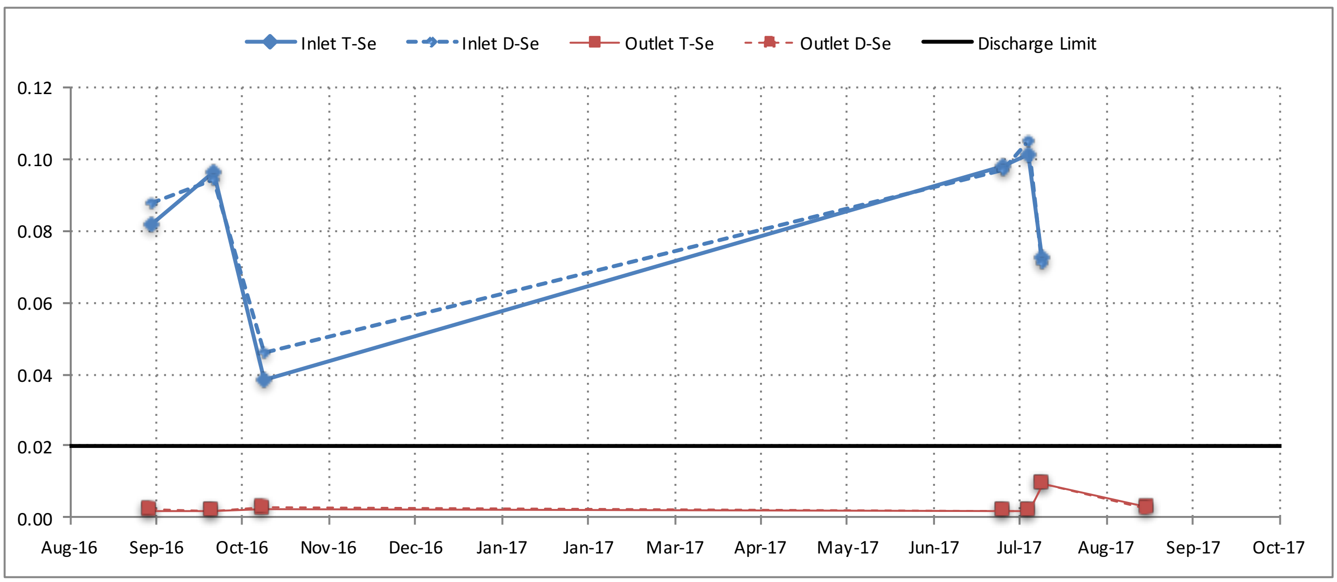

Figure 5-20: Waste Pad #2 Bioreactor Water Quality Results - Selenium

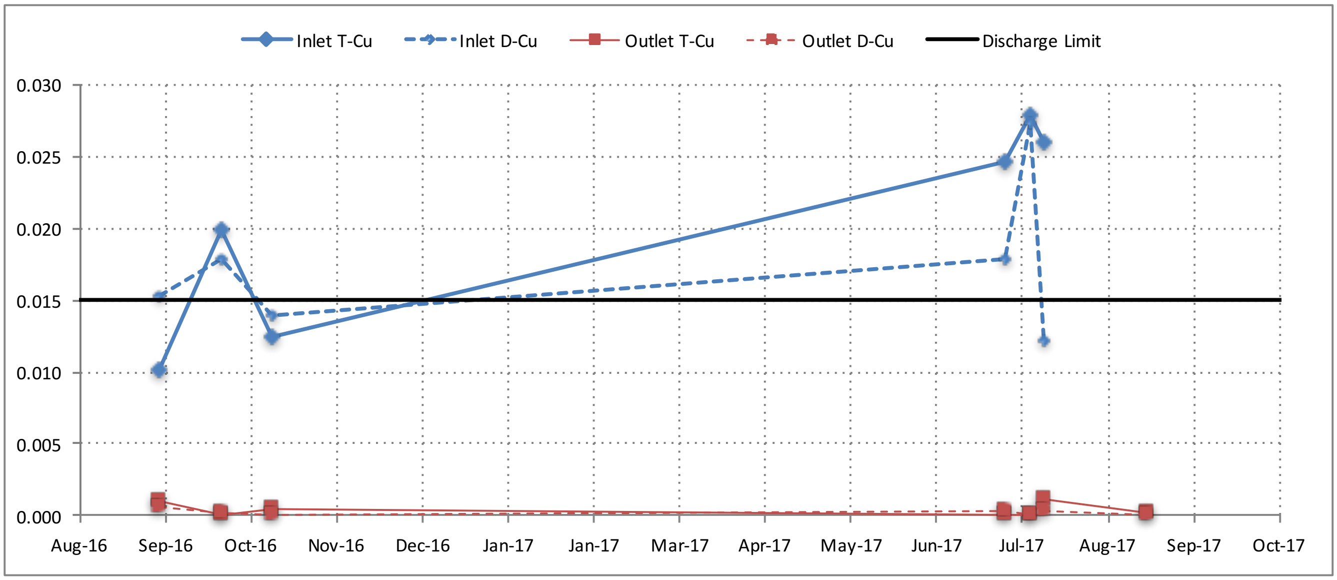

Figure 5-21: Waste Pad #2 Bioreactor Water Quality Results - Zinc

Updated Biopass Design

The Biopass system will be constructed in the Wolverine Creek channel along the stretch of creek that is known to contain higher metal concentrations and could potentially receive groundwater with high selenium and other metal concentrations derived from mine water. Un-impacted water in Wolverine Creek, upstream of the Biopass channel, will be diverted along the western margin of Wolverine Creek in a lined channel and re-introduced into Wolverine Creek below the biopass (see Figures 5-1, 5-2 and 5-3).

While the initial biopass was designed to be 2.5 m deep, 3.5 m wide and 400 m long, the preliminary biopass detailed below will be only 100 m long (Figure 5-23). The intent is to build a larger bioreactor, if required, following treatment results of the preliminary bioreactor.

The biopass is designed to treat groundwater that discharges into upper Wolverine Creek. Groundwater discharge rates in the treatment area are expected to be on the order of 0.5 L/s, and both the laboratory research projects conducted in 2012 and in 2013 ran at rates that mimicked this flow rate, therefore the planned biopass is designed to treat for this flow rate.

The groundwater that discharges into the biopass will be biologically treated while moving in a down-slope direction. Collected groundwater will flow upwards and through the organic substrate where treatment will occur. Before joining Wolverine Creek, effluent from the Biopass system will be collected in a lined collection pond to enable pump back of the discharge, should water quality objectives not be met.

If water quality is acceptable, the collection pond will overflow into a French drain that discharges into Wolverine Creek. While the water exiting from the Biopass system is expected to be depleted of oxygen, this water will be combined with the diverted well-oxygenated water from upper Wolverine Creek. Moreover, this combined flow will then traverse steep terrain for approximately 1000 m before reaching the mouth of Wolverine Creek and is expected to be fully oxygenated by the time it reaches this fish-bearing reach.

Deep groundwater that does not enter into Wolverine Creek will flow towards Little Wolverine Lake where no impacts to water quality are predicted to occur.

The discharge rates that can be treated will depend on the porosity of the organic substrate layer; however, a biopass 3.5 m wide, 2.5 m deep and 100 m long that slopes to 2.5 m wide at the bottom results in a 625 m^3 of treatment volume. At 0.5 L/s, this results in a hydraulic retention time of ~14.5 days, or just under 3.5 days at a flow rate of 2 L/s. For comparison, the maximum flow rate measured in the underground in 2014 was or 4.84 L/s, which would decrease the hydraulic retention time in the biopass to 1.5 days.

Flow rates will be highest during spring melt (May and June), however, water quality at this time is expected to be dominated by snow melt, and should therefore have negligible contaminants.

Biopass construction materials are summarized in Table 5-9 and based on previous experimental test work (Mioska, 2012; Janin, 2014), and should total the full 625 m^3 volume of the biopass.

Table 5-9: Wolverine Creek Biopass Construction Materials

Material	Volume
Gravel: Consistent material of small, crushed rock (between 3/8" to 2" diameter). May use what is available on-site. Rinse prior to use, if possible. Larger sized cobble is also required for the French drain at the outlet of the collection pond.	< 2" gravel: 350 m^3 Cobble: 10 m^3
Creek Substrate: The existing creek substrate is a natural source of microbes and carbon. Therefore the material excavated from the creek bed should be saved and mixed with the gravel.	Volume excavated from frozen creek bed
Peat: Highly sorbent and introduces micro-environments for mineral precipitation reactions. The peat adjacent to the creek, and excavated as part of the biopass channel excavation may be sufficient for this requirement.	50 m^3
Wood Chips: While the carbon amendments in the laboratory scale experiments did not appear to effect the discharge concentrations, they may require more time to become biologically available to the microbes, and will offer a more long term, sustainable source of carbon, once the readily available sources have been consumed. On-site poplar and spruce may be chipped for this usage.	50 m^3
Zero-valent iron: In the 2012 experimental results, the addition of zero-valent iron (e.g., steel wool) drastically improved the selenium removal. Steel wool pads can be used, or, if non-galvanized scrap iron is available (e.g., rusty nails, shotcrete mesh), this can be cut into small pieces and used within the biopass.	100 steel wool pads (or available scrap iron)

Pilot Test System

As outlined under Section 8.6(q) a field trial to test the bioreactor under field conditions is required. To conducted this test, the water pumped from the underground mine in advance of bulkhead installation (Section 5.2.2) will be trucked to the waste pad #2 bioreactor. The water from waste pad #2 will be diverted to the tailings, and water intercepted from the underground mine will be pumped to the bioreactor. Water quality samples will be taken at the inlet and outlet over the duration of the test to evaluate the efficacy of the bioreactor to treat underground mine water. At least five bed volumes (or ~25 m^3 x 5) or 8 water truck loads should be passed through the bioreactor.

