APPENDIX 6-B

Hydrogeological Model Pre-Mining, During Mining and Closure

June 2016
Report No. 1541520

AGNICO EAGLE
Golder Associates

6.B-1 OBJECTIVES

The following presents the results of a hydrogeological assessment of groundwater conditions that are expected to develop in the area of the Whale Tail Pit (the Project) during mining and closure of the mine facilities. Specifically, it addresses the approaches and assumptions adopted in the estimate of the potential groundwater inflow quantity and groundwater quality (total dissolved solids [TDS] only) associated with the development of the Whale Tail Pit. In this assessment, a three-dimensional numerical groundwater model representing the Whale Tail Pit and the surrounding areas was developed using FEFLOW (Diersch 2016). This model incorporates the mine plan described in the Project Description (Volume 1).

During mining, the open pit will act as a sink for groundwater flow. Water originating from Whale Tail Lake and other nearby lakes, the attenuation pond, and from bedrock will be induced to flow through the bedrock to the mine workings. The groundwater quality of mine inflow will be the result of the mixing of fresh groundwater flowing from Whale Tail Lake and other nearby lakes, brackish water (connate water) flowing up from deep bedrock, and groundwater flowing from the attenuation pond.

6.B-2 CONCEPTUAL HYDROGEOLOGICAL MODEL

A conceptual hydrogeological model was developed to aid in the construction of the numerical groundwater model. A conceptual hydrogeological model is a pictorial and descriptive representation of the groundwater regime that organizes and simplifies the site conditions so they can be readily modelled. The conceptual model must retain sufficient complexity so that the analytical or numerical models developed from it adequately reproduce or simulate the actual components of the groundwater flow system to the degree necessary to satisfy the objectives of the modelling study.

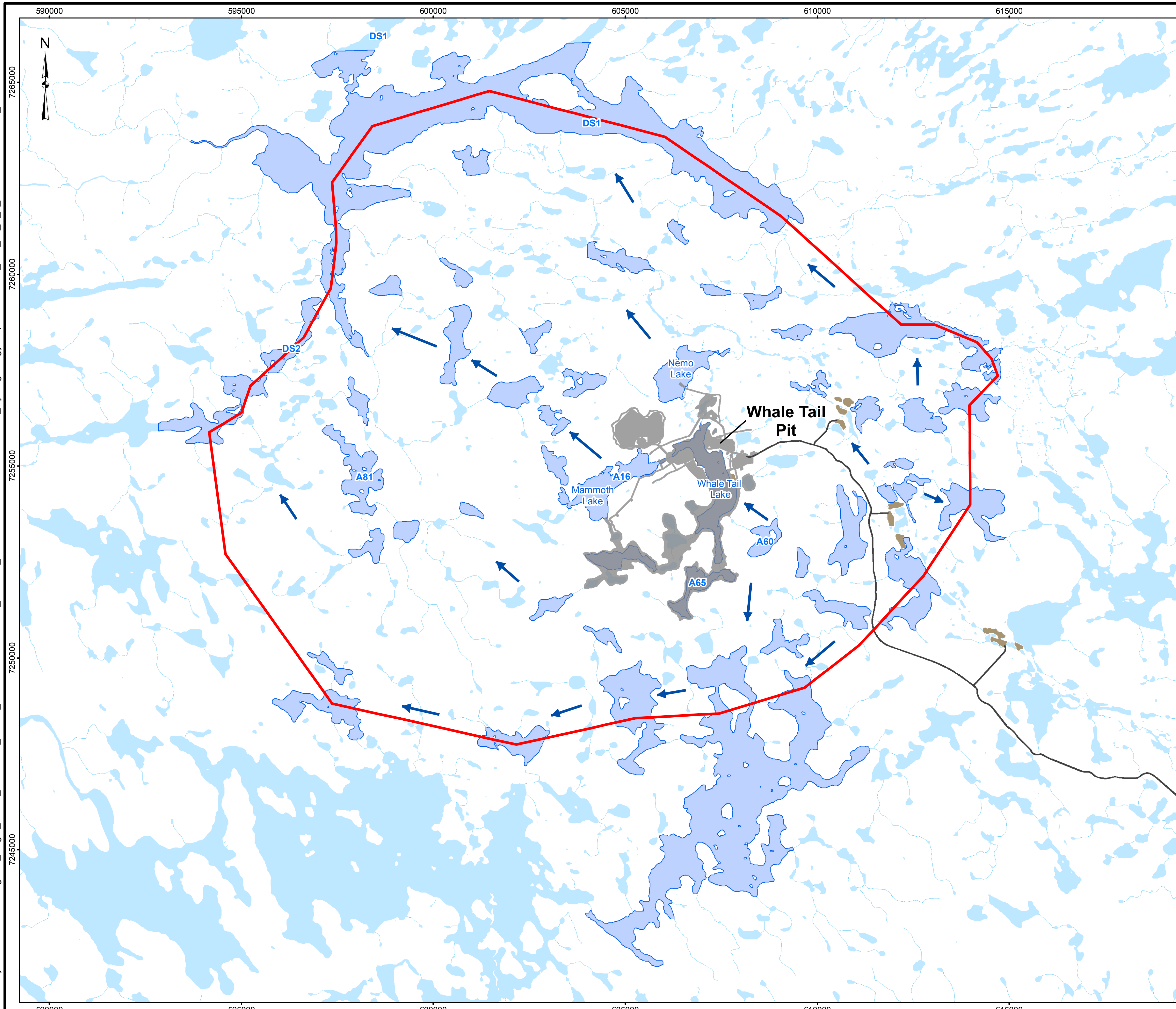
This conceptual model that has been developed to describe key features of the pre-mining hydrogeological regime in the environmental study area is discussed in the Hydrogeology Baseline Report (Volume 6, Appendix 6-A). The key features included in this conceptual model are the groundwater flow quantity and quality and dominant groundwater flow direction. The following sections describe the conceptual hydrogeological models during mining and closure. These conceptual models were used as a basis for the construction of the numerical hydrogeological model.

6.B-2.1 Groundwater Flow – Mining

The conceptual hydrogeological model for groundwater flow conditions near the Project during mining is presented in Figure 6-B-2. The location of the conceptual cross-section is shown in Figure 6-B-1.

The talik below Whale Tail Lake is expected to form a continuous talik channel that is closed at the base in the northern portion of Whale Tail Lake below the open pit and becomes open at the base towards the south and central portion of the lake. The proposed Whale Tail Pit is planned to extend approximately 115 metres (m) below current water level of Whale Tail Lake (152.5 m), with the pit bottom at 37 metres above sea level (masl). The pit is located partially within permafrost and partially within the talik below Whale Tail Lake.

During mining, the open pit will act as a sink for groundwater flow, with seepage faces developing along the pit walls. In response to the deepening of the open pit, groundwater will be induced to flow through bedrock and potentially through enhanced permeability zones (EPZ) to the open pit. Mine inflow will originate from Whale Tail Lake and other nearby lakes with open taliks beneath them, the attenuation pond between the pit and Whale Tail dike, and deep bedrock. The quality of mine inflow will be a result of the mixing from each of these sources.



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LEGEND

- HYDROGEOLOGY BASELINE STUDY AREA
- LAKES WITH TALIK
- WATERBODY (NO TALIK OR OUTSIDE STUDY AREA)
- WATERCOURSE

WHALE TAIL

- BORROW SOURCE
- INFRASTRUCTURE
- PROPOSED HAUL ROAD
- GROUNDWATER FLOW DIRECTION

REFERENCE

1. WHALE TAIL INFRASTRUCTURE OBTAINED FROM AGNICO EAGLE MINES LIMITED ON DECEMBER 21, 2015.
3. WATERCOURSE AND WATERBODY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
4. INSET MAP DATA OBTAINED FROM ESRI

DATUM: NAD 83 CSRS PROJECTION: UTM ZONE 14

2 0 2

KILOMETRES

PROJECT

AGNICO EAGLE

AGNICO EAGLE MINES LIMITED:
MEADOWBANK DIVISION
WHALE TAIL PIT PROJECT

TITLE

HYDROGEOLOGY BASELINE STUDY AREA

Golder Associates

PROJECT		1541520	FILE No.	
DESIGN	JL	06 Apr. 2016	SCALE AS SHOWN	REV. A
GIS	MH	06 Apr. 2016	**FIGURE 6-B-1**	
CHECK	JR	08 Jun. 2016		
REVIEW	JL	08 Jun. 2016		

