2.8 Tailings Facility

2.8.1 Tailings Basin

The tailings facility site is situated in a natural, northwest-southeast trending elongated depression perched on the northeast valley slope of Go Creek (Figure 2.8-1). The depression is flanked on the downhill side by a natural ridge trending in the same direction. The ridge drops its 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.

Figure 2.8-1 Tailings Impoundment – Site Investigation Plan (Vol. 2)

Site investigations indicate that the tailings basin is mantled by glacio-morainal deposits, which may have been altered by a side creek flowing along the rim of the basin. Along the ridge, the depth to bedrock ranges from 30.1-39.6 m, while between the ridge and the northeast valley slope the depth is shallower, ranging from 19.8 m to 24.4 m.

2.8.2 Tailings Storage Facility

The design of the tailings facility is based on field and laboratory investigations of foundation conditions and considerations of geochemical characteristics of tailings and supernatant water, dam borrow materials, storage capacity requirements, the site water balance, dam failure consequence rating, and earthquake and flood potential. A general overview follows and the sections that follow summarize these design considerations.

The tailings facilities includes a L-shaped tailings dam, a seepage recovery dam, two upland diversion ditches, two seepage collection ditches, a spillway and a seepage recovery pond (Figure 2.8-1). The impoundment covers an area of about 750 m long and 500 m wide. The maximum dam height is 22.5 m and 37.5 m high at project start up and at the end of operations, respectively (Figure 2.8-2).

Figure 2.8-2 Impoundment Plan, Storage Volume and Dam Sections (Vol. 2)

Figure 2.8-3 illustrates how the tailings and coarse waste will be deposited within the tailings impoundment. Concurrent to the construction of the Starter Dam, two splitter dykes will be constructed within the tailings basin to subdivide it into three deposition cells. The dykes will initially be constructed using waste rock from the temporary waste rock pad. They will be raised using either waste rock or Dense Media Separation (DMS) reject. Coarse waste, consisting of waste rock and DMS reject, will be trucked in and dumped on the splitter dykes. In turn, dozers will push the coarse waste from both sides of the splitter dykes into the deposition cells. Tailings will also be discharged concurrently into these cells from discharge pipes leading from the main tailings pipeline placed along the northeast flank of the tailings basin. Water will be reclaimed to the industrial complex from the relatively deeper tailings pond located upstream of the Starter Dam.

Figure 2.8-3 Tailings and Coarse Waste Deposition Scheme (Vol. 2)

Water balance modeling indicates that the facility will operate with a net water surplus (refer to Section 2.8.6). Therefore to minimize inflow during mine operation, diversion ditches will be constructed on the upslope (northeast) side of the tailings facility and the seepage recovery pond (Figure 2.8-1).

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 also be maintained during mining operation to discharge flood water for severe hydrological events (exceeding 200-year return period, refer to Section 2.8.9). At closure, the diversion ditches will be decommissioned so that surface runoff will flow down slope into the facility, and a permanent spillway will be constructed. During mine operation and after 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 reject and waste rock materials).

For the start up of tailings operation, flows from Go Creek will be directed via the diversion ditch (Ditch A) into the tailings facility during the spring runoff season prior to commencement of mining operation. 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 2.8-11, to allow for water diversion when required. The diversion structure located in the excavated ditch will consist of a rockfill beam across the ditch and a gated culvert. The diversion structures and the ditch will be decommissioned at closure. Details on the amount and period of diversion are presented in Section 2.8.6.

The seepage recovery dam downstream of the tailings dam will intercept seepage from the tailings pond, and the water will be pumped back. Thus, the tailings pond seepage, the precipitation and runoff collected in the seepage collection ditches and the seepage recovery pond will be recycled back to the tailings pond.

The Starter Dam will assume an L-shaped configuration with a maximum height of 22 m as shown in Figure 2.8-2. It will be constructed prior to the start up of mining operation in order to store the water diverted from Go Creek. The Starter Dam will then be raised by the downstream construction method in four stages. At the end of the mine life, the tailings dam maximum height will be approximately 37.5 m, and the impoundment will have a tailings and water storage capacity of up to 2.3 million m^3, covering an area of about 180,000 m^2.

2.8.3 Geochemical Considerations

2.8.3.1 Tailings, Coarse Waste and Dam Borrow Materials

Tailings

Process plant tailings and the development waste rock (Section 2.4: Rock Characterization) have been shown to be acid generating due to their high sulphide content. In order to avoid acid generation from the tailings and coarse waste stored in the tailings impoundment, a permanent water cover will be established, to maintain a saturated state.

In order to assess the geochemical characteristics of the tailings, four ore composite types were prepared and examined. Three of the samples took into consideration the expected mining dilution and the use of a dense media separation (DMS) plant; one from the Lynx zone (Sample A), one from the Wolverine zone (Sample B) and a composite sample from the Lynx and Wolverine deposits (Sample C), typical of the ore characteristics over the life of the mine. The fourth sample (Sample D) was also a composite ore sample from both ore zones, but without considering the influence of mining dilution. All four ore composites were subject to bench-scale metallurgical Lock Cycle Tests (Lets) each of which generated three tailings streams along with the metal-bearing concentrates. The three streams include a small Pre-Flotation "Concentrate" (PFC), the Rougher (Ro) tailings and the Cleaner Scavenger (CS) tailings. The Ro tailings represent the bulk of the tailings from each of the LCT and are viewed as the "cleanest" tails because of their relatively lower pyrite content and lower heavy metal concentrations. The CS tailings are viewed as the "worst" part of the tailings because of their higher pyrite content and higher heavy metal concentrations. The three tailings streams were combined in the proportions expected to occur in full-scale processing (typically 88% Ro tailings, 10% CS tailings, and PFC tails representing less than 2% of the total tailings) and thus are considered to be representative of the typical tailings expected for each of the ore types examined. The Ro and CS tailings from each LCT were also tested separately. Therefore, for each of the four ore composites subjected to Lets, there are three sets of tailings analyses (Ro, CS and combined tailings).

Table 2.8-1 summarizes the acid-base accounting assessment results for the 12 tailings samples tested. The first column presents the range of results from all of the analyses. The second column presents the results specifically for the overall ore composite (Sample C) considering mining dilution and being subjected to DMS prior to entering the flotation circuit, which is most representative of the "typical" tailings expected to be produced over the life of the mine. The third column contains the data for just the Ro tailings from the Wolverine ore composite (Sample B). This sample was found to be the "cleanest" of all the tailings samples tested. The final column presents the data for just the CS tailings from the Lynx ore composite (Sample A). This material is considered to be the "worst" or "dirtiest" of all the tailings samples tested. The tailings from Sample D ore generally lie within the range between the Sample B Ro tailings and the Sample A CS tailings, and are captured within the variability expressed in the first column of data in the table.

From these results, regardless of whether the ore comes from the Lynx Zone or the Wolverine Zone and regardless of whether the combined (total) tails is evaluated or the Ro and CS tails are taken separately, all the tailings have a high potential to generate acid drainage, if not managed appropriately. The neutral to basic paste pH values show that acidic conditions are not present at the end of ore processing, thus limiting metal mobility to the rates applicable at neutral pH (only neutral metal leaching rather than acidic metal leaching).

The presence of sulphate (SO_4) in most of the tailings samples is consistent with the mineralogical assessment which indicates 1%-2% gypsum in most of the samples. It can therefore be expected that elevated sulphate concentrations will be observed in the tailings pond water but that this will not be an indication of the active oxidation of sulphide minerals. The consistently high sulphide-sulphur (S) content of all the samples is a clear warning that if oxidizing conditions are allowed to persist long enough for all of the neutralizing potential (NP) in the tailings to become depleted, then onset of acidic drainage conditions would be expected to occur. However, the presence of significant amounts of Carbonate NP and Sobek NP confirms that there is enough buffering capacity in the tailings solids to delay the onset of acidic conditions for some time. This is further supported by the mineralogical assessment, which showed that the combined tailings samples from each ore type typically contain 8-10% reactive carbonate mineralization as calcite and dolomite. Nevertheless, the very low Neutralization Potential Ratio (expressed as Sobek NP/SAP, the Sobek NP divided by the Acid Potential calculated from the measured sulphide-S content) indicates that given enough time and oxidizing conditions, the NP will become depleted and acid drainage would occur. Generic guidelines developed for BC (Price 1997) recommend that materials with an NPR<1 be considered to be likely to be acid generating while materials with NPR>2 be considered to have no or low acid generation potential. All the tailings samples tested were found to have NPR much less than 1. This necessitates careful design and operation of the tailings storage facility to ensure that these conditions cannot occur.