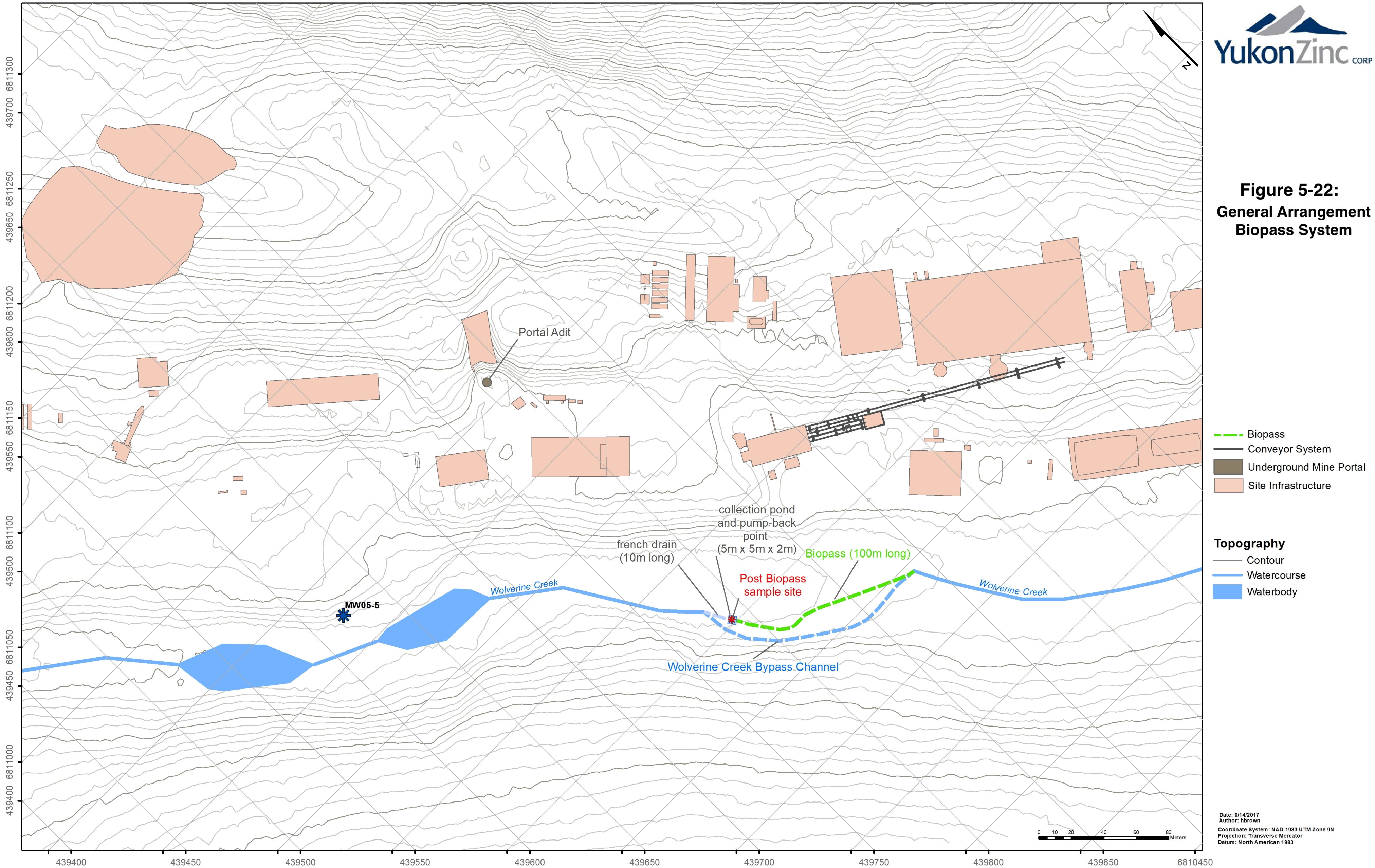

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Figure 5-22:
General Arrangement Biopass System

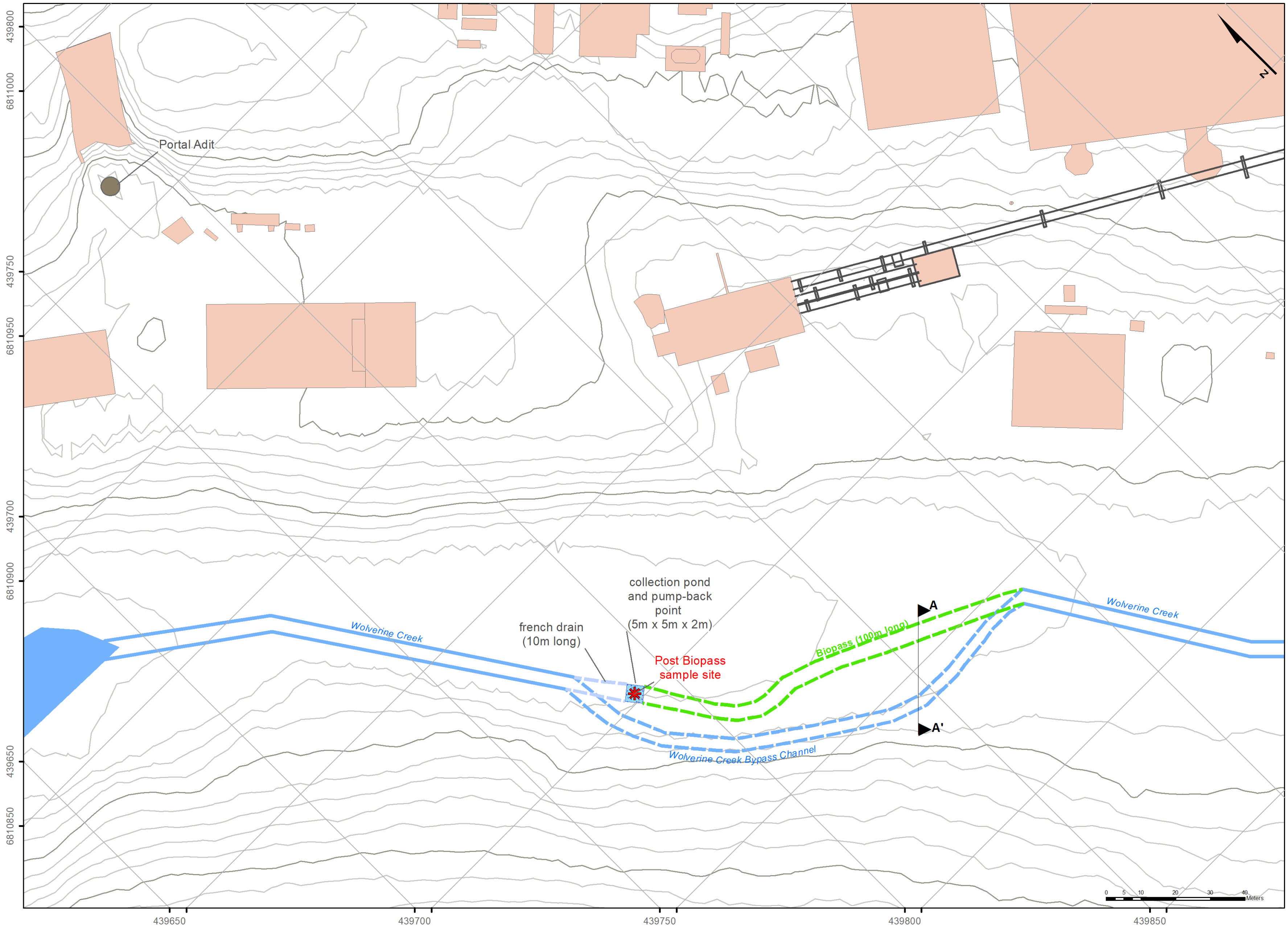

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Figure 5-23

Wolverine Mine: Biopass System

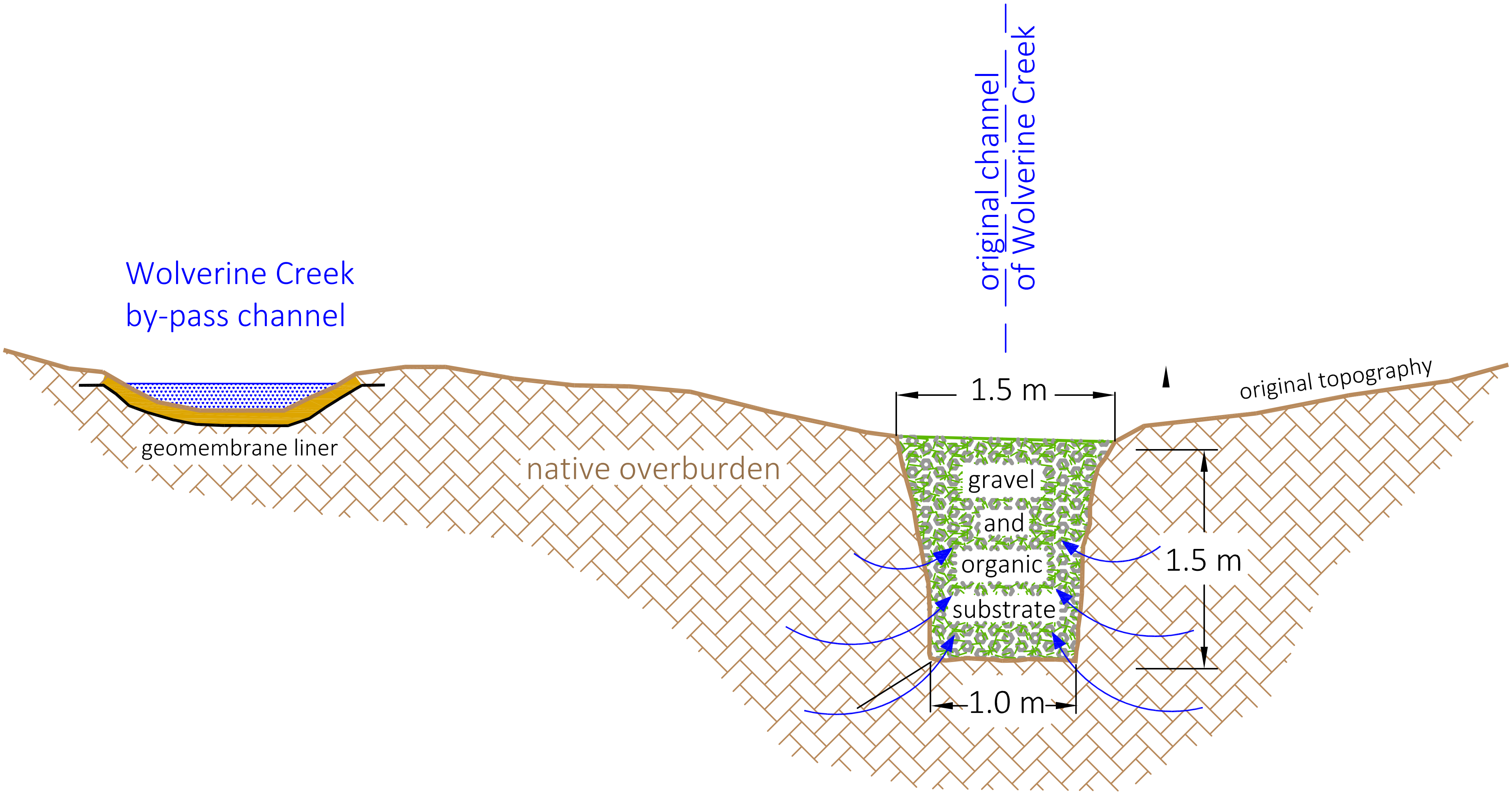
- Biopass
- Conveyor System
- Underground Mine Portal
- Site Infrastructure

Topography

- Contour
- Watercourse
- Waterbody

Date: 9/15/2017
Author: hbrown

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



Yukon Zinc Corporation
Wolverine Mine
Yukon

Figure 5-24:
Biopass Section A-A'

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VANCOUVER, BC

26 October 2015 | DWG No. 1510YZC-003

5.2.3 Tailings Storage Facility (TSF) Area

The TSF is currently used as the main water management infrastructure for the Wolverine Mine. In October 2017, the total volume stored in the TSF is ~1,197,515 m^3 based on a water elevation of 1309.05 m. Approximately 530,000 m^3 is occupied by saturated tailings with the rest occupied by free water. Monitoring of inflow into the TSF indicates that flows into the TSF through precipitation either directly on the TSF or on other site infrastructure that is subsequently pumped/trucked to the TSF, is ~50,000 m^3/year (Table 5-5). Flows from underground have been variable, but have reached as high as 600 m^3/day, and while recently, in December, flows have decreased significantly, down to 160 m^3/day, underground discharge pumped to the TSF is a significant consideration in managing volumes in the TSF.

As discussed above, without intervention the TSF pond will reach the 1310 m elevation in October 2019. As such, an active water treatment plant (WTP) is required to facilitate treatment and discharge of water accumulated in the TSF. The plant will be sized to treat 1,200 m^3/day, and water will be discharged over the permitted May to October discharge period.

To minimize water accumulation in the TSF, water from UG will be treated and discharged May to August 2018 and May – July 2019, as described in Section 5.2.2, and the underground adit will be frozen over the winter 2018/2019 period. Following installation of the bulkheads in July 2019, water from the TSF will be discharged following treatment in the water treatment plant (Figure 5-25). Details of the WTP are provided below.

