6.3.4.3 Post-Production

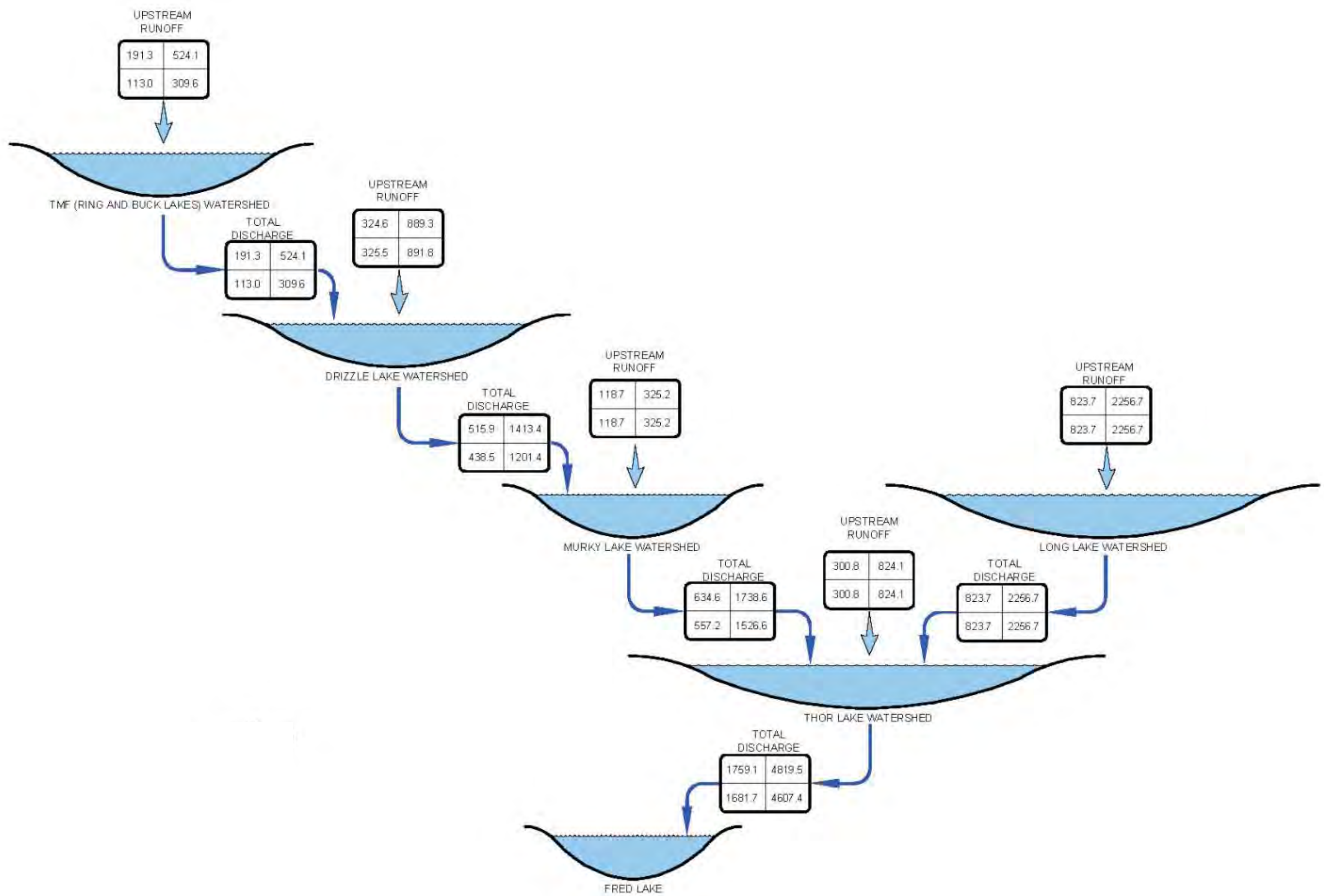
Figure 6.3-7 presents a flowsheet summarizing the estimated annual flows anticipated to occur within the Thor Lake system during the first five years post-production. Estimated outflows from the TMF watershed during the 5 year post-production period drop from 191,300 m^3 in Year 21, to 113,000 m^3 in Year 25 due to a decreasing runoff coefficient in the TMF, attributed to reclamation and expected revegetation of the tailings basin.

6.3.4.4 Summary of Hydrological Discharge Conditions

The pre-production, operations and post-production estimated monthly discharges from the Drizzle Lake and Thor Lake watersheds are shown on Figures 6.3-8 and 6.3-9, respectively. The anticipated annual water discharges from the Drizzle Lake and Thor Lake watershed for dry, average and wet years are summarized in Table 6.3-1.

Based on the results of the watershed modelling the following conclusions are provided:

1. A nominal decrease in discharge (around 9% on annual basis) from the Thor Lake basin is predicted during mine operations mainly due to water losses associated with the TMF and mine backfill operations.
2. The development of a TMF within the Ring and Buck Lakes basin will result in slightly higher flows through Drizzle and Murky Lakes during operations compared to pre-development baseline flows estimated, assuming a 50% maximum recycle rate from the TMF. This increase is expected to be in the order of a 6% increase in flow at the start of operations. This initial increase is expected to slowly decline to an increase of about 3% in later years of operation as expected evaporation and tailings beach size increase.
3. The TMF and mine operations will not affect a significant portion of the Thor Lake watershed. The characteristics of the large Long Lake watershed and the Murky Lake watershed are not expected to change over the course of mine operations.
4. During operations approximately 10% of water discharged from Thor Lake will have originated in the Ring and Buck Lakes watershed.
5. Following closure, effects of the mine facilities on the Thor Lake watershed are expected to be minimal. The change in configuration of the Drizzle Lake watershed, caused by the construction of the Polishing Pond, is expected to decrease annual discharge by approximately 43,300 m^3/year compared to pre-production conditions.



LEGEND:

ANNUAL FLOW IN THOUSAND m³/yr

AVERAGE FLOW IN m³/day

Years 21 to 22	191.3	524.1
Year 25	113.0	309.6

NOTES

1. Estimates are for average precipitation conditions and do not include extreme precipitation events.
2. Upstream runoff to each lake includes direct precipitation and evaporation on the lake.
3. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB11-00132, Figure 6).

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THOR LAKE PROJECT

Annual Watershed Flowsheet Post-Production

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0

OFFICE	DATE
EBA-VANC	April 5, 2011

Figure 6.3-7

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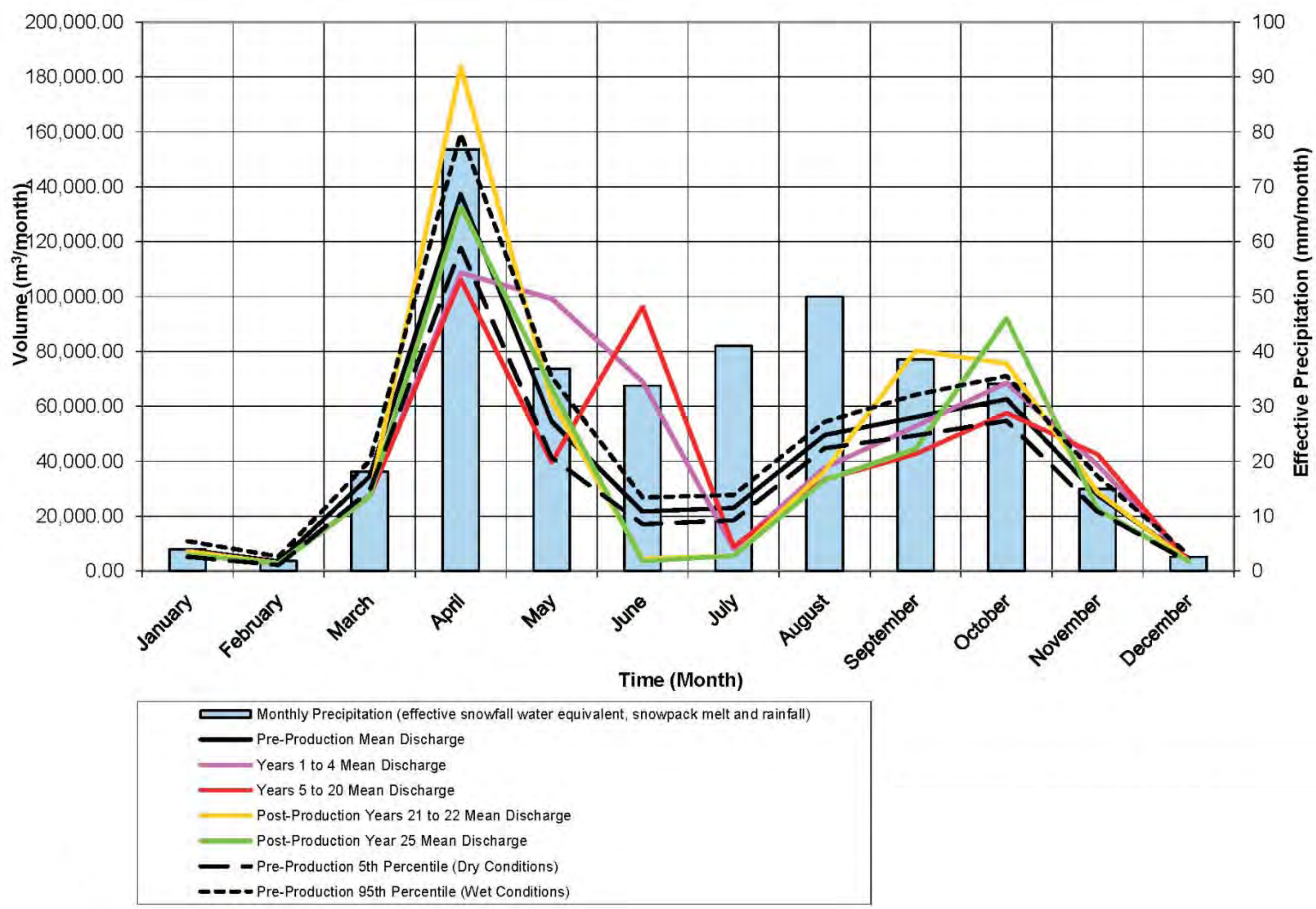
TABLE 6.3-1: WATERSHED FLOW EFFECTS SUMMARY – ANNUAL WATER DISCHARGE FROM DRIZZLE LAKE AND THOR LAKE WATERSHEDS

Period	Drizzle Lake Discharge			Thor Lake Discharge		
	5th Percentile (Dry Conditions) (m^3/year)	Average (m^3/year)	95th Percentile (Wet Conditions) (m^3/year)	5th Percentile (Dry Conditions) (m^3/year)	Average (m^3/year)	95th Percentile (Wet Conditions) (m^3/year)
Pre-Production	404,887	481,844	570,417	1,493,371	1,724,893	1,992,829
Operations (Years 1 to 4)	444,189	521,796	610,663	1,384.060	1,616,232	1,884,462
Operations (Years 5 to 20)	384,087	465,463	465,463	1,338,882	1,574,824	1,848,827
Post-Production (Years 21 to 22)	389,244	515,894	515,894	1,477,728	1,758,943	2,087,017
Post-Production (Year 25)	333,956	521,687	438,525	1,422,439	1,681,575	1,981,526

Notes:

1. Thor Lake discharge volumes for operations and post-production incorporate estimated pre-production upstream runoff values for watersheds that are not changed by mine development.
2. Discharge volumes for operations and post-production are calculated from averaging the values for the years noted.
3. Progressive reclamation will be carried out through years 23 and 24 of post-operations, as such flows from this period vary by year.



NOTES

1. Values for Years 1 to 4 and 5 to 20 are taken from operations water balance issued in KPL Memo Cont. No NB11-00100.
2. Progressive reclamation will be carried out through Years 23 and 24 of post-operations.
3. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB11-00132, Figure 7).

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THOR LAKE PROJECT

Estimated Discharge By Month From Drizzle Lake Watershed

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.3-8

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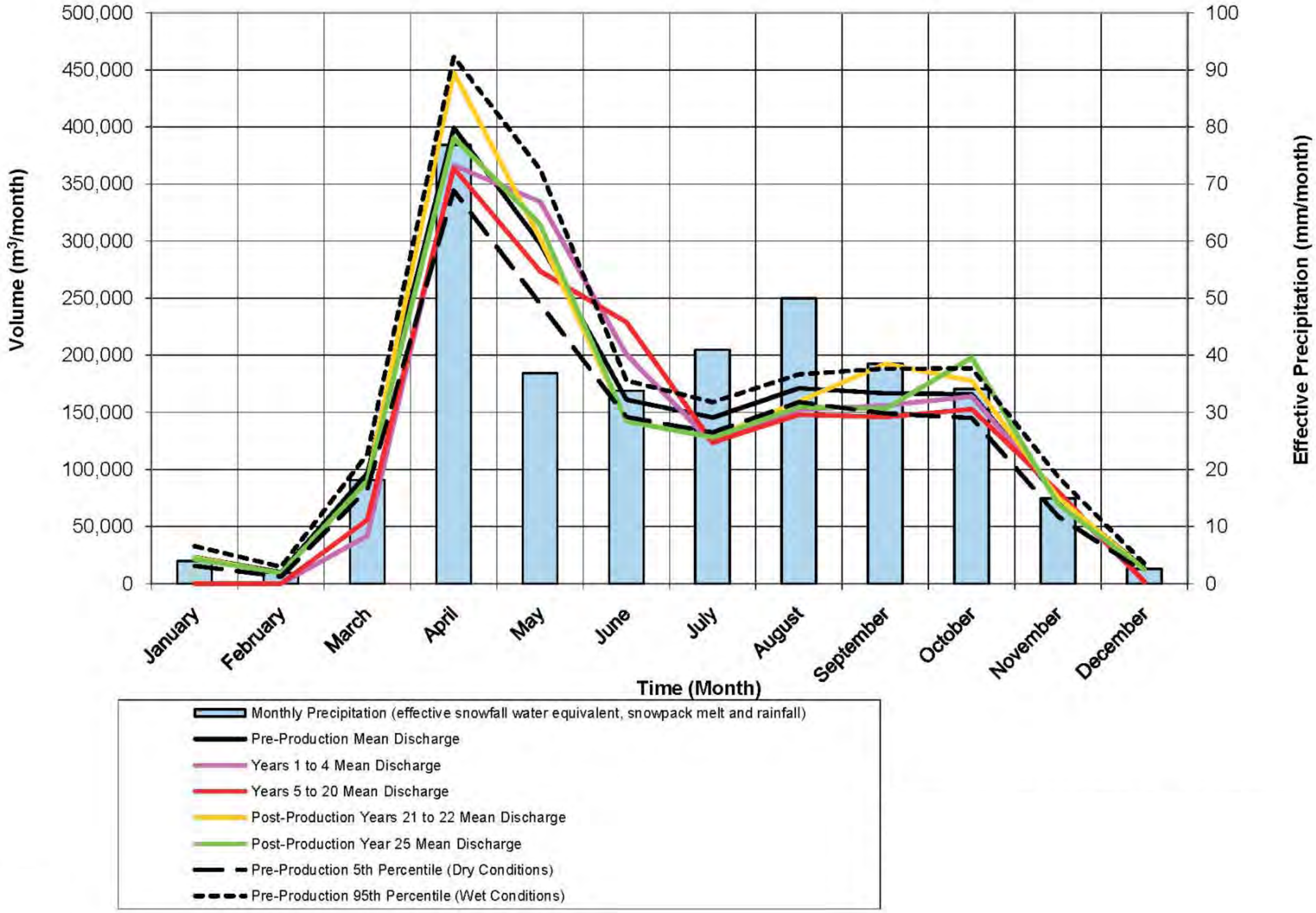

NOTES

1. Values for Years 1 to 4 and 5 to 20 are taken from operations water balance issued in KPL Memo Cont. No NB11-00100.
2. Progressive reclamation will be carried out through Years 23 and 24 of post-operations.
3. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB11-00132, Figure 8).

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THOR LAKE PROJECT

Estimated Discharge By Month From Thor Lake Watershed

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0
OFFICE	DATE		
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Figure 6.3-9

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6.3.5 Project Design Features and Mitigation Measures

As discussed earlier in this section, the proposed site water management for the Thor Lake Project will consist of a closed loop system to minimize effects to the natural hydrologic flows. The Tailings Management Facility (TMF) will be located within a basin in the upper portion of the northern watershed area reporting to Thor Lake. Water will be withdrawn from Thor Lake and recycled from the TMF to operate the Flotation Plant.

Excess water from the TMF will be treated (if necessary) and discharged to Drizzle Lake from the Polishing Pond. Ultimately, all excess water from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system. A Settling Pond will be established to collect runoff water from the Flotation Plant site and may also be used to reclaim small amounts of water for use in the Flotation Plant.

Additional mitigation measures that will be employed during the operations phase will include:

- Mine water and Plant site runoff will be collected and directed into the process as appropriate.
- All excess water released from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system.
- Water will be recycled from the TMF to the greatest extent possible to minimize the fresh water requirement (currently 50% recycle and 50% fresh water has been modelled).
- Extraction of fresh water from Thor Lake will be managed to conform to the 2010 Department of Fisheries and Oceans (DFO) Protocol for Winter Water Withdrawal (DFO 2010), which specifies the use of no more than 10% of the available under-ice water volume.
- Natural flows and conditions will be monitored and mimicked as closely as possible throughout operations to minimize possible effects on the local hydrological regime.

With the application of the mitigative measures as described, the overall effects on the natural hydrologic flows of the Thor Lake area are expected to be localized, low in magnitude and insignificant.

6.4 SURFACE WATER QUALITY

6.4.1 Summary of Existing Water Quality Characteristics

Water Quality has been identified by the Mackenzie Valley Review Board (2011) as a key line of inquiry because of concerns over the potential adverse effects of the Nechalacho Mine site on water quality in lakes and streams within the mine footprint area. Accordingly, the following section discusses the potential effects of the Project on the drainage area downstream of the Tailings Management Facility (TMF).

As indicated in Section 2.6.1.2 of this DAR, waters within the broad footprint of the proposed Nechalacho Mine and Flotation Plant site area have relatively high alkalinity, hardness, and calcium. These characteristics indicate a high acid buffering capacity. Lakes tend to be relatively clear with low suspended sediment levels, and low nutrient and metals concentrations. No CCME exceedances were noted for Thor Lake, into which discharges from the tailings area would ultimately drain. (No CCME exceedances in Thor Lake were noted except for one result for copper (6.03 μg/L) for March, 2008. All subsequent analyses were an order of magnitude or greater less than that value).

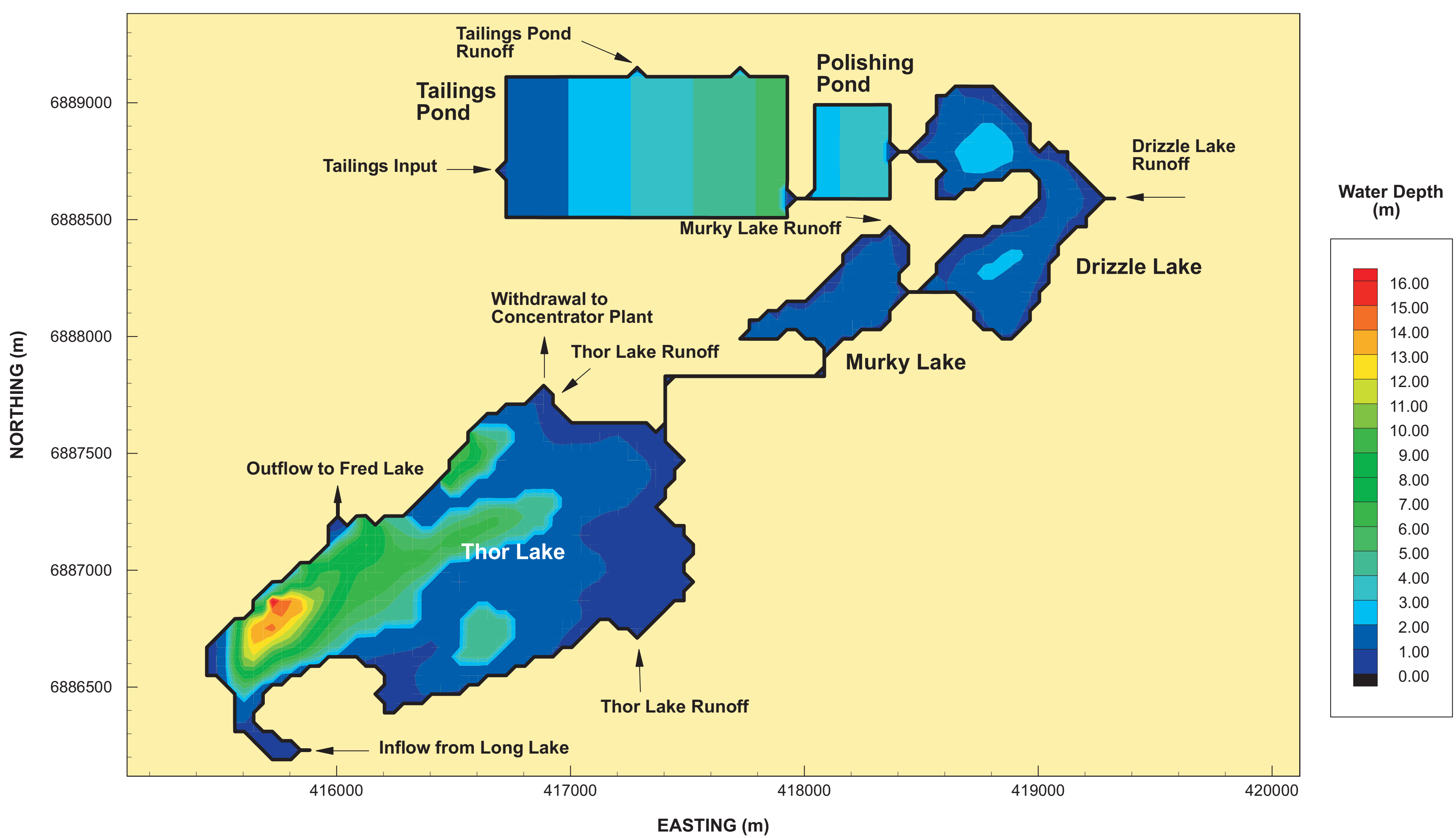
Nitrate, ammonia and total phosphate values were low or below detection at many samples stations, though levels were higher and more variable in smaller lakes. These shallow lakes are typically anoxic under the ice, with decreased pH and increased solubility of some metals and nutrients, resulting in high values for conductivity, hardness, ammonia, total phosphate and total aluminum, arsenic, iron, manganese, molybdenum, and strontium. Winter anoxia and increased metal solubility likely caused the large increases observed in total and dissolved iron and other metals in samples from shallow lakes. For example, the background level of total iron exceeded the CCME guideline in winter by 3.4 to 61 times.

Radionuclide results at all sample stations were typically below detection or less than five times the detection limit. No guideline exceedances were observed for any of the measured radionuclide parameters (lead-210, radium-226, radium-228, thorium-230, and thorium-232).

6.4.2 Metals Modelling

A water quality (metals) modelling study was conducted by EBA to predict the effects of the tailings decant water discharge from the Tailings Management Facility on the water quality in Thor Lake (EBA 2011d; Appendix B). Nutrients are discussed separately in Section 6.4.3. The model encompassed the interconnected Thor Lake system of water bodies: the tailings pond and the polishing pond (collectively called the Tailings Management Facility (TMF), Drizzle Lake, Murky Lake and Thor Lake. The schematic of the Thor Lake system is shown in Figure 6.4-1. Also shown in Figure 6.4-1 is the bathymetry for Thor, Murky and Drizzle lakes. The bathymetry and shape of the tailings and polishing ponds shown are approximations only. Mine tailings are discharged into the TMF from the Flotation Plant. As solids settle out to the bottom of the TMF, significant amounts of contaminant associated with the tailings solids will be removed, leaving only the dissolved contaminants in the water column available to travel downstream.

Hydrologic and meteorologic data were incorporated into the model. The water balance and hydrology of the lake system was determined by Knight Piésold (2011d). Wind, air temperature, humidity and cloud cover data have been collected at Yellowknife Airport since 1953 and the data collected between 1987 and 2007 were utilized in the model.



NOTES
1. The shape, area and bathymetry of the tailings and polishing ponds as shown are only an approximation.
2. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 1.1).

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THOR LAKE PROJECT

Bathymetry Thor Lake System

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V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-1

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6.4.2.1 Hydrology

The Thor Lake system consists of a complex hydrological network that interconnects the water bodies and controls the water balance in the system. The proposed mine water management will modify hydrology and, hence, the water balance in the area, particularly with the plan to recycle water from Thor Lake to the Flotation Plant. Knight Piésold (2011d) conducted a long term study to investigate the water balance in the area for the pre-operation and the 20-year period during mine operations. This information was utilized in the hydrodynamic model (see Figure 6.3-6 in this DAR).

The proposed TMF will replace Ring Lake and Buck Lake and become the main upstream water bodies of Drizzle Lake. Drizzle Lake then drains into Murky Lake which is located slightly to the west. Thereafter, Murky Lake drains into Thor Lake, which also receives significant amounts of runoff from Long Lake and other small tributaries. The Thor Lake outflow drains into Fred Lake immediately to the north. Water will be withdrawn from Thor Lake and recycled to the Flotation plant, which will in turn discharge the processed tailings to the TMF.

Groundwater inflow and outflow were assumed absent in the Thor Lake system, and therefore were not considered in this model study.

6.4.2.2 Meteorology

There is no meteorological station with long term data in the immediate vicinity of the Project site. Therefore, the meteorological station at Yellowknife Airport, maintained by the Meteorological Service of Canada, was used in this study. That station has been collecting hourly climate data, such as wind, air temperature, humidity and cloud cover since 1953.

