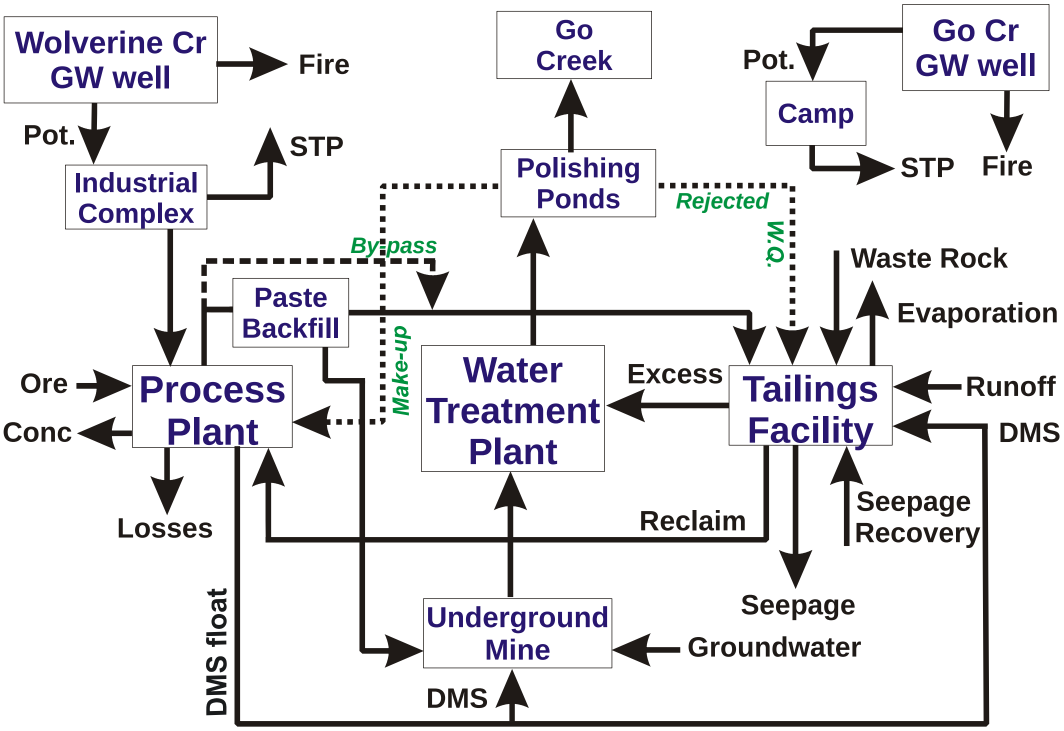
2.9 Site Water Management

2.9.1 General Description of Water Management System

The layout of the mine site with the locations of various facilities, including the tailings facility and the industrial complex with the process plant and the water treatment plant, is shown in Figure 2.10-2. A schematic of the site water management system is shown in Figure 2.9-1. A general description of the water management system is given below, followed by an overview of the site water balance in Section 2.9-3. Water management plans for the underground mine, the process plant, the tailings facility and the water treatment plant are provided in Sections 2.9.3 and 2.9.7, respectively.



Notes: DMS = dense media separation plant; Conc = concentrate; GW = groundwater; Pot = potable water; STP = sewage treatment plant; WQ = water quality.

Figure 2.9-1 Water Management System at the Mine Site

The process plant, the water treatment plant and the tailings facility occupy a central position in the water management plan. Most of the water used in ore processing is obtained (reclaimed) from the tailings facility. Together with a portion of the tailings, the process water is discharged to the tailings facility. Hence, most of the water in the water management system at the mine site is actually recycled between the process plant and the tailings facility. The water treatment plant receives in principle only water from the underground mine and from the tailings facility. However, if surface runoff from the industrial complex is of poor quality, runoff water will also need to be treated. Before being released, the treated water will be temporarily stored in polishing ponds. Treated water will be discharged to Go Creek, used as make-up water for the process plant, or returned to the tailings facility if the water quality does not meet the required discharge criteria.

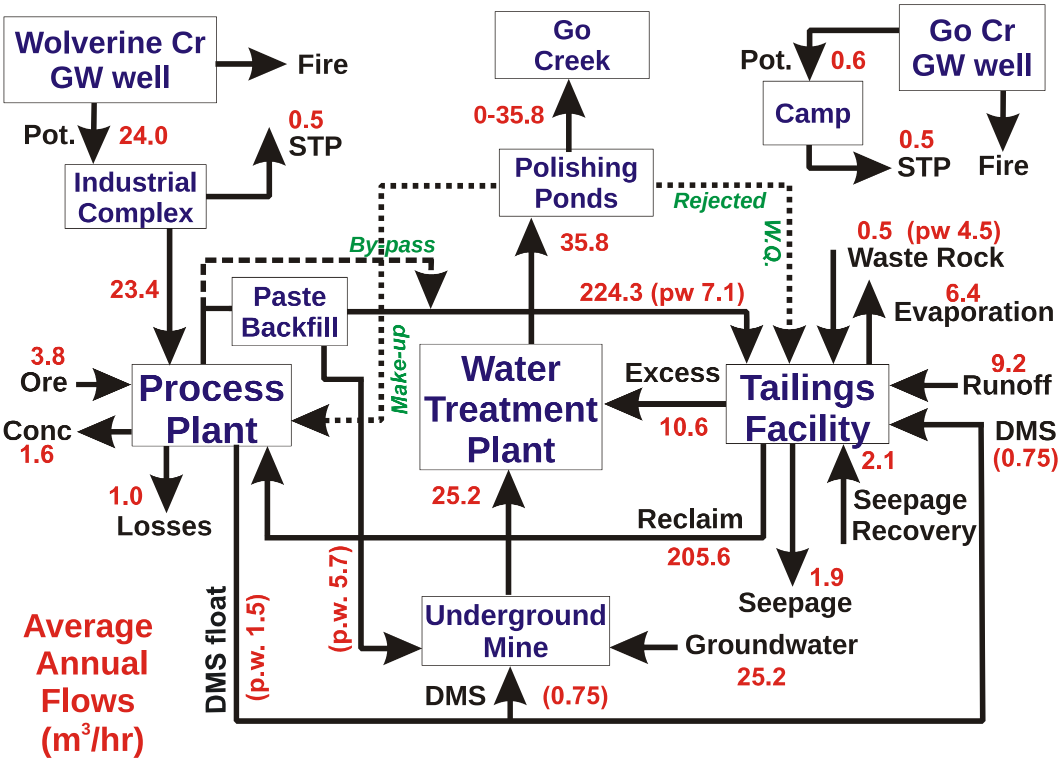
Fresh water used as potable water and firewater at the industrial complex and the camp will be obtained from groundwater wells at Wolverine Creek and Go Creek, respectively. Part of the water from the groundwater well at Wolverine Creek will be used in the process plant for reagent make-up and cooling. Most of the water used for domestic purposes at the camp and industrial complex (80%) will be treated by sewage treatment plants (STP) located at each facility. Water from the STP at the industrial complex will be discharged to the polishing ponds. Treated STP water for the camp will be discharged to Go Creek. During detailed engineering design, the possibility of recycling STP effluents for use as non-potable water will be examined.

To minimize the potential effect of site runoff on the water quality of the natural drainages, a drainage diversion system will route surface runoff around mine site facilities. Surface runoff will be collected in perimeter ditches upslope of the tailings facility (Section 2.8: Tailings Disposal), upslope of the temporary waste rock pad (Section 2.7: Waste Rock Disposal) and around the industrial complex (Section 2.10: Site Facilities and Infrastructure). The ‘clean’ runoff water will be diverted away from the mine site facilities and will ultimately drain into either Go Creek or Wolverine Creek. Similarly, diversion ditches at the portal and vent shafts will be used to prevent the entry of surface runoff into the underground mine. Runoff water that cannot be diverted or that comes in direct contact with mine site facilities will be collected and treated.