Table 2.8-1 Tailings ABA Characteristics

Parameter Units		Range of all 12 Tailings Samples Tested	Sample C - Overall Diluted Ore Combined Tails (Typical Tailings)	Sample B - Wolverine Ore Rougher (Ro) Tails ("cleanest" tailings)	Sample A - Lynx Ore Cleaner Scavenger (CS) Tails ("worst" tailings)
Paste pH	-	6.45 to 7.85	7.27	7.68	6.45
Acid Leach able SO_4	%S	0.02 to 6.98	2.04	0.45	6.45
Sulphide-S	%S	10.1 to 39.4	22.9	10.1	39.4
Carbonate NP	kg $CaCO_3$/t	22 to 105	98	105	22
Sobek NP	kg $CaCO_3$/t	20.9 to 119	82.5	119	20.9
Sobek NP/SAP	Ratio	0.02 to 0.38	0.12	0.38	0.02

Along with the acid generation potential comes associated metal leaching potential. This has been evaluated by examining the metal content of the various tailings samples, the tailings supernatant, and the leachate from deionizer water extraction tests and humidity cell tests. Table 2.8-2 summarizes the primary contaminants of potential concern from each of the four data sets. For each data set, the relative abundance of each contaminant of potential concern is calculated by dividing the average measured concentration by 5 times crustal abundances.

For the total metal content in the solid phase, determined by an ICPMS scan on an *aqua regain* digest of the sample, the analyses are compared with the values taken from *Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in BC,* Appendix 2, Table titled 'Abundances of Chemical Elements in the Earth's Crust and Chon rites', column heading 'Crust as a Whole' (Price, 1997). The comparison indicates that the Wolverine deposit contains anomalous concentrations of quite a few elements. It is enriched in silver (Ag), zinc (Zn), selenium (Se), etc., and depleted in aluminum (Al), manganese (Man) and nickel (Ni). The solid phase testing, however, does not provide any indication of which elements are mobile in the environment, particularly under the neutral pH conditions expected in the tailings impoundment, because the digestion procedure uses strong acids not normally found in the environment.

For the aqueous phase metal concentrations, the measured values were compared with CCME Receiving Water Quality Guidelines for the Protection of Aquatic Life. For a few of the parameters, no CCME guideline has been established and consequently the comparable BC Water Quality Guideline was used (i.e., for Ag, Al, Fe, Man, Mo, Sb). No guidelines exist in BC or under federal jurisdiction for Bi and Son. The solubility of these latter elements is very low and Bi was not detected in any of the samples tested). From these comparisons, it can be seen that cadmium (Cd), Se and Zn are expected to be mobile under neutral pH conditions and may be present in the tailings pond at concentrations in excess of receiving water quality guidelines and thus may necessitate some degree of treatment and/or mixing in the downstream receiving environment when discharge occurs from the impoundment. These conditions are expected to persevere at the site during and following operations. It is therefore expected that the water quality in the tailings impoundment will not exceed the neutral pH concentrations observed in the laboratory.

The minimum water cover depth required within the impoundment to ensure the preclusion of oxygen and hence prevent the onset of acid generation, is a function of the site water balance considering direct precipitation, and run-in to the pond as well as evaporation and seepage losses from the facility. A minimum water depth capable of preventing de-saturation of the tailings during a 1 in 100 year dry year hydrological event has been selected as the design criterion. Preliminary results from the humidity cell test work suggests that it would take many weeks (lab tests have been running for more than 14 weeks – likely equivalent to more than the entire annual open water period at the site) of continuous exposure to atmospheric oxygen to initiate the acid generation process of tailings. The oxidation would cease again with the return of tailings to saturated state, and would likely not reoccur for a considerable period of time since the annual likelihood of equally severe (or worse) drought is 1%. The minimum water cover proposed is approximately 0.5 m, even though the water balance (Section 2.8-6) indicates that in the 1 in 100 year dry year the maximum drawdown expected over the dry summer months (i.e., an assumed 90 day period without rainfall or runoff into the impoundment) from a 15 ha pond area is only 0.13 m. Since the submerged beach will slope towards the centre of the impoundment at approximately 1%, there will be on the order of 2 m of water cover at the low point, or more, depending on the efficiency of the tailings deposition.

Table 2.8-2 Anomalous Elemental Concentrations in Typical Overall Diluted Ore Composite Tailings

Element	Solid phase greater than 5x typical Crustal Abundance[4]		Tailings Supernatant greater than 10x CCME WQ Guideline[4]		Leachate Extraction Test greater than 10x CCME WQ Guideline		Humidity Cell Leachate greater than 10x CCME WQ Guideline	
	Concentration (mg/kg)	Avg. Ratio[1]	Concentration (mg/L)	Avg. Ratio[2]	Concentration (mg/L)	Avg. Ratio[2]	Concentration (mg/L)	Avg. Ratio[3]
Ag*	54.8	763	0.0047	<10	0.0008	<10	*0.0025*	<10
Al*	5800	<1	0.06	<10	0.005	<10	*0.005*	<10
As	2700	1453	0.036	<10	0.007	<10	*0.0025*	<10
Bi	11	1377	*0.00015*	N/A	*0.00015*	N/A	*0.00015*	n/a
Cd	97	836	0.0017	100	0.0051	300	0.301	17706
Cu	820	14	0.0051	<10	0.0014	<10	0.0117	<10
Fe*	240000	<5	*0.01*	<10	*0.01*	<10	*0.01*	<10
Hg*	3.6	52	*0.00005*	<10	*0.00005*	<10	*<0.1*	<10
Man*	670	<1	0.0169	<10	0.215	<10	3.33	<10
Mo*	32.3	26	0.0106	<10	0.0033	<10	*0.00015*	<10
Ni	61	<1	0.012	<10	0.002	<10	0.049	<10
Pb	3900	375	0.0114	<10	0.0392	<10	0.4	57
Sb*	170	1201	0.027	<10	0.0155	<10	*0.025*	<10
Se	364	9512	1.76	1760	0.418	418	0.1	100
Son	13	7	0.008	N/A	*0.0005*	N/A	0.021	N/A0
To	19.1	23	0.0044	<10	0.0063	<10	0.0148	18.5
Zn	9800	218	0.021	<10	0.081	<10	23.4	780

Notes:
1. Average of Measured Concentration: Crustal Abundance
2. OD Combined tailings: Aquatic Life Guideline
3. Data from Overall Composite Combined tailings for Week 1: Aquatic Life guideline
4. Multiplication factors of 5x and 10x are based on typical industry standards.

*BC WQ Guideline for Aquatic Life – 30 day average

Numbers in italics indicate value was less than the detection limit, and have been reported herein at one-half the detection limit.

Upon closure, a permanent pond is intended to remain over the impoundment. This will be ensured by the net positive water balance for the impoundment. A permanent spillway will be constructed on the northeast abutment of the dam to allow the safe passage of flood water through the spillway without overtopping the tailings dam under extreme hydrological events. The spillway approach channel will be covered with coarse grained material to prevent the possibility of local re-suspension of tailings solids and their subsequent entrainment in the spillway discharge.

Yukon Zinc commits to ensuring that the discharge water quality does not exceed Metal Mining Effluent Regulations (MMER) discharge limits (MFO 2002). A water treatment plant will be used during construction, operation and closure phases of the mine to ensure compliance within these limits.

