6-A: Addendum Hydrogeology Baseline Report

REPORT

Hydrogeology Baseline Report

Whale Tail Pit - Expansion Project

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1.0 INTRODUCTION

Agnico Eagle Mines Limited: Meadowbank Division (Agnico Eagle) is proposing to develop the Whale Tail Pit, IVR Pit and Underground operations on the Amaruq property (Figure 1; Expansion Project), in continuation of mine operations and milling of the Meadowbank Mine. The Amaruq Exploration property is a 408 square kilometre (km^2) site located on Inuit Owned Land approximately 150 kilometres (km) north of the hamlet of Baker Lake and approximately 50 km north of the Meadowbank Mine in the Kivalliq region of Nunavut.

The Approved Project supports mining an initial amount of approximately 8.3 million tonnes of ore from one open pit, the Whale Tail Pit, processed over a three to four-year mine life. The Expansion Project proposes mining an additional 15.2 million tonnes of ore from the expanded Whale Tail Pit, the IVR open pit, and underground operations. A detailed project description can be found in the (Addendum Volume 1 of FEIS.

This report presents the results of the hydrogeology baseline conditions for the Expansion Project. The baseline conditions presented in this report represent an update to conditions described in the baseline report for the Approved Project (Golder 2016a) and incorporates the results of field investigations carried out between 2016 and 2018.

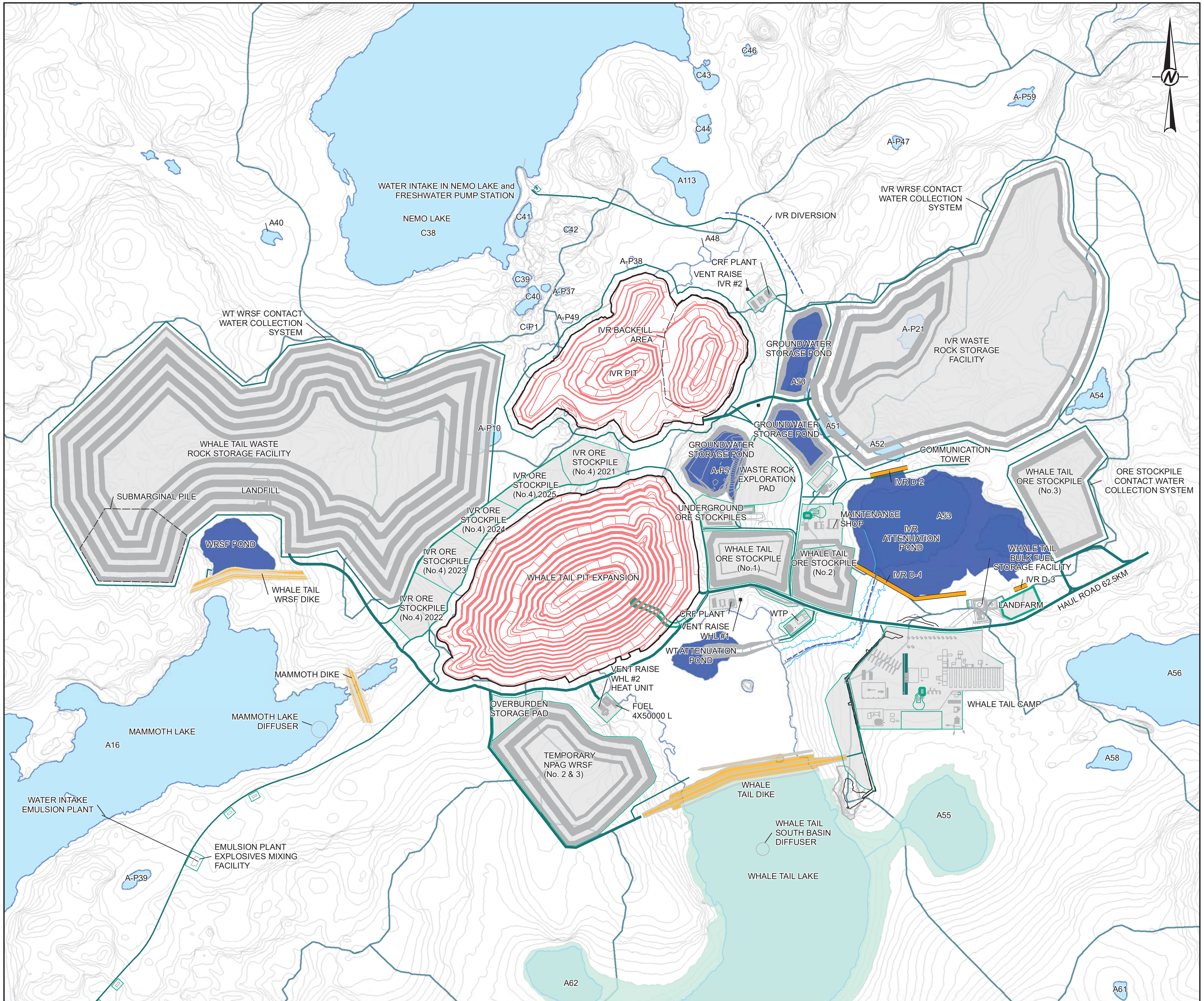
This report is organized as follows:

- Section 2.0 provides a summary of hydrogeological data collection methods;
- Section 3.0 provides an updated description of the hydrogeological settings.
- Section 4.0 provides a description of the hydrostratigraphy
- Section 5.0 provides an updated description of the groundwater quality.
- Section 6.0 provides a summary of the conceptual model for the Expansion Project.

1.1 Hydrogeology Study Area

The hydrogeology baseline study area (Hydrogeology BSA) for the Expansion Project forms an irregular polygon approximately 24,000 hectares in area (Figure 2). Whale Tail Lake and the site of the proposed Whale Tail Pit, Whale Tail Underground and IVR Pit are located in the central-eastern area of the Hydrogeology BSA.

The elevations of large lakes within the Hydrogeology BSA range from approximately 99.8 metres above sea level (masl) at DS1, located over 5 km to the north of Whale Tail Lake, to 170.5 masl at A60, located approximately 750 metres (m) southeast of Whale Tail Lake.



