APPENDIX B.2

Touquoy In-Pit Disposal - Seepage Mitigation Measures

Stantec

Memo

To:	Paul Cobham	From:	Paul Deering, P.Eng.
Cc	Jeff Gilchrist, P.Eng.		
File:	121619250.5500	Date:	March 14, 2022
Doc No.	**MEM-012-5500-B-11MAR22**	Revision:	B

Reference: Touquoy In-Pit Tailings Deposition – Seepage Mitigation Measures

In support of planning for In-Pit tailings disposal for the Touquoy Mine, this memo summarizes seepage mitigation measures that are being considered for incorporation into the design to reduce the risk of contaminated seepage impacting the environment downstream from the Touquoy Open Pit (the Pit).

A detailed field investigation of subsurface conditions in the vicinity of the Pit consisting of borehole drilling including in-situ packer testing and downhole surveys, Ground Penetrating Radar (GPR) and a desktop review of underground workings was completed in the fall and winter of 2021/2022. This information is reported under separate cover (Touquoy in Pit Disposal Factual Data Report, Stantec 2022). In addition, groundwater modeling was completed for the project to assess the environmental impact from the tailings disposal in the Pit (Report Update: Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit, Stantec 2022).

Based on the available information and analysis completed, the hydraulic conductivity for the bedrock in the pit area does not indicate additional seepage mitigations are required to avoid environmental interactions. However, to address any uncertainty related to the presence and interconnectivity of the underground workings, a low permeability liner is proposed on the western side of the Pit. In addition, there were localized fault zones identified where grouting may be required.

The sections below provide additional information of these mitigation measures.

WESTERN SEEPAGE MITIGATION – LOW PERMEABILITY LINER

Drawing No. 1 shows a plan view of the results of the site investigations completed for the Open Pit. As shown on the plan, the underground workings that extend outside of the Pit as well as areas of interest identified during the GPR surveys are located along the west and southwest sections of the Pit. A clay till liner is proposed in this area to mitigate potential seepage from the Pit through the underground workings to the environment.

The concept for the seepage mitigation includes placement of a clay till liner between the tailings and the pit wall as shown on Drawing No 2. Drawing No. 3 shows a 3D view of the same area facing southwest. For the purposes of this memo, the terms upstream and interior are used to describe towards the middle of the Pit and the terms downstream or exterior are used to describe towards the outside of the Pit or the surrounding environment.

Reference: Touquoy In-Pit Tailings Deposition – Seepage Mitigation Measures

A typical cross section of the concept is shown on Drawing No.4 and includes the following components:

- **Low Permeability Layer (Clay Till Liner)** – A low permeability element will be constructed of locally sourced clay till. The total normal thickness of the clay till liner (the liner) will be 3.5 m wide.
- **Drainage/Filter layer** – A drainage/filter layer will be placed to the exterior of the liner to provide drainage control of effluent seeping through the liner from the Pit as well as groundwater flowing into the Pit. This layer will also mitigate the migration of fines from the clay till to the downstream. Additional drainage elements may be required near the base of the liner to accommodate seepage quantities, and this will be determined during detailed design.
- **Upstream Filter (if required)** – A filter layer may also be placed on the interior of the clay till to prevent the migration of fines into the rockfill layer caused by any groundwater seepage into the Pit, particularly during early stages of pit filling. The seepage from the exterior through the liner is considered to be minimal due to the exterior drainage layer discussed above. This could be a granular filter or a geotextile and will be determined during detailed design.
- **Upstream Protection / Stabilization Layer** – A rockfill protection/stabilization zone on the interior of the liner and upstream filter layer will provide overall slope stability of the fill and erosion protection from surface water and wave runup.

The vertical extent of the clay layer is from the crest of the pit to the rock bench at approximate elevation 60 m, which is below most of the underground workings.

Construction sequencing will consist of rockfill placement to the elevation 60 m bench at a slope of 1.5 Horizontal to 1.0 Vertical as shown in Drawing No. 4. Placement of the exterior drainage/filter layer, clay till liner, interior filter and rockfill will then be placed and compacted in horizontal lifts using conventional construction practices to bring the elevation of the liner to the top of the pit. Additional rockfill width was included on the upstream side of the slope to allow for a safety berm and hauling surface to minimize traffic on the clay till and filter layers.

Abutment details at the limits of the liner will include direct abutment of the clay till layer to the Pit wall to seal the sides of the drainage layer from Pit effluent. The same detail of clay till directly over the bedrock bench will be used at the bottom of the clay liner.

SEEPAGE MITIGATION – FRACTURE GROUTING

Although the permeability has been shown to be low, an additional layer of conservatism in mitigation design will be applied to increase confidence in integrity of the localized fracture zones (faults). During detailed design, location specific plans will be developed, focusing on the primary and secondary facture zones. Mitigation zones will be identified based on the location, characteristics, and permeability ratings of the faults. These will be sealed by downhole pressure grouting, which involves drilling borehole(s) near the zone of interest and pumping pressurized grout to infill the fractures to decrease the overall permeability of the zone. Details of the grout hole

Reference: Touquoy In-Pit Tailings Deposition – Seepage Mitigation Measures

depths, locations, orientations, grouting materials and pumping pressures will be assessed for each specific location during detailed design.

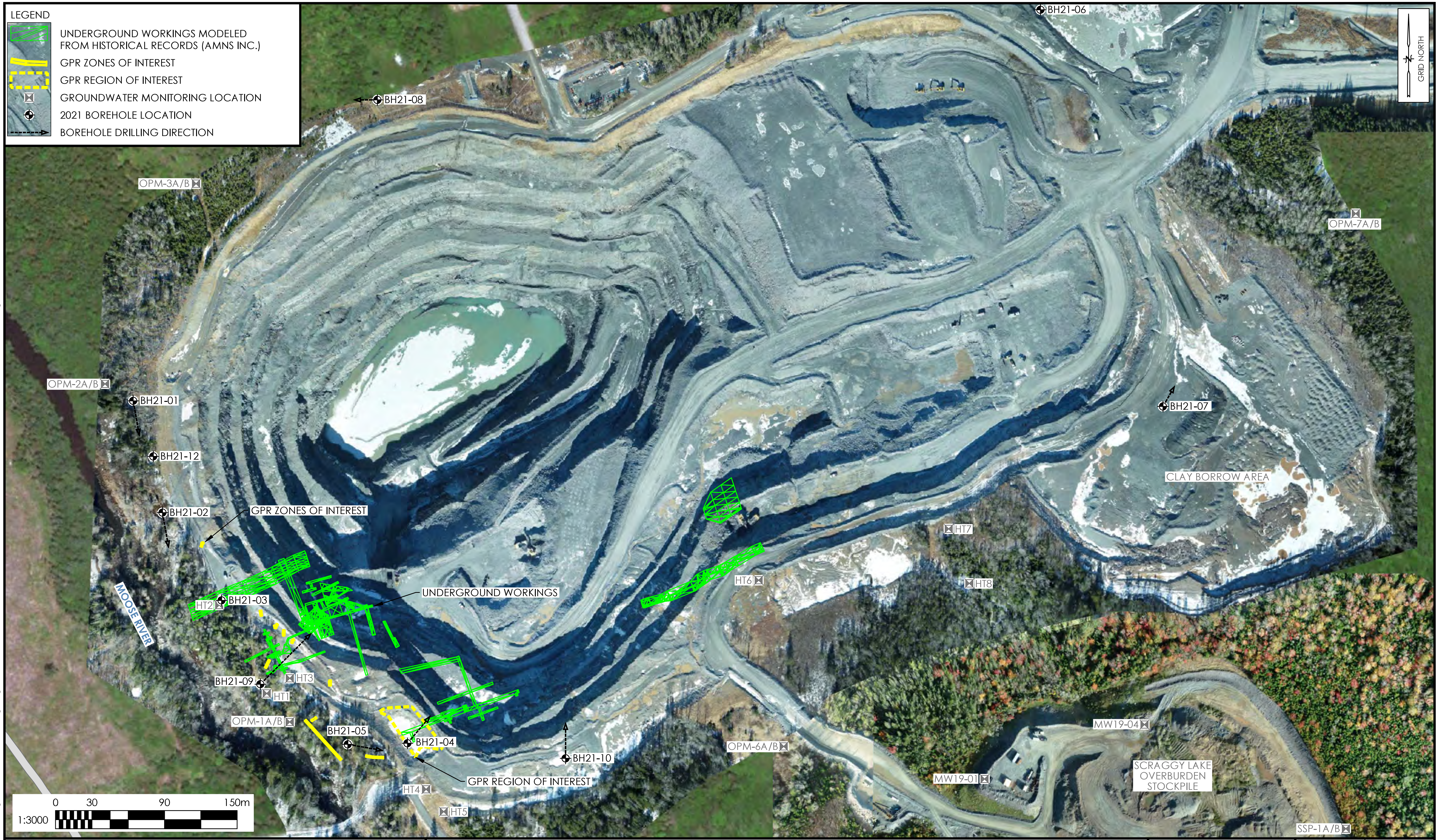
CLOSURE

We trust the information provided within this memorandum meets your current requirements. If you have any questions, please contact us at your convenience.

Stantec Consulting Ltd.

Paul Deering P.Eng.
Senior Principal, Geotechnical Engineer

Attachment:
Drawing No.1 Underground Workings and GPR Features Including Drilling Locations
Drawing No.2 Western Seepage Mitigation Overview
Drawing No.3 3D Model – Facing Southwest
Drawing No.4 Typical Western Seepage Mitigation Section



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4. GPR SURVEY DATA PROVIDED BY d-ANALYTICS SERVICES INC.

UNDERGROUND WORKINGS AND GPR FEATURES INCLUDING DRILLING LOCATIONS

SEEPAGE MITIGATION MEMO
TOUQUOY GOLD PROJECT
HALIFAX COUNTY, NOVA SCOTIA

Client: ATLANTIC MINING NS INC.

Job No.:	121619250
Scale:	1 : 3000
Date:	2022 03 11
Dwn. By:	JL
App'd By:	JG

Dwg. No.	Rev. No.
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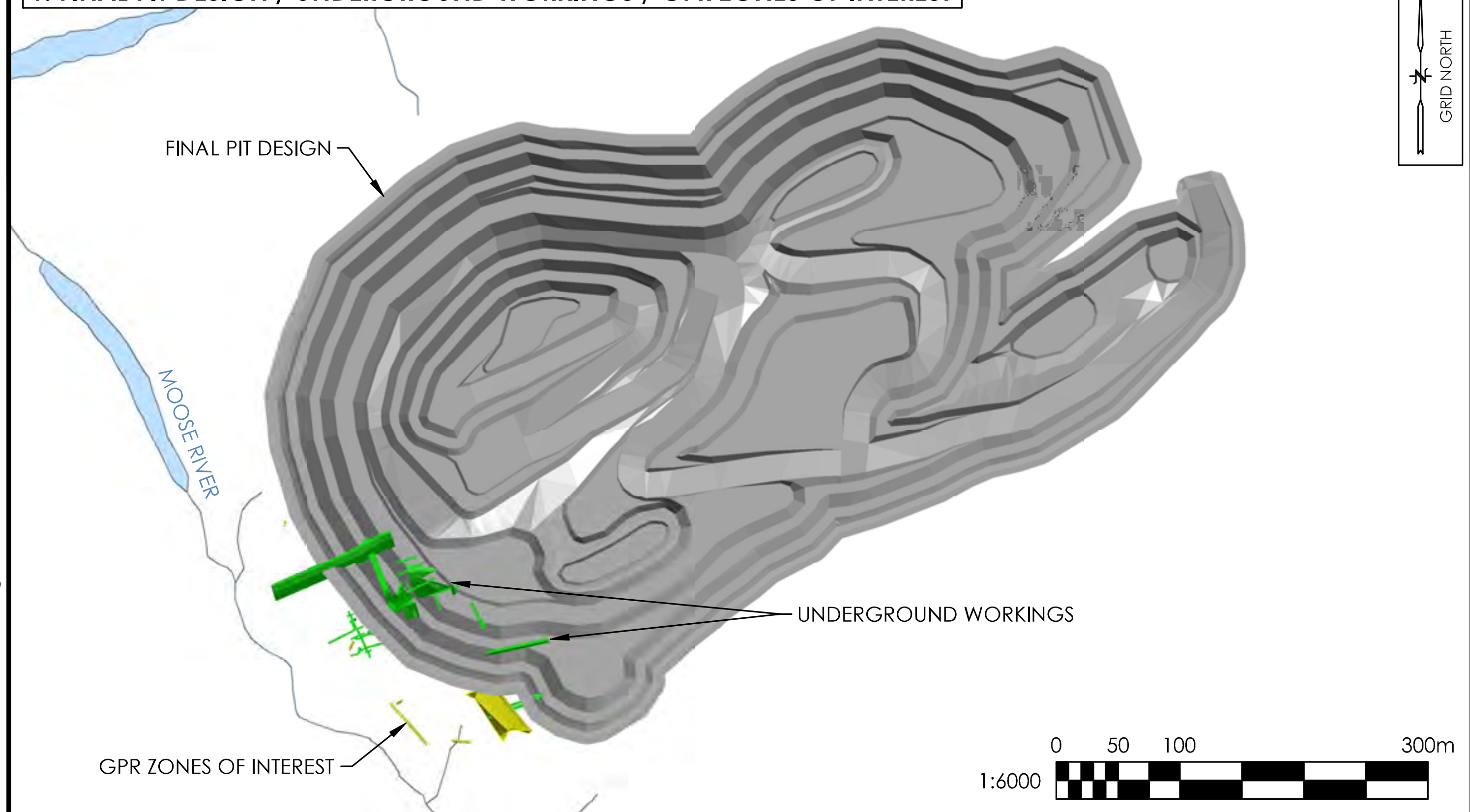
1. FINAL PIT DESIGN / UNDERGROUND WORKINGS / GPR ZONES OF INTEREST



