7 Tailings Facility

Table 7-1 provides a summary of the reviewer comments and the location of the response.

Table 7.1-1 Tailings Facility Table of Conformance

Reviewer	EAR Section	Reviewer Comment	Response Report Section Where Addressed
7 Tailings Facility			
Environment Canada; Natural Resources Canada; SRK Consulting	Section 2.8	**Operating Water Cover Depth** Relocate tailings within the TMF so an even water cover of at least 1 m can be achieved (keeping in mind sludge stability requirements); place a granular cover over the potential beach areas such that a saturated or wet cover can be maintained during dry years; or place an oxygen consuming cover over the potential beach areas. A conceptual monitoring program should be provided.	Section 7.6
Environment Canada	Section 2.8	**Operating Water Cover Depth – Sensitivity Testing** There is insufficient information available in the document to fully assess whether the tailings pond would be fully protected with an adequate cover under all expected hydrologic events.	Section 7.6; Appendix F3
Environment Canada	Section 2.8	**Modeling – Sensitivity Testing** It appears that modeling has not been conducted for post-closure seasonal effects of the hydrologic budget on water cover depth and ensuing water quality.	Section 9; Appendix F3
Environment Canada	Section 2.8	**Rationalization for Facility Design** It isn't clear that the hydrologic estimates used in designing the facility and predicting closure water quality are supported by site data. Additionally, it appears that hydrogeologic conditions at the new tailings impoundment site are only marginally understood. It also is not clear whether the proponent will need to maintain the upper diversion of Go Creek. This needs to be investigated and the results presented as a component of rationalization for facility design.	Section 7.6; Appendix F3
Environment Yukon; Environment Canada	Section 2.8	**Baseline Groundwater Quality** Regarding groundwater under the tailings facility, there is a need to demonstrate what effect the tailings impoundment will have on the underlying groundwater quality.	Sections 7.6 and 7.2
Environment Canada	Section 2.8.3.3	**Tailings Supernatant – Aging Tests** A summation of tailings supernatant aging tests are presented in the EAR. It is very difficult to discern, however, which of the test results the proponent has chosen as being most representative of overall tailings supernatant.	Section 7.4

Reviewer	EAR Section	Reviewer Comment	Response Report Section Where Addressed
Environment Canada	Section 2.8.3.3; Table 2.8-5	**Tailings Supernatant Testing** The test conditions need to be stated, and the full dataset is required to properly understand the chemistry evolution and assess this aspect of the project. The modeling runs should be revisited once the full dataset is available. What may be expected when recycled water reports to the process and then once again to the tailings pond – could there be enrichment for any of the metals or other contaminants? It isn't clear throughout the discussion of tailings supernatant just which sample the proponent suggests is most representative of "typical tailings."	Section 7.4
Environment Yukon; Natural Resources Canada	Section 2.8.3.3	**Tailings Column Leach Test Data Missing** Column leach data should be included in the report. A very short leaching period was conducted on some samples. The testing program needs to be detailed including: methodology, sample size, leachate volumes collected, throughput rate, pore volumes extracted, and other information pertinent to understanding and interpreting the results.	Appendix F2
Environment Yukon	Section 2.8	**Recycled Water Model** The whole EAR water quality hinges on the recycle program so if the recycle proves not acceptable in the mill then we might as well throw the water quality part of the EAR out.	Section 9
Environment Yukon	Section 2.8.3.3	**Tailings Impoundment Water Quality Model** This data is needed to gain insight into the whole data process.	Appendix F3
Environment Yukon	Section 2.8	**Oxidation Rate of the Raw Tailings** No data provided any indication what the oxidation rate of the raw tailings will be.	Appendix F2
SRK Consulting	Section 2.8	**Slope Stability Analysis** YZC should provide a preliminary slope stability analysis for both tailings embankment configurations and under static and pseudo static conditions. YZC should also address the liquefaction potential of the foundation soil under the design earthquake conditions.	Section 7.7
SRK Consulting	Section 2.8	**Seepage Analysis** Preliminary seepage analysis should be provided	Sections 7.5 and 7.6.4

Reviewer	EAR Section	Reviewer Comment	Response Report Section Where Addressed
SRK Consulting; YTG - Environment Yukon	Section 2.8.6; Section 2.9.5; Tables 2.8-9 and 2.8-10; Figure 2.8-10	**Water Balance** It is recommended that YZC provide the basis of the evaporation, runoff, snowmelt and direct precipitation in the discussion, on the tables and in the drawings, or at least a cross reference to a report or appendix where this can be found. Specific details of the runoff calculations should be presented in this section or a reference location provided	Sections 2.2,.2.3, 5.1 and 9; Appendix F3
SRK Consulting	Section 2.8	**Closure Water Cover** YZC should clarify how a water cover will be maintained over the tailings after closure.	Section 7.10
SRK Consulting	Section 2.8	**Diversion Ditches** YZC should demonstrate that during operation of the mine, the diversion ditch from the main tributary of Go Creek is able to divert water away from the tailing impoundment during an extreme flood event.	Section 7.9
SRK Consulting	Section 2.8	**Seepage Recovery Pond** YZC should provide preliminary details of the emergency spillway in the Seepage Recovery Dam.	Section 7.5
YTG - Environment Yukon	Section 2.8.6; Section 7.4.2.2	**Diversion Ditch Steam Flows** The surface water management for the tailings impoundment includes a ditch to divert water from Go Creek into the tailings basin to store water required for the start up of the facility. This plan should be reassessed in light of possibility that annual and monthly flows may have been significantly overestimated.	Section 7.9
Natural Resources Canada	Section 2.9, Section 7.6	**Seepage from the Tailings Management Facility** There is not sufficient information on the analyses of seepage from the tailings impoundment.	Sections 7.5 and 7.6
Natural Resources Canada	Section 2.4.1.3; Section 2.8.7; Section 2.8.8; Section 7.15.1	**Seismic Impacts** A technical study of the tailings impoundment is required, including a more in depth review of seismic risks.	Section 7.2
Natural Resources Canada	Section 2.2.7	**Perpetual Maintenance of the Tailings Dam** Considerations of perpetual maintenance of the tailings dam, a breach of which may result in exposure of acid-generating tailings, leading to acidic drainage, metal leaching and the associated consequences.	Section 7.5
YTG - Environment Yukon	Section 2.8	**Effects on Go Creek** Monitoring of the tailings pond water quality and Go Creek will be required until water chemistry is stable or improving.	Section 9.5

Reviewer	EAR Section	Reviewer Comment	Response Report Section Where Addressed
Environment Canada	Section 2.8	**Supporting Data** Site investigations are indicated, however the supporting data/information (test pit logs, drill logs, etcetera) is not present.	Appendices F1, F2 and F3
Environment Canada	Section 2.8	**Water Balance** The water balance appears to be assuming full interception of groundwater impacted by tailings pore water seepage during operation. Is this attainable?	Section 7.6
Environment Canada	Section 2.8	**Tailings ABA Testwork** This table should be supported by the full dataset of twelve samples, and including the AP data and results for metals content. There should also be information presented to indicate where samples were obtained from the orebody to assess sample representativeness.	Appendices C1, C2, C3 and F2
Environment Canada	Section 2.8	**CCME Guidelines** Discussion and presentation within this section seems to indicate a general unawareness of CCME guideline values for Al, Ag, Fe, Hg, and Mo.	Section 9.1
Environment Canada	Section 2.8; Table 2.8-2	**Incomplete Databases** The information needs to be supported by the full dataset.	Appendices F1, F2 and F3
Environment Canada	Section 2.8	**MMER Discharge Limits** There is considerable experience in the Yukon for setting discharge standards relative to receiving water assimilative capacity and in concert with an understanding of best applicable technology / mitigative strategies for controlling contaminant releases from an operation.	Section 9
Environment Canada	Section 2.8; Table 2.8-3; Figure 2.8-1	**Dam Borrow Materials** It is difficult to envisage that dam borrow material would be taken from within the dam footprint (pit 05-78 and Fig. 2.8-1) – we assume the material tested is consistent with actual defined borrow sources.	Section 7.8
Environment Canada	Section 2.8	**Dilution of Effluent** Improvements on effluent toxicity via “dilution” is not necessarily linear. Much depends upon the chemical characteristics of the effluent as well as that of the water that effluent is discharged to.	Section 9
Environment Canada	Section 2.8	**Tailings Shake Flask Tests** Test conditions and the full supporting dataset should be included with this document in order to understand the geochemistry.	Appendix F2
Environment Canada	Section 2.8	**Tailings Impoundment Water Quality Model** The work behind the tailings impoundment water quality model is required in order to assess this aspect of the project	Appendix F3

Reviewer	EAR Section	Reviewer Comment	Response Report Section Where Addressed
Environment Canada	Section 2.8	**Artesian Conditions** Artesian conditions are suggested (at least during some parts of the year) for the impoundment area. Details need to be presented.	Section 7.2
Environment Canada	Section 2.8	**Water Balance – Sensitivity Testing** This work needs to be completed as well the proponent needs to indicate seasonal fluctuations for wet and for dry year conditions. The source data needs to be produced, and that underlying hydrologic and hydrogeologic (and climatic) estimates which are so important to the calculations and modeling used to derive the data in these tables needs to be confirmed with site data.	Appendix F3
Yukon Dept. of Tourism & Culture; Frances Lake Wilderness Lodge and Tours	Section 2.7	**Downstream Water Impacts** There is no reference to the potential for contamination of water flowing to rivers or lakes utilized for recreation. Is this a realistic concern, and is it addressed?	Sections 7.5 and 9

7.1 Introduction

This section provides an update to the Environmental Assessment Report (EAR) Section 2.8 and incorporates information pertaining to questions and comments provided by reviewers, with respect to the Wolverine Tailings Facility.

Figure 7.1-1 shows the general arrangement plan for the tailings facility and associated structures. The tailings facility is designed to store mine tailings, fine gravel produced with a dense media separation in the mill (DMS) and potentially acid generating waste rock. The material will be stored in an impoundment formed with an earthfill dam and will be lined with a geomembrane and constructed in two stages. Surface water will be diverted around the impoundment and a spillway will be constructed at each stage. The facility is designed to store material for at least 12 years.

Figure 7.1-1 Tailings Facility General Arrangement (Figures Section)

This report presents the following:

- Section 7.2 summarizes the site conditions.
- Section 7.3 presents the results of the site investigation and laboratory testing programs and presents the geotechnical characterization of the site and construction materials.
- Section 7.4 presents a summary of the geochemistry testing and the main conclusions with respect to geochemical characterization of the waste materials and process water quality.
- Section 7.5 presents the design criteria basis for the project.
- Section 7.6 presents the impoundment design, which includes the deposition plan, water balance, liner design and the water quality management plan.
- Section 7.7 presents the dam design and stability analysis of the dam.
- Section 7.8 presents the environmental management and monitoring plan for the facility.
- Section 7.9 presents the water management plan for the tailings facility, including diversion ditches and spillways.
- Section 7.10 presents the closure plan.

7.2 Site Conditions

7.2.1 General

The tailings facility is located within a natural, northwest-southeast trending elongated depression (ephemeral stream), perched on the northeast valley slope of Go Creek, as shown on Figure 7.1-1, near elevation 1300 m. The depression is flanked on the downhill side by a natural ridge trending in the same direction that drops gently in elevation toward the upstream edge of the impoundment, and ends at the turning point of the L-shaped dam.

The topography of the area consists of gently rolling hills and mountains, with elevation ranges up to 1800 m area. The tailings impoundment area is covered with small shrubs and grasslands.

Picture 7.2-1 presents a photograph of the tailings facility area looking northeast, with the tailings impoundment to the left and the right abutment ridge on the left of the photo.

Picture 7.2-1 Photograph of Tailings Facility General Area

7.2.2 Geology

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).

Figure 7.2-1, reproduced from Mougeot (1966), shows the Quaternary surficial geology units in the area. This local mapping is in general agreement with the regional setting presented by Jackson (1993, 1994) and Dyke (1990). The main glacial soils in the vicinity of the tailings impoundment consist of up to 20 m of silty, sand and gravel, with cobbles.

Superimposed on the drawing is the approximate exploration bedrock geology map prepared by Expatriate (2004). 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/arigillic sediments, overlain with basalt. The iron formation, which hosts the ore zone, trends northwest-southeast throughout the project area.

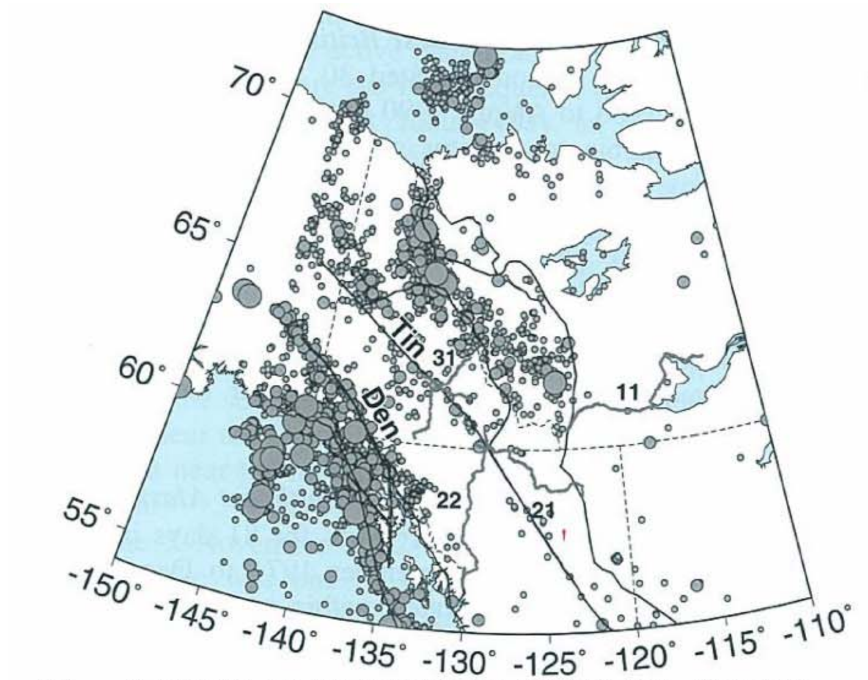
Figure 7.2-1 Surficial and Bedrock Geology Plan (Figures Section)

7.2.3 Seismicity

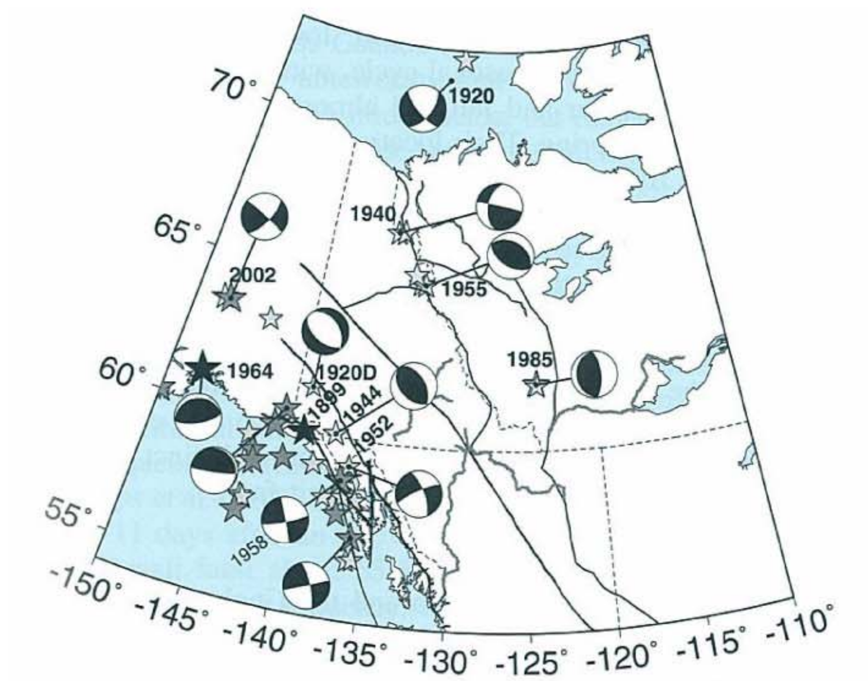
The regional seismicity is shown in Figure 7.2-2A, and the largest historical earthquakes (equal or greater than magnitude 6) are shown in Figure 7.2-2B (Cassidy et al. 2005). The most seismically active region is along the plate boundaries in the coastal and offshore area. The most significant inland 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 aseismic, with relatively few and small earthquakes. There appears to be an alignment of epicentres along the Tintina fault. However, these are all very small earthquakes (M_L less than 3), and most of the activity is at the northern end, close to the Alaska border. Farther inland, the only significant seismicity is along the eastern edge of the Cordillera, more than 600 km from the active plate boundary. This fold and thrust belt seismicity is concentrated in two areas: the MacKenzie-Ogilvie mountains region and the Richardson Mountains region (Hyndman et al. 2005).

Data on recent earthquakes that occurred within about 600 km from the project site (61.41°N and 130.09°W) from September 1899 to December 2005 was extracted from the Canadian EPB/GSC/PGC database. The epicenters of these events, with magnitude equal to or greater than 3, are plotted in Figure 7.2-3. 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 project site with a focal depth of 5 km on May 12, 1999.

The probabilistic seismic hazard assessment has been updated to use both the GSC-H and GSC-R seismic source zonal models developed by the Geological Survey of Canada for the new National Building Code of Canada-NBCC 2005 (Adams and Halchuk 2003). The GSC-H seismogenic zonal boundaries within Western Canada and the approximate location of the project site are shown in Figure 7.2-4. Moreover, the update incorporated the work conducted by Atkinson (2004) for a site-specific seismic hazard analysis for Faro, Yukon (62.2°N and 133.2°W). In that analysis, an apparent linear alignment of seismicity in the region along the Tintina Trench fault system was grouped into a Tintina seismic source zone. Figure 7.2-5A shows the boundary of Tintina source zone and seismicity in the region and Figure 7.2-5B shows the recurrence relationship used to characterize the source zone. This Tintina source zone was incorporated in the updated model for computing site peak horizontal acceleration as shown in Table 7.2-1 and Figure 7.2-6. De-aggregation of the seismic hazard corresponding to the 10,000-year return period for the peak horizontal ground acceleration was carried out to evaluate relative contributions of earthquake sources in terms of magnitude and epicentral distance. Figure 7.2-7 presents the calculated magnitude-distance de-aggregation for the peak horizontal ground acceleration of 0.22 g at the Wolverine site. The mean magnitude is 6.1, and mean epicentral distance is 34.8 km.