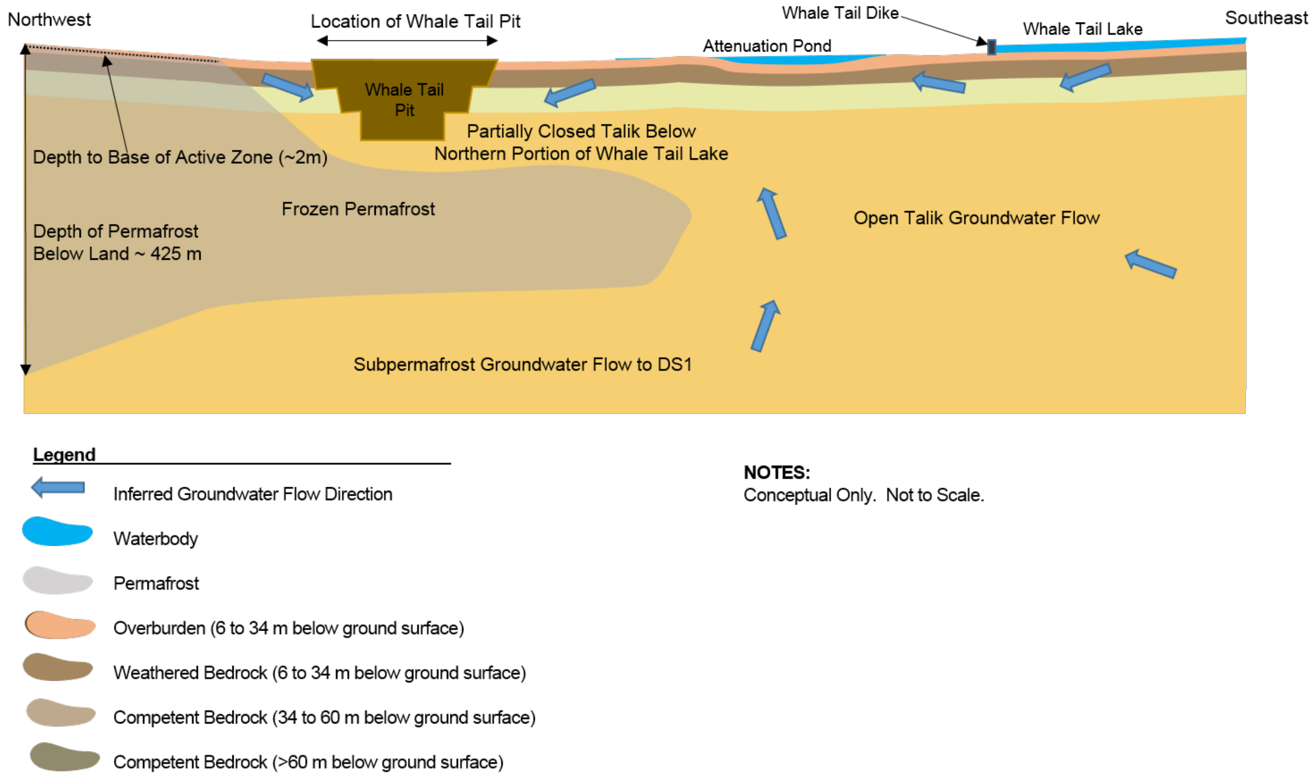

Figure 6-B-2: Conceptual Model of Deep Groundwater Flow Regime during Mining - Cross-Section View

6.B-2.2 Groundwater Flow – Closure

The conceptual hydrogeological model for groundwater flow conditions near the proposed Project during closure is presented in Figure 6-B-3.

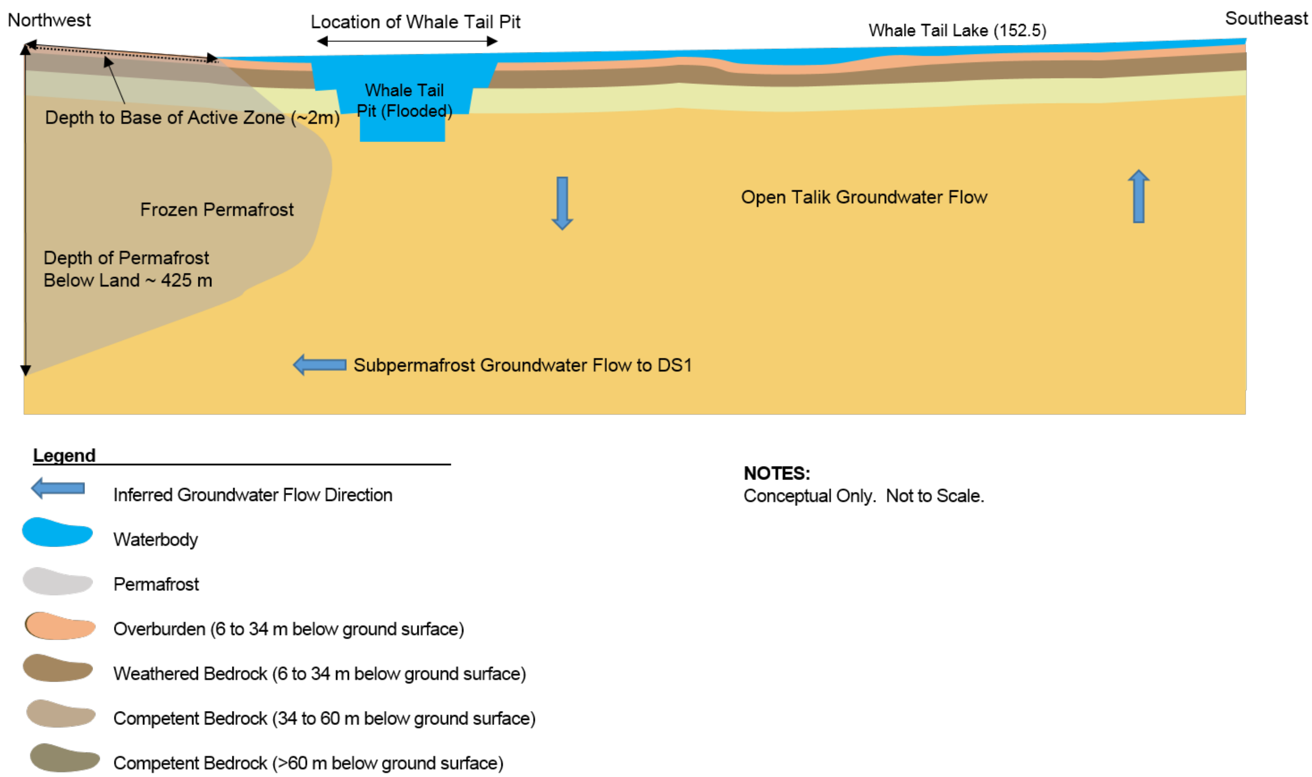

Figure 6-B-3: Conceptual Model of Deep Groundwater Flow Regime during Closure - Cross-Section View

During closure, the open pit will be flooded with water from a variety of sources including: water pumped from the flooded South Whale Tail watershed (shown in Volume 6, Appendix 6-C) until the original Whale Tail Lake level is reached (152.5 m), the north-east watershed (shown in Volume 6, Appendix 6-C) following the breach of the North-East dike, groundwater originating from nearby lakes underlain by open taliks, connate water and water pumped from the attenuation pond (Volume 8, Appendix 8.F-1). This process will dissipate the large hydraulic head differences established during mine operations in the vicinity of the mine workings. The rate of groundwater inflow will decrease as the water level in the open pit rises.

It is estimated that the open pit and dewatered area of Whale Tail Lake surrounding the open pit will be back-flooded over period of approximately seven years.

6.B-3 NUMERICAL HYDROGEOLOGICAL MODEL

A numerical hydrogeological model was constructed based on the conceptual hydrogeological models presented in the previous sections and in the Hydrogeology Baseline Study Area (Volume 6, Appendix 6-A). The purpose of the numerical hydrogeological model is to evaluate the baseline hydrogeological conditions before mining and to estimate the quantity and quality of potential inflows to the open pit during the operations and closure phases of the Project.

6.B-3.1 Model Selection

The numerical code used for the development of a hydrogeological model should be capable of simulating key characteristics and features included in the site conceptual model. Consequently, FEFLOW, a finite-element code from DHI-WASY (Diersch 2016) was chosen for the development of the groundwater model. This code is capable of simulating transient, saturated-unsaturated groundwater flow, and density-coupled solute transport in heterogeneous and anisotropic porous media under a variety of hydrogeologic boundaries and stresses. FEFLOW is particularly well suited for development of the site model because it allows for simultaneous predictions of groundwater flow and solute transport.

6.B-3.2 Model Extent and Mesh Configuration

The extent of the numerical model is based on the understanding of groundwater flow conditions near the Project site, with lateral model boundaries set sufficiently far from the location of the open pit to allow adequate representation of pre-development conditions and potential seepage pathways during operations. The extent of the model corresponds to the extent of the Hydrogeology Baseline Study Area (Volume 6, Appendix 6-A). The mesh is presented on Figure 6-B-4.

Horizontally, the model extends approximately 21 km in an east-west direction and 17 km in a north-south direction, and is roughly centered on the Project. The planar area of the model domain is approximately 242 km^2. In the north and west, the model follows Lake DS1. In the south, the model follows the group of lakes south of watershed A.

The mesh consists of approximately one million triangular elements with uniform spacing of 25 m in the area around Whale Tail Lake where strong hydraulic gradients are expected to develop during mine operations. Elements expand to a size of approximately 350 m along the model perimeter. Overall, the mesh spacing is considered to be of appropriate detail for simulation of hydrogeological conditions at the Project site.