LEGEND

- WHALE TAIL WASTE ROCK STORAGE FACILITY
- WHALE TAIL LAKE (SOUTH BASIN) FLOODED LIMIT (WATER LEVEL 156.0m)
- NATURAL WATERSHED
- DIKE
- POND/SUMP
- ROAD
- WATERCOURSE
- WATERBODY

REFERENCE(S)

1. INFRASTRUCTURE OBTAINED FROM AGNICO EAGLE MINES LIMITED FROM AMQ_2025Q4V7.DWG
2. WATERCOURSE AND WATERBODY DATA OBTAINED FROM PHOTOSAT

DATUM: NAD 83 CSRS PROJECTION: UTM ZONE 14

CLIENT

AGNICO EAGLE

AGNICO EAGLE MINES LIMITED: MEADOWBANK DIVISION

PROJECT

WHALE TAIL PIT - EXPANSION PROJECT

TITLE

SITE LAYOUT

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-01
DESIGNED	JR
PREPARED	CDB
REVIEWED	JR
APPROVED	DF

PROJECT NO.	CONTROL	REV.	FIGURE
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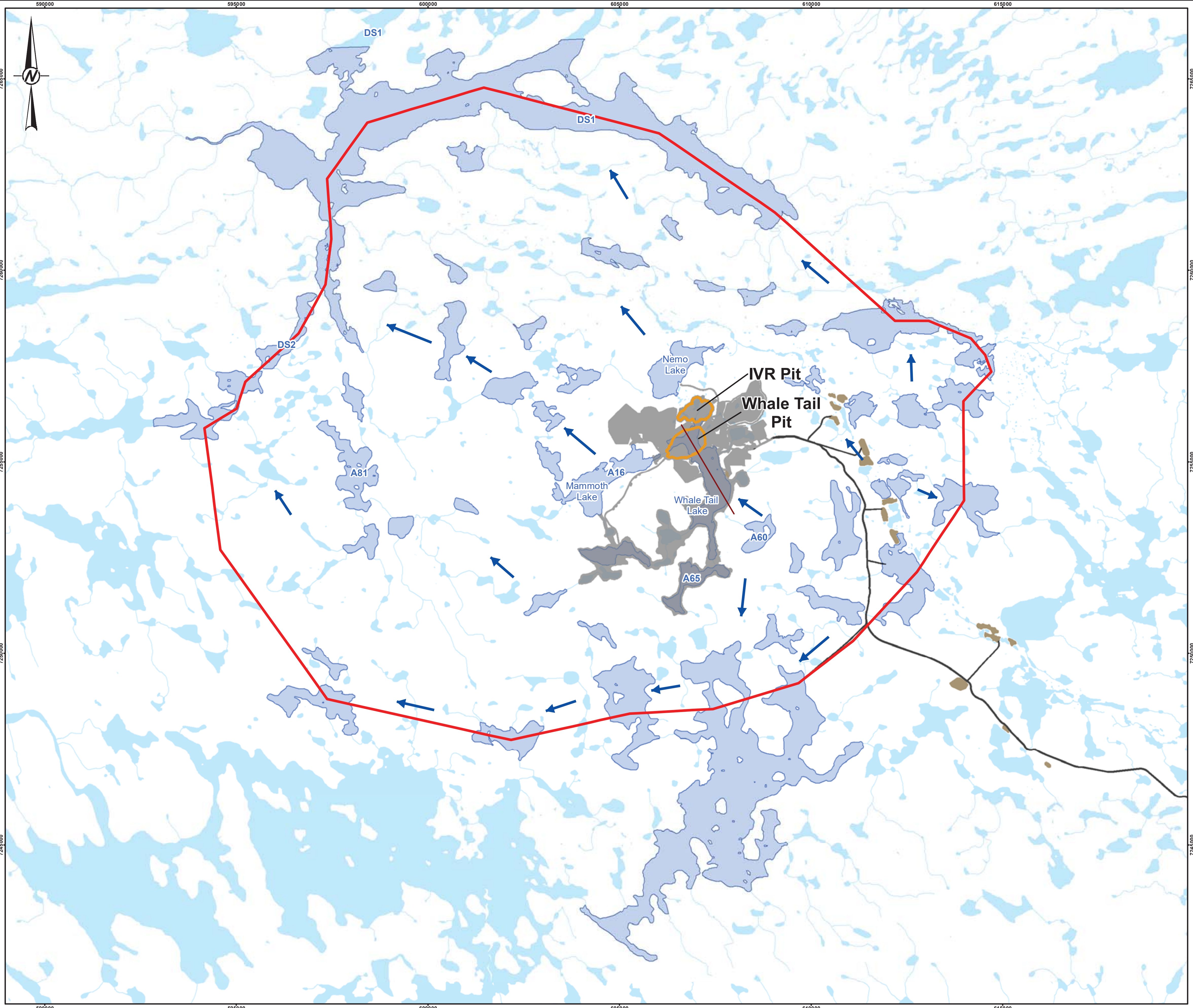

LEGEND

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

WHALE TAIL

- BORROW SOURCE
- INFRASTRUCTURE
- HAUL ROAD
- GROUNDWATER FLOW DIRECTION
- CONCEPTUAL SECTION LOCATION
- PIT BOUNDARY

KEY MAP

0 2 4
1:100,000 KILOMETRES

REFERENCE(S)
1. INFRASTRUCTURE OBTAINED FROM AGNICO EAGLE MINES LIMITED, DRAWING AMQ_2025Q4V7.DWG.
2. WATERCOURSE AND WATERBODY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. INSET MAP DATA OBTAINED FROM ESRI
DATUM: NAD 83 CSRS PROJECTION: UTM ZONE 14

CLIENT
AGNICO EAGLE
AGNICO EAGLE MINES LIMITED: MEADOWBANK DIVISION

PROJECT
WHALE TAIL PIT - EXPANSION PROJECT

TITLE
HYDROGEOLOGY BASELINE STUDY AREA

CONSULTANT
GOLDER

YYYY-MM-DD	2018-11-09
DESIGNED	AP
PREPARED	CDB
REVIEWED	
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1789310	2000/22010	A	2

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2.0 METHODS

The baseline study presents the hydrogeological conditions before Approved Project initiation. Baseline conditions are also used for future reference in identifying environmental changes and for qualitative and quantitative evaluation of potential changes to groundwater regimes. The methods used to characterize the baseline conditions consisted of the following:

- compilation and review of hydrogeological testing data collected in support of the Approved Project and Expansion Project;
- review existing baseline studies;
- review of available data collected at the Meadowbank Mine because these operations provide relevant site analogues;
- review pertinent studies published in the literature; and
- interpretation of information to develop the conceptual hydrogeological model for the Expansion Project.

2.1 Data Review

2.1.1 Lake Elevations and Bathymetry Data

Where available, approximate elevations of lakes within the Hydrogeology BSA were obtained from the local topographic survey data as documented in the Approved Project Baseline Hydrology Report (Golder 2016b). Where local survey data were not available, approximate lake elevations were obtained from the National Topographic System (NTS) map sheets published by the Government of Canada.

Lake bathymetric data (measured as lake bottom depth below water surface) for select lakes were provided by Agnico Eagle.

2.1.2 Hydrogeological Testing

Five investigations have been completed to assess the hydraulic conductivity of the bedrock. These investigations include testing conducted by Knight Piésold (2015a) in support of the Approved Project, and four subsequent investigations undertaken between 2016 and 2017 (Knight Piésold 2016; Golder 2016c, 2017a; SNC 2017).

- Knight Piésold (2015a) - eighteen constant head hydraulic conductivity packer tests in six drill holes, of which six are inferred to be in unfrozen bedrock.
- Knight Piésold (2016) - 10 packer tests along a single drill hole as part of a geomechanical investigation. The tests were conducted over 30 m intervals along the drill hole to a maximum depth of approximately 330 m below ground surface (bgs). The first four tests were interpreted to be conducted in unfrozen rock; the remainder of the tests were inferred to be completed in frozen permafrost below the northern portion of Whale Tail Lake.
- Golder (2016c) - eight packer tests in 2016 along drill hole AMQ16-626 (into which a Westbay well was installed) from a depth of 186 to 466 m bgs.
- Golder (2017a) - 33 packer tests in 2017 along five drill holes from a depth of 10 m bgs to a maximum depth of 735 m bgs; 10 of those tests were inferred to be in talik or unfrozen bedrock.