(A) – SEISMICITY OF NORTHWESTERN CANADA AND ADJACENT PARTS OF ALASKA DURING THE PERIOD 1899–2002



(B) – LOCATIONS OF THE LARGEST (M>6) EARTHQUAKES IN THE NORTHERN CANADIAN CORDILLERA

Figure 7.2-2 Regional Seismicity

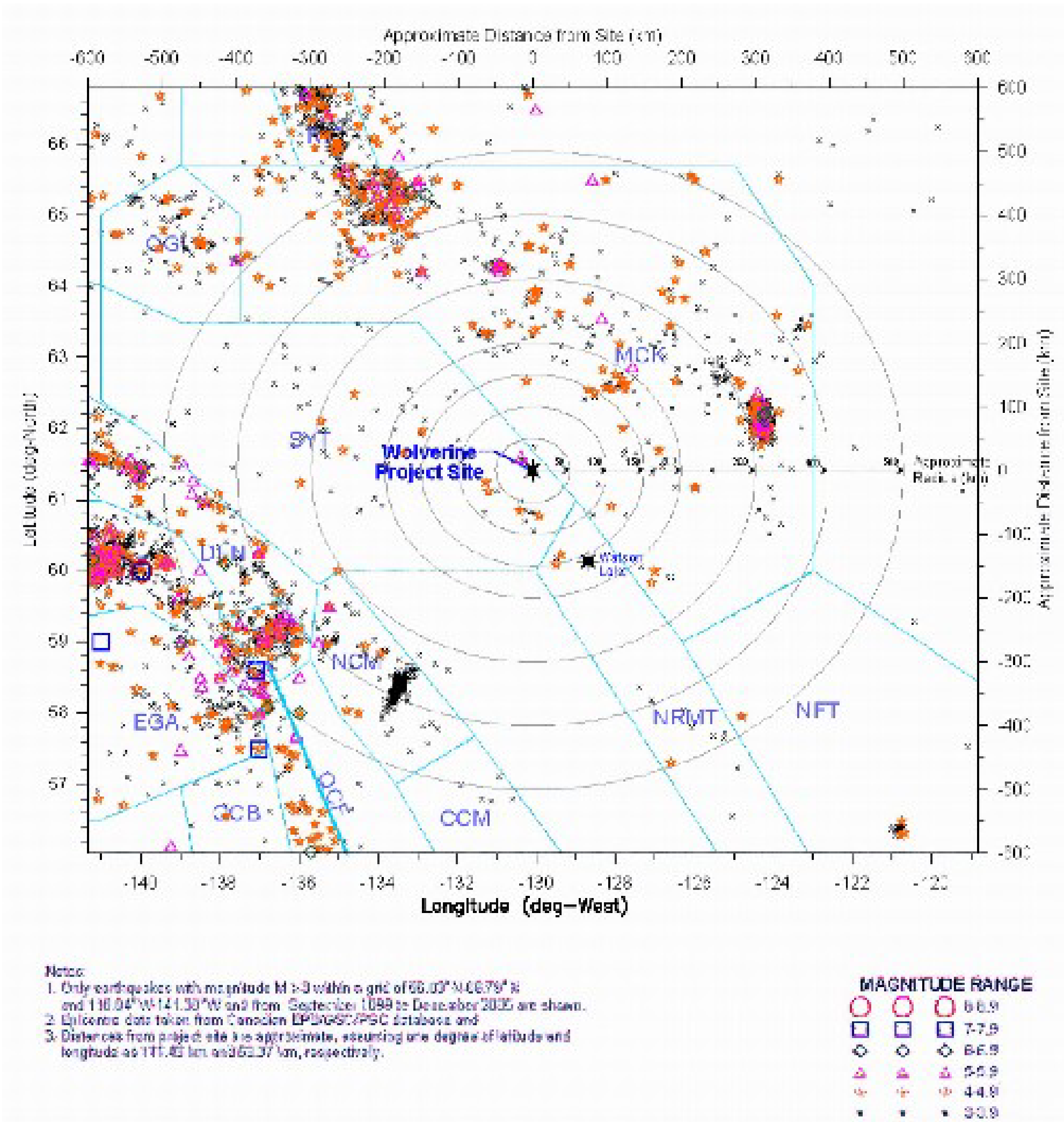
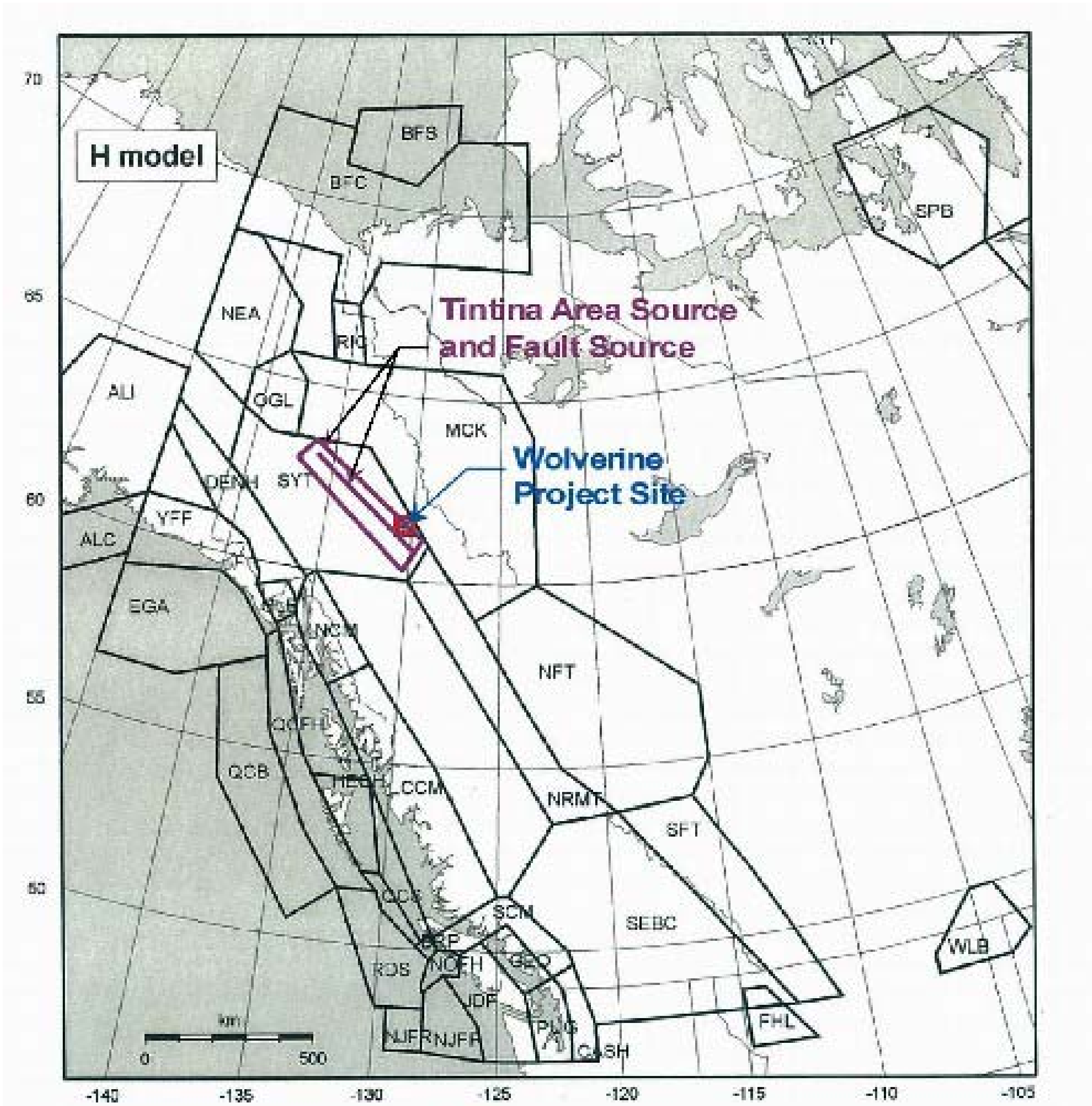
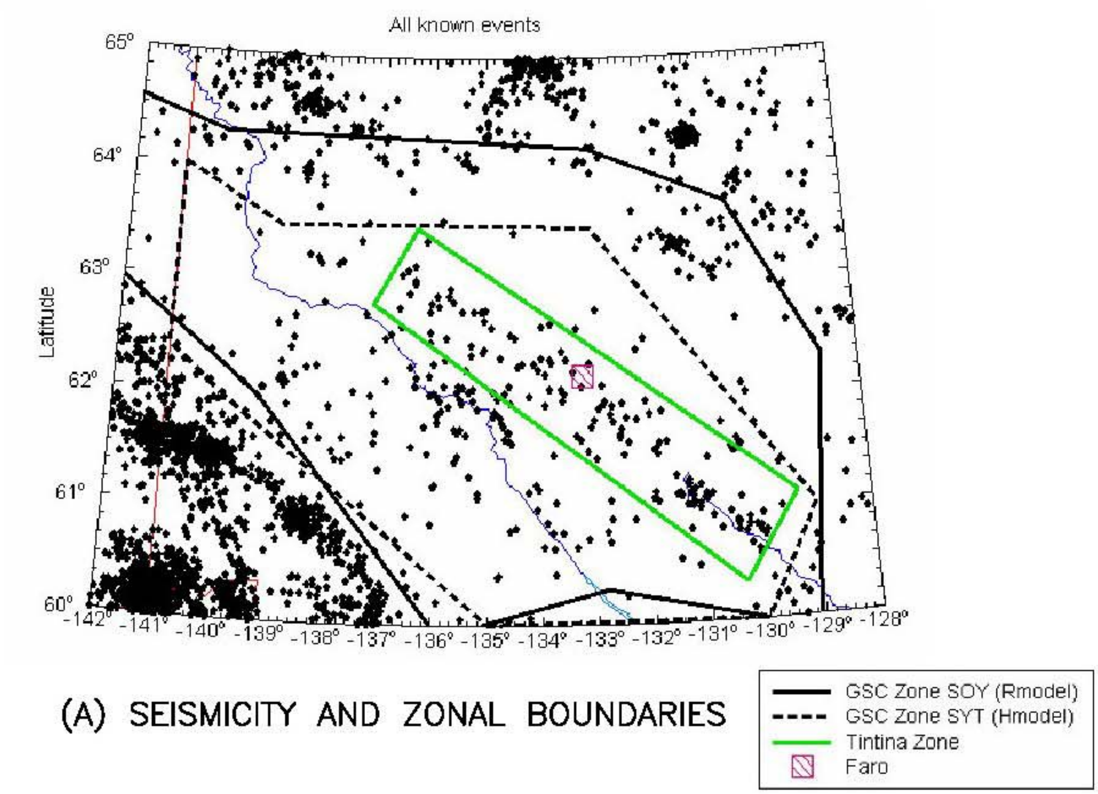


Figure 7.2-3 Location Map of Recent Regional Epicentres

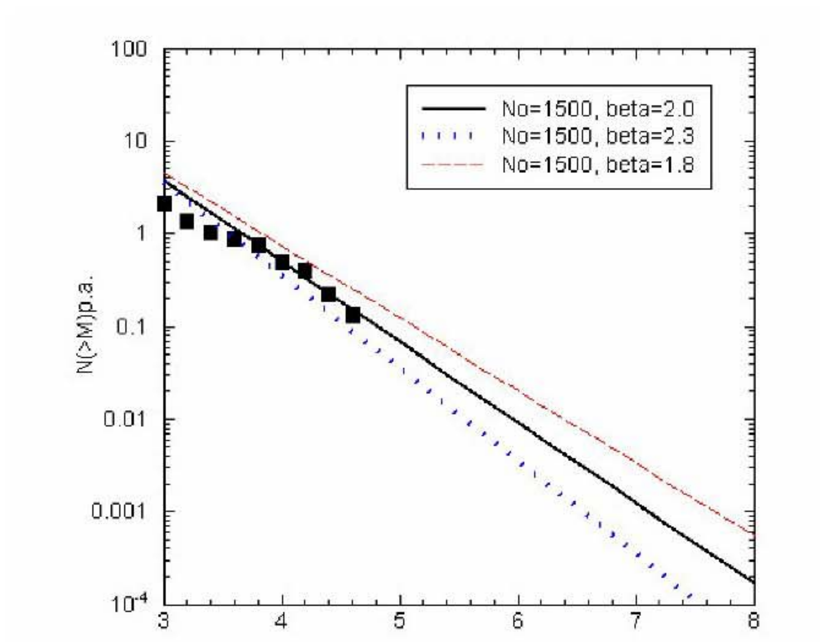


Notes:
(1) This map is taken from Adams, J. and Halchuk, S. (2003), Fourth Generation Seismic Hazard Maps of Canada, Geological Survey of Canada Open File 4459.
(2) Area source zone and fault source for the Tintina Trench are located approximately on this figure.

Figure 7.2-4 Seismogenic Zonal Map – 2005 NBCC H Seismicity Model



(A) SEISMICITY AND ZONAL BOUNDARIES



(B) MAGNITUDE RECURRENCE RELATION

Figure 7.2-5 Characteristics of Tintina Source Zone

Table 7.2-1 Probabilistic Evaluation of Peak Horizontal Ground Acceleration at Project Site

Annual Probability of Exceedance	Return Period (years)	Peak Ground Acceleration PGA (g)	
		GSC-H 2005 Model	GSC-H 2005 Model with Tintina Source zone
0.0021	475		0.097
0.001	1,000		0.12
0.00040	2,475		0.15
0.0001	10,000		0.22

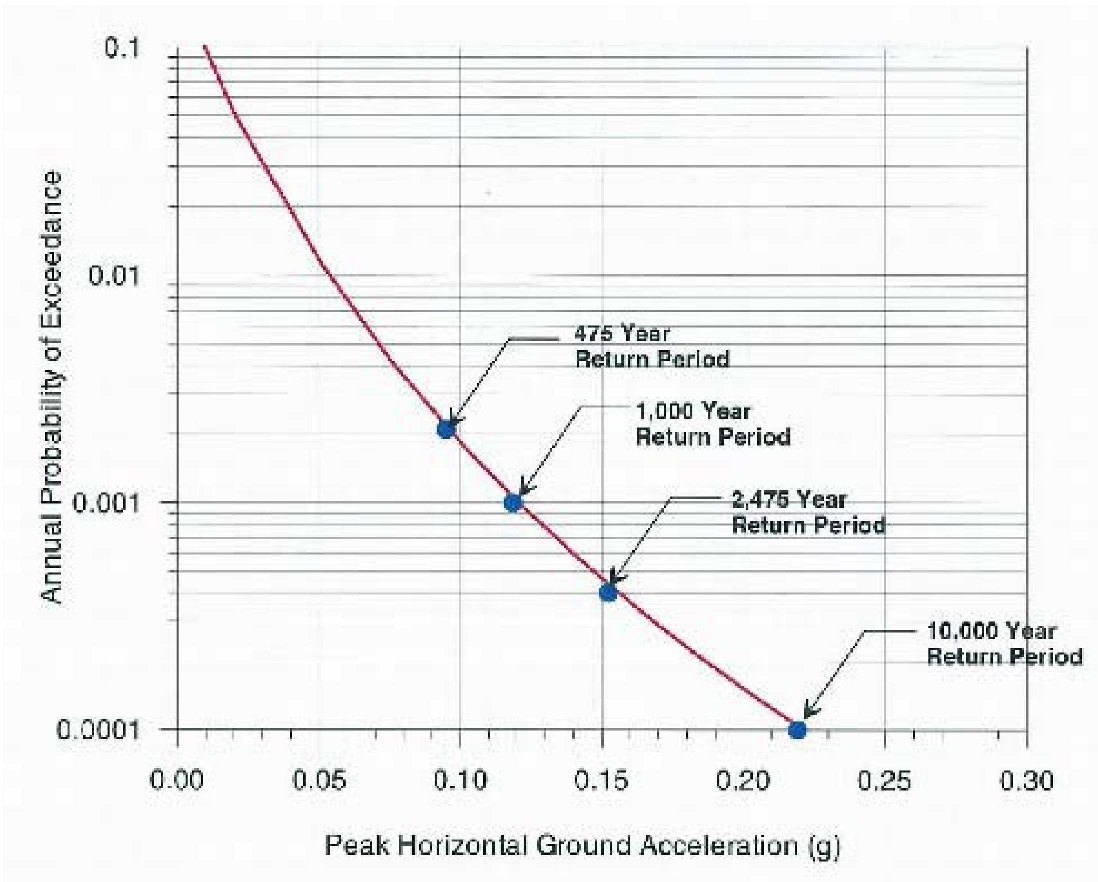


Figure 7.2-6 Peak Horizontal Ground Acceleration at Various Probability of Annual Exceedance

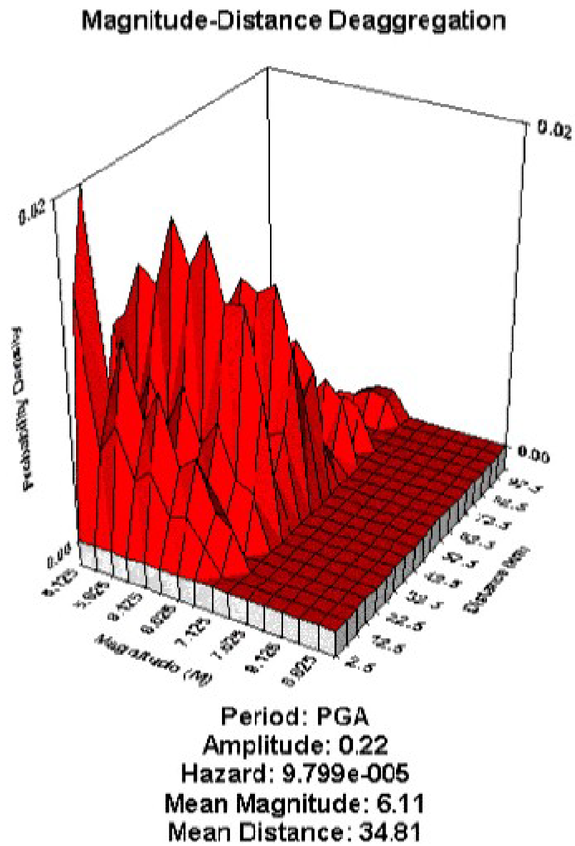


Figure 7.2-7 Deaggregation of Seismic Hazard for Peak Horizontal Ground Acceleration 10,000 year Return Period

Through the interior of the Yukon, there are only three focal mechanisms from recent moderate (Mw = 4 to 5) earthquakes in the vicinity of the Tintina fault system. They are a mixture of right-lateral strike slip and thrust earthquakes, and do not align with the orientation of the Tintina fault system. There has been no evidence found for active faulting along the Tintina fault or the Canadian segments of the Denali fault system (Cassidy et al. 2005). The Tintina fault has been a major strike slip fault through much of the Tertiary. Estimate of displacements for the Tintina Fault ranges from 425 km to 500 km. In the southern part of the Tintina Fault, a set of more northerly trending faults intersect the Tintina at acute angles. Near the Tintina Fault, the faults are steep and are right-lateral strike-slip. Near their southern extremities they appear to be steeply southwest dipping thrust faults. The Tintina Fault is interpreted, therefore, as a shallowly rooted tear fault along which dextral slip took place as the supracrustal rocks were shortened above a basal detachment (Gabrielse and Yorath 1992).

Two earthquake scenarios were considered for the deterministic evaluation for the site peak horizontal ground acceleration as shown in Table 7.2-2 a local earthquake at the site with magnitude 6; and a nearby earthquake at the Tintina Fault with magnitude M=7.2.

Table 7.2-2 Deterministic Evaluation of Peak Horizontal Ground Acceleration at Project Site

Earthquake Scenario	Magnitude	Epicentral Distance (km)	Focal Depth (km)	Peak Ground Acceleration PGA (G)
Local	6	0	2.9	0.34
Tintina Fault	7.2	53	2.9	0.11

7.2.4 Climate and Hydrology

The site climate and surface water hydrology are described in EAR Sections 7.1 and 7.4, respectively, and Section 2 and Section 5 of this document. Precipitation data is included in Appendix F3.

The estimated mean annual precipitation for the Wolverine Minesite is 570 mm, and the estimated mean annual lake evaporation is 400 mm. Average snowpack for the minesite is estimated to be 175 mm snow water equivalent.

Table 7.2-3 presents the ratios of dry and wet year annual precipitations and mean monthly runoff flows, to the average mean annual precipitation and mean monthly flows, respectively (Madrone 2006). Additional hydrology data is provided in the Environmental Assessment Report (YZC and AXYS 2005).

Table 7.2-3 Ratios of Dry and Wet Year Annual Precipitations and Mean Monthly Runoff Flows

Event	Ratio								
	200 yr dry	100 yr dry	10 yr dry	Average	10 yr wet	100 yr wet	200 yr wet	1,000 yr wet	10,000 yr wet
Precipitation	0.586	0.622	0.762	1	1.159	1.388	1.441	1.561	
Runoff flow	0.611	0.641	0.779		1.248	1.524	1.60	1.773	

Table 7.2-4 presents the monthly precipitation distribution and the monthly runoff distribution and Table 7.2-5 presents a summary of monthly flows for various site locations, which are shown on Figure 7.2-8.

Table 7.2-4 Monthly Precipitation and Runoff Distribution

Month	% Precipitation	% Flow
January	8	0
February	6	0
March	5	0
April	4	1
May	7	19
June	11	35
July	14	17
August	11	9
September	10	9
October	9	6
November	8	3
December	8	1

Table 7.2-5 Expected Mean Monthly and Annual Flows (m^3/s) for Selected Stations

Station	W31	W16	W12	W44	W14
Month	Go Creek at Airstrip (4.7 km^2)	Go Creek at Hawkowl Creek (10.2 km^2)	Go Creek at Money Creek (36.5 km^2)	Tailings Dam Catchment (1.05 km^2)	Money Cr. Downstream of Go (238 km^2)
Jan	0.007	0.017	0.065	0.0015	0.479
Feb	0.007	0.016	0.061	0.0015	0.435
Mar	0.007	0.015	0.055	0.0014	0.392
Apr	0.010	0.021	0.079	0.0021	0.537
May	.0.048	0.108	0.410	0.0099	2.938
Jun	0.045	0.111	0.490	0.0079	4.324
Jul	0.034	0.083	0..352	0.0062	2.970
Aug	0.021	0.050	0.212	0.0038	1.772
Sep	0.020	0.047	0.198	0.0036	1.642
Oct	0.018	0.044	0.180	0.0035	1.450
Nov	0.013	0.030	0.119	0.0025	0.906
Dec	0.009	0.021	0.083	0.0018	0.631
Year	0.022	0.051	0.207	0.0041	1.643

7.2.5 Groundwater

In the vicinity of tailings impoundment area the groundwater table within the bedrock is generally sloping southeast following the trend of the topography. Near the downstream end of the impoundment basin at TH05-8 and MW05-7, the piezometric pressure in the bedrock is slightly artesian and the water table rises on the dam abutments. In general, the water table in the overburden is slightly lower than that in the bedrock except at TH05-9. The groundwater table exhibits seasonal variation, reaching highest elevation after spring runoff season. Table 7.2-6 summarizes piezometric elevations monitored during September 7-9, 2005 at the test hole locations and monitoring wells installed in the general tailings impoundment area.

Table 7.2-6 Summary of Piezometric Elevations in Tailings Impoundment Area

Monitoring Well or Test Hole	Ground El. (m)	Stick Up to Top of Riser Pipe (m)	Depth to Water from top of Riser Pipe (m)	Piezometric El. (m)	Stick Up to Pressure Gauge (m)	Artesian Pressure (above gauge el.)
MW05-6A (Bedrock)	1348	0	6.93	1341.07		
MW05-6B (Overburden)	1348	0.12	7.32	1340.8		
MW05-7A (Bedrock)	1286	0.46	0.17	1286.29	0.53	-
MW05-7B (Overburden)	1286	0.37	0.5	1285.87		
TH05-7A (Bedrock)	1305	0.53	10.26	1295.27		

Table 7.2-6 Summary of Piezometric Elevations in Tailings Impoundment Area (cont'd)

Monitoring Well or Test Hole	Ground El. (m)	Stick Up to Top of Riser Pipe (m)	Depth to Water from top of Riser Pipe (m)	Piezometric El. (m)	Stick Up to Pressure Gauge (m)	Artesian Pressure (above gauge el.)
TH05-8A (Bedrock)	1290	0.18	-	>1290.25	0.25	<1 psi
TH05-8B (Overburden)	1290	0.15	0.46	1289.79	0.22	-
TH05-9A (Bedrock)	1303	0.25	10.71	1292.54		
TH05-9B (Overburden)	1303	0.3	3.82	1299.48		
TH05-10A (Bedrock)	1308	0.25	1.35	1306.9		
TH05-10B (Overburden)	1308	0.25	3.37	1304.88		

Baseline groundwater flow rates for the region have been estimated on the basis of a 10% infiltration rate, over the hydrologic catchment area, and an annual precipitation of 550 mm, and are summarized in Table 7.2-7.

Table 7.2-7 Summary of Baseline Groundwater Flow for Selected Locations

Location	Catchment Area (km^2)	Groundwater Flow (m^3/s)	Predicted March Average Flow (m^3/s)*
Go Creek, Near Dam	10	0.015	0.01
W – 12 (Go Creek)	36.5	0.060	0.083
W – 14 (Money Creek)	420	0.420	0.54

The main groundwater aquifer is the 10 to 20 m thick overburden overlying bedrock within the Go Creek Valley. Downstream of Go Creek, 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.

7.2.6 Water Quality

7.2.6.1 Surface Water

The locations of surface water quality monitoring stations in the vicinity of the tailings impoundment area are shown in Figure 7.2-8. Baseline surface water quality samples were collected since June 2005 from Station W44 located on a small stream that drains through the proposed tailings impoundment area. W45 is downstream of W44.

General parameters show consistent trends amongst the sites, and indicate the streams are slightly alkaline in pH, low to moderate in hardness, low in sulphate and generally low in nutrients.

The data specific for the tailings impoundment area at W44 and W45 are presented in Table 7.2-8.