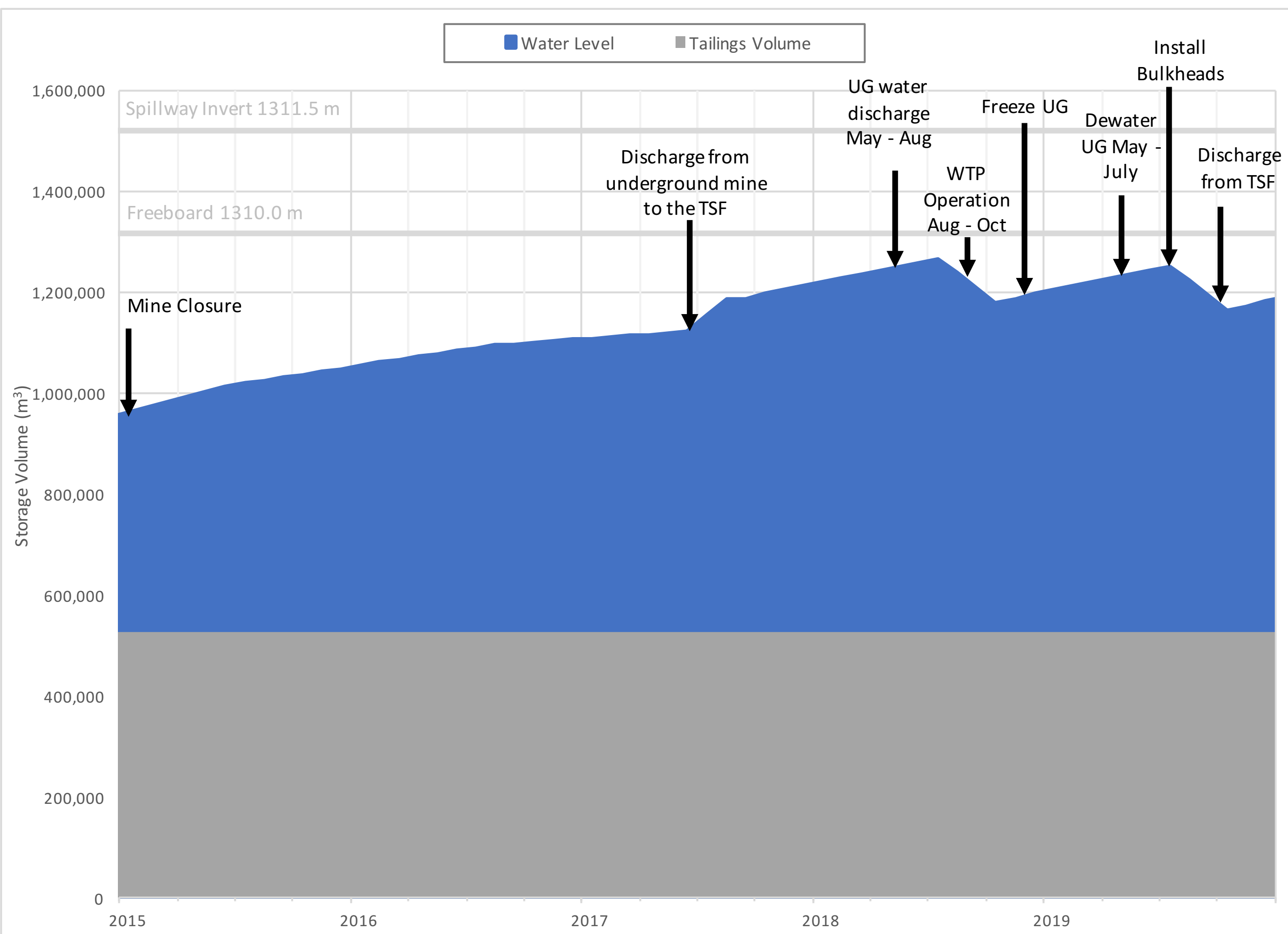

Figure 5-25: TSF Storage Balance Temporary Closure Period

5.2.3.1 Water Treatment

BQE Water (BQE) was engaged by YZC in 2017 to assess treatment options and provide recommendations for treatment of the water stored in the TSF (Appendix D). BQE completed an assessment of different treatment options for removing all constituents of concern; a selection of the most appropriate methods for lab scale testing; treatability testing of the selected treatment options to demonstrate the level of contaminant removal achievable; and development of the overall process flowsheet based on the results of tests along with scoping level cost estimates for possible implementation of the recommended treatment at Wolverine.

The key constituents of concern to be removed from the water are summarized in Table 5-10.

Table 5-10: TSF Contaminants of Concern for Treatment

Dissolved Species	Concentration in Feed, mg/L	Treatment Target, mg/L
Cu	0.429	0.015
Pb	0.11	0.02
Cd	0.0103	0.002
Zn	1.5	0.5
Ag	0.00370	0.001
Se	1.73	0.02
WAD CN	0.0513	0.025

The chemical assays of Wolverine tailings pond water revealed the following:

- Three different classes of contaminants are present in the current tailings pond water that require removal to ultralow levels for discharge: heavy metals, selenium, and WAD cyanide.
- A significant portion of the total selenium present in the water is selenocyanate and “unknown” organoselenium species that are not normally present in mine impacted waters. A significant level of removal of these species is required to meet the discharge limit yet little is known about the removal efficiency of these species by treatment systems typically considered by the mining industry.
- The water composition is indicative of highly reducing conditions in the tailings pond with elevated organic carbon and thiosulphate levels, low dissolved oxygen level, and reduced selenium species dominating in the water column.

Based on BQE’s assessment, there is no single stage treatment that would be able to remove all three classes of contaminants at the same time to the required discharge limits while producing stable residue suitable for long term disposal in the tailings pond. Instead, several treatment steps will be required to comprehensively address the contamination in the pond. Recognizing this, BQE evaluated a wide range of treatment options and narrowed these down using a set of selection criteria that take into account technical ability, residue management, risks, and costs.

The options that were advanced to bench scale testing included: sulphidization with ferric addition for metals removal, ion exchange (IX) and electrocell treatment (ERC) for selenium removal, and activated carbon adsorption and IX for polishing WAD cyanide removal. In addition, Reverse Osmosis (RO) passed through the screening criteria with the caveat that it would have to be combined with other treatment steps to ensure that all contaminants end up reporting into stable, compact solid residue.

Based on the results of BQE's assessment and bench scale tests, BQE recommends that the full scale treatment be composed of the steps summarized in Table 18-4 in shown in Figure 5-26. During temporary closure, when no new tailings are being deposited, an additional desaturation of RO retentate will need to be added to the flowsheet and recycled to the TSF pond.

Table 5-11: Recommended Treatment for Full Scale Implementation

Treatment Step	Objective	Bench Scale Test Verification
Sulphidization with ferric iron addition	Removal of all heavy metals of concern from water into solid residue suitable for disposal or blending with flotation concentrate produced at site Pre-treatment for suspended solids removal upstream of RO. Removal of WAD cyanide concentrated by RO.	Verified in study
Reverse Osmosis	Rejection of selenium and WAD cyanide	Bench scale testing not representative of actual performance
ERC treatment	Removal of selenium from RO reject water into stable solid residue suitable for disposal in the tailings pond	Verified in study

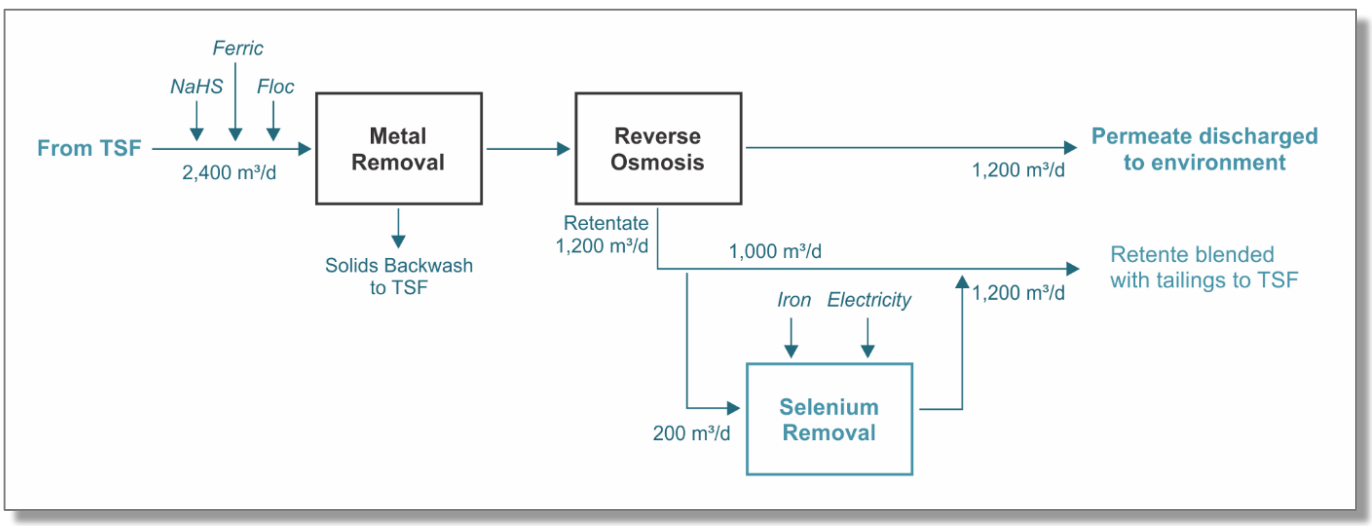

Figure 5-26: Water Treatment Plant Flowsheet

The design, construction, and installation of the WTP will be completed in 2018. As such, it is not included in the cost estimates provided in Section 8.

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 5 years of temporary closure. As such, final closure activities would commence in January 2020, 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 year period, followed by 6 years of seasonal water treatment, and completed in the final 2 years with TSF landform construction, decommissioning of water treatment and road infrastructure. 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 decommissioned infrastructure from site.

The experimental test work 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 decommissioning 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 LTF.

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)	Component	Quantity (ha)
Industrial Complex Area	**21.7**	Dam Face	2.4
Mill Buildings, Truck Shop, Offices	14.5	Diversions	0.5
		Seepage Recovery Pond	0.8
Diversion Ditches	0.5	Tailings Lines Corridor	1.8
Organic Stockpiles	2.4	Organic Stockpiles and Borrow Areas	6.0
Camp and Support Facilities	2.8		
Landfill	1.5	**Site Access Road**	**31.2**
TSF Area	**28.1**	**Mine Site Roads**	**7.0**
Impoundment	16.6	**TOTAL**	**88**

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Figure 6-1

Wolverine Mine: Site Disturbance

- Existing Road
- Mine Access Road
- Winter Road
- Tailings Pipeline
- Culvert
- Diversion Ditch
- Area of Disturbance
- Infrastructure
- Seepage Collection Pond
- Spillway Stage 2
- Pump House
- Bioreactor
- Airstrip

Date: 14/12/2016
Author: H.Seeley, P.Geo, Wolfbear Geological Consulting

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

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 5.2.2). 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). Revegetation success will be monitored as described in Section 6.9.2.

6.2 Tailings Storage Facility (TSF) Area

Ultimately, all free water in the TSF will be dewatered; however the tailings will remain saturated to prevent acid generation. The facility with be enveloped 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.

Following dewatering of the TSF, materials from Waste Rock Pad #1 and #2 (including the liners) will be deposited into the TSF. The total volume of waste rock is ~135,000 m^3 (Figure 6-2). 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 for deconstruction of the TSF are provided in Figure 6-2 and the ultimate design will be verified by the engineer of record prior to final construction.

