MEMORANDUM

TO Sandra Pouliot; Canadian Malartic Corporation **DATE** January 1, 2018

CC Devin Hannan, Ken De Vos; Golder Associates Ltd.

FROM Adam Auckland **PROJECT No.** 1656263.1000.1001

FEDERAL INFORMATION REQUEST T(3)-08 – COMPILED RESPONSE DOCUMENTS AND RELEVANT COMMUNICATIONS

Following submission of the Version 2 Hammond Reef Gold Project Environmental Impact Statement/Environmental Assessment (EIS/EA), the Canadian Environmental Assessment Agency (CEAA) requested additional information in Information Request T(3)-08 regarding seepage from the Tailings Management Facility (TMF) and the potential impact to water quality in the downstream receiving environment as a result of TMF seepage.

CMC worked closely with CEAA to develop an approach to respond to T(3)-08. Additional field data collection, background data compilation and three-dimensional groundwater and water quality modelling were undertaken. This response package includes all documentation with respect to the development of the response approach, the development, calibration and results of the groundwater model, the results of the water quality modelling and seepage impact assessment, and relevant communication with CEAA throughout the execution of the work. The following are included in this document package:

- Part A – Background Information and Response Approach
- Part B – CEAA Comments on Response Approach
- Part C – Field Data Collection and Conceptual Model Development
- Part D – CEAA Comments on Conceptual Model Development
- Part E – Baseline Model Construction and Calibration
- Part F – CEAA Comments on Baseline Model Construction and Calibration
- Part G – Groundwater Modelling of TMF and Seepage Impact Assessment
- Part H – CEAA and MOECC Comments on Groundwater Modelling of TMF and Seepage Impact Assessment
- Part I – CMC Response Letters to CEAA and MOECC

Final responses to all components of T(3)-08 are provided in Section 8.0 of Part G of this document package.

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PART A

Background Information and Response Approach

TECHNICAL MEMORANDUM

DATE December 12, 2017 **PROJECT No.** 1408383 3500 3501

TO Cathryn Moffett
Canadian Malartic Corporation **DOC No**. 008 (Rev 0)

FROM Adam Auckland and Devin Hannan **EMAIL** adam_auckland@golder.com

HAMMOND REEF GOLD PROJECT – TAILINGS MANAGEMENT FACILITY, ADDITIONAL 3D GROUNDWATER MODELLING

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has prepared this memorandum for Canadian Malartic Corporation (CMC) as a basis for further discussion with the Government Review Team (GRT) regarding additional numerical groundwater modelling of the proposed tailings management facility (TMF) at the Hammond Reef Gold Project (the Project). The purpose of the additional groundwater modelling proposed herein is to address concerns raised by the GRT following their review of the Project's Environmental Impact Statement/Environmental Impact (EIS/EA) and responses submitted by CMC to Information Requests (IRs) received after submittal of the EIS/EA. A summary of the GRT concerns and previous responses from CMC are documented in the attached TMF Seepage Issue Tracking Log.

Following a recent Project meeting between CMC, Golder and federal and provincial government reviewers (February 2, 2016), it was agreed that CMC would complete the following:

- Conduct a search for historic borehole data not previously presented or considered in the EIS/EA (e.g., exploration drilling data); and
- Request that Golder develop a scope of work to address the concerns of the GRT for review by and discussion with the GRT.

2.0 BACKGROUND

2.1 Previous Groundwater Modelling of the TMF

In response to comments on the final EIS/EA regarding seepage related impacts to Lizard Lake, a 3D MODFLOW model of the eastern portion of the TMF was developed in 2014 to evaluate the capture efficiency of the proposed seepage collection system and to quantify potential residual seepage rates to Lizard Lake (Golder, 2014). This modelling demonstrated that the assumptions made in the EIS/EA regarding seepage capture were valid but the GRT raised additional concerns about the modelling assumptions and impacts to other potential receivers.

2.2 Government Review Team Commentary

The GRT conducted a review of the TMF modelling and communicated concerns (summarized in the attached comment log). In summary, we understand the key issues / requests to be as follows:

- Address the applicability of the currently available data to adequately characterize the site baseline hydrogeology and, if necessary, collect additional field data.
- Provide a detailed conceptual hydrogeologic model that will serve as the basis for the numerical model. Particular consideration should be given to: 1) granular troughs underlying the TMF and their potential as seepage pathways; 2) hydraulic conductivity assignments, particularly anisotropy, in lieu of heterogeneity observed in borehole logs across the site. The adequacy of the existing slug testing and grain size data as a basis for characterizing the hydraulic conductivity is also questioned.
- Develop a more regional-scale model that encompasses the entirety of the TMF, as opposed to just the eastern flank.
- Conduct a model calibration using baseline data.
- Based on the expanded domain, estimate the amount of seepage by-pass to downgradient receptors other than Lizard Lake, for example, Sawbill Bay and smaller water bodies around the perimeter of the TMF.
- Quantify the proportion of seepage occurring below the TMF base versus through the TMF dams.
- Consider all project phases from baseline to closure.
- Conduct a sensitivity analysis to examine the potential range of seepage rates emanating from the TMF.
- Evaluate potential environment impacts to all receiving water bodies.

3.0 ADDITIONAL GEOTECHNICAL DATA

Following the meeting with the GRT on February 2, 2016, a search was completed for additional geotechnical data in the area of the TMF that was not available or considered in the previous groundwater modelling analysis. This search resulted in the following information:

- Sixty (60) exploration/condemnation boreholes within the footprint of the TMF facility (Figure 1). These holes do not provide detailed stratigraphy of the overburden but do indicate depth to bedrock, allowing for improved characterization of the underlying bedrock surface.
- Five (5) detailed geotechnical boreholes (BH13-1 to BH13-5) completed in 2013 along the proposed TMF dam alignment (Figure 1).
- The attached report entitled '*Surficial Geology update of the Golden Winner area; sedimentology and stratigraphy of glaciofluvial deposits and recommendations for recce samples*' prepared in 2010, including overburden characterization of seven (7) sampling trenches within the TMF footprint (Figure 1).

This information will be integrated with the existing data to provide an improved basis for the proposed scope of work to address the concerns of the GRT.

4.0 PROPOSED SCOPE OF WORK

Golder proposes to address the GRT concerns through the expansion and refinement of the current groundwater model as well as integration of the above identified data. The proposed scope of work will consist of the following:

1) **Model Domain Expansion.** Expand the model domain to include the entirety of the TMF and delineate the extents based on regional hydrologic boundaries. This will allow for the simulation of a comprehensive site groundwater budget and TMF seepage tracking to all collection systems and potential downgradient receptors.
2) **Overburden Isopach Development.** Incorporate additional data (as identified in Section 3.0) and regional surficial geology mapping with previously used logs to develop a detailed overburden isopach underneath the TMF. In our view the incorporation of this additional data, which provides good coverage over the TMF footprint, negates the need for additional boreholes. External to the TMF, where overburden data may not exist, the isopach will be extended into the broader model domain based on conservative assumptions (for example, assuming lateral continuity at an appropriate uniform thickness).
3) **Hydraulic Conductivity Review.** Review hydraulic conductivity data within the model domain. Discrete hydraulic conductivity zones may be developed if the data suggests significant heterogeneity exists across the site. If anisotropy is not clearly supported by either the data or calibration effort (below), an isotropic system may be conservatively assumed. In our view the existing slug testing and grain size analysis results provide for a reasonable means to characterize hydraulic conductivity and additional testing is not warranted. In any event, the model sensitivity to a range of hydraulic conductivities will be tested during sensitivity analysis (described below).
4) **Calibration.** Model calibration typically involves adjusting initial model input parameters within a reasonable range until simulated results reasonably approximate field observations. The model will be calibrated in steady-state to average water levels at monitoring wells within domain. In addition, stream / baseflow data may be considered, depending on the gauge location relative to the model domain. Finally, a base case, pre-TMF groundwater flow budget will be derived based on the calibrated model output. It is likely that an iterative, trial-and-error approach to calibration will be employed as per ASTM D 5490- 93 (Reapproved 2002) *Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information.*
5) **Project Phase Analysis.** The modelling will consider two phases of Project development: 1) current conditions (i.e. pre-TMF baseline) – this is the calibrated model described above; and 2) TMF during operational phase at full build-out. The operational phase at full build-out considers the period where impacts are expected to be maximal because the aerial extent of the tailings stack and elevation of the reclaim water pond will be at their highest. From an environmental impact perspective, detailed evaluation of the construction, closure, and post-closure phases is not considered necessary for the following reasons:
   a. **Construction** – During construction, no tailings placement will occur and no water will be stored within the TMF, therefore no change to existing conditions is expected.
   b. **Closure** – At closure, tailings deposition and discharge of process water to the TMF reclaim pond will cease and TMF water is expected to improve with time (see Site Water Quality TSD, pp 106). Consequently, both the potential for seepage and its associated environmental impact will decrease with over time given that the tailings are non-acid generating with excess neutralizing capacity (See Geochemistry TSD). Furthermore, as indicated in Section 4.2 of the Conceptual Closure and Rehabilitation Plan TSD, seepage will continue to be collected and

pumped back to the TMF until it is determined that the seepage water quality is suitable for release. At such time, the active seepage collection system will be decommissioned.

c. **Post-Closure** – During the post-closure period, seepage water quality will have been deemed to be suitable for discharge and the TMF reclaim pond spillway will be lowered, reducing the potential for seepage.

6) **Groundwater Flow and Seepage Simulation.** Groundwater conditions during the TMF operational phase at full-build out will be simulated. A comprehensive flow budget will be developed based on the model output. Particle tracking will be employed to illustrate seepage pathways. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. Additional mitigation or modifications to the presently proposed seepage collection system may be identified during this analysis.
7) **Sensitivity Analysis.** A sensitivity analysis will be performed to establish an upper bound on results by varying select input parameters within a reasonable range about the base case input value. Golder will seek the Government Review Team's opinion in selecting parameters to test during the sensitivity analysis. Currently, we feel that recharge rates, and hydraulic conductivities/anisotropies of tailings, overburden and weathered bedrock may be potential candidates for analysis. For the purpose of scoping, we have assumed four (4) variables will be examined. Model calibration is not planned to be re-assessed during this task.
8) **Environment Impacts.** The potential impacts to the water bodies receiving TMF seepage will be re-assessed based on the predicted residual seepage rates and TMF seepage water quality. This scope of this assessment will only include Lizard Lake and Sawbill Bay. Aquatic habitat in the smaller lakes and streams around the perimeter of the TMF has already been determined to be 'impacted' by the project due to loss of inflow (due to watershed reduction) or loss of connectivity to larger water bodies. As a result, these water bodies have been included in the No Net Loss/Fish Habitat Offset Plan and compensation for the loss of habitat is planned (see Part B of the Version 2 Aquatic Environment TSD).
9) **Report**. A report documenting model conceptualization, construction, calibration, TMF seepage collection mitigations applied, predictive analysis, sensitivity analysis and conclusions will be provided as a supporting document to the responses to Information Request T(3)-08.

5.0 CLOSURE

We trust that this memorandum serves as sufficient foundation for further discussions on refining a path forward to fully satisfy the requirements of the Government Review Team. Please contact the undersigned if you have any questions.

Prepared by:

<Original signed by>

Adam Auckland, M.Sc., P.Eng.
Project Manager, Water Resources Engineer

Reviewed by:

<Original signed by>

Devin Hannan, P.Eng.
Associate, Environmental Engineer

DAH/AA/sk

Attachments:

Figure 1 – Available Subsurface Information in the TMF Area

Report - '*Surficial Geology update of the Golden Winner area; sedimentology and stratigraphy of glaciofluvial deposits and recommendations for recce samples*'

TMF Seepage Issue Tracking Log

REFERENCES

Golder, 2014. *Technical Memorandum: Osisko Hammond Reef Gold Project – Tailings Management Facility, 3D Groundwater Modelling.* 13-1118-0010 (5008). May 27, 2014.

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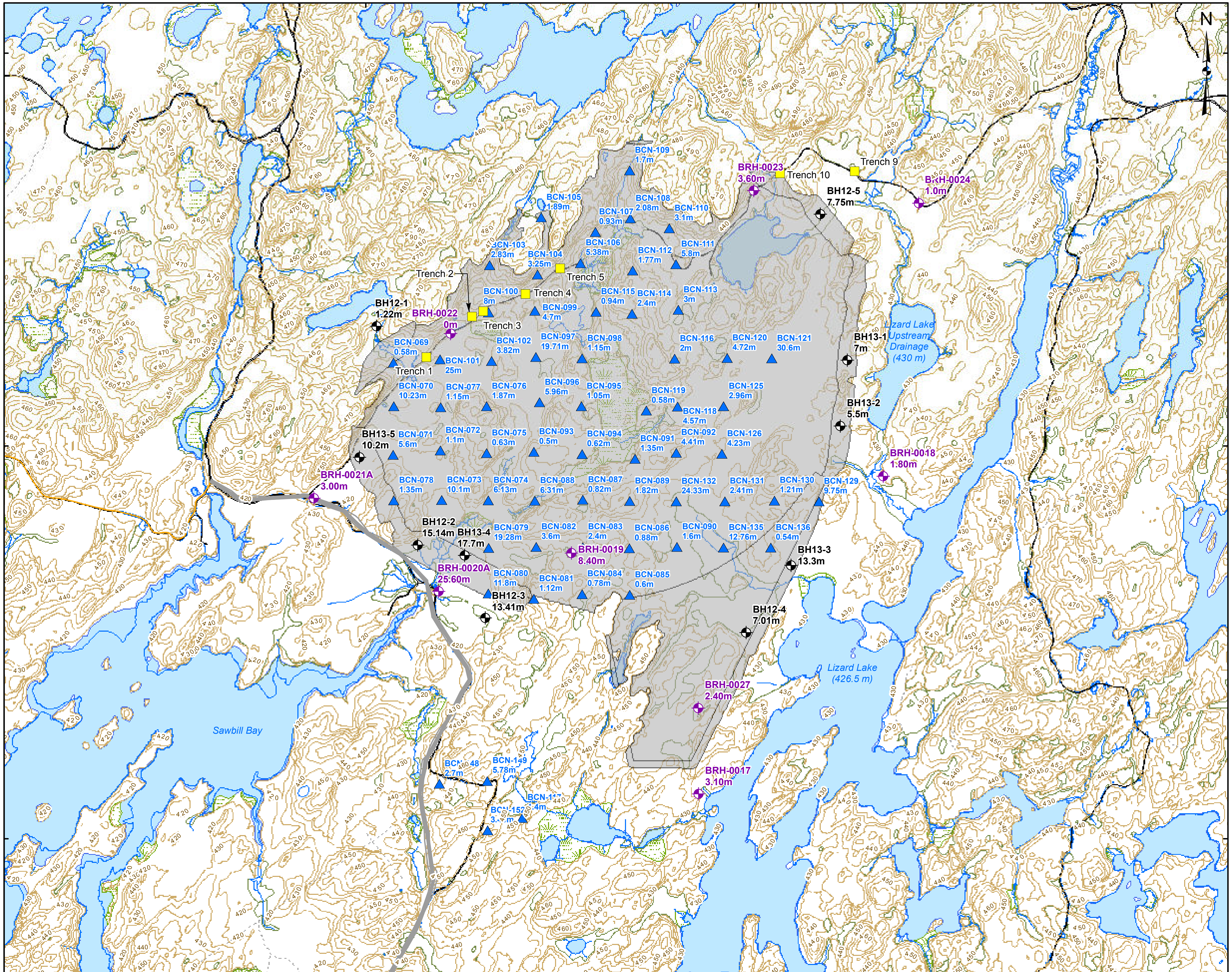

LEGEND

- Index Contour (5m interval)
- Ditch
- Marsh/Swamp
- River/Stream
- Road
- Trail
- Lake
- Wetland
- Osisko Exploration/Condemnation Borehole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Surficial Geology Study Investigation Trench
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Tailings Management Facility

DRAFT

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

500 0 500
SCALE 1:25,000 METERS

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

AVAILABLE SUBSURFACE INFORMATION IN TMF AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 1408383			SCALE AS SHOWN	REV. 0
DESIGN	CGE	14 Nov. 2008	FIGURE: 1	
GIS	CGE	25 Feb. 2016		
CHECK	AA	25 Feb. 2016		
REVIEW				

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Surficial Geology update of the Golden Winner area: sedimentology and stratigraphy of glaciofluvial deposits and recommendations for recce sampling.

Stea Surficial Geology Services

Photo. Looking eastward from a granite ridge into the valley south of the Golden Winner prospect; lowland areas covered by thick outwash deposits.).

Surficial Geology update of the Golden Winner area: sedimentology and stratigraphy of glaciofluvial deposits and recommendations for recce sampling

Prepared for:

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June 10th , 2010

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Introduction

In the spring of 2010 Stea Surficial Geology Services was contracted by Brett Resources Inc. to conduct a pilot sampling study on the area surrounding the Golden Winner property on the northern part of the Hammond Reef claim areas (Map 1). This area is characterized by a broad basin and numerous granite-cored ridges and hills, in which the basin is host to thick glaciofluvial deposits and muskeg (Stea, 2009a). The purpose of this study was to:

1 Assess the sedimentology and stratigraphy of glaciofluvial deposits and the potential of sampling glaciofluvial deposits for gold content.

2. Ascertain if it is possible to sample topographic highs for locally-derived glacial till.

In the initial mapping (Stea, 2009a) this area was not extensively surveyed, so it was not known whether glaciofluvial deposits covered some or all of these hills. If it can be shown that this is not the case, these hills would be useful sites for sampling during a planned reconnaissance till sampling survey as envisioned by Stea (2009b).

Methods

Forty-three sites were examined over 6 days at the site (Appendix 1; Map 1). Thirty two ~8-10 kg samples were taken at selected locations of both till and glaciofluvial/glaciolacustrine sediments (Appendix 1; Map 1). These samples were taken to quantitatively assess the properties of the sediments including grain size and lithology, but most importantly, to investigate the heavy mineral fraction for economic mineral content. Several samples were obtained from tills near and down-ice of the main Hammond Reef showing as a check that local gold mineralization is represented in till samples and to assess what other indicator mineral types may be best suited for regional exploration.

In order to understand the thickness, extent and origin of the glaciofluvial deposits in the broad basins north of the main Hammond Property a trenching program was begun. A large excavator was used for this purpose. Unfortunately, ATV trails at present have access to only the small part of the Golden Winner basins. .

Samples were sent for evaluation of free gold content to Overburden Drilling Management Limited in Ottawa, Ontario (ODM; results pending).

Results

Hills in the Golden Winner area vary from 20-50m in height and have the form of drumlins (inverted spoon shaped hills, streamlined by ice action), ridges and knolls. Sampling of the topographic highs in the Golden Winner property produced some interesting results. Generally the topographic highs were dominated by moss-covered granite outcrop. Enclaves of sediment were found in areas between granite bedrock knobs, often marked by poplar stands. The sediment was either a stony sandy diamicton (till) or silty-fine sand sediment without stones, or both (Map 1). In some localities the till was found underneath the fine-grained sediment. The origin of the fine sediment is uncertain, but it is thought to be a deep water lacustrine facies of glaciolacustrine deposition in Glacial Lake Agassiz.

In addition to sampling topographic highs a trenching program was initiated. Five trenches were dug across the eastern part of the basin and five in the western part (Map 1; Figs. 1, 3). In the western basin an ATV trail runs at the base of a prominent granite scarp. Five trenches were dug along this trail in what was originally mapped as till and glaciofluvial sediments (Stea, 2009a). In all five trenches glaciofluvial sediments were encountered, with Trench 1 exceeding 5 meters in thickness. The main sediment facies encountered were:

1 Parallel-laminated medium to coarse sand with graded beds (Trench 1) becoming finer at depth (Trench 1; Figs. 1, 2)

2. Coarse, matrix-supported gravelly sand with boulder-cobble facies. Well rounded granite boulders becoming larger to the west, exceeding one metre in diameter in some cases (Figs. 1-4).