2.9.2 Site Water Balance

Using estimates of average annual flows (m^3/hr) between the different facilities in the site water management system (Figure 2.9-1) a site water balance was generated for average annual conditions (Figure 2.9-2). Additional water balance scenarios that have been considered for the tailings facility are discussed in Section 2.9.5.

In the water balance, it is assumed that the estimated water inputs to each mine site facility match the estimated water outputs and there is no water storage. For example, the excess of water from the tailings facility that is directed to the water treatment plant (10.6 m^3/hr) represents the difference between total inputs (236.1 m^3/hr) and total outputs (225.5 m^3/hr) at the tailings facility.



Notes: DMS = dense media separation plant; Conc = concentrate; GW = groundwater; Pot = potable water; pw = pore water; STP = sewage treatment plant; WQ = water quality.

Figure 2.9-2 Water Balance of the Mine Site During Operation

Most of the water in the site water balance (205-225 m^3/hr) is continuously recycled between the process plant and the tailings facility. The input to the site water balance is dominated by groundwater contributions from the Wolverine Creek wells (24.0 m^3/hr) and the underground mine (25.2 m^3/hr). Additional (net) input contributions occur at the process plant (1.2 m^3/hr) and the tailings facility (3.5 m^3/hr). The discharge of treated water into Go Creek (0-35.8 m^3/hr), the pore water accumulating in the deposited tailings and waste rock (11.6 m^3/hr) and evaporation (6.4 m^3/hr) are the main contributions to the output from the site water balance (18.0-53.8 m^3/hr). The estimated total consumption of potable water at the industrial complex and the camp is based on a consumption rate of 250 L/d by 120 persons (0.625 m^3/hr) used for showers, drinking water, cokking etc., at the industrial complex and the camp.

Compared to the amount of water being recycled, the input and output of water in the site water balance are relatively small (25%). The treated water will meet metal mine effluent (MMER) guidelines prior to discharge into Go Creek. The discharge point is near the confluence with Hawkowl Creek, downstream of water quality stations W15 and W16 (Figure 7.5-2). Water quality station W12 has been selected as the compliance point for meeting the site-specific water quality objectives. Treated water in the polishing ponds that does not meet regulations MMER criteria will be returned to the tailings facility. It is anticipated that water from the polishing ponds will be used as often as possible as make-up water for the process plant to minimize pumping to and from the tailings facility.

2.9.3 Underground Mine

The groundwater and surface water within the footprint of the proposed mine naturally drains into the Wolverine Creek watershed. With mine dewatering, water will be removed from the Wolverine Creek watershed and discharged into the Go Creek watershed. Section 7.6: Groundwater presents the results of hydrogeologic characterization of the mine area and predictions of groundwater flow into the mine as a result of mine dewatering.

The permeability (i.e., hydraulic conductivity) of the rock at the mine site was measured in two deep exploration boreholes. The hydraulic conductivity values measured in the test intervals ranged from 1.7×10^{-7} cm/sec to 1.8×10^{-4} cm/sec. The rate of groundwater flow into the mine was estimated using several analytical methods. An analytical equation developed by Goodman et al. (1965) estimated inflow rates of at least 10 L/s (36.0 m^3/hr) following development of a 300 m mine drift. Development of the conceptual hydrogeologic flow nets, and the assessment of dewatering data collected during initial advancement of a test mine decline confirmed that a groundwater inflow rate of at least 10 L/s will be expected during mine development and operation. The resultant radius of the groundwater cone of depression (i.e., lowered groundwater table) extends up to 1 km from the perimeter of the mine.

Inflow rates may be higher immediately following underground development and should decrease with time as the saturated rock above the mine is drained. After the rock above the mine is drained and a cone of depression has developed around the dewatered mine area, infiltration from precipitation and lateral ground water flow will continue to provide inflow to the mine workings. The minimum rate of mine water inflow from precipitation infiltration is estimated to be about 7 L/s (25.2 m^3/hr) based on an infiltration rate of 40% over the dewatered catchment area using an average annual precipitation of 479 mm. Inflows encountered during the current test mining program and during pre-production development can be used to calibrate these initial inflow calculations.

Assuming a minimum groundwater inflow, the total water input to the underground mine amounts to 25.2 m^3/hr. To avoid accumulation of water in the underground mine an equivalent amount of mine water and any additional volume (e.g., seepage) will be pumped to the water treatment plant and ultimately discharged into Go Creek.

Following closure of the mine and cessation of mine dewatering, the mine will flood and groundwater levels are expected to return to near pre-mining conditions. Post-closure groundwater conditions are expected to be similar to pre-mining conditions as the mine will be backfilled and the portal sealed. It is unlikely that the mine will decant as the portal entrance is the highest point of the mine, and above the pre-mining groundwater table elevation.

Groundwater samples were collected from two exploration boreholes at depths up to 150 m below ground surface during the in-situ bedrock permeability-testing program. In addition, groundwater samples were collected during advancement of the decline to establish background groundwater quality. The results indicate that baseline groundwater quality is relatively dilute with conductivity values of 145-389 µS/cm and neutral pH values of 7.7-8.2. The groundwater quality results along with CCME Canadian Water Quality Guidelines for the protection of aquatic life (CCME Guidelines) are presented in Section 7.6: Groundwater. Dissolved trace metals with elevated baseline concentrations in groundwater include selenium, lead, zinc, cadmium and copper. Cadmium, copper, iron, lead, selenium, and zinc exceed the CCME Guidelines.

During test mining, samples of mine dewatering water (i.e., groundwater mixed with drill water, explosives residue, drill waste etc.) have been collected in a ‘dirty’ sump. The dewatered water is most likely representative of mine water; its average chemical composition is shown in Table 2.9-1. Although the initial pH is very high, it is expected to drop to pH ~8 once the water is in equilibrium with the atmosphere. Apart from high nitrate and ammonia concentrations, the mine water (as observed in the ‘dirty’ sump in July and August 2005) is also characterized by high dissolved selenium and antimony concentrations.

2.9.4 Process Plant

Except for the fresh water used for reagent make-up and cooling (23.4 m^3/hr), most of the water used in the process plant (mill) will be reclaimed supernatant from the tailings facility (205.6 m^3/hr). Make-up water will also be available from the polishing ponds. Together with the water in the mined ore (3.8 m^3/hr), the total input of water to the process plant is 232.8 m^3/hr.

The largest output from the process plant will be the water that is pumped to the tailings facility (224.3 m^3/hr). The estimated output accounts for the time that the paste backfill plant is expected to be operational (approximately 10 h/d) and when it is by-passed. Additional outputs from the process plant include water in the concentrate (1.6 m^3/hr), process water losses (1.0 m^3/hr), and pore waters in the paste backfill (5.7 m^3/hr) and the DMS float (1.5 m^3/hr).

It is assumed that the chemistry data for the supernatant from composite tailings samples provide the best available information for an estimate of the chemical composition of the process water. To simulate aging of the tailings, the supernatant of composite tailings samples was collected for chemical analysis at various time intervals ranging from 1 hr to 90 days. The supernatant of the composite tailings samples with the least amount of aging (1 hr) were assumed to be representative of the water from the process plant (mill discharge water). The chemistry of the supernatant from composite tailings samples with the least amount of aging were used to calculate median, maximum and minimum values. The results for 0 days (1 hr) shown in Table 2.9-1, are assumed to represent the chemical composition of the mill discharge water (process water). Once the discharge water from the mill is pumped into the tailings facility, natural degradation processes will change the chemical composition. It was assumed that the tailings water has a chemical composition similar to that of the supernatant of composite tailings samples that have aged for 60 days (Section 2.9-5).

The chemical composition of the mill discharge or process water is characterized by relatively high concentrations of thiosalts, total cyanide (CNT), cyanate (CNO) and thiocyanate (CNS). However, it was observed that those concentrations decrease rapidly with time due to natural degradation processes. The same trend applies to the acidity and the total suspended sediment (TSS) concentrations. The concentrations of several metals (e.g., Ag, As, Cd, Cu, Pb, Sb, Se and Zn) are high and depending on the retention mechanism, the concentrations may increase or decrease with time.

