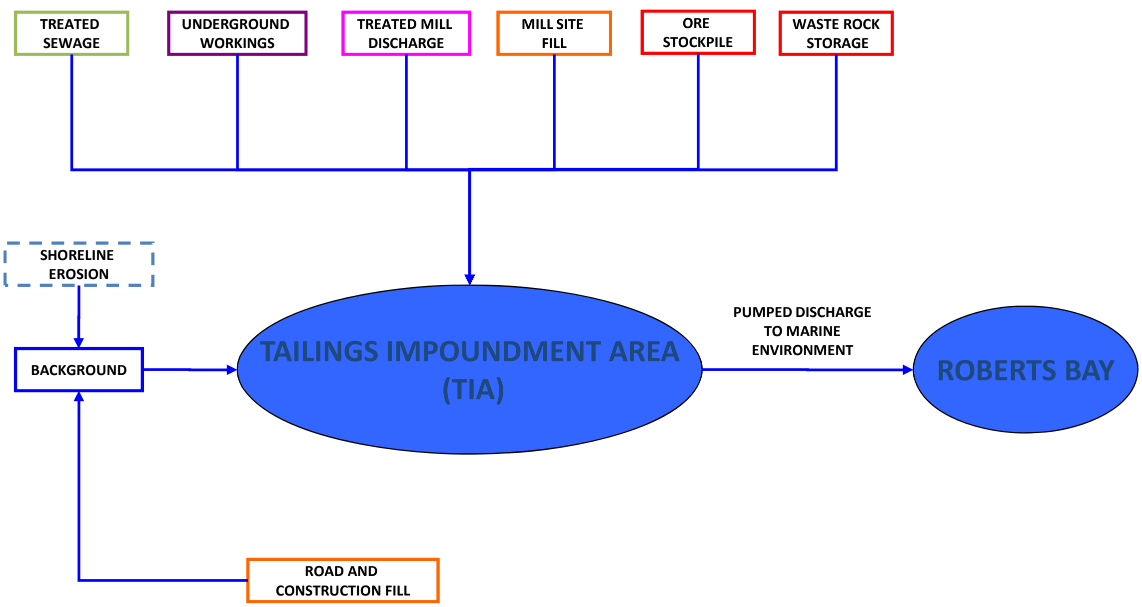
Water Quality Model, Hope Bay Project, Nunavut, Canada

Report Prepared for

Hope Bay Mining Ltd.



Report Prepared by

SRK Consulting (Canada) Inc.
1CH008.047
November 2011

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November 2011

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Water Quality Model, Hope Bay Project, Nunavut, Canada – Summary

This report provides a summary of the water and load balance model for the Doris North Project. This report takes into consideration the revised water management and discharge strategy for the project. The model was run for three scenarios to provide a range of potential tailings impoundment area (TIA) discharge water quality predictions that led to selection of a preferred discharge strategy.

The model predicts that by using this preferred discharge management strategy, discharges from the TIA would meet both the TIA discharge limits and the proposed TIA marine discharge targets. Additionally, the TIA could be operated according to the original design criteria.

Immap Qanugitnia Uuktugut, Hope Bay Havanga, Nunavut, Kanata - Nainaqhimayut

Una tuhagakhaliat piqagutauyuq nainaqhimayumik imaq pitaqninutlu ihuaqhihimani uuktugut taphumunga Doris North Havanga. Una tuhagakhaliat ihumagiqahiutiyai tapkuat nutanguqni imaqmut aulatyutit kuvittaqninutlu atugakhaliat taphumunga havanguyumut. Tamna uuktugut atuqtauyuq pingahunut piyauninut piqaqtitninut allatqit pilaqnit uyagaktaqnikut hiamaktailivi (TIA-nga) kuvipkagauyuq immap qanugitnia atuqniagahugiyauni tapkuat pityutauyut niguaqninik kuvipkaqni atuqgakhaliat.

Tapkuat uuktugaqnit piniagahugini tapkuat atuqnit ukuat atuguminaqniqhat kuvipkaqni aulatyutai atugakhaliat, kuvipkaqnit talvanga TIA-nga naamakniat tapkuknunga tamatkiknut TIA-nga kuvipkaqnia kiklikhait tapkuatlu uuktugutauyut TIA-nga tagiumi kuvipkaqnit tugagat. Ilagiplugulu, tamna TIA-nga aulataulaq malikhugit tapkuat hanatyuhikhaliuqhimayutuqaq maligakhai.

ᖃᐅᔨᓴᖅᑕᐅᑎᓪᓗᒋᑦ ᐃᒪᐅᑉ ᖃᓄᐃᑦᑑᓂᖓᓂᒃ ᐊᑐᖅᑕᐅᔪᔪᑦ, Hope Bay_ᒥ ᐱᓕᕆᕝᕕᒥ, ᓄᓇᕗᑦᒥ, ᑲᓇᑕᒥ _ ᑐᓴᒐᒃᓴᑦ ᓇᐃᓈᖅᓯᒪᔪᑦ

ᐅᑯᐊ ᑐᓴᒐᑦᓴᑦ ᐱᑕᓖᑦ ᐅᓂᒃᑳᓂᒃ ᓇᐃᓈᖅᓯᒪᔪᓂᒃ ᐃᒥᓕᕆᔾᔪᑎᑦ ᐊᒻᒪ ᖃᓄᑎᒋ ᓇᓕᒧᖕᓂᓕᖕᓂᒃ ᐆᒃᑐᕋᖅᑕᐅᓪᓗᑎᒃ ᑕᒫᓂ Doris North−ᒥ ᐱᓕᕆᕝᕕᒥ. ᐅᑯᐊ ᑐᒐᒃᓴᑦ ᖃᓄᖅᑑᕈᑎᒃᓴᓅᖕᒐᓂᐊᕐᒪᑕ ᐋᕿᒋᐊᕈᑎᒃᓵᓄᑦ ᐃᒥᓕᕆᔾᔪᑎᓅᖕᒐᔪᓄᑦ ᐊᒻᒪ ᖃᓄᐃᓪᓗᐊᖅᑐᒥᒃ ᐊᑐᖅᑕᐅᖃᑦᑕᕋᔭᖅᑐᓂᒃ ᐱᓕᕆᕝᕕᒥ. ᐊᑑᑕᐅᓛᐅᖅᓯᒪᔪᑦ ᐱᖕᒐᓲᓕᖕᒐᔪᑦ ᐆᒃᑐᕋᐅᑏᑦ ᖃᓄᐃᓕᖕᒐᓂᓇᒐᔭᖅᑕᖕᒋᑦ ᐊᒃᑕᑯᖃᐅᑕᐅᒐᔭᖅᑑᑉ ᐃᓂᒃᓴᖕᒐ ᐱᑕᖃᖃᑦᑕᕋᔭᖅᑐᖅ ᐊᒃᑕᑯᓂᒃ ᑕᒡᕗᖕᒐᖕᒐᔪᑦ ᓯᕗᕐᖕᒐᒍᑦ ᖃᐅᔨᓴᖅᑕᐅᓯᓐᓇᖅᑐᖅ ᑭᖑᕐᖕᒐᒍᑦ ᐊᑑᑕᐅᒐᔭᖅᑐᑦ ᓂᕈᐊᑕᐅᒐᔭᕐᒪᑕ ᖃᓄᖅ ᓴᓇᔭᐅᓯᒪᒐᔭᕐᓂᖕᒋᑦ ᑯᕕᕕᐅᖅᑕᑦᑕᕋᔭᖅᑐᒎᖕᒐᔪᑦ.

ᑖᒃᑯᐊ ᖃᓄᐃᓕᖕᒐᒐᔭᕐᓂᖕᒋᓐᓂᒃ ᓯᕗᕐᖕᒐᒍᑦ ᖃᐅᔨᒪᔾᔭᑕᐅᓯᓐᓇᕐᓂᐊᕐᒪᑕ ᖃᐅᔨᓴᖅᑐᑦ ᐊᑐᕐᓗᑎᒃ ᐅᑯᓄᖕᒐᖕᒐᔪᓂᒃ ᐊᖁᑕᐅᖃᑦᑕᕋᔭᖅᑐᓂᒃ ᑯᕕᔪᓄᑦ ᐊᒃᑕᑯᖃᐅᓪᒥᖕᒑᖅᑐᓂᒃ ᐅᔭᖃᒃᓴᓕᕆᔾᔪᑎᒥᓂᖅᑲᐅᓪᒥᒃ ᐱᔪᑦ ᒪᓕᒃᑕᐅᒋᐊᓖᑦ ᐊᑑᑕᐅᒐᔭᕐᒪᑕ ᑭᒡᓕᓕᐅᖅᓯᒪᑎᓪᓗᒋᑦ ᐊᒻᒪ ᑐᒃᓯᖀᖕᒍᒻᒪᑕ ᐊᒃᑕᑯᖃᐅᑎᒃᓴᐅᑉ ᐃᓂᒃᓴᖕᒐ ᑕᓇᐅᓪᒧᑦ ᑐᖀᖃᑦᑕᕋᔭᖅᑐᒎᖕᒐᔪᑦ. ᐃᓚᖃᓪᓗᑎᒃ ᐊᒃᑕᑯᖃᐅᑦ ᐅᔭᖃᒃᓴᓕᕆᔾᔪᑎᒥᓂᖅᑕᓕᖕᒥᒃ ᐱᔪᑦ ᐊᐅᓚᑕᐅᖃᑦᑕᕋᔭᕐᒪᑕ ᓴᓇᔭᐅᒋᐊᖕᒐᖅᓯᒪᔪᒥᓂᖅᒥᒃ ᐋᖅᑭᒃᓯᒪᔪᑦ ᐊᑑᑕᐅᒐᔪᒃᑐᑎᒍᑦ.

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1 Introduction

1.1 Terms of reference

A water and load balance model (SRK 2005) was developed for the Doris North Project and reported as part of the Environmental Impact Assessment (EIA) submitted to the Nunavut Impact Review Board (NIRB). That model was subsequently revised to support the water licence application submitted to the Nunavut Water Board (NWB) in 2007 to incorporate revisions to the project, recommendations stemming from the environmental assessment, and to support the water management strategy proposed for the project at that time (SRK 2007). Through both the environmental assessment and water licencing processes, the original water and load balance model underwent rigorous review by the various stakeholders, including the NWB, Kitikmeot Inuit Association (KIA), INAC, and Environment Canada.

The model for the original two year Doris North Project indicated that the Tail Lake Tailings Impoundment Area (TIA) could be operated in such a way that the discharge would not exceed Metal Mining Effluent Regulations (MMER) criteria and would meet the Canadian Council of Ministers for the Environment (CCME) water quality guidelines for the protection of freshwater aquatic life downstream of the waterfall in Doris Creek. A water licence was issued for the Doris North Project in 2007 with clauses that relate specifically to the discharge of water from the TIA.

Hope Bay Mining Limited (HBML) are now planning to expand their underground mine development into the Doris Connector and Doris Central deposits, located to the south of the Doris North mine. These deposits are located beneath Doris Lake, and are situated in talik, or unfrozen ground. Groundwater investigations have shown that saline groundwater may be present in these areas of the mine. HBML are proposing to use the TIA for temporary storage of this potentially saline groundwater during operations, which could have an effect of the water balance and discharge water quality from the TIA. Once water levels in the TIA approach maximum storage capacity, and to ensure sufficient storage for the full range of anticipated groundwater inflows, water from the TIA will be conveyed via a pipeline to a marine outfall in Roberts Bay. Prior to discharge, this water will require treatment for suspended solids removal and possible pH adjustment. During operations and closure, water from the TIA will not be discharged to the freshwater environment.

The TIA will continue to be used to manage tailings, tailings process water, and other water influenced by mining activities. Some of these inputs have been revised to reflect other minor changes in the project design. Tailings will continue to be deposited in the TIA subaqueously, and there will be a permanent water cover over the tailings. No changes to the configuration of the dams is required.

To support the assessment of this revised water management scenario for the project, the water and load balance model has been updated from the version submitted to NWB in 2007, specifically focusing on the TIA and associated discharges from the TIA. In addition to updating the model with revised assumptions and input data, the model was also converted from EXCEL to GoldSim.

Given that the original model (and NWB update) previously underwent a rigorous review process, this report provides only a summary of the model, focussing on revision in methodology, input data, as well as the details of the revised water management and discharge strategy. Any assumptions that are carried over, unchanged, from the original model are summarized in Appendix B. Where applicable, any modifications to the original model assumptions are highlighted and discussed in detail in the following sections.

2 Tail Lake Water Balance

2.1 General

The water balance model forms the basis for the Tail Lake Tailings Impoundment Area (TIA) and marine discharge water quality predictions for the operational, closure periods and post-closure periods. This section provides an overview of the Tail Lake water balance and water quality predictions.

2.2 Primary Assumptions

The primary assumptions for the water balance include the following:

- The TIA is completely isolated with respect to surface and groundwater from the adjoining Doris Lake and Ogama Lake catchments by two water retaining structures (the North and South Dams).
- Tailings deposition will be sub-aqueous and will be managed such that the final tailings surface will be relatively horizontal.
- Tail Lake was conservatively assumed to be not pumped out prior to constructing the dams or prior to tailings deposition. The volume of Tail Lake at its natural elevation of 28.3 m is approximately 2,196,000 m^3.
- The water balance is calculated in monthly time steps. The water balance calculations use a year that starts in January and ends in December.
- All values in this water balance are expressed in terms of the dam full supply level (FSL), which excludes any allowance for freeboard.
- Design full supply level is 33.5 m and target maximum operating water level is 32.5 m.
- Minimum long-term tailings water cover depth is 2.3 m.

2.3 Water Balance Calculations

The TIA has a total surface catchment area of 450 ha. The stage curves for the TIA are illustrated in Figure 2-1. These data are a composite of elevation data between the between Bathymetric Survey (below 28. 3 m) and topographical interpolation (over 28.3 m). The lake water elevation and corresponding surface area and storage volume were tabulated in Lookup Tables in GoldSim. The model then uses the tabulated data and linear interpolation to determine the lake water elevation and corresponding surface area as a function of volume for each monthly time step.

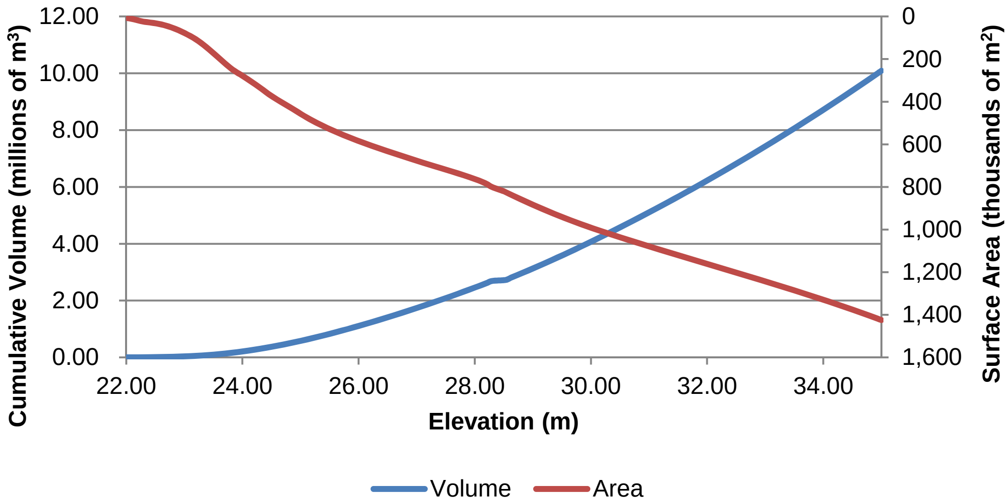

Figure 2-1: Tailings Impoundment Area Stage Curves

The TIA water balance is schematically illustrated in Figure 2-2. The water balance for the TIA is calculated for each monthly time step according to the following expression:

$$\Delta S = Q_1 - Q_2 + Q_3 + Q_4 - Q_5 - Q_6 \pm Q_7 + Q_8 + Q_9$$

Where ΔS = change in TIA storage volume (m^3),
Q_1 = volume of direct precipitation falling onto Tail Lake (m^3),
Q_2 = volume of potential evaporation from Tail Lake (m^3),
Q_3 = volume of runoff entering Tail Lake (m^3),
Q_4 = volume of tailings feed pumped to Tail Lake (m^3),
Q_5 = volume of reclaim water pumped back to mill Tail Lake (m^3),
Q_6 = volume of decant/discharge from Tail Lake (m^3),
Q_7 = volume of dam(s) seepage pumped back to Tail Lake (m^3),
Q_8 = volume of treated sewage water pumped Tail Lake (m^3), and
Q_9 = volume of underground mine water pumped to Tail Lake (m^3),

Each of the above TIA water balance inputs and outputs are discussed in detail in the following sections. For each time step, the TIA water volume and corresponding TIA solids volume are calculated. The corresponding TIA volume at each time step is then calculated as the sum of the TIA water volume plus the TIA solids volume minus the interstitial pore water volume.

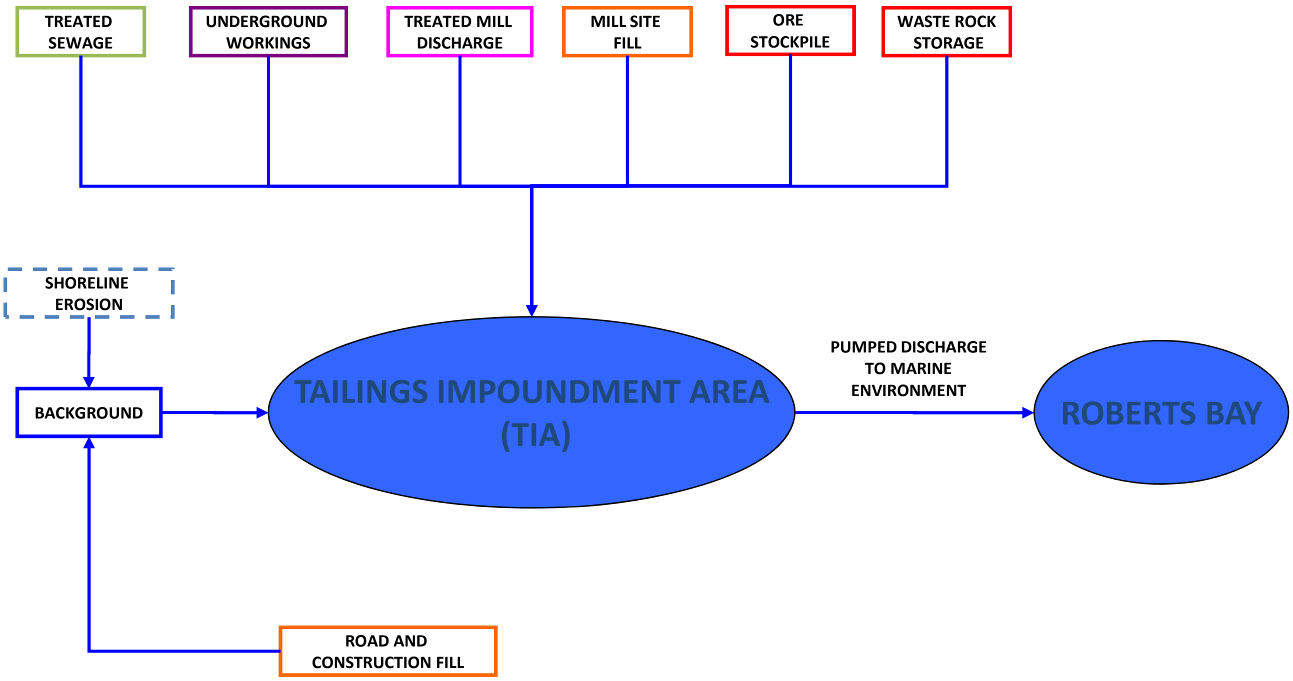

Figure 2-2: Schematic of Tailings Impoundment Area Water Balance Model

2.3.1 Precipitation

Annual precipitation data used in the model were based on the derived 61-year historical precipitation record (1948 to 2008) generated for the site by Golder (2009) and summarized in Table 2-1. The mean annual derived precipitation for the site is 232.5 mm. The model is run stochastically and for each simulation, the GoldSim model randomly selects a year in the historical site precipitation record and cycles through the record until the final year of the model. The purpose of having 100 simulations is to quantify the sensitivity of the model to variable precipitation. In configuring and running the model in this manner, over the 100 realizations, the model calculates the various water balance results over a wide range of precipitation conditions that mimic range of precipitation conditions that could be experienced at the site during the life time of the project. For example, for one realization the start year of 1976 is selected, then for the 20 year model run, the precipitation cycles annually through the total precipitation starting with the value of 193.9 mm in 1976 and ending with 250.2 mm in 1995. The annual precipitation values used in the model for this realization run are illustrated in Figure 2-3.

Table 2-1: Summary of 61-Year Historical Precipitation Record for the Project Area

Year	Total Precipitation (mm)	Year	Total Precipitation (mm)	Year	Total Precipitation (mm)
1948	183.9	1969	229.7	1990	262.3
1949	231	1970	234	1991	284.4
1950	229.1	1971	339.9	1992	277.9
1951	193.3	1972	262.3	1993	272.8
1952	185.6	1973	230.9	1994	251
1953	185.4	1974	236.5	1995	250.2
1954	139.9	1975	232.2	1996	263.1
1955	221.9	1976	193.9	1997	242.6
1956	252.4	1977	219.6	1998	213.1
1957	234.3	1978	204.2	1999	217.4
1958	180.4	1979	206.7	2000	172.6
1959	219.1	1980	221.6	2001	240.9
1960	225.6	1981	206.8	2002	182.5
1961	197.4	1982	229.4	2003	267.7
1962	195.7	1983	169.4	2004	215.3
1963	330.3	1984	214.6	2005	214.6
1964	262.2	1985	224.1	2006	160.5
1965	223.6	1986	227.8	2007	225
1966	271.8	1987	336.3	2008	319.7
1967	280.5	1988	279.7		
1968	275.2	1989	228.7		

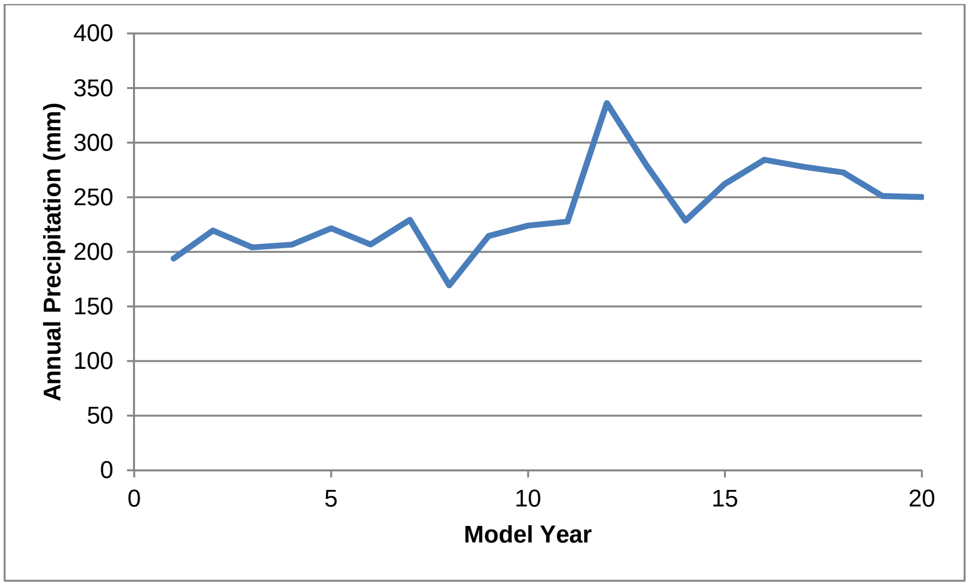

Figure 2-3: Example Realization Annual Precipitation Cycle

For each time step the model generates a suite of statistics (minimum, maximum, mean, median and percentiles) for each of the modeled parameters and results from the model are time-based predictions with ranges for each time step. In running the model in this manner, the impact of varying precipitation on the water balance, and water quality predictions, is estimated. For water balance purposes, the 90th percentile of the predicted values are used..

A frequency analysis of derived precipitation, snowfall and rainfall at Doris North is presented in Table 2-2 (Golder 2009). As outlined in Golder (2009), the 1:2 year value represents the statistical median and is not the same as the arithmetic mean of 232.5 mm.

Table 2-2: Precipitation Return Periods for the Project Area

Return Period (Years)		Precipitation (mm)
Wet	200	358.5
	100	343.6
	50	327.9
	20	305.6
	10	287.0
	5	265.9
Median	2	229.3
Dry	5	197.3
	10	182.1
	20	170.4
	50	158.0
	100	150.2
	200	143.3

2.3.2 Evaporation

The average lake evaporation used in the original model of 220 mm per year was adopted for the updated model (AMEC 2003). The monthly and annual lake evaporation data used in the model is presented in Table 2-3.

Table 2-3: Mean and Annual Lake Evaporation Data

Period	Days with Evaporation	Average Evaporation (mm)
June	15	35
July	31	95
August	31	77
September	30	13
Annual	105	220

2.3.3 Runoff/Water Yield

The original model utilized a base case water yield of 180 mm per year based on Golder (2006). More recent hydrological assessment work carried out indicates a much lower average annual water yield for the various drainages in the project area (Golder 2009 and Rescan 2009). Based on the additional years of available on-site hydrological and climate data, Golder (2009) developed a detailed water balance in 2008 for 10 lakes in the Project Area. The water balance model ran on a daily time step for the period 1948 to 2008, using the synthetic precipitation record derived for the site based on 17 years of climate records from Cambridge Bay. The model predicted daily outflow from each lake. Frequency analyses were performed. Based on the water balance model, the updated mean annual water yields for Doris Lake and Tail Lake outflows are 99 mm and 72 mm. A summary of the annual runoff return periods estimates for Tail Lake and Doris Lake outflows from Golder (2009) are presented in Table 2-4. Assessment of Golder's more detailed water balance model indicated that the model provides good estimates of annual runoff for the Project Area (Rescan 2009).

Table 2-4: Annual Runoff Return Period Estimates for Doris Lake and Tail Lake

Return Period (Years)		Doris Lake (mm)	Tail Lake (mm)
Wet	100	189	153
	50	176	141
	20	157	124
	10	141	111
	5	125	96
Mean	2	99	72
Dry	5	77	53
	10	68	44
	20	60	37
	50	52	30
	100	47	25

The precipitation and runoff return period estimates were used in the model to develop a relationship between precipitation and runoff that can be used to estimate runoff for each of the simulations. For runoff from land area in TIA catchment area, a runoff coefficient of 0.6 was applied to the annual precipitation. This land runoff coefficient is based on that used by Golder in their detailed water balance model of the major waterbodies in the project area for both snowmelt and rainfall (Golder 2009). The monthly runoff into the TIA was then determined using the site hydrograph.

2.3.4 Tailings Slurry Feed

The average constant tailings production rate assumed in the model is 800 tonnes/day at a solids moisture content of 50% (w/w), a solids specific gravity of 2.7 and a submerged in-place tailings void ratio of 1.1. This will result in a daily slurry feed of 1422 m^3/d (622 m^3/day solids and 800 m^3/day water). Tailings deposition in the TIA is assumed to start in year 3 (April 2013) of the model and continues for 4 years and 1 month. This corresponds to processing of Doris North ore for 2 years, followed by Doris Central/Doris Connector ore for two years followed by 1 month of processing of ore from the Patch 14 bulk exploration program.

2.3.5 Pore Water Entrainment

Water entrained in tailings voids is removed from the system. The volume of water entrained in tailings voids is a function of the void ratio and the density of the tailings. In the model, the entrained water volume is calculated each time step and permanently removed from the system.

2.3.6 Reclaim

No reclaim from the TIA is assumed for the updated model. Fresh water make-up will be from Doris Lake, as per the existing licence. The mill will internally recycle a significant volume of water, reducing the use of “new” from Doris Lake.

2.3.7 Discharge/Decant

As described later in this report, a discharge management strategy has been developed for the operational, closure and post-closure periods. The following summarizes the key components of this strategy with respect to discharge volumes and timing that have been incorporated into the model:

- From year 1 to year 5 (2011 to 2015) there is no discharge from the TIA;
- TIA is operated with a target maximum operating water level of 32.5 m and a full supply level of 33.5 m;
- Discharge to a marine outfall in Roberts Bay from the TIA starts in year 5 (April 2015);
- Discharge can be seasonal or year-round depending on water quality and water storage requirements;
- If required to avoid discharge of non-compliant effluent, water can be stored in the TIA without discharge, utilizing the increased storage volume provided by temporary operating with the maximum operating water level equivalent to the FSL of 33.5 m;
- For year 8 and year 9, continue seasonal discharge from TIA at 120 L/s with an interim open water season minimum water level of 1.0 m to maximize drawdown the lake during this period.
- Starting in November of year 9 and continuing annually from November to April, pump water from Doris Lake to the TIA;
- Seasonal pumping from the TIA to the ocean (June to October) at 120 L/s from year 10 on until the water quality in the TIA is suitable for freshwater discharge; and

- Once the TIA water quality reaches the target closure criteria the outflow will be routed to Doris Lake in the original Tail Lake outflow channel, following the natural open water season hydrograph of Tail Lake.