The data collected were used as the meteorological inputs to the model. Although the wind direction at the Yellowknife Airport and the Project site should be similar, because there are no significant terrain features to alter the local air flow, reduction of the wind speed as measured at Yellowknife Airport was required to take account of the shielding effects of the trees that surround the water bodies of such small size. A reduction of wind speed by 50% was deemed appropriate after model calibration by comparing the simulated temperature profiles with measured profiles (Stantec 2010a).

The wind data were used in the model to mainly drive the circulation in a water body. Coupled with the air temperature, relative humidity, and cloud cover, the winds also govern the heat exchange of the water body with the atmosphere. These complex processes ultimately control the physical structure of the water column, which in turn governs the lake circulation pattern.

6.4.2.3 Physical Limnology

Typical of inland, mid to high-latitude lakes, the Thor Lake system demonstrates significant seasonality in circulation dynamics and patterns, which vary according to the physical structure of the lake. In summer, deeper lakes normally form a two-layer system: a relatively shallow surface warm layer (epilimnion) and a cool deep layer (hypolimnion), separated by a thermocline of rapidly changing temperature. The depth and appearance of the thermocline changes throughout the course of the summer season, and the two layers can have considerably different motions.

The two-layer structure was observed in areas of Thor Lake where the water depth was greater than four metres. In those locations, the thermocline was located at about 2-4 metres depth depending on the time in the season. This was reproduced from the model; the section view of water temperature is shown in Figure 6.4-2. Large parts of the water bodies in the Thor Lake system are relatively shallow with depths less than three metres. The shallow water depths, coupled with the wind, leads to local vertical mixing and a uniformly mixed region in shallow areas.

In fall, the surface water temperature decreases and eventually becomes the same as the temperature in the bottom layer, leading to overturn. A roughly uniform temperature distribution throughout the water column is formed as a result.

In winter, surface water continues to cool. Reverse thermal stratification forms as the water temperature drops below 40C, the temperature of highest density for freshwater. As water continues to cool, ice starts to form on the surface, forming an insulating layer and cutting off the energy from the wind to the water bodies.

Ice melts in spring as air temperature rises and the water bodies once again become exposed to atmospheric and wind forcing. The lakes, as mentioned before, are exposed to wind-driven forcing during the ice-free period that, in conjunction with other meteorological parameters such as air temperature, humidity and cloud cover, causes water circulation patterns such as seiching and stratification.

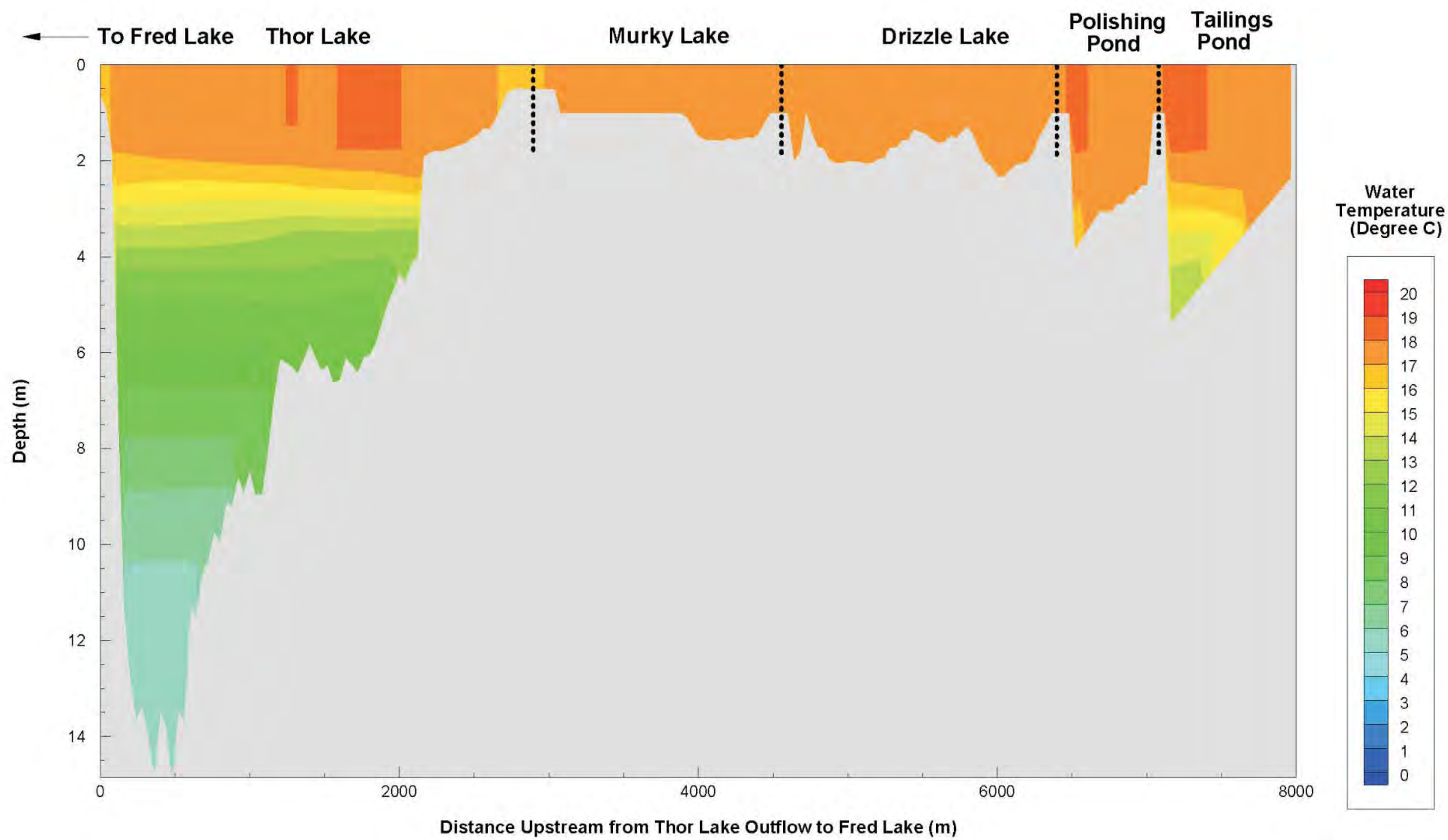
The main driving force for currents and circulations within each water body, and hence movement of contaminants, is wind. Wind forcing will drive surface currents in the up-wind and down-wind directions, and will also generate a return flow at depth.

The major factor controlling lake stratification is the water temperature. When the lake is stratified, it experiences internal seiching, an internal wave motion of the stratified layers, in response to wind forcing, which leads to a complex current and mixing pattern. When the lake is unstratified, the barrier preventing contaminants from being transported down to deeper water disappears; as a result, vertical mixing becomes significant.

6.4.2.4 Hydrodynamic Model

General Description of H_3D

Releases and fate of dissolved metal contaminants from the tailings discharge were simulated by EBA using the proprietary three-dimensional hydrodynamic model H_3D. The model is derived from GF8 (Stronach et al. 1993), originally developed for Fisheries and Oceans Canada. It is a three-dimensional time-stepping model that computes the three components of velocity (u,v,w) on a rectangular grid in three dimensions (x,y,z), as well as scalar fields such as temperature and contaminant concentrations. The metal contaminants are modelled as tracer, added at the tailings decant water release point and closely tracked in the model until it leaves the model domain.



NOTES

1. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 2.1).

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THOR LAKE PROJECT

Cross Section Water Temperatures Summer Season After Commencement of Mine Operations

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-2

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The spatial grid may be visualized as a number of interconnecting computational cells, collectively representing the water body. Velocities are determined on the faces of each cell, and non-vector variables, such as temperature or dissolved contaminant concentrations, are computed at the centre of each cell. All cells have identical width and length dimensions in the horizontal plane, with the selection of grid size established by considerations of the scale of the phenomena of interest. In the vertical, the cells are configured such that they are relatively thin near the surface and increase in thickness with depth. The increased vertical resolution near the surface is required because much of the variability (stratification, wind mixing, inputs from streams and land drainage) is concentrated near the surface.

The following discussion provides characteristics common to the implementation of H_3D:

- Wind forcing produces currents within enclosed water bodies as well as water level differences. It also significantly affects vertical mixing, and hence scalar distribution.
- Turbulence modelling is important in determining the distribution of velocity and scalars such as water temperature and dissolved contaminants. The diffusion coefficients for momentum and scalars at each computational cell depend on the level of turbulence at that point. For momentum, H_3D uses a shear-dependent turbulence formulation in the horizontal, and a shear stratification dependent formulation in the vertical. These parameters have been shown to correctly simulate the annual temperature cycle within several lakes in British Columbia, and are consistent with current practice. For scalars, the eddy diffusivity values are set equal to the corresponding eddy viscosity values.
- The model operates in a time-stepping mode over the period of simulation. During each time step, values of velocity, temperature and concentration of other scalars are updated in each cell.

Model Implementation

A 40 m resolution model of the entire Thor Lake system was constructed, encompassing the tailings pond, polishing pond, Drizzle Lake, Murky Lake and Thor Lake. Also included in the model are the tailings decant water discharge, the freshwater drainage and withdrawal, as well as channels that interconnect the water bodies.

The vertical resolution was chosen so that the layers are sufficiently close together near the surface where processes such as the thermocline occur. The layers become progressively further apart as they go deeper into the water column. The model used the bathymetry data made available from Stantec Inc. (Email communication 2011). Freshwater inflows from runoffs and upstream discharges are included in the model. In addition, tailings decant water discharge enters the Thor Lake system in the TMA. Figure 6.4-1 illustrates the model showing the lake bathymetry and the approximate locations of major inflows and outflows. Note that the shape and area of the tailings and polishing ponds are approximations, and their locations are for illustrative purpose only.

The model was run for a 20-year period starting at the commencement of mine operations. The transport and fate of the dissolved contaminants modelled in the study were represented as a conservative tracer. The tracer with unity concentration (i.e., 1.0) was released into the tailings pond. The concentration of any dissolved metal contaminants of concern can be readily calculated anywhere in the model domain by multiplying the tracer concentration by the actual concentration of the metal contaminants at the release point. At model initiation, a tracer concentration of zero in all water bodies in the model was assumed.

In the model, water is withdrawn from Thor Lake to the Flotation Plant. The tracer concentration in the recycled water going to the plant is the same as that at the withdrawal point in Thor Lake. The tracer concentrations in the tailings discharge were assumed to remain the same as specified.

The main concern of this study is the possible degradation of water quality in the Thor Lake system due to excessive concentration of metals during mine operations. The modelled data have been compared to the Metal Mining Effluent Regulation (MMER) criteria and Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life. The metals of concern are Mercury (Hg), silver (Ag), Aluminum (Al), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Selenium (Se), and Zinc (Zn) and their concentrations were simulated in the model. Three radioactive metals, Uranium (U), Thorium (Th), and Radium-226 (Ra-226) are also included in the simulation. U, Th and Ra-226 have very long half-life, therefore, they were treated as conservative elements. Ra-226 is expressed in units of Becquerel per litre (Bq/L), a standard SI unit for radioactivity. In this study, the radioactivity of Ra-226 is assumed linearly proportional to the concentration of Ra-226 in water.

Table 6.4-1 shows the Day 5 decant concentration of the concerned metals analyzed in November, 2010 (Avalon Rare Metals Inc. 2010). For the metals with decant concentration below detection limits, the detection limits were used as the concentration input to the tailings effluent in the model. The metal concentrations of concern at any time and location can be calculated by multiplying the modelled tracer concentration by the decant concentration.

TABLE 6.4-1: DAY 5 DECANT METAL CONCENTRATION IN TAILINGS DISCHARGE

Metal	Day 5 Decant Metal Concentration	Metal
Hg	Below detection limit of 0.0001 mg/L	-
Ag	0.00003	-
Al	0.62	-
As	0.0022	0.50
Cd	0.000067	-
Cr	0.0011	-
Cu	0.0023	0.30
Fe	0.570	-
Mo	0.0471	-
Ni	0.0070	0.50
Pb	0.00060	0.20

TABLE 6.4-1: DAY 5 DECANT METAL CONCENTRATION IN TAILINGS DISCHARGE		
Metal	**Day 5 Decant Metal Concentration**	**Metal**
Se	Below detection limit of 0.001 mg/L	-
Zn	0.007	0.50
U	0.00880	-
Th	0.000694	-
Ra-226	Below detection limit of 0.01 Bq/L	0.37 Bq/L

Note: A '-' indicates that the MMER does not specify limits for that metal.

6.4.2.5 Model Results

The simulation covers the 20-year period after the commencement of mine operations. Table 6.4-2 details the evolution of the inert tracer concentration at the surface in the Thor Lake system over the course of the simulation period. Surface concentrations are presented here because higher concentrations were always found near the top of the water column. While the tracer concentrations presented in the table do not represent the concentration of metals of concern, they indicate the trend of contaminant dilution by the natural surface runoff flow in the Thor Lake system.

TABLE 6.4-2: AVERAGE CONCENTRATION OF INERT TRACER IN THE THOR LAKE SYSTEM						
Year of Simulation	**Plant Discharge**	**Tailings Pond**	**Polishing Pond**	**Drizzle Lake**	**Murky Lake**	**Thor Lake**
1	1.0	0.00091	0.00026	0.00004	0.00003	<0.00001
2	1.0	0.00160	0.00073	0.00021	0.00017	0.00001
3	1.0	0.00215	0.00119	0.00043	0.00037	0.00004
4	1.0	0.00260	0.00164	0.00064	0.00058	0.00009
5	1.0	0.00299	0.00208	0.00092	0.00085	0.00016
6	1.0	0.00331	0.00241	0.00111	0.00104	0.00024
7	1.0	0.00360	0.00269	0.00126	0.00119	0.00031
8	1.0	0.00386	0.00292	0.00138	0.00132	0.00038
9	1.0	0.00408	0.00313	0.00152	0.00144	0.00044
10	1.0	0.00423	0.00330	0.00159	0.00152	0.00050
11	1.0	0.00437	0.00342	0.00178	0.00159	0.00057
12	1.0	0.00455	0.00355	0.00179	0.00166	0.00058
13	1.0	0.00466	0.00369	0.00180	0.00171	0.00061
14	1.0	0.00477	0.00379	0.00185	0.00177	0.00063
15	1.0	0.00485	0.00387	0.00190	0.00183	0.00066
16	1.0	0.00492	0.00394	0.00199	0.00186	0.00070
17	1.0	0.00500	0.00392	0.00194	0.00186	0.00068
18	1.0	0.00500	0.00389	0.00191	0.00176	0.00067
19	1.0	0.00504	0.00400	0.00199	0.00186	0.00070
20	1.0	0.00508	0.00408	0.00207	0.00191	0.00071

In general, the tracer concentrations in all water bodies increase and the rate of increase slows with time. Meanwhile, the tracer concentration decreases progressively from one water body to another as the water travels downstream. This is mainly due to mixing of the tracer with the large volumes of water in the downstream water bodies. As well, the fresh natural runoff entering into different parts of the Thor Lake system leads to further dilution of the tracer.

While thermal stratification occurs in Thor Lake, vertical variation of temperature in the other water bodies remains small because they are very shallow. Tracer concentration in each of the individual water bodies remains relatively constant, indicating the tracer is well mixed horizontally and vertically within each water body. This is because the stratification has been maintained only by temperature, which results in relatively weak density stratification. Combined with the shallow depths of the Thor Lake system, wind energy at the site is sufficient to cause mixing and transport of the tracer throughout all depths of the water bodies. As well, overturn in fall and spring results as surface and bottom water temperatures converge, leading to additional vertical transport and mixing.

Figures 6.4-3 and 6.4-4 illustrate in plan view the concentration of Al and Fe, the two metal species with tailings decant water concentration over the applicable CCME water quality guideline criteria (no MMER criteria exist for these metals), in the Thor Lake system at the end of the model simulation in Year 20. Figures 6.4-5 and 6.4-6 show the cross-section view the concentrations of Al and Fe in Year 20. Figure 6.4-7 shows the time series concentration of Al, Fe, U and Th at the outflow to Fred Lake. Table 6.4-3 summarizes the maximum concentration of all metal species in Drizzle, Murky and Thor lakes. Also included in the table are the MMER effluent criteria and CCME water quality guideline values.

TABLE 6.4-3: MAXIMUM METAL CONCENTRATIONS IN THE THOR LAKE SYSTEM AND WATER QUALITY GUIDELINES FOR METALS OF CONCERN

Metal Species	Thor Lake	Murky Lake	Drizzle Lake	CCME Water Quality Guideline	MMER Effluent Criteria
Al (mg/L)	0.0005	0.0013	0.0017	0.1	-
Fe (mg/L)	0.0004	0.0012	0.0015	0.3	-
Cd (mg/L)	5.1E-8	1.4E-7	1.8E-7	0.00002-0.00013	-
Hg (mg/L)	7.6E-8	2.1E-7	2.7E-7	0.000026	-
Ag (mg/L)	2.3E-8	6.4E-8	8.1E-8	0.0001	-
As (mg/L)	1.7E-6	4.7E-6	5.9E-6	0.005	0.5
Cr (mg/L)	8.3E-7	2.3E-6	3.0E-6	0.0089	-
Cu (mg/L)	1.7E-6	4.9E-6	6.2E-6	0.002-0.004	0.30
Mo (mg/L)	3.6E-5	1.0E-4	1.3E-4	0.073	-
Ni (mg/L)	5.3E-6	1.5E-5	1.9E-5	0.025-0.150	0.50
Pb (mg/L)	4.5E-7	1.3E-6	1.6E-6	0.001-0.007	0.20
Zn (mg/L)	5.3E-6	1.5E-5	1.9E-5	0.03	0.50
U (mg/L)	7.3E-6	1.7E-5	2.3e-5	0.015	-
Th (mg/L)	5.8E-7	1.3E-6	1.8E-6	-	-
Ra-226(Bq/L)	8.3E-6	1.9E-5	2.6E-5	-	0.37

The important factor controlling the metal concentrations in the Thor Lake system is the balance of the tailings decant water inflow, the freshwater inflows, the outflow at Thor Lake and the water withdrawal from Thor Lake to the Flotation Plant. The metal concentrations continue to increase from year to year while showing an annual fluctuation cycle which coincides with the freshwater water input, indicating the fluctuation of the freshwater inflow control.

6.4.2.6 Assessment

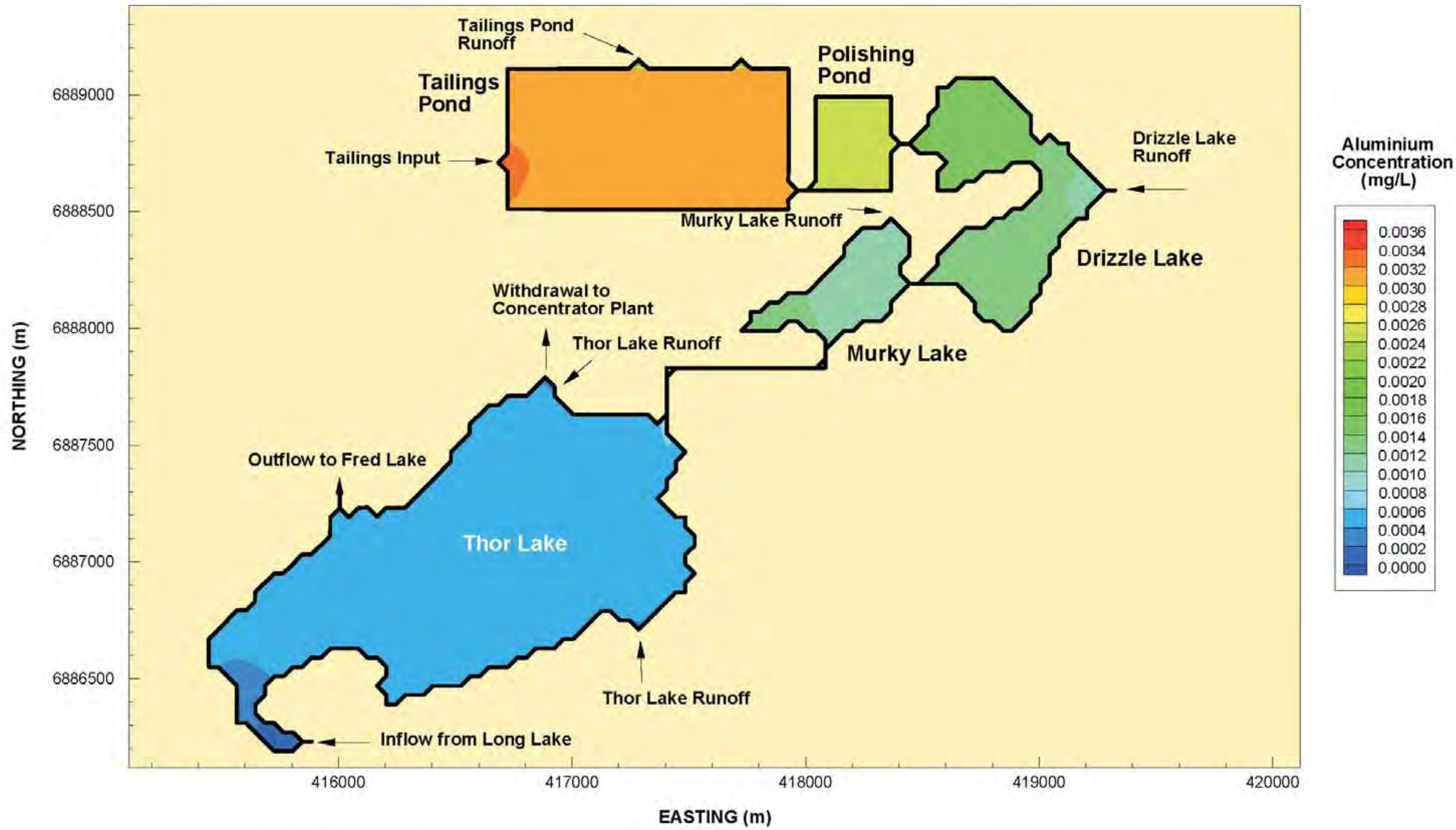
As shown in Table 6.4-3, the model predicts that the MMER effluent criteria for all parameters will be met over the entire 20 year simulation period, in each of the lakes within the Thor Lake system. This is the case even for aluminum and iron, which are the only metals in the effluent predicted to exceed CCME guideline values. Concentrations of metals reaching Thor Lake are predicted to be extremely low. For example, arsenic will be 0.034% of the CCME guideline; mercury 0.3% of the CCME guideline; and, copper, 0.04% of the MMER guideline.

It is noted that the concentrations shown in Table 6.4-3 represent conservative values, since no allowance was made in the model for decreases in concentration due to natural remediation processes including degradation, chemical oxidation, precipitation, and biodegradation.

All metals considered in this report, including the radioactive Uranium, Thorium and Radium-226, which all have very long half-life, were assumed chemically inert. The results shown in this study with regard to the radioactive metal species would be conservative as a result.

Considerable further dilution of water flowing out of Thor Lake is anticipated as it progresses through a series of wetlands, streams and lakes towards Great Slave Lake comprising a watershed estimated to be more than three times the catchment of Thor Lake. As such, it is expected that metal levels in water entering Great Slave Lake will be similar to pre-development background levels.

Based on the foregoing, water quality in Thor Lake and further downstream is not anticipated to be adversely affected by mining activities and discharges of decant water from the TMF. No adverse residual effects are therefore predicted. Water quality and biological monitoring will be carried out according to requirements of the Water License and the MMER. Monitoring results will be used to confirm that water quality downstream of the TMF discharge remains within allowable limits.



NOTES

1. The shape and area of the tailings and polishing ponds as shown are only an approximation.
2. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 3.1).

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THOR LAKE PROJECT

Concentration of Aluminum Year 20 After Commencement of Mine Operations

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-3

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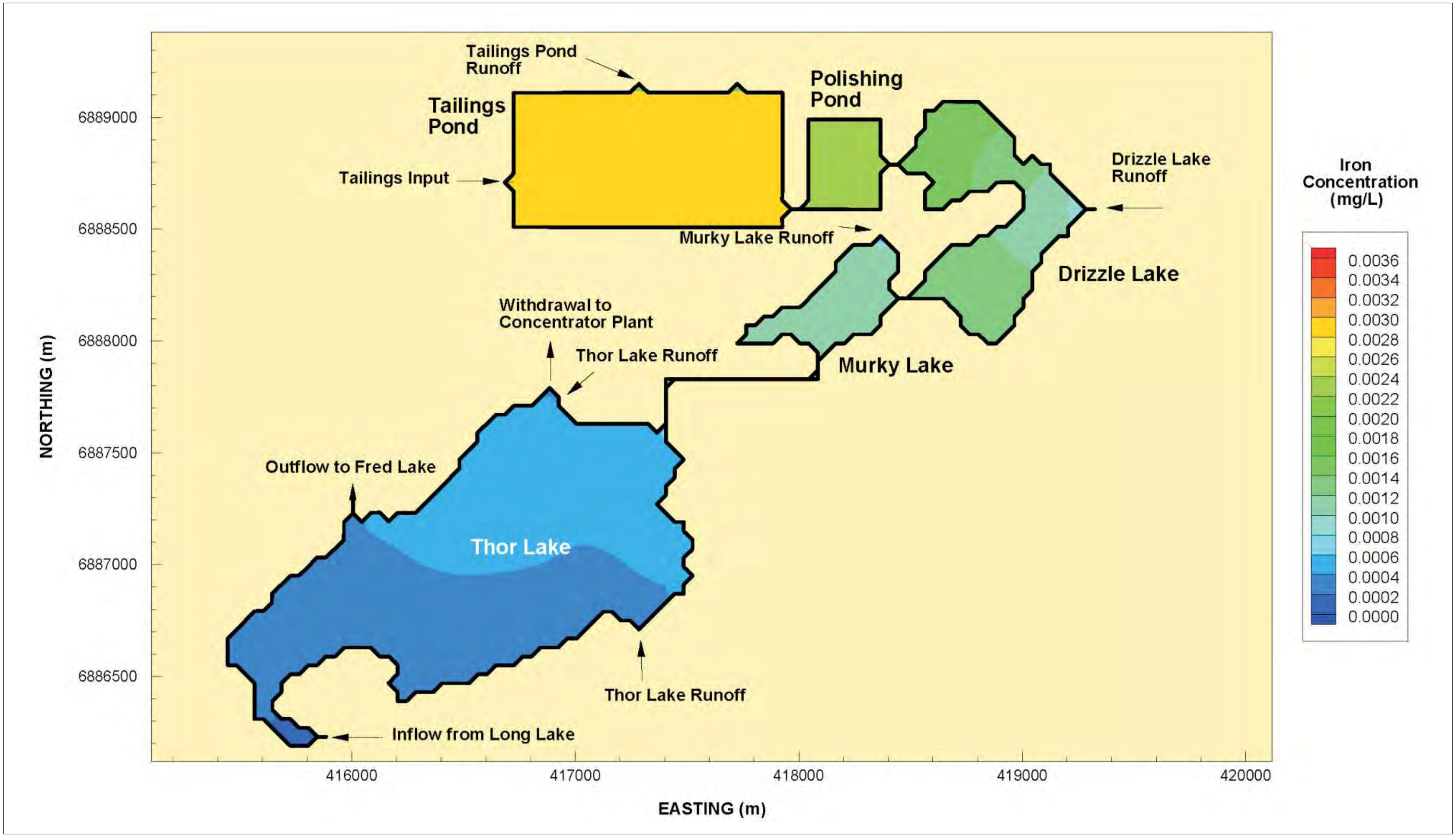

NOTES

1. The shape and area of the tailings and polishing ponds as shown are only an approximation.
2. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 3.2).