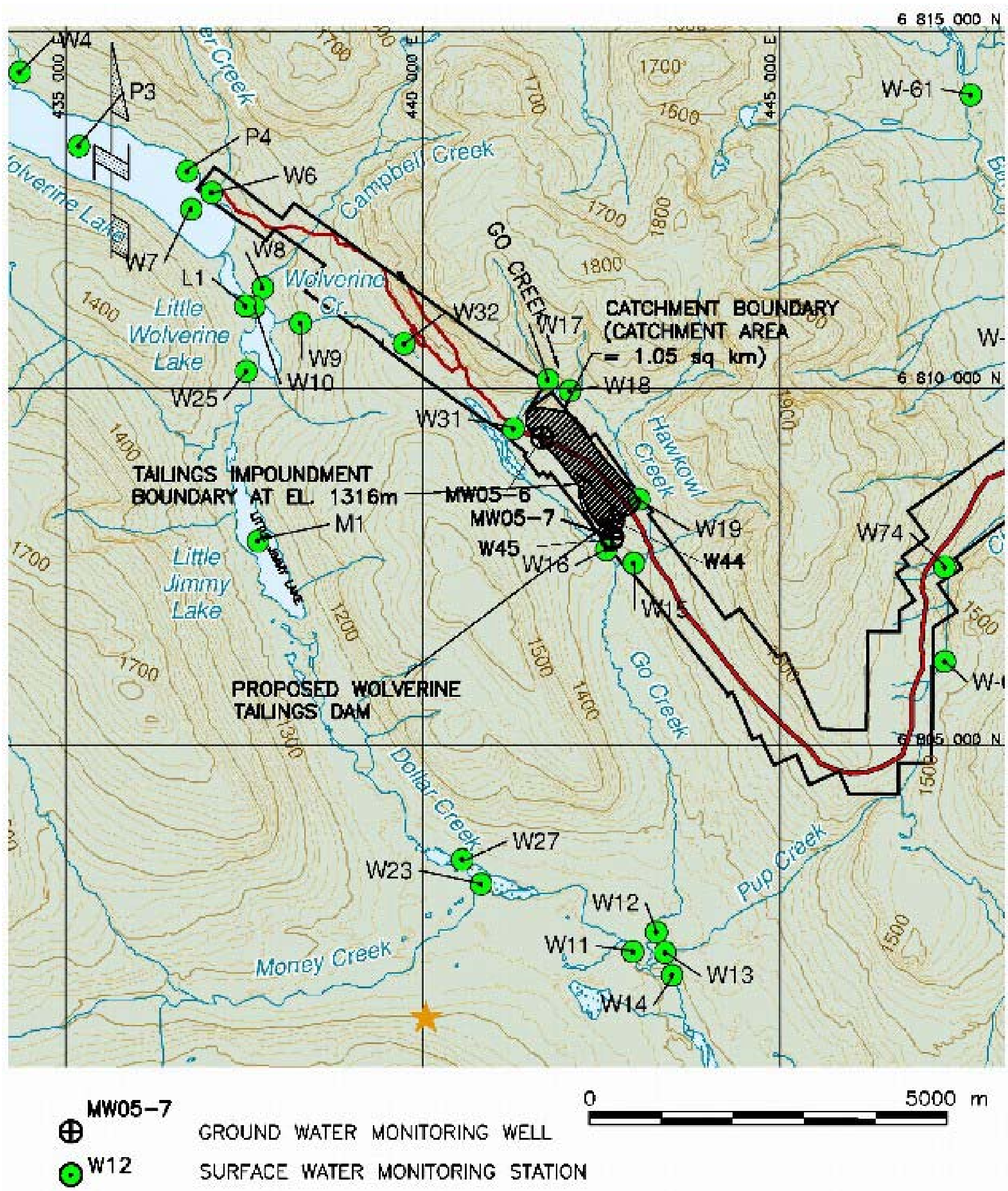


Figure 7.2-8 **Location Map of Surface Water Monitoring Stations, Groundwater Monitoring Wells and Catchment Boundary**

Table 7.2-8 Background Surface Water Quality in Tailings Impoundment Area

Sample Id	W44	W-44	W-44	W-44
Date Sampled	16-Jun-2005	29-Jul-2005	10-Sep-2005	23-Oct-2005
Physical Tests				
Conductivity (uS/cm)	123		150	143
Total Dissolved Solids	82		95	90
Hardness CaCO3	63.1	70.0	75.1	
pH	7.90		7.66	7.79
Total Suspended Solids	<3.0		<3.0	5.4
Turbidity (NTU)			0.44	
Dissolved Anions				
Alkalinity-Total CaCO3	61.5		66.3	
Bromide Br	<0.050		<0.050	<0.050
Chloride Cl	<0.50		<0.50	<0.50
Fluoride F	0.033		0.037	0.029
Sulphate SO4	7.8		8.83	9.34
Nutrients				
Ammonia Nitrogen N		<0.0050	<0.020	<0.020
Nitrate Nitrogen N	<0.0050	<0.0050	<0.0050	0.0370
Nitrite Nitrogen N	<0.0010	<0.0010	<0.0010	0.0024
Total Phosphate P			<0.0020	0.0042
Total Metals				
Aluminum T-Al	0.0209	0.0258	0.0120	<0.20
Antimony T-Sb	<0.00050	<0.00050	<0.00050	<0.20
Arsenic T-As	<0.00050	<0.00050	<0.00050	<0.20
Barium T-Ba	0.134	0.145	0.161	0.137
Beryllium T-Be	<0.0010	<0.0010	<0.0010	<0.0050
Bismuth T-Bi				<0.20
Boron T-B	<0.10	<0.10	<0.10	<0.10
Cadmium T-Cd	<0.000015	<0.000017	<0.000017	<0.010
Calcium T-Ca	22.4	25.0	25.7	27.0
Chromium T-Cr	<0.0010	<0.0010	<0.0010	<0.010
Cobalt T-Co	<0.00030	<0.00030	<0.00030	<0.010
Copper T-Cu	<0.0010	0.0010	<0.0010	<0.010
Iron T-Fe	<0.030	<0.030	<0.030	<0.030
Lead T-Pb	<0.00050	<0.00050	<0.00050	<0.050
Lithium T-Li	<0.0050	<0.0050	<0.0050	<0.010
Magnesium T-Mg	1.75	1.99	2.15	2.15
Manganese T-Mn	0.00178	0.00334	0.00415	<0.0050
Mercury T-Hg	<0.000020	<0.000020	<0.000020	
Molybdenum T-Mo	<0.0010	<0.0010	<0.0010	<0.030
Nickel T-Ni	<0.0010	<0.0010	<0.0010	<0.050
Phosphorus T-P				<0.30
Potassium T-K	<2.0	<2.0	<2.0	<2.0
Selenium T-Se	<0.00050	<0.0010	<0.0010	<0.20
Silicon T-Si				3.59
Silver T-Ag	<0.000020	<0.000020	<0.000020	<0.010
Sodium T-Na	<2.0	<2.0	<2.0	<2.0
Strontium T-Sr				0.0651
Thallium T-Tl	<0.00020	<0.00020	<0.00020	<0.20

Table 7.2-8 Background Surface Water Quality in Tailings Impoundment Area (cont'd)

Sample Id	W44	W-44	W-44	W-44
Date Sampled	**16-Jun-2005**	**29-Jul-2005**	**10-Sep-2005**	**23-Oct-2005**
Tin T-Sn	<0.00050	<0.00050	<0.00050	<0.030
Titanium T-Ti	<0.010	<0.010	<0.010	<0.010
Uranium T-U	<0.00020	<0.00020	<0.00020	
Vanadium T-V	<0.030	<0.030	<0.030	<0.030
Zinc T-Zn	<0.0050	<0.0050	<0.0050	<0.0050
Organic Parameters				
Dissolved Organic Carbon C		4.23	3.03	2.87

7.2.6.2 Groundwater

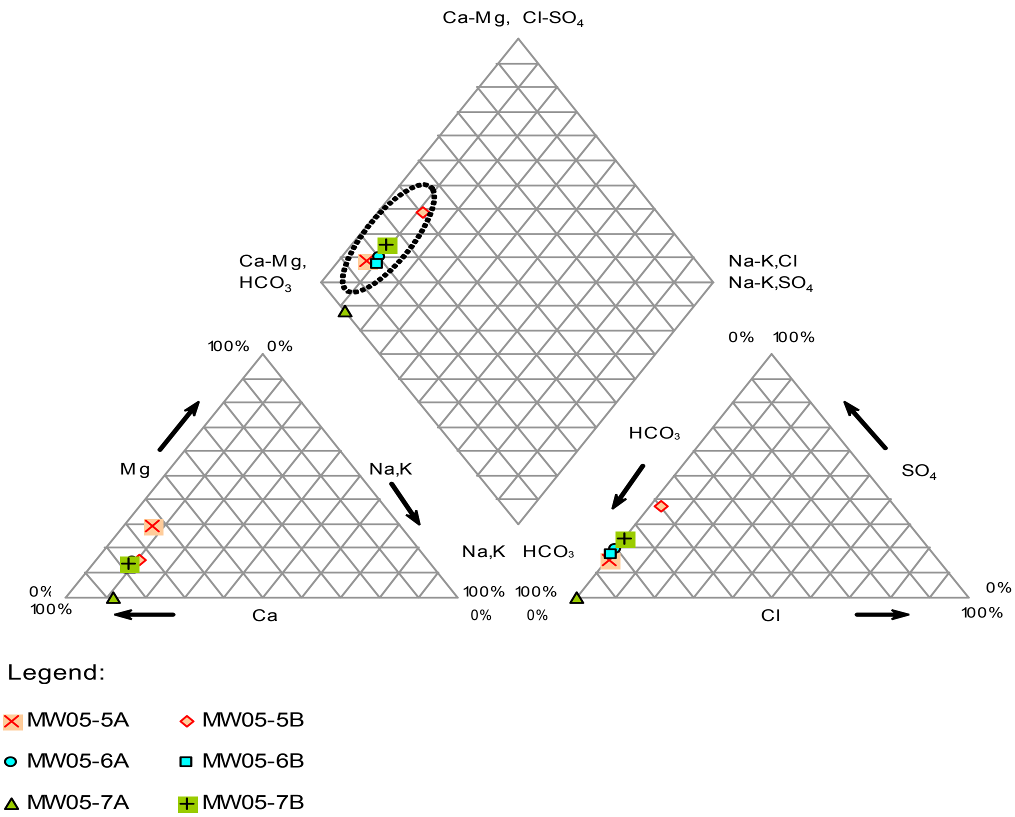
Baseline groundwater quality data were collected during September 2005 at the Wolverine tailings impoundment area monitoring wells MW05-6A, MW05-6B, MW05-7A, and MW05-7B. Locations of wells MW05-6 and MW05-7 are shown on Figure 7.3-1. Only a single sample at each well has been collected to date (Table 7.2-9). In 2006, ongoing sampling is scheduled quarterly during non-freezing period.

The results indicate that the groundwater has a neutral to slightly alkaline pH (7.6 to 9.1) and low conductivity values (99 µS/cm to 271 µS/cm). Based on the Piper Trilinear plot for September 2005 (Figure 7.2-9), the groundwater is generally calcium-bicarbonate ($Ca\text{-}HCO_3$) type water, which is associated with glacio-fluvial sediments and ground moraine. These are the main soils underlying the tailings area. MW05-5 is also included on this plot as it is located at the headwaters of the Wolverine Creek watershed.

Table 7.2-9 Background Groundwater Quality in Tailings Impoundment Area

Sample ID	Date Sampled	Electrical Conductivity (µS/cm)	pH	Total Alkalinity (mg $CaCO_3$/L)	Fluoride (mg/L)	Sulphate (mg/L)	Aluminum (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Calcium (mg/L)	Copper (mg/L)	Selenium (mg/L)	Zinc (mg/L)
MW05-6A	9/8/2005	166	7.75	78.2	0.135	18.5	0.0219	0.00446	0.000076	25.3	0.00094	<0.0010	0.0092
MW05-6B	9/8/2005	172	9.11	81.0	0.068	16.6	0.0667	<0.0010	<0.000050	31.2	0.00262	<0.0010	0.0013
MW05-7A[1]	9/8/2005	10000	11.3	2700	<2.0	<50	0.167	<0.0020	<0.0010	885	0.0035	<0.020	<0.020
MW05-7B	9/8/2005	177	7.58	71.8	0.166	22.2	0.112	0.00054	<0.000050	27.8	0.00552	<0.0010	0.0047

Notes: 1. High values of measured electrical conductivity, pH, total alkalinity and calcium of this sample suggest that the groundwater sample was affected by the drilling fluids and/or cement grout backfill. These effects are expected to diminish with time.



Notes:
Sample date September 8, 2005.

Sample MW05-7B was affected by the cement grout during well installation. Datapoint should be updated when more results become available.

Figure 7.2-9 Piper Trilinear Plot of Background Groundwater Chemistry

7.3 Geotechnical Characterization

7.3.1 Site Investigations

Geotechnical site investigations for the tailings facility were carried out from July to September 2005 for the proposed site on the northeast valley slope of Go Creek. Drill hole and test pit logs are included in Appendix F1. Geotechnical investigations for the tailings facility included 6 test holes, 2 groundwater monitoring wells and 23 test pits, summarized as follows:

- Test Holes TH05-7 to TH05-11 were drilled along the dam alignment, and TH05-12 was drilled inside the tailings impoundment.
- Test Pits TP05-71 to TP05-83, TP05-94 and TP05-95 were excavated in the footprint of tailings dam, TP05-84 to TP05-86 excavated in the footprint of the seepage dam,

and TP05-91 to TP05-93, TP05-96 and TP05-97 excavated along the diversion ditches and spillway channels.

- Groundwater monitoring well MW05-6 was drilled upstream of the impoundment, while MW05-7 drilled near the downstream toe of the tailings dam.

The site investigation programs were mainly carried out using a 420D Cat backhoe mounted on rubber tires, and a BBS-25A diamond drill rig. Locations of test pits, test holes and groundwater monitoring wells for the tailings facility are shown in Figure 7.3-1. Geologic cross sections in the tailings facility area are provided in Figure 7.3-2.

Figure 7.3-1 Site Investigation Plan (Figures Section)

Figure 7.3-2 Geologic Cross Sections (Figures Section)

The drilling program consisted of Standard or Large Penetration (SPT's and LPT's) tests and falling-head permeability tests in overburden materials, packer permeability tests and diamond drill coring with HQ_3 or NQ_2 core barrel in bedrock. The penetration tests were carried out to retrieve soil samples for further laboratory testing as well as to evaluate in situ soil density. Similarly, core samples of bedrock were obtained by diamond coring.

In situ permeability of subsoil and bedrock were obtained by the falling-head and packer tests.

Most of the test pits were excavated to a maximum depth of about 5 m using the backhoe. In areas inaccessible to the backhoe, shallower test pits were excavated manually or drilled manually using a hand-operated auger drill to a maximum depth of 1 m. All test hole and test pit locations were surveyed using a GPS unit, and the ground surface elevations were estimated using the site contour map with 2 m contour intervals. Samples retrieved from the drillholes and test pits were further tested in Klohn Crippen's laboratory in Vancouver. Geotechnical laboratory testing included visual classification, moisture content, gradation, standard Proctor compaction, triaxial permeability and shear strength tests.

Two 1" diameter, 30 cm long piezometer tips were installed in most test holes with 1" Schedule 40 PVC riser pipes. One 2" diameter well screen with Schedule 80 PVC well pipe was installed in each monitoring well. A pressure gauge with a by-pass valve set up was installed at the top of each artesian installation. Temperature profiles were also recorded at test holes.

Standard or Large Penetrometer tests (SPT's and LPT's) and permeability test results are summarized in Tables 7.3–1, through 7.3–5.

Falling-head permeability tests were conducted through the bottom of the monitoring wells or test holes and the test results appear to overestimate the in situ permeability, based on comparison with gradations. This may be due to the boundary condition at the test hole bottom/seal contact, which could increase the measured permeability values significantly.

Table 7.3-1 Summary of Large and Standard Penetrometer Test Results

Test Hole	Depth (m)	SPT or LPT	SPT or LPT Blow Count per foot, N	Converted SPT Blow Count, N	Converted $(N_1)_{60}$
TH05-7	1.52	LPT	101	65	112
	3.05	LPT	81	52	89
	4.57	LPT	29 blows per 6"	-	-
	6.10	LPT	30 blows per 5"	-	-
	9.14	LPT	35 blows per 6"	-	-
	12.19	LPT	30+ blows per 1"	-	-
	15.24	LPT	32+ blows per 4"	-	-
	18.29	LPT	21+ blows per 2"	-	-
	21.34	LPT	37 blows per 3"	-	-
	24.38	LPT	21 blows per 3"	-	-
TH05-8	1.52	LPT	20+ blows per 6"	-	-
	3.05	LPT	47 blows per 12"	-	-
	4.57	LPT	48+ blows per 12"	-	-
	6.10	LPT	42+ blows per 10"	-	-
	9.14	LPT	50+ blows per 12"	-	-
	12.19	LPT	30+ blows per 6"	-	-
	15.24	LPT	60 blows per 6"	-	-
	18.29	LPT	80+ blows per 9"	-	-
TH05-9	1.52	SPT	57	57	97
	3.05	SPT	51	51	86
	4.57	SPT	125	125	172
	6.10	SPT	20 blows per 6"	-	-
	9.14	SPT	26 blows per 5"	-	-
	12.19	SPT	23 blows per 2"	-	-
	15.24	SPT	23 blows per 4"	-	-
	18.29	SPT	23 blows per 2"	-	-
	21.34	SPT	26 blows per 2"	-	-
	24.38	SPT	24 blows per 3.5"	-	-
	27.43	SPT	24 blows per 2.5"	-	-
	30.48	SPT	25 blows per 3"	-	-
TH05-10	1.52	SPT	20+ blows per 6"	-	-
	3.05	SPT	20+ blows per 6"	-	-

Table 7.3-2 Summary of Falling-Head Permeability Test Results

Test Hole No.	Test Section Depth (m)		Test Section Diam. (mm)	k
	from	to		cm/sec
TH05-7	1.52	1.52	101.6	7.8E-02
	3.05	3.05	101.6	8.4E-03
	4.57	4.57	101.6	6.9E-02
	6.10	6.10	101.6	2.7E-02
	9.14	9.14	101.6	2.9E-02
	12.19	12.19	101.6	7.7E-03
	15.24	15.24	101.6	1.0E-02
	18.29	18.29	101.6	2.8E-04
	21.34	21.34	101.6	1.4E-03
	24.38	24.38	101.6	4.3E-03

Table 7.3-2 Summary of Falling-Head Permeability Test Results (cont'd)

Test Hole No.	Test Section Depth (m)		Test Section Diam. (mm)	k
	from	to		cm/sec
TH05-8	1.52	1.52	101.6	1.7E-01
	3.05	3.05	101.6	7.0E-02
	4.57	4.57	101.6	2.9E-02
	6.10	6.10	101.6	6.9E-03
TH05-9	1.52	1.52	76.2	1.3E-02
	3.05	3.05	76.2	2.3E-02
	6.10	6.10	76.2	9.5E-03
	9.14	9.14	76.2	5.7E-02
	12.19	12.19	76.2	1.0E-01
	15.24	15.24	76.2	4.1E-01
	18.29	18.29	76.2	5.2E-02
	21.34	21.34	76.2	1.5E-02
	24.38	24.38	76.2	5.7E-02
	27.43	27.43	76.2	9.2E-02
	30.48	30.48	76.2	3.1E-03
TH05-10	1.52	1.52	76.2	5.7E-03
	4.57	4.57	76.2	4.4E-02
	6.10	6.10	76.2	5.0E-02
	9.14	9.14	76.2	3.4E-02
	12.19	12.19	76.2	2.5E-02
	15.24	15.24	76.2	5.0E-02
	18.29	18.29	76.2	7.1E-02
	31.09	31.09	76.2	3.6E-03
	33.53	33.53	76.2	4.0E-03
TH05-11A	3.05	3.05	76.2	1.2E-01
	4.57	4.57	76.2	3.6E-03
	6.10	6.10	76.2	7.7E-03
	9.14	9.14	76.2	4.1E-03
TH05-11B	6.10	6.10	76.2	6.6E-02
	9.14	9.14	76.2	6.0E-03
	12.19	12.19	76.2	1.1E-02
	21.34	21.34	76.2	2.1E-01
	24.38	24.38	76.2	9.4E-03
	28.35	28.35	76.2	2.6E-02
	30.48	30.48	76.2	1.9E-03
	33.53	33.53	76.2	6.6E-03
	36.58	36.58	76.2	6.8E-03
	42.67	42.67	76.2	1.8E-02
	1.52	1.52	76.2	2.6E-01
	3.05	3.05	76.2	6.1E-04
	4.57	4.57	76.2	6.9E-03
	6.10	6.10	76.2	4.1E-03
	9.14	9.14	76.2	3.1E-03
TH05-12	12.19	12.19	76.2	1.1E-02
	18.29	18.29	76.2	1.4E-02
	21.34	21.34	76.2	1.6E-02
	24.38	24.38	76.2	1.5E-02

Table 7.3-3 Summary of Packer Permeability Test Results

Test Hole No.	Test Section Depth (m)		Test Section Diam. (mm)	Average k
	from	from		cm/s
TH05-8	24.70	30.80	96.0	5.5E-05
TH05-9	30.50	35.10	75.7	3.1E-04
TH05-10	35.05	38.10	75.7	1.5E-04
TH05-11	44.20	46.30	75.7	1.4E-05
TH05-12	27.58	29.60	75.7	1.6E-05

Table 7.3-4 Summary of Falling-Head Permeability Test Results – Monitoring Wells

Test Hole No.	Depth (m)		Hole Dia. (mm)	k
	from	to		cm/sec
MW05-3A	1.07	1.52	96	2.8E-04
	2.60	3.05	96	0.0E+00[1]
	4.12	4.57	96	0.0E+00[1]
	5.65	6.10	96	1.7E-04
	8.69	9.14	96	4.9E-04
	11.74	12.19	96	3.5E-04
	14.79	15.24	96	0.0E+00[1]
	17.84	18.29	96	0.0E+00[1]
MW05-5A	3.05	3.05	76	1.0E-01
	6.10	6.10	76	1.2E-02
	9.14	9.14	76	6.7E-03
	12.19	12.19	76	8.0E-03
	15.24	15.24	76	6.3E-03
	18.29	18.29	76	6.6E-03
MW05-6	1.52	1.52	102	2.0E-04
	3.05	3.05	102	7.8E-04
	4.57	4.57	102	3.6E-03
	6.10	6.10	102	1.3E-03
	9.14	9.14	102	4.8E-03
	12.19	12.19	102	2.3E-04
	15.24	15.24	102	3.1E-03
	18.29	18.29	102	1.4E-02
	21.34	21.34	102	1.8E-02

Notes:
1. No visible change in piezometric head during test.
2. MW05-3A is located northwest of the impoundment.

Table 7.3-5 Summary of Packer Permeability Test Results – Monitoring Wells

Test Hole No.	Depth (m)		Hole Dia. (mm)	Average k
	from	to		cm/s
MW05-1A	18.29	22.86	96	5.4E-04
MW05-2A	18.29	22.86	96	0.0E+00[1]
MW05-3A	18.75	22.86	96	0.0E+00[1]
MW05-5	21.10	26.50	76	4.7E-05
MW05-6A	21.30	25.70	96	1.2E-05
MW05-7A	24.70	30.20	96	3.6E-05

Notes: 1. No visible change in piezometric head during test.
2. MW05-1A, MW05-2A and MW05-3A are located northwest of the impoundment.

7.3.2 Laboratory Testing

Geotechnical laboratory testing included visual classification, moisture content, and gradation tests for overburden samples retrieved from field investigations. Additional standard Proctor compaction tests, triaxial permeability and shear strength tests were carried on the potential borrow materials for the dam fill as well as waste materials including tailings, DMS float and waste rock. These results are summarized in Table 7.3-6, and test results are included in Appendix F1.

Table 7.3-6 Summary of Engineering Properties Determined from Laboratory Tests on Dam Fill, Tailings, DMS Float and Waste Rock

Type of Material	Unit Weight γ_{dry} (kN/m^3)	Effective Shear Strength		Hydraulic Permeability k (cm/s)
		Cohesion c' (kPa)	Friction Angle ϕ' (degree)	
Dam Fill	~2.1	0	37	3 E-6
Tailings	~1.85	0	34	7 E-6
Waste Rock	~1.9	0	35	5 E-6
DMS Float	~1.9	0	46	3 E-1

Test results for dam fill, waste rock and tailings were obtained by consolidated-undrained triaxial shear tests with permeability measurement after consolidation and pore pressure measurement during shear. The shear strength and permeability results for the DMS float were determined by direct shear test and permeability test in a permeameter. The consolidation stresses used in the laboratory are selected to simulate the field condition.