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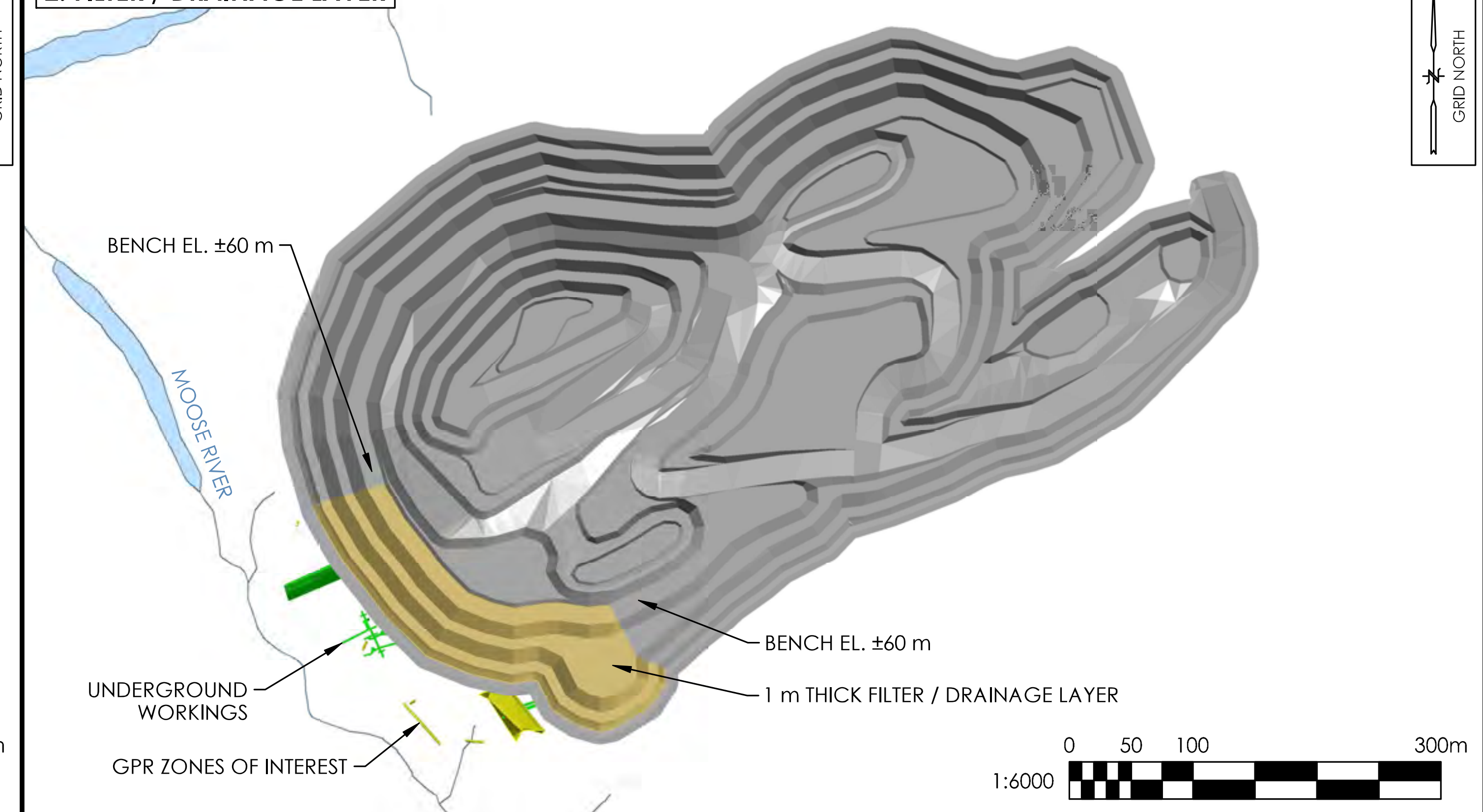
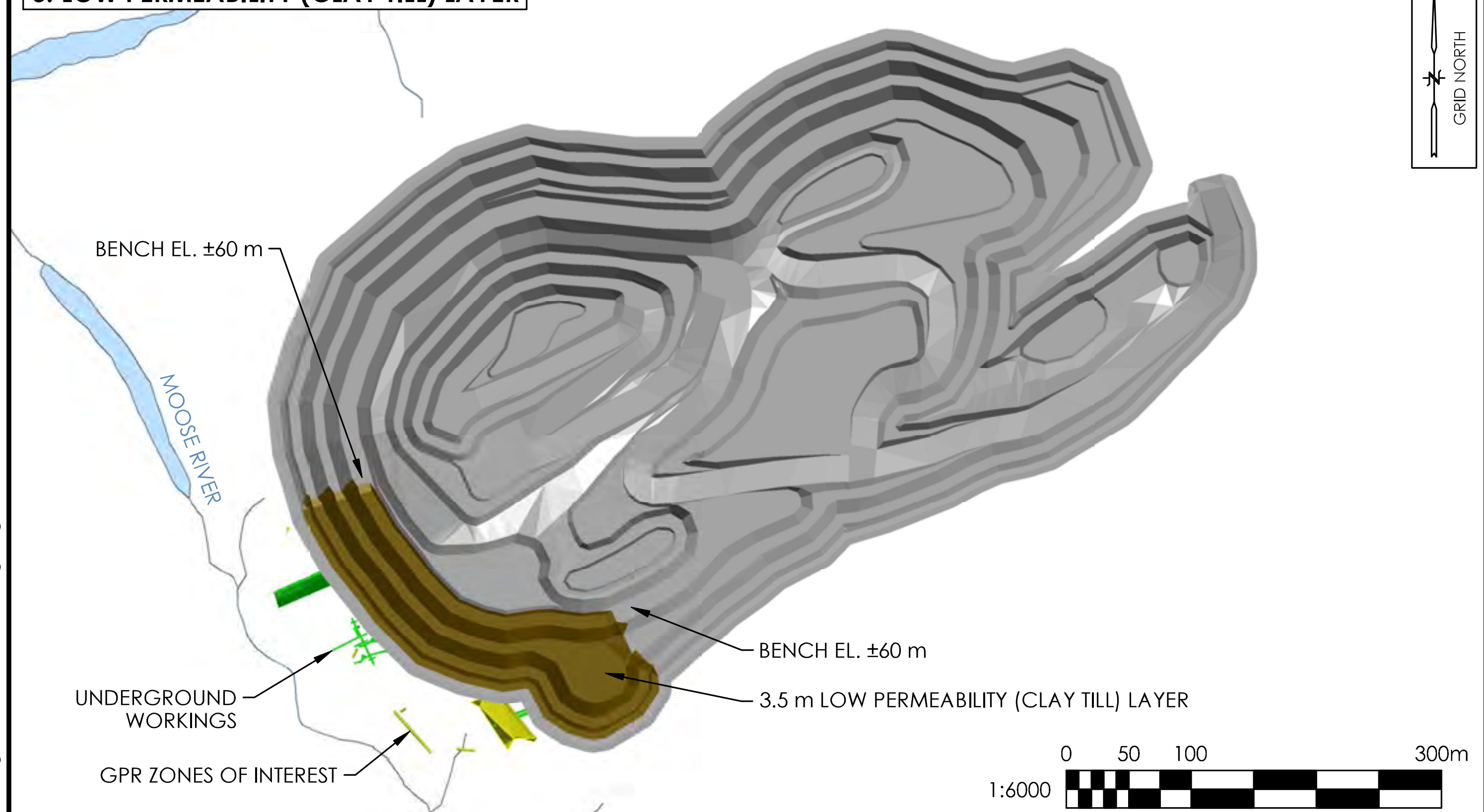
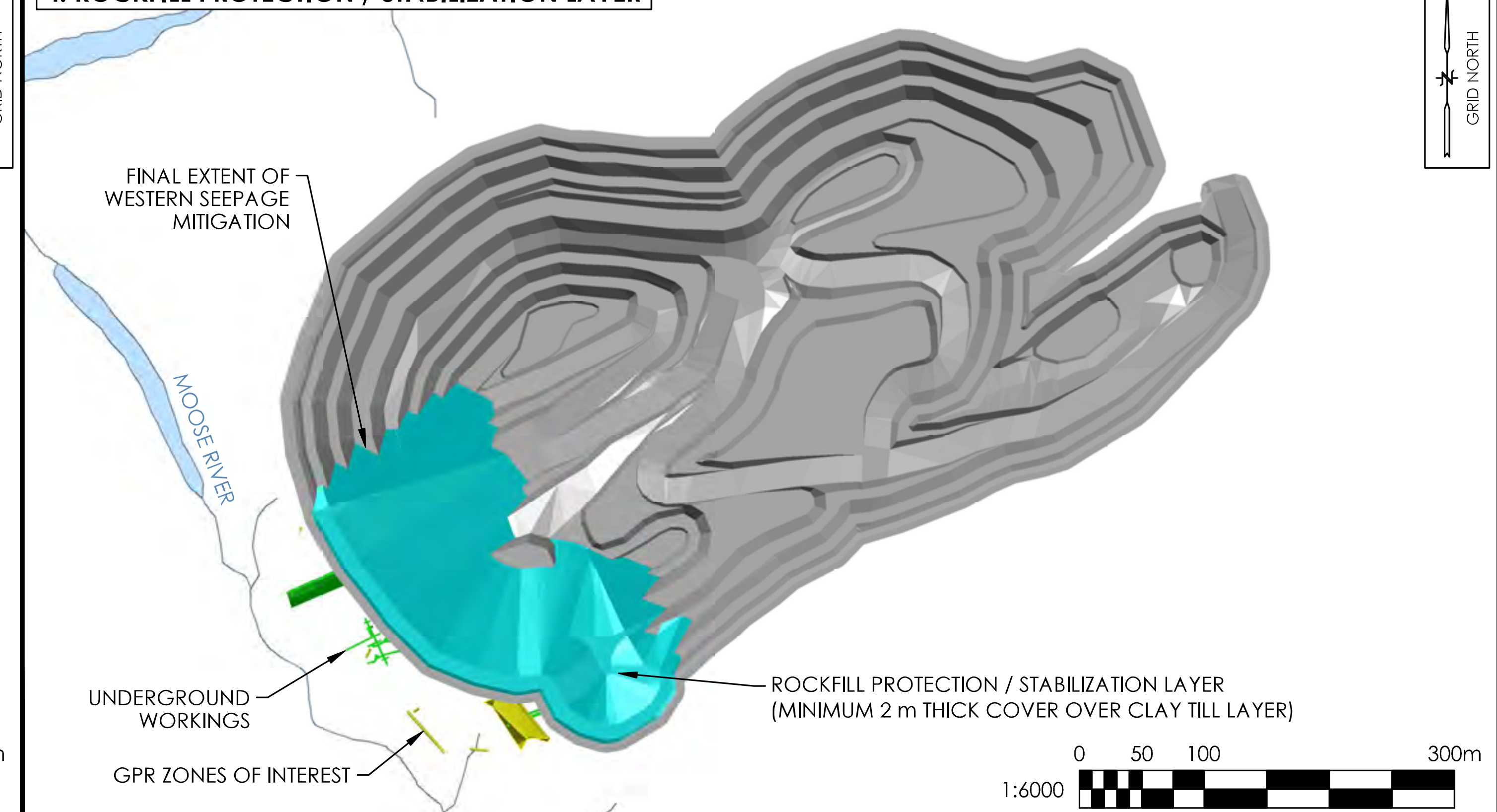


3. LOW PERMEABILITY (CLAY TILL) LAYER



4. ROCKFILL PROTECTION / STABILIZATION LAYER



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2. SITE DATA PROVIDED BY ATLANTIC MINING NS INC., McCALLUM ENVIRONMENTAL AND d-ANALYTICS SERVICES INC.

WESTERN SEEPAGE MITIGATION OVERVIEW

SEEPAGE MITIGATION MEMO
TOUQUOY GOLD PROJECT
HALIFAX COUNTY, NOVA SCOTIA

Client: ATLANTIC MINING NS INC.

Job No.:	121619250
Scale:	1 : 6000
Date:	2022 03 11
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Dwg. No.	2
Rev. No.	0

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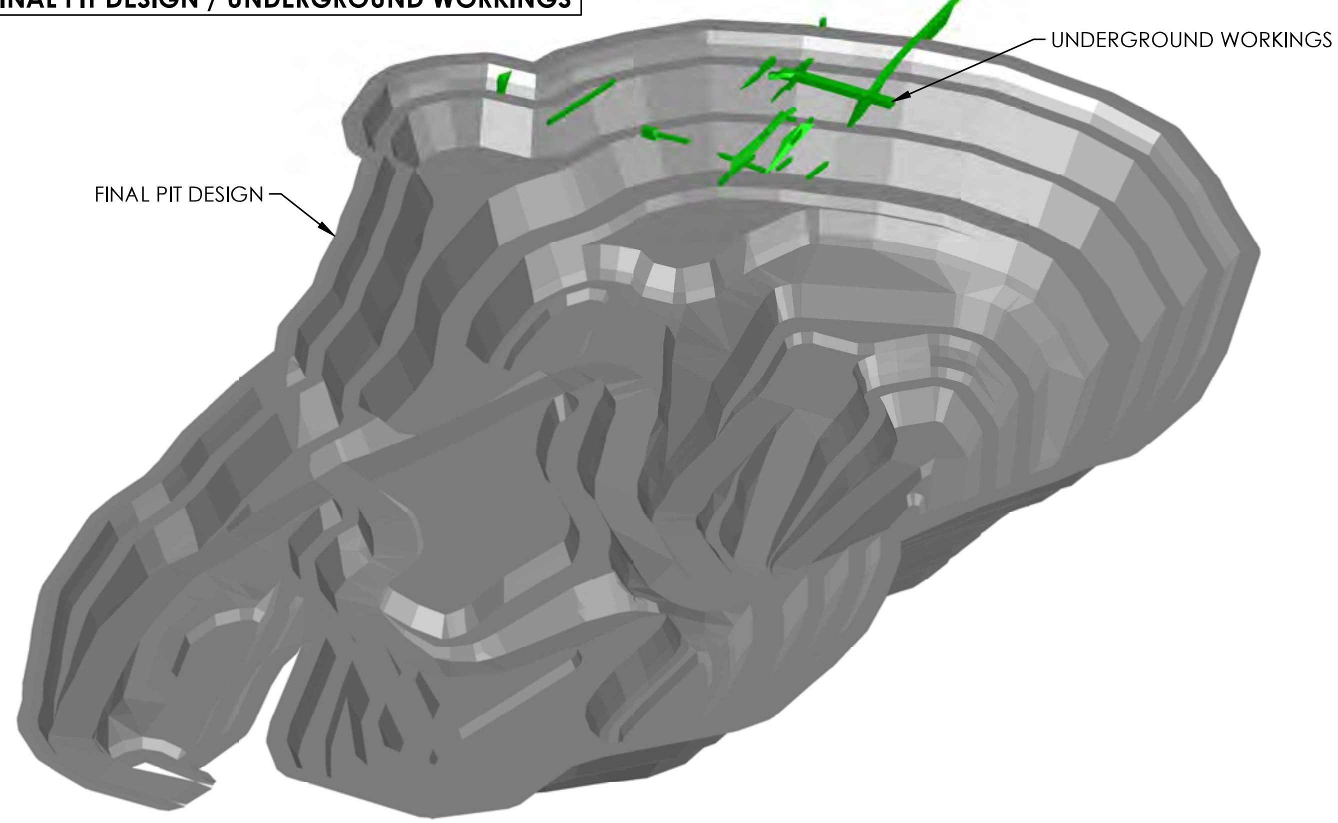
1. FINAL PIT DESIGN / UNDERGROUND WORKINGS



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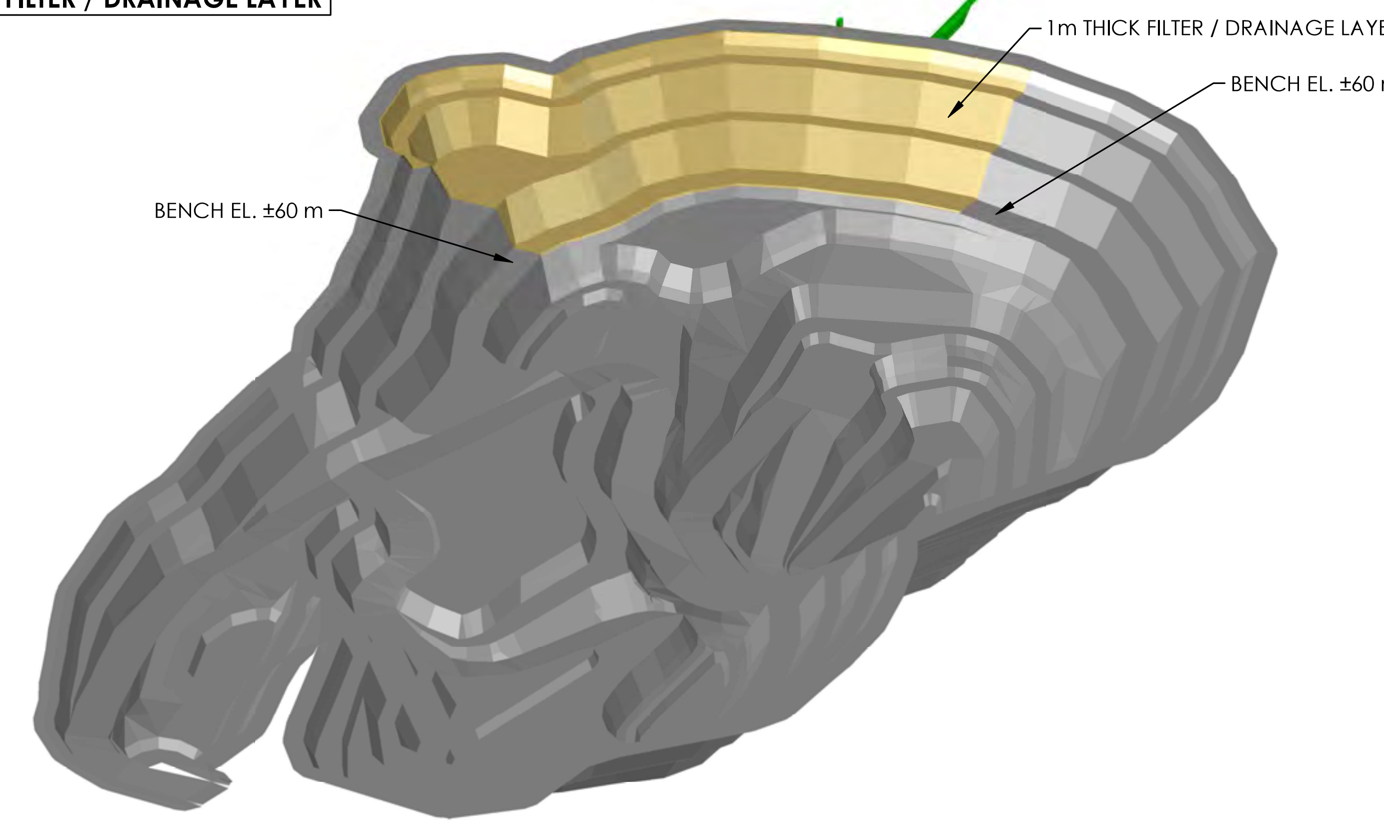

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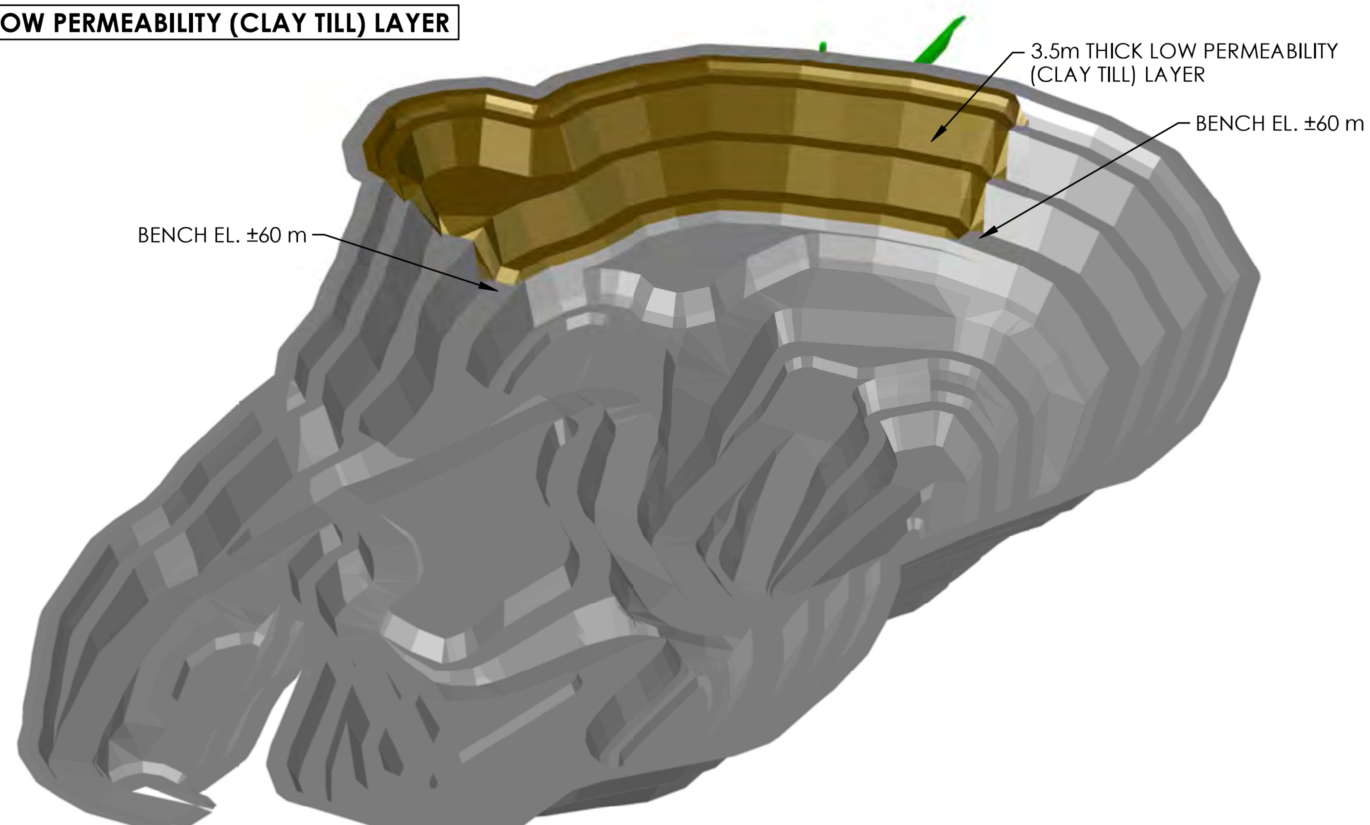

