TRUE GRIT
CONSULTING LTD

Appendix D: Impact Assessment – Hydrogeology Marathon Cu-PGM Project (TGCL)

Stillwater Canada Inc.

Impact Assessment - Hydrogeology

Marathon Cu-PGM Project

DRAFT REPORT

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Executive Summary

True Grit Consulting Ltd. (TGCL) was retained by Stillwater Canada Inc. (SCI) to complete a groundwater impact assessment of the proposed mine site located north of the Town of Marathon, Ontario.

The purpose of the work is to assess the impact of the proposed mine and associated infrastructure on groundwater quality and quantity at the local, site and regional scales in support of the overall Environmental Assessment (EA) process under the Canadian Environmental Assessment Act (CEA Act).

Transient numerical groundwater modelling of the potential impacts of mine infrastructure on groundwater quantity and quality was carried out for the proposed Stillwater Marathon PGM-Cu project. The transient modelling builds upon steady state modelling of baseline conditions previously reported.

The progression of the open pits and associated impacts on groundwater elevations was modelled in the MODFLOW groundwater model at years 3, 6 and 11. In addition, the rate of groundwater inflow to the pits was calculated for each of the modelled years.

Drawdown of groundwater levels around the open pits will not extend beyond the sub-watershed or to the Pic River. Baseflow to streams in the vicinity of the pits will be reduced or eliminated (these streams may be impacted by other mining activities as well, such as the mine rock storage area) but the reduction in flow to the Pic River will not be significant.

Impacts to groundwater elevations surrounding the Process Solids Management Facility (PSMF) were modeled by assigning constant water elevations provided by others within the both of the cells over a 100 year model life.

Groundwater levels around the PSMF will generally increase but the boundaries of these structures are constrained on several sides by topography so increase in groundwater flow rates and velocities will likely be limited to areas downgradient of dams (north and northwest of cell #2 and east and west of cell #1). Due to the nature of the groundwater flow systems present at those locations the increased groundwater flow rates will result in increased discharge to local surface water bodies downgradient of the dams. Areas of increased groundwater flow rates and velocities are also predicted to be areas of dissolved contaminant migration. Large plumes of dissolved contaminants are not anticipated to form because of the short local flow systems which will result in discharge of impacted groundwater to surface water in the areas downgradient of the PSMF.

Migration of dissolved constituents from the PSMF and the Mine Rock Storage Area (MRSA) was modeled using the MT3DMS code in conjunction with MODFLOW. A relative constant concentration of 1.0 was assigned within the boundaries of the PSMF and MRSA and only the processes of dilution and dispersion will decrease the concentrations so the results presented are representative of a conservative tracer.

Impacted groundwater originating beneath the MRSA will predominantly migrate east towards the Pic River. The drawdown in groundwater levels caused by the open pit, which is directly west of the MRSA will redirect some portion of the impacted groundwater towards the pit as the pit refills and a new sub-watershed is established. The plume downgradient of the MRSA is much wider than the plume downgradient of the PSMF; however, the same source concentration was assumed in both locations but it is anticipated that geochemical test results will indicate that the actual source concentrations will differ making direct comparisons invalid. The model does not account for the presence of low hydraulic conductivity sediments beneath the Pic River that will retard groundwater and dissolved contaminant flow from the fractured bedrock to the river.

A spreadsheet based model was utilized in conjunction with data on volumetric pit refilling rates (precipitation, surface water and groundwater) and proposed pit topography to estimate the amount of time it will take to refill the open pits. The pits are predicted to fill 44 years after the completion of active pit dewatering with water elevations rising between approximately 56 (year 1) and 3 (years 30 to 44) metres per year.

Table of Contents

Tables within Text

Figure within Text

Figures

Appendices

ASL	Above Sea Level
BH	Borehole
BHP	BHP Engineering Pty Ltd.
CARs	Canadian Aviation Regulations
CEA Act	Canadian Environmental Assessment Act (Canada)
CEA Agency	Canadian Environmental Assessment Agency
Cu	Copper
e.g.	For example
EA	Environmental Assessment
EIS	Environmental Impact Statement
EMP	Equivalent Porous Medium
Fe	Iron
GD	Grouted Dam
HO	Harmonization Order
Hwy	Highway
JRP	Joint Review Panel
K	Hydraulic Conductivity
Kx and Ky	Horizontal Hydraulic Conductivity
Kz	Vertical Hydraulic Conductivity
km	Kilometre
KP	Knight Piésold
m	Metre
mbgs	Metres Below Ground Surface
MPGM	Marathon PGM Corporation
MPI	Marathon Pulp Inc.
MRSA	Mine Rock Storage Area
MW	Monitoring Well
NoC	Notice of Commencement
O. Reg	Ontario Regulation
OEA Act	Ontario Environmental Assessment Act (Ontario)
OMOE	Ontario Ministry of the Environment
OMOEE	Ontario Ministry of the Environment and Energy
ON	Ontario
PGE	Platinum Group Element
PGM	Platinum Group Metal
PSMF	Process Solids Management Facility

s	Second
Ss	Specific Storage
SCI	Stillwater Canada Incorporated
SFL	Sustainable Forestry License
SWC	Stillwater Mining Company
TGCL	True Grit Consulting Limited
ToR	Terms of Reference
UI	Unimproved
UK	Uniform Hydraulic Conductivity
UTM	Universal Transverse Mercator
ZB	Zone Budget

1.0 Introduction

Stillwater Canada Inc. (SCI) proposes to develop a platinum group metals (PGMs), copper (Cu) and iron (Fe) open-pit mine and milling operation near Marathon, Ontario. A Notice of Commencement (NoC) of an environmental assessment (EA) in relation to the proposed Marathon PGM-Cu Project (the "Project") was filed by the Canadian Environmental Assessment Agency (CEA Agency) under Section 5 of the *Canadian Environmental Assessment Act* on April 29, 2010 (updated July 19, 2010).

The EA was referred to an independent Review Panel by the Minister of the Environment on October 7, 2010. On March 23, 2011 SCI entered into a Voluntary Agreement (VA) with the Province of Ontario to have the Project subject to the Ontario Environmental Assessment Act (OEA Act). This agreement was the instrument that permitted provincial government to issue a Harmonization Order (HO) under Section 18(2) of the Canada-Ontario Agreement on Environmental Assessment Cooperation to Establish a Joint Review Panel for the Project between the Minister of the Environment, Canada and the Minister of the Environment, Ontario.

The HO was issued on March 25, 2011. The Terms of Reference (ToR) for the Project Environmental Impact Statement (EIS) and the agreement establishing the Joint Review Panel (JRP) were issued on August 8, 2011.

The following provides an overview of the proposed development including its location, surrounding land uses, the exploration history of the site and the primary features of the mining and milling facilities.

1.1 Project Location

The Project is located approximately 10 km north of the Town of Marathon, Ontario (Figure A). The town, population approximately 3,000, is situated adjacent to the Trans-Canada Highway 17 (Hwy 17) on the northeast shore of Lake Superior, about 300 km east and 400 km northwest (by highway) of Thunder Bay and Sault Ste. Marie, respectively.

The centre of the Project footprint sits at approximately 48° 47' N latitude and 86° 19' W longitude. The Project site is in an area characterized by relatively dense vegetation, comprised largely of a birch- and, to a lesser extent, spruce-dominated mixed wood forest. The terrain is moderate to steep, with frequent bedrock outcrops and prominent east-west oriented valleys. The climate of this area is typical of northern areas within the Canadian Shield, with long winters and short, warm summers.

Drawn By KP	Date Dec 14, 2009
Reviewed By BF	Date Dec 14, 2009
Revised By KP	Date Aug 4, 2011
Approved By BF	Date Aug 4, 2011

Figure A: Location of the Proposed Marathon PGM-Cu Project Site near Marathon, Ontario.

1.2 Surrounding Land Uses

The Project site lies partially within the municipal boundaries of the Town of Marathon, as well as partially within the unorganized townships of Pic, O'Neil and McCoy. The primary zoning designation within the Project Site is 'rural'.

In the immediate vicinity of the Project there are several authorized aggregate sites, including SCI's licensed aggregate site located to the east of Hwy 17 along the existing site access road (the Camp 19 Road).

The Marathon Municipal Airport (CYSP), which operates as a Registered Airport (Aerodrome class) under the Canadian Aviation Regulations (CARs; Subsection 302), is adjacent to, and south of the Project site. The airport occupies a land area of approximately 219 hectares and is accessed from Hwy 17.

Several First Nations and Métis groups claim the Project site as falling within their traditional land use boundaries, though no formal land claim that includes the Project site has been accepted by the Canadian government at this time. Historically, as is the case today, land and water uses associated with (or close to) the site would have typically been limited to the Pic River corridor, the Bamoos Lake-Hare Lake-Lake Superior corridor and the Lake Superior shoreline and near-shore area, rather than the interior of the Project site. Traditional land and water uses (or rights conferred by Treaty) that can be ascribed to the site could include:

- Hunting;
- Trapping;
- Fishing;
- Plant harvesting for food (e.g., blueberries) or cultural/medicinal uses; and,
- Occupancy.

Primary industries supporting the Town of Marathon, as well as the region, have historically been forestry, pulp and paper, mining and tourism. The Project site is located within the Big Pic Forest Management Area. The Big Pic Forest includes Crown land east and north of Lake Superior and is generally north, south and west of the community of Manitouwadge and includes the communities of Marathon, Caramat and Hillsport.

Until July 2010 the forest was managed under the authority of a Sustainable Forest License (SFL), which was held by Marathon Pulp Inc. This SFL was revoked, with the forest reverting to the Crown as a Crown Forest. Until recently, Marathon Pulp Inc. (MPI) operated a kraft pulp mill in Marathon on the shore of Peninsula Harbour. The mill announced its indefinite shut down (effective at the end of February 2009) on February 11, 2009, and as a result there has been a significant downturn in the local economy. A second mill operated in Terrace Bay was temporarily shut down in December 2011.

The Hemlo Mining Camp is located 30 km to the southeast. There are currently two mines in production at the Camp (David Bell Mine, Williams Mine), which are slated to be in operations until about 2025.

1.3 Exploration History of the Site

Exploration for copper and nickel deposits on the Project site started in the 1920s and continued until the 1940s with the discovery of titaniferous magnetite and disseminated chalcopyrite occurrences. During the past four decades, the site has undergone several phases of exploration and economic evaluation, including geophysical surveys, prospecting, trenching, diamond drilling programs, geological studies, resource estimates, metallurgical studies, mining studies, and economic analyses. These studies successively enhanced the knowledge base of the deposit.

In 1963, Anaconda acquired the Marathon property and carried out systematic exploration work including diamond drilling of 36,531 m in 173 drill holes. This culminated in the discovery of a large copper-PGM deposit. Many of the holes were drilled in areas off the present Marathon property. Anaconda carried out a test pitting program that recovered 350 tonnes of material and had it tested at its Extraction Metallurgy Research Division (EMRD) facilities. Anaconda conducted a number of metallurgical tests intermittently from 1965 to 1982. Anaconda's primary objective was to improve metallurgical recoveries of copper and increase the copper concentrate grade. Anaconda discontinued further work on the project in the early 1980s due to low metal prices at the time.

In 1985, Fleck purchased a 100% interest in the Marathon PGM-Cu Project with the objective of improving the project economics by focusing on the platinum group element (PGE) values of the deposit. Fleck carried out an extensive program which included re-assaying of the Anaconda drill core, further diamond drilling, surface trenching of the mineralized zones, bulk sampling and a pilot plant test program at Lakefield Research Limited. The Fleck drilling totaled 3,615 m in 37 diamond drill holes. On June 10, 1998, Fleck changed its name to PolyMet Mining Corp.

In 1986, H.A. Symons carried out a feasibility study for Fleck based on a 9,000 tonnes per day conventional flotation plant with marketing of copper concentrate. The study indicated a low internal rate of return. Also in 1986, Kilborn Limited carried out a prefeasibility review for Fleck that included preliminary results from the Lakefield pilot plant tests (Kilborn Limited, 1987). The study envisaged a 13,400 tonnes per day conventional flotation plant with marketing of copper concentrate. In late 1986, Teck Corporation prepared a preliminary economic feasibility report on Fleck's Marathon PGM-Cu Project based on a conventional open pit operation and concluded that the project was uneconomic due to low metal prices at that time.

In 1989, BHP Engineering Pty Ltd. (BHP) carried out a prefeasibility study for Euralba Mining Ltd. (Euralba), an Australian Junior mining company that had entered into a joint venture agreement with Fleck in 1987. Euralba re-sampled some 2,500 samples of drill core and had them assayed at Lakefield. Euralba retained Geostat Systems International (Geostat) to develop a block model of the Marathon deposit that was used by BHP to design an optimized open pit. BHP considered several metallurgical processes, including an on-site smelter process.

In 2000, Geomaque acquired certain rights to the Project through an option agreement with Polymet. Geomaque and its consultants carried out a study of the economic potential of the Project. The study included a review of the geology and drill hole database, interpretation of the mineralized zones, statistics and geostatistics, computerized block model, resource estimation, open pit design and optimization, metallurgy, process design, environmental aspects, capital and operating cost.

Marathon PGM Corp. (MPGM) acquired the Marathon PGM-Cu deposit from Polymet in December, 2003. MPGM funded programs of advanced exploration and diamond drilling on a continuous basis between June, 2004 and 2009. Over this period a total of 100,694 metres was drilled in 511 holes. Drilling was conducted across the Project site for various purposes including: to upgrade or expand the resource; for condemnation holes at the process solids management area, crusher and mills sites; and, to further define the resource, improving drill density and to reduce the strip ration of the planned open pits. MPGM did not drill any holes in the Project area during 2010.

Stillwater Mining Company (SWC) and MPGM entered into an agreement on September 7th, 2010 pursuant to which SWC would acquire all of the outstanding shares of MPGM. The acquisition agreement received ministerial approval under the Investment Canada Act on November 24th, 2010 and the agreement closed on November 30, 2010. On December 31st, 2010 SWC formed a Canadian corporation, Stillwater Canada Inc. (SCI), who officially became the new proponent of the Marathon PGM-Cu Project.

In 2011, SCI drilled 25 holes totalling 6,550 metres at the Marathon PGM-Cu deposit. Of the 25 holes, nineteen were drilled to improve the ore zone definition within the potential open pit, and six holes were drilled beneath the planned process water treatment plant to evaluate the nature of the rock and to test the size of a small sulphide zone.

1.4 Project Overview

The Project consists of the development of an open pit mining and milling operation. One primary pit (approximately 2 km in length, 600 m maximum width and 340 m maximum depth) and smaller satellite pits will be mined. Ore will be processed (crushed, ground, concentrated) at on-site processing facilities. Final concentrates containing copper, platinum group metals (gold, platinum and palladium) and iron will be transported off-site via road and/or rail to a smelter and refinery for subsequent metal extraction and separation. The total mineral reserve is estimated to be about 91 million tonnes.

Mine construction is anticipated to begin in 2013. During the operations phase of the Project, production will be on average approximately 22,000 tonnes per day. The operating life of the mine is proposed to be 11.5 years. The construction workforce will average 400 people and will be required for between 18 and 24 months. The mine will create as many as 350 full time positions during the height of operations. The mine workforce will reside in local and surrounding communities, as there will be no living facilities on-site

Approximately 288 x 10^6 tonnes of mine rock[1] will be produced and permanently stored in a purposefully built Mine Rock Storage Area (MRSA) located east of the primary pit. Type 1 (low-sulphur, non-acid generating) mine rock will be used in the construction of access roads, dams and other site infrastructure as needed. Process solids[2] will be managed in the Process Solids Management Facility (PSMF). The PSMF will be designed to hold approximately 61 x10^6 m^3 of process solids material. Type 2 (higher sulphur potentially acid generating and metal leaching) is equal to 10 to 15% of the total mine rock and process solids produced on site and over the long term will be storage under water in the PSMF and/or pits and covered by Type 1 material.

Creation of the PSMF will require the construction of a number of dams. Water collected in the PSMF, as well as water collected around the mine site (water pumped from the pits, run-off collected around the mill site) will be directed to a PSMF for eventual reclamation in the milling process. Excess water not needed in the mill will be discharged (monitored and controlled) to the environment through an existing surface water course after meeting federal and provincial requirements.

Access to the Project site is currently provided by the Camp 19 Road, opposite the Peninsula Road at Hwy 17. The existing road runs east towards the Pic River before turning north along the river to the Project site (approximately 8 km). The existing road will be upgraded and utilized from its junction with Hwy 17 for approximately 2.0 km. At this point a new road running north will be constructed to the future plant site. The primary rationale for developing the new road is to move traffic away from the Pic River, where erosion of the existing road is a safety and environmental concern. The new section of road will link two sections of abandoned forest access roads located on the site.

Power to the Project site will be provided via a new 115 kV transmission line that will be constructed from a purposefully built junction point on the Terrace Bay-Manitouwadge transmission line located to the northwest of the primary pit. The new transmission line will run approximately 4.1 km to a substation at the mill site. The width of the transmission corridor will be approximately 30 m.

Disturbed areas of the Project footprint will be reclaimed in a progressive manner during all Project phases. The ultimate goal of mine decommissioning will be to reclaim land within the Project footprint to permit future use by resident biota and for traditional land-use activities. A certified Closure Plan for the Project will be prepared as required by Ontario Regulation (O.Reg.) 240/00 as amended by O.Reg.194/06

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[1] Mine rock is rock that has been excavated from active mining areas but does not have sufficient ore grades to process for mineral extraction.

[2] Process solids are solids generated during the ore milling process following extraction of the ore (minerals) from the host material.

“Mine Development and Closure under Part VII of the Mining Act” and “Mine Rehabilitation Code of Ontario”.

Maps showing the existing features and topography of the site, as well as the proposed development of the site are provided in Figure B and C.

2.0 Site Setting

2.1 Regional Setting

The regional physiography of the area is strongly influenced by the massive and rugged bedrock hills which dominate the landscape through the area and the glacial activity that occurred during the Wisconsinan Stage of the Pleistocene Epoch. Relief in excess of 150 metres (m) is common and the slopes of the sides of hills and valleys are complex and steep. Drainage is generally good, with localized areas of poor drainage.

Higher elevations consist almost entirely of rugged bedrock with a thin veneer of ground moraine. Within the valleys, in particular the Pic River valley, thick sequences of glaciolacustrine silt and clay have been deposited. These deposits were formed as the ice margin retreated northward and the ancestral Lake Superior inundated the valleys.