- SNC (2017) conducted 43 packer tests along nine drill holes near the Whale Tail dike from a depth of 6 m bgs to a maximum depth of 48 m bgs; 27 of these tests were inferred to be completed in unfrozen bedrock.

2.1.3 Permafrost Assessment

Permafrost conditions have been described in the Terrain, Permafrost and Soils Baseline Reports for the Approved Project (Golder 2016d) and for the Expansion Project in Volume 5, Section 5.3.2.

Data for the Approved Project included the installation of six thermistor strings targeting the potential talik below Whale Tail Lake near the open pit. This data was used to determine baseline permafrost conditions, as documented in a report by Knight Piésold (2015b) that was included in Appendix 6-A of the Approved Project FEIS.

Since the completion of the Approved Project, two thermal assessments have been completed (Golder 2017b; 2018) to collect additional thermistor data and to refine the thermal modelling in localized areas. The 2017 thermal study was completed to evaluate permafrost and talik characteristics in the vicinity of Whale Tail Lake to provide input for planning of the 2017 field thermistor installation program in the northern portion of the lake, which resulted in the installation of three thermistors. The 2018 thermal assessment was completed to predict the evolution of the permafrost regime beneath the Whale Tail Pit and IVR Pit for the post-closure hydrogeological modelling. This report includes recent thermistor data, which was used to refine the understanding of the depth of permafrost.

2.1.4 Groundwater Quality

Knight Piésold (2015b) installed three drill holes to collect representative groundwater samples for the Approved Project. One well was developed following installation, but the heat trace was damaged, the drill hole froze, and sampling could not be conducted. Despite repeated well development from the other two drill holes, inflow rates were low and therefore groundwater samples collected from these locations had high salinity concentrations that are attributed to the brine solution used to install the monitoring wells. The samples collected, therefore, are not representative of the natural groundwater quality, likely due to the low permeability and frozen conditions in areas presumed to be an active talik.

Site-specific information on groundwater quality at depth (sub-permafrost) was obtained in 2016 through the installation and sampling of a Westbay system which provided groundwater flow and quality information at various depth intervals (Golder 2016c, 2016e). The Westbay system borehole was drilled to a depth of 466 m bgs. The well was installed to measure hydraulic heads and hydraulic conductivity, and to collect groundwater samples from multiple (up to six) depth intervals.

3.0 HYDROGEOLOGICAL SETTING

The information presented in this section incorporates information presented in information sources presented in the data review (Section 2.1).

3.1 Permafrost

The Expansion Project is located in an area of continuous permafrost. In this region, the layer of permanently frozen subsoil and rock is generally deep and overlain by an active layer that thaws during summer. The depth of the active layer is typically expected to range between 1 and 3 m (Golder 2012). Depending on lake size, depth, and thermal storage capacity, the talik beneath lakes may fully penetrate the permafrost layer resulting in an open talik. The thickness of the permanently frozen permafrost was estimated to be between 425 and 495 m bgs (Knight Piésold 2015b, Golder 2018). Based on the measured salinity concentration of 0.3% to 0.4% from the groundwater samples collected at depths from 276 m to 392 m from a Westbay well system installed in borehole AMQ16-626 (Golder

2016d), a freezing point depression of about 0.2 °C was obtained, which may reduce the frozen ground depth by approximately 20 m (thickness of the basal cryopeg).

In areas of continuous permafrost, there are two groundwater flow regimes: a deep groundwater flow regime beneath permafrost, and a shallow groundwater flow regime located in the active (seasonally thawed) layer near the ground surface. Because of the thick layer of low permeability permafrost, there is little to no hydraulic connection between these two flow regimes in areas where there are no open taliks.

3.2 Shallow Groundwater Regime

The shallow groundwater flow regime is active only seasonally during summer, and the magnitude of the flow in this layer is expected to be several times less than runoff from snowmelt (Woo 2011). Within the active layer, the water table is expected to be generally a subdued replica of topography and roughly parallel to the topographic surface. Hydraulic gradients with the shallow active layer in the Project area are estimated from topography to range from approximately 0.004 to 0.09 m/m and the annual groundwater velocities are in the order of 0.004 to 0.08 m per day. Groundwater in the active layer primarily flows to local depressions and ponds that drain to larger lakes; therefore, the total travel distance would generally extend only to the nearest pond, lake, or stream.

During winter, land is underlain by seasonal frost, which is in turn underlain by permafrost. From late spring to early autumn, when temperatures are above 0^0C, the seasonal frost in the active layer becomes thawed. Water in the active layer is stored in ground ice during the cold season, and then released when it thaws in late spring or early summer, thus providing flow to surface waterbodies (Woo 2011). During the warm season, groundwater in the active layer is recharged primarily by infiltration of precipitation falling on the land surface.

The thickness of the active layer is variable and depends on several factors. The most important factors are the thaw index, thermal resistance of the vegetative cover, moisture content, and composition of soil or rock. In general, the active layer thickness at the end of the summer season is expected to range from 1 to 3 m of the ground surface.

Permafrost reduces the hydraulic conductivity of the bedrock by several orders of magnitude (Burt and Williams 1976; McCauley et al. 2002). Consequently, the permafrost in the rock would be virtually impermeable to groundwater flow. The shallow groundwater flow regime, therefore, has little to no hydraulic connection with the deep groundwater regime which is overlain by massive and continuous permafrost.

3.3 Deep Groundwater Regime

Water levels in lakes overlying open taliks provides the driving force for groundwater flow in the deep groundwater regime. Taliks (areas of unfrozen ground) exist beneath lakes that have sufficient depth so that they do not freeze to the bottom over the winter. If the lake is sufficiently large and deep, the talik can extend down to the deep groundwater regime. These taliks are referred to as open taliks. If the talik does not extend down to the deep groundwater, it is referred to as a closed or an isolated talik. Recharge to the deep groundwater flow regime is predominantly limited to open taliks.

Generally, deep groundwater will flow from higher-elevation lakes with open taliks to lower-elevation lakes with open taliks. To a lesser degree, groundwater beneath the permafrost is influenced by density differences due to saline water conditions (density-driven flow).

Taliks are to be expected where lake depths are greater than 2 m. Formation of an open-talik, which penetrates through the permafrost, would be expected for lakes that exceed a critical depth and size. The salinity of groundwater also influences the temperature at which the groundwater will freeze.

The width and shape of lakes in the Hydrogeology BSA were reviewed as part of the Approved Project to estimate if open taliks could be present below the lakes. Based on 1-D analytical solutions presented in Burn (2002), Golder estimated that open taliks could be present for circular lakes with a radius of approximately 300 m and for elongated lakes with a half-width of approximately 150 m. Beneath smaller lakes that do not freeze to the bottom over the winter, a talik bulb may form; however, the talik bulb is not expected to extend to the deep groundwater flow system (i.e., a closed talik will form). Based on these criteria, all lakes in the Hydrogeology BSA meeting the minimum radius or half width are assumed to be underlain by open taliks that connect these lakes to the deep groundwater flow regime. This assumption is conservative as some lakes within sufficient radius/width may be shallow and, therefore, may not be underlain by taliks. Figure 2 presents the assumed locations of lakes with open taliks.