2.3.8 Dam Seepage

The assumptions related to seepage used in the original model have been carried through to the updated model. Seepage from the TIA can be via three primary routes: North Dam, South Dam and deep recharge through the lake basin. The North and South Dams are frozen core dams, which in reality, should not have any seepage.

Average condition theoretical seepage calculations for the TIA are described in detail in SRK (2007) and summarized in Appendix B. For modeling purposes, similar to the original model, it is assumed that all seepage from the North and South Dams would be intercepted and pumped back to the TIA. Therefore this seepage has not net-impact on the TIA water balance. In addition, given that the average groundwater recharge from the lake is so low that is has been omitted from the water balance calculations.

2.3.9 Sewage

The sewage treatment plant effluent will be pumped to the TIA. The treated effluent flow rate is dependent on the size of the camp. For the purpose of this model, a 360-man camp was assumed, for a total sewage treatment plant outflow of 141.12 m^3/day. Sewage treatment plant outflow will not be routed to the TIA until tailings deposition begins in the TIA. Prior to that time it will be discharged to land as per the existing licence. Discharge of treated sewage effluent to the TIA is assumed to continue through operations and for 1 year post operations. After that time, the camp size will be significantly smaller and the sewage discharge is assumed to discharge to land.

2.3.10 Underground Mine Water

During mining of the Doris North deposit during the first two years of operations, mining will take place in permafrost and as such it is assumed that there will be negligible mine water inflows during this period. Once mining expands into the Doris Connector and Doris Central deposits, located to the south of the Doris North mine, beneath Doris Lake and situated in talik or unfrozen ground, saline groundwater may be present.

Mining of areas within the Doris Lake talik will occur over a period of two years, with a planned initiation date corresponding to the end of year two of mining of the Doris North deposit. Inflows to the mining areas within the talik are likely to come from three sources: fractured bedrock, structures and former exploration drill holes. Analytical and numerical estimates of groundwater inflow quantity have been determined from available hydraulic conductivity data and include inflows from the bulk fractured bedrock system and exploration drill holes. A detailed description of the methodology and assumptions utilized to generate the groundwater inflow estimates used in the water balance are presented in Appendix B.

Quantifying groundwater inflow to the mine workings is difficult because of uncertainty and variability in the parameters (e.g. hydraulic conductivity) used to estimate groundwater flow in fractured bedrock. In this analysis, groundwater inflow is assumed to be only proportional to the hydraulic conductivity estimate because the boundary conditions of the model do not change. The best estimate of hydraulic conductivity is the geometric mean of the observed hydraulic conductivities for each hydrogeologic domain. The geometric mean hydraulic conductivity is used to estimate groundwater inflow.

Bedrock Inflow for Water Balance

Without a mining schedule, it is not possible to estimate the cumulative inflow over time. To account for increased mining areas developing over time, two inflow periods were assumed for the water balance:

- Period 1, corresponding to 3rd year of ore processing (Year 5, 2015) 50% of cumulative inflow was assumed = 3,500 m^3/day.
- Period 2, corresponding to 4th year of ore processing (Year 6, 2016) 100% of cumulative inflow was assumed = 7,000 m^3/day.

Drill holes

Exploration drill holes were not explicitly included in the numerical model. Based on a general review of mine plans, assumed mining rates and exploration drill hole locations, two exploration drill holes are assumed to be the maximum number that might be intersected at a given time in a given stope. Flow through an open NQ-diameter exploration drill hole (75.7 mm) was assumed to be 2,680 m^3/day from calculations based on the Darcy-Weisbach equation. For the water balance model, 0, 1 or 2 drill holes were randomly turned on over a given model time step and assumed to flow unimpeded for a period of one week, at which point, it was assumed that the drill hole was grouted shut by operations.

3 Water Quality Model

3.1 Model Description

The water quality component of the model integrates the water balance discussed in the previous section with the mining related sources and inflows from the surrounding catchment area. The potential sources that may contribute solute release to the TIA include:

- Mine waste rock stored above ground;
- Ore stockpiled during milling operations;
- Quarried rock used as fill, construction material, road base and other infrastructure construction fill;
- Treated mill tailings discharged to the TIA;
- Treated sewage effluent discharge to the TIA;
- Saline groundwater;
- Saline drilling fluids;
- Blasting residuals present in waste rock, quarried rock, ore and mine water (groundwater);
- Solute and suspended matter released to the TIA from shoreline erosion and re-suspension by wave action; and
- Salinity release to the TIA due to thawing where permafrost is present along the shores of the TIA.

The runoff from the mill site, including runoff from the fill, waste rock in storage and the ore stockpile, will be collected and pumped to the TIA from year 2 on until closure. Solute released from road base materials and fill used for infrastructure development will report directly to either Doris Lake or the TIA, depending on catchment.

The mine water or groundwater encountered during underground mining operations will be pumped directly to the TIA. During the first two years of mining, there is not expected to be any dewatering from the underground workings. Saline drilling fluid brought to surface with waste rock and ore will also report to the TIA.

Blast residuals present in all quarried rock, waste rock and ore produced at the site, and may contribute loadings to Doris Lake and the TIA, depending on catchment area. Treated sewage will also be pumped to the TIA.

As the water level rises, the permafrost in the banks of the TIA will thaw. The porewater from the thawed banks, which are saline, will be released to the TIA only once the hydraulic gradient develops to displace the pore water. This will occur once the water level in the lake is lowered at the end of operations.

Some nitrogen based contaminants such as cyanide and its derivative compounds (e.g. thiocyanide and cyanate) will be subject to natural degradation processes. These reactions will lead to the formation of nitrogen-based nutrients (ammonia, nitrite and nitrate) which themselves will be subject to natural degradation reactions. These reactions have been incorporated into the model.

The load balance in the model is based on conservation of mass. The model does not include the potential effects of equilibrium reactions that could lead to the formation of secondary minerals, which, in some cases, would result in a net removal of solutes from solution, reducing the concentrations of some parameters in the TIA. Predicted concentrations of these parameters would therefore be overestimated.

3.2 Model Input Assumptions and Calculations

3.2.1 Background Water Quality

The water and load balance model is based on a monthly time-step and therefore monthly background concentrations were used as inputs to the model. The background concentrations used in the model are based on the same data set as the original model from 2004 to 2006. During this period Tail Lake outflow water quality was extensively monitored. Table 3-1 shows the background monitoring results summarized by month, and include the total number of samples, the number of samples below detection, the mean, the median and the maximum values. These values were derived from the entire data set from 2004 to 2006, with the results for corresponding months from each year grouped together (e.g. average concentrations for June were obtained by averaging the results for June 2004, June 2005 and June 2006). It should also be noted that where results were below the method detection limit, the numerical value of the detection limit was used to determine the mean and median values.

Although mean and median concentrations in general are very similar for most parameters (indicating little bias in the results), the means of some parameters are clearly influenced by outliers. Median values were therefore adopted as input to the water quality model.

Table 3-1: Summary of Model Background Water Quality

			June					July					August					September				
Parameter	**Units**	**CWQG**	**N (total)**	**N<DL**	**Mean**	**Median**	**Maximum**	**N (total)**	**N<DL**	**Mean**	**Median**	**Maximum**	**N (total)**	**N<DL**	**Mean**	**Median**	**Maximum**	**N (total)**	**N<DL**	**Mean**	**Median**	**Maximum**
Total Metals																						
Aluminum (AL)	µg/L	100	5		18.2	16.5	27.6	7		14.7	12.1	28.8	8		21.8	16.5	45.7	6		23.4	16.1	65.2
Aresenic (As)	µg/L	5	5		0.239	0.238	0.291	7		0.256	0.261	0.286	8		0.407	0.332	0.741	6		0.366	0.229	0.761
Cadmium (Cd)	µg/L	0.017	5	2	0.012	0.002	0.050	7	5	0.017	0.003	0.050	8	6	0.002	0.002	0.003	6	6	0.002	0.002	0.002
Chromium (Cr)	µg/L	1	5		0.324	0.248	0.649	7		0.237	0.158	0.74	8	1	0.295	0.25	0.855	6		0.287	0.2215	0.744
Copper (Cu)	µg/L	2	5		0.93	0.90	1.13	7		0.76	0.80	1.00	8		0.70	0.70	0.80	6		0.71	0.71	0.79
Iron (Fe)	µg/L	300	5		54	42	85	7		132	89	358	8		406	404	853	6		412	68	1150
Lead (Pb)	µg/L	1	5	1	0.041	0.025	0.107	7	2	0.052	0.050	0.094	8		0.069	0.062	0.132	6		0.023	0.012	0.055
Mercury (Hg)	ng/L	26	5	4	0.620	0.600	0.700	7	6	0.671	0.600	1.100	8	8	0.600	0.600	0.600	6	6	0.600	0.600	0.600
Molybdenum (Mo)	µg/L	73	5		0.091	0.100	0.110	7		0.081	0.073	0.110	8		0.068	0.070	0.091	6		0.074	0.075	0.117
Nickel (Ni)	µg/L	25	5		0.509	0.520	0.588	7		0.547	0.513	0.709	8		0.521	0.507	0.660	6		0.437	0.433	0.550
Selenium (Se)	µg/L	1	5		0.419	0.400	0.517	7	1	0.380	0.421	0.520	8		0.858	0.615	1.960	6		0.922	0.464	2.230
Silver (Ag)	µg/L	0.1	5	2	0.0206	0.0007	0.1000	7	2	0.0299	0.0022	0.1000	8	3	0.0009	0.0008	0.0021	6	3	0.0014	0.0007	0.0041
Thallium (Tl)		0.8	5	1	0.034	0.006	0.127	7	3	0.017	0.014	0.030	6	1	0.005	0.002	0.015	4	2	0.004	0.002	0.012
Zinc (Zn)	µg/L	30	5	1	4.57	5.35	7.28	7	2	4.16	2.07	16.00	8		3.69	2.63	11.10	6		3.37	2.37	8.24
Nutrients																						
Phosphorus, Total	mg/L		5		0.008	0.008	0.009	7		0.009	0.006	0.014	8		0.011	0.006	0.026	6		0.009	0.004	0.021
Ammonia-N	mg/L	1.27	5	1	0.027	0.008	0.104	7	2	0.012	0.008	0.039	8	2	0.008	0.007	0.014	6	1	0.011	0.008	0.028
Total Dissolved Solids	mg/L		1		110	110	110	2		80	80	120	2		90	90	100	2		105	105	120
Total Suspended Solids	mg/L		5	4	1.4	1.0	3.0	7	5	1.7	1.0	3.0	8	6	2.1	1.5	5.0	6	5	2.0	2.0	3.0
Routine Water Analysis – Low Level																						
Chloride (Cl)	mg/L		5		32.9	30.1	43.5	7		32.4	30.0	40.0	8		49.0	37.0	88.3	6		56.8	37.0	107.0
Nitrate+Nitrate-N	mg/L		5	5	0.005	0.005	0.006	7	4	0.007	0.006	0.010	8	8	0.005	0.005	0.006	6	4	0.011	0.006	0.029
Nitrate-N	mg/L	2.94	5	5	0.005	0.005	0.006	7	4	0.006	0.006	0.010	8	8	0.005	0.005	0.006	6	4	0.010	0.006	0.026
Nitrate-N	mg/L	0.018	5	5	0.001	0.001	0.002	7	6	0.001	0.001	0.002	8	8	0.001	0.001	0.002	6	4	0.002	0.002	0.003
Sulphate (SO_4)	mg/L		5	2	4.0	3.0	6.0	7	4	2.9	3.0	4.0	8	3	3.3	3.0	6.0	6	1	4.2	3.3	7.0
pH, Conductivity and Total Alkalinity																						
pH	pH	6.5-9.0	5		7.09	7.01	7.40	7		7.33	7.07	8.47	8		7.16	7.20	7.30	6		7.26	7.29	7.50
Conductivity (EC)	uS/cm		5		168	159	219	7		162	151	186	8		230	189	388	6		253	176	449
Alkalinity, Total	mgCaCO$_3$/L		5		29.0	27.6	35.9	7		29.6	28.5	37.8	8		30.5	29.7	37.0	6		26.6	25.3	31.7
Other																						
Cyanide, Total	mg/L		5	5	0.001	0.001	0.002	7	7	0.001	0.001	0.002	7	6	0.001	0.001	0.002	6	4	0.002	0.002	0.002
Radium 226	Bq/L		2	2	0.005	0.005	0.005	3	2	0.005	0.005	0.006	3	2	0.013	0.005	0.030	3	3	0.005	0.005	0.005

3.2.2 Solute Release from Mine Waste Rock and Ore

Waste rock that will be produced during the development stages of the underground mine workings will need to be stored above ground until it is backfilled in the mined out stopes. Based on the current mine plan, approximately 375,000 tonnes of waste rock will remain on surface and will need to be stored in perpetuity. The estimated amount of waste rock that will be stored above ground at any given time are summarized in Table 3-2 along with the surface storage assumptions that have been incorporated into the model.

Table 3-2: Summary of Above Ground Waste Rock Storage and Model Assumptions

Year		Doris North (tonnes)	Other Doris (Tonnes)	Total Waste Rock	Model Assumption (tonnes)
1	2011	320,000		320,000	320,000
2	2012	500,000		500,000*	500,000
3	2013	190,000		190,000	500,000
4	2014	190,000	197,000	387,000	500,000
5	2015	110,000	314,000	424,000	500,000
6	2016	110,000	299,000	409,000	500,000
7	2017 on	110,000	265,000	375,000**	375,000

*Peak requirement
** Long-term requirement

The monthly solute release from waste rock stored on surface were developed using the same humidity cell data and methodology presented in SRK (2007) with the exceptions of the following modifications. Details of the original model assumptions related to solute release are presented in Appendix A. The average solute release rates used in the model are presented in Table 3-3.

As discussed in “Kinetic Testing of Waste Rock and Ore from the Doris Deposits” (SRK 2011a), the samples used for these humidity cell tests all have total sulphur concentrations greater than the 90th percentile values of their respective rock types, and therefore would be expected to have higher sulphate and metal release rates in comparison to most of the waste rock that will be produced during mining. Nonetheless, the results showed very low solute release, with many parameters below detection limits. A comparison of these rates to more recent kinetic test results (SRK 2011a), indicated that these rates were generally higher and are a conservative estimate for assessing impacts from the waste rock.

In addition, geochemical investigations completed by SRK (SRK 2011a,b) showed that the majority of the waste rock would not be net acid generating. For the minor proportion of the waste rock that might be acid generating, the humidity cell tests generally indicated that there would be a lag of many years before acid generation would occur. The current waste rock management plan has provisions to ensure that the more mineralized waste rock is segregated for use as backfill. This will help to ensure that the waste rock that would remain on surface at closure would have a negligible potential for metal leaching and/or acid generation.

The original calculations of solute release from the waste rock in the original model (SRK 2007) were based on data from four humidity cell tests completed by Rescan (Rescan 2001). Details of the original model assumptions and calculations are provided in Appendix A. At the time those tests were completed, the detection limit for chromium was 0.005 mg/L, corresponding to a release rate of 0.0011 mg/kg/week, and all of the test results were below that value. Initial predictions for the TIA completed for this assessment indicated that the waste rock was an appreciable source of chromium, and the original predictions for this parameter were re-evaluated. Therefore, rates from the new humidity cell tests reported in SRK 2011a were used. The new tests have a detection limit of 0.0001 mg/L, and the corresponding chromium release rates ranged from 0.00004 to 0.00007 mg/kg/week. The maximum rate of 0.00007 mg/kg/week from the new tests was used in the updated source term predictions for waste rock.

The release rates were multiplied by the number of weeks for which the rock will not be frozen to estimate the overall annual solute generation. To estimate the net release, a surface area correction factor of 0.3 and a release factor of 40% were adopted (SRK 2007). The annual loading was then prorated on a monthly basis according to the site hydrograph.

During mine operations, runoff from the waste rock will be routed to the TIA. Waste rock remaining on surface at the end of the mine life is assumed to contribute solute release in perpetuity. Following cessation of mining, runoff from waste rock will be routed underground until ammonia and nitrate concentrations have stabilized and the water can be release without impacting water quality into Doris Lake.

For the ore, as it is expected to remain in the stockpile for a very short period of time, for modeling purposes is it assumed to not release any solutes to the pollution pond and ultimately the TIA. Given the short duration of time on surface, the source terms for the ore stockpile would be very similar to those for waste rock. Therefore the overly conservative model assumptions for the tonnage of waste rock on surface, account for any potential release of solute from the ore stockpile.

Table 3-3: Summary of Average Solute Release Rates from Waste Rock Samples Tested in the Humidity Cells

Parameter	Units	Description				Overall Average
		Mafic Volcanic	Gabbro	Mafic with Veining	Quartz	
Sulphate	mg/kg/week	1.55	6.43	5.68	79	23
Total Metals						
Aluminium Al	mg/kg/week	0.026	0.010	0.0093	0.0043	0.013
Antimony Sb	mg/kg/week	0.022	0.020	0.023	0.022	0.022
Arsenic As	mg/kg/week	0.00044	0.00040	0.00046	0.00065	0.00049
Barium Ba	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Beryllium Be	mg/kg/week	0.00055	0.00050	0.00058	0.00054	0.00054
Bismuth Bi	mg/kg/week	0.022	0.020	0.023	0.022	0.022
Boron B	mg/kg/week	0.011	0.010	0.012	0.011	0.011
Cadmium Cd	mg/kg/week	$2.2x10^{-7}$	$2.0x10^{-7}$	$2.3x10^{-7}$	$2.2x10^{-7}$	$2.2x10^{-7}$
Calcium Ca	mg/kg/week	3.9	4.8	5.8	4.5	4.7
Chromium Cr	mg/kg/week	na*	na*	na*	na*	0.00007
Cobalt Co	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Copper Cu	mg/kg/week	0.00044	0.00040	0.00046	0.00043	0.00043
Iron Fe	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Lead Pb	mg/kg/week	0.00022	0.00020	0.00023	0.00022	0.00022
Lithium Li	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Magnesium Mg	mg/kg/week	2.2	2.5	2.4	1.6	2.2
Manganese Mn	mg/kg/week	0.0015	0.0051	0.0040	0.0008	0.0029
Mercury Hg	mg/kg/week	$4.4x10^{-7}$	$4.0x10^{-7}$	$4.6x10^{-7}$	$4.3x10^{-7}$	$4.3x10^{-7}$
Molybdenum Mo	mg/kg/week	0.00022	0.00020	0.00023	0.00022	0.00022
Nickel Ni	mg/kg/week	0.0022	0.0020	0.0023	0.0022	0.0022
Phosphorus P	mg/kg/week	0.033	0.030	0.035	0.032	0.033
Potassium K	mg/kg/week	0.22	1.15	0.23	0.22	0.45
Selenium Se	mg/kg/week	$2.2x10^{-6}$	$2.0x10^{-6}$	$2.3x10^{-6}$	$2.2x10^{-6}$	$2.2x10^{-6}$
Silicon Si	mg/kg/week	0.17	0.25	0.14	0.14	0.18
Silver Ag	mg/kg/week	$4.4x10^{-5}$	$4.0x10^{-5}$	$4.6x10^{-5}$	$4.3x10^{-5}$	$4.3x10^{-5}$
Sodium Na	mg/kg/week	0.22	0.20	0.23	0.22	0.22
Strontium Sr	mg/kg/week	0.002	0.0122	0.005	0.004	0.006
Thallium Tl	mg/kg/week	$4.4x10^{-7}$	$4.0x10^{-7}$	$4.6x10^{-7}$	$4.3x10^{-7}$	$4.3x10^{-7}$
Tin Sn	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Titanium Ti	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Vanadium V	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Zinc Zn	mg/kg/week	0.0022	0.0026	0.0028	0.0073	0.0037

Notes: * chromium data was taken from SRK 2011a

3.2.3 Solute Release from Quarried Rock

The monthly solute release from stored quarried rock were developed using the same humidity cell data and methodology presented in SRK (2007) with the exceptions of the following modifications. Details of the original model assumptions related to solute release are presented in Appendix A. The tonnage of quarried rock is summarized in Table 3-4. The average solute release rates used in the model are presented in Table 3-5. Similar to waste rock, for chromium the rates from the new humidity cell tests undertaken by HBML were used.

The release rates were multiplied by the number of weeks for which the rock will not be frozen to estimate the overall annual solute generation. As before, to estimate the net release, a surface area correction factor of 0.3 and a release factor of 40% were adopted. The annual loading was then prorated on a monthly basis according to the site hydrograph.

Solute loading from site fill is assumed to continue until 4 years after the cessation of mine operations. At this time it is assumed that permafrost will have aggraded into the fill, essentially limiting the ongoing contribution of loadings to the surrounding environment.

Table 3-4: Tonnage of Quarried Rock on Surface

Infrastructure Components	General Detail	Estimated Quantity		Footprint Surface Area (m^2)	Distribution		Quantity		Comment
		ECM (m^3)	Dry Tonnes		Doris Lake	Tail Lake	Doris Lake	Tail Lake	
Doris North Tank Farm, Located on Pad R	71m x 71m surface area; 1.2:1 side slopes; 0.5m thick; 0.8m high berm	7,260	15,072	4,700	0.00%	100.00%	-	15,100	Drains to sump for treatment.
North Dam Frozen Core Plant Pad	Based on 2011 As-built.	10,249	21,277	8,115	0.00%	100.00%	-	21,300	
Tail Lake Access Road	Based on 2010 design material volumes.	2,530	5,252	2,459	0.00%	100.00%	-	5,300	
Primary Road and Float Plane Access Road from drainage divide.	Based on 2010 as-built.	35,196	73,067	22,334	100.00%	0.00%	73,100	-	
Secondary Road from Doris Camp to Doris Creek excluding the portion that drains to the waste rock expansion.	Based on 2010 design material volumes.	11,895	24,694	9,660	100.00%	0.00%	24,700	-	
Secondary Road from Doris Creek to South Dam	Based on 2010 design material volumes.	82,833	171,961	50,368	14.20%	85.80%	24,400	147,500	To be built in 2012
Explosives Facility	Based on 2010 design material volumes.	71,241	147,896	40,765	0.00%	100.00%	-	147,900	To be built in 2013
Caribou crossings (15) for Primary, Secondary and Windy Roads.	10m long; 5:1 approach slopes; 2.0m thick	2,100	4,360	3,000	46.67%	53.33%	2,000	2,300	
Road turnouts (31) for Primary, Secondary and Windy Roads.	10m wide; 30m long; 1.2:1 side slopes; 2.0m thick & 10m x 10m turnaround	10,726	22,267	8,680	64.52%	35.48%	14,400	7,900	
Doris Camp [West] See Figure 2.	Pads: X/Y, B, R, C, E/P and the Heli-pad.; Overburden Dump and the sediment control berm. Half of the North Access Road and 41% of the diversion berm. Does not include footprint of the Fuel Tank Farm.	173,300	359,771	82,128	100.00%	0.00%	359,800	-	All surface water drains to Doris Lake with the exception of the Fuel Tank Farm.
Doris Camp [East] See Figure 2.	Pads: T, D, Q, J/H, I, G, F and the Underground Fuel Transfer Station. Half the North Access Road and 59% of the Diversion Berm.	205,023	425,628	102,032	0.00%	100.00%	-	425,600	All surface water drains to the pollution control pond before being pumped to Tail Lake. 80% built - remainder in 2013
Waste Rock Expansion See Figure 2.	The Waste Rock Expansion Pile, pollution, it's control berm and 0.5km of the Secondary Road.	74,500	154,662	74,960	0.00%	100.00%	-	154,700	All surface water drains to the pollution control pond before being pumped to Tail Lake. To be built in 2013
Overburden Dump	Estimate based on average thickness of 10m.	284,139	589,873	28,414	100.00%	0.00%	589,900	-	
North Dam	Based on 2010 design material volumes.	57,925	120,252	22,462	50.00%	50.00%	60,100	60,100	
South Dam	Used volume from the North Dam with alternate surface footprint.	57,925	120,252	20,282	0.00%	50.00%	-	60,100	
All surface road maintenance (includes Primary Road, Secondary Road, Float Plane Dock Access Road)	Allowance for all surface road maintenance @ 5cm new surfacing grade every year for 8 years	37,620	78,099	94,042	31.20%	68.80%	24,400	53,700	
Shoreline erosion (contingency)	20% of 12.9 ha surface area (up to elev. 29.4m); 0.5m thickness (SRK 2005c)	40,000	83,040	25,800	0.00%	100.00%	-	83,000	

Table 3-5: Summary of Average Solute Release Rates from Quarry Rock Sample Humidity Cell Testing

Parameter	Units	Sample Description			Overall Average
		Quarry # Q1	Quarry # Q2	Quarry # Q3	
Sulphate	mg/kg/week	0.82	0.86	0.89	0.85666667
Total Metals					
Aluminium Al	mg/kg/week	0.026	0.024	0.025	0.025
Antimony Sb	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Arsenic As	mg/kg/week	0.00099	0.00062	0.00012	0.00058
Barium Ba	mg/kg/week	0.000060	0.000055	0.000115	0.000077
Beryllium Be	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Bismuth Bi	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Boron B	mg/kg/week	0.0060	0.0055	0.0060	0.0058
Cadmium Cd	mg/kg/week	0.000029	0.000032	0.000026	0.000029
Calcium Ca	mg/kg/week	1.5	1.5	1.4	1.5
Chromium Cr	mg/kg/week	na*	na*	na*	0.00007
Cobalt Co	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Copper Cu	mg/kg/week	0.00023	0.00012	0.00012	0.00015
Iron Fe	mg/kg/week	0.0060	0.0055	0.0060	0.0058
Lead Pb	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Lithium Li	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Magnesium Mg	mg/kg/week	0.14	0.25	0.05	0.15
Manganese Mn	mg/kg/week	0.00018	0.00012	0.00012	0.00014
Mercury Hg	mg/kg/week	0.0000024	0.0000023	0.0000023	0.0000023
Molybdenum Mo	mg/kg/week	0.000000060	0.000000055	0.000000060	0.000000058
Nickel Ni	mg/kg/week	0.00015	0.00012	0.00012	0.00013
Phosphorus P	mg/kg/week	0.018	0.017	0.018	0.017
Potassium K	mg/kg/week	0.053	0.029	0.029	0.037
Selenium Se	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Silicon Si	mg/kg/week	0.30	0.29	0.24	0.28
Silver Ag	mg/kg/week	0.000030	0.000029	0.000058	0.000039
Sodium Na	mg/kg/week	0.052	0.036	0.02	0.036
Strontium Sr	mg/kg/week	0.00094	0.00086	0.00053	0.00078
Thallium Tl	mg/kg/week	0.000012	0.000012	0.000012	0.000012
Tin Sn	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Titanium Ti	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Vanadium V	mg/kg/week	0.00047	0.00012	0.00012	0.00023
Zinc Zn	mg/kg/week	0.00060	0.00055	0.00060	0.00058

Notes: * chromium data was taken from SRK 2011a.

3.2.4 Mine Water Inflows (Groundwater)

Estimates of groundwater quality that may be observed during operations are based on results from Westbay well 10WBW001, a multi-level monitoring system which was completed in 2010 within the Doris Lake talik of the Doris Central area. Westbay wells can be thought of as multi-level piezometers with multiple “screenzones” at various depths. Three zones were selected for sampling at Doris Central to provide water quality samples from shallow (Zone 10), medium (Zone 6) and deep talik water (Zone 1).

The groundwater quality results for Zones 6 and 10 are assumed to be representative of the expected initial range in inflowing water quality at Doris Upper mine areas. The results from Zone 1 are assumed to be representative of the initial inflows to the Doris Lower mine areas. Over time, inflowing groundwater is assumed to trend towards the lake water quality. It is not currently possible to estimate the time frame over which this may occur.

To allow for flexibility in the future mining planning, it was assumed that the mine inflows could be from either Doris Upper or Doris Lower, or from a combination of both at any time over the life of the mine water discharge. To be conservative in representing these scenarios in the water and load balance, for each parameter the highest of the 75th percentile concentration from either Zone 1 (Doris Lower) or Zones 6 and 10 (Doris Upper) was used and is summarized in Table 3-6. Full details of groundwater inflows and water quality are presented in Appendix B.

3.2.5 Process Water Effluent

Newmont Metallurgical Services (NMS) has developed a METSIM computer simulation model of the metallurgical circuit currently planned for the Hope Bay project. The objective was to model the process water balance and to estimate the tailings solution chemistry discharged into the tailings impoundment for Doris North tailings, Doris Connector tailings, Doris Central tailings and Patch 14 tailings. As there was no available data for Patch 14 for this modeling exercise, data from Naartook was used as a surrogate. The estimated mill effluent water quality is summarized in Table 3-7 for each of the deposits. Given that the timing of processing of Doris Connector and Doris Central ore is not fully defined, for each parameter the source term was set to the maximum concentration of these two ores. Furthermore, it is assumed that there will be pretreatment using lime prior to discharge and therefore the zinc source term assumes lime treatment.