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THOR LAKE PROJECT

Concentration of Iron
Year 20
After Commencement of Mine Operations

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-4

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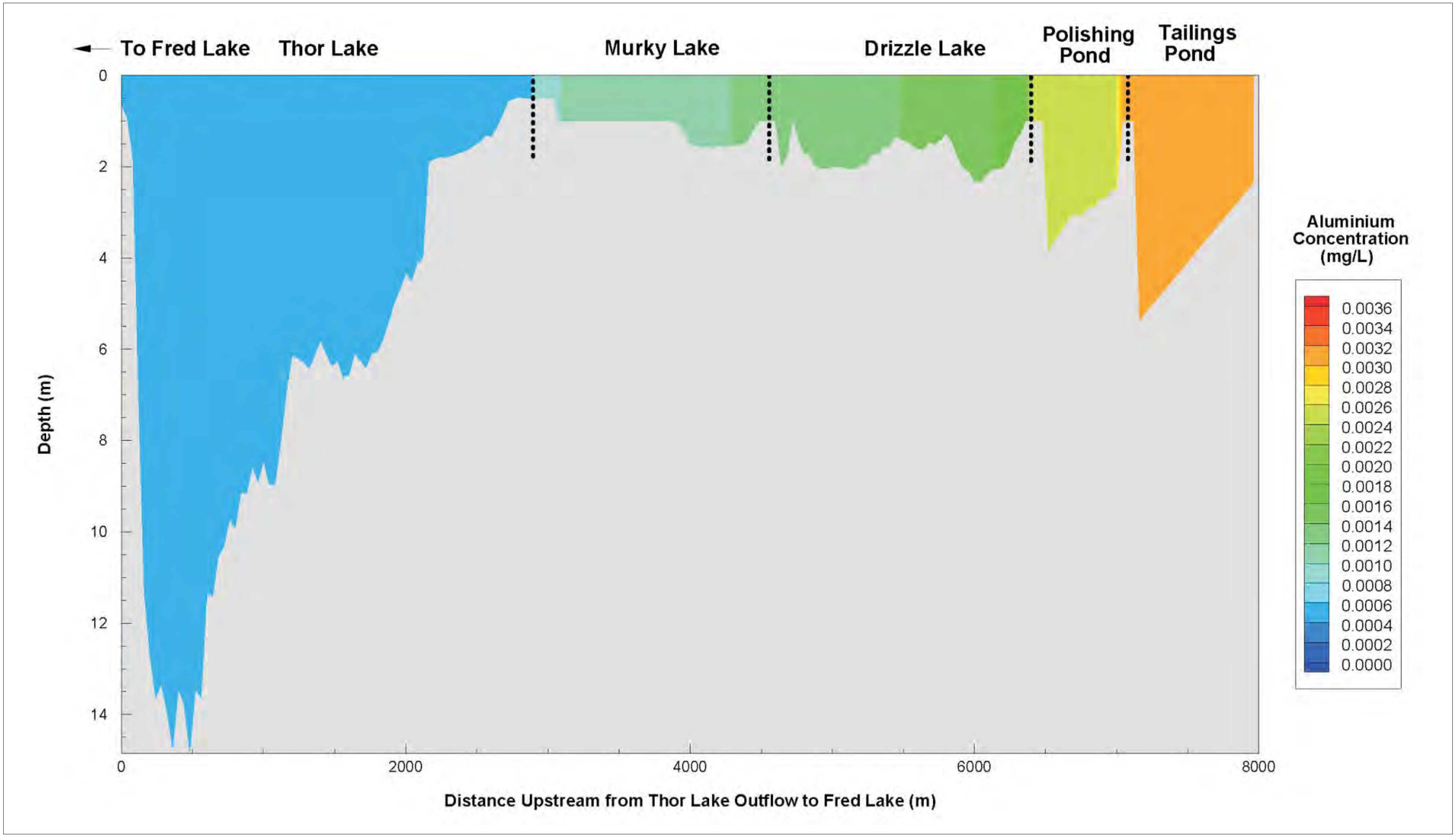

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NOTES

1. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 3.3).

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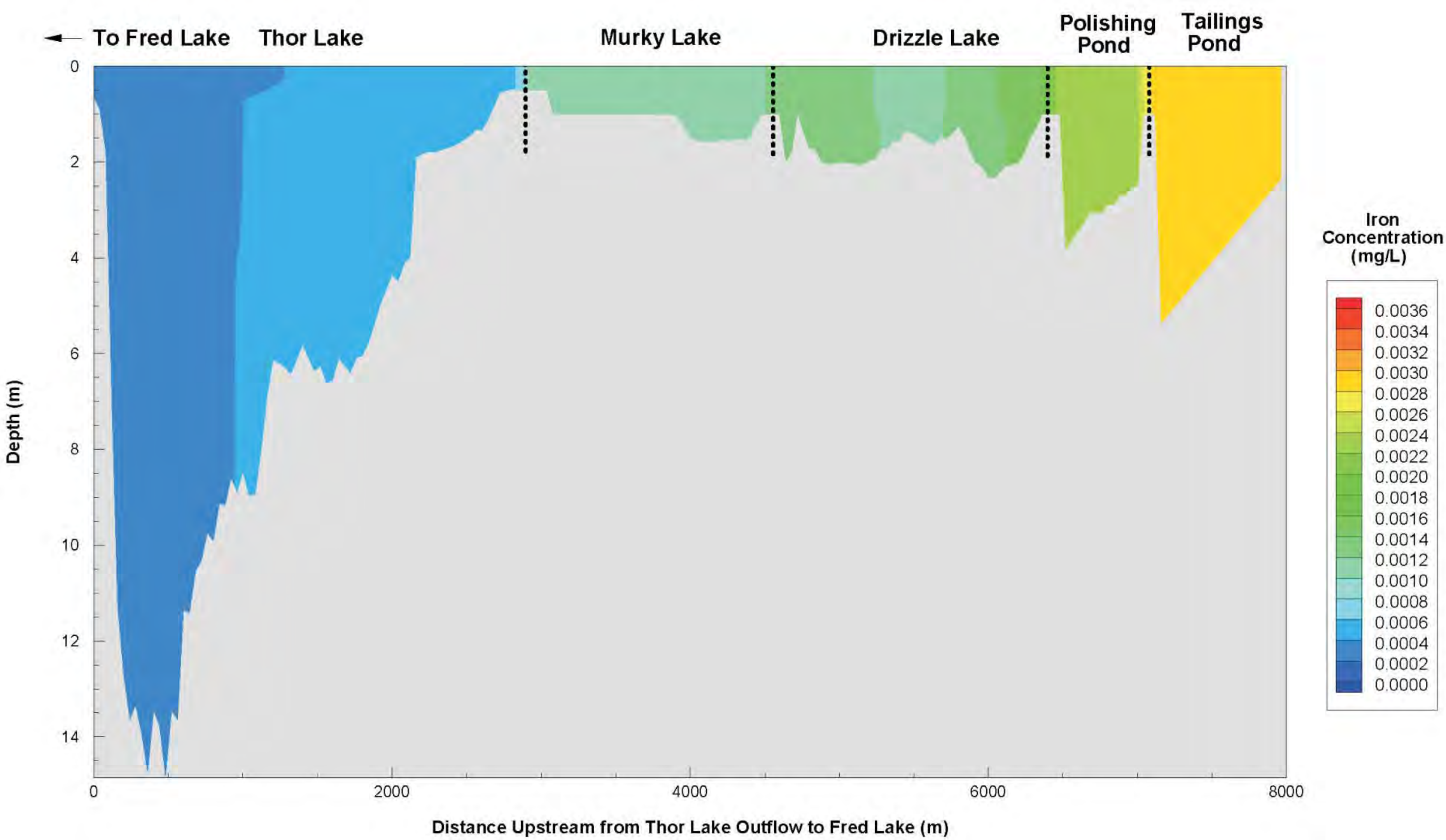
THOR LAKE PROJECT

Sectional Concentration of Aluminum Year 20 After Commencement of Mine Operations

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-5



NOTES

1. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 3.4).

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THOR LAKE PROJECT

Sectional Concentration of Iron Year 20 After Commencement of Mine Operations

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-6

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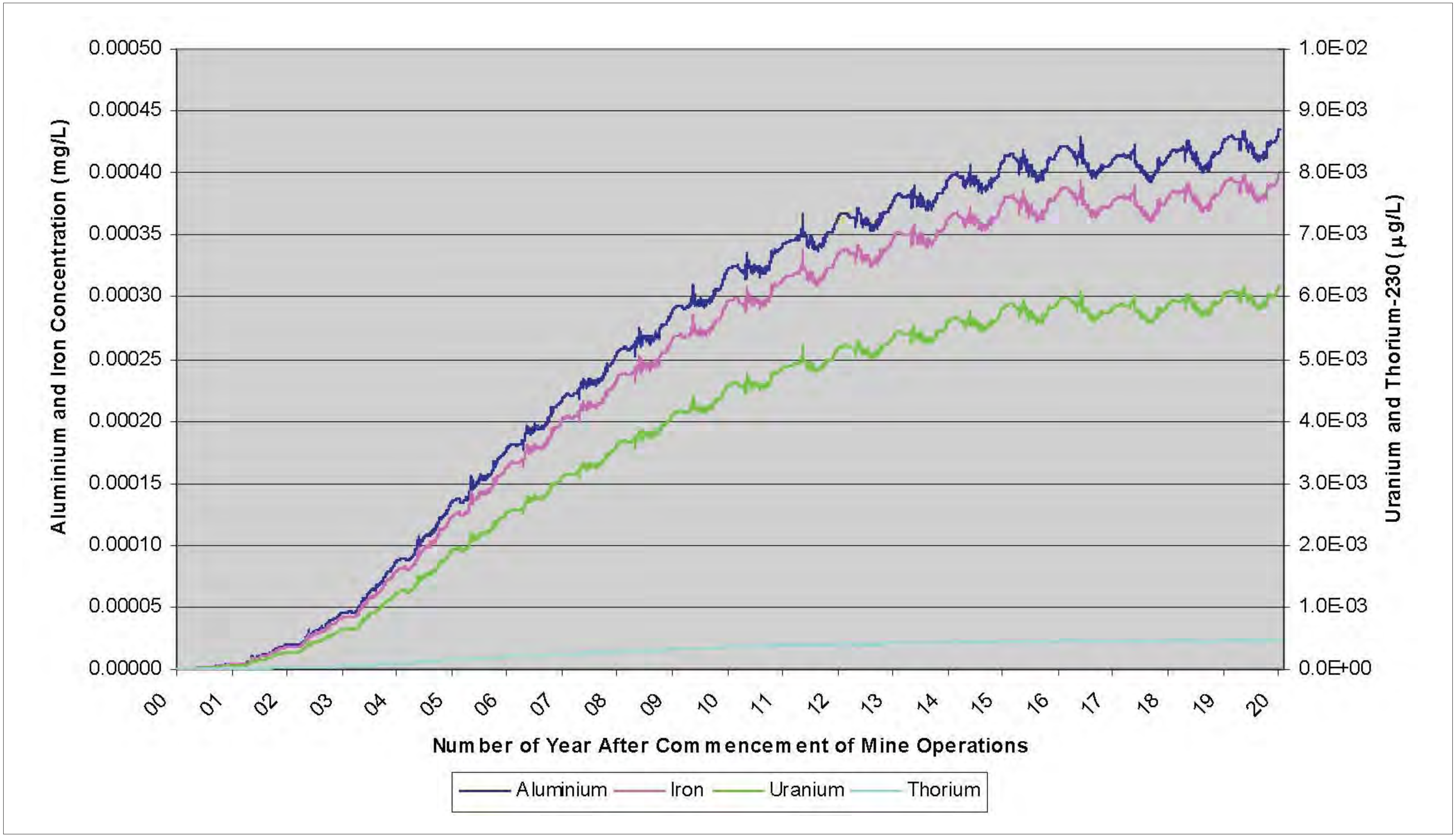

NOTES

1. Modelling period starts in May 1987 and ends in December 2008.
2. CCME Water Quality Guideline: Aluminium = 0.1 mg/L; Iron = 0.3 mg/L; Uranium = 0.015 mg/L
3. Uranium and Thorium have long half-life and therefore are considered conservative in the study.
4. Figure Source: Water Quality Modelling for the Thor Lake Project, EBA Technical Memo No. 001, File V15101007.006 (March 2011, Figure 3.5).

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THOR LAKE PROJECT

Time Series Concentration of Aluminium, Iron, Uranium and Thorium at the Outlet of Thor Lake to Fred Lake

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	April 5, 2011		

Figure 6.4-7

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6.4.3 Nutrient Modelling

The Flotation Plant at the proposed Nechalacho Mine site will discharge process tailings into the Tailings Management Facility (TMF). Decant water from the TMF will be directed into Drizzle Lake which drains into Murky Lake, Thor Lake, and eventually other downstream water bodies of the Thor Lake system. The water fraction of the tailings is expected to contain elevated levels of nitrogen, due mainly to the explosive chemicals (ANFO) used for underground mine blasting during the mining operation. Such discharges will lead to increased concentrations of nitrogen in these water bodies. This additional nitrogen, upon reaching the downstream lake system, will become available for phytoplankton growth and may result in increased productivity of phytoplankton in the downstream lakes.

Potential issues associated with excess phytoplankton productivity may relate to depletion of dissolved oxygen through bacterial processes fed by the enhanced production and degradation of the aquatic environment. Because the response of phytoplankton to increased nitrogen is a complex process, related also to levels of phosphorous, water temperature and sunlight primarily, a numerical model of the phytoplankton population, considering these additional processes, was used to determine the possible effects of nitrogen enrichment on phytoplankton productivity during mine operations (EBA 2011e; Appendix B).

6.4.3.1 Numerical Model

The dynamics of the phytoplankton population and possible changes have been simulated through the use of a three-dimensional hydrodynamic model, H_3D, coupled with the phytoplankton equations as employed in CE-QUAL-W2, (Cole and Wells 2008), supported by the Army Corps of Engineers, a widely used two-dimensional, laterally averaged hydrodynamic and water quality model. The water quality module is readily transported to three dimensional systems such as H_3D. The phytoplankton model also simulates the population of herbivorous zooplankton, which forms an essential part of the population dynamics of phytoplankton, the nitrogen and phosphorous uptakes by phytoplankton, and the regeneration of nitrogen and phosphorus from phytoplankton and herbivore respiration, metabolic products and death/decay.

Model Description

While H_3D simulates the hydrodynamics and thereby the transport and movement of biological populations and nutrients in the Thor Lake system (Tetra Tech 2011), the CE-QUAL portion embedded in H_3D simulates the biological dynamics between the nutrients and zooplankton and phytoplankton populations. The input parameters to the biological component of the model are listed below with values in parentheses:

- Sinking rate for replete phytoplankton (0.1 m/day)
- Sinking rate for deplete phytoplankton (0.1 m/day)
- Carbon to nitrogen mass ratio (10)

- Carbon to phosphorous mass ratio (140)
- Gross production rate of phytoplankton (5.0 mg C / mg C /day)
- Light saturation for plant growth (30 Watt/m^2)
- Half saturation concentration for nitrogen limitation (0.025 mg/L)
- Half saturation concentration for phosphorus limitation (0.01 mg/L)
- Self-shading (0)
- Herbivore grazing efficiency (0.5)
- Maximum herbivore grazing rate (1.5/day)
- Phytoplankton concentration for grazing threshold (10 μg/L)
- Phytoplankton saturation concentration (300 μg/L)
- Herbivore excretion - ratio of herbivore respiration to grazing (0.1)
- Dark respiration rate (0.1/day)
- Photorespiration rate (0.03/day)
- Maximum mortality rate for phytoplankton (0.1/day)
- Respiration rate for herbivores (0.1/day)
- Mortality for herbivores (0.01/day)
- Minimum mass concentrations of nitrogen, phosphorus, phytoplankton and herbivore zooplankton (0.001 mg/L, 0.001 mg/L, 1 μg/L, 10 μg/L, respectively)

The above values were based on values published in the CE-QUAL-W2 manual for species of phytoplankton and herbivores that were found in the Thor Lake system, but in all cases, a range of values for each parameter presented itself. Ultimately, the selection of numerical values was also informed by the calibration process described below. The units of phytoplankton and herbivore concentrations in the model are micrograms of biomass per litre.

In additional to the above parameters, initial concentrations of nitrogen (0.04 mg/L), phosphorus (0.001 mg/L), phytoplankton (100 μg/L), and herbivore zooplankton (10 μg/L) are given to the model. The nitrogen, phosphorous, phytoplankton and herbivore levels are based on data reported for the Thor Lake system (Stantec 2010). Chlorophyll concentrations ranged between 3 to 10 μg/L. Assuming a carbon to chlorophyll ratio of 10, and a biomass to carbon ration of 2, the phytoplankton biomass values found in the Thor lake system range from about 60 μg/L to 200 μg/L. EBA utilized a representative value of 100 μg/L as the initial condition. The herbivore initial concentration was taken to be one tenth the phytoplankton biomass concentration.

The model outputs include water temperature, and concentrations of nitrogen, phosphorus, phytoplankton, and herbivore zooplankton.

Model Calibration

Calibration of the model was conducted based on measurements of existing (baseline) water quality in the Thor Lake System (Stantec 2010c). The water quality parameter available for model calibration is the phytoplankton concentration. Generally, nutrient levels are prescribed to the model, based on observed data and then the model parameters provided are adjusted until reasonably repeatable observed phytoplankton and herbivore zooplankton concentrations are achieved.

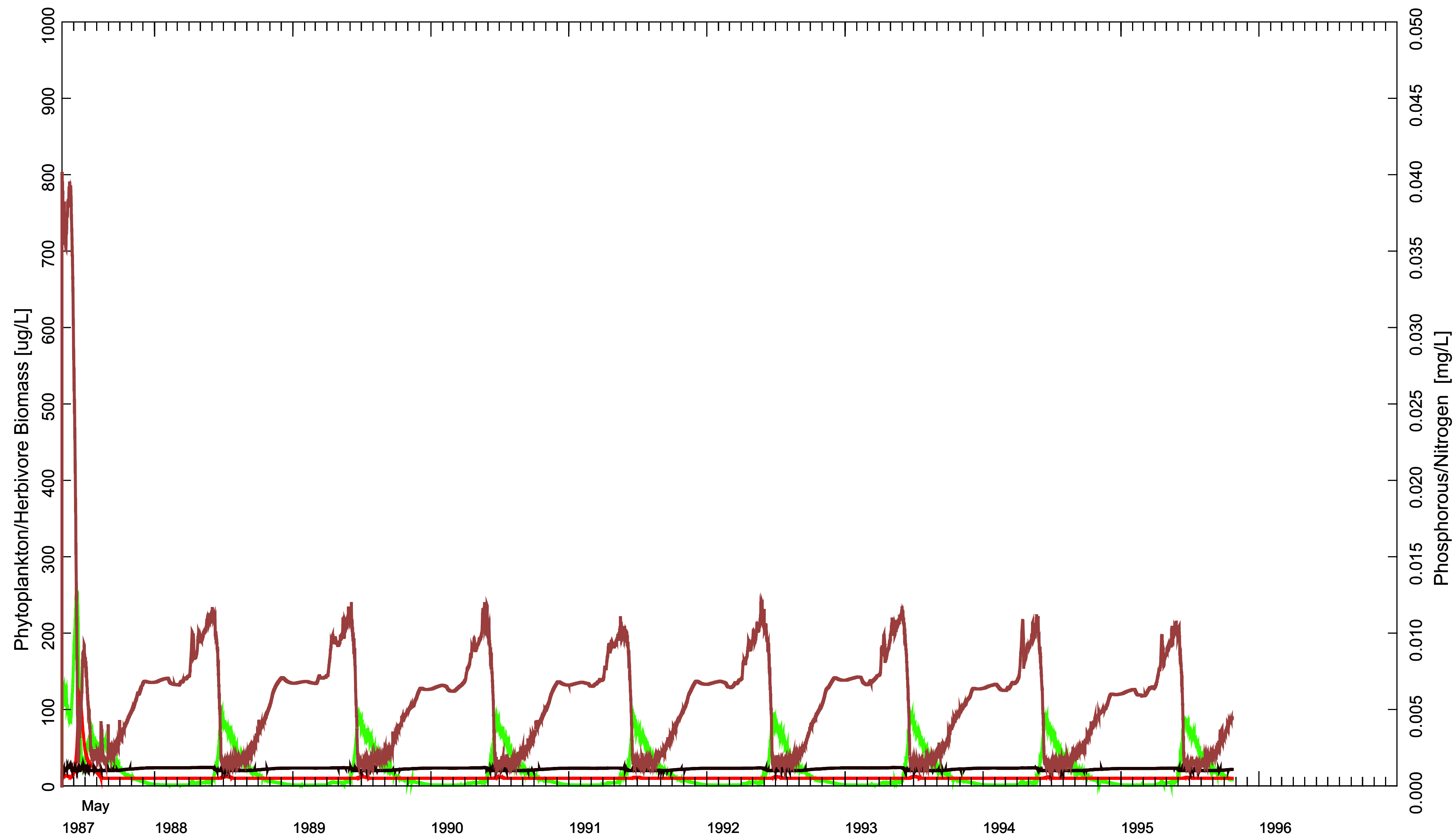
The peak phytoplankton biomass concentration in Thor Lake during annual spring blooms (Figure 6.4-8) is predicted to reach approximately 100 μg/L, while the herbivore biomass concentration remains relatively stable at 10 μg/L. Nitrogen level displays annual fluctuation cycles, with most of the nitrogen depleted during the spring blooms and replenished during late fall and winter seasons. In the meantime, phosphorous level remains low. The achievement of similar levels of phytoplankton biomass during the modelled spring bloom to the largest spring/summer values reported by Stantec is taken to be an indication that the model is a reasonable representation of the major characteristics of phytoplankton dynamics in the Thor Lake system. As well, the annual dissolved nitrogen cycle is similar in the model and in the observations, except that winter regeneration is underestimated in the model.

TMF Decant Water Nitrogen Concentration

A parallel simulation to that described above was conducted, but with a nitrogen concentration of 8.9 mg/L in the TMF decant water discharge. The nitrogen concentration level in the TMF decant water was determined based on the discharge flow rate and the daily amount of nitrogen as ammonia and nitrate discharged in the tailings, as provided by Avalon.

The model simulation output predicts that the added nitrogen may lead to enhanced phytoplankton growth, and the peak phytoplankton biomass concentration during annual spring blooms may reach a level of 300 μg/L in Thor Lake and 400 μg/L in the TMF (Figures 6.4-9 and 6.4-10). The model also shows that the elevated phytoplankton population in turn will likely lead to an increase in the herbivore population, especially during the spring bloom periods, with biomass concentrations potentially reaching 150 μg/L in Thor Lake and 200 μg/L in the TMF.

The model predicts that nitrogen levels will continue to build up with time in the downstream water bodies; however the peak biomass concentration for phytoplankton remains relatively constant from year to year. This suggests that nitrogen, once reaching a certain level, will become a non-limiting nutrient for phytoplankton growth. It is interesting to note that predicted nitrogen levels in the TMF are about ten (10) times the levels predicted in Thor Lake, but the phytoplankton and herbivore concentrations are nearly identical in the two water bodies. It should also be noted that the predicted levels of nitrogen in Thor Lake range up to 0.35 mg/L after ten (10) years of operation. This value is similar to the current peak levels in Thor Lake, indicating that the system is already subject to significant nitrogen concentration at the start of the growing season.



LEGEND

- Phytoplankton
- Herbivore
- Phosphorous
- Nitrogen

NOTES

Source: Phytoplankton in Thor Lake, EBA Technical Memo No. 001, File V15101007.006 (May 2011, Figure 2.1).