Table 2.9-1 Estimated Water Quality at the Mine Site During Operation

Parameter	Units	Process and Tailings Water[1]				Mine[2] Water (3)	Water Mixture[3] (2+3)	MMER[4] Guideline	WQ Guideline	Source
		0 Days			60 Days					
		Max (1b)	Median (1a)	Min (1c)	(2)					
pH		8.59	8.25	7.47	7.67	11.40	8.25	6.0-5.0		
Conductivity	uS/cm	2000	1860	1570	2010	626	1036			
TDS	mg/L	1640	1510	1290	1690					
TSS	mg/L	100	31	23	3			25-50		
Acidity	mg/L as $CaCO_3$	432	365	175	1					
Alkalinity	mg/L as $CaCO_3$	47	37	26	44	102	61			
Hardness	mg/L as $CaCO_3$	510	452	435	811	151	346		100	BC Drinking Water Guideline
F	mg/L	0.42	0.25	0.22	0.38					
Cl	mg/L	19	19	19	18					
NO_3	mg/L as N	0.43	0.22	0.15	0.025	8.74	6.2		13	CCME Freshwater Aquatic Life
SO_4	mg/L	630	605	520	1100	106	400		50	BC Water Quality Alert Level
NH_3+NH_4	mg/L as N	1.3	1.3	1.1	1.4	3.66	3.0		0.019	CCME Freshwater Aquatic Life
Thiosalts	mg/L as S_2O_3	553	452	397	5	*1*	2			
CN(T)	mg/L	0.03	0.02	0.01	0.005	0	0.001		0.005	CCME Freshwater Aquatic Life
CNO	mg/L	2.1	1.85	1.2	0.4	0	0.12			
CNS	mg/L	16	3.7	2.2	0.01	0	0.003			
Dissolved Metals										
Ag	mg/L	0.022	0.0113	0.0039	0.00005	*0.00005*	0.0001		0.0001	CCME Freshwater Aquatic Life
Al	mg/L	0.190	0.070	0.031	0.002	0.415	0.293			
As	mg/L	0.036	0.012	0.008	0.011	0.001	0.004	0.5-1.0	0.005	CCME Freshwater Aquatic Life
Ba	mg/L	0.407	0.3485	0.114	0.039	0.08	0.068			
Be	mg/L	*0.005*	*0.0038*	*0.0025*	0.0025	*0.0001*	0.0008			
B	mg/L	0.04	0.019	0.011	0.017	0.1	0.075			
Bi	mg/L	*0.0003*	*0.00023*	*0.00015*	0.00015	*0.025*	0.0176			
Ca	mg/L	194	175	165	302	59.2	131			
Cd	mg/L	0.0045	0.0020	0.0005	0.0062	*0.00005*	0.0019		0.00003	CCME Freshwater Aquatic Life*
Co	mg/L	0.0011	0.0008	0.0007	0.0009	*0.00025*	0.0004			
Cr	mg/L	0.002	0.00125	0.0005	0.0005	0.013	0.0093			
Cu	mg/L	0.0499	0.0267	0.0051	0.004	*0.0025*	0.0029	0.3-0.6	0.002	CCME Freshwater Aquatic Life*
Fe	mg/L	*0.04*	*0.03*	*0.01*	0.01	0.82	0.58			
Hg	mg/L	*0.0001*	*0.000075*	*0.00005*	0.00005	*0.000025*	0.000032			
K	mg/L	11.1	10.0	8.05	12	11.6	11.7			
Li	mg/L	*0.005*	*0.0038*	*0.0025*	0.0025	*0.005*	0.0043			
Mg	mg/L	6	4.97	3.3	14	0.51	4.5			
Mn	mg/L	0.0872	0.0165	0.0013	1.64	*0.0005*	0.486			
Mo	mg/L	0.0503	0.03015	0.0042	0.0115	0.013	0.013		0.073	CCME Freshwater Aquatic Life
Na	mg/L	235	201	193	180	53.1	91			
Ni	mg/L	0.018	0.014	0.004	0.01	*0.004*	0.0058	0.5-1.0		
P	mg/L	*0.1*	*0.08*	*0.05*	0.05	*0.05*	0.05			
Pb	mg/L	0.0255	0.0166	0.0089	0.0151	*0.00025*	0.005	0.2-0.4	0.002	CCME Freshwater Aquatic Life*
Sb	mg/L	0.0645	0.0216	0.0129	0.0222	0.0322	0.029		0.006	CCME Drinking Water
Se	mg/L	1.95	1.825	1.66	0.237	0.006	0.07		0.001	CCME Freshwater Aquatic Life*
Si	mg/L	0.42	0.35	0.27	2.05	15.3	11.4			
Sn	mg/L	0.008	0.007	0.006	0.005	*0.01*	0.0085			
Sr	mg/L	0.308	0.293	0.272	0.495	0.253	0.325			
Ti	mg/L	*0.003*	*0.0023*	*0.0015*	0.0015	*0.0015*	0.0015			
Tl	mg/L	0.0100	0.0056	0.0021	0.006	*0.00005*	0.0018		0.0008	CCME Freshwater Aquatic Life
U	mg/L	0.0006	0.0003	0.0001	0.0011	*0.00005*	0.0004			
V	mg/L	0.0011	0.0005	0.00045	0.0011	0.016	0.0116			
Zn	mg/L	0.076	0.024	0.01	1.78	*0.0025*	0.529	0.5-1.0	0.03	CCME Freshwater Aquatic Life

Notes:

1. supernatant chemistry of tailings samples after 0 days (1 hr) and 60 days aging
2. water chemistry of dirty sump
3. 70.4% mine water and 29.6% tailings water (water balance)
4. first value represents monthly average concentration, second value refers to concentration in grab sample

values in italics are ½ the detection limit; highlighted cells are Potential Contaminants of Concern; values in red exceed WQ Guidelines;
* for hardness of 85 mg/L (yr 100)

2.9.5 Tailings Facility

The tailings facility consists of an impoundment with a surface area of ~163,000 m^2 and an initial volume of ~500,000 m^3 (Figure 2.8-2). Using available climate and hydrology data, water balances of the tailings pond with and without diversion ditches have been prepared for different scenarios. The purpose of the ditches is to divert runoff water from the upland catchment area away from the tailings pond. The results presented in this section apply to the situation where diversion ditches are used as without them there would be a water surplus in the tailings pond. Using data for the average year, the 1:200 wet year and the 1:100 dry year, the following three scenarios are evaluated:

1. the first year of facility operation
2. the final year of facility operation
3. after mine closure when diversion ditches are decommissioned

The water balances of the tailings pond for the three different scenarios are shown in Table 2.8-9. The data reported for the site water balance (Figure 2.9-2) represent data for an average year during the final year of the operations. The mill discharge water (224.3 m^3/hr) constitutes the main input to the tailings facility. Other inputs to the tailings pond are surface runoff (9.2 m^3/hr) that includes snowmelt and direct precipitation, water from the seepage recovery pond (2.1 m^3/hr), and water with the waste rock (0.5 m^3/hr) that is ultimately deposited in the tailings facility. Finally, treated water in the polishing ponds not meeting MMER criteria will be returned to the tailings facility. The major output from the tailings facility is reclaim water recycled to the mill (205.6 m^3/hr). Other outputs include evaporation (6.4 m^3/hr), seepage from the tailings pond (1.9 m^3/hr) and pore water in the waste rock (4.5 m^3/hr) and in the tailings (7.1 m^3/hr). The difference between total inputs (236.1 m^3/hr) and outputs (225.5 m^3/hr) is a surplus of water (10.6 m^3/hr) that is directed to the water treatment plant. According to the data in Table 2.8-9, there will be surplus water in the tailings facility during mine operation and after closure for the average year, the 1:200 wet year and the 1:100 dry year. This ensures an adequate water cover in the tailings facility. Therefore, without decommissioning the diversion ditches after mine closure there will be a water deficit in the tailings pond during the 1:100 dry year.