The tailings sample was a mixture of four samples provided by Lakefield SGS (referred to as: F11 and F12 (Zn, Rougher Scavenger Tail), F23 and F32 (Zn 1st Cleaner Scavenger Tail) and F32). The specific gravity of tailings sample was 3.71 and its grain size distribution was 80% silt and 10% clay, as obtained by a hydrometer analysis. The tailings settled out readily from tailings slurry of about 14% solid content.

7.4 Geochemical Characterization

7.4.1 Borrow and Construction Materials

Borrow material from the impoundment will be used to provide soils for construction of the earthfill tailings dam. Samples collected from test pits located in the impoundment and from the project borrow area located northwest of the tailings facility (Figure 7.3-1). The results of shake flask tests and acid base accounting tests (ABA) are summarized in Table 7.4-1 and Table 7.4-2.

Table 7.4-1 Summary of Metal Leachate Analyses for Borrow Materials

Sample Name	Units	Project Borrow (Near Airstrip)	Project Borrow (Sample #1)	Project Borrow (Sample #3)	Impoundment Borrow Site (TP05-78, 1.5 m)
Conventional Parameters					
Hardness (Total) CaCO3	mg/L	3.2	1.1	0.6	1.3
Metals Analysis					
Aluminum Al	mg/L	0.059	0.25	0.13	0.066
Antimony Sb	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Arsenic As	mg/L	0.0005	0.0002	< 0.0002	0.0005
Cadmium Cd	ug/L	< 0.04	< 0.04	< 0.04	< 0.04
Copper Cu	mg/L	0.0073	0.0053	0.0027	0.0049
Iron Fe	mg/L	0.04	0.13	0.01	0.08
Manganese Mn	mg/L	0.0067	0.01	0.013	0.0039
Mercury Hg	ug/L	< 0.02	< 0.02	0.03	< 0.02
Molybdenum Mo	mg/L	0.0003	< 0.0001	< 0.0001	< 0.0001
Nickel Ni	mg/L	0.0005	0.0003	0.0002	0.0004
Selenium Se	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Silver Ag	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Thallium Tl	mg/L	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Tin Sn	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Zinc Zn	mg/L	0.002	0.004	0.003	0.002

The testing confirms that metal leaching from the borrow materials are not a concern and that the soils are not potentially acid generating.

Table 7.4-2 ABA Results For Dam Borrow Materials

Sample ID	Unit	Project Borrow Impoundment Site 1 (Near Airstrip)	Project Borrow (Sample #1 East)	Project Borrow (Sample #2 central)	Project Borrow (Sample #3 West)	Tailings Dam Borrow Material						
						Near MW05-6	TP05-72 @2.5 m	TP05-75 @1.5 m	TP05-78 @1.5 m	TP05-81 @1.5 m	TP05-87 @3.3 m	TP05-89 @1.5 m
Paste pH	-	7.66	5.74	6.00	6.53	6.54	8.45	8.80	7.89	7.62	8.06	8.11
Rinse pH	-	6.42	4.87	5.01	4.99	5.63	5.88	7.54	6.12	5.7	6.34	6.2
Total Sulphur	%S	*0.005*	0.04	0.07	0.09	0.05	0.06	0.08	0.09	0.02	0.03	*0.005*
Sulphate Sulphur	%S	0.01	0.01	0.02	0.01	0.01	0.005	0.005	0.005	0.005	0.005	0.005
Sulphide Sulphur	%S	0.005	0.005	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Insoluble Sulphur	%S	0.01	0.03	0.05	0.08	0.04	0.06	0.08	0.09	0.02	0.03	0.005
AP	kg CaCO3/t	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Modified Sobek NP	kg CaCO3/t	3	-4.4	-3.1	-2.4	-1.2	3.1	5.1	2.6	0.2	3.3	2.9
Total Carbon	% C	0.51	1.74	1.52	1.13	0.31	0.14	0.21	0.43	0.25	0.18	0.16
Total Inorganic Carbon	% C	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Carb NP	kg CaCO3/t	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Net Sobek NP	kg CaCO3/t	3	-4.4	-3.1	-2.4	-1.2	3.1	5.1	2.6	0.2	3.3	2.9
Sobek NPR	-	20.00	-29.33	-20.67	-16.00	-8.00	20.67	34.00	17.33	1.33	22.00	19.33
Carb NPR	-	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67

Note: Values in *italics* were reported by the laboratory as less than their detection limit and are shown here at one-half the detection limit.

7.4.2 Tailings and Supernatant Water Geochemistry

7.4.2.1 Sample Preparation, Acid Base Accounting and Mineralogy

To assess the geochemical characteristics of the tailings, four ore composite types were prepared and examined. The four samples were prepared with lock cycle tests (LCT) carried out to simulate the milling process, which produces three tailing sub-streams: ~2% pre-float concentrate (PFC), 88% rougher tails (Ro), and 10% cleaner scavenger tails (CS). The composite ore samples include the following:

- Combined overall diluted ore composite (Comb OD Comp) tailings: Combines the three tailings streams generated by using ore and dilution rock from both Wolverine and Lynx ore zones (LCT3).
- Combined overall ore composite (Comb Overall Ore Comp) tailings: Combines the tailings generated from using only ore only from the Wolverine and Lynx ore zones, and does not include any dilution rock. The sample is a composite of two lock cycle tests (LCT1 & LCT2).
- Combined Wolverine composite ore with dilution rock (Comb Wolv D Comp) tailings: Combines all three tailings streams generated from ore with dilution rock from the Wolverine ore zone (LCT4).
- Combined Lynx ore with dilution rock composite (Comb Lynx D Comp) tailings: Combines all three tailings streams generated from ore with dilution rock from the Lynx ore zone (LCT5).

It is important to not that subsequent to the above testing program, the milling procedure was modified with a dense media separation (DMS), which produces a fine gravel sized by-product (DMS float), which mainly contains the dilution waste rock products. Therefore, the Comb Overall Ore Comp samples are likely more representative of the actual tailings than the diluted samples, nonetheless the four samples provide a range of geochemistry that could be anticipated.

<u>Test Program</u>

Mineralogy, kinetic tests and toxicity tests were carried out for the four composite tailing samples as well as the Ro and CS tailings streams, separately. Acid base accounting (ABA) tests and solids phase metals analyses were carried out for all of the tailings sub-streams. Table 7.4-3 provides a summary of the testing program carried out for the samples.

Table 7.4-3 Number of Tailings Tests by Geochemical Test Method

Test Type	Number of Tests
ABA Testing	
Paste pH	12
Total Sulphur	12
Acid Leachable Sulphate	12
Insoluble Sulphate	12
Total Sulphide	12
Organic Sulphide	12
Total Carbon	12
Total Inorganic Carbon	12

Table 7.4-3 Number of Tailings Tests by Geochemical Test Method (cont'd)

Test Type	Number of Tests
Total Organic Carbon	12
Total Carbon as %CO_3	12
Sobek-NP	12
Mineralogy	
Optical Analysis	4
XRD	4
Solid Phase Metals Analysis	
Solid Phase ICP-MS	13
Kinetic Testing	
Humidity Cells	4
Sub-aqueous Column Leach Tests	2
Environmental Aging Tests	4
Toxicity Testing	
Daphnia magna Acute Lethality	8
Rainbow trout Acute Lethality	4

Mineralogy

Mineral assemblage percentages were assessed using optical microscopy on the four samples and the results are summarized in Table 7.4-4.

Table 7.4-4 Mineral Assemblages and Modal Abundances by Optical Microscopy (wt. %)

Mineral	Comb OD Comp	Comb Overall Ore Comp	Comb Wolv D Comp	Comb Lynx D Comp
Pyrite	53.1	60.1	38.3	60.3
Quartz	20.9	17.1	26.7	16.7
Carbonate	10.5	10.6	14.2	11.6
Muscovite	11.9	5.2	14.3	8.9
Chlorite	1.0	1.1	0.9	0.0
Sphalerite	1.1	1.6	1.3	1.8
Pyrrhotite	0.5	1.6	2.1	0
Amphibole	0	0.6	0.5	0
Arsenopyrite	0.3	0.8	0	0.3
Pyroxene	0.2	0.3	1.5	0.0
Chalcopyrite	0.5	0.4	0.2	0.0
Galena	0.0	0.4	0	0.8
Biotite	0	0.2	0	0
Magnetite	0	0.1	0	0
Total	**100**	**100**	**100**	**100**

In addition, quantitative phase analysis using x-ray diffraction (XRD) with Rietveld refinement was carried out, to identify the carbonate and sulphide species. Based on the analyses, the following has been observed:

- Pyrite is the dominant sulphide, with moderate concentrations of quartz and muscovite. Minor sulphides (arsenopyrite and sphalerite) were not detected, although these are shown in the optical mineralogical analysis (< 1.8%).

- The abundance of reactive carbonates and non-carbonate minerals (<10 wt % total), relative to the high sulphide content indicates that the materials are likely acid generating.
- The abundance of reactive carbonates indicates that there would be a lag time of likely several years prior to onset of acid generation.
- Rietveld analyses identified the main carbonates as dolomite (5 to 7.4%), calcite (2.6 to 3.6%) and siderite (0.4 to 0.5%). Note that the Rietveld method quantifies minerals phases relative to each other so the sum of the carbonates may exceed the quantitative estimate from the optical assessment.

Trace element analyses by ICP-MS were carried out on the twelve samples of the tailing sub-streams, to quantify the solid-phase concentrations of various elements within the samples. Thirteen trace elements, listed in Table 7.4-5, show concentrations greater than five times crustal abundance, which were measured in most of the samples.

Table 7.4-5 Elemental Concentrations Greater than 5X Crustal Abundance

Element	Anomalous Samples (%)	Avg. Ratio[1]	Maximum (mg/kg)	Median (mg/kg)	Minimum (mg/kg)
Se	100	9512	979	362	261
As	93	1453	4800	2700	760
Bi	100	1377	42	8.5	6.0
Sb	100	1201	820	200	130
Cd	93	836	500	103	29
Ag	100	763	170	57	39
Pb	93	375	15000	4700	1900
Zn	93	218	74000	10400	2900
Hg	93	52	9.5	3.4	1.5
Mo	93	26	58	32.2	17
Tl	93	23	25	17.5	13
Cu	93	14	2110	840	630
Sn	71	7	34	13	8

Notes: [1] Median Measured Concentration: Crustal Abundance

These results suggest the onset of acidic conditions may have the potential to release metal(loid)s from mineral phases, likely from the sulphide phases confirmed by mineralogical characterization. Furthermore, any of the elements listed in Table 7.4-5 that are mobile under neutral pH conditions (e.g., Se, Zn, etc.) may have the potential to be released.

Acid Base Accounting

The results of the ABA tests are summarized in Table 7.4-6. All samples have high sulphide content and a low Neutralization Potential Ratio (NPR) of less than one, and are classified as having a high potential for producing acid rock drainage. However, the samples have enough NP (carbonate neutralization potential of 20-100 kg $CaCO_3$/t) to remain at a near-neutral pH, when initially exposed to oxygen. This is confirmed with the relatively high paste pH values of 6.9 to 7.85. In addition, most samples indicate the presence of non-carbonate neutralization potential, possibly from the muscovite, clinochlore and kaolinite, indicated by the mineralogical analysis.

Table 7.4-6 Tailings Acid Base Accounting Results

Parameter	Units	Overall Comp LCT2 Ro	Overall Comp LCT2 Cl Sc	Overall Comp LCT2 Comb	OD Ro	OD Cl Sc	OD Comb	Wolv Ro	Wolv Cl Sc	Wolv Comb	Lynx Ro	Lynx Cl Sc	Lynx Comb
Paste pH	-	7.79	7.26	7.42	7.85	6.69	7.27	7.68	6.91	7.35	7.67	6.45	7.36
Fizz Rate	-	3	3	3	3	2	2*	3	2	2**	3	2	2
Total S	%S	22.3	39.5	29.2	17.5	43.0	26.6	12.3	39.4	19.7	23.7	48.4	31.2
Acid Leachable SO_4^{2-}	%S	1.07	6.98	2.51	0.02	1.18	2.04	0.45	1.63	1.74	0.92	6.45	0.74
Sulphide S	%S	20.2	28.5	25.0	15.7	39.0	22.9	10.1	34.1	15.7	20.4	39.4	27.8
Insoluble SO_4^{2-}	%S	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Organic S	%S	1.10	4.00	1.73	1.72	2.83	1.67	1.79	3.64	2.34	2.35	2.61	2.68
AP	kg $CaCO_3$/t	631	891	781	491	1220	715	315	1070	489	638	1230	869
Sobek NP	kg $CaCO_3$/t	103	41.8	72.8	114	21.9	82.5	119	32.1	94.6	111	20.9	49.4
Net NP	kg $CaCO_3$/t	-528	-849	-708	-377	-1198	-632	-196	-1038	-395	-526	-1209	-820
Sobek NP/AP	-	0.16	0.05	0.09	0.23	0.02	0.12	0.38	0.03	0.19	0.17	0.02	0.06
Carb NP	kg $CaCO_3$/t	72.6	23.4	59.4	91.4	20.5	98.3	105	24.6	106	94.4	22.1	52.3
Carb NP/AP	-	0.11	0.56	0.08	0.19	0.02	0.14	0.33	0.02	0.22	0.15	0.02	0.06
TOC	%C	na	na	na	0.54	0.43	0.62	0.69	0.75	0.98	0.49	0.25	0.48
TIC	%C	na	na	na	1.32	0.11	0.94	1.39	0.14	1.2	1.30	0.21	0.79
C(t)	%C	1.72	0.87	1.48	1.86	0.54	1.56	2.07	0.88	2.14	1.79	0.46	1.27

7.4.2.2 Shake Flask Tests

The results of the shake flask extraction from the four Combined Tailings samples are summarized in Table 7.4-7.

Results show the final pH was near neutral to slightly alkaline and ranged from pH 7.3-8.4. The initial exposure of tailings to atmospheric conditions should result in minimal trace metal(loid) releases, except for the Combined Overall Ore Composite tailings, which shows Cd (0.134 mg/L), Se (0.20 mg/L), Tl (0.022 mg/L) and Zn (6.87 mg/L) releases. The major ions (Ca^{2+}, Na^{+}, Mg^{2+}, Mn^{2+}, Cl^{-}, SO_4^{2-} and thiosalts) also show releases, most likely due to the dissolution of gypsum ($CaSO_4$) and other salts and sulfosalts present at low abundances.

The test sample for the Comb Overall Ore Comp appears to have undergone some drying and oxidation prior to the test, which would account for the elevated SO_4 and Zn concentrations.

Table 7.4-7 Shake Flask Extraction Test Results

Parameter	Units	Comb Overall Ore Comp	Comb OD Comp	Comb Wolv D Comp	Comb Lynx D Comp
Moisture	%	1.0	16	16.8	29.9
Sample Weight	g	50	50	50	50
DI Water Volume	mL	990	992	991.6	985
Initial pH	units	7.1	9.4	9.2	9.15
Final pH	units	7.3	8.2	8.4	8.3
pH	units	7.3	7.6	7.6	7.7
Conductivity	uS/cm	813	263	274	242
Tot. Dissolved Solids	mg/L	740	231	220	186
Tot Suspended Solids	mg/L	3	*1.5*	*1*	*1.5*
Alkalinity	mg $CaCO_3$ /L	52	na	na	Na
Acidity	mg $CaCO_3$ /L	17	na	na	Na
F	mg/L	0.06	na	na	Na
$NH_3 + NH_4^+$	mg N /L	0.3	0.2	1	0.2
Cl	mg/L	1.5	*1*	*1*	*1*
NO_3^-	mg N/L	*0.25*	*0.25*	0.79	*0.25*
SO_4^{2-}	mg/L	430	41	41	38.5
$CN_{(T)}$	mg/L	0.02	0.07	*0.005*	*0.005*
CNO	mg/L	*0.05*	*0.05*	*0.05*	*0.05*
CNS	mg/L	*1*	*1*	*1*	*1*
Thiosalts	mg S_2O_3/L	44	Na	na	Na
Ag	mg/L	*0.00005*	0.0008	0.0006	0.00075
Al	mg/L	*0.002*	0.005	0.007	0.007
As	mg/L	*0.0025*	0.007	0.007	0.0095
Cd	mg/L	0.13	0.0051	0.0025	0.0049
Cu	mg/L	0.0015	0.0014	0.0009	0.0021

Table 7.4-7 Shake Flask Extraction Test Results (cont'd)

Parameter	Units	Comb Overall Ore Comp	Comb OD Comp	Comb Wolv D Comp	Comb Lynx D Comp
Fe	mg/L	*0.01*	*0.01*	*0.01*	*0.01*
Hg	mg/L	*0.00005*	*0.00005*	*0.00005*	*0.00005*
Pb	mg/L	0.17	0.039	0.020	0.061
Sb	mg/L	0.0034	0.016	0.047	0.011
Se	mg/L	0.20	0.42	0.60	0.53
Tl	mg/L	0.022	0.0063	0.0023	0.0087
Zn	mg/L	6.87	0.081	0.037	0.064

Note: All concentrations are dissolved.

7.4.2.3 Tailings Supernatant, Aging and Subaqueous Column Tests

Supernatant Water Chemistry

The tailings supernatant water quality, from the lock cycle testing of the four composite samples, is summarized in Table 7.4-8. During operations, variations outside of this range may occur with fluctuations, or alterations in reagent dosage because of variations in ore processing behaviour. Certain dissolved parameters (e.g., Na, K, Cl and SO_4) may tend to recirculate through the mill in the reclaim water and may not be strongly affected by the operation of the water treatment system and pH control in the mill. Eventually these parameters will reach a recirculating equilibrium concentration, that may in part be controlled by the solubility limit of the parameter of interest (e.g., sulphate can be expected to eventually be limited by gypsum solubility in the presence of calcium addition as lime in the mill circuit).

Table 7.4-8 Tailings Supernatant Chemistry

Parameter	Units (dissolved)	Range of all 4 Tailings Samples Tested	Combined Overall Diluted Ore Composite Tails	Combined Overall Ore Composite Tails
pH	-	7.28 to 8.59	8.13	7.47
SO_4	mg/L	520 to 630	630	520
Hardness	mg $CaCO_3$/L	415 to 510	510	435
Cd	mg/L	0.0005 to 0.0045	0.0017	0.0045
Cu	mg/L	0.0027 to 0.0499	0.0051	0.045
Pb	mg/L	0.0060 to 0.0255	0.011	0.026
Se	mg/L	1.20 to 1.95	1.76	1.89
Tl	mg/L	0.0021 to 0.0100	0.0044	0.0067
Zn	mg/L	0.01 to 0.076	0.021	0.076

The tailings supernatant chemistry will be typical of the pore water quality in the tailings. The main parameter of potential concern is selenium, which has a typical concentration of approximately 1.8 mg/L.

Tailings Aging Tests

The four composite tailing samples were "aged" in the laboratory for up to 120 days, to assess the water chemistry changes in the tailings pond over time. During aging, the supernatant was exposed to atmospheric oxygen and carbon dioxide, as would be the case in the tailings impoundment during temporary suspension of milling activities (e.g., maintenance shutdowns) or post-closure. A clear trend was observable in the behaviour of several of the parameters, most notably, thiosalts, pH, Cd, Se and Zn as shown in Figures 7.4–1 to 7.4–5.