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THOR LAKE PROJECT

Phytoplankton Modelling - Thor Lake Pre-Mining Conditions Normal P, Normal N

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0
OFFICE	DATE		
EBA-VANC	May 9, 2011		

Figure 6.4-8

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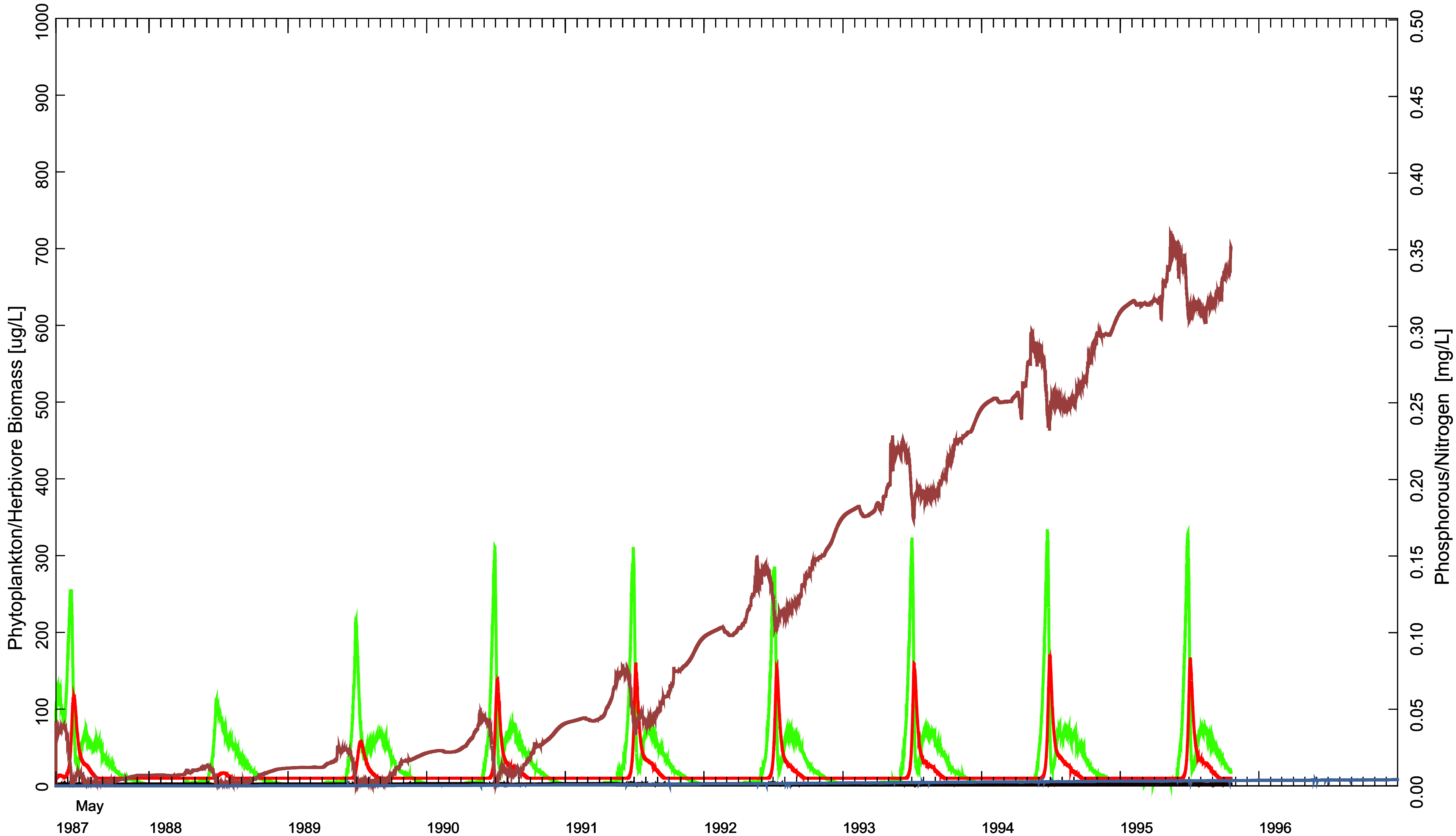

LEGEND

- Phytoplankton
- Herbivore
- Phosphorous
- Nitrogen
- Conservative Nitrogen

NOTES

Source: Phytoplankton in Thor Lake, EBA Technical Memo No. 001, File V15101007.006 (May 2011, Figure 2.2).

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THOR LAKE PROJECT

Phytoplankton Modelling - Thor Lake Operating Mine Conditions Normal P, Elevated N, Surface

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0

OFFICE	DATE
EBA-VANC	May 9, 2011

Figure 6.4-9

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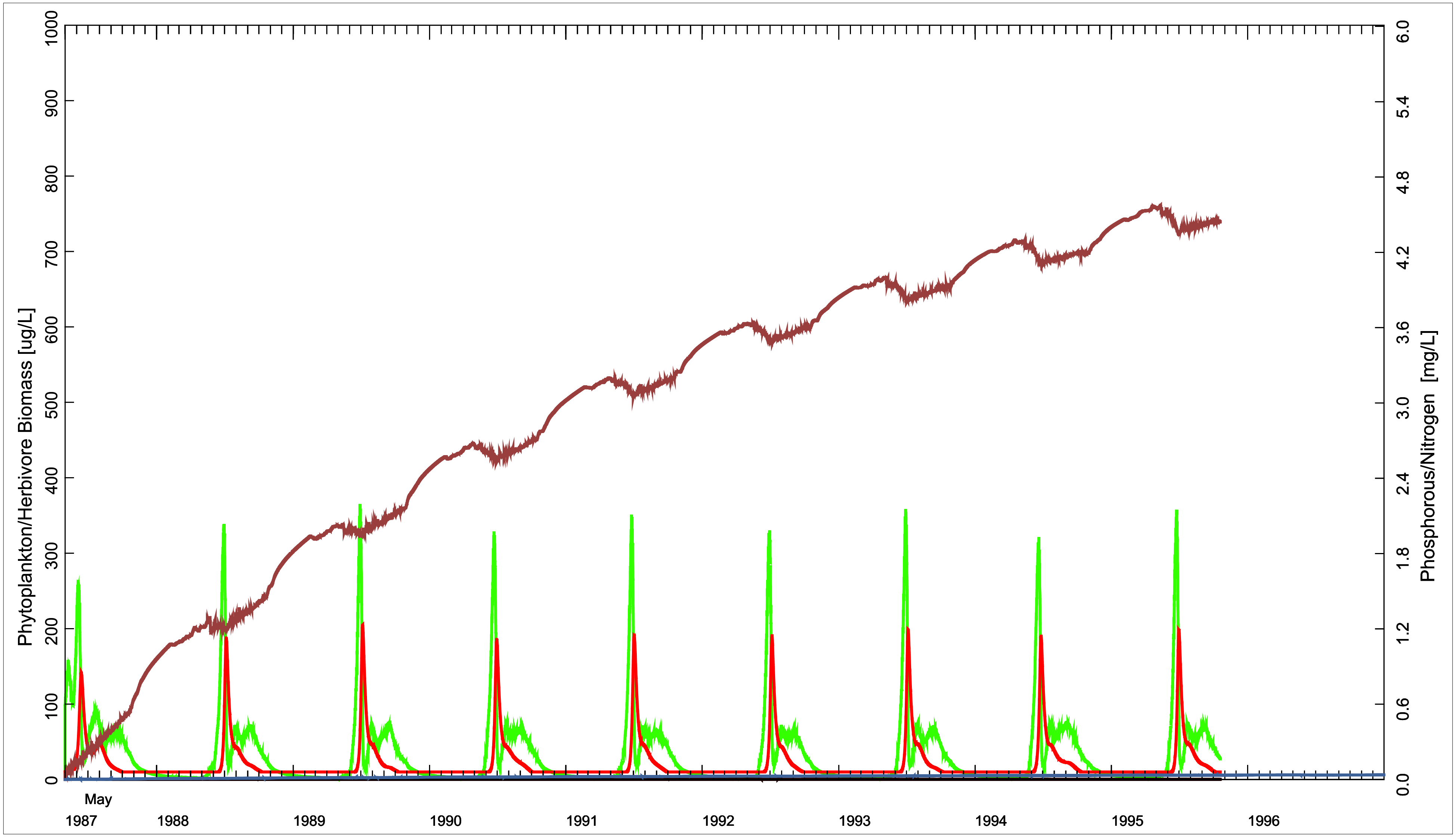

LEGEND

- Phytoplankton
- Herbivore
- Phosphorous
- Nitrogen
- Conservative Nitrogen

NOTES

Source: Phytoplankton in Thor Lake, EBA Technical Memo No. 001, File V15101007.006 (May 2011, Figure 2.3).

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THOR LAKE PROJECT

Phytoplankton Modelling - Tailings Pond Operating Mine Conditions Normal P, Elevated N, Surface

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0
OFFICE	DATE		
EBA-VANC	May 9, 2011		

Figure 6.4-10

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Based on the results of the model, the additional nitrogen introduced by the TMF decant water appears to trigger an additional early and short-lived spring bloom, followed by a more typical extended summer bloom. Although phytoplankton concentrations in the early spring bloom are predicted by the model to be about 2-3 times higher than the summer bloom, the summer bloom remains about the same as the existing baseline case. The phytoplankton produced in the early spring bloom are predicted to be quickly consumed by the herbivore population, which is also higher in the case with the added nitrogen. It appears that the added nitrogen from the mining operations serves to kick-start the system once sufficiently warm conditions occur, compared to the present baseline case, where nitrogen may not be quite as available in the early spring.

Consequently, the growth-limiting nutrient is primarily phosphorus, which remains low in concentration throughout the simulation period.

6.4.3.2 Assessment

The model predicts that the input of additional nitrogen from the TMF decant water to the Thor Lake system may lead to seasonally increased phytoplankton growth and concentration. Although the nitrogen level is predicted to continue to increase over the ten-year model simulation period, phytoplankton productivity appears to remain very similar from year to year.

It also appears that the phytoplankton biomass is likely limited by the amount of bio-available phosphorus in the water body as the annual peak phytoplankton biomass remains stable even as the annual peak nitrogen values rise in the system. It is important to note that with the input from the TMF decant water and the dilutions available in the Thor Lake system, nitrogen levels in Thor Lake and in the outflow from Thor Lake are predicted to be no more than approximately double their current observed peak values. That is, the current system appears to produce significant natural nitrogen concentrations in the water over the winter months as organic material collected on the bottom decays.

The natural production of nitrogen can be inferred from the dissolved oxygen profiles taken in the Thor Lake system (Stantec 2010c), which show a decline of dissolved oxygen, particularly at the bottom, during the winter months.

The model predicts that the input of additional nitrogen into the downstream lake environment may trigger a change in timing of the spring bloom, and an overall increase in planktonic biomass. Preliminary estimates, comparing the increase in standing stock to the potential rate of supply of oxygen due to wind and waves, are that the system can readily supply many times more oxygen than what would be consumed by the decay of the additional planktonic biomass.

It has been assumed in the model that the additional input of phosphorus from the TMF decant will be negligible, equivalent to existing baseline levels. Since the phosphorous level in all tributaries and the TMF decant water discharge is assumed to remain low (~0.001 mg/L), the phytoplankton concentration and its evolution during mine operations are predicted to be generally similar to those predicted for the existing baseline condition, except for the development of an additional short-lived early-spring bloom. Water quality is not negatively affected by this additional spring bloom because oxygen input from the atmosphere can readily handle the additional oxygen demand associated with this bloom.

Seasonal increases in phytoplankton and zooplankton due to nutrient enrichment have the potential to result in increased fish production in Thor Lake due to supplementation of the planktonic food supply. However, since the spike in phytoplankton biomass is expected to occur over a very short time period before reverting to background levels, it is unlikely that this alone will result in a significant conversion to fish biomass. Biotic production is limited by a variety of variables, including water temperature, solar radiation, habitat availability, and predation, to name a few. As such, the preliminary assessment is that the short-lived spikes in planktonic biomass will not adversely affect biological community structure in Thor Lake or downstream.

However, since the potential for seasonally increased primary and secondary production of the system exists, a major focus of the biological and water quality monitoring program will be identification of changes in phytoplankton, zooplankton, fish, and nutrient levels. These measurements will be used to validate the model results and to determine whether the assessment of no significant adverse effect is correct. Early identification of changes beyond those that are anticipated will permit the design and implementation of treatment systems to reduce levels of nitrogen prior to release to the TMF.

6.4.3.3 Residual Effects

In the absence of nutrient (nitrogen) removal prior to tailings discharge to the TMF, modelling indicates that seasonal increases in phytoplankton and zooplankton can be expected. As indicated in Section 6.4.3.2, these annual increases in spring are anticipated to be short term and are not expected to affect overall water quality or fish community composition or production. Although effects on primary and secondary production are expected to occur seasonally over the life of the mine, they are rated as being of low consequence and are not significant (Table 6.4-4).

TABLE 6.4-4: RESIDUAL EFFECTS ASSESSMENT FOR NUTRIENT DISCHARGES

Description of Residual Effect (after Mitigation)	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood	Consequence
Seasonal increases in nitrogen levels discharged to the TMF	Low	Local	Long term (Project life)	Isolated	Reversible Long-term	High	Magnitude: L; Duration: L (X)

Consequence matrix (Magnitude H/M/L vs. Duration S/M/L/I):

Magnitude	S	M	L	I
H				
M				
L			X	

6.4.4 Project Design Features and Mitigation Measures

The proposed site water management for the Thor Lake Project will consist of a closed loop system to minimize effects to the natural hydrologic flows. The Tailings Management Facility (TMF) will be located within a basin in the upper portion of the northern watershed area reporting to Thor Lake. Water will be withdrawn from Thor Lake and recycled from the TMF to operate the Flotation Plant.

Excess water from the TMF will be treated (if necessary) and discharged to Drizzle Lake from the Polishing Pond. Ultimately, all excess water from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system. A Settling Pond will be established to collect runoff water from the Flotation Plant site and may also be used to reclaim small amounts of water for use in the Flotation Plant.

Additional mitigation measures that will be employed during the operations phase will include:

- Mine water and Plant site runoff will be collected and directed into the process as appropriate.
- All excess water released from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system.
- Water will be recycled from the TMF to the greatest extent possible to minimize the fresh water requirement (currently 50% recycle and 50% fresh water has been modelled).
- Extraction of fresh water from Thor Lake will be managed to conform to the 2010 Department of Fisheries and Oceans (DFO) Protocol for Winter Water Withdrawal (DFO 2010), which specifies the use of no more than 10% of the available under-ice water volume.
- Natural flows and conditions will be monitored and mimicked as closely as possible throughout operations to minimize possible effects on the local hydrological regime.
- All decant water released from the TMF into Drizzle Lake will comply with the requirements of the MVLWB Water License and the federal MMER regulations.
- Water quality and biological monitoring will be carried out according to requirements of the Water License and the MMER. Monitoring results will be used to confirm that water quality downstream of the TMF discharge remains within allowable limits.

With the application of the mitigative measures as described, the overall effects on the water quality of the downstream lakes, including Thor Lake, are expected to be localized, low in magnitude and insignificant.

6.5 HYDROGEOLOGY

6.5.1 Nechalacho Mine Site

Prior to final underground mining activities, all underground infrastructure, including piping, electrical, stationary and mobile equipment, etc., will be removed from the underground environment. The mine portal will be backfilled with local till material to restrict incidental entry by wildlife or persons. The mine workings will be allowed to flood naturally from seepage and precipitation inflows similar to the historic portal entrance of the T-zone deposit that was developed in the late 1980s.

6.5.1.1 Groundwater Quantity

The quantity of water that will come into contact with the underground operations will be partially from mine inflow water (Knight Piésold 2011f) and partially from water brought into the underground for use in drilling, crushing, etc.

As previously discussed in Section 2.7, a hydrogeological site investigation program was undertaken by Knight Piésold at the Nechalacho Mine site in the summer of 2010 as part of the site geomechanical investigations to determine the hydraulic characteristics of the Nechalacho Deposit rock mass. The results of the hydrogeological program have been used here to estimate groundwater inflows associated with the proposed underground mine. The results of the modelling completed to estimate mine water inflows into the underground mine are as follows.

For the purpose of estimating groundwater inflows to the proposed underground mine, a simple conceptual model was developed by Knight Piésold (2011f). The boundaries of the model were primarily based on the estimated Project site watershed areas, as presented in Knight Piésold (2011b). There are several lakes within the watershed area of the deposit, and the lakes in the immediate vicinity of the Nechalacho Deposit are expected to represent the primary groundwater flow boundaries.

Hydraulic conductivity values estimated from the 2010 packer testing results are relatively low. The hydraulic conductivity ranges from approximately $3x10^{-9}$ m/s to $2x10^{-7}$ m/s, which is consistent with expected values for intrusive and metamorphic crystalline rock (Freeze and Cherry 1979). Results of the geomechanical program (Knight Piésold 2010e)) suggested that the Rock Mass Rating in the area of the deposit indicates good to very good rock with the design values typically being in the upper end of the good range. Based on the data from the 2010 geomechanical investigations, flat-lying (horizontal) joints form the dominant joint set. Vertical to sub-vertical joint sets are also present although not as prominent.

The Deposit area is surrounded by a sodalite cumulate zone, a cap rock of the Nechalacho mineralized intrusion that was subsequently eroded away. The sodalite cumulate material is described as hydrothermally altered and is a mixture of illitic clays and sericite. There are no persistent records of drill fluid loss within this zone and it is expected to have very low hydraulic conductivity.

Temperature data were collected from thermistors installed by Stantec (2010d), and by Knight Piésold (2010f) during winter 2010 to assess the presence of permafrost. Temperature data suggests that permafrost is discontinuous in the area and absent beneath the lakes and in some areas close to the lakes. No permafrost was encountered in the Knight Piésold drillholes equipped with thermistors.

6.5.1.2 Groundwater Inflow Model

Groundwater inflow was modeled by Knight Piésold (2011f) using Visual MODFLOW software. The model was run in steady state. Boundary conditions included: constant head cells for nearby lakes, recharge boundaries for precipitation at surface and drain cells for the proposed underground workings.

One hydrogeologic unit was used to simulate bedrock in the area of the deposit. It was assumed that the sodalite cumulate zone has similar hydraulic conductivity as the un-altered bedrock. The horizontal hydraulic conductivity is likely greater than the vertical hydraulic conductivity due to the orientation of the dominant joint sets. It was assumed that the horizontal hydraulic conductivity is two times higher than the vertical hydraulic conductivity.

A range of hydraulic conductivity values were used to account for low and high hydraulic conductivities for bedrock. The estimated hydraulic conductivities assigned for the sensitivity analysis are included in Table 6.5-1. The range of selected hydraulic conductivity values is within a more narrow range than the results of packer testing. The highest hydraulic conductivity recorded ($2x10^{-7}$m/s) was tested along a relatively shallow interval and is not representative of the bedrock at the depth of the deposit. The range of values selected for the sensitivity analysis provides a relatively conservative range of possible hydraulic conductivity values within the area of the deposit.

TABLE 6.5-1: ESTIMATE OF GROUNDWATER INFLOWS TO UNDERGROUND MINE MODEL PARAMETERS AND SENSITIVITY ANALYSIS

Geologic Unit	Low Hydraulic Conductivity (m/s)	High Hydraulic Conductivity (m/s)
Bedrock (horizontal)	8.E-09	2.E-08
Bedrock (vertical)	4.E-09	1.E-08

Notes:

1. Hydraulic conductivity estimates based on the range of packer test results and typical ranges For geologic units (Freeze and Cherry 1979).

A simplified version of the Pre-Feasibility Study mine layout was entered into the model as drain cells representing the ramp and the base of the deposit area. Arbitrarily high hydraulic conductivity was assigned to cells in the area of the deposit to represent the mine workings. Groundwater inflows were estimated at steady state conditions prior to initiation of paste backfilling. It was assumed that the open area of the mine was greatest just prior to the start of paste backfilling (at the end of Year 4).

6.5.1.3 Estimated Groundwater Inflow

The estimated range of groundwater inflows is between 3 L/s and 10 L/s. It is estimated that approximately 60% of the groundwater will inflow along the ramp and approximately 40% will inflow into the underground workings through the surrounding rock. The predicted groundwater drawdown in bedrock at ground surface for the 10 L/s case is illustrated in Figure 6.5-1.

During mine development, groundwater inflows may be higher than the range that has been estimated herein. Higher inflows may occur if mine development intersects any relatively high permeability features. It is expected that high inflows would decrease quickly as the groundwater stored in high permeability features was drained. There is also a possibility that a high permeability feature may provide a conduit for groundwater flow from a surface water body to the mine, resulting in persistent higher than predicted groundwater inflows.

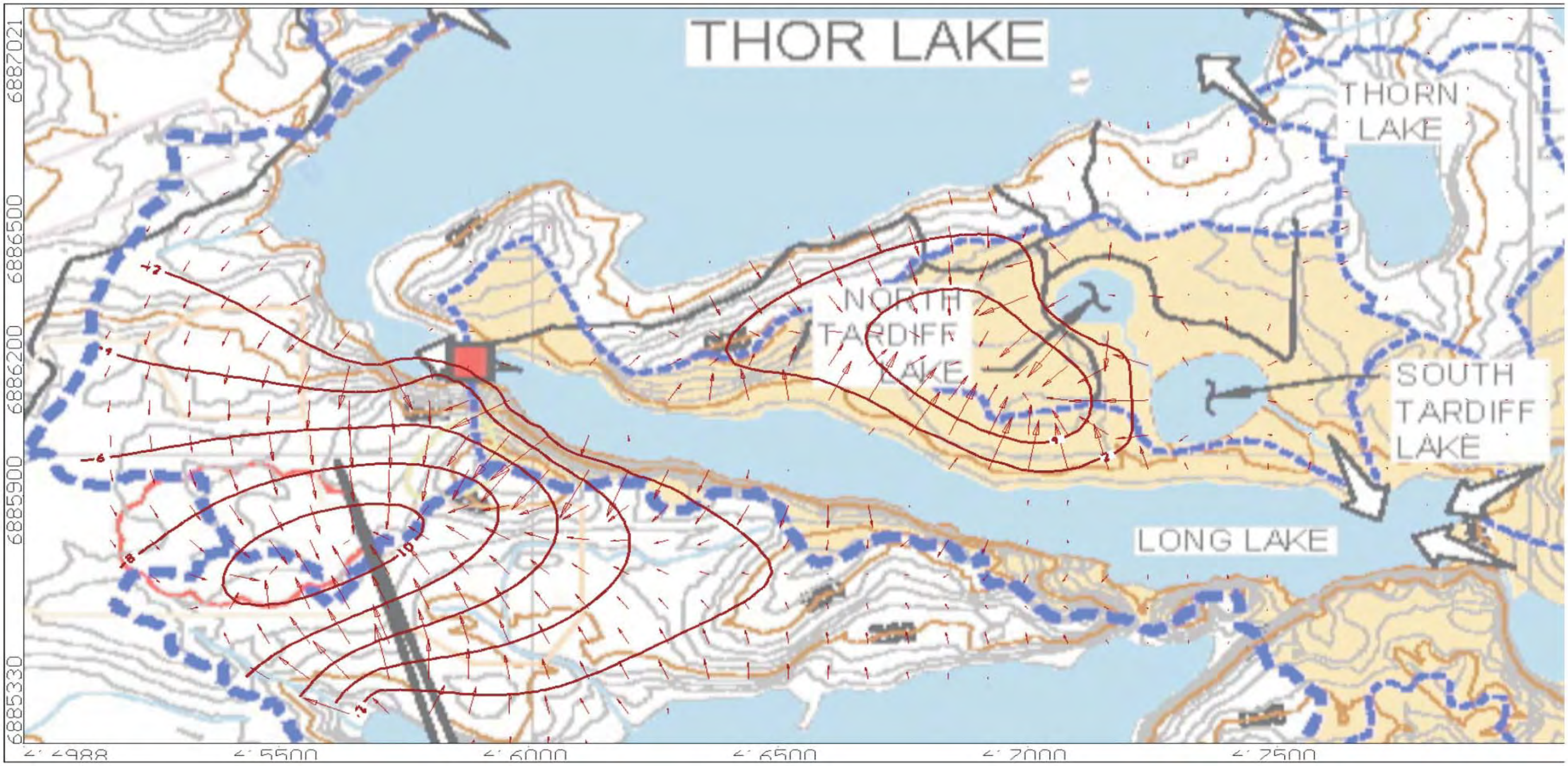
To date, there have been no geologic units or structures that have been intersected during site investigations that are interpreted to potentially produce relatively high long term inflows. Knight Piésold understands that Avalon intends to drill additional drillholes along the alignment of the proposed ramp. The results of additional drilling can be evaluated in the future to update the current hydrogeological characterization.

The possibility of relatively higher long term groundwater inflows can be reduced during advancement of the ramp. Further investigations will be undertaken in advance of the face during ramp development to avoid potentially high groundwater inflows. If high inflows are observed during investigation, the area can be grouted prior to advancing the ramp.

6.5.1.4 Estimated Underground Flooding

During post-closure the underground workings will be allowed to flood naturally. The current mine plan estimates that 95% of the void space of the underground mine will eventually be filled with paste backfill. The remaining void space will be flooded with groundwater. The MODFLOW simulation of the groundwater inflows was also used to model underground mine flooding by modifying the elevation of the drain boundaries. Results suggest that the inflow rate does not change significantly during underground mine flooding.

The volume of the void space including the ramp and non-backfilled stopes for the end of mine is estimated to be approximately 500,000 m^3. Based on the estimated void volume and the simulated mine inflows, the underground mine will be flooded in approximately 5.3 years after mine closure assuming the lower inflow projections and more rapidly (1.6 years) if the higher inflow projections are applied. Once the water level in the mine reaches the pre-development or natural level, seepage inflow will cease and the groundwater regime will return to pre-development conditions.