Similar to the chemistry of the water discharged from the mill, the supernatant of the composite tailings samples were assumed to be representative of the water from the tailings facility. However, unlike the water from the process plant, the chemistry of the tailings water is likely best represented by the supernatant of composite tailings samples that have aged. Considering the estimated residence time of three months for water in the tailings pond, various natural degradation processes are likely to affect the chemical composition of the water discharged from the mill. Among the available data, the chemical composition of the supernatant from composite tailings that have aged for 60 days was assumed to represent the tailings water. Its chemical composition is shown in Table 2.9-1.

Compared to the water discharged from the mill (0 days aging), the concentrations of several constituents have changed in the tailings water (60 days aging). Acidity and concentrations of TSS, nitrate, thiosalts, cyanate and thiocyanate have all decreased considerably, whereas the concentration of sulphate has increased. Changes in metal concentrations are more variable. Depending on the specific retention mechanism involved, concentrations of several dissolved metals have declined (e.g., Ag, Cu, Se) during aging whereas those of other metals have risen (e.g., Cd, Zn). This suggests that in recycling tailings water to the process plant, the process water (mill) may gradually become enriched in some metals but impoverished in others. For example, compared to their initial concentrations in the process water, the As and Se concentrations decrease in the tailings water (Table 2.9-1). By recycling tailings water to the process plant, the As and Se loadings in the mill water will gradually decrease.

2.9.6 Water Treatment Plant

2.9.6.1 Water Quality Predictions

The water treatment plant will receive surplus water from the tailings facility (10.6 m^3/hr) and mine water from the underground mine (25.2 m^3/hr). After treatment, the water will be temporarily stored in polishing ponds before being discharged into Go Creek, used in the process plant, or discharged into the tailings pond.

Assuming that the excess tailings water and the mine water are mixed in the same proportion that they are discharged to the treatment plant, the chemical composition of the mixture (70.4 % mine water and 29.6 % tailings water) is calculated. The chemical composition of the water mixture, along with specific water quality objectives or guidelines, are shown in Table 2.9-1. Except for zinc, the concentrations of deleterious substances in the water mixture before treatment are all well below the authorized levels prescribed in the MMER guidelines. The estimated concentration of zinc in the water mixture (0.529 mg/L) is only slightly higher than the authorized mean monthly concentration (0.5 mg/L) in the MMER guidelines.

A comparison between the concentrations of specific constituents in the water mixture and different water quality objectives (e.g., CCME Guidelines) in Table 2.9-1 indicates that the concentrations of ammonia and several metals will exceed guideline criteria. To reduce the concentrations of several constituents (e.g., NH_3, Cd, Se and Zn) water treatment will be necessary. For other constituents (e.g., Sb, Cu, Pb, To), dilution with water from Go Creek following discharge will be sufficient to reduce their concentrations below CCME Guidelines.

2.9.6.2 Required Water Treatment during Operation

An alternative (mass balance) approach to determine water treatment is to use the existing baseline conditions (discharge and chemistry) in Go Creek and specific water quality objectives (e.g., CCME Guidelines) to estimate the required concentration levels of constituents in the treated water that will achieve sufficient dilution when discharged into Go Creek. Assuming that treated effluent will be discharged just downstream of the confluence with Hawkowl Creek, monitoring station W-12 in Go Creek is proposed as the compliance point for site-specific water quality objectives (e.g., for the purpose of m asl balance calculations those similar to CCME Guidelines). Average baseline water quality data for station W-12 are shown in Table 2.9-2 along with the required compliance levels. Mean monthly flow (Q) and monthly 10 year 7-day low flow (7Q10) for station W-12 in Go Creek (just upstream of the confluence with Pup Creek) were reported in the Wolverine Project Description Report (Gartner Lee Ltd. 2004). The monthly flows (Q & 7Q10) for monitoring station W-12 are shown in Table 2.9-2 together with the treatment levels (concentrations) required to meet water quality objectives (i.e., CCME guidelines in Table 2.9-1) at compliance point W-12. Concentration values reported in bold red indicate that water treatment will be required for that specific constituent in the water mixture.

The concentrations of contaminants of concern shown in Table 2.9-2, represent the maximum levels of contaminants that are allowed in the treated water when it is discharged from the polishing ponds into Go Creek. Taking into account the baseline conditions (chemistry and hydrology) at W-12 and the water discharge rate from the polishing ponds (35.8 m^3/hr), the concentrations shown in Table 2.9-2 will result in exactly the water quality compliance levels shown (with dilution). Hence, actual treatment must achieve levels below the concentration levels shown in Table 2.9-2.

Since dilution of the treated water will largely occur in the May-October period when the high monthly flow rates are predicted at W-12, water treatment and discharge of treated water will be generally encouraged during that period. The estimated mean monthly concentrations (last column in Table 2.9-2) can be used as treatment level targets for that period. For the monthly 10-year 7-day low flows (7Q10), the required treatment levels will be considerably lower than those required for the mean monthly flows (Q). Hence, it will be important to monitor flow conditions at W-12 during the period when the treated water will be discharged into Go Creek.

A comparison between the concentrations of the contaminants of concern in the water mixture (Table 2.9-1) and the required treatment levels that correspond to mean monthly flow conditions (Table 2.9-2), provides the list of potential contaminants of concern that require treating (bold red values). If water treatment and discharge to Go Creek is conducted for the May-October period, water treatment will only be necessary to reduce concentrations of ammonia, cadmium and selenium. For all other contaminants of concern, water treatment will not be necessary as compliance levels at W-12 are already achieved by dilution only.

Table 2.9-2 Required Water Treatment Levels During Operation

		Baseline Chem	Compliance Levels	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Q W12	m^3/hr			385	331	299	367	2340	4712	2884	1577	1397	1188	6912	486	1907
7Q10 W12.	m^3/hr			142	123	78.2	101	166	320	946	17.4	580	420	25.8	164	257
Physical Tests																
Conductivity (uS/cm)	uS/cm	138														
Total Dissolved Solids	mg/L	78														
Hardness CaCO3	mg/L	63														
pH		7.77														
Total Suspended Solids	mg/L	3.6														
Turbidity (NTU)	NTU	0.8														
Dissolved Anions																
Alkalinity-Total CaCO3	mg/L	55.1														
Chloride Cl	mg/L	0.34														
Fluoride F	mg/L	0.05														
Sulphate SO4	mg/L	10.6														
Nutrients																
Ammonia Nitrogen N	mg/L	0.003	0.019	**0.197**	**0.172**	**0.157**	**0.157**	**1.097**	**2.191**	**1.348**	**0.746**	**0.663**	**0.567**	3.205	**0.243**	**0.898**
Nitrate	mg/L	0.023	13	153	133	121	121	861	1721	1058	585	519	444	2518	189	704
Nitrite	mg/L	0.0021														
Nitrite/Nitrate	mg/L	0.0173														
Total Metals																
Aluminum T-Al	mg/L	0.03														
Antimony T-Sb	mg/L	0.00011	0.006	0.069	0.060	0.055	0.055	0.391	0.781	0.480	0.265	0.236	0.201	1.143	0.086	0.320
Arsenic T-As	mg/L	0.00024	0.005	0.056	0.049	0.045	0.045	0.316	0.631	0.388	0.214	0.191	0.163	0.923	0.070	0.258
Barium T-Ba	mg/L	0.059														
Beryllium T-Be	mg/L	0.00025														
Bismuth T-Bi	mg/L	0.00025														
Boron T-B	mg/L	0.00057														
Cadmium T-Cd	mg/L	0.000025	0.000030	**0.000086**	**0.000078**	**0.000073**	**0.000073**	**0.000368**	**0.000711**	**0.000447**	**0.000258**	**0.000232**	**0.000202**	**0.001029**	**0.000100**	**0.000306**
Calcium T-Ca	mg/L	19.6														
Chromium T-Cr	mg/L	0.00017														
Cobalt T-Co	mg/L	0.00008														
Copper T-Cu	mg/L	0.0013	0.002	0.0097	0.0086	0.0080	0.0080	0.0490	0.0966	0.0599	0.0337	0.0300	0.0259	0.1408	0.0118	0.0403
Iron T-Fe	mg/L	0.07														
Lead T-Pb	mg/L	0.00010	0.002	0.0225	0.0196	0.0179	0.0179	0.1263	0.2523	0.1552	0.0858	0.0762	0.0651	0.3692	0.0278	0.1033
Lithium T-Li	mg/L	0.00050														
Magnesium T-Mg	mg/L	3.4														
Manganese T-Mn	mg/L	0.014														
Mercury T-Hg	mg/L	0.00001														
Molybdenum T-Mo	mg/L	0.00037	0.073	0.85	0.74	0.68	0.68	4.82	9.63	5.92	3.27	2.91	2.48	14.10	1.06	3.94
Nickel T-Ni	mg/L	0.00028														
Phosphorus T-P	mg/L	<0.3														
Potassium T-K	mg/L	<2														
Selenium T-Se	mg/L	0.00057	0.001	**0.0056**	**0.0049**	**0.0046**	**0.0046**	**0.0289**	**0.0571**	**0.0353**	**0.0198**	**0.0176**	**0.0151**	0.0833	**0.0068**	**0.0237**
Silicon T-Si	mg/L	2.9														
Silver T-Ag	mg/L	0.000005														
Sodium T-Na	mg/L	1.205														
Strontium T-Sr	mg/L	0.041														
Thallium T-Tl	mg/L	0.000025	0.0008	0.0091	0.0080	0.0073	0.0073	0.0515	0.1028	0.0632	0.0349	0.0310	0.0265	0.1504	0.0113	0.0421
Tin T-Sn	mg/L	0.00005														
Titanium T-Ti	mg/L	<0.01														
Uranium T-U	mg/L	0.00017														
Vanadium T-V	mg/L	<0.001														
Zinc T-Zn	mg/L	0.0012	0.03	**0.340**	**0.296**	**0.270**	**0.270**	1.912	3.819	2.349	1.298	1.153	0.985	5.588	**0.421**	1.563