Table 3-6: Summary of Groundwater Quality used in the Model

Parameter	Groundwater Concentrations (mg/L) (75th percentile)
Total Dissolved Solids	46000
Free Cyanide	0
WAD Cyanide	0
Total Cyanide	0
Cyanate	0
Thiocyanate	0
Sulphate	2000
Chloride	19000
Ammonia-N	3.6
Nitrate-N	1
Nitrite_N	0.2
Alkalinity (Total as $CaCO_3$)	97
Ortho_P	0.018
Phosphate_P	0.033
TOC	0
Hardness (as $CaCO_3$)	13000

Parameter	Groundwater Concentrations (mg/L) (75th percentile)
Aluminum	0.005
Antimony	0.0033
Arsenic	0.002
Barium	0.17
Beryllium	0.0005
Bismuth	0.0005
Boron	3.1
Cadmium	0.00011
Calcium	4900
Chromium	0.00063
Cobalt	0.00031
Copper	0.00087
Iron	4.9
Lead	0.00048
Lithium	0.38
Magnesium	1400
Manganese	2
Mercury	0.00001
Molybdenum	0.032
Nickel	0.0018
Phosphorus	1
Potassium	250
Selenium	0.002
Silicon	3.3
Sodium	9000
Strontium	57
Tellurium	0.0005
Thallium	0.00016
Thorium	0.0005
Tin	0.001
Titanium	0.005
Uranium	0.00023
Vanadium	0.0005
Zinc Zn	0.14
Zirconium	0.0005

Table 3-7: Summary of Mill Effluent Water Quality

Parameter	Doris North Final Tailings	Connector Final Tailings	Central Final Tailings	Max Central/Connector Tailings	Patch 14 Final Tailings
Total Dissolved Solids	5100	2100	920	2100	1900
Free Cyanide	0.017	0.01	0.01	0.01	0.037
WAD Cyanide	0.045	0.05	0.11	0.11	0.014
Total Cyanide	2.4	1.6	0.2	1.6	1.8
Cyanate	280	83	95	95	62
Thiocyanate	220	13	220	220	77
Chloride	140	91	12	91	55
Sulphate	2200	2200	2200	2200	2200
Ammonia	11	23	1.1	23	12
Nitrate	0.23	0.74	0.28	0.74	0.28
Nitrite	0.085	0.01	0.28	0.28	9.4
Alkalinity (as $CaCO_3$)	460	370	130	370	170
Ortho -P	0	0	0	0	0
Phosphate-P	0	0	0	0	0
Org. Carbon	0	0	0	0	0
Hardness (as $CaCO_3$)	1000	1100	1100	1100	1200
Aluminum Al	0.12	0.59	0.07	0.59	0.05
Antimony Sb	0.08	0.08	0.0062	0.08	0.044
Arsenic As	0.0065	0.005	0.0036	0.005	0.4
Barium Ba	0.0077	0.0098	0.13	0.13	0.013
Beryllium Be	0.0011	0.00007	0.0001	0.0001	0.0093
Bismuth Bi	0	0	0	0	0
Boron B	0.19	0.27	0	0.27	0.66
Cadmium Cd	0.00015	0.00069	0.00026	0.00069	0.00002
Calcium Ca	400	400	400	400	400
Chromium Cr	0.02	0.002	0.024	0.024	0.001
Cobalt Co	0.095	0.017	0.071	0.071	0.36
Copper Cu	0.023	0.64	0.042	0.64	0.072
Iron Fe	1.5	2.6	2.8	2.8	1.1
Lead Pb	0.00023	0.00023	0.011	0.011	0.00015
Lithium Li	0.013	0.011	0	0.011	0
Magnesium Mg	7.4	35	15	35	46
Manganese Mn	0.0091	0.14	0.096	0.14	0.04
Mercury Hg	0.000095	0.000037	0.0001	0.0001	0.0001
Molybdenum Mo	0.045	0.12	0.094	0.12	0.16
Nickel Ni	0.24	0.058	0.016	0.058	0.026
Phosphorus P	0.97	1.2	0.071	1.2	0.27
Potassium K	54	43	14	43	42
Selenium Se	0.011	0.0004	0.025	0.025	0.23
Silver Ag	0.0011	0.00031	0.047	0.047	0.00021
Sodium Na	1900	570	570	570	440
Strontium Sr	0.2	0.3	0.12	0.3	0.29
Tellurium Te	0	0	0	0	0

Parameter	Doris North Final Tailings	Connector Final Tailings	Central Final Tailings	Max Central/Connector Tailings	Patch 14 Final Tailings
Thallium Tl	0.00044	0.00002	0.00011	0.00011	0.000069
Thorium Th	0	0	0	0	0
Tin Sn	0.05	0.05	0	0.05	0.05
Titanium Ti	0.099	0.099	0	0.099	0.05
Uranium U	0.00042	0.00042	0	0.00042	0.00032
Vanadium V	0.0061	0.0015	0	0.0015	0.023
Zinc Zn	0.5	0.5	0.5	0.5	0.5

3.2.6 Sewage Effluent

The sewage effluent chemistry source term in the model is based on the water quality performance estimates that were used in the original model, originally provided by a manufacturer of package sewage treatment plants (PJ Equipment Sales Corp). Expected average solute concentrations and annual loadings for a 360 person camp are summarized in Table 3.8. This is an increase in camp size from the original project (175 person camp). It was assumed that these loadings would report to TIA continuously throughout the mill operational period, and for one year thereafter.

It should be noted that the phosphorus speciation is not known. In an attempt to quantify orthophosphate concentrations, the phosphorus for this source was input to the model as both total phosphate and orthophosphate. In reality, the orthophosphate estimates provided in the model run outputs should be treated as total phosphate rather than orthophosphate.

Table 3-8: Summary of Estimated Treated Sewage Water Quality and Loadings

Parameter	Average Concentration (mg/L)	Average Loading (kg/year)
Total Ammonia-N	10	515
Nitrate-N	1.0	52
Nitrite-N	30	1546
Total Metals		
Aluminium	0.052	2.7
Arsenic	0.0002	0.008
Cadmium	0.0001	0.003
Chromium	0.0025	0.13
Copper	0.0020	0.10
Iron	0.025	1.3
Lead	0.0001	0.0025
Molybdenum	0.0001	0.0026
Nickel	0.0005	0.026
Phosphorus	1.0	515
Uranium	0.0002	0.01
Zinc	0.002	0.10

Note: Ammonia, Nitrate and Nitrite expressed as nitrogen

3.2.7 Nitrogen Release from Blast Residuals (Waste Rock, Ore, Tailings, Quarried Rock and Groundwater)

Estimates for Waste Rock, Ore, Tailings and Quarry Rock

The estimates of ammonia-N, nitrate-N and nitrite-N were derived following the methods used in the original model (SRK 2007) which were based on Ferguson and Leask (1988), with the exception of increasing the blast residue factor from 1% to a more conservative value of 10%. A detailed summary of this methodology for estimating the nitrogen release from blast residuals is provided in Appendix A. An annual waste rock production rate of 320,000 tonnes per year and a powder factor of about 1.14 kg per tonne of rock mines were assumed for this assessment.

One modification has been incorporated in the revised model related to the flushing of the residual from the mined material. The revised model now assumes that each year 40% of the ‘available’ residual nitrogen will be flushed annually from the waste rock. This release was assumed to occur over a 5 month period, prorated to the site hydrograph. The same approach was adopted to calculate the release from the construction fill. This assumption is a change from the original model, which assumed that the blasting residual in the waste rock will be evenly flushed out over a period of three years.

The annual waste rock contribution of blasting residual is based on an annual production rate of 320,000 tonnes. The estimated weights of construction fill that would contribute to nutrient release from blast residues are summarised in Table 3.4. Note that the table makes provision for four cases where fill may be used for shoreline erosion protection in the TIA. The base case model scenario assumes no placement of fill for shoreline erosion protection. All these scenarios do not allow for bedrock correction of 40% and are therefore very conservative. In addition to the estimates provided in Table 3.4, approximately 292,000 tonnes of milled ore would annually contribute blast residue to TIA.

Groundwater

Groundwater data from the Westbay monitoring program indicate that ammonia concentrations are naturally elevated in the groundwater system, with baseline concentrations on the order of 4 mg N/L. Ammonia, nitrate and nitrite concentrations in the groundwater are expected to increase as a result of blasting activities underground.

Estimates of nitrogen nutrient (ammonia, nitrate and nitrite) loading rates for the underground mine were based on data reported in a comprehensive study on ammonium nitrate dissolution rates for the Diavik Diamond Mine in Northwest Territories (Wek'eezhii Land and Water Board, 2007). The study reported a range of ANFO dissolution rates associated with blasting in open pit and underground operations. An ANFO dissolution rate of 2.94% was deemed representative for underground blasting.

For the Hope Bay underground mine workings the estimated ANFO dissolution rate was 5.9% calculated as the rate reported for Diavik multiplied by a factor of 2. The factor of 2 was incorporated to account for uncertainties associated with operating conditions (i.e. potential for wetter underground workings) and operating practices. In the model, the annual loading rates were obtained by multiplying the total production of development rock and ore (tonnes/year) by a powder factor of 1.14 (kg ANFO/tonnes material) and the estimated ANFO dissolution rate. The ammonium nitrate content of ANFO was assumed to be 94%. The speciation of nitrogen nutrients was estimated based on the Diavik study and other case studies for mines in the Northwest Territories.

The estimated daily nutrient loadings to the groundwater from blasting residuals used in the model are summarized in Table 3-9.

Table 3-9: Summary of Estimated Daily Loading to Groundwater from Blasting Residuals

Nutrient	Daily Loading (kg/day)
Ammonia-N	13
Nitrate-N	21
Nitrite-n	1.0

3.2.8 Sources of Salinity

Drilling Fluids

Drilling fluids were assumed to be present in all mine and quarry products, i.e. construction fill, waste rock and ore.

Saline fluid losses to the construction fill, ore and waste rock are expected to occur. To estimate these loadings, it was assumed that:

- Brine usage is 5,000 L/day at a rate of 908 kg/day of $CaCl_2$ (based on a usage rate of 40 - 22.7 kg bags of $CaCl_2$ per day); and
- Saline drilling fluids will contribute a 3% increase in moisture content of the quarried construction fill, waste rock and ore.

The total saline fluid content of the rock and fill was determined from the weight distributions given in Table 3.2 and 3.4. Salinity releases were calculated assuming 40% of the waste rock or fill would be flushed annually. Each following year, the salinity releases were calculated based on the flushing of 40% of the residual salinity associated with the mine and quarry products. The annual loadings were prorated to monthly release rates based on the Doris Lake outflow hydrograph.

Porewater Release from Permafrost Thaw

Salinity released due to thawing of permafrost surrounding TIA was included in the load balance calculations and is based on the same methodology used in the original model. It is anticipated that the permafrost thaw will occur as the water level in TIA rises. Because of the outward hydraulic gradients that will be generated by the rising water level in the lake, little porewater release to the lake water will occur during the time that the water level continues to rise. However, as soon as the water level is lowered to the final water elevation, hydraulic gradients will be reversed toward the lake, and there will be a release of porewater from the thawed areas. The volume of porewater that could be released from the thawed areas was estimated as follows.

A shoreline survey indicated that approximately 5,100 m of TIA shore may contain permafrost that could be thawed by a rise in the water elevation. Thermal modeling suggests that the permafrost could be thawed to a depth of about 3 m, over a shore width of about 50 m. Assuming an average slope of about 6% for the shore, an initial moisture content of 50%, and a drained field moisture content of 35% for the soils, it can be shown that a volume of about 57,000 m^3 of saline water could be released. It was assumed that the permafrost thaw water would approximate seawater quality, i.e. it would contain about 17.1 g/L chloride, 1 g/L sulphate, 9.3 g/L sodium and about 1.7 g/L calcium.

A conservative estimate was made that the entire volume of thawed porewater that would drain to the TIA would occur within one year of the water level in Tail Lake being lowered to its final spill elevation, or when the rise in water level is reversed.

Porewater Release from Permafrost Soil Erosion

Subsequent to lowering the water level in Tail Lake, erosion of the thawed soils may continue to contribute salinity to Tail Lake. As discussed in the next section, ongoing salinity release from this source is calculated inclusive of the sediment release calculations.

3.2.9 Shoreline Erosion

As a result of the expected rise in the water level in the TIA during operations, permafrost soils around the perimeter of the TIA are expected the thaw. The thawed soils may become susceptible to re-suspension due to wave action while submerged. The water management strategy after operations cease is to lower the water level in the TIA to its original elevation. The thawed soils above the will be subject to physical erosion caused by overland runoff and wave action impacting the shoreline.

The original model, detailed calculations were completed that estimated the potential sediment loadings from shoreline erosion and re-suspension (Appendix A). These calculations are included in the updated model.

The estimated potential sediment loading to the TIA from shoreline erosion and re-suspension, before any correction for particle settling are summarized in Table 3-10. Due to the depth of water cover over the tailings, the effect of wave action on re-suspension of tailings will be negligible.

Table 3-10: Summary of Estimated Solids Loading to TIA at Elevation 28.3 m

Case	Loading by Physical Shoreline Erosion (kg/year)	Loading Resulting from Re-Suspension of Eroded Material (kg/year)	Estimated Total Annual Loading (kg/year)
Base Case	2,800,000	210,000	3,100,000
Upper Limit	7,400,000	280,000	7,600,000
Lower Limit	930,000	120,000	1,100,000

Settling tests were carried out to assess the residual total suspended solids concentrations and total solute release that may result from these sediment loadings. The results of the settling tests were then scaled to the estimated sediment loadings and total solute release to the actual inflow conditions of the TIA using the following expression:

Solute Release Concentration = Test Conc"n x (Total Annual Load/Annual Inflow)/Test Sediment Concentration

These are summarized in Table 3-11 for average flow conditions and represent incremental loadings to the TIA without erosion control measures. For modeling purposes it is assumed that these shoreline erosion processes will begin in year 9 and continue for 5 years until the end of year 13. After year 13, it is assumed that revegetation and re-establishment of permafrost will reduce sediment loadings to the TIA.

Table 3-11: Estimated Steady State Total Solute Concentrations in TIA (Mean)

Parameter	Steady State Total Solute Concentrations (mg/L) (Mean)
Total Dissolved Solids	5
Free Cyanide	0
WAD Cyanide	0
Total Cyanide	0
Cyanate	0
Thiocyanate	0
Sulphate	0
Chloride	0
Ammonia-N	0
Nitrate-N	0
Nitrite_N	0
Alkalinity (Total as $CaCO_3$)	0
Ortho_P	0
Phosphate_P	0.033
TOC	0
Hardness (as $CaCO_3$)	0
Aluminum	0.44
Antimony	0.00012
Arsenic	0.00073
Barium	0
Beryllium	0
Bismuth	0.000018
Boron	0.055
Cadmium	0.000018
Calcium	4.2
Chromium	0.00087
Cobalt	0.00022
Copper	0.0014
Iron	0.43
Lead	0.000082
Lithium	0.004
Magnesium	5.8
Manganese	0.01
Mercury	0.000035
Molybdenum	0.00056
Nickel	0.00045
Phosphorus	0.000082
Potassium	4.6
Selenium	0.0018
Silicon	1.1

Parameter	Steady State Total Solute Concentrations (mg/L) (Mean)
Sodium	0.000018
Strontium	81
Tellurium	0.029
Thallium	0.000018
Thorium	0.0000035
Tin	0.00013
Titanium	0.000067
Uranium	0.025
Vanadium	0.000082
Zinc Zn	0.0037
Zirconium	0.0024

3.3 Overall TIA Mass Balance Calculations

The contaminant load and water quality calculations for Tail Lake were estimated using a Goldsim® model. The model calculates solute loadings and concentrations on a monthly basis as follows:

- The TIA model accounts for the inventory of contaminants in the tailings impoundment over the operational period, closure period and post closure period;
- The total contaminant inventory was used to calculate the water quality at each time step, which was then used to predict contaminant concentration changes from dilution, nutrient degradation reactions and/or operational decant for that time step; and
- At each time step, the lake inventory was updated to account for the total **gain (loading)** to and/or **loss (removal)** of solute from the system. **Loadings** of solutes included all flows to the TIA from all the sources (mill, mine water, sewage and background) and products generated from nutrient degradation reactions. **Losses** included pore water lock-up, decant or discharges, and removals by nutrient degradation reactions.

The rise in water level in TIA will be minimized, and the lake will remain relatively shallow. The maximum water depth will be approximately 8 m. The lake is unlikely to thermally stratify in the summer because the lake will remain shallow and the winds at the site. Therefore, the TIA was regarded as a completely mixed system. The overall Tail Lake mass balance calculation for each solute, at each time step was as follows:

$$TM_t = MC + MI - MO - MR + MG$$

Where TM_t = mass contained at the end of the time step t (kg);
MC = mass contained at the beginning of the time step (kg);
MI = mass in all **inflows** to Tail Lake over the entire time step (kg);
MO = mass in all **outflows** from Tail Lake over the entire time step (kg);
MR = mass **removed** by nutrient degradation or conversion reactions (kg); and
MG = mass **generated** by nutrient degradation or conversion reactions (kg).

The loadings in the inflows included all the sources discussed in the preceding sections. Background loadings to TIA were estimated using surface runoff flows and concentrations, and background solute concentrations measured in Tail Lake outflow.

The solute concentration at the end of the time step was then calculated as follows:

$$SC = TM_t / V_t / 1000$$

Where SC = solute concentration at the end of time step t (mg/L),
TM_t = mass contained at the end of time step t (kg),
V_t = volume of free water contained in TIA at the end of time step t (m^3), and
1000 = conversion factor from kg/m^3 to mg/L.

3.3.1 Cryoconcentration

In the original Doris North Project, the discharge from the TIA only occurred during open water conditions. As such the impact of any under-ice concentration of parameters (or cryoconcentration) was avoided. The revised project may include additional underground mine water and discharge from the TIA to a marine outfall may occur during under-ice conditions. Therefore, during under-ice conditions, the model conservatively assumes that there will be 100% exclusion of parameters from the ice, resulting in higher concentrations in the TIA. During this period, the contaminant load in the TIA is concentrated in the unfrozen portion of the water column. A maximum ice thickness of 2.1 m is assumed in the model. Ice is assumed to start forming in October and remains until end of May.

3.4 Natural Degradation Reactions

The solute loading to Tail Lake included degradable cyanide and its derivative compounds (predominantly cyanate) and ammonia-N. A number of nitrogen-nutrient degradation reactions are expected to occur within the TIA including:

- Cyanide and cyanate to ammonia;
- Ammonia to nitrite;
- Nitrite to nitrate; and
- Denitrification of nitrate to nitrogen gas.

The assumptions related to the degradation of nitrogen species used in the updated model are the same as those used in the original model and are summarized in detail in Appendix A. Similar to the previous model, a simple empirical approach was adopted for these calculations and all calculations were applied only for open water conditions (June through October) with the exception of nitrate removal which occurs under ice throughout winter. For each time step pond surface area was calculated from the pond level and used to calculate the potential monthly conversion rates using the estimated removal rates for each parameter shown in Table 3.12. The table shows removal rates for a ‘natural case’ which generally correspond to removal rates observed for natural systems, and an ‘enhanced case’ which reflect rates estimated from the Colomac site where natural removal of ammonia-N was enhanced by the addition of phosphorous (as mono-ammonium phosphate). To ensure compliance with the TIA discharge limit of 6 mg/L ammonia-N, enhanced biological degradation will be used in the lake and the ‘enhanced case’ is carried through the model as the base case for the TIA.

Table 3-12: Summary of Assumed Conversion Rates

Parameter	Natural Case (kg/m^2/month)	Enhanced (kg/m^2/month)
Free Cyanide to Ammonia-N	0.000036	0.00029
Total Cyanide to Ammonia-N	0.00013	0.0011
WAD CN to ammonia	0.000036	0.00029
Cyanate (CNO) to Ammonia-N	0.034	0.28
Ammonia-N oxidation to NO_2-N	0.0044	0.036
NO_2-N oxidation to NO_3-N	0.00023	0.0012
Denitrification (NO_3-N to N_2)	0.0012	0.0023

It should furthermore be noted that phosphorus will also be removed from solution through biological uptake. Because of the comparatively low overall concentration of phosphorus, its removal was not included in the calculations.

Thiocyanate (SCN^-) is also expected to be present in the tailings process waters. Degradation of thiocyanate would also contribute to ammonia loading. However, aging test data suggests that the rate of thiocyanate degradation would be very slow. Therefore, degradation of thiocyanate to ammonia was not considered in the modelling.

4 Discharge Scenarios/Water Management Options

4.1 Operations

The model was run for the three following scenarios to provide a range of potential TIA discharge water quality and enable the development of appropriate discharge strategies to ensure compliance with the proposed discharge limits (Table 4-1) under a range of conditions.

- Base case groundwater inflows from mine workings:
  - Groundwater from underground routed to TIA starting in year 5 to year 7 (2 years of operation plus 6 months post-operations);
  - Year 5 groundwater flows = 3500 m^3/day, Year 2 groundwater flows = 7000 m^3/day; and
  - During this period additional inflow from drill holes.
- Low flow groundwater inflows from mine workings:
  - Groundwater from underground routed to TIA starting in year 5 to year 7 (2 years of operation plus 6 months post-operations);
  - During this period groundwater flows = 1000 m^3/day; and
  - During this period additional inflow from drill holes.
- No groundwater inflow from the mine workings.

For all scenarios, the following are the key components of the proposed discharge strategy.

- Operate TIA with a maximum operating water level of 32.5 m (1 m below the actual 33.5 m FSL) when concentrations in TIA are suitable for discharge.
- Discharge compliant effluent at 120 L/s.

- For periods of time when concentrations exceed discharge limits, cease discharge and operate TIA with the maximum operating water level at the FSL (33.5 m) until such time that concentrations in the TIA are compliant.
- Resume discharge at 120 L/s once concentrations in the TIA meet discharge limits and return to the maximum operating level of 32.5 m.
- There are no changes to the original design and configuration of the dams and TIA required and for all three scenarios, the TIA will operate within the original design criteria.

The ability to discharge water from the TIA was assessed based on meeting the following requirements which are summarized below in Table 4-1:

- The TIA discharge standards from current licence 2AM-DOH0713 (Part G, Clause 28); and
- TIA Marine Environment End-of-Pipe Targets back calculated based on meeting CCME in the marine environment (Rescan 2011).

Table 4-1: Summary of TIA Discharge Standards and Targets

Parameter	TIA Discharge Standard – Maximum Average Concentration (mg/L) (Part G. Clause 26)	TIA Marine End-of-Pipe Target (mg/L) (Rescan 2011)
pH	6.0 – 9.0	
Salinity (‰)		0 – 116
Total Suspended Solids	15	
Total Ammonia-N	6.0	
Nitrate-N		118
Total Cyanide (CN)	1.0	
Total Aluminum	1.0	
Total Arsenic	0.5	0.381
Total Cadmium		0.0025
Total Chromium		0.017
Total Copper	0.3	
Total Lead	0.2	
Total Mercury		0.00037
Total Nickel	0.5	
Total Zinc	0.5	

4.2 Closure

For all the groundwater scenarios, the following are the key components of the proposed closure water management strategy for the TIA:

1. For years 8 and 9, continue seasonal discharge from TIA at 120 L/s with an interim open water season minimum water level of 1.0 m. The objective of this interim minimum level is to drawdown the lake as much as possible during this period.
2. At the end of the open water season of year 9, the TIA has reached the target minimum water level.

3. Starting in November of year 9 and continuing annually from November to April, pump water from Doris Lake to the TIA. The annual pumping volume from Doris Lake is 480,000 m^3 based on the maximum allowable water withdrawal from Doris Lake as per the existing licence (Part E, Clause 1). The winter period was chosen for the pumping from Doris Lake as it would enable the maintenance of the required water level in the TIA to avoid freezing to the lake bottom and possible tailings re-suspension issues during spring freshet.
4. Seasonal pumping from the TIA to Roberts Bay (June to October) at 120 L/s from year 10 on.
5. Continuation of this annual cycle of flushing from Doris Lake and pumping to the ocean until the target closure criteria are met (Table 4-1).
6. Once the TIA water quality reaches the target closure criteria it is assumed that the lake will be returned to its natural elevation of 28.3 and all outflows will be routed to Doris Lake, following the natural open water season hydrograph of Tail Lake.
7. For waste rock, it is assumed that once underground operations are complete, the drainage from the waste rock will be routed underground for an interim period. Following this, it will be ultimately routed into the Doris Creek water shed.
8. Inputs from potential erosion of the previously flooded shoreline of Tail Lake are assumed to occur for the first 5 years of the flushing period: starting in year 9 when the lake level is at its minimum and continuing over the next 5 years.

For each scenario, the assessment of the timing of routing the TIA discharge back to Doris Lake is based on the water quality in the TIA meeting the TIA Closure Targets summarized in Table 4-2. These targets are based on the standards set out in Part G Clause 28 of the current water licence.

Table 4-2: Summary of TIA Closure Targets

Parameter	TIA Closure Target (mg/L)
Total Suspended Solids	15
Chloride	150
Free Cyanide	0.005
Total Cyanide	0.01
Total Ammonia-N	1.54
Nitrate-N	2.9
Nitrite-N	0.06
Total Aluminum	0.10
Total Arsenic	0.005
Total Cadmium	0.000017
Total Chromium (VI)	0.001
Total Copper	0.002
Total Iron	0.3
Total Lead	0.001

Parameter	TIA Closure Target (mg/L)
Total Mercury	0.000026
Total Molybdenum	0.073
Total Nickel	0.025
Total Selenium	0.001
Total Silver	0.0001
Total Thallium	0.0008
Total Zinc	0.5

5 Predicted Results

The model has been run on a monthly time step for a period of 300 months or 24 years. As described in Section 2.3.1 the model was run stochastically varying the annual precipitation and subsequently annual runoff and provides statistical summaries of the predicted monthly results. For the purposes of assessing the model predictions for both water balance and water quality predictions the 90th percentile values have been used. For water balance predictions this corresponds to the 90^{th} percentile flow conditions. For the water quality predictions, the 90^{th} percentile TIA water quality predictions correspond to the 10^{th} percentile flow conditions (low precipitation and runoff).

For each of the scenarios the following sections summarize the water balance and water quality predictions for operations, closure and post closure including:

- Predicted TIA water volume and level;
- Predicted loading contributions to the TIA for key parameters;
- Predicted TIA discharge water quality and timing; and
- Predicted timing for meeting long-term closure targets.

The predicted water quality in the TIA discharge for each scenario is presented in the following sections for both the operational and closure periods. The minimum and maximum 90^{th} percentile concentrations are provided for each along with the TIA discharge limits and the TIA Marine Discharge Targets. Any exceedences about the discharge limits and targets are highlighted. For all scenarios, ammonia-N is the key parameter driving the ability to discharge from the TIA to the marine environment. Therefore the timing of discharge from the TIA for each of the scenarios is driven by when the predicted concentrations of ammonia-N exceed the discharge limit of 6 mg/L.

5.1 Base Case Groundwater Inflows

5.1.1 Discharge Strategy – Base Case Groundwater Inflows

The specific discharge strategy for the Base Case groundwater scenario is as follows based on the predicted 90^{th} percentile water quality in the TIA.

- Year-round discharge of effluent from TIA at 120 L/s starts in year 5 (year 3 of operations) until end of year 7 except during periods of elevated ammonia-N concentrations.
- To ensure compliance with the 6 mg/L ammonia-N discharge limit, the model predicts that the discharge from the TIA must be shut down during the periods of elevated concentrations of ammonia-N, primarily during under-ice discharge conditions:

- February, year 6
- January to March, year 7

- During this period of discharge shut-down the model predicts (Figure 5-1) that there is sufficient capacity to store the additional water with the predicted 90th percentile water level in the pond remaining below the target operating water level of 32.5 (90th percentile flow conditions).
- During operations, the TIA is predicted to reach a maximum (90th percentile) elevation of about 31.8 m, resulting in a maximum rise of approximately 3.5 m from the original lake elevation, within the current design criteria of the TIA.
- Seasonal discharge of compliant effluent at 120 L/s starting in year 8 as per the closure discharge water management strategy described in Section 4.2.
- The flushing period during closure for the Base Case Groundwater Inflow scenario is driven by chloride concentrations in the TIA. The model shows that in order to meet the target closure criteria, the TIA would need to be flushed until approximately year 16. However, further refinement, including an assessment of the relative benefits of achieving this goal versus the potential impacts of prolonged water use and discharges from this facility need to be considered in the development of closure plans.

5.1.2 Predicted TIA Discharge Water Quality – Base Case Groundwater Inflows

The predicted water quality in the TIA discharge for the Base Case Groundwater Inflow scenario is summarized in Table 5-1 for both the operational and closure periods. During both the operational and closure periods the predicted 90th percentile water quality in the TIA discharge meets both the TIA discharge limits and the TIA marine discharge targets. The following is a discussion of some of the key parameters of concern in the TIA and associated discharge.

Ammonia-N

As discussed previously, the predicted ammonia-N concentrations in the TIA drive the timing of the discharge from the TIA to the marine environment. To ensure compliance with the 6 mg/L discharge limit for ammonia-N during operations, it is predicted that the discharge will need to be temporarily shut down during periods of elevated ammonia-N concentrations during under-ice conditions. During operations, the predicted range of ammonia-N concentrations in the discharge remain below the discharge limit of 6 mg/L, ranging from 0.6 mg/L to 4.3 mg/L (Figure 5.2). During closure, the predicted concentrations of ammonia are significantly lower, primarily due to the removal via natural degradation process, ranging from 0.0005 to 0.37 mg/L. The predicted concentrations of ammonia-N in the TIA reach the target closure concentrations at the start of the flushing period.