Coarse Waste

Both DMS float and waste rock are expected to be acid generating. Therefore, they will be deposited within the tailings impoundment and will be covered by water to prevent significant oxidation.

Dam Borrow Materials

Results of leachate analyses for borrow materials are summarized in Table 2.8-3. The representative sample for the tailings dam construction material was retrieved from Test

Pit 05-78 at a depth of 1.5 m. As indicated in Table 2.8-3, no metal leaching problem is anticipated for tailings dam borrow materials.

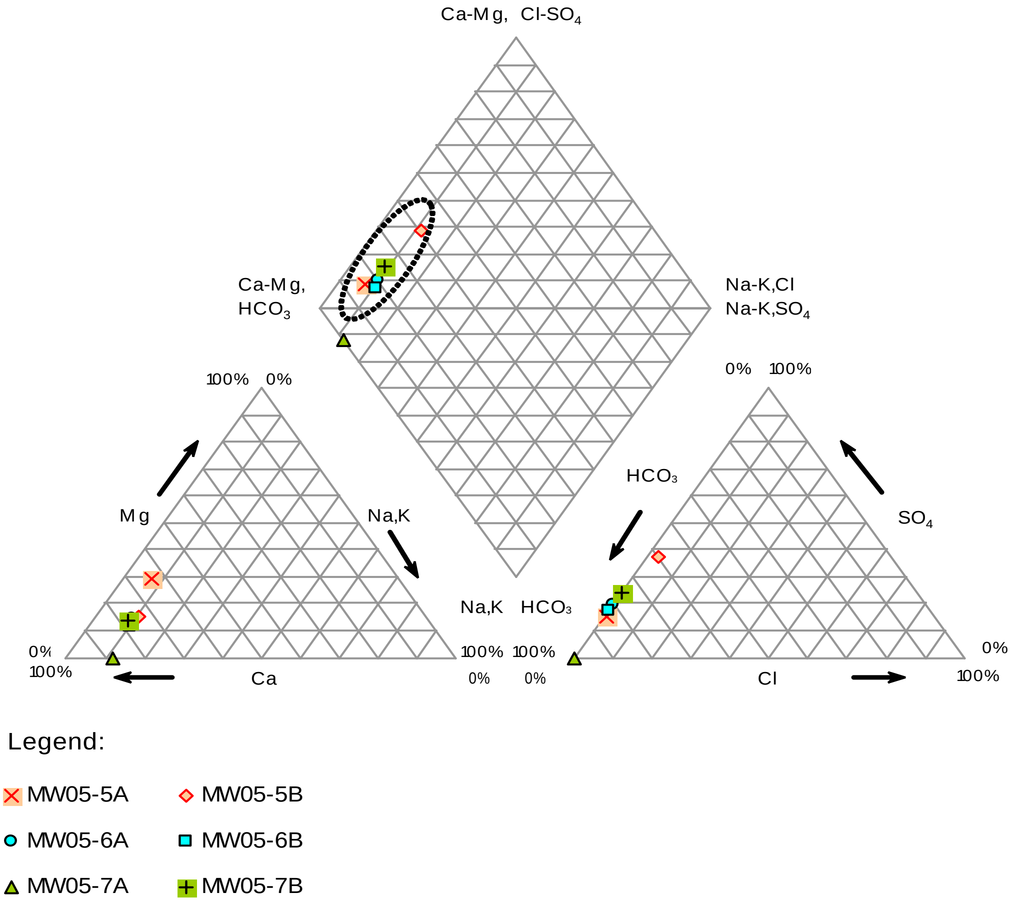
Table 2.8-3 Summary of Leachate Analyses for Borrow Materials

Sample Name:	Units	Go Greek Dam Borrow	Project Borrow Sample #1 East	Project Borrow Sample #3 West	Tailings Dam Borrow (TP05-78 1.5m)	Blank
Conventional Parameters						
Hardness (Total) CaCO3	mg/L	3.2	1.1	0.6	1.3	< 0.2
Metals Analysis						
Aluminum Al	mg/L	0.059	0.25	0.13	0.066	< 0.001
Antimony Sb	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Arsenic As	mg/L	0.0005	0.0002	< 0.0002	0.0005	0.0003
Cadmium Cd	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Copper Cu	mg/L	0.0073	0.0053	0.0027	0.0049	0.0033
Iron Fe	mg/L	0.04	0.13	0.01	0.08	< 0.01
Manganese Man	mg/L	0.0067	0.01	0.013	0.0039	0.0009
Mercury Hg	ug/L	< 0.02	< 0.02	0.03	< 0.02	< 0.02
Molybdenum Mo	mg/L	0.0003	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel Ni	mg/L	0.0005	0.0003	0.0002	0.0004	< 0.0002
Selenium Se	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Silver Ag	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005	0.00077
Thallium To	mg/L	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Tin Son	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Zinc Zn	mg/L	0.002	0.004	0.003	0.002	0.001

2.8.3.2 Groundwater Quality

Baseline groundwater quality data were collected during September 2005 at the Wolverine area monitoring wells MW05-5A, MW05-5B, MW05-6A, MW05-6B, MW05-7A, and MW05-7B. Locations of wells MW05-6 and MW05-7 are shown on Figure 2.8-1. Well MW05-5 is located at the plant site. Ongoing sampling is scheduled quarterly. Only a single sample at each well has been collected to date (Table 2.8-4).

The results indicate that the groundwater has a neutral to slightly alkaline pH (7.6-9.1) and low conductivity values between 99 µS/cm to 271 µS/cm. Based on the Piper Trilinear plot for September 2005 (Figure 2.8-4), the groundwater is generally calcium-bicarbonate (Ca-HCO_3) type water, which is associated with glacio-fluvial sediments and ground moraine. These are the main soils underlying the tailings area.



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 2.8-4 Piper Trilinear Plot of Groundwater Chemistry

The water quality generally meets CCME aquatic life criteria except for a few parameters in all the sampled monitoring wells. The inorganic constituents at MW05-6A/B that were not within the aquatic life criteria are listed below, with the highest concentrations analyzed to date shown in brackets:

- aluminum (0.0667 mg/L)
- cadmium (0.000076 mg/L)
- copper (0.00262 mg/L)
- fluoride (0.135 mg/L)

These naturally elevated metals in groundwater at the location of the proposed tailings facility need to be taken into account when determining the discharge quality requirements for seepages during operations.

Table 2.8-4 Summary of Key Inorganic Constituents in Groundwater

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)
MW05-5A	9/8/2005	440	8.11	224	1.98	38.5	0.0112	<0.0020	0.000136	62.4	0.00107	0.0017	0.0143
MW05-5B	9/8/2005	329	8.11	104	0.423	62.2	0.0126	0.00068	0.000157	49.3	0.00043	<0.0010	0.0053
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	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

The analytical results for the sample collected at MW05-7A indicates that the monitoring well was affected by the cement grout used during well installation. The influence of cement grout is identified by high pH (11.3) and high calcium (885 mg/L) concentrations. MW05-7A will need to be re-developed if future samples continue to show high pH and high Ca concentrations.

2.8.3.3 Tailings Impoundment Water Quality

This section presents the laboratory data and associated predictions for tailings impoundment water quality during operations and subsequent to cessation of mining and mine closure.

Tailings Supernatant

The tailings supernatant quality can be expected to be similar in character to the supernatant produced in the laboratory-scale Lock Cycle metallurgical test program. As discussed in Section 2.8.3.1, several different ore composites were tested. Table 2.8-5 illustrates the range of values expected for the Wolverine mill tailings supernatant chemistry, depending on ore type being processed. The data presented in the table is generally taken from the Time = 1 h data from the tailings aging tests. 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 by controlled by the solubility limit of the parameter of interest (e.g., sulphate may eventually be limited by gypsum solubility in the presence of calcium addition as lime in the mill circuit).