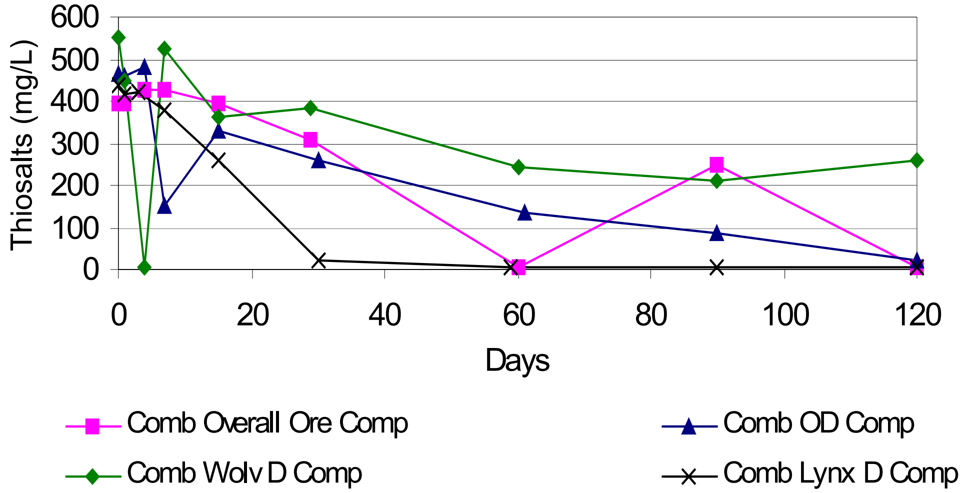


Figure 7.4-1 Variation in Thiosalt concentration over time

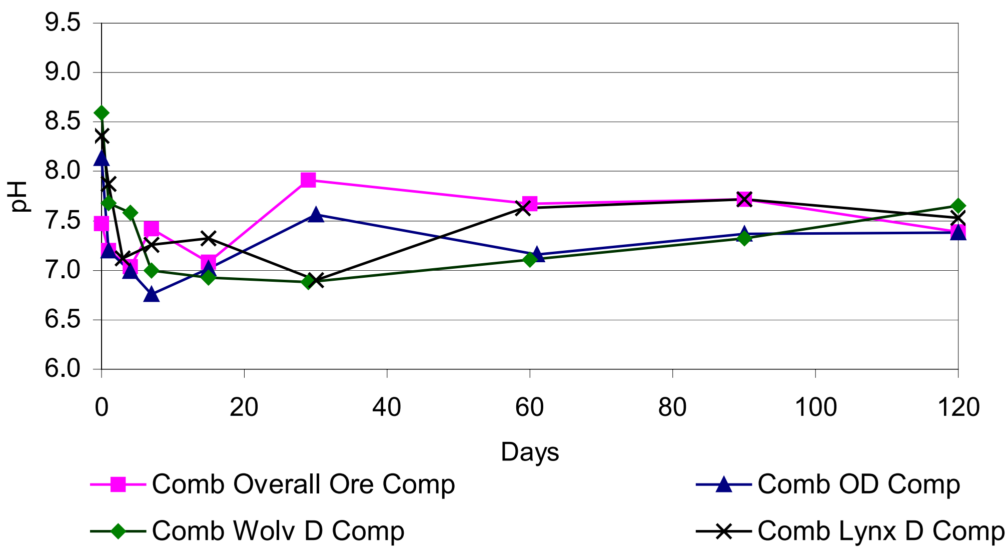


Figure 7.4-2 Variation in pH over time

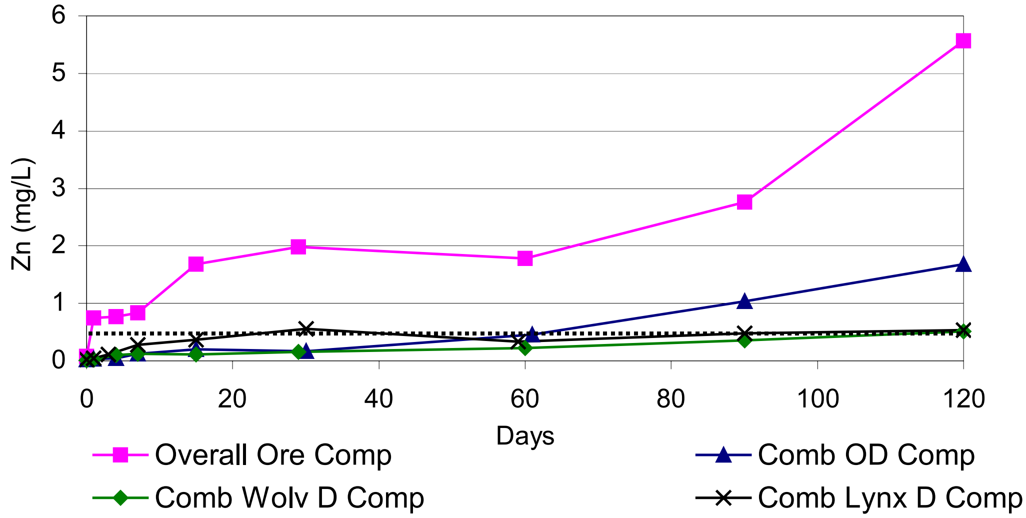


Figure 7.4-3 Variation in Dissolved Zinc Concentration Over Time

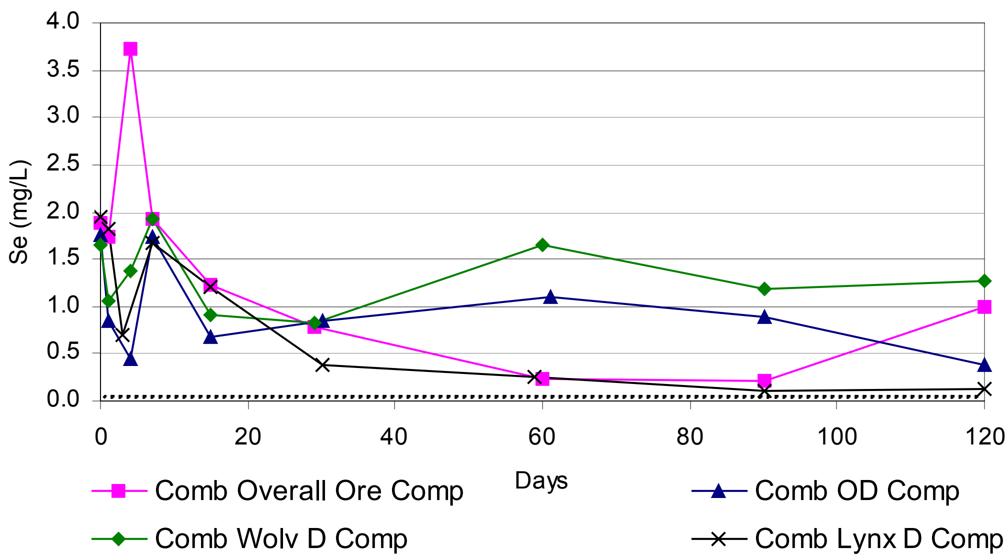


Figure 7.4-4 Variation in Selenium Concentration Over Time

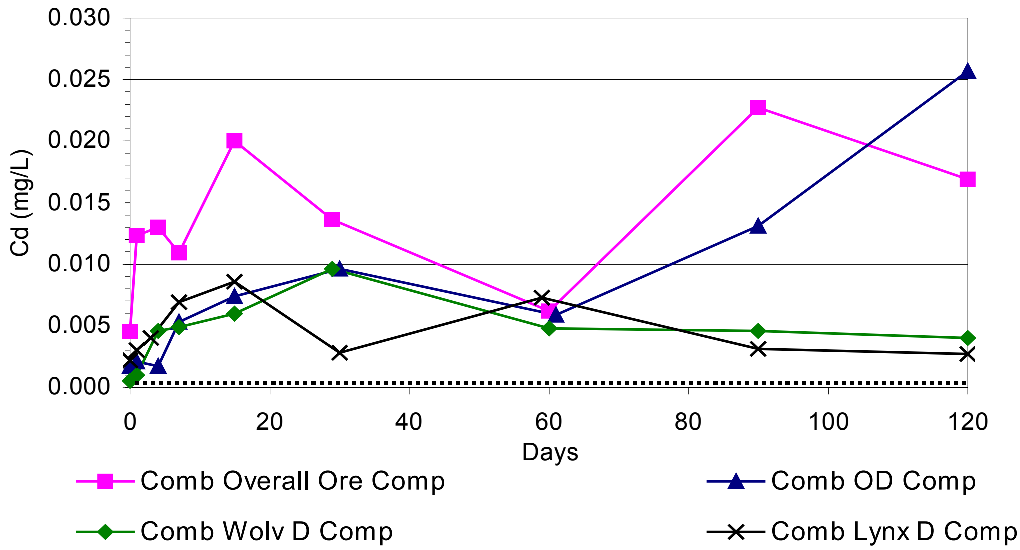


Figure 7.4-5 Variation in Cadmium Concentration Over Time

At closure, or during sustained shutdown, there will be a short lag time (up to 9 months) until the remaining thiosalts are oxidized and water quality stabilizes. During this period there is a slight depression in pH, which then rises after the thiosalts are oxidized.

Selenium, cadmium and zinc, show elevated concentrations, for some of the samples, after 120 days and measured concentrations at 120 days are summarized in Table 7.4-9.

Concentrations of some parameters had not reached equilibrium after 120 days. Additional testing will be conducted following mill start-up to refine the estimates of post-closure tailings pond water quality behaviour.

Table 7.4-9 Summary of Tailings Aging Tests at 120 Days

Parameter	COMB Overall ore comp	Comb OD Comp	Comb Wolverine D Comp	Comb Lynx D Comp
pH	7.39	7.16	7.11	7.63
Hardness	860	560	544	813
Sulphate	1200	920	890	1200
Thiosalts	<10	133	243	<10
Total Cyanide	0.01	<0.01	<0.01	<0.01
Ammonia	0.2	1.2	1.1	0.9
Ag	<0.0001	0.0003	0.0039	<0.0001
As	0.021	0.006	0.016	0.0050
Cd	0.0169	0.0257	0.0040	0.0027
Cu	0.0024	0.0038	0.0048	0.0050
Pb	0.0266	0.0053	0.0031	0.0047
Hg	<0.0001	<0.0001	0.0002	<0.0001
Sb	0.0142	0.0094	0.0297	0.0072

Table 7.4-9 Summary of Tailings Aging Tests at 120 Days (cont'd)

Parameter	COMB Overall ore comp	Comb OD Comp	Comb Wolverine D Comp	Comb Lynx D Comp
Se	0.994	0.388	1.26	0.12
Tl	0.0089	0.0029	0.0034	0.0020
Zn	5.57	1.68	0.514	0.54

Notes: All metals are dissolved concentrations.

Sub-aqueous Column Leach Tests

Sub-aqueous column leach tests were conducted on the two combined ore composite samples to simulate the leaching effects from material stored under water cover, and the results are summarized in Table 7.4-10. The columns have similar construction to the humidity cells, however a water cover was maintained on the sample, and leachate was collected weekly. The leachate volume of each weekly sample was approximately 7 times the pore volume of the sample.

The leachate of the sub-aqueous columns was collected and analyzed for pH, conductivity, acidity, alkalinity, thiosalts, anions (F^-, Cl^-, $SO_4^{2-}$and NO_3^-), cyanide (CN), thiocyanate (CNS), cyanate (CNO), ammonia + ammonium (NH_3 + NH_4^+) and a suite of dissolved metal(loid)s via ICP-MS (including mercury) by SGS Lakefield.

Table 7.4-10 Summary of Subaqueous Column Results after 8 Weeks

Parameter	COMB Overall Ore Comp	Comb OD Comp
pH	7.86	7.65
Hardness		
Sulphate	52	38
Thiosalts	5	5
Total Cyanide	*0.005*	*0.005*
Ammonia	0.1	0.7
Ag	*0.00005*	*0.00005*
As	*0.0025*	*0.002*
Cd	***0.00005***	*0.000015*
Cu	*0.004*	*0.0005*
Pb	0.0005	0.0003
Hg	*0.00005*	0.0014
Sb	0.0092	0.0228
Se	0.008	0.010
Tl	*0.0001*	0.0021
Zn	0.005	0.009

Notes: All metals are dissolved concentrations.

The water quality of the leachate stabilized after 4 weeks to typical values shown in Table 7.4-10. The test indicates that the water quality improves with time, as the process water is "flushed" out. For example, the number of pore water volumes in the four weeks was approximately 30 times indicating that a leaching water volume of approximately 2 L/kg is required to "flush" residual contaminants.

7.4.2.4 Acute Lethality Testing of Tailings Supernatant

The 36 hour decant from the aged Combined Overall Ore Tailings and the 24 hour decant from the aged Combined OD Composite, Combined Wolverine D Composite and Combined Lynx D Composite Tailings were subjected to LC_{50} acute lethality testing of *Daphnia magna*.

In addition, the LC_{50} acute lethality of rainbow trout and *Daphnia magna* was completed on the 120 Day decant from the aged Combined Overall Ore Tailings, the OD Combined tailings, the Wolverine D tailings and the Lynx D tailings. The test measured the percent mortality of *Daphnia magna* and rainbow trout in varying concentrations of effluent using standardized test procedures following the *Daphnia magna* Acute Lethality Toxicity Test Protocol EPS 1/RM/14 and Acute Lethality of Liquid Effluents to Fish EPS 1/RM/13 protocols from Environment Canada. Analyses were performed by Stantec Consulting Ltd.

Tailings supernatant from acute lethality aging test results on *Daphnia magna* at Day 1 and Day 120 are presented in Table 7.4-11. The LC_{50} values (concentrations of effluent at which 50% of the test organisms die) indicate that significant dilution or water treatment would be required to render the samples non-toxic. Similar results are seen for testing results on rainbow trout, presented in Table 7.4-12.

Table 7.4-11 Tailings Supernatant Acute Lethality Results for D*aphnia Magna*

Tailings Sample	Day of Testing	Toxicity Test Species	% Mortality at 100% Effluent Concentration	48 h LC50
Comb Overall Ore Comp	1.5	*Daphnia magna*	100	37.7 %
Comb OD Comp	1	*Daphnia magna*	100	15.5 %
Comb Wolv D Comp	1	*Daphnia magna*	100	9.7 %
Comb Lynx D Comp	1	*Daphnia magna*	100	19.2%
Comb Overall Ore Comp	120	*Daphnia magna*	100	19.1%
Comb OD Comp	120	*Daphnia magna*	100	<6
Comb Wolv D Comp	120	*Daphnia magna*	100	7.7
Comb Lynx D Comp	120	*Daphnia magna*	33	>100

Table 7.4-12 Tailings Supernatant Acute Lethality Results for Rainbow Trout

Tailings Sample	Day of Testing	Toxicity Test Species	% Mortality at 100% Effluent Concentration	96 h LC50
Comb Overall Ore Comp	120	Rainbow Trout	100	10.9 %
Comb OD Comp	120	Rainbow Trout	100	4.2 %
Comb Wolv D Comp	120	Rainbow Trout	100*	< 3.1 %
Comb Lynx D Comp	120	Rainbow Trout	n/a	> 50 %

Notes: * tested in 50 % effluent; n/a – insufficient sample for testing at full-strength. No mortality or morbidity observed at 50% of full –strength.

A dilution ratio of 2.5:1 to 6:1 is required to render the solution non-toxic to *Daphnia magna* for the combined ore samples.

A dilution ratio of 10:1 to 20:1 is required to render the solution non-toxic to rainbow trout for the combined ore samples.

7.4.2.5 Humidity Cell Testing

Humidity cell testing is currently underway on the four composite samples. Preliminary results from the test on the combined OD composite tailings are presented in Table 7.4-13. The samples have not yet gone acid and will need to run for a longer period of time to simulate long term conditions.

Preliminary test results indicate elevated concentrations of sulphate, Cd, Se, Tl and Zn. Tests are still active and have not yet used all of the alkalinity.

Table 7.4-13 Preliminary Humidity Cell Results for Combined OD Composite Tailings

Parameter	Units	Minimum	Median	Average	Maximum
Leachate Volume	ml	234	444	426	503
pH	units	3.41	6.63	6.14	6.97
Alkalinity	mg $CaCO_3$/L	0.150	7.50	7.13	15.0
Acidity	mg $CaCO_3$/L	76.0	564	615	1190
Conductivity	µS/cm	370	1520	1418	1980
SO_4^{2-}	mg/L	110	680	628	890
Cl	mg/L	0.100	1.00	0.828	3.20
F	mg/L	0.0300	0.135	0.133	0.180
NO_3^-	mg N /L	0.0250	0.0250	0.0906	0.710
$NH_3 + NH_4^+$	mg N /L	0.100	0.350	0.378	0.800
Thiosalts	mg S_2O_3/L	53.0	480	544	1110
$CN_{(T)}$	mg/L	0.00100	0.00500	0.00539	0.030
CNO	mg/L	0.050	0.05	0.225	0.500
CNS	mg/L	1.00	1.00	2.50	10.0
Hg	µg/l	0.0500	0.0500	0.0500	0.0500
Ag	mg/L	0.0006	0.00250	0.00353	0.0230
Al	mg/L	0.00500	0.00500	0.00583	0.0100
As	mg/L	0.00250	0.0155	0.0146	0.0240
Cd	mg/L	0.00270	0.0696	0.0674	0.115
Cu	mg/L	0.00100	0.00290	0.00350	0.0116
Pb	mg/L	0.00180	0.0126	0.0314	0.3140
Sb	mg/L	0.0250	0.0250	0.0261	0.0450
Se	mg/L	0.325	0.942	0.921	1.96
Tl	mg/L	0.00320	0.0139	0.0147	0.0250
Zn	mg/L	0.0600	3.36	4.18	9.05

Notes: All metals are dissolved concentrations

7.4.3 DMS Float and Waste Rock

Dense media separation (DMS) will be used to separate mining dilution rock from the ore. To assess the geochemical characteristics of the DMS Float Rock, three ore zones (using drill core) were tested including both the Lynx and Wolverine ore bodies as well as the barrier pillar (pillar) zone that connects the two main zones. The actual material separation method used to generate these samples was Heavy Liquid Separation, which uses a methylene iodide solution, rather than ferro-silicon slurry to effect the density separation of the ore particles from the gangue.

Small quantities of waste rock will be stored in the impoundment. Geochemical characterization of this material is being carried out by others, and the material is potentially acid generating.

Static testing included Acid Base Accounting (ABA), ICP-MS element determinations and Shake Flask Extractions (SFE) for the DMS, are presented in the following sections.

Whole Rock Analysis

The results of the whole rock analysis, using x-ray fluorescence are presented in Table 7.4-14.

Table 7.4-14 DMS Whole Rock Analysis (%)

Element	HLS PillarFloats	HLS Wolv Floats	HLS Lynx Floats
SiO_2	57.68	66.69	68.09
TiO_2	0.18	0.28	0.20
Al_2O_3	4.88	8.31	3.58
Fe_2O_3	4.03	3.91	3.58
FeO			
MnO	0.15	0.07	0.07
MgO	1.92	2.08	1.70
CaO	12.44	4.61	5.98
Na_2O	0.01	0.01	0.01
K_2O	1.21	1.82	1.62
P_2O_5	0.31	0.63	0.25
Ba(F)	0.67	0.95	0.90
LOI	9.90	0.95	0.90
Total	93.38	95.41	93.81

Notes: HLS: Henry Liquid Separation

Acid Base Accounting

Table 7.4-15 provides DMS float rock acid base accounting results.

Table 7.4-15 DMS Float Rock Acid Base Accounting Results

Parameter	Units	HLS Pillar Floats	HLS Wolv Floats	HLS Lynx Floats
Paste pH	-	8.3	7.9	8.4
Fizz Rate	-	strong	strong	strong
Total S	%S	1.94	1.17	1.78
Acid Leachable SO_4^{2-}	%S	0.06	0.07	0.06
Sulphide S	%S	1.77	0.90	1.62
Insoluble S	%S	0.11	0.20	0.10
AP	kg $CaCO_3$/t	55.3	28.1	50.6
Sobek NP	kg $CaCO_3$/t	240.9	84.4	120.9

Table 7.4-15 DMS Float Rock Acid Base Accounting Results (cont'd)

Parameter	Units	HLS Pillar Floats	HLS Wolv Floats	HLS Lynx Floats
Net NP	kg $CaCO_3$/t	185.6	56.3	70.3
Sobek NP/AP	-	4.36	3.00	2.39
Carb NP	kg $CaCO_3$/t	247.7	85.7	132.7
Carb NP/AP	-	4.48	3.05	2.62
CO_2	$\%CO_2$	10.9	3.77	5.84
C(T)	%C	4.76	4.12	3.11

Notes: HLS: Henry Liquid Separation

All samples have some sulphide content but with sufficient NP to achieve a Neutralization Potential Ratio (NPR) of greater than 2.4 and are thus classified as having a low to no potential for acid drainage.

The samples have significant carbonate Neutralization Potential (NP) of greater than 85 kg $CaCO_3$/t resulting in slightly alkaline paste pH values of pH 7.9 to 8.4. These carbonates are most likely reactive phases similar to those identified in the tailings samples (Section 7.4.2)

Trace Elemental Concentrations

When measured sample concentrations are compared to known crustal abundances, it can give an indication as to which elements may be of environmental concern under neutral or acidic drainage conditions. Anomalous elemental concentrations are defined here as greater than five times normal crustal abundance as listed in Appendix 3 of Price (1997). Table 7.4-16 lists a summary of the trace element determinations for the three DMS samples, and show concentrations for those parameters with greater than five times crustal abundance for all three samples analyzed.

Table 7.4-16 Summary of Anomalous elements in DMS Float Rock

Element	Avg Ratio	Maximum (mg/kg)	Median (mg/kg)	Minimum (mg/kg)
Se	689	41	29	18
Sb	191	39	39	37
Ag	135	14.7	10.7	7.0
Bi	118	1.2	1.0	0.70
Cd	95	16	15	14
As	46	93	83	72
Mo	24	41	28.6	18
Zn	18	1577	1248	1229
Pb	12	199	141	130
Tl	14	3.8	3.8	72
Cu	7	754	568	158
Th	6	9.8	5.2	5.0
Au	5	0.040	0.014	0.0069

Notes: Avg Ratio = measured concentration divided by typical crustal abundance. Values greater than 5 are considered anomalous for this assessment.

Shake Flask Extraction

This short-term leach test was used to determine what contaminants might flush from the DMS solids when exposed to rain, snowmelt or groundwater flow. The results of the shake flask test are summarized in Table 7.4-17. This procedure is a recommended component of static tests and is used to determine the presence of easily soluble mineral components (Price, 1997).

Table 7.4-17 Summary of Shake Flask Tests in DMS Float Rock

Parameter	Units	HLS Pillar Floats	HLS Wolv Floats	HLS Lynx Floats	Blank
Nanopure water volume	mL	1000	1000	1000	1000
Sample Weight	g	50	50	50	-
pH		7.56	7.33	7.4	5.33
Conductivity	µS/cm	113	77	89	1
Total Acidity (to pH 8.3)	mg CaCO3/L	4	4	5	2.5
Alkalinity	mg CaCO3/L	44.5	26.5	32.75	1.25
Hardness $CaCO_3$	mg/L	57.1	42	46.5	< 0.2
Sulphate	mg/L	15	15	12	<1
Dissolved Metals					
Aluminum Al	mg/L	0.019	0.009	0.005	0.001
Antimony Sb	mg/L	0.029	0.024	0.026	< 0.0002
Arsenic As	mg/L	0.0019	0.0033	0.0015	< 0.0002
Barium Ba	mg/L	0.036	0.042	0.059	< 0.0002
Beryllium Be	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth Bi	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Boron B	mg/L	< 0.01	< 0.01	< 0.01	< 0.01
Cadmium Cd	mg/L	0.0014	0.0042	0.003	< 0.00004
Calcium Ca	mg/L	20.9	14.7	16.8	< 0.01
Chromium Cr*	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Cobalt Co	mg/L	0.0015	0.0019	0.0036	< 0.0002
Copper Cu	mg/L	0.0006	0.0022	0.0038	0.0013
Iron Fe	mg/L	< 0.01	< 0.01	< 0.01	< 0.01
Lead Pb	mg/L	0.0018	0.0037	0.0058	< 0.0002
Lithium Li	mg/L	0.0006	0.0006	0.0006	< 0.0002
Magnesium Mg	mg/L	1.19	1.29	1.1	< 0.01
Manganese Mn	mg/L	0.164	0.172	0.169	< 0.0002
Mercury Hg	µg/L	< 0.02	< 0.02	< 0.02	< 0.02
Molybdenum Mo	mg/L	0.001	0.0008	0.0017	< 0.0001
Nickel Ni	mg/L	0.014	0.038	0.024	< 0.0002
Phosphorus PO_4	mg/L	< 0.03	< 0.03	< 0.03	< 0.03
Potassium K	mg/L	0.63	0.71	0.81	< 0.02
Selenium Se	mg/L	0.01	0.0083	0.019	< 0.0002
Silicon SiO_2	mg/L	0.34	0.35	0.29	< 0.05
Silver Ag	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Sodium Na	mg/L	0.24	0.44	0.49	< 0.01
Strontium Sr	mg/L	0.055	0.039	0.05	< 0.0002
Tellurium Te	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002

Table 7.4-17 Summary of Shake Flask Tests in DMS Float Rock (cont'd)

Parameter	Units	HLS Pillar Floats	HLS Wolv Floats	HLS Lynx Floats	Blank
Thallium Tl	mg/L	0.0004	0.00025	0.002	< 0.00002
Thorium Th	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Tin Sn	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Titanium Ti	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Uranium U	mg/L	0.0008	0.0002	< 0.0001	< 0.0001
Vanadium V	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Zinc Zn	mg/L	0.064	0.3	0.21	< 0.001
Zirconium Zr	mg/L	< 0.002	< 0.002	< 0.002	< 0.002

Notes: All metals are dissolved concentrations.

Results of the shake flask tests show the final pH was near neutral to alkaline and ranged from pH 7.1 to 9.4. No parameters exceeded the limit value in the Metal Mining Effluent Regulations (MFO 2002).

DMS float rock could be classified as non acid generating, although additional testing and assessment is required to confirm this potential.

7.5 Design Criteria

7.5.1 General

The tailings dam is designed to international standards, using International Congress of Large Dams ICOLD Guidelines (1989) and Canadian Dam Safety Guidelines (CDA, 1999). The main design criteria are summarized in Table 7.5-1 and discussed in the following sections.