The distribution of annual source loading of ammonia-N to the TIA during operations is illustrated in Figure 5-3. Prior to the introduction of the groundwater to TIA, the mill effluent, including degradation of cyanide species and cyanate in the mill effluent, contributes the majority of the load of ammonia-N to the TIA. Once the saline groundwater is routed to the TIA, both the loading from groundwater and mill effluent are the primary sources of ammonia-N loading to the TIA.

Chloride

Due to the large inflow of saline groundwater in the Base Case Groundwater scenario, the predicted concentrations of chloride in the TIA discharge are high, although the resulting salinity of the discharge water is well below the marine discharge targets (Figure 5-4). It is the chloride levels in the TIA discharge that determine the years required for flushing with Doris Lake water, reaching the target closure criteria in year 16. The distribution of annual source loading of chloride to the TIA during operations is illustrated in Figure 5-5. As expected the primary source of chloride loading to the TIA is the saline groundwater from the underground mine once mining proceeds into the Doris Central and Doris Connector deposits.

Copper

During operations and closure the copper concentrations are well below the discharge limit of 0.3 mg/L, ranging from 0.005 to 0.063 mg/L during operations and 0.001 to 0.026 mg/L during closure (Figure 5-6). The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-7. The primary source of copper loading to the TIA is the mill effluent during operations.

Zinc

During operations and closure the zinc concentrations are well below the discharge limit of 0.5 mg/L, ranging from 0.07 to 0.17 mg/L during operations and 0.003 to 0.10 during closure (Figure 5-8). The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-9. Similar to copper, the primary source of zinc loading to the TIA is the mill effluent, followed by the saline groundwater, once routed to the TIA.

Table 5-1: Summary of Predicted TIA Discharge Water Quality – Base Case Groundwater Scenario

Parameter	Range of TIA Operational Discharge Concentrations (90th Percentile concentrations)		Range of TIA Closure Discharge Concentrations (90th Percentile)		TIA Discharge Standards (Part G. Section 26)	TIA Marine Discharge Targets[b]
	Minimum	Maximum	Minimum	Maximum		
TDS	890	41000	340	24000		
Free Cyanide	0.0000089	0.00082	9.4E-27	0.0000038		
Total Cyanide	0.000083	0.0062	0.000028	0.00025	1	
WAD Cyanide	0.001	0.12	1.1E-24	0.00044		
Cyanate	0.056	13	6E-23	0.024		
Thiocyanate	12	39	0.097	11		
Sulphate	49	1700	13	1000		
Chloride	2100	18000	150	11000		
Salinity[a]	3.8	32	0.27	19		0 - 116
Ammonia-N	0.6	4.3	0.00046	0.37	6	
Nitrate-N	1.2	5.6	0.00039	1		118
Nitrite-N	0.21	0.84	0.00018	0.37		
Alkalinity (as $CaCO_3$)	76	130	27	79		
Hardness (as $CaCO_3$)	190	11000	95	6400		
Aluminum	0.064	0.15	0.059	0.37		
Antimony	0.013	0.041	0.00015	0.014		
Arsenic	0.0019	0.0058	0.00045	0.0049	0.5	0.381
Barium	0.0047	0.16	0.0036	0.094		
Beryllium	0.0005	0.0012	0.000025	0.00084		
Boron	0.068	2.7	0.035	1.6		
Cadmium	0.000074	0.00019	0.0000079	0.00018		0.0025
Calcium	980	4700	34	2800		
Chromium	0.0018	0.0046	0.00034	0.0018		0.017
Cobalt	0.0064	0.019	0.00012	0.0057		
Copper	0.0053	0.064	0.0014	0.026	0.3	
Iron	0.31	4.4	0.14	2.6		
Lead	0.0005	0.0017	0.000065	0.0011	0.2	
Manganese	0.0062	1.7	0.017	1		
Mercury	0.000014	0.000027	0.0000029	0.00003		0.00037
Molybdenum	0.0072	0.036	0.00033	0.022		
Nickel	0.0077	0.047	0.00055	0.007	0.5	
Selenium	0.002	0.0051	0.00074	0.0035		
Silver	0.0003	0.0047	0.000024	0.002		
Thallium	0.000077	0.00017	0.000015	0.00012		
Uranium	0.00016	0.00033	0.000033	0.00037		
Vanadium	0.0017	0.0062	0.00066	0.0036		
Zinc	0.071	0.17	0.0036	0.1	0.5	

Notes:

a. Predicted salinity calculated from predicted chloride concentration (Salinity = 1.80655 X [Chloride] X [Chloride]

b. Based on values prepared by Rescan for 120 L/s discharge (Rescan 2011).

Bold above either of the standards/thesholds

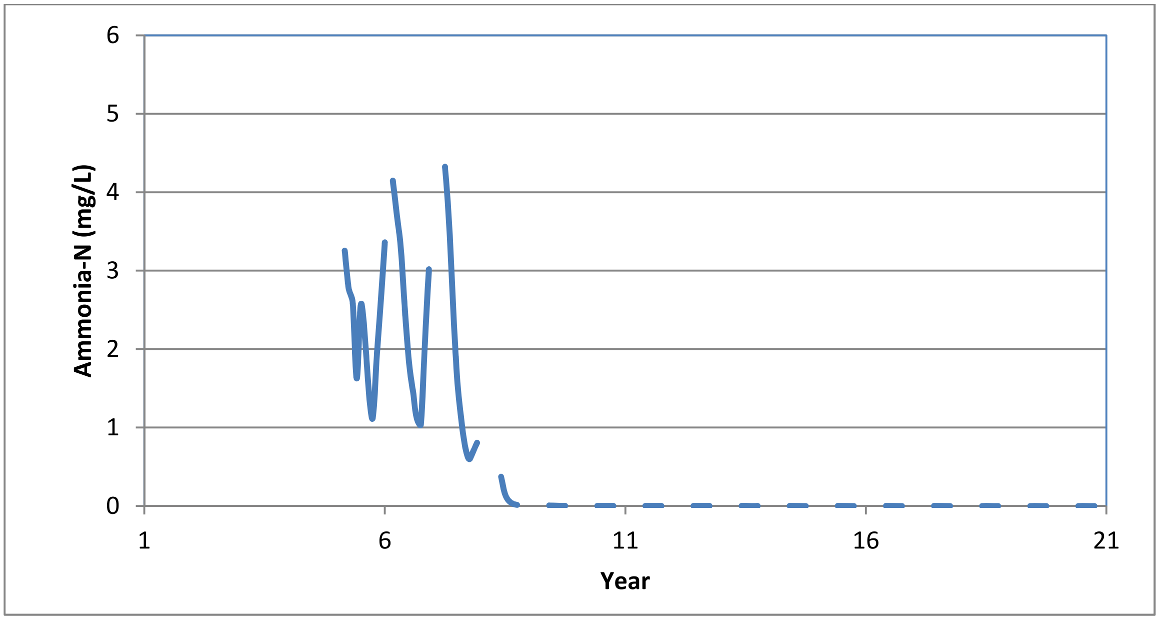

Figure 5-1: Base Case Groundwater Scenario – Time Trends – TIA Discharge Ammonia-N (mg/L)

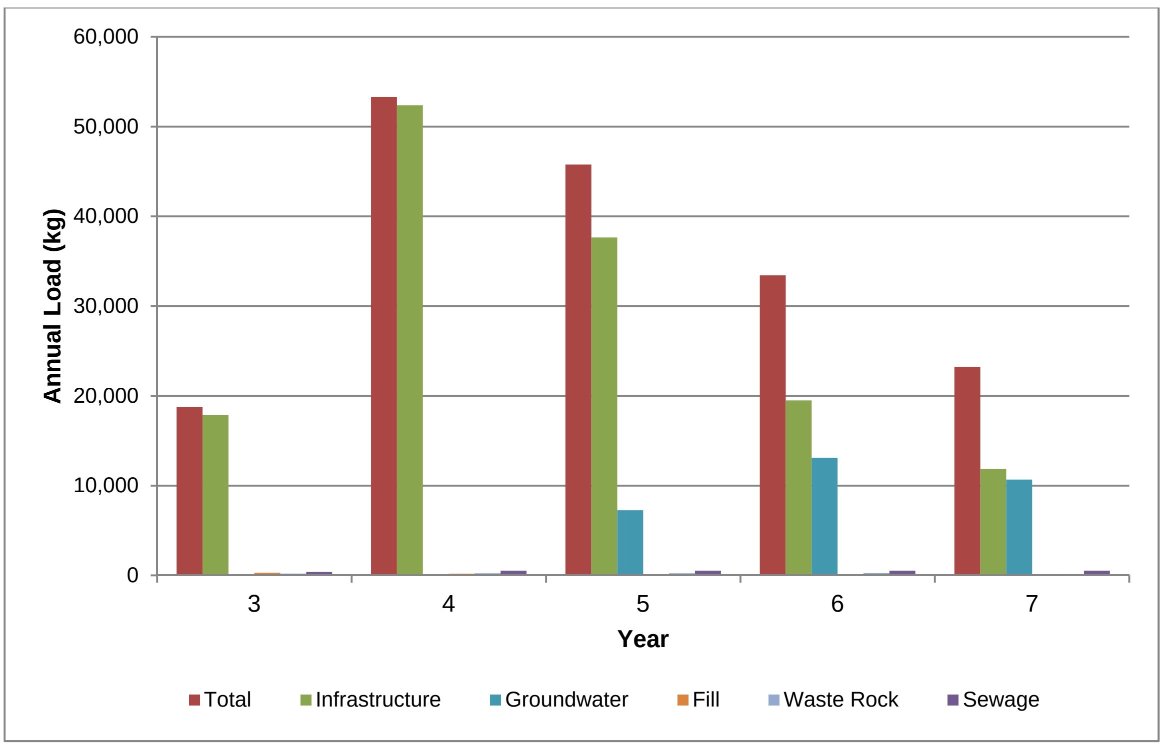

Figure 5-2: Base Case Groundwater Scenario – Annual Load Distribution – Ammonia-N (kg)

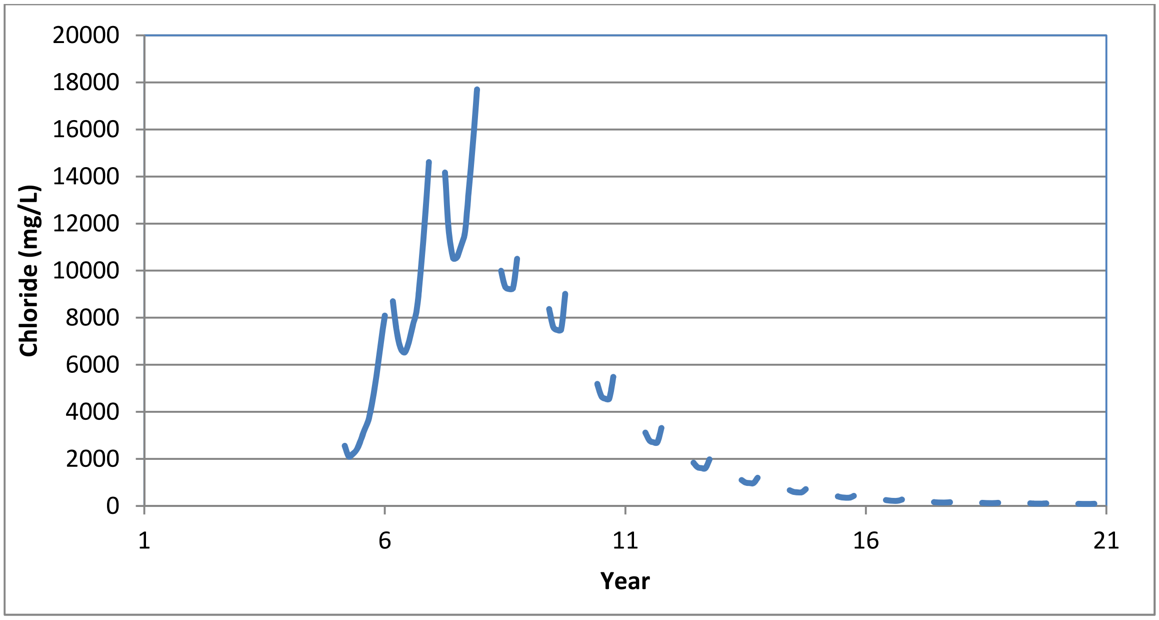

Figure 5-3: Base Case Groundwater Scenario – Time Trends – TIA Discharge Chloride (mg/L)

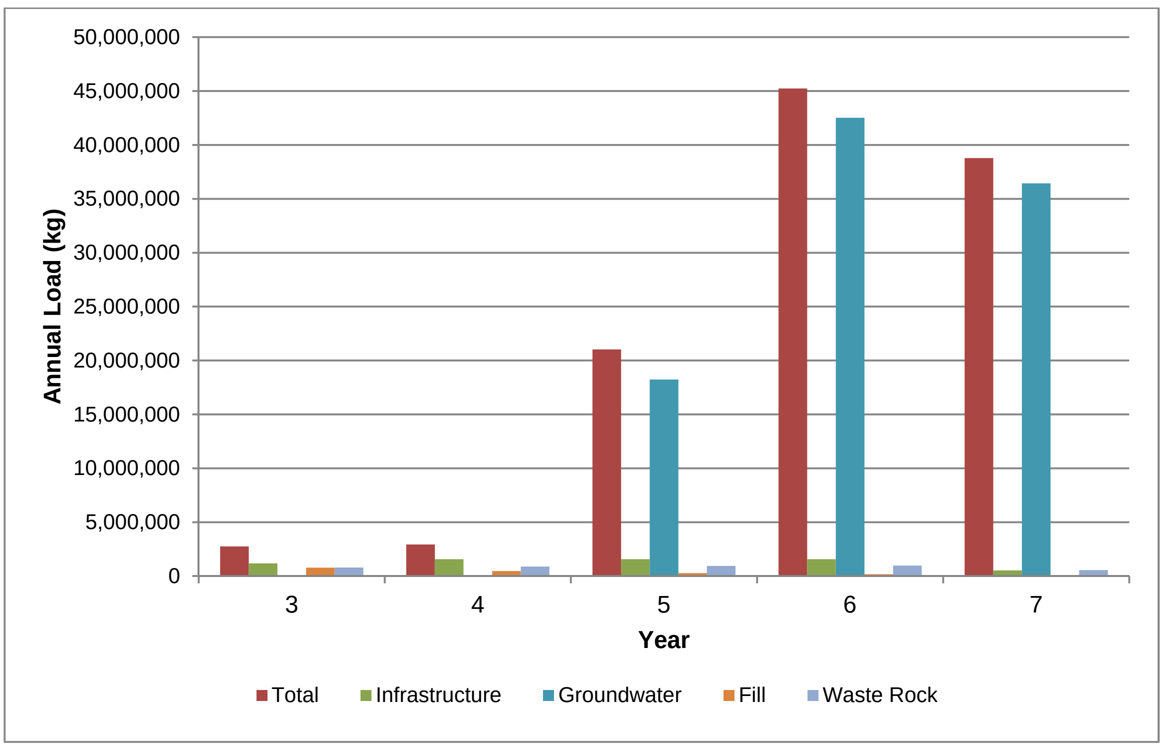

Figure 5-4: Base Case Groundwater Scenario – Annual Load Distribution – Chloride (kg)

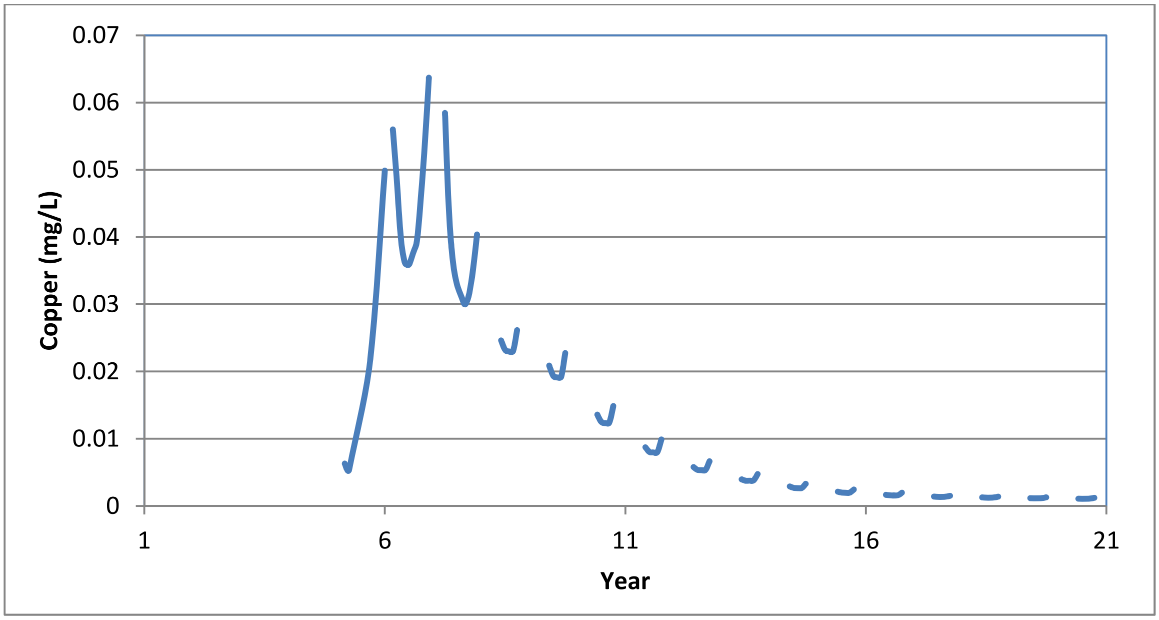

Figure 5-5: Base Case Groundwater Scenario – Time Trends – TIA Discharge Copper (mg/L)

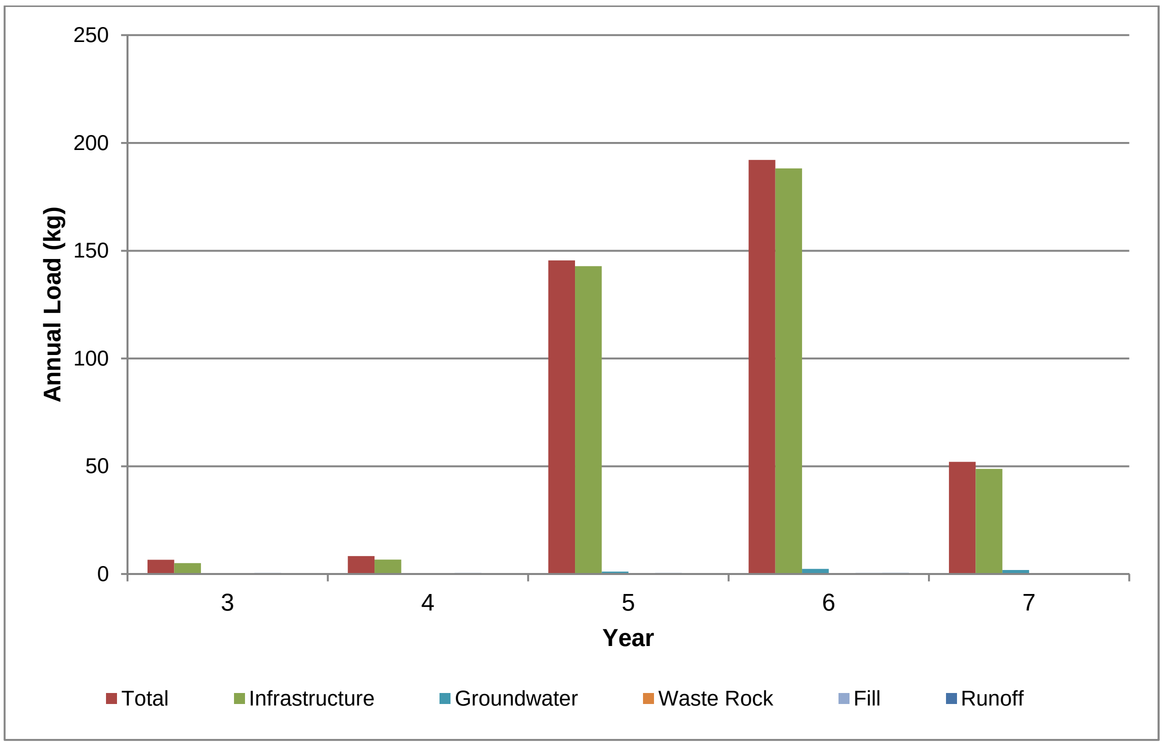

Figure 5-6: Base Case Groundwater Scenario – Annual Load Distribution – Copper (kg)

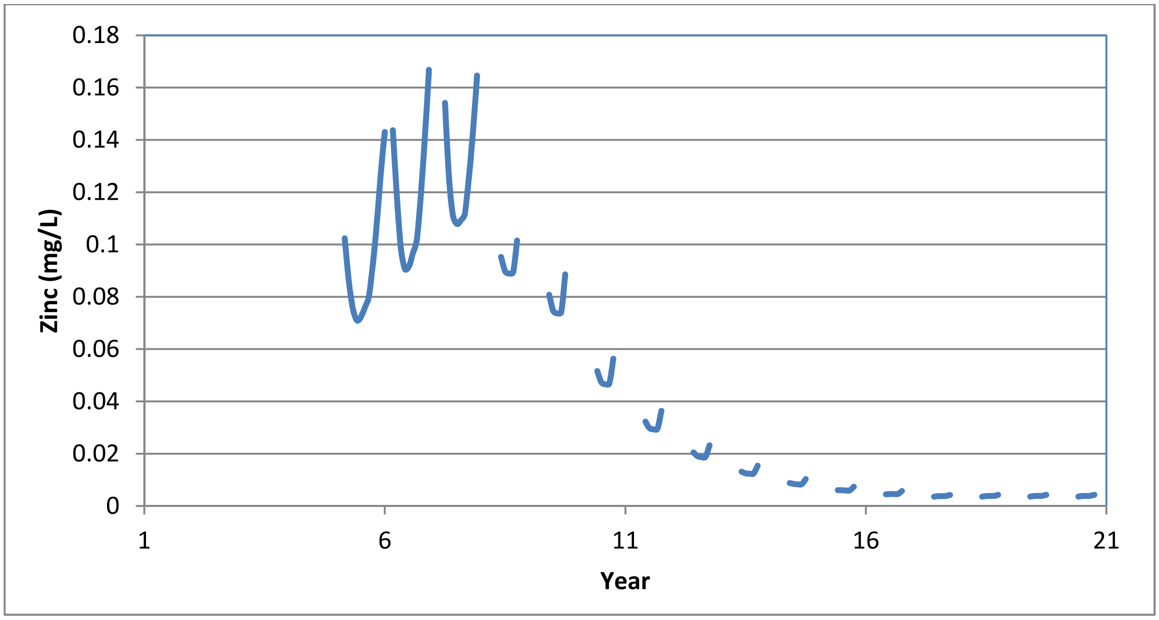

Figure 5-7: Base Case Groundwater Scenario – Time Trends – TIA Discharge Zinc (mg/L)

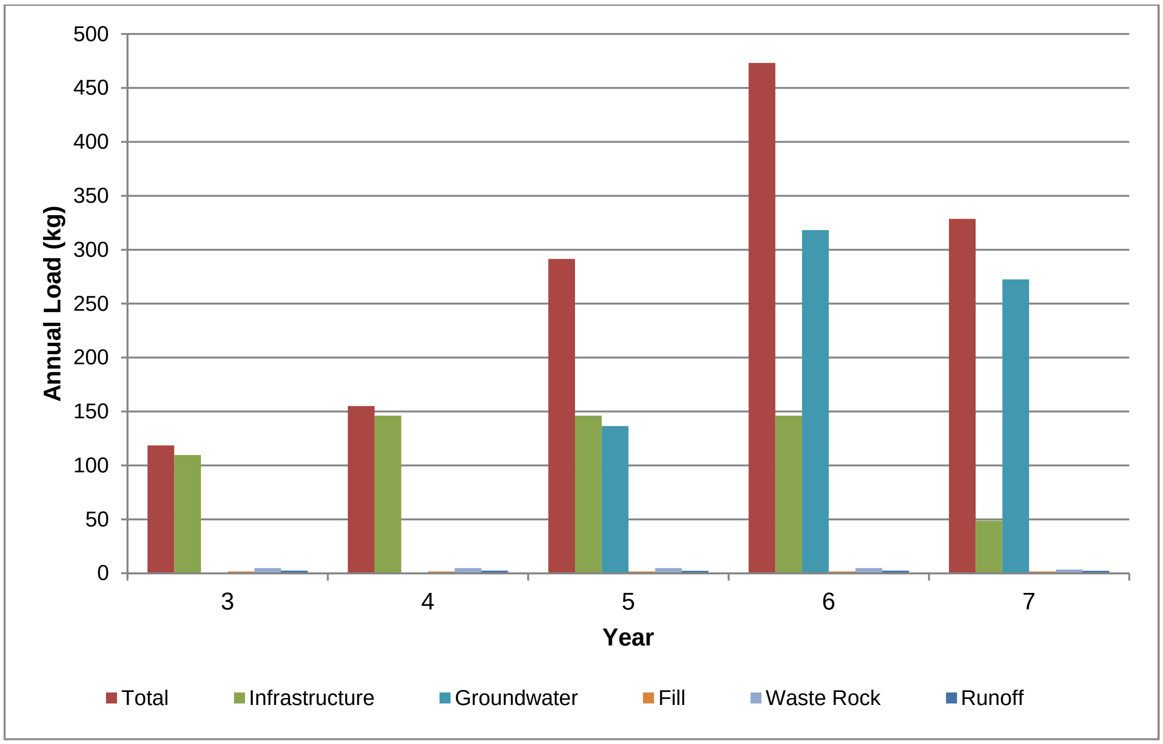

Figure 5-8: Base Case Groundwater Scenario – Annual Load Distribution – Zinc (kg)

5.2 Low Flow Groundwater Inflows

5.2.1 Discharge Strategy – Low Flow Groundwater Inflows

The specific discharge strategy for the Low Flow groundwater scenario is as follows based on the predicted 90th percentile water quality in the TIA.

- Year-round discharge of effluent from TIA at 120 L/s starts in year 5 (year 3 of operations) until end of year 7 except during periods of elevated ammonia-N concentrations
- To ensure compliance with the 6 mg/L ammonia-N discharge limit, the model predicts that the discharge from the TIA must be shut down during the periods of elevated concentrations of ammonia-N, primarily during under-ice discharge conditions:
  - December to April, year 6 and year 7
- During this period of discharge shut-down the model predicts (Figure 5-1) that there is sufficient capacity to store the additional water with the predicted 90th percentile water level in the pond remaining below the target operating water level of 32.5 (90th percentile flow conditions).
- During operations, the TIA is predicted to reach a maximum (90th percentile) elevation of about 31.8 m, resulting in a maximum rise of approximately 3.5 m from the original lake elevation, within the current design criteria of the TIA.
- Seasonal discharge of compliant effluent at 120 L/s starting in year 8 as per the closure discharge water management strategy described in Section 4.2.
- The flushing period during closure for the Base Case Groundwater Inflow scenario is driven by chloride, aluminum and copper concentrations in the TIA. The model shows that in order to meet the target closure criteria, the TIA would need to be flushed until approximately year 15.

5.2.2 Predicted TIA Discharge Water Quality – Low Flow Groundwater Inflows

The predicted water quality in the TIA discharge for the Low Flow Groundwater Inflow scenario is summarized in Table 5-2 for both the operational and closure periods. During both the operational and closure periods the predicted 90th percentile water quality in the TIA discharge meets both the TIA discharge limits and the TIA marine discharge targets. The following is a discussion of some of the key parameters of concern in the TIA and associated discharge.

Ammonia-N

Similar to the Base Case groundwater scenario, the predicted ammonia-N concentrations in the TIA drive the timing of the discharge from the TIA to the marine environment. To ensure compliance with the 6 mg/L discharge limit for ammonia-N during operations, it is predicted that the discharge will need to be temporarily shut down during periods of elevated ammonia-N concentrations during under-ice conditions. During operations, the predicted range of ammonia-N concentrations in the discharge remain below the discharge limit of 6 mg/L, ranging from 0.7 mg/L to 4.5 mg/L (Figure 5.10). During closure, the predicted concentrations of ammonia are significantly lower, primarily due to the removal via natural degradation process, ranging from 0.0007 to 0.53 mg/L. The predicted concentrations of ammonia-N in the TIA reach the target closure concentrations at the start of the flushing period.

The distribution of annual source loading of ammonia-N to the TIA during operations is illustrated in Figure 5-11. Prior to the introduction of the groundwater to TIA, the mill effluent, including degradation of cyanide species and cyanate in the mill effluent, contribute the majority of the ammonia-N load to the TIA. Once the saline groundwater is routed to the TIA, the loading from mill effluent still remains the dominant source of ammonia-N loading to the TIA.