A significant feature of the site’s bedrock geology that strongly influences the surficial drainage and likely influences the hydrogeology is the presence of an extensive network of radial and concentric lineaments that are clearly visible on air photos and topographic maps of the area. One of these lineaments contains the proposed locations of cell #1 of the PSMF. Where these geologic structures are permeable, they may provide a preferential pathway for the movement of groundwater through the area.

The surficial geology can be generally subdivided into two areas based primarily on elevation. Below an elevation of approximately 320 m, thick deposits of massive to varved glaciolacustrine silts and clays are present within the numerous valleys. These deposits formed by deep water deposition when the ancestral Lake Superior was much higher than it is today. As the lake level receded, shallow water deposits of silty sand and fine sand formed. In general, the low permeability of these fine grained deposits will inhibit the movement of groundwater.

Above an elevation of approximately 320 m, the geology is dominated by the rugged bedrock topography. A thin veneer of ground moraine is generally present, as are localized areas of organics where drainage is poor, and/or thick accumulations of fine sediments in the deeper ravines and valleys. The ground moraine generally consists of silty sand till with abundant gravel, cobbles and boulders. As the ground moraine is thin, groundwater flow will be controlled by the underlying bedrock topography and the surface water drainage courses. Some groundwater flow into the underlying bedrock may occur where the bedrock is fractured and/or pervious structures are present.

The hydrology of the study area can be subdivided into three drainage areas. The majority of the study area drains east via a series of small creeks to the Pic River. This area includes the open pits, plant site, waste rock storage area and a small portion of cell #1 of the Process Solids Management Facility (PSMF). The northwest portion of the study area, including cell #2 of the PSMF, drains west to Hare Lake. The southwest portion of the study area including most of cell #1 of the PSMF drains southwest towards Lake Superior via two small streams. All drainage ultimately discharges to Lake Superior.

2.2 Site Investigations

Extensive hydrogeological investigations, monitoring and sampling have been undertaken at the Project site between 2007 and 2011 to characterize baseline conditions. The hydrostratigraphy of the site has been investigated through borehole drilling, drill core observation, grain size analysis and hydraulic conductivity testing. Evaluation of this data and experience with sites in similar environments allowed the construction of a conceptual model of groundwater flow at the site. In this model groundwater flow is recharged at higher elevations and discharged at lower elevations generally within local sub-watersheds.

Active groundwater flow is concentrated in the shallow subsurface, in the overburden and upper (40 to 60 m) of fractured and weathered bedrock. The overburden is generally relatively shallow, less than 20 m, with the notable exception of the Pic River Valley where low hydraulic conductivity silt and clay extend beyond 20 m, the maximum depth investigated.

A total of 36 monitoring wells have been installed at the Project site between 2008 and 2011 and they have been monitored for groundwater water elevations and sampled for chemical analysis on a regular basis. Groundwater quality is similar to that encountered at sites across northern Ontario with consistent exceedances of the Ontario Drinking Water Standards for parameters such as hardness, iron and manganese. At monitoring wells that have been sampled over several years trends in water quality are not apparent but there is variation in the concentrations of several parameters such as iron.

2.3 Baseline Modelling

The data collected during hydrogeologic investigations was also used to construct and calibrate a numerical groundwater flow model in MODFLOW (McDonald and Harbaugh, 1983) of the site to further understanding of hydrogeologic conditions at the Project site and provide a baseline for modelling impacts of site development on groundwater. The model was able to achieve a good calibration despite the size and topographic complexity of the site. The model validates the conceptual model developed for the site and provides a baseline for predictive modelling of site impacts.

3.0 Methods

3.1 Open Pit Progression

The progression of the open pits over time and their impacts on groundwater levels in its vicinity were modelled in Visual MODFLOW. The calibrated MODFLOW model of the site previously developed (TGCL, 2011) was used as the steady state baseline for pre-development groundwater elevations around the pits (Figure 2).

The model was modified to simulate the pits after three years of mining by setting the boundary between layers 1 and 2 of the model at 288 metres above sea level (masl) within the boundaries of the pit (unless the ground elevation was less than 288 masl). The pit boundary is based on the conceptual design of the mine at the time that the model was constructed and is subject to change as more detailed design of the mine is completed. Figure A1 in Appendix A shows the planned outline of the pit after three years of mine life. Layers 1 and 2 both represent the overburden/fractured bedrock and are assigned a hydraulic conductivity value of 1×10^{-7} m/s. The elevation of 288 masl is based on the planned progression of the mine and the common timeframes being evaluated in all related reports. Cells in layer 1 within the pit boundaries were then classified as inactive in the model. This resulted in the elimination of the drain cells representing streams in the area of the pit; in addition, all streams (represented as drain cells in the model) within two cells of the pit were eliminated. The cells surrounding the newly inactive cells, which represent the walls of the mine pit, were then designated as drain cells by assigning the drain boundary condition to each. These wall cells were modelled as vertical seepage faces (wall drains) with the drain elevation set as the bottom of the cell and the conductance of the cell (m^2/day) defined as:

$$DY \times DZ \times KX \times 86{,}400 * 10 \div DX$$

Where: DY is the length of the cell in the Y (horizontal) direction (m)

DZ is the length of the cell in the Z (vertical) direction (m)

KX is the hydraulic conductivity in the X (horizontal) direction (m/s)

DX is the length of the cell in the X (horizontal) direction (m)

86400 converts m/s to m/day (s/day)

100 is a constant that accounts for the increased hydraulic conductivity of the rock at the edge of the pit

The cells in layer 2 directly beneath the newly inactive cells in layer 1, which represent the floor of the pit, were also designated as drain cells by assigning the drain boundary condition to each. These cells were modelled with the drain elevation as the top of the cell (floor drains) and the conductance of the cell (m^2/day) defined as:

$$DX \times DY \times KZ \times 86{,}400 \times 10 \div DZ$$

Where: KZ is the hydraulic conductivity in the Z (vertical) direction (m/s)

DZ was approximated as 13.5 m to standardize the conductance across all cells of the pit floor. Next the Zone Budget module (Harbaugh, 1990) was used to assign all of the drain cells surrounding and beneath the inactive pit cells to a common Zone Budget zone (ZB zone). This allows Zone Budget to calculate the volume of water entering the pit.

The model was then run as a transient simulation for three years with the heads from the steady state simulation as the initial heads.

To simulate the mine after six years, the boundary between layers 2 and 3 was set at 240 masl within the 288 masl contour of the pit (Appendix A). In a few locations this shift resulted in raising or lowering the interface between the fractured bedrock and the deeper bedrock (although lowering the interface would not impact the model results because the cells in layer 2 (the fractured bedrock) become inactive. The cells within the 288 masl contour of the pit were designated as inactive (these cells were previously part of the pit floor). The cells in layer 2 surrounding the newly inactivated cells were switched from floor drains to wall drains and the cells in layer 3 directly beneath the newly inactivated cells in layer 2 were assigned as floor drains using the formulas provided above. The floor drains in layer 3 were added to the ZB zone. The model was then run for three years (years four through six) with the heads from the previous transient simulation (years 1 through 3) as the initial heads.

The same procedure was used to simulate the mine after 11 and 11.5 years. 11.5 years represents the final mine depth at the end of the mine's planned life. A cross-section through the modelled pit at 11.5 years is presented in Figure 3.

To support the pit refilling model, the model was re-run at 11.5 years with the ZB zone divided in two, with one zone representing the main pit and the other zone representing the four other pits.

3.2 Impacts of the Mine Rock Storage Area

The model assessing the impacts of the MRSA assumes that it will be sufficiently porous due to the large grain size typical of waste rock that a significant mound of groundwater will not develop beneath the pile.

A constant concentration boundary condition was applied to the top of layer 1 over the areas covered by the MRSA. Transport modelling was conducted with the MT3DMS code (Zheng, 1990) which is a reactive transport code that is included in the Visual MODFLOW package. The constant concentration beneath the MRSA was set to 1.0 and no reactions or sorption processes were included in the simulations. As a result the concentration will only decrease through dilution and dispersion; it will act as a conservative tracer in the groundwater flow system. A conservative concentration of any parameter at any point in the modelled area can then be calculated simply by multiplying the modelled concentration (which will have a value between 0 and 1) and the source concentration of the parameter of interest.

A 100 year transient simulation was run to assess the impact of the MRSA on transport of dissolved constituents from the MRSA. This simulation assumes that the mine rock is placed all at once at the beginning of the simulation, rather than over the 11.5 year mine life. Due to the relatively slow movement of groundwater (and therefore contaminants in groundwater) this assumption will not have a significant impact on the results.

3.3 Impacts of PSMF

The impacts of the PSMF were modelled by assigning a constant head boundary condition to layer 1 over the areas covered by the PSMF. Constant head elevations of 327 masl and 373 masl were assigned to cells 1 and 2 of the PSMF respectively; the elevations were obtained from Knight Piésold (2012).

Additionally a constant concentration boundary condition was applied to the top of layer 1 over the areas covered by the PSMF. Transport modelling was conducted with the MT3DMS code. The constant concentration within the boundaries of the PSFM was set to 1.0 and no reactions or sorption processes were included in the simulations. As a result, the concentration will only decrease through dilution and dispersion; it will act as a conservative tracer in the groundwater flow system. A conservative concentration of any parameter at any point in the modelled area can then be calculated simply by multiplying the modelled concentration (which will have a value between 0 and 1) and the source concentration.

A 100 year transient simulation was run to assess the impact of the PSMF on groundwater levels and flow patterns as well as transport of dissolved constituents from the PSMF to the surrounding environment. This simulation assumes that the PSMF is filled all at once at the beginning of the simulation, rather than over the 11.5 year mine life. It also assumes that a water cover will remain in place over the process solids following closure. These conditions are possible closure scenarios but the current preferred closure scenarios include capping and re-vegetating the PSMF which would result in a lower water table elevation in the PSMF.

In order to determine the impact of the higher hydraulic conductivity zone interpreted to be present in the model beneath portions of cell #1 of the PSMF (TGCL, 2011), a version of the model that does not contain the higher conductivity zone was run. During the construction, testing and calibration of the steady state model (TGCL, 2011) a variation of the model was constructed that did not contain the higher hydraulic conductivity zone. The model that contained the higher hydraulic conductivity zone produced a better calibration, especially in the vicinity of the PSMF and therefore the model that did not contain the higher conductivity zone was not presented. However, that variation of the model can be utilized here as the calibrated steady state basis for a transient model that can be compared to the transient model that is the same in all respects except for the initial heads and the presence of the higher conductivity zone.

Three scenarios were modelled; a base case where hydraulic conductivities were not changed from those in the steady state model (TGCL, 2011) referred to in this report as the unimproved (UI) scenario because it assumes that the ground beneath the PSMF dams has not been grouted, a variation where the proposed locations of dams were assigned a hydraulic conductivity of $1x10^{-8}$ m/s to represent grouting of the bedrock (the grouted dam (GD) scenario), and a variation that included the grouting beneath the dams but removed the zone of higher hydraulic conductivity in the vicinity of cell #1 of the PSMF (the uniform K (UK) scenario).

3.4 Pit Refilling

The future pit lake water levels are calculated using a void filling approach similar to those presented in Shevenel, 2000, Surrano, 1997 and Younger and others, 2002 where the volume of the pits are defined and a water balance in calculated.

To allow calculation of the pit lake surface area at each elevation given a vertical spacing of 1 m, linear interpolation was used between contours marking the top and bottom of each bench to a 1 m scale. Auto CAD was used to do the interpolation and to calculate the pit lake surface area at each contour for each pit.

Then the volume of each pit was calculated using the pit lake surface areas at a 1 m interval determined by linear interpolation and the equation:

$$\text{Volume } (m^3) = [(a_1 + a_2) \div 2] \times h$$

Where: h is the contour interval (m)
a_1 is the area of lower contour (m^2)
a_2 is the area of upper contour (m^2)

Two scenarios have been considered; in the first, the five pits are considered to be hydraulically connected and therefore the volumes of each pit have been added together. In the second scenario the main pit is isolated and considered by itself and the other four pits are considered together and considered to be hydraulically connected to one another. The total volume of the pits was calculated by summing the volume of each contour interval from the bottom up. The contour elevation, surface area, volume and accumulated volume were tabulated to create a look up table.

The water balance of the pits is calculated on an annual basis and defined as:

$$\text{Runoff}_{\text{Lake}} + \text{Runoff}_{\text{Land}} - \text{Evaporation}_{\text{Lake}} + \text{Groundwater Inflow} = \text{Volume Increment}$$

Where: $\text{Runoff}_{\text{Lake}}$ is the additional volume of water landing on the pit lake surface
$\text{Runoff}_{\text{Land}}$ is the volume of water landing on the watershed that enters the pit
$\text{Evaporation}_{\text{Lake}}$ is the volume of water evaporating from the pit lake surface
Groundwater Inflow is the volume of groundwater inflow
Volume Increment is the volume of water that accumulated in the pit lake that year.

All units are in cubic metres per year.

$\text{Runoff}_{\text{Lake}}$ is calculated using the equation:

$$\text{Runoff}_{\text{Lake}} = \text{Annual Precipitation Rate (mm/year)} / 1000 * \text{Pit Lake Surface Area } (\text{m}^2) * 0.4$$

The annual precipitation rate is 826.5 mm/year as presented in Calder (2012). The pit lake surface area is equal to that determined for the previous year. The surface runoff volume was determined for mine operation (i.e. no pit lake) and is not varied in the model, so at all times in the model the entire watershed area (including the area of the pit lake) is contributing runoff, which has been calculated as 60% of the precipitation (Calder, 2012). To avoid overestimating the amount of water in the areas of the model occupied by the pit lake, the precipitation rate has been multiplied by 40%.

Evaporation is calculated using the equation:

$$\text{Evaporation}_{\text{Lake}} = \text{Annual Evaporation Rate (mm/year)}/1000 * \text{Pit Lake Surface Area } (\text{m}^2)$$

The annual evaporation rate is 488.2 mm/year, the potential evapotranspiration rate presented in the Golder (2007) report. The pit lake surface area is equal to that determined for the previous year.

The groundwater inflow volume was determined as described in Section 3.1 for both scenarios and the inflow after 11 years was used (Section 4.1). The surface runoff volume was determined by Calder Engineering and presented in Calder (2012).

Table A: Pit Inflows for Pit Refilling

	Groundwater Inflow (m^3/year)	$\text{Runoff}_{\text{Land}}$ (m^3/year)
Connected Pits	253,675	2,439,683
Main Pit – Isolated	121,910	937,309
Other Pits – Isolated	131,765	1,502,375
Source	Section 4.1	Calder, 2012

The accumulated volume of water in the pit lakes was calculated each year by adding the current year's volume increment to the previous year's accumulated volume. The accumulated volume after each year is used to determine the water elevation using the look up table. Then the newly determined water elevation is used to determine the next year's pit lake surface area.

The outlet of the pit lakes, as they are currently configured is at an elevation of 258 masl and is located along the eastern edge of the pits. Once the water level reaches 258 masl the pit lake water level prediction model terminates.

4.0 Results and Discussion

4.1 Drawdown of Groundwater Levels around the Open Pits

Figure 4 presents the drawdown of groundwater levels in the top layer of the model at year 11 and similar figures for years 3 and 6 are provided in Appendix B. Year 11.5 was also modelled which is when the pit will reach its final depth, however, the results are not presented in Appendix B because the drawdown in layer 1 does not change significantly between years 11 and 11.5 due to the depth at which the excavation is being extended versus the depth of layer 1 and the low hydraulic conductivity in which the excavation is being extended. As anticipated, the drawdown cone in layer 1 increases in areal extent throughout the mine life but a significant amount of the drawdown occurs within the first three to six years which is the time when mining is progressing through the fractured upper bedrock.

The irregular shape of the drawdown is due to the complex interaction of topography, stratigraphy, water table elevations, streams and the pit elevations. For example the nearly linear edge of the drawdown in a few locations in years 3, 6 and 11 to the west of the main pit is strongly influenced by the representation of a stream at that location. Drawdown occurs on all sides of the pits, and the despite the small scale complexities, the edge of the drawdown (defined here as 0.1 m of drawdown) is broadly similar on all sides.

Drawdown in layer 1 around pits 3, 4 and 5 appears to approach steady state by year 6 implying that discharge to the pits is matched by recharge over the capture zone. The edge of the drawdown does not reach the Pic River and therefore will not result in withdrawing water from the river. However, the mine pit will intercept some groundwater that would otherwise have discharged to the river. The Zone Budget application approximated this reduction as a maximum of 57.9 m^3/day after 11.5 years of mine life, which when compared to the average flow in the Pic River of approximately 4.4×10^6 m^3/day would represent a reduction of 0.001%.

This model represents the subsurface as an equivalent porous medium (EPM) which means that when applied to fractured rock, as it is at this site, it averages out some properties such as porosity and hydraulic conductivity. One implication of this is that the actual distribution of the drawdown will not precisely match the model results; the model results are best viewed as averages. For example, a monitoring well installed in a section of un-fractured rock would show less drawdown than predicted while a monitoring well installed in fractured rock, especially if the fractures are connected to the pit, would show more drawdown. This is a result of the un-fractured rock having less porosity and lower hydraulic conductivity than the EPM while the fractured rock will have more porosity and higher hydraulic conductivity as a result of the fracture(s).

With respect to potential impacts to the Pic River uncertainties inherent in the EPM approach are mitigated by the thick layers of silts and clays that have been deposited over time beneath the river. As a result the fractured bedrock is not connected directly to the river; there is an up to 20+ m thick layer of low conductivity sediment separating the bedrock from the river. The hydraulic conductivity of this layer is approximately 2.9×10^{-9} m/s compared to approximately 1.6×10^{-6} m/s for the fractured bedrock (TGCL, 2011). So even if drawdown in areas of more heavily fractured rock extended towards the Pic River, the potential influence on the river would be significantly reduced by the low hydraulic conductivity sediments. In other areas the extent of drawdown would be less than predicted so that overall the predictions provided here will be representative even though the small scale details may not be accurately predicted.

The drawdown caused by pit dewatering will decrease or eliminate baseflow to creeks and streams in the vicinity of the pits. The approximate extent of these impacts is shown on Figure 4. Some of these areas will also be impacted by other mine related activities such as the creation of the mine rock storage area.

The extent of the drawdown is contained within the Pic River watershed. Based on the conceptual model of the site where local flow systems controlled by topography dominate with recharged water discharging at adjacent discharge areas, groundwater divides will coincide with surface watershed divides and therefore the drawdown in groundwater levels will not influence the water balance or groundwater flows in adjacent watersheds.