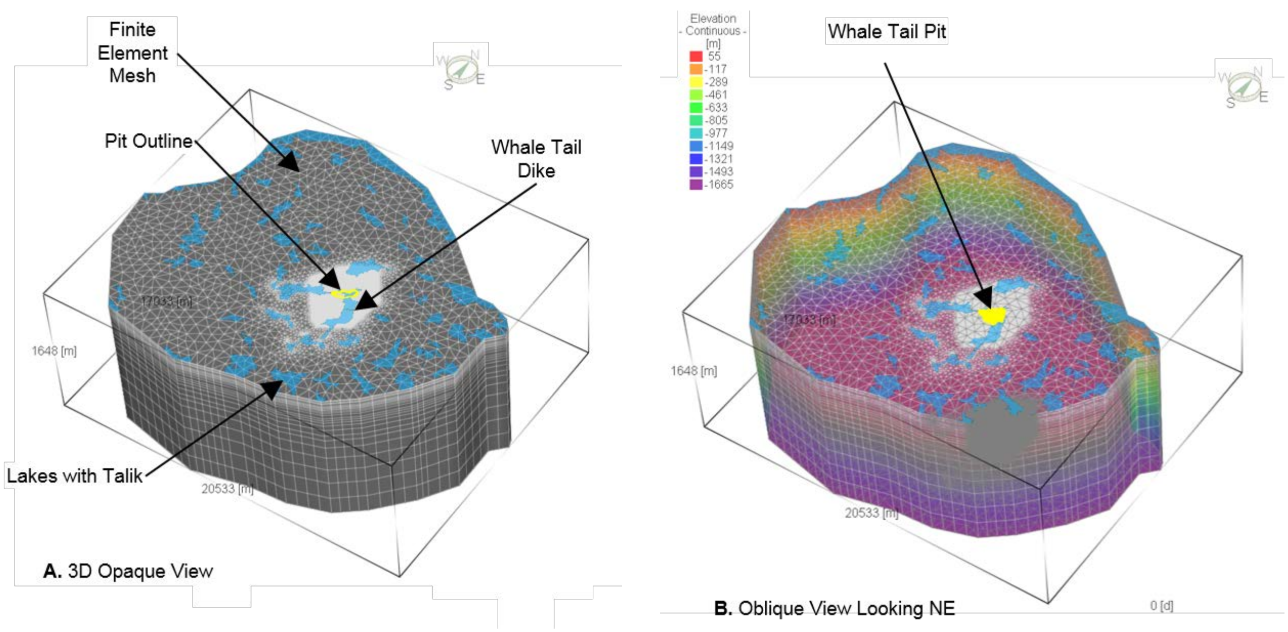

Figure 6-B-4: Hydrogeological Model Finite Element Mesh

Vertically, the model domain is discretized into 29 layers. The top of Layer 1 was set equal to the average planned elevation of dewatering for the area around the open pit during operations (148 masl). The bottom of Layer 29 was set to a constant elevation of -1,500 masl, which is approximately 1,500 m below the ultimate depth of the deepest planned open pit mine level at the Whale Tail Pit (37 masl).

6.B-3.3 Hydrostratigraphy and Model Parameters

Three hydrostratigraphic units, consisting of overburden, weathered bedrock and competent rock were represented in the model as a Base Case Scenario. A summary of the hydrogeological properties of each unit is provided in Table 6-B-1. The Base Case scenario reflects the most likely estimate of hydrogeological conditions that are expected to be encountered during mining. Values of hydrogeological parameters were obtained from in-situ hydrogeologic testing, where available, as discussed in the Hydrogeology Baseline Report (Volume 6, Appendix 6-A). Where in-situ values were not available, values were derived from testing near open pits at the Meadowbank Mine, from other nearby mining sites, and from typical values published in literature. Conservative assumptions have been made for model parameters such that they result in conservative (i.e., high) predictions of mine inflow quantity and quality, including travel times and saline upwelling. For example, the hydraulic conductivity of the competent bedrock below 60 m depth was conservatively assumed to be three times higher than the geometric mean of the packer test results (Volume 6, Appendix 6-A).

Table 6-B-1: Hydrogeological Parameters Used in Model

Hydrostratigraphic Unit	Depth Interval (m)	Reference Case Hydraulic Conductivity (m/s)[a]	Specific Storage (1/m)[b]	Specific Yield (-)[b]	Effective Porosity (-)[b]	Longitudinal Dispersivity (m)[d]	Transverse Dispersivity (m)[d]	Effective Diffusion Coefficient (m^2/s)
Overburden	0 to 6	2×10^{-6}	1×10^{-4}	0.2	0.2	10	1	2×10^{-10}
Weathered bedrock	6 to 34	1×10^{-7}	2×10^{-4}	0.03	0.03	10	1	2×10^{-10}
Competent bedrock	34 to 60	3×10^{-8}	1×10^{-05}	0.0006	0.001	10	1	2×10^{-10}
Competent bedrock	>60	1×10^{-8}	1×10^{-05}	0.0006	0.001	10	1	2×10^{-10}
EPZ[c]	-	5×10^{-7}	1×10^{-4}	0.01	0.01	10	1	2×10^{-10}

[a] Derived from hydraulic testing results as presented in Golder (2016). Ratio of vertical to horizontal hydraulic conductivity assumed to 1:1.

[b] Parameter values within ranges documented in literature (Maidment 1992; Stober and Bucher 2007).

[c] The enhanced permeability zones were included in the sensitivity and in the EA Conservative Scenario presented in Section 6.B-4a. The EPZs were assumed to be vertical and 10 m wide. One EPZ was assumed to strike northwest – south east and hydraulically connect the Whale Tail Pit to Whale Tail Lake. The second EPZ was assumed to strike northeast – southwest. The EPZs were assumed to be continuous and hydraulically connected over the width of the model (approximately 17 kilometres).

[d] Values are consistent with literature values (Schulze-Makuch 2005).

m = metre; m/s = metres per second; m^2/s = squared metres per second.

In-situ hydrogeological testing was inconclusive as to the presence of enhanced permeability zones (EPZs), as indicated by relatively low hydraulic conductivity measurements in packer test intervals that insected potential faults (1×10^{-9} m/s to 5×10^{-8} m/s; Volume 6, Appendix 6-A). Enhanced permeability zones were therefore not included in the Base Case Scenario but their potential effect on groundwater inflow quantity and quality were assessed through sensitivity analysis.

An overall summary of the assumptions and limitations of the numerical modelling is provided in Table 6-B-2, including those associated with the underlying modelling codes.

Table 6-B-2: Assumption and Limitations of the Groundwater Model

Groundwater flow in the bedrock was simulated as "equivalent porous media." Flow in bedrock is assumed to be laminar, steady, and governed by Darcy's Law.
Horizontal mesh discretization of approximately 25 m, and vertical mesh discretization between 6 and 20 m, were used to provide sufficient spatial resolution for simulation of groundwater flow and transport near the open pit.
Values assigned to model input parameters were based on hydrogeological investigations conducted by Knight Piésold (2015), values published for nearby pits at the Meadowbank project, other nearby mining projects, or published in the literature where site-specific data were not available.
Surface waterbodies were simulated using specified head boundaries. It was assumed that the permeability of sediments beneath these waterbodies is similar to the underlying geologic strata. Thus, no restriction of flow between the surface water and individual hydrostratigraphic units was simulated.
Groundwater flow deeper than approximately 1.5 km below ground surface was assumed to be negligible and to have negligible influence on model predictions.

m = metres; km = kilometres.

6.B-3.4 Mine Schedule

The mine schedule discussed in the Project Description (Volume 1, Section 1.4) is summarized in this section. Mining on land is expected to be initiated in approximately June 2018, with active mining in talik below dewatered portions of Whale Tail Lake expected to start in approximately the third quarter (Q3) of 2019. Mining is expected to finish in Q4 of 2021.

Dewatering of pool behind the dike is expected to be initiated and finished in 2019. Pit flooding will commence in 2022 and is expected to reach the top of the pit / base of Whale Tail Lake (138 masl) in 2025. Subsequent re-flooding of Whale Tail Lake (North Basin) will continue until 2028.

6.B-3.5 Model Boundary Conditions

Model boundary conditions provide a link between the model domain and the surrounding hydrologic and hydrogeologic systems. Two types of flow boundary conditions were used in the model; specified head and no-flow (zero-flux) boundaries. The locations of these boundaries are shown in Figure 6-B-5 and are summarized below.