For the Whale Tail Lake area, more detailed information is available from the collection and analysis of thermal data from 10 thermistors (Knight Piésold 2015b; Golder 2017b, 2018). Based on this data analysis, the following summarizes the understanding of permafrost conditions for the Expansion Project area.

- The extrapolate mean annual ground temperatures from the thermistors ranged from -3.4ºC to -9.9ºC.
- The estimated depths of zero amplitude from the temperature profiles range from 18 m to 35 m, and the temperatures at the depths of zero amplitude are in the range of -3.1ºC to -8.4ºC.
- The geothermal gradient is in the range of 0.005ºC/m to 0.025ºC/m.
- The depth of permafrost is estimated to be in the order of 425 m to 495 m for areas outside of Whale Tail Lake. In the area of Whale Tail Lake, data from thermistor AMQ17-1265A suggests that the talik near the central portion of the North Basin of Whale Tail Lake extends about 112 m below the lake water level of 152.5 masl. Toward the South Basin, the closed talik below the North Basin is predicted by thermal modelling to transition to open talik with direct connection to the deeper groundwater flow system.
- Whale Tail Pit is present in the North Basin in the area of the closed talik. The pit extends through this talik and into the underlying permafrost, with the base of the pit located in permafrost.
- The IVR Pit, which has a maximum depth of approximately 105 m, is located within the regional permafrost that extends to 425 m to 495 m bgs. The edge of this pit slightly intersects the north eastern edge of Whale Tail Lake; however, thermistors at two locations (AMQ17-1277A and AMQ15-294) do not indicate significant open talik is present in this area. These two thermistors are drilled at an angle from shoreline and it is possible that thermistors have missed a shallow bulb of talik. If this shallow talik is present, groundwater in this localized area would drain towards the deeper portions of Whale Tail Lake during lake dewatering.
- Based on the measured salinity concentration of 0.3 to 0.4% from the groundwater samples collected at depths from 276 m to 392 m from a Westbay well system installed in borehole AMQ16-626 (Golder 2016c), a freezing point depression of about 0.2 °C was obtained, which may reduce the frozen ground depth by approximately 20 m (thickness of the basal cryopeg).
- With the formation of the Whale Tail pit lake during closure, permafrost near and beneath Whale Tail Pit is predicted to start melting. After approximately 11 years of closure, the base of the Whale Tail Pit Lake is predicted to be hydraulically connected to the deeper groundwater flow system, and after 50 years, the permafrost below a significant portion of the pit footprint is predicted to have nearly completely melted.

The formation of the IVR Pit lake during closure is also predicted to melt the underlying permafrost. Unlike Whale Tail Pit, IVR Pit is located within the regional permafrost and it is predicted that it will take approximately 1,000 years to fully melt the permafrost below the pit footprint.

3.4 Groundwater Usage

Groundwater sources from the active layer and from the deep groundwater below the permafrost are not currently used for drinking water; nor are they currently used in other continuous permafrost regions in Canada. Due to the presence of deep permafrost, the seasonal nature of the active layer, and the availability of good-quality drinking water from surface water sources near the Expansion Project, groundwater will not be used as a drinking water source in the future.

4.0 HYDROSTRATIGRAPHY

The Expansion Project area is underlain by three main hydrostratigraphic units composed of overburden, weathered bedrock, and competent rock. Relatively competent bedrock is assumed to comprise the majority of the rock domain, and the hydraulic conductivity of the competent rock is assumed to decrease with depth.

4.1 Overburden

The Expansion Project area is dominated by veneers and blankets of till overlying undulating bedrock. The till has a silty sand matrix and clasts that range from granule gravel to large boulders in size. Glaciofluvial deposits in the form of eskers and terraces are found in the northeast section of the satellite deposit study area and they continue in a southeast direction intersecting the haul road study area in several locations. The deposits are composed of well sorted fine to coarse-grained sand and varying amounts of granule, pebble and cobble gravel. These deposits tend to be thick but are often found adjacent to exposures of bedrock. Organic and fluvial deposits are rare, but where they do exist, they are thin (less than 1 m) and overlie till (Golder 2016d).

Overburden thickness in test holes completed by Knight Piésold near the peripheral of Whale Tail Lake ranged from approximately 4 to 13 m, as inferred from the reported depth to bedrock relative to the top of the borehole casing. In the area of the planned dikes, the combined thickness of lakebed sediments and the glacial till ranges from less than 1 m and up to 5 m (Agnico Eagle 2015b). An average thickness of 6 m was estimated based on both sets of data.

Hydraulic conductivity testing of the overburden has not been conducted. The hydraulic conductivity of the shallow overburden beneath Whale Tail was estimated to be 2×10^{-6} m/s (Cumberland 2005) based on testing in the Meadowbank area, which is consistent with the assumption adopted for the Approved Project.

4.2 Bedrock

The bedrock geology in the Expansion Project region consists of Archean and Proterozoic supercrustal sequences and plutonic rocks. The Woodburn Lake Group (Archean supercrustal sequence) was intruded by orogenic granites, which in turn were unconformably overlain by a Proterozoic basin deposit known as the Amer Group (Sherlock et al. 2001; Zaleski 2005).

The Woodburn Lake Group is a sequence of Archean supercrustal rocks which are thought to have been deposited in a continental rift setting (Zaleski 2005). The group is composed of:

- a variety of ultramafic to felsic volcanic and volcaniclastic rocks, iron-formation, and related sedimentary rocks;
- quartz arenite, conglomerate, and related sedimentary rocks; and

- arkosic wacke and mudstone that are interlayered with iron formation (NRCAN 2015).

Although the Woodburn Lake Group is Archean, several phases of deformation have affected the stratigraphy, with four events recognised regionally (Sherlock et al. 2001).

The Amer Group was formed during the Early Proterozoic and is a succession of terrestrial and marine sedimentary rocks which outcrop in the north part of the Expansion Project area near the satellite deposit. This group is composed of quartzarenite, carbonate rock, carbonaceous shale, siltstone, mudstone and sandstone, and tectonized mafic volcanic rock. It overlies the Neoarchean granite and lesser supercrustal rocks of the Woodburn Lake Group (NRCAN 2015).

4.3 Weathered Bedrock

In the Canadian Shield, the uppermost 10 to 30 m of bedrock is generally more highly fractured and correspondingly has greater hydraulic conductivity than the deeper underlying more competent rock, as has been observed where hydrogeologic testing data have been collected in shallow unfrozen bedrock (De Beers 2010; Golder 2005). This greater level of fracturing in the shallow rock is interpreted to be present because of the formation of stress relief joints due to isostatic rebound following glacial retreat. These stress relief joints are preferentially oriented horizontally, likely resulting in greater horizontal than vertical hydraulic conductivity in shallow rock.

