APPENDIX N

WATER QUALITY TECHNICAL SUPPORT DOCUMENT

N-1 Surface Water Quality Baseline
N-2 Surface Water Quality Modelling Report
N-3 Surface Water Quality Predictive Modeling of Pit Lake Water Quality

Springpole Gold Project: Predictive Modeling of Open Pit Basin Water Quality (2024 Update)

Prepared by:
Lorax Environmental Services Ltd.
305-1770 West 7th Avenue
Vancouver, BC, V6J 4Y6

Prepared for:
First Mining Gold Corp.
Suite 2070 – 1188 West Georgia Street
Vancouver, BC, V6E 4A2

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FINAL

Executive Summary

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First Mining Gold Corp. (FMG) proposes to develop, operate, and eventually decommission / close an open pit gold and silver mine and ore process plant with supporting facilities known as the Springpole Gold Project (Project). The Project is in a remote area of northwestern Ontario, approximately 110 kilometres (km) northeast of the Municipality of Red Lake and 145 km north of the Municipality of Sioux Lookout. An Environmental Assessment (EA) pursuant to the Canadian Environmental Assessment Act and the Ontario Environmental Assessment Act is required to be completed for the Project. This report is one of a series of Technical Support Documents prepared on behalf of FMG to support the predicted environmental effects of the Project.

The Project is proposed to be mined as an open pit. To allow the development and safe operation of the open pit mine, two dikes will be established to facilitate controlled dewatering of the open pit basin. At mine closure, the open pit basin will be filled in a controlled manner and ultimately reconnected to Springpole Lake via lowering of the east and west dikes. Filling of the open pit basin will commence after ~10 years.

As part of the Draft Environmental Impact Statement/Environmental Assessment (EIS/EA) for the Project, modelling of open pit basin water quality was conducted to predict the physical and chemical evolution of the water column (Lorax, 2022). In support of the final EIS/EA for the project, the pit lake model was revisited to account for revised: 1) pit geometry; 2) volume of re-contouring material within the pit; 3) water balance for the various inflows; and 4) geochemical source terms for the various inflows. Of key importance was to predict water quality conditions at the time the open pit basin will be reconnected to the North Basin of Springpole Lake. This report, prepared by Lorax Environmental Services Ltd., presents the results of the revised (2024) pit lake model.

At the time of connection to Springpole Lake, the open pit basin will occupy a surface area of ~252 ha (206 ha for the open pit plus a further 46 ha for the fish habitat development area), have a maximum water depth of 303 m, and a volume of ~173 Mm^3. The pit lake is predicted to reach its maximum elevation of 391 masl (elevation of Springpole Lake) in 4.8 years. Accelerated filling is afforded by the conveyance of make-up water from Springpole Lake to the open pit basin. An engineered spillway or siphon, within one or both dikes, is proposed to enable the controlled transfer of water from Springpole Lake to the open pit basin.

Model outputs for temperature, dissolved oxygen and total dissolved solids demonstrate that the water column will evolve to form a permanently stratified density structure

(meromixis), which will limit mixing between the surface mixed layer and deeper depths. These model observations specifically indicate that the effects of wind-driven and convective mixing are not sufficient to mix the water column below a surface (oxygenated) mixed layer depth ranging seasonally from 20 to 40 m. Under conditions of meromixis, suboxic conditions are predicted to develop below the surface mixed layer over time.

Model predictions show an improvement in surface water quality over time in response to several time-dependent factors: 1) loadings associated with pit wall runoff decrease as the open pit basin fills (in response to pit wall submergence and cessation of sulphide mineral oxidation); 2) loadings associated with seepage from the Co-Disposal Facility decrease as the hydraulic gradient and associated groundwater flux lessen; 3) as the basin fills, and the water surface area of the basin increases, the input of direct precipitation to the lake surface increases relative to pit wall runoff; and 4) development of water column stratification serves to isolate more saline water quality in pit bottom waters.

At this time of connection to the North Basin of Springpole Lake (after ~4.8 years of filling), all predicted parameter values remain below applicable WQGs. Monitoring during the early stages of mine closure will be used to validate the predictions presented herein. Given the time scales of pit filling (4 to 5 years), monitoring during the filling period will afford considerable time to validate model predictions and identify the need for additional mitigation measures, if required.

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First Mining Gold Corp. (FMG) proposes to develop, operate, and eventually decommission / close an open pit gold and silver mine and ore process plant with supporting facilities known as the Springpole Gold Project (Project). The Project is in a remote area of northwestern Ontario, approximately 110 kilometres (km) northeast of the Municipality of Red Lake and 145 km north of the Municipality of Sioux Lookout. An environmental assessment (EA) pursuant to the *Canadian Environmental Assessment Act* and the *Ontario Environmental Assessment Act* is required to be completed for the Project. This report is one of a series of Technical Support Documents prepared on behalf of FMG to support the predicted environmental effects of the Project.

During the consultation process, Project-specific input from regulatory agencies and Indigenous communities was considered at key milestones of the EA process, including baseline studies, alternatives, assessment approach, mitigation, and monitoring where appropriate. A comprehensive draft Environment Impact Statement / Environmental Assessment (EIS/EA) document (Wood, 2022) was consulted on over the course of more than 2 years leading up the final submission. An overview of the consultation input that was considered during the effects assessment in relation to this report is summarized in Sections 6.6 to 6.9 of the final EIS/EA. The updated modelling, presented in this report, includes consideration of the feedback provided on the draft EIS/EA.

The Project is proposed to be mined as an open pit. To allow the development and safe operation of the open pit mine, two dikes will be established to facilitate controlled dewatering of the open pit basin. Ore from the open pit will be processed in an onsite process plant at approximately 30,000 tonnes per day (tpd). Tailings resulting from the processing of ore will be stored in a Co-Disposal facility with mine rock (CDF).

The main components of the Project include:

- Open pit;
- Dikes (west dike and east dike);
- CDF for mine rock and tailings (north cell and south cell);
- Surficial soil stockpile
- Ore stockpiles;
- Process plant complex;
- Buildings and supporting infrastructure;

- Explosives storage facility;
- Water management and treatment facilities;
- Fish habitat development area;
- Accommodations complex;
- Aggregate and quarry operation(s);
- Transmission line; and
- Mine access road and co-located airstrip.

At mine closure, the open pit will be filled in a controlled manner to form an open pit basin that will ultimately be reconnected to Springpole Lake, once the water quality in the refilled basin meets all regulatory requirements. As part of the Draft Environmental Impact Statement/Environmental Assessment (EIS/EA) for the Project (Wood, 2022), modelling of the open pit basin was conducted to predict the physical and chemical evolution of the water column (Lorax, 2022). Of key importance was to predict water quality conditions at the time the open pit basin will be reconnected to the North Basin of Springpole Lake via lowering of the dikes. The initial results showed that at the time of connection to the North Basin of Springpole Lake, all parameter values would meet applicable water quality guidelines (WQGs) for the protection of aquatic life (Lorax, 2022).

In support of the final EIS/EA for the project, the pit lake model was revisited to account for revised: 1) pit geometry; 2) volume of re-contouring material within the pit; 3) water balance for the various inflows; 4) geochemical source terms for the various inflows; and 5) geochemical reactions that will occur upon the neutralization of acidic pit wall runoff.

This report, prepared by Lorax Environmental Services Ltd. (Lorax), presents the methods and results for the revised pit lake modelling component. Specific objectives of this report include the following:

1. Develop water quantity and quality inputs for the open pit based on site-specific information, regional data, and information from site analogues;
2. Generate water quality predictions for the water column up until the re-connection of the open pit basin with Springpole Lake; and
3. Recommend post-closure monitoring measures to ground truth the water balance
4. and water quality predictions described herein.

In the chapters to follow, the functionality of the pit lake model is described (Chapter 2). This is followed by a detailed description of the model inputs and assumptions specific to the Springpole open pit basin (Chapter 3). Model results are presented in Chapter 4, while conclusions and monitoring recommendations are provided in Chapter 5.

2. Description of Pit Lake Model

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2.1 Overview

Model simulations were conducted using PitMod, a one-dimensional numerical hydrodynamic model used for predicting the spatial and temporal distribution of temperature, density, dissolved oxygen and water quality parameters in lakes (Martin *et al.*, 2017; Dunbar, 2013). The one-dimensional approximation is particularly applicable to pit lakes due to their high depth to surface area ratios and the fact that there are few, if any, barriers to horizontal mixing relative to those observed in the vertical dimension.

Model results provide information on the chemistry of water layers with depth and time in the pit lake. Various aspects of the model are described in the sections to follow with respect to physical processes, biogeochemical process, and geochemical modeling. Examples of field calibration studies are also summarized. PitMod has been used at over 50 sites globally and is an accepted tool by both Canadian and U.S. regulatory agencies.

2.2 Physical Processes

The physical component of PitMod simulates the water column structure of a pit lake over time by predicting the evolution of total dissolved solids (TDS), temperature, density (calculated from TDS and temperature) and dissolved oxygen in the water column. The physical component of the model is 1-dimensional, divided into a vertical stack of 1 m-thick layers. Each layer is assumed to be homogeneous. The principal physical processes simulated by the model include the following (illustrated schematically in Figure 2-1):

- *Heating and cooling of the lake surface*: Thermal energy from the sun warms surface waters and influences water temperature (and hence density) of the mixed surface layer. Heat is transferred to deeper layers through diffusion, mixing and convection;
- *Wind-driven circulation*: The influence of the wind causes adjacent water layers to mix to varying degrees according to the wind speed. The surface flux of kinetic energy for wind-driven mixing is proportional to the cubed wind speed and is strongest at the lake surface. Mixing occurs readily between adjacent layers of similar density. In contrast, mixing is hindered where density differences (density gradients) exist between water layers;
- *Convectional mixing:* Convection describes motion within a fluid resulting from temperature driven density differences. Freshwater achieves its maximum density at a temperature of ~4°. When surface waters approach this temperature (in both

the spring and the fall), density increases, resulting in a decrease in the density difference between adjacent layers. Consequently, the energy required by wind to mix adjacent water layers is reduced, and the depth of the mixed layer deepens. The model also accommodates the input of any number of inflows which may promote convectional mixing due to the density differences between water types; and

- *Ice formation and melting*: PitMod includes the formation and melting of ice on the lake. The formation of surface ice has no bearing on water losses or gains, but influences the surface exchange of thermal and kinetic energy, as well as the loss of mass through evaporation. Ice temporarily also stores water for later release when the air temperature increases.

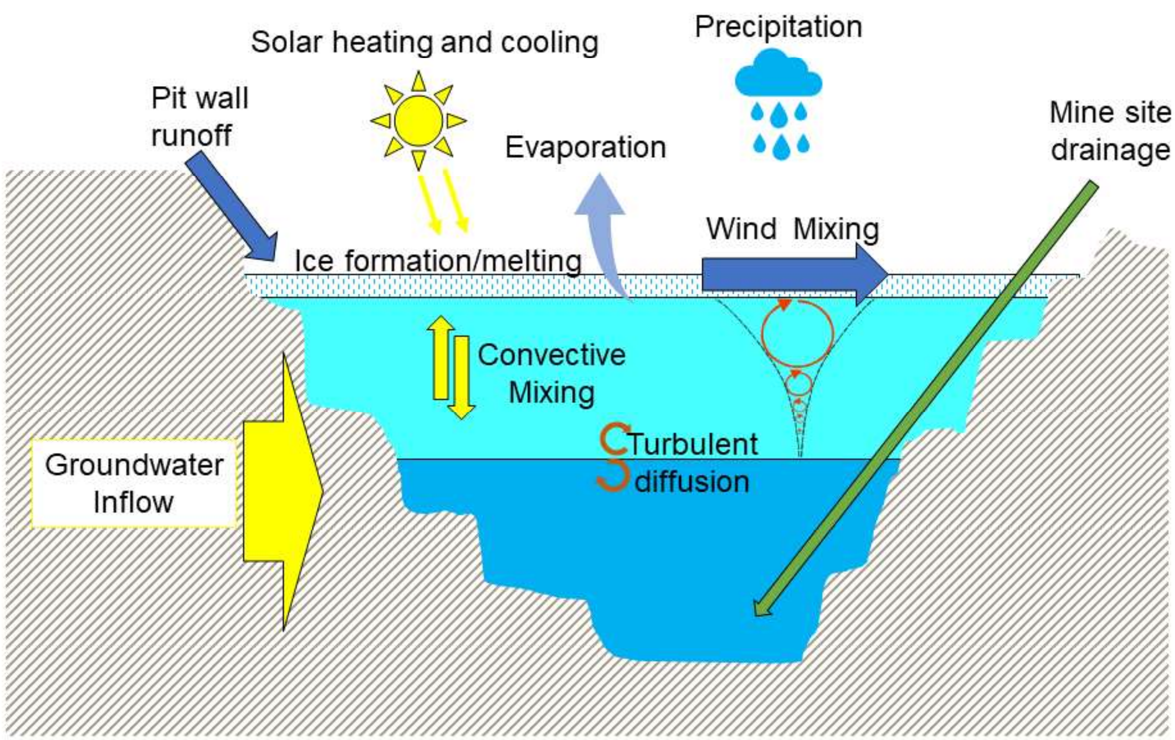

Figure 2-1: Schematic illustrating physical processes simulated by PitMod

In addition to the processes outlined above, PitMod can accommodate the introduction of external sources water (*e.g.*, CDF seepage, groundwater, seepage from ore stockpile areas, *etc*.) and predicts the resultant mixing and water quality throughout the pit lake.

In order to simulate the above processes in computer code, assumptions are made in order to increase computational efficiency and to approximate complex physical processes:

- All properties in the pit lake are horizontally homogeneous at all times; that is, they are functions of depth and time only;
- The effect of all currents may be parameterized as a single vertical turbulent diffusion equation. Hence, direct calculation of the velocity field in the pit lake is omitted;
- The value of the vertical turbulent diffusion coefficient, which regulates the degree of vertical mixing of water properties, varies with depth and time, and is solely a function of the local stratification. This term may be calculated directly from the static stability; and
- Instabilities in the water column (*i.e.*, heavier water overlying lighter water) are dealt with immediately in the model by vertically mixing adjacent water parcels until the instability is removed. All water properties are conserved in this process which simulates convective mixing.

2.3 Oxygen Consumption

Dissolved oxygen (DO) can be used to illustrate mixing behaviour as well as redox conditions. In PitMod, DO is introduced to surface waters through interaction with the atmosphere and is distributed throughout the water column by mixing and diffusion. DO is also introduced via the input of surface water and groundwater/seepage inflows. PitMod allows for the consumption of DO in both in the water column and bottom substrates via the bacterial degradation of organic matter. For the pit lake model, DO consumption rates were based on empirically-derived rates for deep oligotrophic lakes (as described in Martin *et al.,* 2024).

Other redox pathways were not modelled (*e.g.,* nitrate reduction, Mn-oxide reduction, Fe-oxide reduction and sulfate reduction). This relates to the large uncertainty relating to the availability of these secondary oxidants. In particular, the availability of Mn- and Fe-oxides, which are particulate species, will largely be dependent of pit wall erosion rates which are very difficult to quantify.

2.4 Geochemical Modelling

Pit lake modelling was conducted using PHREEQC, a geochemical model originally produced by the U.S. Geological Survey (Parkhurst and Appelo, 1999). PHREEQC is capable of a wide variety of aqueous geochemical calculations, including speciation and saturation index calculations, mineral and gas equilibria, surface complexation (adsorption) reactions, ion exchange and redox processes. PHREEQC is well established and has been rigorously validated. In addition, it allows for use of several thermodynamic databases including those for both WATEQ4F and MINTEQ. Furthermore, PHREEQC's treatment of aqueous solution chemistry is valid from very fresh water through to high ionic strength media often observed in pit lake systems (Parkhurst, personal communication, 1998).