Table 7.5-1 Summary of Design Criteria

Item	Criteria
Storage Capacity • Tailings • Waste rock • DMS Float	 • 0.76 Mt @ 1.85 t/m^3 • 0.12 Mt @ 1.9 t/m^3 (portion of waste rock to be used for constructing lower upstream zone of Starter Tailings Dam) • 0.80 Mt @ 1.9 t/m^3
Flood Management during Operation • Diversion of upland catchment • Flood storage in impoundment • Flood discharge	 • 1: 100 year peak flow • 200 year return period (approx. 0.3 m of pond rise) + seasonal storage of water • exceeding 1:200 year peak flow, no dam overtopping during 1:10,000 year
Seismic Return Period During Operation and Closure	• 10,000 year return period
Geotechnical Factors of Safety during operations • Static • Pseudo-static, seismic coefficient = 0.126 g	 FS = 1.3 FS = 1.1

Table 7.5-1 Summary of Design Criteria (cont'd)

Item	Criteria
Environment - Operations • Tailings pond • Total seepage flows out of impoundment	 • Saturated tailings and DMS to prevent acid rock drainage • Effluent treated until water quality meets discharge limits • < 1 L/s to be collected and returned to tailings pond during operation
Closure • Flood Handling 7.6 Diversion Ditches 7.7 Spillway • Geotechnical stability Safety Factor 7.8 Static 7.9 Pseudo-static, seismic coefficient = 0.126 g • Geochemical stability	 • All diversion ditches to be decommissioned • 1:10,000 year return period routed peak flow FS = 1.5 FS = 1.10 (Seed, 1989) • 0.5 m to 1 m minimum water cover to maintain saturation to prevent acid rock drainage • Effluent treated until water quality meets discharge limits • Seepage <0.5 L/s

7.9.1 Dam Failure Consequence Classification

The consequence classification of the tailings facility was assessed during the pre-feasibility study (Klohn Crippen 2004) to guide the selection of criteria for the flood and seismic design. That assessment was based on a preliminary screening-level review with consideration of the potential incremental life safety, socioeconomic, financial and environmental consequences of failure, and the associated hazard ratings as provided for in the Canadian Dam Safety Guidelines (CDA 1999). Although the pre-feasibility study rated the consequence of failure as "Low", more stringent criteria within the "Low" category was chosen for the design criteria. Based on comments received from regulatory agencies and further analysis and review carried out during 2005, the consequence category for the tailings dam has been upgraded to "High" as described below.

The tailings facility is located in a remote area of Yukon and, except for a campsite on Frances Lake, there are no major population centres or commercial and industrial activities downstream of the impoundment. In the event of an incident at the tailings impoundment, the discharge from the facility would enter Go Creek and then Money Creek. Money Creek discharges into Frances Lake, which is located east of the mine about 40 km downstream of the tailings impoundment. The most significant infrastructure crossing along this flow path is the Robert Campbell Highway over Money Creek just before the creek enters Frances Lake.

The expected peak flood outflow from the tailings pond occurring as a result of a dam breach was estimated using charts compiled by MacDonald and Monopolis (1984), and by Wahl (1998), based on dam failure case studies. It should be noted that these charts are based on failures of water storage dams. Tailings stored in the tailings ponds have higher viscosity than water and, in the event of a tailings dam failure, usually not all the tailings are released from the pond. Furthermore, tailings tend not travel as far downstream as water. The estimated total storage volume of 1 million m^3 (Mm^3) at closure in the Wolverine tailings pond will comprise of approximately 0.4 Mm^3 of tailings, 0.06 Mm^3 of waste rock, 0.4 Mm^3 of DMS float and 0.14 Mm^3 of water.

Tailings and water make up about 47% and 14% of storage, respectively. For estimating the peak discharge resulting due to a breach at the Wolverine tailings dam, the following simplifying assumptions were made:

- The total storage volume was taken as 100% of the free water in the pond (0.14 Mm^3) plus 30% of the stored tailings and coarse waste (0.25 Mm^3).
- The tailings and coarse waste were assumed to behave the same as water, i.e., the entire volume of water plus the 30% of tailings and coarse waste is released from the pond and all of it travels downstream as if it was water.

The analysis of data presented by United States Congress of Large Dams (USCOLD) on tailings dam failures (USCOLD 1995) indicates that, on average, only 30% of the tailings are released from the impoundment as a result of a dam failure. Since the charts being used are based on failures of water storage dams where the entire storage volume above the dam foundation would be released, only 30% of the total tailings and coarse waste is assumed to be part of the storage volume for the analysis of the Wolverine tailings dam. The above assumptions are considered to be conservative since coarse waste is less mobile than tailings, and tailings is less mobile than water.

The estimated peak outflow released from the dam is 2700 m^3/s, which is expected to attenuate as the flood wave travels downstream. The downstream flows were estimated using the attenuation charts prepared by Petrascheck and Sydler (1984), and the results are summarized in Table 7.5-2.

Table 7.5-2 Estimated Dam Breach Flood Peaks Downstream of Tailings Dam

Location	Distance from Dam (km)	Estimated Peak Flow (m^3/s)
At Wolverine Tailings Dam	0	2700
Confluence of Go Creek and Money Creek	5	2600
Robert Campbell Highway and Frances Lake	40	1600

The assumptions made and the charts used herein provide approximate estimates of expected dam breach discharge and downstream attenuation. A more detailed dam breach and inundation analysis should be carried out for determining the flows for emergency planning purposes.

As Table 7.5-2 indicates, little attenuation of the flow is expected by the time the flood peak reaches Money Creek, but it is expected to decrease to about 60% of the original flow by the time the flood peak reaches Robert Campbell Highway and Frances Lake. A comparison of the estimated flood peak resulting from a breach at the tailings dam with the natural stream flows indicates that the dam breach flood peak will be about 200 times the naturally expected 200-year peak flow in Go Creek above Money Creek, and it will be about 20 times the naturally expected 200-year peak flow in Money Creek at the Robert Campbell Highway.

Since the area downstream of the tailings dam is relatively undeveloped and has very little infrastructure, minor to moderate financial damages are expected in the event of a breach at the tailings dam. Similarly, very few fatalities are anticipated. However, since the flood flows resulting from a dam breach are relatively high compared to the expected naturally occurring flows, large socio-economic and environmental damages could be expected. The expected attenuation of the flood peak presented in Table 7.5-2 is based on the assumption that the tailings released from the dam migrate downstream the same as water. In reality, the tailings will not be as mobile and a substantial portion of the tailings is expected to be deposited close to the dam. The tailings released from the pond as well as those left in the pond are expected to become acid generating if left exposed to atmosphere and would remain acid generating indefinitely until the oxidation process is complete. The potential environmental damage in that case could be substantial and could require recovery of all of the tailings and construction of a new containment facility. Given the potential for large socio-economic and environmental damage, as well as substantial clean-up costs, the tailings impoundment is classified as a "High" consequence facility.

7.9.2 Design Earthquakes

The design earthquake selected for the tailings dam was based on the Canadian Dam Safety Guidelines (CDA 1999). Since the tailings facility is classified as "High" consequence, the annual probability of exceedance of horizontal peak ground acceleration is chosen as 0.0001, corresponding to a return period of 10,000 years. The recent work by Atkinson (2004) on Seismic Hazard Assessment for Faro, Yukon has been incorporated in our seismic hazard assessment as presented in Section 7.2.2. The Tintina Trench area was modeled as a localized seismogenic zone with higher seismicity than the model used for the 2005 National Building Code of Canada (Adams and Halchuk 2003). For the seepage recovery dam, the annual probability of exceedance of horizontal peak ground acceleration is selected as 0.0021, corresponding to a return period of 475 years, as no tailings are stored behind the dam.

7.9.3 Design Floods

The design flood criteria selected for various components of the water management facilities associated with the tailings impoundment are summarized in Table 7.5-3. The selection of the design floods was based on the Canadian Dam Safety Guidelines (CDA 1999). The expected operating life of the mine was also taken into account in the selection of the design floods for temporary facilities, such as the surface runoff diversion ditches, the starter dam emergency spillway, the seepage collection ditches and the seepage recovery pond. Based on current resources, the mine is expected to be active for a period of about 12 years. During this time all facilities related to the tailings impoundment would be closely and frequently monitored, and personnel, equipment and materials are expected to be readily available in the event that remedial measures are required to be taken under routine and/or emergency maintenance. Therefore, lower design criteria for temporary facilities are proposed. However, as shown in Table 7.5-3, the design flood of 10,000-year return period is proposed for the tailings pond closure spillway.

Table 7.5-3 Selected Flood Design Criteria for Water Management Facilities

Facility	Min. Design Flood Return Period (years)	Flood Storage & Freeboard Allowance	Comments
Surface water diversion ditches	100		-
Starter Dam and Stage-Raised Dam Emergency Spillway	200		Assume that upland surface water diversion ditches have failed. Spillway also must be able to pass the 10,000-year flood without overtopping the dam.
Tailings Dam Closure Spillway	10,000		Assume that upland surface water diversion ditches have been decommissioned.
Seepage Collection Ditches	100		-
Seepage Recovery Pond Spillway	100		Assume that upland surface water diversion ditch is functioning.
Tailings Pond flood storage allowance below spillway level during mine operation		0.3 m	For routing of design flood through the tailings pond after closure, the initial water level is assumed to be at the spillway level, i.e., flood storage allowance is assumed to be zero.
Tailings Dam freeboard to normal pond water level		2.0 m	Freeboard will be less than this during passage of flood

7.9.4 Design “Allowable” Seepage Assessment

This section presents the design basis for determining the “allowable” seepage rate from the impoundment. The assessment is based on determining the fate and transport of potential contaminants from the impoundment to the receiving environment.

During operations, seepage through the dam will be collected with a seepage collection ditch and pond for return to the impoundment, as required. In addition, a portion of seepage from the impoundment (potentially 25% of total seepage) may bypass the seepage collection system and mix with the regional groundwater flow. The groundwater flow system downstream of the seepage recovery dam can be characterized as follows:

- In the immediate vicinity of Go Creek and the tailings impoundment, the groundwater aquifer comprises up to 20 m of overburden, estimated groundwater flow is 15 L/s.
- In the vicinity of W12, upstream of the confluence of Money Creek and Go Creek. This area appears to have a similar overburden cover as near the dam and the estimated groundwater flow is 60 L/s.
- In the vicinity of W14, downstream of the confluence of Money Creek and Go Creek where the morphology changes to a terrace glacial outwash regime with a thicker overburden aquifer and an estimated groundwater flow of 420 L/s.

A portion of the groundwater flow downstream of the dam will report to Go Creek and the remainder will flow towards the groundwater regime in the vicinity of W14.

Upon closure, the seepage will be collected and monitored to confirm flows and ensure that concentrations are acceptable and, if necessary, treated or mixed with the impoundment water.

The criteria for allowable seepage has been estimated on the basis of a simple dilution model, using predicted concentrations of cadmium, selenium and zinc in the impoundment and the predicted flow from a two dimensional SEEPW groundwater model. In addition, a factor of 10% has been applied to account for attenuation and adsorption, which will occur along the flow path. Seepage of contaminated water from the impoundment is a temporal event, which will occur during the life of the mine, and for a period of time after closure. An estimate of the length of time required to "flush" contaminants from the tailings has been made on the basis of the column leach tests presented in Section 7.4.2. The testing indicates that flushing of the tailing voids with 30 times the pore volume results in significantly reduced contaminant levels, with concentrations similar to existing baseline values. The time required for this, assuming an impoundment basin permeability of 10^{-6} cm/s, is approximately 12 years.

Table summarizes the concentrations of cadmium, selenium and zinc in the tailings/waste rock pore water, baseline values at W14 and "tolerable" seepage based on the groundwater "dilution" flow and a 10% factor for adsorption. The pore water chemistry is based on the data presented in Section 7.4.2 of this report, and is primarily controlled by the process water chemistry during operations. Supporting data includes shake flask extraction tests and aging tests of the tailings supernatant.

Table 7.5-4 Summary of Concentrations of Parameters of Potential Concern and "Tolerable" Seepage Rates

Parameter of Potential Concern	CCME Limit (mg/L)	Baseline Concentration (mg/L)	Impoundment Pore Water - Range (mg/L)	"Tolerable" Seepage (L/s)* W-14	"Tolerable" Seepage (L/s)* W-12
Cadmium	0.000 017	0.000 05	0.01	20	3
Selenium	0.001	<0.001	1	40	6
Zinc	0.03	<0.005	1 to 5	50	7

Notes: * "Tolerable" seepage based on groundwater dilution flow at W-12 and W-14, with 10% adsorption factor.

Based on the above, a "tolerable" seepage criterion could be approximately 5 L/s, however if adsorption is discounted, the "tolerable" seepage could be 0.5 L/s. Accordingly, a conservative design criteria of <0.5 L/s has been adopted.

7.10 Tailings Impoundment

7.10.1 General Layout

The tailings impoundment site is located in a natural, northwest-southeast trending elongated ephemeral drainage channel perched on the northeast valley slope of Go Creek (Figure 7.1-1). The depression is flanked on the downhill side by a natural ridge trending in the same direction that drops in elevation gently towards the upstream end of the tailings facility, and ends rather abruptly at the elbow point of the proposed L-shaped tailings dam at the downstream end.

Site investigations indicate that the tailings basin is mantled by glacio-morainal deposits, which may have been altered by the stream flowing along the thalweg. Along the ridge, the depth to bedrock ranges from 30 to 40 m, while between the ridge and the northeast valley slope the depth is shallower, ranging from 20 to 25 m.

The design of the tailings facility is based on field and laboratory investigations of foundation conditions and considerations of geochemical characteristics of tailings, course waste, supernatant water, dam borrow materials, storage capacity requirements, site water balance, dam failure consequence rating, and earthquake and flood potential.

The tailings facilities include a L-shaped tailings dam, a tailings pond a seepage recovery dam, a seepage recovery pond, two upland diversion ditches, two seepage collection ditches and a spillway, (Figure 7.1-1). The impoundment covers an area approximately 600 m long and 300 m wide. The maximum dam height is 28 and 34 m high at project start up and at the end of operations, respectively. The design of the tailings dam is presented in Section 7.7.

7.10.2 Storage Capacity

The tailings dam is designed as a water-retention structure, and a net water balance is maintained. The required storage volumes for tailings and coarse waste are summarized in Table 7.10-1. Actual volumes of each material are expected to vary with continued optimization of the mine plan, nonetheless the overall volume is sufficient to provide storage of materials for approximately 12 years of operations. Tailings are produced at an average rate of 923 t/d or 0.34 million t/y. However, only a portion of tailings will be stored in the tailings impoundment, while the rest will be returned underground as paste backfill. A total solids storage volume of 0.90 Mm^3 is required. The ultimate pond elevation, at elevation 1314 m, will cover an area of about 120,000 m^2. The proposed impoundment site could also accommodate additional storage volume, if required.

Table 7.10-1 Tailings and Coarse Waste Storage Volumes

Material	Tonnage (Mt)	Volume (Mm^3)
Tailings	0.76	0.41
Waste Rock	0.12	0.06
DMS Float Rock	0.80	0.42
Total	1.68	0.90

The storage capacity of the impoundment is shown in Figure 7.6.1 and, in additional to storage of solids, will provide for the following:

- minimum operational water volume for settling of solids and operation of pumps of 30,000 m^3;
- seasonal storage for average conditions of 75,000 m^3;
- 200 year flood storage consisting of 200 yr wet month precipitation with snowmelt of 37,500 m^3; and
- 2 m of freeboard, which provides for routing of the 10,000 year return period flood event through the spillway (0.5m) and 1.5 m of freeboard.

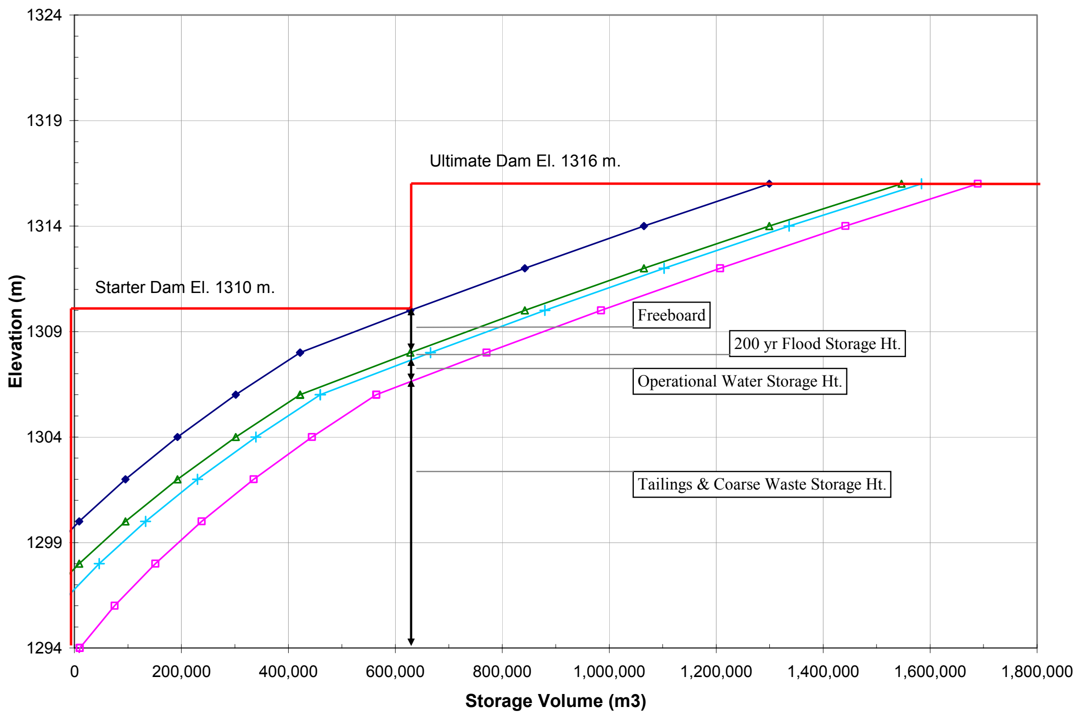


Figure 7.10-1 Stage Storage Curve – Tailings Impoundment

7.10.3 Deposition Strategy and Staged Development

The tailings and coarse waste will be deposited within the tailings impoundment as shown in Figure 7.10-2 and Figure 7.10-3 (Starter Dam and Ultimate Dam on closure, respectively). Typical sections are shown schematically in Figure 7.10-4and Figure 7.10-5 for various stages of operations. The tailings will be spigotted from a single point on the left flank of the impoundment and a water reclaim barge will be located near the left abutment of the dam. The tailings will form a beach above water, which will slope at approximately 1% towards the water pond. The DMS material will be placed by trucks in the interior sections of the impoundment. Waste rock will be placed by trucks within the active tailings area.

Figure 7.10-2 Starter Impoundment – Tailings and DMS Placement Plan (Figures Section)

Figure 7.10-3 Final Impoundment – Closure Plan (Figures Section)

Figure 7.10-4 Starter Impoundment – Typical Section (Figures Section)

Figure 7.10-5 Ultimate Impoundment – Typical Section (Figures Section)

For start up of the tailings facility, flows from Go Creek will be directed via a diversion ditch (Ditch A) into the tailings facility during the spring runoff season prior to commencement of mining operations. The diversion structure located across the existing stream channel will consist of a concrete lock-block barrier with a gated culvert, as shown in Figure 7.10-6and discussed in Section 7.8.2.

Figure 7.10-6 Go Creek and Ditch A Diversion Structures (Figures Section)

As discussed in Section 7.6.5, the water balance modeling indicates that the facility will operate with a net water surplus. Therefore, to minimize inflow during mine operation, diversion ditches will be constructed on the upslope (northeast) side of the tailings facility.

Treatment and discharge of tailings supernatant will be required during the operational phase of the mine to prevent accumulation of excess water within the tailings impoundment. An emergency spillway will be maintained during mine operations to discharge floodwater for severe hydrological events. At closure, the diversion ditches will be decommissioned and a permanent spillway will be constructed. On closure, a minimum water cover of 0.5 m will be maintained within the impoundment to prevent the development of acid rock drainage from the mine waste (combined tailings, DMS float and waste rock materials).

Precipitation runoff and any tailings pond seepage will be collected in collection ditches and the seepage recovery pond will be recycled back to the tailings pond.

7.10.4 Liner Design

A steady state seepage analysis was carried out using the computer program SEEP/W (Geo-slope 2004). A 2-D representative section through the main part of the impoundment was used, with an average applicable width of 250 m used for calculation of total seepage. A parametric analysis was carried out for various impoundment basin and dam core permeabilities to determine the lining requirements for the facility, and the results are summarized in Table 7.10-2.

Table 7.10-2 Summary of Seepage Analyses for Ultimate Tailings Dam

Impoundment Condition		Seepage @ Toe (L/s)	Seepage @ Depth (L/s)	Total Seepage (L/s)
Liner Preparation	Basin Permeability (cm/s)			
Unlined facility	10^{-4}	11.5	3.5	12.5
Soil lined facility	10^{-6}	5	1.5	6.5
Complete geomembrane liner	-	-	-	$2\ (10)^{-4}$

An estimate of potential liner leakage has been made on the basis of a 2-D SEEP/W model, simulating defect holes in the liner, based on medium quality installation procedures. Unlike liner leakage calculations associated with the Heap Leach and landfill industries, the leakage is "inflow" controlled by the permeability of the tailings. The Wolverine tailings permeability is in the order of $7\ (10)^{-6}$ cm/s, although there could be some segregation and areas where tailings may not be placed prior to placement of DMS material. Based on the conservative tailings permeability, the liner leakage rate would be equivalent to 700 L/Ha/year, or $2\ (10)^{-4}$ L/s, which is negligible. For comparison purposes, an estimate of the liner leakage assuming no tailings, and an impoundment full of water, was made on the basis of standard EPA liner calculations for heap leach and landfill facility. For a moderate level of quality control, the estimated leakage would be 0.2 L/s, which is below the design criteria.

The geomembrane liner is a 20 mil Enviro Liner 6000 polyolefin material produced by Layfield Geosynthetics. The foundation base will be prepared by heavily compacting the natural soils in place. Local placement of finer material will be required in areas of very coarse gravel or boulders. In the very low area of the impoundment, near the upstream toe of the dam, it may be necessary to install a short underdrain to prevent uplift pressures during construction.

The lining system will be constructed in two stages as shown on Figure 7.10-7 and Figure 7.10-8. Material from the impoundment will be excavated and used for dam construction. Typical cut and fill sections for the impoundment are shown in Figure 7.10-9.

Figure 7.10-7 Starter Dam Excavation and Fill Plan (Figures Section)

Figure 7.10-8 Ultimate Dam Excavation and Fill Plan (Figures Section)

Figure 7.10-9 Impoundment – Excavation and Fill – Typical Sections (Figures Section)

7.10.5 Water Balance

The water balances for the proposed tailings impoundment, with and without the upland diversion ditches, were carried out for the following four scenarios:

- the first year of tailings facility operation;
- the final year of tailings facility operation;
- after mine closure, with diversions; and
- after mine closure, without diversions.

The cases were run for the average year, 100 year wet, and 100 year dry.