In Trenches 2-5 granite bedrock was encountered at depths between 3 and 5m (Fig. 1). Approximately 20-40% of the cobbles/boulders were thought to be locally derived tonalitic granitoids, but there were also a high percentages of reddish syenite-or syeno-granite (which may also be locally derived) and ~10-20% mafic and felsic volcanic and metasedimentary erratics.

The eastern transect (Trenches 5-10) encountered both glacial till and glaciofluvial sediments. Till areas (Trenches 6, 7, 10) revealed a stony, sandy, matrix-supported diamicton (till) with a bouldery surface layer (Figs. 3, 4). A quasi-layering was observed in the till at Trenches 6 and 7. Granite bedrock was encountered at between 2-4m depth in all these trenches. Till samples were obtained at the till/bedrock interface in all these trenches (Fig. 4). Thick glaciofluvial sediments were seen at Trenches 8 and 9 (Figs 3, 4), with similar facies to the eastern basin with the addition of cross-bedded, coarse sand. Stea (2009a) suggested a subareal deltaic origin for these glaciofluvial sediments, but the lack of identifiable surface landforms (moraines/delta-fans), the presence of fine-grained

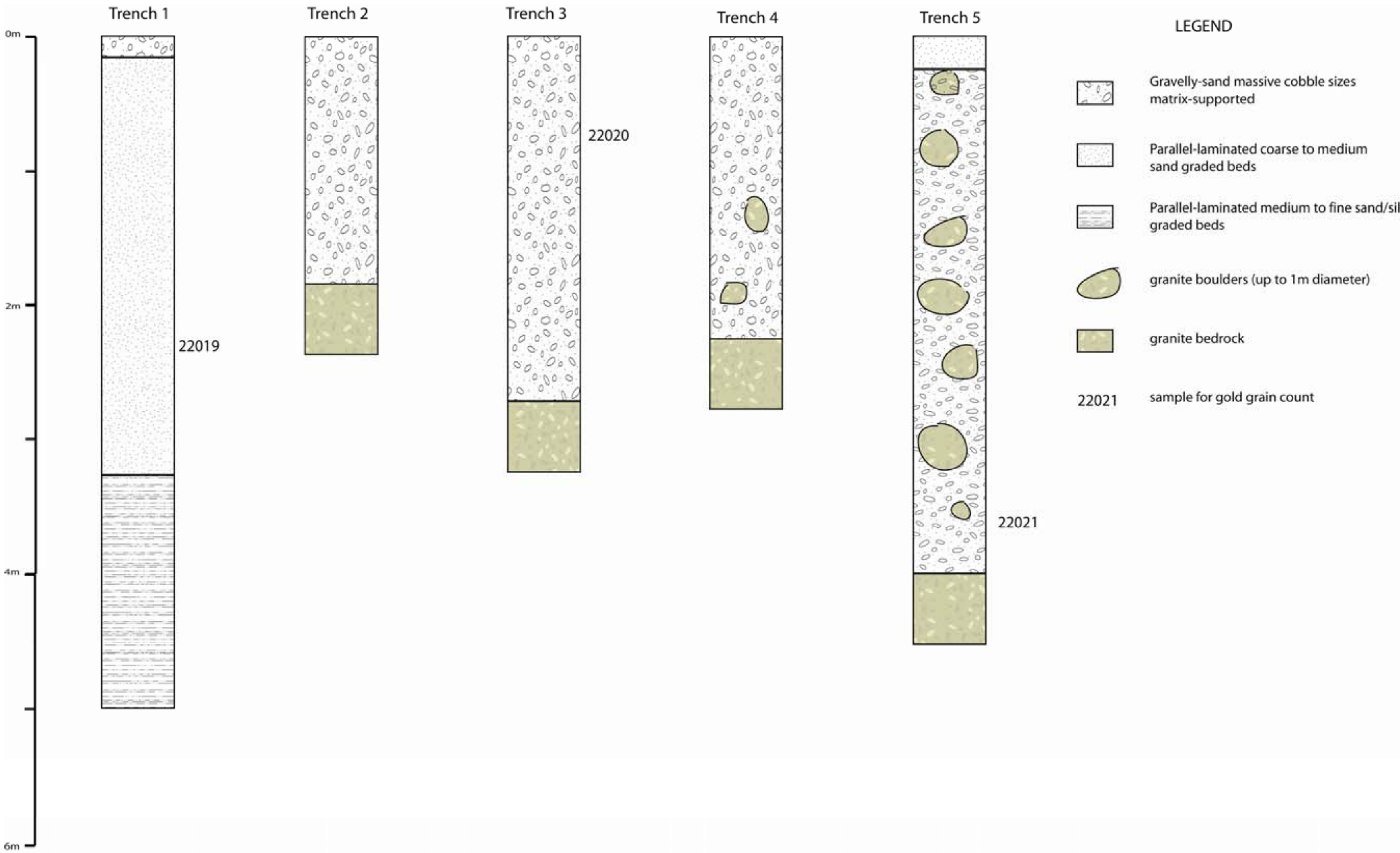


Figure 1. Trench sections along the western portion of the glaciofluvial basin in the Golden Winner property (Map 1-trench locations)

Figure 2. A Trench 1. B. Trench 1 sand facies C. Trench 2 bouldery facies D. Large rounded boulders Trench 5

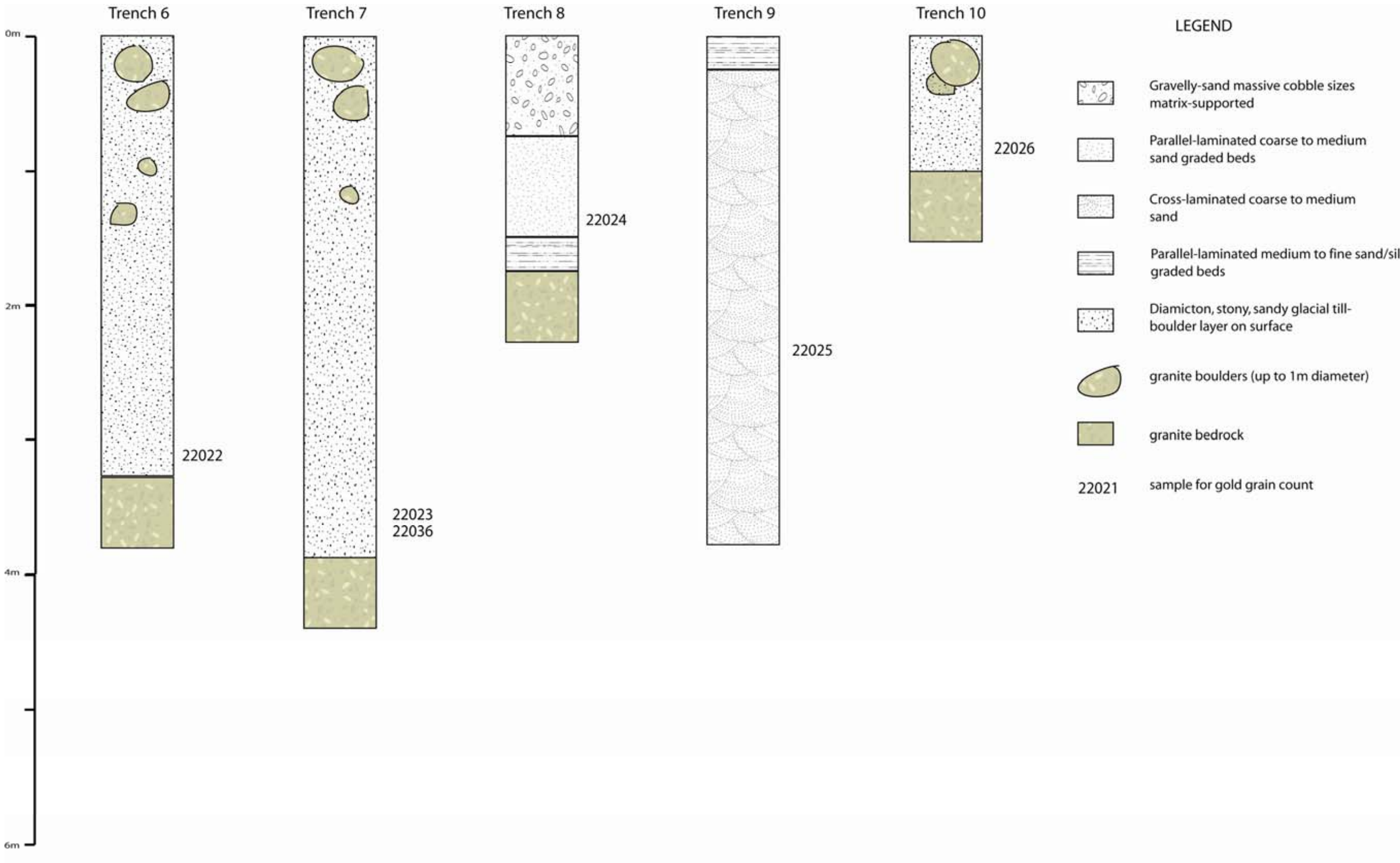


Figure 3. Trench sections along the eastern portion of the glaciofluvial basin in the Golden Winner property (Map 1-trench locations)

Figure 4 A. Bullet boulder in till indicating basal lodgement process Trench 6 B. Trench 8 C. Trench 9 sand D Trench 7 sampling till

sediments (rhythmites), complex sedimentology, and the evidence of deep water lacustrine facies on topographic highs suggests that the glaciofluvial sediments are facies of subaqueous outwash or grounding-line fans (Rust and Romanelli, 1975; Powell and Domack, 1995). These sediments were deposited by subglacial streams at the base of a glacier, into a flanking glacial lake (Glacial Lake Agassiz).

Recommendations

The para-autochthonous nature and thickness of glaciofluvial sediments in the lowland portions of the Golden Winner area make sampling of these sediments as a reconnaissance exploration tool for local gold deposits problematic. Glaciofluvial sediment samples obtained in the western basin trench transect are all down-ice of the Golden Winner prospect so these conclusions are tentative until the gold count results are in. Theoretically, the subglacial streams that deposit subaqueous outwash, are deriving a lot of material from the basal zone of the glacier base which should be locally derived. However, unlike till, which is essentially crushed bedrock, the complex sedimentology of subaqueous outwash renders the possibility of discerning a dispersal fan of gold concentrations from an up-ice ore body less likely. Conventional soil sampling on the surface of these deposits seems an even more problematic venture.

Sampling topographic highs in the area may be a better alternative as locally-derived glacial till is a common sediment found as a discontinuous veneer on these highs. The purpose of a recce survey is to eliminate barren ground, so till sampling is preferred over soil sampling because of the large dispersal fans produced from moderate sized ore bodies (Stea, 2009a). Silty-sand deposits found on some highs may be a masking allochthonous sediment, but till can be found under these sediment veneers in most cases, and digging is relatively easy. Soil sampling can also be considered, but the effect of the lacustrine sand veneer covering some of these highs on soil results is unknown.

The ubiquity of outcrop in both lowland and highland areas of Golden Winner makes prospecting and lithogeochemical sampling an important tool.

In this study and the earlier 2009 sampling survey the author sampled several trenches near and within the Hammond Reef orebody and obtained substantial gold counts in till. It seems like a good opportunity while the trenches are open to re-sample these sites in more detail using both till and conventional soil samples within the same profiles. Differing till fractions can be analyzed to determine if a cheaper analytical method can be used and the geochemical relationships of soil, till and bedrock can be better established.

Some practical sampling recommendations. Existing trails should be cleared to get better ATV access to sites like Golden Winner. Map 1 shows only accessible trails. All others in the Brett resources trail database tested by the author were proven to be non-existent or impassable. In order to gain access for till and rock sampling of more remote muskeg-dominated parts of Golden Winner the company could consider the use of an ARGO eight wheel transport vehicle which can take three or four geologists across bog areas with little difficulty and carry lots of cargo.

References

Powell, R. D., and Domack, E., 1995 Modern glacimarine environments *in Modern glacial environments processes, dynamics and sediments*, Butterworth, p. 445-486

Rust, B. R., and Romanelli, R., 1975, Late Quaternary subaqueous outwash deposits near Ottawa, Canada, *in Glaciofluvial and glaciolacustrine sedimentation* SEPM special publication, 23, p. 177-192.

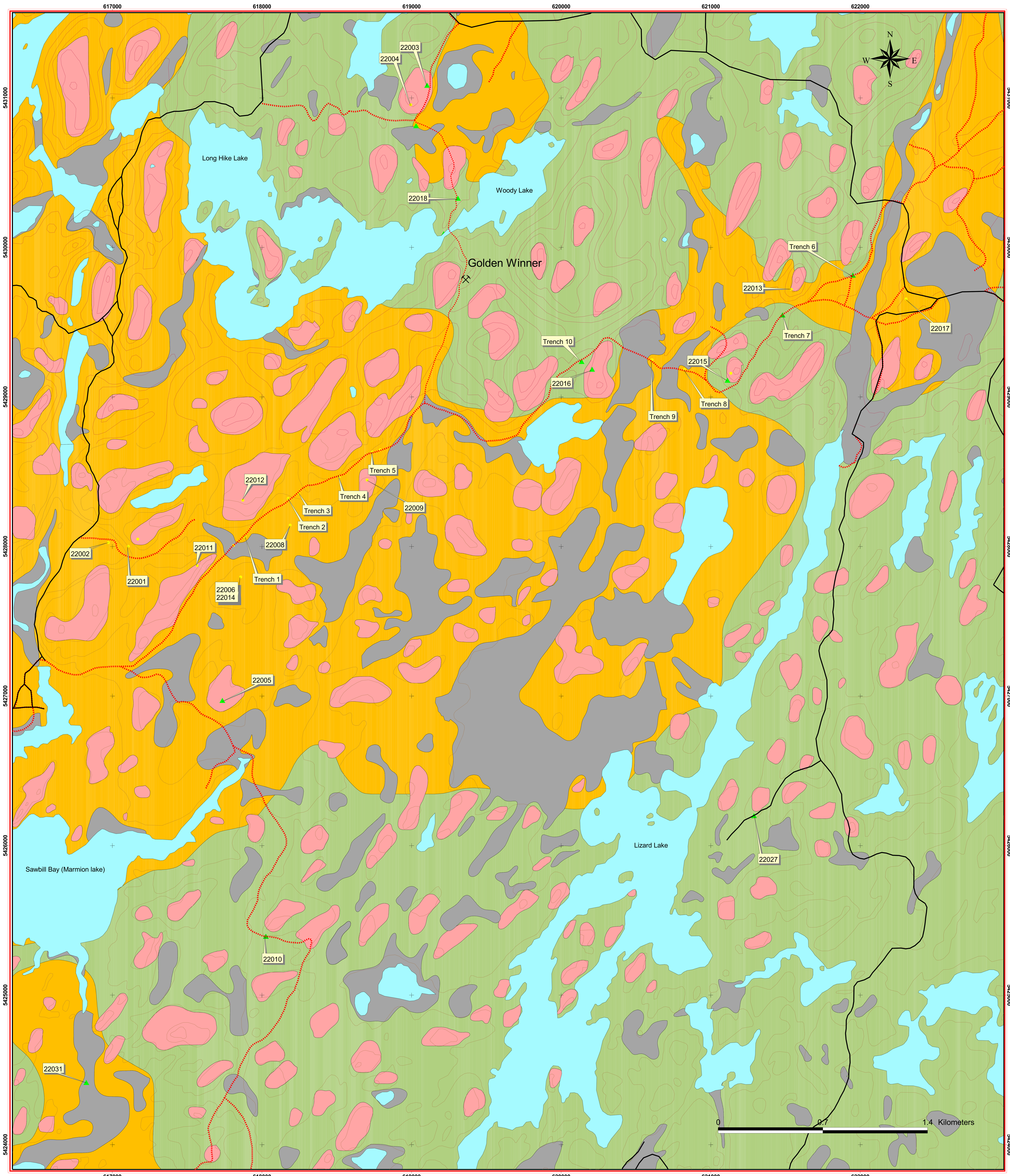
Stea, R. R., 2009a Surficial Geology of the Hammond Reef Property, West-Central Ontario. Internal report Brett ResourcesInc.28p.

Stea, R. R., 2009b Till sampling pilot study on the Hammond Reef Property, West-Central Ontario. Brett Resources Inc (addendum); Internal report Brett resources Inc. 12p.

Appendix 1:

Terrain Unit		Strat unit	Sed description
Tb	Till blanket >10 m thick masking bedrock structure	Unit 1- basal till lodgement-meltout	sDmm sandy diamicton-till matrix support
Tvd	Till veneer discontinuous <2m thick topography controlled by bedrock	Unit 2 - englacial/ablation till	sDmc sandy diamicton-till clast support
GFb	Glaciofluvial- blanket- >20m thick		BGSc -bouldery gravelly sand clast support
GFvd	Glaciofluvial- veneer discontinuous <2m thick		m-f S medium to fine sand
			F/Dmm silt+clay over till
BR	bedrock		