For the Springpole open pit basin, PHREEQC was used to: 1) predict the pH of the pit lake during the filling period; and 2) predict water quality conditions in the pit lake following the neutralization of acidic pit wall runoff.

2.5 Model Validation

PitMod has been used at over 50 sites globally and is an accepted tool by both Canadian and U.S. regulatory agencies. Through work in Idaho (Thompson Creek Mining Company) and Alaska (Donlin Gold), PitMod has gained regulatory acceptance by several U.S. agencies including the U.S. Environmental Protection Agency, U.S. Bureau of Land Management, U.S. Forest Service and the U.S. Army Corps of Engineers. Through work in Sweden at the Aitik Mine (Martin *et al*., 2017), PitMod has received exposure to the Sweden Environmental Court. Most recently in Ontario, PitMod was used in support of closure plan development for the Detour Mine.

A primary strength of PitMod is that it has undergone rigorous validation using empirical data collected from modeled sites. These include: 1) the Island Copper Mine (ICM) Pit Lake; and 2) the Equity Silver Mine (Main Zone Pit Lake). The conceptual plan for ICM's open pit was to develop a meromictic lake (seawater capped by freshwater) characterized by strong vertical stratification and anoxic bottom waters (Poling *et al*., 2003). Acid rock drainage (ARD) would then be injected into the suboxic zone to take advantage of acid consuming and metal-removal processes.

PitMod was validated by comparing model predictions for the ICM pit lake with measured parameters in the lake water column subsequent to pit filling. This independent model assessment/verification study was conducted by Lorax in conjunction with Professor Greg Lawrence at the Department of Civil Engineering, University of British Columbia (UBC). Overall, there was excellent agreement between modeled and measured density of the water column in the ICM pit lake (Figure 2-2). The density structure revealed by both the model and empirical data showed a two-layer system, comprising a surface layer of low density (brackish water), and a deep dense layer comprising seawater. Modeled and measured TDS also showed good agreement at all depths in the pit lake (Wilton, 1998; Wilton and Lawrence, 1998).

PitMod was also validated against dissolved oxygen (DO) data which were collected at ICM by UBC between August 1996 and April 1998. PitMod was used to predict DO concentrations over the same period at three water depths (Figure 2-3). The measured and modeled DO values show good agreement, with a rapid decrease observed at 300 m, a more moderate decrease at 100 m, and fluctuating levels at 3 m driven by temperature-dependent saturation in the surface mixed layer.

As part of a second model validation study, PitMod was the subject of a 3-year research project funded by the National Science and Engineering Research Council (NSERC) of Canada (Crusius *et al.,* 2002 a,b; Dunbar *et al*., 2004; Dunbar and Pieters, 2008). This work was conducted at the Equity Silver Mine, near Houston, British Columbia, Canada, which operated from 1981-1994. PitMod validation work was conducted in the Main Zone Pit, which received a low-density-sludge (LDS) slurry associated with the lime neutralization of ARD. The water quality of the Main Zone Pit is characterized by elevated trace metal concentrations in the lake surface (particularly Zn) during the late spring and summer. From November through May, the pit lake is ice covered.

As part of the NSERC-funded program, PitMod was used to model water quality in the pit lake over a 400-day simulation period that overlapped with field measurements (Figure 2-4). In order to compare modeled *versus* observed values, modeled Zn concentrations were extracted from the model output corresponding to water depths of 1, 5 and 100 m and compared with field measurements at the same depths. The model time series for Zn agreed well with measured concentrations (Figure 2-4).

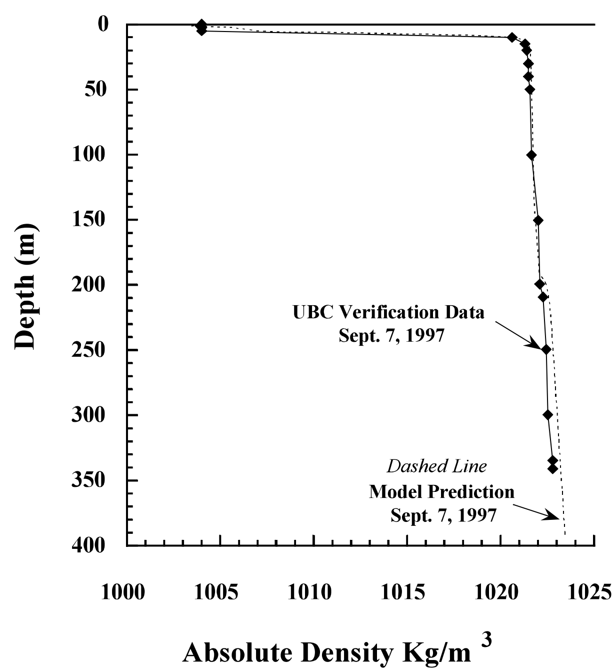

Figure 2-2: Modeled (PitMod) versus measured density in the Island Copper pit lake, September 7, 1997 (plot from Crusius et al., 2002a).

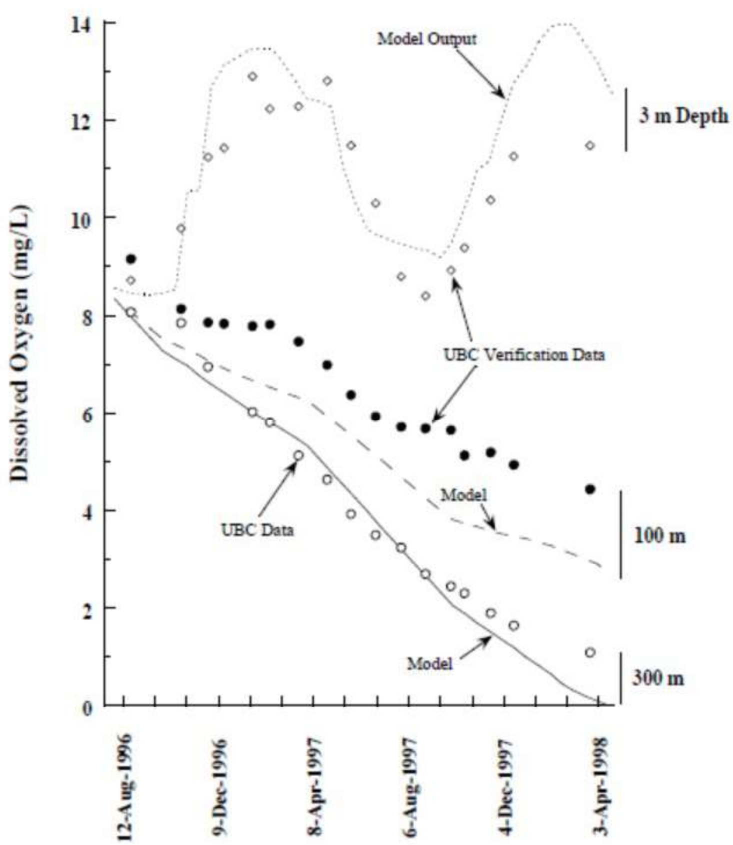

Figure 2-3: Modeled (PitMod) *versus* measured dissolved oxygen concentrations at three depths in the Island Copper Pit Lake, spanning a two-year period from 1996 to 1998 (plot from Crusius *et al.,* 2002a). UBC = University of British Columbia.

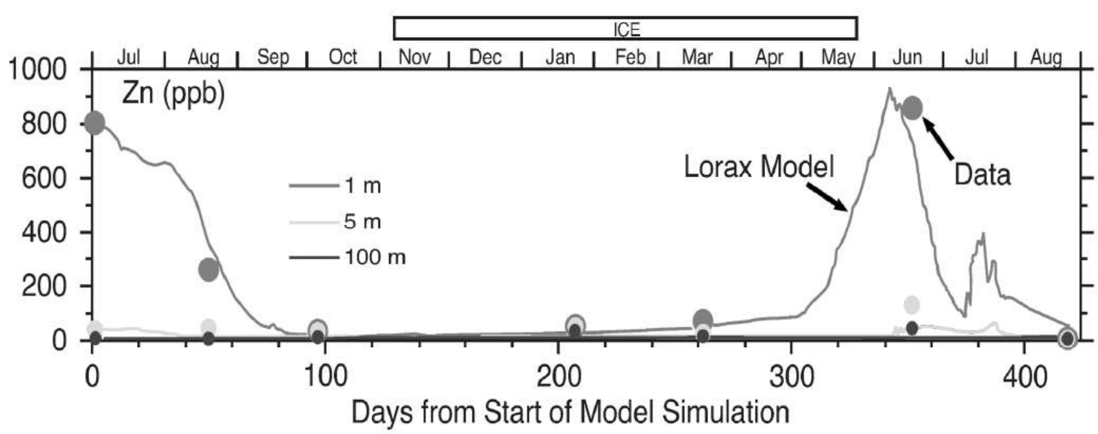

Figure 2-4: Modeled (PitMod) versus measured dissolved Zn concentration in the Main Zone Pit Lake (Equity Mine, British Columbia) at 1, 5 and 100 m depths (plot from Dunbar and Pieters, 2008).

3. Model Inputs and Assumptions

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3.1 Model Inflows and Outflows

The model for the open pit basin comprises 10 inflow terms and 2 outflow terms (Table 3-1 and Figure 3-1). Of key importance is the controlled conveyance of water from Springpole Lake which serves to accelerate basin re-filling. Accelerated filling offers benefits with regards to both habitat and geochemical factors. From a habitat perspective, a shorter filling period serves to re-instate fish habitat sooner as part of the Fish Habitat Development Area (area of exposed lake sediment). From a geochemical perspective, accelerated pit re-filling is considered best management practices to minimize the accumulation of pit wall oxidation products and associated loading.

Table 3-1:
Inflow and Outflow Terms for the Springpole Open Pit Basin Model

#	Inflow Term	Description
1	Disturbed Ground Runoff	Runoff from disturbed areas adjacent to the open pit basin. Reports as an inflow to the pit lake surface
2	Natural Ground Runoff	Runoff from upgradient natural ground areas adjacent to the open pit basin. Reports as an inflow to the pit lake surface.
3	Springpole Lake Inflow	Conveyance of flows from Springpole Lake. Reports as an inflow to the pit lake surface.
4	Groundwater	Regional groundwater inflow. Reports as vertically-distributed inflow to the pit lake.
5	CDF Seepage	Seepage Inflow from Co-Disposal Facility (CDF). Reports as vertically-distributed inflow to the pit lake.
6	Pit wall Runoff	Runoff from Pit Walls. Reports as an inflow to the pit lake surface.
7	Direct Lake Precipitation	Precipitation on lake surface as rain or snow. Reports as an inflow to the pit lake surface.
8	Fish Habitat Development Area	Runoff associated with exposed rock surfaces. Reports as an inflow to the pit lake surface.
9	Lake sediment	Runoff from exposed lake sediments (impounded by dikes). Reports as an inflow to the pit lake surface.
10	Re-Contouring Material	Runoff from in-pit Re-Contouring Material. Reports as inflow to pit lake surface.
#	**Outflow Term**	**Description**
1	Evaporation	Evaporation from pit lake surface
2	Basin Exchange	Water exchange of open pit basin with Springpole Lake upon their connection.

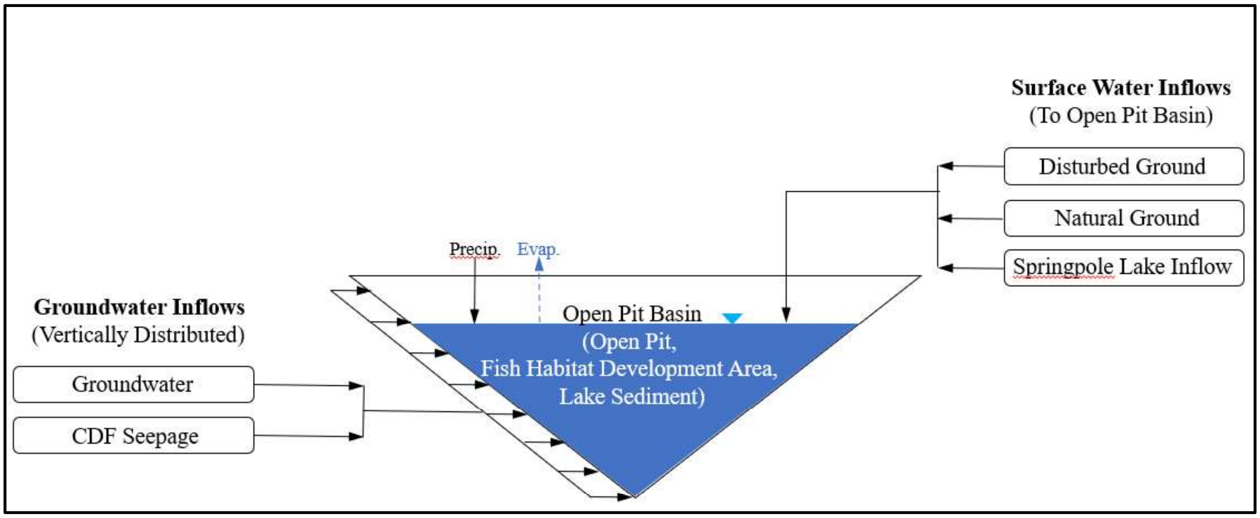


Figure 3-1: Springpole Open Pit Basin model flow diagram illustrating various surface water and groundwater inflows.

Within the boundaries of the open pit, loadings are realized from both exposed pit walls, as well as from placed re-contouring material that will create more optimum bathymetric conditions for fish habitat. Further details with regards to each input term are provided in Section 3.5 (Water Balance Terms) and Section 3.6 (Water Quality Source Terms).