Results of the packer testing conducted within the talik (unfrozen rock) by Knight Piésold (2015a, 2016), Golder (2016c, 2017a) and SNC (2017) are summarized on Figure 3. The larger dataset, relative to the Approved Project, indicates that the near surface bedrock is significantly more permeable than previously identified. The hydraulic conductivity of the near surface bedrock (up to 40 m bgs) ranged from 2 x 10^{-4} m/s to 5 x 10^{-8} m/s, with a geometric average of 4.7 x 10^{-6} m/s. In general, single-well response tests have been found to underestimate large-scale hydraulic conductivity. This effect is observed as single-well response tests are conducted over a small-scale volume of rock near the well screen and are more often representative of the lower-permeability rock composed of poorly connected and small aperture discontinuities. It was therefore considered reasonable to conservatively assume the hydraulic conductivity of the weathered bedrock was up to three times higher (1 x 10^{-5} m/s).

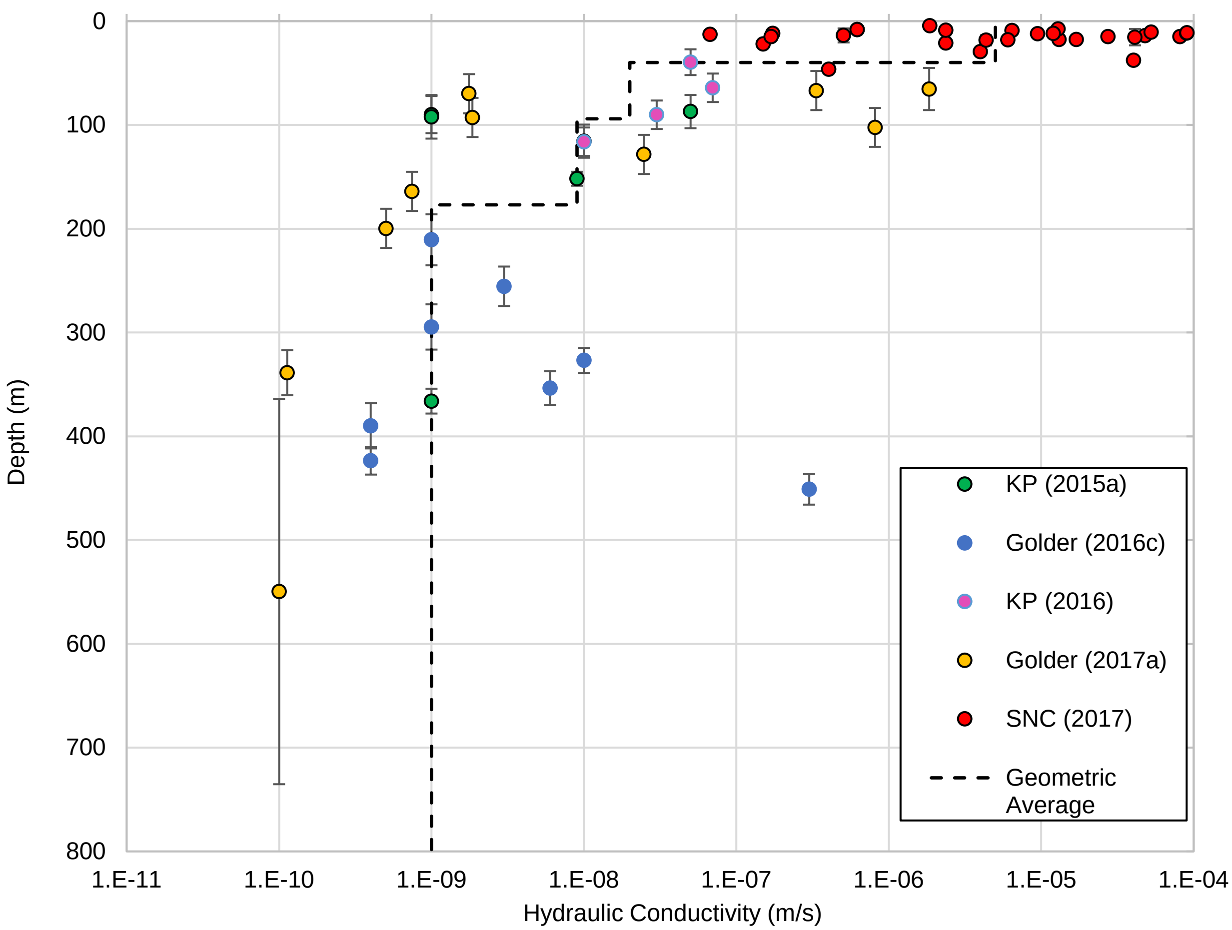

Figure 3: Summary of Hydraulic Conductivity Test Results

4.4 Competent Bedrock

The hydraulic conductivity measurements for the Competent Bedrock (greater than 40 m bgs) ranged from less than 1 x 10^{-10} m/s to 3 x 10^{-7} m/s (Figure 3). The highest hydraulic conductivity measured in the deeper bedrock corresponded to a hydraulic conductivity value of 3 x 10^{-7} m/s measured at the Westbay well location over a depth interval of 467 to 499 m. Based on the geotechnical summary log, the higher hydraulic conductivity in this interval is likely attributed to localised multiple joint sets with carbonate infilling. The data collected thus far does not indicate the presence of enhanced permeability zone associated with a major structure or fault.

Results of the packer testing and single well response tests indicate the hydraulic conductivity of competent bedrock decreases with depth. For the purposes of assigning representative hydraulic conductivity for the bedrock, the competent bedrock was sub-divided into three depth intervals, based on the observed trend in hydraulic conductivity versus depth (40 m to 100 m bgs; 100 to 200 m bgs; and greater than 200).

The geometric average of the measurements made between 40 and 100 m bgs was 2.5 x 10^{-8} m/s. Like the weathered bedrock, it was considered reasonable to conservatively assume that the hydraulic conductivity the competent bedrock between 40 and 100 m bgs was up to three times higher than the geometric average (7 x 10^{-8} m/s).

The geometric average of the measurements made between 100 and 200 m bgs was 9.5 x 10^{-9} m/s, which is slightly higher than the geometric average of measurements below 200 m bgs (1.5 x 10^{-9} m/s). For both depth intervals, the representative hydraulic conductivity of the competent bedrock was assumed to be equal to the geometric average. In our experience, the hydraulic conductivity of deep bedrock tends to be more closely correlated to the geometric average, and in addition, multiple measurements over these intervals were reported to be less than resolution of the testing methodology (1 x 10^{-9} m/s or 1 x 10^{-10} m/s depending on the investigation). The geometric averages are therefore biased high.

The deepest measurement was between approximately 363.9 and 735.3 m bgs. Further reduction in hydraulic conductivity with depth is expected below the tested intervals, however, the hydraulic conductivity of competent bedrock has been assumed to remain constant at greater depths (1 x 10^{-9} m/s).