Notes: numbers in bold red indicate required treatment level to achieve compliance at W-12 (after dilution)
high flow data for November, as reported (Gartner Lee Ltd. 2004),have not been confirmed

2.9.6.3 Required Water Treatment During Inactivity Stages

The water treatment required during inactivity stages was estimated in a similar way to the operation phase. First, a revised site (inactivity) water balance was derived for the inactivity stages. The inactivity water balance, shown in Figure 2.9-3, was used to predict the composition of the mixture of excess water from the tailings facility and mine water. Using revised discharge rates of treated water into Go Creek, required treatment levels to achieve compliance at W-12 were calculated and compared with the chemical composition of the water mixture to determine if treatment will be necessary.

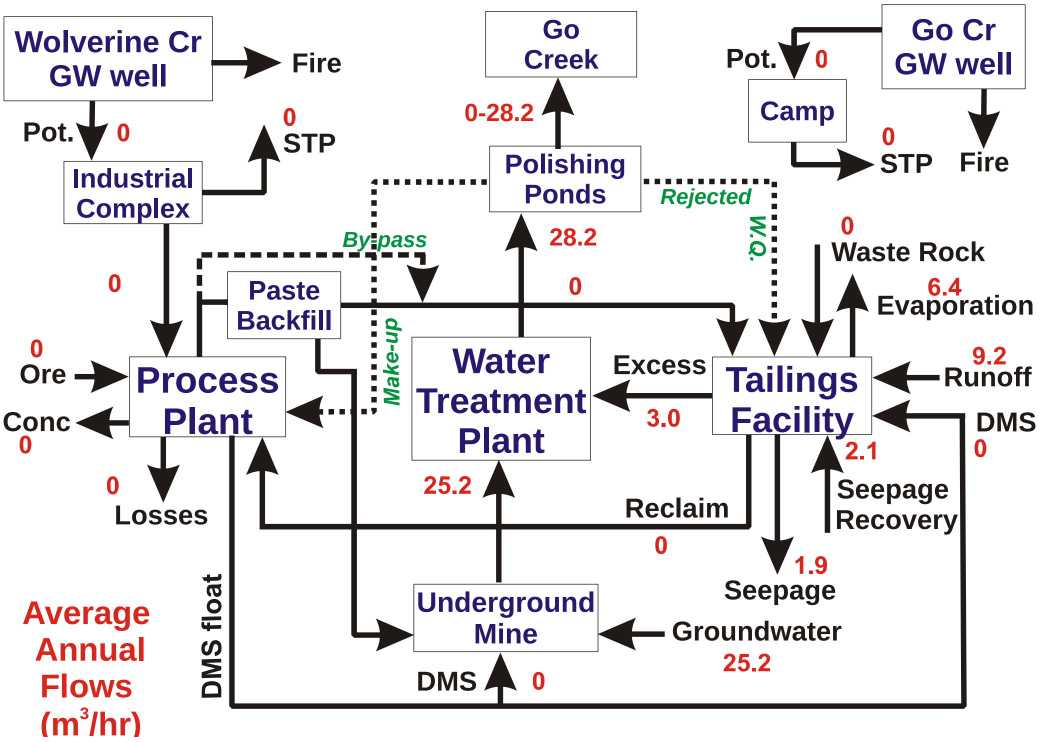


Figure 2.9-3 Water Balance of the Mine Site During Inactivity Stages

The site water balance during inactivity stages shows that all activities at the process plant have ceased. Only runoff, evaporation and net seepage contribute to the excess water from the tailings facility. Compared to the operational phase, the amount (89.4% mine water plus 10.6% tailings water) and composition of water to be treated have changed as shown by the chemical composition of the water mixture in Table 2.9-3.