Inflows to the tailings pond include:

- surface water runoff and snowmelt from the Tailings facility catchment, and direct precipitation on the tailings facility;
- milling transport water, which included: tailings transport water, sewage treatment plant effluent and underground mine water;
- water in the DMS float reject and mine development waste rock trucked to the tailings facility; and
- water transferred from the seepage recovery pond to the tailings pond.

Outflows from the tailings facility include:

- evaporation from the pond;
- reclaim water recycled to the mill during mining operation;
- water lost to tailing voids, DMS float and waste rock, as porewater;
- water conveyed to the water treatment plant; and
- seepage losses from the tailings pond.

The groundwater table is near surface and after placement of tailings the groundwater gradients will be downward. Therefore, the contribution of groundwater into the impoundment is considered negligible.

The tailings pond has a total natural catchment area of about 105 ha. With the upland diversion ditches in place, the reduced tailings facility catchment is about 16 ha.

Table 7.10-3 presents the results of the annual water balances for the initial operations. As the table indicates, there will be surplus water in the tailings pond during mine operation for the average year (16 m^3/hr), the 1:100 year wet year (19 m^3/hr) as well as the 1:100 dry year (12 m^3/hr).

The water balance for the post mine closure scenario indicates that there will be a surplus water during the average year and the 1:100 year wet year, a water neutral condition is expected to occur during the 1:100 year dry year if the upland diversion ditches are left in place. Therefore, the upland diversion ditches will be decommissioned after mine closure such that the water cover on the deposited tailings is maintained.

As a comparison, Table 7.10-4 presents a summary of water balance conditions for operations and closure assuming diversion ditches are not in place. The water balance for the average year during initial operations is shown schematically in Figure 7.10-10. Monthly water balances for all conditions are included in Appendix F3.

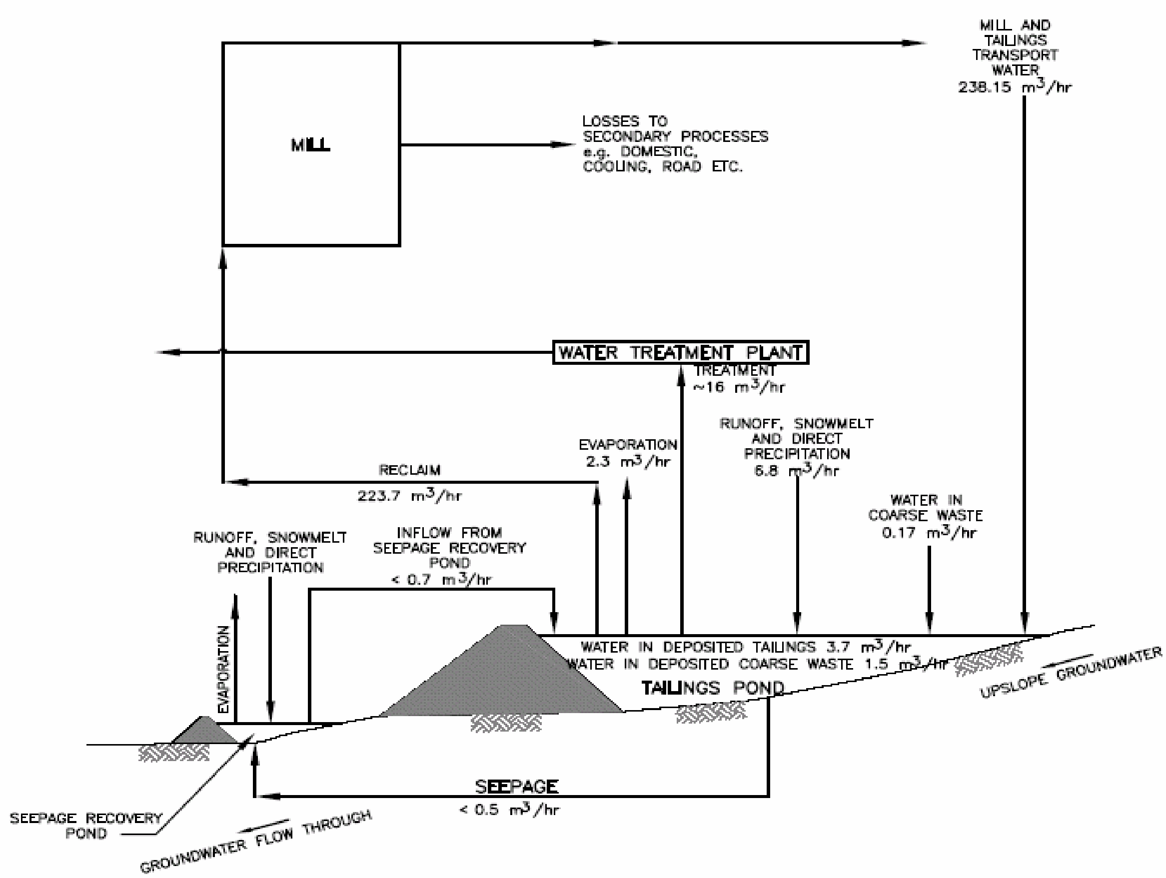


Figure 7.10-10 Water Balance Schematic

Table 7.10-3 Tailings Pond Annual Water Balances with Diversion Ditches

DATA

	Daily tonnage (tpd)	% Solids Transport	% Solids Starter	% Solids Final
Tailings production	268	15.630%	75%	80%
DMS production	186	90%	85%	85%
WR production	23	97%	85%	85%
Paste production	680	76%	76%	76%
Paste plant bypass	18	0.4%	75%	80%

Annual Precipitation (mm)	570
Runoff Coefficient	0.23
Water pond area	0.03
Catchment runoff area (sq.km.)	0.16
DMS & beach area (sq.km)	0.05
Uphill catchment area (sq.km.)	1.05
% Diversion ditch seepage	0.15

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.
Mean Monthly Temperature	-15	-16	-12	-8	2	9	11	8	2	-7
Monthly percent of annual evap.	8%	6%	5%	4%	7%	11%	14%	11%	10%	9%
Average Monthly Precipitation (mm)	42.8	33.2	26.5	20.0	42.3	65.3	77.7	62.3	57.1	48.8
Average monthly runoff (% of annual)	0%	0%	0%	1%	19%	35%	17%	9%	9%	6%
Monthly Evaporation (mm)	5	4.5	9.5	21	72	86.5	90	61.5	32	14.5
Incremental ice thickness on pond (m)	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Inputs (m3/hr)										
Mine groundwater	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Recirculated drill u/g water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage water	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Tailngs transport water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantsite Tailings, etc.	238.15	238.15	238.15	238.15	238.15	238.15	238.15	238.15	238.15	238.15
DMS transport water	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
WR transport water	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Precipitation on pond	1.78	1.38	1.11	0.83	1.76	2.72	3.24	2.60	2.38	2.03
Runoff from catchment	0.00	0.00	0.00	0.29	5.54	10.20	4.95	2.62	2.54	1.73
Seepage from diversion ditch	0.00	0.00	0.00	0.29	5.45	10.04	4.88	2.58	2.50	1.70
Seepage reclaim	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Subtotal	268	268	267	268	279	289	279	274	274	272
Water Losses (m3/hr)										
Pond evapor.	0	0	0.66	1.46	5.00	6.01	6.25	4.27	2.22	1.01
Tailing voids	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72
DMS voids	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
WR voids	0.2	0.2	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Paste Voids	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Process water low level treatment	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Mine water low level treatment	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck wash low level treatment	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seepage	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water reclaim to process plant (Hatch)	223.71	223.71	223.71	223.71	223.71	223.71	223.71	223.71	223.71	223.71
Subtotal	255	255	256	256	260	261	261	259	257	256
Net water surplus (deficit)	**13**	**12**	**12**	**11**	**19**	**28**	**18**	**15**	**16**	**16**
Environmental water treatment	0	0	0	0	31	31	31	31	31	31
Operational pond volume	64,000									
Incremental pond volume	9,149	8,886	8,437	8,083	(8,960)	(2,336)	(9,630)	(11,997)	(10,789)	(11,328)
Seasonal pond volume	73,149	82,035	90,472	98,555	89,596	87,260	77,630	65,633	54,843	43,515

Table 7.10-4 Tailings Pond Annual Water Balances Assuming Diversion Ditches Were Not in Place

Condition	Net Average Water Surplus (m^3/hr) Average	100 yr dry	100 yr wet
Initial operations	16	12	19
Final operations	16	10	20
Closure with diversions	7	0	0
Closure without diversion	18	5	14

Ditch A will be used to divert water from Go Creek into the tailings basin, as shown in Figure 7.1-1. It is expected that the diversion structure on Go Creek, the diversion ditch between Go Creek and the tailings pond (Ditch A), and a substantial portion of the starter dam will be constructed in the year prior to start up of mining operations in order to allow diversion of water from Go Creek during the spring freshet of the first year of operation. The mean annual flow in Go Creek at the airstrip (Station W31), which is located close to the proposed stream diversion site, is estimated to be 0.022 m^3/s (79 m^3/hr). High flows in Go Creek occur during the months of May, June and July, with estimated mean monthly flows of 0.048 m^3/s, 0.045 m^3/s and 0.034 m^3/s, respectively. Go Creek will have sufficient flow during the months of May to July to allow diversion to the tailings pond, while maintaining base flows in the creek downstream of the diversion structure. The diversion structure and the ditch will be decommissioned, when its use for supplementing the make-up water in the tailings pond is no longer needed. In the water balance for operation phase, no water inflow from Go Creek is assumed.

7.10.6 Water Quality Management

The water balance shows that during operations over 90% of the water entering the impoundment is tailings slurry water. During operations, the impoundment will have a net water surplus, as indicated in the water balance presented in the previous section of this report. Discharge from the impoundment will be managed to maintain receiving water quality, which will comprise two main components:

- Discharge concentrations and flows will be managed to meet CCME aquatic life limits for cadmium, selenium and zinc at the compliance point.
- Excess water will be treated as required to meet the “tolerable” discharge loading. Excess water will be stored in the tailings impoundment during the low flow months of November to April, and treated and discharged during the high flow months of May to October.

Details pertaining to water management at treatment are provided in Section 9.

7.10.7 Seepage Recovery Facility

The seepage recovery facility will consist of a low-dyke forming a storage basin with a capacity of approximately 5000 m^3. Construction material for the dyke will be borrowed from the basin. Seepage collection ditches will be excavated along the downstream toe of the tailings dam. All water will be collected and pumped to the tailings impoundment. The volume is sufficient to store the average runoff for the month of July (i.e., the month with the highest runoff) plus about 30 days of seepage from the tailings pond. The pond will have an emergency spillway to release floodwater from the pond when the inflow exceeds both the storage and pumping capacities.

The following are the estimated flow rate and heads for pumping the water from the seepage recovery pond to the tailings pond:

- Flow rate 350 USgpm
- Head to Starter Tailings Dam crest 26 m
- Head to Closure Tailings Dam crest 32 m

The pumping rate of 350 USgpm is approximately equal to the average pond inflow rate for a 5-year, 24-hour rainfall. The heads given above are the difference in elevation between the minimum seepage pond water level and the crest of the tailings dam. They do not include any hydraulic losses in the pumping system, such as pipe friction, valve and fitting losses, inlet and exit losses, etc. At 350 USgpm, it will take about 2.6 days to pump 5000 m^3 out of the pond.

7.11 Tailings Dam Design

7.11.1 Dam Design Section

The Starter and Ultimate Tailings Dam are shown in plan and section in Figure 7.11-1. The following features are incorporated in the dam design:

- A centreline dam geometry, with a zoned embankment dam with a central vertical low permeability core, a downstream structural shell and horizontal drainage blanket will be constructed of borrowed earthfill materials.
- A geomembrane liner will be placed within the low permeability core zone. The liner will be extended over the footprint of the impoundment to minimize seepage potential.
- Upstream of the core, fine waste rock will be incorporated in the structural zone of the Starter Dam below elevation 1306 m. Tailings placed further upstream will provide an additional seepage barrier.
- A 2 m freeboard above the normal pond water level will provide additional flood storage and hydraulic head for spillway discharge.
- On closure, a 0.5 m minimum depth of water over the stored tailings and coarse waste will provide an oxygen barrier to prevent acid generation and metal leaching of the solids.

The proposed layout will provide sufficient storage for tailings and coarse waste produced over 12 years of mine life, although additional storage volume is available at the site. The L-shaped dam has two segments: a 250 m long section that crosses a ephemeral sub-drainage basin, and a 500 m long section over the flanking ridge on the downhill side of the tailings basin.

A dam crest width of 10 m will be used for both the Starter Dam and Ultimate Dam. The upstream slope will be 2H:1V and the downstream slope will be 3H:1V (Figure 7.11-1).

Figure 7.11-1 Tailings Dam Plan and Sections (Figures Section)

7.11.2 Geotechnical Parameters

The dam foundation consists of up to 20 m thick competent till-like overburden overlying bedrock. A layer of about 0.3 m thick topsoil overlying the till-like material will be removed in the dam footprint, and the foundation surface proofrolled to receive damfill.

The test pits excavated in the vicinity of the tailings basin indicate that competent silt-sand-gravel-cobble till-like borrow materials are available from within the footprint of the impoundment. Lower permeability soils with a higher fines content will be used in the dam core zone, while materials with less fines will be used to construct the downstream structural shell. Pervious granular materials required for constructing the horizontal drainage blanket will either be hauled in from suitable sources or be produced from locally available materials using processing plants.

Figure 7.11-2 shows the geometry and zoning of the Starter Dam and Ultimate Dam used in the seepage and stability analyses. Table 7.11-1 lists the properties of various materials used in the seepage and limit equilibrium slope stability analyses. These properties are based on field and laboratory test data acquired for the project as discussed in Section 7.3 and supplemented by general properties available in literature.

Table 7.11-1 Summary of Material Properties Used in Seepage and Slope Stability Analyses

Material	Unit Weight γ_{bulk} (kN/m^3)	Effective Shear Strength		Hydraulic Conductivity k (cm/s)
		Cohesion c' (kPa)	Friction ϕ' (deg)	
Overburden	21.8	0	34	3.00E-03
Bedrock	22.8	0	40	1.00E-05
Waste Rock	21.8	0	32	1.00E-05
Dam Core	21.8	0	34	1.00E-06
Enviro Liner	-		24	1.00E-11
Dam Shell	21.8	0	36	5.00E-05
Blanket Drain	21.8	0	32	1.00E-03
Tailings	23.2	0	25	7.00E-06
DMS Float	21.8	0	35	5.00E+00

7.11.3 Slope Stability Analyses

Static and pseudo-static stability analyses were carried out using the computer program SLOPE-W (Geo-Slope 2004) and the Morgenstern-Price method to determine the factor of safety.

Results of static slope stability analyses are presented in Figure 7.11-2, and summarized in Table 7.11-1.

Pseudo-static slope stability analyses were carried out using a seismic coefficient (k_h) of 0.125, corresponding to a design earthquake magnitude of 7.2 based on interpolation from Seed (1979). In the analyses, no seismic-induced excess pore pressure was assumed in either the dam of foundation material. Results of pseudo-static slope stability analyses are also included in Figure 7.11-2 and Table 7.11-2.

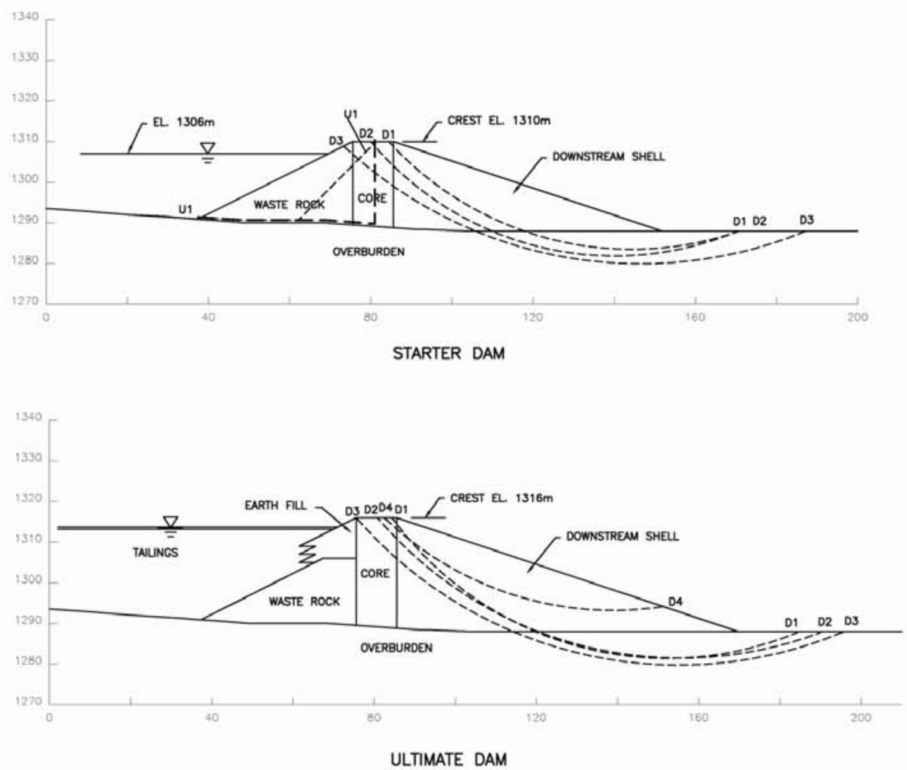
Table 7.11-2 Summary of Safety Factors for Tailings Dam

a) Starter Dam – Crest El. 1310 m

Failure Surface	Static	Pseudo-Static Seismic Coefficient (0.125) a = 0.125 g
D1	2.2	1.5
D2	2.2	1.5
D3	2.4	1.6
U1	1.5	1.0

b) Ultimate Dam – Crest El. 1316 m

Failure Surface	Static	Pseudo-Static Seismic Coefficient (0.125) a = 0.125 g
D1	2.2	1.5
D2	2.2	1.5
D3	2.3	1.5
D4	2.4	1.7



SUMMARY OF MATERIAL PROPERTIES

MATERIAL	UNIT WEIGHT, γ bulk (kN/m³)	EFFECTIVE SHEAR STRENGTH		HYDRAULIC CONDUCTIVITY, k (cm/s)
		FRICTION, ϕ' (deg)	COHESION, C' (kPa)	
OVERBURDEN	21.8	34	0	3.0×10^{-3}
BEDROCK	22.8	40	0	1.0×10^{-5}
WASTE ROCK	21.8	32	0	1.0×10^{-5}
EARTHFILL	21.8	34	0	1.0×10^{-6}
DAM CORE	21.8	34	0	1.0×10^{-6}
DAM SHELL	21.8	36	0	5.0×10^{-5}
BLANKET DRAIN	21.8	32	0	1.0×10^{-3}
TAILINGS	23.2	25	0	7.0×10^{-6}
DMS	21.8	35	0	5.0
LINER	21.0	24	0	1.0×10^{-8}

SUMMARY OF FACTOR OF SAFETY FOR STARTER DAM

FAILURE SURFACE	STATIC FACTOR OF SAFETY (MORGENSTERN–PRICE)	PSEUDO–STATIC FACTOR OF SAFETY (MORGENSTERN–PRICE)(1)
D1	2.2	1.5
D2	2.2	1.5
D3	2.4	1.6
U1	1.5	1.0

SUMMARY OF FACTOR OF SAFETY FOR ULTIMATE DAM

FAILURE SURFACE	STATIC FACTOR OF SAFETY (MORGENSTERN–PRICE)	PSEUDO–STATIC FACTOR OF SAFETY (MORGENSTERN–PRICE)(1)
D1	2.2	1.5
D2	2.2	1.5
D3	2.3	1.5
D4	2.4	1.7

NOTE
1. HORIZONTAL SEISMIC COEFFICIENT OF 0.125 WAS USED IN THE PSEUDO–STATIC ANALYSES

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TAILINGS DAM –
STABILITY ANALYSES FOR
STARTER DAM AND ULTIMATE DAM SECTIONS

Figure 7.11-2 Tailings Dam – Stability Analyses for Starter Dam and Ultimate Dam Sections.

7.11.4 Dam Foundation Liquefaction Assessment

The liquefaction assessment was carried out in general accordance with the Seed simplified approach as described in Youd et al. (2001). The earthquake induced Cyclic Stress Ratios (CSR) were computed using the Seed's simplified relationship for level ground conditions. The Cyclic Resistance Ratios (CRR) were estimated based on SPT $(N_1)_{60cs}$ values derived from the measured SPT and LPT blowcount data. The factor of safety against liquefaction (FOS_{Liq}), which is defined as the ratio of CRR to CSR was determined to evaluate the liquefaction potential of granular soils at the site. Table 7.11-3 shows the liquefaction assessment based on the LPT data at test holes TH05-07 and TH05-08 and SPT data at test holes, TH05-09 and TH05-10.

Based on the seismic hazard analyses, the following two design earthquake scenarios were considered in the liquefaction assessment:

- Scenario 1: Earthquake with magnitude M7 and Peak Ground Acceleration (PGA) of 0.22 g
- Scenario 2: Earthquake with magnitude M6 and PGA of 0.34 g

The PGAs listed above are representative for the "firm ground" conditions and they were amplified at the surface. Note that conventional method was used to determine the LPT/SPT blowcounts N_{LPT}/N_{SPT}. However, if refusal was reached after 150 mm of penetration during the LPT or SPT testing, the LPT/SPT blow counts were estimated based on the data up to the point of refusal.

As can be seen from Table 7.11-3, the measured SPT and LPT data at these hole locations suggest that liquefaction will not occur under both design earthquake scenarios.