4.5 Enhanced Permeability Zones with Associated Faults

In crystalline rocks, fault zones may act as groundwater flow conduits, barriers, or a combination of the two in different regions of the fault depending on the direction of groundwater flow and the fault zone architecture (Gleeson and Novakowski 2009). Agnico Eagle has identified evidence of large-scale structures based on the results of geophysical surveys, exploration drilling, surface mapping, and topographic interpretation. The dominant structural orientation is east north east (ENE) – west south west (WSW), which is the trend of the deposit lithologies. Knight Piésold (2015a) also identified the presence of a series of diffuse ductile structures that trend northeast (NE) – southwest (SW), which offset both the lithologies and the mineralization near the Expansion Project, and a sub-horizontal set of structures.

The faults are typically less than one metre thick (though some may be in the order of ten metres thick) and consist of zones of broken rock and fault gouge. Hydraulic conductivity testing thus far has not identified that the hydraulic conductivity of these structures is greater than the surrounding bedrock, though limited specific testing of these structures has been completed. In general, inflow to the open pit would be expected to be controlled by the high permeability of the fractured weathered bedrock.

4.6 Summary of Hydrostratigraphy and Estimated Hydraulic Properties

The conceptual model for the Project area consists of three hydrostratigraphic units comprised of overburden, weathered rock and competent rock. Structures such as fault zones may be present in the Hydrogeology BSA, but current data does not indicate that the permeability of structures intersected to date are higher than the surrounding competent bedrock.

Overburden and weathered bedrock are limited to the near surface, whereas relatively competent bedrock is assumed to comprise most of the rock domain. The hydraulic conductivity of competent rock is assumed to decrease with depth. The assumed hydraulic properties of hydrostratigraphy units near the mine developments are summarized in Table 1. Permafrost is assumed to be essentially impermeable.

Table 1: Hydrogeological Parameters

Hydrostratigraphic Unit	Depth Interval (m)	Hydraulic Conductivity (m/s)[a]	Specific Storage (1/m)[b]	Specific Yield (-)[b]	Effective Porosity (-)[b]	Longitudinal Dispersivity (m)[c]	Transverse Dispersivity (m)[c]	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 40	1×10^{-5}	2×10^{-4}	0.03	0.03	10	1	2×10^{-10}
Competent bedrock	40 to 100	7×10^{-8}	1×10^{-5}	0.0006	0.001	10	1	2×10^{-10}
	100 to 200	9×10^{-9}	1×10^{-5}	0.0006	0.001	10	1	2×10^{-10}
	>200	1×10^{-9}	1×10^{-5}	0.0006	0.001	10	1	2×10^{-10}

[a] Derived from hydraulic testing results as presented in Golder (2016c, 2017a), Knight Piésold (2015a, 2016) and SNC (2017). 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] Values are consistent with literature values (Schulze-Makuch 2005).

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

5.0 GROUNDWATER QUALITY

5.1 Water Quality Summary

Groundwater quality for the Approved Project has been inferred to be similar to the Meadowbank Mine based on similar geology and permafrost conditions (Knight Piésold 2015b), namely, that the majority of groundwater inflow to the Whale Tail Pit is from a shallow closed talik. This is also the case for the Expansion Project with most of the groundwater originating from the shallow closed talik. Site-specific information on groundwater quality at depth (sub-permafrost) was obtained in 2016 through the installation and sampling of a Westbay system which provided groundwater flow and quality information at various depth intervals. This information is used to represent deep, sub-permafrost groundwater inflow to the base of the Whale Tail Pit and to the Underground workings. IVR Pit is within permafrost and is not expected to have groundwater inflow.

Shallow groundwater quality: Groundwater quality in the shallow, closed talik at the Whale Tail pit is assumed to be that of the Meadowbank Mine as previously defined (Knight Piésold 2015b). It has high to very high hardness, neutral to slightly basic pH and good buffering capacity. Total dissolved solids concentrations range from 193 to 1,900 mg/L. Concentrations of fluoride, copper, iron, and selenium are elevated in comparison to guidelines for the protection of aquatic life and drinking water. The higher percentile values for nitrogen-containing compounds, aluminum, arsenic, boron, hexavalent chromium, molybdenum, and zinc exceed the Canadian Environmental Quality Guidelines. Additionally, several of these parameters as well as chloride, manganese and sodium exceed aesthetic drinking water guidelines. During mining, most of the groundwater reporting to the pit is predicted to come from seepage through the shallow fractured bedrock on the south pit wall. The source of this water is predicted to be a mixture of lake water and seepage from the Attenuation Pond, both of which will have relatively low TDS.

Sub-permafrost groundwater quality: The groundwater quality results obtained from the Westbay well system at Whale Tail provide reliable information on site-specific composition of groundwater to depths of 392 mbgs. Table 2 presents the range of concentrations of formation water at each port sampled. Water quality was calculated based on analytical results received from each sample collected, from which was removed the proportion of fresh water introduced during drilling defined based on the range of fluorescein values observed during well development. Details of the test program are included in Golder (2016e).

Table 2: Sub-permafrost Groundwater Quality Data from the Westbay Well System at Whale Tail

Sample		Zone 6 Average		Zone 4 Average		Zone 3 Average	
Date		08/02/2016		07/20/2016		14/09/2016	
Certificate No.		V-56700, V-56788		V-56266, V-56267		V-58376, V-58377	
Formation Water Proportion		0.76	0.96	0.82	0.91	0.53	0.92
Sampling interval depth (mbgs)		276 m - 287 m		349 m - 359 m		381 m - 392 m	
Estimated concentration range		maximum	minimum	maximum	minimum	maximum	minimum
Conventional parameters							
Total dissolved solids	mg/L	4042	3198	3966	3581	3918	3483
Total solids	mg/L	9022	7138	8777	7922	6502	5778
pH	S.U.	7	7.4	8	8	7.9	8.0
Conductivity	µmhos/cm	6042	4797	5938	5366	5866	5220
Hardness	mg $CaCO_3$/L	3030	2397	2910	2627	1891	1680
Alkalinity	mg $CaCO_3$/L	51	40	20	18	58	52
Total Organic Carbon	mg/L	1.5	1.1	2	2	1.9	1.7
Total Inorganic Carbon	mg/L	569	450	94	85	172	152
Bicarbonate (HCO3)	mg $CaCO_3$/L	51	40	20	18	58	52
Major ions							
Calcium (Ca)	mg/L	1213	960	1143	1032	756	671
Magnesium (Mg)	mg/L	27	22	14	12	1	1
Potassium (K)	mg/L	10	8	42	38	18.3	16.2
Sodium (Na)	mg/L	293	232	296	267	344	306
Bromide (Br)	mg/L	32	25	35	32	25	22
Chloride (Cl)	mg/L	2641	2089	2860	2582	1929	1714
Fluoride (F)	mg/L	0.27	0.21	0.5	0.5	1.22	1.08
Sulphate (SO4)	mg SO_4/L	-	-	-	-	-	-
Nutrients							
Ammonia N (NH3+NH4)	mg N/L	0.36	0.29	0.18	0.17	<0.01	<0.01
NH3 (NH3 non-ionized)	mg N/L	0.01	0.01	0.012	0.011	0.012	0.011
NH4	mg N/L	0.36	0.28	0.18	0.17	0.2	0.18
Nitrates (NO3)	mg N/L	0.079	0.063	0.06	0.06	0.018	0.016
Nitrites (NO2)	mg N/L	0.013	0.010	0.012	0.011	0.043	0.038
Total Phosphorous (P)	mg P/L	0.026	0.021	0.012	0.011	0.055	0.049
Metals (dissolved)							
Aluminium (Al)	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Antimony (Sb)	mg/L	0.0003	0.0002	0.004	0.003	0.00294	0.00261
Silver (Ag)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic (As)	mg/L	0.0063	0.0050	0.003	0.003	<0.0005	<0.0005
Barium (Ba)	mg/L	0.67	0.53	0.15	0.13	0.065	0.057
Beryllium (Be)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth (Bi)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bore (B)	mg/L	0.38	0.30	0.64	0.58	0.60	0.53
Cadmium (Cd)	mg/L	0.000033	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Chromium (Cr)	mg/L	0.0089	0.0070	0.0060	0.0054	0.0055	0.0048
Cobalt (Co)	mg/L	0.0019	0.0015	0.0018	0.0017	0.0012	0.0011
Copper (Cu)	mg/L	0.0069	0.0055	0.0023	0.0020	0.0052	0.0046
Tin (Sn)	mg/L	<0.001	0.0010	0.0012	0.0011	<0.001	<0.001
Iron (Fe)	mg/L	0.21	0.17	0.16	0.15	0.09	0.08
Lithium (Li)	mg/L	0.4	0.3	0.7	0.6	0.34	0.31
Manganese (Mn)	mg/L	0.05	0.04	0.024	0.022	0.009	0.008
Mercury (Hg)	mg/L	0.0010	0.0008	0.0031	0.0028	0.00242	0.00215
Dissolved Mercury (Hg)	mg/L	0.0006	0.0005	0.0034	0.0031	0.0024	0.0022
Molybdenum (Mo)	mg/L	0.02	0.02	0.0068	0.0062	0.021	0.019
Nickel (Ni)	mg/L	0.06	0.05	0.05	0.05	0.047	0.041
Lead (Pb)	mg/L	<0.0003	<0.0003	0.0030	0.0027	<0.0003	<0.0003