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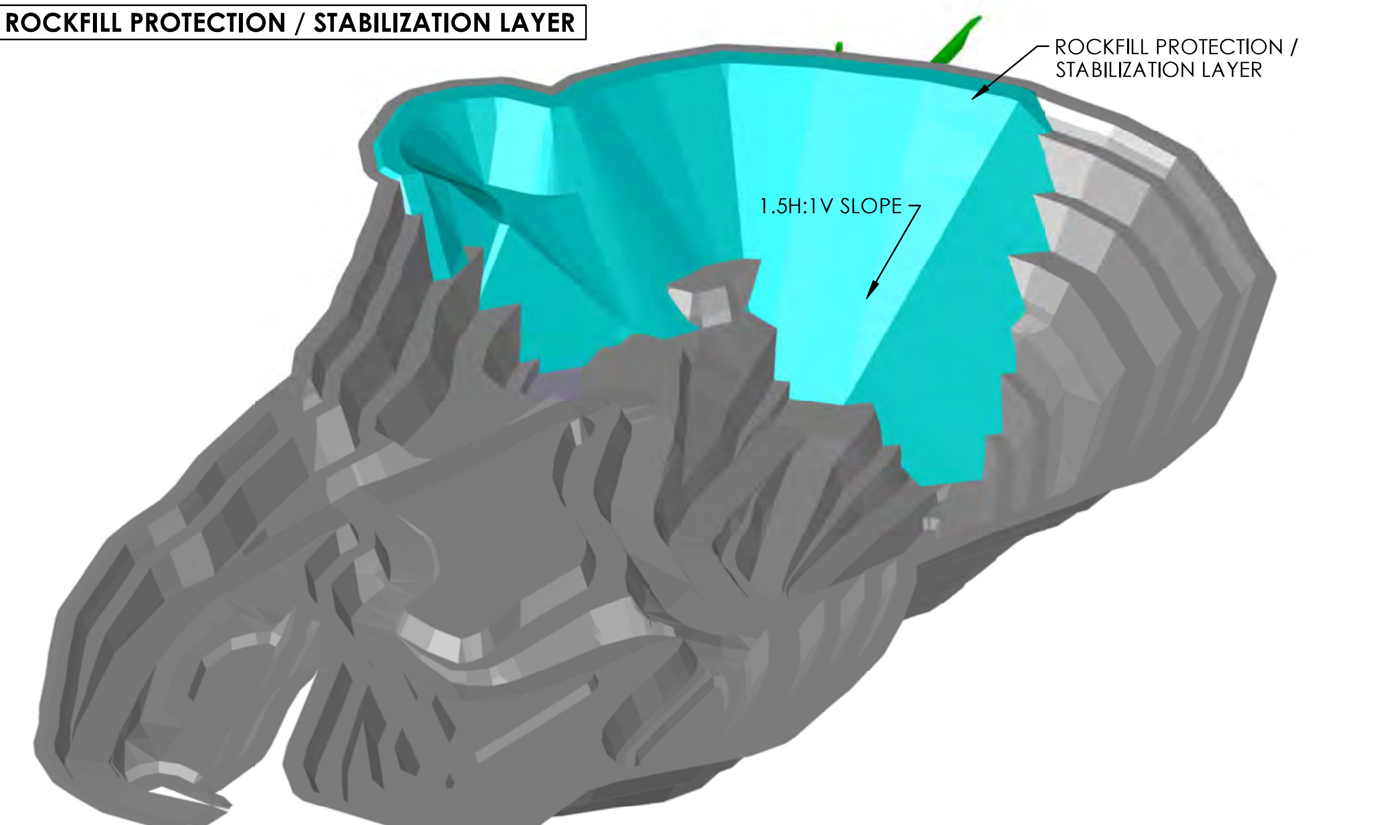

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3D MODEL - FACING SOUTHWEST

SEEPAGE MITIGATION MEMO
TOUQUOY GOLD PROJECT
HALIFAX COUNTY, NOVA SCOTIA

Client: ATLANTIC MINING NS INC.

Job No.:	121619250
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Rev. No.	0

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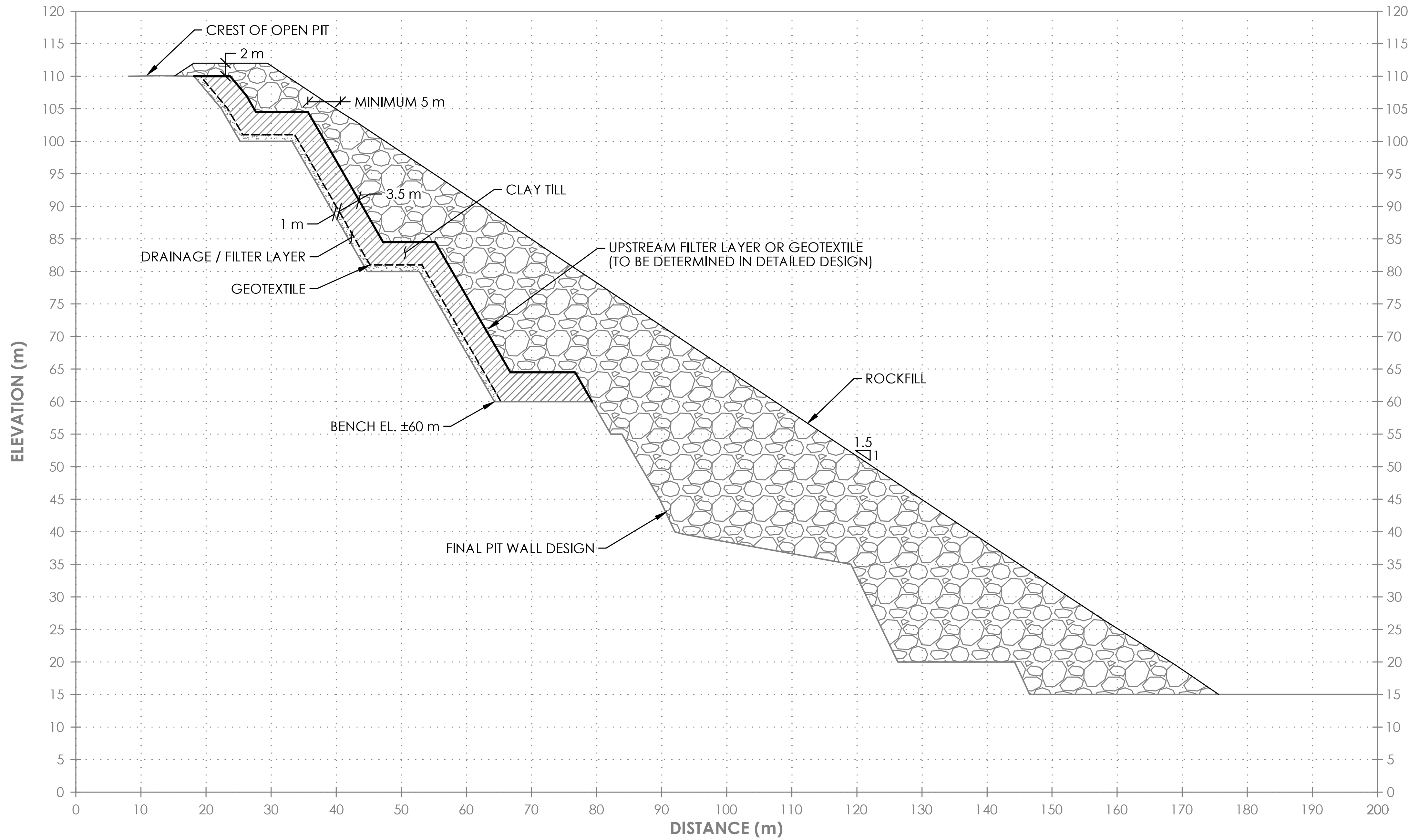

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TYPICAL WESTERN SEEPAGE MITIGATION SECTION

SEEPAGE MITIGATION MEMO
TOUQUOY GOLD PROJECT
HALIFAX COUNTY, NOVA SCOTIA

Client: ATLANTIC MINING NS INC.

Job No.:	121619250
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Date:	2022 03 11
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Dwg. No.	4
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APPENDIX B.3

Report Update: Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit

Report Update: Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit

March 2022

Atlantic Mining NS Inc.
409 Billybell Way, Mooseland
Middle Musquodoboit, NS   B0X 1X0

File: 121619250

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LIST OF TABLES

1.0 INTRODUCTION

This document forms part of the Touquoy Gold Project Modifications – Addendum to the Environmental Assessment Registration Document (EARD).

The Touquoy Gold Project is an open pit gold mine located in Moose River, NS and operated by Atlantic Mining NS Inc (AMNS) under Industrial Approval (IA) No. 2012-0824244-11. AMNS is proposing modifications to the Approved Project that are required to support ongoing operation. These modifications include: use of the exhausted Open Pit for tailings disposal; expansion of the Waste Rock Storage Area (WRSA); expansion of the Clay Borrow Area; and realignment of the Plant Access Road used to access the Plant Site.

AMNS retained Stantec Consulting Ltd. (Stantec) to conduct an assessment of the disposal of tailings from the processing of the ore into the open pit at Touquoy. As part of this assessment, Stantec constructed a groundwater flow and solute transport model to assist in the evaluation of the potential changes to water quality in the receiving environment that are likely to result from this activity. The groundwater flow and solute transport model would also allow for the future assessment of potential mitigation measures that could be implemented to reduce the potential release of contaminants.

AMNS registered a Class I Environmental Assessment Registration Document (EARD) under the *Environment Act* on July 16, 2021. The groundwater flow and solute transport model construction, calibration, and predictive results are documented in Appendix D.1 of the EARD. As part of the assessment of potential project interactions with groundwater, the assessment (Section 6 of the EARD) recommended additional characterization of the hydrogeological parameters in the vicinity of the Touquoy Open Pit, to confirm the properties of faults and identify potential high permeability fractures and previous underground mine workings. This work was initiated in Fall 2021, and was completed in January 2022. The results of this work are presented in Appendix B to the Main Addendum Report.

On September 8, 2021, the Minister of Environment determined that additional information was required regarding in-pit mine tailings disposal, ground and surface water, fish and fish habitat, protected areas, wildlife, wetlands and historical mine tailings. The additional information request included the requirement for a third party review to be undertaken on groundwater and surface water modelling undertaken in support of the EARD.

This document provides a description of updates made to the groundwater flow and solute transport model, which were made to consider new information gathered through the additional work described in Appendix B to the Main Addendum report. The information provided herein also addresses the outcomes of the third party review (also refer to Section 3.1 of the Main Addendum Report).

Please note that figure base layers depict pre-development conditions.

2.0 CHANGES TO EARD NUMERICAL GROUNDWATER FLOW AND TRANSPORT MODEL

The original numerical groundwater flow model (Stantec, 2021) was revised to incorporate additional data collected from the hydrogeological site investigation (Appendix B.1 to the Main Addendum Report). The model was updated and recalibrated to incorporate data from drilling, packer testing, and geophysics investigations performed in 2021 and early 2022.

Specific changes made to the groundwater flow model include:

- Incorporating new estimates of hydraulic conductivity in the bedrock units and selected fault zones.
- Refining the locations of underground mine workings based on additional information from AMNS and a surface geophysical investigation
- Recalibrating the groundwater flow model to reflect the new field data.
- Re-running the groundwater flow and transport model to update the predicted mass fluxes of dissolved constituents from the open pit that have the potential to affect Moose River.

Other than the changes above, the groundwater flow and transport model was unchanged from that submitted in support of the EARD. The modelling presented in the EARD and described in this document was conducted using the Groundwater Vistas (Environmental Simulations, Inc. 2017) graphical user interface (GUI) for MODFLOW-NWT (Niswonger et al. 2011) as the groundwater flow code and MT3D-USGS (Bedekar et al. 2016) as the numerical solute transport code. MT3D-USGS is a modular three-dimensional multispecies transport code for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems.

The GMRES solver package was used in the MODFLOW-NWT runs. Solver control parameters included:

- Convergence: 0.001 meters
- Maximum iterations: 500

The GCG solver package was used in the MT3D transport runs. Solver control parameters included:

- Convergence: $1x10^{-6}$ mg/L
- Maximum time step: 90 days
- Maximum iterations: 50

2.1 UPDATED MODEL RECALIBRATION AND PARAMETERS

The hydrogeological site investigation (Appendix B.1 to the Main Addendum Report) resulted in additional data regarding aquifer parameters and the potential extent of historic underground workings on the west side of the Open Pit, between the pit and Moose River. The field investigations included drilling and coring, packer testing, downhole geophysics, and surface geophysics. Details of the investigation methods and results are presented in Appendix B.1 to the Main Addendum Report.

Results of the field investigations were used in three ways. First, the boring logs and surface geophysics were used to evaluate the nature and potential extent of underground workings that had been previously identified in the zone between the pit and Moose River. Those data were also used to refine the locations of faults in the area around the pit and better identify the flow characteristics associated with those faults. Second, the packer test data were used to better characterize hydraulic conductivity of the hydrostratigraphic units identified in the original EARD model. Third, the new groundwater elevation data were combined with the stream elevation of Moose River to provide updated groundwater elevation contours and calibration targets.

After incorporating the field data into the model grid and initial parameterization, groundwater flow model was recalibrated. The recalibrated groundwater flow model included water level measurements at 17 additional locations around the Open Pit. These 17 additional calibration targets included water level measurements at various levels in the competent bedrock in the Touquoy pit area. Residual statistics used to evaluate the “goodness of fit” of the calibration in the EARD model were used to evaluate the calibration of the updated model. This included the calibration to water levels measured in monitoring wells, operational dewatering pumping rates for the Open Pit, and estimated baseflow of Moose River. Similar to the original EARD model, a hybrid calibration approach was used that combined automated parameter estimation, facilitated using the Parameter Estimation (PEST) code (Doherty 2018), together with professional judgement and interpretation of the calibration results.

2.1.1 Calibration to Water Levels

The statistical measures of the calibration to water levels included standard error of the estimate and the Root Mean Squared (RMS) error. In evaluating the fit between the observed and the simulated water levels, the RMS error is usually regarded as the best measure (Anderson and Woessner 1991). The RMS error is calculated as the average of the squared differences between the measured and the simulated water levels. If the ratio of the RMS error to the total water level differential over the model area (normalized RMS error) is small (i.e., less than 10%; Spitz and Moreno 1996), then the errors are only a small part of the overall hydraulic response of the model. Additionally, the mean error and absolute mean errors are also used, with a goal of achieving mean and absolute mean errors as close to zero as possible.

Table 2.1 summarizes residuals and calibration statistics for the updated groundwater model. Figure 2.1 shows a scatterplot of the simulated and observed groundwater levels used in the calibration. Residuals and calibration statistics indicate an acceptable match between observed and simulated values.

Table 2.1 Water Level Calibration Residuals and Statistics

Number of Wells	83
Sum of Squared Error (m^2)	378
Mean Error (m)	0.06
Absolute Mean Error (m)	1.61
Root Mean Squared Error (m)	2.13
Normalized Mean Squared Error (%)	5.2

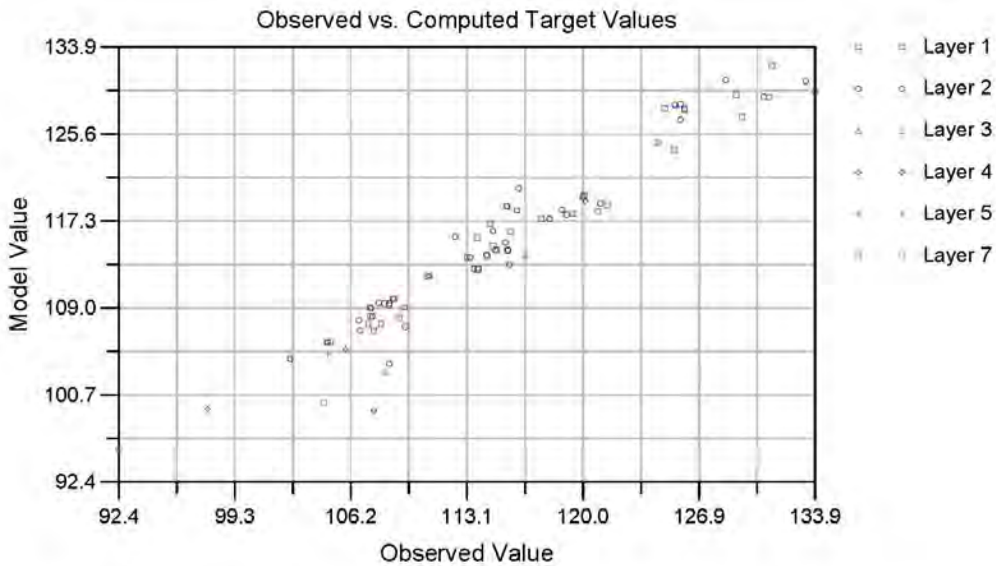

Figure 2.1 Scatterplot Showing the Match of Observed and Simulated Water Levels

2.1.2 Calibration to Groundwater Flow Rates

Model calibration was also assessed by comparing model simulated groundwater baseflow rates to Moose River, and groundwater inflow rates to the Touquoy open pit. The match of the groundwater flow targets in Moose River and to the Touquoy open pit are presented on Table 2.2. As shown on the table, the groundwater baseflow rates to Moose River are slightly (2%) overpredicted for the average annual condition. The average annual pit inflow rates were underpredicted by 11% for the annual conditions. These are considered good matches for the complete set of flow targets.