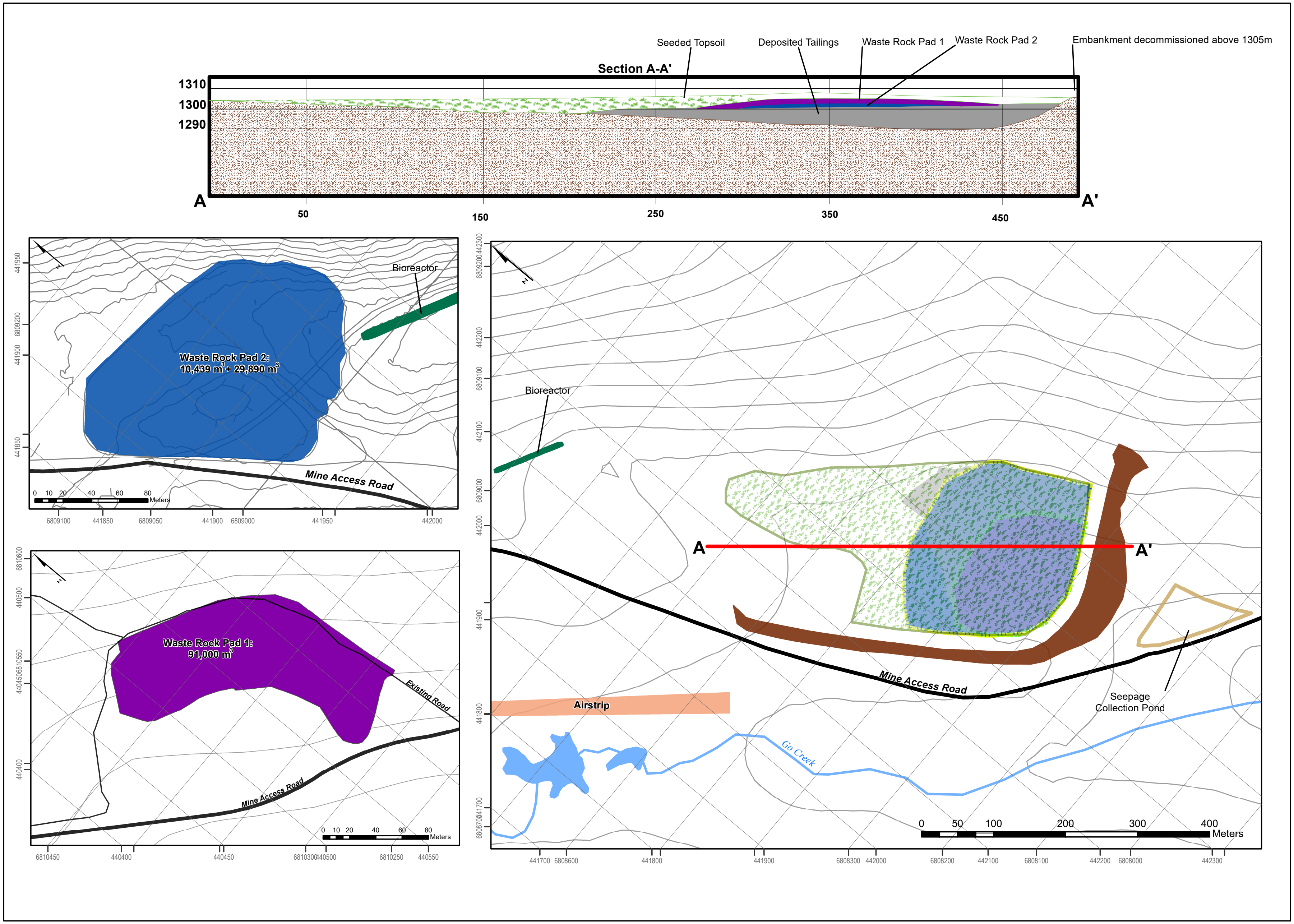

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Figure 6-2: Conceptual Waste Storage Closure Plan

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: 9/15/2017
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. Humidity cell tests indicated that the onset of acid generation under laboratory conditions could take five years for the diluted ore tailings sample. As such, this material will be kept saturated with water retained in the pore space of the tailings. Also, by surrounding the tailings and waste rock material with an impermeable liner and layering clay/sand and organics over the top to protect the liner, the potential effects of any potential acid generation are mitigated.

The TSF landform will be covered with organics and overburden material, and 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 that remains protective of the liner. 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 supernatant water will be treated via the water treatment plant described in Section 5.2.3.1. At a rate or 1200 m^3/day, with seasonal discharge May to October, it will take until Q3 2023 to fully dewater the facility down to the level of the waste rock and tailings (Figure 6-3).

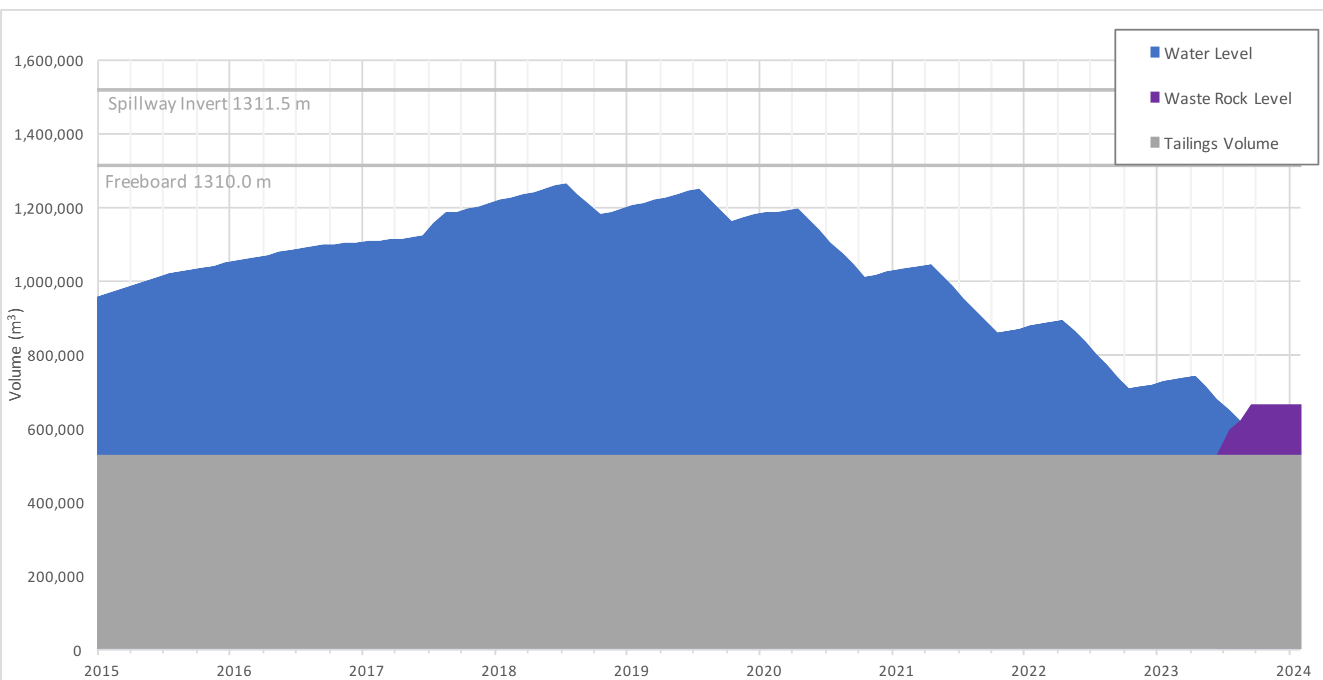

Figure 6-3: TSF Storage Balance Permanent Closure Period

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 near the end of pond dewatering (Figure 6-3). Following this work, the footprints of the waste rock pads will be reclaimed in conjunction 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 conjunction 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 landfill. 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.

Temporary camps will be required to support water treatment and final decommissioning at the mine site, and at the Robert Campbell Highway to support access road decommissioning.

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. At the end of the decommissioning phase, the landfill and storage areas will be covered with a 600 mm thick compacted layer of glacial till and graded to encourage the shedding of water. The sites will then be revegetated. Decommissioning of the landfill and waste storage area will be conducted in accordance with Commercial Dump Permit 81-014, and will follow the guidelines issued by Yukon Environment Solid Waste Regulations *Requirements for Commercial Dumps*[1], which includes submission of cell closure details to the Environmental Protections Branch.

6.5.5 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.

[1] http://www.env.gov.yk.ca/air-water-waste/documents/SOLW9RequirementsforCommercialDumps2014.pdf

Soils present in the land treatment facility during the final year of operation will be tested to determine if material is acceptable for use in reclamation programs around the industrial complex. Depending on the level of contamination, contaminated soils excavated during decommissioning may be placed in the land treatment facility for remediation for subsequent use in reclamation activities in the closure phase. If the various soils are found to contain residual contamination that does not permit use in reclamation, they will be hauled off site to an approved facility.

Once soils are removed from the facility, in accordance with an approved plan from Yukon Environment, the facility will be decommissioned, the liner disposed of in the landfill, and the area revegetated.

6.5.6 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 and quarries 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 junction 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 (2020-2023), the TSF dam will be maintained in accordance with the *Wolverine Mine Tailings Facility Operation, Maintenance and Surveillance Manual*. 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 decommissioning phase (2020-2023), surface water and groundwater monitoring will be conducted in accordance with the WUL, as outlined in Table 6-2 and Table 6-3. Once the site is fully decommissioned (>2024), annual monitoring of surface water and groundwater will be conducted for 10 years to ensure stable chemistry and flow in surface and ground water systems. Once steady state conditions have been reached, the sampling sites and frequencies should be re-evaluated.

Once the TSF is dewatered and decommissioned, site T1 will no longer be monitored, but conditions around the TSF will be monitored by groundwater well monitoring.

Table 6-2: Surface Water Quality Sampling Program During Closure

Station Number	Station Location	Watershed	Sampling Frequency	
			Decommissioning	Post-closure
T1	Tailings Barge	TSF	Monthly	-
W82	Upper Wolverine Creek	Wolverine Creek	Monthly	Annually
W9	Wolverine Creek at Little Wolverine Lake		Monthly	Annually
W1	Wolverine Lake outlet		Monthly	Annually
L1	Little Wolverine Lake		Monthly	Annually
W21	Nougha Creek at Campbell Highway		Monthly	Annually
W8	Campbell Creek		Monthly	Annually
W15	Hawkowl Creek above Go Creek	Go Creek	Monthly	Annually
W16	Go Creek below tailings facility		Monthly	Annually
W81	Go Creek below Hawkowl Creek		Monthly	Annually
W31	Go Creek above TSF		Monthly	Annually
W80*	Go Creek		Monthly (Daily when discharging)	Annually
W12	Go Creek above Money Creek		Monthly	Annually
W14	Upper Money Creek	Money Creek	Monthly	Annually
W22	Money Creek above Campbell Highway		Monthly	Annually
W40	Money Creek below Campbell Highway		Monthly	Annually
W71	Pitch Creek below road crossing	Site Access Road	Monthly	Annually
W72	Light Creek		Monthly	Annually
W73	Bunker Creek at road crossing		Monthly	Annually

Table 6-3: Groundwater Quality Sampling Program During Closure

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

Reclamation monitoring will be completed annually during the first three years after permanent closure (2024-2027). 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 occurring in the vegetation. Monitoring will continue on an annual basis during the 10 year 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

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, an evaluation of the TSF as a water management facility was conducted in 2017 (Appendix A) and water management and treatment will be conducted to maintain an appropriate water level as advised in that evaluation. Additionally, TSF dam monitoring will be carried out as per the *Tailings Facility Operation, Maintenance and Surveillance Manual* 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.