Table 2.8-5 Tailings Supernatant Chemistry

Parameter	Units	Range of all Tailings Samples Tested	Overall Diluted Ore Combined Tails (Typical Tailings)
pH	-	7.28 to 8.59	8.13
SO_4	mg/L	520 to 630	630
Hardness	mg $CaCO_3$/L	415 to 510	510
Cd	mg/L	0.0005 to 0.0045	0.0017
Cu	mg/L	0.0027 to 0.0499	0.0051
Pb	mg/L	0.0060 to 0.0255	0.0114
Se	mg/L	1.20 to 1.95	1.76
Zn	mg/L	0.01 to 0.076	0.021

Tailings Aging Tests

Each of the four tailings samples generated in the metallurgical test program were divided into discrete samples and left to “age” for defined time periods. During aging, the supernatant was exposed to atmospheric oxygen and carbon dioxide, as would be the case in the tailings impoundment during maintenance shutdowns or post-closure. A clear trend was observable in the behaviour of several of the parameters, most notably, thiosalts, sulphate, Cd, Se and Zn as shown in Figures 2.8-5 to 2.8-8.

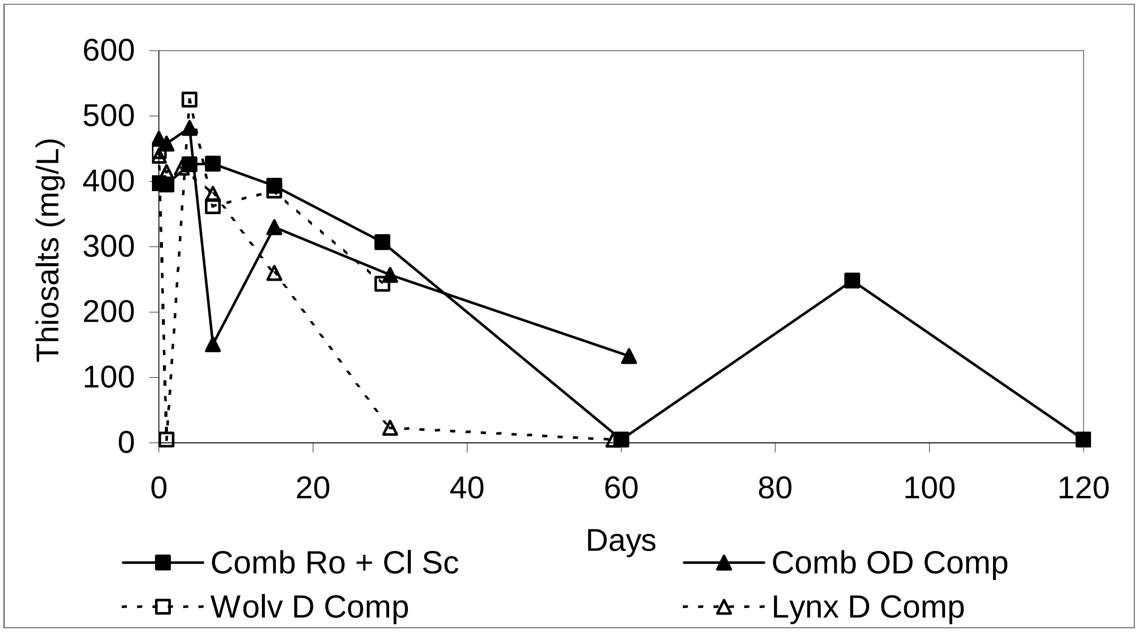


Figure 2.8-5 **Variation in Thiosalt Concentration over Time**

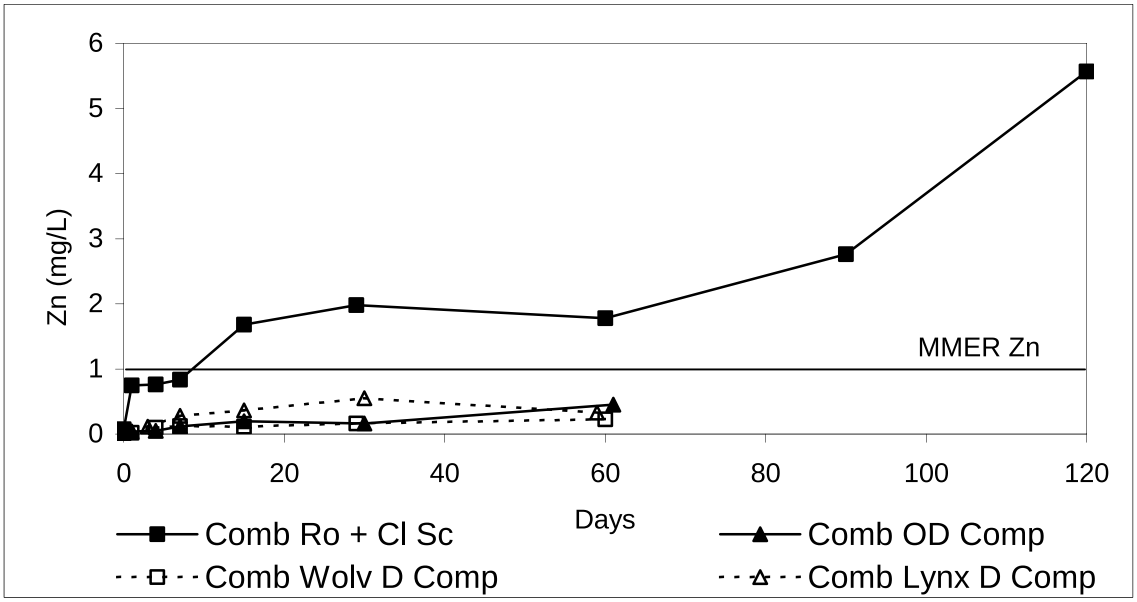


Figure 2.8-6 **Variation in Dissolved Zinc Concentration over Time**

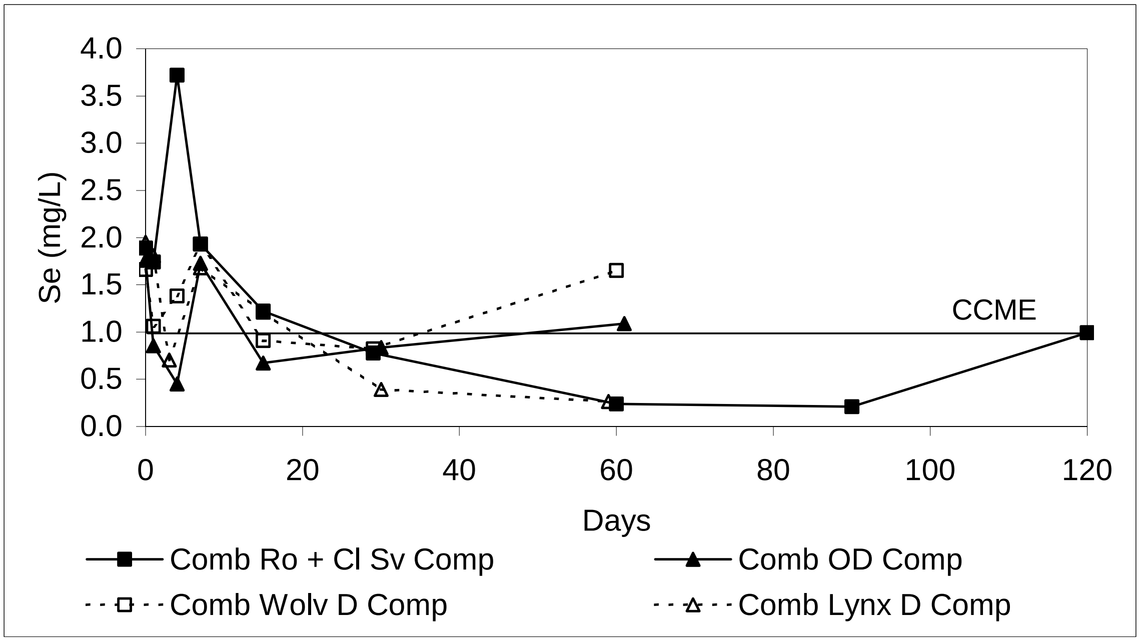


Figure 2.8-7 Variation in Selenium Concentration over Time

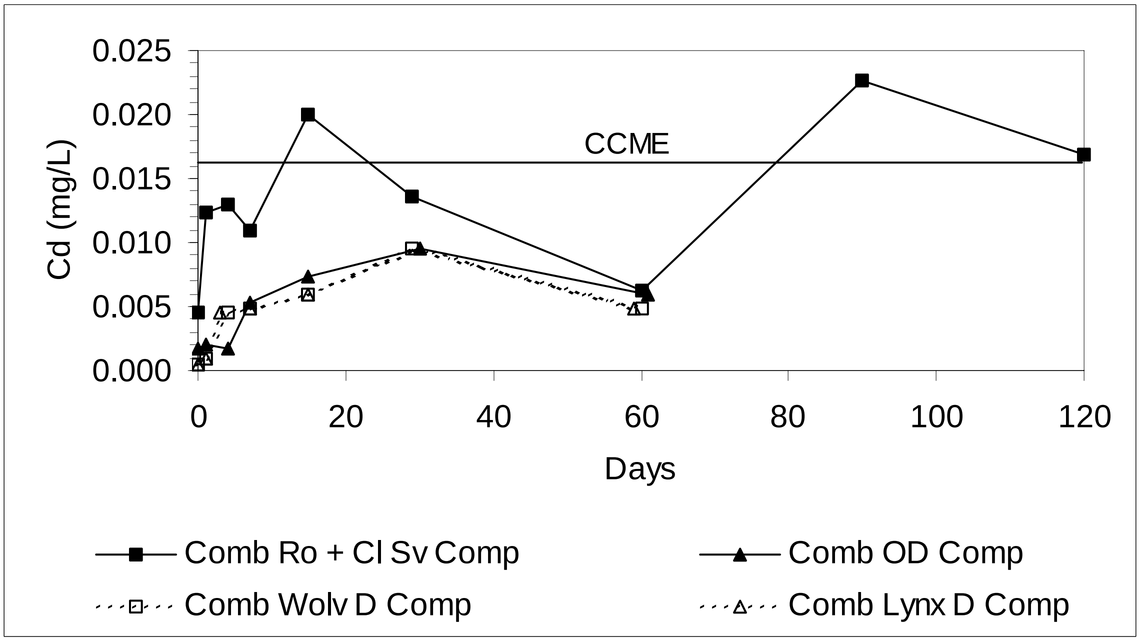


Figure 2.8-8 Variation in Cadmium Concentration over Time

Table 2.8-6 summarizes the latest values seen in aging tests so far (to ~Day 60 for Samples A, B and C and Day 120 for Sample D) for the key parameters. The aging tests will all be completed at Day 120. The aging tests provide an indication of the changes to be expected in pond water chemistry over time. Clearly it can be expected that the thiosalts remaining in solution in the tailings pond will gradually decompose over a 4 to 6 month period following cessation of milling. Conversely, it can be expected that sulphate concentrations may continue to rise for some time after mine closure, perhaps even reaching gypsum saturation. In reality, this may even occur during operations, as the gypsum in previously deposited tailings dissolves. The shake flask test results confirm this equilibrium condition of elevated sulphate. Similarly, zinc appears to continue to report to the aqueous phase over time. It is believed that this zinc is derived from the zinc sulphate added in the flotation circuit in conjunction with NaCN. While this reagent addition results in very little cyanide in solution (<1 mg/L) it does appear to result in elevated zinc. The addition rate of 300 g of $ZnSO_4$/NaCN complex is equivalent to adding 94 g of soluble Zn/t, which, if it all were to report to the tailings supernatant, could theoretically result in 15-20 mg/L of dissolved zinc in the tailings pond and reclaim water. However, the aging tests and the shake flask tests (which achieve equilibrium within 24 h by agitating the sample) suggest that the dissolved zinc concentration in the tailings supernatant is not likely to exceed 7 mg/L.

The variation of Cd and Se over time follows a less defined trend. While they both exhibit considerable variability from one sampling date to the next as well as between tailings types, there is no clear trend upwards or downwards. However, both parameters consistently exceed BC/CCME receiving water quality guidelines by a wide margin. Monitoring of these parameters post-closure will most likely dictate the time required for on-going treatment of the tailings pond discharge post-closure. That said, it is important to note that the rainbow trout bioassay suggests that once the tailings pond has experienced a 10-fold dilution from local runoff and direct precipitation, it is likely that a direct discharge from the impoundment would not be considered a deleterious substance under the MMER because more that 50% of the test organisms would likely survive in the effluent.