Inflows to the pit were calculated during the same modelling exercise through the Zone Budget application and presented in Table A below.

Table A: Groundwater Discharge to Pits

Year	Discharge (m^3/day)
3	437
6	547
11	695

In addition, each transient simulation was modelled with 6 month time steps and the more detailed results with results every 6 months are presented below in Figure D.

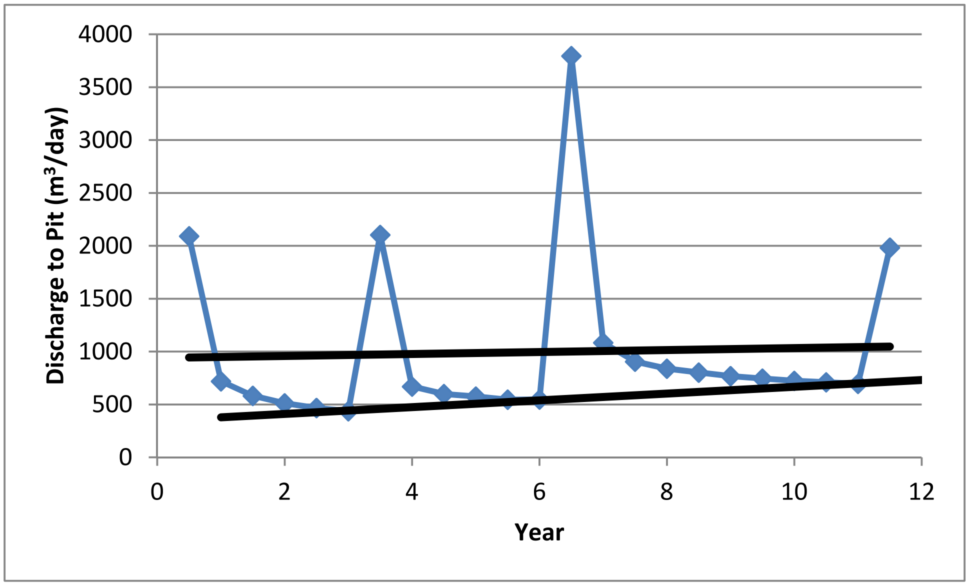

Figure D: Groundwater Discharge to Pits over Time

Figure D shows that in the first 6 months after the pit is enlarged in the model (years 0, 3, 6 and 11) the discharge rate spikes upwards as a result of the water discharging to the newly created drain cells around and below the expanded pit. Discharge rates fall sharply after the spike but to a level higher than before the spike and then slowly decrease over time until the pit is enlarged again. This pattern of spikes and slow declines is an artifact of the way in which the model was created and the limitations of finite element models such as MODFLOW. Open pit mines expand in steps much smaller than the steps in the model so a more realistic pattern would be an increase over time as the pit deepens creating a greater depth over which water can enter the pit walls and increasing the difference in elevation between the bottom of the pit and water in the surrounding rock. Two lines are plotted on Figure D using the linear regression function in Microsoft Excel. The top line, which is fairly flat at a rate of approximately 1,000 m^3/day is the linear regression based on all of the data while the lower line which has a larger slope is the linear regression through the values at 3, 6 and 11 years (Table A).

When the model was rerun to 11.5 years with two ZoneBudget zones, one representing the main pit and the other representing the four satellite pits, the model predicted discharge rates of 334 and 361 m^3/day respectively.

During closure the water level in the pits will rise after the dewatering system has been turned off. As a result the groundwater elevations adjacent to the pit will also rebound until the elevation of the water in the pit reaches its final elevation. The pit lake will be a location of groundwater discharge, similar to other surface water bodies in the general area and consistent with the conceptual model of the site. Since the pit is located in the Pic River watershed the presence of the pit lake is not anticipated to significantly alter regional groundwater flow or baseflow to the Pic River.

4.2 Impacts of PSMF

4.2.1 Overview

The presence of the PSMF will generally raise groundwater levels in its vicinity because of the elevated water levels within the cells. However, the steep topography in which the PSMF is located will still play a strong role in constraining groundwater movement. Groundwater and any dissolved constituents will primarily migrate away from cell #1 towards the east and west and from cell #2 towards the north (and likely northwest). Due to the nature of the local groundwater flow systems, where recharged groundwater discharges to nearby surface water features, extensive plumes of impacted groundwater are not anticipated.

4.2.2 Changes in Groundwater Levels and Flow

The model predicts that groundwater levels will increase significantly all around the cell #1 and south of cell #2 (Figures 5A and 5B) as a result of the presence of the PSMF. In addition, the model predicts less significant water level increases will occur to the northeast of cell #2. The UI scenario (no grouting beneath the dams) model predicts an increase in groundwater levels north of cell #2 (Figure 6A) while the model containing lower hydraulic conductivity grouting beneath the dams (the GD scenario) predicts a decrease in groundwater levels north of cell #2 (Figure 5B). This is the only significant difference between the two scenarios although the magnitude and extent of groundwater level changes occurs more quickly in the UI scenario.

Both scenarios predict a decrease in groundwater levels northwest of cell #2 and under the UI scenario this area of decreased groundwater levels continues to the north of cell #2. This predicted decrease is likely an artefact of the model and the manner in which it was calibrated. Groundwater levels to the northwest of cell #2 (and north of cell #2 in the UI scenario) will likely increase or not change significantly as they are predicted to elsewhere around the structures. The existing monitoring wells on site, which were used in model calibration (TGCL, 2011), are generally located in relatively low lying areas and near water bodies. As a result the model calibration was based on groundwater elevations in low lying areas and did not explicitly consider groundwater elevations in areas at higher elevations. The area northwest of cell #2 of the PSMF is at a relatively high elevation and the calibrated model appears to have overestimated groundwater levels in this area as modelled water levels are metres above the ground surface. Another factor in the elevated groundwater levels northwest of cell #2 is the relative scarcity of surface water features included in the model (as drains and constant head boundaries) in the vicinity. Recharge occurs uniformly across the model and is the source of the majority of water entering the model; discharge occurs primarily to drains and constant head boundaries (model representations of streams and lakes) and these are not as regularly distributed throughout the model. As a result water levels in areas relatively distant from drains and constant head boundaries (which represent surface water features) are prone to higher modelled groundwater elevations. This general relationship between mounding (the difference in groundwater elevation between a point and a surface water boundary) and the distance between the point and the surface water boundary has been shown analytically by Haitjema

(2006) provided that recharge, hydraulic conductivity and aquifer thickness remain constant, as they do in this case.

The majority of the increase in magnitude and areal extent of groundwater elevation change (drawdown) occurs within first 3 years with slow increases throughout the 100 year model duration.

As with many of the groundwater related characteristics at this site, the distribution of groundwater elevation change is strongly influenced by surface water features. This influence can clearly be identified north of cell #2 where the extent of water level changes has reached the stream north of the cell by year 3 and does not progress significantly over the next 97 years of model life. In addition, the influence of the streams directly east and west of cell #1 is clearly visible.

The increased groundwater elevations also result in increased groundwater flow velocities and discharge rates to surface water bodies in the vicinity of the structures, especially downgradient of the dams east and west of cell #1.

4.2.3 Migration from PSMF

Migration of groundwater from the PSMF is presented visually at 3, 20 and 100 years into the transient model run in Figures 6A/B, 7A/B and 8A/B/C, respectively. For each figure the UI scenario is presented in Figure -A and the GD scenario is presented in Figure -B (the UK scenario is presented in Figure 8C).

In the model groundwater originating in cell #1 of the PSMF will migrate east and west along the axis of the valley in which it resides before discharging to surface water bodies directly downstream of the dams at the east and west ends of the cell. This general scenario is true of both the UI and GD scenarios and is due to the higher topography to the south of the cell and cell #2 north of the cell.

At the west end of cell #1, the plume that develops in the UI scenario after three years (Figure 6A) is significantly larger, it has a predicted relative concentration approaching 0.5 at BH10-01B, than the plume predicted in the GD scenario which has not progressed significantly past the dam after three years (Figure 6B). After 20 years, the plume in the UI scenario has not grown much longer along its centre line because it is likely discharging to the surface water feature but it has grown wider (Figure 7A) whereas the plume in the GD scenario has migrated beyond the dam but is somewhat thinner and contains lower concentrations than the UI scenario plume. After 100 years, the plume in the GD scenario has grown somewhat thicker again but the core of the plume has not changed significantly. In the GD scenario the plume has grown longer, wider and spread southwest, but also at lower concentrations than the UI scenario. After 100 years in the GD scenario the 0.5 contour has not progressed much past the toe of the western dam. When the GD scenario (Figure 8B) is compared to the UK (uniform hydraulic conductivity) scenario (Figure 8C) after 100 years it is evident that the plume in the UK scenario is smaller than it is in the GD scenario. The plume in the GD scenario likely would be larger still if it did not discharge to a surface water feature.

At the east end of the cell #1, after three years the plume in the UI scenario has progressed beyond the dam and is discharging to the surface water body below the dam (Figure 7A). In the GD scenario the plume does not appear to have migrated noticeably beyond its initial configuration within the cell after three years (Figure 7B). After 20 years the plume in the UI scenario has progressed further east while maintain a similar width to the plume at 3 years (Figure 8A); the plume in the GD scenario has generally migrated slightly east relative to its position after 3 years and is also characterized by a thin “finger” of relatively low concentration jutting east from the main body of the plume. After 100 years the plume in the UI scenario has not changed noticeably from its position after 20 years; in the GD scenario the core of the plume has not progressed significantly and has not migrated much farther than the dam footprint but the edge of the plume has grown longer and thicker. The plume in the UK scenario has not migrated noticeably beyond its initial position after 100 years.

The model predicts that groundwater originating in cell #2 of the PSMF will primarily migrate north, with some migration to the southwest, south and southeast as well. When the UI scenario is compared to the GD scenario, the primary difference is that the dam cells, where present, impede the progression of the plume. Another notable characteristic of the modelled plume is that it becomes truncated once it encounters the stream north of the cell because the groundwater is discharging to the stream preventing migration farther north. As discussed in section 4.2.2, the steady state heads in the high lands northwest of cell #2 are interpreted to be anomalously high. The elevation of the water in cell #2 will be several metres higher than the elevation of the land directly northwest of the cell (as evidenced by the need for a dam in that location). As a result it is interpreted that impacted groundwater will migrate from cell #2 towards the northwest. However, the rate of migration will likely be less than the rate of migration towards the north because of the flatter topography northwest in comparison to the topography directly north which drops quickly towards a stream.

In fractured rock environments such as this one, MODFLOW treats the subsurface as an equivalent porous medium which means that hydrogeologic parameters are averaged out across the subsurface because they vary over a scale that is too small to accommodate in the model grid and impractical to characterize in the field. Actual groundwater flow will primarily be controlled by fractures within the rock where hydraulic conductivity will be higher and as a result impacts may spread further than predicted in some areas while not occurring, or being minimized in other areas where impact was predicted (e.g. Cook, 2003). However, these approximations are appropriate and necessary when modelling groundwater flow and transport at this scale.

Dissolved constituents are generally predicted to migrate north (and northwest) from cell #2 of the PSMF and east and west from cell #1 of the PSMF. However, the nature of the local groundwater flow systems where travel distances in the subsurface are relatively short with recharged groundwater discharging at the nearest downgradient discharge area will result in truncated areas of impacted groundwater that will likely not extend off site. The closest impacted groundwater is anticipated to come to the property boundaries is directly south of cell #1 of the PSMF, where the property boundary approaches the southern edge of the cell.

4.2.4 Summary

The results of the modeling presented here should be viewed as more qualitative than quantitative at this stage. The steady state model was calibrated at the scale of the entire site and surrounding area and as a result there are inherent inaccuracies when the model is scaled down. Also many of the assumptions made were conservative, such as assuming a permanent water cover over the PSMF which will result in high gradients around the structures for the duration of the model's life. In addition, the transport modelling only considered advection and dispersion and not precipitation of metals or retardation of other constituents.

With those caveats in mind, the results of the model are still very informative because they show the most likely migration pathways and illustrate the impacts of dams and hydraulic conductivity distribution. The model results will help guide the placement of additional monitoring wells and could provide a starting point for more detailed site specific modelling if necessary.

4.3 Impacts of Mine Rock Storage Area

The results of the modelling show that impacted groundwater originating beneath the MRSA generally migrate east towards the Pic River over time. The plume downgradient of the waste rock pile is predicted to be more uniform than the plume originating from the PSMF because the topography downgradient of the waste rock stockpile slopes towards the river. As a result of this fairly uniform plume it is predicted that impacts will first approach the river directly downgradient (east) of the points where the waste rock pile is the smallest distance from the river (Figure 9). These points are at the north and south ends of the pile and approximately two-thirds of the way down (north to south).

This application of the model does not take into account the presence of the mine pit that will be located directly west of the majority of the waste rock pile. The pit will have an impact on groundwater levels beneath portions of the MRSA (Section 4.1 and Figure 4) that will result in a) some of the groundwater originating beneath the MRSA migrating into the pit, b) the gradient between the groundwater level beneath the waste rock and the river will decrease in some areas (and therefore the average groundwater flow velocity will also decrease) and c) some areas beneath the MRSA will not be impacted. These areas and the magnitudes of the effects will change over time as the pit is advanced over the mine's life and then fills with water during closure. As a result, the impacts on groundwater east of the MRSA produced by the model can be considered conservative.

As is the case in the calibrated steady state groundwater flow model, this transient flow model does not account for the low hydraulic conductivity silts and clays deposited beneath the Pic River. TGCL's investigations found silt and clay up to 20+ m beside the river and the hydraulic conductivity averaged 2.9×10^{-9} m/s compared to an average of 1.6×10^{-6} m/s for the fractured bedrock (TGCL, 2011). Groundwater flow velocities would be much slower in these sediments than in the adjacent shallow fractured bedrock.

A common source concentration of 1.0 was used in the simulations of the PSMF and MRSA. However, the actual source concentrations will likely vary between the three sources and this factor should be taken into consideration if comparing the modelled plumes.

4.4 Pit Refilling

The water level in the open pits is predicted to reach the outlet elevation of 258 masl 44 years after the cessation of active pit dewatering when all of the pits are modeled as hydraulically connected. When the main pit is considered by itself, the model predicts that it will require 110 years to fill because the majority of the rock removed will be from the main pit but the main pit only collects runoff and surface water flows from about half of the drainage area. When the four satellite pits are considered in isolation from the main pit but hydraulically connected between themselves, the model predicts that they will fill in four years.

Results of the predictive pit lake filing model are shown on Figure E, below. As shown on Figure E, the rate of filling (in m/year) in the connected pits model decreases from approximately 56 m/year in the first year to approximately 3 m/year in years 30 through 44 as the surface area of the lake increases.

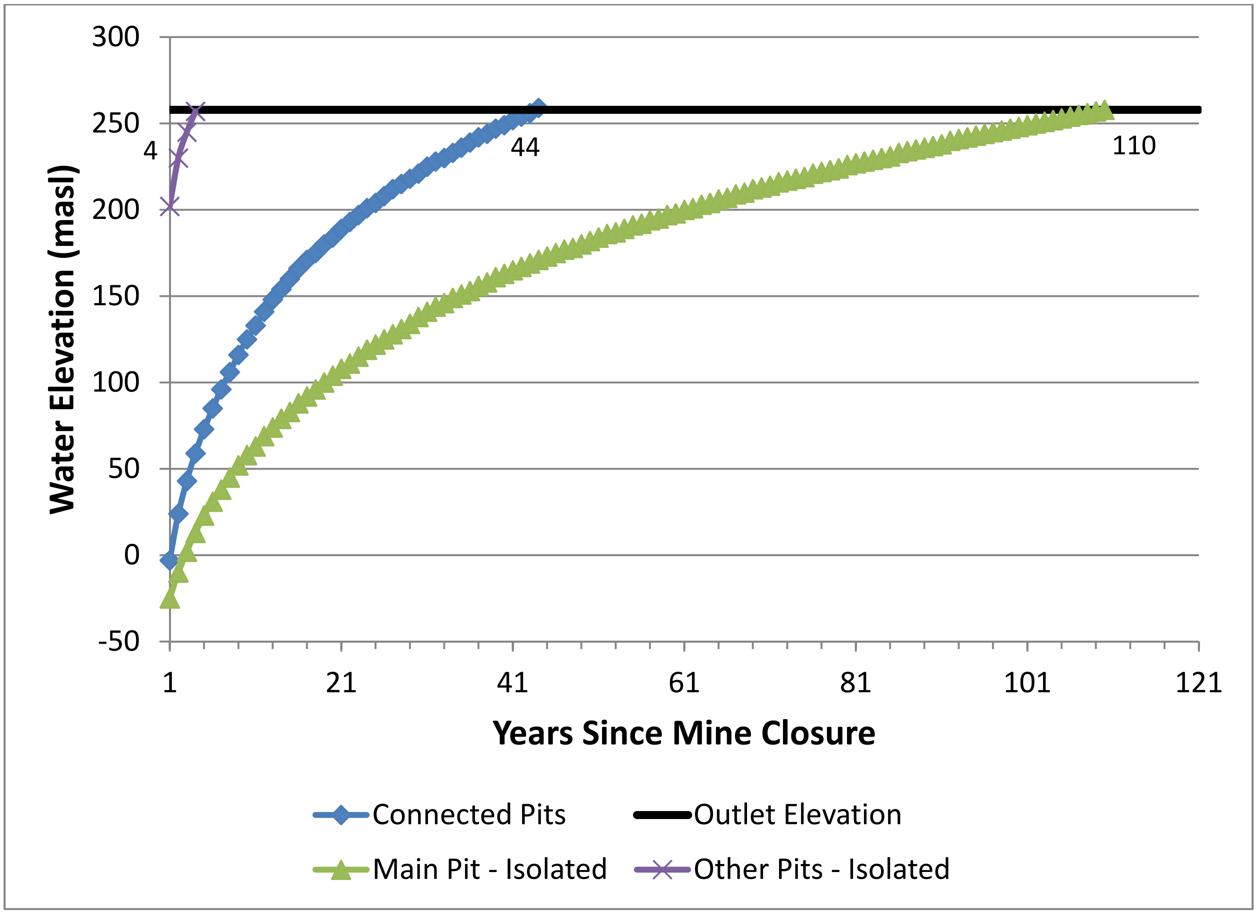

Figure E: Water Elevation in Pits over Time

The majority of the water refilling the pits will be surface water; for example at year 11 of mine life, 91% of the water entering the pit is expected to be surface water related and 9% groundwater related (Calder, 2012).