Table 2.2 Calibrated Groudnwater Inflow Rates

Flow Target	Target Rate (m^3/d)	Simulated Rate (m^3/d)
Moose River Baseflow 2019 (Annual)	28,814	29,369
Pit Inflow 2019 (Annual)	719	642

2.1.3 Comparison of Original EARD and Updated Model Calibration

The calibration quality of the updated model is similar to the calibration quality of the original EARD model. Note that the revised model calibration contains 17 addition water level calibration targets around the Open Pit and that several of these additional targets are located in the lower model layers representing competent bedrock. Table 2.3 summarizes the calibration statistics for the original and revised groundwater flow models.

Table 2.3 Comparison of Water Level Calibration Statistics for Original EARD Model and Revised Model

Statistic	Original EARD Model	Revised Model
Mean Error (m)	0.130	0.060
Absolute Mean Error (m)	1.256	1.61
Normalized Root Mean Squared Error (%)	4.6	5.2

2.1.4 Calibrated Model Flow Parameters and Inputs

The values of the hydrogeologic parameters that were determined from the calibration process are presented in Table 2.4. Figures 2.2 through 2.11 show the distribution of hydraulic conductivity by layer in the updated flow model. Groundwater recharge and evapotranspiration (ET) input rates were unchanged from the original EARD model. Overall modeled recharge and ETare included in Table 2.. Net annual recharge (recharge – ET) is about 14% higher in the revised model.

The hydraulic conductivity values for the various hydrostratigraphic units generated by the model are generally within the ranges expected for the materials based on measured and literature values. As shown on Table 2.4, the hydraulic conductivity of the overburden units with the exception of the drumlins was at the high end of the expected range. This may conservatively overestimate the flow into the overburden from groundwater recharge, but provides a reasonable match of water levels in the overburden across the site, and was therefore considered acceptable for this model.

As also shown on Table 2.4, the hydraulic conductivity of the competent Tangier and Moose River Member and Moose River Member are below the expected ranges. These lower than expected values were required in order to calibrate to water level targets completed in the lower model layers. These hydraulic conductivity values do not have a significant effect on the predictive model results as shown in sensitivity runs discussed in Section 3.

Table 2.4 Calibrated Flow Model Parameters

Parameter	Value at End of Calibration	Expected Range	
Groundwater Recharge and Evaporatranspiration (mm/yr)			
Annual Recharge	323	135	405
Annual Evapotranspiration	53		
Hydraulic Conductivity (m/s)			
Stony Till Plain	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Silt Till Plain	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Organics	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Drumlin	4.5×10^{-6}	1.0×10^{-8}	1.0×10^{-4}
Weathered Cunard Member	5.6×10^{-8}	3.9×10^{-9}	4.4×10^{-4}

Table 2.4 Calibrated Flow Model Parameters

Parameter	Value at End of Calibration	Expected Range	
Weathered Beaverbank Member	3.7×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Taylor's Head Member	3.7×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Tangier & Moose River Members	2.4×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Moose River Member	1.3×10^{-8}	3.9×10^{-9}	4.4×10^{-4}
Competent Cunard Member	3.9×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Competent Beaverbank Member	1.1×10^{-8}	3.9×10^{-9}	4.4×10^{-4}
Competent Taylor's Head Member	6.7×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Competent Tangier & Moose River Members	8.4×10^{-10}	3.5×10^{-10}	4.4×10^{-4}
Competent Moose River Member	7.4×10^{-12}	3.5×10^{-10}	4.4×10^{-4}
Primary Faults	5.9×10^{-9}	3.5×10^{-10}	4.4×10^{-4}
Secondary Faults	$1.1\text{x}10^{-10}$	3.5×10^{-10}	4.4×10^{-4}
Underground Mine Workings	$5.8\text{x}10^{-4}$	3.7×10^{-7}	$1\text{x}10^{-2}$
Vertical Anisotropy (K_v/K_h)			
Stony Till Plain	1.0	0.001	5.0
Silt Till Plain	1.0	0.001	5.0
Organics	1.0	0.001	5.0
Drumlin	2.0	0.001	5.0
Cunard Member	0.23	0.001	5.0
Beaverbank Member	0.98	0.001	5.0
Taylor's Head Member	4.3	0.001	5.0
Tangier & Moose River Members	0.81	0.001	5.0
Moose River Member	0.30	0.001	5.0
Cunard Member	1.0	0.001	5.0
Beaverbank Member	0.34	0.001	5.0
Taylor's Head Member	1.0	0.001	5.0
Tangier & Moose River Members	0.36	0.001	5.0
Moose River Member	32	0.001	5.0
Primary Faults	1.0		
Secondary Faults	1.0		
Underground Mine Workings	1.0		