NOTES

1. Drawdown is change in water levels (m) from static conditions as a result of mine dewatering.
2. Arrows represent estimated groundwater flow directions.
3. Figure Source: Knight Piesold Consulting, February 2011 (Ref No. NB11-00076, Figure 1).

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THOR LAKE PROJECT

Predicted Groundwater Drawdown due to Mine Dewatering

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EBA-VANC	April 5, 2011		

Figure 6.5-1

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6.5.1.5 Groundwater Quality

The quality of the mine water will be potentially impacted by the underground operations (dust, ammonia, nitrates, nitrites, hydrocarbons). In addition, when the paste backfill is first placed, 2"-3" PVC pipes will be installed to allow water drainage from the paste. Once the paste has set it will behave like concrete and will be relatively impermeable. Any water interaction with the paste is expected to make the pH slightly basic.

All excess mine water from the underground operations will be pumped up to surface for use in the Flotation Plant and will ultimately be directed to the Tailings Management Facility (TMF).

As previously discussed in Section 2.6.3, Stantec (2010b) reported on the analytical results of groundwater quality sampling conducted over multiple events during the period 2008-2010. All groundwater samples were analyzed for their concentrations of total and dissolved metals. The measured dissolved metal concentrations were compared to CSR and CCME water quality guidelines for the protection of aquatic life. The CSR guideline values apply to both surface and groundwater, whereas the CCME guidelines only apply to surface water. However, as groundwater ultimately discharges to surface water bodies, the CCME guideline values are included here for reference.

Exceedances of the CSR and/or CCME guidelines are shown in Table 6.5-2. These exceedances of the CCME and/or CSR guidelines do not imply that the groundwater at the study area is currently contaminated; only that background concentrations of these parameters are higher than typically found in groundwater at other natural sites in Canada. These background groundwater quality results merely reflect the natural geologic and hydrogeologic conditions within these specific areas of the property (Stantec 2010b).

It is anticipated that the existing groundwater quality conditions described are likely to be altered somewhat by the future and ongoing underground mining activities. However, as previously indicted, all excess mine water from the underground operations will be pumped to surface for use in the Flotation Plant and will report to the Tailings Management Facility (TMF). Effluent discharged from the TMF will be required to comply with the terms and conditions, including effluent quality criteria, of the future MVLWB Water License and the effluent quality criteria of the Metal Mining Effluent Regulations.

TABLE 6.5-2: SUMMARY OF BASELINE GROUNDWATER GUIDELINE EXCEEDENCES (STANTEC 2010b)				
Monitoring Well	TDS (mg/L)	EC (µS/cm)	pH	Exceeds CSR and/or CCME Guidelines
L08-124	274-422	460-738	8.10-8.25	Aluminum, cadmium, copper, iron, silver
MW08-127	240-487	404-878	6.86-8.16	Aluminum, cadmium, copper, iron, silver, lead
MW08-128	230-335	367-482	7.41-7.90	Aluminum, arsenic, cadmium, iron, silver
MW08-130	331-335	557-558	8.10-8.21	Aluminum, cadmium, copper, iron, silver
MW09-152	388-464	587-721	8.17-8.56	n.a.

Notes:
TDS-total dissolved solids
EC-Electrical activity
mg/L-milligrams per litre
µS/cm-microsiemen per centimetre
n.a.-total metals not collected

In addition, aquatic environmental effects monitoring, which will also be required, will assist in ensuring that the downstream aquatic environment in the area of the Nechalacho Mine site will be protected.

6.5.2 Hydrometallurgical Plant Site

As previously discussed in Section 4.8.4, the main components of the water management plan for the proposed Hydrometallurgical site include:

- Pumping of fresh water from an historic open pit (T-37 pit) where the water table associated with the Presqu'ile aquifer has resulted in the pit filling with water
- Disposal of tailings in an historic open pit (L-37 pit) where solids and a controlled amount of water will be stored
- Pumping of excess supernatant water from the L-37 pit to the N-42 historic open pit where the water will infiltrate the Presqu'ile aquifer

This section presents the results of a groundwater flow model that was prepared by Knight Piésold (2011h) to estimate the potential effects of the water management plan on the Pine Point regional groundwater regime. In order to develop the flow model, it was necessary to understand the hydrogeology of the Pine Point region. Section 2.7.2 discusses the regional and local hydrogeology for the Pine Point area.

6.5.2.1 Groundwater Flow

A groundwater flow model (using visual MODFLOW software) was created to simulate the current hydrogeological flow conditions at the Pine Point site and to estimate the effects of implementing the water management plan for the Hydrometallurgical Site, including the withdrawal of water from the T-37 pit and the infiltration of excess water into the N-42 pit.

The boundary conditions used in the model included:

- Constant head boundaries to represent Buffalo River and Little Buffalo River

- River boundaries to represent Great Slave Lake and regional inflow from south of the Pine Point area
- Recharge boundary within higher permeability zones to represent infiltration of water at the model surface. Recharge was not applied to areas near Great Slave Lake where groundwater is expected to be discharging.

Several geologic units were used to define the hydrostratigraphic units on site, as presented in Table 6.5-3. The aerial extent of each geologic unit was based on the geologic plan of the area, as shown on Figure 6.5-2. The geologic units in the Hydrometallurgical site area were simplified for the purpose of the model by representing the hydrostratigraphy as a single layer.

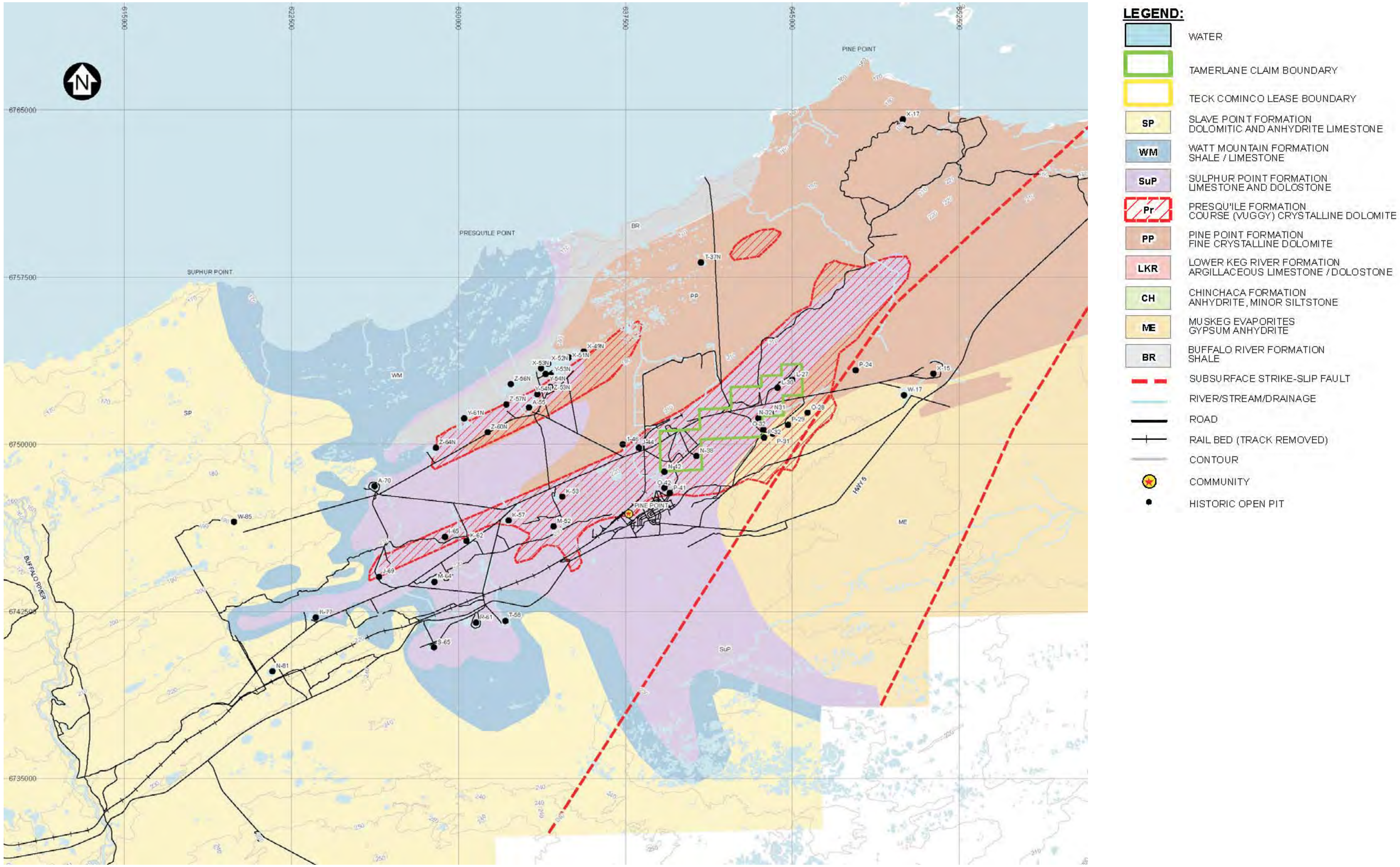
TABLE 6.5-3: PINE POINT REGIONAL HISTORICAL HYDROGEOLOGY SUMMARY AND GROUNDWATER FLOW MODEL – MODELLED HYDROSTRATIGRAPHIC UNITS

Hydrostratigraphic Unit	Hydraulic Conductivity (m/s)	Porosity
Basal Glacial Till	1E-08	0.1
Slave Point Formation	5E-08	0.001
Watt Mountain Limestones	5E-07	0.01
Presqu'ile Formation	5E-04	0.1
Sulphur Point Formation	2E-04	0.01
Buffalo River Shales	5E-08	0.005
Muskeg Evaporites	5E-08	0.001
Pine Point Formation	5E-05	0.005

Source: Knight Piésold (2011h)

Notes:

1. Hydraulic conductivity from Geologic Testing Consultants (1983) and adjusted for model simulation.
2. Porosity values are assumed based on knowledge of the site and from ranges provided in Domenico and Schwartz (1998).



NOTES

1. Base Map: © Her Majesty the Queen in Rights of Canada, Department of Natural Resources (2004). All Rights Reserved.
2. Coordinate grid is shown in UTM (NAD83) Zone 11 and is in metres.
3. Contour interval is in metres. Contour interval is 10 metres.
4. Claim boundaries have been digitized at a 1:50,000 scale.
5. Geology obtained from Hannigan 2007, The Metallogeny of the Pine Point Mississippi Valley - Type Zinc - Lead District, Southern Northwest Territories, Geological Survey of Canada.
6. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB10-00665, Figure 2).

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Pine Point Area Geological Plan

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Figure 6.5-2

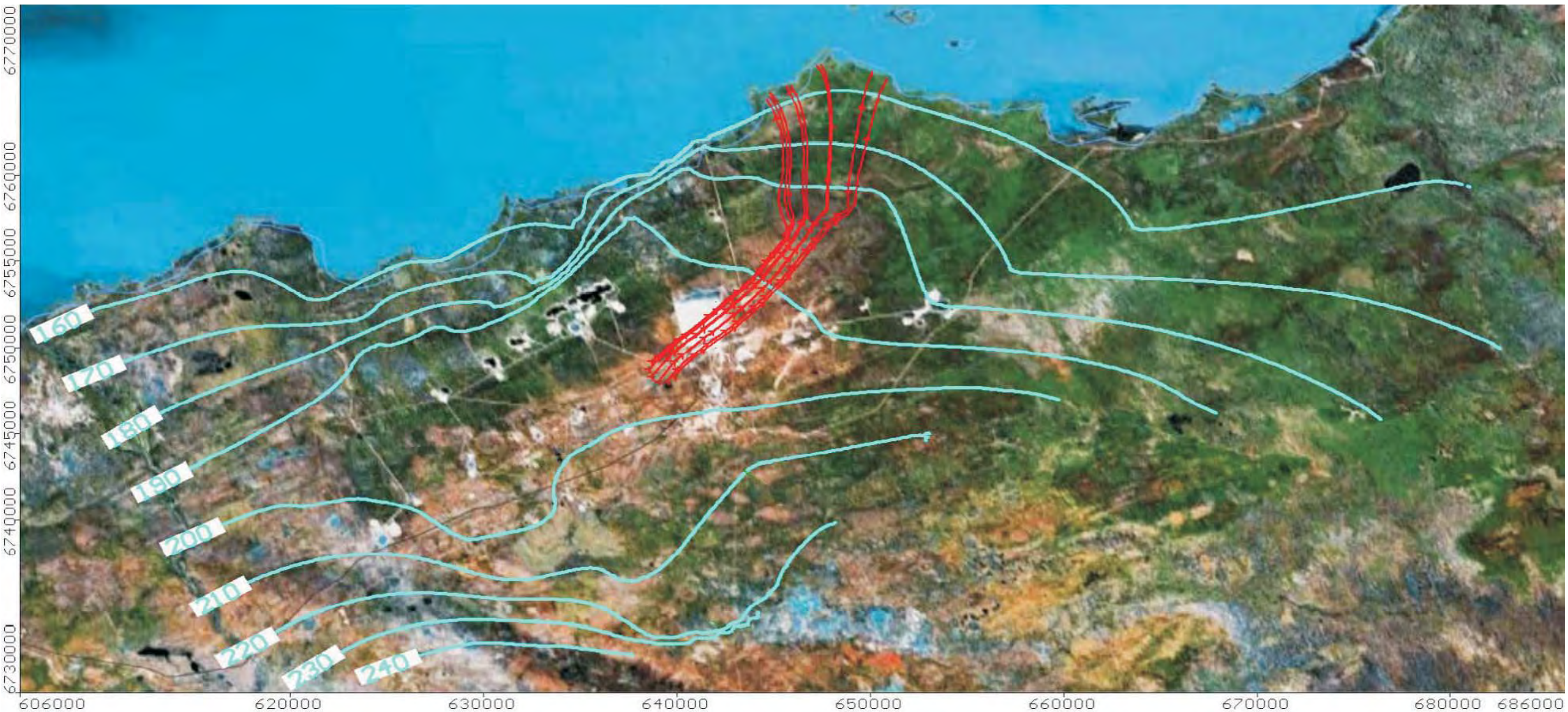
The model was run using steady state conditions. Hydrogeologic properties and boundary conditions were adjusted to simulate groundwater flow that is consistent with the conceptual model of the site. Modelling results were compared to existing water levels in the historic open pits nearby the proposed Hydrometallurgical Plant site. Particle tracking was used to simulate the groundwater flow path from the N-42 pit and to estimate the travel time from the N-42 pit to Great Slave Lake.

Based on the conceptual model of the site and the steady state modelling results, groundwater flowing through the N-42 pit would take approximately 80 years to discharge into Great Slave Lake. The average groundwater velocity along the flow path from the N-42 pit to Great Slave Lake was simulated as 0.75 m/day. Within the Presqu'ile Formation, the average simulated velocity was about 0.5 m/day. The travel time estimation assumes that groundwater will not discharge to surface between the N-42 pit and Great Slave Lake. Travel time may be reduced if groundwater discharged to surface and flowed towards Great Slave Lake. Figure 6.5-3 illustrates simulated piezometric contours and particle tracking results based on current baseline conditions for the area, as predicted by the model.

The baseline groundwater flow model was modified to include pumping of groundwater from the T-37 pit and discharge/infiltration of water into the N-42 pit. This model was completed using transient conditions where pumping and discharge/infiltration was simulated for the projected 20 year operational life. The simulated pumping rate from the T-37 pit was 1,950 m^3/day and the simulated discharge rate into the N 42 pit was 420 m^3/day, based on Knight Piésold's design criteria and the water/solids balance analysis (Knight Piésold 2011g).

Results of the groundwater flow model suggest that there is expected to be very little effect on the groundwater regime at the Pine Point site in response to the pumping and discharge/infiltration proposed as part of the Hydrometallurgical Plant site water management plan, given the rates used in the model. Groundwater drawdown in the vicinity of the T-37 pit is estimated to be approximately 1 m below the expected pre-pumping level after 20 years of pumping. Groundwater levels in the vicinity of the N-42 pit are expected to increase by approximately 0.1 m above the simulated pre-discharge conditions after 20 years of discharge/infiltration.

Particle tracing was used to track flow from the N-42 pit to Great Slave Lake during the 20 year operations life and there were no noticeable effects to the groundwater flow directions or travel times over existing conditions. Figure 6.5-4 illustrates simulated piezometric contours and particle tracking for the Pine Point area after 20 years of pumping and discharge. Figure 6.5-5 illustrates the expected groundwater drawdown in response to pumping from the T-37 pit.



NOTES
1. Arrows on particle tracks represent 10 years of time passing between them.
2. Background imagery from Google Earth.
3. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB10-00665, Figure 3).

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Simulated Piezometric Conditions and Particle Tracking Results - Baseline Conditions

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Figure 6.5-3

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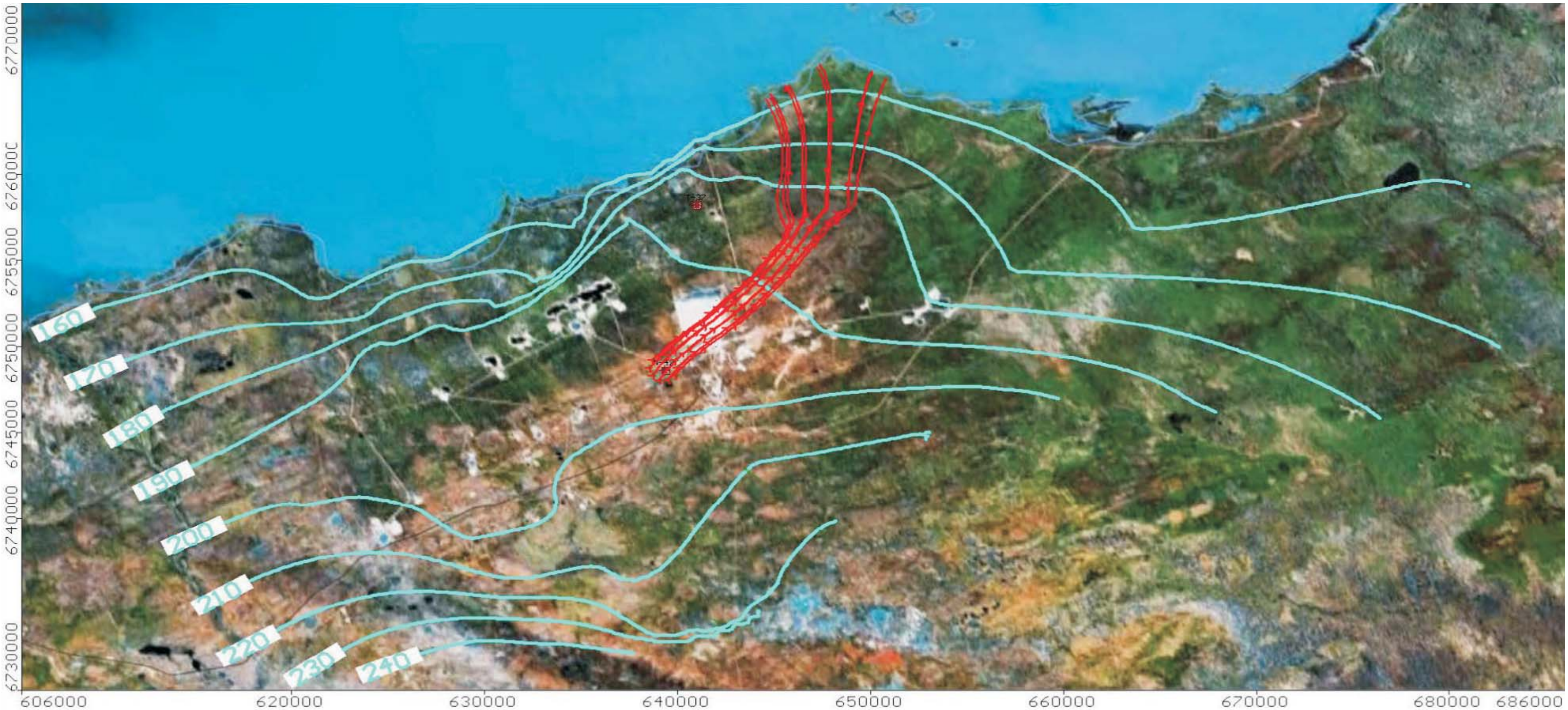

NOTES

1. Arrows on particle tracks represent 10 years of time passing between them.
2. Background imagery from Google Earth.
3. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB10-00665, Figure 4).

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Simulated Piezometric Conditions and Particle Tracking Results - After 20 Years of Pumping and Infiltration

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Figure 6.5-4

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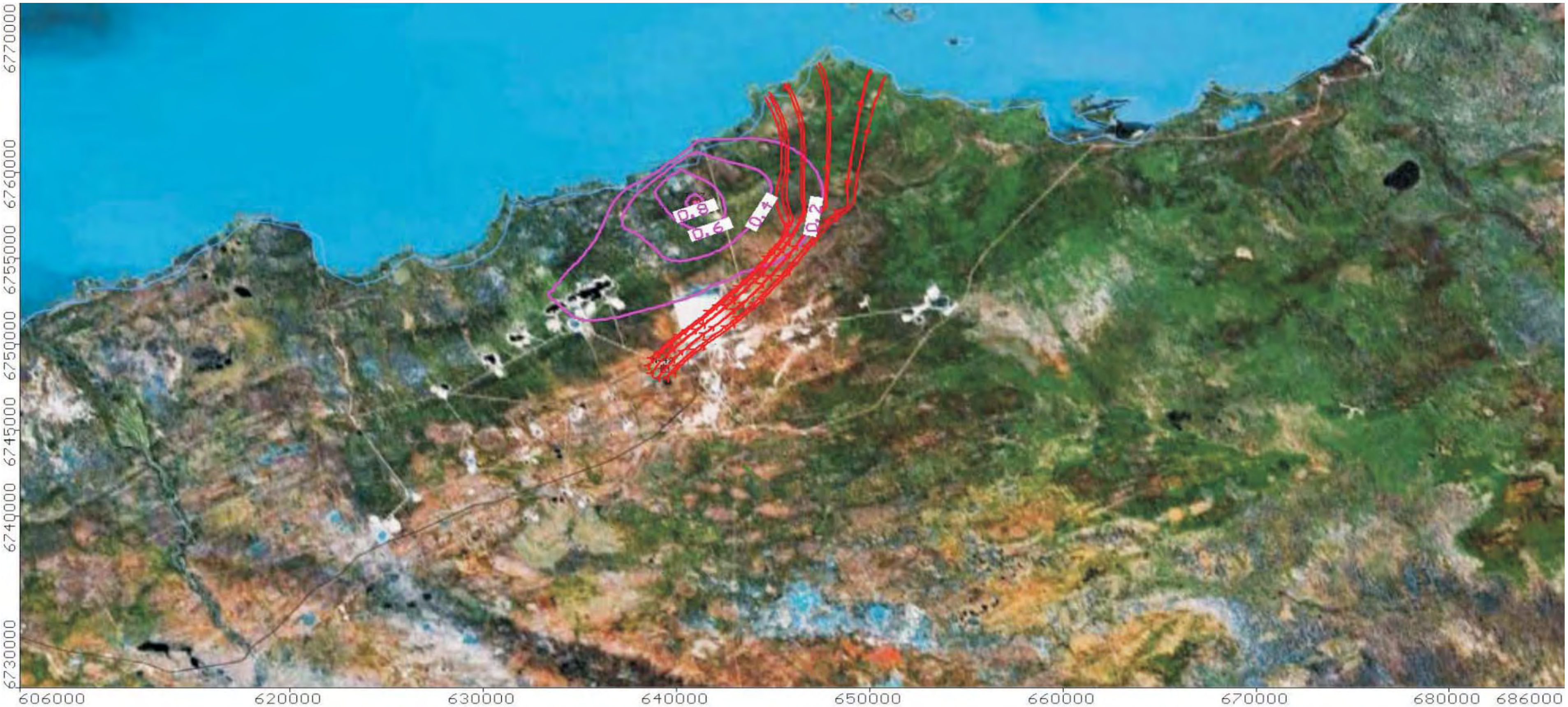

NOTES
1. Drawdown is change in water levels (m) from static baseline conditions as a result of pumping water from pit.
2. Arrows on particle tracks represent 10 years of time passing between them.
3. Background imagery from Google Earth.
4. Figure Source: Knight Piesold Consulting, March 2011 (Ref No. NB10-00665, Figure 5).

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THOR LAKE PROJECT

Expected Groundwater Drawdown due to Pumping from T-37 Pit

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Figure 6.5-5

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6.5.2.2 Groundwater Quality

Groundwater quality in the Pine Point area, including the location of the Hydrometallurgical Plant and associated infrastructure, is strongly influenced by the geological characteristics of the underground formations as discussed previously in Section 2.7.2. As discussed in that section, groundwater occurs as both a shallow phreatic water table associated with the overburden and also under confined pressure conditions in the bedrock. The natural groundwater table in the Pine Point area varies in depth below surface from approximately 1 m to 18 m depth.

Weyer et al. (1978, 1979) reported that three basic types of groundwater occur in the Pine Point area:

- A calcium bicarbonate water, found locally in glacial drifts. Conductivities are less than 1000 µmho/cm. This type of groundwater has been found at a number of locations along the Buffalo River.
- Sulphur water, a sulphate-bicarbonate with Ca^{2+} as the main cation (with $S0_4^{2-}$). This water is probably derived from the Devonian gypsum layers. Conductivities are usually between 1,000 and 2,000 µmho/cm. This type of groundwater is commonly found in the springs along the south shore of Great Slave Lake from Little Buffalo River to Sulphur Point and across to Windy Point.
- Salty water, sodium chloride brines, derived from groundwater contact with the Devonian evaporite layers. Brandon (1965) reported 420 mg/l chloride in a water sample collected in 1961 at the mouth of the Buffalo River.