Table 2.9-3 Estimated Water Quality at the Mine Site During Inactivity Stages

Parameter	Units	Process and Tailings Water[1]				Mine[2] Water	Water Mixture[3]	MMER[4] Guideline	WQ Guideline	Source
		0 Days			60 Days					
		Max (1b)	Median (1a)	Min (1c)	(2)	(3)	(2+3)			
pH		8.59	8.25	7.47	7.67	11.40	8.33	6.0-5.0		
Conductivity	uS/cm	2000	1860	1570	2010	626	773			
TDS	mg/L	1640	1510	1290	1690					
TSS	mg/L	100	31	23	3			25-50		
Acidity	mg/L as $CaCO_3$	432	365	175	1					
Alkalinity	mg/L as $CaCO_3$	47	37	26	44	102	96			
Hardness	mg/L as $CaCO_3$	510	452	435	811	151	221		100	BC Drinking Water Guideline
F	mg/L	0.42	0.25	0.22	0.38					
Cl	mg/L	19	19	19	18					
NO_3	mg/L as N	0.43	0.22	0.15	0.025	8.74	7.8		13	CCME Freshwater Aquatic Life
SO_4	mg/L	630	605	520	1100	106	212		50	BC Water Quality Alert Level
NH_3+NH_4	mg/L as N	1.3	1.3	1.1	1.4	3.66	3.4		0.019	CCME Freshwater Aquatic Life
Thiosalts	mg/L as S_2O_3	553	452	397	5	*1*	1			
CN(T)	mg/L	0.03	0.02	0.01	0.005	0	0.001		0.005	CCME Freshwater Aquatic Life
CNO	mg/L	2.1	1.85	1.2	0.4	0	0.04			
CNS	mg/L	16	3.7	2.2	0.01	0	0.001			
Dissolved Metals										
Ag	mg/L	0.022	0.0113	0.0039	0.00005	*0.00005*	0.0001		0.0001	CCME Freshwater Aquatic Life
Al	mg/L	0.190	0.070	0.031	0.002	0.415	0.371			
As	mg/L	0.036	0.012	0.008	0.011	0.001	0.002	0.5-1.0	0.005	CCME Freshwater Aquatic Life
Ba	mg/L	0.407	0.3485	0.114	0.039	0.08	0.076			
Be	mg/L	*0.005*	*0.0038*	*0.0025*	0.0025	*0.0001*	0.0004			
B	mg/L	0.04	0.019	0.011	0.017	0.1	0.091			
Bi	mg/L	*0.0003*	*0.00023*	*0.00015*	0.00015	*0.025*	0.0224			
Ca	mg/L	194	175	165	302	59.2	85			
Cd	mg/L	0.0045	0.0020	0.0005	0.0062	*0.00005*	0.0007		0.00003	CCME Freshwater Aquatic Life*
Co	mg/L	0.0011	0.0008	0.0007	0.0009	*0.00025*	0.0003			
Cr	mg/L	0.002	0.00125	0.0005	0.0005	0.013	0.0117			
Cu	mg/L	0.0499	0.0267	0.0051	0.004	*0.0025*	0.0027	0.3-0.6	0.002	CCME Freshwater Aquatic Life*
Fe	mg/L	*0.04*	*0.03*	*0.01*	0.01	0.82	0.73			
Hg	mg/L	*0.0001*	*0.000075*	*0.00005*	0.00005	*0.000025*	0.000028			
K	mg/L	11.1	10.0	8.05	12	11.6	11.6			
Li	mg/L	*0.005*	*0.0038*	*0.0025*	0.0025	*0.005*	0.0047			
Mg	mg/L	6	4.97	3.3	14	0.51	1.9			
Mn	mg/L	0.0872	0.0165	0.0013	1.64	*0.0005*	0.175			
Mo	mg/L	0.0503	0.03015	0.0042	0.0115	0.013	0.013		0.073	CCME Freshwater Aquatic Life
Na	mg/L	235	201	193	180	53.1	67			
Ni	mg/L	0.018	0.014	0.004	0.01	*0.004*	0.0046	0.5-1.0		
P	mg/L	*0.1*	*0.08*	*0.05*	0.05	*0.05*	0.05			
Pb	mg/L	0.0255	0.0166	0.0089	0.0151	*0.00025*	0.002	0.2-0.4	0.002	CCME Freshwater Aquatic Life*
Sb	mg/L	0.0645	0.0216	0.0129	0.0222	0.0322	0.031		0.006	CCME Drinking Water
Se	mg/L	1.95	1.825	1.66	0.237	0.006	0.03		0.001	CCME Freshwater Aquatic Life*
Si	mg/L	0.42	0.35	0.27	2.05	15.3	13.9			
Sn	mg/L	0.008	0.007	0.006	0.005	*0.01*	0.0095			
Sr	mg/L	0.308	0.293	0.272	0.495	0.253	0.279			
Ti	mg/L	*0.003*	*0.0023*	*0.0015*	0.0015	*0.0015*	0.0015			
Tl	mg/L	0.0100	0.0056	0.0021	0.006	*0.00005*	0.0007		0.0008	CCME Freshwater Aquatic Life
U	mg/L	0.0006	0.0003	0.0001	0.0011	*0.00005*	0.0002			
V	mg/L	0.0011	0.0005	0.00045	0.0011	0.016	0.0144			
Zn	mg/L	0.076	0.024	0.01	1.78	*0.0025*	0.192	0.5-1.0	0.03	CCME Freshwater Aquatic Life

Notes:

1. supernatant chemistry of tailings samples after 0 days (1 hr) and 60 days aging
2. water chemistry of dirty sump
3. 89.4% mine water and 10.6% tailings water (water balance)
4. first value represents monthly average concentration, second value refers to concentration in grab sample

values in italics are ½ the detection limit; highlighted cells are Potential Contaminants of Concern; values in red exceed WQ Guidelines;
* for hardness of 85 mg/L (yr 100)

The required treatment levels to achieve compliance at W-12 with water quality objectives (e.g., CCME guidelines) are shown in Table 2.9-4. A comparison with data in Table 2.9-2 shows that treatment for Zn will no longer be required throughout the year. However, treatment for NH_3, Cd and Se will still be required although not as frequently as during operations.

Table 2.9-4 Required Water Treatment Levels During Inactivity Stages

		Baseline Chem	Compliance Levels	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Q W12	m^3/hr			**385**	**331**	**299**	**367**	**2340**	**4712**	**2884**	**1577**	**1397**	**1188**	**6912**	**486**	**1907**
7Q10 W12.	m^3/hr			142	123	78.2	101	166	320	946	17.4	580	420	25.8	164	257
Physical Tests																
Conductivity (uS/cm)	uS/cm	**138**														
Total Dissolved Solids	mg/L	**78**														
Hardness CaCO3	mg/L	**63**														
pH		**7.77**														
Total Suspended Solids	mg/L	**3.6**														
Turbidity (NTU)	NTU	**0.8**														
Dissolved Anions																
Alkalinity-Total CaCO3	mg/L	**55.1**														
Chloride Cl	mg/L	**0.34**														
Fluoride F	mg/L	**0.05**														
Sulphate SO4	mg/L	**10.6**														
Nutrients																
Ammonia Nitrogen N	mg/L	**0.003**	**0.019**	**0.244**	**0.213**	**0.194**	**0.194**	**1.388**	**2.776**	**1.706**	**0.942**	**0.836**	**0.714**	4.063	**0.303**	**1.135**
Nitrate	mg/L	**0.023**	**13**	190	165	150	150	1090	2181	1340	739	656	560	3194	237	890
Nitrite	mg/L	**0.0021**														
Nitrite/Nitrate	mg/L	**0.0173**														
Total Metals																
Aluminum T-Al	mg/L	**0.03**														
Antimony T-Sb	mg/L	**0.00011**	**0.006**	0.086	0.075	0.068	0.068	0.494	0.990	0.608	0.335	0.298	0.254	1.449	0.107	0.404
Arsenic T-As	mg/L	**0.00024**	**0.005**	0.070	0.061	0.055	0.055	0.400	0.800	0.491	0.271	0.241	0.205	1.171	0.087	0.327
Barium T-Ba	mg/L	**0.059**														
Beryllium T-Be	mg/L	**0.00025**														
Bismuth T-Bi	mg/L	**0.00025**														
Boron T-B	mg/L	**0.00057**														
Cadmium T-Cd	mg/L	**0.000025**	**0.000030**	**0.000101**	**0.000091**	**0.000085**	**0.000085**	**0.000460**	0.000895	**0.000559**	**0.000319**	**0.000286**	**0.000248**	0.001299	**0.000119**	**0.000380**
Calcium T-Ca	mg/L	**19.6**														
Chromium T-Cr	mg/L	**0.00017**														
Cobalt T-Co	mg/L	**0.00008**														
Copper T-Cu	mg/L	**0.0013**	**0.002**	0.0118	0.0104	0.0096	0.0096	0.0616	0.1221	0.0755	0.0422	0.0376	0.0323	0.1782	0.0144	0.0506
Iron T-Fe	mg/L	**0.07**														
Lead T-Pb	mg/L	**0.00010**	**0.002**	0.0280	0.0243	0.0222	0.0222	0.1598	0.3198	0.1965	0.1083	0.0962	0.0821	0.4682	0.0348	0.1306
Lithium T-Li	mg/L	**0.00050**														
Magnesium T-Mg	mg/L	**3.4**														
Manganese T-Mn	mg/L	**0.014**														
Mercury T-Hg	mg/L	**0.00001**														
Molybdenum T-Mo	mg/L	**0.00037**	**0.073**	1.07	0.93	0.84	0.84	6.10	12.21	7.50	4.13	3.67	3.13	17.88	1.32	4.98
Nickel T-Ni	mg/L	**0.00028**														
Phosphorus T-P	mg/L	**<0.3**														
Potassium T-K	mg/L	**<2**														
Selenium T-Se	mg/L	**0.00057**	**0.001**	**0.0068**	**0.0060**	**0.0055**	**0.0055**	0.0364	0.0722	0.0446	**0.0248**	**0.0221**	**0.0190**	0.1055	**0.0083**	**0.0298**
Silicon T-Si	mg/L	**2.9**														
Silver T-Ag	mg/L	**0.000005**														
Sodium T-Na	mg/L	**1.205**														
Strontium T-Sr	mg/L	**0.041**														
Thallium T-Tl	mg/L	**0.000025**	**0.0008**	0.0114	0.0099	0.0090	0.0090	0.0651	0.1303	0.0800	0.0441	0.0392	0.0334	0.1908	0.0142	0.0532
Tin T-Sn	mg/L	**0.00005**														
Titanium T-Ti	mg/L	**<0.01**														
Uranium T-U	mg/L	**0.00017**														
Vanadium T-V	mg/L	**<0.001**														
Zinc T-Zn	mg/L	**0.0012**	**0.03**	0.423	0.368	0.335	0.335	2.419	4.840	2.973	1.640	1.456	1.243	7.086	0.526	1.976