The other key risk is discharge of contaminated water to the environment. This could occur through unplanned discharge from the underground mine, or overtopping of the spillway at the TSF. This risk has been mitigated through the proposed construction and operation of a water treatment plant, and adaptive management for a bioreactor in Wolverine Creek. Sequential decommissioning starting during the temporary closure period will significantly de-risk the mine during the permanent 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 2020	Decommissioning Closure Year 1 – Year 10	Post-Closure Closure Year 11 – Year 20
Underground Mine	• Excess underground discharge will be pumped to the TSF. • The hydraulic bulkheads for the portal and ventilation raise will be installed during 2019. • Underground mine water may be treated in sump #2 if appropriate. Discharge to Go Creek will occur in May – October if water quality discharge limits are met.	• Watertight bulkheads are not expected to discharge water. • Water quality in Wolverine Creek will be adaptively managed. • Bioreactor in Wolverine Creek will only be installed if required to mitigate water quality effects. • The portal apron will be reclaimed.	• Water quality in Wolverine Creek will be monitored. • The bulkheads will be monitored to ensure they are functioning as planned. • Revegetation will be monitored to ensure it is meeting reclamation objectives.
TSF	• The TSF will continue to receive water from site and from the underground mine. • Design and installation of a water treatment plant will occur in early 2018. • Treatment and discharge of water stored in the TSF will occur May to October at a rate of 1,200 m^3/day.	• 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 the responsibility of the decommissioning contractor.	Reclamation monitoring will be ongoing during post-closure.
Land treatment facility	The LTF will remain operational.	• The LTF will accept any hydrocarbon contaminated	• Reclamation monitoring will be ongoing during post-

Component	Temporary Closure Present to January 2020	Decommissioning Closure Year 1 – Year 10	Post-Closure Closure Year 11 – Year 20
(LTF)		material in the early years of decommissioning. • Once soil quality objectives are met, the soil will be used in reclamation. • The LTF will be decommissioned in accordance with approvals from Yukon Environment. • The footprint will be revegetated.	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 Year 1 – Year 10**	**Post-Closure Year 11 – Year 20**
Underground mine	Installation of hydraulic bulkheads and closure of underground mine portals	• Lead engineer • Senior environmental consultant • Site staff • Installation contractor	• Geotechnical engineer	• Geotechnical engineer
	Wolverine Creek bioreactor construction	• 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	• Site Supervisor • Senior environmental consultant • Site staff • Water treatment design and installation consultants	• 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 • Seepage collection pond		N/A	• Site Supervisor • Senior environmental consultant	• Reclamation monitor

Closure Component		Personnel Required		
		Temporary Closure Present to January 2018	Decommissioning Year 1 – Year 10	Post-Closure Year 11 – Year 20
underground mine portal • Waste rock / stockpile footprints • Camp • Mine roads	• Airstrip • Landfill • LTF • Exploration camp and roads • Site access road		• Site staff • Construction workers	

8 Reclamation and Closure Liability

The closure cost estimate has been updated to reflect a decommissioning and post-closure period effective immediately upon the decision to close the mine. Previous estimates had included the costs during temporary closure. However, as requested by YG in a letter November 8, 2017[2], temporary closure costs included maintenance and monitoring of the site over the optional extended temporary closure period, which are not required for the calculation of total closure costs.

Therefore, the below updated costing calculations assumes permanent closure is undertaken directly after temporary closure, and there is no re-start of the mine or change in site conditions. The cost estimates assume that work will be undertaken by a third party contractor and use best available costing information.

The final reclamation and closure cost estimate is reflective of activities taking place following a decision to permanently close the mine. Previously this was preceded by the temporary closure period, but this section has been updated to remove specific dates, and just present costing on a year by year basis. The decommissioning phase is assumed to take 10 years, and the post-closure phase is assumed take 10 years. The estimates have assumed de-classification of the TSF, and that 10 years of post-closure monitoring is sufficient to establish steady state conditions and achievement of closure objectives.

Unit rates for equipment for dry conditions were obtained from Government of Yukon Third Party Equipment Rental Rates[3] and focused on contractors and rates published out of Whitehorse, Ross River, and Watson Lake. Where possible, rates out of Ross River have been used. The cost to execute activities using this equipment has also been increased to reflect the increase in unit rates for equipment.

Personnel rates are derived from the *Fair Wage Schedule,* effective April 1, 2017[4] with an increased rate to account for contractor rates, as opposed to employee rates, as advised by Yukon Government in the November 20, 2017 meeting. 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.

The unit rates used in these cost estimates are summarized in Table 8-1. Miscellaneous costs in Table 8-1 have been updated to reflect the increase in equipment costs. Surface water quality costs have also been increased by a factor of 10% to consider QA/QC sampling requirements. Several contingency measures have been discussed, but have not been included in the overall costs for temporary and decommissioning, including metals in small mammals analysis. The cost for this work is $13,800. The cost to install the biopass has been incorporated into the total closure costs (Table 8-2).

[2] Memorandum: Closure Cost and Liability Review for Yukon Zinc Corp's Wolverine Mine Site. Asterisk Mining Services Ltd. November 8, 2017.

[3] http://www.geology.gov.yk.ca/pdf/YG_Third_Party_Equipment_Rentals_2017.pdf

[4] http://www.community.gov.yk.ca/pdf/FWS_rate_update_2017.pdf

The cost to design and install the WTP has been omitted, as it is assumed to be completed in 2018, prior to permanent closure.

Table 8-2 provides a summary of reclamation and closure costs for the decommissioning and post-closure phases. An inflation rate of 1.84% was used, based on the Bank of Canada rates for the past 17 years. An interest rate of 1.65% was used based on the Bank of Canada average 5 year yield[5]. Details are provided in Appendix F. The total security requirement for the Wolverine Mine is $25,907,086.

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

Equipment	Hourly Rate	Daily Rate	Rate
Cat D8N Dozer	$350.00		$350.00
A30D Rock Truck	$300.00		$300.00
Compactor	$185.00		$185.00
Cat 320CL Excavator	$175.00		$175.00
Cat 320 Excavator + Hammer	$220.00		$220.00
Cat 14G Grader	$185.00		$185.00
Cat 950H Loader	$195.00		$195.00
Crane	$195.00		$195.00
Light-duty vehicle		$125.00	$125.00
Personnel	**Hourly Rate**	**Column1**	**Rate**
Labourer	$50.00	$50.00	$50
Camp Helper	$50.00	$50.00	$50
First Aid Attendant	$50.00	$50.00	$50
Head Cook	$50.00	$50.00	$50
Tradesman	$90.00	$90.00	$90
Site Supervisor	$95.00	$95.00	$95
Design Engineer	$104.00		$104
Project Engineer	$140.00		$140
Environmental Consultant	$130.00		$130
Project Manager			$36,000
Site Caretaker			$8,853
Environmental Monitoring Consultants			$17,569
Misc. Costs	**Units**	**Column1**	**Cost**
Excavation of Soil in Stockpile	m^3		$6
Supply and place geotextile	m^2		$12
Load, haul and place topsoil	m^3		$9
Load, haul and place tailings cover (CIM)	m^3		$12
Load, haul and place rock cover, organics, granular till and clay	m^3		$14

[5] https://www.bankofcanada.ca/rates/interest-rates/canadian-bonds/

Equipment	Hourly Rate	Daily Rate	Rate
Drill, Blast and Haul Rip Rap	m^3		$38
Place Rip Rap	m^3		$18
Camp Costs	day/person		$100
Concrete	m^3		$85
Culvert Removal (<1200mm)	each		$1,875
Culvert Removal (>1200mm or multiple/location)	each		$6,250
Flights	each		$3,855
Revegetation Rates	**Units**	**Column1**	**Cost**
Scarify	ha	D8N Dozer	$714
Revegetation Seed Mix	kg		$13
Fertilizer	kg		$1
Seed and Fertilizer Application	ha		$1,500
Erosion barrier	per linear km		$3,000
Water Treatment Rates	**Units**	**Column1**	**Cost**
Water Treatment Cost	m^3		$8.66
Monitoring Rates	**Units**	**Column1**	**Cost**
Surface water quality analysis	Sample set	225	$248
Groundwater quality analysis	Sample set	125	$138
Rainbow Trout LC50	Sample set	300	$300
Metals in Vegetation analysis	Sample set	94.5	$95
Metals in small mammals analysis	Sample set	138	$138
Fish species	Sample set	300	$300
Invertebrate species	Sample set	215	$215
Plant species	Sample set	200	$200
Algal species	Sample set	200	$200

Table 8-2: Summary of Final Reclamation and Closure Costs

Work Item Description	Description	Decommissioning Period (Year 1-4)	Post-closure Phase (Year 5-14)
Organization, Security and Overhead			
Personnel	Site supervisor, caretaker, corporate oversight, environmental monitoring, decommissioning personnel	1,076,472	
Camp Costs	Site maintenance, office supply, security, etc.	1,274,966	
Fuel	Camp Power Generation (based on 700 l/day @ $1.00/litre)	1,008,000	
Transportation	Flights and vehicles	778,452	77,100
	Sub Total	**4,137,890**	**77,100**
Decommissioning			
Tailings Storage Facility			
Decommission Diversion Ditches	Decommission ditches A & B; reclaim and revegetate	33,755	
Remove Tailings & Reclaim Pipeline	Dispose of tailings and reclaim pipelines in landfill; reclaim and revegetate	88,275	
Water Treatment	Demob and reclaim WTP site	33,050	
Construct Final TSF Landform	Overlap TSF liner; decommission stage 2 dam; cover and revegetate landform	2,955,043	
Underground Mine			
Dewatering well installation	Required to dewater in advance of bulkhead installation	122,800	
Bulkhead installations	Install bulkhead in adit and vent raise	2,064,000	
Portal & Vent Raise Closures	Place waste rock cap over tires	20,125	

Work Item Description	Description	Decommissioning Period (Year 1-4)	Post-closure Phase (Year 5-14)
Industrial Complex			
Industrial Complex + Office Buildings	Dismantle buildings, salvage materials, recontour area	776,394	
Power Supply - Gensets	Dismantle buildings, salvage materials, recontour area	57,280	
Site Diversions	Decommissioning ditches, recontour area, seed	42,375	
Water Supply Wells	Plug wells, seed area	11,885	
Explosive Magazines	Reclaim area	225	
Miscellaneous Buildings and Structures	Dismantle buildings, salvage materials, recontour area	133,590	
Industrial Reagents Fuels and Waste	Remove from site	210,000	
Spill Cleanup	Remove contaminated soils	30,000	
Waste Rock Pads	Move waste to TSF, remove liner, reclaim area	1,360,360	
Stockpiles	Reclaim temporary stockpile areas	3,600	
Land Treatment Facility	Decommission LTF, move contents to landfill once remediated, reclaim footprint	8,400	
Landfill	Cover and reclaim area	4,500	
Mine Site Roads	Remove culverts, scarify and seed	124,475	
Demolition Overhead	Supervision and admin costs	115,000	
Wolverine Creek Biopass			
Installation of 400 m long Biopass		135,739	
Access Road			
Temporary camp	Camp at the Robert Campbell Highway when reclaiming road	250,000	
Decommission and Reclaim Access Road		551,414	
Reclaim Seepage Recovery Dam		24,673	
	Sub Total	**9,156,958**	
Water Treatment			
Design WTP	Design WTP	Completed in 2017/2018	
Capital WTP	Construct and install WTP	To be completed in 2018	
Water treatment costs	Seasonal operation of WTP for 4 years to dewater the TSF	7,581,930	
	Sub Total	**7,581,930**	
Monitoring			
MMER Monitoring	Cycle 4 Biological Monitoring, Study Design and Interpretive Report; Final Biological Monitoring Study prior to Closing Mine; EEM Sublethal Toxicity Testing;	186,405	
Water Quality Analysis	Surface and groundwater quality monitoring	132,660	62,425
Metals in Vegetation analysis		11,340	11,340
Environmental Monitoring Consultants	Monthly/quarterly/annual sampling	843,324	175,693
Environmental Consultant	Monthly/annual reporting	249,600	104,000
Hydrogeological assessment	Required to improve condition of groundwater wells; assume repairs conducted as well	120,000	
Geotechnical Inspections	Annual tailings dam inspection; Dam Safety Review every 5 years; Annual earthen structures inspection	180,000	235,000
	Sub Total	**1,723,329**	**588,458**
	Sub Total	22,600,107	665,558
	Contingency	2,470,637	37,133
	Total	25,070,744	702,690
	Adjustment for Inflation	26,306,570	812,078
	NPV	25,194,015	713,071
	TOTAL SECURITY REQUIREMENT	***25,907,086***	