A criteria of 10x receiving water quality guideline value was selected because for the parameters where there is an MMER limit, those limits exceed the respective CCME receiving water quality guidelines by a factor of 16 (for Zn) to 100 (for As). Consequently, a factor of 10 provides a level of conservatism for protecting downstream aquatic resources similar to or better than the MMER limits.

Table 2.8-6 Summary of Tailings Aging Tests

Parameter	Water Quality Guideline[1]	Sample A Lynx D (Day 59)	Sample B Wolverine D (Day 60)	Sample C – OD (Day 61)	Sample D – Overall (Day 120)
pH	6.0 to 9.5	7.63	7.11	7.16	7.39
Hardness	-	813	544	560	860
Sulphate	1000	1200	890	920	1200
Thiosalts	-	<10	243	133	<10
Total Cyanide	1.0	<0.01	<0.01	<0.01	0.01
Ammonia	17.7 (at T=15 C and pH 7)	0.9	1.1	1.2	0.2
Ag	0.015				<0.0001
As	0.5				0.021
Cd	*0.00017*				0.0169
Cu	0.3				0.0024
Pb	0.2				0.0266
Hg	0.0002				<0.0001
Sb	0.06				0.0142
Se	*0.01*				0.994
To	*0.008*				0.0089
Zn	0.5				5.57
Acute Toxicity (LC$_{50}$)[2]	100%				10.9%

Notes: 1. MMER or 10 times *CCME* WQG when no MMER limit exists, or 10 times BC WQG where no *CCME* Guideline exists, assuming Hardness of 400 mg/L.
2. Concentration at which 50% of Rainbow trout test organisms survive.

Tailings Shake Flask Tests

Shake flask test results for typical tailings were summarized in Table 2.8-2. These data are expected to represent the maximum concentrations achievable in the tailings supernatant under neutral metal leaching conditions, if complete equilibrium dissolution of soluble parameters is able to occur. This is a conservative assessment.

Tailings Column Leach Tests

A pair of column leach tests were run to assess the contaminant load that might be expected in seepage leaving the impoundment after passing through the tailings solids. The tests were run for 8 weeks, with a constant 0.6 m of water head to simulate the minimum water cover expected over the tailings post-closure. For the Overall Ore Composite tailings, there was a distinct flushing curve for all parameters with conductivity dropping from 2500 µS/cm to 240 µS/cm over 7 weeks. There was a slight resurgence in Ca, K, and Si in the last 2 weeks as compared to the lowest values observed for those parameters, but still far below the initial values. This may have been related in some way to some short-circuiting observed when the seepage water was withdrawn from the cells in the last few weeks of the test.

The Overall Dilute Composite tailings has seen a similar flushing pattern over the first 3 weeks of testing for which data is available, although at the lower concentrations as has typically been observed with this sample in other tests.

Tailings Impoundment Water Quality Model

In order to predict the long term water quality in the tailings impoundment during and following operations, a water quality model has been developed, coupled with the water balance established for the tailings impoundment. The model helps to show that water treatment of the tailings impoundment discharge would probably not be required for more than 5 to 10 years following mine closure.