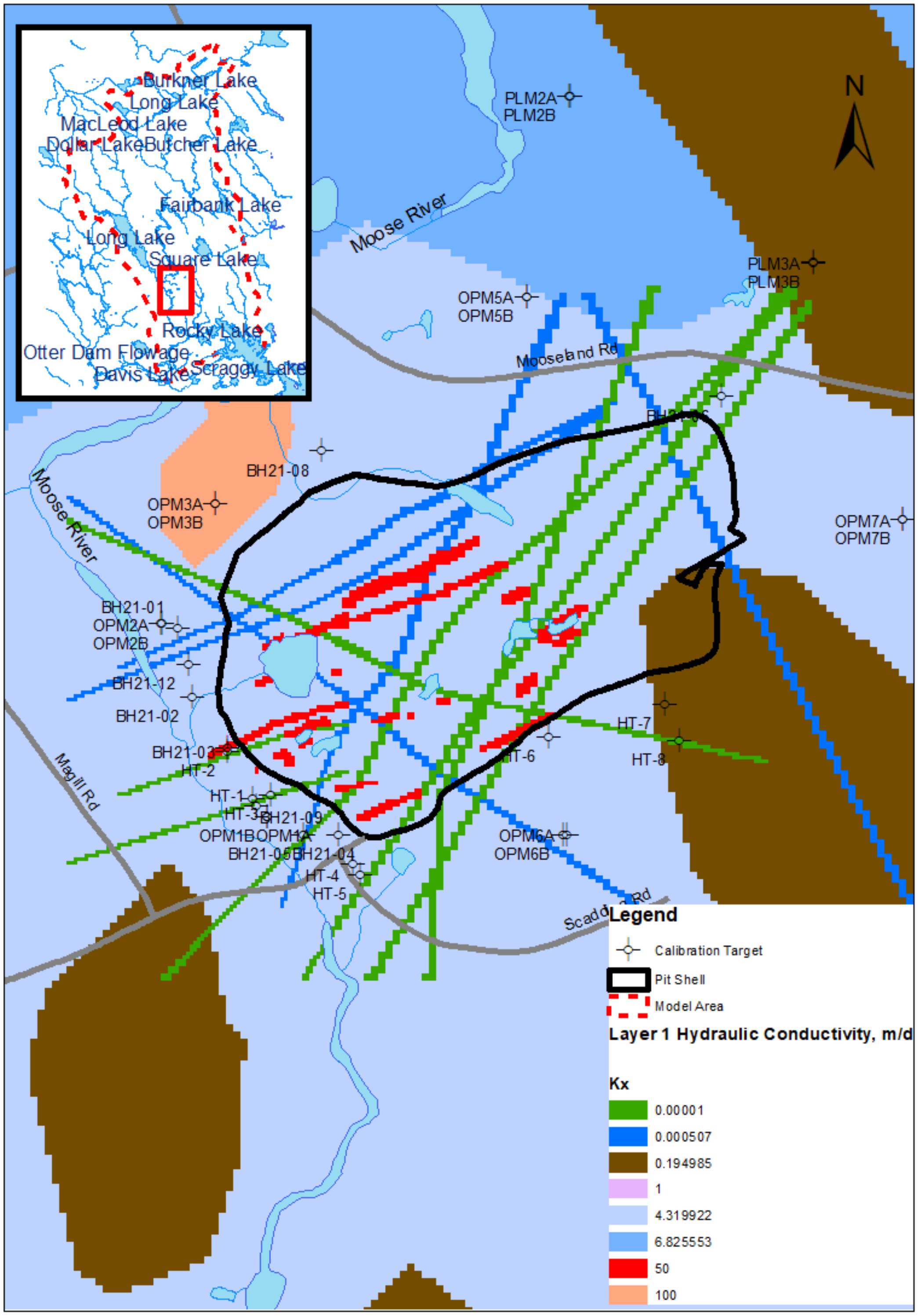

Figure 2.2 Distribution of Hydraulic Conductivity in Layer 1

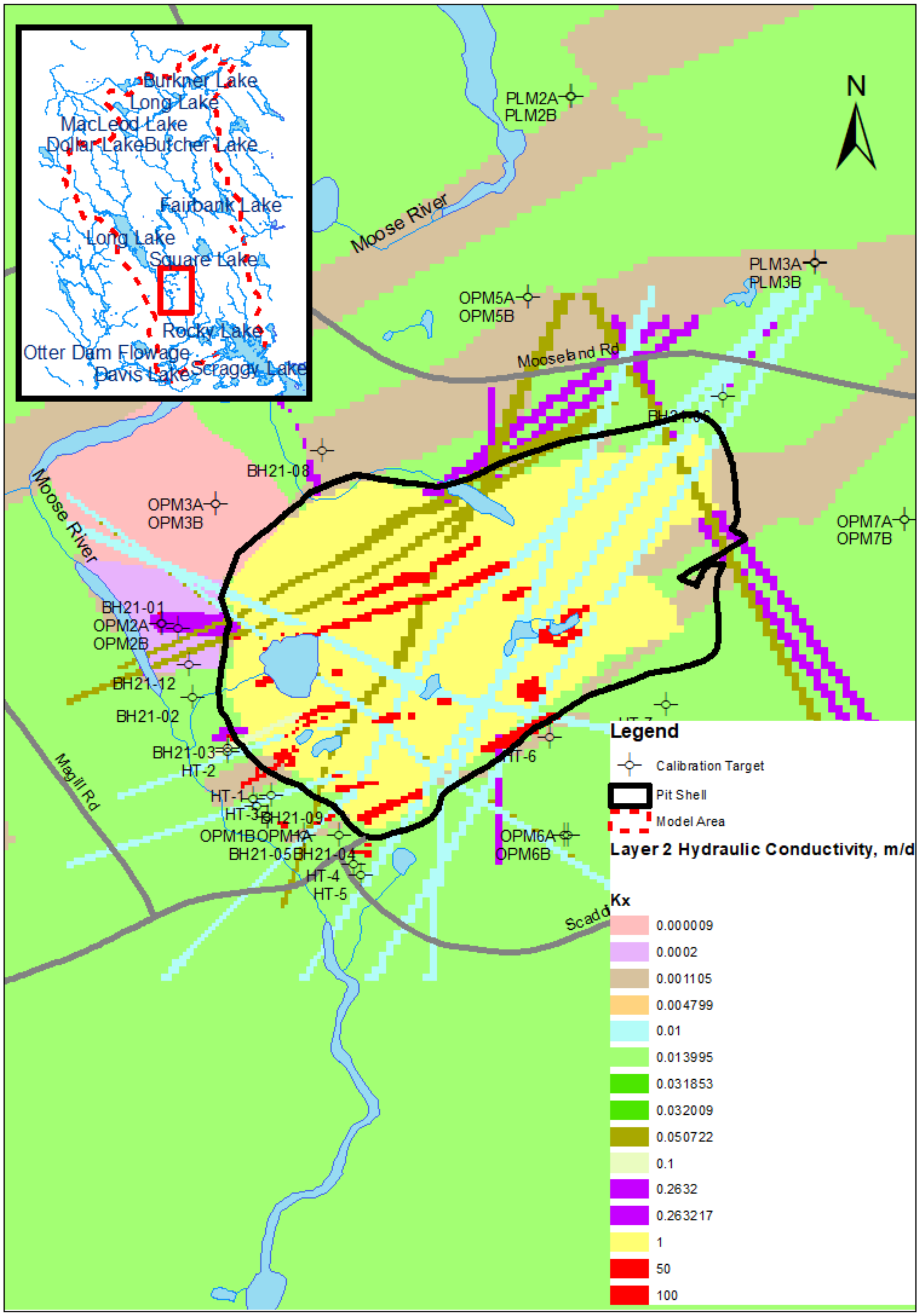

Figure 2.3 Distribution of Hydraulic Conductivity in Layer 2

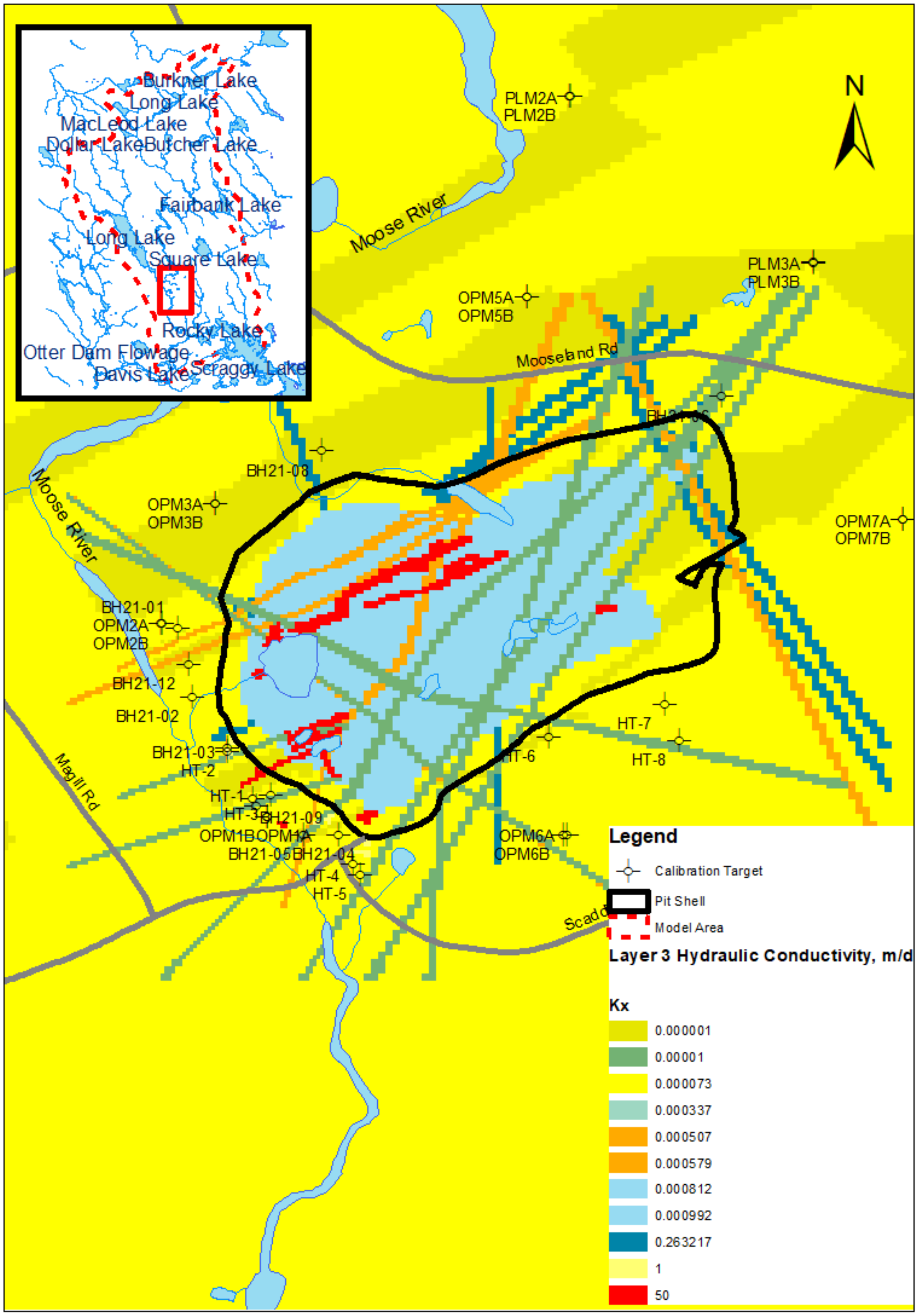

Figure 2.4 Distribution of Hydraulic Conductivity in Layer 3

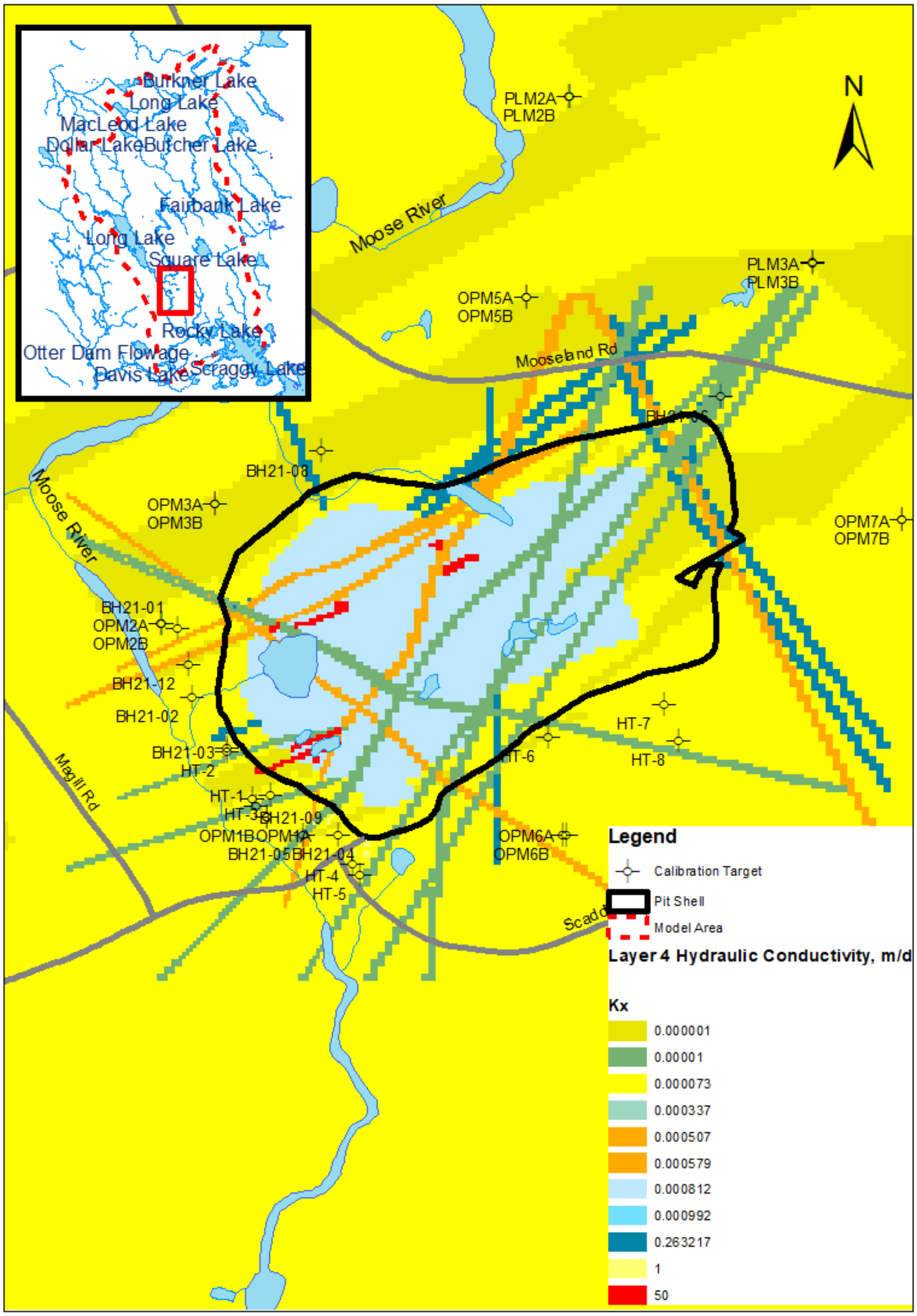

Figure 2.5 Distribution of Hydraulic Conductivity in Layer 4

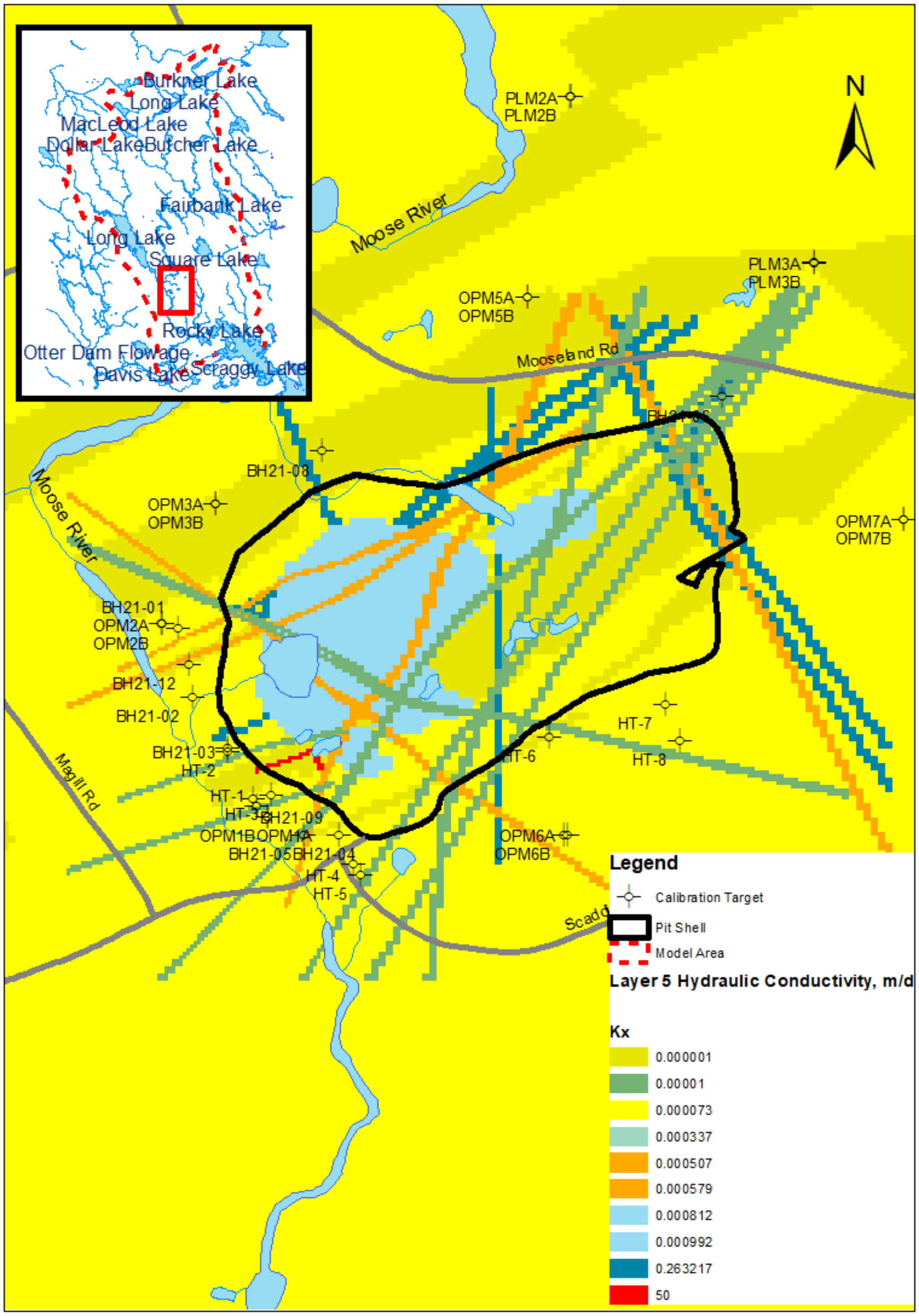

Figure 2.6 Distribution of Hydraulic Conductivity in Layer 5

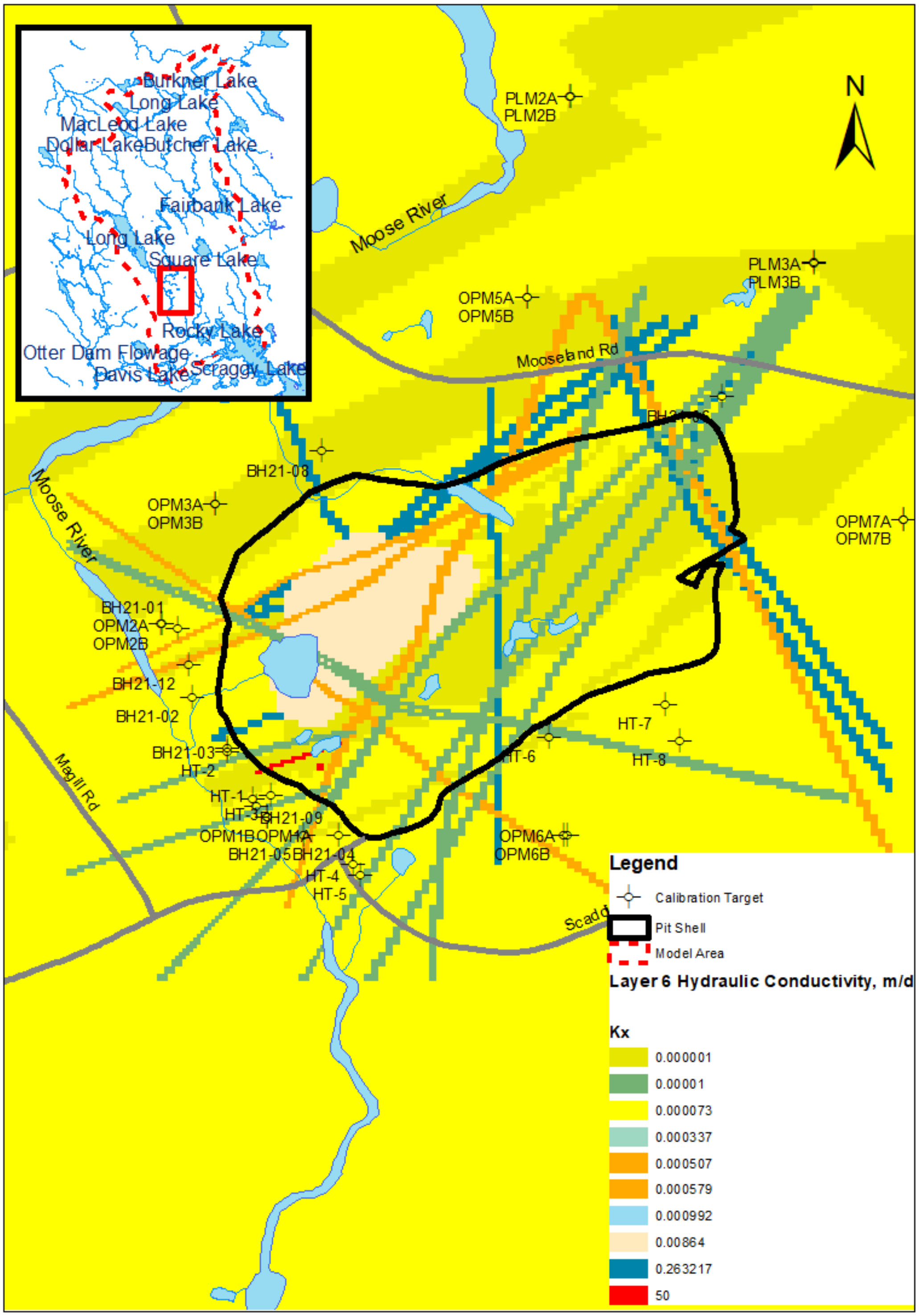

Figure 2.7 Distribution of Hydraulic Conductivity in Layer 6

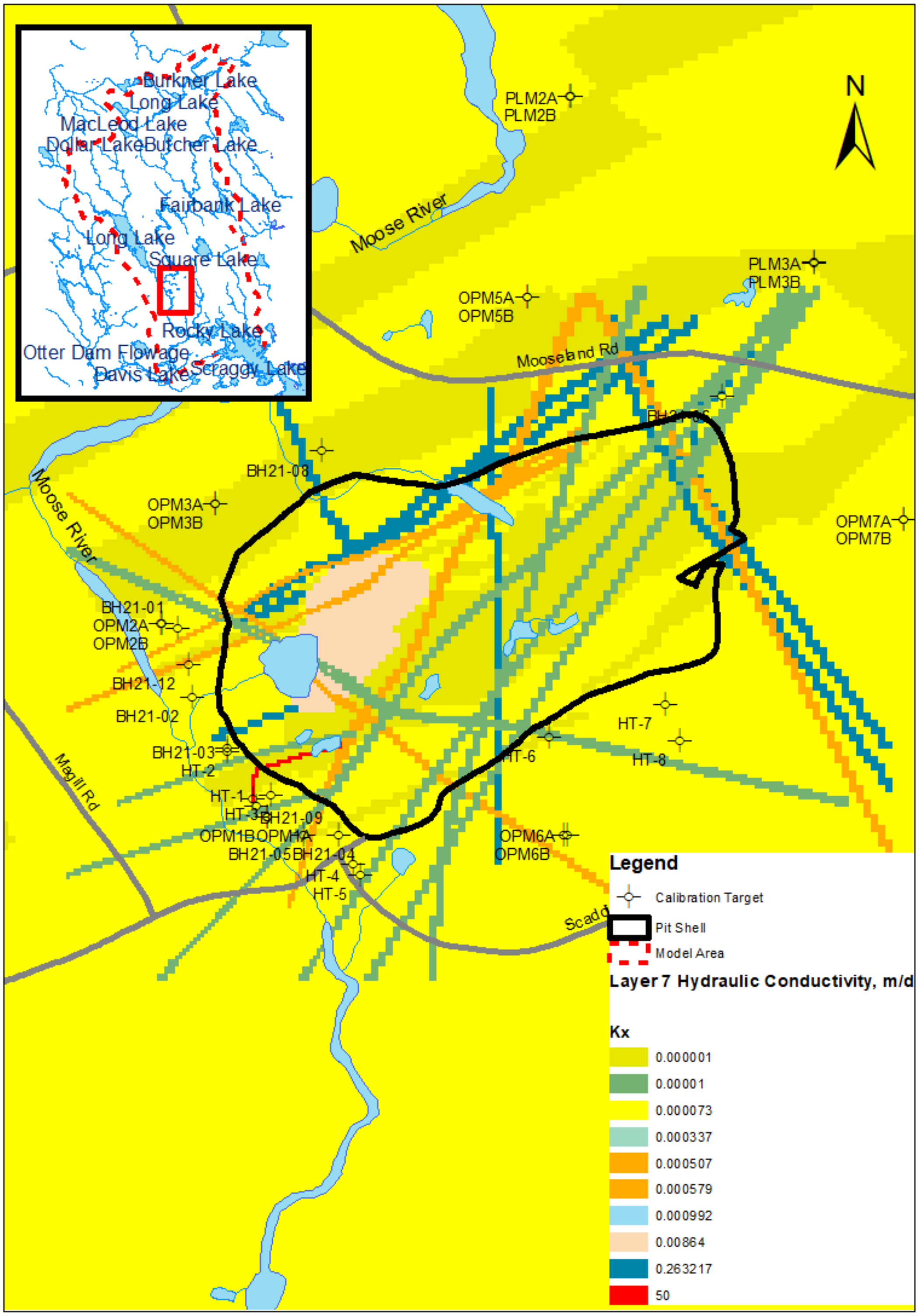

Figure 2.8 Distribution of Hydraulic Conductivity in Layer 7

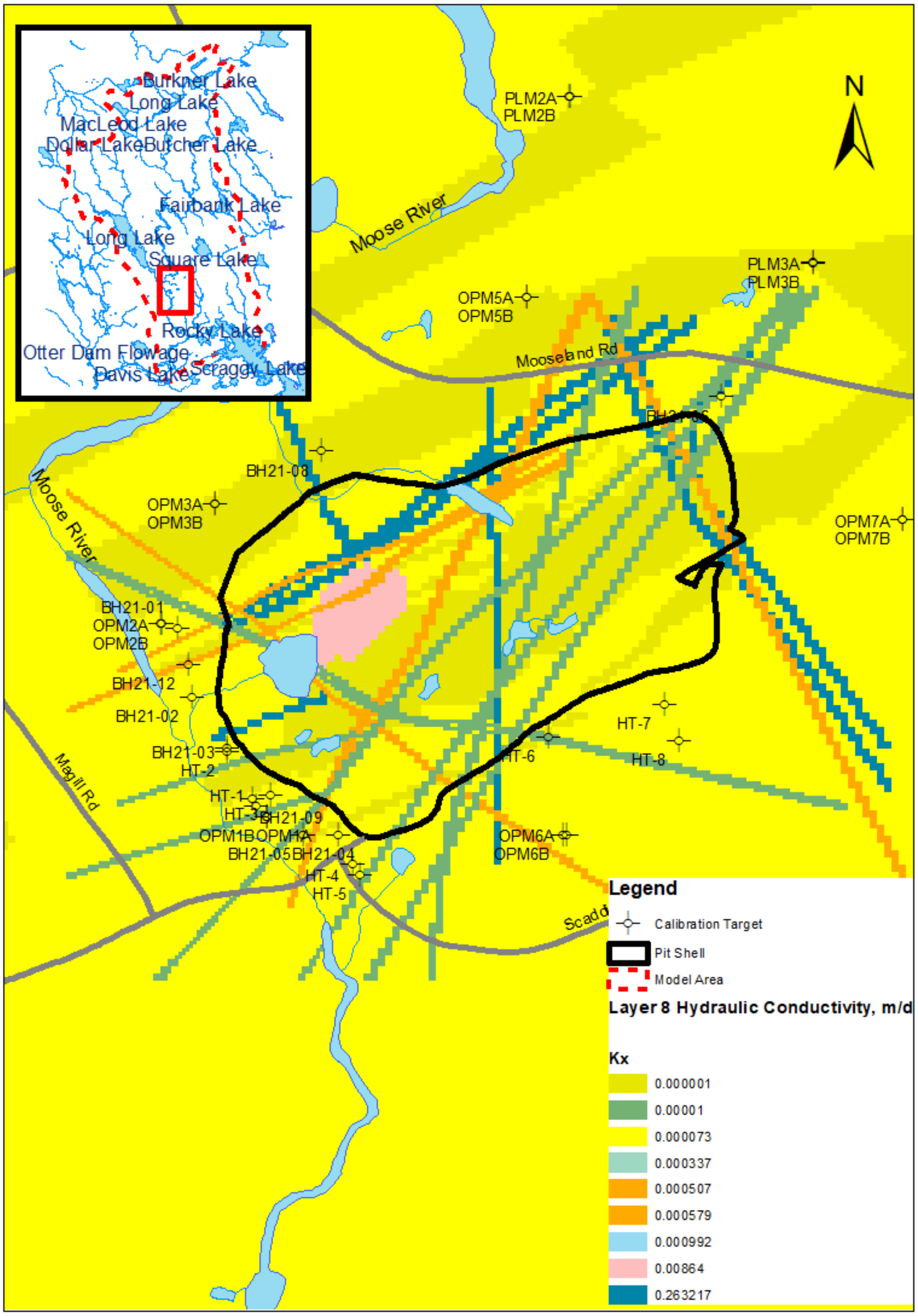

Figure 2.9 Distribution of Hydraulic Conductivity in Layer 8

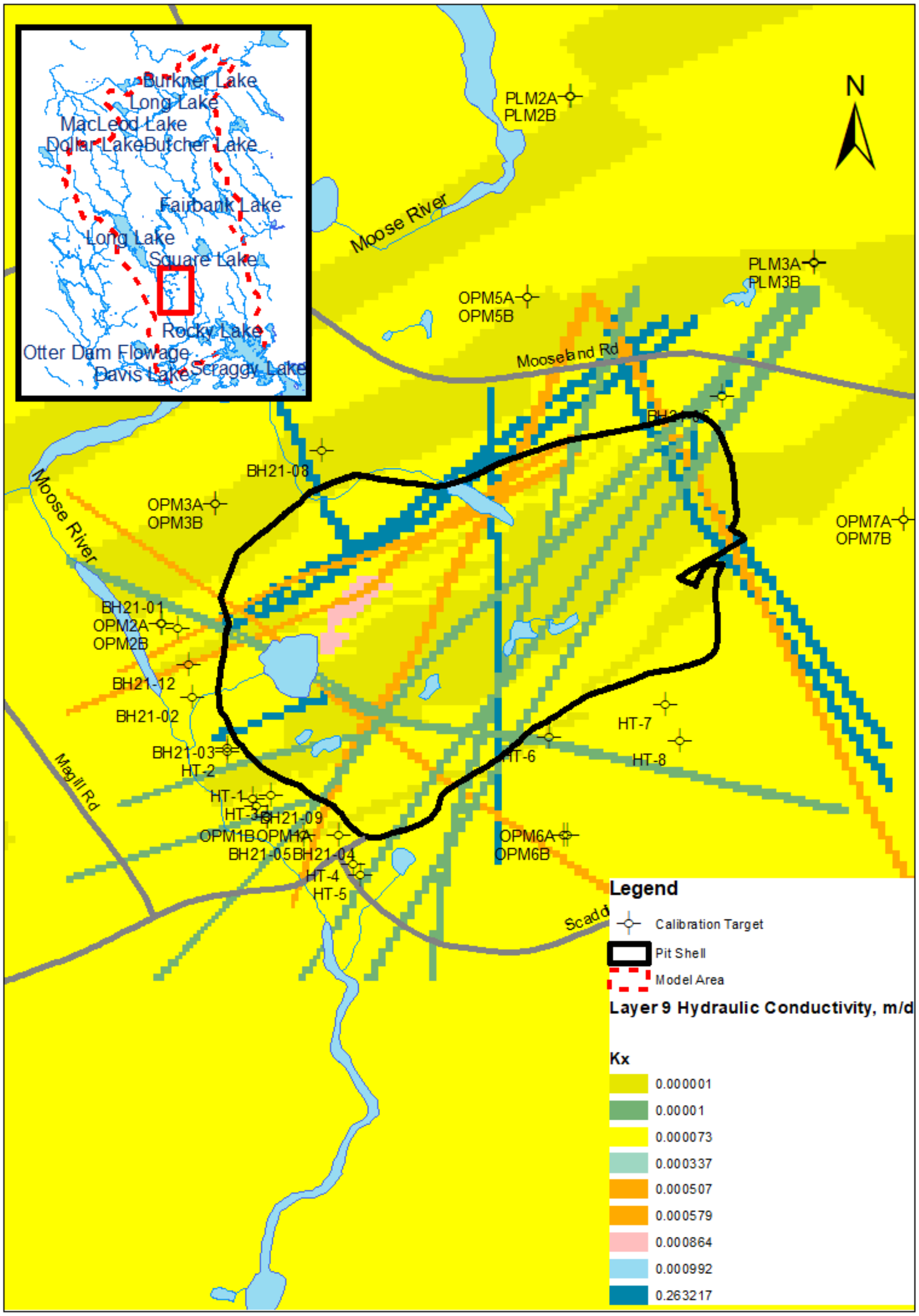

Figure 2.10 Distribution of Hydraulic Conductivity in Layer 9

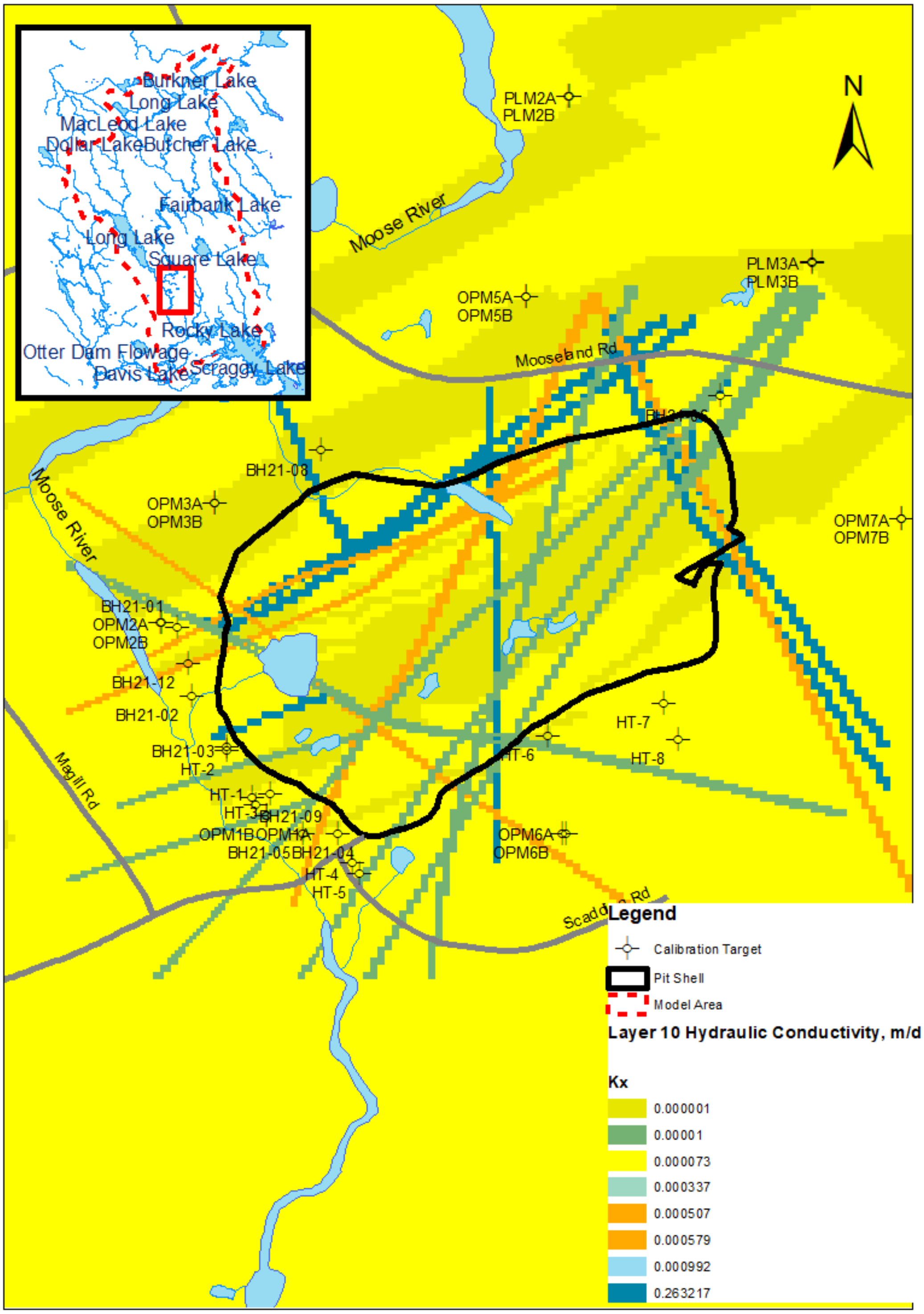

Figure 2.11 Distribution of Hydraulic Conductivity in Layer 10

2.1.5 Boundary Condition Conductance

The values of the pit wall, streambed, and drain conductance parameters were unchanged from the original EARD model. Conductance values for these boundary conditions are summarized in Table 2.4.

Table 2.5 Boundary Condition Conductance Values

Boundary Condition	Conductance (m^2/d)
Open Pit DRAIN	0.0126
GENERAL HEAD	2.71 - $6x10^5$
RIVER	.0257 - 9,000

3.0 CHANGES TO RESULTS

This section describes the changes to the results of the groundwater flow and solute transport models due to the model updates.

3.1 PRE-DEVELOPMENT CONDITIONS FLOW MODEL RESULTS

The water table elevation under pre-development conditions based on the updated groundwater flow model are shown on Figure 3.1. The model provides a good representation of the expected pre-development groundwater flow conditions with groundwater in the area of the open pit flowing from the water table high near east of the existing pit toward Moose River. The updated model results are similar to the results from the original EARD model.

The mass-balance error in the updated pre-development flow model was 0.19%. This is an acceptable mass balance for the groundwater flow model.

3.2 BASELINE CONDITIONS FLOW MODEL RESULTS