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Appendix A: Wolverine Mine Water Storage in TSF, August 31, 2017

Appendix B: Wolverine Tailings Storage Facility Temporary Closure Update, September 29, 2017

Appendix C: Portal Plug Design for Yukon Zinc Corp. Wolverine Mine – Yukon Territories, Golder Associates Ltd., July 2017

Appendix D: Assessment and Bench Scale Testing of Water Treatment Options for Wolverine Tailings Supernatant, BQE Water, August 29, 2017

Appendix E: Wolverine Mine Dam Safety Review Tailing Storage Facility and Earth Structures, Klohn Crippen Berger, August 2017

Appendix F: Detailed Closure Cost Estimates

Table G-1: Tailings Area

Work Item Description	Description	Equipment	Units	Quantity	Unit Cost	Total Cost
Decommission Diversion Ditches						
Decommission Diversion Ditches A & B	Regrade and contour	Cat D8N Dozer	hrs	60	350	21,000
Decommission Diversion Ditch B	Steep slopes	Cat 320CL Excavator	hrs	20	175	3,500
Revegetate and Stabilize	Seed and Fertilize area 1.56 km x 5 m	Seed and Fertilizer Application	ha	0.8	1,500	1,170
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	Seed and Fertilizer Application	ha	0.39	1,500	585
Culvert removal (800 mm)	Uncovering and removal	Culvert Removal (<1200mm)	each	4	1,875	7,500
					Sub Total	**33,755**
Remove Tailings & Reclaim Pipeline						
Remove Pipeline	Cat 320CL Excavator	Cat 320CL Excavator	hrs	150	175	26,250
Remove Pipeline	A30D Rock Truck	A30D Rock Truck	hrs	150	300	45,000
Remove Pipeline	Labour	Labourer	hrs	300	50	15,000
Reclaim area	Seed, fertilize - 3km length x 3 m corridor	Seed and Fertilizer Application	ha	0.90	1,500	1,350
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	Seed and Fertilizer Application	ha	0.45	1,500	675
					Sub Total	**88,275**
Water Treatment						
Remove WTP and Pipelines	Remove WTP	Crane	hrs	40	195	7,800
Demob WTP	Demob WTP		L.S		10,000	10,000
Decommission WTP	Regrade and contour	Cat 320CL Excavator	hrs	40	175	7,000
Decommission WTP	General labour	Labourer	hrs	120	50	6,000
Revegetate and Stabilize	Seed and Fertilize area	Seed and Fertilizer Application	ha	1	1,500	1,500
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	Seed and Fertilizer Application	ha	0.5	1,500	750
					Sub Total	**33,050**
Construct Final TSF Landform						
Landform engineering + design	detailed design		L.S			50,000
Push Stage 2 material to Stage 1	Cat D8N Dozer	Cat D8N Dozer	hrs	400	350	140,000
Remove TSF dam above 1305 level	Cat D8N Dozer	Cat D8N Dozer	hrs	400	350	140,000
Impermeable cover installation	New Liner Installation	installed	m^2	115,000	20	2,300,000
Spread dam material over TSF landform	Cat D8N Dozer	Cat D8N Dozer	hrs	300	350	105,000
Spread dam material over TSF landform	Compactor	Compactor		200	185	37,000
Load, haul and place topsoil			m^2	16,400	9	141,643
Seed and fertilize TSF landform and Stage 2 area	Seed and Fertilizer application	Seed and Fertilizer application	ha	16	1,500	24,600
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	Seed and Fertilizer application	ha	8	1,500	12,300
Reclaim borrow areas	Seed and Fertilize	Seed and Fertilizer application	ha	2	1,500	3,000
Reclamation maintenance after 1 year	Assume coverage of 50% with seed & fertilizer	Seed and Fertilizer application	ha	1	1,500	1,500
					Sub Total	**2,955,043**
					Total	**3,076,368**

Table G-2: Surface Water Sampling Stations

Station Number	Station Location	Watershed	Sampling Frequency	Notes on access
T1	Tailings Barge	TSF	Monthly	Accessible year round
W82	Upper Wolverine Creek	Wolverine Creek	Monthly	Frozen to ground November - May
W9	Wolverine Creek at Little Wolverine Lake		Monthly	Only accessible when lake is thawed
W1	Wolverine Lake outlet		Monthly	Only accessible when lake is thawed
L1	Little Wolverine Lake		Monthly	Only accessible when lake is thawed
W21	Nougha Creek at Campbell Highway		Monthly	Only accessible when road is open
W8	Campbell Creek		Monthly	Only accessible when lake is thawed
W15	Hawkowl Creek above Go Creek	Go Creek	Monthly	
W16	Go Creek below tailings facility		Monthly	
W81	Go Creek below Hawkowl Creek		Monthly	
W31	Go Creek above TSF		Monthly	Frozen to ground November - May
W80	Go Creek		Monthly	Daily required when discharging May - October
W12	Go Creek above Money Creek		Monthly	Only accessible by ATV in summer
W14	Upper Money Creek	Money Creek	Monthly	Only accessible by ATV in summer
W22	Money Creek above Campbell Highway		Monthly	Only accessible when road is open
W40	Money Creek below Campbell Highway		Monthly	Only accessible when road is open
W71	Pitch Creek below road crossing	Site Access Road	Monthly	Only accessible when road is open
W72	Light Creek		Monthly	Only accessible when road is open
W73	Bunker Creek at road crossing		Monthly	Only accessible when road is open

Table G-3: Surface Water Sampling Frequencies

	T1	W82	W9	W1	L1	W21	W8	W15	W16	W81	W31	W80*	W12	W14	W22	W40	W71	W72	W73	Total
January	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
February	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
March	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
April	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
May	1	1	0	0	0	1	0	1	1	1	1	4	0	0	1	1	1	1	1	43
June	1	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1	48
July	1	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1	49
August	1	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1	49
September	1	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1	48
October	1	1	0	0	0	1	0	1	1	1	1	4	0	0	1	1	1	1	1	43
November	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
December	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4
Total	**12**	**6**	**4**	**4**	**4**	**6**	**4**	**12**	**12**	**12**	**6**	**184**	**4**	**4**	**6**	**6**	**6**	**6**	**6**	**304**

*Daily sampling when discharging

Table G-4: Groundwater Sampling Stations

Groundwater Station	Location	Watershed	Sampling Frequency	Notes on Status
MW05-1A, 1B	Airstrip North	Go Creek	Quarterly	
MW05-2A, 2B	TSF – Southwest	TSF	Quarterly	
MW05-3A, 3B	Mine	Wolverine Creek	Quarterly	MW05-3A and -3B appear to be hydraulically connected, and are therefore redundant
MW05-4A, 4B	Mine		Quarterly	
MW05-5A, 5B	Mine		Monthly	MW05-5B needs to be re-developed
MW05-6A, 6B	Airstrip East	Go Creek	Quarterly	
MW05-7B	Mine	TSF	Quarterly	Covered with water in the seepage pond
MW06-8S, 8M, 8D	Mine	Wolverine Creek	Quarterly	Tubing has fallen into the well; which prohibits sampling
MW06-9S, 9M	Mine		Quarterly	
MW06-10S, 10M, 10D	Mine		Quarterly	Tubing has fallen into the well; which prohibits sampling
MW06-11S	Mine		Monthly	
MW06-12S	Mine		Quarterly	Needs to be re-developed
MW08-13	TSF - West	TSF	Quarterly	

Table G-5: Groundwater Sampling Frequencies

	January	February	March	April	May	June	July	August	September	October	November	December	Samples/site
MW05-1A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-1B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-2A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-2B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-3A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-3B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-4A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-4B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-5A	1	1	1	1	1	1	1	1	1	1	1	1	**12**
MW05-5B	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW05-6A	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-6B	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-7B	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW056-8S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-8M	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-8D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-9S	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW05-9D	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW06-10S	0	0	1	0	0	1	0	0	1	1	0	0	**4**
MW06-10M	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-10D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW06-11S	1	1	1	1	1	1	1	1	1	1	1	1	**12**
MW06-12S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MW08-13	0	0	1	0	0	1	0	0	1	1	0	0	**4**
Monthly Total	**2**	**2**	**16**	**2**	**2**	**16**	**2**	**2**	**16**	**16**	**2**	**2**	**80**

Table G-6: Infrastructure Decomissioning

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Industrial Complex + Office Buildings					
Remove salvageable equipment	Labourer	hrs	1,152	50	57,600
Remove salvageable equipment	Tradesman	hrs	1,128	90	101,520
Dismantle Building - Manpower	Labourer	hrs	1,152	50	57,600
Dismantle Building - Manpower	Tradesman	hrs	576	90	51,840
Dismantle Building - Equipment and Loading	Cat 320CL Excavator	hrs	160	175	28,000
Dismantle Building - Equipment and Loading	Crane	hrs	80	195	15,600
Concrete Demolition	Cat 320 Excavator + Hammer	hrs	80	220	17,600
Misc. Supplies & Tools	Misc.	L.S.			10,000
Scrap haul to landfill	A30D Rock Truck	hrs	208	300	62,400
Reslope and contour and bury	Cat D8N Dozer	hrs	80	350	28,000
Load, Haul and place topsoil	Area of 145244 m^2 x 0.25 m depth	m^3	36,311	9	313,609
Reclaim area	Seed and Fertilizer Application	ha	14.5	1,500	21,750
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	7.3	1,500	10,875
				Sub Total	**776,394**
Power Supply - Gensets					
Remove salvageable equipment	Labourer	hrs	180	50	9,000
Remove salvageable equipment	Tradesman	hrs	108	90	9,720
Salvage and remove power line and poles		L.S.			25,000
Dismantle Building - Manpower	Labourer	hrs	96	50	4,800
Dismantle Building - Manpower	Tradesman	hrs	48	90	4,320
Dismantle Building - Equipment	Cat 320CL Excavator	hrs	12	175	2,100
Dismantle Building - Equipment	Crane	hrs	12	195	2,340
				Sub Total	**57,280**
Site Diversions					
Decommission 1500 m of diversion ditches	Cat 320CL Excavator	hrs	150	175	26,250
Culvert Removal (<1200mm)	Culvert Removal (<1200mm)	L.S.	8	1,875	15,000
Reclaim area	Seed and Fertilizer Application	ha	0.5	1,500	750
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	0.3	1,500	375
				Sub Total	**42,375**
Water Supply Wells					
Remove salvageable equipment - pipeline/pumps and tank	Labourer	hrs	24	50	1,200
Remove salvageable equipment - pipeline/pumps and tank	Tradesman	hrs	24	90	2,160
Remove pipeline and haul to TSF	A30D Rock Truck	hrs	8	300	2,400
Remove pipeline and haul to TSF	Cat 320CL Excavator	hrs	8	175	1,400
Decommission water supply wells	fill with concrete	each	2	2,000	4,000
Misc. Supplies & Tools	Misc.	L.S.		500	500