5.0 Groundwater Monitoring

Groundwater monitoring should continue at the site in the event that approval is received to progress with development of the mine. All of the existing monitoring wells should be included in the monitoring program and it is also recommended that additional monitoring wells be added to the program based on the results of the predictive modelling contained in this report.

5.1 Monitoring Wells

It is recommended that monitoring wells be installed at five additional locations (Figure 11). The locations are downgradient of sources of impact and within predicted migration pathways; one location is between the Waste Rock Stockpile and the Pic River (MW13-113) and four locations are downgradient of the PSMF (MW13-114, -115 -116 and -117). A single shallow well is recommended at MW13-113 and nested shallow and deep monitoring wells are recommended at the other four locations.

Additional wells may be required if this project proceeds to the permitting and approvals stage and would be located based on discussions between Stillwater's representatives and regulatory agencies such as the Ontario Ministry of the Environment

Consideration should also be given to adding additional monitoring wells downgradient of other potential sources of contamination that have not been sited at this time such as tank farms, septic systems, stockpiles and so on.

Some wells (BH08-1A/B, BH08-7A/B, BH09-9A and KP11-03A/B) are located in areas that are currently proposed to be mined or buried beneath process solids and will therefore eventually be removed from the monitoring program. However, they should be maintained as long as practical. Prior to their burial, BH08-1A/B, BH09-9A and KP11-03A/B must be abandoned in accordance with Ontario Regulation 903 so that they do not act as preferential pathways for groundwater migration.

5.2 Annual Monitoring

For the purposes of an annual monitoring program, the monitoring wells should be divided into two groups. Wells directly down-gradient of potential sources of groundwater impact should be placed in one group and monitored more frequently and the remaining wells should be monitored less frequently.

Wells in Group A are listed below in Table B and should be monitored and sampled three times per year for a list of field and analytical parameters consistent with the groundwater sampling done to date. Wells in Group B, should be monitored and sampled once per year for the same list of field and analytical parameters as Group A.

Table B: Proposed Annual Monitoring Program Groups

Group A		Group B	
BH08-1A/B	MW11-103A	BH08-3A/B	MW11-104A/B
BH08-4	MW11-105B/C	BH08-5A/B	MW11-106A/B
BH09-8A/B	MW11-112A	BH08-7A/B	MW11-107A
BH09-9A	MW13-113A	BH09-6A	MW11-108A
BH10-01A/B	MW13-114A/B	MW11-101B	MW11-110A/B
BH10-26	MW13-115A/B	MW11-102B	MW11-111A/B
KP11-03A/B	MW13-116A/B	MW11-103B	

Table B: Proposed Annual Monitoring Program Groups			
Group A		Group B	
MW11-101A	MW13-117A/B		
MW11-102A			

6.0 Mitigation Strategies

Several potential mitigation strategies to deal with mining related impacts to groundwater exist and have been implemented at mine sites throughout the world. The strategies can be broadly lumped into two categories, ones that minimize the amount of water that comes into contact with mine wastes and ones that collect, remediate or prevent the discharge of impacted waters.

The main way that the amount of water that contacts mine wastes can be minimized is through capping the wastes. This approach is currently being proposed for both cells of the PSMF. Capping with a low permeability material and re-vegetating the surface minimizes the infiltration of precipitation and therefore the amount of water that can become impacted and eventually return to the environment.

Impacted water can be collected from above a liner or other low permeability surface beneath mine wastes or from below the ground through wells or trenches. An aboveground collection system is being considered for the waste rock pile to collect impacted water that discharges at the toe of the pile before it can infiltrate into the ground or flow overland to a surface water body (i.e. the Pic River). Collection wells or trenches that are part of a “pump and treat” system could be considered downgradient of the dam west of cell #1 of the PSMF. However, the effectiveness of pumping wells in fractured bedrock can be variable and will depend greatly on intercepting the fractures containing impacted groundwater.

Groundwater impacted by mine wastes can be remediated in-situ through a permeable reactive barrier (e.g. Brenner and others, 1997). The concept behind a permeable reactive barrier is that a trench is excavated across the path of a plume of impacted groundwater and filled with reagents such as organic matter that will remediate impacted groundwater as it flows across the trench. This technique may be well suited to the area west of the dam at the west end of cell #1 of the PSMF where the predicted plume would be relatively thin and constrained by topography.

As shown by the comparison of the base case and the dam variation, grouting the upper fractured bedrock beneath the PSMF dams will decrease the migration of impacted groundwater outward from the structures.

7.0 Conclusions

The excavation of an open pit mine and the construction and filling of a mine rock storage area and process solids management facility are large scale engineering projects that will inevitably affect the quality and quantity of groundwater in their vicinity. However, due to the generally low hydraulic conductivity overburden and bedrock and local scale groundwater flow systems encountered at this site and characteristic of the Canadian Shield of northern Ontario (Sykes and others, 2009), impacts to groundwater quality and quantity will not be as extensive as would otherwise be the case.

Drawdown of groundwater levels around the open pits will not extend beyond the sub-watershed or to the Pic River. Baseflow to streams in the vicinity of the pits will be reduced or eliminated (these streams may be impacted by other mining activities as well such as the mine rock storage area) but the reduction in flow to the Pic River will not be significant.

Groundwater levels around the PSMF will generally increase but the boundaries of these structures are constrained on most sides by topography so increase in groundwater flow rates and velocities will likely be limited to areas downgradient of dams (north and northwest of cell #2 of the PSMF and east and west of cell #1 of the PSMF). Due to the nature of the groundwater flow systems present at those locations the increased groundwater flow rates will result in increased discharge to local surface water bodies downgradient of the dams. Areas of increased groundwater flow rates and velocities are also areas of dissolved contaminant migration. Large plumes of dissolved contaminants are not anticipated to form because of the short local flow systems which will result in discharge of impacted groundwater to surface water in the areas downgradient of the PSMF.

Impacted groundwater originating beneath the MRSA will predominantly migrate east towards the Pic River. The drawdown in groundwater levels caused by the open pit, which is directly west of the MRSA will redirect some portion of the impacted groundwater towards the pit as the pit refills and a new sub-watershed is established. The plume downgradient of the MRSA is much wider than the plume downgradient of the PSMF, however, a source concentration of 1.0 was assumed in both locations but it is anticipated that geochemical test results will indicate that the actual source concentrations will differ making direct comparisons invalid. The model does not account for the presence of low hydraulic conductivity sediments beneath the Pic River that will slow groundwater and dissolved contaminant flow from the fractured bedrock to the river.

The pits are predicted to fill 40 years after the completion of active pit dewatering through a combination of surface water and groundwater in flows.

8.0 Closure

The information and data contained in this report, including without limitation, the results of any sampling and analyses conducted by TGCL pursuant to its Agreement with the client, have been developed or obtained through the exercise of TGCL's professional judgment and are set forth to the best of TGCL's knowledge, information and belief. Although every effort has been made to confirm that this information is factual, complete and accurate, TGCL makes no guarantees or warranties whatsoever, whether express or implied, with respect to such information or data.

The information and data presented in this report are based on the purpose and scope of the project and form the basis for any conclusions and recommendations presented herein. Any conclusions and recommendations presented herein do not preclude the existence of environmental concerns other than those that may have been identified.

Work performed by TGCL personnel employed sound environmental assessment principles. TGCL cannot guarantee the accuracy and reliability of information provided by others or third parties. Therefore, TGCL does not claim responsibility for undisclosed environmental concerns or conditions that may result in costs for environmental clean-up and/or remediation. This report is intended for information purposes only.

Respectfully submitted by:

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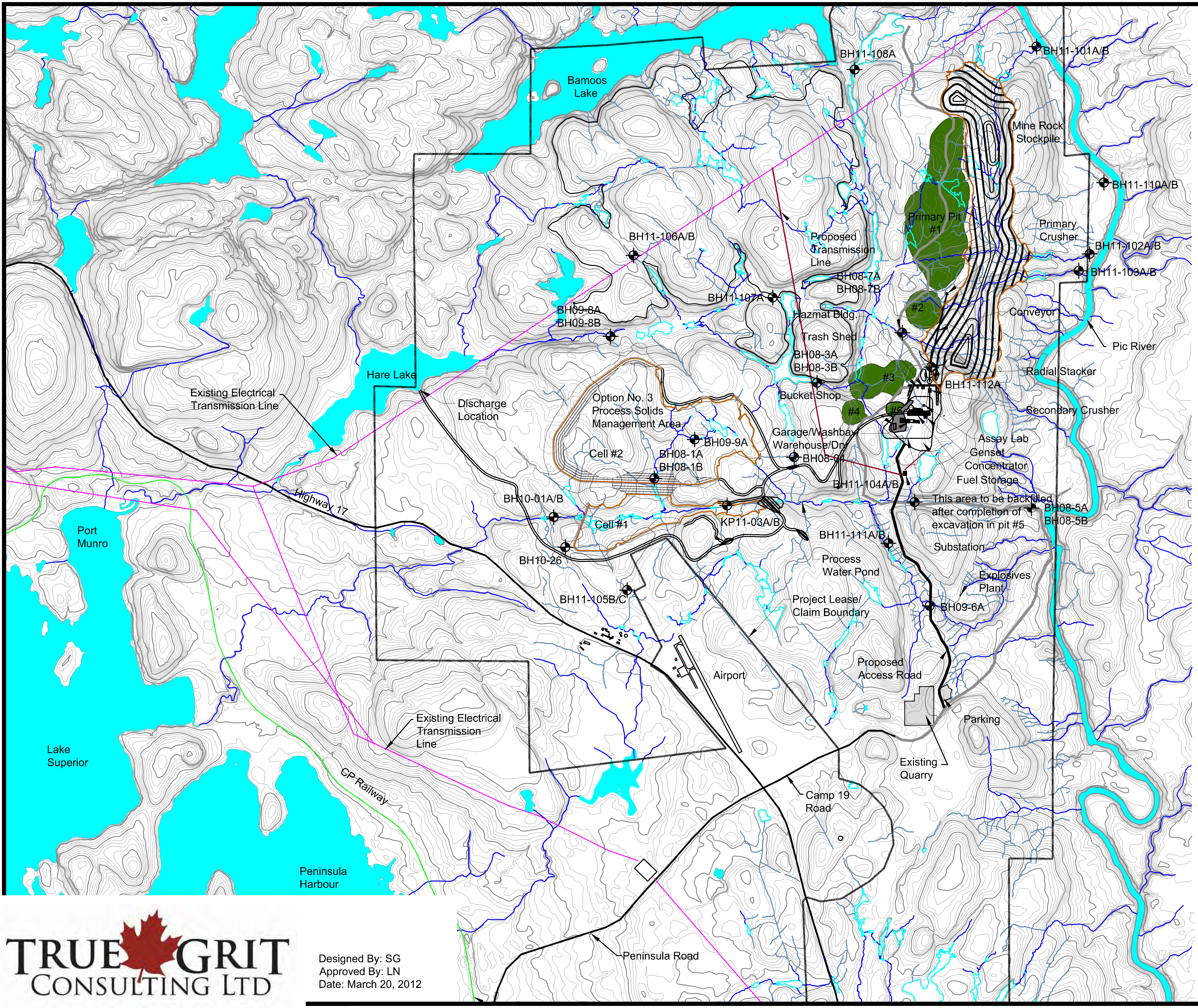
Figures



Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

Scale

0 400 800 m SCALE 1:40000

N

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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Date: March 20, 2012

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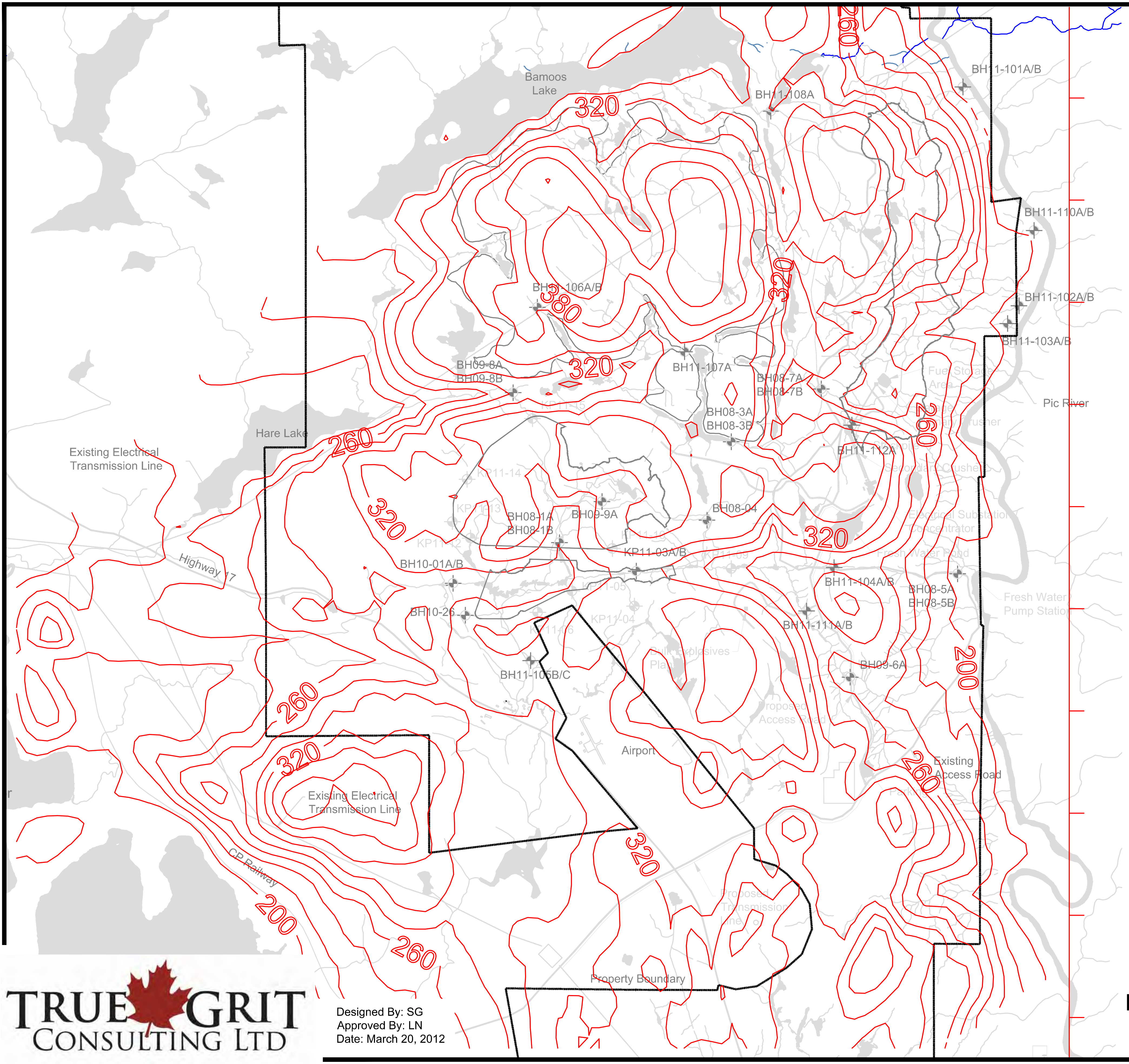
Site Layout, Site Features and Monitoring Well Locations

FIGURE 1



Scale

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SCALE 1:40000

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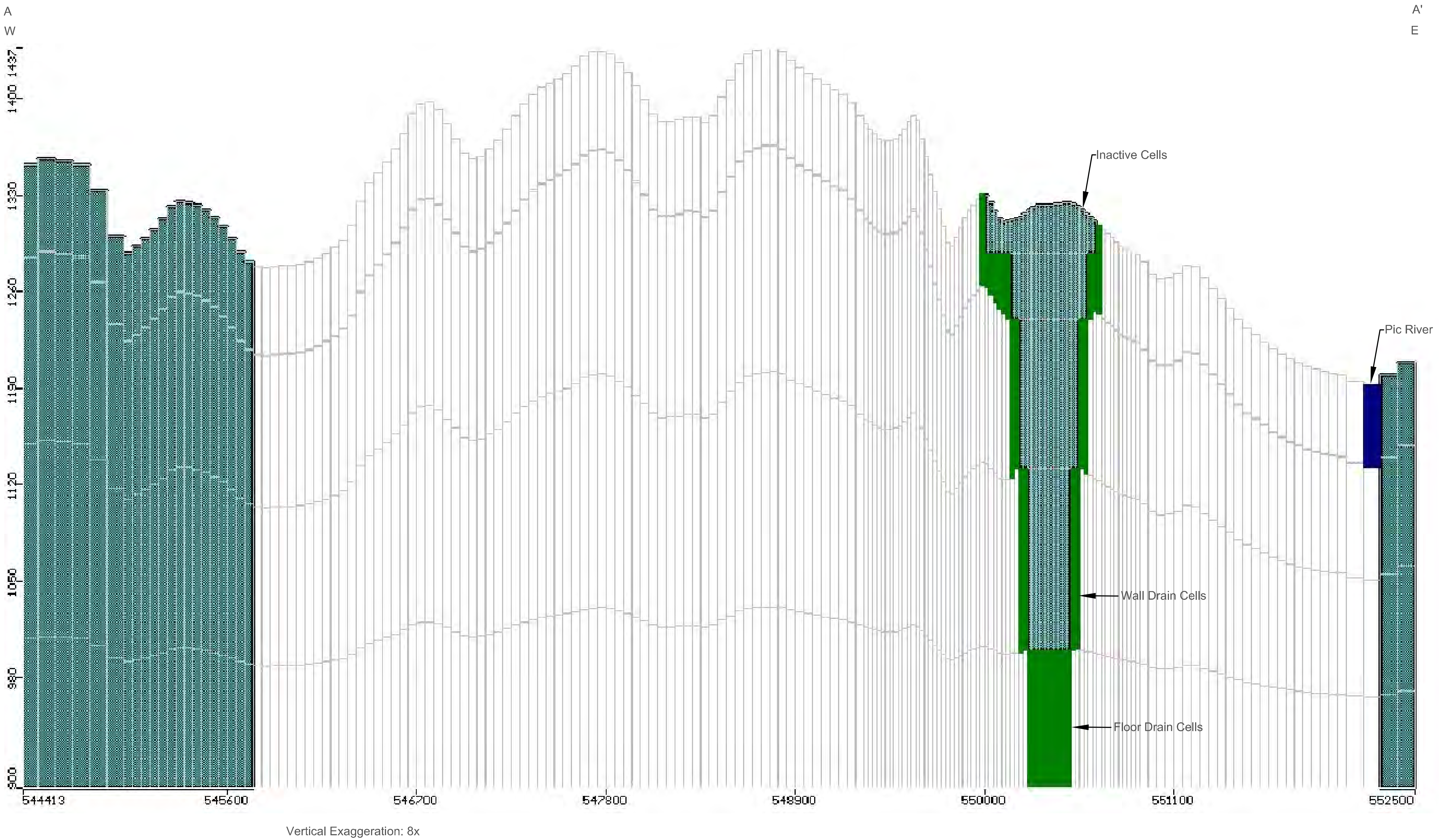
Modelled Steady State Groundwater Elevations