Notes: numbers in bold red indicate required treatment level to achieve compliance at W-12 (after dilution)

2.9.6.4 Required Water Treatment During Closure

Similar to the procedures followed in the previous two sections, the required water treatment during closure is based on the altered site water balance as shown in Figure 2.9-4. Compared to the inactivity water balance there is no longer contribution from mine water during closure. Hence the water mixture to be treated will consist entirely of tailings water.

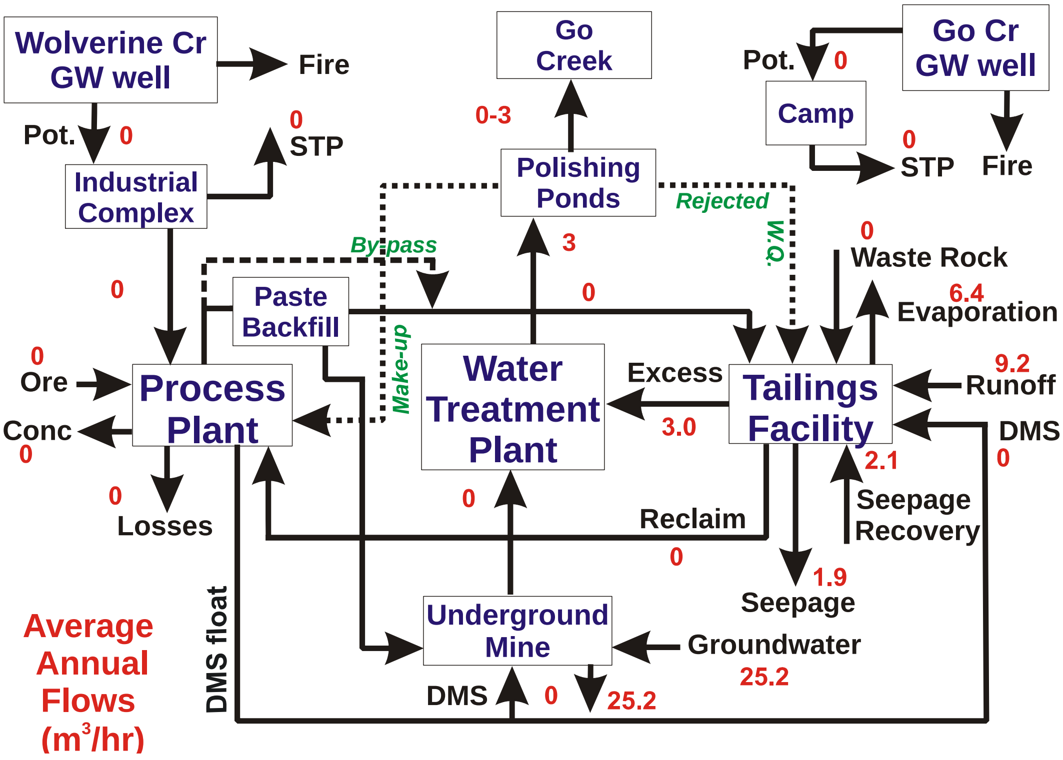


Figure 2.9-4 Water Balance of the Mine Site During Closure

Using the significantly reduced discharge rates of treated (tailings) water into Go Creek, required treatment levels to achieve compliance at W-12 were calculated and compared with the chemical composition of the tailings water to verify if treatment is necessary. The results, indicate that during closure treatment for NH_3 will no longer be required to achieve compliance at W-12 (Table 2.9-5). However, similar to the inactivity phase, treatment during closure for Cd and Se will still be necessary during most of the year.

Table 2.9-5 Required Water Treatment Levels during Closure

		Baseline Chem	Compliance Levels	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Q W12	m^3/hr			385	331	299	367	2340	4712	2884	1577	1397	1188	6912	486	1907
7Q10 W12.	m^3/hr			142	123	78.2	101	166	320	946	17.4	580	420	25.8	164	257
Physical Tests																
Conductivity (uS/cm)	uS/cm	138														
Total Dissolved Solids	mg/L	78														
Hardness CaCO3	mg/L	63														
pH		7.77														
Total Suspended Solids	mg/L	3.6														
Turbidity (NTU)	NTU	0.8														
Dissolved Anions																
Alkalinity-Total CaCO3	mg/L	55.1														
Chloride Cl	mg/L	0.34														
Fluoride F	mg/L	0.05														
Sulphate SO4	mg/L	10.6														
Nutrients																
Ammonia Nitrogen N	mg/L	0.003	0.019	2.138	1.841	1.662	1.662	12.889	25.937	15.879	8.691	7.701	6.553	38.035	2.692	10.505
Nitrate	mg/L	0.023	13	1679	1446	1305	1305	10135	20397	12486	6834	6055	5152	29911	2115	8260
Nitrite	mg/L	0.0021														
Nitrite/Nitrate	mg/L	0.0173														
Total Metals																
Aluminum T-Al	mg/L	0.03														
Antimony T-Sb	mg/L	0.00011	0.006	0.762	0.656	0.592	0.592	4.598	9.253	5.665	3.100	2.747	2.337	13.570	0.960	3.747
Arsenic T-As	mg/L	0.00024	0.005	0.616	0.530	0.479	0.479	3.715	7.477	4.577	2.505	2.220	1.889	10.964	0.776	3.028
Barium T-Ba	mg/L	0.059														
Beryllium T-Be	mg/L	0.00025														
Bismuth T-Bi	mg/L	0.00025														
Boron T-B	mg/L	0.00057														
Cadmium T-Cd	mg/L	0.000025	0.000030	**0.000695**	**0.000601**	**0.000546**	**0.000546**	**0.004068**	0.008161	**0.005006**	**0.002751**	**0.002440**	**0.002080**	0.011957	**0.000869**	**0.003320**
Calcium T-Ca	mg/L	19.6														
Chromium T-Cr	mg/L	0.00017														
Cobalt T-Co	mg/L	0.00008														
Copper T-Cu	mg/L	0.0013	0.002	0.0943	0.0814	0.0736	0.0736	0.5626	1.1310	0.6929	0.3798	0.3367	0.2866	1.6580	0.1184	0.4588
Iron T-Fe	mg/L	0.07														
Lead T-Pb	mg/L	0.00010	0.002	0.2462	0.2120	0.1914	0.1914	1.4855	2.9895	1.8301	1.0016	0.8875	0.7551	4.3839	0.3101	1.2106
Lithium T-Li	mg/L	0.00050														
Magnesium T-Mg	mg/L	3.4														
Manganese T-Mn	mg/L	0.014														
Mercury T-Hg	mg/L	0.00001														
Molybdenum T-Mo	mg/L	0.00037	0.073	9.40	8.09	7.31	7.31	56.72	114.16	69.88	38.25	33.89	28.83	167.41	11.84	46.23
Nickel T-Ni	mg/L	0.00028														
Phosphorus T-P	mg/L	<0.3														
Potassium T-K	mg/L	<2														
Selenium T-Se	mg/L	0.00057	0.001	**0.0557**	**0.0481**	**0.0435**	**0.0435**	0.3335	0.6707	0.4108	**0.2251**	**0.1995**	**0.1698**	0.9832	**0.0701**	0.2719
Silicon T-Si	mg/L	2.9														
Silver T-Ag	mg/L	0.000005														
Sodium T-Na	mg/L	1.205														
Strontium T-Sr	mg/L	0.041														
Thallium T-Tl	mg/L	0.000025	0.0008	0.1003	0.0864	0.0780	0.0780	0.6053	1.2182	0.7457	0.4081	0.3616	0.3077	1.7864	0.1264	0.4933
Tin T-Sn	mg/L	0.00005														
Titanium T-Ti	mg/L	<0.01														
Uranium T-U	mg/L	0.00017														
Vanadium T-V	mg/L	<0.001														
Zinc T-Zn	mg/L	0.0012	0.03	3.726	3.208	2.897	2.897	22.483	45.247	27.699	15.160	13.433	11.429	66.352	4.693	18.323