Baseline conditions for the operation of the Touquoy open pit as a tailings management area will be the conditions when the Touquoy pit has been fully excavated and completely dewatered. Under these conditions groundwater flow is toward the pit and tailings would not have been placed in the pit, so no transport modelling was performed. To simulate these conditions, the model drain cells representing seepage into the pit in the model were adapted to reflect the fully developed open pit in the same way as the original model.

The predicted pit inflow rates and net baseflow to Moose River at SW-2 are presented on Table 3.1 for the original and updated models. The updated model predictions are similar to the original EARD model for Moose River baseflow and annual pit inflows.

The drawdown contours for the updated model at average annual baseline conditions are presented on Figure 3.2. The extent of the predicted drawdown cone, as delineated by the 0.5 m drawdown contour, in the updated model is similar to the extent predicted by the original EARD model with the 0.5m drawdown contour extending slightly further to the south.

The mass-balance error in the updated baseline conditions model was 0.00002%. This is an acceptable mass balance for the groundwater flow model.

Table 3.1 Comparison of Baseline Predicted Average Annual Flows Between Original and Updated Models (m^3/d)

Flow Target	Existing (2019) Conditions	Original EARD Model	Updated Model
Moose River Annual Baseflow	29,346	29,297	29,369
Annual Pit Inflow	700	768	642

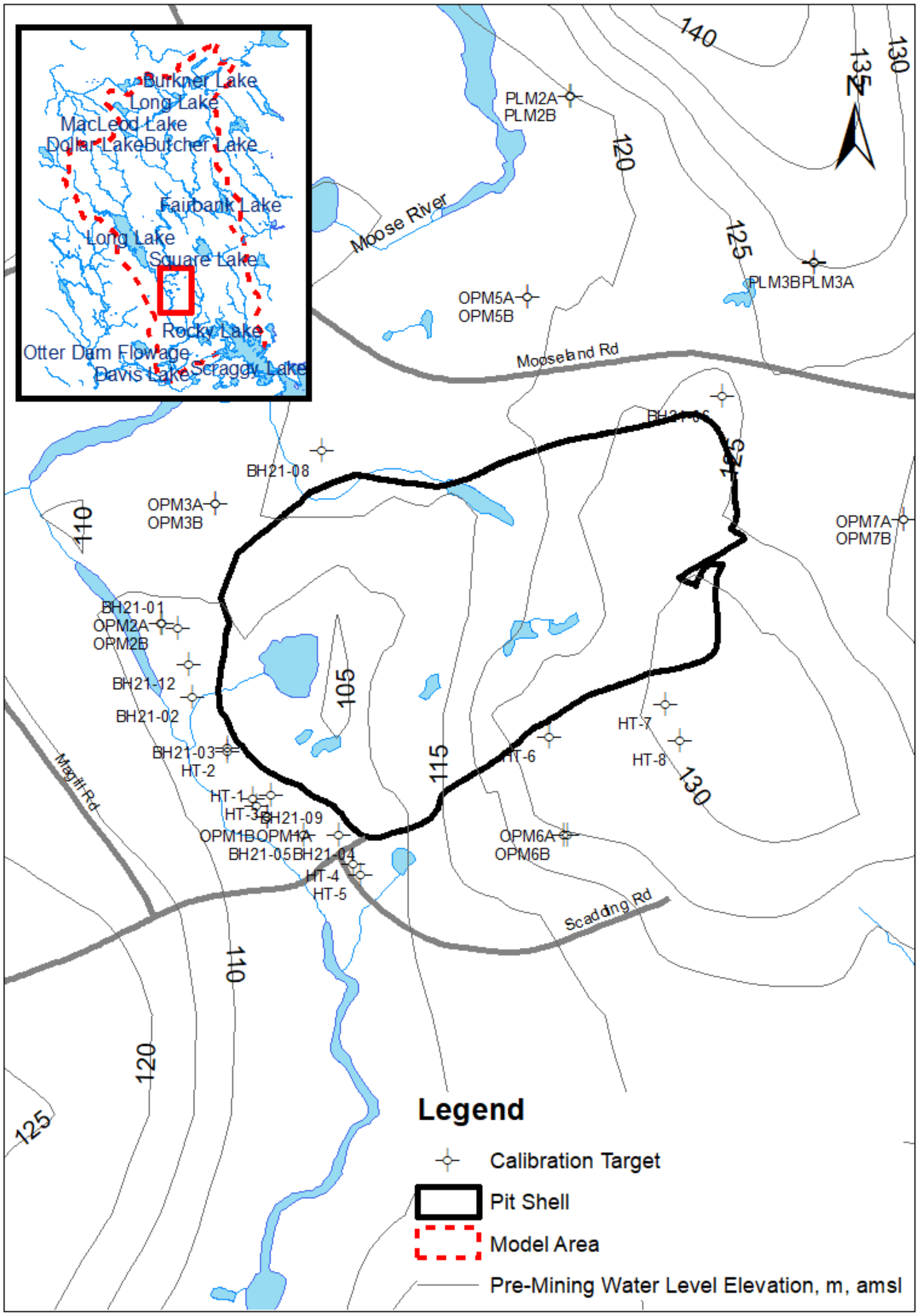

Figure 3.1 Predicted Water Table Elevation Contours under Pre-development Conditions, Updated Model

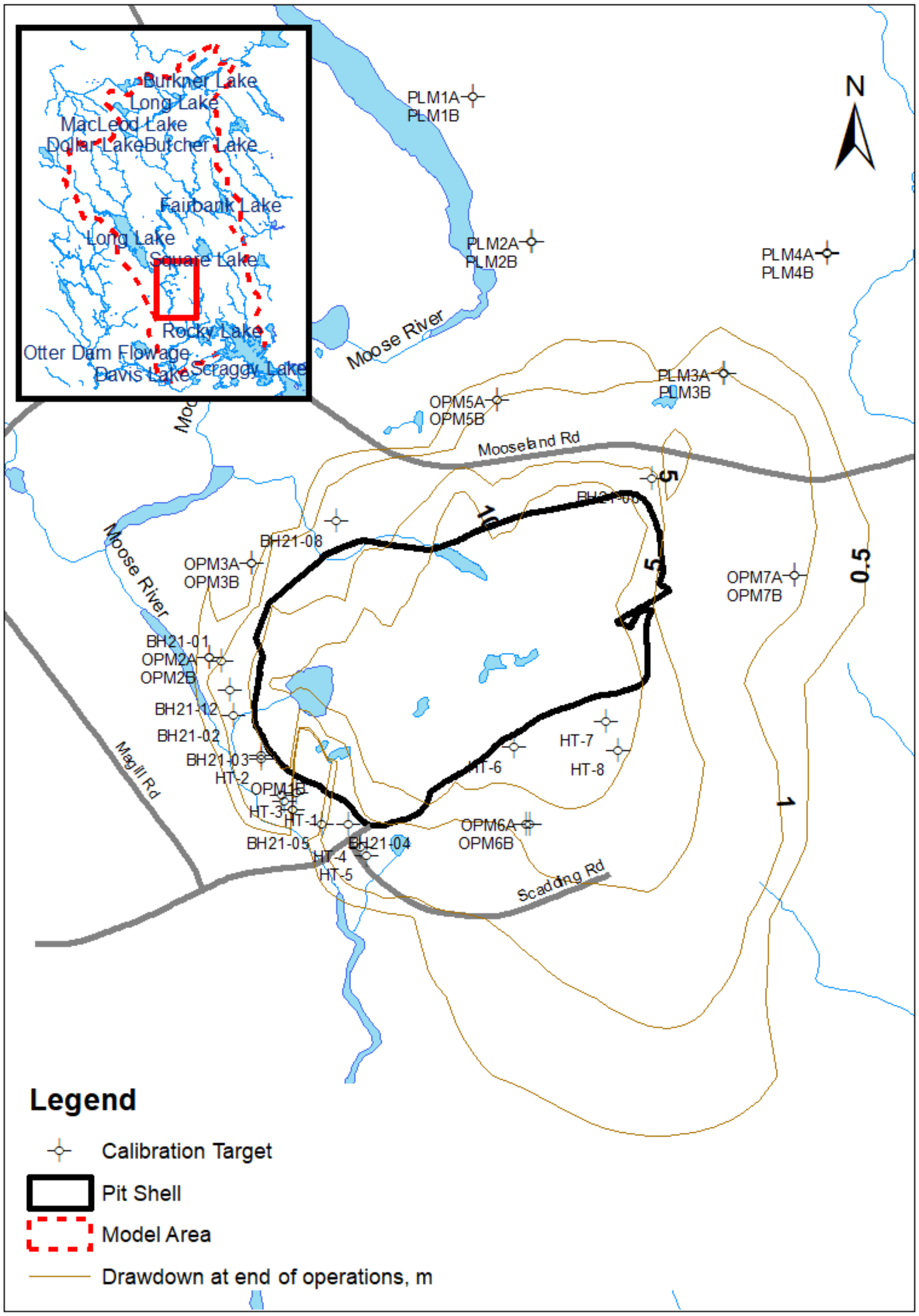

Figure 3.2 Predicted Drawdown at Average Annual Baseline Conditions for Updated Model

3.3 PROJECT OPERATION PHASE FLOW MODEL RESULTS

The operation of the Touquoy open pit as a tailings disposal area will result in the deposition of tailings and associated tailings slurry water to the open pit. As the pit fills, the rate of groundwater inflow to the open pit will decrease. The groundwater inflow to the open pit after dewatering is terminated was simulated to provide estimated flow rates for use in the water balance model. Groundwater inflow was simulated by adjusting the stage of the drain cells representing the seepage faces and the addition of tailings to layers below those stages.