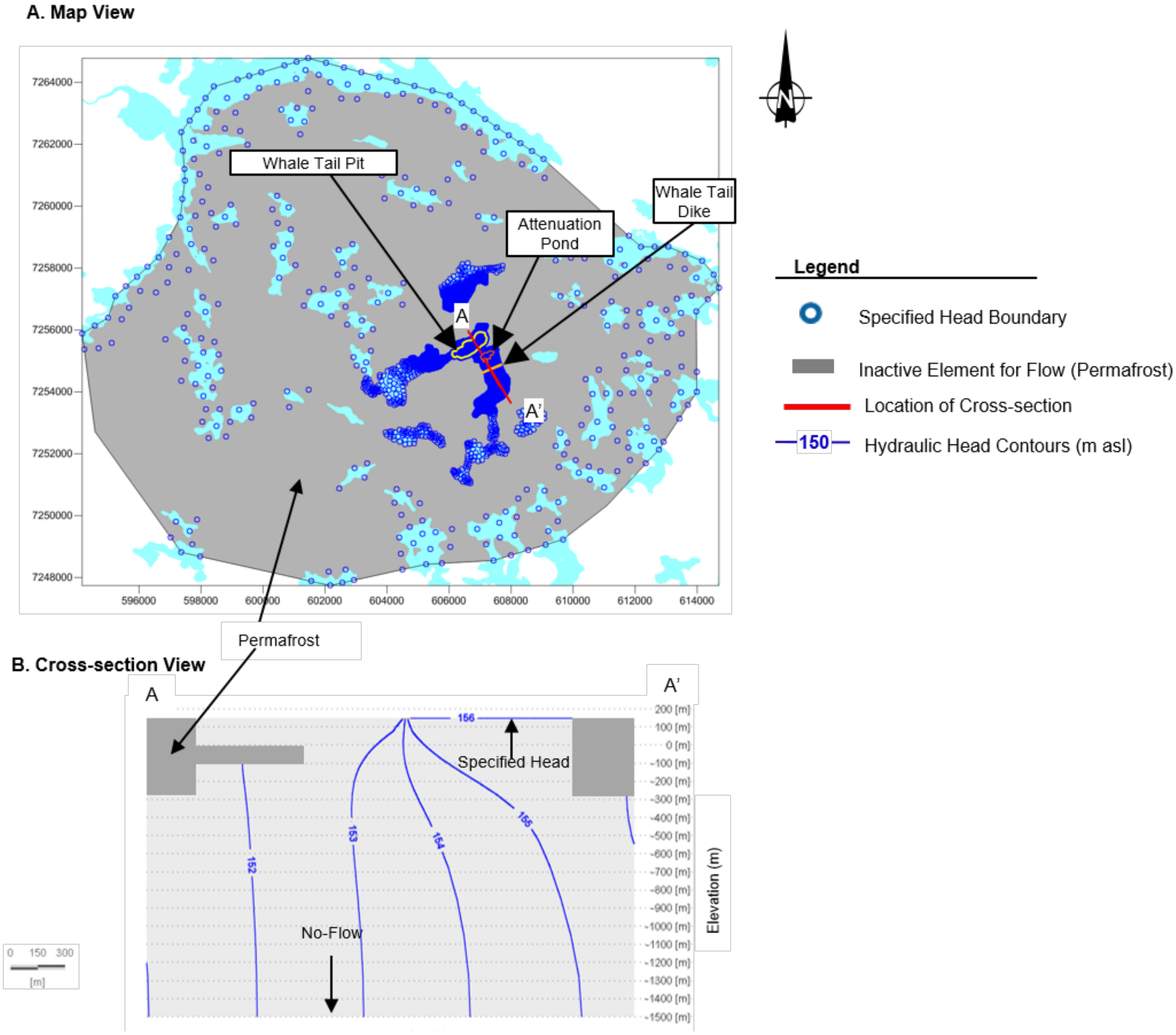

Figure 6-B-5: Boundary and Initial Conditions - Groundwater Flow Hydrogeological Model

Specified head boundaries are assigned to Layer 1 of the model to represent all lakes assumed to have open taliks connected to the deep groundwater flow regime. Each of these boundaries was set to the surveyed average lake elevation. It was conservatively assumed that the surface water/groundwater interaction at all lakes is not impeded by lower-permeability lakebed sediments that may exist on the bottom of some of these lakes.

Specified head boundaries are assigned to Layer 1 of the model to represent the attenuation pond which was conservatively assumed to be unlined. For simplicity this boundary was set to 148 m, the average elevation of the base of dewatered portion of Whale Tail Lake. This hydraulic head is higher than the anticipated operating level of the pond by 3 to 5 m, and this assumption will result in conservatively high gradients between the attenuation pond and the open pit.

During operations, time-variable specified head boundaries were assigned to Layer 1 of the model to represent the lake dewatering and back-flooding in the area within the dike. In the dewatering period, the water level was varied from the original water elevation of Whale Tail Lake (152.5 masl) to the average bottom of lake elevation (148 masl), which varies from approximately 138 masl to 152.5 masl. At the end of mining and after the back-flooding of the open pit during closure, these boundaries were modified such that they represented lake water level recovery to the original elevation of 152.5 masl.

Mine workings (i.e., the open pit) were simulated in the model using time-variable specific head boundaries. At each mesh node within the perimeter of the open pit, a specified head boundary was assigned and the head value at this boundary was varied over time to represent progress of pit excavation according to the mine schedule described in Section 6.B-3.4. In addition, all boundaries representing mine workings during mining were constrained to allow only outflow from surrounding sediments/bedrock into the mine (i.e., these boundaries act as seepage faces). Furthermore, mesh elements inside the open pit in a given model layer were deactivated over time as the mine reached the bottom of the model layer. During closure, these boundaries were modified to reflect the pit lake elevation, with the seepage face constraint removed once the pit lake was above the nodal elevation.

No-flow boundaries were used to represent inferred groundwater flow divides and flow lines along the perimeter of the model. These boundaries were located sufficiently far from the mine to have only a negligible impact on model predictions. The effect of these no-flow boundaries on model predictions was assessed as part of the sensitivity analysis discussed in Section 6.B-3.7.3. A no-flow boundary was also applied along the bottom of the model at a depth of 1.6 km below ground surface (-1,500 masl). Flow at greater depth is expected to be negligible, and therefore, to have negligible impact on model predictions. No-flow boundaries were also assigned along the edges of the permafrost as the permafrost is essentially impermeable. Mesh elements representing permafrost were deactivated in all model simulations.

Initial groundwater flow conditions represent the pre-mining flow regime described in the Hydrogeology Baseline Report (Volume 6, Appendix 6-A), where the groundwater flow pattern is controlled by the water elevations of the large lakes in the hydrogeology study area. The groundwater flow pattern predicted by the hydrogeologyical model simulating pre-mining conditions was evaluated qualitatively to assess if it was in agreement with the conceptual understanding of baseline groundwater conditions. This groundwater flow pattern was then used as initial conditions in the hydrogeological model.

6.B-3.6 Transport Boundary Conditions and Initial Conditions

Three types of boundary conditions were used to simulate transport of TDS in groundwater: specified concentration boundaries, zero flux boundaries, and exit (Cauchy type) boundaries. The location of these boundaries is shown in Figure 6-B-6.

Specified concentration boundaries of zero milligrams per litre (mg/L) (freshwater) were assigned along the bottom of all lakes assumed to have open taliks in connection with the deep groundwater flow regime.

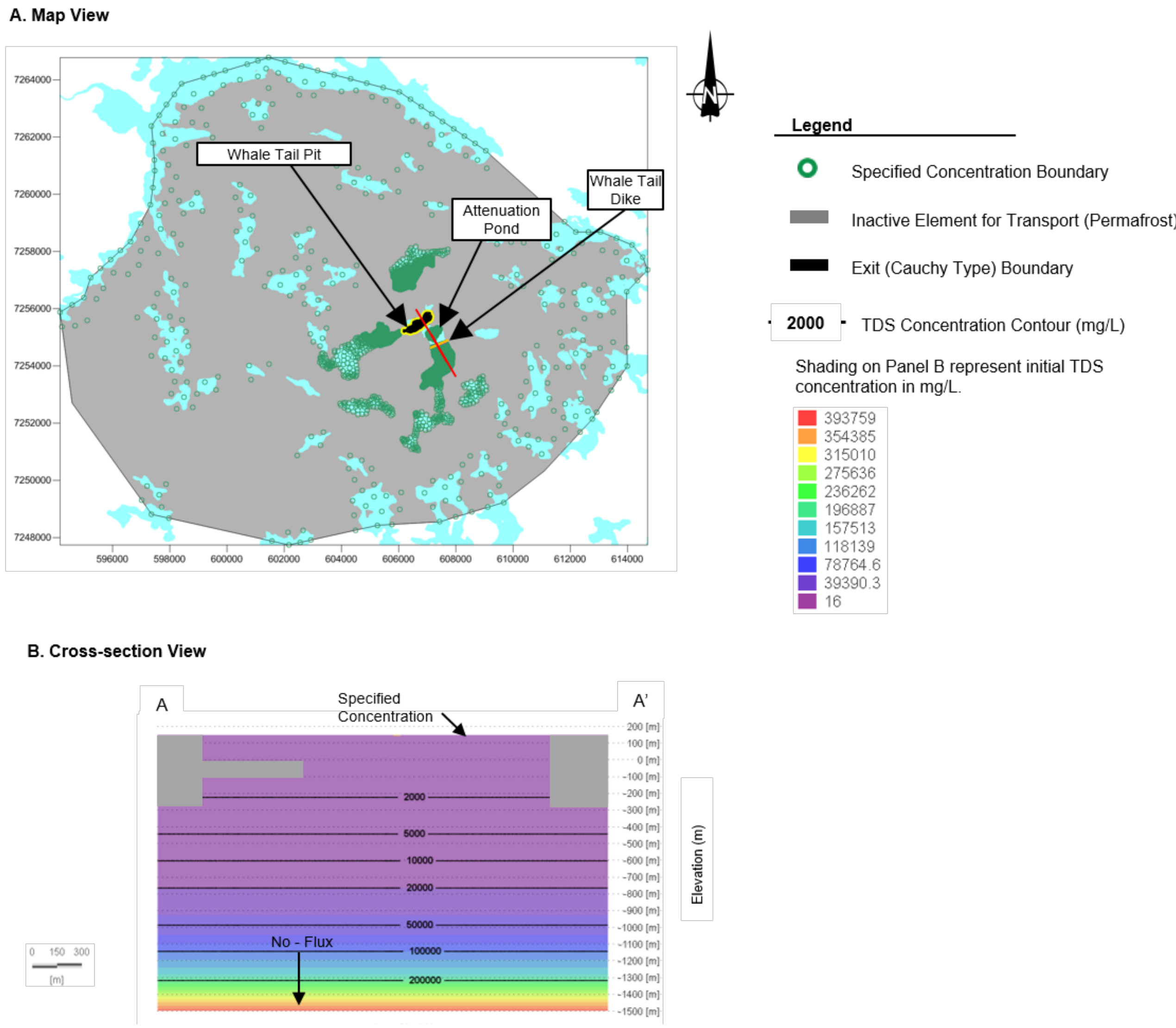

Figure 6-B-6: Boundary and Initial Conditions - Solute Transport Hydrogeological Model

A specified concentration boundary of 499 mg/L was assigned along the bottom of the attenuation pond, to represent the TDS concentration in pond water seeping into the groundwater flow system. The specified concentration was constrained such that if groundwater was predicted to discharge to the pond, the boundary switches to an Exit (Cauchy type) boundary, which simulates the movement of TDS out of the surrounding groundwater flow system and into the pond. Groundwater inflow pumped from Whale Tail Pit will be placed in the attenuation pond and was assumed to control the TDS concentration of seepage loss from the pond to the groundwater flow system. A concentration of 499 mg/L represents the average TDS concentration within the talik in the area of the open pit, and therefore represents a conservative estimate of the potential TDS concentration in the attenuation pond water. In reality the TDS concentration will likely be lower as the pond receives some fresh water sources, and because initially the pit intersects less saline water.