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Reclaim area	Seed and Fertilizer Application	ha	0.1	1,500	150
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	0.1	1,500	75
				Sub Total	**11,885**
Explosive Magazines					
Reclaim area	Seed and Fertilizer Application	ha	0.1	1,500	150
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	0.1	1,500	75
				Sub Total	**225**
Miscellaneous Buildings and Structures					
Remove salvageable equipment	Labourer	hrs	216	50	10,800
Remove salvageable equipment	Tradesman	hrs	216	90	19,440
Remove salvageable equipment	Cat 950H loader	hrs	150	195	29,250
Dismantle Building - Manpower	Labourer	hrs	216	50	10,800
Dismantle Building - Manpower	Tradesman	hrs	216	90	19,440
Dismantle Building - Equipment and Loading	Cat 320CL Excavator	hrs	40	175	7,000
Dismantle Building - Equipment and Loading	Crane	hrs	8	195	1,560
Concrete Demolition	Cat 320 Excavator + Hammer	hrs	40	220	8,800
Reslope, contour & bury	Cat D8N Dozer	hrs	60	350	21,000
Misc. Supplies & Tools	Misc.	L.S.			2,500
Scrap haul to landfill	A30D Rock Truck	hrs	10	300	3,000
				Sub Total	**133,590**
Industrial Reagents Fuels and Waste					
Industrial Reagents - truck to Swan Hills, AB	remove from site	tonnes	50	$100.00	$5,000
Industrial reagents - incineration cost	remove from site	tonnes	50	$3,000.00	$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
Other building site contamination clean up		L.S.			15,000
				Sub Total	**30,000**
Waste Rock Pads					
Move WRD #1 to TSF	Load, haul and place tailings cover (CIM)	m^3	91,000	12.71	1,156,712
Reclaim WRD #1 footprint	Seed and Fertilizer Application	ha	0.6	1,500	900
Move WRD #2 to TSF	Load, haul and place tailings cover (CIM)	m^3	34,100	5.35	182,548
Reclaim WRD #2 footprint	Seed and Fertilizer Application	ha	1.8	1,500	2,700
Remove liners and deposit in TSF	2 liners	L.S.	2.0	8,000	16,000
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	1.0	1,500	1,500
				Sub Total	**1,360,360**

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Stockpiles					
Reclaim temporary stockpile areas	Seed and Fertilizer Application	ha	2	1,500	3,600
				Sub Total	**3,600**
Land Treatment Facility					
LTF decommissioning	Labourer	hrs	20	50	1,000
Move contents to landfill	A30D Rock Truck	hrs	10	300	3,000
Move contents to landfill	Cat 320CL Excavator	hrs	20	175	3,500
Reclaim footprint	Seed and Fertilizer Application	ha	0.4	1,500	600
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	0.2	1,500	300
				Sub Total	**8,400**
Landfill					
Reclaim Landfill area	Seed and Fertilizer Application	ha	2.0	1,500	3,000
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	1.0	1,500	1,500
				Sub Total	**4,500**
Mine Site Roads					
Lower road grade	Cat 14G Grader	hrs	60	185	11,100
Lower road grade	Cat 320CL Excavator	hrs	80	175	14,000
Lower road grade	A30D Rock Truck	hrs	80	300	24,000
Stabilize slopes	Cat 320CL Excavator	hrs	40	175	7,000
Culvert Removal (<1200mm)	Culvert Removal (<1200mm)	each	15	1,875	28,125
Scarify	Cat D8N Dozer	hrs	70	350	24,500
Reclaim mine road footprints	Seed and Fertilizer Application	ha	7.0	1,500	10,500
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	3.5	1,500	5,250
				Sub Total	**124,475**
Demolition Overhead					
Supervision	Site Supervisor	hrs	1,000.0	95	95,000
Office/Admin Costs	Contracts oversight	year	4	5,000	20,000
				Sub Total	**115,000**
Wolverine Creek Biopass					
Installation of 400 m long Biopass	see table for details	each	1		135,739
				Sub Total	**135,739**
Portal & Vent Raise Closures					
Plug portal and ventilation raise with tires	Cat 320CL Excavator	hrs	10	175	1,750
Place waste rock cap over tires	Cat 320CL Excavator	hrs	15	175	2,625
Place waste rock cap over tires	A30D Rock Truck	hrs	15	300	4,500
Supply broken rock at base of plug and discharge channel riprap	Cat 320CL Excavator	hrs	10	175	1,750
Supply broken rock at base of plug and discharge channel riprap	A30D Rock Truck	hrs	10	300	3,000
Construct rock drain at base of plug	Cat 320CL Excavator	hrs	10	175	1,750
Supply fill to seal discharge channel	Cat 320CL Excavator	hrs	10	175	1,750

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Supply fill to seal discharge channel	A30D Rock Truck	hrs	10	300	3,000
				Sub Total	**20,125**
				Total	**3,033,947**

Table G-7: Biopass Detailed Costs

Work Item Description	Description	Unit Cost	Units	Quantity	Cost
Wolverine Creek Bioreactor Installation					
Bioreactor material	Gravel	Accessible on site			
Bioreactor material	Wood Chips	$75	bag	200	$15,000
Bioreactor material	Peat	$75	bag	200	$15,000
Bioreactor material	Delivery to site	$1,200	each	4	$4,800
Excavate bypass channel	Cat 320CL Excavator	$175	hrs	60	$10,500
Excavate bypass channel	A30D Rock Truck	$300	hrs	60	$18,000
Install geomembrane liner and gravel	Cat 320CL Excavator	$175	hrs	40	$7,000
Labour for channel construction	Labourer	$36	hrs	120	$4,270
Excavate upper Wolverine Creek for bioreactor	Cat 320CL Excavator	$175	hrs	60	$10,500
Excavate upper Wolverine Creek for bioreactor	A30D Rock Truck	$300	hrs	60	$18,000
Install bioreactor mix material	Cat 320CL Excavator	$175	hrs	60	$10,500
Labour for bioreactor construction	Labourer	$36	hrs	120	$4,270
Compact the top of the bioreactor	Compactor	$185	hrs	40	$7,400
Construct collection pond and french drain	Cat 320CL Excavator	$175	hrs	60	$10,500
				Total	**$135,739**

Table G-8: Waste Pad Detailed Costs

Move Waste Pad #1 to TSF

Volume to Move:	91,000	m3 waste on pad					
	-	m3 granular till on liner					
	91,000	m3 total		3,170	m one-way distance	20	km/hr
Cycle time per trip:				Time Required:			
distance (one way)	3,170	m					
load	3	mins		17	m3 payload		
out full	10	mins		5,385	trips		
dump	1	mins		22	trips/shift per truck		
return empty	10	mins		245	truck shifts reqd		
total time	23	mins		2	trucks		
Hrs/day	12	hrs		2	shifts		
break, eqt checks	2	hrs		61	days (operating 2 shifts)		
delays	1	hrs		1	day to remove liner		
effective hour	50	mins		62	days total		
working time	10	hrs					
	475	mins					
	22	trips/shift					

Costs:

Type	**#/shift**	**Days**	**Hrs**	**$/h**	**Cost, $/d**		**Total**
Cat 320CL Exc	1	62	1,493	175	261,193		261,193
AD 30 Truck	2	62	2,985	300	895,519		895,519
						TOTAL	**1,156,712**

Move Waste Pad #2 to TSF

Volume to Move:	34,100	m3 waste on pad					
	-	m3 granular till on liner					
	34,100	m3 total		800	m one-way distance	20	km/hr
Cycle time per trip:				Time Required:			
distance (one way)	800	m					
load	3	mins		17	m3 payload		
out full	2	mins		2,018	trips		
dump	1	mins		57	trips/shift per truck		
return empty	2	mins		35	truck shifts reqd		
total time	8	mins		2	trucks		
Hrs/day	12	hrs		2	shifts		
break, eqt checks	2	hrs		9	days (operating 2 shifts)		
delays	1	hrs		1	day to remove liner		
effective hour	50	mins		10	days total		
working time	10	hrs					
	475	mins					
	57	trips/shift					

Costs:

Type	**#/shift**	**Days**	**Hrs**	**$/h**	**Cost, $/d**		**Total**
Cat 320CL Exc	1	10	236	175	41,220		41,220
AD 30 Truck	2	10	471	300	141,327		141,327
						TOTAL	**182,548**

Table G-8: Bulkhead Installation Detailed Costs

Phase	Task	Labour	Equipment	Materials & Shipping	Estimated Cost
Underground Rehab	Underground rehab for safe access to bulkhead installation site	$200,000	$50,000	$500,000	$750,000
Underground Construction	Mobilization and Setup	$31,000	$10,000	$44,000	$85,000
	Foundation Preparation	$108,000	$29,000	$0	$137,000
	Formwork Construction	$166,000	$38,000	$180,000	$384,000
	Bulkhead Form Stripping	$21,000	$10,000	$0	$31,000
	Demobilization	$38,000	$10,000	$24,000	$72,000
SCC Installation	Mobilization and setup	$58,000	$3,000	$44,000	$105,000
	SCC Pour	$63,000	$50,000	$94,000	$207,000
	Demobilization	$53,000	$3,000	$44,000	$100,000
Contact and Consolidation Grouting	Mobilization and Setup	$21,000	$3,000	$10,000	$34,000
	Contact grouting	$44,000	$5,000	$4,000	$53,000
	Consolidation Grouting	$54,000	$5,000	$18,000	$77,000
	Demobilization	$16,000	$3,000	$10,000	$29,000
				Subtotal	**$2,064,000**

Table G-9: Water Treatment Detailed Costs

~~**Engineering**~~	-	-	-	~~**Cost**~~
~~Pre-design work required for establishing design basis~~				~~$22,000~~
~~IFC engineering~~				~~$430,000~~
~~Procurement support~~				~~$52,000~~
~~Fabrication, construction and implementation~~				~~$157,300~~
~~Commissioning~~				~~$166,700~~
			~~**Subtotal**~~	~~**$748,000**~~
~~**Construction**~~	-	-	-	-
~~Metals removal~~				~~$400,000~~
~~Reverse osmosis~~				~~$1,100,000~~
~~Selenium removal~~				~~$1,600,000~~
~~RO retentate desaturation~~				~~$400,000~~
~~Shipping (allowance)~~				~~$20,000~~
			~~**Subtotal**~~	~~**$3,520,000**~~
Operating Costs	**Unit Price**	**Units**	**Consumption rate (t/a)**	**$CAD/year**
NaHS	$1,930	$/t	1.8	$3,500
Ferric iron	$3,470	$/t	7.2	$25,000
H2SO4	$269	$/t	32	$8,700
RO Reagents	$4,250	$/t	14	$60,000
RO Membranes	$30,000	set of elements	1	$30,000
Iron Anodes	$1,153	$/t	142	$164,000
Power	$0.40	$/kwh	575	$828,000
Shipping	$200	$/t	198	$39,600
Sample analysis	$248	Sample set	27	$6,683
Labour	$50	$/h	14,600	$730,000
			Subtotal	**$1,895,483**