FIGURE 2



File No. 11-317-12

Scale

SCALE 1:25000

0 250 500 m

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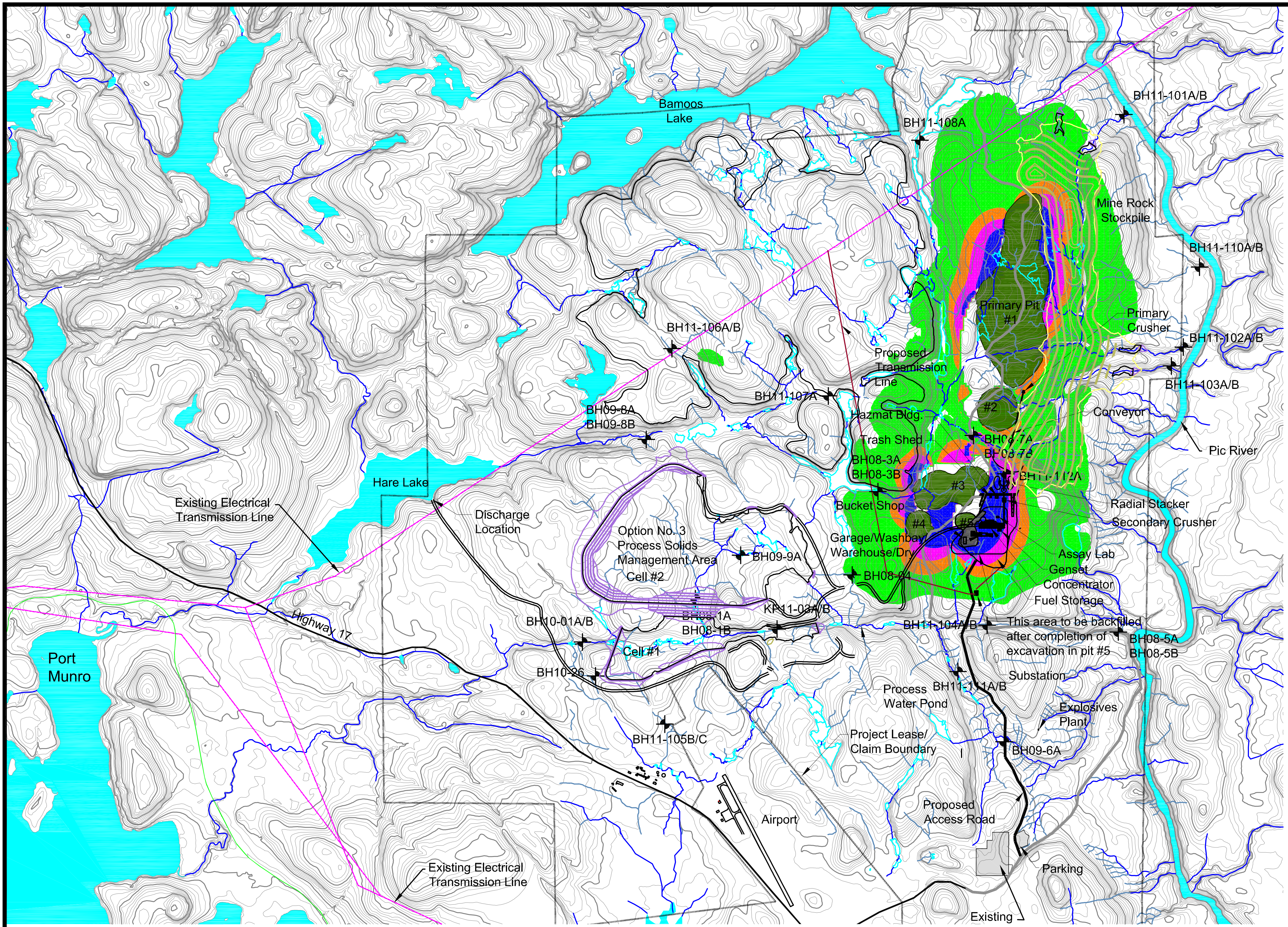
Cross Section A-A'

FIGURE 3



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2	5.00	10.00	🟧
3	10.00	20.00	🟪
4	20.00	75.00	🟦

Scale

N

0 400 800 m

SCALE 1:40000

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Drawdown of Groundwater Levels Around Open Pits After 11 Years

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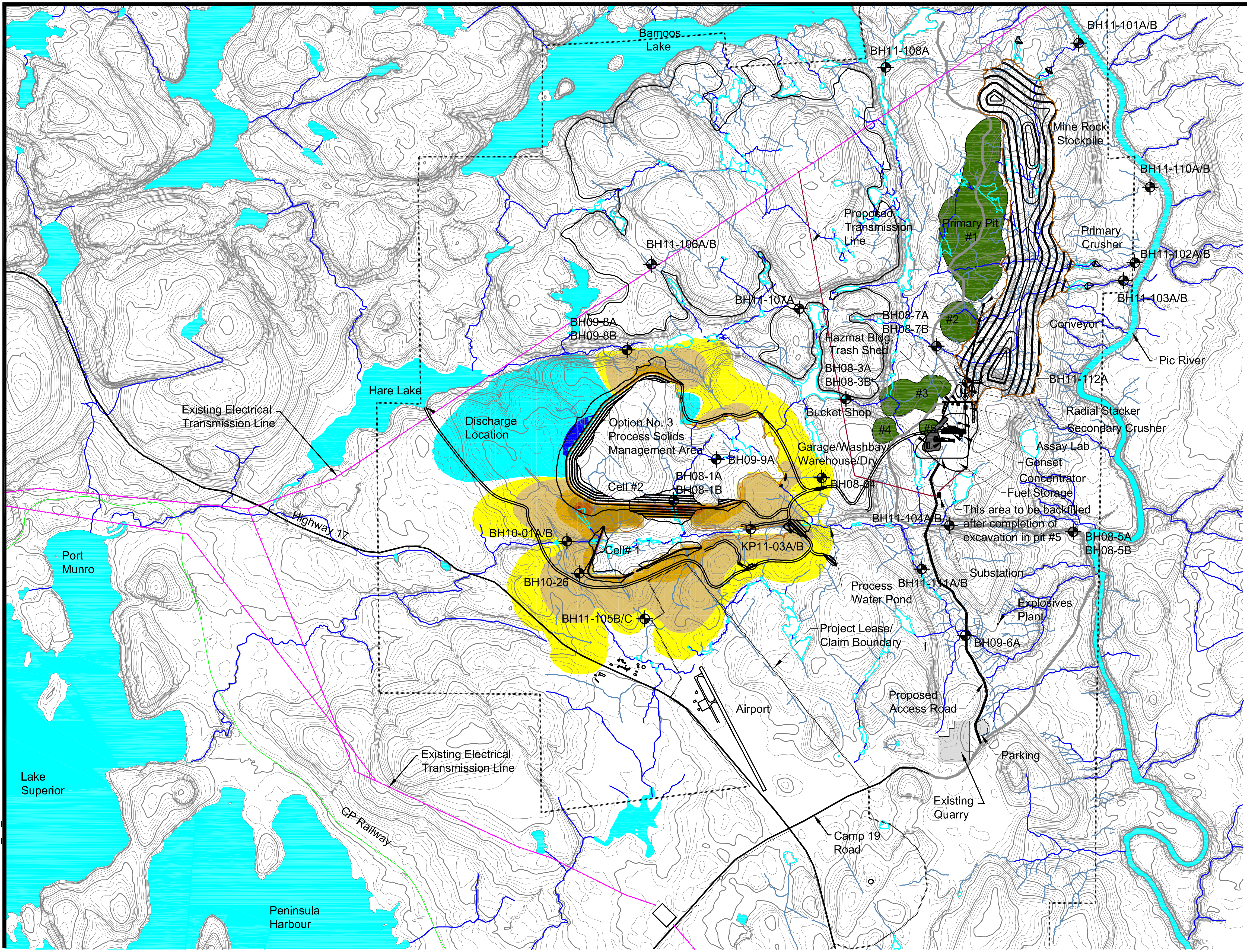
FIGURE 4



Drawdown			
Number	Minimum Drawdown	Maximum Drawdown	Color
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3	−40.00	−30.00	🟧
4	−30.00	−20.00	🟧
5	−20.00	−10.00	🟨
6	−10.00	−1.00	🟫
7	−1.00	−0.10	🟨
8	0.10	10.00	🟦
9	10.00	15.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 400 800 m SCALE 1:40000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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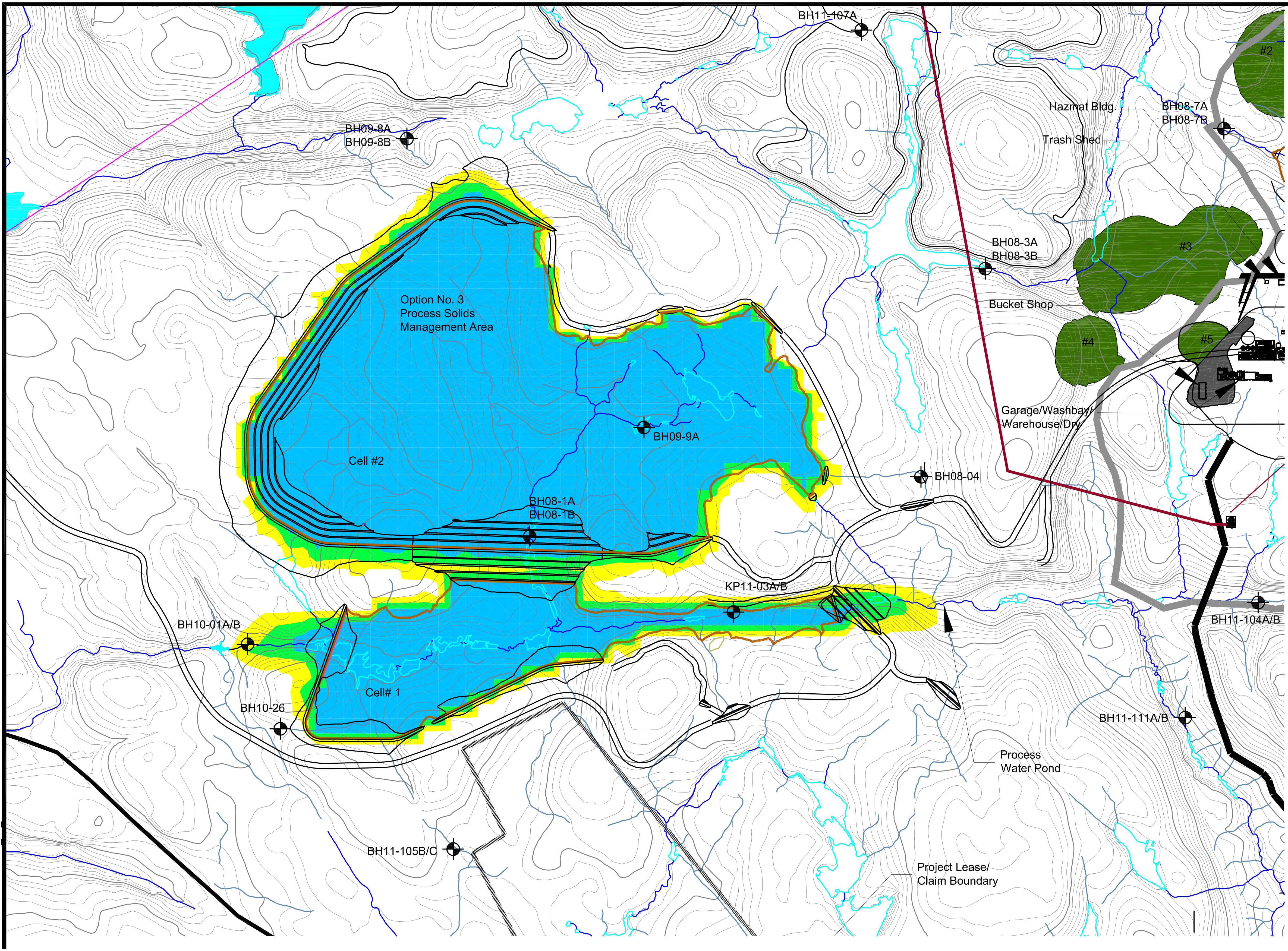
Drawdown of Groundwater Levels Around PSMF After 11 Years (Unimproved (UI) Scenario)

FIGURE 5A



Migration			
Number	Minimum	Maximum	Colour
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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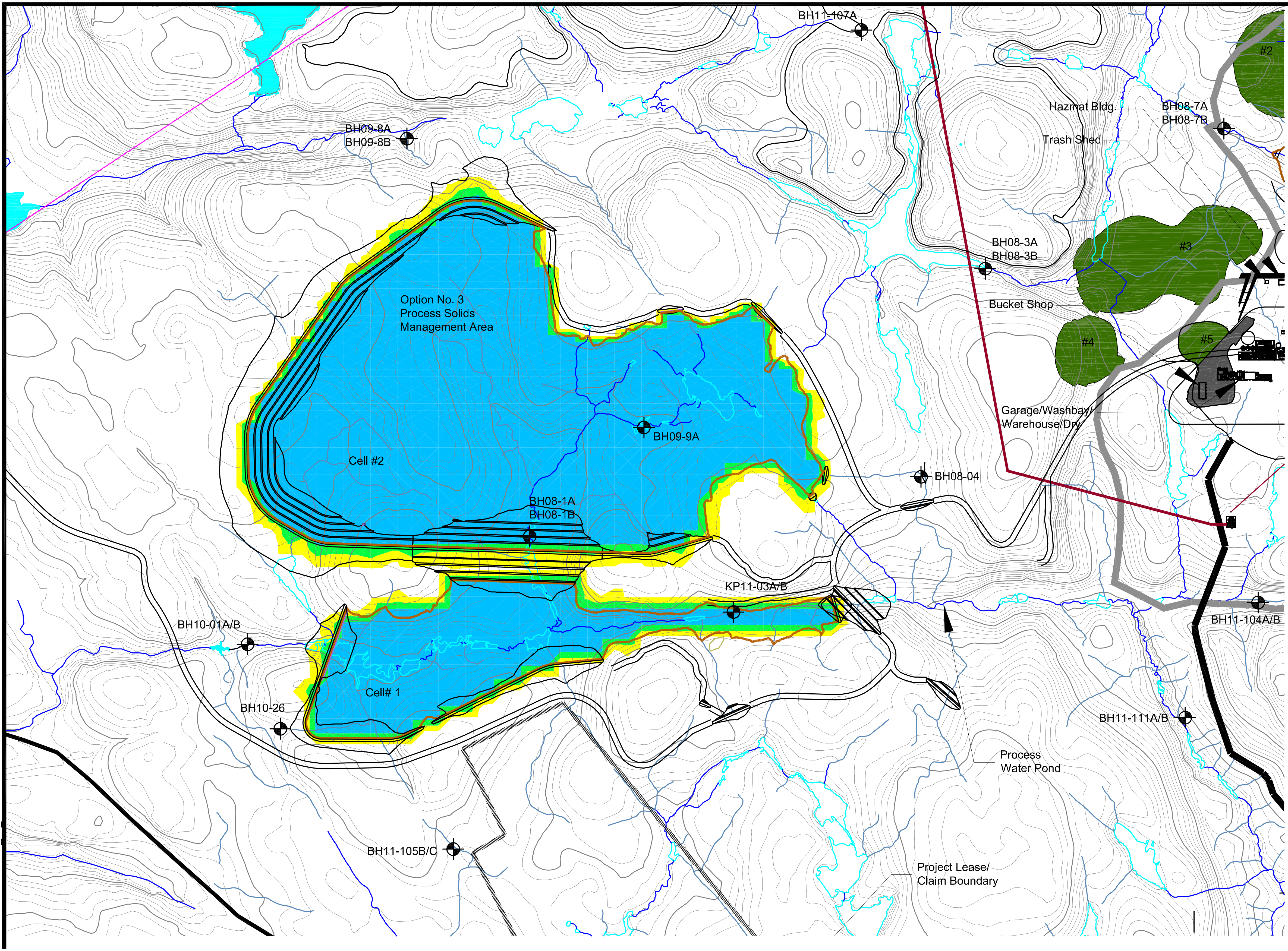
Migration of a Conservative Tracer from PSMF After 3 Years (Unimproved (UI) Scenario)

FIGURE 6A



Migration			
Number	Minimum	Maximum	Colour
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3	0.90	1.00	🟦