SAMPLE_NUM	STOP_NUMBE	NORTHING	EASTING_	TERRAIN_UN	STRAT_UNIT	SED_DEST	STRIAE	STRI	PHOTOS	COMMENTS
22001	BR-10-1	5427999.90	617106.84	GFvd	GF	S-m-f			2	Fine to medium sand discontinuos vener over granite knobs
	BR-10-2	5428048.16	617168.81	GFvd	GF	G-S			2	Gravelly-sand btween bedrock knobs of granite-
22002	BR-10-3	5428024.53	616972.72	GFvd	GF	ROCK			3	Bedrock exposed in tree throw quartz vein
22003	BR-10-4	5431082.67	619103.81	Tvd	Unit 1	Dmm			2	glacial till with 10cm sand veneer
	BR-10-5	5430812.98	619029.77	Tvd	Unit 1	Dmm			1	glacial till abundant in hollowsma few isolated granite knob
22004	BR-10-6	5430952.65	618994.48	GFvd/Tvd					2	top of rock drumlin veneer of sand/silt over till over bedrock.
22005	BR-10-7	5426969.13	617734.47	Tvd	Unit 1	Dmm			2	till veneer discontinuous top of knob wet hole.
	BR-10-8	5428006.17	617808.77	GFb	GF	G-S			2	gravelly-sand in low area near swamp
22006	BR-10-9	5427794.74	617857.78	GFb	GF	G-S			2	top of hig spot-flat area-poplars
22014	BR-10-9	5427794.74	617857.78	GFb	GF	G-S			2	top of hig spot-flat area-poplars
22007	BR-10-11	5428319.47	618174.94	GFb	GF	G-S			2	borrow pit polymictic gravel >4m thick gr-mafic, metased, gneiss mineralized granite
22008	BR-10-12	5428141.65	618188.25	GFv	GF	G-S			2	top of small knob -outcrop nearby
22009	BR-10-13	5428443.48	618702.33	GFvd	GF	m-fS			2	top of high knob in GF terrain medium to fine sand with 30& silt lacustrine?
	BR-10-14	5428645.04	618789.74	GFb	GF	G-S			2	road cut large rounded boulders Gf
22010	BR-10-15	5425392.41	618025.60	Tb	Unit 2	Dmm			2	road cut till deposit, melt-out till washed layers clay skins
	BR-10-16	5427862.22	617595.52	BR	BR	BR			4	top of high ridge granite outcrop 40m cliff.
22011	BR-10-17	5427871.30	617566.50	GFvd	GF	m-fS			3	top of high ridge granite outcrop area between outcrops silt!!!.
22012	BR-10-18	5428308.48	617871.61	GFvd	GF	m-fS			2	top of knoll silty sand material few cobbles wet hole 2m
22013	BR-10-19	5429718.56	621538.73	GFvd	GF	m-fS			2	top of knoll, bedrock oucrop around, silty-sand well sorted poor B
22015	BR-10-20	5429110.65	621111.14	Tvd	Unit 1	Dmm			2	halfway up slope till exposed in hole well developed B/C transition
	BR-10-21	5429157.39	621134.83	GFvd/Tvd					2	Silty sediment thin overlying till at top of knoll among bedrock outcrop
22016	BR-10-22	5429184.06	620206.02	Tvd	Unit 1	Dmm			3	great transitions from B/C till well developed
22017	BR-10-23	5429654.52	622306.03	GFb		m-fS/F				delta exposure fine grained beds sampled to compare with knoll silt.
	BR-10-24	5430090.49	619214.30	Tvd					3	end of atv acess at Woody lake-
22018	BR-10-25	5430327.85	619309.38	Tvd	Unit 1	Dmm			2	bouldery diamicton near granite outcrop
	BR-10-26	5431235.96	620609.09							no access by atv along trail
	BR-10-27	5432242.86	618704.95							BOAT ACCESS Claw Lake
	BR-10-28	5430917.08	617574.73							BOAT ACCESS Long Hike Lake
	BR-10-29	5428787.05	621913.23							BOAT ACCESS LIZARD LAKE
22019	BR-10-30	5428065.75	617885.27	GFb	GF	m-fS			4	Trench 1 me-f S conformably bedded graded beds-lacustrine 5m+ deep
22020	BR-10-31	5428356.24	618246.32	GFb	GF	G-S			3	Trench 3 3.5 me cobbly gravelly sand lage angular gr bldrs near bedrock 3.5m
	BR-10-32	5428466.18	618516.53	GFb	GF	G-S			2	Trench 4-bouldery gravelly sand -g-s matrix, bedrock 3.5m.
22021	BR-10-33	5428631.04	618735.59	GFb	GF	G-S			4	Trench 5-bouldery (1-2m d) gravely sand overlain by m-fS, bedrock 4m.
22022	BR-10-34	5429813.02	621949.68	Tb	Unit 1	Dmm			3	Trench 6 3.5 m of till overlyinh granite bedrock big glacial bullet boulder
22023	BR-10-35	5429547.10	621479.53	Tb	Unit2?	Dmm			3	Trench 7 Stony sandy consolidated till granite clasts quasi-layered/bedrock 4m
22036	BR-10-35	5429547.10	621479.53	Tb	Unit2?	Dmm			3	Trench 7 Stony sandy consolidated till granite clasts quasi-layered
22024	BR-10-36	5429182.52	620824.54	GFb	GF/GL	BGS/c-mS			3	Trench 8 Bouldery GS overlying medium sand parallel lam, then fine sand/silt/bed 3m
22025	BR-10-37	5429247.27	620608.39	GFb	GF/GL	m-fS/cS-GS			2	Trench 9 Medium-fine sand overlying par lam coarse sand-granules, x-beds, local
22026	BR-10-38	5429235.75	620135.77	Tvd	Unit 1	Dmm			3	Trench 10 Sandy stony till 2m over bedrock local derviation
22027	BR-10-39	5426198.65	621288.30	Tvd	Unit 1	Dmm			2	Old borrow pit, vener os sandy till over granite bedrock
22028	BR-10-40	5422200.28	615060.46	Tvd					3	Hole 20" good B 40cm, Till stony,sandy olive grey
22029	BR-10-41	5422149.98	614631.55	Tvd	Unit 2	Dmm	206		3	trench for bedrock sampling Hammond reef infill hollow
22030	BR-10-42	5422490.33	614039.29	Tvd	Unit 2	Dmm			3	trench for bedrock sampling Hammond reef infill hollow
22031	BR-10-43	5424414.91	616825.21	Tvd	unit 1	Dmm			3	hole 40 inches deep B hor BC/ till



LEGEND

HOLOCENE NONGLACIAL ENVIRONMENT

Terrain Unit and Significance to Mineral Exploration

Organic Terrain:
(deposits of peat laid down in areas of high water table)

Areas where peat and muck are greater than 1m, constituting bogs and muskeg, low-lying floodplains (peat underlain by sand) and lake shore swamps. Significant detriment to exploration due to masking effect of thick organic material and creation of false anomalies by spurious concentration of metals.

PLEISTOCENE GLACIAL ENVIRONMENT

Subaqueous outwash and associated glacio-lacustrine facies:
(deposits of sand and gravel formed at a glacier margin where subglacial meltwater streams empty into glacial lakes).

Sand and gravel deposits are found in broad valleys at the head of Marmion and Finlayson Lakes. Thicknesses vary widely from >10m to less than 1m and bedrock is exposed sporadically. These deposits consist of subaqueously deposited, parallel-laminated, graded beds of coarse/fine sand and coarse open-work gravels interbedded with high energy bouldery, gravel deposits. Deposits are considered detrimental to geochemical prospecting because of far-travelled material diluting a local bedrock signature. Sand deposits are probably more extensive than mapped.

Till Veneer-Discontinuous:
(unsorted deposits of boulders/gravel/mud deposited directly by a glacier;
basal facies formed near base of glacier,
ablation facies from debris higher in the ice)

Bedrock outcrop interspersed with deposits of till, 10-80% outcrop. Topography controlled by bedrock. Till is divisible into two facies: Unit 1- silty-sandy, locally -derived basal facies; Unit 2: Bouldery sandy ablation facies with high erratic content. Terrain is suitable for prospecting and geochemical/geophysical surveys as local bedrock is either at surface or within 1m, buried by a locally-derived till. Soil may be too thin for sampling. Occasional deposits of thick ablation till may mask local bedrock.

Bedrock with sediment veneer:
(bedrock scoured by ice and meltwater action, remnants of till and glaciolacustine silt in hollows between bedrock knobs.

Bedrock outcrop or moss/boulder covered outcrop, with a thin, discontinuous cover of till and glaciolacustrine sediment . A period of intense meltwater flow may be indicated and may account for the lack of sediment cover. Terrain suitable for prospecting because bedrock is ubiquitous. Soils may be thin or absent.

Symbols

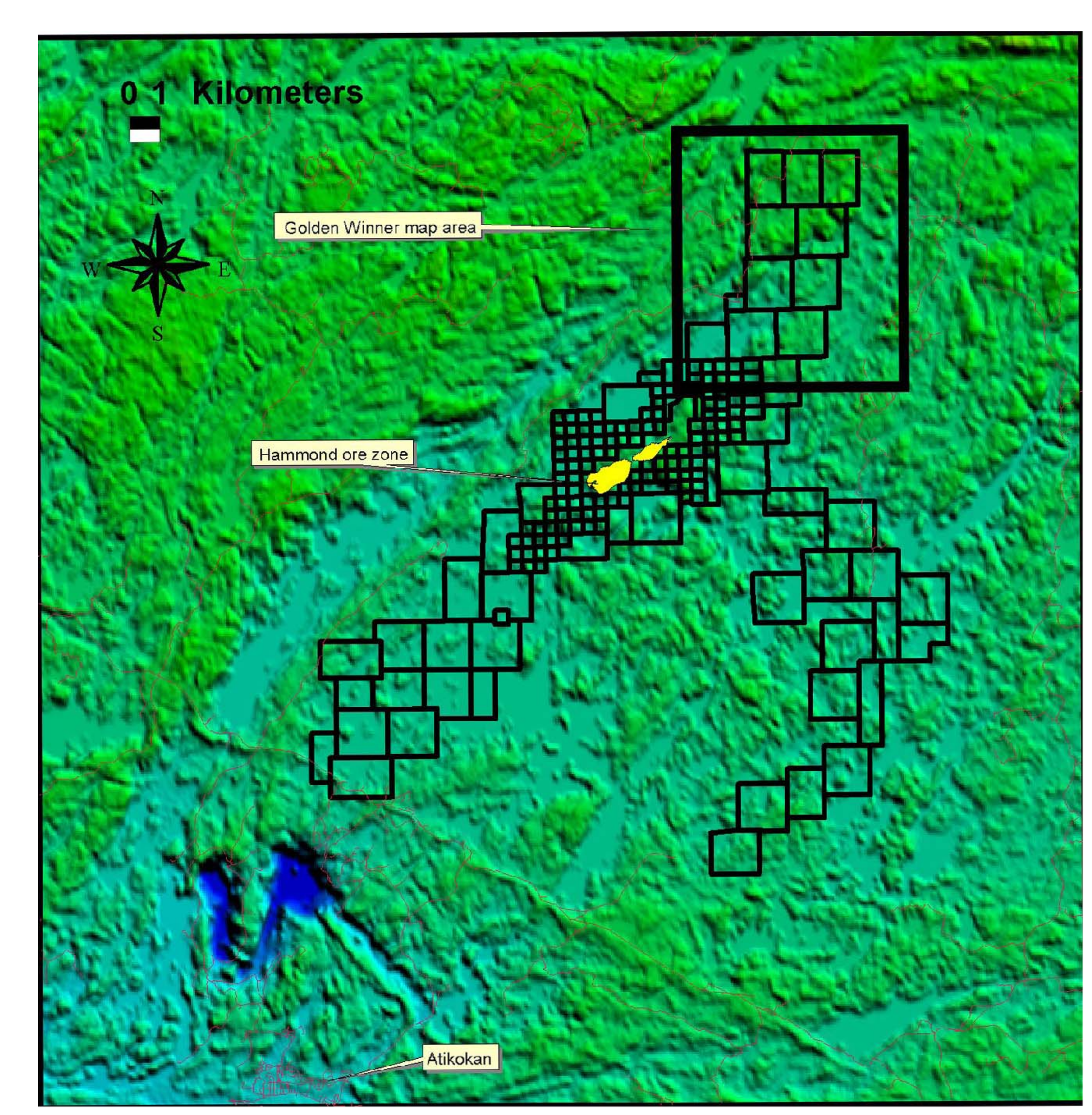
Trails accessible by ATV

Truck accesible roads

Trench 2 — Trench site- 2010 survey glaciofluvial sediments -sample number on accomapnying figure

22019 — Sample site- glacial till sample number

Golden Winner prospect (gold)



Stea Surficial Geology Services

Surficial Geology of the Golden Winner prospect area, Hammond Reef Property (Brett Resources Inc.)

Universal Transverse Mercator
North American Datum 1983

Scale 1:10,000

IR1

Ref #	Summary of Comment	Information Request	CMC Response
T-39	An essential component of all numerical hydrogeological models is a sensitivity analysis. Such an assessment of the proponent's water balance model is absent, but presumably could be conducted in order to assess the sensitivity of the water balance model to variations in input parameters. All models, including the one utilized by the proponent are subject to error. The proponent states in the response to NRCan-8 that "In the water balance model all runoff and seepage is captured and the mass is therefore included in the final discharge water quality…", indicating that in order for model results to be valid, all seepage must be collected. In order to collect all seepage, the proponent will need to quantify seepage beneath the TMF and determine the proportion of seepage below the TMF versus through dams. This information will be needed in order to develop an appropriate seepage collection system at the detailed design phase. For example, if a significant amount of seepage occurs beneath the TMF, then the proponent will need to take measures to reduce seepage beneath the TMF (e.g. liner) and/or collect seepage via pumping wells that intercept this flow.	Provide an evaluation of the accuracy of the water balance model used to evaluate potential for near surface versus groundwater water quality influence, including a sensitivity analysis of the model to varied input parameters. Provide clarification on the seepage collection system. Specifically, will pumping wells be utilized to collect seepage from underneath the TMF? If not, please provide justification for this decision. Estimate seepage losses from the TMF, WRMF, PPCP and overburden storage using the groundwater model. Assess the effectiveness of the proposed seepage control measures, and assess the potential impact of seepage discharge to receptors.	In response to comments received on the Final EIS/EA Report, Canadian Malartic Corporation hosted a water quality workshop on April 28, 2014 with the Government Review Team. We also initiated communications with the Regional Groundwater Group Leader for MOE's Northern Region who stated on May 15, 2014 that upon further clarification he is "satisfied at this time with the estimates of seepage to Lizard Lake." Measures to limit, prevent and collect seepage from the TMF, WRMA, ore, low-grade ore, and overburden stockpiles have been developed at the conceptual level only at this time and consist of a series of collection ditches, and pumping stations. There are many proven ways to intercept seepage from a given site. During the detailed design stage for the Project additional drilling will be undertaken along the dam alignments, ditch alignments and near the edges of proposed stockpiles, and at that time it will be appropriate to further specify the details of the seepage collection system design. Considerations during detailed design will include bedrock and depth of overburden conditions, and use of pumping; however it is not possible for Canadian Malartic Corporation to fully define these measures at a detailed design level without appropriate funding and Project EIS/EA approval.
	In the proponent's response to MOE's comment, it is noted that 10% of the seepage reporting to the collection system along the east side of the TMF would likely report to Lizard Lake (a total of 227 m3/day of seepage). However it is not clear what impact this would have on Lizard Lake. This information will be necessary to have a clear understanding of what the effects of seepage will be on water quality in the receiving environment, as well as inform the design of mitigation to intercept seepage, and any monitoring networks.	Provide a determination of seepage below the TMF versus seepage through dams. Identify contingency plans and mitigation measures if seepage beneath the TMF is greater than initially predicted. Provide a more detailed assessment of the impacts to Lizard Lake, which should be based on a more suitable and defensible estimate of seepage from the TMF to Lizard Lake.	As all incident water is accounted for in the receiving waters, it is immaterial whether the water flows through the dams or beneath the TMF. Further detail regarding the conservativeness of the water quality modelling approach is in the memorandum entitled 'Water Quality Background Information', provided as Attachment 4 of the Final EIS/EA Report Addendum. The water quality of seepage has been predicted and assessed in the Final EIS/EA Report. All infiltration from Project facilities was assigned a water quality (as identified and discussed in the responses to information requests from the Draft EIS/EA Report) and direct discharge of this water from the facilities was evaluated. Infiltration water is expected to be compliant with applicable MMER and O. Reg 560/94 criteria. In addition, concentrations for each potential point source were considered (as part of IR-MOE-NR-GW-16 in Appendix 1.IV of the Final EIS/EA Report) and it was found that direct discharge of these concentrations into a water body would not result in adverse aquatic impacts. The water quality assessment considered sensitivity in relation to flows and water quality as provided in both the Site Water Quality TSD (Section 4.3) and the Lake Water Quality TSD (Section 4.2 and 4.3.2). The sensitivity analysis considered a range of flow conditions ranging from 100-year dry to 100-year wet and "average" case and "upper bound" water quality scenarios (using 75th percentile values for chemistry inputs). It is considered that the sensitivity model runs as provided are appropriate since they are based on measured and modelled data developed following standard procedures such as those provided in MEND 2009 and GARD, 2012.
			At the request of the Government Review Team, additional 3D groundwater modelling efforts were undertaken for the eastern portion of the TMF. The preliminary 3D groundwater model was constructed using available information and, through this evaluation, it was shown that capture of greater than 90% of seepage could be achieved by the proposed control system given the current TMF design configuration and the current understanding of the tailing properties and geologic conditions of the site. Further details of this modelling evaluation are provided in the memorandum entitled 'Tailings Management Facility, 3D Groundwater Modelling' provided as Attachment 3 of the Final EIS/EA Report Addendum. In light of the results of the newly undertaken groundwater modelling, it is considered that the assumed seepage capture efficiency is realistically achievable based on the conceptual design. During the detailed design stage additional information collected will be used to develop a more robust modelling evaluation to refine and optimize the design of the seepage collection system. It is the intent of Canadian Malartic Corporation to work with the design engineers and the applicable regulatory agencies to ensure that future data collection and the development of predictive models will meet both the requirements of engineering design and needs of the agencies with respect to permitting requirements.

IR2

Ref #	Summary of Comment	Information Request	CMC Response
T(2)-17	In the review of the draft EIS, it was noted in the Hydrogeology Technical Supporting Document (TSD), dated February 2013 that a trough of granular material was encountered to depths of approximately 25m at the southwest section of the tailings management facility (TMF). Groundwater elevations at the monitoring well (BRH-0020) are about 2 metres above those of the Upper Marmion Reservoir. This suggests that overburden groundwater in this area readily discharges to Upper Marmion Reservoir through a permeable pathway in granular materials. The proponent plans to collect seepage from the TMF along the downstream toe of the TMF dams but did not consider seepage from the base of the TMF. Thus, it was requested that the proponent provide an evaluation of the potential seepage to groundwater underneath the TMF and assessment of the potential effect the seepage could have on groundwater quality and the resultant surface water quality in Lizard Lake and Upper Marmion Reservoir. In response the proponent used a water balance approach and noted that it contains less uncertainty than a hydrogeological modelling approach. The proponent also stated that In the water balance model all runoff and seepage is captured and the mass is therefore included in the final discharge water quality, indicating that in order for model results to be valid, all seepage must be collected. However, federal reviewers noted that the model results do not take into account the seepage losses from the base of the TMF or through dams. Thus, in the first information request dated March 25, 2014, comment T-39 indicated that in order to collect all seepage, the proponent would need to quantify seepage losses from the base of the TMF, using a groundwater model and determine the proportion of seepage below the TMF versus through dams. Comment T-39 also included the request to assess the effectiveness of the proposed seepage control measures and assess the potential impact of seepage discharge to receptors. In response, the proponent conducted numerical groundwater modelling on a portion of the TMF. The proponent's model assumes that there is a presence of clay lenses within the overburden material that would tend to impede vertical flow. However, federal reviewers noted that Figure 2-5 of the Hydrogeology TSD shows the overburden as primarily comprised of silts and sand, and much of the footprint of the TMF is classified as "Outwash Deltas/Channels" and "Organic Terrain". The clay layers that do exist in some boreholes do not show lateral continuity. It also appears that the 3D groundwater modelling conducted does not adequately characterize the site because it only covers a portion of the TMF and is based on very limited data. This approach does not provide an understanding of the permeability of the overburden underneath the TMF nor does it provide an understanding of groundwater seepage flow paths from the TMF into adjacent waterbodies such as Lizard Lake and Upper Marmion Reservoir. It is not clear what the magnitude and geographic extent (direction and distance) of the effects from seepage losses from the base of the TMF are on surface water quality and fish and fish habitat in Lizard Lake and in Upper Marmion Reservoir. The entire TMF needs to be modelled with sufficient monitoring well data and the use of particle tracking in order to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. The 3D groundwater modeling must be re-run and the sensitivity analysis and model results provided. Based on the review of the Technical Memorandum on the 3D groundwater Modelling (dated May 21, 2014), the following deficiencies were noted: • The model is not calibrated properly nor was a detailed conceptual model presented. The conceptual model provides a visual depiction of the existing groundwater system including stratigraphic layers (shown in cross sections or block diagrams) and information on groundwater flow directions. • The hydraulic conductivity for the overburden is poorly characterized and based on limited single-well response tests and estimates based on grain-size distribution. Hydraulic conductivity is an important model parameter that can significantly affect model outcomes. • The assumption Khorizontal:Kvertical = 1:0.1 is not supported by the borehole data. The borehole logs do not show thick sequences of clay that are continuous across the TMF site. • The proponent's response to previous comments about seepage effects on Lizard Lake have focused on the operating phase of the mine, or the immediate post-operating phase when human intervention is still available to manage seepage. Seepage loss during post-closure phase could be a concern if permeability of units underneath TMF is higher than modeled, even with revegetation. The proponent needs to adequately model the post-closure (abandonment) phase to assess the long-term effects of seepage losses to Lizard Lake and the Upper Marmion Reservoir. The proponent indicates that there "are many additional options to intercept seepage" but does not identify other possible mitigation measures. The proponent indicated that the current plan for the seepage collection systems is in the conceptual stage only and that ditching and pumping stations will be utilized. However, no further details are provided. It is important to provide details on the seepage collection systems, taking into consideration the results of the 3D groundwater model for the entire TMF, in order to assess not only the effectiveness and suitability of the proposed mitigation measures, but also the comparative suitability of the proposed site itself. Furthermore, it is important to have information on the framework of the follow-up program to monitor seepage and to identify the response actions that would be undertaken in the event that a malfunction were to occur or in the event seepage beneath the TMF is greater than predicted. This information will assist the Agency in assessing the adverse environmental effects of seepage losses from the TMF, the magnitude and geographic extent (direction and distance) of any seepage that may pass underneath the TMF to Lizard Lake and Upper Marmion Reservoir and the effectiveness of the proposed mitigation measures. This information is required in order for the Agency to provide a recommendation to the federal Minister of Environment on whether the project is likely to cause significant adverse environmental effects.	1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint. 2. If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7. 3. Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional monitoring wells in discussion with relevant government agencies to ensure baseline information is gathered in regions where more granular material is found within the proposed TMF footprint. 4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model. 5. Re-run the 3D model based on the following: a) perform more robust calibration using additional monitoring well data; b) present a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions; c) model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment); d) as described in 2., include the information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and if the assumption Khorizontal:Kvertical = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the Khorizontal:Kvertical relationship; and e) provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity. 6. Provide the methodology, analysis and model results. 7. Based on the results from question 1-6 above, provide a detailed description of the mitigation measures proposed to intercept seepage and contingency plans in the event seepage beneath the TMF would be greater than predicted.	To complete the requested undertaking would require a level of effort commensurate with the detailed feasibility and design phases of a project. The EIS/EA must adequately address potential for impact to the environment at a level that allows for appropriate decision making with respect to the potential for impacts of a given project. The current assessment is suitable and appropriate to make these decisions for the following reasons as documented in the TSD and subsequent IR Responses as provided in the Final EIS/EA Report Addendum (June 2015): 1. All water and chemical mass load placed on the TMF is accounted for in the discharge, and is used in analysis of basin impact, with no resulting aquatic effects (see TSDs as identified and IR T-34, T-39 and IR MOE-NR-GW-16 from the first round of IRS) a. To state this differently, we assign water the same concentration, based on the chemistry of the tailings, weather it leaves as surface water or groundwater, and both of these waters report to Marmion Basin in our assessment – if we increase groundwater discharge, then there will be more infiltration, and less surface runoff so the total amount of water, and mass load, will be the same – regardless of the outcome of any groundwater modelling. 2. Even at full predicted concentrations of the tailings water (i.e. groundwater reporting directly to surface water in the basin) there are no resulting aquatic impacts (IR MOE-NR-GW-16 from the first round of IRS) Therefore it follows that 3. As a result of points 1, and 2, above it is inconsequential weather the water (or chemical mass) reports via a surface water pathway or groundwater pathway, it is all accounted for, and at full concentrations (and full mass loads) does not cause aquatic impacts, either as a point source, or overall mass load to the basin. Based on the above CMC submits that: - there is ample evidence and analyses completed to reasonably conclude there will be no impact to human health, terrestrial life, or aquatic life, regardless of the outcome of any proposed groundwater modelling conducted, - as a result CMC further submits that the current groundwater analyses and model is sufficient to reasonably make decisions regarding potential project impacts at the Hammond reef property. CMC did conduct some supplemental modelling in response to regulator concerns (see IR T-40 located in Appendix 1.IV of the Final EIS/EA Report) , it was directed at responding to questions related to the North and West sides of the TMF, and demonstrating that seepage capture was feasible under typical conditions, as was requested by the reviewers. The intent was not to model the entire basin at the level of detail design. CMC acknowledges that understanding the groundwater will be important during construction and operation of the facility, such that appropriate seepage reduction or collection measures can be incorporated into the final design. CMC is willing to commit to the following course of action (as a condition of approval of the EIS/EA), but only as part of the detailed design engineering work to be completed prior to construction: - collection of the requested additional drilling data in Item 1 of the request during the detailed design phase of the project through installation of 3 to 5 monitoring wells within the central area of the impoundment. - Collection of additional data through drilling, including depth to bedrock, and sediment profiles along all proposed dam alignments. - Re-evaluation of all potential seepage pathways for each proposed dam of the facility, including 2D seepage models (or a 3D model if needed depending on the results of drilling in the center of the impoundment), in order to produce: o Phreatic surface detail and seepage rates for dam stability analysis o Detailed design drawings for each dam o Construction specifications and material specifications for the dam proper o Construction specifications for seepage interception and collection, including depths of ditches, pumping requirements, and interception well requirements as needed to achieve the seepage design objectives. o This will satisfy the overall request, and in particular Item 7 of the above request To be clear CMC believes that seepage capture objectives as stated in the EIS/EA document are effectively achievable through engineering controls that will be put in place for the project, additional data will be collected and modelling will be completed during the detailed design phase, and CMC is willing to accept these requirements as conditions of EIS/EA approval, however given the cost of the proposed course of action in the request it is not realistic or feasible for CMC to undertake this at this time.