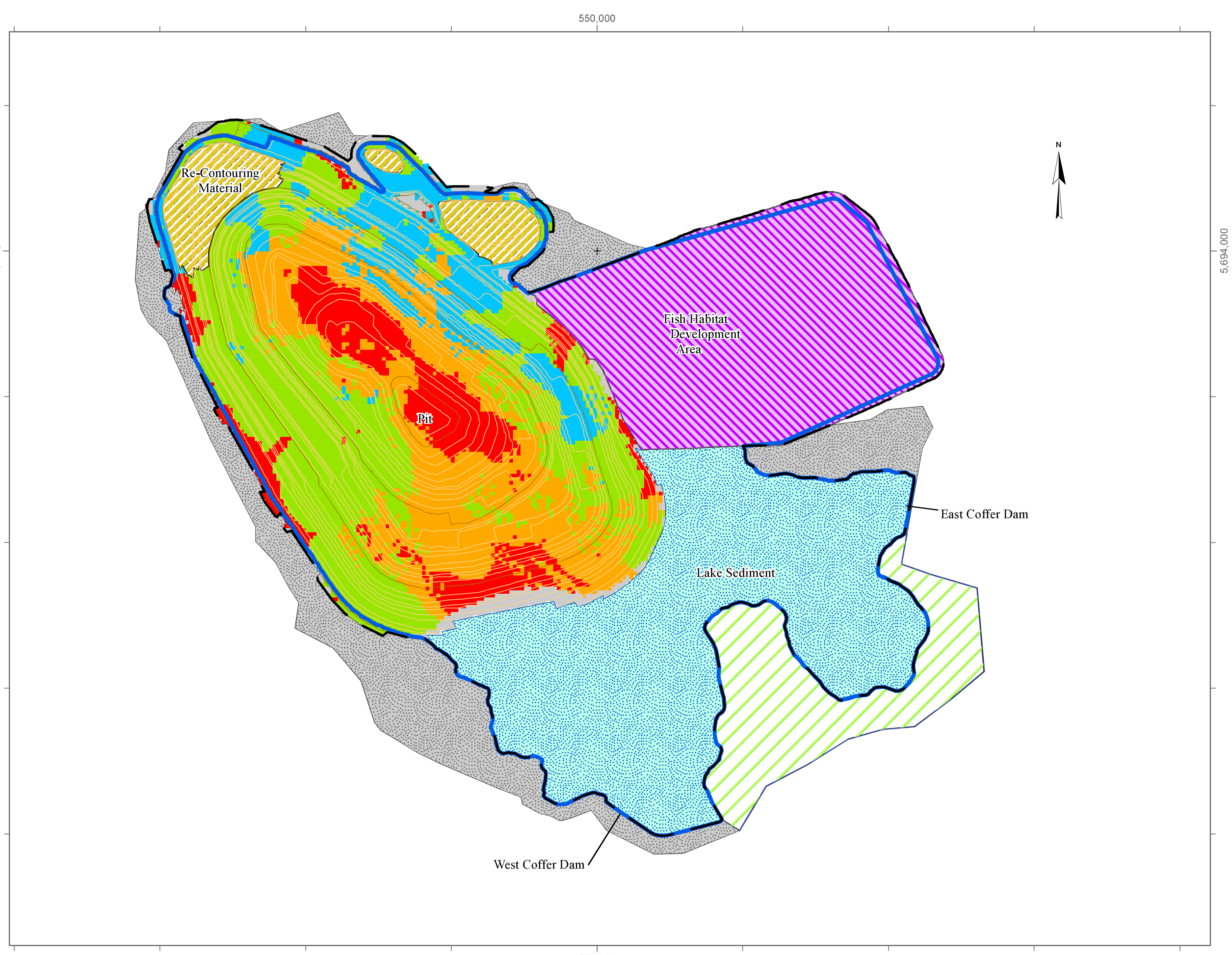
3.2 Model Spatial and Temporal Boundaries

Spatial boundaries for the open pit basin are shown in Figure 3-2. The spatial domain for open pit basin model includes the following key facilities and areas:

- Open pit
- Fish Habitat Development Area
- Exposed lake sediments as bounded by the east and west dikes

Disturbed and natural ground are situated outside the boundaries of the open pit basin as illustrated in Figure 3-2. As such, runoff from these areas is not computed by PitMod and is instead included as an inflow to the pit lake surface. Derivation of the inflows from disturbed and natural ground is described in Section 3.5.1. In addition to the areas above, the model also allows for the input of unrecoverable seepage from the CDF that bypasses the seepage collection system, and that reports to the pit basin via subsurface pathways.

In terms of temporal boundaries, the open pit basin model was run for a period of seven years. This 7-year period includes the period of pit filling in isolation from Springpole Lake (4.8 years) followed by 2.2 years of basin exchange upon re-connection with the North Basin of Springpole Lake. The total model duration of 7 years allows for steady-state water quality conditions to be achieved within the pit lake basin.



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LORAX ENVIRONMENTAL

PROJECT: **Springpole Gold Project: Predictive Modeling of Pit Lake Water Quality**

TITLE: Model Domain of Springpole Pit Lake

PROJECT #: A621 FIGURE: 3-2

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3.3 Open Pit Basin Volume Elevation Curve

The open pit basin comprises the following areas (illustrated on Figure 3-2):

- Open Pit
- Fish Habitat Development Area
- Lake Sediment Area, as bounded by the east and west dikes.

Planar areas of the open pit basin were processed in PitMod to quantify pit wall runoff, direct precipitation to the lake surface, and evaporation, while incremental volumes were used to calculate pit water levels as a function of time. In this regard, incremental volumes up to the spillway elevation were calculated for each reference elevation (Figure 3-3).

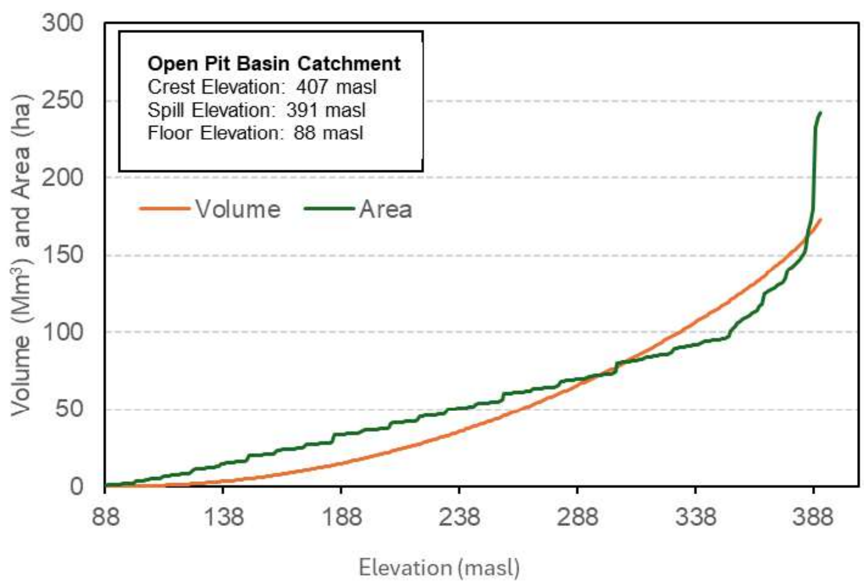

Figure 3-3: Volume-area-elevation curve for the Springpole open pit basin expressing volume and surface area as a function of elevation. Spill elevation (391 masl) is equal to the elevation of Springpole Lake.

3.4 Meteorological Inputs

In addition to driving the pit water balance, meteorological inputs were used to compute various physical components in PitMod, including wind mixing, heat exchange, ice formation/melting, and convective mixing. Consistent with other Project-related water balance assessments (*e.g.*, WSP, 2023a), Red Lake climate station monthly average data were used as meteorological inputs for the pit lake model (Table 3-2). Downward irradiance data (shortwave and longwave) were not available for the Red Lake climate station; therefore, these data were extracted from the Prediction of Worldwide Energy Resources (POWER) gridded data (POWER, 2019) (Table 3-2).

**Table 3-2:
Meteorological Inputs for the Springpole Open Pit Basin Model**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (mm) (Average)	26.8	17.3	28.4	34	73.4	99	103.4	88.3	83	59.7	42.9	30.2	686.4
Monthly Distribution of Precipitation (%)	3.9	2.5	4.1	5.0	10.7	14.4	15.1	12.9	12.1	8.7	6.3	4.4	100
Minimum Daily Temperature (°C)	-23.9	-21.3	-13.9	-4.2	3.1	9.1	12.4	11.4	5.9	-0.4	-9.4	-20	-4.3
Average Daily Temperature (°C)	-18.3	-15	-7.4	2.2	9.6	15.1	18.1	17	11	3.7	-5.7	-15.3	1.3
Maximum Daily Temperature (°C)	-12.7	-8.6	-0.8	8.6	16	21.1	23.8	22.7	16	7.8	-2	-10.5	6.8
Average Wind Speed (km/h)	9.8	10.1	11.3	12	12.4	11.8	10.8	10.9	12.1	13	12.6	10.5	11.4
Relative Humidity (%)	73.4	70.4	68.3	62.8	64.5	69.2	71.2	72.5	75.8	77.7	80.6	77.9	72.0
[a]Shortwave Downward Irradiance (kW-h/m^2/day)	1.2	2.3	3.6	5.0	5.5	5.6	5.4	4.6	3.1	1.9	1.2	0.9	3.4
[a]Longwave Downward Irradiance (W/m^2)	200.7	205.2	231.5	265.4	306.2	341.0	354.4	349.4	320.6	283.5	240.0	212.5	276.2

a - derived from POWER gridded dataset (POWER, 2019)

3.5 Water Balance Terms

Inflow and outflow terms associated with the Springpole open pit basin model are listed in Table 3-1 and illustrated in Figure 3-1. Key assumptions relating to each water balance terms are described below.

3.5.1 Surface Runoff Inflows

Surface runoff from several Project areas is captured and conveyed to the open pit basin. These inflows include runoff from the following areas (as illustrated in Figure 3-2):

- *Disturbed Ground Runoff.* Runoff from disturbed ground adjacent to the Pit.
- *Natural Ground Runoff.* Surface runoff from upgradient natural ground reporting to the Open Pit.

Monthly inflow values for these areas were derived by calculating monthly unit yields (L/s/km^2) based on runoff relationships presented in WSP (2023a) and then multiplying the unit yields by their respective catchment area reporting to the open pit basin. The calculated inflows are presented in (Table 3-3).

Table 3-3:
Surface Runoff Inflows for the Springpole Open Pit Basin Model (units in m^3/day)

Inflow Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Disturbed Ground Runoff [1]	30	46	97	613	1,054	847	856	731	710	494	219	64
Natural Ground Runoff [1]	11	17	36	227	391	314	317	271	263	183	81	24
Springpole Lake Inflow [2]	59,616	50,112	44,064	63,936	180,576	186,624	139,104	101,088	95,904	98,496	95,904	75,168

Notes:
1. Inflow derived using surface area and monthly units yields (L/s/km^2) as presented in WSP (2023a)
2. WSP (2023b).

3.5.2 Springpole Lake Inflow

The controlled transfer of water from Springpole Lake to the pit was included at a rate of 10% of monthly flow estimates for Station F7-HS1 (inflow to Springpole Lake). Allowable inflows were calculated from flows reported in WSP (2023b) and are presented in Table 3-3. Inputs from Springpole Lake, that range from 0.51 m^3/s (~44,000 m^3/day) in March to 2.2 m^3/s (~187,000 m^3/day) in June, dominate the open pit basin water balance.

3.5.3 Groundwater

Groundwater inflows are controlled by open pit basin water elevation, with flows declining as the water surface rises and the hydraulic gradient decreases. Elevation-dependent inflows were calculated based on linear interpolation between pit empty (flow = 2,637 m^3/day) and pit full (flow = 240 m^3/day) end members, as provided in WSP (2023a). Specifically, elevation-dependent inflows were calculated using the following equation:

$$Inflow_{elev} = Inflow_{Empty} - \left(\left(\frac{PitLake_{elev} - PitLake_{bottom}}{PitLake_{top} - PitLake_{bottom}}\right) * (Inflow_{Empty} - Inflow_{Full})\right) \quad \text{Eq. 1}$$

Where:

- $Inflow_{elev}$ is the inflow rate (m^3/day) at a given water elevation in the open pit basin
- $PitLake_{elev}$ is the given water elevation in the open pit basin
- $PitLake_{bottom}$ is the minimum water elevation (88 masl) of the open pit basin
- $PitLake_{Full}$ is the maximum elevation (391 masl) of the open pit basin, and elevation of Springpole Lake
- $Inflow_{Full}$ is the inflow rate (240 m^3/day) at the maximum water elevation (391 masl), and
- $Inflow_{Empty}$ is the inflow rate (2,637 m^3/day) at start of the start of filling when the open pit basin is empty.

The relationship between total groundwater inflow and water elevation is shown in Figure 3-4. The equation describing this slope was built directly into PitMod to calculate the total groundwater inflow.

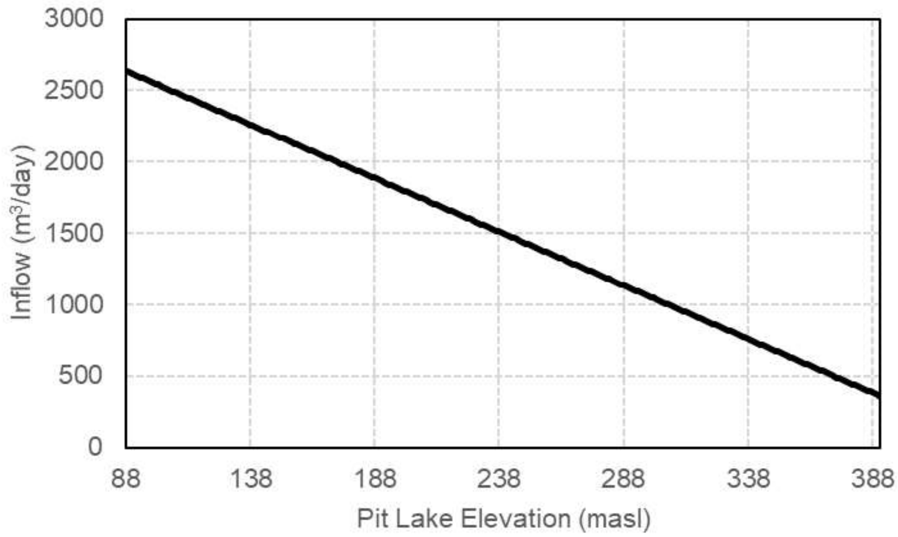

Figure 3-4: Groundwater inflow to the open pit as a function of water elevation in the Springpole Open Pit Basin.

While Equation 1 was used to calculate the change in total groundwater input as the basin fills, the depth distribution of the groundwater inflow was assumed to be proportional to the relationship between basin volume and depth (as shown in Figure 3-3). In other words, more groundwater is allowed to report to the upper regions of the open pit basin where the volume and associated cross-sectional surface area are higher.

3.5.4 Co-Disposal Facility Seepage

As for groundwater, CDF seepage inflows to the open pit basin are also controlled by water elevation in the open pit, with flows declining as the water surface rises and the hydraulic gradient decreases. Elevation-dependent values were calculated based on linear interpolation between pit empty (flow = 301 m^3/s) and pit full (flow = 40 m^3/s) end members (as provided in WSP, 2023a), as per the equation described above for groundwater. The relationship between the total CDF seepage inflow and water elevation in the open pit basin is shown in Figure 3-5. The equation describing the slope was incorporated into PitMod to calculate the total CDF seepage inflow. The depth distribution of the CDF seepage was assumed to be proportional to the relationship between basin volume and depth, as described above for groundwater.

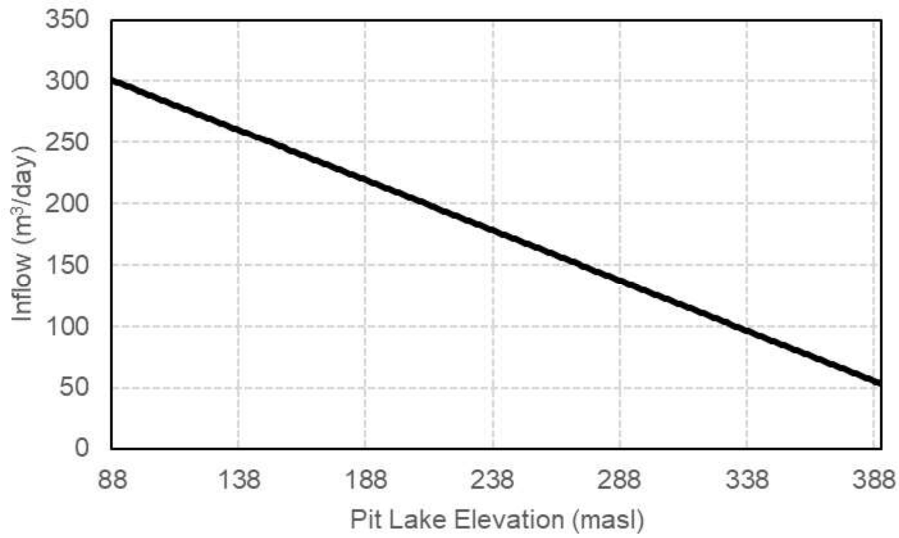

Figure 3-5: Seepage inflow to the open pit from the Co-Disposal Facility (CDF) as a function of water elevation in the Springpole Open Pit Basin.