Legend

⊕ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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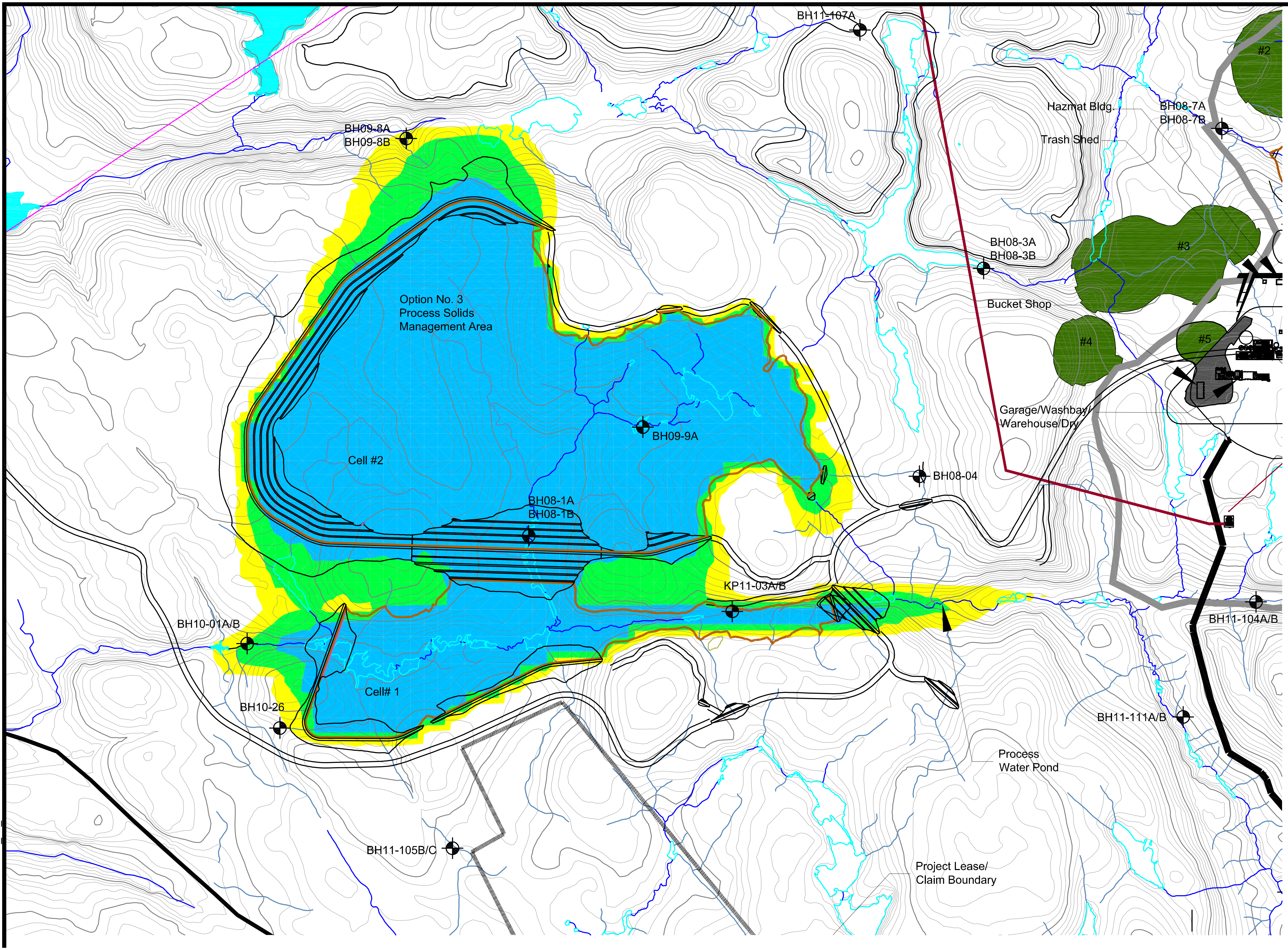
Migration of a Conservative Tracer from PSMF After 3 Years (Grouted Dam (GD) Scenario)

FIGURE 6B



Migration			
Number	Minimum	Maximum	Colour
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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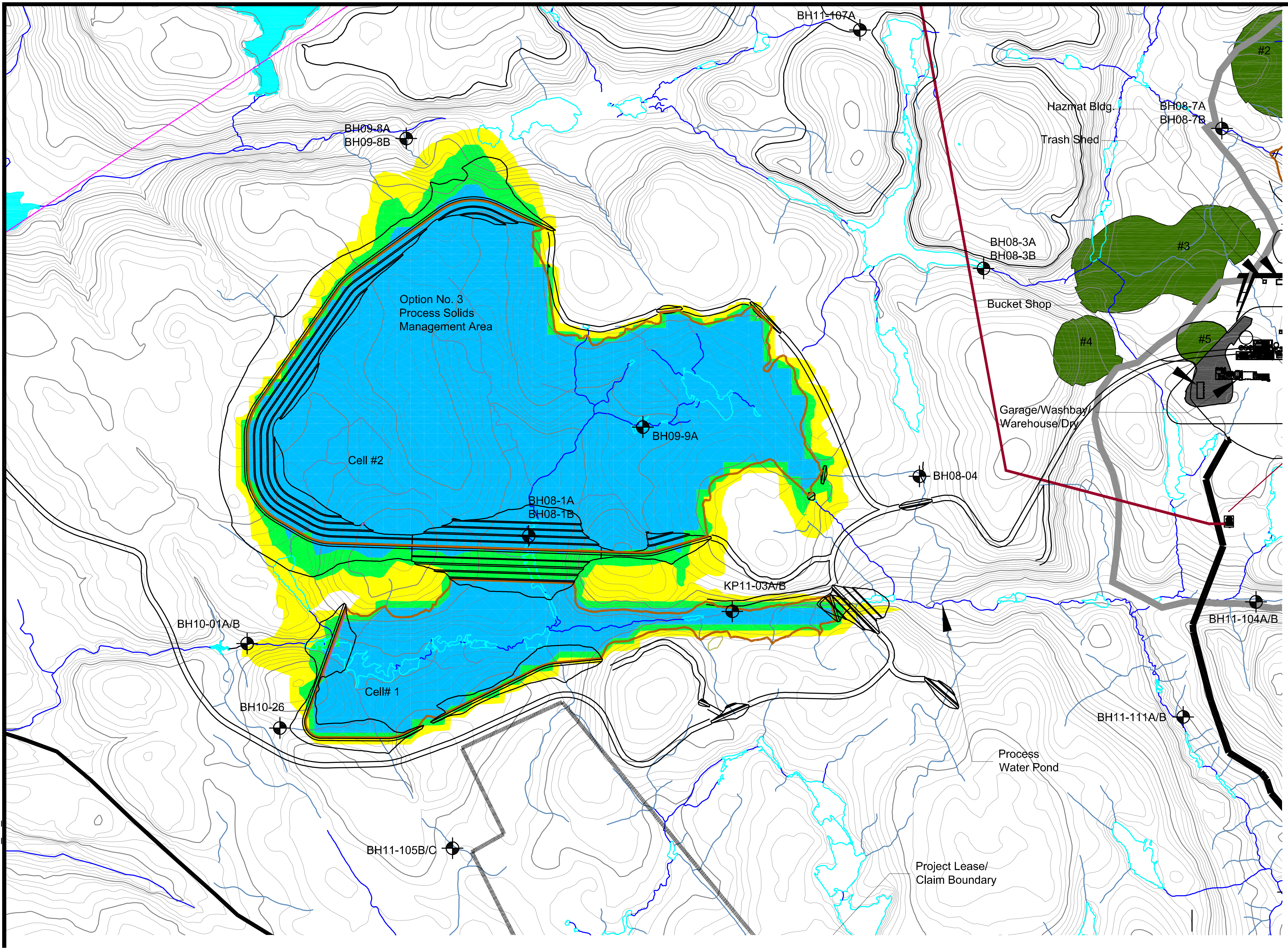
Migration of a Conservative Tracer from PSMF After 20 Years (Unimproved (UI) Scenario)

FIGURE 7A



Migration			
Number	Minimum	Maximum	Colour
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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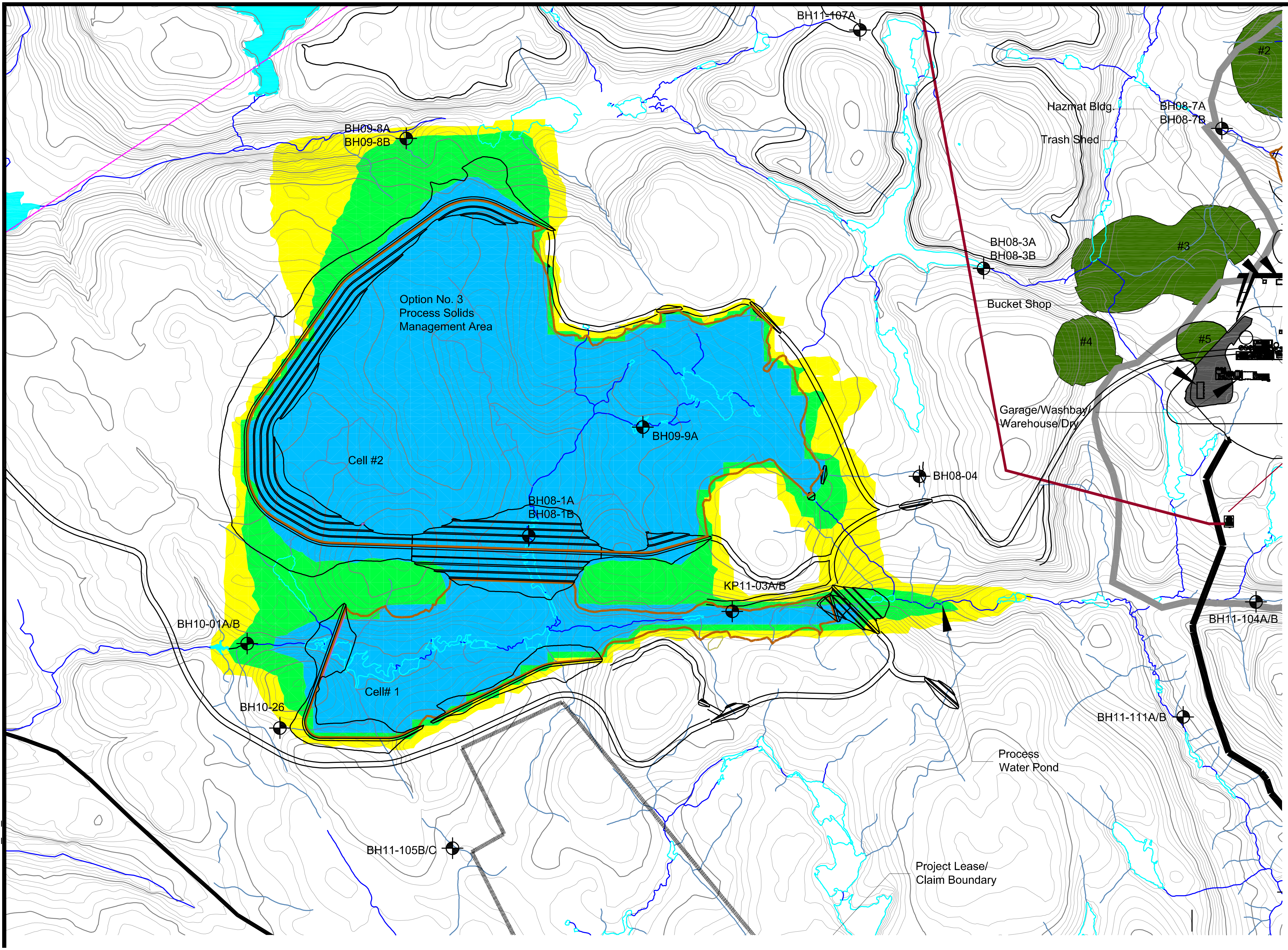
Migration of a Conservative Tracer from PSMF After 20 Years (Grouted Dam (GD) Scenario)

FIGURE 7B



Migration			
Number	Minimum	Maximum	Colour
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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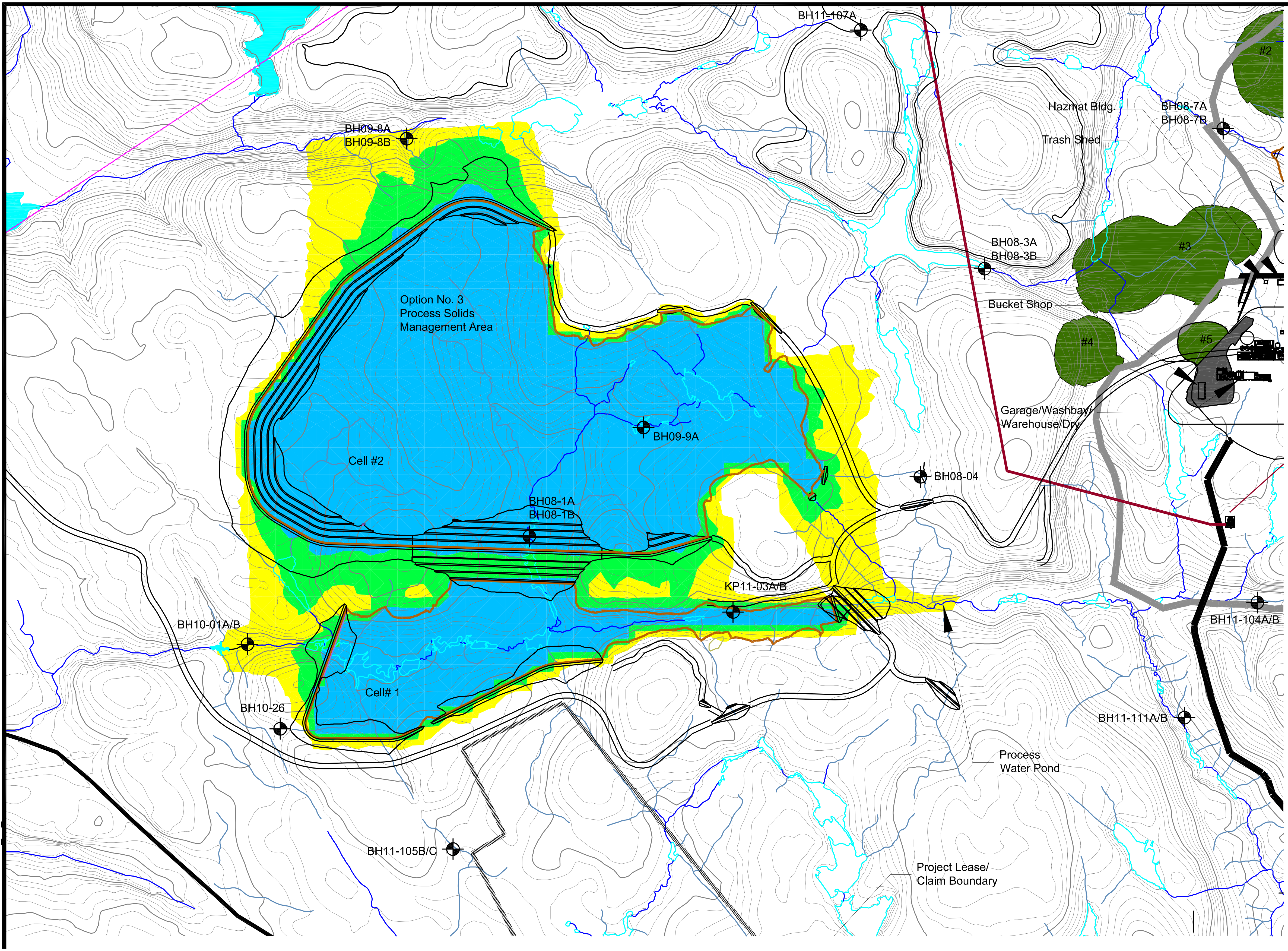
Migration of a Conservative Tracer from PSMF After 100 Years (Unimproved (UI) Scenario)

FIGURE 8A



Migration			
Number	Minimum	Maximum	Colour
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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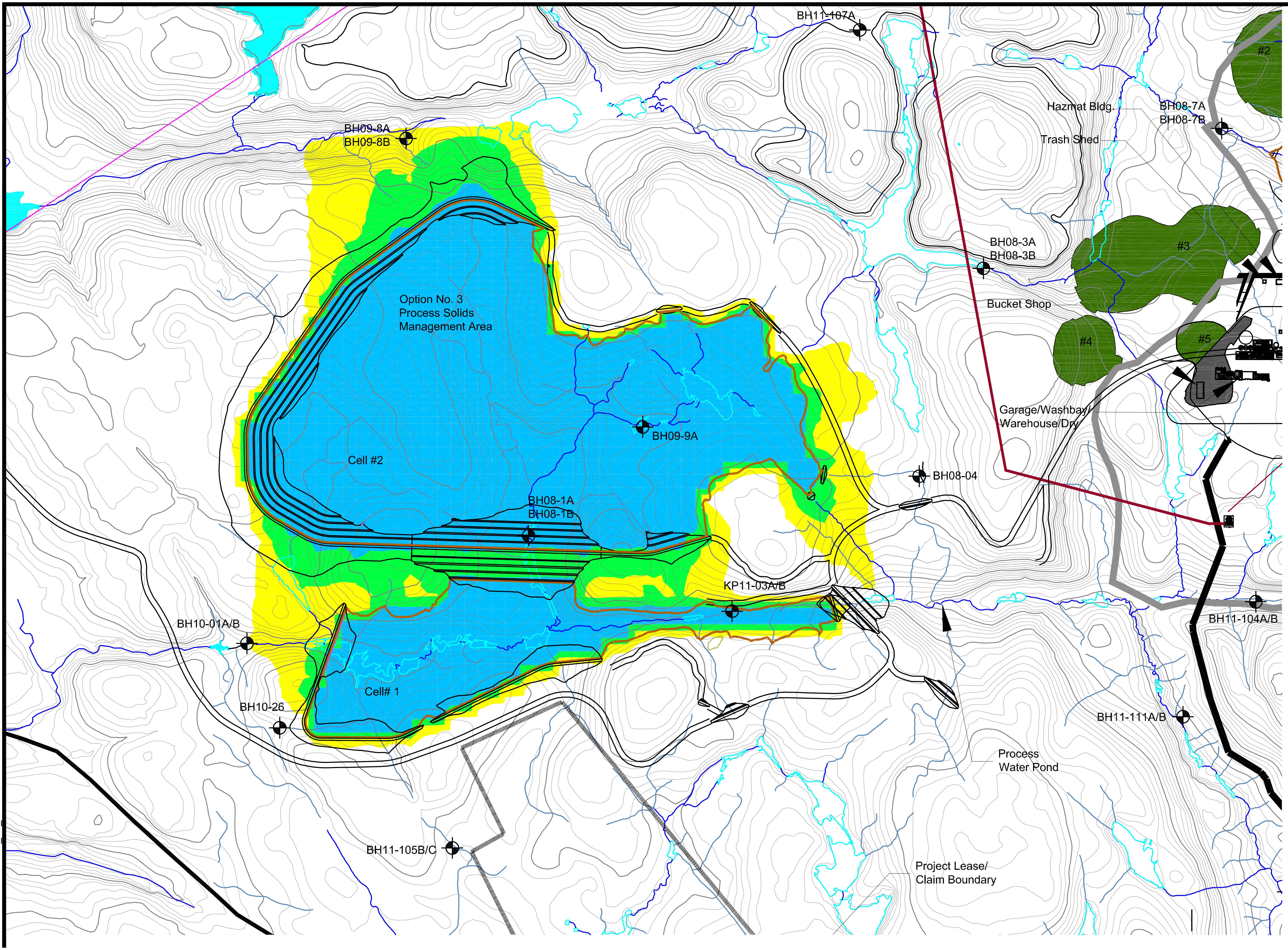
Migration of a Conservative Tracer from PSMF After 100 Years (Grouted Dam (GD) Scenario)