Chloride

Although the groundwater flow is lower for this scenario, the predicted concentrations of chloride in the TIA discharge remain high, although the resulting salinity of the discharge water is well below the marine discharge targets (Figure 5-12). The distribution of annual source loading of chloride to the TIA during operations is illustrated in Figure 5-13. The primary source of chloride loading to the TIA is the saline groundwater from the underground mine once mining proceeds into the Doris Central and Doris Connector deposits. Prior to that it is the mill effluent that contributes the dominant loading of chloride to the TIA, primarily due to the brine fluid losses associated with the ore and subsequently processed tailings.

Copper

Similar to the Base Case groundwater scenario, during operations and closure the copper concentrations are below the discharge limit of 0.3 mg/L, ranging from 0.005 to 0.1 mg/L during operations and 0.003 to 0.05 during closure (Figure 5-14). As expected, due to the lower volume of groundwater into the TIA, the concentrations of copper, and other non-groundwater associated parameters are higher than the Base Case scenario due to the reduction in available dilution that is provided by the groundwater inflows. The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-15. The primary source of copper loading to the TIA is the mill effluent during operations.

Zinc

During operations and closure the zinc concentrations are well below the discharge limit of 0.5 mg/L, ranging from 0.07 to 0.17 mg/L during operations and 0.005 to 0.08 during closure (Figure 5-16). The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-17. Similar to copper, the primary source of zinc loading to the TIA is the mill effluent, followed by the saline groundwater, once routed to the TIA.

Table 5-2: Summary of Predicted TIA Discharge Water Quality – No Flow Groundwater Scenario

Parameter	Range of TIA Operational Discharge Concentrations (90th Percentile concentrations)		Range of TIA Closure Discharge Concentrations (90th Percentile)		TIA Discharge Standards (Part G. Section 26)	TIA Marine Discharge Targets[b]
	Minimum	Maximum	Minimum	Maximum		
TDS	890	19000	330	9000		
Free Cyanide	0.000017	0.0012	3.8E-22	0.0000077		
Total Cyanide	0.00016	0.0083	0.000041	0.00025	1	
WAD Cyanide	0.002	0.14	4.4E-20	0.0009		
Cyanate	0.11	13	2.4E-18	0.05		
Thiocyanate	25	46	0.55	22		
Sulphate	49	750	12	360		
Chloride	1800	10000	190	5000		
Salinity[a]	3.3	19	0.35	9		0 - 116
Ammonia-N	0.78	4.5	0.00066	0.53	6	
Nitrate-N	1.2	8.6	0.0004	1.5		118
Nitrite-N	0.32	0.97	0.00024	0.62		
Alkalinity (as $CaCO_3$)	76	150	28	73		
Hardness (as $CaCO_3$)	190	4600	90	2300		
Aluminum	0.081	0.26	0.13	0.4		
Antimony	0.024	0.054	0.00071	0.026		
Arsenic	0.0022	0.011	0.00079	0.0066	0.5	0.381
Barium	0.0047	0.086	0.0037	0.042		
Beryllium	0.00063	0.0017	0.000073	0.0011		
Boron	0.068	1.2	0.041	0.58		
Cadmium	0.000073	0.00028	0.00002	0.00022		0.0025
Calcium	840	3100	48	1500		
Chromium	0.0028	0.0059	0.0005	0.0029		0.017
Cobalt	0.012	0.023	0.0004	0.011		
Copper	0.0053	0.11	0.0026	0.052	0.3	
Iron	0.31	2.3	0.19	1.1		
Lead	0.00051	0.0028	0.00013	0.0015	0.2	
Manganese	0.0062	0.74	0.017	0.36		
Mercury	0.000016	0.000036	0.0000076	0.000033		0.00037
Molybdenum	0.0068	0.036	0.0006	0.017		
Nickel	0.015	0.047	0.0009	0.013	0.5	
Selenium	0.002	0.0096	0.001	0.0048		
Silver	0.0003	0.0079	0.00011	0.0038		
Thallium	0.00007	0.00015	0.000019	0.0001		
Uranium	0.00016	0.00045	0.000062	0.0004		
Vanadium	0.003	0.0076	0.0012	0.0049		
Zinc	0.069	0.17	0.0053	0.083	0.5	

Notes:
a. Predicted salinity calculated from predicted chloride concentration (Salinity = 1.80655 X [Chloride]
b. Based on values prepared by Rescan for 120 L/s discharge (Rescan 2011).
Bold above either of the standards/thesholds

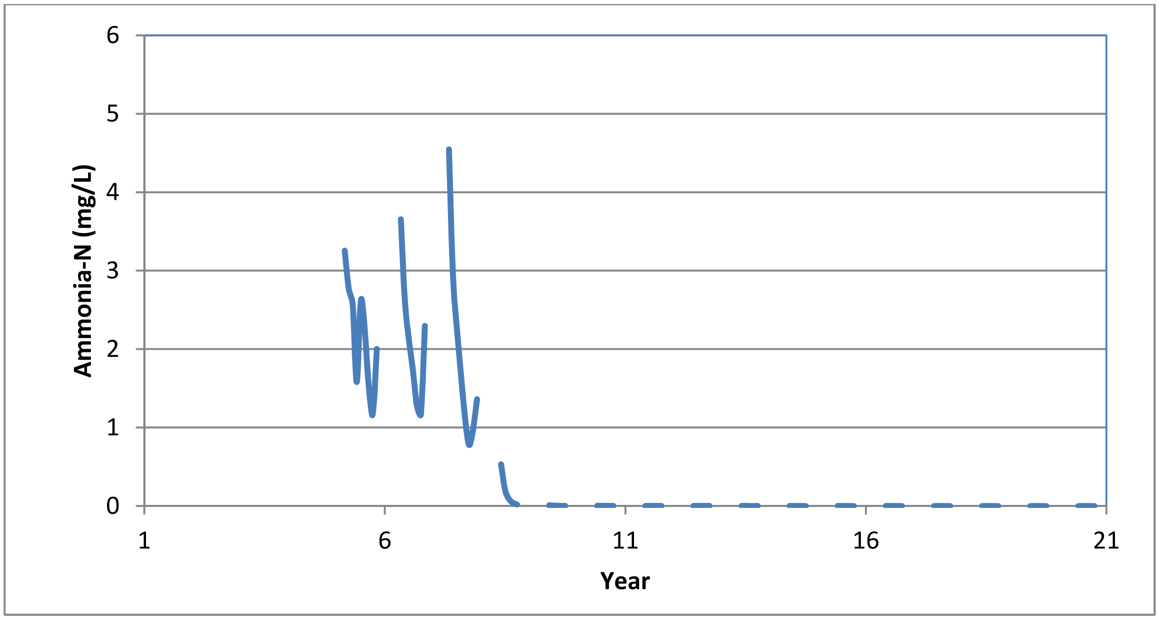

Figure 5-9: Low Flow Groundwater Scenario – Time Trends – TIA Discharge Ammonia-N (mg/L)

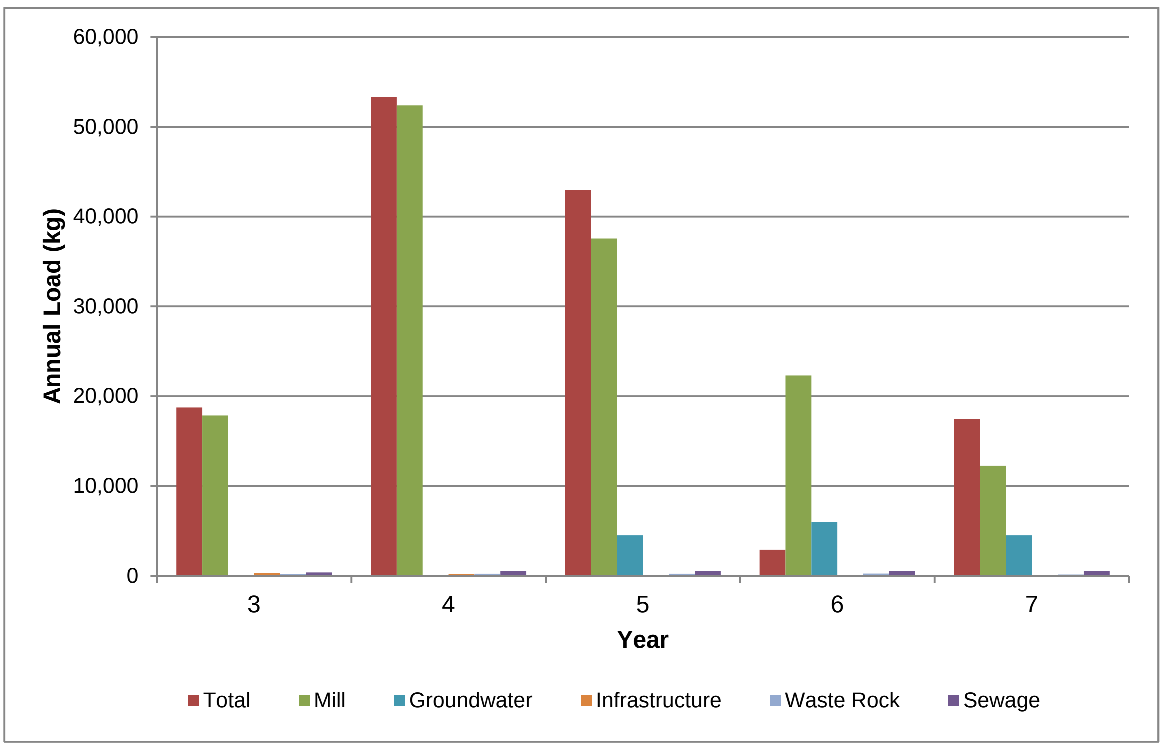

Figure 5-10: Low Flow Groundwater Scenario – Annual Load Distribution – Ammonia-N (kg)

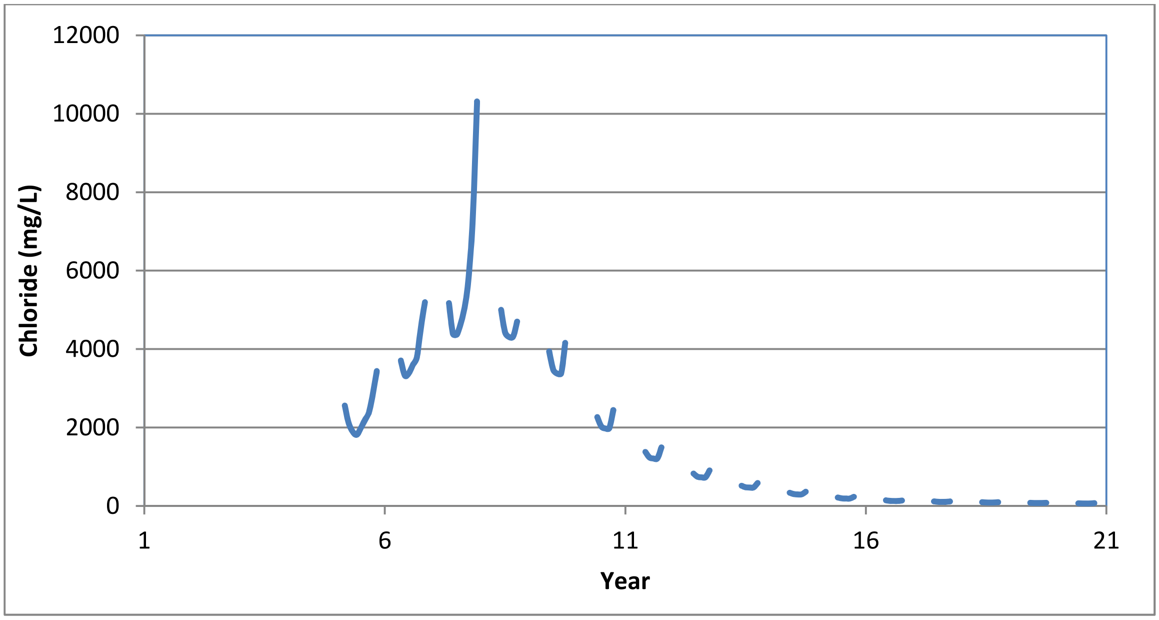

Figure 5-11: Low Flow Groundwater Scenario – Time Trends – TIA Discharge Chloride (mg/L)

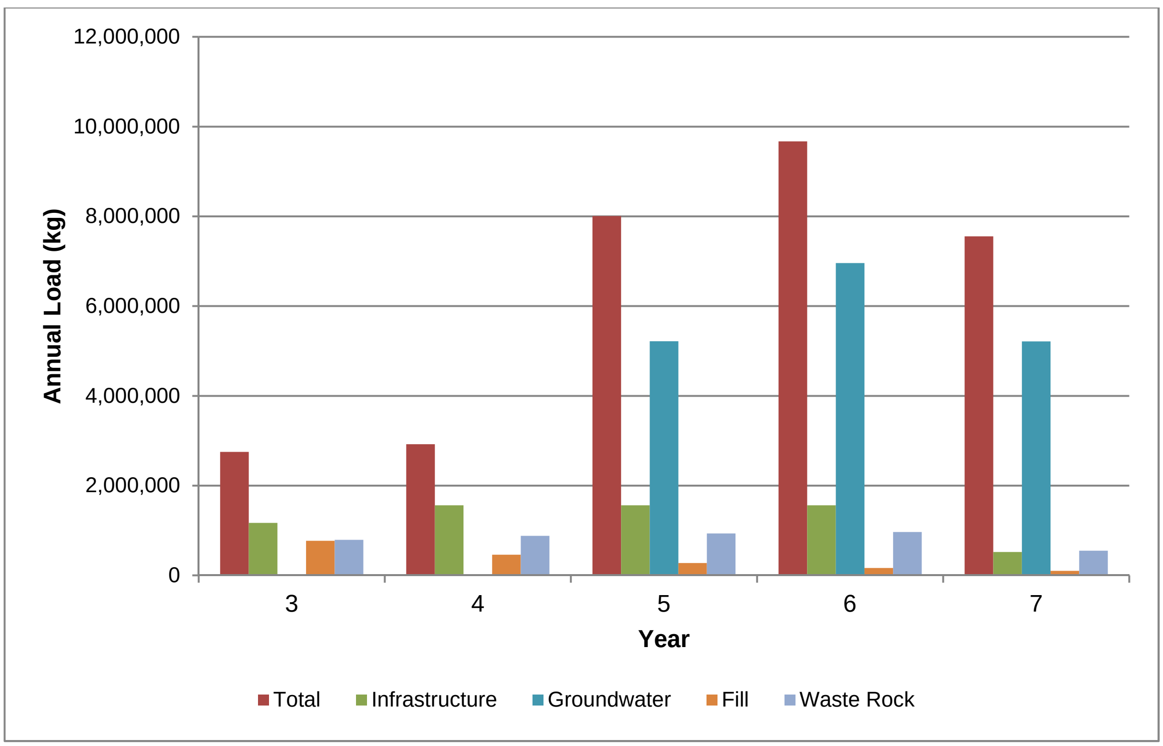

Figure 5-12: Low Flow Groundwater Scenario – Annual Load Distribution – Chloride (kg)

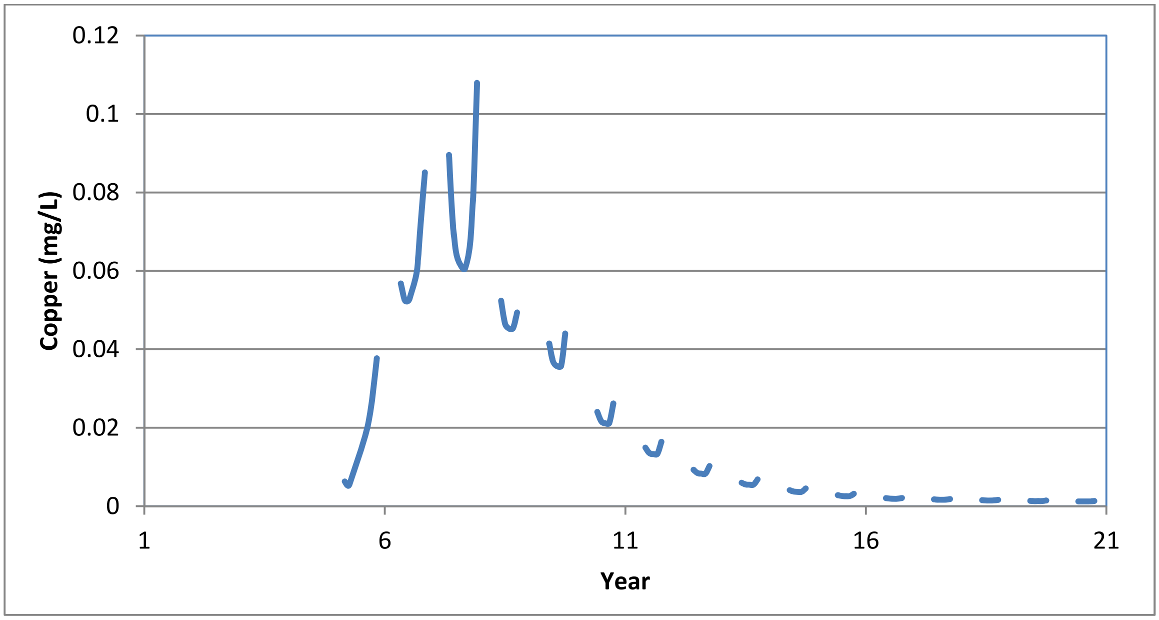

Figure 5-13: Low Flow Groundwater Scenario – Time Trends – TIA Discharge Copper (mg/L)

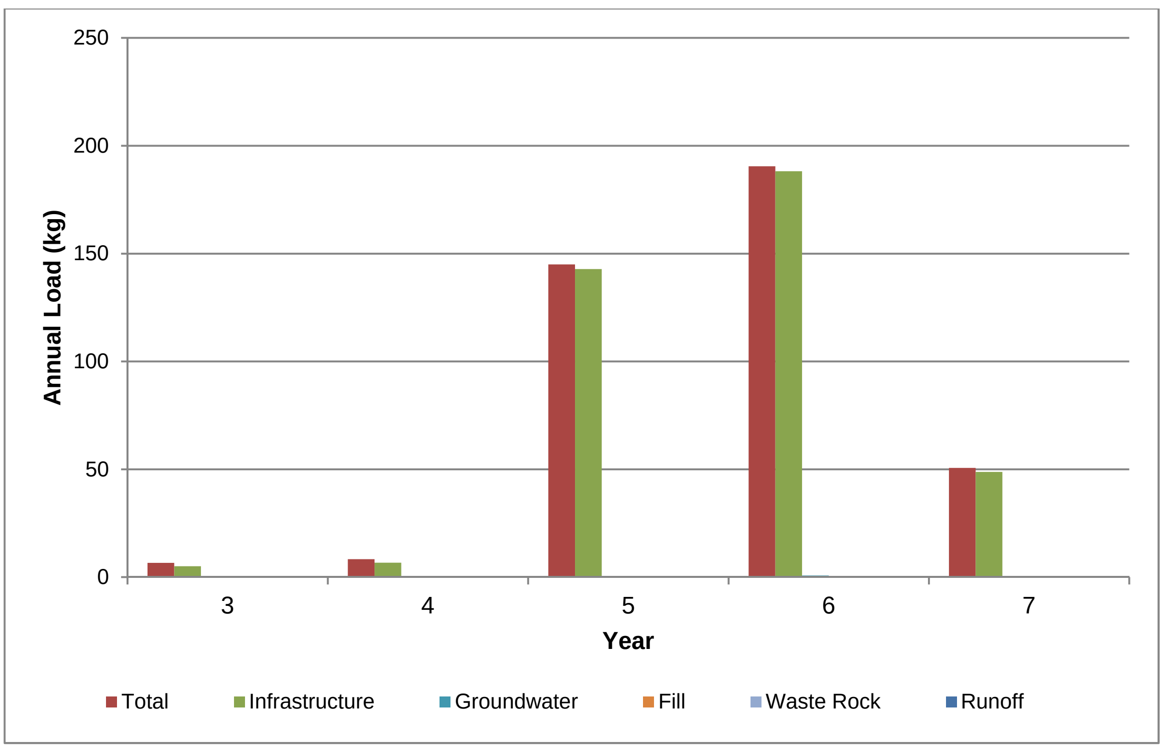

Figure 5-14: Low Flow Groundwater Scenario – Annual Load Distribution – Copper (kg)

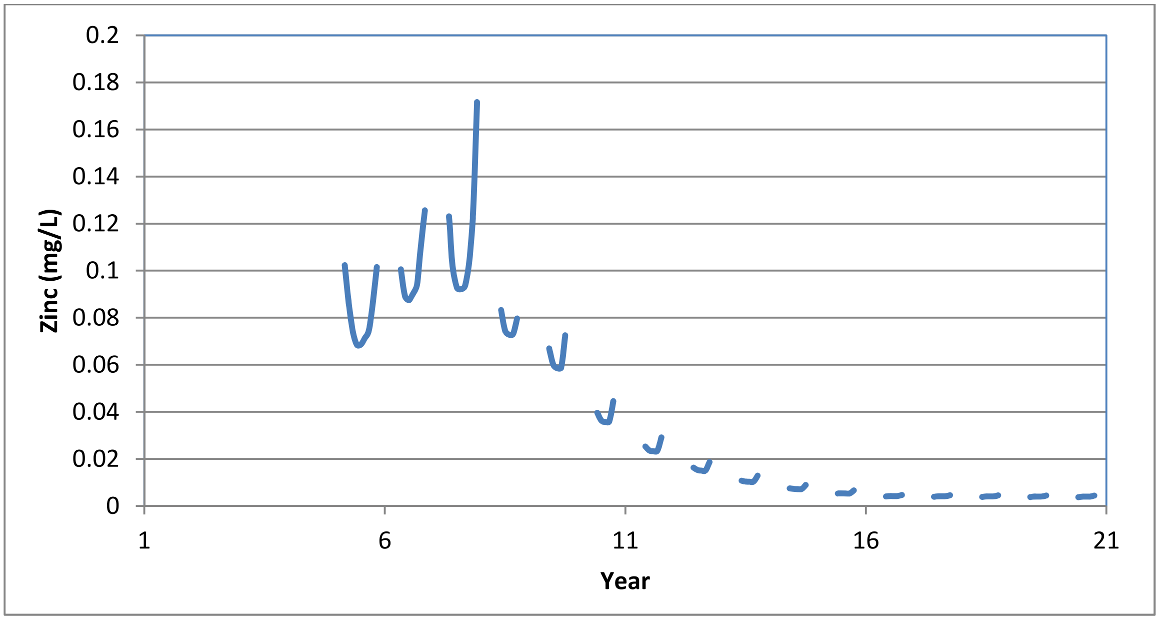

Figure 5-15: Low Flow Groundwater Scenario – Time Trends – TIA Discharge Zinc (mg/L)

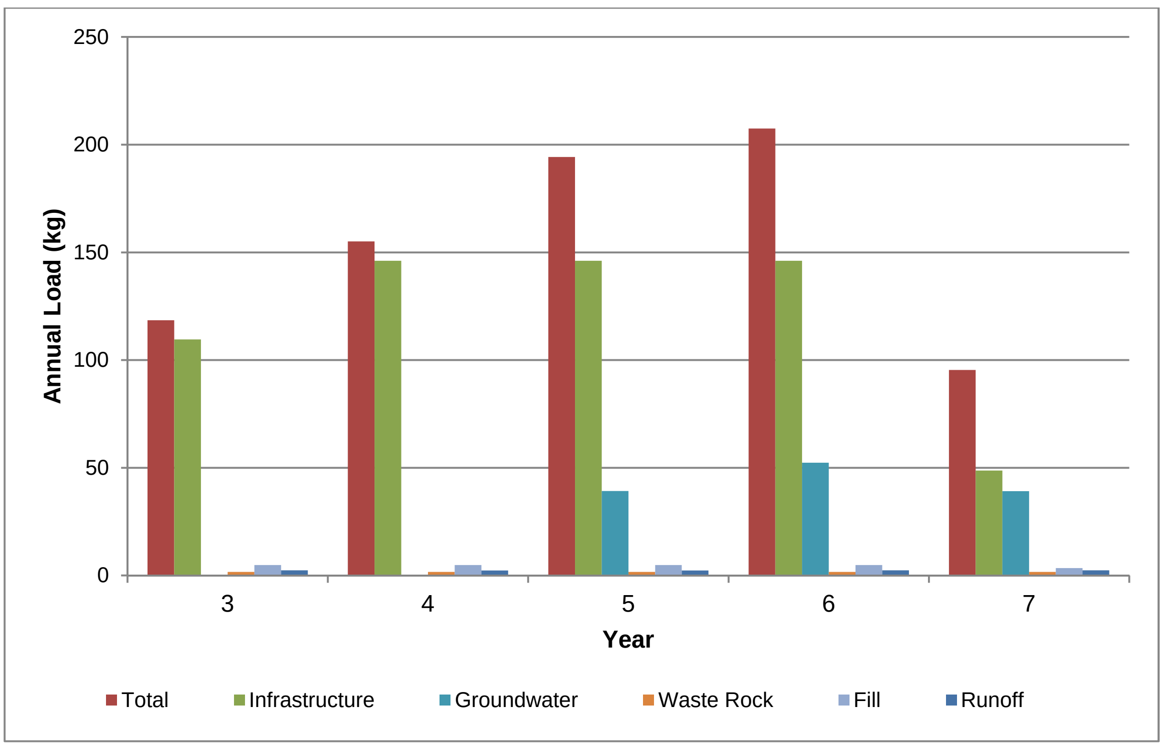

Figure 5-16: Low Flow Groundwater Scenario – Annual Load Distribution – Zinc (kg)

5.3 No Groundwater Inflows

5.3.1 Discharge Strategy – No Groundwater Inflows

The specific discharge strategy for the No Flow groundwater scenario is as follows based on the predicted 90th percentile water quality in the TIA.

- Discharge of compliant effluent from TIA at 120 L/s starts in year 5 from March to October.
- For year 6 and year 7, seasonal discharge of compliant effluent at 120 L/s from June to October.
- During operations, the TIA is predicted to reach a maximum (90th percentile) elevation of about 31.8 m, resulting in a maximum rise of approximately 3.5 m from the original lake elevation, within the current design criteria of the TIA.
- Seasonal discharge of compliant effluent at 120 L/s starting in year 8 as per the closure discharge water management strategy described in Section 4.2.
- The flushing period during closure for the Base Case Groundwater Inflow scenario is driven by copper concentrations in the TIA. The model shows that in order to meet the target closure criteria, the TIA would need to be flushed until approximately year 16.

5.3.2 Predicted TIA Discharge Water Quality – No Groundwater Inflows

The predicted water quality in the TIA discharge for the No Flow Groundwater Inflow scenario is summarized in Table 5-3 for both the operational and closure periods. During both the operational and closure periods the predicted 90th percentile water quality in the TIA discharge meets both the TIA discharge limits and the TIA marine discharge targets. The following is a discussion of some of the key parameters of concern in the TIA and associated discharge.

Ammonia-N

During operations, the predicted range of ammonia-N concentrations in the discharge remain below the discharge limit of 6 mg/L, ranging from 0.6 mg/L to 3.3 mg/L (Figure 5.18). During closure, the predicted concentrations of ammonia are significantly lower, primarily due to the removal via natural degradation process, ranging from 0.0007 to 0.44 mg/L. The predicted concentrations of ammonia-N in the TIA reach the target closure concentrations at the start of the flushing period.

The distribution of annual source loading of ammonia-N to the TIA during operations is illustrated in Figure 5-19. During operations the mill effluent, including the degradation of cyanide species and cyanate from the mill effluent, is the primary contributor of ammonia-N loading to the TIA.

Chloride

Without the saline groundwater inflows, the predicted concentrations of chloride in the TIA discharge are lower than those predicted for the groundwater inflows (Figure 5-20). The distribution of annual source loading of chloride to the TIA during operations is illustrated in Figure 5-21. The primary source of chloride loading to the TIA for this scenario the mill effluent, brine fluid losses associated with the ore and subsequently processed tailings and chloride releases from waste rock from residual drilling brine all contribute similar chloride loadings to the TIA.

Copper

Similar to the Base Case groundwater scenario, during operations and closure the copper concentrations are below the discharge limit of 0.3 mg/L, ranging from 0.005 to 0.1 mg/L during operations and 0.002 to 0.08 during closure (Figure 5-22). As expected, due to the loss of groundwater inflow into the TIA, the concentrations of copper, and other non-groundwater associated parameters are higher than the Base Case scenario due to the reduction in available dilution that is provided by the groundwater inflows. The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-23. The primary source of copper loading to the TIA is the mill effluent during operations. For this scenario, it is the concentrations of copper in the TIA that drive the period required for flushing with Doris Lake water, reaching the target closure criteria in year 16.

Zinc

During operations and closure the zinc concentrations are well below the discharge limit of 0.5 mg/L, ranging from 0.07 to 0.12 mg/L during operations and 0.004 to 0.10 during closure (Figure 5-24). The distribution of annual source loading of total copper to the TIA during operations is illustrated in Figure 5-25. The primary source of zinc loading to the TIA is the mill effluent, contributing approximately 94% of the load during operations.