The chemistry of most other groundwater samples collected in the Pine Point area over the past 30 years seem to reflect mixing or evolution of these three basic water types.

Analysis of natural spring water and of deep well pump discharges by Cominco Ltd Pine Point Operations in 1978 (Durston 1978) indicated two distinct types, salty and sulphur water. The range of analyses of these waters is presented in Table 6.5-4. Their differing characteristics were believed to reflect different flow regimes. The Devonian limestones and dolomites are underlain by evaporate beds of salt and gypsum. The temperature of the pumped groundwater appeared to be consistent through the seasons and varied throughout the mining area from about 2 to 5°C.

Analysis of groundwater samples collected in a pump test conducted for Western Mines at the X-25 deposit near Polar Lake by DIAND in 1978 reported the results presented in Table 6.5-5 (cited in Beak 1980).

TABLE 6.5-4: RANGE OF ANALYSES OF PUMPED GROUNDWATER AT PINE POINT (CIRCA 1978)	
Parameter	**Value**
pH	7.0 – 8.0
Suspended solids	0 – 200
Dissolved solids	1,500 – 3,000
Hardness, as $CaCo_3$	1,000 – 2,000
Dissolved anions	
- chloride	20 – 300
- sulphate	1,000 – 1,500
Dissolved cations	
- calcium	150 – 500
- magnesium	75 – 200
- sodium	20 – 100
- potassium	2 – 10
- copper, iron, lead, zinc	less than 0.1
Total copper, iron lead, zinc	less than 1.0 each
Specific conductivities (2)	
- salt water	3,000 – 80,000
- sulphur water	1,000 – 20,000

Source: Duration 1978

*Note: All values are parts per million, except for specific conductivities, which are in µmho/cm, and for pH.

TABLE 6.5-5: GROUNDWATER QUALITY FROM PUMP TEST AT X-25 DEPOSIT – 1978	
Water Quality Parameter	**Concentration**
pH	7.1 – 8.1
Conductivity (µmho/cm)	3,048 – 3,122
Turbidity (JTU)	25 – 39
Colour (colour units)	40 – 79
Suspended Solids (mg/l)	160 – 3,120
Calcium (mg/l)	407 – 457
Magnesium (mg/l)	167 – 177
Total Hardness (mg/l as $CaC0_3$)	1,706 – 1,784
Total Alkalinity (mg/l as $CaC0_3$	366 – 420
Sodium (mg/l)	106 – 122
Potassium (mg/l)	<0.1
Cl^{-} (mg/l)	93.5 – 108
SO_4^{--} (mg/l)	145 – 204
Ammonia Nitrogen (mg/l as N)	0.1 – 0.7
Nitrate Nitrogen (mg/l as N)	<0.01
Total Phosphorus (mg/l as P)	<0.005

TABLE 6.5-5: GROUNDWATER QUALITY FROM PUMP TEST AT X-25 DEPOSIT – 1978	
Water Quality Parameter	**Concentration**
Total Arsenic (mg/l)	<0.01
Total Cadmium (mg/l)	0.01
Total Copper (mg/l)	0.01 – 0.03
Total Iron (mg/l)	0.48 – 1.59
Total Lead (mg/l)	0.06 – 0.17
Total Mercury (mg/l)	0.01
Total Nickel (mg/l)	0.04 – 0.11
Total Zinc (mg/l)	0.02 – 0.16

Note: Range of data is based on 6 samples taken on August 5, 7, 9, 12, 13, 14, 1978

Source: DIAND 1979 cited in Beak 1980

As previously discussed in Section 4.8.3, the proposed Hydrometallurgical Plant tailings facility (HTF) will be located within an historic open pit (L-37 pit) located south-southwest of the proposed Hydrometallurgical Plant location. Excess supernatant water from the HTF will be pumped to another historic open pit (N-42 pit), located to the southwest, for discharge and infiltration into the Presqu'ile aquifer.

The Hydrometallurgical tailings properties will consist of solids from the proposed milling process made up predominantly of gypsum (approx. 85%) with some leach residue (approx. 6%) and miscellaneous other solids (approx. 9%) and are expected to be similar to phosphogypsum tailings in terms of void ratio, dry densities and consolidation properties.

Table 6.5-6 summarizes the chemical properties of the water component of the tailings solution based on test work completed by SGS (2011) that will be infiltrated into the Presqu'ile aquifer.

A comparison of the projected chemical properties of the tailings water with the historically documented groundwater quality results shows that the concentrations of all metals parameters in the tailings water will be lower than or within the same range of concentrations for these parameters in the existing groundwater of the area. In particular, the concentrations of arsenic, mercury, iron, lead and zinc are expected to be lower, and the concentrations of copper and nickel will be within the same range as existing conditions.

The pH of the tailings water is expected to be slightly above neutral (7.7), while conductivity, sodium, chloride and other parameters that contribute to water hardness, including calcium, magnesium and sulphate will be elevated compared to current background conditions.

However, these elevated levels are expected to rapidly diffuse and dilute to natural background values within the Presqu'ile Formation. The radionuclide parameters including ^{226}Ra, ^{228}Ra and ^{210}Pb are all expected to be at or below detection limits.

Since the projected concentrations of all of the parameters of potential concern will be lower than or within the range of existing conditions, the anticipated effects on groundwater quality are expected to be insignificant.

TABLE 6.5-6: SOLUTION ANALYSIS RESULTS – HYDROMET SOLUTIONS			
Parameter	**Unit**	***MMER**	**CH-WT1 PLS +Wash Simulated Hydromet Tls Filtrate**
Radionuclide Analyses			
^{226}Ra	Bq/L	.37	0.10
^{228}Ra	Bq/L		<0.2
^{210}Pb	Bq/L		<0.1
General Analyses			
pH	Units	6.0-9.5	7.73
Alkalinity	mg/L as $CaCO_3$		118
EMF	mV		214
Conductivity	µS/cm		13,400
TDS	mg/L		16,800
TSS	mg/L	15.00	---
Cl	mg/L		55
SO4	mg/L		11,000
F	mg/L		1.82
TOC	mg/L		53.9
NH_3+NH_4	as N mg/L		91.7
Metal Analyses			**Diss**
Hg	mg/L		<0.0001
As	mg/L	.50	0.0022
Ca	mg/L		393
Cu	mg/L	.30	0.0226
Fe	mg/L		0.150
K	mg/L		86.8
Li	mg/L		2.18
Mg	mg/L		1,530
Mn	mg/L		6.15
Na	mg/L		1,580
Ni	mg/L	.50	0.0701
Pb	mg/L	.20	0.00052
Se	mg/L		0.005
Si	mg/L		2.47
Sr	mg/L		11.2
Th	mg/L		0.002945
U	mg/L		0.0239
Zn	mg/L	.50	<0.002

*Department of Justice Canada. 2002. Metal Mining Effluent Regulations, Fisheries Act SOR-2002-222.

6.5.3 Project Design Features and Mitigation Measures

6.5.3.1 Nechalacho Mine Site

As previously discussed in Section 6.5.1, the current estimated range of groundwater inflows into the underground mine area is between 3 L/s and 10 L/s. It is estimated that approximately 60% of the groundwater will inflow along the ramp and approximately 40% will inflow into the underground workings through the surrounding rock.

During mine development, groundwater inflows may be higher than the range that has been estimated herein. Higher inflows may occur if mine development intersects any relatively high permeability features. It is expected that high inflows would decrease quickly as the groundwater stored in high permeability features was drained. There is also a possibility that a high permeability feature may provide a conduit for groundwater flow from a surface water body to the mine, resulting in persistent higher than predicted groundwater inflows.

To date, there have been no geologic units or structures that have been intersected during site investigations that are interpreted to potentially produce relatively high long term inflows. Avalon intends to drill additional drillholes along the alignment of the proposed ramp. The results of additional drilling will be evaluated in the future to update the current hydrogeological characterization.

The possibility of relatively higher long term groundwater inflows can also be reduced during advancement of the ramp. Further investigations will be undertaken in advance of the face during ramp development to avoid potentially high groundwater inflows. If high inflows are observed during investigation, the area can be grouted prior to advancing the ramp.

During post-closure the underground workings will be allowed to flood naturally. The current mine plan estimates that 95% of the void space of the underground mine will eventually be filled with paste backfill. The remaining void space will be flooded with groundwater.

The volume of the void space including the ramp and non-backfilled stopes for the end of mine is estimated to be approximately 500,000 m^3. Based on the estimated void volume and the simulated mine inflows, the underground mine will be flooded in approximately 5.3 years after mine closure assuming the lower inflow projections and more rapidly (1.6 years) if the higher inflow projections are applied. Once the water level in the mine reaches the pre-development or natural level, seepage inflow will cease and the groundwater regime will return to pre-development conditions.

It is anticipated that the existing groundwater quality conditions in the underground mine are likely to be altered somewhat by the future and ongoing underground mining activities. However, as previously indicted, all excess mine water from the underground operations will be pumped to surface for use in the Flotation Plant and will report to the Tailings Management Facility (TMF).

Effluent discharged from the TMF will be required to comply with the terms and conditions, including effluent quality criteria, of the future MVLWB Water License and the effluent quality criteria of the Metal Mining Effluent Regulations. In addition, aquatic environmental effects monitoring, which will also be required, will assist in ensuring that the downstream aquatic environment in the area of the Nechalacho Mine site will be protected.

6.5.3.2 Hydrometalllurgical Plant Site

As previously discussed, the proposed Hydrometallurgical Plant tailings facility (HTF) will be located within an historic open pit (L-37 pit) located south-southwest of the proposed Hydrometallurgical Plant location. Excess supernatant water from the HTF will be pumped to another historic open pit (N-42 pit), located to the southwest, for discharge and infiltration into the Presqu'ile aquifer.

The Hydrometallurgical tailings properties will consist of solids from the proposed milling process made up predominantly of gypsum (approx. 85%) with some leach residue (approx. 6%) and miscellaneous other solids (approx. 9%) and are expected to be similar to phosphogypsum tailings in terms of void ratio, dry densities and consolidation properties.

The results of the groundwater flow model suggest that there is expected to be very little effect on the groundwater regime at the Pine Point site in response to the pumping and discharge/infiltration proposed as part of the Hydrometallurgical Plant site water management plan. Groundwater drawdown in the vicinity of the T-37 pit is estimated to be approximately 1 m below the expected pre-pumping level after 20 years of pumping. Groundwater levels in the vicinity of the N-42 pit are expected to increase by approximately 0.1 m above the simulated pre-discharge conditions after 20 years of discharge/infiltration.

Based on the conceptual model of the site and the steady state modelling results, groundwater flowing through the N-42 pit would take approximately 80 years to discharge into Great Slave Lake. Travel time may be reduced if groundwater discharged to surface and flowed towards Great Slave Lake.

A comparison of the projected chemical properties of the tailings water with the historically documented groundwater quality results shows that the concentrations of all metals parameters in the tailings water will be lower than or within the same range of concentrations for these parameters in the existing groundwater of the area. The radionuclide parameters including ^{226}Ra, ^{228}Ra and ^{210}Pb are all expected to be at or below detection limits.

The pH of the tailings water is expected to be slightly above neutral (7.7), while conductivity, sodium, chloride and other parameters that contribute to water hardness, including calcium, magnesium and sulphate will be elevated compared to current background conditions. However, these elevated levels are expected to rapidly diffuse and dilute to natural background values within the Presqu'ile Formation.

With the application of the mitigation measures as described, the anticipated effects on groundwater quantity and quality in the Nechalacho Mine area are expected to be insignificant.

Similarly for the Hydrometallurgical Plant site, since the projected concentrations of all of the parameters of potential concern will be lower than or within the range of existing conditions, the anticipated effects on groundwater quantity and quality are expected to be insignificant. Nevertheless, Avalon is committed to implementing a groundwater quality monitoring program designed to monitor the effects of the proposed tailings water infiltration program on the quality of the groundwater in the area of the Hydrometallurgical Plant and associated infrastructure.

6.6 FISH AND FISH HABITAT

According to the MVEIRB Terms of Reference (MVEIRB 2011), Avalon is to address a number of issues pertaining to the potential effects of the Nechalacho Mine and Flotation Plant development on fish and fish habitat. This section of the DAR will address the questions raised in the TOR in the following systematic manner:

- Identification and discussion of potential pathways of effects;
- Identification of mitigation strategies;
- Determination of residual effects; and
- Assessment of levels of risk associated with identified residual effects.

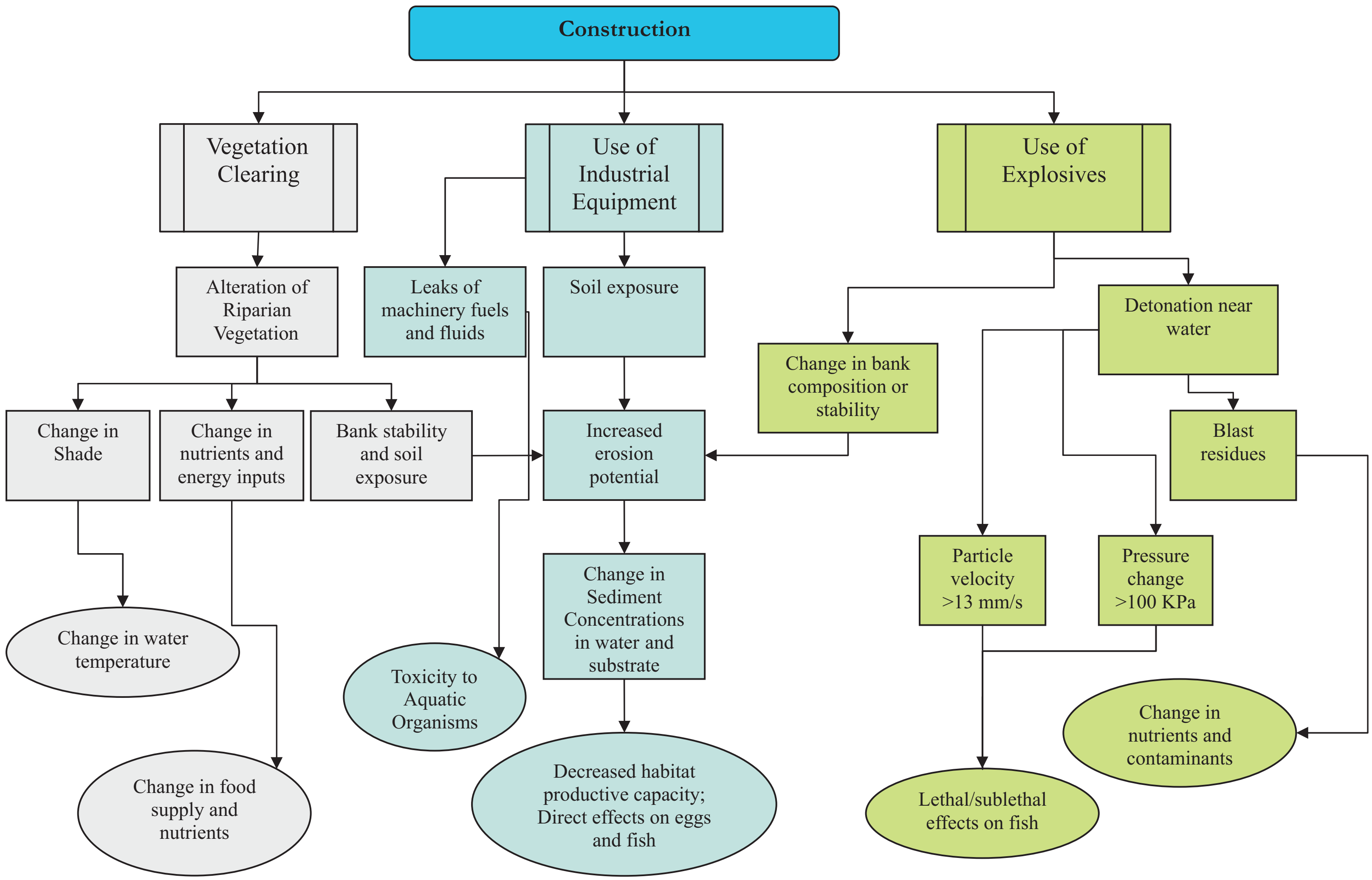
Due to possible effects on fish and fish habitat that may result from changes to water flows and water quality, Sections 7.3 and 7.4 of the *Fisheries Act*, which relates to these issues, will be referenced in this section of the report. (Fish habitat, as defined in the *Fisheries Act*, "… means spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.").

As previously discussed in Section 4.9.6, a screening-level radioactivity pathways assessment of the Thor Lake Project was completed to determine if there were any potential environmental pathways for radiological exposures, in particular, to vegetation, wildlife or fish and fish habitat. The assessment considered all potential pathways associated with the Project and concluded there were no potential environmental effects including effects on fish and fish habitat (Appendix G); therefore this issue is not discussed further in this section of the DAR.

6.6.1 Effects Identification

Cause and effect relationships resulting from stressors that arise from various Project activities have been described using Pathways of Effects (PoE). Schematically, PoE diagrams illustrate the activity-stressor-effect relationship through interconnecting lines. It is along these lines that mitigation measures can be applied to avoid or substantially reduce potential effects. Effects remaining after the implementation of mitigation are known as residual effects, which can then be assessed for significance.

Figures 6.6-1 and 6.6-2 display aquatic PoE diagrams for the construction and operations phases, respectively, of the Nechalacho Mine and Flotation Plant component of the Thor Lake Project. The various linkages identified in each figure are discussed below, along with the identification of avoidance or mitigation measures and the potential for residual effects if mitigation measures are not anticipated to fully prevent adverse effects on fish or fish habitat.



LEGEND

- Activity
- Stressor
- Effect

NOTES

1.

ISSUED FOR USE

CLIENT

AVALON RARE METALS INC.

EBA Engineering Consultants Ltd.

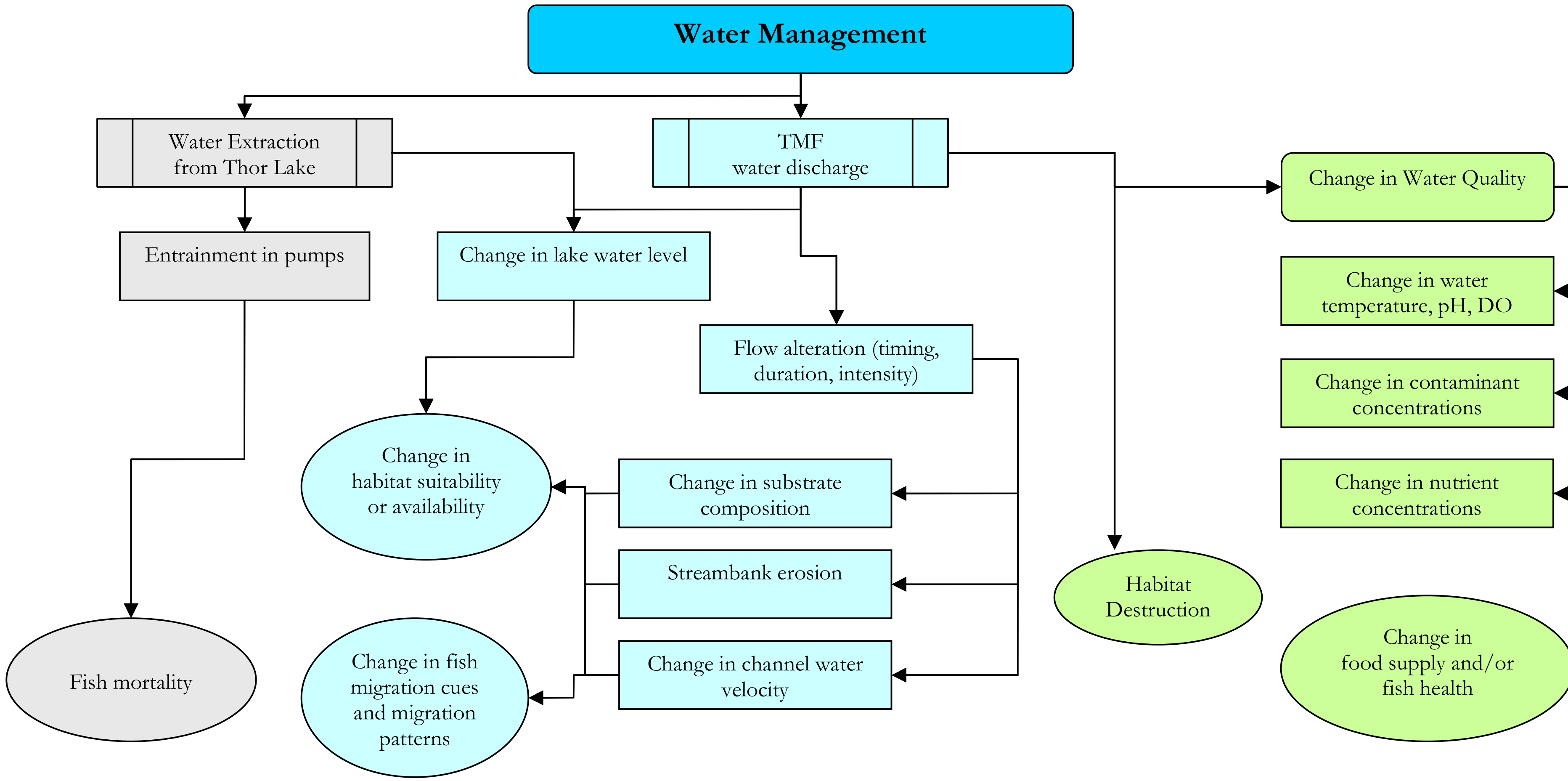
THOR LAKE PROJECT

Aquatic Pathways of Effects for the Construction Phase of the Nechalacho Mine Site

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0

OFFICE	DATE
EBA-VANC	April 5, 2011

Figure 6.6-1



LEGEND

Activity

Stressor

Effect

NOTES

1.

ISSUED FOR USE

CLIENT

AVALON RARE METALS INC.

EBA Engineering Consultants Ltd.

eba

THOR LAKE PROJECT

Aquatic Pathways of Effects for the Operations Phase of the Nechalacho Mine Site

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	DM	0
OFFICE	DATE		
EBA-VANC	May 3, 2011		

Figure 6.6-2

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6.6.2 Construction Phase Effects

6.6.2.1 Vegetation Clearing

Construction of mine site facilities and infrastructure, including buildings, roads, berms, staging areas, and upgrading the existing landing strip and barge landing site, will involve vegetation clearance. Riparian vegetation removal has the potential to result in adverse changes to aquatic habitats in a number of ways, including:

- Loss of shade, which can result in elevated water temperatures or relatively rapid temperature fluctuations during open water periods;
- Reductions in the input of food and nutrients due to the loss or reduction of insect fall and organic inputs, including small and large woody debris, which directly and indirectly contribute to fish growth and health, and habitat complexity; and,
- Destabilization of stream banks and lake shore areas due to the reduction or loss of root systems that contribute to soil binding and erosion protection.

Riparian vegetation clearance is to be restricted to the stream crossing area on the Cressy Lake outlet stream, due to road construction. No other construction is planned for lake or stream riparian areas. The Cressy Lake outlet stream is a vegetated flowage that is non-fish bearing and does not provide a migratory connection between Cressy and Fred lakes. However, precautions are necessary when working in this area to restrict potential effects to downstream areas.

Mitigation Measures

Riparian vegetation clearance will be conducted according to the DFO Land Development Guidelines (DFO 1993), which provides comprehensive guidance to protect watercourses from construction activities, including incursions into the riparian zone. The measures that will be followed include:

- Carefully selecting access points to minimize the size and duration of disturbance, and preserve streamside vegetation and undergrowth, and;
- Limiting machinery and equipment access and direct disturbance to streambank areas.

Based on the very limited riparian areas that will be affected and the mitigation measures to be applied, no residual effects from this activity on the quality or quantity of fish habitat are anticipated.

6.6.2.2 Use of Industrial Equipment

The use of heavy construction and transportation equipment can result in soil exposure, leading to increased soil erosion and sedimentation of watercourses, as particulates are mobilized in runoff and carried in overland or channel flow. As indicated above, site clearance and construction using heavy equipment is necessary for the construction of buildings and infrastructure associated with mining activities.

Increased sedimentation of streams and lakes is known to result in a variety of adverse effects, including: changes in fish feeding behaviour and fish growth, displacement of fish from preferred habitats, and smothering of fish eggs, fish larvae, benthic invertebrates, and periphyton (Larkin et al. 1998; Birtwell, 1999; Shaw and Richardson 2001).

As indicated above, construction activities, and hence equipment operation, will occur to only a very limited extent within riparian areas in the Project footprint area. As a result, direct erosion and sedimentation impacts to watercourses are unlikely. However, soil exposure distant from streams and lakes can ultimately result in sedimentation effects if runoff is considerable and channelled downslope to a watercourse.

Heavy equipment may also be subject to leaks of fuel, lubricants, and other machinery fluids that may be deleterious to aquatic life.

Mitigation Measures

Mitigation of erosion that results in sedimentation of streams and lakes within the mine development footprint will be effected by limiting areas of soil exposure to specified sites, stabilizing or protecting exposed areas as soon as is practical, and channelling runoff through filters or ponds, if necessary, to prevent sedimentation of watercourses. Erosion and sediment control measures will be guided by the DFO Land Development Guidelines (DFO 1993). No residual effect on fish and fish habitat is therefore anticipated due to the operation of industrial equipment.

Leaks of machinery fluids in volumes sufficient to harmfully affect aquatic life are unlikely and chances of leaks in the proximity of streams or lakes are even more remote since very little construction activity is to occur in these areas. The risk of effects to fish and fish habitat from such spills is therefore negligible and no residual effects are anticipated.

6.6.2.3 Use of Explosives

During the construction phase at the Nechalacho mine site, blasting may be necessary during site preparation for buildings and other infrastructure, or to obtain suitable material for road construction or extension of the existing landing strip.