3.5.5 Pit Wall Runoff

Pit wall runoff was calculated internal to PitMod and was determined by multiplying the daily precipitation value by the exposed planar pit wall areas above the lake surface. Exposed areas extend from the lake surface to the crest of the pit highwalls, and therefore pit wall exposure area decreases as the pit fills. Total runoff volumes were corrected by applying a surface-specific runoff coefficient (as provided in WSP, 2023a), to account for infiltration, evapotranspiration, and sublimation. Runoff coefficients for each surface type are listed in Table 3-4.

Table 3-4:
Open Pit Basin Runoff Coefficients

Pit Wall Surface Type	Runoff Coefficient
Pit Walls (Type1A, Type1B, Type1C and Type 2)	0.9
Re-Contouring Material	0.5
Lake Sediment	0.5
Fish Habitat Development Area	0.9

3.5.6 Re-Contouring Material

The north end of the open pit will be re-contoured to optimize basin bathymetry for fish habitat. Approximately 2 Mm^3 of mine rock will be placed over an area of approximately 10 ha (Figure 3-6). Re-contouring material will be placed to a maximum elevation of approximately 367 masl, and therefore all material will eventually be under water at the maximum water elevation (391 masl). Runoff from the re-contouring material was calculated internal to PitMod in a similar manner to other open pit basin surfaces, whereby precipitation is multiplied by the exposed (unsubmerged) planar area and then corrected for by the material-specific runoff coefficient (Table 3-4).

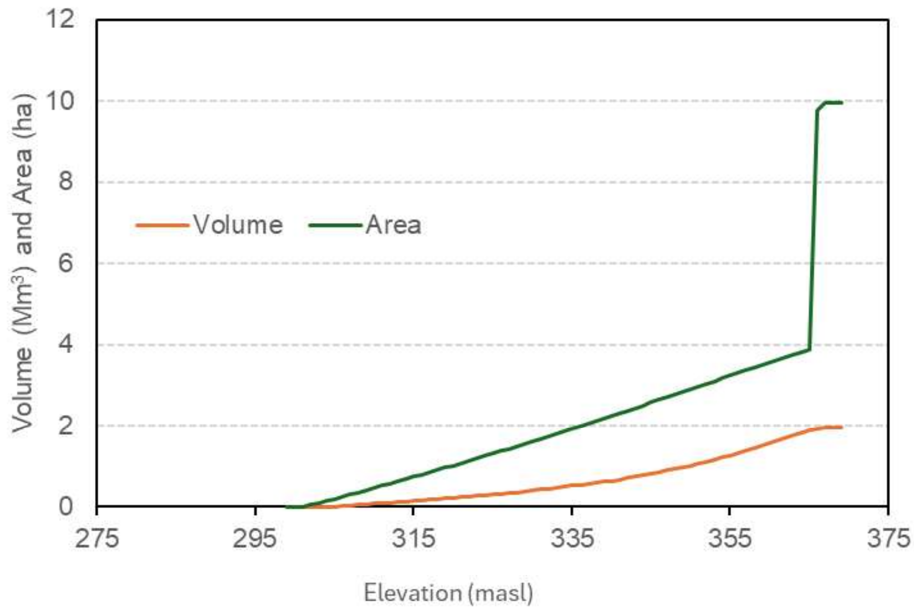

Figure 3-6: Volume and area (by elevation) of re-contouring material in open pit basin.

3.5.7 Precipitation

Direct precipitation to the water surface of the open pit basin in the form of rain and snow is described by a single flow term. Precipitation reporting directly to the basin surface enters the basin with a runoff coefficient of 1.0 (*i.e.,* 100% of this volume enters the basin). PitMod uses a threshold of 0°C to partition direct precipitation as either rainfall (>0°C) or snowfall (≤0°C).

3.5.8 Ice Formation and Melting

PitMod includes a snowmelt sub-model that melts stored snow in accordance with air temperature and radiation algorithms. The formation of surface ice in PitMod has no bearing on water losses or gains but affects the way water is stored.

3.5.9 Outflows

Outflows from the model domain include:

- *Evaporation:* Potential evaporation (daily) was computed internally by PitMod and used to represent evaporative loss from the water surface of the open pit basin during the ice-free period. During periods of ice cover, PitMod sets the temperature in the surface water layer to 0°C and assumes that solar radiation penetrating the ice into the lake is negligible and that there is no momentum flux from the surface wind. Under such conditions, evaporative losses (sublimation) from the lake surface are assumed to be zero. In this regard, evaporative losses are sensitive to the duration of ice cover.

- *Basin Exchange:* The dikes will remain in place during the filling period such that the open pit basin will remain isolated from Springpole Lake as the basin fills. Upon completion of filling (to elevation 391 masl), the open pit basin will be allowed to exchange with the North Basin of Springpole Lake. The exchange rate was calculated as sum of surface inflows, groundwater inflows and meteoric inputs less outflows (evaporation). As previously discussed, the pit lake model was run for a duration of 7 years to predict steady-state water quality conditions within the pit lake basin. This 7 year period includes approximately of 4.8 years of pit filling (in isolation from Springpole Lake) followed by two years of basin exchange upon re-connection with Springpole Lake.

3.6 Water Quality Source Terms

The following sections describe data sources and assumptions for water quality source terms. The source terms, or the data used for their calculation, were provided by WSP (2023c, 2024a and 2024b). The steps undertaken by Lorax to generate source terms otherwise not included in WSP (2024b) are also discussed in this section.

Water quality predictions were based on source terms most likely to be realized for the Project, and were generated for a full suite of environmentally relevant parameters, including all those with applicable WQGs for the protection of freshwater aquatic life.

3.6.1 Surface Runoff, Springpole Lake Inflow, and Precipitation

Source terms for surface runoff, inflow from Springpole Lake, and precipitation were provided by WSP (2023c, 2024b) (Table 3-5). The Springpole Lake inflow source term was derived as the average concentration at the Springpole Lake water quality sampling location (SW-01) closest to the Project. Water quality from SW-01 was assumed to be most representative of Springpole Lake water due to proximity and is further discussed in WSP (2023c). Precipitation that falls on the pit lake surface is assumed to host no solute loading.

3.6.2 Groundwater and CDF Seepage

Water quality source terms for groundwater and CDF seepage inflows were provided by WSP (2024b) (Figure 3-6). Baseline groundwater source terms were applied to groundwater entering the pit below the water table. For groundwater entering the pit above the water table, pit wall source terms of the specific lithological unit were applied (assuming some interaction of groundwater with exposed pit walls).

Table 3-5:
Geochemical Source Terms for Surface Runoff, Springpole Lake Inflow, and Precipitation to Pit Lake Surface (all values in mg/L)

Parameter	Natural Ground Runoff [1]	Disturbed Ground Runoff [1]	Springpole Lake Inflow [2]	Precipitation to Lake Surface [3]
pH	7.5	7.5	7.4	5.0
SO_4	1.3	6.5	1.9	0
Al	0.005	0.025	0.016	0
Sb	0.0001	0.0005	0.00011	0
As	0.00054	0.0027	0.00056	0
Be	0.00002	0.0001	0.000095	0
B	0.01	0.05	0.0053	0
Cd	0.000005	0.000025	0.000021	0
Cr	0.00016	0.0008	0.00052	0
Co	0.0001	0.0005	0.00011	0
Cu	0.00063	0.0032	0.0011	0
Fe	0.011	0.055	0.041	0
Pb	0.00005	0.00025	0.00012	0
P	0.05	0.25	0.022	0
Mo	0.000089	0.00045	0.00018	0
Ni	0.0005	0.0025	0.00075	0
Se	0.000072	0.00036	0.019	0
Ag	0.00001	0.00005	0.00002	0
Tl	0.00001	0.00005	0.000013	0
W	0.0001	0.0005	0.00018	0
U	0.000011	0.000055	0.000029	0
V	0.0005	0.0025	0.00032	0
Zn	0.0011	0.0055	0.0026	0
Hg	0.000005	0.000025	0.0000027	0
Ca	11	55	10	0
Mg	1.5	7.5	1.5	0
Na	0.55	2.8	0.75	0
K	0.71	3.6	0.65	0

Notes:
1 Source: WSP (2024b)
2. Source: WSP (2023c). Average water quality from Station SW-01.
3 Source term only for precipitation on Pit Lake surface. Model onto lake surface contributes volume but no loading.

Table 3-6:
Geochemical Source Terms for Inflows Reporting to Open Pit Basin along Subsurface Pathways (all values in mg/L)

Parameter	Co-Disposal Facility Seepage [1]	Regional Groundwater [1]
pH	8	8
SO_4	2200	4.4
Al	0.64	0.0048
Sb	0.55	0.00005
As	0.000024	0.00052
Be	0.000000017	0.00001
B	0.33	0.01
Cd	0.00011	0.000005
Cr	0.0043	0.00025
Co	0.057	0.00018
Cu	0.00077	0.00048
Fe	0.000048	0.12
Pb	0.00000044	0.000025
P	0.0054	0.026
Mo	0.030 [2]	0.0021
Ni	0.0038	0.00094
Se	0.036	0.00008
Ag	0.00052	0.000005
Tl	0.0044	0.000005
W	0.030 [2]	0.00056
U	0.093	0.00058
V	0.0000027	0.00025
Zn	0.0028	0.0013
Hg	0.00014	0.0000025
Ca	630	38
Mg	85	7.4
Na	500	6.7
K	600	2.4

Notes:
1. WSP (2024b)

3.6.3 Pit Wall Runoff

3.6.3.1 Overview

In support of the Springpole Pit Lake model, pit wall source terms were developed by Lorax. Geochemical source terms were derived by upscaling loading rates derived from humidity cell tests and validated against field barrel leachate and site water quality monitoring results. A flow chart of the work stages involved in the source term model is shown in Figure 3-7.

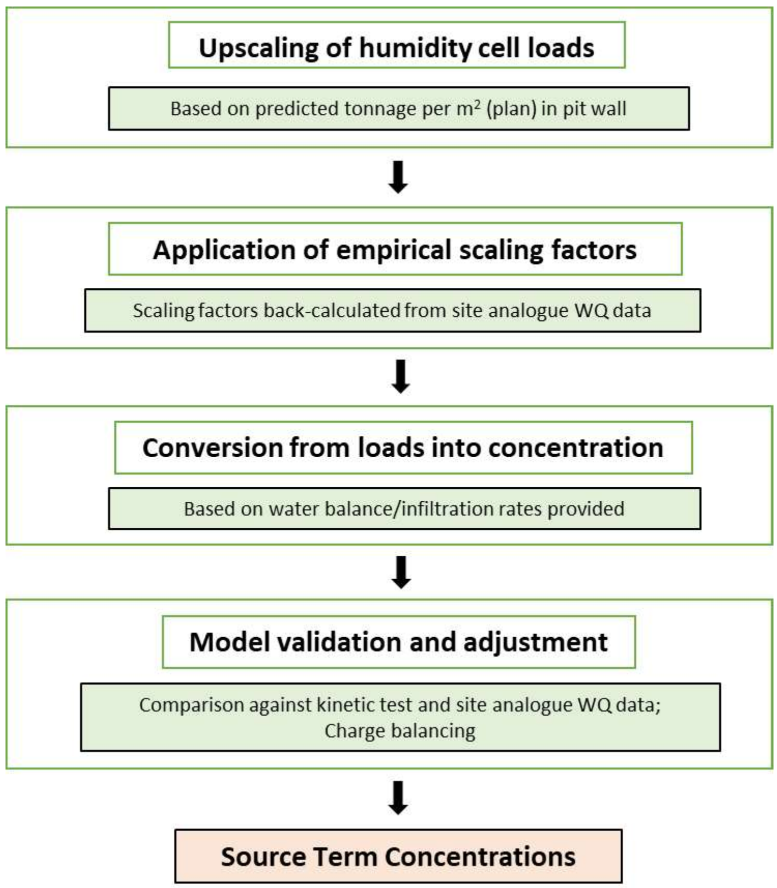

Figure 3-7: Work stages involved in the derivation of geochemical source terms for Springpole pit wall runoff.

3.6.3.2 Humidity Cell Loading Rates

Humidity cell loading rates form the basis for the source term model as they were used to generate input solutions for different mine rock lithologies at different model time steps. The selection of humidity cells, review of the kinetic test data, as well as proportioning of humidity cell loading rates to reflect the units expected to be exposed in the pit walls, was conducted by others and is described in detail in WSP (2024a). An overview of stable humidity cell loading rates for neutral and, where necessary, acidic conditions is given in Table 3-7.

Table 3-7:
Humidity Cell Loading Rates used in the Derivation of Pit Wall Source Terms

Geological Unit		Neutral NAG Type 2 (non-ML)	Neutral NAG Type 1C (ML)	Neutral PAG Type 1B	Acidic PAG Type 1A
pH	-	7.5	7.5	7.5	2.5
Alkalinity	mg/kg/wk	8.7	8.7	8.7	0
SO_4	mg/kg/wk	1.5	3.1	3.1	885
Ag	mg/kg/wk	0.0000057	0.0000074	0.0000074	0.0014
Al	mg/kg/wk	0.032	0.03	0.03	3.4
As	mg/kg/wk	0.00089	0.0024	0.0011	0.3
B	mg/kg/wk	0.0013	0.001	0.001	0.0037
Be	mg/kg/wk	0.0000057	0.0000067	0.0000067	0.00081
Ca	mg/kg/wk	2.7	3.2	3.2	13
Cd	mg/kg/wk	0.0000013	0.0000051	0.0000051	0.003
Co	mg/kg/wk	0.000028	0.000026	0.000026	0.18
Cr	mg/kg/wk	0.00025	0.00024	0.00024	0.0028
Cu	mg/kg/wk	0.00018	0.00026	0.00026	0.24
Fe	mg/kg/wk	0.0015	0.0011	0.0011	221
Hg	mg/kg/wk	0.0000023	0.0000025	0.0000025	0.0000087
K	mg/kg/wk	0.31	0.23	0.23	0.46
Mg	mg/kg/wk	0.39	0.54	0.54	0.91
Mo	mg/kg/wk	0.00018	0.00068	0.00068	0.016
Na	mg/kg/wk	0.032	0.033	0.033	0.068
Ni	mg/kg/wk	0.00014	0.000088	0.000088	0.15
P	mg/kg/wk	0.0057	0.0067	0.0067	1
Pb	mg/kg/wk	0.000023	0.000025	0.000025	0.0023
Sb	mg/kg/wk	0.00067	0.00055	0.00055	0.0018
Se	mg/kg/wk	0.000058	0.00025	0.00025	0.006
Tl	mg/kg/wk	0.0000084	0.0000093	0.0000093	0.00027
U	mg/kg/wk	0.000099	0.000037	0.000037	0.017
V	mg/kg/wk	0.00049	0.0005	0.0005	0.015
W	mg/kg/wk	0.00011	0.00011	0.00011	0.00025
Zn	mg/kg/wk	0.00047	0.0006	0.0006	0.28

Notes: PAG = potentially acid generating; NAG = non-acid generating; ML = metal leaching.

3.6.3.3 Mass Scale-Up

Pit wall exposures contain a reactive mass that is available for reaction with meteoric water prior to its reporting to the pit lake. This reactive mass was calculated using typical thicknesses for blast-damaged zones in bedrock described in Hustrulid (1999). In brief, this blast-damaged transition zone comprises a "fractured zone" and an "influenced zone". A portion of the outermost fracture-zone is expected to collapse and form layers of mixed-particle size bedrock talus collecting on the pit benches. Average thicknesses of 1.0 and 3.0 m were chosen for the blast-fractured and the blast-influenced zones, respectively. Using a bulk density of 2.78 t/m^3 and an average pit wall slope angle of 24°, these thicknesses translate to 12.2 t per plan m^2 of pit wall exposed.