Zero-flux boundaries were applied along the bottom of Layer 23, 1.6 km below ground surface. Mass flux from beneath this depth was considered to have negligible impact on model predictions.

Exit (Cauchy type) boundaries were assigned to the nodes representing the pit walls. These boundaries simulated the movement of TDS mass out of the surrounding groundwater system and into the mine workings.

Initial TDS concentrations in each model layer were assigned based on the assumed Whale Tail TDS depth profile discussed in the Hydrogeology Baseline Report (Volume 6, Appendix 6-A) and shown in Figure 6-B-6.

6.B-3.7 Model Predictions – Base Case

The following sections presents predicted hydrogeological conditions for the Project based on the hydrogeological parameters discussed in Section 6.B-3.3 and presented in Table 6-B-1. These predictions are hereafter referred to as Base Case predictions. Uncertainty in the predicted groundwater quantity and quality resulting from the uncertainty in these parameters is discussed Section 6.B-3.7.3.

6.B-3.7.1 Current Conditions

Predicted hydrogeological conditions for pre-mining flow are presented in Figure 6-B-7. The predominant groundwater flow direction in the deep groundwater flow regime is to the northwest to Lake DS1. During pre-mining the northern portion of Whale Tail Lake represents a groundwater recharge zone, with water discharging from the Lake to DS1. The southern portion of the lake represents a groundwater discharge zone, with water discharging to Whale Tail Lake from A60 to the southeast.

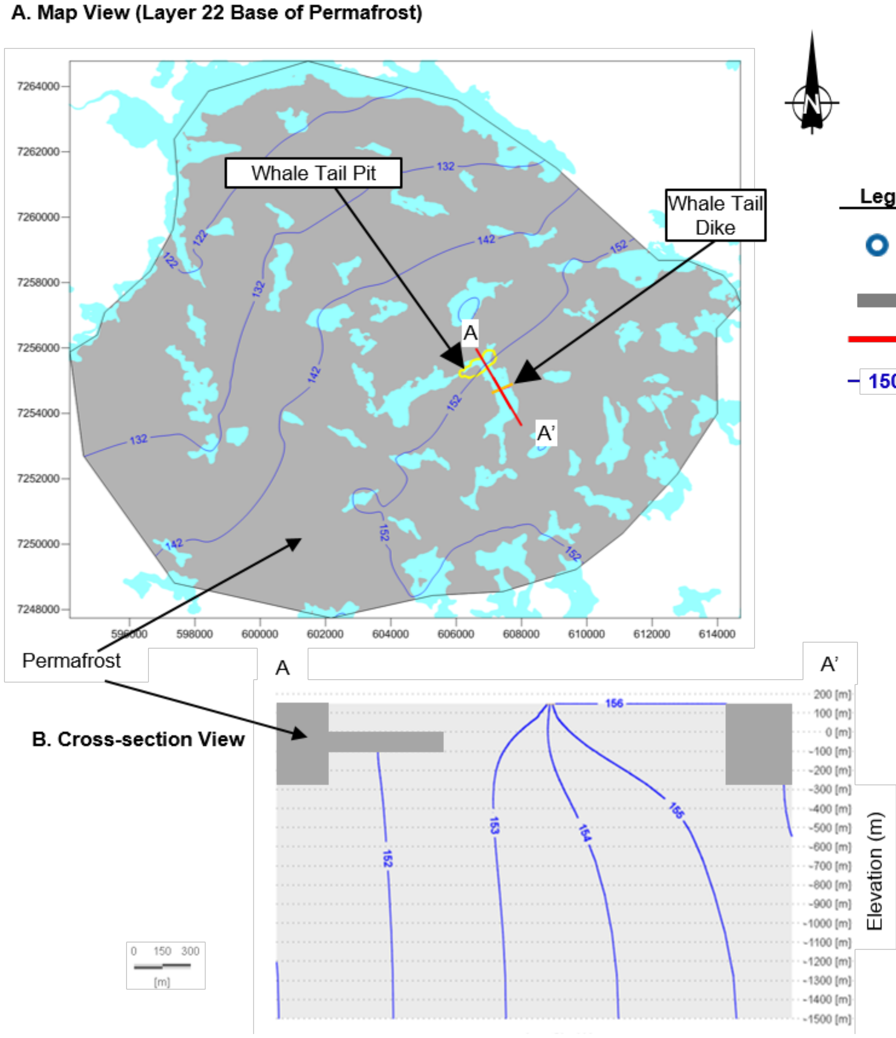

Figure 6-B-7: Predicted Hydraulic Heads - Pre-mining Conditions Hydrogeological Model

6.B-3.7.2 Mining and Closure

Predicted hydrogeological conditions when the open pit reaches its ultimate depth (37 masl) are presented in Figure 6-B-8 and Figure 6-B-9 for the Base Case. Predicted groundwater inflow quantity and quality over the mine life including closure are presented in Table 6-B-3. Initial mining outside of the in-water area (i.e., within the permafrost) in 2018 and 2019 is excluded as groundwater flow through permafrost is expected to be negligible.