IR3

Ref #	Summary of Comment	Information Request	CMC Response
T(3)-08	The T(2)-17 response does not provide information to assess the potential adverse effects of seepage from the tailings management facility (TMF) on particular receiving water bodies that are frequented by fish, including but necessarily limited to Lizard Lake and Sawbill Bay. Instead CMC's response outlines a perspective on the potential impacts of seepage to aquatic life in the Marmion basin. By focusing on the entire basin, rather than individual water bodies within the basin, the approach fails to predict whether seepage may affect any particular water body. According to subsection 10.2.3.1 of the EIS Guidelines, the EIS shall … provide results of the hydrogeological assessment that determines: groundwater seepage location, rates, seepage quality, and direction into or from the open pits, mine rock stockpiles and other stockpiles, TIA facilities, primary sedimentation pond and process water pond, and from the pits during future overflow. Clarity on seepage is required to understand the flow regime, including whether the seepage flow through the base of the TMF and/or through the TMF dam potentially will enter any receiving water body frequented by fish. Also, Subsection 13.1.2 of the EIS Guidelines requires the EIS to include a description of the follow-up program to evaluate the predictions of effects and the effectiveness of the proposed mitigation. T(2)-17 is re-submitted, with minor changes in items 1 and 3, to request the information needed by the Agency to assess the adverse environmental effects of seepage losses from the TMF, the magnitude and geographic extent (direction and distance), of any seepage that may discharge into any receiving water body frequented by fish, and the effectiveness of the proposed mitigation measures. Discussion on the potential adverse effects and their significance linked to the findings should also be provided. This information is required in order for the Agency to provide a recommendation to the federal Minister of Environment and Climate Change on whether the Project is likely to cause significant adverse environmental effects.	*The response to T(2)-17 of Information Request #2 does not meet the expectations of the Agency and federal reviewers. Therefore, we are repeating the request and have synthesized it to provide additional clarity.* 1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint. 2. If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7. 3. Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint. 4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model. 5. Re-run the 3D model based on the following: a) perform a more robust calibration using additional monitoring well data; b) presenting a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions; c) model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment); d) as described in 2., include information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and to determine if the assumption Khorizontal:Kvertical = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the Khorizontal:Kvertical relationship; and e) provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity. 6. Provide the methodology, analysis and model results. 7. Based on the results from question 1-6 above, provide a detailed description of the mitigation measures proposed to intercept seepage and contingency plans in the event seepage beneath the TMF would be greater than predicted. 8. Describe the residual effects on water quality; the significance of those residual effects based on the Agency's methodology for assessing significance (including the criteria of magnitude, geographic extent, duration, frequency, reversibility, ecological/social/cultural context); and the follow-up program, including any monitoring measures, which will be implemented to evaluate the predictions of effects and the effectiveness of the proposed mitigation.	

TECHNICAL MEMORANDUM

DATE December 12, 2017 **PROJECT No.** 1408383 3500 3501

TO Sandra Pouliot
Canadian Malartic Corporation **DOC No.** 011 (Rev 0)

FROM Adam Auckland and Devin Hannan **EMAIL** adam_auckland@golder.com

HAMMOND REEF GOLD PROJECT – TAILINGS MANAGEMENT FACILITY, ADDITIONAL STRATIGRAPHIC INFORMATION AND PROPOSED 3D GROUNDWATER MODELLING

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has prepared this draft Technical Memorandum (memorandum) for Canadian Malartic Corporation (CMC) as clarification for the Government Review Team (GRT) regarding questions brought forward relating to the need for additional field data collection, assessing the assumption of isotropy / anisotropy and additional numerical groundwater modelling of the proposed tailings management facility (TMF) at the Hammond Reef Gold Project (the Project). This is a supplementary memorandum to the Hammond Reef Gold Project – Tailings Management Facility, Additional 3D Groundwater modelling memorandum, dated March 1, 2016. The review comments by the GRT on the aforementioned memorandum were provided to CMC in a letter dated May 6, 2016 titled "Federal Review of the Draft Technical Memorandum on the Additional 3D Groundwater Modelling for the Hammond Reef Gold Project Federal Environmental Assessment".

Key items that were identified by the GRT included: 1) additional information on stratigraphy; 2) additional hydraulic conductivity data; 3) assessment of anisotropy; 4) completion of modelling for closure and post closure phases; and, 5) inclusion of the conceptual seepage collection system in the model. These items were discussed in a conference call between CMC, the GRT and Golder on May 18, 2016. During this call, the GRT requested that items clarified on the call also be provided in a memo in order to have the opportunity to review the additional information provided.

Baseline Hydrogeological Conditions

A review of the current hydrogeological conditions in the vicinity of the Tailings Management Facility (TMF) was provided in order to explain our rational for the locations of existing boreholes / monitoring wells and why we consider that there is sufficient subsurface information to complete the proposed hydrogeological model as described in the aforementioned March 1, 2016 memorandum. The following is a summary of the baseline conditions and existing information.

Stratigraphy

In total, there are 22 single and nested borehole locations with detailed stratigraphic information and an additional 64 condemnation drillholes for which overburden thickness is available. The locations of these boreholes and drillholes are shown in Figure 1. We wish to note that, in our opinion, the dataset as illustrated in Figure 1 provides excellent coverage within and around the boundaries of the propose TMF and is in our view sufficient to adequately characterize overburden thickness in the area.

Local relief in the Marmion Lake area is commonly less than 45 m but may exceed 60 m in some areas (Mollard and Mollard 1980). Over the project area, overburden is generally thin and discontinuous. The proposed TMF is located in a low lying area, bounded to the north, northwest and northeast by a generally continuous topographic high, with elevations on the order of 470 to 480 metres above mean sea level (m amsl) compared to elevations of approximately 420 m amsl in the low lying areas of the centre of the proposed TMF. The southwest, south and east of the proposed TMF are characterized by troughs or valleys between extensive bedrock outcrops (Figure 1). As such, borehole drilling and monitoring well installations in the area were primarily focused in the valleys between bedrock outcrops along the perimeter of the TMF as these would be considered the key potential seepage pathways. In order to illustrate this topography and constraints on groundwater flow, topographic cross-sections were produced around the perimeter of the proposed TMF and are presented in Figures 2A through 2E.

As can be observed in these cross-sections, overburden aquifers are generally of limited lateral extent due to significant bedrock outcropping. Bedrock, which is situated at or near the ground surface over much of the project area, controls the topography and therefore the surface drainage conditions (Mollard and Mollard 1980). In general, the overburden, overlying bedrock, ranges from not present to greater than 30 m in thickness in the area of the TMF. The stratigraphy encountered by boreholes in the area of the TMF is detailed in Table 1 below (data from condemnation holes is not listed as the bulk overburden logged was not separated into sub-units). Note that not all of the layers were present in all boreholes. Boreholes were either advanced into the bedrock (19 of 21 holes) or terminated upon refusal on probable bedrock (3 of 21 holes). It is possible that the maximum thickness of the overburden is greater than recorded in the boreholes that were terminated upon refusal.

Table 1: General Stratigraphy at the TMF

Borehole Location	Peat/ Organics Thickness (m)	Silt and Sand Thickness (m)	Silty clay to clayey silt Thickness (m)	Till (Sand and Gravel/ Boulders, Sand, Clay) Thickness (m)	Overburden/ Bedrock contact Depth (m)
BRH-0016	-	1.1	-	0.4	1.5
BRH-0017	-	2.3	-	0.8	3.1
BRH-0018	-	1.8	-	-	1.8
BRH-0019	0.3	1.2	6.1	0.8	8.4
BRH-0020	0.2	0.6	14	10.8	25.6
BRH-0021	0.6	0.6	1.4	0.4	3.0
BRH-0022	-	-	-	0.1	0.1
BRH-0023	0.5	1.0	-	2.1	3.6
BRH-0024	-	-	-	1.0	1.0
BRH-0025	1.2	0.3	-	0.2	1.7
RH-0026	0.2	1.0	-	0.3	1.5
BRH-0027	0.6	1.1	-	0.7	2.4
BH12-1	0.1	0.81		0.3	1.2
BH12-2		2.9	5.7	6.53	15.14
BH12-3	1.37	2.9	4.57	4.57	13.41

Borehole Location	Peat/ Organics Thickness (m)	Silt and Sand Thickness (m)	Silty clay to clayey silt Thickness (m)	Till (Sand and Gravel/ Boulders, Sand, Clay) Thickness (m)	Overburden/ Bedrock contact Depth (m)
BH12-4	2.13		3.05	1.83	7.01
BH12-5	1.65	3.91		2.19	7.75
BH13-1	2.74	1.53	0.91	1.83	7.01
BH13-2	0.61	3.96		0.92	5.49
BH13-3	2.59		6.25	4.42	13.26*
BH13-4		1.52	4.58	13.1	17.68*
BH13-5	1.68		2.74	7.47	10.21*

Notes: * indicates borehole terminated upon auger refusal.

Stratigraphy across the TMF, based upon the above noted boreholes, is generally consistent, with peat at surface underlain by silt and sand. A silty clay / clayey silt layer is observed in approximately half of the boreholes. It is consistently observed in all of the boreholes located along the south and east of the TMF, and seems to be correlated to areas of thicker overburden deposits. The silty clay / clayey silt layer is generally not observed in boreholes with less than 5 metres total overburden and generally present in boreholes with more than 5 metres of overburden. This can be accounted for in the model, such that the silty clay / clayey silt unit would not be considered in the areas of shallow overburden. The silty clay / clayey silt unit is underlain by a sandy, gravelly till. Overall the thickness of these units are relative to the overall thickness of the overburden.

The combination of detailed stratigraphic information from the 22 boreholes and the laterally extensive information on overburden thickness from the condemnation drillholes provides sufficient information to characterize the hydrostratigraphic setting in the area of the TMF in order to develop the proposed groundwater model. Key areas for assessing potential seepage pathways will be the bedrock valleys along the perimeter of the TMF footprint, as most seepage from the base of the TMF in the overburden would be expected to report laterally through the overburden in these valleys. These are the areas where most of the available hydrogeological / geotechnical boreholes have been completed.

Hydraulic Conductivity

The hydraulic conductivity of the subsurface materials were estimated by conducting rising head tests and analysis of grain size. Within the TMF footprint, a total of 11 overburden and 6 bedrock hydraulic conductivities were obtained through either rising head tests or grain size (Hazen) method. In addition to hydraulic conductivities measured in the immediate vicinity of the TMF, an additional 20 bedrock and 19 overburden measurements were obtained from locations around the proposed Open Pit, Mine Rock Area and alternative TMF areas. Based on a review of the borehole logs, the stratigraphic units logged at these locations are similar to those encountered at the TMF and would supplement the data available for the TMF groundwater model.

Recognizing the concern brought forward by the GRT of providing additional hydraulic conductivity information, it is proposed that rising / falling head tests be completed at the monitoring wells that have been installed in 2012. These include 3 bedrock monitoring wells and 4 overburden monitoring wells at the TMF as well as 6 additional overburden monitoring wells located to the west and south of the TMF with well screens considered to be in units representative of the stratigraphy at the TMF. With these additional locations, a total of 29 bedrock and 36 overburden hydraulic conductivity measurements will be available to be used in the development of the groundwater model.

Anisotropy

Although Vertical Hydraulic Conductivity (Kv) is considered an important hydraulic characteristic, it is rarely measured in the field, generally for lack of practical field tests. Laboratory analyses for Kv are generally based on permeameter measurements but these are often difficult when applied to cores from heterogeneous and especially unconsolidated formations because these measurements are generally small scale and representative of the disturbed sample (Kabala, 1993). Although some studies have been completed that suggest options for measurement of Kv in the field, in practice, Kv/Kh is often based on the review of stratigraphic logs and assessment of the presence or absence of horizontally bedded formations. It can then be further assessed through sensitivity analyses within a groundwater model. In reviewing borehole logs at the TMF, and the project site in general, and as summarized in Table 1 above, a Silt and Sand or Silty Sand unit is observed in almost every borehole. In general, wherever overburden deposits tend to be thicker than approximately 10 m, a Clayey Silt / Silty Clay is also observed. The presence of these units would indicate that the ratio of Kv / Kh in the bulk overburden aquifer would be less than 1 and that the originally proposed anisotropy ratio of 0.1 is within the generally accepted range. Freeze and Cheery (1979) summarize a study completed by Jonson and Morris (1962) in which vertical and horizontal conductivities of 61 laboratory samples of fluvial and lacustrine sediments were assessed. From this study, it was determined that horizontal conductivities were between 2 to 10 times larger than the vertical values, which would consist of Kv/Kh of between 0.5 and 0.1.

Nonetheless, in order to address concerns raised by the GRT, it is proposed that the anisotropy be evaluated as a sensitivity analysis in the groundwater model. Two anisotropy ratios will be assessed, and calibrations performed on both a ratio of Kv/Kh of 0.1 and 1.0; the latter implying conservative isotropic conditions.

Operational Seepage collection

Conceptual seepage collection measures, which consist of a perimeter seepage collection system of ditches and pump stations is proposed downstream of the TMF containment dams to collect and pump seepage back into the TMF, have been proposed to date. It should be recognized however that the detailed design of the seepage collection measures has not completed and is not available for the proposed groundwater model. Reasonable assumptions will be made with respect to the location and depth of these ditches and a summary of these assumptions will be provided. A review will be completed to confirm viability of seepage collection using reasonable and proven methods, based on the observed borehole conditions, stratigraphy, modelled flow and literature data following the model runs. Once the Project progresses to the permitting phase, detailed designs will be completed of the collection system and the groundwater model can be updated at that time if deemed necessary.

As is typical for operating tailings facilities, monitoring wells will be installed along the perimeter of the TMF, in low lying areas along which key seepage pathways would be expected, and monitoring will be completed throughout the life of the Project and into closure. This monitoring would be used to confirm if the seepage control measures are operating as anticipated. As part of the report that will be prepared to accompany the groundwater model, high level monitoring plans for the TMF will be proposed and possible contingency measures, beyond the seepage collection system described above, will be proposed.

Closure and Post-closure modelling

As requested by the GRT, the groundwater modelling will also be completed for the closure and post-closure phases of the project.

CLOSURE

We trust that this memorandum serves as sufficient foundation for further discussions on refining a path forward to fully satisfy the requirements of the Government Review Team. Please contact the undersigned if you have any questions.

Prepared by:

<Original signed by>

Adam Auckland, M.Sc., P.Eng.
Project Manager, Water Resources Engineer

Reviewed by:

<Original signed by>

Devin Hannan, P.Eng.
Associate, Enviromental Engineer

KB/DH/AA/sk

Attachments:

Figure 1 – Topographic Cross-Section Locations

Figures 2A – 2E – Topographic Cross-Sections A through E

REFERENCES

Golder, 2014. *Technical Memorandum: Osisko Hammond Reef Gold Project – Tailings Management Facility, 3D Groundwater Modelling.* 13-1118-0010 (5008). May 27, 2014.

Freeze R.A. and Cheery J.A. 1979. *Groundwater.* Prentice Hall. New Jersey.