Table G-10: Access Road Decomissioning Costs

Work Item Description	Description	Units	Quantity	Unit Cost	Total Cost
Decommission and Reclaim Access Road					
Lower road grade	Cat 14G Grader	hrs	100	$185	18,500
Lower road grade	Cat 320CL Excavator	hrs	140	$175	24,500
Lower road grade	A30D Rock Truck	hrs	140	$300	42,000
Stabilize cut/fill slopes	Cat 320CL Excavator	hrs	80	$175	14,000
Culvert Removal (<1200mm)	Culvert Removal (<1200mm)	each	69	$1,875	129,375
Culvert Removal (>1200mm or multiple/location)	Culvert Removal (>1200mm or multiple/location)	each	3	$6,250	18,750
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	Scarify	ha	31.2	$714	22,286
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	Cat D8N Dozer	hrs	30	$350	10,500
Borrow Sources- revegetate	Seed and Fertilizer Application	ha	10	$1,500	15,000
Revegetation of road surface + disturbed areas	Seed and Fertilizer Application	ha	37.5	$1,500	56,250
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	18.75	$1,500	28,125
Engineering	For major components, particularly removal of bridge			5%	25,064
Surveying	For final as-builts of new contours and stream crossings			5%	25,064
				Sub Total	**551,414**
Reclaim Seepage Recovery Dam					
Seepage Dam Regrade and Contour	Cat D8N Dozer	hrs	16	$350.00	5,600
Load, haul and place topsoil	Area of 8000 m^2 with 0.25 m depth	m^3	2000	$9	17,273
Reclaim area	Seed and Fertilizer Application	ha	0.8	$1,500	1,200
Reclamation maintenance after 1 year	Seed and Fertilizer Application	ha	0.4	$1,500	600

Sub Total	**24,673**
Total	**576,088**

Table G-11: Site Management Costs

Work Item Description	Description	Units	Unit Cost	Decommissioning Phase (Year 1-4)		Post-closure Phase (Year 5-14)		Total Cost
				Quantity	Cost	Quantity	Cost	
Site Manager	Project Manager	month	36,000	24	864,000			864,000
Camp Costs	per day per person	day	100	11,750	1,174,966			1,174,966
Site Caretaker	Security, camp operation, general maintenance	month	8,853	24	212,472			212,472
Vehicles for security and manager	light-duty vehicle	hr.	125	2,880	360,000			360,000
Site maintenance costs	general maintenance	year	10,000	4	40,000			40,000
Flights	Whitehorse charter and commercial connections	flights	3,855	53	204,315	20	77,100	281,415
Flights	Water Sampling Flights	flights	2,079	103	214,137			214,137
Mobilization, Eqt Fleet	Allowance	ea	1	50,000	50,000			50,000
Demobilization, Eqt Fleet	Allowance	ea	1	50,000	50,000			50,000
Temporary Camp Mobilization	When reclaiming road only	ea	1	25,000	25,000			25,000
Temporary Camp Rental	When reclaiming road only	months	2	50,000	100,000			100,000
Temporary Camp Mobilization	When reclaiming road only	ea	1	25,000	25,000			25,000
Fuel	Camp Power Generation (based on 700 l/day @ $1.00/litre)	$/day	700	1,440	1,008,000			1,008,000
miscellaneous office/supply/costs	miscellaneous	year	15,000	4	60,000			60,000
							Sub Total	**4,464,990**
							Total	**4,464,990**

Table G-12: Monitoring Costs

Work Item Description	Description	Unit Cost	Units	Decommissioning Phase (Year 1-4)		Post-closure Phase (Year 5-14)		Total Cost	Notes
				Quantity	Cost	Quantity	Cost		
Cycle 4 Biological Monitoring Study	Study Design Benthic & fish population sampling and analytical Interpretive report	$90,000	L.S	1	$90,000			90,000	Required by September 2020. Study Design is required 6 months before study is conducted (i.e., April 2020). Interpretive Report Required to be submitted by December 5, 2020.
Final Biological Monitoring Study prior to Closing Mine	Final Study Design Final Biological Monitoring Studies (benthic and fish population) Final Interpretative Report	$90,000	L.S	1	$90,000			90,000	Biological monitoring study must be completed during a 3 year period after the operator gives notice to ECCC that the mine is intended to be closed
EEM Sublethal Toxicity Testing	Fish species	$300	each	4	$1,200			1,200	Once per year during discharge
	Invertebrate species	$215	each	4	$860			860	Once per year during discharge
	Plant species	$200	each	4	$800			800	Once per year during discharge
	Algal species	$200	each	4	$800			800	Once per year during discharge
Surface Water Quality Analysis	Surface water quality sampling required monthly at all sites; and weekly at station W80 when discharging (May - October) during decommissioning. Annual sampling required at all sites post-closure.	$248	samples/ year	94	$93,060	18	$44,550	137,610	
Groundwater Quality Analysis	Quarterly sampling at all sites required during decommissioning. Annual sampling at all sites post-closure.	$138	samples/ year	72	$39,600	13	$17,875	57,475	
Metals in Vegetation analysis	Collection and analysis for metals in lichen, willow and horsetail	$95	L.S	1	$11,340	1	$11,340	22,680	If statistical increases in metal concentrations in plants are found, conduct metal analysis in small mammals
Environmental Monitoring	Monthly/quarterly/annual sampling	$17,569	sampling period	48	$843,324	10	$175,693	1,019,017	Monthly sampling during decommissioning; annual

Work Item Description	Description	Unit Cost	Units	Decommissioning Phase (Year 1-4)		Post-closure Phase (Year 5-14)		Total Cost	Notes
				Quantity	Cost	Quantity	Cost		
Consultants									sampling post-closure
Environmental Consultant	Monthly/annual reporting	$130	hour	1920	$249,600	800	$104,000	353,600	40 hours/month during decommissioning for monthly and annual reporting; 80 hours per year post-closure for annual reporting
Geotechnical Inspections	Annual tailings dam inspection	$20,000	year	4	$80,000	1	$150,000	230,000	
	Dam Safety Review every 5 years	$80,000	each	1	$80,000	1	$80,000	160,000	Assume declassification of the dam in post-closure
	Annual earthen structures inspection	$5,000	year	4	$20,000	1	$5,000	25,000	
TOTAL DECOMMISSIONING PHASE COSTS								**1,600,584**	
TOTAL POST-CLOSURE PHASE COSTS								**588,458**	
TOTAL PERMANENT CLOSURE COSTS								**2,189,042**	

Table G-13: NPV and Inflation Calculations

Work Item Description	Description	Decommissioning Period				Post-closure Phase									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Organization, Security and Overhead															
Personnel	Site supervisor, caretaker, corporate oversight, environmental monitoring, decommissioning personnel	269,118	269,118	269,118	269,118										
Camp Costs	Site maintenance, office supply, security, etc.	318,741	318,741	318,741	318,741										
Fuel	Camp Power Generation (based on 700 l/day @ $1.00/litre)	252,000	252,000	252,000	252,000										
Transportation	Flights and vehicles	194,613	194,613	194,613	194,613	7,710	7,710	7,710	7,710	7,710	7,710	7,710	7,710	7,710	7,710
	Sub Total	**1,034,472**	**1,034,472**	**1,034,472**	**1,034,472**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**	**7,710**
Decommissioning															
Tailings Storage Facility															
Decommission Diversion Ditches	Decommission ditches A & B; reclaim and revegetate		33,755												
Remove Tailings & Reclaim Pipeline	Dispose of tailings and reclaim pipelines in landfill; reclaim and revegetate			88,275											
Water Treatment	Demob and reclaim WTP site				33,050										
Construct Final TSF Landform	Overlap TSF liner; decommission stage 2 dam; cover and revegetate landform				2,955,043										
Underground Mine															
Dewatering well installation	Required to dewater in advance of bulkhead installation	122,800													
Bulkhead installations	Install bulkhead in adit and vent raise	2,064,000													
Portal & Vent Raise Closures	Place waste rock cap over tires	20,125													
Industrial Complex															
Industrial Complex + Office Buildings	Dismantle buildings, salvage materials, recontour area	388,197	388,197												
Power Supply - Gensets	Dismantle buildings, salvage materials, recontour area	28,640	28,640												
Site Diversions	Decommission ditches, recontour area, seed			21,188	21,188										
Water Supply	Plug wells, seed area				11,885										

Work Item Description	Description	Decommissioning Period				Post-closure Phase									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Wells															
Explosive Magazines	Reclaim area	225													
Miscellaneous Buildings and Structures	Dismantle buildings, salvage materials, recontour area	133,590													
Industrial Reagents Fuels and Waste	Remove from site	210,000													
Spill Cleanup	Remove contaminated soils			30,000											
Waste Rock Pads	Move waste to TSF, remove liner, reclaim area			680,180	680,180										
Stockpiles	Reclaim temporary stockpile areas	3,600													
Land Treatment Facility	Decommission LTF, move contents to landfill once remediated, reclaim footprint				8,400										
Landfill	Cover and reclaim area				4,500										
Mine Site Roads	Remove culverts, scarify and seed			62,238	62,238										
Demolition Overhead	Supervision and admin costs	28,750	28,750	28,750	28,750										
Wolverine Creek Biopass															
Installation of 400 m long Biopass		135,739													
Access Road															
Temporary camp	Camp at the Robert Campbell Highway when reclaiming road				250,000										
Decommission and Reclaim Access Road					551,414										
Reclaim Seepage Recovery Dam					24,673										
	Sub Total	**3,135,666**	**479,342**	**910,630**	**4,631,320**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Water Treatment															
Water treatment costs	Operation of WTP May - October for 4 years to dewater	1,895,483	1,895,483	1,895,483	1,895,483										
	Sub Total	**1,895,483**	**1,895,483**	**1,895,483**	**1,895,483**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Monitoring															
MMER Monitoring	Cycle 4 Biological Monitoring, Study Design and Interpretive Report; Final Biological	183,660	915	915	915										

Work Item Description	Description	Decommissioning Period				Post-closure Phase									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
	Monitoring Study prior to Closing Mine; EEM Sublethal Toxicity Testing;														
Water Quality Analysis	Surface and groundwater quality monitoring	33,165	33,165	33,165	33,165	6,243	6,243	6,243	6,243	6,243	6,243	6,243	6,243	6,243	6,243
Metals in Vegetation analysis			11,340			11,340									
Environmental Monitoring Consultants	Monthly/quarterly/annual sampling	210,831	210,831	210,831	210,831	17,569	17,569	17,569	17,569	17,569	17,569	17,569	17,569	17,569	17,569
Environmental Consultant	Monthly/annual reporting	62,400	62,400	62,400	62,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
Hydrogeological assessment	Required to improve condition of groundwater wells; assume repairs conducted as well	120,000													
Geotechnical Inspections	Annual tailings dam inspection; Dam Safety Review every 5 years; Annual earthen structures inspection	25,000	25,000	105,000	25,000	235,000									
	Sub Total	**635,056**	**343,651**	**412,311**	**332,311**	**280,552**	**34,212**	**34,212**	**34,212**	**34,212**	**34,212**	**34,212**	**34,212**	**34,212**	**34,212**
	Sub Total	6,700,677	3,752,948	4,252,896	7,893,586	288,262	41,922	41,922	41,922	41,922	41,922	41,922	41,922	41,922	41,922
	Contingency	458,579	380,846	470,537	1,160,675	14,799	2,482	2,482	2,482	2,482	2,482	2,482	2,482	2,482	2,482
	Total	7,159,256	4,133,794	4,723,433	9,054,261	303,060	44,403	44,403	44,403	44,403	44,403	44,403	44,403	44,403	44,403
	Adjustment for Inflation	7,290,986	4,287,317	4,988,993	9,739,274	331,987	49,537	50,448	51,376	52,322	53,284	54,265	55,263	56,280	57,316
	NPV	7,172,637	4,149,262	4,749,969	9,122,147	305,903	44,904	44,988	45,072	45,156	45,240	45,325	45,410	45,494	45,580
	TOTAL SECURITY REQUIREMENT	***25,907,086***													