Methodology

The tailings impoundment water quality model is comprised of two models serving distinct purposes:

- The water balance model tracks the hydrologic inflows and outflows to and from the impoundment as well as the tailings and waste rock inflows to the impoundment. The primary function of the water balance model is to estimate the monthly height of solids and water stored in the impoundment during mining. The incremental rise in solids and water provides the basis for generating the dam raising construction schedule and provides the ultimate closure dam height. The water balance model is presented in Section 2.8.6.
- The dilution water quality model is an extension of the water balance model and operates on a mass balance basis. Using the hydrologic inflows and outflows from the water balance model combined with the masses known from the baseline average annual water quality data from the surrounding catchment, the mass of individual parameters can be tracked in the impoundment. The mass loading of parameters from both the tailings and waste rock are inputs to the model. The end of year concentration for each parameter is calculated from the net mass accumulated in the impoundment divided by the end of year free water[1] available for dilution.

The water balance and water quality calculations have been undertaken during the following two time periods:

1. mining, operational phase
2. post-mining, closure and post-closure phase

The tailings impoundment dilution water quality model was set up on an annual basis and uses Microsoft Excel. It is comprised of a number of worksheets with the end goal of determining the impoundment water quality over the life of the mine and into the post-closure period. Details of the model development and model output are issued under separate cover in the tailings feasibility study report by Klohn Crippen.

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[1] Free water is the volume of water above the solids level available for dilution.

The tailings impoundment dilution water quality model operates on the following major assumptions. The water quality model:

1. Is a dilution model only. It does not take into account the solubility constraints of those parameters for which solubility limits are a factor.
2. Assumes complete dilution of the mass entering the tailings impoundment (i.e., 100% mixing efficiency).
3. Is achieved by the end of every year; input parameters to the water quality model are assigned for every component of the water balance, including the tailings supernatant, the local runoff and groundwater seepage.

Results

During Operations

The water balance shows that during operations nearly 90% of the water entering the impoundment is tailings slurry water. Given this insignificant amount of dilution it can be expected that the tailings pond, water quality will be very similar to the tailings supernatant water quality as characterized by the results of the analyses of the samples collected after the first hour of the aging tests.

During Closure

The closure water quality model assumes that once milling ceases, the tailings pond water will “age” in a similar manner to what has been observed in the laboratory aging tests. The preliminary model runs were based on Day 60 aging test results for the Overall Ore Composite. Once the Day 120 data for the Overall Dilute Ore Composite (the “typical” tailings) are available, these will become the “Base Case” data for the model. Sensitivity analyses will also be conducted examining the highest and lowest concentrations observed in any of the aging tests at any of the last 3 sampling dates (i.e., Day 60, Day 90 or Day 120).

For the Base Case condition modeled, the results are presented in Table 2.8-7. Figure 2.8-9 illustrates how long each parameter will require treatment prior to achieving the appropriate receiving water guideline value. If sufficient dilution is available downstream, it may be appropriate to commence discharge earlier than suggested by this model run.

Sensitivity analyses are not yet complete, but it is clear that flushing of Cd and Se from the tailings solids will dictate how long water treatment will actually be required following operations.

Table 2.8-7 Summary of Closure Water Quality Modeling Results (Vol. 2)

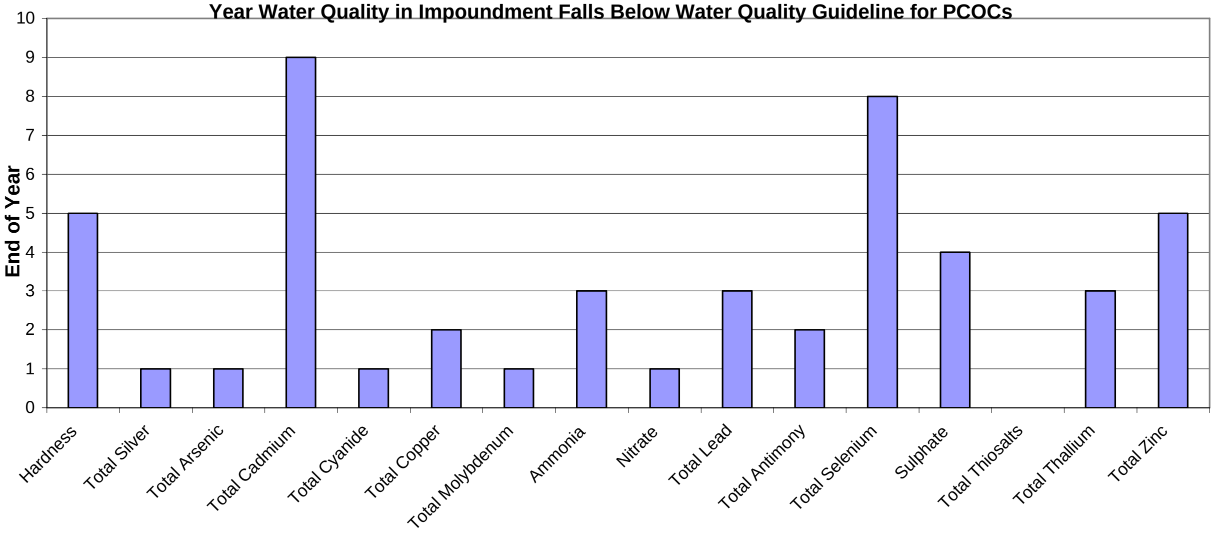

Figure 2.8-9 **Time for tailings pond to achieve water quality guideline post-operations**

2.8.4 Field and Laboratory Investigations

Two phases of site investigations were carried out in 2005: Phase 1 from May to June for an alternative site in the Go Creek valley, and Phase 2 from July to September for the proposed site on the northeast valley slope of Go Creek.

The site investigation programs were mainly carried out using a 420D Cat backhoe mounted on rubber tires from Yukon Zinc, and a BBS-25A diamond drill rig from Advanced Drilling Ltd. of Surrey, B.C. Locations of test pits, test holes and groundwater monitoring wells for the proposed tailings facility are shown in Figure 2.8-1.

The drilling program consisted of Standard or Large Penetration tests and falling-head permeability tests in overburden materials; and performing packer permeability tests and diamond coring with HQ3 or NQ3 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 420D Cat 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 5-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, and gradation tests. Additional standard Proctor compaction tests, triaxial permeability and shear strength tests were either carried out or are planned using the potential borrow materials for the dam fill.

Two 1-in diam. 30-cm long piezometer tips were installed in most test holes with 1-in Schedule 40 PVC riser pipes. One 2-in diam. 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.

2.8.5 Design and Capacity Requirements

As outlined above, a water cover was selected as the design basis for the storage facility owing to the acid generating potential of the tailings and coarse waste. Thus, the tailings dam is to be designed as a water-retention structure, and a net water balance is to be maintained in the impoundment. Other design parameters for the tailings facility summarized in Table 2.8-8 include:

- total tailings in the order of 1.25 Mt and total coarse waste in the order of 1.68 Mt (1.05 Mt of DMS float and 0.63 Mt of waste rock) correspond to the current ore resources and mining plan
- tailings are produced at an average rate of 923 t/d or 0.34 Mt/y per year;
- in situ densities of stored materials are estimated as 1.85 t/m^3 for tailings, 1.9 t/m^3 for DMS float and waste rock; thus the required storage volume for the tailings and coarse waste is estimated at 1.56 Mm^3
- a nominal storage capacity of the impoundment is 2.1 Mm^3, including tailings, coarse waste and water

Table 2.8-8 Design Parameters for the Tailings Facility

Type of Material	Materials (t)	In-situ Density (t/m^3)	Volume (m^3)
Tails	1,250,000	1.85	676,000
DMS Float Rock	1,050,000	1.9	553,000
Development Waste Rock	630,000	1.9	332,000
Total	2,930,000		1,561,000

The estimated dam volume for the above storage is about 1.1 Mm^3. The proposed impoundment site could accommodate additional storage volume, if required. However, this would require the adjustment of the centreline and ultimate crest of the dam. A maximum storage volume of 4.5 Mm^3 is estimated to be available at the site. However, a dam volume of about 3.6 Mm^3 will be required for the scheme.