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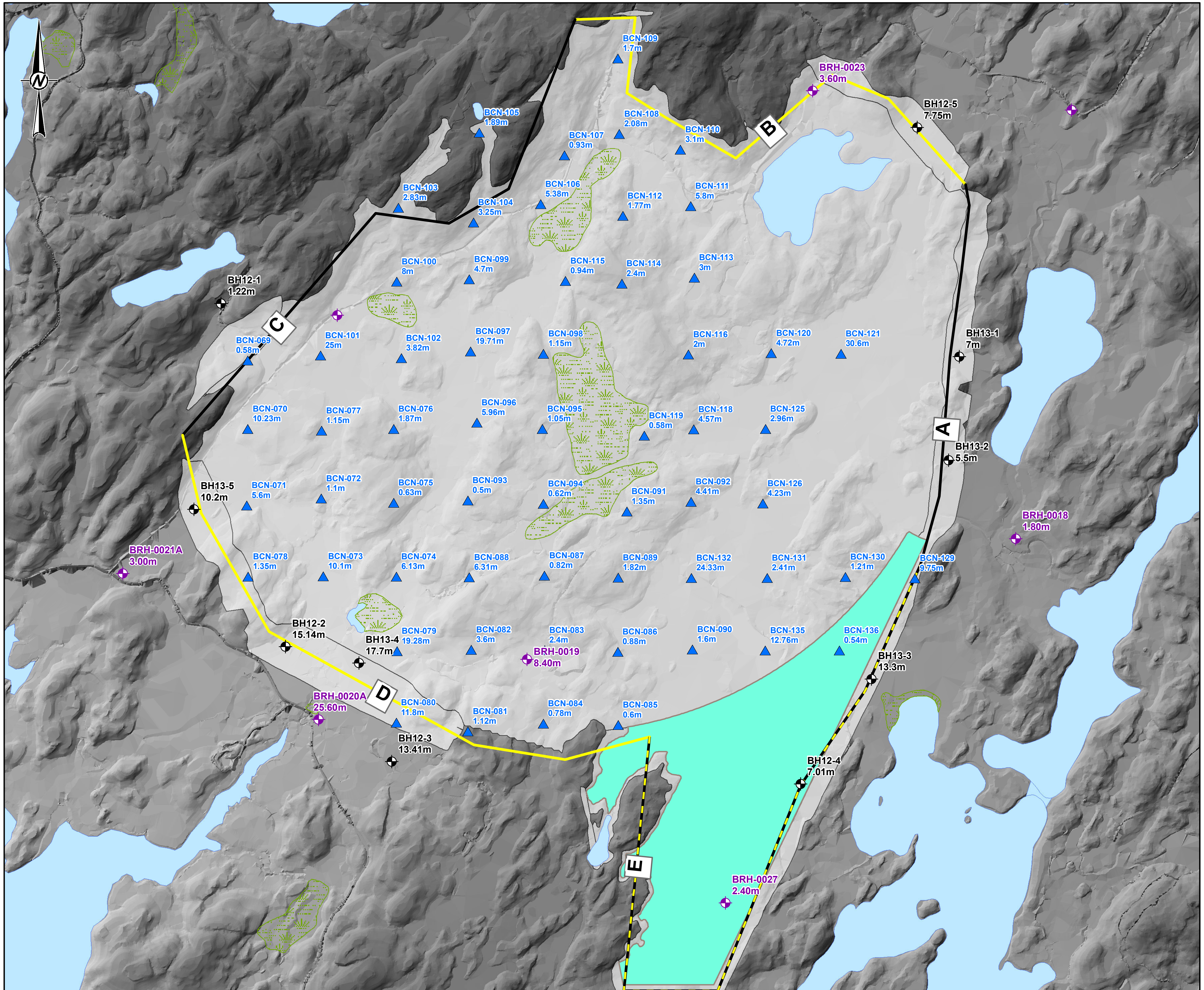
Mollard, D.G., Mollard, J.D. 1980. Northern Ontario Engineering Geology Terrain Study 55: Marmion Lake Area (NTS 52B/NW) District of Rainy River. Ontario Geological Survey, Ministry of Natural Resources.



LEGEND

- Condemnation Hole(Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Cross-Section
- Cross-Section
- Polishing Pond
- Tailings Management Facility
- Lake
- Wetland

NOTES

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT NO. 1408383/3500

REFERENCE

CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE – ONTARIO.
HTTPS://WWW.ONTARIO.CA/GOVERNMENT/OPEN-GOVERNMENT-LICENCE-ONTARIO
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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METRES
SCALE 1:16,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION LOCATIONS

CONSULTANT		
Golder Associates	YYYY-MM-DD	2016-06-03
	PREPARED	RRD
	DESIGN	RRD
	REVIEW	KAB
	APPROVED	--

PROJECT No.	PHASE	Rev.	FIGURE
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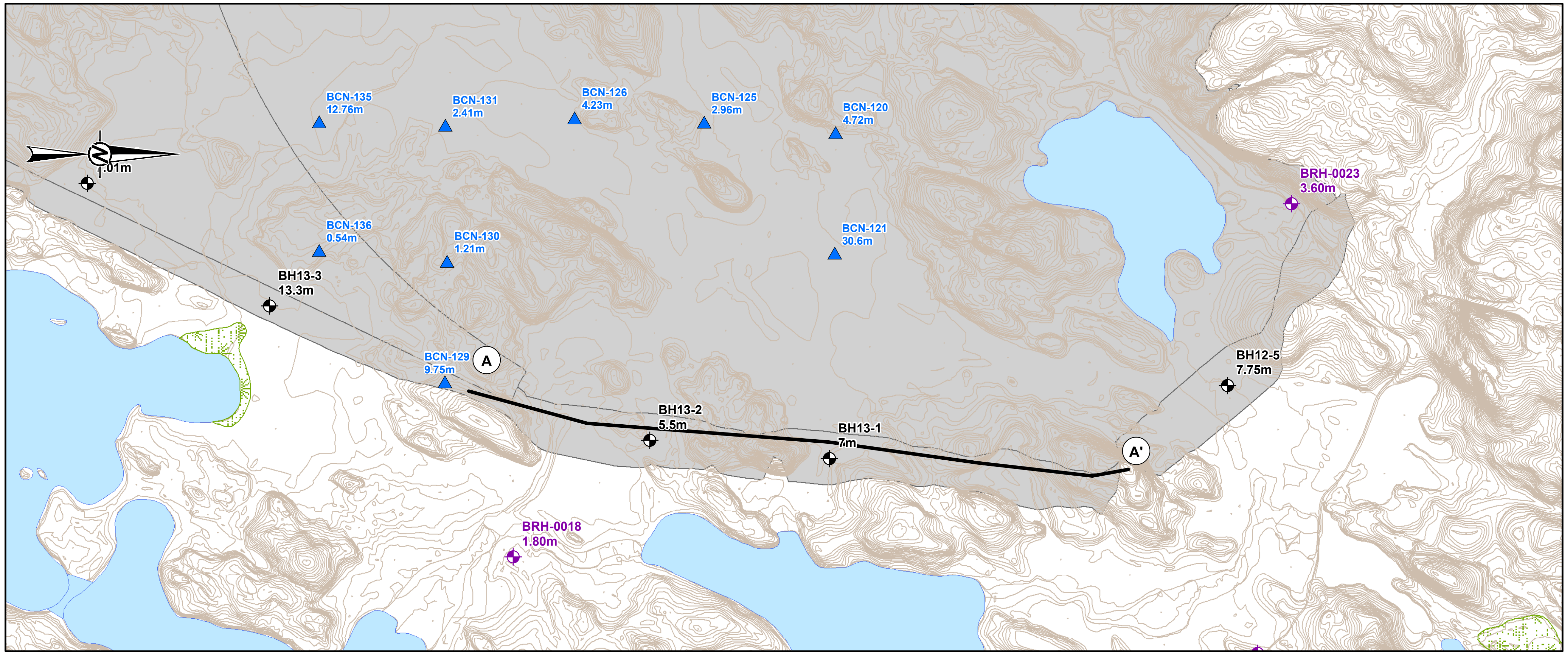

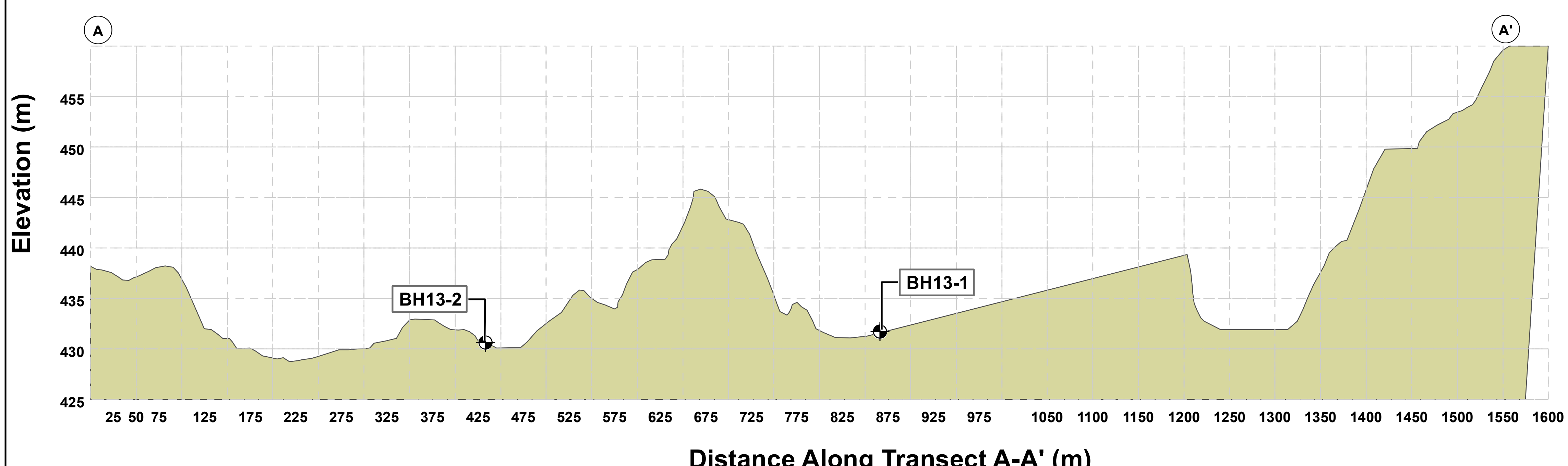

LEGEND

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- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Tailings Management Facility
- Contour
- Lake
- Wetland

NOTES

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COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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METRES
SCALE 1:12,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION A-A'

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-06-03
PREPARED	RRD
DESIGN	RRD
REVIEW	KAB
APPROVED	--

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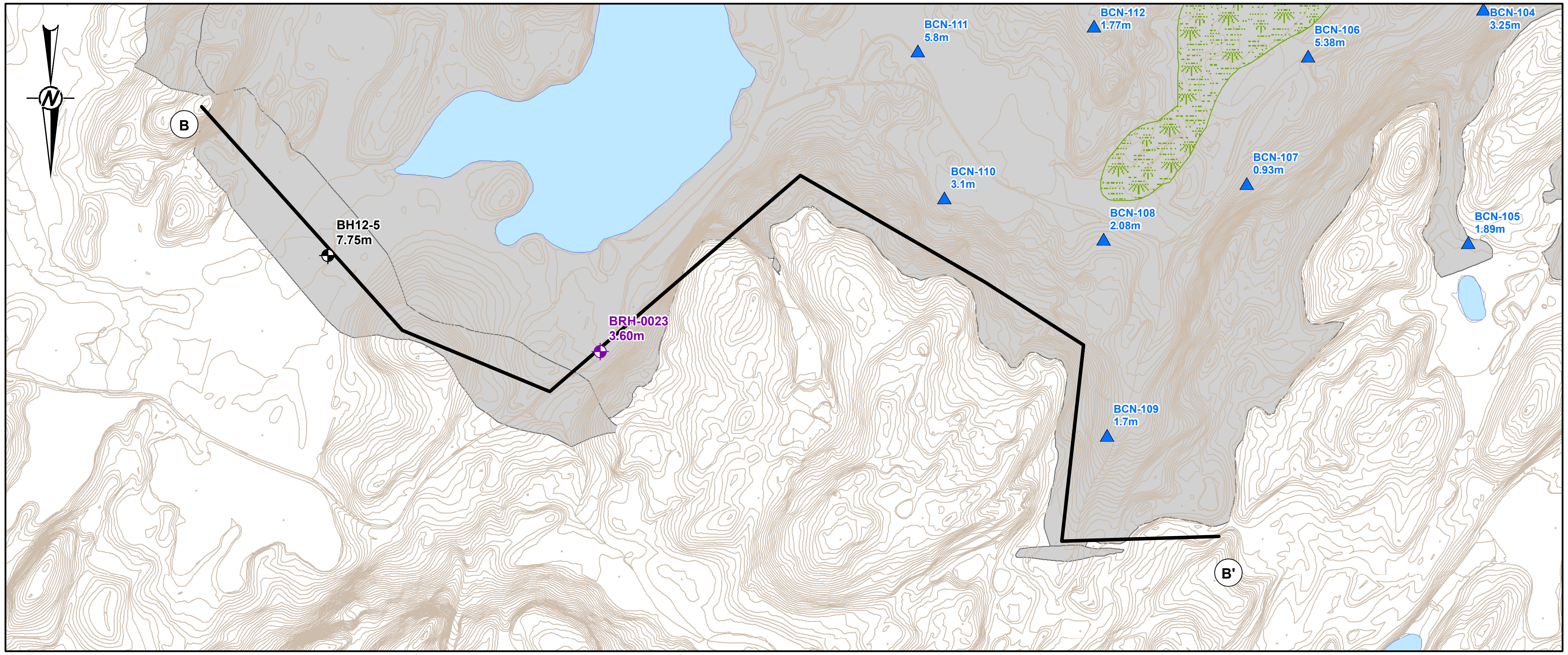

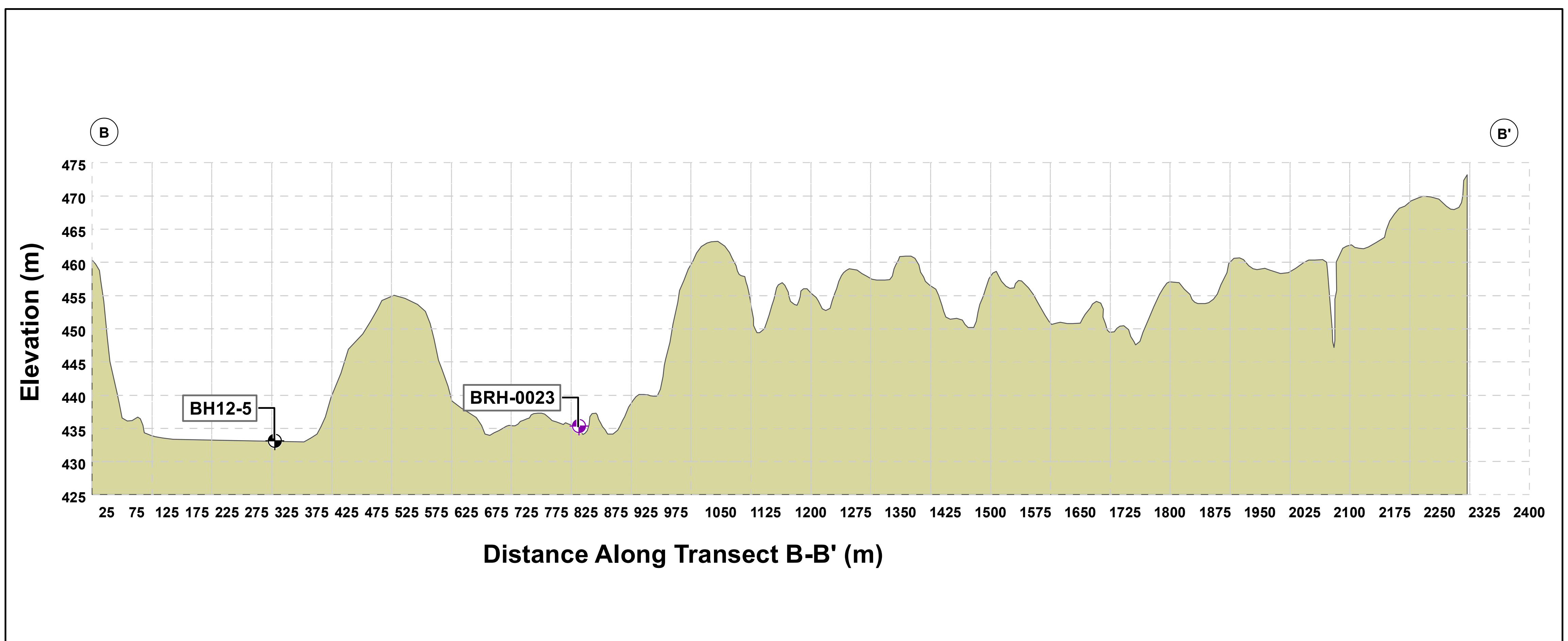

LEGEND

- CondemnationHole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Tailings Management Facility
- Contour
- Lake
- Wetland

NOTES

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COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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METRES
SCALE 1:8,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION B-B'

CONSULTANT	
YYYY-MM-DD	2016-06-03
PREPARED	RRD
DESIGN	RRD
REVIEW	KAB
APPROVED	--

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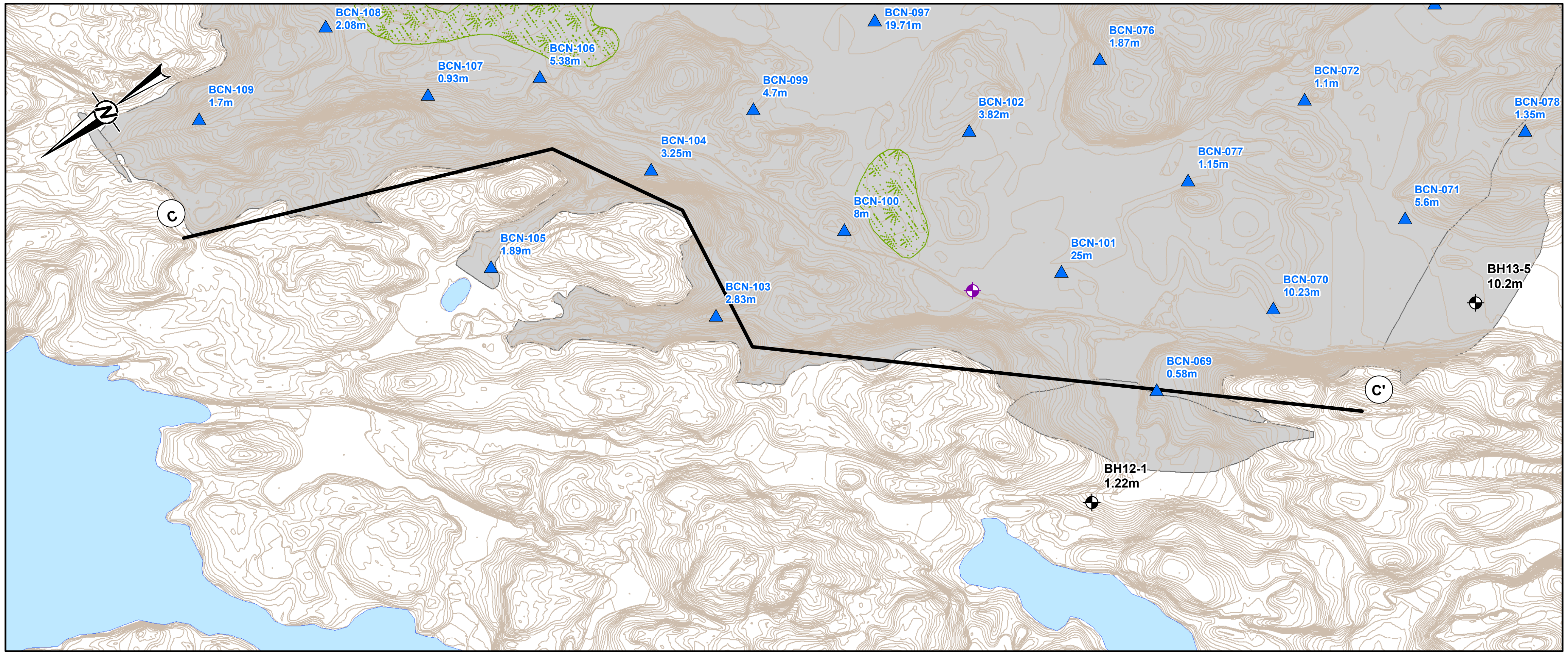
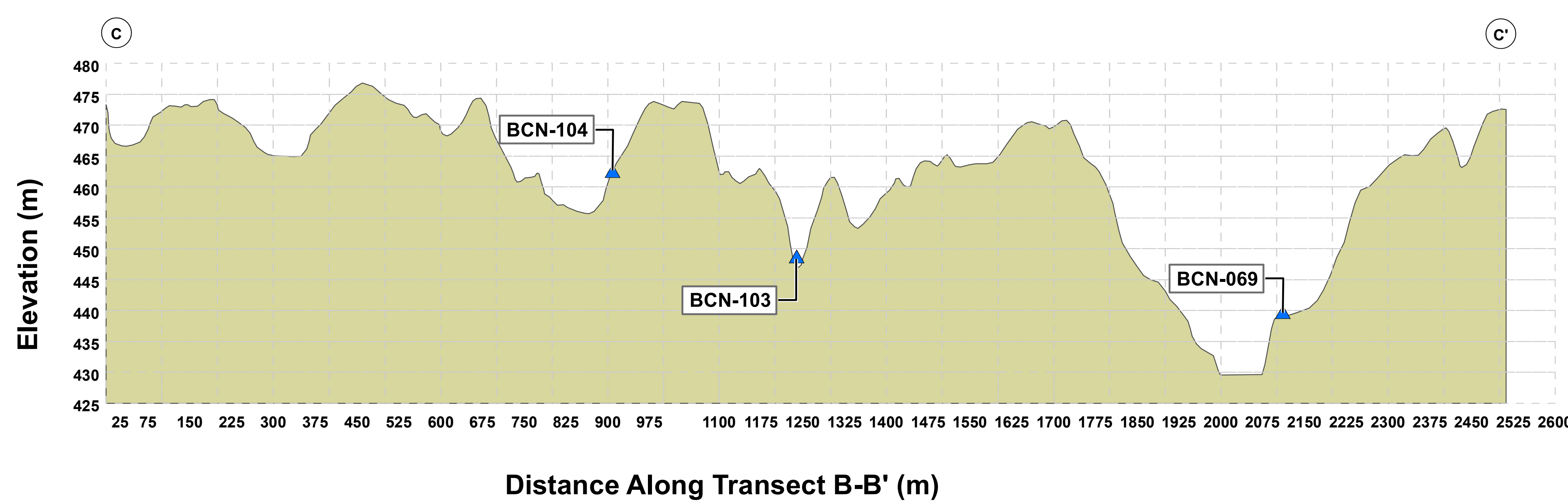