FIGURE 8B



File No. 11-317-12_01_8C

Migration			
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2	0.50	0.90	🟩
3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 150 300 m SCALE 1:15000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

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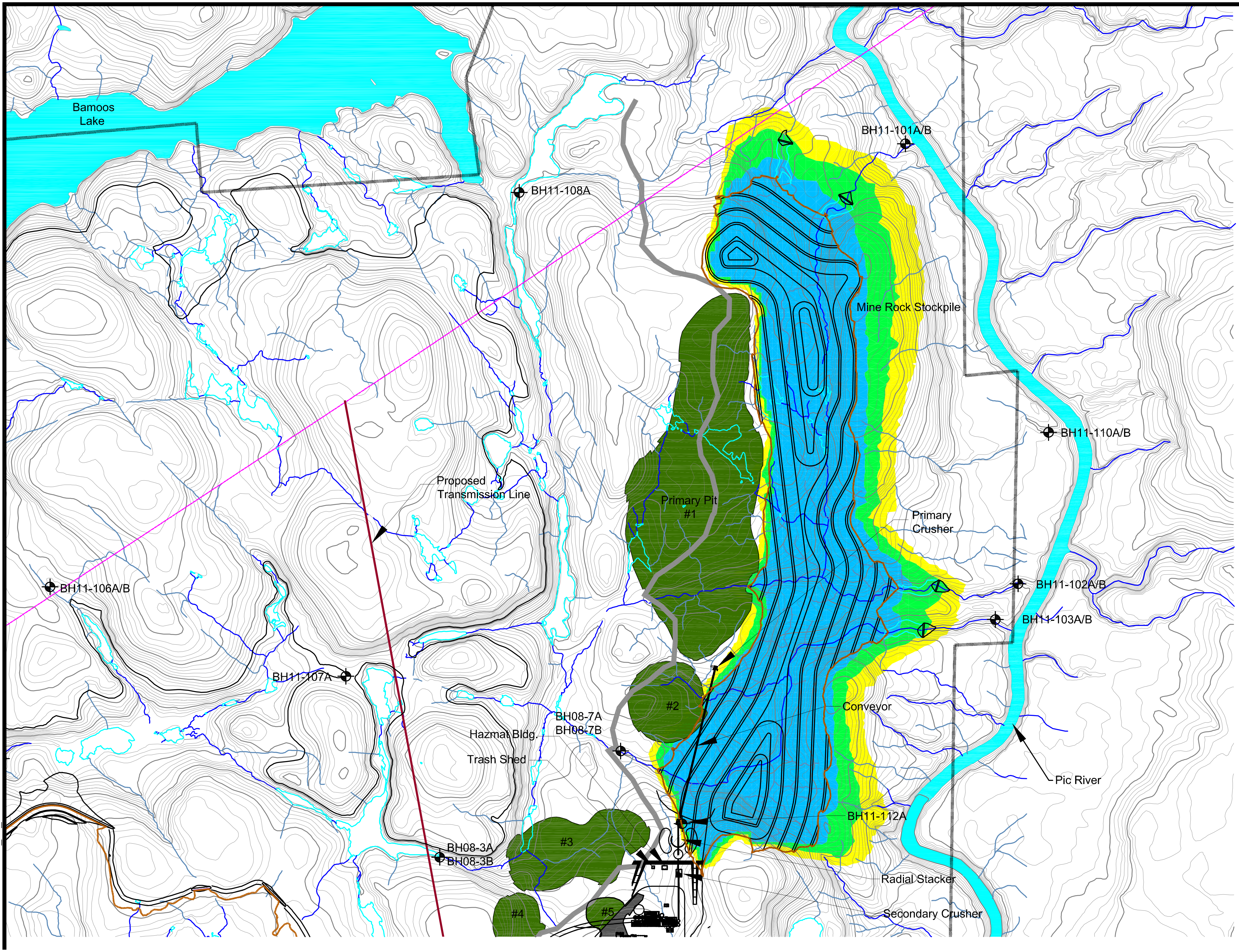
Migration of a Conservative Tracer from PSMF After 100 Years (Uniform Hydraulic Conductivity (UK) Scenario)

FIGURE 8C



Migration			
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3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

N

Scale

0 200 400 m

SCALE 1:20000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

File No. 11-317-12_01_09

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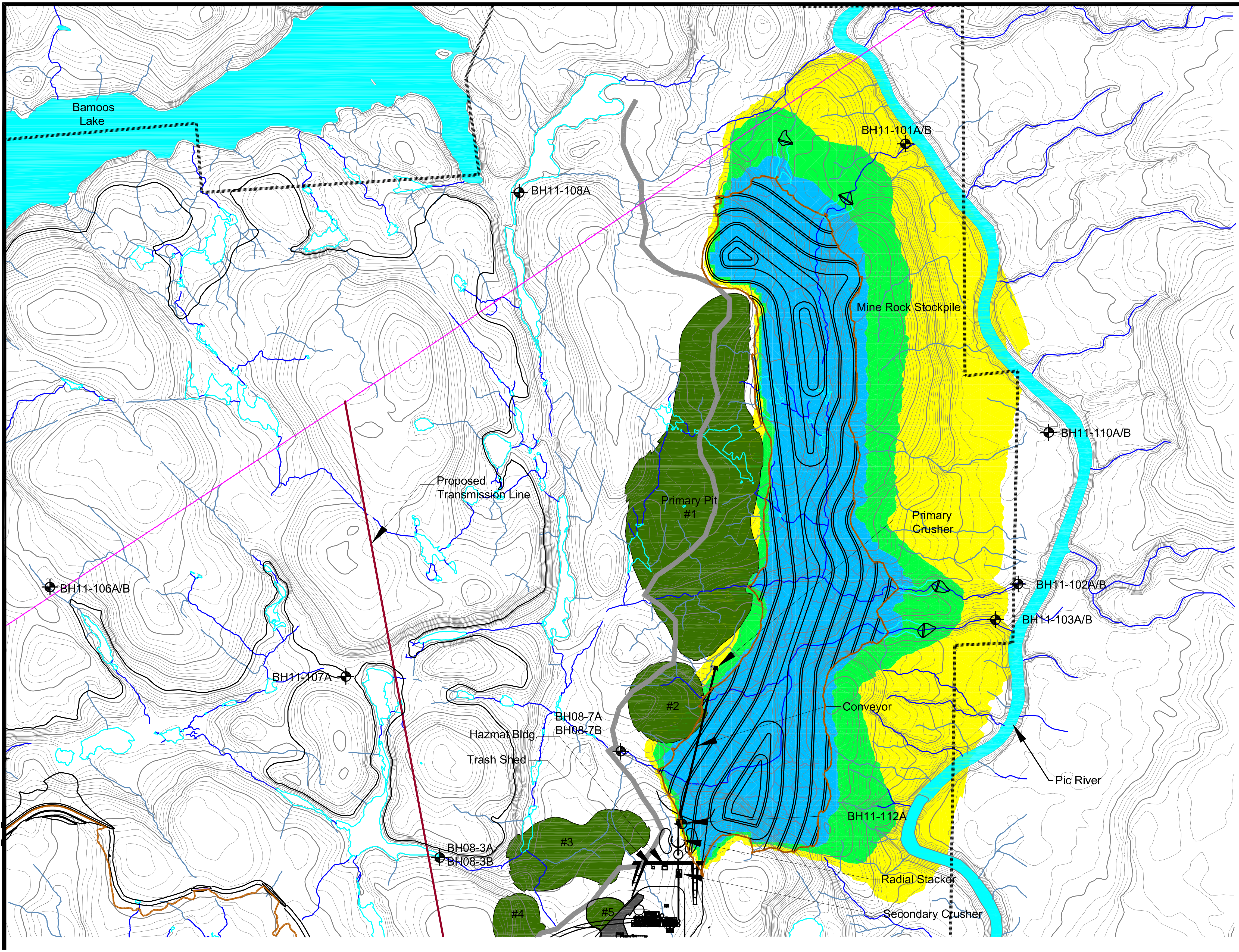
Migration of a Conservative Tracer from MRSA After 20 Years

FIGURE 9



Migration			
Number	Minimum	Maximum	Colour
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3	0.90	1.00	🟦

Legend

⌖ BH08-3A Existing Groundwater Monitoring Well

Scale

SCALE 1:20000

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

File No. 11-317-12_01_10

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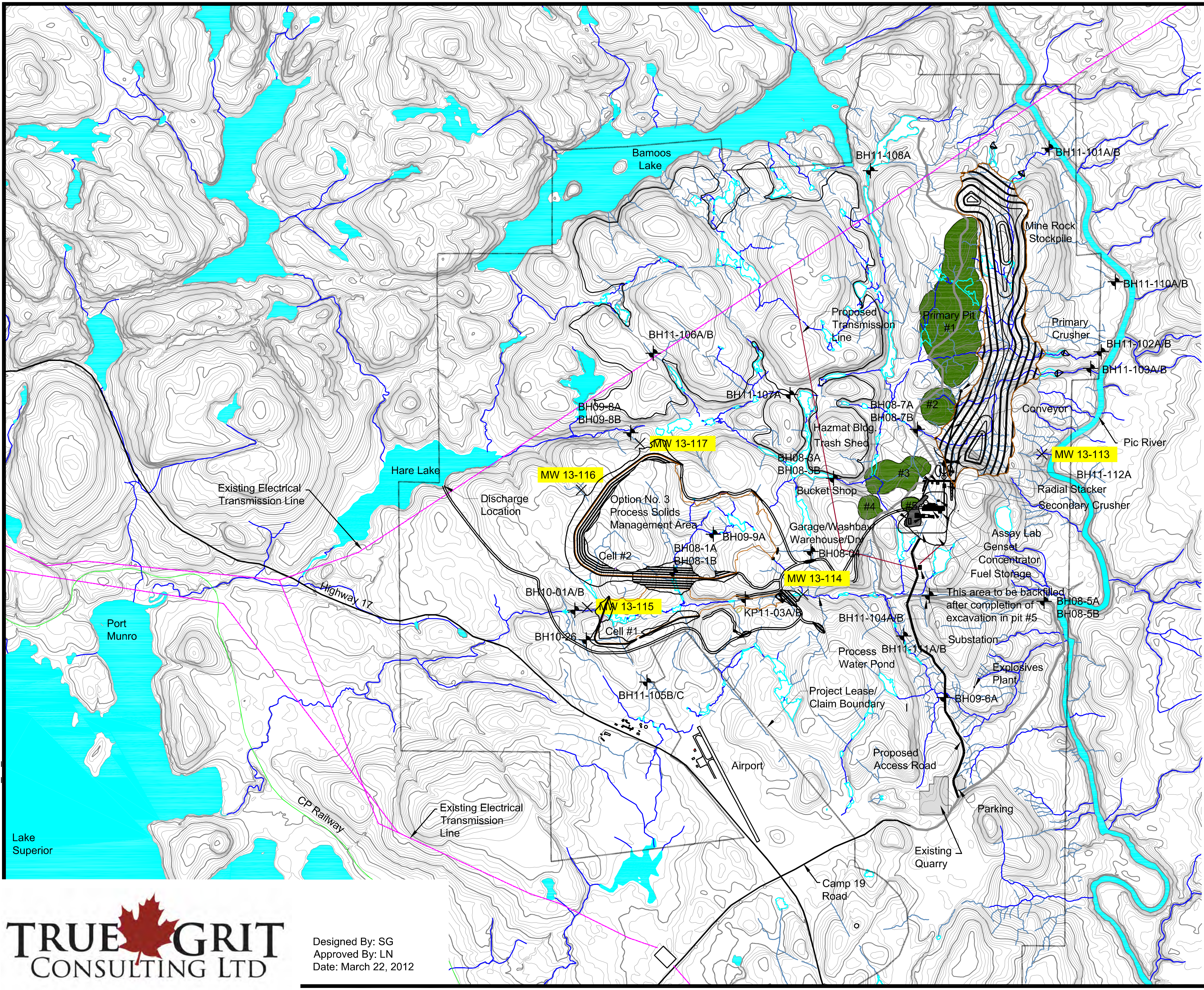
Migration of a Conservative Tracer from MRSA After 100 Years

FIGURE 10



Legend

BH08-3A	Existing Groundwater Monitoring Well
MW 13-113	Proposed Groundwater Monitoring Well

Scale

0 400 800 m SCALE 1:40000

N

Note: Mine Pits and Process Areas derived from Knight Piesold Consultings "Proposed Site Investigation Plan Summer 2011" Figure 1.
Mine Rock Storage and Process Solids Management Facility Areas derived from Knight Piesold Consultings "Combined Storage Area PSMF - Year 10" Figure 6.

File No. 11-317-12_01_11

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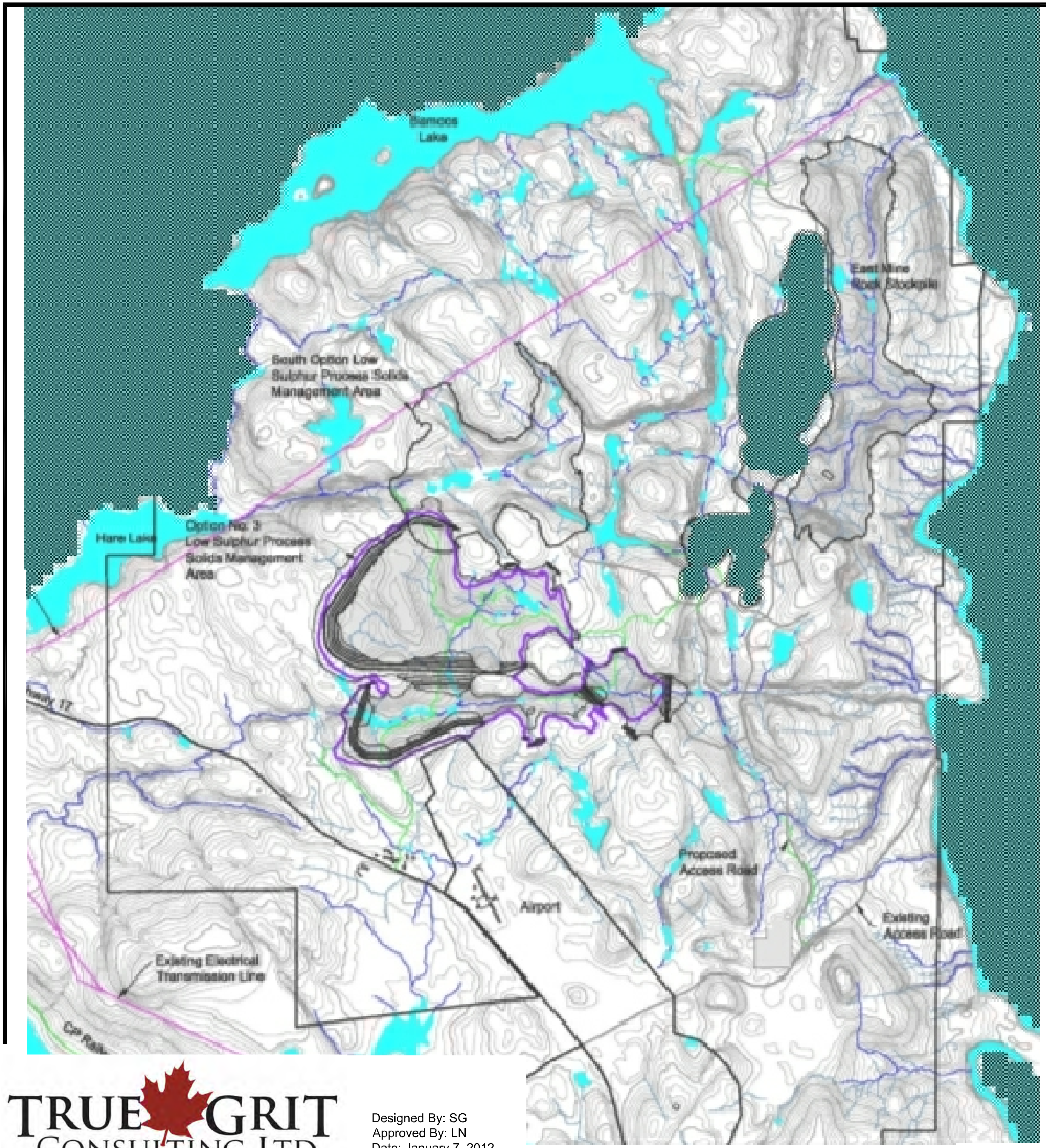
Proposed Monitoring Well Locations

FIGURE 11

Appendix A:
Progression of Open Pits



LEGEND

▨	INACTIVE CELLS

(NOT TO SCALE)