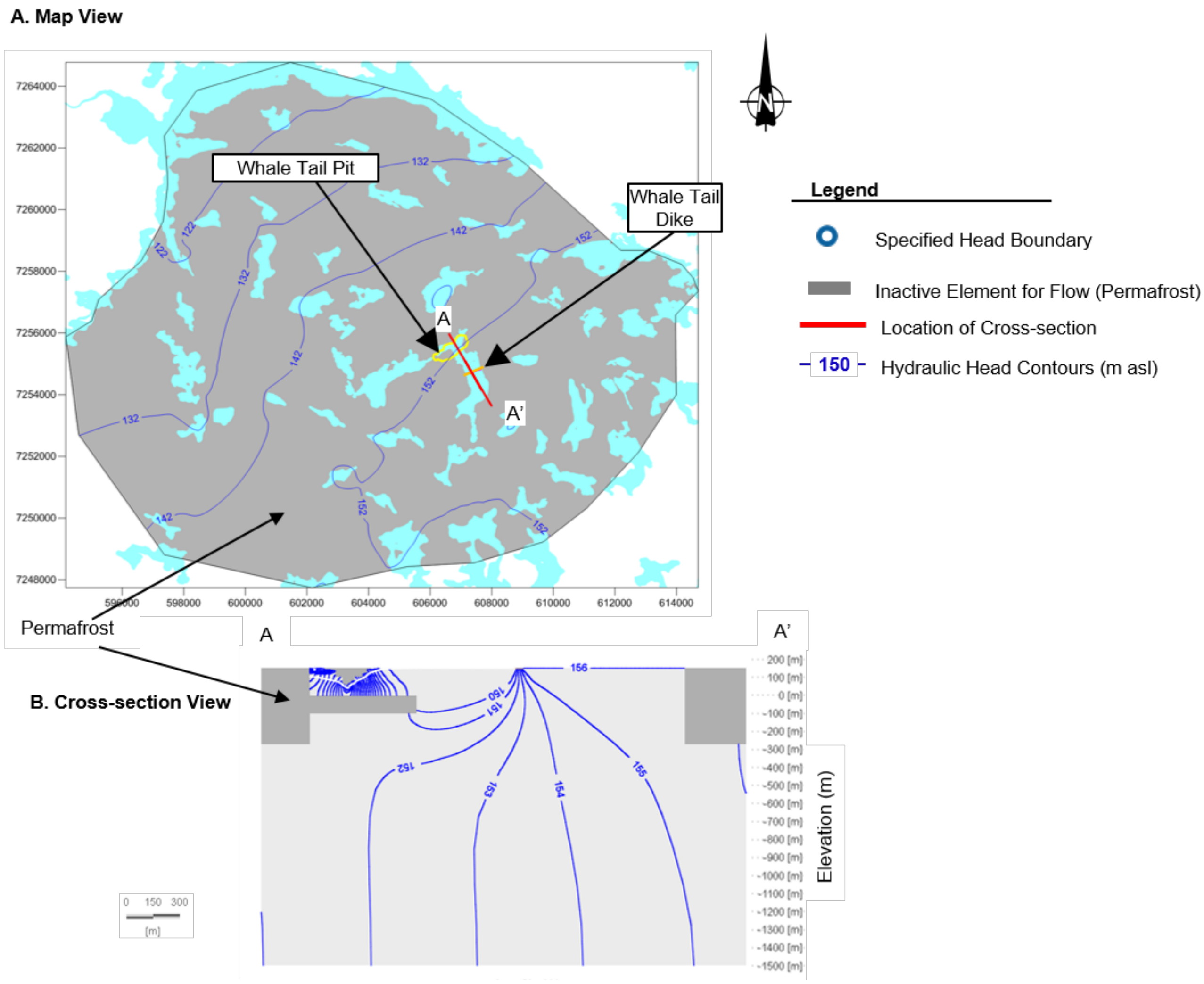

Figure 6-B-8: Predicted Hydraulic Heads - End of Mining - Base Case Scenario

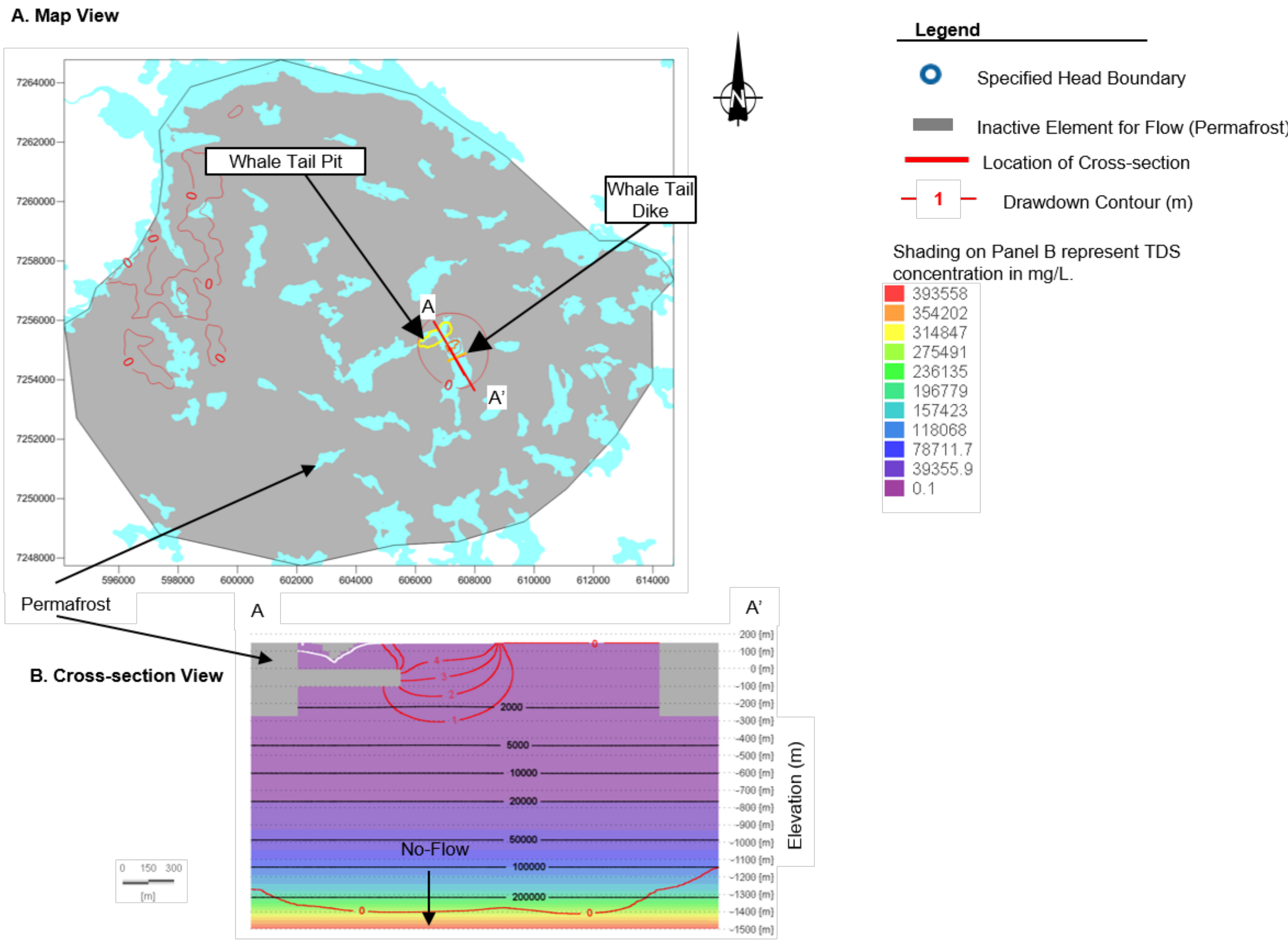

Figure 6-B-9: Predicted Drawdown and Total Dissolved Solids - End of Mining - Base Case Scenario

Table 6-B-3: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life - Whale Tail Pit (Base Case)

Phase	Period	Whale Tail Pit – Base Case Scenario			
		Groundwater Inflow (m^3/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m^3/day)
Dewatering	Mar 2019 to Oct 2019	-	-	-	-
Mining	Q4 2019 to 2020	195	390	<5%	-
	2021	65	440	<5%	-
Filling	2022	30	380	<5%	5
	2023	20	350	<5%	5
	2024	15	350	<5%	5
	Jan to Oct 2025	5	345	<5%	5
	Nov 2025 to Oct 2028	0	340	<5%	30

Note: Mining prior to Q4 2019 is within permafrost and groundwater inflow will be negligible.
TDS = total dissolved solids; m^3/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

In the first year of mining within the talik (Q4 2019 to end of 2020), much of the groundwater inflow to the pit is attributed to water released from storage in the overburden and shallow bedrock beneath Whale Tail Lake but within the footprint of the dike. In the second year of mining within the talik (2021), these units will have generally dewatered, and groundwater inflow to the pit is through the surrounding bedrock. As shown in Table 6-B-3, groundwater inflow to the Whale Tail Pit is therefore predicted to decrease from 195 m^3/day (Q4 2019 – 2020) to 65 m^3/day at the end of mining (pit bottom of 37 masl; 2021).

Predictions of groundwater inflow only consider groundwater inflow to the proposed open pit, and do not include potential inputs from direct precipitation within the footprint of the open pit and/or surface water runoff from the surrounding areas. Therefore, dewatering rates may be higher than the groundwater inflow rates described in this section. The site wide water balance assumes a runoff coefficient of one for the area surrounding Whale Tail Lake and the open pit (Volume 6, Appendix 6-H). The water balance therefore accounts for the potential flow of water through the active layer (which is hydraulically driven by snow melt and precipitation), and this flow is not included in this analysis.

Predictions of TDS concentration in mine inflow were based on the Whale Tail TDS depth profile presented in the Hydrogeology Baseline Report (Volume 6, Appendix 6-A). Based on this profile, the groundwater model predicts that the TDS concentration in inflow to the open pit would increase during mining from approximately 390 mg/L to 440 mg/L once the pit reaches its ultimate configuration in 2021 (Table 6-B-3). The limited increase in TDS reflects the short mine life within the talik and the minimal upwelling of higher salinity waters at depth.

Groundwater inflow to the open pit during the refilling is predicted to gradually decrease from 20 m^3/day to near zero in the final year of filling. The majority of this inflow originates from the bedrock between the Whale Tail Dike and the pit. To the north of the Whale Tail Pit, where the bedrock is somewhat isolated from the diked Whale Tail Lake, the pit lake recharges the groundwater flow system. The groundwater recharge during the pit refilling is approximately 5 m³/day. During the refilling of the dewatered area of Whale Tail Lake, the recharge to the groundwater flow system from this reflooding increases to 30 m³/day as the overburden and remaining weathered bedrock is re-saturated. The TDS level in the groundwater inflow to the pit during refiling is predicted to decrease to an average of 340 mg/L at the end of filling.

Contribution to groundwater inflow to the pit from lake water or from the attenuation pond during mining and closure is predicted to be negligible (less than 5%; Table 6-B-3). This is attributed to the relatively short period of mining within the talik (Q4 2019 to the end of 2020) with majority of the groundwater originating from these sources not reaching the open pit within the mine life. Table 6-B-4 and Table 6-B-5 present the predicted groundwater inflow quantity and quality to the attenuation pond and diked area between the pit and the diked Whale Tail Lake during mining and closure.

Table 6-B-4: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life – Attenuation Pond (Base Case)

Phase	Period	Attenuation Pond – Base Case Scenario			
		Groundwater Inflow (m³/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m³/day)
Dewatering	Mar 2019 to Oct 2019	-	-	-	-
Mining	Q4 2019 to 2020	2	160	<5	1
	2021	1	170	<5	1
Filling	2022	1	195	<5	3
	2023	1	175	<5	4
	2024	1	175	<5	5
	Jan to Oct 2025	1	175	<5	6
	Nov 2025 to Oct 2028	-	-	-	-

m³/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

Table 6-B-5: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life – Diked Area Outside of Whale Tail Pit and Attenuation Pond (Base Case)

Phase	Period	Diked Area – Base Case Scenario			
		Groundwater Inflow (m^3/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m^3/day)
Dewatering	Mar 2019 to Oct 2019	100	115	<5%	-
Mining	Q4 2019 to 2020	30	270	<5%	-
	2021	30	290	5	-
Filling	2022	25	285	10	-
	2023	20	275	10	-
	2024	20	265	15	-
	Jan to Oct 2025	20	260	20	-
	Nov 2025 to Oct 2028	20	250	20	100

m^3/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

At the end of pit filling, the hydraulic gradient between the flooded pit and the surrounding surface water is expected to be negligible. An open talik would likely form below the footprint of the open pit, based on the depth and radius of the mine workings. Predictive simulations with an open talik below the pit lake indicate that the post closure groundwater flow directions would be similar to pre-mining conditions.

6.B-3.7.3 Sensitivity Analysis

Due to the inherent uncertainty in the subsurface conditions and parameters controlling groundwater flow, uncertainty exists in the model predictions such that the actual inflow could be higher or lower than the Base Case values. This uncertainty was evaluated using sensitivity analysis. As part of this analysis, selected model parameters were systematically varied from the Base Case values, and the results were used to identify the parameters to which predicted groundwater inflow was most sensitive.