LEGEND

- Condemnation Hole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Tailings Management Facility
- Contour
- Lake
- Wetland



NOTES

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COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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SCALE 1:10,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION C-C'

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-06-03
PREPARED	RRD
DESIGN	RRD
REVIEW	KAB
APPROVED	--

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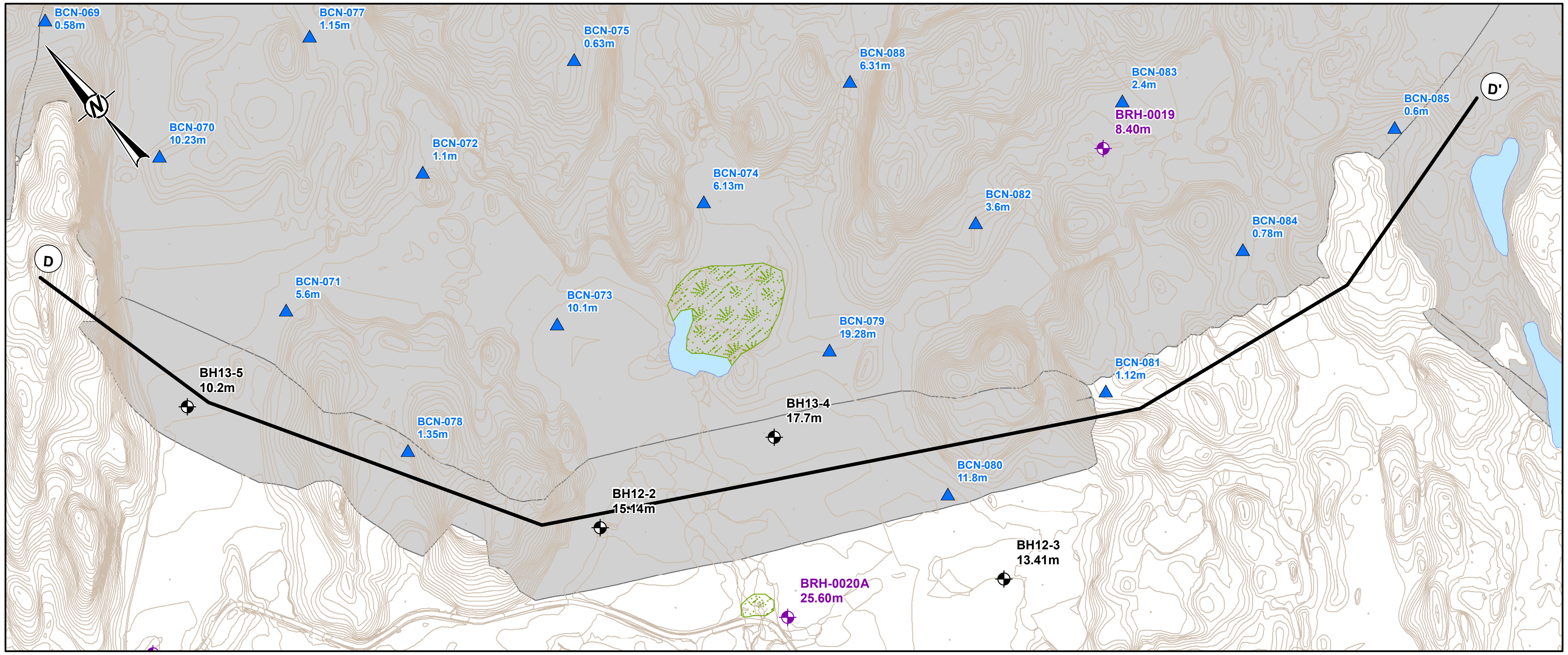

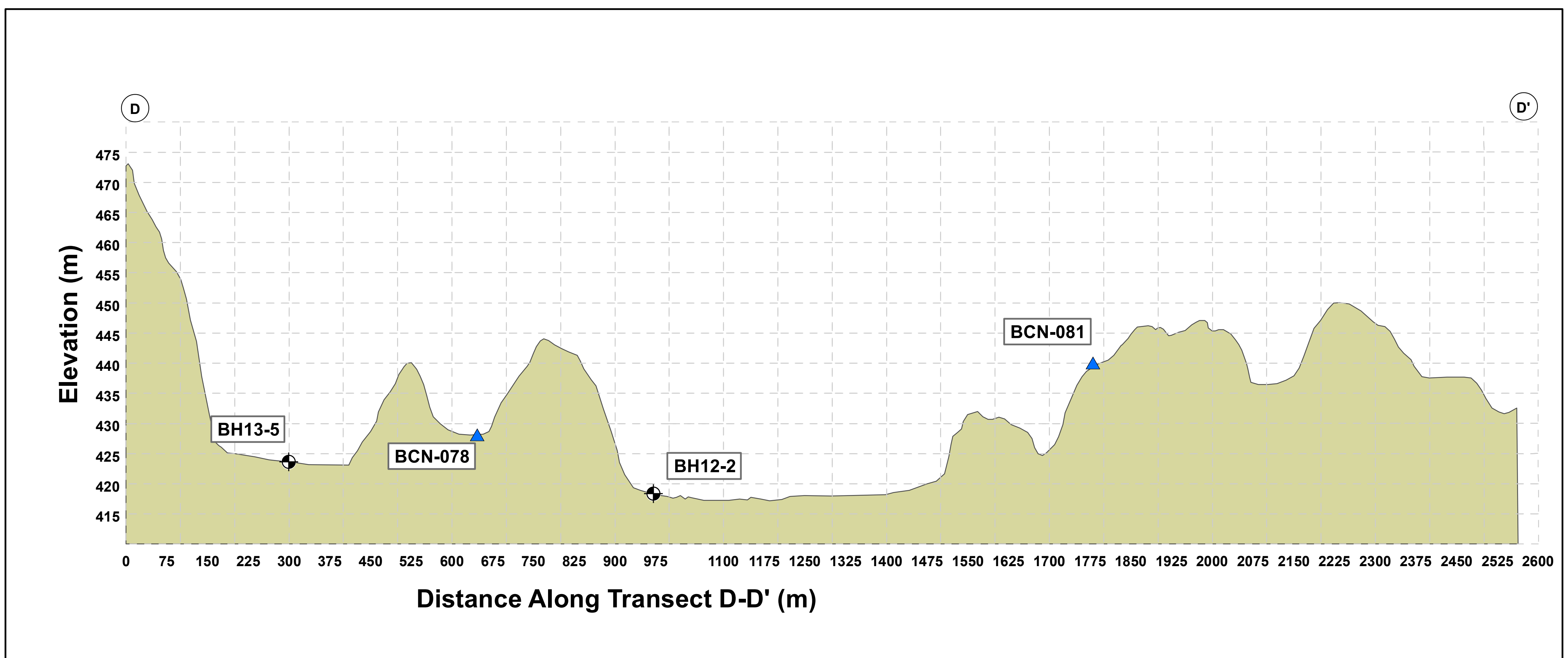

LEGEND

- Condemnation Hole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Tailings Management Facility
- Contour
- Lake
- Wetland

NOTES

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COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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METRES
SCALE 1:8,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION D-D'

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-06-03
PREPARED	RRD
DESIGN	RRD
REVIEW	KAB
APPROVED	--

PROJECT No.	PHASE	Rev.	FIGURE
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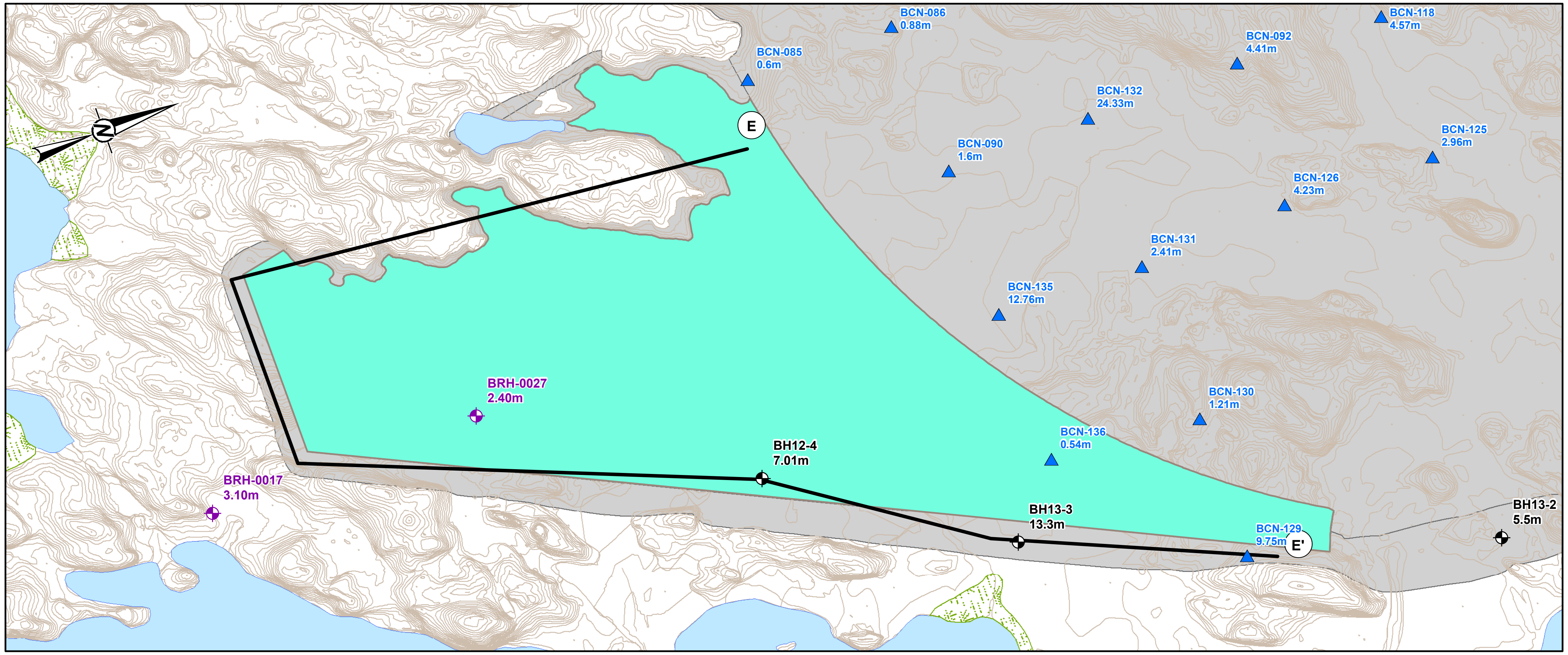

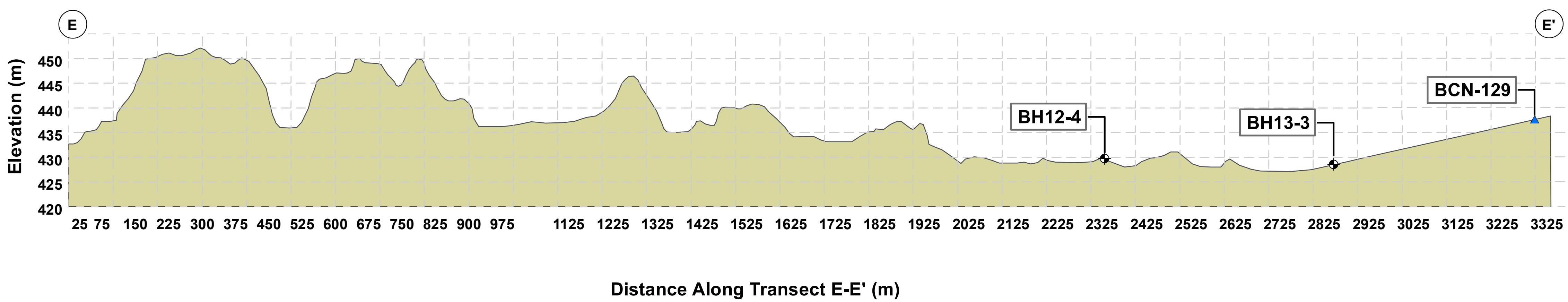

LEGEND

- Condemnation Hole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Cross-Section
- Polishing Pond
- Tailings Management Facility
- Contour
- Lake
- Wetland

NOTES

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REFERENCE

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COORDINATE SYSTEM: UTM ZONE 15 VERTICAL DATUM: CGVD28

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METRES
SCALE 1:10,000

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
HAMMOND REEF GOLD P ROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHIC CROSS-SECTION E-E'

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-06-03
PREPARED	RRD
DESIGN	RRD
REVIEW	KAB
APPROVED	--

PROJECT No.	PHASE	Rev.	FIGURE
1408383	3500	A	2E

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PART B

CEAA Comments on Response Approach

Canadian Environmental Assessment Agency
Ontario Regional Office
55 St. Clair Avenue East,
Room 907
Toronto, ON M4T 1M2

Agence canadienne d'évaluation environnementale
Bureau régional de l'Ontario
55, avenue St-Clair est,
bureau 907
Toronto (Ontario) M4T 1M2

May 6, 2016

Ms. Sandra Pouliot, ing.
Project Manager, Environment
Canadian Malartic Corporation
100, chemin du Lac Mourier
Malartic, QC J0Y 1Z0

ELECTRONIC MAIL

SUBJECT: Federal Review of the Draft Technical Memorandum on the Additional 3D Groundwater Modelling for the Hammond Reef Gold Project Federal Environmental Assessment

Dear Ms. Pouliot:

The Canadian Environmental Assessment Agency (the Agency), along with Natural Resources Canada and Environment and Climate Change Canada, completed the review of the Canadian Malartic Corporation (CMC) March 1, 2016 draft technical memorandum on the additional 3D groundwater modelling for the proposed Hammond Reef Gold Project.

The Agency recognizes the work done by CMC to produce the draft technical memorandum in response to expectations of the proposed scope of work recommended by T(3)-08 of Information Request #3 and the related discussions held during the teleconference of February 2, 2016. However, upon review, the draft technical memorandum outlines a proposed scope of work that will not fully address T(3)-08.

The proposed scope of work proposes to expand the hydrogeological model to encompass the entire tailings management facility by using the historic borehole data described in the memorandum. Federal experts have reviewed the dataset and the limitations of this dataset, as acknowledged in the draft technical memorandum, do not provide sufficient geotechnical information for the modeling. Of particular note is the lack of stratigraphic information and information for analysis of hydraulic conductivity and anisotropy data. Annexes 1 and 2, attached to this letter, link the deficiencies identified in the draft technical memorandum to the parts of T(3)-08.

.../2

Annex 1 provides a cross reference between the Information Request and deficiencies with the proposed scope of work, while Annex 2 provides an overview of the technical deficiencies with the proposed scope of work. Of particular note, as identified in parts 6 and 7 of the Information Request and noted in Annex 1, in some specific cases the scope of work does not respond directly to how some of the Information Request will be addressed.

To support CMC duly responding to T(3)-08 of Information Request #3, the Agency and federal reviewers are willing to meet with CMC to discuss this correspondence and the attachments. It is expected that the deficiencies identified in the scope of work will be addressed to the satisfaction of the federal reviewers before CMC prepares its response to T(3)-08.

Please feel free to contact me at 416-797-3402, 416-952-1574 or HammondReef@ceaa-acee.gc.ca, if there are questions about the content of this letter or the attachments and to schedule a meeting.

Sincerely,
<Original signed by>

Loraine Cox
Project Manager

Attachment:

- Annex 1: Table Linking T(3)-08 of Information Request #3 to the Deficiencies Identified During the Federal Review of the Additional 3D Groundwater Modelling Memorandum (one page)
- Annex 2: NRCan's Technical Review of the 3D Groundwater Modelling Memorandum, Hammond Reef Project, Ontario (eight pages)

cc. Angélique Magee, Natural Resources Canada
Jennifer Dorr, Natural Resources Canada
Sheryl Lusk, Environment and Climate Change Canada
Antonia Testa, Ontario Ministry of the Environment and Climate Change

Annex 1: Table Linking T(3)-08 of Information Request #3 to the Deficiencies Identified During the Federal Review of the Additional 3D Groundwater Modelling Memorandum

T(3)-08 Part #	Review Findings
1	Refer to Sections 2.1.3 and 2.1.4, page 4 of Annex 2
2	Refer to Sections 2.1.3 and 2.1.4, page 4 of Annex 2
3	Refer to Sections 2.1.3 and 2.1.4, page 4 and section 2.5.3, page 7 of Annex 2
4	Refer to Section 2.3.3 page 6 of Annex 2
5a	Refer to Sections 2.2.3 and 2.2.4, page 5 and Section 2.4.3 page 6 of Annex 2
5b	Refer to Sections 2.2.3 and 2.2.4, page 5 of Annex 2
5c	Refer to Sections 2.2.3 and 2.2.4, page 5 and Section 2.6.3 and 2.6.4 page 7 of Annex 2
5d	Refer to Sections 2.2.3 and 2.2.4, page 5 of Annex 2
5e	Refer to Sections 2.2.3 and 2.2.4, page 5 and Section 2.7.3, pages 7 and 8 of Annex 2
6	The proponent did not respond directly to Part 6 of T(3)-08. It is expected that the proponent will provide methodology, analysis and model results with the new model.
7	The proponent did not respond directly to Part 7 of T(3)-08. It is expected that based on the revised 3D numerical groundwater model, the proponent will provide a detailed description of the mitigation measures proposed to intercept seepage and the contingency plans in the event seepage is greater than predicted.
8	The proposed scope of work indicates that the potential impacts to Lizard Lake and Sawbill Bay receiving TMF seepage will be re-assessed based on the predicted residual seepage rates and TMF seepage water quality. Depending on factors such as the depositional type and permeability of the surficial deposits, scoping the assessment to Lizard Lake and Sawbill Bay may not be sufficient. The assessment needs to include all waterbodies that are frequented by fish that could potentially be affected by TMF seepage. Also, the proposed scope of work needs to include a commitment to describe the groundwater and surface water quality monitoring measures to verify seepage effects on water quality.