Sample		Zone 6 Average		Zone 4 Average		Zone 3 Average	
Date		08/02/2016		07/20/2016		14/09/2016	
Certificate No.		V-56700, V-56788		V-56266, V-56267		V-58376, V-58377	
Formation Water Proportion		0.76	0.96	0.82	0.91	0.53	0.92
Sampling interval depth (mbgs)		276 m - 287 m		349 m - 359 m		381 m - 392 m	
Estimated concentration range		maximum	minimum	maximum	minimum	maximum	minimum
Selenium (Se)	mg/L	0.14	0.11	0.13	0.12	0.086	0.076
Silica (Si)	mg/L	5.1	4.0	4.6	4.2	4.8	4.3
Strontium (Sr)	mg/L	16.7	13.2	20.9	18.9	14	13
Telluride (Te)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Thallium (Tl)	mg/L	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
Titanium (Ti)	mg/L	0.44	0.35	0.37	0.34	0.26	0.23
Tungsten (W)	mg/L	0.046	0.04	0.17	0.15	0.072	0.064
Uranium (U)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	mg/L	0.002	0.002	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	mg/L	1.7	1.3	0.70	0.63	0.24	0.21
Radioactive Ions							
Radium (Ra 226)	Becquerels/L	0.52	0.43	0.13	0.13	0.16	0.15
Hydrocarbons							
Hydrocarbons (C10-C50)	mg/L	0.20	0.15	<0.1	<0.1	0.31	0.27

Source (Golder 2016e)

5.2 Salinity (Total Dissolved Solids)

Site-specific groundwater samples collected from the Westbay system at depths between 276 and 392 m indicate that the TDS content in the groundwater was between 3,198 and 4,042 mg/L (Golder 2016e). This range is slightly higher than the groundwater TDS concentration measured at Meadowbank from shallower depths (less than 200 m vertical depth), which is expected based on the deeper sample collection. The Westbay well data along with data from other sites in the Canadian shield were used to help extrapolate the TDS concentrations to deeper depths. Consistent with other sites in the Canadian Shield, concentrations of TDS in groundwater are inferred to increase with depth, primarily in response to upward diffusion of deep-seated brines. The interpreted groundwater salinity profile is provided in Figure 4, along with profiles developed for other mines in the Arctic.