Six model input parameters were included in the sensitivity analysis. These included:

- **Bedrock Hydraulic Conductivity** – Hydraulic conductivity of weathered and competent bedrock was increased by a factor of three from Base Case Values.
- **Presence of Enhanced Permeability Zones** – Two EPZs were inferred to be present based on the review of the structural features of the Project Area (Volume 6, Appendix 6-A). The EPZs were assumed to be vertical and 10 m wide with a hydraulic conductivity of 5×10^{-7} m/s. One fault was assumed to strike northwest – south east and hydraulically connect the Whale Tail Pit to Whale Tail Lake. The second fault was assumed to strike northeast – southwest. The EPZs were assumed to be continuous and hydraulically connected over the width of the model (approximately 17 km).
- **TDS** – The TDS profile was increased by a factor of two at all depths.

- **Specific Yield and Specific Storage** – Specific storage was increased by a factor of 5 and specific yield (was increased by a factor of 2.5 in weathered and competent bedrock.
- **Boundary Conditions** – Constant head boundary conditions were set along the perimeter of the model in all layers to assess the potential effect of lateral boundaries on predicted inflow.
- **Permafrost** – The permafrost present below the open pit was removed and an open talik was assumed to be present.

The sensitivity factors summarized above were selected to adequately represent potential uncertainty in each model parameter. During analysis, six simulations were completed (one adjustment for each parameter considered). At the end of each simulation, predicted maximum average groundwater inflow and maximum TDS concentrations in the open pit were compared to the values predicted in the Base Case (Table 6-B-6).

Table 6-B-6: Hydrogeological Model - Results of Sensitivity Analysis

Sensitivity Simulation	Groundwater Inflow				TDS Concentration			
	m^3/day		% change		m^3/day		% change	
	Q4 2019 to 2020	2021	Q4 2019 to 2020	2021	Q4 2019 to 2020	2021	Q4 2019 to 2020	2021
Base Case	195	65	NA	NA	390	440	NA	NA
Bedrock Hydraulic Conductivity	260	90	33	39	405	395	4	-10
Presence of EPZs	205	75	5	15	410	460	5	5
TDS	195	65	0	0	780	880	100	100
Sy and Ss	285	105	46	62	440	500	13	14
Boundary Conditions	195	65	0	0	390	440	0	0
Permafrost	210	95	8	46	420	660	8	50

EPZs = enhanced permeability zones; Ss = specific storage; Sy = specific yield; NA = not applicable; m^3/day = cubic metres per day; % = percent; TDS = Total Dissolved Solids; Q4 = Fourth Quarter.

Results of the sensitivity analysis indicate that the quantity of groundwater inflow predicted for the Whale Tail Pit is most sensitive to the hydrogeological parameters assigned to bedrock (specific storage, specific yield and hydraulic conductivity), and to the presence of permafrost below Whale Tail Pit. Considering the range of these properties simulated, the predicted groundwater inflow to the pit could be between 33 and 62% higher than the Base Case depending on the simulated year of mining. Predicted groundwater inflow to the pit was somewhat sensitive to the presence of EPZs. With the inclusion of the two EPZs, the predicted groundwater inflow to the pit was predicted 5 to 15% higher than the Base Case predictions depending on the simulated year of mining. Other parameters considered in the sensitivity analysis had negligible influence on predicted groundwater inflow quantity.

Results of the sensitivity analysis indicate that the predicted TDS concentration of mine inflows is directly related to the TDS depth profile. When the TDS concentrations were increased by a factor of two at all depths, the maximum concentration in groundwater inflow was also predicted to double (100% higher than the Base Case). Predicted mine inflow quality was also sensitive to the presence of permafrost at the base of the pit. If an open talik is assumed below the pit, the predicted TDS concentration in the groundwater inflow to the pit was predicted to increase to 660 mg/L at the end of mining (or 49% higher than the Base Case) because of increased saline upwelling.

6.B-4 MODEL PREDICTIONS – ENVIRONMENTAL ASSESSMENT CONSERVATIVE SCENARIO

The Base Case predictions discussed in the preceding section provide the most likely predictions of groundwater inflow quantity and quality for the Project and the associated sensitivity analyses quantify the uncertainty in these predictions. Based on these results, a model scenario was prepared that provides a reasonable upper bound of potential groundwater inflow to the mine. This scenario, hereafter referred to as the Environmental Assessment (EA) Conservative Scenario, results in a sufficient level of conservatism to provide a high level of confidence that the potential effects on the environment have not been underestimated.

In the EA Conservative Scenario, the following changes were made to the model parameters adopted in the Base Case.

- the hydraulic conductivity of the weathered bedrock and competent bedrock was assumed to be approximately three times higher than the base case values; and
- the two theoretical EPZs included in the Base Case sensitivity analysis were assumed to be present.

6.B-4.1 Predicted Groundwater Inflow Quantity and Quality

Predicted groundwater inflow quantity and quality over the mine life for the EA Conservative Scenario are presented in Table 6-B-7 to Table 6-B-9. Predicted hydrogeological conditions when the mine workings reach the ultimate depth are presented on Figure 6-B-10 and Figure 6-B-11.

Table 6-B-7: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life - Whale Tail Pit (EA Conservative Scenario)

Phase	Period	Whale Tail Pit – EA Conservative Scenario			
		Groundwater Inflow (m^3/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m^3/day)
Dewatering	Mar 2019 to Oct 2019	-	-	-	-
Mining	Q4 2019 to 2020	275	415	<5%	-
	2021	100	410	<5%	-
Filling	2022	65	370	<5%	10
	2023	55	365	<5%	1
	2024	30	370	<5%	2
	Jan to Oct 2025	15	370	<5%	5
	Nov 2025 to Oct 2028	1	370	<5%	18

Note: Mining prior to Q4 2019 is within permafrost and groundwater inflow will be negligible.
TDS = total dissolved solids; m^3/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

Table 6-B-8: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life – Attenuation Pond (EA Conservative Scenario)

Phase	Period	Attenuation Pond – EA Conservative Scenario			
		Groundwater Inflow (m^3/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m^3/day)
Dewatering	Mar 2019 to Oct 2019	-	-	-	-
Mining	Q4 2019 to 2020	4	175	<5	2
	2021	2	200	<5	10
Filling	2022	2	220	<5	15
	2023	1	215	<5	20
	2024	1	215	<5	25
	Jan to Oct 2025	1	215	<5	25
	Nov 2025 to Oct 2028	-	-	-	-

m^3/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

Table 6-B-9: Predicted Groundwater Inflow and Groundwater Quality Over the Mine Life – Diked Area Outside of Whale Tail Pit and Attenuation Pond (EA Conservative Scenario)

Phase	Period	Diked Area – EA Conservative Scenario			
		Groundwater Inflow (m^3/day)	TDS Concentration (mg/L)	Lakewater or Pondwater in Total Inflow (%)	Pit Lake Outflow to Groundwater (m^3/day)
Dewatering	Mar 2019 to Oct 2019	140	145	<5%	-
Mining	Q4 2019 to 2020	75	295	<5%	-
	2021	70	280	15	-
Filling	2022	60	250	25	-
	2023	40	225	35	-
	2024	40	210	40	-
	Jan to Oct 2025	40	195	45	-
	Nov 2025 to Oct 2028	40	180	50	160

m^3/day = cubic metres per day; mg/L = milligrams per litre; % = percent.