Natural Resources Canada   Ressources naturelles Canada

NRCan's Technical Review of the 3D Groundwater Modelling Memorandum, Hammond Reef Project, Ontario

a) Overview of Comments and Information Request T(3)-08

1.1. NRCan's General Comments Regarding the Proponent's Response

The Proponent has proposed a plan and approach to responding to information request T(3)-08 in their memo: *Hammond Reef Gold Project- Tailings Management Facility, Additional 3D Groundwater Modelling, Draft Technical Memorandum, March 1, 2016*. The Canadian Environmental Assessment Agency requested a review of the memo from the federal review team. The provincial review team plans to review the information proposed as well in the context of their potential permits and authorizations for the project. The Proponent outlined issues below in an attempt to address information request T(3)-08, but NRCan notes the issues they outline are not a complete representation of the information request submitted to the Proponent. The comments and rationale for T(3)-08, as well as the information request (IR) is restated below. The relevant section of the IR in relation to the issues outlined by the Proponent in their Memo are also restated in sections within NRCan's review, for further clarity regarding the sufficiency of the approach the Proponent is proposing to responding to IR T(3)-08.

1.2. Comments and Rationale from T(3)-08 (copied verbatim, Jan. 29, 2016 IR Table)

The T(2)-17 response does not provide information to assess the potential adverse effects of seepage from the tailings management facility (TMF) on particular receiving water bodies that are frequented by fish, including but not necessarily limited to Lizard Lake and Sawbill Bay. Instead CMC's response outlines a perspective on the potential impacts of seepage to aquatic life in the Marmion basin. By focusing on the entire basin, rather than individual water bodies within the basin, the approach fails to predict whether seepage may affect any particular water body.

According to subsection 10.2.3.1 of the EIS Guidelines, *the EIS shall … provide results of the hydrogeological assessment that determines: groundwater seepage location, rates, seepage quality, and direction into or from the open pits, mine rock stockpiles and other stockpiles, TIA facilities, primary sedimentation pond and process water pond, and from the pits during future overflow*. Clarity on seepage is required to understand the flow regime, including whether the seepage flow through the base of the TMF and/or through the TMF dam potentially will enter any receiving water body frequented by fish.

Also, Subsection 13.1.2 of the EIS Guidelines requires the EIS to include a description of the follow-up program to evaluate the predictions of effects and the effectiveness of the proposed mitigation.

T(2)-17 is re-submitted, with minor changes in items 1 and 3, to request the information needed by the Agency to assess the adverse environmental effects of seepage losses from the TMF, the magnitude and geographic extent (direction and distance), of any seepage that may discharge into any receiving water body frequented by fish, and the effectiveness of the proposed mitigation measures. Discussion on the potential adverse effects and their significance linked to the findings should also be provided.

Canada

This information is required in order for the Agency to provide a recommendation to the federal Minister of Environment and Climate Change on whether the Project is likely to cause significant adverse environmental effects.

1.3 Information Request T(3)-08

The response to T(2)-17 from Information Request #2 was insufficient. The IR was reworked and submitted to the proponent on Jan 29, 2016:

1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint.

2. If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7.

3. Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint.

4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model.

5. Re-run the 3D model based on the following:
   a) perform a more robust calibration using additional monitoring well data;
   b) presenting a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions;
   c) model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment);
   d) as described in 2., include information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and to determine if the assumption $K_{horizontal}:K_{vertical}$ = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the $K_{horizontal}:K_{vertical}$ relationship; and
   e) provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity.

6. Provide the methodology, analysis and model results.

7. Based on the results from question 1-6 above, provide a detailed description of the mitigation measures proposed to intercept seepage and contingency plans in the event seepage beneath the TMF would be greater than predicted.

8. Describe the residual effects on water quality; the significance of those residual effects based on the Agency's methodology for assessing significance (including the criteria of magnitude, geographic extent, duration, frequency, reversibility, ecological/social/cultural context); and the follow-up program, including any monitoring measures, which will be implemented to evaluate the predictions of effects and the effectiveness of the proposed mitigation.

2. NRCan's Technical Review Comments on the 3D Groundwater Modelling Memo

2.1. Baseline Data in Relation to Hydrogeology Modelling

2.1.1. Parts 1, 2 and 3 of IR (3)-08

1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint.

2. If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7.

3. Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint.

2.1.2. Issue as Outlined by the Proponent

Address the applicability of the currently available data to adequately characterize the site baseline hydrogeology and, if necessary, collect additional field data.

2.1.3. NRCan's Review of the Ability of Proposed Plan to Address Parts 1-3 of IR(3)-08

The Proponent has completed a search for additional geotechnical data in the area of the TMF that was not available or considered in the previous groundwater modelling analysis. It is NRCan's opinion that the usefulness of the information that was found is limited on its own, but may help in the development of the more comprehensive model that the proponent has proposed. The majority of this data provides only depth to bedrock, but seems to provide good coverage over the TMF. Trench data provides surficial geology information around the periphery of the TMF, but little information for the interior of the TMF.

The Proponent plans to incorporate additional data and regional surficial geology mapping with previously used logs to develop a detailed overburden isopach map for the TMF. The Proponent is of the view that this information negates the need to drill additional boreholes. It is NRCan's view that development of an isopach map will greatly improve the understanding of the distribution and thickness of permeable surficial sediments within the TMF footprint. However, NRCan recommends that the Proponent consider collection of additional data, as it is important to have additional detailed stratigraphic information to better delineate the depositional type and permeability of the surficial deposits.

2.1.4. NRCan's Recommendation

NRCan recommends that the proponent consider collection of additional data, as it is important to better delineate the depositional type and permeability of the surficial deposits in order to ensure adequate baseline data for the site is used in hydrogeology model.

2.2. Hydrogeology and Numerical Model for TMF

2.2.1. Part 5 of IR (3)-08

5. Re-run the 3D model based on the following:
   a) perform a more robust calibration using additional monitoring well data;
   b) presenting a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions;
   c) model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment);
   d) as described in 2., include information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and to determine if the assumption $K_{horizontal}$:$K_{vertical}$ = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the $K_{horizontal}$:$K_{vertical}$ relationship; and
   e) provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity.

6. Provide the methodology, analysis and model results.

2.2.2. Issue as outlined by the Proponent

Provide a detailed conceptual hydrogeologic model that will serve as the basis for the numerical model. Particular consideration should be given to: 1) granular troughs underlying the TMF and their potential as seepage pathways; 2) hydraulic conductivity assignments, particularly anisotropy, in lieu of heterogeneity observed in borehole logs across the site. The adequacy of the existing slug testing and grain size data as a basis for characterizing the hydraulic conductivity is also questioned.

2.2.3. NRCan's review of the ability of proposed plan to address Part 5 of IR(3)-08

The Proponent plans to expand the hydrogeological model to encompass the entire TMF and will be using the additional well data found during their existing data search. NRCan presumes that the updated information will be used to develop new cross sections. The Proponent has committed to developing an isopach map for the overburden. This is an important part of the conceptual model along with cross sections.

With respect to granular troughs within surficial materials, the Proponent may not be able to adequately delineate these without additional data and as such it is recommended by NRCan that the Proponent consider collection of additional data.

With respect to hydraulic conductivity, the proponent plans to review hydraulic conductivity data within the model domain and discrete hydraulic conductivity zones may be developed if the data suggests significant heterogeneity exists across the site. If anisotropy is not clearly supported by either the data or calibration effort (below), an isotropic system may be conservatively assumed. The Proponent is of the opinion that existing slug testing and grain size analysis results provide a reasonable means to characterize hydraulic conductivity. It is NRCan's view that there is still significant uncertainty with respect to hydraulic conductivity and no new hydraulic conductivity data has been made available.

It is not clear how the Proponent plans to provide a better analysis of hydraulic conductivity/anisotropy data.

2.2.4. NRCan's Recommendations

With respect to granular troughs within surficial materials, the Proponent may not be able to adequately delineate these without additional data and as such it is recommended by NRCan that the Proponent consider collection of additional data.

It is NRCan's view that there is significant uncertainty with respect to hydraulic conductivity in the footprint of the TMF, and no new hydraulic conductivity data has been made available. NRCan recommends that the Proponent clarify in their proposed plan how they will provide a better analysis of hydraulic conductivity and anisotropy data. NRCan notes that additional baseline data may be required in order to do this.

2.3 Expansion of Model Domain to Cover Entire TMF

2.3.1. Part 4 of IR(3)-08

4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model.

2.3.2. Issue as outlined by the Proponent

Develop a more regional-scale model that encompasses the entirety of the TMF, as opposed to just the eastern flank.

2.3.3. NRCan's review of the ability of proposed plan to address Part 4 of IR (3)-08

The proponent plans to expand the model domain to include the entire TMF and will delineate the extents based on regional hydrologic boundaries. It is NRCan's view that with the incorporation of an appropriate level of sufficient baseline data within the TMF into the model, this plan should be sufficient to address Part 4 of IR(3)-08.

2.4. Calibration of Hydrogeology Model to Adequate Baseline Data

2.4.1. Part 5 a) of IR (3)-08

5. a) perform a more robust calibration using additional monitoring well data;

2.4.2. Issue as Outlined by the Proponent

Conduct a model calibration using baseline data.

2.4.3. NRCan's Review of the Ability of Proposed Plan to Address Part 5 a) of IR (3)-08

The model will be calibrated in steady-state to average water levels at monitoring wells within domain. In addition, stream / baseflow data may be considered, depending on the gauge location relative to the model domain. A base case, pre-TMF groundwater flow budget will be derived based on the calibrated model output. It is an iterative, trial-and-error approach to calibration. It is NRCan's view that this approach is reasonable.

2.5. Potential Seepage from TMF

2.5.1. Part 3 of IR (3)-08

3. Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint.

2.5.2 Issue as Outlined by the proponent

Based on the expanded domain, estimate the amount of seepage by-pass to downgradient receptors other than Lizard Lake, for example, Sawbill Bay and smaller water bodies around the perimeter of the TMF. Quantify the proportion of seepage occurring below the TMF base versus through the TMF dams.

2.5.3. NRCan's Review of the Ability of Proposed Plan to Address Part 3 of IR (3)- 08

The expanded model should allow for seepage tracking from the TMF to all collection systems and potential downgradient receptors. A comprehensive flow budget will be developed based on the model output. Particle tracking will be employed to illustrate seepage pathways. Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. It is NRCan's view that this is a reasonable approach and with proper calibration of the model, should address this issue.

2.6. Modeling Different Phases of Project

2.6.1. Part 5 c) of IR(3)-08

5. c) model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment).

2.6.2. Issue as Outlined by Proponent:

Consider all project phases from baseline to closure.

2.6.3. NRCan's review of ability of proposed plan to address Part 5 c) of IR (3)-08

The modelling will consider current conditions (baseline) and operations phase at full build-out. The proponent will not consider post-closure conditions and has provided the following justification for that decision. The proponent claims that during the post-closure period, seepage water quality will have been deemed to be suitable for discharge and the TMF reclaim pond spillway will be lowered, reducing the potential for seepage.

2.6.4 NRCan's Recommendations

However, NRCan recommends that closure/post-closure modeling be conducted in case the water quality is not deemed suitable for discharge into the receiving water bodies. This is standard practice for modelling closure/post-closure modelling in conjunction with a sensitivity analysis and is a useful tool for showing the closure/post-closure effects of the project and how these predictions may vary if some of the assumptions are not accurate.

2.7. Sensitivity Analysis

2.7.1. Part 5 e) of IR (3)-08

5. e) provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity.

2.7.2 Issue as Outlined by Proponent

Conduct a sensitivity analysis to examine the potential range of seepage rates emanating from the TMF.

2.7.3 NRCan's Review of the Ability of Proposed Plan to Address Part 5 e) of IR (3)-08:

A sensitivity analysis will be performed to establish an upper bound on results by varying select input parameters within a reasonable range about the base case input value. Golder will seek the Federal review team's opinion in selecting parameters to test during the sensitivity analysis. The proponent proposes recharge rates, and hydraulic conductivities/anisotropies of tailings, overburden and weathered bedrock as potential candidates for analysis. It is NRCan's view that this is a good approach and that the suggested variables are reasonable.

2.8 Environmental Effects on Receiving Water Bodies

2.8.1. Part 8 of IR (3)-08

Describe the residual effects on water quality; the significance of those residual effects based on the Agency's methodology for assessing significance (including the criteria of magnitude, geographic extent, duration, frequency, reversibility, ecological/social/cultural context); and the follow-up program, including any monitoring measures, which will be implemented to evaluate the predictions of effects and the effectiveness of the proposed mitigation.

2.8.2. Issue as Outlined by the Proponent

Evaluate potential environmental impacts to all receiving water bodies.

2.8.3. NRCan's Review of the Ability of Proposed Plan to Address Part 8 of IR (3)-08:

The expanded model should allow for seepage tracking from the TMF to all collection systems and potential downgradient receptors. A comprehensive flow budget will be developed based on the model output. Particle tracking will be employed to illustrate seepage pathways. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. It is NRCan's view that the modelling part of this approach is quite reasonable. However, it is outside of NRCan's area of expertise to comment on potential environmental impacts to surface water receptors.

Document Reviewed:
Hammond Reef Gold Project- Tailings Management Facility, Additional 3D Groundwater Modelling, Draft Technical Memorandum, March 1, 2016

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July 29, 2016

Ms. Sandra Pouliot, ing.
Project Manager, Environment
Canadian Malartic Corporation
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Malartic, QC J0Y 1Z0

ELECTRONIC MAIL

SUBJECT: Federal Comments on the June 15, 2016 Supplementary Memorandum on the Scope of Work for the 3D Groundwater Modeling for the Federal Environmental Assessment of the Hammond Reef Gold Project

Dear Ms. Pouliot:

The Canadian Environmental Assessment Agency, along with Environment and Climate Change Canada and Natural Resources Canada, completed the review of the June 15, 2016 supplementary memorandum on the scope of work (SOW) for the 3D groundwater modeling for the proposed Hammond Reef Gold Project.

Upon review of the original March 1, 2016 memorandum and June 15, 2016 supplementary memorandum, clarification has been provided on the proposed SOW's model domain expansion, calibration, project phase analysis, groundwater flow and seepage simulation and sensitivity analysis. However, there are other components of the SOW, including characterization of stratigraphy and hydraulic conductivity, which require further clarification. The attached table provides a summary of the items that remain unresolved, along with the federal review findings and recommendations.

The first six recommendations contained in the table outline elements, which form the basis of the assumptions and inputs necessary for building a conservative 3D hydrogeological model. The Agency and federal reviewers are seeking clarification on how Canadian Malartic Corporation (CMC) will wholly incorporate the recommendations and expect to review and approve a written submission of the model assumptions and inputs before CMC conducts any model runs. The submission should also explain how the unresolved items in the attached table are addressed.

.../2

The seventh recommendation seeks to ensure the report on the modeling results is used to inform all analyses required to wholly respond to Information Request T(3)-08 and make certain the scope of work includes not only the report on the modeling results, but also the responses to all parts of T(3)-08.

Efforts by CMC and federal reviewers to resolve the issues are recognized by the Agency. The Agency and federal reviewers have cooperated with CMC in exploring the option of using historic borehole data in lieu of drilling new boreholes to improve the hydrogeological model. However, CMC should also recognize and consider revisiting the viable option to conduct additional fieldwork to address the dataset issues of the proposed scope of work.

The Agency and federal reviewers are seeking to meet with CMC to discuss its written submission. Please contact Loraine Cox at (416) 952-1574 or me at (416) 564-1589, or alternatively send an email to HammondReef@ceaa-acee.gc.ca to organize a meeting.

Sincerely,
<Original signed by>

Carl Johansson
Project Manager

Attachment: Table of Federal Review Findings on the Proposed Scope of Work for the 3D Groundwater Modeling (six pages)

cc. Sheryl Lusk, Environment and Climate Change Canada
Jennifer Dorr, Natural Resources Canada
Antonia Testa, Ministry of the Environment and Climate Change

Table of Federal Review Findings on the Proposed Scope of Work for the 3D Groundwater Modeling

Components of Proposed Scope of Work (from March 1, 2016 memo)	Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)	Federal Review Findings and Recommendations	Status
Model Domain Expansion	• Expand the model domain to include the entirety of the TMF and delineate the extents based on regional hydrologic boundaries. This will allow for the simulation of a comprehensive site groundwater budget and TMF seepage tracking to all collection systems and potential downgradient receptors. [March 1, 2016 memo]	• With the incorporation of an appropriate level of sufficient baseline data within the TMF into the model, this plan should be sufficient to address Part 4 of IR T(3)-08. ***RECOMMENDATION:*** #1 Prior to executing any model runs, the proponent should provide the Government Review Team (GRT) a written submission on the model assumptions and inputs to verify that the proposed approach is reasonable to the GRT.	• Resolved

Components of Proposed Scope of Work (from March 1, 2016 memo)	**Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)**	**Federal Review Findings and Recommendations**	**Status**
Overburden Isopach Development	• Incorporate additional data (as identified in Section 3.0) and regional surficial geology mapping with previously used logs to develop a detailed overburden isopach underneath the TMF. [March 1, 2016 memo] • In our view the incorporation of this additional data, which provides good coverage over the TMF footprint, negates the need for additional boreholes. [March 1, 2016 memo] • External to the TMF, where overburden data may not exist, the isopach will be extended into the broader model domain based on conservative assumptions (for example, assuming lateral continuity at an appropriate uniform thickness). [March 1, 2016 memo]	• The stratigraphy indicated in the June 15, 2016 Technical Memo does not address the extensive glaciofluvial sand and gravel deposits reported and mapped by Stea (2010) presented as part of the March 1st 2016 draft TM. Although the cross-sections in the June 15th, 2016 Technical Memo only show surface topography and do not show subsurface materials, the topographic profiles clearly suggest the presence of filled valleys (also previously referred to as "granular troughs"). These filled valleys are mapped by Stea (2010) predominantly as "subaqueous outwash and associated glacio-lacustrine facies". Consequently, these deposits may be expected to be extensive within the filled valleys (possibly at depth). Although the condemnation holes provide distributed coverage of depth to bedrock across the TMF area, many of the holes are on or near the edges of bedrock ridges and there is only partial delineation of the depth to bedrock in filled valleys. Most of the deeper boreholes are located in the middle of these filled valleys. • The initial groundwater model presented in the June 15, 2015 EIS amendment lumps the entire overburden into one hydrostratigraphic unit and therefore does not distinguish between higher hydraulic conductivity sand and gravel and lower hydraulic conductivity silt, clay and till. The different hydraulic conductivity layers could be significant for groundwater flow within the filled valleys as there may be confined flow beneath the layer of silty clay to clayey silt. • The initial groundwater model presented in the June 15, 2015 EIS amendment indicates a continuous overburden layer between the tailings and bedrock. It is clear from the condemnation borehole data that there will be areas where the tailings will be in direct contact with the weathered bedrock or that the overburden will be very thin (i.e. not likely a low hydraulic conductivity barrier between tailings and bedrock). • The proponent plans to incorporate additional data and regional surficial geology mapping with previously used logs to develop a detailed overburden isopach map for the TMF. The proponent is of the view that this information negates the need to drill additional boreholes. It is NRCan's view that development of an isopach map will greatly improve the understanding of the distribution and thickness of permeable surficial sediments within the TMF footprint. However, NRCan recommends that the proponent consider collection of additional data, as it is important to have additional detailed stratigraphic information to better delineate the depositional type and permeability of the surficial deposits. ***RECOMMENDATIONS:*** #2 The stratigraphy in the groundwater model should be based on a conceptual geological model that incorporates both the existing stratigraphy as presented in the Technical Memo and the sedimentological and mapping results by Stea (2010). The possibility that coarse sediment in filled valleys may be pathways for flow under the TMF should be assessed in the modelling. #3 The groundwater model should include separate model layers for distinct hydrostratigraphic units where these may be important to the interpretation of groundwater flow (e.g., filled valleys and beneath the TMF dams). #4 The groundwater model should include areas where the tailings are in direct contact with the bedrock (e.g., current bedrock ridges) where sediment is thin or absent. This could be a direct pathway for water to flow from the tailings to more permeable units beneath the silt and clay layer. Recommendation #1 also applies	• Further clarification required