Notes: numbers in bold red indicate required treatment level to achieve compliance at W-12 (after dilution)

2.9.6.5 Water Treatment Plant

A high-density sludge (HDS) plant will be used to treat underground mine water and excess tailings water. The HDS process will effectively remove base metals in a chemically stable the formation of co-precipitates.

The water treatment plant will be installed near the process plant in the primary industrial complex building (Section 2.10-3). The primary equipment and layout of the water treatment plant is presented in Figure 2.6-12. The processes steps required for HDS water treatment facility can be summarized as follows. These processes are conceptual at this stage as an additional test work is required. Lime and recycled sludge are added to the lime-sludge mix tank at the head of the process, providing the main neutralization agent. This mixture is discharged to the lime/sludge tank where it is mixed with influent, thereby achieving neutralization. Iron salts are typically added to the influent to achieve the required iron to metals ratio. The lime/sludge mixture is fed to the main Lime Reactor 1 and Lime Reactor 2 where a combination of aggressive aeration and high shear agitation ensures optimum process chemistry and subsequent clarifier performance. The discharge from the lime reactors is treated with flocculent. In the final step, the clarifier separates the treated effluent from the sludge; a portion of the sludge is recycled to the head of the process. The HDS process is operated most effectively at a pH between 9.0 and 9.5, the operating pH for Wolverine Project will be set at pH 9.5, as most metals encountered will precipitate at or below this concentration of hydroxide ions. Oxidation of ferrous to ferric takes place rapidly at this pH, with air being the most common oxidizing agent. For efficiency, the process relies on sludge recycle from a treated effluent. This will take place in a thickener-style clarifier, which provides sludge in the underflow as the separated solids product.

The HDS water treatment plant will treat most contaminants of concern; additional processes will be included for selenium, ammonia and cadmium to ensure removal. A number of proven processes will be employed to treat these contaminants, as described below.

Additional Water Treatment Processes for NH_3, Cd and Se

Ammonia in the influent will come from a number of sources including the use of explosive compounds (primarily ammonium nitrate fuel oil (ANFO)), and from the breakdown of cyanide during process operations, either by natural degradation or by chemical oxidation/cyanate hydrolysis. A number of proven technologies exist to treat ammonia and these including: natural degradation, air stripping, steam stripping, biological nitrification – denitrification, break-point chlorination, ion exchange, and reverse osmosis.

Natural degradation is one of the most widely used methods in the mining industry and it is proposed for the project. Natural degradation of ammonia involves the transpiration of dissolved ammonia gas from wastewaters by retaining wastewaters in holding ponds. Ammonia removal will be achieved in the tailings facility and in the polishing ponds, the discharge point for effluent from the water treatment plant.

Ammonia removal by natural degradation is influenced by a number of factors including:

- pond conditions (surface area, depth, turbidity, turbulence, ice cover, and retention time

- effluent pH >8
- concentration and temperature
- aeration

These factors will be taken into consideration when finalizing the design of the polishing ponds. The extended retention times provided by well-engineered natural degradation systems encourage dissipation and volatization of free ammonia. The effluent will be kept above neutral pH levels to avoid the formation of NH^{+4}, which does not volatilize.

Although the HDS lime treatment system is a reliable robust system, cadmium may not always be removed in the lime treatment system. Additional processes will be implemented to remove Cd from the effluent in order to meet discharge criteria. Cadmium can be successfully treated with implementation of sulfide addition in a flash mix tank to precipitate cadmium sulfide ahead of the HDS circuit. There are several forms of sulfide reagents but the most common one used in industrial plants is sodium hydrosulfide. Based on the successful in removal of Cd from a mine in Alaska, liquid sodium hydrosulfide will be added in a tank with a retention time of 30-60 seconds. Cadmium precipitates and the overflow will be pumped directly to the lime reactors in the HDS plant.

Selenium can also be removed successfully in a lime treatment system as experienced at number of sites in British Columbia. However, in cases where a high degree of oxidation is expected, a secondary process may be required to meet the discharge criteria. The higher oxidation state of selenium prevents precipitation and typically a reduction step is required in order to precipitate selenium. There are other techniques such as biological treatment, chemical reducing using reagents, ion absorption resins, and most recently the development of Activated Silica Gel. The Silica Gel technology is capable of removing selenium to concentration of less than 1 ppb. The process is easily automated and does not require a major infrastructure. A brief process description for Silica gel, namely Octolig®, is provided below.

Octolig® is a granular media that is very effective at removing heavy metals down to extremely low levels from wastewater and groundwater. Octolig® consists of an organic ligand that has been chemically immobilized onto a silica gel substrate. It is used in columnar systems very similar to ion exchange systems, however it is not an ion exchange resin. Octolig® has several unique chemical characteristics that differentiate from heavy metal selective ion exchange resins. These chemical and physical characteristics are:

- Very large stability constants (ranging from 10^{13}–10^{47}) for heavy metals. These large stability constants enable the effective removal of the heavy metals even when other chelating agents such as EDTA and ammonia are present.
- Highly selective for heavy metals and only the heavy metals. Octolig® will not remove dissolved solids and other benign ions. The high degree of selectivity allows all of its useful capacity to be used solely for the removal of heavy metals, enabling operation for a long period before regeneration is required.
- All of the chemical reactions take place at the surface of the Octolig® product, and hence it can be regenerated using a relatively small volume of regenerate solution.
- Octolig® is not plagued by problems associated with fouling ions, therefore it can be regenerated hundreds of times without any appreciable loss of capacity.

For the parameters given for the Wolverine HDS clarifier overflow, the Octolig® treatment system will consist of approximately two to four columns, each filled with 300 kg of Octolig®. As with any columnar system the water to be treated should first be passed through a 5–10 micron filter. This filtration step will prevent any suspended solids from entering the columns. If there are organic compounds present it may be necessary to remove these compounds using activated carbon. The filtered solution will then be pumped through the columns. The resultant treated water will then be passed through a course (50–80 micron) filter. This post filtration step will prevent any selenium-loaded material from exiting the system.

2.9.6.6 Bench Scale Testing

Bench scale level testing will be carried out during the feasibility stage to generate the expected treated effluent. These tests will confirm the treatment parameters as well as allow for the evaluation of the effluent quality. A selection of the waste rock will be tested in a large column test to generate the ARD with metal loadings. In addition, simulated process water will be obtained to combine with the column drainage to conduct bench scale HDS simulations. The sample selection will be critical to accurately characterize the influent chemistry as predicted. The bench scale testing results will refine the conceptual water treatment processes described herein.

2.9.6.7 Water Treatment Plant Sludge

The sludge produced at most of the HDS plants has historically passed the EPA TCLP extractions tests because the sludge is fully oxidized and does not release any metals. The lime treatment process offers extra alkalinity in the sludge as the lime is a slow reacting reagent and there is typically excess lime present in the sludge to keep the sludge pH at or above the treatment (precipitation) pH. Testing with a full sweep of analysis and testing will need to be carried on the sludge. This will be conducted during the feasibility stage of the project to confirm sludge characteristics.