The stage of the water level forming a pit lake was specified at intervals corresponding to the model layer thicknesses over the entire depth of the open pit by conducting several steady-state runs, one for each model stage, based on the mean annual conditions. The placement of tailings in the open pit was assigned using a hydraulic conductivity of 1×10^{-8} m/s in the bottom pit layers to represent more compacted material and 1×10^{-7} m/s above this representing less compacted material. At these values, the flow rates to the open pit are governed by the lower pit wall hydraulic conductivity.

Predicted groundwater inflows to the open pit with tailings at successively increasing elevations using the updated model are summarized in Table 3.2. The values are similar to those predicted with the original EARD model. Drawdown contours with the pit lake at elevation 108 m CGVD2013 are presented in Figure 3.3 and water table contours with the pit lake at 108 m CGVD2013 are presented in Figure 3.4.

The predicted volumetric flux of groundwater to Moose River upstream of SW-2 is 29,369 m^3/d.

The mass-balance error in the updated operational-phase flow models ranged from 0.0000044% to 0.32%. These are acceptable mass balances for the groundwater flow models.

Table 3.2 Simulated Groundwater Inflow Rates at Pit Lake Stages, Updated Model

Pit Lake Stage (Drain Cell Elevation) (m CGVD2013)	Simulated Inflow Rate (m^3/d)
-25	642.5
0	642.6
25	641.9
50	639.3
75	632.4
100	590.9
108	380.8
120	116

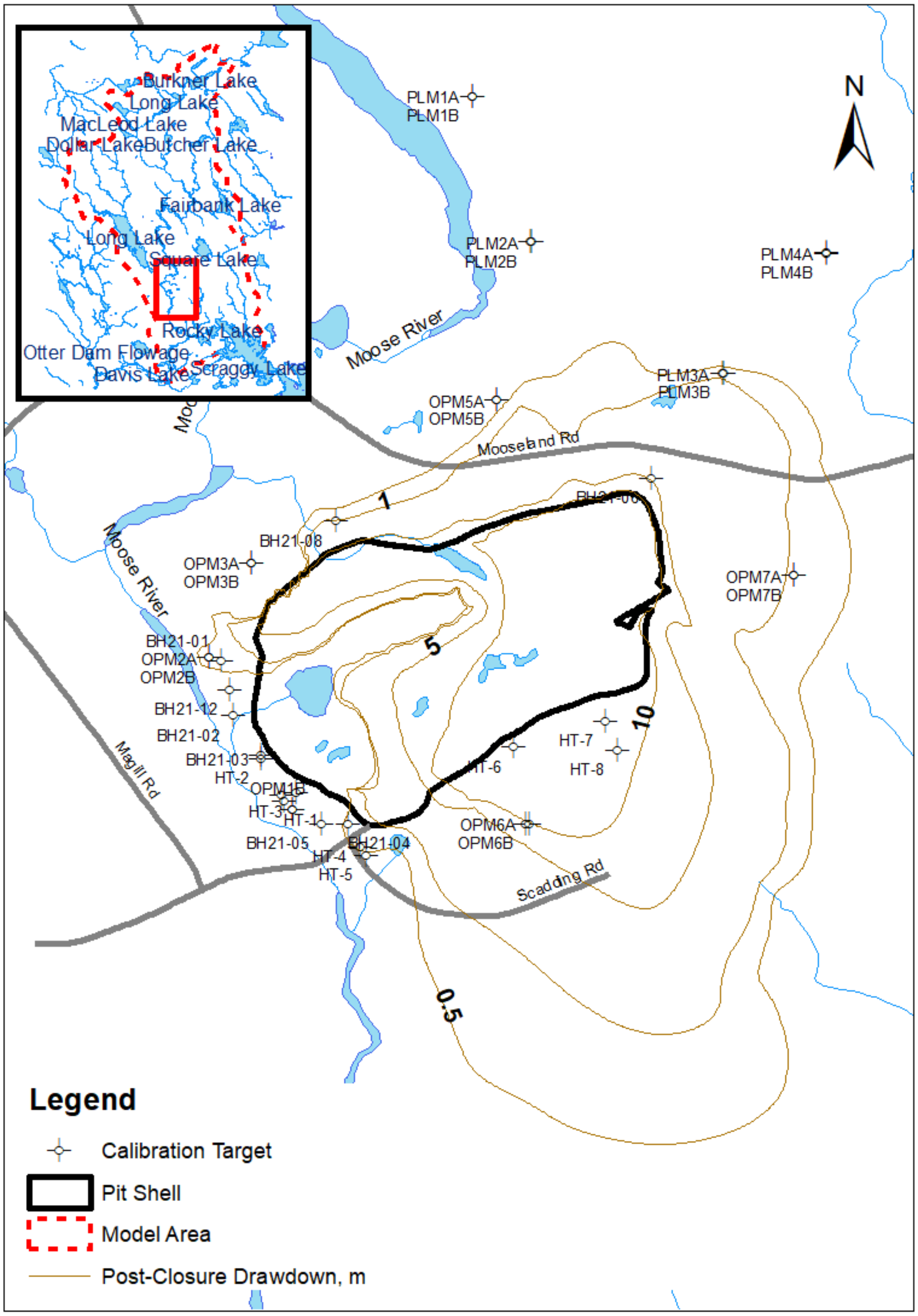

Figure 3.3 Predicted Drawdown Contours with Pit Lake Elevation of 108 m CGVD2013, Updated Model

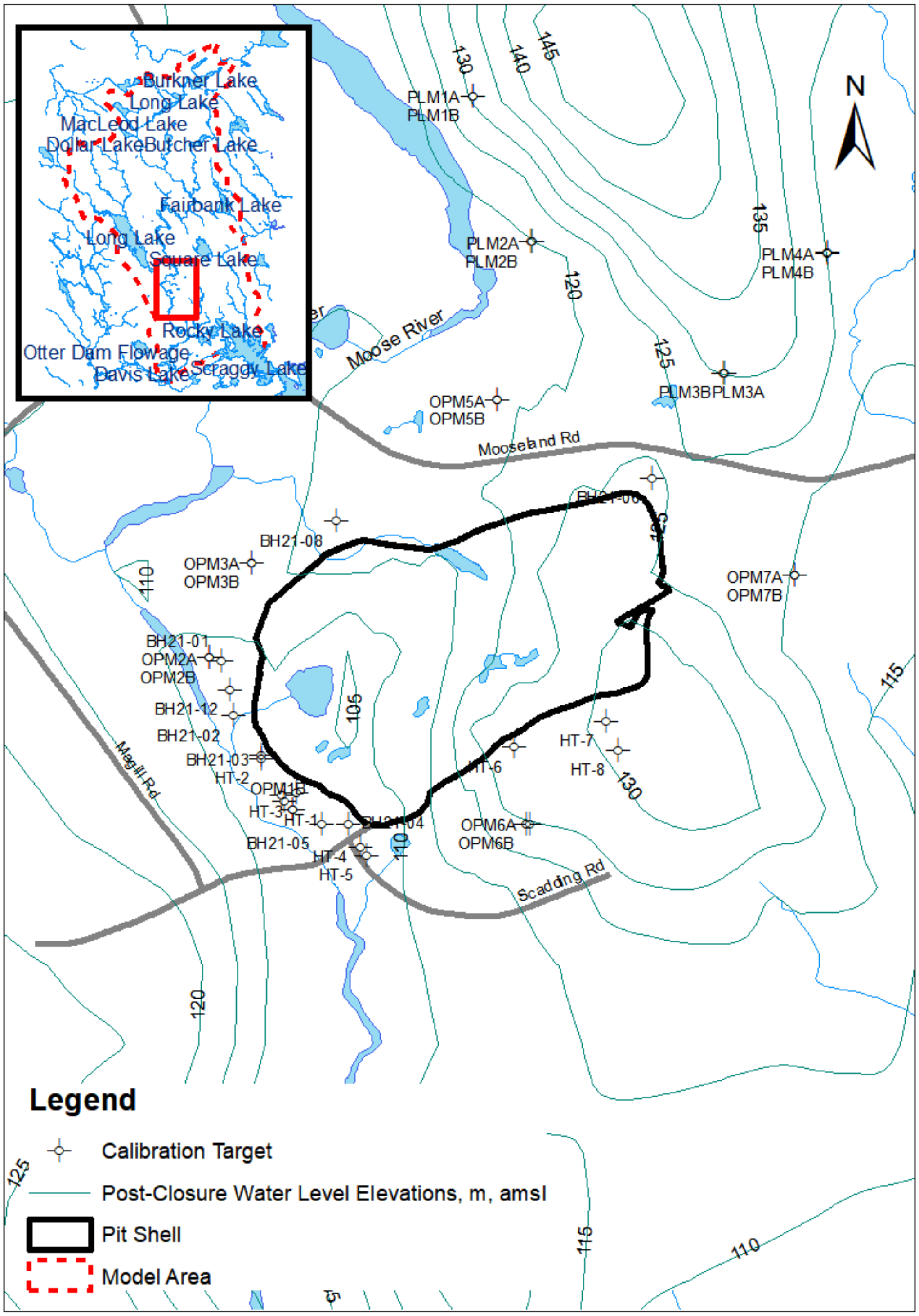

Figure 3.4 Predicted Water Table Contours with Pit Lake Elevation of 108 m CGVD2013, Updated Model

3.4 POST-CLOSURE TRANSPORT MODEL RESULTS

The disposal of tailings in the open pit has the potential to degrade the water quality in the open pit. This water can then migrate from the open pit through groundwater and degrade the water quality in the receiving environments. Therefore, the transport of dissolved constituents from the Touquoy pit to potential downgradient receptors was simulated by use of a solute transport model (MT3D-USGS).

The solute transport model incorporated the changes in hydraulic conductivity and material characterization from the updated flow model. The updated transport model uses the same source boundary cells and concentrations as the original EARD model. The simulation considers the transport of a conservative solute from the water in the open pit with a constant source concentration of 1 mg/L through the groundwater to the receiving environment over time. Figure 3.5 shows the cells defined as constant-concentration boundaries for the top layer of the tailings in the open pit. Cells representing tailings in the deeper layers of the open pit were also defined as constant-concentration boundaries with the same source strength.

Solute transport was simulated for a period of 500 years. The solute transport model was set up using the transport parameters as the original EARD shown in Table 3.3 with an additional value of porosity for the underground workings of 0.75. Dispersivity is assumed based on the spatial scale of solute transport. The solute is assumed to have the diffusion coefficient of chloride, a conservative tracer, although chloride is not a constituent for which transport was simulated.

Table 3.3 Assigned and Calibrated Solute Transport Model Parameter Values

Parameter	Assigned Value
Porosity	
Overburden Units	0.3
Weathered Bedrock Units	0.1
Competent Bedrock	0.05
Underground Workings	0.75
Tailings	0.3
Dispersivity (All Geologic Media)	
Longitudinal (m)	5
Transverse and Vertical (m)	1
Solute Species	
Diffusion Coefficient[1] (m^2/s)	1.4×10^{-9}

Notes:
Diffusion coefficient is the product of the free-water diffusion coefficient (2.8×10^{-9} m^2/s for chloride) and an assumed value of tortuosity (0.5).

The mass balance error for the solute transport model was 0.0029%. This is considered acceptable for a transport model.

The predicted distributions of relative concentrations from the updated model after 50 years are shown on Figure 3.5, after 100 years on Figure 3.6, and after 500 years on Figure 3.7. These relative concentrations can be multiplied by the source term concentrations for the various parameters of concern provided by Lorax (2018) for the original EARD model to estimate the mass loading to, and average concentration in, Moose River over time, as shown on Table 3.4 and Table 3.5, respectively.

Predicted mass loading and concentrations at Moose River using the updated model are lower than those predicted using the original EARD model due to the lower competent bedrock hydraulic conductivity. An updated model run using the same competent bedrock hydraulic conductivity as the original EARD model results in similar mass loading and concentrations at the Moose River to those reported in the EARD model results.

Table 3.4 Predicted Mass Loading to Moose River from Groundwater, Updated Model

Parameter	Source Term Concentration (mg/L)	Mass Loading (g/d)			
Elapsed Time (years)		5	60	150	500
Sulphate	897	1.00E-04	6.63E-03	1.08E-02	1.87E-02
Aluminum	0.0469	5.24E-09	3.47E-07	5.67E-07	9.80E-07
Silver	0.00001	1.12E-12	7.39E-11	1.21E-10	2.09E-10
Arsenic	3.07	3.43E-07	2.27E-05	3.71E-05	6.41E-05
Calcium	86.9	9.71E-06	6.42E-04	1.05E-03	1.82E-03
Cadmium	0.00002	2.23E-12	1.48E-10	2.42E-10	4.18E-10
Cobalt	0.0262	2.93E-09	1.94E-07	3.17E-07	5.47E-07
Chromium	0.0002	2.23E-11	1.48E-09	2.42E-09	4.18E-09
Copper	0.00937	1.05E-09	6.92E-08	1.13E-07	1.96E-07
Iron	0.0326	3.64E-09	2.41E-07	3.94E-07	6.81E-07
Mercury	0.000005	5.59E-13	3.69E-11	6.05E-11	1.04E-10
Magnesium	14.8	1.65E-06	1.09E-04	1.79E-04	3.09E-04
Manganese	0.37	4.13E-08	2.73E-06	4.47E-06	7.73E-06
Molybdenum	0.0603	6.74E-09	4.46E-07	7.29E-07	1.26E-06
Nickel	0.00685	7.65E-10	5.06E-08	8.28E-08	1.43E-07
Lead	0.0000248	2.77E-12	1.83E-10	3.00E-10	5.18E-10
Tin	0.00604	6.75E-10	4.46E-08	7.30E-08	1.26E-07
Selenium	0.000193	2.16E-11	1.43E-09	2.33E-09	4.03E-09
Tellurium	0.0000154	1.72E-12	1.14E-10	1.86E-10	3.22E-10
Uranium	0.00203	2.27E-10	1.50E-08	2.45E-08	4.24E-08
Zinc	0.0096	1.07E-09	7.09E-08	1.16E-07	2.01E-07
WAD CN	0.005	5.59E-10	3.69E-08	6.05E-08	1.04E-07

Table 3.4 Predicted Mass Loading to Moose River from Groundwater, Updated Model

Parameter	Source Term Concentration (mg/L)	Mass Loading (g/d)			
Elapsed Time (years)		5	60	150	500
Total CN	0.087	9.72E-09	6.43E-07	1.05E-06	1.82E-06
Nitrate (as N)	0.053	5.92E-09	3.92E-07	6.41E-07	1.11E-06
Nitrite (as N)	0.11	1.23E-08	8.13E-07	1.33E-06	2.30E-06
Ammonia	34	3.80E-06	2.51E-04	4.11E-04	7.10E-04

Table 3.5 Predicted Average Groundwater Concentration Discharging to Moose River, Updated Model

Parameter	Source Term Concentration (mg/L)	Average Concentration (mg/L)			
Elapsed Time (years)		5	60	150	500
Sulphate	897	1.73E-07	1.15E-05	1.88E-05	3.24E-05
Aluminum	0.0469	9.07E-12	6.00E-10	9.81E-10	1.70E-09
Silver	0.00001	1.93E-15	1.28E-13	2.09E-13	3.61E-13
Arsenic	3.07	5.93E-10	3.93E-08	6.42E-08	1.11E-07
Calcium	86.9	1.68E-08	1.11E-06	1.82E-06	3.14E-06
Cadmium	0.00002	3.87E-15	2.56E-13	4.18E-13	7.23E-13
Cobalt	0.0262	5.06E-12	3.35E-10	5.48E-10	9.47E-10
Chromium	0.0002	3.87E-14	2.56E-12	4.18E-12	7.23E-12
Copper	0.00937	1.81E-12	1.20E-10	1.96E-10	3.39E-10
Iron	0.0326	6.30E-12	4.17E-10	6.82E-10	1.18E-09
Mercury	0.000005	9.67E-16	6.39E-14	1.05E-13	1.81E-13
Magnesium	14.8	2.86E-09	1.89E-07	3.10E-07	5.35E-07
Manganese	0.37	7.15E-11	4.73E-09	7.74E-09	1.34E-08
Molybdenum	0.0603	1.17E-11	7.71E-10	1.26E-09	2.18E-09
Nickel	0.00685	1.32E-12	8.76E-11	1.43E-10	2.48E-10
Lead	0.0000248	4.79E-15	3.17E-13	5.19E-13	8.96E-13
Tin	0.00604	1.17E-12	7.72E-11	1.26E-10	2.18E-10
Selenium	0.000193	3.73E-14	2.47E-12	4.04E-12	6.98E-12
Tellurium	0.0000154	2.98E-15	1.97E-13	3.22E-13	5.57E-13