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Date: January 7, 2012

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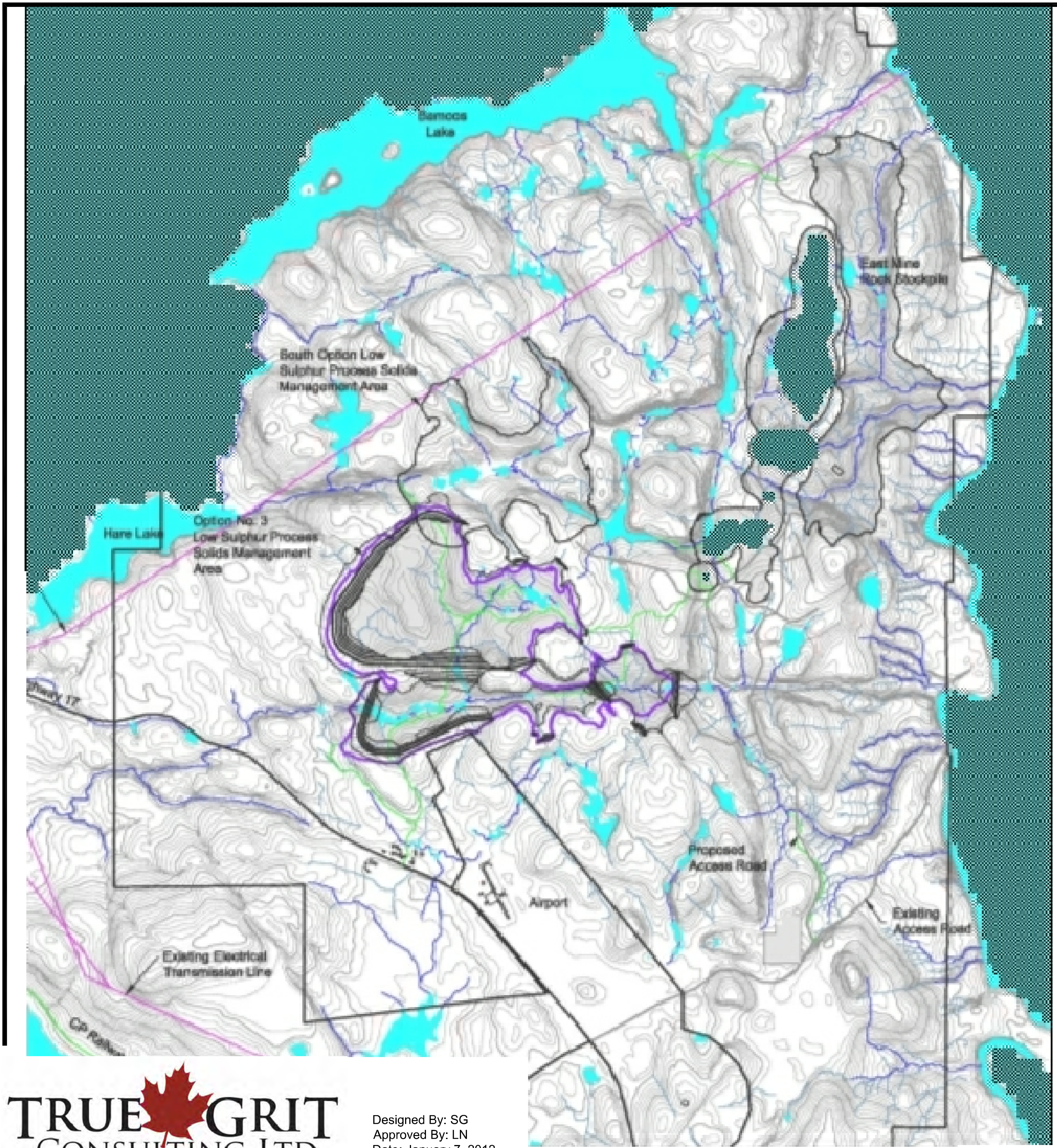
Extent of Open Pit in Layer 1 (to 288m asl)

FIGURE A1



LEGEND

▨ INACTIVE CELLS

(NOT TO SCALE)

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Extent of Open Pit in Layer 2 (to 240m asl)

FIGURE A2

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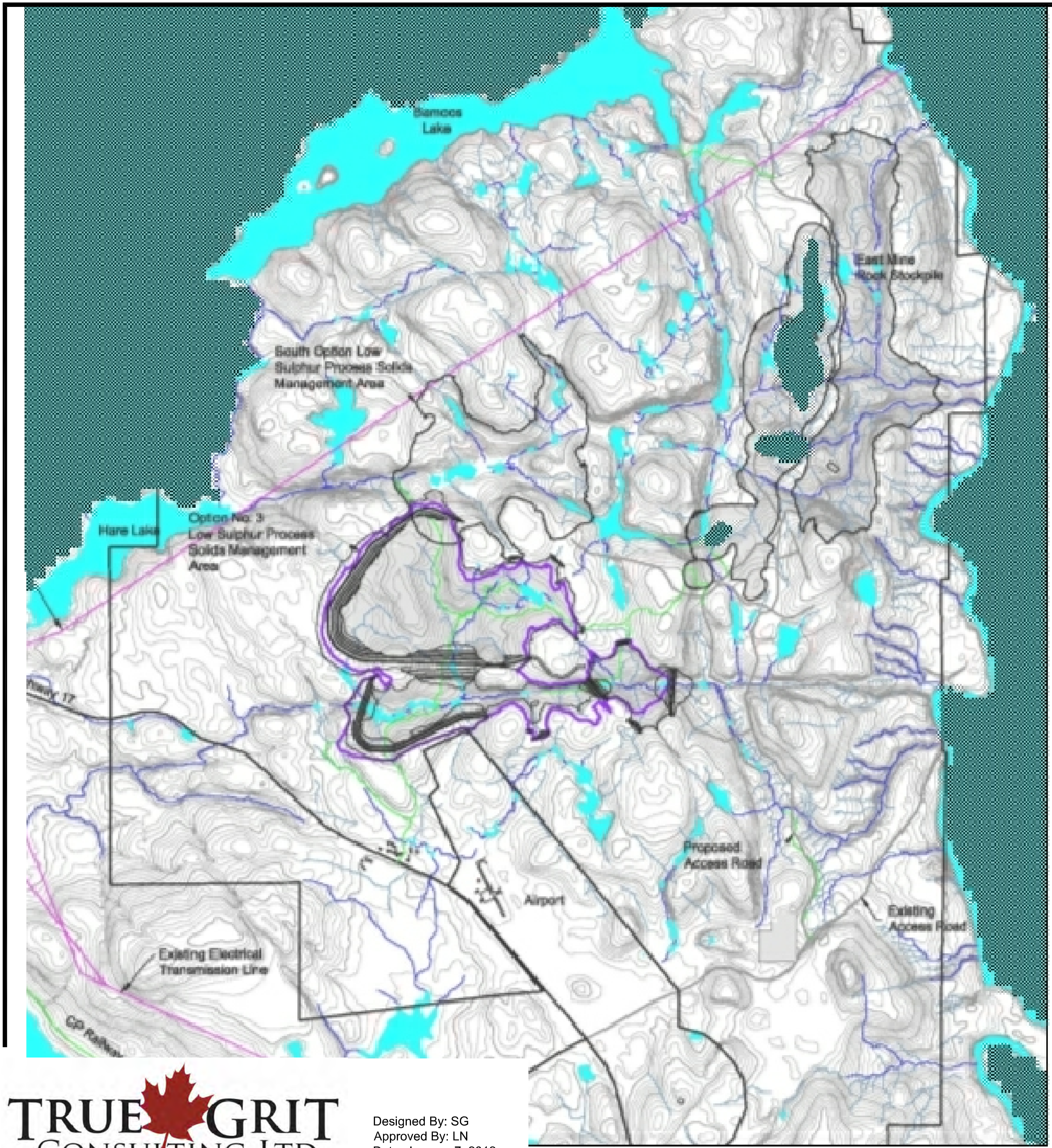

LEGEND

▨ INACTIVE CELLS

(NOT TO SCALE)

File No. 11-317-12

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Date: January 7, 2012

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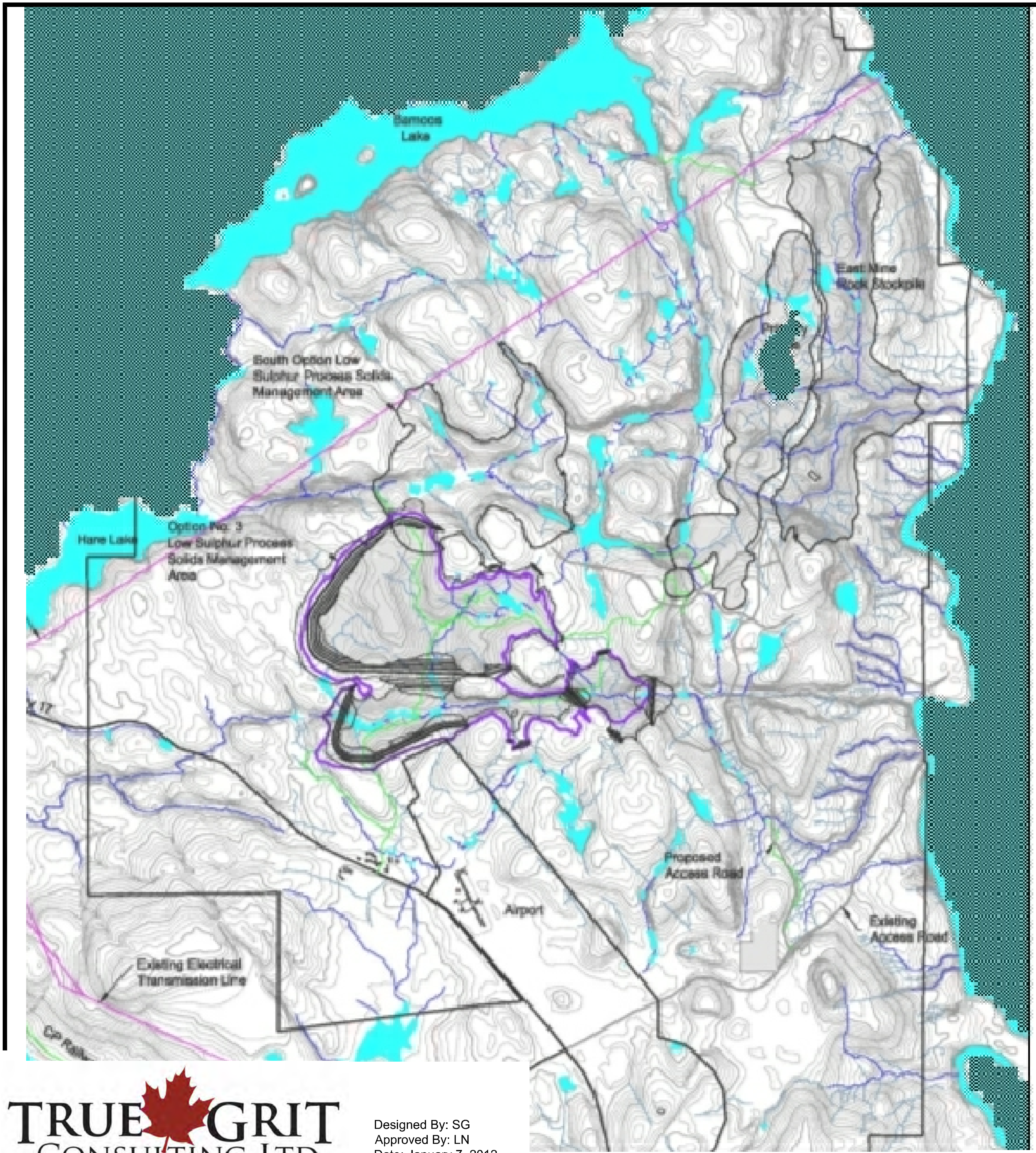
Extent of Open Pit in Layer 3 (to 132m asl)

FIGURE A3



LEGEND

▇	INACTIVE CELLS

(NOT TO SCALE)

File No. 11-317-12

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Date: January 7, 2012

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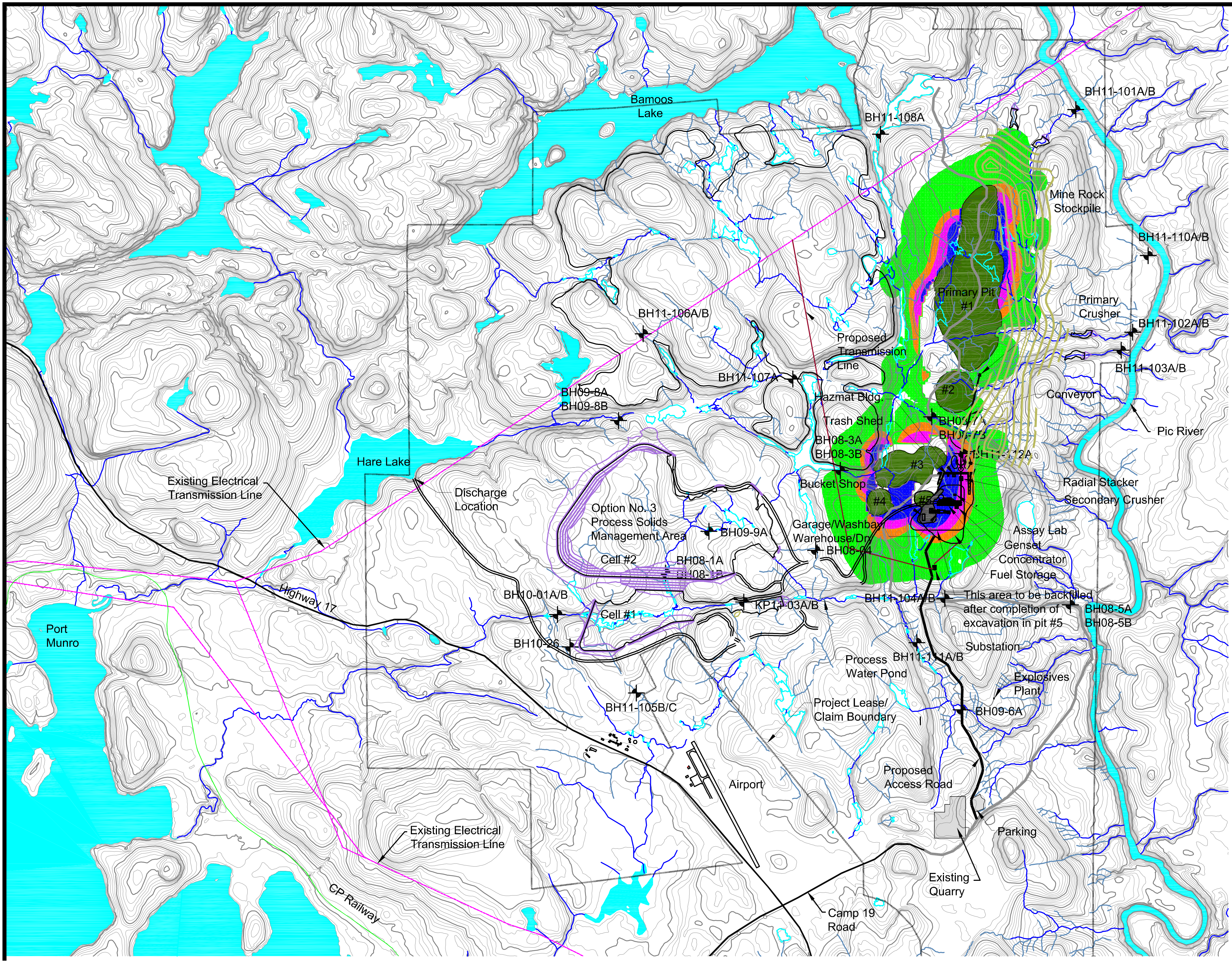
Extent of Open Pit in Layer 4 (to sea level)

FIGURE A4

Appendix B:
Drawdown of Groundwater Levels around Open Pits



Drawdown			
Number	Minimum Drawdown	Maximum Drawdown	Color
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3	10.00	20.00	🟪
4	20.00	75.00	🟦

N

Scale

0 400 800 m

SCALE 1:40000

File No. 11-317-12

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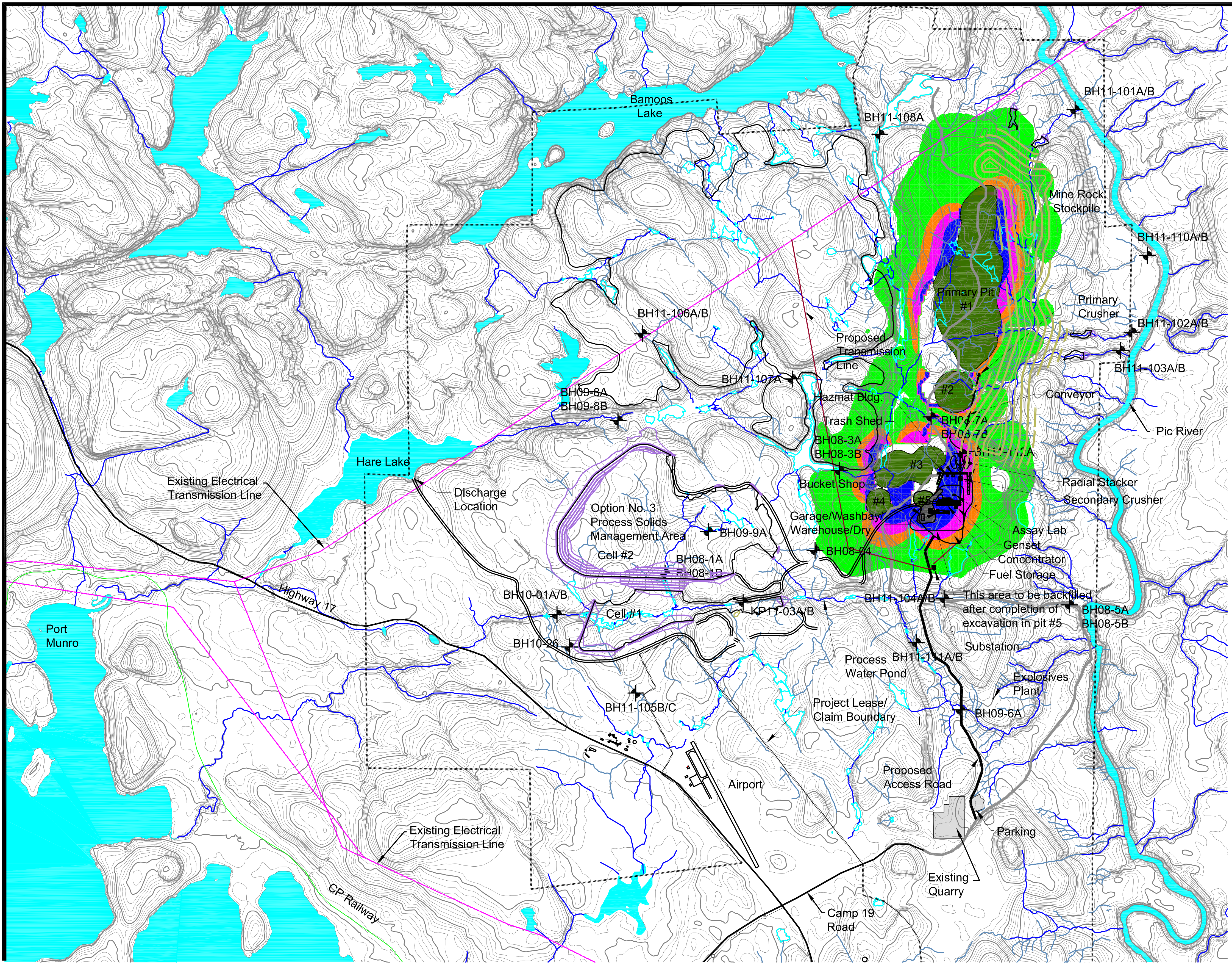
Drawdown of Groundwater Levels Around Open Pits After 3 Years

FIGURE B1



Drawdown			
Number	Minimum Drawdown	Maximum Drawdown	Color
1	0.10	5.00	🟩
2	5.00	10.00	🟧
3	10.00	20.00	🟪
4	20.00	75.00	🟦

N

Scale

0 400 800 m

SCALE 1:40000

File No. 11-317-12

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Drawdown of Groundwater Levels Around Open Pits After 6 Years

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Date: March 29, 2012

FIGURE B2