Figure 6.6-1 graphically displays the potential effects of blasting on aquatic systems. The following describe these potential effects:

- Direct effects on fish or other aquatic organisms occur only when blasting takes place in or near watercourses, and results in shock waves that can damage fish organs, resulting in mortality. Vibrations from the use of explosives may also kill or damage fish eggs and larvae (Wright and Hopkey 1998).
- The ammonium nitrate/fuel oil mixture (ANFO) is a commonly used explosive in the mining and construction industries. By-products from the use of this explosive include ammonia or similar compounds that may be directly toxic to fish or result in increases in nutrient levels, which in sufficient quantity, may cause lake eutrophication. Eutrophication, in turn, can result in substantial changes in biotic community abundance and composition, and reduced dissolved water and sediment oxygen levels.

Blasting in or near streams and lakes can reduce bank or shoreline stability and result in soil exposure, resulting in erosion and mobilization of sediments, which in sufficient quantity, are harmful to aquatic life.

Mitigation Measures

Blasting contractors will be required to adhere to DFO Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (DFO 1998). In particular:

- for confined explosives, setback distances from the land-water interface (e.g. the shoreline), or burial depths from fish habitat (e.g., from under the riverbed or lake bed) will ensure that explosive charges meet the 100 kPa overpressure guideline;
- confined or unconfined explosives use near fisheries waters will not occur; and,
- precautions will be taken to prevent the escape of potentially toxic by-products, such as ammonia, to any aquatic systems.

As a result of applying appropriate blasting guidelines and best management practices, and in particular, avoiding the use of explosives in or near fisheries waters, no residual effects from this activity are anticipated.

6.6.3 Operations Phase Effects

The PoE for the Operations Phase at the Nechalacho Mine site is shown on Figure 6.6-2. Following is a description of possible activity-stressor-effect linkages identified in that figure, and discussion of avoidance or mitigation measures, and the potential for residual effects.

6.6.3.1 Water Extraction from Thor Lake

The extraction of Thor Lake water for both domestic and process purposes, and the resultant water balance calculations, is described in Section 4.7.5 of this DAR. An assessment of effects on water flows and water levels due to changes in overall flows through the Thor Lake watershed is discussed in Section 6.3. Effects due to water extraction potentially result from:

1. Entrainment and or/ impingement at water intakes. Entrainment occurs when fish are drawn into an intake and cannot escape, or are injured while attempting to escape. Impingement occurs when fish are trapped against intake fish screens and cannot escape, or are injured during their attempt to escape.
2. Loss of habitat due to lake drawdown. Changes in lake levels, beyond those which occur naturally due to seasonal variation in surface water elevations, potentially result in habitat degradation or loss. This can occur due to lake drawdowns, which result in spawning or rearing habitat exposure, or reduction in habitat quality due to insufficient depth. Reduced lake levels in winter, in particular, can lead to freezing of eggs deposited by fall spawners, such as whitefish and cisco. As a result, DFO has developed a protocol for winter water withdrawal in the NWT (DFO unpublished report), which restricts water extraction to not more than 10% of the available water

volume of a lake (i.e. volume of water under the ice), and prescribes methods for the accurate calculation of water volumes.

Design Features and Mitigation Measures

1. The water intake in Thor Lake will be designed and operated according to the DFO Freshwater Intake End-of-Pipe Fish Screen Guideline (DFO 1995), which focuses on the protection of small fish because of their susceptibility to entrainment and impingement. That document provides guidance on screen area sizing and construction based on anticipated flow rates and the fish species within the intake area. The intake will be located in deep water where densities of small fish are anticipated to be low. Water intake rates are anticipated to be very low; the maximum extraction flow rate is 849 m^3/day, or 9.8 L/s (see Figure 6.3-6 in this DAR). This flow rate can then be used to calculate the effective screen area that would minimize potential interaction with fish.
2. Water extraction during the winter months will vary from a net maximum value of 51,000 m^3 during initial years to about 38,000 m^3 during later years of operations (Appendix C). However, a sensitivity analysis was conducted assuming worst case conditions involving no reclaim from the TMF and no inflow into Thor Lake over a four month period in the winter. Under such conditions, the total extraction of water from Thor Lake would amount to about 82,000 m^3 in winter. In comparison, the DFO winter water withdrawal limit of 10% of water volume under the ice is estimated to be 360,000 m^3. As such, even under extreme conditions, water withdrawal in winter would be well within the limits established by DFO.
3. It is estimated that there will be a small reduction in annual discharge from the Thor Lake watershed of about 9% during the operations phase of the Project (see Section 6.3.4.2) resulting from:
   - water located in Tailings voids within TMF;
   - evaporation from TMF resulting in lower net upstream runoff; and,
   - moisture stored underground in paste backfill.

   Under average conditions, during the pre-production, the water balance shows that there is discharge from Thor Lake to Fred Lake each month and Thor Lake will be at its maximum volume/elevation at the end of each month. This elevation is equal to the point at which water currently discharges from Thor Lake to Fred Lake.

   In comparison, the water balance shows that on average during operations, there is discharge from Thor Lake to Fred Lake every month except January and February. The corresponding reduction in pond volume at the end of each these two months is less than 1%, and the drop in the Thor Lake water level is estimated as less than 0.1 m for each of these two months. Thor Lake will start discharging again in March through December, which means the Thor Lake volume and elevation reaches its maximum during these months.

A reduction of 0.1 m during the two mid-winter months represents a very minor change in water level that is not anticipated to adversely affect fish, fish eggs, or available fish habitat. Within the Nechalacho area, freeze-up generally begins in October and ice depth ranges from 1-2 metres. A 0.1 m reduction in water level in January and February may result in a small subsidence in the ice cover, which would not be sufficient to affect deposited eggs or overwintering habitat. Year-to-year variation in ice cover depth due to variable meteorological conditions would likely overlap areas affected by the small decrease in winter water levels, thereby precluding these as suitable egg deposition areas.

The proposed water management regime for the Nechalacho Project site is anticipated to preclude adverse effects on Thor Lake water levels and hence, on fish and fish habitat, and as such, further mitigation is not deemed to be necessary.

6.6.3.2 Tailings Management Facility

As shown in Figure 6.6-2, there are a number of effects pathways potentially resulting from construction and operation of the TMF. The discussion of each of these pathways below includes recommendations for mitigation, identification of potential residual effects, and an assessment of the significance of these effects.

Habitat Loss

The TMF will be constructed within the footprints of Ring, Buck, and Ball lakes. This conversion would result in fish and fish habitat loss if these lakes had been found to be fish bearing. However, no fish have been captured or observed during several sampling attempts in these lakes, including recent gill netting in 2009 and 2010 in Ring and Buck lakes, and minnow trapping in 2009. Similarly, no fish were captured during gill netting in 2010 in Ball Lake, a very small pond between Ring and Buck lakes that will also form part of the TMF.

In addition, gill net sets of 48 hours using two different mesh sizes were used in September 1988, to sample fish in Ring Lake (Melville et al. 1989), resulting in no fish captured. No fish were captured in 2009 and 2010 in Drizzle Lake using both gill netting and minnow trapping (in 2009). Drizzle Lake receives flow from Buck and Ring lakes. Sampling effort for fish studies carried out during 2009 and 2010 is shown in Table 2.8-8 in Section 2.8.4.5.

Ring, Buck and Drizzle are considered to be non-fish bearing. This designation is based upon fish sampling results, the likelihood that these shallow lakes freeze to the bottom in winter, and the presence of large zooplankton (Melville et al. 1989), which often corresponds to fish absence.

Since these lakes are not fish bearing, no residual effects on fish or fish habitat in these water bodies will result due to placement of the TMF in this location.

Flow Alteration

Changes in flow volumes and timing, if substantially greater than natural variability, has the potential to affect fish migration, survival of eggs and fish larvae, and habitat quality and availability. Elevated flows result in high water velocities, which can: impede upstream fish movements; flush small fish into undesirable downstream habitats; scour invertebrates from substrate surfaces; and, cause bed and bank erosion and subsequent downstream sediment transport. Conversely, reduced discharges can cause: desiccation of deposited eggs in lakeshore and stream habitats; elevated summer water temperatures; reduction in available rearing and spawning habitats; inhibition of upstream migration; and, accretion of sediments. In addition, rapid changes in flows disrupt the ability of fish to adapt to the changing flow regime, resulting in displacement from preferred habitats.

Design Features and Mitigation Measures

Flow volumes and timing will be somewhat modified due to the development of the TMF in the footprints of Ring, Buck, and Ball lakes, recycling of TMF decant water to reduce the need for water extraction from Thor Lake, and pumping of water from Thor Lake for operations purposes. Details of the proposed flow modifications and water balance are provided in Sections 4.7.5.1 and 6.3.3 of this DAR. In summary, the tailings and water management strategy for the Nechalacho Mine and Flotation Plant site consists of a closed loop system to minimize effects on the natural hydrologic flows within the Thor Lake watershed area. All tailings solids and fluids, as well as, process effluent from the Flotation Plant will report to the tailings basin. The TMF design currently includes a polishing pond. Excess water from the tailings basin will be treated (if necessary) and discharged from the polishing pond to Drizzle Lake. Ultimately, all water from the TMF will return to Thor Lake via Drizzle and Murky lakes. No water bypass is contemplated in this design, thereby maintaining flow through all natural waterbodies downstream of the TMF.

Freshwater for operations will be drawn from Thor Lake and reclaim water will be drawn from the tailings basin. The water balance assumes that the process water fed to the Flotation Plant will consist of 50% freshwater and 50% recycled water from the TMF.

The conversion of Ring and Buck lakes to a tailings management facility (TMF) will not result in the elimination of flows from this upper portion of the Thor Lake watershed. To the extent possible, water discharges from the TMF will simulate pre-development flow volumes and seasonal patterns (Figure 6.3-8) to minimize possible effects on the local hydrological regime.

Drainage from Murky Lake into Thor Lake (draining a total of ~800 ha) accounts for about 38% of the Thor Lake watershed. Thor Lake also receives flows from a large watershed to the southeast through Long Lake (~950 ha) accounting for 45% of the Thor Lake watershed. The remaining watershed reporting to Thor Lake (i.e. Megan and Thorn lakes ~350 ha) makes up the remaining 17% of the Thor Lake basin, which totals approximately 2,100 ha. The Thor Lake watershed drains to Fred Lake, which then ultimately reports to Great Slave Lake through numerous lakes and marshes along a drainage path flowing southwest, an estimated 18 km, that collects an additional 6,700 ha of watershed. As such, the Thor Lake watershed makes up only about 24% of the total watershed that drains to Great Slave Lake along this path.

The following assessment of the potential changes in flow due to the Project is reproduced from Section 6.3.4.4 of this DAR:

1. A nominal average decrease in discharge (around 9% on annual basis) from the Thor Lake basin is predicted during mine operations mainly due to water losses associated with the TMF and mine backfill operations. As shown on Figure 6.3-9, this average decrease, when considered over the course of a year and compared against background seasonal discharges (Figure 6.3-9), is within the range of natural flow variability.
2. The development of a TMF within the Ring and Buck lakes basin will result in slightly higher flows through Drizzle and Murky lakes during operations compared to pre-development baseline flows estimated, assuming a 50% maximum recycle rate from the TMF. This increase is expected to be in the order of a 6% increase in flow at the start of operations. This initial increase is expected to slowly decline to an increase of about 3% in later years of operation as expected evaporation and tailings beach size increase.
3. The TMF and mine operations will not impact a significant portion of the Thor Lake watershed. The characteristics of the large Long Lake watershed and the Murky Lake watershed are not expected to change over the course of mine operations.
4. During operations approximately 10% of water discharged from Thor Lake will have originated in the Ring and Buck lakes watershed.
5. Following closure, impacts of the mine facilities on the Thor Lake watershed are expected to be minimal. The change in configuration of the Drizzle Lake watershed, caused by the construction of the Polishing Pond, is expected to decrease annual discharge by approximately 43,300 m^3/year compared to pre-production conditions.

As a result of flow regulation to mimic background flows and considering the natural variability in the seasonal flow regime, no residual effects on stream channel habitats, substrate composition, bank erosion, stream velocities or lake levels (shown as potential effects on Figure 6.6-2) are anticipated due to conversion of the upper portion of the Thor Lake watershed to a TMF. The stream channel between Murky Lake and Thor Lake, which has been found to support northern pike, will not be adversely affected by TMF operations.

As such, from the perspective of surface flows, no adverse residual effects are anticipated on fish habitat availability or quality.

6.6.3.3 Water Quality Effects

Background water quality in the Thor Lake system has the potential to be affected by Nechalacho Mine site activities due to the discharge to the TMF of process tailings, pumped mine water, and domestic sewage. Decant water from the TMF will flow through Drizzle and Murky lakes before reaching Thor Lake, and then another 18 km through a series of lakes, streams, and wetlands to Great Slave Lake.

Generally, concerns from mining activities focus on contaminants such as arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids, and radium 226, which are the potentially deleterious substances regulated under the MMER. In addition, other substances can result in water quality degradation, resulting in toxicity to aquatic organisms or changes to biotic community structure. For example, elevated nutrient inputs, particularly of nitrogen and phosphorous, can result in algal blooms and subsequent lake eutrophication (Smith et al. 1999), reduced oxygen levels, and selection of invertebrate and fish species adapted to such conditions.

The Nechalacho Mine site operation will be required to meet specific effluent MMER discharge criteria (identified in Table 6.4-3), discharge requirements established in the Water License, and in addition, carry out periodic water quality analyses and Environmental Effects Monitoring (EEM) studies to detect changes in water quality and biotic community composition and health (Environment Canada 2002)

Design Features and Mitigation Measures

A water quality modelling study was carried out to estimate probable water quality conditions over a 20 year period. The results of this study are detailed in Section 6.4.2 of this DAR. As indicated in that section, the model predicts that the MMER effluent criteria for all parameters will be met over the entire 20 year simulation period, in each of the lakes within the Thor Lake system, and that all parameters will be well within CCME guideline levels. As well, the modelled concentrations (shown in Table 6.4-3) represent conservative values, since no allowance was made in the model for decreases in concentration due to natural remediation processes including degradation, chemical oxidation, precipitation, and biodegradation. In addition, the modelled values for all potential contaminants were based on analyses of samples decanted for five days (see Section 6.4.2.4 in this DAR); actual residence time for water in the TMF is predicted to be greater than 100 days.

Based on the design of the water management system and the results of modelling, it is apparent that no adverse effects are anticipated and consequently, additional mitigation to remove potential contaminants at source will not be required. Water quality and aquatic biological monitoring required by the water license and the MMER will be used to assess these predictions and if necessary, provide early indications that additional mitigation may be necessary.

6.6.4 Project Design Features and Mitigation Measures

The proposed Tailings Management Facilility (TMF) will be located up slope from the Flotation Plant and northeast of Thor Lake in the local catchment that currently hosts Ring Lake and Buck Lake. The location was selected based on a review of available sites within the Project area and consideration of environmental and economic factors:

- The Ring and Buck lakes catchment area forms a natural basin that will provide adequate and efficient storage, thereby minimizing embankment construction and development costs;
- Discharge from the TMF will be to Drizzle Lake, which flows to Thor Lake via Murky Lake. This will allow return of excess water from the TMF supernatant pond to Thor Lake during Mine operations to minimize impacts to pre-production flows; and,
- Baseline studies to date indicate that Ring, Buck and Drizzle lakes are non-fish-bearing water bodies.

The proposed site water management for the Thor Lake Project will consist of a closed loop system to minimize effects to the natural hydrologic flows. Water will be withdrawn from Thor Lake and recycled from the TMF to operate the Flotation Plant.

Excess water from the TMF will be treated (if necessary) and discharged to Drizzle Lake from the Polishing Pond. Ultimately, all excess water from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system. A Settling Pond will be established to collect runoff water from the Flotation Plant site and may also be used to reclaim small amounts of water for use in the Flotation Plant.

Additional mitigation measures that will be employed during the operations phase will include:

- Mine water and Plant site runoff will be collected and directed into the process as appropriate.
- All excess water released from the TMF will be returned to Thor Lake via the Drizzle Lake/Murky Lake drainage system.
- Water will be recycled from the TMF to the greatest extent possible to minimize the fresh water requirement (currently 50% recycle and 50% fresh water has been modelled).
- Extraction of fresh water from Thor Lake will be managed to conform to the 2010 Department of Fisheries and Oceans (DFO) Protocol for Winter Water Withdrawal (DFO 2010), which specifies the use of no more than 10% of the available under-ice water volume.
- Natural flows and conditions will be monitored and mimicked as closely as possible throughout operations to minimize possible effects on the local hydrological regime.
- Riparian vegetation clearance and erosion control will be conducted according to the DFO Land Development Guidelines (DFO 1993), which provides comprehensive guidance to protect watercourses from construction activities, including incursions into the riparian zone.
- All blasting activities near waterbodies will comply with DFO Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (DFO 1998).
- Water intake will be designed to conform with the DFO Freshwater Intake End-of-Pipe Fish Screen Guideline (DFO 1995).
- All decant water released from the TMF into Drizzle Lake will comply with the requirements of the MVLWB Water License and the federal MMER regulations.
- Water quality and biological monitoring will be carried out according to requirements of the Water License and the MMER. Monitoring results will be used to confirm that water quality downstream of the TMF discharge remains within allowable limits.

With the application of the mitigative measures as described, the overall effects on fish and fish habitat in the downstream lakes, including Thor Lake, are expected to be localized, low in magnitude and insignificant.

6.7 SURFICIAL GEOLOGY AND SOILS

6.7.1 Nechalacho Mine Site

The primary effects of the Nechalacho Mine site on surficial geology (terrain) and soils will be largely associated with infrastructure development. During the construction phase in particular, soils and terrain will be disturbed as areas are prepared to support infrastructure. The total amount of direct disturbance anticipated at the Nechalacho Mine site is approximately 173 ha, of which the majority (109 ha or 63%) is attributable to the Tailings Management Facility (TMF) (Table 6.7-1).

TABLE 6.7-1: NECHALACHO MINE SITE FOOTPRINT

Footprint Component	Area (ha)	Proportion of Footprint (%)
Tailings Management Facility	109.1	63.0
Roads	21.0	12.1
Flotation Plant and Miscellaneous Infrastructure	17.5	10.1
Polishing Pond	12.5	7.2
Rock Quarry	8.7	5.0
Airstrip	2.7	1.6
Pipelines and Pumps	0.8	0.4
Seasonal Dock Facility	0.7	0.4
Total	**173.1**	**100.0**

6.7.2 Hydrometallurgical Plant Site

At the Hydrometallurgical Plant site, the footprint covers approximately 62 ha and is situated almost completely (i.e., 92%) on previously disturbed ground (Table 6.7-2). This was an important consideration in the siting of the Hydrometallurgical Plant and associated infrastructure as this strategy will ensure that no residual effects to terrain and soils will occur in this area.

TABLE 6.7-2: HYDROMETALLURGICAL PLANT SITE FOOTPRINT

Footprint Component	Area (ha)	Proportion of Footprint (%)
Roads	32.4	51.9
L37 Pit	23.4	37.6
Hydrometallurgical Plant	5.0	8.1
Seasonal Dock Facility	1.5	2.5
Total	**62.3**	**100.0**

Potential changes to surficial geology and soil conditions are addressed for both the Nechalacho Mine site and Hydrometallurgical Plant site concurrently as they are anticipated to be similar. References to permafrost relate primarily to the Nechalacho Mine site as permafrost in the vicinity of the Hydrometallurgical Plant site is highly localized and restricted to low lying organic deposits that are situated beyond the proposed development area to the north. Permafrost was never encountered in upland areas developed as part of the Cominco plant site, which will also serve as part of the Hydrometallurgical Plant site.

6.7.3 Influences on Geotechnical Stability

All items raised in the TOR (MVERB 2011) relating to the geotechnical stability of TLP infrastructure can and will be addressed through conscientious mine layout and appropriate engineering design. For example, seismicity and permafrost conditions have both been factored in to the design of the TMF at the Nechalacho Mine site (Section 4.4.4 and Section 4.7.4.3, respectively), and abundant information and expertise with respect to the responsible construction and operation of facilities in discontinuous permafrost regions are available and will be incorporated into the detailed engineering phases as required. Infrastructure has also been deliberately sited, wherever possible, on competent bedrock, further adding to the geotechnical stability of facilities.

6.7.4 Potential Changes to Permafrost

Surface disturbances in permafrost areas can be problematic as they can promote ground warming which can lead to the progressive thaw and possibly the loss of permafrost in localized areas. In the context of infrastructure development, permafrost thaw can pose substantial geotechnical challenges, largely due to softening of the soil structure, increased substrate instability, and thaw settlement.

Within the Nechalacho Mine site, areas that were most likely to support permafrost were linked with fine-textured soils, thick organic deposits, and north-facing slopes (Stantec 2010d). Mine planning and design has avoided permafrost areas wherever possible, with most structures being situated on bedrock or ecosystem types with thin organics over bedrock. Where permafrost cannot be avoided, development plans will either strip overlying materials to bedrock prior to construction or will incorporate the use of features such as Arctic foundations to ensure any heat generated does not transfer into the subsurface, thereby compromising the integrity of the permafrost.

The ecological implications of potentially changing localized areas of permafrost are discussed in Section 6.8.

6.7.5 Project Design Features and Mitigation Measures

Prior to the implementation of mitigation measures, the current footprint layout has undergone several iterations to optimize its design to minimize potential effects on the surrounding environment. One such design feature pertains to the potential presence of permafrost in areas that are to support infrastructure. Permafrost is most relevant to the Nechalacho Mine site and the TMF specifically. To ensure geotechnical stability and the overall structural integrity of the TMF, the dams in particular will be constructed directly on bedrock. All overlying material will be stripped, thus removing potential instability issues related to permafrost. Stripped material will be stockpiled for later use in reclamation efforts.

With respect to other infrastructure that may overlie permafrost, in the event that stripping material to bedrock is not an option, engineered structures such as Arctic foundations will be incorporated into the design if determined to be necessary.

Mitigation strategies that help reduce the potential effects to permafrost and soils include restricting the overall size of the development, siting infrastructure on bedrock wherever possible, avoiding areas that could potentially support permafrost, and minimizing the pooling and ponding of water on surfaces.

The potential effects of the TLP on permafrost and soils can be effectively addressed with appropriate engineering design and mitigation strategies. As such, no residual effects are anticipated.

6.8 ECOSYSTEMS AND VEGETATION

The main effects of the proposed TLP on ecosystems and plant species will be their removal and/or burial as a result of infrastructure development. Other effects that were considered include changes to soil and permafrost conditions, an increase in air emissions in the form of fugitive dust and vehicle, Project equipment, and power plant emissions, and the potential to introduce invasive or non-native plant species into previously undisturbed areas. All of these effects can directly or indirectly influence the overall health, productivity, and function of ecosystems and plant species present (Figure 6.8-1). With reclamation, the majority of these anticipated effects will be reversible in the long-term.

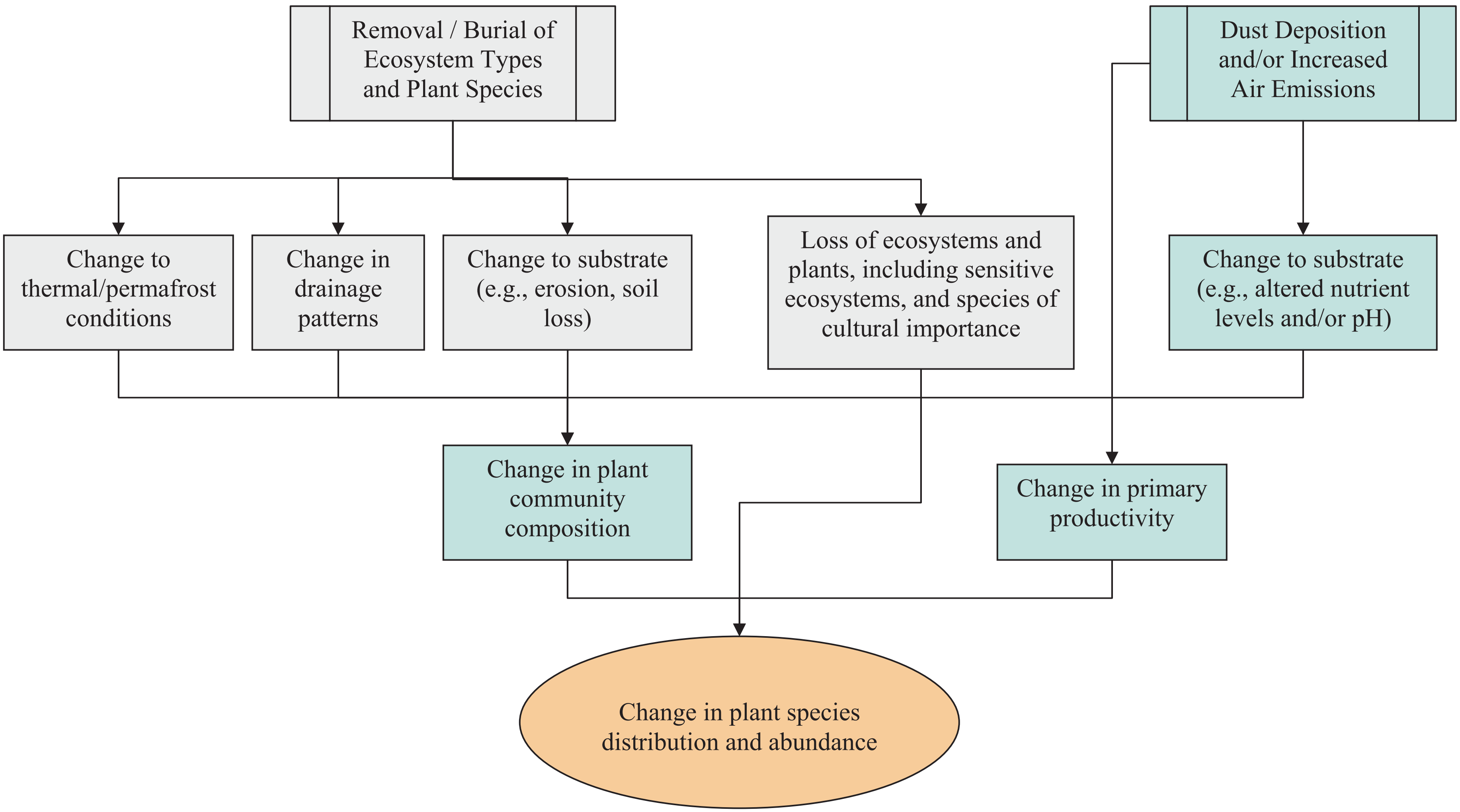
The extent of Project effects on ecosystems and plants was assessed using the site footprints and mapped distribution of ecosystems within the LSA (Figure 6.8-2). Some forms of disturbance, such as fugitive dust deposition and air emissions, are anticipated to only occur immediately adjacent to Project infrastructure.