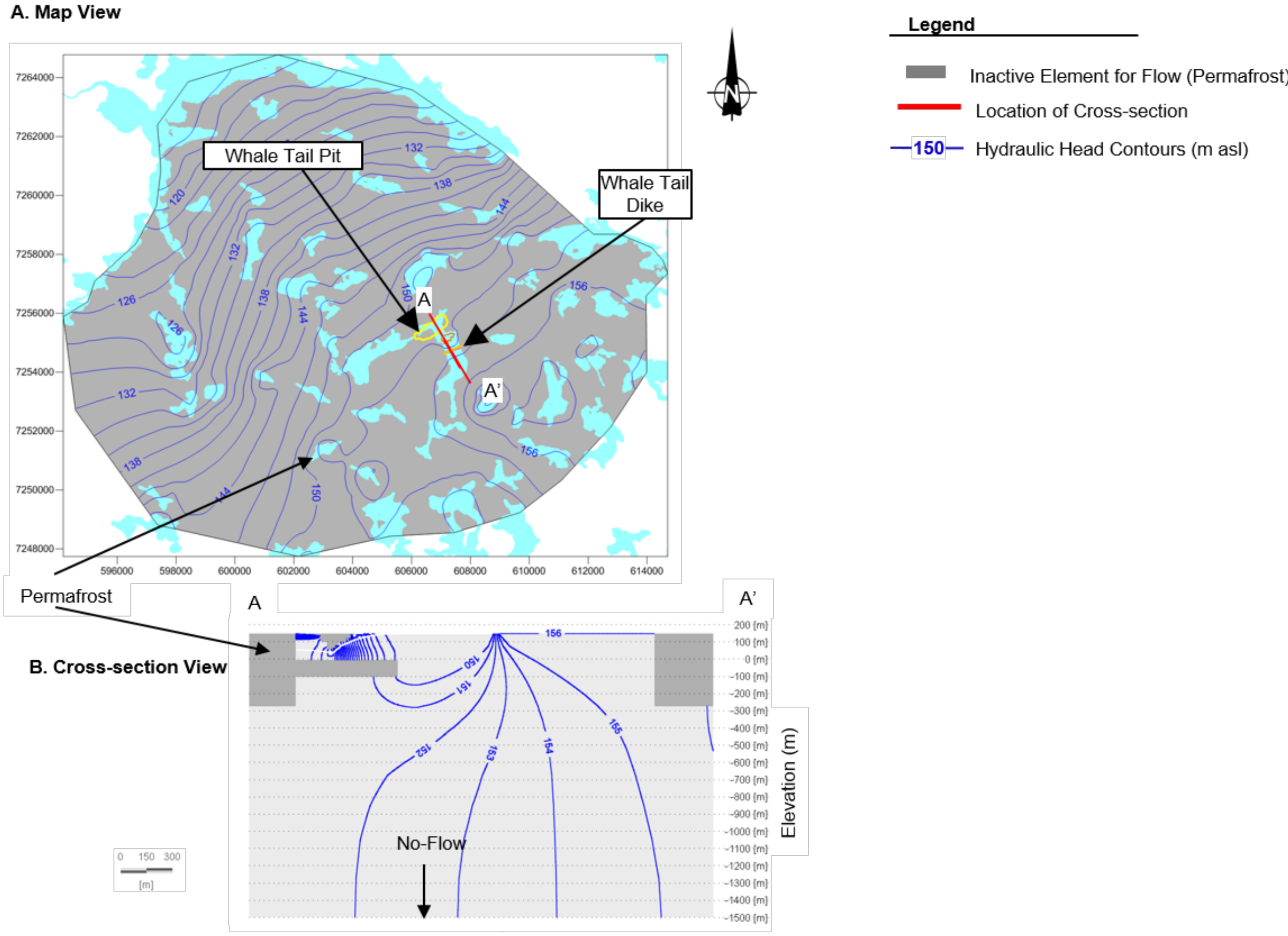

Figure 6-B-10: Predicted Hydraulic Heads - End of Mining – Environmental Assessment Conservative Scenario

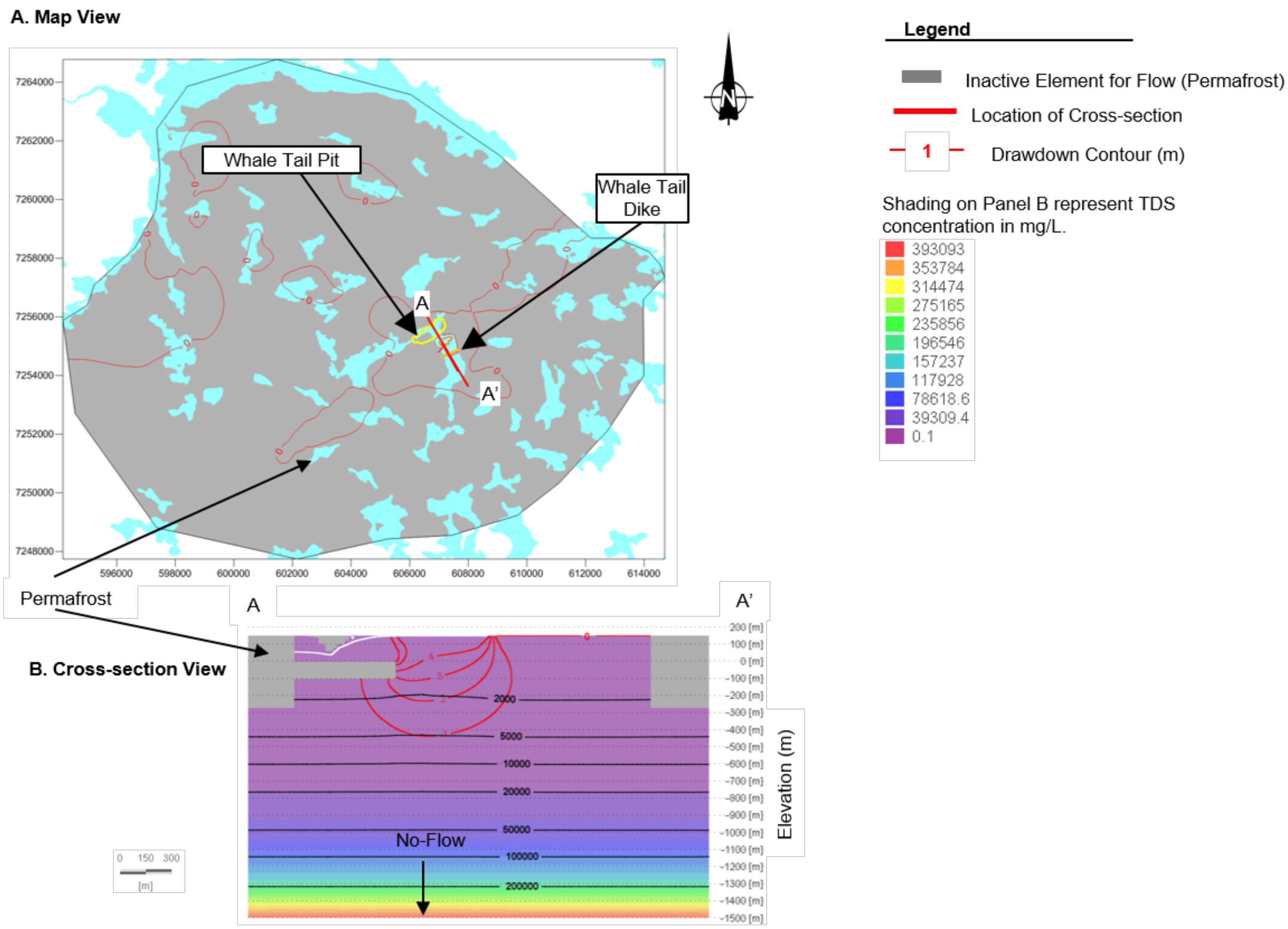

Figure 6-B-11: Predicted Drawdown and Total Dissolved Solids End of Mining - Environmental Assessment Conservative Scenario

The quantity of groundwater inflow predicted in the EA Conservative Scenario over the mine life is overall higher than the Base Case. For the EA Conservative Scenario, the groundwater inflow to the open pit was predicted decrease from an average of 275 m^3/day (Q4 2019 – 2020) to 100 m^3/day (2022). These groundwater inflow rates are 41% and 54% higher than the Base Case values respectively for the same period of mining.

The predicted TDS concentrations in inflow are generally similar to the Base Case values; however, the TDS mass loading into the open pit is predicted to increase by approximately 41% to 54% compared to the Base Case predictions due to higher groundwater inflow quantity predicted tin the EA Conservative Scenario.

6.B-4.2 Predicted Changes to Groundwater Inflows and Outflows from Lakes

Budget analyses were performed to estimate the changes to pre-mining groundwater inflows and outflows from lakes within the Hydrogeology Baseline Study area during mining and following closure (i.e., after the pit and Whale Tail Lake is flooded back to 152.5 m).

Table 6-B-10 presents a summary of lakes within the Hydrogeology Baseline Study area that had a predicted change (greater than 1 m^3/day) in groundwater inflow and outflow relative to pre-Project (current) conditions. Long-term closure conditions considers the potential formation of an open talik below the pit footprint, as a result of the widening/deepening of the lake in this area.

Table 6-B-10: Predicted Groundwater Inflows and Outflows from Lakes at End of Mining and Following Closure

Lake	Pre-Project (Current) Conditions	End of Mining (2021)		Post-closure	
	(m^3/day)	(m^3/day)	(% change of Pre-Project)	(m^3/day)	(% change of Pre-Project)
A16	16	15	-6	16	0
A60	29	28	-3	29	0
A65	3	2	-33	3	0
A81	-47	-42	-11	-47	0
DS1	-171	-140	-18	-171	0
DS2	-25	-21	-16	-21	0

Note: Positive number denotes that the lake is a source of groundwater recharge. Negative number denotes that the lake is a groundwater discharge zone.

m^3/day = cubic metres per day; % = percent.

As presented in Table 6-B-10, groundwater inflow/outflow to these six lakes was predicted to decrease during mining relative to pre-mining conditions by between 3 to 33% depending on the lake. Following closure, near to pre-mining hydraulic gradients and groundwater flow directions will be re-established once the open pit and dewatered portion of Whale Tail Lake are flooded during closure. Consistent with pre-development conditions, groundwater from Whale Tail Lake and the open pit is predicted to discharge to Lake DS1. Groundwater inflow to southern portion of Whale Tail Lake will also occur from Lake A60 to the southeast.

Hydraulic gradients following closure were used to estimate groundwater travel times from the Whale Tail Lake and the open pit to DS1. Based on the shortest travel time, water from Whale Tail Lake or the open pit was predicted to take over 1,000 years to reach Lake DS1.

6.B-5 CONCLUSION

The results of hydrogeological modelling were used to estimate the quantity and quality (TDS) of groundwater inflow to the Whale Tail Pit. In the Base Case, which is based on conservative estimates of hydrogeological parameters controlling groundwater conditions near the open pit, the average groundwater inflow is predicted to decrease over the approximate two years of mining from 195 m^3/day (Q4 2019 to 2020) to 65 m^3/day (2021). Over these same periods, the predicted TDS concentration in the groundwater inflow to the pit was predicted to increase from 390 mg/L to 440 mg/L.

In the EA Conservative Scenario, which represents a reasonable upper bound of conditions that could be encountered during mining, the groundwater inflow to the proposed pit is predicted to decrease from 275 m^3/day (Q4 2019 to 2020) to 100 m^3/day (2022), or approximately 41% to 55% higher than the Base Case. As the TDS in groundwater mine inflow predicted in the EA Conservative Scenario is similar to the one predicted in the Base Case, this corresponds to an approximate 41% to 55% increase in TDS mass loading to the open pit. The EA

Conservative Scenario results in a sufficient level of conservatism to provide a high level of confidence that the potential effects on the environment from changes to groundwater have not been underestimated.

6.B-6 REFERENCES

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