Annual loading rates ($L_{i,y}$) produced by a given lithological unit *y* were calculated as follows:

$$L_{i,y} = r_{i,y} * m * t$$

where $r_{i,y}$ is the humidity cell loading rate in mg/kg/wk for species i and lithology *y*; *m* is the mass (in kg) of the material contained in the facility of interest; and *t* (in wk) is the time interval of interest which for annual loads is set at 52.

3.6.3.4 Scaling Factors

Owing to various studies comparing lab-to-field geochemical scaling effects, it has been recognized that drainage chemistry predictions based on quantitative mass upscaling often significantly overestimate the concentrations of dissolved solutes leached from mine rock (Malmström *et al.,* 2000; Sapsford *et al*., 2009; Andrina *et al*., 2012; Plante *et al*., 2014; Kirchner & Mattson, 2015). This is due to a variety of physiochemical factors affecting mineral dissolution rates and in-situ attenuation effects which differ between lab and field conditions. Metrics controlling differences in leaching behaviour include water/rock ratio, grain size distribution, and temperature, most of which act to reduce geochemical loads per mass contacted on larger mine site scales.

It is also known that dissolved parameters do not scale proportionally, especially under neutral pH conditions. To this end, the inclusion of and calibration to site water quality data in the scaling approach can help reduce the uncertainty of such scaling artifacts. To support Springpole pit wall source term derivation, parameter-specific scaling factors derived for the Red Chris Mine (Lorax, 2024a) and Touquoy Mine (Lorax, 2024b) were incorporated for this purpose rather than relying on theoretical scaling approaches. Both of these analogue sites are active or recently closed open pit mines in Canada and have maintained comprehensive pit sump operational water quality monitoring databases. The derivation of empirical parameter specific scaling factors at these sites was undertaken as follows:

- Pit sump water quality data were assembled, reviewed, and processed;
- The highest median pit sump water quality concentrations observed annually over several years of water quality monitoring were calculated;
- A dilution factor of 15-30% was then applied to account for the possibility of non-contact water runoff affecting the water quality within the pit sump to derive a back-calculated runoff water chemistry for each species i ($C_{i,obs}$). In other words, concentrations were increased by 15-30% depending on the reported water balance for a given site;
- Scaling factors (SF) for each species i were then back-calculated as follows:

$$SF_i = C_{i,sim}/C_{i,obs}$$

where $C_{i,sim}$ represents the uncorrected, predicted concentration. This concentration is based on upscaled lithology specific humidity cell data under consideration of the water balance:

$$C_{i,sim} = L_{i,x}/V_{con}$$

where $L_{i,x}$ is the annual humidity cell loading rate of waste rock unit x scaled to the reactive mass contributing a geochemical load from the pit wall per m^2 (plan). V_{con} is the annual runoff water volume per m^2 of the exposed pit wall under corresponding climatic settings. For the calculation of the upscaled loading rate produced by site analogue pit walls, site-specific pit slopes were used while thicknesses of the described blast-damaged zones were assumed to be the same as those used for the Springpole open pit.

The parameter-specific scaling factors SF_i were then carried over to the Springpole source term model to yield site-specific, corrected loading rates for each Springpole pit wall unit y ($SL_{i,y}$):

$$SL_{i,y} = SF_i * L_{i,y}$$

3.6.3.5 Water Balance Assumptions

A key step in source term development is the validation of model outputs against reference databases to identify potential model errors, or unexplained model under- and over-predictions. For this purpose, the model needed to be evaluated in terms of concentrations rather than loads ($SL_{i,y}$), since the latter are a relatively abstract metric that does not allow for the evaluation of geochemical first principles such as solubility limits in aqueous solutions. For this reason, the scaled geochemical loads $SL_{i,y}$ were divided by the expected annual contact water volumes based on water balance information used in the pit lake model. These assumptions are summarized in Table 3-8.

**Table 3-8:
Water Balance Assumptions used for the Conversion from Geochemical Loads to Concentrations for Springpole Pit Lake Source Terms**

Parameter	Units	Pit Walls
Footprint (plan)	m^2	1.0
Annual precipitation	mm	618
Runoff coefficient	-	0.90
Runoff per m^2 (plan)	L	556

3.6.3.6 Model Validation

Model validation was performed via the comparison of the source term output concentrations against kinetic test results as well as site analogue operational pit sump water quality monitoring datasets available for Lorax to ensure unrealistically low or high model output values are identified and investigated. Predicted source terms concentrations were also assessed for charge balance to as a secondary model validation step since significant charge imbalances are a common artifact of inconsistent scaling approaches or other model deficiencies.

The final pit wall source term model predictions feeding into the PitMod model are presented in Table 3-9. Acidic Type 1A pit walls were assumed to be acidic upon the commencement of pit filling. All other pit wall runoff source terms remain neutral for the duration of the filling period.

3.6.4 Re-Contouring Material and Open Pit Basin Surface Runoff

In addition to pit walls, other sources of geochemical loadings to the open pit basin include runoff from Re-Contouring Material, Fish Habitat Development Area and exposed lake sediment. Source terms for these areas were provided by WSP (2024b) (Table 3-10). The source terms are applied to exposed (subaerial) surfaces only. Once submerged, the loadings from these materials, as well as exposed pit walls, were assumed to be zero in response to the cessation of sulphide mineral oxidation. In this regard, loadings from these sources decrease over the pit filling period.

Table 3-9:
Pit Wall Source Terms

Geological Unit		Neutral NAG Type 2 (non-ML)	Neutral NAG Type 1C (ML)	Neutral PAG Type 1B	Acidic PAG Type 1A
pH	-	7.5	7.5	7.5	2.5
Alkalinity	mg $CaCO_3$/L	100	100	50	0
SO_4	mg/L	124	171	219	9470
Ag	mg/L	0.000024	0.000031	0.000031	0.0057
Al	mg/L	0.016	0.015	0.015	94
As	mg/L	0.024	0.066	0.031	8
B	mg/L	0.021	0.016	0.016	0.059
Be	mg/L	0.0009	0.0011	0.0011	0.13
Ca	mg/L	55	65	65	265
Cd	mg/L	0.0000056	0.000023	0.000023	0.013
Co	mg/L	0.0024	0.0023	0.0023	16
Cr	mg/L	0.006	0.0059	0.0059	0.068
Cu	mg/L	0.0027	0.004	0.004	3.6
Fe	mg/L	0.021	0.015	0.015	3155
Hg	mg/L	0.0000039	0.0000042	0.0000042	0.000015
K	mg/L	5.1	3.8	3.8	7.7
Mg	mg/L	17	23	23	38
Mo	mg/L	0.006	0.022	0.022	0.51
Na	mg/L	7.4	7.8	7.8	16
Ni	mg/L	0.0064	0.0041	0.0041	6.9
P	mg/L	0.0027	0.0032	0.0032	0.49
Pb	mg/L	0.00025	0.00027	0.00027	0.026
Sb	mg/L	0.078	0.064	0.064	0.21
Se	mg/L	0.0014	0.006	0.006	0.14
Tl	mg/L	0.00014	0.00016	0.00016	0.0046
U	mg/L	0.0089	0.0033	0.0033	1.5
V	mg/L	0.00091	0.00093	0.00093	0.027
W	mg/L	0.0037	0.0035	0.0035	0.0081
Zn	mg/L	0.0035	0.0045	0.0045	2.1

Notes: PAG = potentially acid generating; NAG = non-acid generating; ML = metal leaching.

Table 3-10:
Geochemical Source Terms for Re-Contouring Material and Open Pit Basin Surfaces

Parameter	Re-Contouring Material [1,2]	Exposed Lake Sediment [1]	Fish Habitat Development Area [3]
pH	7.5	6.7	7.5
SO_4	46	25	124
Al	0.44	0.031	0.016
Sb	0.0071	0.00047	0.078
As	0.041	0.002	0.024
Be	0.00013	0.00001	0.0009
B	0.024	0.017	0.021
Cd	0.000089	0.000014	0.0000056
Cr	0.004	0.00057	0.006
Co	0.00034	0.00025	0.0024
Cu	0.003	0.0046	0.0027
Fe	0.026	0.021	0.021
Pb	0.0006	0.000064	0.00025
P	0.13 [4]	0.067	0.0027
Mo	0.0053	0.0037	0.006
Ni	0.0013	0.0012	0.0064
Se	0.0036	0.0008	0.0014
Ag	0.00013	0.000012	0.000024
Tl	0.00019	0.00003	0.00014
W	0.0022	0.0002	0.0037
U	0.0006	0.000067	0.0089
V	0.01	0.0024	0.00091
Zn	0.011	0.0023	0.0035
Hg	0.000048	0.00002	0.0000039
Ca	48	20	55
Mg	11	2.5	17
Na	0.69	2.4	7
K	4	2.9	5.1

Notes:
1. WSP (2024b)
2. Source terms are based on available humidity cell data. Source terms represent average annual concentrations for contact water for specified material type. Source terms are based on mass balance calculation with humidity cell release rates, scaled to contact areas (*i.e.*, 3D surface area) of a given feature, and water balance data. Potential solubility controls have not been accounted for in the data provided.
3. Fish Habitat Development Area source terms assumed to equivalent to Type2 pit walls.
4. Phosphorus is artificially elevated due to scaling of lab data. Humidity cell leachates are at the analytical detection limit.

3.7 Geochemical Modelling

As presented above in Table 3-9 (Pit Wall Runoff), Type 1A pit walls were assumed to be immediately acid generating upon the commencement of pit filling. These acidic inputs will be expected to be neutralized with non-acidic (neutral pH) waters associated with neutral-pH inputs from Springpole Lake, pit wall runoff from NAG materials, and groundwater. Specific reactions that can be expected upon the neutralization of acidic pit wall runoff will include:

- Neutralization of acidity by bicarbonate: $H^+ + HCO_3^- \rightarrow H_2O + CO_{2(g)}$
- Precipitation of Fe oxides: $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$
- Precipitation of Al oxides: $Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+$

These Fe and Al solid phases will then serve as sites for the sorption of various trace elements and phosphate.

To quantify the effects of these reactions, detailed modelling was conducted using PHREEQC (Parkhurst and Appelo, 1999). The modelling work encompassed two components: 1) confirm that the pit lake will maintain circum-neutral pH conditions throughout the filling period; and 2) define solubility limits for parameters of concern associated with trace element sorption onto the surfaces of Fe and Al hydroxides. These modelling components are described in turn below.

3.7.1 Confirmation of Circum-Neutral pH Conditions

To provide a quantitative basis for the assumption that acidic pit wall runoff will be neutralized, a PHREEQC model was constructed. For this exercise, a synthetic pit lake chemistry without the influence of acidic flows (NAG source terms and Springpole Lake inflows only) was titrated with varying amounts (5-50% in 5% intervals) of the acidic Type 1A pit wall runoff. The resulting mixed solution was then equilibrated with atmospheric conditions and allowed to precipitate $Fe(OH)_3$ (ferrihydrite) and $Al(OH)_3$ (gibbsite). As described above, the precipitation of these secondary phases generates acidity, potentially affecting pit lake pH.

The results of this model illustrate that the development of acidic lake conditions would only materialize if >25-30% of the pit wall exposures were of Type 1A composition (Figure 3-8). Since the proportion of exposed Type 1A rock in the pit walls is <10%, it can be concluded with some confidence that neutral pH conditions in the pit lake will be maintained.

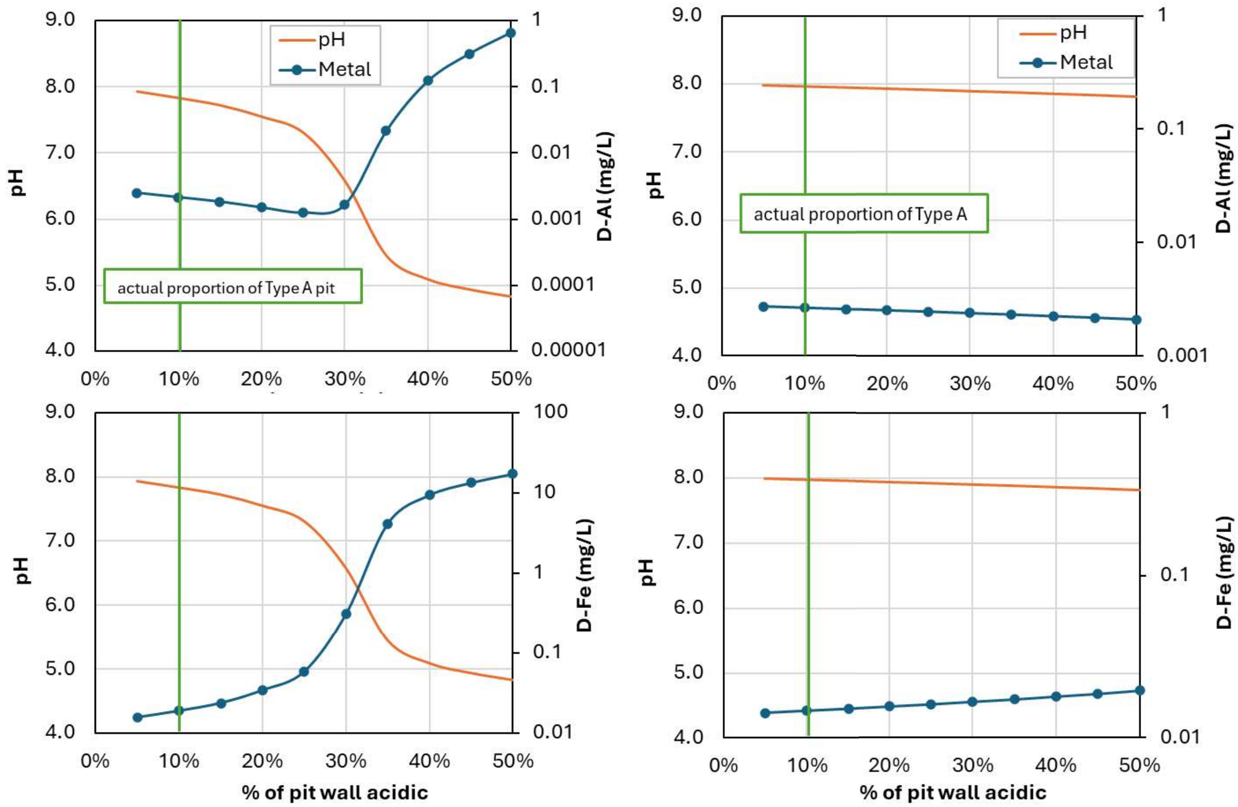

Figure 3-8: PHREEQC model output results for titration model of acidic pit wall source term (Type 1A) with synthetic pit lake water using iron source term concentrations of 3155 mg/L (left panel) and 316 mg/L (right panel).

It should be noted that the modelled Fe source term concentration for acidic Type 1A pit walls (3155 mg/L; Table 3-9) is considered to be conservatively high, due to assumptions relating to humidity cell loading rates. Therefore, the acidity generated in response to $Fe(OH)_3$ precipitation is likely overestimated. To test the sensitivity of the model to a lower dissolved Fe concentration in the acidic Type 1a source term, the predicted concentration (3155 mg/L) was divided by a factor of 10 (*i.e.,* 316 mg/L) and the model was re-run. The results showed that if the Type 1A pit walls rock produce lower concentrations of iron (*e.g.,* in the hundreds of mg/L), a pH-neutral pit lake chemistry would be maintained even if >50% of the pit wall exposures were to acidify (Figure 3-8). These model results add confidence in the conclusion that pit lake will maintain neutral pH.

The finding that the pit lake as a whole will remain at circumneutral pH constituted an important assumption for the evaluation of solubility limits for various parameters of concern (discussed in next section).