2.8.6 Water Balance

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

- the first year of tailings facility operation
- the final year of tailings facility operation
- after mine closure

Inflows to the tailings facility include:

- surface water runoff and snowmelt from the tailings facility catchment, and direct precipitation on the tailings pond
- groundwater inflow
- tailings transport water from the mill during mining operation
- water in the DMS float reject trucked to the tailings facility
- water in the mine development waste rock trucked to the tailings facility
- water transferred from the seepage recovery pond to the tailings facility

Outflows from the tailings facility include:

- evaporation from the pond
- reclaim water recycled to the mill during mining operation
- water lost to tailing voids as porewater
- water lost to coarse waste voids (coarse waste includes DMS float reject and mine development waste rock deposited in the impoundment)
- water conveyed to the water treatment plant
- seepage losses from the tailings facility

Ponded water observed in the tailings pond area, as well as artesian conditions encountered during drilling suggests minor upwelling of groundwater (springs). Water level monitoring shows that the artesian conditions are low and occur mainly during the freshet. Also, once tailings deposition begins, the hydraulic head of the impounded water will prevent any upgradient water from upwelling into the tailings pond. Thus, for the purpose of ascertaining the quantity of water entering and leaving the pond, the contribution of groundwater into the tailings area is considered negligible, and the upgradient groundwater entering the water balance model is assumed to pass underneath the tailings facility.

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.

The updated climate and hydrology data, provided by Madrone Environmental Services Ltd. in August and September, 2005, were used for the water balance analyses. Table 2.8-9 presents the results of the annual water balances for the first and final year of mining operation, and after mine closure with the upland diversion ditches in place. As the table indicates, there will be surplus water in the tailings pond during mine operation for the average year, the 1:200 year wet year as well as the 1:100 dry year. The water balance for the post mine closure scenario indicates that, although there will be surplus water during the average year and the 1:200 year wet year, a water deficit is expected to occur during the 1:100 and the 1:200 dry years if the upland diversion ditches are left in place. Therefore, the upland diversion ditches must be decommissioned after mine closure such that the water cover on the deposited tailings is maintained.

Table 2.8-10 presents water balances similar to Table 2.8-9, but without the upland diversion ditches. As the table indicates, there will be surplus water in the tailings pond under all scenarios examined, including the 1:100 and the 1:200 dry years.

The water balance for the average year during the final year of operation is shown schematically in Figure 2.8-10.

Figure 2.8-10 Impoundment Water Balance for Average Year (Vol. 2)

Table 2.8-9 Tailings Pond Annual Water Balances with Diversion Ditches

Description	First Year of Operation			Final Year of Operation			After Closure			
	Average Year (m^3/hr)	200-Year Wet Year (m^3/hr)	100-Year Dry Year (m^3/hr)	Average Year (m^3/hr)	200-Year Wet Year (m^3/hr)	100-Year Dry Year (m^3/hr)	Average Year (m^3/hr)	200-Year Wet Year (m^3/hr)	100- Year Dry Year (m^3/hr)	200-Year Dry Year (m^3/hr)
INFLOW to Tailings Pond:										
Runoff into tailings pond (includes runoff from upslope catchment, snowmelt and direct precipitation)	7.8	11.5	3.8	9.2	13.6	4.5	9.2	13.6	4.5	4.0
Tailings transport water (note 1)	224.3	224.3	224.3	224.3	224.3	224.3	-	-	-	-
Water from mine development waste rock	0.5	0.5	0.5	0.5	0.5	0.5	-	-	-	-
Water pumped from seepage recovery pond	3.7	4.1	3.1	2.1	2.5	1.5	2.1	2.5	1.5	1.5
TOTAL INFLOW	236.3	240.4	231.7	236.1	240.9	230.8	11.3	16.1	6.0	5.5
OUTFLOW OR LOSS OF WATER from Tailings Pond:										
Evaporation	1.7	1.4	1.9	6.4	5.5	7.2	6.4	5.5	7.2	7.2
Loss to tailing voids	7.1	7.1	7.1	7.1	7.1	7.1	-	-	-	-
Loss to coarse waste voids	4.5	4.5	4.5	4.5	4.5	4.5	-	-	-	-
Reclaim water directly to Mill	205.6	205.6	205.6	205.6	205.6	205.6	-	-	-	-
Seepage losses	3.5	3.5	3.5	1.9	1.9	1.9	1.9	1.9	1.9	1.9
TOTAL OUTFLOW	222.4	222.1	222.6	225.5	224.6	226.3	8.3	7.4	9.1	9.1
SURPLUS	**13.9**	**18.3**	**9.1**	**10.6**	**16.3**	**4.5**	**3.0**	**8.7**	**(3.1)**	**(3.6)**

Notes: The paste backfill plant is assumed to be operated 10 hours per day.
Flow rates shown are average rates over the 12 month period.
Flow rates to and from mill assume 92 % mill availability.
Precipitation and runoff transferred from seepage recovery pond is net flow to tailings pond after deducting seepage recovery pond evaporation.
Water balance for period after closure assumes the upland diversion ditches, the seepage collection ditches and the seepage recovery pond are operating.

Table 2.8-10 Tailings Pond Annual Water Balances without Diversion Ditches

Description	**First Year of Operation**			**Final Year of Operation**			**After Closure**			
	Average Year (m^3/hr)	**200-Year wet Year (m^3/hr)**	**100-Year Dry Year (m^3/hr)**	**Average Year (m^3/hr)**	**200-Year wet Year (m^3/hr)**	**100-Year Dry Year (m^3/hr)**	**Average Year (m^3/hr)**	**200-Year wet Year (m^3/hr)**	**100-Year Dry Year (m^3/hr)**	**200-Year Dry Year** (m^3/hr
INFLOW to Tailings Pond:										
Runoff into tailings pond (includes runoff from upslope catchment, snowmelt and direct precipitation)	28.9	42.7	14.2	35.8	53	17.6	35.8	53	17.6	15.4
Tailings transport water (note 1)	224.3	224.3	224.3	224.3	224.3	224.3	-	-	-	-
Water from mine development waste rock	.5	0.5	0.5	0.5	0.5	0.5	-	-	-	-
Water pumped from seepage recovery pond	3.7	4.1	3.1	2.1	2.5	1.5	-	-	-	-
TOTAL INFLOW	257.4	271.6	242.1	262.7	280.3	243.9	35.8	53	17.6	15.4
OUTFLOW OR LOSS OF WATER from Tailings Pond:										
Evaporation	1.7	1.4	1.9	6.4	5.5	7.2	6.4	5.5	7.2	7.2
Loss to tailing voids	7.1	7.1	7.1	7.1	7.1	7.1	-	-	-	-
Loss to coarse waste voids	4.5	4.5	4.5	4.5	4.5	4.5	-	-	-	-
Reclaim water directly to Mill	205.6	205.6	205.6	205.6	205.6	205.6	-	-	-	-
Seepage losses	3.5	3.5	3.5	1.9	1.9	1.9	1.9	1.9	1.9	1.9
TOTAL OUTFLOW	222.4	222.1	222.6	225.5	224.6	226.3	8.3	7.4	9.1	9.1
SURPLUS	**35.0**	**49.5**	**19.5**	**37.2**	**55.7**	**17.6**	**27.5**	**45.6**	**8.5**	**6.3**

Notes: The paste backfill plant is assumed to be operated 10 hours per day.
Flow rates shown are average rates over the 12 month period.
Precipitation and runoff transferred from seepage recovery pond is net flow to tailings facility after deducting seepage recovery pond evaporation.
Water balance for period after closure assumes seepage collection ditches and seepage recovery pond have been decommissioned.

In our surface water management layout for the tailings impoundment, a ditch will be used to divert water from Go Creek into the tailings basin, as shown in Figure 2.8-1, for storing fresh water required for the start up of facility. 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 proposed average diversion rate is approximately 200 m^3/hr, which is about 10% of the average annual flow in the creek near the diversion location. Streamflow estimates indicate that Go Creek will have sufficient flow during the months of May to July to allow diversion to the tailings pond, while maintaining a minimum of 350 m^3/hr 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 balances for the mining operation, no water inflow from this ditch is assumed.