Table 5-3: Summary of Predicted TIA Discharge Water Quality – No Flow Groundwater Scenario

Parameter	Range of TIA Operational Discharge Concentrations (90th Percentile Concentrations)		Range of TIA Closure Discharge Concentrations (90th Percentile)		TIA Discharge Standards (Part G. Section 26)	TIA Marine Discharge Targets[b]
	Minimum	Maximum	Minimum	Maximum		
TDS	7.5	13	2.7	11		
Free Cyanide	0.000022	0.00084	3.2E-24	0.00001		
Total Cyanide	0.0002	0.0062	0.000041	0.00025	1	
WAD Cyanide	0.0027	0.12	4E-22	0.0013		
Cyanate	0.15	13	2.1E-20	0.067		
Thiocyanate	26	48	0.52	38		
Sulphate	37	59	4.1	49		
Chloride	1600	3000	96	2600		
Salinity[a]	2.9	5.4	0.17	4.7		0 - 116
Ammonia-N	0.61	3.3	0.00064	0.45	6	
Nitrate-N	0.86	4.7	0.0004	1.4		118
Nitrite-N	0.29	0.84	0.00024	0.59		
Alkalinity (as $CaCO_3$)	76	120	27	88		
Hardness (as $CaCO_3$)	150	270	38	220		
Aluminum	0.082	0.21	0.093	0.41		
Antimony	0.026	0.047	0.00059	0.039		
Arsenic	0.0022	0.0082	0.0006	0.0078	0.5	0.381
Barium	0.0047	0.024	0.003	0.02		
Beryllium	0.0007	0.0013	0.000047	0.0013		
Boron	0.053	0.1	0.024	0.11		
Cadmium	0.000073	0.00021	0.000013	0.00025		0.0025
Calcium	790	1300	24	1100		
Chromium	0.0029	0.0055	0.00042	0.0045		0.017
Cobalt	0.012	0.022	0.00034	0.018		
Copper	0.0053	0.11	0.0023	0.083	0.3	
Iron	0.26	0.6	0.14	0.58		
Lead	0.00051	0.0024	0.0001	0.002	0.2	
Manganese	0.006	0.027	0.0079	0.023		
Mercury	0.000016	0.00003	0.0000047	0.000038		0.00037
Molybdenum	0.0066	0.024	0.00041	0.019		
Nickel	0.024	0.047	0.00085	0.022	0.5	
Selenium	0.0021	0.0077	0.00087	0.0063		
Silver	0.0003	0.0077	0.000094	0.0061		
Thallium	0.000071	0.00012	0.000016	0.0001		
Uranium	0.00016	0.00031	0.000044	0.00044		
Vanadium	0.0037	0.0063	0.00087	0.0062		
Zinc	0.068	0.12	0.0043	0.099	0.5	

Notes:

a. Predicted salinity calculated from predicted chloride concentration (Salinity = 1.80655 X [Chloride]

b. Based on values prepared by Rescan for 120 L/s discharge (Rescan 2011).

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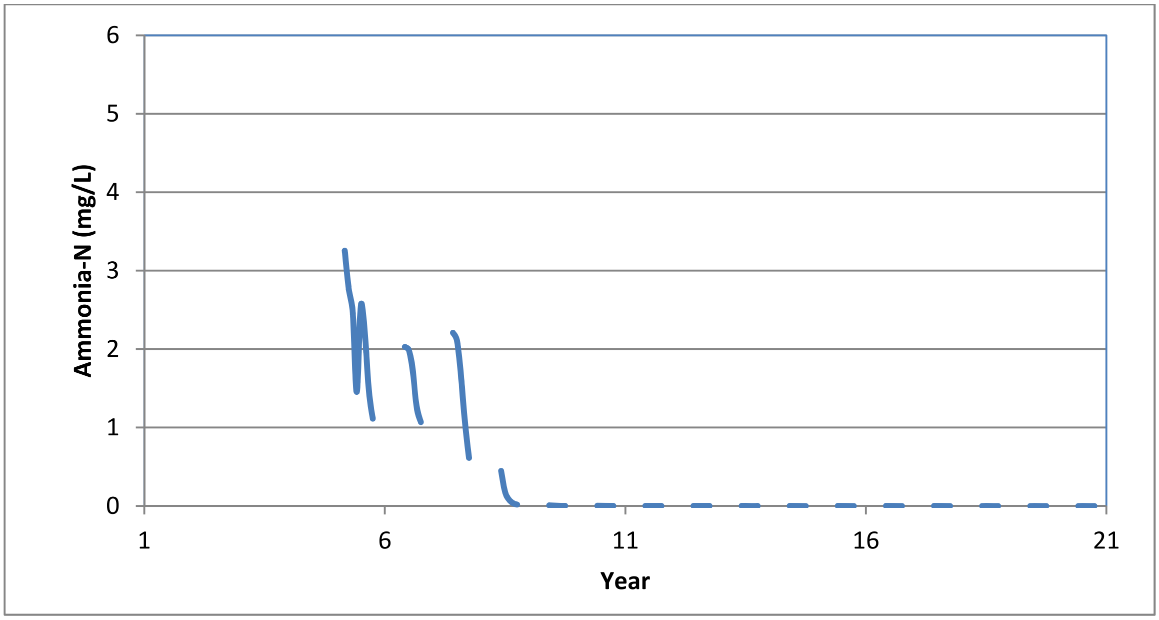

Figure 5-17: No Flow Groundwater Scenario – Time Trends – TIA Discharge Ammonia-N (mg/L)

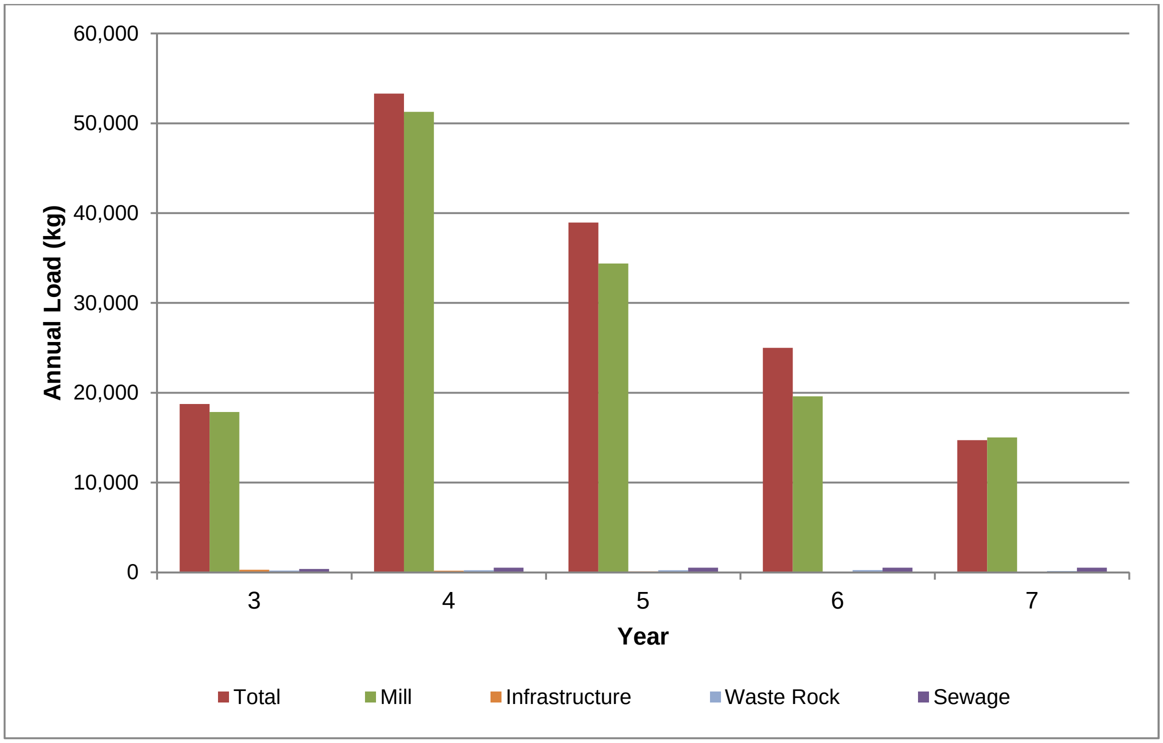

Figure 5-18: No Flow Groundwater Scenario – Annual Load Distribution – Ammonia-N (kg)

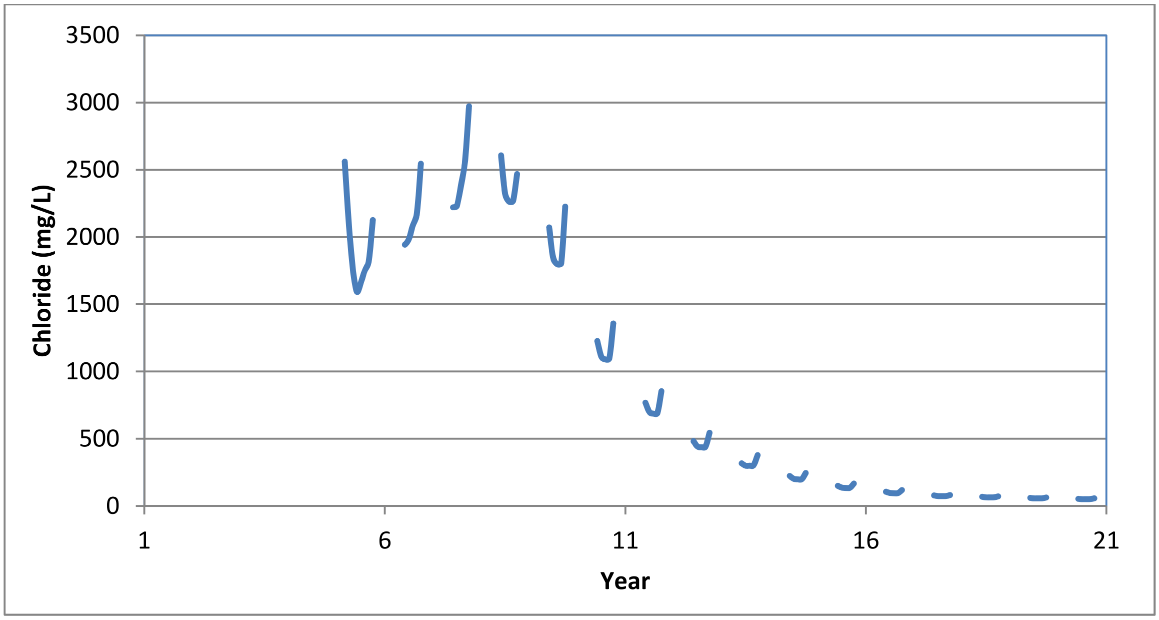

Figure 5-19: No Flow Groundwater Scenario – Time Trends – TIA Discharge Chloride (mg/L)

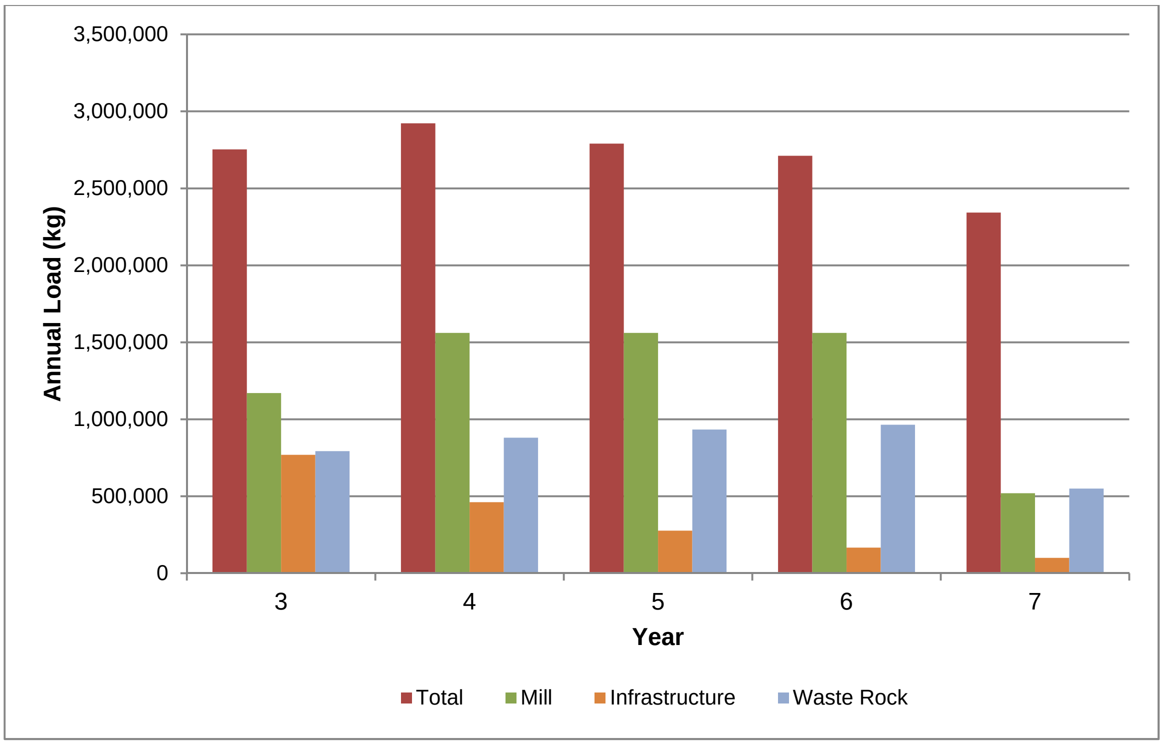

Figure 5-20: No Flow Groundwater Scenario – Annual Load Distribution – Chloride (kg)

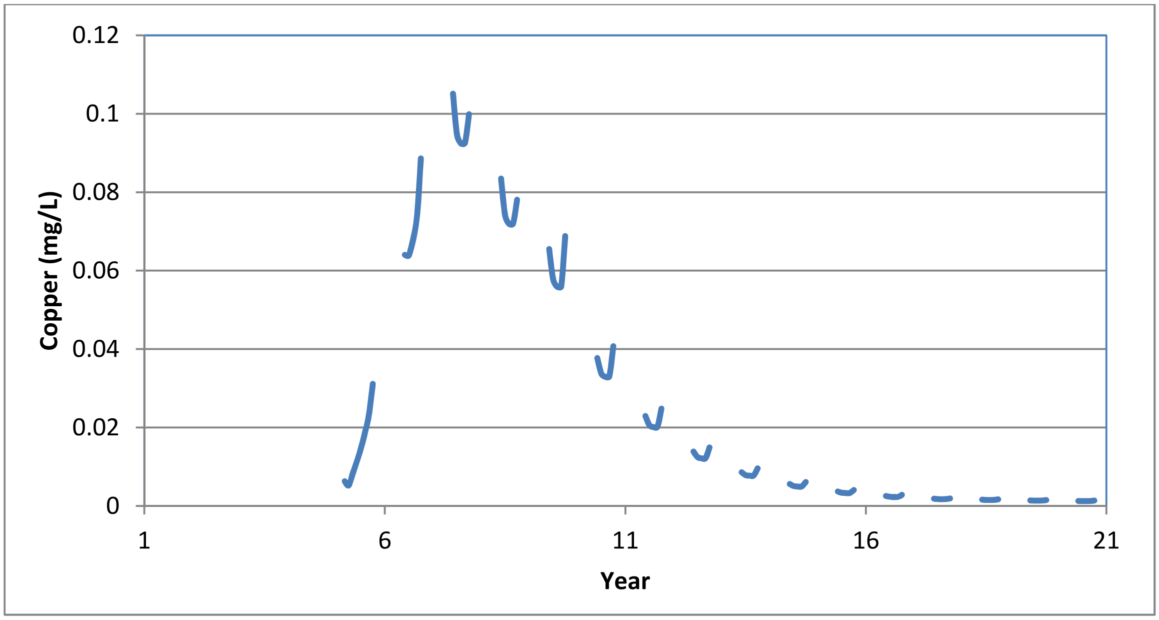

Figure 5-21: No Flow Groundwater Scenario – Time Trends – TIA Discharge Copper (mg/L)

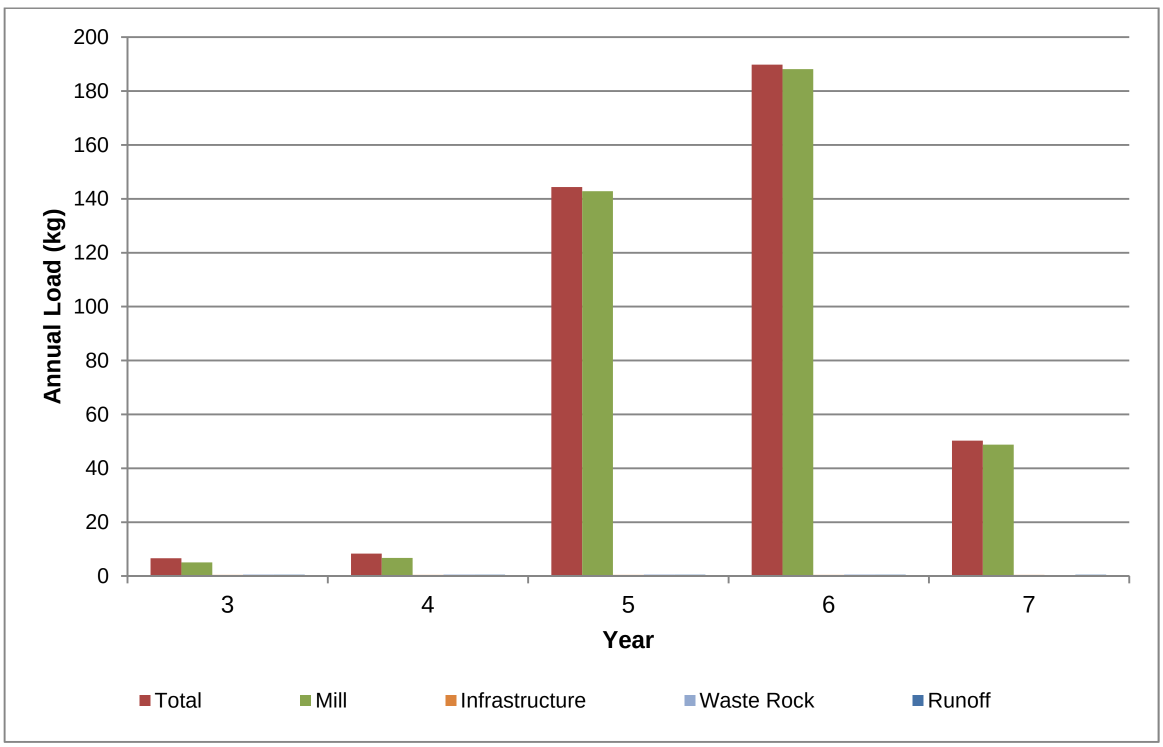

Figure 5-22: No Flow Groundwater Scenario – Annual Load Distribution – Copper (kg)

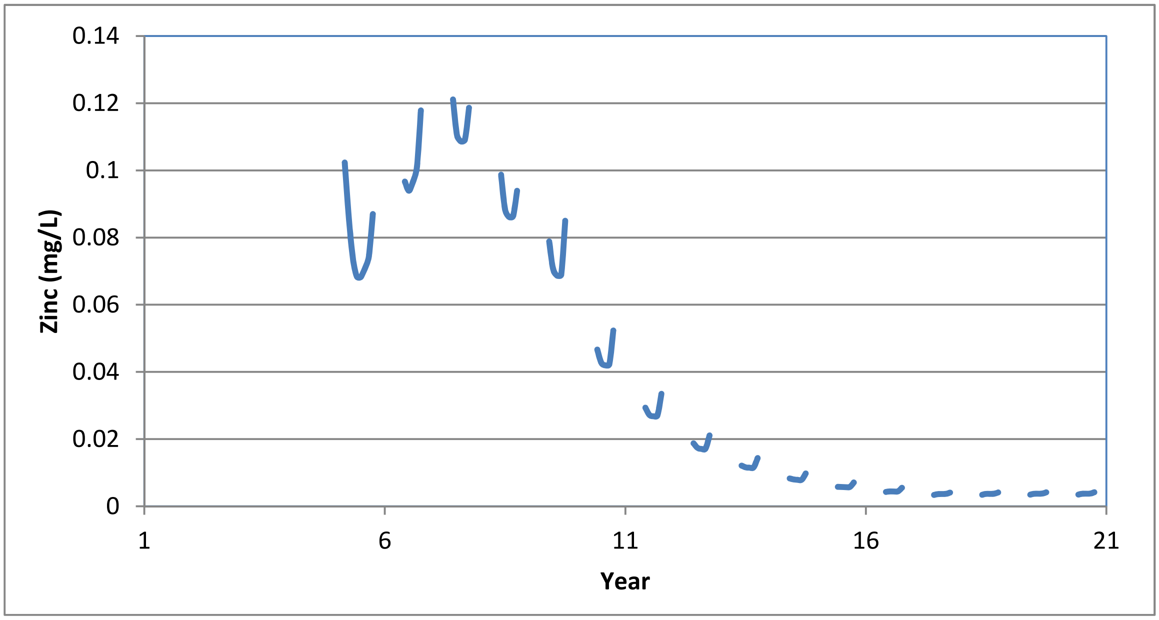

Figure 5-23: No Flow Groundwater Scenario – Time Trends – Tia Discharge Zinc (mg/L)

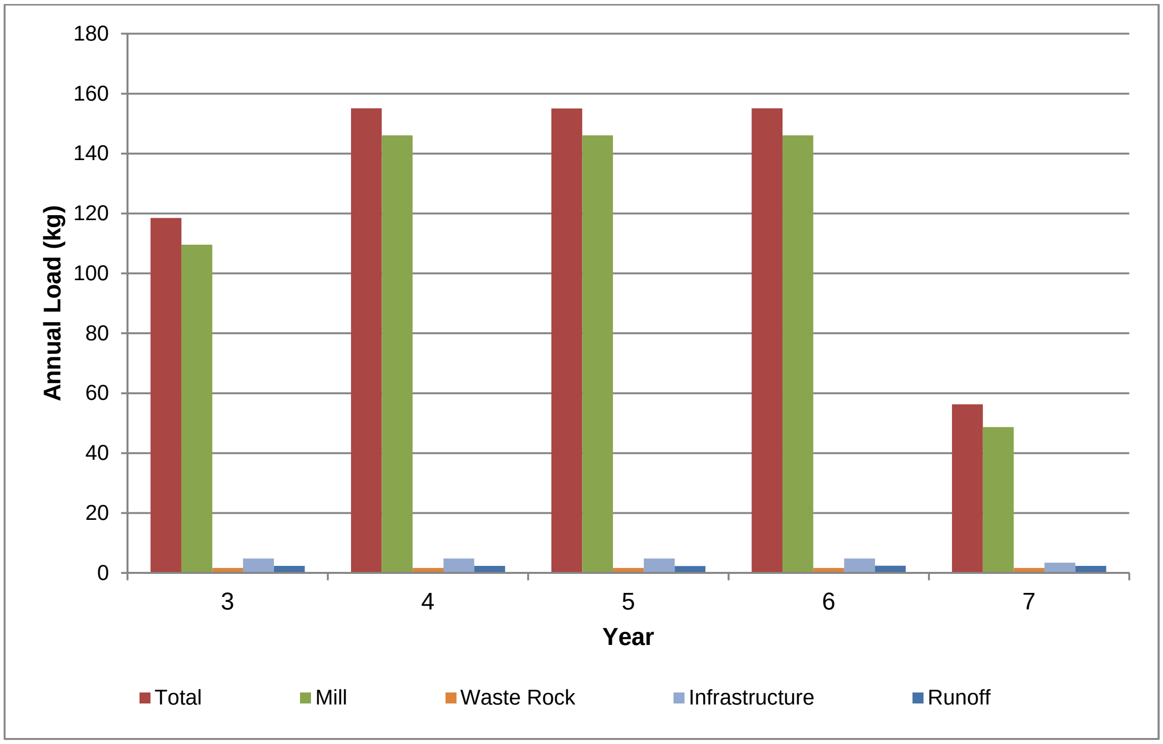

Figure 5-24: No Flow Groundwater Scenario – Annual Load Distribution – Zinc (kg)

6 Summary

To support the assessment of the range of proposed water management scenarios for the project, the original water and load balance model prepared to support the original Doris North Project has been updated, specifically focusing on the TIA and associated discharges from the TIA. The update model utilized the same methodology as the original model with the exception of the following:

- Where applicable, input assumptions were revised to reflect modifications in the proposed project plans and updated environmental baseline data; and
- The model was converted from EXCEL to Goldsim.

The model was run for the three following scenarios to provide a range of potential TIA discharge water quality and enable the development of appropriate discharge strategies to ensure compliance with the proposed discharge limits under a range of conditions.

- Base case groundwater inflows from mine workings:
- Low flow groundwater inflows from mine workings:
- No groundwater inflow from the mine workings.

For each scenario, the following are the key components of the proposed discharge strategy during operations and closure.

- The TIA would be operated with a maximum operating water level of 32.5 m (1 m below the actual 33.5 m FSL) when concentrations in TIA are suitable for discharge.
- Effluent would be discharged at 120 L/s.
- For periods of time when concentrations exceed discharge limits, discharges would cease, and the TIA would be operated at the maximum operating water level of at the FSL (33.5 m) until such time that concentrations in the TIA are compliant.
- Discharges would resume at 120 L/s once concentrations in the TIA meet discharge limits and return to the maximum operating level of 32.5 m.
- During closure, Doris Lake water will be used to flush the TIA until the target closure criteria are met. During the flushing period, a seasonal discharge of 120 L/s will be routed to the marine environment for discharge. Once the TIA water meets the target closure criteria, the discharge from the TIA will be routed to the original lake discharge outlet.

The model predicts that by using this discharge management strategy, discharges from the TIA would meet both the TIA discharge limits and the proposed TIA marine discharge targets (Rescan 2011). Additionally, the TIA could be operated according to the original design criteria.

This report, “**Water Quality Modelling**”, has been prepared by SRK Consulting (Canada) Inc.

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

7 References

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Appendices

Appendix A:
Original Model Assumptions (excerpted from SRK 2005 and SRK 2007)

Solute Release from Mine Waste Rock and Ore

Excerpted text from Water Quality Model, Doris North Project, Hope Bay, Nunavut, Canada (SRK 2007)

The rates of solute release for the waste rock were extrapolated from the humidity cell test results completed by Rescan Consultants, as reported in the Rescan December 2001 report entitled "Acid Rock Drainage Characterization - Boston and Doris Lake Properties" – Rescan (2001). The tests were completed on four samples described as i) mafic volcanic, ii) gabbro, iii) mafic volcanic with possible veining, and, iv) quartz (>1% pyrite). The samples were obtained from the Doris Lake Property during a diamond drilling program undertaken in 2001. Of the four samples tested, three come from diamond drill holes into the Doris Connector zone under Doris Lake. These three samples are the gabbro, mafic volcanic with possible veining, and the quartz (> 1% pyrite) samples. The fourth sample tested in the humidity cell is from a shallow sample, the mafic volcanic sample, located at the extreme south of the Doris Hinge Zone.

The samples selected for these humidity cells all fall well above the average total sulphur and sulphide sulphur contents of the waste rock samples tested for acid base account (ABA) (AMEC 2003a). The sulphide sulphur concentrations for these four samples were as follows:

i) Mafic Volcanic 1.68% (wt) total sulphur and 1.68% (wt) sulphide sulphur;
ii) Gabbro 1.85% (wt) total sulphur and 1.85% (wt) sulphide sulphur;
iii) Mafic Volcanic Possible Veining 6.57% (wt) total sulphur and 6.54% (wt) sulphide sulphur; and
iv) Quartz 1.87% (wt) total sulphur and 1.87% (wt) sulphide sulphur.

As part of the waste rock characterization program, 166 samples were tested for ABA. The total sulphur concentrations for these samples ranged from 0.01% (wt) to 6.57% (wt) with an average of 0.79% (wt). Furthermore, out of the 166 samples only 21 samples had sulphide sulphur concentrations in excess of 1.50% (wt), and comprised ten samples of mafic volcanic, nine samples of quartz, and two samples of gabbro. It is apparent therefore that all four samples used in the humidity cell tests tend to over represent the sulphide mineralization in the waste rock.

The distribution of the rock type that will likely be brought to surface for temporary storage will comprise:

i) 75.3% Fe tholeiites, consisting primarily of mafic volcanic and mafic volcanic with quartz veining;
ii) 0.5% Mg tholeiites, consisting primarily of Gabbro and altered wall rock (altered basalts); and,
iii) 24.2% diabase dike material.

While there are no representative humidity cell test data for the diabase dike material, it is noted that none of this material had a sulphur content in excess of 0.5 %.

The Fe tholeiites are probably best represented by the three humidity cells completed on the mafic volcanic, mafic volcanic with possible veining and the quartz samples. The Mg tholeiites is likely best represented by the humidity cell test completed on the gabbro sample. However, in both cases, the sulphide mineral content is to be over represented.

The investigation showed that the majority of the waste rock would not be net acid generating. For the minor proportion of the waste rock that might be acid generating, the humidity cell tests generally indicated that there would be a lag of many years before acid generating conditions would occur. Therefore, the waste rock would not generate acid within the three year period while stored on surface.