3.7.2 Quantification Solubility Limits for Parameters of Concern

Solubility limits for various elements in the pit lake were calculated as either solubility caps or percent attenuation. The precipitation of $Fe(OH)_3$ and $Al(OH)_3$, for example, will limit the concentrations of dissolved Fe and Al. For these elements, predicted concentrations for the pit lake were capped at values dictated by PHREEQC output (Table 3-11).

Table 3-11:
Solubility caps and attenuation factors (% adsorption) applied to PitMod output to calculate pit lake water quality

Parameter	Solubility Cap or % Adsorption	Value Applied to Pit Lake Predictions
Al	Solubility cap – $Al(OH)_3$	0.0026 mg/L
As	% adsorbed	95%
Be	% adsorbed	100%
Cd	% adsorbed	29%
Co	Solubility cap – HC stats	0.00051 mg/L
Cu	% adsorbed	99%
Fe	Solubility cap **-** $Fe(OH)_3$	0.017 mg/L
Pb	% adsorbed	100%
P	% adsorbed	28%
Ni	% adsorbed	38%
V	% adsorbed	89%
Zn	% adsorbed	68%
Hg	% adsorbed	100%

Notes: HC = Humidity cell

The precipitation of $Fe(OH)_3$ and $Al(OH)_3$ that will occur during the neutralization of acid pit wall runoff will provide sorption sites for various trace elements. The PHREEQC evaluation specifically demonstrated that sorption will act to reduce the concentrations of As, Be, Cd, Cu, Hg, Ni, P, Pb, V, and Zn in the pit lake (Table 3-11). For these elements, the percent attenuation were calculated.

To quantify the magnitude of sorption that may occur, the standard set of surface complexation parameters incorporated into the PHREEQC code were utilized as discussed in Dzombak and Morel (1990). To this end, the mass of Fe precipitated under the low-Fe sensitivity scenario described above (Section 3.7.1) was used to model the attenuation capacity for various elements. Note that the low-Fe scenario (*i.e.,* 316 mg/L Fe) was selected to build in a layer of conservatism, since using a lower Fe value will limit the mass of hydrous ferric oxides affording sorption sites.

Calculated attenuation factors (in % removal) for the various elements are provided in (Table 3-11). These values were applied to the PitMod output to generate expected concentrations in the pit lake. For some parameters, predicted concentrations in the pit lake fell below baseline water quality conditions, defined as the 75th percentile of baseline values in Springpole Lake. For these parameters (Al, Be, Cd, Fe, Pb, Hg and P), predicted concentrations in the pit lake were set equivalent to the 75th percentile background values.

The PHREEQC model predicted Co to be supersaturated in the pit lake with respect to Co_3O_4. If this phase is allowed to precipitate, the resulting concentrations dropped well below the detection limit. For this element, kinetic or nucleation constraints conceivably led to an overestimation of Co attenuation. Given the uncertainty in the PHREEQC output, data for the neutral-pH humidity cells were utilized instead. Under such conditions, concentrations of Co are consistently low. To provide a conservative solubility control for Co in the oxygenated water column of the pit lake, the 95th percentile concentration calculated across all Springpole humidity cells was used as a concentration cap for the pit lake (Table 3-11).

3.8 Model Conservatisms

Numerous model conservatisms apply to the pit lake predictions herein. Specifically, various measures relating to closure as well as in-pit processes, that were not accounted for in the predictions, will serve to decrease parameter concentrations in the pit lake. These include:

- At closure, pit wall slopes that will not be underwater will be regraded to promote stable slopes. During the regrading process, PAG pit wall exposures will be covered to the extent practicable with NAG materials. These regrading measures will serve to minimize PAG exposures and reduce parameter loadings (acidity and metals) to the pit lake.
- At closure, a growth medium of locally derived overburden and organic materials will be placed on the regraded pit slopes to promote sustainable revegetation. Such measures will serve to reduce water-rock interactions with PAG pit walls and reduce loadings to the pit lake.
- Natural phytoplankton growth in the pit lake water column will result in the assimilation of trace elements (*e.g.*, Al, Cd, Cu, Co, Fe, Ni, Zn) and their transport to the lake bottom via particle settling. Settling particles, especially organic aggregates (*e.g.*, algal particles), represent the dominant process in the binding and transfer of trace elements in natural lakes, thereby regulating the concentrations of dissolved species in surface waters (Sigg, 1985). Such processes were not accounted for in the model.
- Algal growth will result in the uptake of phosphorus and nitrogen. This will serve to reduce concentrations of these parameters in the pit basin during and after the filling period.

4. Results and Discussion

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4. Results and Discussion

4.1 Open Pit Basin General Features

General features of the Springpole open pit basin are provided in Table 4-1 and illustrated in Figure 4-1. At the final water elevation of 391 masl (at the time of connection to Springpole Lake), the basin will have a maximum water depth of 303 m, a length of ~2.4 km, and a maximum width of 1.8 km. The basin will occupy a surface area of ~252 ha (206 ha for the open pit plus a further 46 ha for the fish habitat development area), and a volume of ~173 Mm^3. The time to reach maximum water elevation (391 masl) is predicted to be approximately 4.8 years. Area-elevation and volume-elevation curves are presented for the open pit basin in Figure 3-3.

Table 4-1:
General Features of the Springpole Open Pit Basin at the maximum lake elevation (391 masl)

Parameter	Value
Length	2.4 km
Maximum width	1.8 km
Maximum water depth	303 m
Basin water volume	173 Mm^3
Basin water surface area	252 ha
Time to fill	4.8 years

4.2 Water Balance

Filling of the open pit basin to the elevation of Springpole Lake (391 masl) occurs over a period of ~4.8 years, at which time the basin will be reconnected with Springpole Lake through lowering of the east and west dikes. The surface elevation of the open pit basin is presented in Figure 4-2. The surface elevation shows higher rates of increase during the spring months when rates of water withdrawal from Springpole Lake are at a maximum.

The composition of the open pit basin water volume throughout the filling period is dominated by Springpole Lake inflows (Figure 4-3). Upon the open pit basin reaching the final elevation (391 masl), Springpole Lake inflow contributes ~95% of the total volume (Table 4-2). Direct precipitation to the pit lake surface represents and second largest input (1.6%). The remaining sources contribute <1% each, with Type2 runoff contributing the third highest percentage (0.89%) and CDF seepage the lowest (0.04%) (Table 4-2).

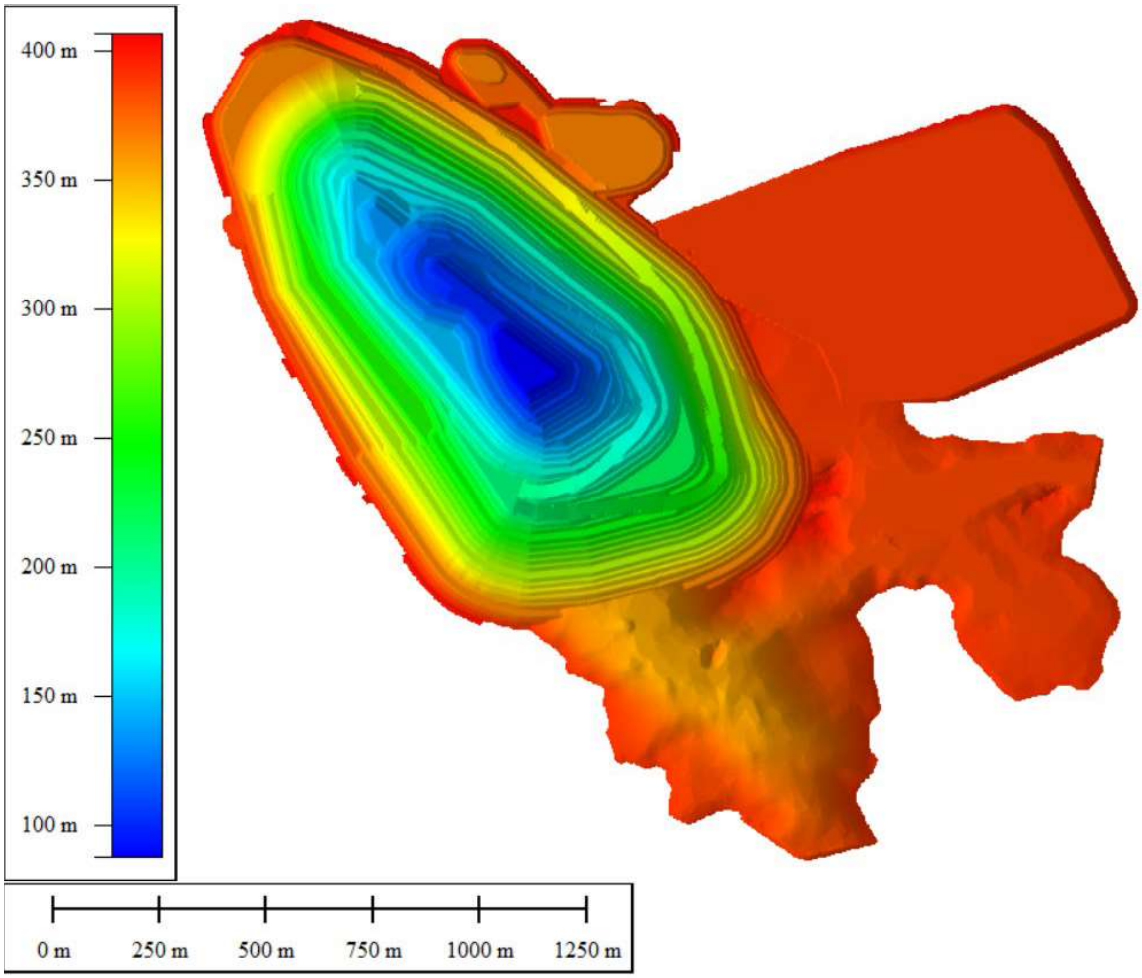

Figure 4-1: Bathymetry of Open Pit Basin showing final water depths.

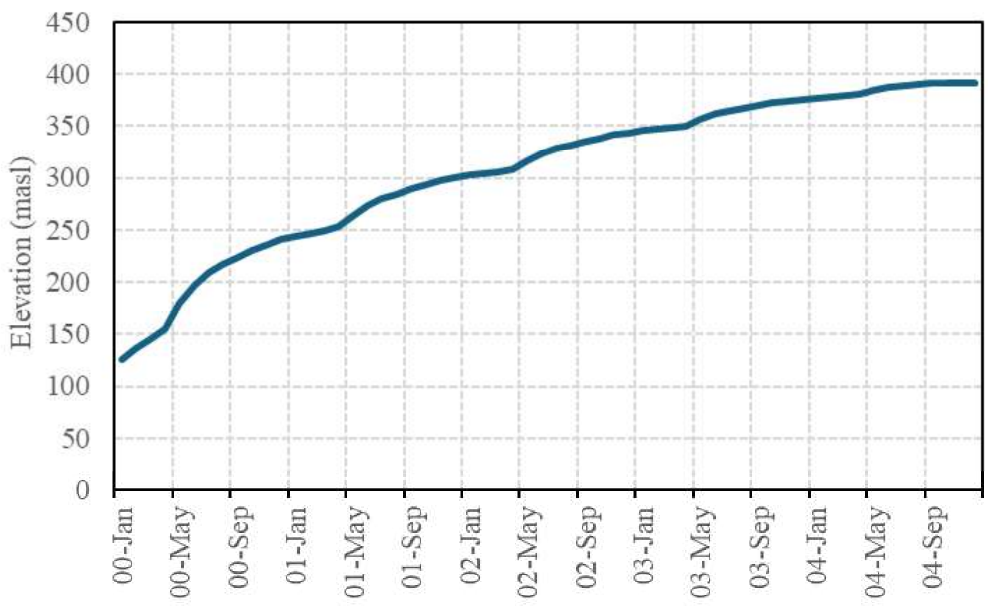

Figure 4-2: Pit lake surface elevation during the filling period.

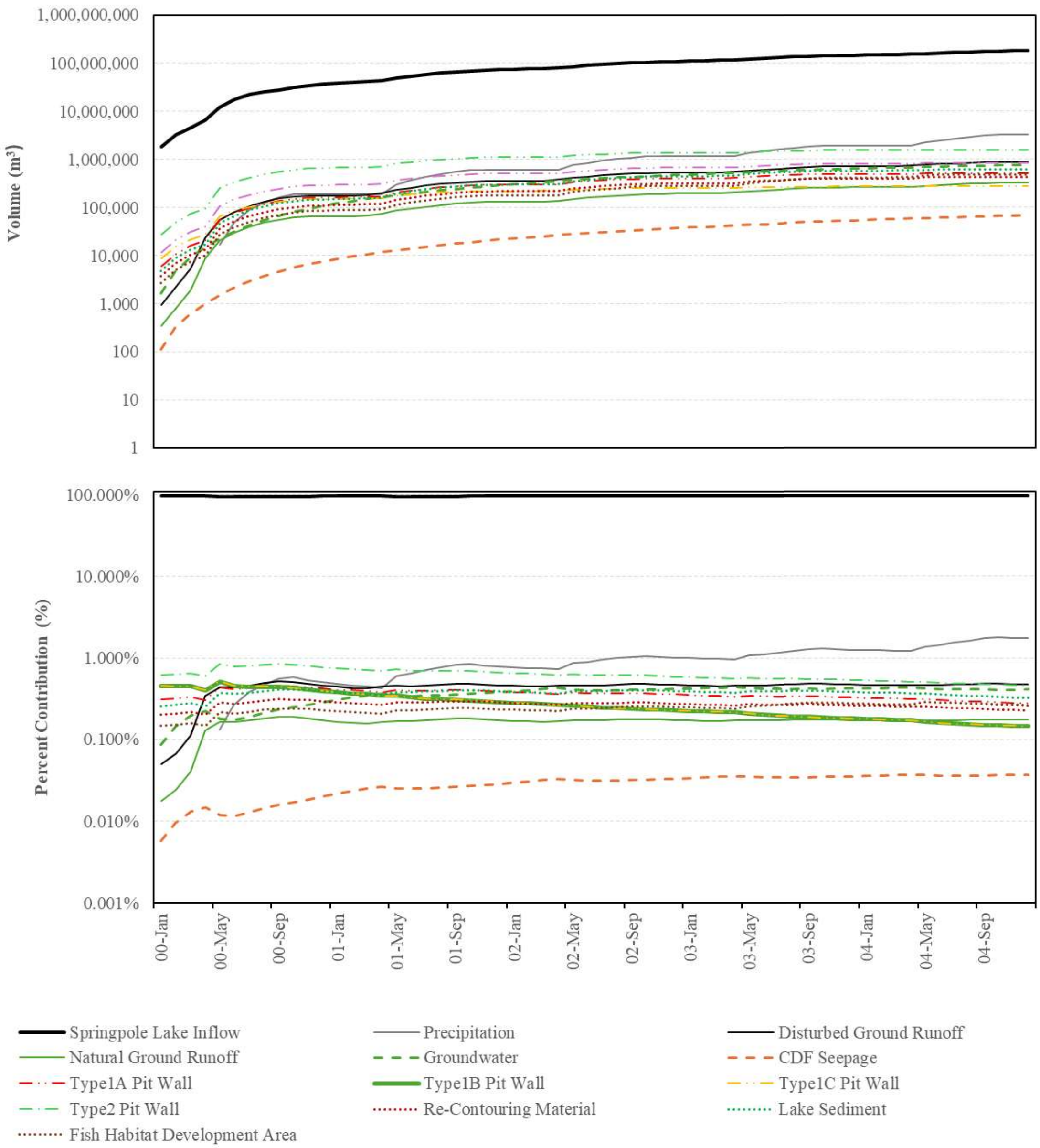

Figure 4-3: Total (top panel) and percent (lower panel) contribution from each source to the open pit basin during the pit filling phase. Note: y-axis is log scale.