2.8.7 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 reviews, 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.

Regionally, significant wildlife resources occur in the Wolverine Project area, notably the Finlayson caribou herd. The herd uses the uplands around the project area from the spring to the fall, and the lowlands of the Pelly River in the winter. These caribou provide a valuable food source for the Ross River Kaska Dena and are also of economic significance to sport hunters and the guiding industry. Moose are also a significant wildlife resource. Furbearer populations are also utilized by the Kaska. Fish in the larger lakes (including Finlayson Lake) and streams include arctic grayling, whitefish, lake trout and bull trout (Gartner Lee Ltd. 2004).

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 to travel as far downstream as water. The estimated total storage volume of 2.1 million m^3 at closure in the Wolverine tailings pond will comprise the following:

- approximately 0.6 m m^3 of DMS float reject
- approximately 0.3 m m^3 of mine development waste rock
- approximately 0.7 m m^3 of tailings
- approximately 0.5 m m^3 of water

As can be seen from the above breakdown of storage, coarse waste (i.e., DMS float reject and waste rock) make up about 43% of the total storage. Tailings and water make up about 33% and 24% 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 plus 30% of the stored tailings and coarse waste.
- 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 above assumptions are considered to be conservative since in the proposed deposition scheme for the tailings facility, shown in Figure 2.8-3, the tailings will be deposited in three cells divided by the splitter dykes and the coarse waste. The dyke and the coarse waste will tend to hold the tailings in place in the unlikely event of a breach of the tailings dam.

The estimated peak outflow released from the dam is in the order of 2,000 m^3/s. This peak flow 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 2.8-11.

Table 2.8-11 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	2,000
Confluence of Go Creek and Money Creek	5	1,900
Robert Campbell Highway and Frances Lake	40	1,200

It should be noted that the assumptions made and the charts used herein provide rough estimates of expected dam breach discharge and downstream attenuation.

As Table 2.8-11 indicates, very 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. The estimated natural flows in Go Creek and Money Creek are given in Section 7.4: Surface Water Hydrology. A comparison of the estimated flood peak resulting from a breach at the tailings dam with the natural flows in the streams indicates that the dam breach flood peak will be about 200 times the naturally expected 200-year peak flow in

Go Creek, and it will be about 30 times the naturally expected 200-year peak flow in Money Creek.

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. On the other hand, 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 2.8-11 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 or mitigated by other means. The potential environmental damage in that case could be substantial. However, if clean-up of the downstream area and repair of the tailings facility is carried out right away, say within a couple of months, the bulk of the tailings may not be acid generating with the possible exception of the thin crust near the surface, if any. 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.

2.8.8 Design Earthquake

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 in Section 2.8.7, 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 site horizontal peak ground acceleration value will be determined during the feasibility study for this annual probability of exceedance. The recent work by Atkinson (2004) on Seismic Hazard Assessment for Faro, Yukon will be referenced to, in arranging this work. Essentially, the Tintina Trench area will be 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.

2.8.9 Design Floods

The design flood criteria selected for various components of the water management facilities associated with the tailings impoundment are summarized in Table 2.8-12. 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 2.8-12, the design flood of 10,000-year return period is proposed for the tailings pond closure spillway. The preliminary sizes for the diversion and seepage collection ditches, and the starter dam and the closure dam spillways are shown in Figures 2.8-11 and 2.8.12. These channel sizes will be further refined based on flood runoff routing during the feasibility study.

Table 2.8-12 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.
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		0.3 m	
Tailings Dam Freeboard		2.0 m	

Figure 2.8-11 Diversion Ditches and Spillways – Plan and Sections (Vol. 2)

Figure 2.8-12 Go Creek and Ditch a Diversion Structure (Vol. 2)

As Table 2.8-12 indicates, the tailings pond will have an allowance of 0.3 m depth for flood storage. The pond will be operated such that 0.3 m of pond depth is kept free for flood storage. In the event of a large flood inflow, the water will be treated and discharged from the pond as soon as possible in order to regain the flood storage capacity. At the starter dam level, the 0.3 m depth is adequate for storage of runoff from a 200-year, 30-day rainfall event, with the upland diversion ditches functioning. As the dam is raised during subsequent years and the pond surface area increases, the 0.3 m storage allowance will accommodate larger flood events. The 2.0 m freeboard for the tailings dam will be over and above the 0.3 m flood storage allowance.

2.8.10 Dam Construction

The tailings dam will be constructed as a homogeneous embankment dam over the relatively dense glacial and glacio-fluvial foundation. It will have a horizontal downstream drainage blanket in the valley section and along the dam toe as shown in Figure 2.8-2. The preliminary estimates for dam-related construction quantities are summarized in Table 2.8-13. Potential borrow areas for dam fill will be either within the tailings basin or close to it. A representative sample of damfill borrow material was subjected to leachate analyses, and no geochemical problems were identified as indicated in Section 2.8.3.

Table 2.8-13 Estimated Quantities for Tailings Dam

Excavation or Fill Items	Description of Materials or Extent	Estimated Quantities (m^3)	
		Starter Dam	Ultimate Dam
Dam Fill above Original Ground Surface	Select Pit-run Silt-Sand-Gravel	155,000	1,031,000
Filter/Drainage Blanket, As Required	Screened Sand and Gravel Creek and Glacial Deposits	-	35,000
Foundation Topsoil Stripping	0.3 m depth within dam footprint area	8,000	32,000
Foundation Backfill to Original Ground Surface	Select Pit-run Silt-Sand-Gravel	8,000	32,000
Total Dam Fill	-	163,000	1,098,000

As shown in the above table, the bulk of dam fill materials will be pit-run silt-sand-gravel glacial and glacio-fluvial materials within the tailings basin and in its vicinity. A nominal amount of clean filter/drainage material will be required for the horizontal downstream drainage blanket in the valley section and along the dam toe. This material will most likely be obtained from screening of sand and gravel creek and glacial deposits.

In order to store water from the spring freshet prior to the start of mining operation, the Starter Dam will be constructed one year earlier. As shown in Figure 2.8-2, the footprint area of the Starter Dam will be first stripped off about 0.3-m thick of topsoil, proofrolled and backfilled with damfill material. After the completion of the Starter Dam, the dam will be raised in the following four stages by the downstream construction method:

Year 1 to Crest El. 1314 m;

Year 4 to Crest El. 1318 m;

Year 7 to Crest El. 1322 m; and

Year 10 to Ultimate Crest El. 1325 m.

Dam volumes for incremental raises of the dam are shown in Table 2.8-14.

Table 2.8-14 Estimated Dam-Raise Quantities Above Starter Dam

Year of Dam Construction and Crest El. (m)	Dam Crest Raise above Starter Dam (m)	Incremental Dam Volume above Starter Dam (m^3)	Cumulative Dam Volume (m^3)
Year -1, Starter Dam 1310	0	0	155,000
Year 1, 1314	4 m	129,000	284,000
Year 4, 1318	4 m	187,000	471,000
Year 7, 1322	4 m	271,000	742,000
Year 10, Ultimate Dam 1325	3 m	324,000	1,066,000

Notes: 1. The above table shows incremental dam volumes above the original ground surface, including the volume of clean sand and gravel filter/drainage blanket.

For other items included in Table 2.8-14, incremental quantities could be obtained approximately by dividing the differences between the corresponding items for the Ultimate Dam and Starter Dam by 4, assuming the mine will be in operation for 12 years.

As shown in Figure 2.8-2, for each dam construction stage, the foundation stripping, proofrolling and backfill operation will be carried out for a strip immediately downstream of the existing dam toe. Then the dam will be extended further downstream over the prepared foundation area and raised in horizontal lifts. The dam fill shall be spread in horizontal layers with 0.3-m lift thickness. The density of the dam fill in place shall not be less than 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.