The contaminant release that may occur from the waste rock was calculated as follows:

1. The average solute release rates, in units of mg/kg/week, were calculated from the final cycles of the humidity cell tests for each of the rock types to provide estimates of ‘steady state’ solute production rates. Where the concentrations of parameters were consistently below the detection limit (reported in Appendix H of the Rescan kinetic testing report, December 2001), solute concentrations were assumed to be at 50 % of the detection limit and were used to estimate solute release rates. An average production rate was then estimated for each solute. For simplicity, the average was obtained for all the rock types on an equal weight basis. Because of the similarity in release rates, and the over representation of sulphide minerals in the samples tested, averaging across the samples on an equal weight basis remains conservative. The results are summarised in Table 3.7. The average rate was then used to calculate overall solute releases from the bulk of the waste rock as described below.

2. The average solute release rates were multiplied by the total mass of waste rock to yield a total generation rate.

3. The humidity cell tests were performed on rock samples crushed to 80% less than 6 mm. The actual fines content (< 6 mm) of the waste rock will be significantly lower, depending on the friability of the rock, and the fraction of fines is expected to range from 0.1 to 0.4 mm. Since the specific surface area (surface area per unit mass) increases inversely with particle size, and thus the area of available reactive surfaces, the lower proportion of fines in the waste rock compared to the samples tested will result in reduced rates of solute release. A correction factor of 0.3 was adopted. Therefore, the total solute release rates from Step 2 were multiplied by a factor of 0.3 to correct for surface area exposure.

4. The humidity cell tests were operated under conditions of high and frequent flushing which promotes the release of solutes generated from oxidation. In the humidity cell tests, 1 kg of rock was flushed weekly with 500 mL of water, which equates to an infiltration rate of about 28 mm/week. At the site, infiltration to the waste rock is expected to occur only 4 to 5 months per year. The infiltration to the waste rock is expected to be less than 50% of the mean annual precipitation, or about 104 mm per year, which equates to be 5 to 6 mm/week. The lower infiltration rate in the field is expected to lead to the formation of selective flowpaths and thus, compared to the humidity cell tests, a lower proportion of the waste rock will be contacted by infiltrating water which will further limit solute release. Experience elsewhere indicated that only about 10% to 40% of the soluble loads that are generated are released to seepage. For the purpose of this calculation, conservatively a factor of 40% was adopted.

5. The annual solute release was prorated on a monthly basis over the summer months according to the site runoff hydrograph (Golder 2006).

In summary, the overall calculation to determine the average monthly load was as follows:

$$M_i = L_{HC})_i * W_R *20* 0.3 * 0.4 /1000$$

Where M_i = loading of solute *i* in kg/year,

$L_{HC})_i$ = solute *i* production rate in the humidity cell (mg/kg/wk),

W_R = tonnes of waste rock in storage,

0.4 and 0.3 are correction factors as discussed above in points 3 and 4,

20 is the assumed number of weeks per year (5 months) for which the waste rock is not frozen, and

1000 is a unit conversion factor to obtain kg.

The same calculations were applied to the ore stockpile even though the ore is expected to remain on the stockpile for a very short period only.

In general, the samples tested in the humidity cells showed little solute release during the initial flush, and concentrations in the leachate remained low and generally below detection throughout testing. It is important to note in particular:

- Chromium concentrations were below the detection limit of 0.005 mg/L (five times the CCME guideline) and although 50% of the detection limit was adopted in the calculations this still represents 2.5 times the CCME guideline, and chromium loadings are likely to be overestimated.
- Selenium concentrations were below the detection limit of 0.01 mg/L (ten times the CCME guideline) and again although 50% of the detection limit was adopted in the calculation (five times the CCME guideline) it is considered that the selenium loadings are likely overestimated in the calculations.

Table 3.7: Summary of average solute release rates from waste rock samples tested in the humidity cells

Parameter	Units	Description				Overall Average
		Mafic Volcanic	Gabbro	Mafic with Veining	Quartz	
Sulphate	mg/kg/week	1.55	6.43	5.68	79	23
Total Metals						
Aluminium Al	mg/kg/week	0.026	0.010	0.0093	0.0043	0.013
Antimony Sb	mg/kg/week	0.022	0.020	0.023	0.022	0.022
Arsenic As	mg/kg/week	0.00044	0.00040	0.00046	0.00065	0.00049
Barium Ba	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Beryllium Be	mg/kg/week	0.00055	0.00050	0.00058	0.00054	0.00054
Bismuth Bi	mg/kg/week	0.022	0.020	0.023	0.022	0.022
Boron B	mg/kg/week	0.011	0.010	0.012	0.011	0.011
Cadmium Cd	mg/kg/week	$2.2x10^{-7}$	$2.0x10^{-7}$	$2.3x10^{-7}$	$2.2x10^{-7}$	$2.2x10^{-7}$
Calcium Ca	mg/kg/week	3.9	4.8	5.8	4.5	4.7
Chromium Cr	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Cobalt Co	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Copper Cu	mg/kg/week	0.00044	0.00040	0.00046	0.00043	0.00043
Iron Fe	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Lead Pb	mg/kg/week	0.00022	0.00020	0.00023	0.00022	0.00022
Lithium Li	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Magnesium Mg	mg/kg/week	2.2	2.5	2.4	1.6	2.2
Manganese Mn	mg/kg/week	0.0015	0.0051	0.0040	0.0008	0.0029
Mercury Hg	mg/kg/week	$4.4x10^{-7}$	$4.0x10^{-7}$	$4.6x10^{-7}$	$4.3x10^{-7}$	$4.3x10^{-7}$
Molybdenum Mo	mg/kg/week	0.00022	0.00020	0.00023	0.00022	0.00022
Nickel Ni	mg/kg/week	0.0022	0.0020	0.0023	0.0022	0.0022
Phosphorus P	mg/kg/week	0.033	0.030	0.035	0.032	0.033
Potassium K	mg/kg/week	0.22	1.15	0.23	0.22	0.45
Selenium Se	mg/kg/week	$2.2x10^{-6}$	$2.0x10^{-6}$	$2.3x10^{-6}$	$2.2x10^{-6}$	$2.2x10^{-6}$
Silicon Si	mg/kg/week	0.17	0.25	0.14	0.14	0.18
Silver Ag	mg/kg/week	$4.4x10^{-5}$	$4.0x10^{-5}$	$4.6x10^{-5}$	$4.3x10^{-5}$	$4.3x10^{-5}$
Sodium Na	mg/kg/week	0.22	0.20	0.23	0.22	0.22
Strontium Sr	mg/kg/week	0.002	0.0122	0.005	0.004	0.006
Thallium Tl	mg/kg/week	$4.4x10^{-7}$	$4.0x10^{-7}$	$4.6x10^{-7}$	$4.3x10^{-7}$	$4.3x10^{-7}$
Tin Sn	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Titanium Ti	mg/kg/week	0.0011	0.0010	0.0012	0.0011	0.0011
Vanadium V	mg/kg/week	0.0033	0.0030	0.0035	0.0032	0.0033
Zinc Zn	mg/kg/week	0.0022	0.0026	0.0028	0.0073	0.0037

Solute Release from Quarried Rock

Excerpted text from Water Quality Model, Doris North Project, Hope Bay, Nunavut, Canada (SRK 2007)

Sources of quarried rock that were tested by AMEC (AMEC 2003a) included the Doris North mine portal adit, rock from the proposed new barge loading area (Quarry #1), the quarry west of the proposed camp (Quarry #2) and the area east of Tail Lake (Quarry #3). Acid base account test results completed on samples from these sources indicated that the quarry rock will be non-acid forming and that the sulphide content of the proposed fill rock is very low (< 0.04%).

Three humidity cell tests were completed on quarry rock samples, designated as Quarry #Q1, #Q2 and #Q3 (AMEC 2003a). Using the results from the humidity cell tests, solute release calculations were completed as described above for the waste rock samples. Briefly, the average solute release rates, in units of mg/kg/week, were calculated from the final ‘steady state’ cycles of the humidity cell tests. Where the concentrations of parameters were consistently below the detection limit, solute concentrations were assumed to be at 50 % of the detection limit and were used to estimate solute release rates. An average production rate was then estimated for each solute by obtaining an equal weight average for the three samples. The results are summarised in Table 3.8. The average rate was then used to calculate overall solute releases from the bulk of the construction rock as described below. The average solute release rates were multiplied by the total mass of waste rock, as shown in Table 3.8, to yield a total generation rate within each of the designated catchments.

The release rates were multiplied by the number of weeks for which the rock will not be frozen to estimate the overall annual solute generation. As before, to estimate the net release, a surface area correction factor of 0.3 and a release factor of 40% were adopted. The annual loading was then prorated on a monthly basis according to the site hydrograph (Golder 2006).

In summary, the overall calculation to determine the average monthly load was as follows:

$$M_i = L_{HC})_i * W_R *20* 0.3 * 0.4 /1000)$$

Where M_i = loading of solute i in kg/year,

$L_{HC})_i$ = solute i production rate in the humidity cell (mg/kg/wk),

W_R = tonnes of waste rock in storage,

0.4 and 0.3 are correction factors as discussed above in points 3 and 4,

20 is the assumed number of weeks (5 months per year) for which the construction rock is not frozen, and

1000 is a unit conversion factor to obtain kg.

It should be noted that the entire loading generated by the fill is modelled to contribute to contaminant concentrations from time of placement, and it is assumed that transport of the leachate to each of Doris Lake and Tail Lake occurs instantaneously. In many cases this will lead to conservative estimates of solute concentrations in each of the lakes, because the actual transport of solutes to the lakes will depend on the:

- Distance from the lake that the fill is placed; and
- Potential sorption reactions that may occur as water flows over and through the tundra soil that will remove and attenuate solutes, thus increasing the time before the solutes will enter the respective lakes.

Furthermore, it was assumed that all of the site fill will generate solutes. In reality, a significant proportion of the fill will be covered by buildings and concrete pads and the actual loadings will be proportionately lower. The approach therefore is conservative.

Table 3.8: Summary of average solute release rates from quarry rock sample humidity cell testing

Parameter	Units	Sample Description			Overall Average
		Quarry # Q1	Quarry # Q2	Quarry # Q3	
Sulphate	mg/kg/week	0.82	0.86	0.89	0.85666667
Total Metals					
Aluminium Al	mg/kg/week	0.026	0.024	0.025	0.025
Antimony Sb	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Arsenic As	mg/kg/week	0.00099	0.00062	0.00012	0.00058
Barium Ba	mg/kg/week	0.000060	0.000055	0.000115	0.000077
Beryllium Be	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Bismuth Bi	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Boron B	mg/kg/week	0.0060	0.0055	0.0060	0.0058
Cadmium Cd	mg/kg/week	0.000029	0.000032	0.000026	0.000029
Calcium Ca	mg/kg/week	1.5	1.5	1.4	1.5
Chromium Cr	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Cobalt Co	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Copper Cu	mg/kg/week	0.00023	0.00012	0.00012	0.00015
Iron Fe	mg/kg/week	0.0060	0.0055	0.0060	0.0058
Lead Pb	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Lithium Li	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Magnesium Mg	mg/kg/week	0.14	0.25	0.05	0.15
Manganese Mn	mg/kg/week	0.00018	0.00012	0.00012	0.00014
Mercury Hg	mg/kg/week	0.0000024	0.0000023	0.0000023	0.0000023
Molybdenum Mo	mg/kg/week	0.000000060	0.000000055	0.000000060	0.000000058
Nickel Ni	mg/kg/week	0.00015	0.00012	0.00012	0.00013
Phosphorus P	mg/kg/week	0.018	0.017	0.018	0.017
Potassium K	mg/kg/week	0.053	0.029	0.029	0.037
Selenium Se	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Silicon Si	mg/kg/week	0.30	0.29	0.24	0.28
Silver Ag	mg/kg/week	0.000030	0.000029	0.000058	0.000039
Sodium Na	mg/kg/week	0.052	0.036	0.02	0.036
Strontium Sr	mg/kg/week	0.00094	0.00086	0.00053	0.00078
Thallium Tl	mg/kg/week	0.000012	0.000012	0.000012	0.000012
Tin Sn	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Titanium Ti	mg/kg/week	0.00012	0.00012	0.00012	0.00012
Vanadium V	mg/kg/week	0.00047	0.00012	0.00012	0.00023
Zinc Zn	mg/kg/week	0.00060	0.00055	0.00060	0.00058

Nitrogen Release from Blast Residuals (Waste Rock, Ore, Tailings, Quarried Rock and Groundwater)

Excerpted text from Water Quality Model, Doris North Project, Hope Bay, Nunavut, Canada (SRK 2007)

In general, the estimates of ammonia-N, nitrate-N and nitrite-N were derived following the methods described in Ferguson and Leask (1988), with the exception of increasing the blast residue factor as described below.

Mine production rates and estimated explosives usage rates provided by MHBL indicated a powder factor of about 1.14 kg per tonne of rock mined. This is marginally higher than a typical powder factor for underground drifting of about 0.9 kg per tonne as reported by McIntosh Redpath Engineering (2003).

Ferguson and Leask (1988) suggest that about 1% of the total mass of ANFO used during mining will remain as blast residues within the mined rock, accounting for missed fires, spillage and incomplete detonation. However, for the purpose of this assessment a conservative blast residue content of ten times that recommended by Ferguson and Leask (1988), or about 10%, was adopted for the base case evaluation.

Subsequent to mining, the proportion of blast residues that will be released from the mined rock will depend on a number of factors, including rate of infiltration, water – rock contact ratio and duration of exposure. Therefore, the steps to calculate the release of ammonia and nitrate from the mined rock were as follows:

1. An estimate of the amount of ANFO used in the blasting of each of the waste rock and ore materials was calculated by multiplying the amount of each material by the powder factor.
2. The residual mass of ANFO was then estimated by multiplying the total mass of ANFO used to produce the rock and ore with the overall residue factor (i.e. 10%).
3. The amount of nitrogen in the ANFO was calculated assuming that the ANFO comprises 94% NH4NO3, and 6% fuel oil. The mass weight equivalent of the N in ammonium nitrate is 35%, therefore the total N content of the ANFO is 33%.
4. The amount of nitrogen released from the waste rock in storage was calculated assuming that about 20% of the residual nitrogen will be flushed from the waste rock over a three year period, i.e. about 6.7% of the residual nitrogen would be flushed annually. The release was assumed to occur over a 5 month period, prorated to the site hydrograph (Golder 2006). The same approach was adopted to calculate the release from the construction fill.
5. Although the ore will reside on the stockpile for about 2 weeks on average, the ore stockpile is expected to respond similar to the waste rock storage pile, and the calculations described above in Step 4 were applied to the ore stockpile as well.
6. The nitrogen release to the tailings slurry was calculated assuming that all of the remaining blast residues will be flushed from the ore and released to the tailings water due to the high solubility of ammonia and nitrate compounds.
7. A proportion of the waste rock will be directly backfilled to the underground workings. That rock will be less exposed to flushing, since the mine is expected to be dry. Nonetheless, the calculations for waste rock stored on surface were also applied to the waste rock backfill, with the exception that the blast residues would be released year round to mine water.
8. The speciation of the nitrogen in the blast residues was assumed to be 28% ammonia, 70% nitrate, and 2% nitrite. In contrast to the recommendations in Ferguson and Leask (1988), this conservatively assumes a higher portion of the nitrogen will be present as ammonia.

The overall calculation to estimate annual nitrogen release from the fill and waste rock therefore was as follows:

NT = (PF * Wr) * Rf * 0.33* Ar

Where: NT = annual release of total nitrogen (kg/year),
PF = powder factor (1.14 kg ANFO per tonne of rock),
Wr = mass of rock produced/placed (tonnes),
Rf = residual nitrogen remaining (assumed to be 10%),
Ar = fraction released annually (0.067), and
0.33= total nitrogen content of blast residues (fraction).

The total nitrogen was then apportioned to ammonia, nitrate and nitrite as in Step 8. The annual releases of nutrients from blasting residual were calculated assuming 40% of the waste rock or fill would be flushed annually. The annual loadings were prorated to monthly release rates based on the Doris Lake outflow hydrograph (Golder 2006).The calculations do not consider any effects from natural nutrient degradation or attenuation within the waste rock and fill.

Shoreline Erosion

As a result of the expected rise in water level in Tail Lake during tailings deposition, permafrost soils around the perimeter of Tail Lake are expected to thaw. The thawed soils may become susceptible to re-suspension due to wave action while submerged.

After tailings deposition ceases, as part of the water management strategy, the water level in Tail Lake will be lowered to its original elevation. At that time, the soils above the waterline that have thawed will be subject to physical erosion caused by overland runoff and wave action impacting on the shoreline. This erosion may lead to sloughing and slumping of thawed soils at steep gradients, which may further exacerbate particulate transport to Tail Lake.

The combined effects of physical erosion and re-suspension by wave action may increase the suspended solids concentration in Tail Lake. Calculations have been completed that estimated potential total sediment loadings from three possible erosion mechanisms as follows:

- *Re-suspension of tailings by wave action.* The calculations considered the depth of the water cover, the tailings solids size distribution, and the prevailing wind fetch and speed (SRK 2007b).
- *Physical shoreline erosion from overland runoff and wave action.* Calculations completed to estimate the potential sediment transport due to shoreline erosion processes considered only the mass transport that occurs as a result of the physical process of erosion (Appendix E *of SRK 2007*).
- *Shoreline material re-suspension by wave action.* These calculations address soil that had been eroded from the shoreline and has accumulated on the bed of Tail Lake and the shallow fringes near the lake shore (Appendix F *of SRK 2007).*

Due to the depth of the water cover that will exist over the tailings, the effect of wave action on re-suspension of tailings will be negligible (SRK 2007b).

The estimated potential sediment loadings to Tail Lake generated from shoreline erosion and through re-suspension, before any correction for particles settling from the water column, derived from these calculations are summarized in Table 3.12.

Table 3.12: Summary of estimated solids loadings to Tail Lake at elevation 28.3 m

Case	Loading by Physical Shoreline Erosion (kg/year)	Loading Resulting from Re-Suspension of Eroded Material (kg/year)	Estimated Total Annual Loading (kg/year)
Base Case	2,846,891	206,066	3,052,957
Upper Limit	7,354,467	281,115	7,635,582
Lower Limit	948,964	122,261	1,071,225

Settling tests were carried out to assess the residual total suspended solids concentration that may result from these sediment loadings. The test procedures and results for the settling tests are provided in Appendix G (*of SRK 2007*). As part of that investigation, the properties of the suspended solids as well as total solute release from the sediments were assessed. The results can briefly be summarized as follows:

- While X-ray diffraction testing indicated the presence of pyrite in the sediments, analytical results indicate that the actual sulphide mineral content is very low, and, that the sediments are not net acid generating.
- Illite and mica are the dominant clay minerals present in the sediments.
- Irrespective of the initial clay content (with particle sizes ranging from 15 % to 40 % less than 2 µm), the settling tests indicated that the solids settled from the water column fairly rapidly, with total suspended solids decreasing to below a detection limit of 1 mg/L within a 72 hour period.

The settling tests were conducted to reflect the estimated potential upper limit sediment loadings (see Table 3.12) to Tail Lake, corrected for low flow conditions (yield of 111 mm/year) at steady state (i.e. the worst case conditions). The results from the settling tests were therefore corrected to reflect both low (111 mm/year) and high (180 mm/year) yield conditions, and for the estimated base case and lower limit conditions. The correction method is discussed in Appendix G. The resulting estimated suspended solids and total solute concentrations that may result from the erosion effects are summarized in Table 3.13 and represent incremental loadings to Tail Lake in the absence of erosion control measures.

It is however important to note the following:

- These concentrations could occur only if: i) sediment loadings reach the estimated maximum rates, and, ii) they persist at those rates indefinitely. In the absence of any physical interventions, effects such as natural revegetation and re-establishment of permafrost in time are likely to reduce overall sediment loadings.
- The solute loading estimates include salinity release (elevated chloride, sodium and potassium concentrations), which somewhat double accounts for the salinity release calculations described previously.

Table 3.13: Estimated steady state total solute concentrations in Tail Lake

Description	Units	CCME	Test Average	Low Yield (111 mm/year)			High Yield (180 mm/year)		
Inflow	m^3/year		-	500,000			812,000		
Case			-	Lower Limit	Base case	Upper Limit	Lower Limit	Base case	Upper Limit
Total Sediment Load	g/L		14.5	2.14	6.11	15.27	1.32	3.76	9.40
TSS (measured)	mg/L		1.0	0.1	0.4	1.1	0.1	0.3	0.6
TSS (calc.)	mg/L		7.2	1.1	3.0	7.6	0.7	1.9	4.7
Chloride	mg/L		195	29	82	205	18	50	126
Total Metals									
Aluminium Al	µg/L	100	623	92	*262*	*656*	57	*162*	*404*
Antimony Sb	µg/L		0.17	0.025	0.070	0.176	0.015	0.043	0.108
Arsenic As	µg/L	5	1.0	0.15	0.44	1.1	0.09	0.27	0.67
Bismuth Bi	µg/L		0.025	0.004	0.011	0.026	0.002	0.006	0.016
Boron B	µg/L		78	11	33	82	7	20	50
Cadmium Cd	µg/L	0.038	0.025	0.004	0.011	0.026	0.002	0.006	0.016
Calcium Ca	µg/L		5,906	8,73	2,488	6,223	538	1,532	3,832
Chromium Cr	µg/L	1	1.2	0.18	0.52	*1.29*	0.11	0.32	0.80
Cobalt Co	µg/L		0.31	0.046	0.13	0.33	0.028	0.080	0.20
Copper Cu	µg/L	2	1.97	0.29	0.83	2.0	0.18	0.51	1.3
Iron Fe	µg/L	300	605	89	255	*638*	55	157	*393*
Lead Pb	µg/L	2	0.12	0.017	0.049	0.12	0.011	0.030	0.076
Lithium Li	µg/L		5.7	0.85	2.4	6.0	0.52	1.5	3.7
Magnesium Mg	µg/L		8,264	1,222	3,481	8,707	752	2,144	5,361
Manganese Mn	µg/L		14	2.1	6.1	15	1.3	3.7	9.4
Mercury Hg	µg/L	0.1	0.050	0.007	0.021	0.053	0.005	0.013	0.032
Molybdenum Mo	µg/L	73	0.80	0.12	0.34	0.84	0.073	0.21	0.52
Nickel Ni	µg/L	25	0.63	0.094	0.27	0.67	0.058	0.16	0.41
Phosphorus P	µg/L		47	7	20	49	4	12	30
Potassium K	µg/L		6,485	959	2,732	6,833	590	1,682	4,208
Selenium Se	µg/L	1	2.5	0.37	1.0	*2.6*	0.23	0.66	*1.6*
Silicon Si	µg/L		1,518	224	640	1,600	138	394	985
Silver Ag	µg/L		0.025	0.004	0.011	0.026	0.002	0.006	0.016
Sodium Na	µg/L		115,565	17,083	48,685	121,764	10,519	29,979	74,978
Strontium Sr	µg/L		41	6	17	43	4	11	26
Thallium Tl	µg/L	0.8	0.005	0.001	0.002	0.005	0.0001	0.001	0.003
Tin Sn	µg/L		0.095	0.014	0.040	0.100	0.009	0.025	0.062
Titanium Ti	µg/L		35	5.2	15	37	3.2	9.2	22
Vanadium V	µg/L		5.20	0.77	2.2	5.5	0.47	1.4	3.4
Zinc Zn	µg/L	30	3.40	0.50	1.4	3.6	0.31	0.88	2.2

Note: Values in bold italics exceed CCME guidelines

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Appendix B: Groundwater Inflow and Water Quality Estimates

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Memo

To:	Bill Patterson	**Date:**	November 4, 2011
Company:	Hope Bay Mining Limited	**From:**	Dan Mackie and Tom Sharp
Copy to:	-	**Project #:**	1CH008.053
Subject:	Groundwater Inflows and Inflow Water Quality Used for the Revised Doris North Project Amendment Package No. 3 to Water License No. 2AM-DOH0713 - AMENDED		

Groundwater Inflows and Inflow Water Quality Used for the Revised Doris North Project Amendment Package No. 3 to Water License No. 2AM-DOH0713

This memo provides a description of the assumptions and methods SRK Consulting (Canada) Inc. (SRK) has used to estimate groundwater inflows and inflow water quality inputs to the water and load balance prepared for the revised Doris North Project, Nunavut.

Maniqap Imaa Immiqtuqvi Immap Qanugitnia Atuqtaunia taphumunga Nutanguqhimayuq Doris North Havanga Ihuaqhigiagut Katihimayut Nappaa 3 taphumunga Imaqmut Lasia Nappaa 2AM-DOH0713

Una tuhaqhit piqagutauyuq unniqtuqninik piniagahugiyauni pityuhitlu SRK-kut Qauyimayiuyut (Kanata) Nanminilgit (SRK-kut) atuqtai mikhauttaqninut maniqap imaqta immiqtuqvi immiqtuqvitlu immat qanugitni tapkununga imaq pitaqnitlu naamakhihimani hannaiyaqhimayut tapkununga nutanguqni Doris North Havanga, Nunavutmi.

ᓄᓇᐅᑉ ᐃᓗᐊᒍᑦ ᐃᒦᑦ ᑰᒃᑐᑦ ᐊᒻᒪᓗ ᐃᒥᖅ ᓄᓇᐅᑉ ᐃᓗᐊᓃᑦᑐᖅ ᖃᓄᐃᑦᑑᖕᒪᖕᖑᖅ ᐊᑐᖅᑕᐅᒐᔾᖅᑐᖅ ᐋᖏᕐᐊᖅᑕᐅᓕᖅᐸᑕ ᐅᕗᖖᒐᖖᒐᔪᑦ Doris North−ᒥ ᐱᓕᕆᕖᖕᒨᖕᒐᔪᑦ ᐋᖏᕐᐊᖅᑕᐅᒍᑎᒃᓴᖕᕆᓐᓅᖕᒐᔪᑦ No. 3_ᒥ ᐃᒥᖄᕈᑎᒃᓴᖅ ᓚᐃᓴᑦ No. 2AM-DOH0713

ᐅᑯᐊ ᑎᑎᖃᑦ ᐊᑐᐃᓐᓇᑦ ᐱᑕᖅᑦ ᐅᓂᒃᑳᖃᖅᓱᑎᒃ ᖃᓄᐃᑦᑐᑦᓚᕆᒃᑕᖃᒻᒪᖕᖑᖅ ᐃᓱᒪᕆᔭᓂᒃ ᐊᒻᒪᓗ ᐋᑐᑎᔾᖕᕆᑦ ᐅᑭᐊ ᐱᒃᑯᔾᔨᔾᔫᑦ SRK Consulting Inc.−ᑯᑦ ᑲᓇᑕᒥ, ᐊᑐᖃᑦᑕᔪᒻᒪᑕ ᒪᓕᒡᓗᕆᑦ ᒥᒃᓴᐅᓴᖕᓂᖕᕆᑦᑎᒍᑦ ᓄᓇᐅᑉ ᐃᓗᐊᓂᖕᖑᖅᑐᖅ ᐃᒥᖅ ᐊᒻᒪᓗ ᑰᒃᑐᖅ ᐃᒥᖅ ᖃᓄᐃᑦᑑᖕᒪᖕᖑᖅ ᐊᒻᒪᓗ ᖃᓄᐃᓪᓗᐊᖅᑎᕆᔪᒥᒃ ᐊᑐᖅᑕᐅᖃᑦᑕᖅᑐᖅ ᑕᒪᒃᑯᓄᖕᒐᖕᒐᔪᓂᒃ ᐋᖏᕐᐊᖅᑕᐅᒐᔾᒪᑦ ᐅᕗᖕᒐᖕᒐᔪᑦ Doris North−ᒥ ᐱᓕᕆᕖᖕᒥ, ᓄᓇᕗᑦᒥ.

1 Introduction

Hope Bay Mining Ltd. (HBML) is submitting an application for amendment to Water License No. 2AM-DOH0713 to allow for an expansion of underground mining at the Doris North project. The area of expansion will extend into the talik, or unfrozen ground, underneath Doris Lake. Unlike the currently permitted Doris North mining area, which is completely within frozen ground to the north of Doris Lake, the expanded mine area will likely be subject to groundwater inflows.

This memo describes the basis for groundwater inflow and inflow water quality estimates used in the water and load balance presented as part of the permit amendment package.

2 Mine Plan & Schedule

The mine plan used as the basis for the estimates was provided by HBML and is shown on Figure 1. Mining areas included in this assessment include Doris Central Upper, Doris Connector Upper and Doris Lower as well as the development required to access these mining areas. The boundary between the Central and Connector areas is shown on Figure 1. The boundary between Doris Upper and Lower is defined by the diabase sill, also shown on Figure 1.

Mining of areas within the Doris Lake talik will occur over a period of two years, with a planned initiation date corresponding to the end of year two of mining at Doris North. The preferred mining method is still being assessed by HBML, but is anticipated to be some form of cut-and-fill. Access, including the main decline and spirals, will be developed first. Start and end dates for individual stopes are not specifically defined.