**Table 4-2:
Total and Percent Volume Contribution from Individual Sources to the Pit Lake at End of Pit Filling (4.8 years). Sources listed from highest to lowest proportions.**

Source	Volume (Mm^3) [1]	Percent of Pit Lake Volume [2]
Springpole Lake Inflow	170	95%
Precipitation to pit lake surface	2.9	1.6%
Pit Wall Type2	1.6	0.89%
Disturbed Ground Runoff	0.86	0.48%
Pit Wall Type1C	0.85	0.47%
Groundwater	0.74	0.41%
Lake Sediment	0.61	0.34%
Pit Wall Type1A	0.52	0.29%
Fish Habitat Development Area	0.49	0.27%
Re-Contouring Material	0.43	0.24%
Natural Ground Runoff	0.32	0.18%
Pit Wall Type1B	0.27	0.15%
CDF Seepage	0.066	0.04%

Notes:
1. Volume contributed to pit lake at end of pit filling (Year 4.8)
2. Calculated using total inflow volume at end of pit filling.

4.3 Lake Physical Structure

The evolution of physical properties in the water column of the Springpole open pit basin can be illustrated by the spatial and temporal distributions of temperature, dissolved oxygen (DO) and total dissolved solids (TDS) (Figure 4-4Figure 4-5, and Figure 4-6, respectively).

Model output for temperature shows pronounced seasonality in lake surface waters, with values ranging from approximately 0 to 18°C (Figure 4-4). Below the surface mixed layer, which ranges in depth seasonally from approximately 20 to 40 m, water temperature remains near the temperature of maximum density (4°C). Based on the temperature data, seasonal thermal stratification of the water column can be expected during the summer period, as would be predicted for other lakes in the local region.

The model output illustrates the temperature-dependent solubility of DO in water, with higher values observed in the lake surface during the colder months (Figure 4-5). The seasonal trends in DO in surface waters can also be used to define the thickness of the surface mixed layer, which is inferred to range seasonally from 25 to 40 m.

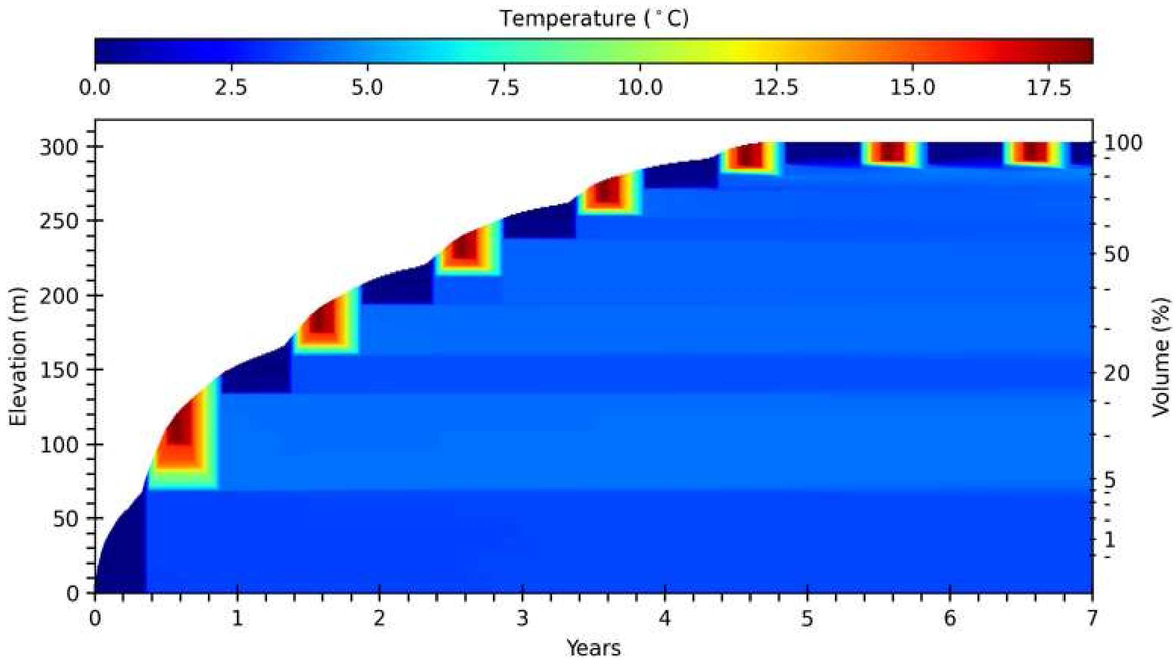

Figure 4-4: Predictions of the vertical and temporal evolution of water temperature for the open pit basin. Predictions are shown as a function of depth (primary Y-axis), pit volume % (secondary Y-axis) and time (X-axis).

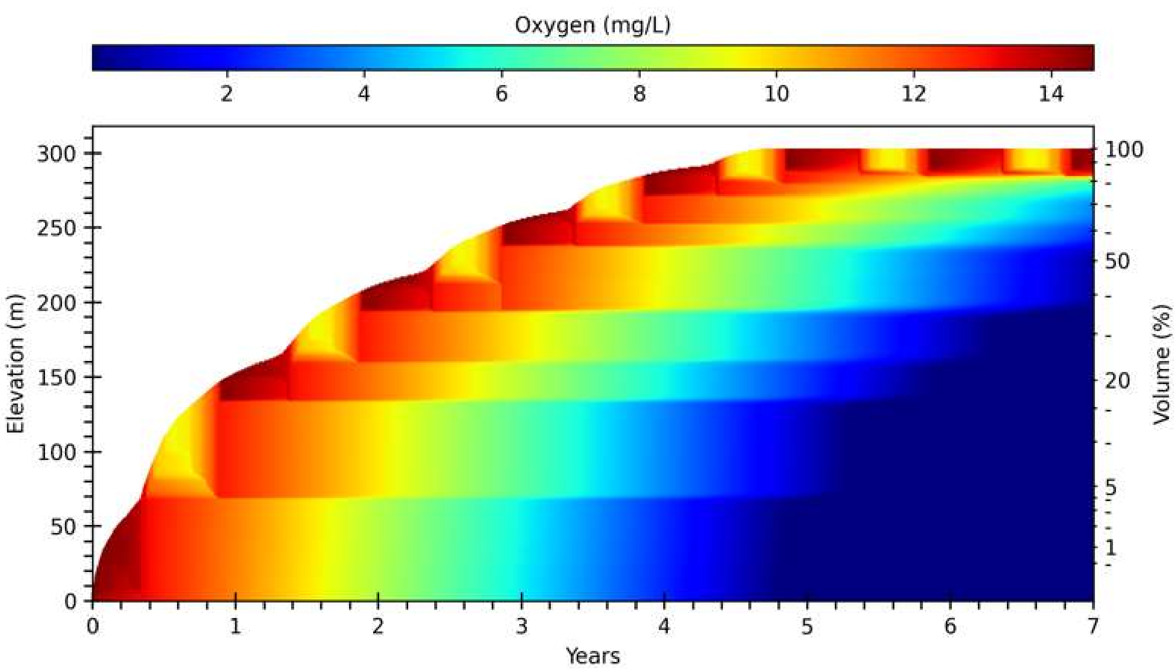

Figure 4-5: Predictions of the vertical and temporal evolution of dissolved oxygen for the open pit basin. Predictions are shown as a function of depth (primary Y-axis), pit volume % (secondary Y-axis) and time (X-axis).

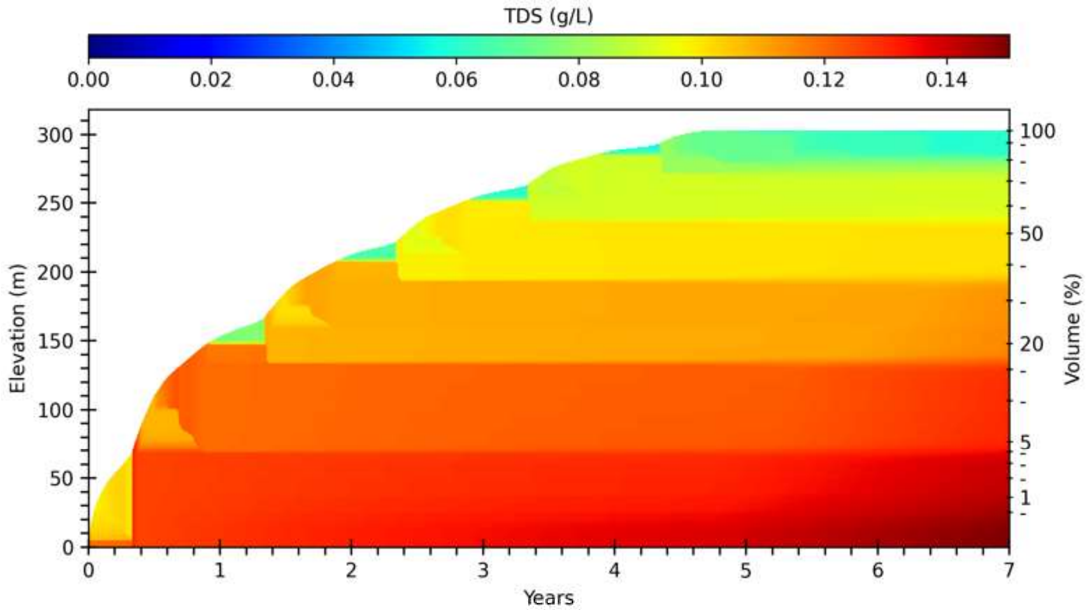

Figure 4-6: Predictions of the vertical and temporal evolution of total dissolved solids (TDS) for the open pit basin. Predictions are shown as a function of depth (primary Y-axis), pit volume % (secondary Y-axis) and time (X-axis). Units of TDS in grams per litre (g/L).

During the filling period, a progressive decline in DO can be observed in the lake water column below the surface mixed layer. This can be attributed to the establishment of permanently stratified conditions (meromixis), which serves to physically isolate deeper waters from atmospheric influences (the dominant source of DO). The observed rate of DO depletion suggests that suboxic (<1 mg/L DO) conditions below the mixed layer may develop within 5 to 10 years. Overall, observations of meromixis indicate that the effects of wind-driven mixing and convective mixing are not sufficient to mix the water column below a depth of approximately 40 m.

TDS exerts a strong control on water density, and hence is an important variable governing lake mixing. Model output for TDS shows higher values in lake bottom waters due to the early introduction of more saline waters associated with pit wall runoff, re-contouring material runoff, and CDF seepage (Figure 4-6). In deep waters, TDS shows a slight increase over time. This can be attributed to the continued input of CDF seepage, a proportion of which reports to the bit bottom. TDS increases in bottom waters are restricted to the lowermost 100 m of the water column, which represents <5% of the total lake volume (Figure 4-6).

In the surface mixed layer (that extends seasonally to a depth of 20 to 40 m), TDS shows a progressive decline over time (Figure 4-7). The sinusoidal nature of the TDS curve reflects changes in the seasonal make-up flow (and dilutionary input) from Springpole Lake, which ranges from 0.5 to 2.2 m^3/s on a monthly basis.

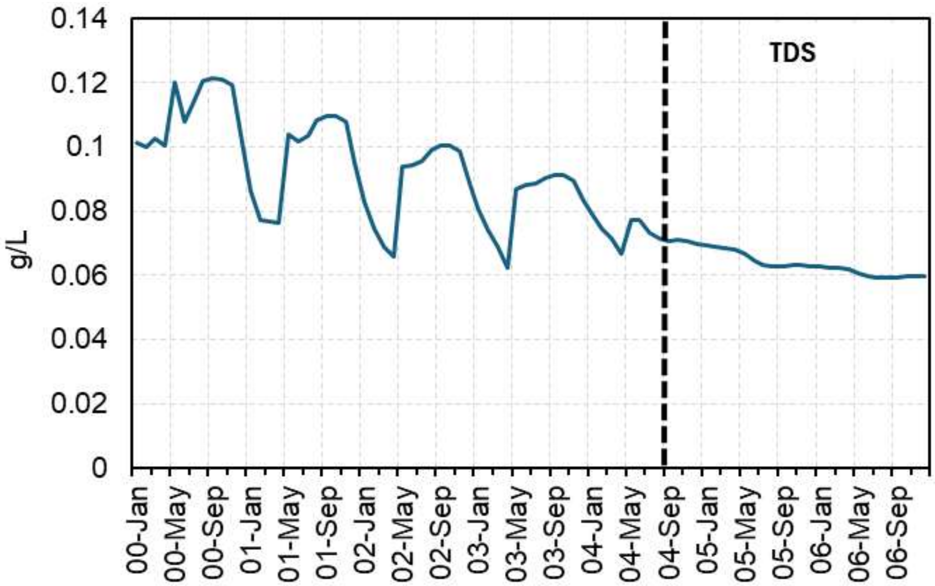

Figure 4-7: Predictions of Total Dissolved Solids (TDS) concentration in the surface mixed layer (uppermost 20 to 40 m) of the open pit basin. Timing of basin connection to Springpole Lake shown as vertical black dashed line (4.8 years).

Overall, declines in TDS in lake surface waters can be attributed to several time-dependent factors, including:

- Loadings associated with pit wall runoff decrease as the basin fills in association with: a) decrease in subaerial pit wall exposure area (sulphide mineral oxidation is assumed to cease upon pit wall submergence); and b) decrease in groundwater flux as hydraulic gradients lessen. As outlined in Section 3.6, pit wall runoff source terms apply to both precipitation that falls on pit wall surfaces as well as groundwater that enters the pit above the water surface;
- Loadings associated with re-contouring material decrease as the basin fills in association with a decrease in subaerial exposure volume and area (sulphide mineral oxidation is assumed to cease upon submergence);
- Loadings associated with CDF seepage decrease as the basin fills in response to a lessening of the hydraulic gradient and associated decrease in the groundwater flux;
- As the basin fills, and the surface area of the lake increases, the input of direct precipitation to the lake surface increases relative to pit wall runoff; and
- Development of water column stratification serves to isolate poorer (more saline) water quality in pit bottom waters.

4.4 Water Quality

4.4.1 Interpretation of Water Quality Predictions

Water quality predictions for the surface mixed layer (uppermost 20 to 40 m of water column) for the open pit basin at the time of connection to Springpole Lake are summarized in Table 4-3 and discussed in the sections to follow.

Water quality predictions for the open-pit basin represent a combination of loadings derived from dissolved and total source terms. For source terms associated with the metal leaching of exposed rock and tailings (*e.g.*, CDF seepage, pit walls, re-contouring material, fish habitat development area), loadings were derived based on dissolved measurements (*e.g.*, humidity cell leachate chemistry). Similarly, for loadings associated with groundwater, source terms are expressed as dissolved species (consistent with collection methods in the field). In contrast, loadings associated with Springpole inflows were derived from total concentrations. From an ecological/toxicity perspective, the addition of dissolved loadings from mine materials to total loadings from Springpole Lake imparts a level of conservatism to the predictions given that a portion of the total fraction can be expected to be present as particulate/colloidal fractions that will be largely unavailable to aquatic biota.

4.4.2 Major Ions and pH

TDS predictions for the Springpole open pit basin are governed by inputs of several major ions including calcium (Ca), magnesium (Mg), sulphate (SO_4) and bicarbonate alkalinity (HCO_3). In general, the spatial and temporal distributions of major ions show strong parallels to TDS, as illustrated by the model output for sulfate (Figure 4-8).

Decreases in the concentrations of major ions over time in the lake surface layer, as illustrated for SO_4, Ca, Mg and potassium (K) (Figure 4-9), can be attributed to the same processes described above for TDS. The sinusoidal nature of the time series curves reflects changes in the seasonal make-up flow from Springpole Lake, which ranges from 0.5 to 2.2 m^3/s on a monthly basis.