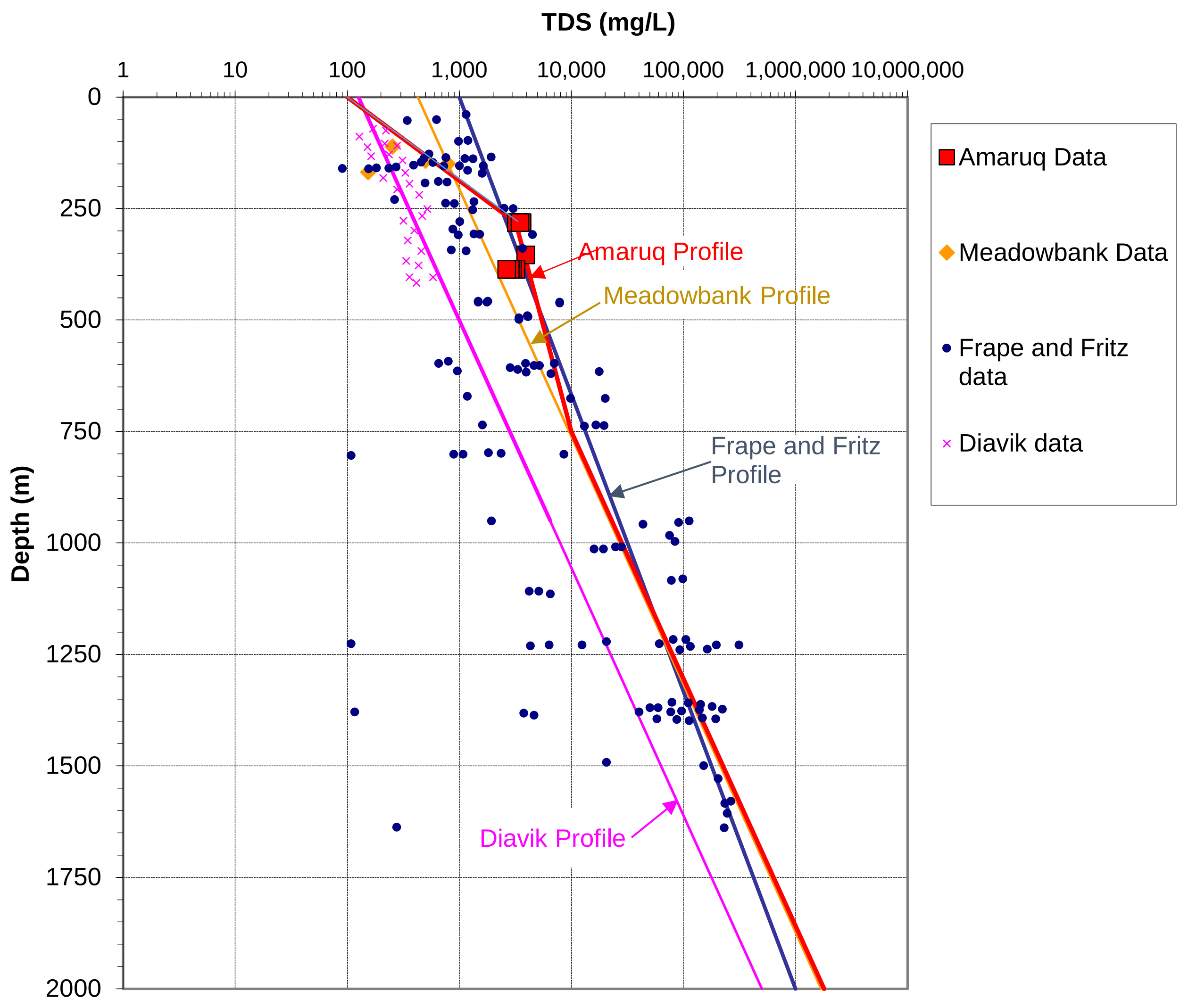

Figure 4: TDS Concentration vs Depth Profile – Expansion Project

6.0 SUMMARY OF CONCEPTUAL HYDROGEOLOGICAL MODEL

Available hydrogeological data collected at the site, together with the information collected elsewhere in the Canadian Shield, were used to develop a conceptual understanding of groundwater conditions for the Expansion Project. A conceptual hydrogeological model is a pictorial and descriptive representation of the groundwater regime that organizes and simplifies the site conditions so that 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. The baseline conceptual model has been developed to describe key features of the hydrogeological regime before mining. The key features include the groundwater flow, groundwater quality, and dominant groundwater flow direction, all of which are described in more detail below. The baseline conceptual model is presented in and described below on Figure 5. The conceptual cross-section location is shown on Figure 2.

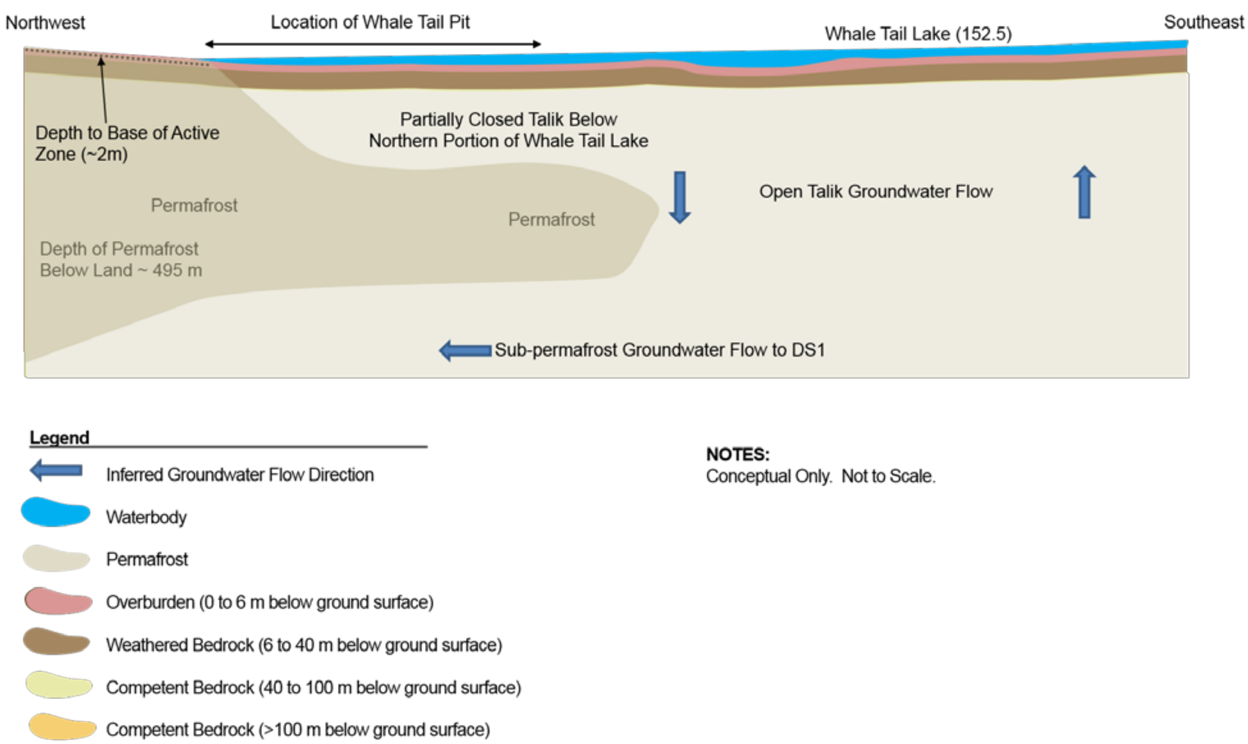

Figure 5: Conceptual Model of Deep Groundwater Flow Regime - Pre-mining Cross-Section View

The conceptual model consists of three hydrostratigraphic units comprised of overburden, weathered rock and competent rock. Structures such as fault zones may be present, but current data does not indicate that the permeability of structures intersected to date are higher than the surrounding competent bedrock. Overburden and weathered bedrock are limited to the near surface, while relatively competent bedrock is assumed to comprise most of the rock domain.

Two groundwater flow regimes occur: a deep groundwater flow regime beneath permafrost, and a shallow groundwater flow regime located in the active (seasonally thawed) layer near the ground surface. Except for areas of taliks beneath lakes, the two groundwater regimes are isolated from one another by thick permafrost. The depth of the active layer is estimated to range between 1 to 3 m. Permafrost thickness is expected to be approximately 425 to 495 m. Below Whale Tail Lake, the talik is expected to form a continuous channel that is closed at the base of the talik in the North Basin of Whale Tail Lake and becomes an open talik towards the south and central portion of the lake. Portions of Whale Tail Pit and the Underground are located within the unfrozen rock (both within the talik underlying Whale Tail Lake and for the underground, also below the regional permafrost). The IVR Pit is fully contained within permafrost.

Groundwater flow within the deep groundwater flow regime is limited to the sub-permafrost zone. This deep groundwater flow regime is connected to the ground surface by open taliks underlying larger lakes. The elevations of these lakes are expected to be the primary control of groundwater flow directions in the deep groundwater flow regime, with density gradients providing a secondary control. The elevations of these lakes in the Hydrogeology BSA indicate that Whale Tail Lake is likely a groundwater discharge zone at the south end of the Lake, with flow from Lake A60 to Whale Tail Lake, and a groundwater recharge zone at the north end of the Lake, with flow from Whale Tail Lake to Lake DS1.

The TDS concentrations near the Expansion Project are similar to those observed at other sites in the Canadian Shield at corresponding depths and locations away from the influence of sea water. Consistent with other sites in the Canadian Shield, concentrations of TDS in groundwater are inferred to increase with depth, primarily in response to upward diffusion of deep-seated brines.

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Date Nov 16, 2018
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https://golderassociates.sharepoint.com/sites/1896037/03_feis_typea_amendment/p2100_hydrogeology/v6-expansionproject_app_6-a_hydrogeologybaseline.docx

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