The air quality effects assessment (Section 6.2) for all criteria air contaminants (CACs) has determined that air emissions associated with all phases of the TLP will be localized, short-term, periodic, of low magnitude, and rapidly reversible. Additionally, CAC levels are predicted to be lower than the corresponding NWT AQ Standards. As such, air emissions are not anticipated to have a measurable effect on ecosystem and vegetation Valued Components (VCs), and therefore will not be assessed further.

In addition, as previously discussed in Section 4.9.6, a screening-level radioactivity pathways assessment of the Thor Lake Project was completed to determine if there were any potential environmental pathways for radiological exposures, in particular, to vegetation, wildlife or fish and fish habitat. The assessment considered all potential pathways associated with the Project and concluded there were no potential environmental effects including effects on vegetation (Appendix G).

VCs considered in the effects assessment include ecosystems and plant species in general, as well as ecosystems that may be particularly sensitive to disturbance. Sensitive ecosystems were identified as those growing in permafrost areas (where applicable), those with a high lichen or *Sphagnum* component, or those associated with acidic and/or nutrient poor conditions (Table 6.8-1).

To characterize potential effects to plants currently included under the *Species at Risk Act*, ecosystems with a high or very high potential of providing suitable habitat for rare plants were also included in the assessment of Project effects (Table 6.8-1). The determination of rare plant habitat potential is described in Section 2.10.1.4 for the Nechalacho Mine site, and Section 2.10.2.3 for the Hydrometallurgical Plant site; both Sections include lists of the plant species considered.



LEGEND

Activity

Stressor

Effect

NOTES

1.

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THOR LAKE PROJECT

Vegetation Pathways of Effects

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	TP	0

OFFICE	DATE
EBA-VANC	April 6, 2011

Figure 6.8-1

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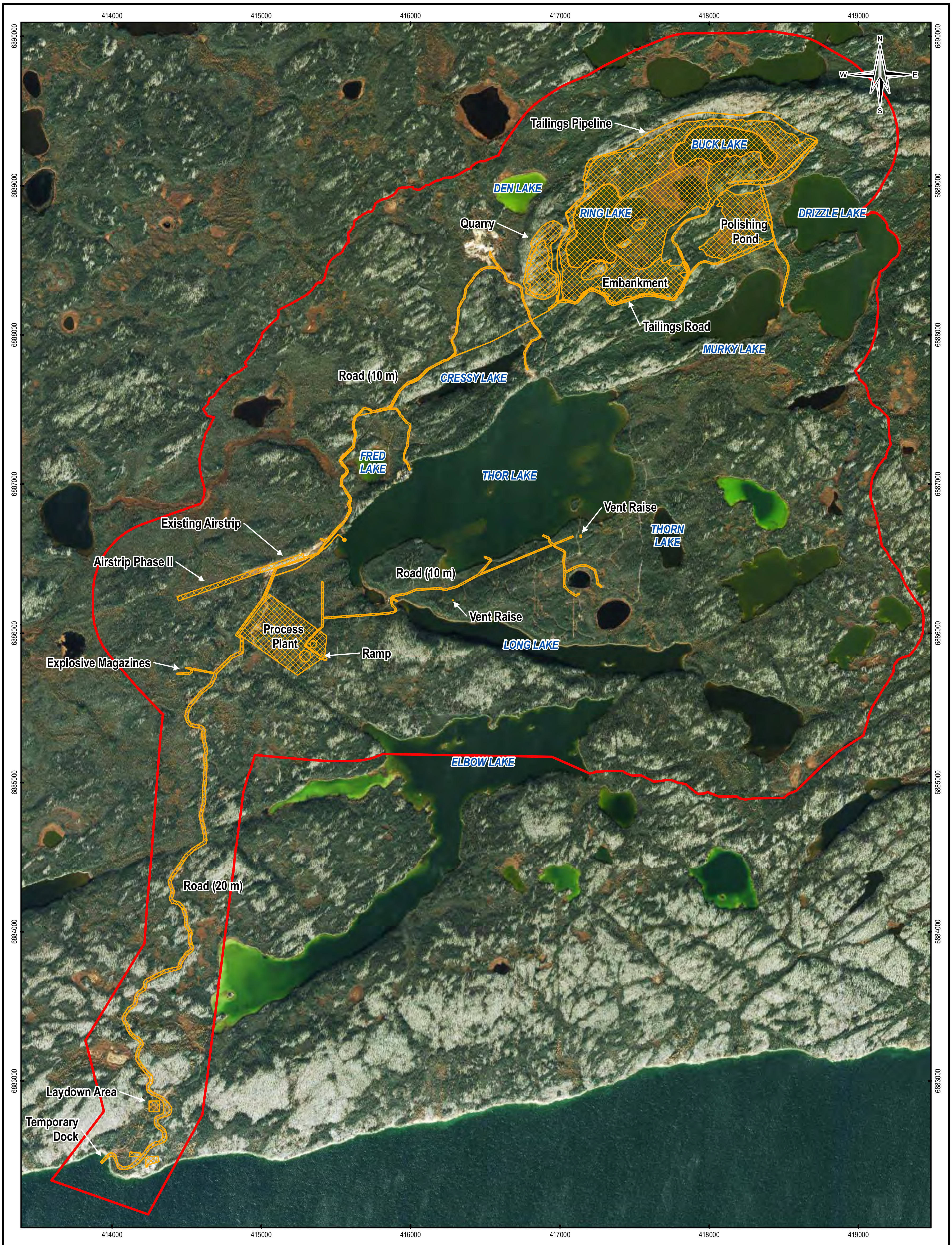

LEGEND

- Local Study Area
- Infrastructure Footprint

NOTES

1. Base footprint generated from data provided from Avalon, April 2011.
2. Base data source: Imagery provided by Avalon (October 2010).

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THOR LAKE PROJECT

Nechalacho Mine Site Footprint

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:24,000 (500 250 0 500 Metres)	
FILE NO.: V15101007_DAR_Map046_NechFootprint.mxd	
PROJECT NO.: V15101007.006	DWN: SL; CKD: TP; REV: 0
OFFICE: EBA-VANC	DATE: April 19, 2011

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Figure 6.8-2

TABLE 6.8-1: VALUED COMPONENTS CONSIDERED IN THE ASSESSMENT OF POTENTIAL PROJECT EFFECTS		
Valued Component	**VC Description**	**Mapped Ecosystem Types**
Sensitive ecosystems	Ecosystems in permafrost areas	Various
	High lichen cover	LL, LW, RL, JH, bearberry – jack pine forest
	High *Sphagnum* cover	BG
	Acidic/nutrient poor ecosystems	BG, LL
Rare plant habitat potential	Field identification	Site specific
	High potential	BF, BG, RL, WH, graminoid fen, shrubby fen
	Very High potential	OW[1], PD[1], treed fen

[1]Rare plant habitat is restricted to shallow waters and margins of these mapped ecosystem units

6.8.1 Removal/Burial of Ecosystems and Plant Species

6.8.1.1 Nechalacho Mine Site

Infrastructure placement will result in the disturbance or burial of approximately 173 ha of surface area, the majority of which is attributable to the tailings management facility (Table 6.8-2). Wherever possible, the placement of infrastructure has incorporated areas of existing disturbance, such as previously exposed soil and existing roads; these are collectively termed "Anthropogenic" in Table 6.8-3 and account for 1% of the footprint area.

TABLE 6.8-2: NECHALACHO MINE SITE FOOTPRINT		
Footprint Component	**Area (ha)**	**Proportion of Footprint (%)**
Tailings Management Facility	109.1	63.0
Roads	21.0	12.1
Flotation Plant and Miscellaneous Infrastructure	17.5	10.1
Polishing Pond	12.5	7.2
Rock Quarry	8.7	5.0
Airstrip	2.7	1.6
Pipelines and Pumps	0.8	0.4
Seasonal Dock Facility	0.7	0.4
Total	**173.1**	**100.0**

Ecosystem types that will likely be most affected by development of the Nechalacho Mine site footprint include white spruce – green alder – prickly rose forest (WA), spruce – paper birch – toadflax forest (SP), and lichen – bearberry woodland (LW), which collectively cover approximately 39% of the total footprint area (Table 6.8-3). In addition, each of the following ecosystem types each account for approximately 10% of the total footprint area:

Ponds (PD), black spruce – feathermoss – crowberry upland forest (BF), and black spruce – tamarack – water sedge fen (BT).

Ecosystem types occurring within the Nechalacho Mine site footprint are predominantly well to rapidly drained woodlands and forests, often with shallow soils over bedrock (the exception being ponds and the BT ecosystem type). All of the ecosystem types that may be directly affected by footprint development are well represented within the LSA.

Sensitive ecosystems, particularly those with a high lichen component, comprise approximately 46 ha (26%) of the Nechalacho Mine site infrastructure footprint (Table 6.8-3). The disturbance to individual ecosystem types in relation to their presence within the LSA ranges between 0% (not present within the footprint area, as is the case with the Jack pine – heath – lichen – upland (JH) ecosystem type) and 23% (for the Labrador tea – reindeer lichen – black spruce bog (LL) ecosystem type). This level of disturbance is unlikely to affect the persistence and sustainability of these ecosystem types as the majority of the area identified occurs within the LSA, not the footprint. These ecosystem types were also characterized within the larger regional study area.

No rare plant species were found within the proposed Project footprint. In particular, rock polypody (ranked as "undetermined" in the NWT) was identified during field surveys only in areas outside of the proposed infrastructure development. Ecosystem types with a higher potential of providing rare plant habitat are, however, present within the footprint, covering approximately 59 ha (34%) of the total area (Table 6.8-3). The most prevalent ecosystem types with a higher potential of providing rare plant habitat are Ponds (PD), black spruce – feathermoss – crowberry upland forest (BF), and black spruce – cloudberry – *Sphagnum* moss bog forest (BG). Disturbances to individual ecosystem types compared to their distribution in the LSA range between 2% (WH ecosystem type) and 12% (ponds located within the TMF).

TABLE 6.8-3: ECOSYSTEM DISTRIBUTION WITHIN THE NECHALACHO MINE SITE FOOTPRINT AND LSA

Broad Habitat Type	Ecosystem Type[1]	Footprint Area (ha)	Ecosystem Proportion of Footprint (%)	Ecosystem Distribution within LSA (ha)	Footprint Proportion of LSA (%)
Anthropogenic	ES	0.3	0.2	3.0	11.2
	MI	0.04	0.02	4.9	0.8
	RW	0.1	0.04	1.2	5.9
	RZ	1.0	0.6	4.6	21.4
Bedrock-Lichen	JH^{L}		0.0	0.6	0.0
	LW^{L}	20.9	12.1	325.2	6.4
	RL^{LH}	10.1	5.8	116.4	8.6
Broadleaf Upland	PA		0.0	0.8	0.0
Herb Marsh	SH		0.0	2.0	0.0
Mixed Upland	SP	23.5	13.6	302.9	7.8
Open Water	LA	12.7	7.3	266.1	4.8

TABLE 6.8-3: ECOSYSTEM DISTRIBUTION WITHIN THE NECHALACHO MINE SITE FOOTPRINT AND LSA

Broad Habitat Type	Ecosystem Type[1]	Footprint Area (ha)	Ecosystem Proportion of Footprint (%)	Ecosystem Distribution within LSA (ha)	Footprint Proportion of LSA (%)
	OW[V]	1.1	0.6	15.8	6.7
	PD[V]	18.9	10.9	153.6	12.3
Riparian Shrub	SW	0.005	0.003	2.8	0.2
Rock	RO	0.3	0.2	6.9	4.9
Sedge Fen	WB	8.8	5.1	30.7	28.6
Shrub Fen	SS	2.8	1.6	38.7	7.2
Shrub Wet	BG[SAH]	11.7	6.8	291.2	4.0
	LL[LA]	3.2	1.9	13.9	23.2
Spruce Upland	BF[H]	17.4	10.0	208.2	8.4
	WA	23.8	13.7	223.2	10.6
Spruce Wet	WH[H]	0.02	0.01	1.1	1.9
Treed Fen	BT	16.5	9.5	175.2	9.4
Total		**173.1**	**100.0**	**2,188.8**	**7.9**

[1]Codes as per Stantec (2010e)

[L,S,A]Sensitive ecosystem: L = high lichen cover; S = high *Sphagnum* cover; A = acidic/nutrient poor

[H,V]Rare plant habitat potential: H = high potential; V = very high potential

6.8.1.2 Hydrometallurgical Plant Site

The Hydrometallurgical Plant site footprint covers approximately 62 ha (Table 6.8-4) and is situated almost completely (i.e., 92%) on previously disturbed ground (Figure 6.8-3). This was an important consideration in the siting of the Hydrometallurgical Plant and associated infrastructure as this greatly reduces the effects to ecosystems and vegetation.

TABLE 6.8-4: HYDROMETALLURGICAL PLANT SITE FOOTPRINT

Footprint Component	Area (ha)	Proportion of Footprint (%)
Roads	32.4	51.9
L37 Pit	23.4	37.6
Hydrometallurgical Plant	5.0	8.1
Seasonal Dock Facility	1.5	2.5
Total	**62.3**	**100.0**

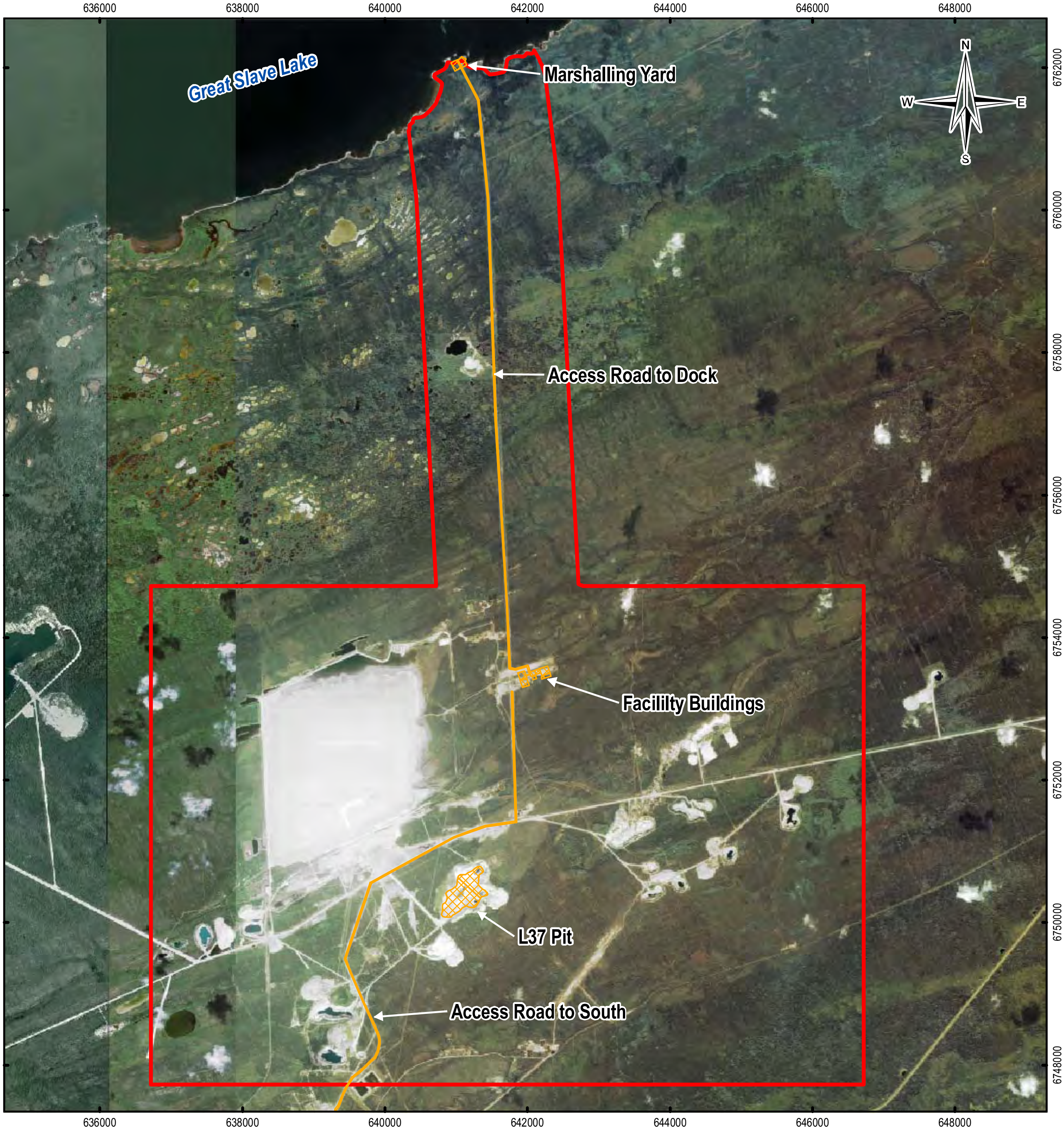
Natural ecosystem types form a very small portion (8%) of the overall infrastructure footprint, and are represented primarily by mesic and subhygric forest dominated by Labrador tea, as well as treed fens (Table 6.8-5). These three ecosystem types represent a moisture gradient from well drained upland sites (i.e., mesic forest), to transitional sites (i.e., subhygric forest), to wetlands (i.e., treed fen). The distribution of these ecosystem types within the infrastructure footprint area represents less than 1% (both individually and combined) of their total presence within the LSA overall. Given their abundance and widespread nature within the LSA, this level of disturbance is unlikely to affect their sustainability within the larger landscape.

Treed fens and graminoid fens have a very high and high potential, respectively, of providing suitable habitat for rare plant species potentially occurring within the area. No rare plant species were identified during previous surveys and both of these ecosystem types occur within the LSA. Sensitive ecosystems do not occur within the infrastructure footprint area, and as such will not be directly disturbed by Project development.

TABLE 6.8-5: ECOSYSTEM DISTRIBUTION WITHIN THE HYDROMETALLURGICAL PLANT SITE FOOTPRINT AND LSA

Ecosystem Type	Footprint Area (ha)	Ecosystem Proportion of Footprint (%)	Ecosystem Distribution within LSA (ha)	Footprint Proportion of LSA (%)
Anthropogenic	57.6	92.4	1,771.2	3.3
Labrador Tea – Subhygic Forest	2.4	3.8	4,519.0	0.1
Treed Fen[V]	1.2	2.0	581.3	0.2
Labrador Tea – Mesic	0.9	1.4	952.7	0.1
Graminoid Fen[H]	0.2	0.3	5.3	4.1
Open Water	0.1	0.1	25.0	0.3
Bearberry – Jack Pine Forest[L]	0.0	0.0	219.8	0.0
Shrubby Fen[H]	0.0	0.0	359.4	0.0
Total	**62.3**	**100.0**	**8,433.7**	**0.7**

[L]Sensitive ecosystem: L = high lichen cover
[H,V]Rare plant habitat potential: H = high potential; V = very high potential



LEGEND

- Local Study Area
- Infrastructure Footprint

THOR LAKE PROJECT

Hydrometallurgical Plant Site Footprint

PROJECTION	DATUM
UTM Zone 11	NAD83

Scale: 1:80,000

1 0.5 0 1 2

Kilometres

FILE NO.
V15101007_DAR_Map047_HydrometFootprint.mxd

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	TP	0

OFFICE	DATE
EBA-VANC	April 5, 2011

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Figure 6.8-3

NOTES
Base data source: Imagery provided by Avalon (October, 2010).

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6.8.2 Changes to Soil and Permafrost Conditions

Potential changes to soil conditions are addressed for both the Nechalacho Mine site and Hydrometallurgical Plant site concurrently as they are anticipated to be similar. References to permafrost relate primarily to the Nechalacho Mine site as permafrost in the vicinity of the Hydrometallurgical Plant site is highly localized and restricted to low lying organic deposits primarily to the north of the proposed development area. Permafrost was never encountered in upland areas developed as part of the Cominco plant site, which will also serve as part of the Hydrometallurgical Plant site.

Changes to soil and permafrost conditions could result in changes to the ecosystem types and plant species present, particularly if disturbed surficial materials are ice-rich. Thawing of ice-rich permafrost can lead to localized settling, slumping, and erosion, and can increase the depth of the active layer and water infiltration (Burgess and Smith 2001; ACIA 2005; Furgal and Prowse 2008). These types of changes to the substrate can physically damage to the plants present and can also lead to shifts in species composition as plants respond to altered growing conditions.

6.8.3 Effects of Dust Deposition

Certain Project activities, such as general construction and road use during the summer months, are likely to produce dust. The potential effects of dust deposition on plant species varies with the deposition frequency, load, and duration, as well as the physical and chemical properties of the dust, and the plant species involved.

A variety of factors can influence dust deposition patterns, such as particle size, wind direction and velocity, terrain, vegetation density and structure (e.g., tall vs. short), vehicle size, speed, and traffic volumes. Several studies of the effects of road dust on vegetation have highlighted the variability in particle transport, with effects being detected 100 m away (Auerbach et al. 1997), 200 m away (Santelmann and Gorham 1988; Angold 1997), and up to 400 m away (Lamprecht and Graber 1996). Walker and Everett (1987) discovered that up to 75% of the total dust load can generally be deposited within the first 10 m of the road, irrespective of site conditions.

Studies carried out by the United States Environmental Protection Agency (US EPA 1995) also highlight the influence of particle size on dust deposition patterns. Larger particles (e.g., those with an aerodynamic diameter >100 μm) tended to settle within 10 m of the source, while particles with moderate sizes (e.g., with diameters between 30 – 100 μm) settled out within 100 m. Particulates with aerodynamic diameters <15 μm were transported over much greater distances because they were less influenced by gravitational settling. Road dust generally contains particles ranging in size from >3 to <10 μm, and is the result of road surface aggregate being thrown into suspension by road traffic (Walker and Everett 1987).

Dust particles that settle directly onto plants can have both a physical and physiological effect. Dust can block stomata, smother leaf surfaces, and increase leaf surface temperature, all of which can reduce the overall photosynthetic efficiency in the plant (Thompson et al. 1984; Pyatt and Haywood 1989; Farmer 1993).

The surrounding environment can also be modified by an increase in dust deposition. Studies have reported changes in substrate properties such as soil pH, soil nutrient regime, earlier snowmelt due to changes in surface albedo, and depth of permafrost thaw (Walker and Everett 1991; Auerbach et al. 1997; Gunn 1998). Longer-term studies have shown that these substrate changes can influence subsequent changes in plant community composition, most notably as a decline in *Sphagnum* and lichen species abundance and vigour and an increase in graminoids nearer the dust source (Myers-Smith et al. 2006; Auerbach et al. 1997).

Plant groups such as lichens and *Sphagnum* moss species tend to have a higher sensitivity to disturbance and are often used as indicators of environmental conditions (Myers-Smith et al. 2006; Markert 1993; Tyler 1989; Spatt and Miller 1981). Documented declines in lichen abundance in studies of road dust deposition have been attributed primarily to the sensitivity of lichens to the physical and chemical properties of the dust, as well as being out-competed by other species that are responding more favourably to the changes in local growing conditions (Myers-Smith et al. 2006; Auerbach et al. 1997). Declines in *Sphagnum* abundance were largely attributed to changes in soil pH, from acidic to more neutral conditions (Myers-Smith et al. 2006; Auerbach et al. 1997).

The primary dust-related effects resulting from the TLP are anticipated to occur within 10 m of the main development footprint, as this is where the majority of dust is expected to settle out. Dust effects may occur up to 100 m away, depending, in part, on site conditions and particle size characteristics.

Within the Nechalacho Mine site, the ecosystem types most likely to be affected include jack pine – heath – lichen – upland (JH), lichen – bearberry woodland (LW), bedrock – lichen – juniper – saxifrage complex (RL), black spruce – cloudberry – *Sphagnum* moss bog forest (BG), and Labrador tea – reindeer lichen – black spruce bog (LL). At the Hydrometallurgical Plant site, the bearberry – jack pine ecosystem type would be expected to be the most affected by dust deposition. All of these ecosystem types have either a lichen or *Sphagnum* component, some are acidic in nature, and all are generally more sensitive to atmospheric and pH changes.

6.8.4 Potential Introduction of Invasive Plant Species

Trends in invasive alien plant species presence and establishment in the north are being monitored with increasing interest by scientists and regulatory agencies alike. Invasive alien plant species are those that have been introduced into areas beyond their natural range by humans and are capable of causing significant harm to the environment, economy, or society (GNWT and NWT Biodiversity Team 2010). Though the incidence of invasive plant species in the north is still much lower compared to areas further south, the prospect of climate change and increased development could lead to more frequent, unintentional introductions.