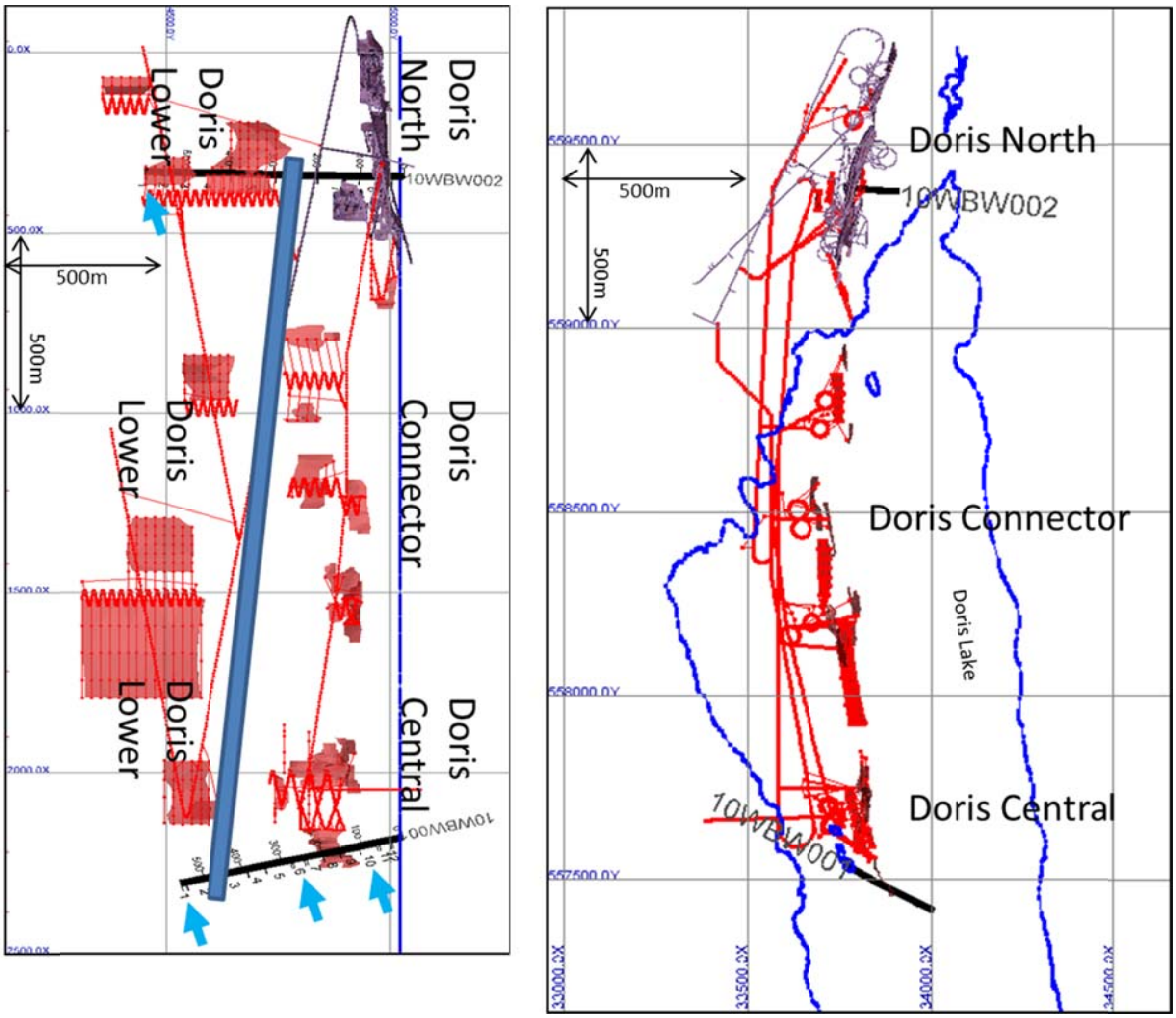

Figure 1: Map and Cross Section of Doris Mine Area

3 Available Hydrogeologic Information

Investigations related to mining of ore bodies under Doris Lake have been on-going since 2008. Information sources used as part of the groundwater assessment were as follows:

- SRK, 2009a. Geotechnical and Hydrogeological Assessment for the Doris North Open Pit and Doris Central Underground. Report prepared for Hope Bay Mining Limited. 143p plus appendices. SRK Project Number 2CH009.000, June 2009.
- SRK 2009b. Hope Bay Gold Project: Stage 2 Overburden Characterization Report. Report prepared for Hope Bay Mining Limited. 95p plus appendices. SRK Project Number 1CH008.002, June 2009.
- SRK 2011a. Hope Bay 2010 Westbay Program Data Report. Report prepared for Hope Bay Mining Limited. SRK Project Number 1CH008.013, February 2011.

- SRK, 2011b [inprep]. Hope Bay Updated Hydrogeologic Conceptual Models and Groundwater Inflow Estimates. Report in preparation to Newmont.

Hydrogeologic investigations have also been conducted during the 2011 ice drilling season. Data collected as part of these studies has included additional hydraulic testing and water quality sampling. Reporting has not yet been finalized for these investigations but data available at the time of preparation of these inflow quantity and quality estimates was incorporated.

4 Hydrogeologic Conceptual Model

The current hydrogeological understanding, or ‘conceptual model’ is based on information from hydrogeological field investigations completed by SRK in 2004, 2008 and 2010, ongoing thermistor monitoring at the site and updates to the geological model and mine plans by HBML, as were available in December 2010.

Based on available data, the hydrogeological system for the entire Hope Bay belt can be generally considered as a low flux, lake-dominated flow system. Regional flow is primarily controlled by the presence or absence of permafrost, which is widespread and deep away from lakes and considered to be essentially impermeable. Away from lakes, permafrost may exist to depths of 400 m below ground surface. Unfrozen zones under lakes (taliks) can provide connection between surface water and groundwater.

Definition of talik boundaries (the boundary between frozen and unfrozen ground) has been determined from thermistor strings installed at the various Hope Bay mining areas. In 2008, seven thermistor strings were installed specifically to define the presence and location of the boundary. Additionally, in 2010 a multi-level Westbay groundwater monitoring system (Well # 10WBW-001) was installed from a small island in the middle of Doris Lake to provide information in the vicinity of Doris Central, which is located approximately under the center of Doris Lake. In general, the talik boundary can be considered as a vertical plane extending downwards from the Doris Lake shoreline. Data collected from the Westbay well confirm that rock under Doris Lake is unfrozen and that the talik can be assumed to be connected to deeper groundwater.

Within taliks, the groundwater system is fracture-controlled. At the local scale, bedrock hydraulic conductivity is comprised of a relatively low bulk hydraulic conductivity background system intersected by discrete relatively high hydraulic conductivity fractures and, geologic structures. Fracture apertures may be more open at shallow depths, hence higher permeabilities due to lesser confining pressures or relationships with different lithologies. Assuming constant fluid properties, hydraulic conductivity may also be higher. Geologic structures are present in all mining areas that may influence groundwater pathways.

Hydraulic conductivity information available for estimating inflows is available from multiple field programs. These include:

- 25 packer injection tests conducted around the Doris Central area in 2008/09;
- 15 packer tests conducted during installation of the Westbay well in 2010;
- More than 30 additional tests conducted in 2011. Only some of the 2011 data was available when the inflow estimates presented herein were calculated; and
- 7 cone penetrometer (CPT) pressure-dissipation tests conducted in sediments lining the bottom of Doris Lake.

4.1 Sources of Inflows

Doris Lake represents a significant source of water that could have an influence on inflows. Once mining areas are established, the surface water elevation of the lake will be a primary control on gradient towards the development areas within the talik (head difference equal to lake elevation minus elevation of stope). Water within the lake will represent a large source of available recharge to the underlying bedrock groundwater system. Low permeability silt and clay sediments lining the bottom of the lake may impede the rate of recharge. Inflows to the mining areas within the talik are likely to come from three sources:

4.1.1 Fractured Bedrock

Water flowing along joints in the fractured rock will permeate into the underground workings. Hydraulic testing data suggests that shallow bedrock and/or the ore zone and surrounding altered zones may have relatively high hydraulic conductivities compared to greater depths and other lithologies (e.g., 9×10^{-8} m/s for shallow rock vs. 2×10^{-8} m/s for deep rock). Available data indicates that the diabase sill underlying the area of development has significantly lower hydraulic conductivity (2×10^{-11} m/s) which may reduce the inflows to Doris Lower, at depths of 300 – 750 m below the lake. A summary of average hydraulic conductivities is presented later in this report.

4.1.2 Structures

Multiple geologic structures are present, some of which may have relatively high permeability and will intersect the development. Individual faults and permeable sections of the contact with the diabase dyke may produce water when intersected by mining development, either: stopes, ramps or cross-cuts, or both. The likelihood of intersecting such structures is considered high, though uncertainty exists regarding specifically where or if they will act as conduits.

4.1.3 Former Exploration Drill Holes

A large number of exploration drill holes have been completed within the Doris Central area. The condition of a majority of these is unknown. Many of these intersect the proposed mining areas. For drill holes completed prior to 2008, there is uncertainty as to if and how these drill holes were sealed upon completion.

As these exploration holes were collared on ice, surface casing was pulled. Therefore, there is no way to assess their condition. It is possible that many of these became plugged with lake sediments upon casing retrieval, if not purposely sealed, but the possibility cannot be ruled out that some drill holes may convey water when intersected by mining. The potential for inflow from open drill holes to Doris Central was discussed in the report 'Geotechnical and Hydrogeological Assessment for the Doris North Open Pit and Doris Central Underground, SRK, June 2009'.

5 Underground Water Management

Management of underground inflows will be on-going effort. Inflows from the fracture-controlled groundwater system are anticipated to be heterogeneously distributed and often discrete, as opposed to flows that would be anticipated from a more homogeneous porous media such as, for example, a sand aquifer. At this stage, a specific management plan has not been developed, but a number of different conventional strategies are under consideration. These include:

- Probe drilling ahead of development to identify areas of high water pressure or inflow and the capacity for pressure grouting.
- Grouting discrete fractures or structures as they are identified.
- Having equipment and materials available to plug exploration drill holes as quickly as possible.
- Planning development and stopes to avoid areas of known higher permeabilities or exploration hole densities.
- Installing water tight bulkheads at key locations.
- Scheduling the mining to minimize the total area open at a given time by sealing off areas that are mined out.
- Using a mined out stope to provide surge capacity.

It is likely that a number of these strategies will be implemented to provide flexibility in the manner of response. In practice, due to the heterogeneous nature of the fractured bedrock groundwater system, most inflow locations to the mine will not be known until mining is underway and, ultimately, management plans will aim to minimize the total inflow at any given time.

6 Methods

6.1 Inflow Quantity

Estimates of groundwater inflow quantity have been determined using available hydraulic conductivity data and a combination of analytical and numerical calculation methods. Inflows for use in the water balance included those from the bulk fractured bedrock system and exploration drill holes. Methods for each of these components are described below and followed by a description of how they have been incorporated into the water and load balance.

6.1.1 Bedrock Inflow

At this stage, the exact location of discrete structures or fractures along which flow may occur is generally uncertain, thus an “equivalent porous medium” approach has been used to estimate fractured bedrock inflows. This approach assumes that the fractured bedrock can be represented by a bulk hydraulic conductivity, similar to a porous medium such as sand. This approach is considered reasonable for mine-scale inflow estimates and has been applied at many other mine sites in Canada.

Inflow from fractured bedrock was assessed using the numerical groundwater code Feflow, a commercially available code produced by DHI-Wasy of Germany. Multiple model configurations were constructed to assess variation in inflow to underground workings of different geometric shape (i.e., length, vertical height and width) and depth below Doris Lake. Correlations between inflow rate, geometric shape and depth were then developed based on the numerical results to allow estimation of inflow to any given stope. The primary benefit of this approach is that it provides the ability to add inflows from individual stopes in any order or combination. Figure 2 illustrates the general numerical domain used to quantify stope inflow.

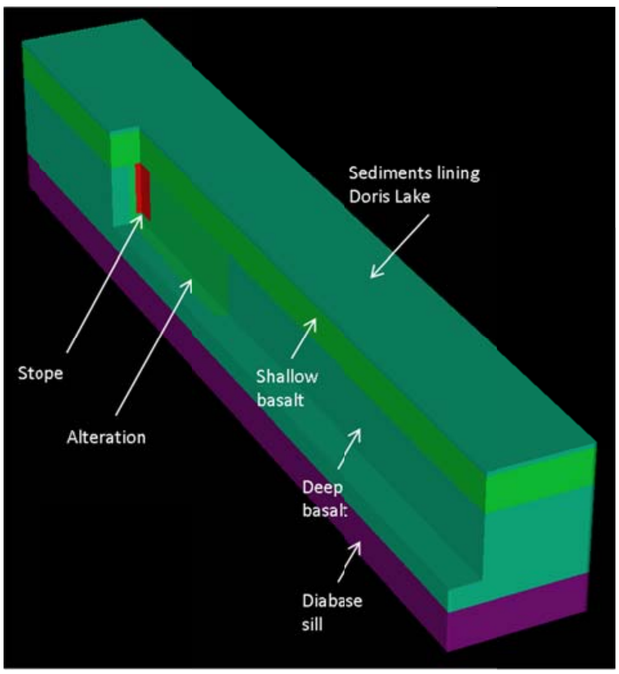

Figure 2: Inflow Numerical Model

Inflow to mine development (i.e., decline, ramps and spirals) was determined using the same numerical domain, but with development incorporated using what are called “discrete elements” in Feflow terminology. Discrete elements are essentially pipes of infinite hydraulic conductivity and a set cross-sectional area that can be inserted in the numerical mesh to simulate tunnels (e.g., the main decline).

Cumulative inflows were calculated by adding inflows for individual stopes and related access development plus the decline. The following assumptions and/or parameters were applied:

- Geometric mean of bedrock hydraulic conductivity for each hydrogeologic domain.
  - Shallow Bedrock (0 to 100m below lake bottom) $9x10^{-8}$ m/s
  - Deep Bedrock (100 to 300m below lake bottom) $2x10^{-8}$ m/s
  - Alteration/ore zone (100 to 300m below lake bottom) $5x10^{-8}$ m/s
  - Diabase sill (300 to 400m below lake bottom) $2x10^{-11}$ m/s
- Doris Lake is a fixed head boundary (i.e., an infinite supply of water at a given lake elevation).
  - Doris Lake sediments hydraulic conductivity $2x10^{-8}$ m/s
- Permafrost surrounding Doris Lake is impermeable.
- Stopes are fully developed (i.e., inflow estimates are for an entire stope area).
- The decline and ramps are fully developed (i.e., simulated for maximum length).
- Stope backfill has no effect on limiting inflow.
- No water management strategies are assumed to be implemented (i.e., inflow is unimpeded).

6.1.2 Results

Table 1 summarizes inflows to 10 individual stopes and development access. Values in the "Total Flow" column represent cumulative inflow to a given stope number plus inflow to any preceding stope (e.g., Total Flow for stope 10 equals the inflow to stope 10 plus inflow from stopes 1 to 9).

Table 1. Summary of Inflows

Stope -	Vol. m^3	Flow Stope (m^3/d)	Flow Backfill (m^3/d)	Flow Decline (m^3/d)	Flow Ramp (m^3/d)	Total Flow (m^3/d)
1	6,000	270	0	975	185	1430
2	45,000	553	270	975	370	2168
3	18,000	278	823	975	370	2446
4	45,000	411	1101	975	555	3042
5	35,000	442	1512	975	555	3485
6	76,000	661	1955	975	740	4330
7	78,750	461	2615	975	740	4791
8	725,760	1049	3076	975	925	6024
9	60,000	624	4124	975	925	6648
10	15,000	172	4748	975	925	6820

Source: U:\1CH008.053_GW Mgt & Phase 2 GW\020_Project_Data\SRK\3D Doris Model\HOPE BAY_Flow Estimation_20110416.GF.xls

Notes on Table 1:

- "Flow Stope" represents inflow to a given stope at full size
- "Flow Backfill" represents cumulative inflow to stopes up to that specific number (e.g., for Stope 3, the "Flow Backfill" represents flow into stopes 1 and 2, which are assumed to be mined and backfilled. Backfill has no effect on inflow rate.
- "Flow Decline" represents inflow to the main decline when fully developed.
- "Flow Ramp" represents inflow to spiral and ramp associated with a given stope.
- "Total Flow" is the cumulative inflow for any row in a table. Total flow for stope 1 represents inflow to that specific stope, the decline and ramps. Total flow for stope 10 represents cumulative inflow to all stopes, plus the decline and cumulative flow to all ramps and spirals.

6.1.3 Estimating Groundwater Inflows

Quantifying groundwater inflow to the mine workings is difficult because of uncertainty and variability in the parameters used to estimate groundwater flow. In this analysis, groundwater inflow is assumed to be only proportional to the hydraulic conductivity estimate because the boundary conditions of the model do not change. The most likely hydraulic conductivity for each hydrogeologic domain is the geometric mean of the observed hydraulic conductivities within a domain and this geometric mean hydraulic conductivity is used to be to estimate groundwater inflow.

6.1.4 Bedrock Inflow for Water Balance

Without a mining schedule, it is not possible to estimate the specific change in inflow over time. To account for increased mining areas developing over time, two inflow periods were assumed for the water balance:

- Period 1, corresponding to mining year 5, 50% of cumulative inflow was assumed = 3,500 m^3/day.
- Period 2, corresponding to mining year 6, 100% of cumulative inflow was assumed = 7,000 m^3/day.

6.1.5 Drill holes

Exploration drill holes were not explicitly included in the numerical model. Based on a general review of mine plans, assumed mining rates and exploration drill hole locations, two exploration drill holes are assumed to be the maximum number that might be intersected at a given time in a given stope. Flow through an open NQ-diameter exploration drill hole (75.7mm) was assumed to be 2,680 m^3/day from calculations based on the Darcy-Weisbach equation.

For the water balance model, 0, 1 or 2 drill holes were randomly turned on over a given model time step and assumed to flow unimpeded for a period of one week, at which point, it was assumed that the drill hole was plugged.

6.2 Inflow Quality

Estimates of groundwater quality that may be observed during operations are based on results from Westbay well 10WBW001, a multi-level monitoring system which was completed in 2010 within the Doris Lake talik of the Doris Central area. Westbay wells can be thought of as multi-level piezometers with multiple “screen zones” at various depths allowing sampling, water level measurement or hydraulic testing at each point. Each of the monitoring zones is hydraulically isolated at the top and bottom by pneumatic packers. Each zone has a measurement port from which samples can be collected using specialized wireline tools and a larger pumping port that can be used for zone development or hydraulic testing.

The Doris Central Westbay well was designed to provide pressure and temperature profiles throughout the talik under Doris Lake and to provide water samples from different depths to characterize the chemical profile and the interaction between deep connate groundwater and the fresh lake water at the surface. The deepest sampling zone was set below the diabase sill to provide water quality from that hydrogeological domain. The middle sampling zone was set in the area where water was lost during drilling and the packer testing indicated high hydraulic conductivities. Monitoring zones are numbered from the bottom up. Therefore, Zone 1 is at the bottom of the well, and higher numbered zones are shallower.

Three zones were selected for sampling at Doris Central to provide water quality samples from shallow, medium and deep talik water.

Table 2 below shows which zones were targeted and what they represent. Westbay well locations and monitoring zones are shown on Figure 1. Figure 3 is a cross section through 10WBW001 with geology, Westbay zones and hydraulic conductivity results indicated.

Table 2: Zones Targeted for Water Quality Sampling

Well	Zone	Vertical depth (m)	Deposit	Representative Of
10WBW001	10	57-97 m	Doris Central	Shallow talik water, near the upper parts of the proposed Doris Central stopes.
	6	221-246 m		Medium depth talik water, around the area of the proposed Doris Central stopes, possibly influenced by nearby faults.
	1	485-495 m	Doris Central Lower	Deep talik water, below the diabase.

Source:\01_SITES\Hope.Bay\1CH008.013_2010_Westbay_Installation\080_Reporting\20110125 Westbay Data Report\Tables\Table 2 Zones targeted for sampling.xlsx

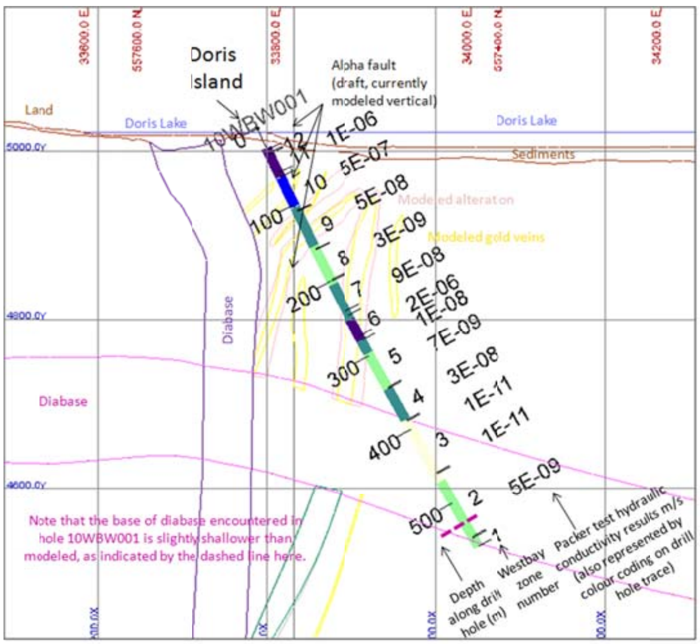

Figure 3: Cross section along drill hole 10WBW001, showing Westbay zones and related packer test results

6.2.1 Method for Purging Drilling Water from the Targeted Zones

The Doris Central well was drilled using fresh lake water, which must be removed from the Westbay zones to enable sampling of the natural groundwater. SRK field staff purged the drilling water from each of the target zones using an airlift pumping method, monitoring field parameters and taking laboratory samples to measure water quality changes as the drill water in the zone was replaced with formation water.

The procedure involved opening the pumping port in a target zone and then injecting compressed air into the internal Westbay PVC pipe above the pumping port. This caused water to flow from the zone into the Westbay internal pipe, displacing the water lifted from the well.

Water quality samples for lab analysis were collected during and at the end of the purging to allow assessment of purge progress, or stabilization of water quality, over time. Samples were also taken for QA/QC including duplicates, rinsate blanks, samples of the drilling water and water samples from the Westbay. A full description of the well and purging process is contained in the report '*Hope Bay 2010 Westbay Program Data Report, SRK, (in progress)*'. Table 3 lists purging information below.

Table 3: Purging Volumes and Methods Used

Zone	Volume of One Zone (L)	Volume Removed (L)	# of Zone Volumes Removed*
10	264	3014	11.0
6	168	Initially 8,096 L; after bulk sample 13,592 L	Initially 46.6; after bulk sample 79.3
1	96	3192	27.5

Source: \01_SITES\Hope.Bay\1CH008.013_2010_Westbay_Installation\080_Reporting\20110125 Westbay Data Report\Tables\Table 3 Purging volumes all targeted zones.xlsx

* Note that for zones purged using the airlift method, the volume of glycol water purged from inside the Westbay was subtracted from the calculation of # of zone volumes removed.

6.2.2 Sampling Methods

After sufficient volumes had been purged from the well, samples representing the groundwater were obtained using two sampling methods: the airlift pumping method and the Westbay sampler bottle method. When reviewing the water quality sample results, the method used to obtain the sample should be considered, as it has an effect on certain parameters:

- Grab samples of the airlift discharge taken at the surface have undergone considerable aeration before sampling. The addition of air to the water changes the concentration of the parameters (eg: alkalinity, redox, isotopes, and other parameters) for chemical analysis. The water samples that were collected during airlifting may not be representative of the formation water. However, as the inflowing mine water would likely be aerated through pumping in the mine, they do provide an interesting comparison with the measurement port samples.
- Measurement port samples collected directly from the zones down hole using a specialised tool do not come into contact with the atmosphere until they are poured into sample bottles at the surface. However, parts of the sample become highly aerated when they are depressurized through the sampler valve to fill the sample bottles. For most parameters, they are considered to be more representative of actual formation water than the airlifted samples.

6.2.3 Lab Analysis Methods

Samples were analysed for routine parameters, total dissolved solids (TDS), total metals, dissolved metals, nutrients, and stable isotopes.

Initial samples, taken during the purging process and at the end of the airlift, were analyzed using the traditional methods of ion chromatography, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). These samples had high detection limits and therefore some parameters were not included in the statistics for the summary water chemistry tables, discussed in the next section. To achieve better detection limits, the analysis method was changed after the initial sampling rounds. All subsequent groundwater samples collected were analyzed using High Resolution Inductively Coupled Plasma Mass Spectrometry (HR-ICPMS). These are labelled 'seawater' analysis in the water quality results table.

The stable isotope samples for oxygen and deuterium were analyzed by Gas Isotope Ratio Mass Spectrometry (GIRMS).

6.2.4 Mine Inflow Water Quality

The groundwater quality results for Zones 6 and 10 are assumed to be representative of the expected initial range in inflowing water quality at Doris Upper mine areas. The results from Zone 1 are assumed to be representative of the initial inflows to the Doris Lower mine areas. Over time, inflowing groundwater is assumed to trend towards the lake water quality. It is not currently possible to estimate the time frame over which this may occur.

To allow for flexibility in the future mining planning, it was assumed that the mine inflows could be from either Doris Upper or Doris Lower, or from a combination of both at any time over the life of the mine water discharge. To be conservative in representing these scenarios in the water and load balance, for each parameter the highest of the 75th percentile concentration from either Zone 1 (Doris Lower) or Zones 6 and 10 (Doris Upper) was used.

Table 4 presents the 75th percentile concentrations for all samples, each zone grouping, and the max of either zones 1 or 6 and 10, as was input into the water balance.

Table 4: 75th Percentile of Doris Central Sample Results

Parameters		Units	DORIS CENTRAL			BOSTON	Average Seawater*
			ZONE 10 57-95m Below Lake	ZONE 6 221-246m Below Lake	ZONE 1 485-491m Below Lake	ZONE 6 271-380m Below Lake	
			11-Apr-11	11-Apr-11	11-Apr-11	23-Apr-11	
Zone Volumes Developed		#	11	79.3	27.5	1.7	--
Field Parameters	pH	pH units	7.32	7.71	7.79	7.13	--
	EC	S/cm	>20	>20	>40	36	--
	DO	g/L	n/a	n/a	n/a	7.86	--
	Salinity	%	n/a	n/a	n/a	2.3	--
	ORP	mV	n/a	n/a	n/a	-80	--
Lab Parameters	pH	pH units	7.59	7.67	7.09	7.00	--
	Total Dissolved Solids (gravimetric)	mg/L	37800	36100	41200	25300	--
	Alkalinity, Total (as $CaCO^3$)	mg/L	119	49.8	2.7	35.4	--
Dissolved Metals	Chloride (Cl)	mg/L	18800	18300	19000	13000	19400
	Sulfate (SO_4)	mg/L	1730	1780	944	295	2700
	Aluminum	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	0.001
	Arsenic	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	0.003
	Cadmium	mg/L	0.00013	<0.00005	<0.00005	<0.0001	0.0001
	Calcium	mg/L	1560	1400	4770	4500	411
	Chromium	mg/L	<0.0005	<0.00050	<0.00050	<0.0001	0.0002
	Cobalt	mg/L	<0.0005	<0.00050	<0.00050	0.00504	0.0004
	Copper	mg/L	<0.0005	<0.00050	0.0083	<0.0005	0.0009
	Iron	mg/L	5.8300	0.624	0.034	0.233	0.003
	Lead	mg/L	<0.0003	<0.00030	<0.00030	<0.0003	0.0000
	Magnesium	mg/L	1200	1270	71.2	404	1290
	Manganese	mg/L	1.20	1.22	0.731	0.840	0.0004
	Molybdenum	mg/L	0.0038	0.0311	0.0112	0.0878	0.01
	Nickel	mg/L	0.00073	0.00100	0.00163	0.0167	0.0066
	Potassium	mg/L	251	208	39	51	392
	Selenium	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	0.0009
	Sodium	mg/L	8700	8270	7020	2400	10800
	Zinc	mg/L	0.0708	0.154	0.157	0.104	0.005
Isotopes **	δD	‰, V-SMOW	-106.52	-96.7	-135.4	-136	n/a
	δ18O	‰, V-SMOW	-13.49	-12.8	-18.63	-17.67	n/a

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\!Project_Data (Not Job Specific)\04 Groundwater Chemistry\6_Working and Graphs\2011-06-06 Water Quality Table Rev02.xlsm

*Average seawater composition from *1 Seawater composition from: http://www.seafriends.org.nz/oceano/seawater.htm#composition

** Isotopes reported are from Fall 2010 sampling event. Results from the April 2011 sampling event were not available at the time this report was prepared. For comparison, Doris Lake water has **δ**D ‰ of -159.7 and **$\delta^{18}O$** ‰ of -19.25.

7 Conservatism and Limitations

At this stage of investigations, uncertainty remains in regards to expected inflows and inflow water quality. In order to address these limitations, conservative assumptions have been used. For inflows, the assumption of an equivalent porous media with an isotropic and homogeneous hydraulic conductivity is considered conservative in that much of the fractured bedrock will essentially have no flow. While discrete fractures or structures may exist, these features will be managed or controlled on an as-needed basis.

For inflow water quality, the volume of water within bedrock fractures in the vicinity of the mine workings is not infinite. Over time, it can be anticipated that water from Doris Lake will permeate into the subsurface, likely leading to relatively lower concentrations of many parameters.

The estimates provided herein are based on the available data. As further investigations are completed, additional information will become available allowing refinement of estimates. During operations, it is reasonable to assume that variations from these estimates could occur. Development of water management plans and strategies will reduce the risk related from these variations.

Regards

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