Table 3.5 Predicted Average Groundwater Concentration Discharging to Moose River, Updated Model

Parameter	Source Term Concentration (mg/L)	Average Concentration (mg/L)			
Elapsed Time (years)		5	60	150	500
Uranium	0.00203	3.92E-13	2.60E-11	4.25E-11	7.34E-11
Zinc	0.0096	1.86E-12	1.23E-10	2.01E-10	3.47E-10
Weak Acid Dissociable Cyanide	0.005	9.67E-13	6.39E-11	1.05E-10	1.81E-10
Total Cyanide	0.087	1.68E-11	1.11E-09	1.82E-09	3.14E-09
Nitrate (as N)	0.053	1.02E-11	6.78E-10	1.11E-09	1.92E-09
Nitrite (as N)	0.11	2.13E-11	1.41E-09	2.30E-09	3.98E-09
Ammonia (as N)	34	6.57E-09	4.35E-07	7.11E-07	1.23E-06

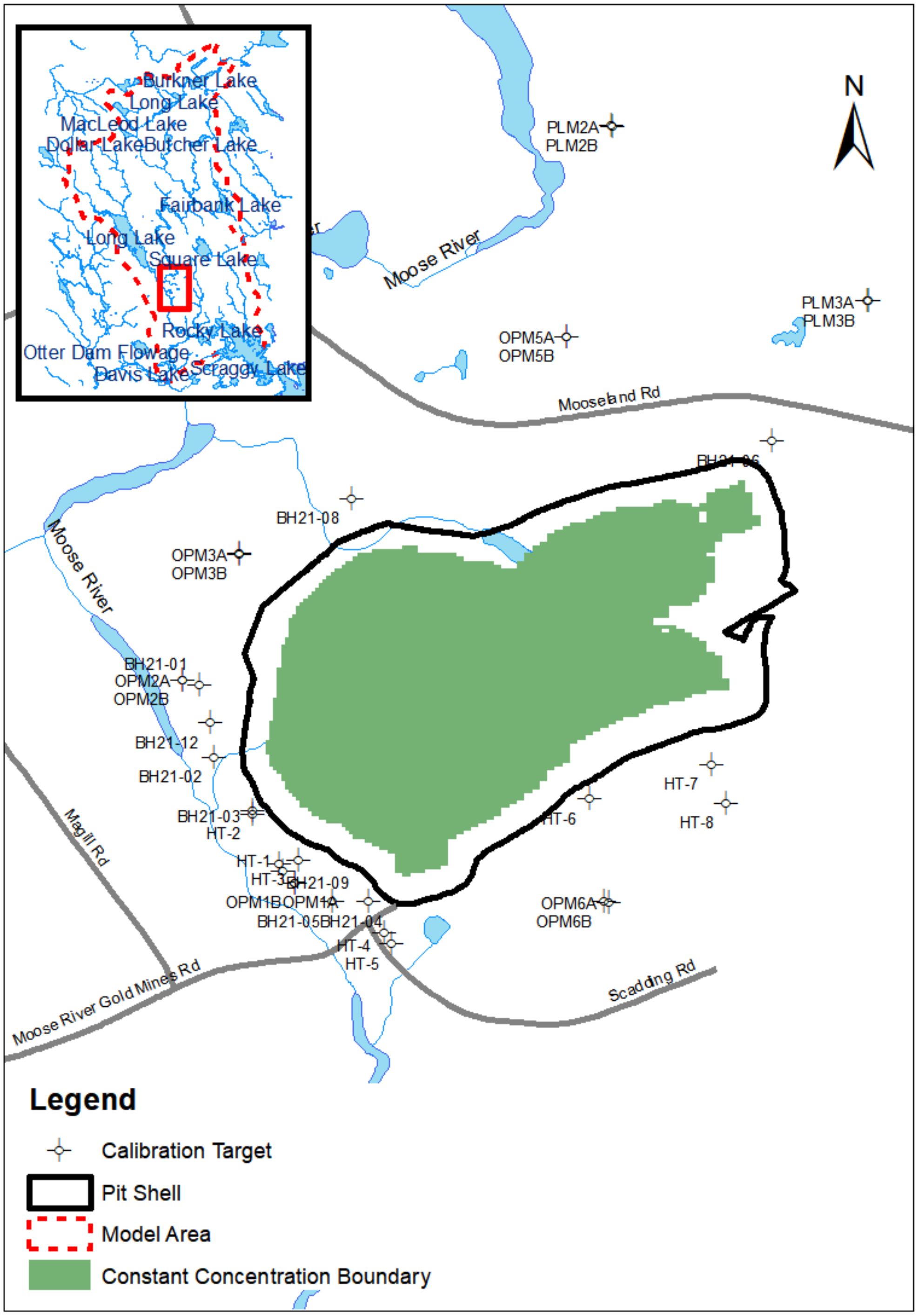

Figure 3.5 Constant-concentration Source Cells in Top Layer of Tailings Within the Pit

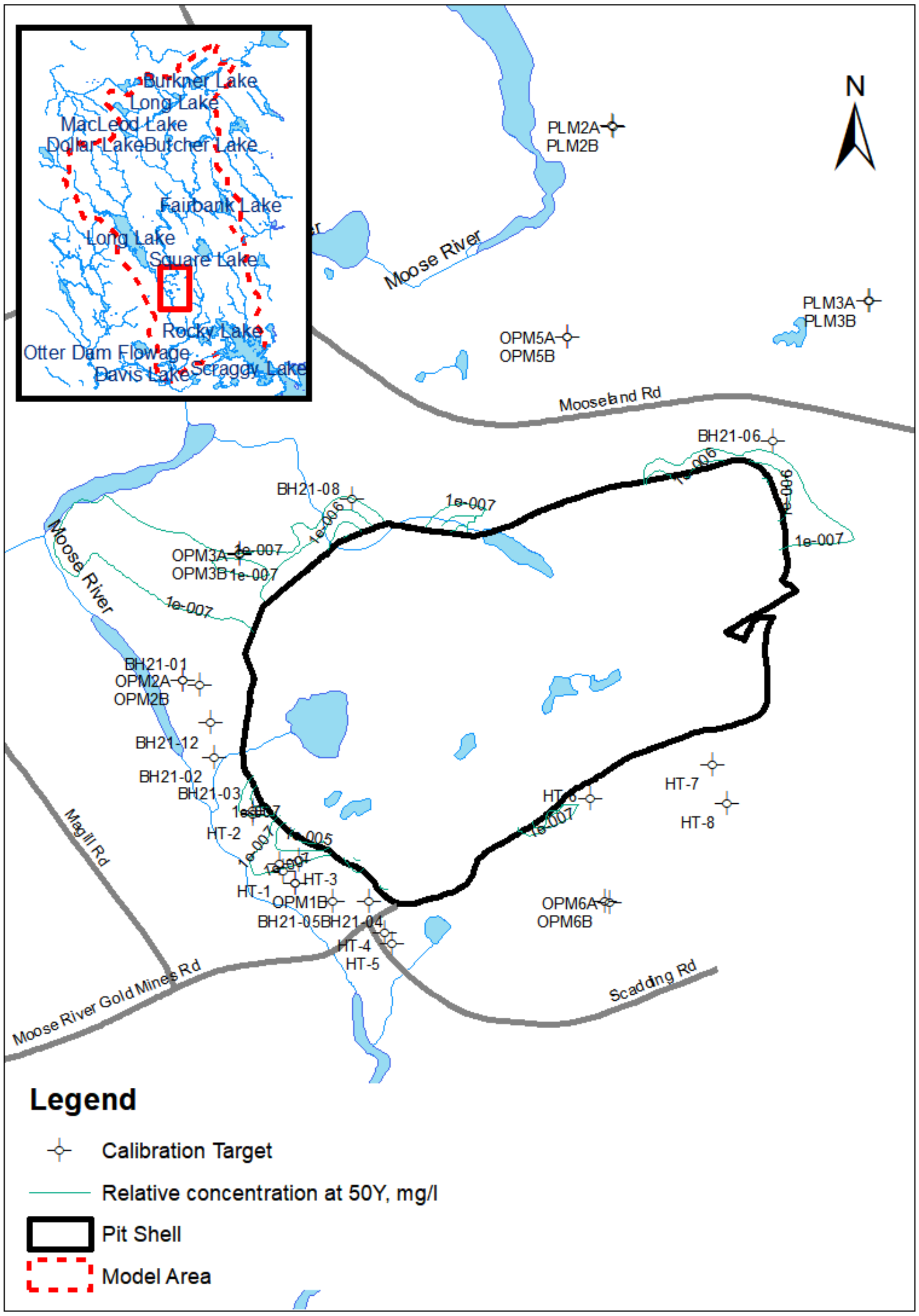

Figure 3.6 Relative Concentration Contours in Groundwater 50 Years Following Pit Lake Stage Achieving 108 m CGVD2013, Updated Model

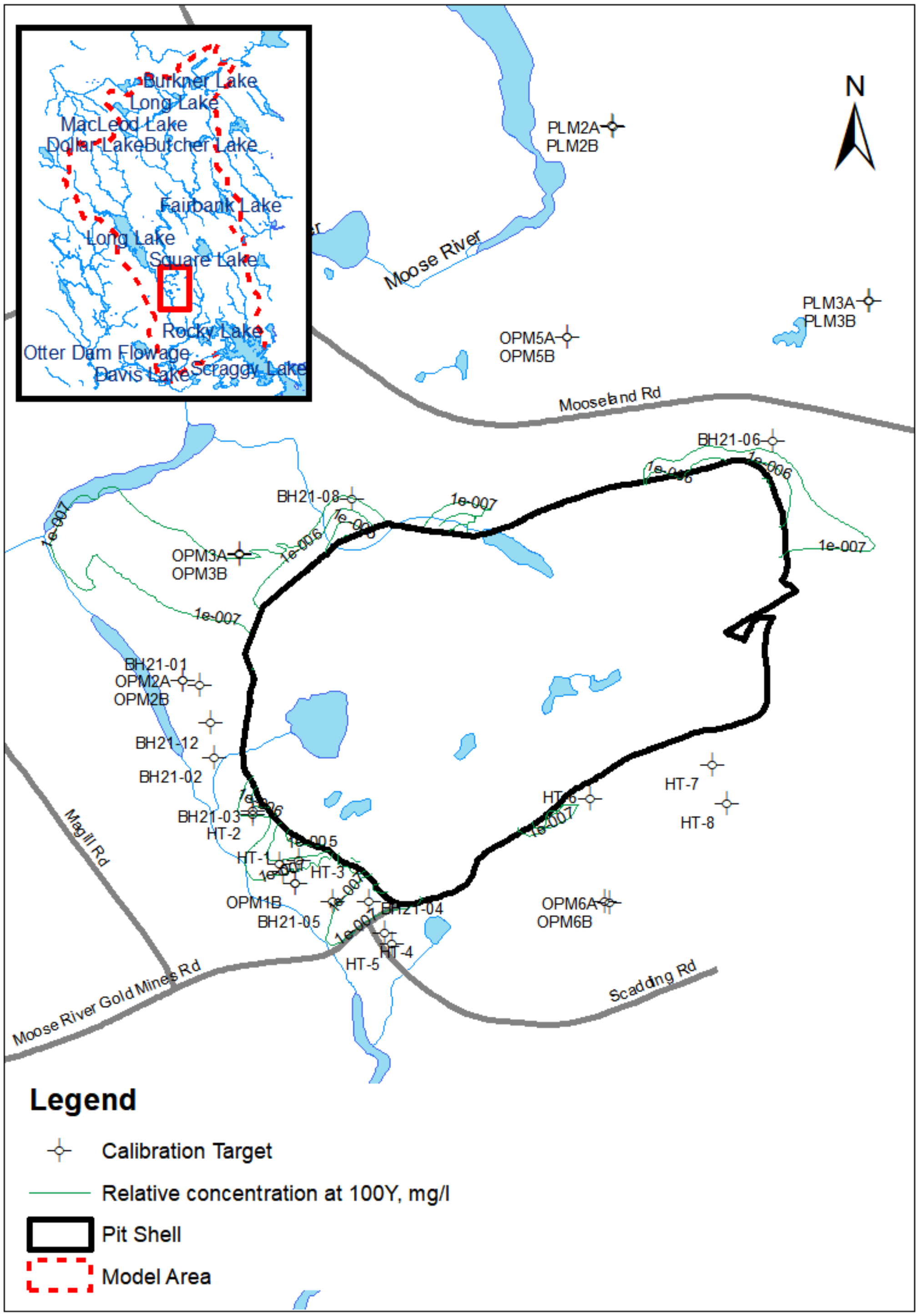

Figure 3.7 Relative Concentration Contours in Groundwater 100 Years Following Pit Lake Stage Achieving 108 m CGVD2013, Updated Model

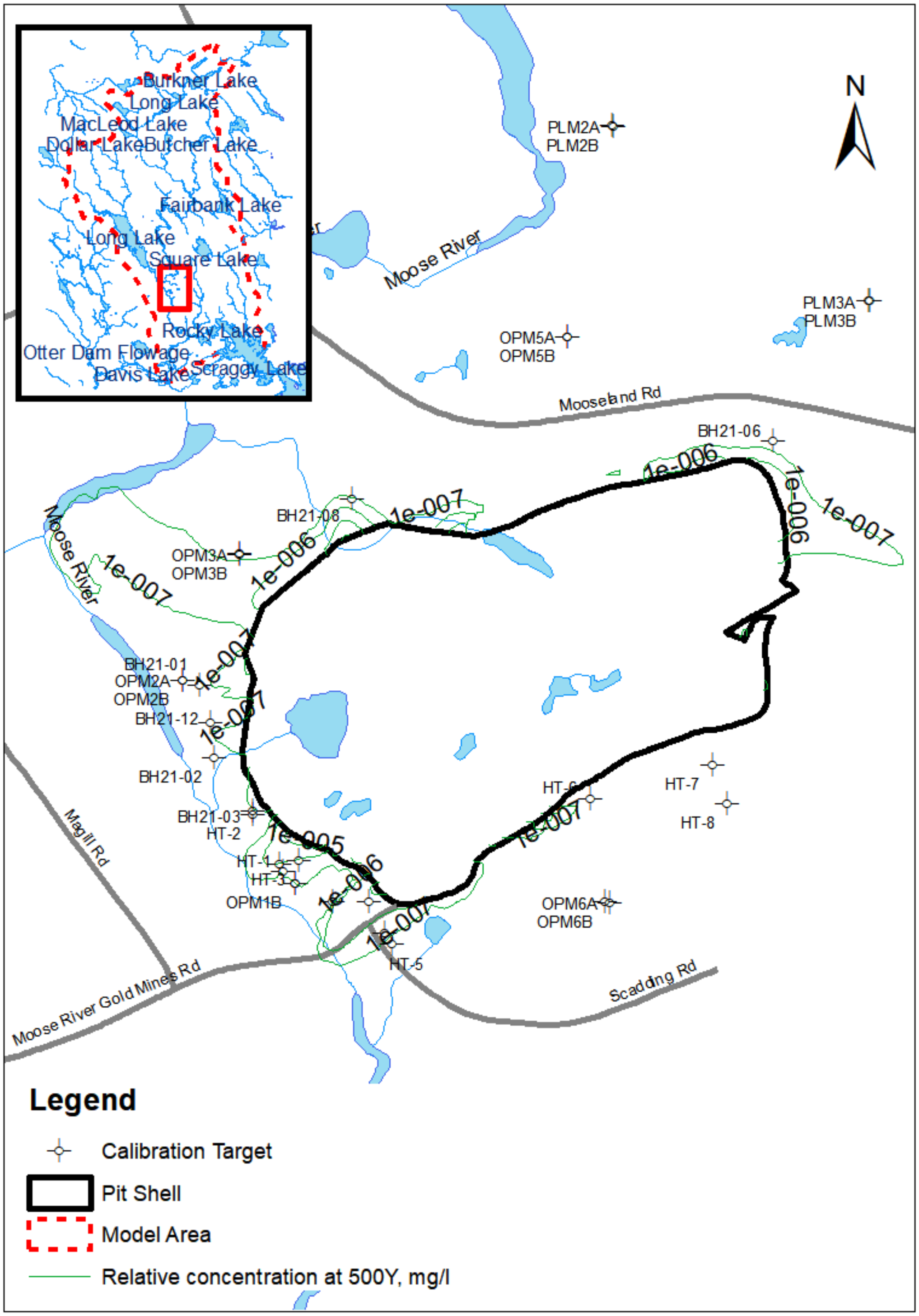

Figure 3.8 Relative Concentration Contours in Groundwater 500 Years Following Pit Lake Stage Achieving 108 m CGVD2013, Updated Model

4.0 INTERPRETATION OF RESULTS

The updated groundwater flow and mass transport model results show overall similar results compared to the original model for the EARD. Therefore, the subsequent interpretations of the effects of changes in groundwater flows and solute transport due to tailings disposal in the Touquoy pit do not change the determination in the EARD.

The results from groundwater flow and transport modelling do not substantively change the groundwater contributions to the assimilative capacity modelling performed for the EARD. In the water balance/water quality models, groundwater flows are added to the calculated surface water flows in Moose River. Since the predicted groundwater seepage quality and mass loading would not be changed based on these results, the predicted overall water quality in Moose River would not be affected by the relatively minor reductions to groundwater seepage rates. Therefore, the effects assessment presented in the EARD is considered to be conservative, and does not require additional evaluation at this time.

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