As described in Section 3.7 (Geochemical Modelling), pit lake pH was modelled using PHREEQC. The model results yielded circum-neutral pH conditions for all stages of filling. The neutral pH conditions can be attributed to the large influence of make-up water from Springpole Lake, which enters the basin at a high flow rate and is characterized by abundant alkalinity (mean value of 30 mg/L as $CaCO_3$). The model output specifically indicates that the relatively small flows of acidic drainage from PAG pit walls will be effectively neutralized by other water types during filling.

Table 4-3:
Water quality predictions for the surface mixed layer (uppermost 20 to 40 m of water column) for the open pit basin at the time of connection to Springpole Lake. Values compared to Water Quality Criteria for the Protection of Aquatic Life and Springpole Lake 75th percentile background.

Parameter	Water Quality Prediction (mg/L)	Springpole Lake 75th Percentile Water Quality	Water Quality Criteria [2]	
			Value	Source [3]
Major Ions (mg/L)				
Ca	11	10	-	-
Mg	1.8	1.5	-	-
Na	0.90	0.74	-	-
K	0.77	0.70	-	-
Sulfate	19	2.0	-	-
Trace Elements and Phosphorus (mg/L)				
Al	*0.0050**	0.0050	0.83	FEQG
Sb	0.0012	0.00025	0.02	PWQO
As	*0.00072*	0.00052	0.005	iPWQO
Be	*0.00025**	0.00025	0.011	PWQO
B	0.0059	0.0050	1.5	CCME
Cd	*0.000050**	0.000050	0.00053	CCME
Cr	0.00070	0.0025	0.0089	CCME
Co	*0.00051*	0.00025	0.00078	FEQG
Cu	*0.00092**	0.00092	0.005	iPWQO
Fe	*0.05**	0.050	0.3	PWQO
Pb	*0.00025**	0.00025	0.009	FEQG
Hg	*0.000005**	0.000005	0.000026	CCME
Mo	0.0012	0.00025	0.073	CCME
Ni	*0.0077*	0.0050	0.025	PWQO
P	*0.014**	0.014	0.02	iPWQO
Se	0.020	0.0010	0.1	PWQO
Ag	0.000031	0.000050	0.00025	CCME
Tl	0.000023	0.000025	NP	NP
W	0.00023	0.00050	NP	NP
U	0.0027	0.000050	0.015	CCME
V	*0.00025**	0.00025	0.12	FEQG
Zn	*0.0025**	0.0025	0.0254	CCME

Notes:
1. Predictions are maximum monthly concentrations in final year of pit filling.
2. Equivalent to water quality guidelines for the protection of aquatic life (long-term exposure). Water quality guidelines represent generic criteria that are inherently conservative as they are developed by governments or international organizations to identify the concentrations of parameters in the receiving environment that are protective of the most sensitive aquatic species for periods of indefinite exposure. As applicable, numerical guideline values summarized here were calculated using the most conservative approach (*i.e.*, 25th percentile Birch Lake baseline values for ameliorating factors, save for zinc, which uses 75th percentile pH for the FEQG calculation).
3. PWQO: Provincial Water Quality Objectives. iPWQO: Interim Provincial Water Quality Objectives. CCME: Canadian Council of Ministers of the Environment water quality guideline for the Protection of Aquatic Life. FEQG: Federal Environmental Quality Guideline for the Protection of Aquatic Life. NP = none proposed

Predictions for parameters in *italics* based on geochemical modelling.
* Predicted value from geochemical modelling was less than Springpole Lake 75th percentile water quality. Therefore, predicted value substituted with 75th percentile Springpole Lake background water quality concentration.

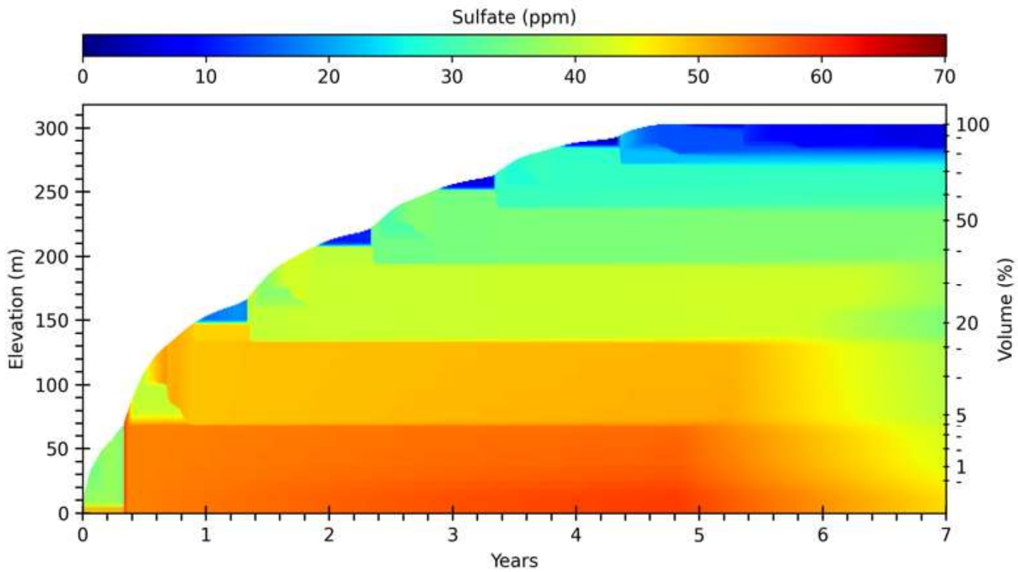

Figure 4-8: Predictions of the vertical and temporal evolution of sulfate for the open pit basin. Predictions are shown as a function of depth (primary Y-axis), pit volume % (secondary Y-axis) and time (X-axis). Values in ppm or mg/L.

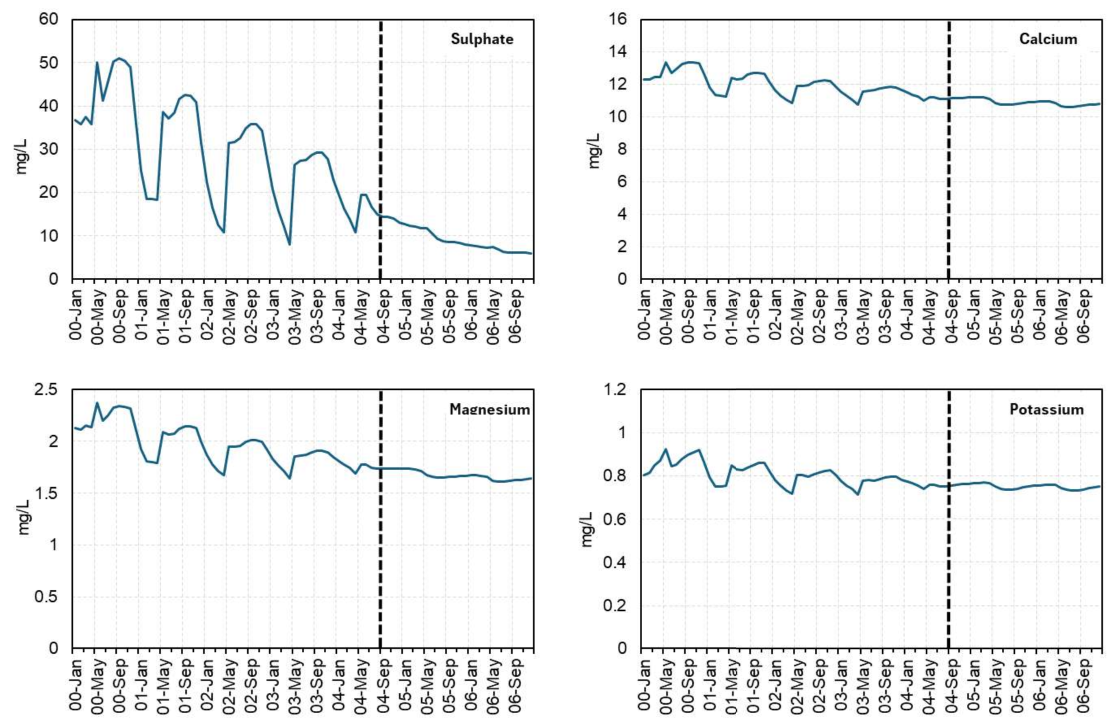

Figure 4-9: Predictions of sulphate, calcium, magnesium and potassium concentrations in the surface mixed layer (uppermost 20 to 40 m) of the open pit basin. Timing of basin connection to Springpole Lake shown as vertical black dashed line (4.8 years). All values expressed as totals in mg/L.

4.4.3 Trace Elements and Phosphorus

At this time of connection to the North Basin of Springpole Lake (after ~4.8 years of filling), all parameter values remain below applicable WQGs (Table 4-3). Temporal trends for trace element concentrations in the surface mixed layer show strong parallels to TDS and sulphate, as illustrated by the model output for arsenic, cadmium, nickel and zinc (Figure 4-10). As described previously for major ions and trace elements, surface concentrations decline over time in a sinusoidal pattern in response to seasonal variations in the inflow from Springpole Lake.

With regards to nutrient parameters, phosphorus shows elevated values in the source terms for pit walls and re-contouring materials. However, the geochemical modelling results indicate significant sorption of phosphate with secondary Fe oxides (Section 3.7.2). Further phosphate will be predicted to be assimilated by phytoplankton and transported to lake sediments via the settling of biogenic particles. Overall, phosphorus concentrations are predicted to remain near background levels (Table 4-3).

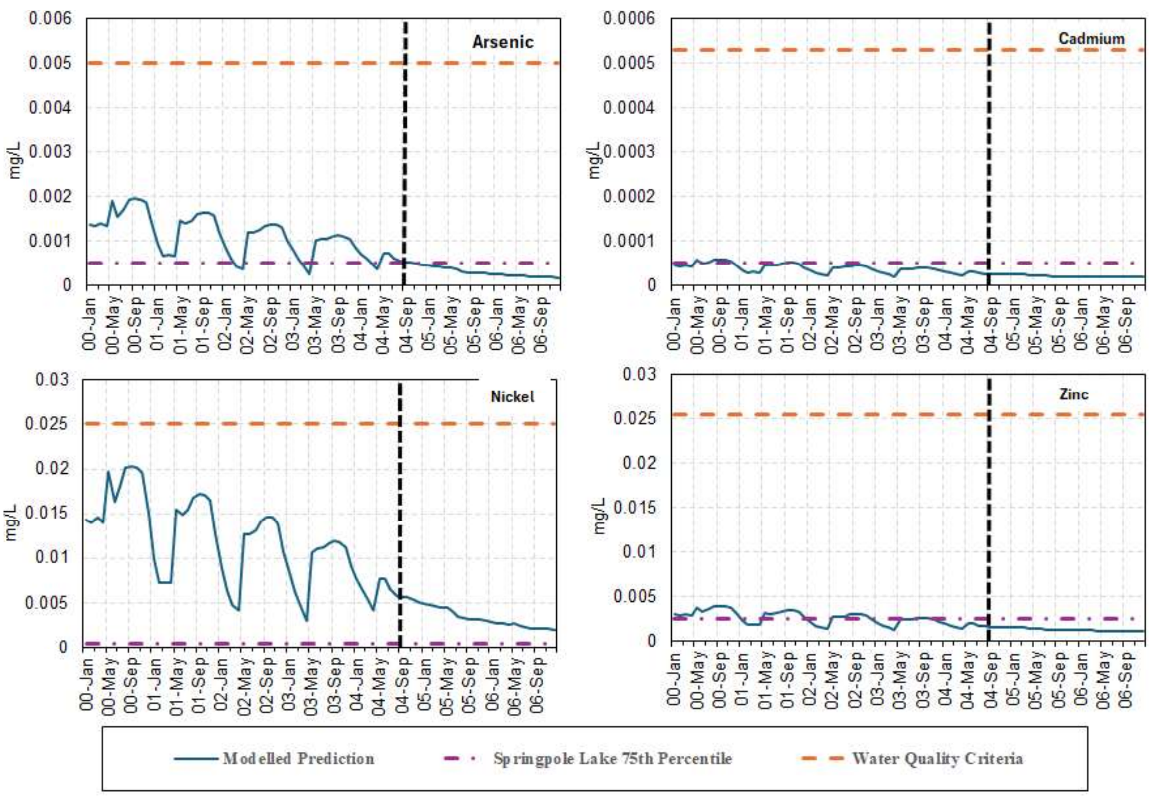

Figure 4-10: Predictions of total arsenic, cadmium, nickel and zinc concentrations in the surface mixed layer (uppermost 20 to 40 m) of the open pit basin. Timing of basin connection to Springpole Lake shown as vertical dashed black line (4.8 years). All values expressed as totals in mg/L. Water Quality Criteria and Springpole Lake 75th percentile background shown for reference.

5. Conclusions and Recommendations

5. Conclusions and Recommendations

The following chapter summarizes the most salient conclusions drawn from the modelling work herein. Recommendations with respect to post-closure monitoring are also presented.

5.1 Conclusions

- At the time of connection to Springpole Lake, the open pit basin will have a maximum water depth of 303 m. The basin will occupy a water surface area of ~252 ha and a volume of ~173 Mm^3.
- The open pit basin is predicted to reach its maximum elevation of 391 masl (elevation of Springpole Lake) in a period of approximately 4.8 years. Accelerated re-filling is afforded by the controlled conveyance of make-up water from Springpole Lake to the open pit basin.
- Model output data for temperature, DO and TDS suggest that the water column will form a permanently stratified (meromictic) density structure, which will limit mixing between the surface mixed layer (extending to a depth of approximately 40 m) and deeper depths. Seasonal thermal stratification of the water column can be expected during the summer months.
- Under conditions of meromixis, suboxic conditions are predicted to develop below the surface mixed layer over time. The observed rate of DO depletion suggests that suboxic (<1 mg/L DO) conditions below the mixed layer will develop over a period of approximately 5-10 years.
- Model predictions show an improvement in surface water quality over time in response to several time-dependent factors: 1) progressive decrease in loadings associated with pit wall runoff, re-contouring material, and CDF seepage; 2) progressive increase in the contribution of direct precipitation to the pit lake surface; and 3) development of water column stratification which serves to isolate more saline water quality in pit bottom waters.
- At this time of connection to the North Basin of Springpole Lake (after ~4.8 years of filling), all parameter values remain below applicable WQGs.

5.2 Recommendations for Post-Closure Monitoring

Monitoring during the early stages of mine closure will be used to validate the model output presented here. Given the time scales of filling of the pit (4 to 5 years), monitoring during the filling period will afford considerable time to validate model predictions, and identify the need for additional mitigation measures, if required.

The post-closure monitoring program specifically be used to address the following:

- Filling rate;
- Timing and magnitude of water column stratification; and
- Evolution of water quality.

Monitoring in support of the above objectives can be achieved during the filling period via: 1) monitoring of water elevation over time; 2) collection of high resolution vertical profiles of key physical variables (temperature, electrical conductivity, dissolved oxygen); and 3) collection of water quality samples from multiple depths.

6. Closure

6. Closure

This report was prepared by Lorax Environmental Services Ltd. on behalf of First Mining Gold.

Sincerely,

LORAX ENVIRONMENTAL SERVICES LTD.

Oct 16, 2024

Alan Martin, M.Sc., R.P.Bio. (BC), P.Geo. (BC, ON)
Principal, Senior Biogeochemist and Limnologist

Amrit Lally, B.Sc., M.GIS
Project Hydrologist and Numerical Modeller

2024-10-16

Timo Kirchner, M.Sc, P.Geo. (BC, ON, NS)
Senior Environmental Geoscientist
(Responsible for pit wall source terms and PHREEQC modelling)

Engineers and Geoscientists British Columbia Permit to Practice Number: 1001840.

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