Table 7.11-3 Dam Foundation Liquefaction Assessment Based on LPT and SPT Data

Test Hole	Depth (m)	SPT / LPT	SPT or LPT Blowcount, N_{LPT} or N_{SPT}	SPT $(N_1)_{60cs}$	Earthquake Scenario 1 (M=7, PGA=0.22g)			Earthquake Scenario 2 (M=6, PGA=0.34g)		
					CRR	CSR	FOS_{Liq}	CRR	CSR	FOS_{Liq}
TH05-7										
TH05-7	1.52	LPT	101	112	>0.6	0.38	>1.5	>0.8	0.45	>1.8
TH05-7	3.05	LPT	81	89	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-7	4.57	LPT	58*	52	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-7	6.10	LPT	60*	46	>0.6	0.37	>1.5	>0.8	0.43	>1.9
TH05-7	9.14	LPT	70*	44	>0.5	0.36	>1.5	>0.8	0.42	>1.9
TH05-7	12.19	LPT	Refusal Before 150mm	-	-	0.33	-	-	0.39	-
TH05-7	15.24	LPT	Refusal Before 150mm	-	-	0.29	-	-	0.35	-
TH05-7	18.29	LPT	Refusal Before 150mm	-	-	0.26	-	-	0.31	-
TH05-7	21.34	LPT	Refusal Before 150mm	-	-	0.23	-	-	0.27	-
TH05-7	24.38	LPT	Refusal Before 150mm	-	-	0.21	-	-	0.25	-

Table 7.7-3 Dam Foundation Liquefaction Assessment Based on LPT and SPT Data (cont'd)

Test Hole	Depth (m)	SPT / LPT	SPT or LPT Blowcount, N_{LPT} or N_{SPT}	SPT $(N_1)_{60cs}$	Earthquake Scenario 1 (M=7, PGA=0.22g)			Earthquake Scenario 2 (M=6, PGA=0.34g)		
					CRR	CSR	FOS_{Liq}	CRR	CSR	FOS_{Liq}
TH05-8										
TH05-8	1.52	LPT	40*	44	>0.6	0.38	>1.5	>0.8	0.45	>1.8
TH05-8	3.05	LPT	47*	51	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-8	4.57	LPT	48*	43	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-8	6.10	LPT	42*	32	>0.6	0.37	>1.5	>0.8	0.43	>1.9
TH05-8	9.14	LPT	50*	31.5		0.36	>1.5	>0.8	0.42	>1.9
TH05-8	12.19	LPT	60*	33.5		0.33	>1.5	>0.7	0.39	>1.9
TH05-8	15.24	LPT	120*	59.4		0.29	>1.5	>0.7	0.35	>1.9
TH05-8	18.29	LPT	Refusal Before 150mm	-	-	0.26	-	-	0.31	-
TH05-9										
TH05-9	1.52	SPT	57	97	>0.6	0.38	>1.5	>0.8	0.45	>1.8
TH05-9	3.05	SPT	51	86	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-9	4.57	SPT	125	172	>0.6	0.37	>1.5	>0.8	0.44	>1.9
TH05-9	6.10	SPT	40*	48	>0.6	0.37	>1.5	>0.8	0.43	>1.9
TH05-9	9.14	SPT	52*	51	>0.5	0.36	>1.5	>0.8	0.42	>1.9
TH05-9	12.19	SPT	Refusal Before 150mm	-	-	0.33	-	-	0.39	-
TH05-9	15.24	SPT	Refusal Before 150mm	-	-	0.29	-	-	0.35	-
TH05-9	18.29	SPT	Refusal Before 150mm	-	-	0.26	-	-	0.31	-
TH05-9	21.34	SPT	Refusal Before 150mm	-	-	0.23	-	-	0.27	-
TH05-9	24.38	SPT	Refusal Before 150mm	-	-	0.21	-	-	0.25	-
TH05-9	27.43	SPT	Refusal Before 150mm	-	-	0.20	-	-	0.24	-
TH05-9	30.48	SPT	Refusal Before 150mm	-	-	0.19	-	-	0.23	-
TH05-10										
TH05-10	1.52	SPT	40*	68	>0.6	0.38	>1.5	0.8	0.45	>1.8
TH05-10	3.05	SPT	40*	67	>0.6	0.37	>1.5	0.8	0.44	>1.9

Notes: * Refusal reached between 150mm and 450 mm penetration and N_{LPT} / N_{SPT} estimated based on blow counts up to the point of refusal.

7.11.5 Monitoring and Environmental Management

A monitoring program will be carried out for the tailings facility to confirm design conditions and to monitor the "as-constructed" conditions of the impoundment. In addition, operational manuals and plans will be prepared to guide management of the facility. A preliminary monitoring program is summarized in Table 7.11-4.

Table 7.11-4 Summary of Tailings Facility Monitoring Program

Item	Description	Purpose
Dam survey monuments	Survey pins located along crest of dam	Monitor potential deformations
Piezometers	Install 4 piezometers in dam foundation	Monitor pore pressures and phreatic levels in dam foundation
Groundwater monitoring wells	Two new wells with screened sections in the upper soils and on the bedrock contact	Monitor groundwater quality.
Bathymetry of impoundment	Survey impoundment annual to determine actual volumes.	Confirm assumed densities for material storage and water balance.
Water flow records	Monitor and measure all water flows (discharge, treatment and diversions	Confirm water balance.
Impoundment water quality	Monthly sampling of water quality	Confirm actual water quality.

In addition to the monitoring program, the following manuals will be prepared prior to operations:

- Operation and Maintenance and Surveillance Manual.
- Emergency Preparedness Plan.

7.12 Construction

The tailings dam will be constructed as a zoned embankment dam over the competent glacial and glacio-fluvial foundation. The general fill will be borrowed from the impoundment. The dam will have a horizontal downstream drainage blanket in the valley section and along the dam toe. The impoundment area and the dam centerline will be lined with a 20 mil Enviro-Liner, which will be placed over a graded compacted ground surface.

A Bill of Quantities for the tailings facility is shown in Table 7.12-1. The table indicates that the bulk of dam fill materials will be pit-run silt-sand- gravel from the interior of the impoundment. The dam fill within the dam core and downstream zones shall be spread in 300 mm thick horizontal layers and compacted to a density of 97% of the Standard Proctor maximum density. The water content of the fill shall be not more than 3% above or 1% below the optimum water content. The upstream waste rock material will be placed in 1 m lift thickness with nominal compaction of hauling equipment.

The estimated quantities for the construction of the upland diversion ditches, seepage collection ditches, spillways, and the two diversion structures associated with Ditch A are also presented in Table 7.12-1. It should be noted that the excavation, riprap and granular filter quantities presented in Table 7.12-1 are based on the assumption that the closure spillway is excavated through soil. The Starter Dam Spillway excavation quantity includes a portion of the permanent spillway channel downstream of the dam. The closure spillway will discharge into this permanent closure. It is preferable to construct the closure spillway through bedrock to provide a permanent stable channel requiring minimum long-term maintenance. The estimated quantities will change if it is determined during detailed design and/or construction that the spillway channel is within bedrock.

Table 7.12-1 Bill of Quantities for the Dam and Associated Water Management Structures

ITEM	DESCRIPTION	Total Quantity	UOM	Unit Cost	Staged Quantities 1	2	closure
100	**Site Preparation**						
101	Clear and grub (grasslands and shrubs)	175,500	m2		175,500		
102	Strip topsoil embankment footprint (assume 0.3 m)	15,191	m3		9,791	5,400	
103	Strip topsoil impoundment (assume 0.3 m)	41,550	m3		20,100	21,450	
104	Excavate unsuitable soils (allowance)	1	Allow.		1		
105	Proof Roll Embankment Footprint	53,169	m2		34,269	18,900	
200	**Tailings Dam Embankment**						
201	General Fill - From impoundment	252,160	m3		116,091	136,069	
202	Low Permeability Fill (Core) - From impoundment	86,398	m3		46,900	39,498	
203	PAG Waste Rock (placement only - delivered by mine)	41,500	m3		41,500		
204	Filter and Drain Fill (screened pit run)	15,800	m3		3,200	12,600	
300	**Geomembrane Liner - Tailings Area**						
301	Liner Bed Preparation - impoundment (grade and compact)	139,000	m2		67,000	72,000	
302	Geomembrane - Impoundment (Supply $4.00/m2)	139,000	m2		67,000	72,000	
303	Geomembrane - Central Core (Supply $4.00/m2) ("zigzag" in dam core)	12,700	m2		6,800	5,900	
304	Anchoring System (trench and sand bags)	1	LS		0.5	0.5	
400	**Water Management**						
401	Channel Excavation - Ditch A	17,200	m3		17,200		
402	Channel Excavation - Ditch B	16,100	m3		16,100		
403	Channel Excavation - Seepage Collection Ditch (C & D)	3,000	m3		3,000		
404	Excavation of Starter Dam Spillway	35,400	m3		35,400		
405	Riprap Class 10 (d50 = 200 mm)	7,380	m3		7,380		
406	Riprap Class 50 (d50 = 350 mm)	1,400	m3		1,400		
407	Riprap Class 250 (d50 = 600 mm)	400	m3		400		
408	Riprap Class 500 (d50 = 800 mm)	14,300	m3		14,300		
409	Granular Filter under riprap	5,200	m3		5,200		
410	Go Creek Diversion Structure						
	A - Lock Blocks	48	m3		48		
	B - 600 mm diam. Slide Gate	1	ea		1		
	C - 600 mm diam. CSP Culvert	15	m		15		
	D - Metal Catwalk	1	ea		1		
411	Ditch A Diversion Structure						
	A - 600 mm diam. Slide Gate	1	ea		1		
	B - 600 mm diam. CSP Culvert	15	m		15		
	C - Metal Catwalk	1	ea		1		
412	Reclamation - Grass seeding	4.4	ha		4.4		
500	**Seepage Control**						
501	Seepage Collection Pond Dyke - Excavation (0.3 m topsoil)	900	m3		900		
502	Seepage Collection Pond Dyke - General Fill	5,000	m3		5,000		
503	Seepage Collection Pond Dyke - Spillway Excavation	400	m3		400		
	Subtotal						
600	**Closure**						
601	Topsoil Cover (assume 0.5 m over outer dam slope)	27,193	m3				27,193
602	Closure Spillway - excavation	2,500	m3				2,500
603	Reclamation - dam slopes	5.5	ha			5.5	
604	Go Creek Diversion						
	A - Remove and dispose structure and re-instate stream channel	1	LS				1
	B - Backfill ditch downstream of structure	300	m3				300
	C - Grass seeding and re-vegetation	0.035	ha				0.035
605	Ditch A Diversion						
	A - Remove and dispose structure	1	LS				1
	B - Backfill ditch downstream of structure	850	m3				850
	C - Grass seeding and re-vegetation	0.060	ha				0.060
606	Ditch B						
	A - Backfill ditch upstream of Closure Spillway	15,900	m3				15,900
	B - Grass seeding and re-vegetation	11,100	m2				11,100
607	Water Treatment Plant Operation						
608	DMS Cover on Tailings	65,000	m3				65,000
	Subtotal						
	Annual Cost ($CDN)						
	TOTAL COST ($CDN)						
700	**Contingency**						
701	15% of Total Costs			15%			
	Annual Cost + Contingency ($CDN)						
	TOTAL COST + CONTINGENCY ($CDN)						

7.13 Water Management

7.13.1 General

The design of the surface water management facilities for the Tailings Pond, such as the diversion and seepage collection ditches and the spillways for the tailings pond and the seepage recovery pond, are based on hydrology data provided by Madrone (2006).

7.13.2 Diversion and Seepage Collection Ditches

The mean annual water balance analysis indicates that there would be a water surplus in the tailings pond and, therefore, diversion ditches are required to minimize runoff into the pond. The proposed layout of the diversion ditches is shown in Figure 7.13-1. These ditches would be constructed on the uphill side of the tailings facility.

Figure 7.13-1 Diversion Ditches and Spillways – Plan and Typical Section (Figures Section)

Upstream of the tailings basin, Ditch A would intercept runoff from the uphill area and bypass the tailings impoundment and would discharge into Go Creek. This ditch will be equipped with a gated culvert at the upstream end, which would allow the diversion of spring runoff from Go Creek into the Starter Tailings Pond prior to the commencement of mining operation to provide mill process water. The proposed culvert will be 600 mm diameter, which will act as a throttle and prevent flood water from entering Ditch A. Immediately upstream of the tailings pond, a second gated culvert would allow the transfer of water from Ditch A to the tailings pond. Water will only be diverted into the tailings basin, as required, otherwise the base case is that water will continue flowing into Go Creek. Diversion structures required for Ditch A and Go Creek are presented in Figure 7.10-6.

The second diversion ditch, Ditch B, would intercept runoff directly uphill of the tailings basin. Ditch B would intercept this runoff and direct it towards Go Creek downstream of Seepage Recovery Dam.

The estimated free water surface areas for the Tailings Pond and the Seepage Recovery Pond are shown in Table 7.13-1. The estimated catchments, the design criteria and the design flows for the diversion ditches are presented in Table 7.13-2, and the proposed sizes of the diversion ditches are shown in Figure 7.10-6. The peak flows for the design of the diversion ditches were estimated using the Rational Method with a coefficient of runoff of 0.6. The storm durations shown in Table 7.13-2 for the ditches are the estimated times of concentration for the individual ditches. Direct measurements of snowmelt for the project site are not available, however regional analysis of snowmelt indicates a peak annual daily change in snowpack of about 5 to 15 cm, with a mean of 8.6 cm. Assuming a snowmelt rate of 15 cm/day and taking that as a snow water equivalent of 15 mm over a 12 hour period, and combining the snowmelt with the rainfall runoff presented in Table 7.13-2 would increase the peak flows in the ditches by less than 10%. This would slightly increase the flow depth in the ditches. The minimum freeboard of 0.3 m provided for each ditch is more than adequate to accommodate this extra flow which may occur due to a rain on snow event.

The layout and sizing of the diversion ditches are based on 5 m contour topography. Field investigations indicate that the ditches are located in silt-sand-gravel-cobble subsoil. Additional geotechnical field investigation will be conducted during dam construction to refine the layout and design of the ditches and associated structures, if required.

Table 7.13-1 Tailings Pond and Seepage Recovery Ponds Free Water Surface Areas

Year and Pond Surface Elevation	Surface Area (ha)
Year 1 Max. Starter Tailings Pond free water surface El. 1308 m	10.5
Year 6 Max. Ultimate Tailings Pond free water surface El. 1314 m	12.0
Seepage Recovery Pond water surface area El. 1287 m	0.5

Table 7.13-2 Estimated Catchment Areas, Design Flood Flows and Freeboards

Water Management Component	Estimated Catchment Area (ha)	Design Storm	Estimated Peak Design Flow (m^3/s)	Min. Channel Freeboard (m)	Estimated Dam Freeboard to Flood Level (m)	Assumptions
Diversion Ditch A	67	100-yr, 25-min	3.2	0.3	N/A	
Diversion Ditch B	34	100-yr, 20-min	1.8	0.3	N/A	
Seepage Collection Ditch C	4	100-yr, 15-min	0.3	0.3	N/A	
Seepage Collection Ditch D	1	100-yr, 10-min	0.25	0.3	N/A	
Starter Dam Spillway	16	200-yr, 30-min	0.0	0.6	2.2	Surface water diversion ditches assumed to be functioning
	16	200-yr, 30-days	0.0	0.6	2.0	
	16	10,000-yr, 24-hour	0.4	0.6	1.9	
	105	200-yr, 30-min	0.0	0.6	2.1	Surface water diversion ditches assumed to be not functioning
	105	10,000-yr, 30-min	0.0	0.6	2.0	
	105	10,000-yr, 30-days	8.0	0.6	0.9	
Tailings Dam Closure Spillway	105	10,000-yr, 30-min	0.2	0.6	1.95	Surface water diversion ditches assumed to be decommissioned
		10,000-yr, 30-days	7.7	0.6	0.95	
Seepage Recovery Pond Spillway	9	100-yr, 10-min	0.7	0.3	0.5	Surface water diversion ditches assumed to be functioning

Notes:

1. The peak design flows and freeboard for spillways are based on a 3 m wide trapezoidal channel with 2H:1V side slopes, with channel invert located 2.0 m below dam crest.
2. For routing of the 200-year flood through the Starter Dam, the 0.3 m flood storage allowance is assumed to be fully available. That is, the initial pond level at the beginning of the storm is assumed to be 0.3 m below the spillway invert. For routing of the 10,000-year flood, the flood storage allowance is assumed to be zero for both the Starter Dam and the Ultimate Dam.

7.13.3 Flood Handling and Spillways

The proposed locations and channel sizes for the Tailings Pond and the Seepage Recovery Pond spillways are shown in Figure 7.13-1. For the Tailings Pond, the Starter Dam Spillway will be constructed at the same time as the Starter Dam. As the Tailings Dam is raised in stages during mine operation, the spillway will be re-located upslope as required to serve the higher pond level. The Closure Spillway for the Tailings Pond will be constructed when the Tailings Dam reaches its final height. The spillway for the Seepage Recovery Pond will be constructed during construction of the Seepage Recovery Dam.

The inflow hydrographs for the Tailings and the Seepage Recovery Ponds are not available at this time, but the estimated precipitation for various return periods and durations are available. The precipitation data was used to estimate the peak runoff for short duration (i.e., 30 min.) rainfall using the Rational Method with a runoff coefficient of 1.0. Rough inflow hydrographs were developed based on the estimated peak runoff and approximately 2 to 4 times the estimated volume of runoff. The inflow hydrographs for various scenarios were routed through the Tailings Pond in order to estimate the peak pond water level and the peak discharge. The size of the spillway was determined by trial and error such that adequate dam freeboard is available under flood conditions with a reasonable spillway size. A 3 m wide trapezoidal channel with 2H:1V side slopes and the channel invert located 2.0 m below dam crest was selected for both the Starter Dam and the Ultimate Dam. The results of the flood routing with the selected spillway size are summarized in Table 7.10-2 and discussed below.

The design criteria for Starter Dam spillway includes a 200-year design return period (Table 7.5-1) and the spillway to pass the 10,000-year flood without overtopping the dam. Both the 200-year and 10,000-year inflows, with and without the upland diversion ditches, were examined for the Starter Dam Spillway. As Table 7.10-2 indicates, the 10,000-year, 30-day storm with the diversion ditches assumed to have failed was found to be more critical in terms of flood discharge rate and dam freeboard. The peak inflow to the pond for the 10,000-year storm is estimated to be about 9.5 m^3/s, which attenuates to about 8.0 m^3/s as the flood passes through the pond and spillway. The pond water level will peak at El. 1309.1, thus leaving a freeboard of about 0.9 m between the dam crest and the peak flood level.

The 10,000-year flood inflows for the Ultimate Dam will be similar to that for the Starter Dam, but the flow will attenuate to about 7.7 m^3/s as the flood passes through the pond. More attenuation of the flood takes place for the Ultimate Dam than that for the Starter Dam because the pond has a slightly larger storage capacity at the higher elevation. For the 10,000-year, 30-min. storm, minimal rise in pond water level is expected and about 1.95 m of freeboard between the peak flood level and the top of the dam will be available. For the 10,000-year, 30-day storm, the available freeboard will reduce to about 0.95 m which is considered to be reasonable for such an extreme event.

The flood routing presented above is based on rainfall. The effect of combined runoff from rainfall and snowmelt on the Tailings Pond freeboard was also investigated. The maximum snowmelt rate of 15 mm/day snow water equivalent, as described in Section 7.6.2, was added as the base flow to the rainfall inflow hydrograph and the combined runoff was routed through the Tailings Pond. The flood routing indicates that the pond water level will rise an additional 0.0 to 0.05 m due to the snowmelt. Therefore, the freeboard between the peak flood level and the top of the dam could be up to 0.05 m less than that indicated in Table 7.10-2. The reduced freeboard would still be within the acceptable range of flood freeboard for this type of facility.

The method used to develop the inflow hydrographs tends to over-estimate the rise in pond water level, and pond outflows. Furthermore, the highest regionally recorded snowmelt rate was assumed for the project. Actual snowmelt rates for the site might be lower. The inflow hydrographs and the snowmelt rates should be re-examined if additional hydrology data become available during the detailed design phase.

7.14 Closure

7.14.1 General

The tailings impoundment stores mine tailings, DMS float tails and waste rock, which have high sulphide contents, with associated elevated concentrations of cadmium, selenium and zinc. In addition, if the waste materials are not maintained in a saturated state, oxidation will lead to acid rock drainage and higher metal concentrations. Accordingly, the waste management plan is to store all of the materials below water, with only occasional temporal storage above water, as required for operational purposes.

During operations, seepage water will be collected and returned to the tailings impoundment. The impoundment has a surplus water balance and excess water will be treated, to Yukon Water Board effluent discharge criteria, prior to release.

Upon closure, excess process water will be treated and replaced with runoff water, which will return the water quality to baseline conditions. There is a potential that some water treatment, for period of a few years, may be required to ensure a stabilized geochemistry of the impoundment water.

The tailings facility will be closed as a saturated deposit with a minimum water cover of 0.5 m. All works will be decommissioned and reclaimed as shown in Figure 7.6–3. The main closure works address the issues of long term groundwater quality, dam safety, and surface water quality and are discussed in the following sections.

7.14.2 Geochemical Stability and Surface Water Quality

On closure, a 1 m thick layer of DMS material will be laid over the ice in winter, over the tailings area, which, when the ice melts, will provide a stable cover for the tailings and reduce the potential for remobilization of solids and pore water. A typical section through the impoundment on closure is shown in Figure 7.6–5.

On closure the excess impoundment water could be in the order of 30,000 m^3 to 150,000 m^3, depending on the time of year, climatic conditions and pond operation management. The excess water will be treated and discharged or used to flood the underground workings. The impoundment water quality, therefore, after treatment of excess water and after infilling from the spring freshet, should return to near baseline conditions. The potential for contaminated porewater, from the DMS cover layer, to mix with the impoundment water to a sufficient degree to impact water quality is considered to be low for the following reasons:

- The groundwater gradients in the DMS should be very low because of the Enviroliner, therefore there would be very little natural transfer of porewater.

- The potential quantity of porewater that could mix with the pond water is low; for example, if we assume that 5% of the porewater in the 1 m thick DMS layer (2000 m^3) mixes with the pond water (100,000 m^3), the dilution ratio would be 50:1.

During decommissioning, the following activities will be carried out to minimize the decommissioning period:

- The water quality will be monitored and water treatment of residual contaminants that could potentially flush from the DMS into the pond water would be carried out, as required until the water quality meets discharge water quality criteria.
- Surface water from the diversion channels will be managed to minimize water treatment and maximize the replacement of impoundment water with fresh diluted runoff.
- Periodic fertilization of the impoundment to promote the development of an organic layer over the DMS surface.

7.14.3 Dam Safety at Closure

The tailings impoundment will be closed as a ‘wet” facility with a water cover over the tailings/waste rock and a permanent spillway to manage flood flows. The main components of the closure plan include the following:

Dam Safety

The dam is designed with a minimum factor of safety of 1.1 for the Maximum Credible Earthquake (MCE). Consequently, the main concerns with dam safety on closure are associated with erosion of the dam or blockage of the spillway. Accordingly, a long term care and maintenance plan will be prepared to confirm that erosion is not occurring and that the spillway is clear. Measures to mitigate these potential concerns include the following:

- Placement of a 25 m wide neutral rockfill, adjacent to the upstream crest of the dam. The rockfill will maintain the “freewater” away from the dam crest, further reducing the potential for water release even with a significant erosion event.
- The downstream slope of the dam will be revegetated to minimize erosion.
- The spillway will be located in an excavated channel lined with large riprap and will have a design capacity for the peak flow from the 10,000-year rainfall plus snowmelt event.

7.14.4 Decommissioning of Water Management Structures

The following work is required for decommissioning of the water management structures associated with the tailings pond once the water is able to be directly discharged to the environment:

- Removal of the Go Creek Diversion Structure, re-instatement of the stream banks and bed, and backfilling of at least 50 m of Ditch A downstream of the structure.
- Removal of the Ditch A Diversion Structure, and backfilling of at least 50 m of Ditch A downstream of the structure.
- Backfilling of Ditch B upstream of the Tailings Pond Closure Spillway.

- Grass seeding and planting in all areas disturbed during the implementation of the above works, as per the mine reclamation plan.

7.14.5 Monitoring

During the decommissioning period the facility will be monitored to confirm design and operating conditions. The monitoring will include the following:

- Foundation and dam piezometers to confirm stabilization of the phreatic surfaces and pore water pressures.
- Water quality sampling of surface and groundwater to confirm predicted concentrations and “stabilization” of the geochemical loadings.
- Visual inspections to ensure dam safety