Components of Proposed Scope of Work (from March 1, 2016 memo)	Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)	Federal Review Findings and Recommendations	Status
Hydraulic Conductivity Review	• Review hydraulic conductivity data within the model domain. [March 1, 2016 memo] • Within the TMF footprint, a total of 11 overburden and 6 bedrock hydraulic conductivities were obtained through either rising head tests or grain size (Hazen) method. In addition to hydraulic conductivities measured in the immediate vicinity of the TMF, an additional 20 bedrock and 19 overburden measurements were obtained from locations around the proposed Open Pit, Mine Rock Area and alternative TMF areas. Based on the review of the borehole logs, the stratigraphic units logged at these locations are similar to those encountered at the TMF and would supplement the data available for the TMF groundwater model. [June 15, 2016 memo] • Discrete hydraulic conductivity zones may be developed if the data suggests significant heterogeneity exists across the site. [March 1, 2016 memo] • If anisotropy is not clearly supported by either the data or calibration effort (below), an isotropic system may be conservatively assumed. [March 1, 2016 memo] • In our view the existing slug testing and grain size analysis results provide for a reasonable means to characterize hydraulic conductivity and additional testing is not warranted. [March 1, 2016 memo] • In any event, the model sensitivity to a range of hydraulic conductivities will be tested during sensitivity analysis (described below). [March 1, 2016 memo] • Recognizing the concern brought forward by the GRT of providing additional hydraulic conductivity information, it is proposed that rising / falling head tests be completed at the monitoring wells that have been installed in 2012. These include 3 bedrock monitoring wells and 4 overburden monitoring wells at the TMF as well as 6 additional overburden monitoring wells located to the west and south of the TMF with well screens considered to be in units representative of the stratigraphy at the TMF. [June 15, 2016 memo] • It is proposed that the anistrophy be evaluated as a sensitivity analysis in the groundwater model. Two anisotropy ratios will be assessed, and calibrations performed on both a ratio of K_v/K_h of 0.1 and 1.0; the latter implying conservative isotropic conditions. [June 15, 2016 memo]	• The stratigraphy indicated in the Technical Memo does not address the extensive glaciofluvial sand and gravel deposits reported and mapped by Stea (2010) presented as part of the March 1st 2016 draft TM. Although the cross-sections in the June 15th, 2016 Technical Memo only show surface topography and do not show subsurface materials, the topographic profiles clearly suggest the presence of filled valleys (also previously referred to as "granular troughs"). These filled valleys are mapped by Stea (2010) predominantly as "subaqueous outwash and associated glacio-lacustrine facies". Consequently, these deposits may be expected to be extensive within the filled valleys (possibly at depth). Although the condemnation holes provide distributed coverage of depth to bedrock across the TMF area, many of the holes are on or near the edges of bedrock ridges and there is only partial delineation of the depth to bedrock in filled valleys. Most of the deeper boreholes are located in the middle of these filled valleys. • The initial groundwater model presented in the June 15, 2015 EIS amendment lumps the entire overburden into one hydrostratigraphic unit and therefore does not distinguish between higher hydraulic conductivity sand and gravel and lower hydraulic conductivity silt, clay and till. The different hydraulic conductivity layers could be significant for groundwater flow within the filled valleys as there may be confined flow beneath the layer of silty clay to clayey silt. • The initial groundwater model presented in the June 15, 2015 EIS amendment indicates a continuous overburden layer between the tailings and bedrock. It is clear from the condemnation borehole data that there will be areas where the tailings will be in direct contact with the weathered bedrock or that the overburden will be very thin (i.e. not likely a low hydraulic conductivity barrier between tailings and bedrock). • Whereas additional hydraulic conductivity data will contribute to better characterization of the sediments and bedrock in general, it is not clear if the sand and gravel deposits studied by Stea (2010) are adequately represented by the hydraulic conductivity dataset. These deposits are mapped over a considerable area of the TMF and therefore may be significant for vertical and horizontal flow within the sediments underlying the TMF. Similarly, it is not clear if there are faulted areas in the bedrock underlying the TMF that might need to be characterized. • ECCC does not agree that these additional borehole sites from locations around the proposed Open Pit, Mine Rock Area and alternative TMF areas will provide useful data to characterize the TMF site, given that these additional measurements are several kilometres away and occur in areas of glacial till, which have different characteristics than the glaciofluvial deposits of the TMF. • NRCan is satisfied with evaluating the issue of anisotropy of units using sensitivity analysis in the modelling. However, it will be important that the model properly address issues of heterogeneity due to stratigraphy. The layering may result in a layered anisotropy at a larger scale. ***RECOMMENDATIONS:*** #5 The preference would be to ensure that each hydrostratigraphic unit is adequately sampled for hydraulic conductivity using field measurements. In the absence of adequate field hydraulic conductivity data for any particular hydrostratigraphic unit, conservative estimates of hydraulic conductivity should be assumed in the groundwater model (i.e. that would tend to favor seepage). Recommendation #1 also applies	• Further clarification required

Components of Proposed Scope of Work (from March 1, 2016 memo)	Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)	Federal Review Findings and Recommendations	Status
Calibration	• Model calibration typically involves adjusting initial model input parameters within a reasonable range until simulated results reasonably approximate field observations. [March 1, 2016 memo] • The model will be calibrated in steady-state to average water levels at monitoring wells within domain. [March 1, 2016 memo] • In addition, stream / baseflow data may be considered, depending on the gauge location relative to the model domain. [March 1, 2016 memo] • Finally, a base case, pre-TMF groundwater flow budget will be derived based on the calibrated model output. It is likely that an iterative, trial-and-error approach to calibration will be employed as per ASTM D 5490- 93 (Reapproved 2002) *Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information.* [March 1, 2016 memo]	• The model will be calibrated in steady-state to average water levels at monitoring wells within domain. In addition, stream /baseflow data may be considered, depending on the gauge location relative to the model domain. A base case, pre-TMF groundwater flow budget will be derived based on the calibrated model output. It is an iterative, trial-and-error approach to calibration. It is NRCan's view that this approach is reasonable. ***RECOMMENDATION:*** Recommendation #1 applies	• Resolved
Project Phase Analysis	• The modelling will consider the following phases: pre-TMF baseline, operations, closure and post-closure. [June 15, 2016 memo] • The operational phase at full build-out considers the period where impacts are expected to be maximal because the aerial extent of the tailings stack and elevation of the reclaim water pond will be at their highest. [March 1, 2016 memo]	• Including closure (decommissioning) and post-closure (abandonment) phases in the modeling is appropriate. This is standard practice for modeling closure and post-closure in conjunction with sensitivity analysis and is a useful tool for showing the closure/post-closure effects of the project and how these predictions may vary if some of the assumptions are not accurate. • Although there may be relatively less seepage occurring during the closure and post-closure phases (as compared to operations), any seepage that may occur during the final post-closure phase will not be intercepted, pumped or treated since the proponent plans on decommissioning these controls during that phase, and therefore, the potential effects on the receiving environment could be greater than during operations.	• Resolved

Components of Proposed Scope of Work (from March 1, 2016 memo)	**Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)**	**Federal Review Findings and Recommendations**	**Status**
Groundwater Flow and Seepage Simulation	• Groundwater conditions during the TMF operational phase at full-build out will be simulated. [March 1, 2016 memo] • A comprehensive flow budget will be developed based on the model output. [March 1, 2016 memo] • Particle tracking will be employed to illustrate seepage pathways. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. [March 1, 2016 memo] • Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. [March 1, 2016 memo] • Conceptual seepage collection measures, which will consist of a perimeter seepage collection system of ditches and pump stations is proposed downstream of the TMF containment dams to collect and pump seepage back into the TMF. Reasonable assumptions will be made with respect to the location and depth of these ditches and a summary of these assumptions will be provided. [June 15, 2016 memo] • A review will be completed to confirm viability of seepage collection using reasonable and proven methods, based on the observed borehole conditions, stratigraphy, modelled flow and literature data following the model runs. [June 15, 2016 memo] • Additional mitigation or modifications to the presently proposed seepage collection system may be identified during this analysis. [March 1, 2016 memo]	• The expanded model should allow for seepage tracking from the TMF to all collection systems and potential downgradient receptors. A comprehensive flow budget will be developed based on the model output. Particle tracking will be employed to illustrate seepage pathways. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. It is NRCan's view that this is a reasonable approach and with proper calibration of the model, should address this issue. • ECCC would like to add that significant seepage can also flow from layers of high hydraulic conductivity (e.g., sand and gravel) into the bedrock (which is typically fractured and weathered), and then outwards from the TMF. In other words, overburden does not necessarily limit the amount of seepage that can flow into and then through the upper bedrock layer; the hydraulic conductivity of the different overburden layers are an important consideration regarding the pathway for seepage into the bedrock and then laterally out of the TMF. • NRCan is satisfied to include conceptual level designs in the groundwater model at this time. NRCan notes that the stratigraphy may not be conducive to the effective functioning of such a system in locations where collection system is located above a low hydraulic conductivity silty or clayey unit that is underlain by more permeable sand and gravel. ***RECOMMENDATION:*** Recommendation #1 applies	• Resolved
Sensitivity Analysis	• A sensitivity analysis will be performed to establish an upper bound on results by varying select input parameters within a reasonable range about the base case input value. [March 1, 2016 memo] • Golder will seek the Government Review Team's opinion in selecting parameters to test during the sensitivity analysis. Currently, we feel that recharge rates, and hydraulic conductivities/anisotropies of tailings, overburden and weathered bedrock may be potential candidates for analysis. [March 1, 2016 memo] • For the purpose of scoping, we have assumed four (4) variables will be examined. Model calibration is not planned to be re-assessed during this task. [March 1, 2016 memo]	• The proponent proposes recharge rates, and hydraulic conductivities/anisotropies of tailings, overburden and weathered bedrock as potential candidates for analysis. It is NRCan's view that this is a good approach and that the suggested variables are reasonable. [Note: In the June 15, 2016 memo, the proponent indicated two anisotropy ratios will be assessed and calibrations performed on both a ratio of K_v/K_h of 0.1 and 1.0.]	• Resolved

Components of Proposed Scope of Work (from March 1, 2016 memo)	Proponent's Proposed Approach (from March 1, 2016 and June 15, 2016 memos)	Federal Review Findings and Recommendations	Status
Environmental Impacts	• The potential impacts to the water bodies receiving TMF seepage will be re-assessed based on the predicted residual seepage rates and TMF seepage water quality. [March 1, 2016 memo] • This scope of this assessment will only include Lizard Lake and Sawbill Bay. [March 1, 2016 memo] • Aquatic habitat in the smaller lakes and streams around the perimeter of the TMF has already been determined to be 'impacted' by the project due to loss of inflow (due to watershed reduction) or loss of connectivity to larger water bodies. As a result, these water bodies have been included in the No Net Loss/Fish Habitat Offset Plan and compensation for the loss of habitat is planned (see Part B of the Version 2 Aquatic Environment TSD). [March 1, 2016 memo]	• The expanded model should allow for seepage tracking from the TMF to all collection systems and potential downgradient receptors. A comprehensive flow budget will be developed based on the model output. Particle tracking will be employed to illustrate seepage pathways. Seepage rates emanating from the TMF vertically through the base and laterally through the flanks / dams will be discretely quantified. Discharge to seepage collection systems and further downgradient receptors will be assessed using the zone budget utility in the modelling software. It is NRCan's view that this is a reasonable approach. • The proposed scope of work indicates that the potential impacts to Lizard Lake and Sawbill Bay receiving TMF seepage will be re-assessed based on the predicted residual seepage rates and TMF seepage water quality. Depending on factors such as the depositional type and permeability of the surficial deposits, scoping the assessment to Lizard Lake and Sawbill Bay may not be sufficient. The assessment needs to include all waterbodies that are frequented by fish that could potentially be affected by TMF seepage. Also, the proposed scope of work needs to include a commitment to describe the groundwater and surface water quality monitoring measures to verify seepage effects on water quality. ***RECOMMENDATIONS:*** #6 The groundwater model should consider whether the seepage collection system will perform adequately in the presence of possible layering of low hydraulic conductivity silt and clay with higher hydraulic conductivity sand and gravel beneath portions of the seepage collection system. Recommendation #1 also applies	• GRT will review the analysis when available
Report	• A report documenting model conceptualization, construction, calibration, TMF seepage collection mitigations applied, predictive analysis, sensitivity analysis and conclusions will be provided as a supporting document to the responses to Information Request T(3)-08. [March 1, 2016 memo]	• It is expected that based on the revised 3D numerical groundwater model, the proponent will provide, in addition to a detailed description of the environmental effects of seepage and mitigation measures proposed to intercept seepage, details on the contingency plans in the event seepage is greater than predicted. • Also, the response to Information Request T(3)-08 needs to describe the water quality monitoring measures to verify seepage effects on water quality over the life of the Project. It is expected the modeling results would suggest a concept for a monitoring program, program objectives and parameters. ***RECOMMENDATION:*** #7 The proponent response to Information Request T(3)-08 should clearly indicate which parts of the modeling report and the subsequent analysis are linked to each part of the response to T(3)-08.	• GRT will review the IR response package when available

PART C

Field Data Collection and Conceptual Model Development

TECHNICAL MEMORANDUM

DATE	October 6, 2016	**PROJECT No.**	1656263 (1000.1001)
TO	Sandra Pouliot, ing Canadian Malartic Corporation	**DOC No.**	004 (Rev 1)
CC	Karen Besemann, Adam Auckland, Ken DeVos (Golder)		
FROM	Devin Hannan, P.Eng.	**EMAIL**	dhannan@golder.com

HAMMOND REEF GOLD PROJECT: TAILINGS MANAGEMENT FACILITY HYDROGEOLOGICAL FIELD WORK AND CONCEPTUAL MODEL DEVELOPMENT

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to present Canadian Malartic Corporation (CMC) with this updated technical memorandum describing recent hydrogeological field work and conceptual groundwater model development pertaining to the proposed Hammond Reef Tailings Management Facility (TMF) site near Atikokan, Ontario (Figure 1). This document supersedes an earlier Golder memorandum of the same title dated September 21, 2016.

This memorandum builds upon technical correspondence between CMC, Golder and the joint government review team of Canadian Environmental Assessment Agency (CEAA), Environment and Climate Change Canada, and Natural Resources Canada (the Government Review Team or GRT). In particular, Golder seeks to address specific hydrogeology-related concerns communicated by the GRT in the following:

- *Information Request #3 from the Technical Review of the Responses to Information Request #2 for the Hammond Reef Gold Project Environmental Assessment, T3-08* (CEAA, January 29 2016).
- *Federal Comments on the June 15, 2016 Supplementary Memorandum on the Scope of Work for the 3D Groundwater Modeling for the Federal Environmental Assessment of the Hammond Reef Gold Project* with *Table of Federal Review Findings on the Proposed Scope of Work for the 3D Groundwater Modeling* (CEAA, July 29 2016).
- Teleconference between CMC, Golder and the GRT on September 27, 2016.

This memorandum is organized into four main sections:

1) **Field Data**. The results of a recent hydrogeology field campaign conducted in support of the model development are reviewed.

2) **Conceptual Model**. A conceptual basis for the eventual numerical groundwater model is presented, including a discussion of model domain, hydrologic boundaries, hydrostratigraphy, hydraulic conductivity, recharge, and flow patterns.

3) **Proposed Next Steps**. The groundwork for next steps in model development, including numerical model construction, calibration, TMF simulation and sensitivity analysis, is set forth.

4) **Review Comment Address**. Specific GRT written comments/questions are addressed using information in the above sections as a basis.

This memorandum provides an interim synopsis of work completed to-date on field data collection and baseline (pre-TMF) conceptual model development. Golder seeks the GRT's approval on the foundational work described herein prior to proceeding with numerical model construction and subsequent predictive scenarios.

2.0 FIELD DATA

Extensive hydrogeological field work has already been conducted at the TMF site as documented in *Hammond Reef Gold Project, Hydrogeology Technical Support Document* (Golder, 2013[1]). A compilation of Golder borehole logs is provided in Appendix A. Whereas these prior data provides an important foundation in the hydrogeological characterization of the site, the following subsections detail additional field data collected or analyzed in support of the current conceptual model development.

2.1 Condemnation Holes

A total of 64 condemnation hole logs (historic mining exploration holes) have been incorporated into the geologic dataset (Figure 1). Table 1 lists condemnation hole ID, easting, northing, and recorded overburden thickness. Most of the condemnation holes are positioned in a semi-uniform spaced grid at roughly 300 metre intervals across a large portion of the TMF, thus providing good coverage over the primary area of model interest. The logs list depth to overburden but do not describe specific overburden materials. The use of these logs as inputs in overburden mapping is further described in Section 3 Conceptual Model.

2.2 Surficial Geology Mapping

The geologic report *Surficial Geology update of the Golden Winner area: sedimentology and stratigraphy of glaciofluvial deposits and recommendations for recce sampling* (Stea, 2010) was reviewed and the data therein incorporated in this current work. Specifically, the surficial geology mapping (Figure 2) and geologic logging of the ten "trenches" (test pits) were incorporated into the overburden thickness and stratigraphic mapping of the current conceptual model. In particular, the surficial geology mapping supplements the pre-existing borehole data to characterize the shallow geology underlying the entirety of the TMF.

2.3 Hydraulic Response Testing and Analysis

A total of 10 hydraulic response (slug) tests were carried out during August 2016. Individual analysis sheets, including water level response curves and mathematical analysis, are included in Appendix B. Wells in the vicinity of the TMF were targeted to supplement the larger hydraulic conductivity dataset (Table 2).

2.3.1 Method

Tests were performed by quickly removing a volume of water from the monitoring well using a Waterra© Inertial Pump (a rising head method). The recovery to the static water level was monitored manually at frequent time intervals by measuring the depth to water using an electric water level meter. In select monitoring wells (BH12-1, BH12-2, BH12-3B, and BH12-7A) the recovery to the static water level was monitored using a data logger set to record in 30 second intervals. The data loggers were installed following a one to three hour period of manual measurement.

Testing could not be completed and/or fully analyzed at all target wells. During the testing in BH12-5A (screened in tonalite bedrock) and BH12-6A (screened in silt) the water level recovered quickly and could not be manually measured; this occurrence suggests a relatively high hydraulic conductivity adjacent to the screened interval.

Golder has assumed a relatively large hydraulic conductivity of 1E-4 m/s at these locations for the purposes of calculating a geometric mean of the larger dataset. BH12-8 was not tested as the static water level was only 0.5 metres above the base of the well. BH12-9 was found to be damaged and could not be tested.

2.3.2 Data Analysis

The Bouwer and Rice (1976) (Bouwer-Rice) solution was applied to the analysis of the tests. The Bouwer-Rice solution is a zero-storage solution that is applicable to both confined and unconfined aquifers with completely or partially penetrating wells, and can be used for tests in which the water level falls within the screened interval. Storage in the formation is neglected by fitting the solution to the linear portion of the data plotted in semi-log space.

The collected data is generally of good quality and no data points were removed from the analysis period. The initial displacement (i.e., the volume of water removed) was not measured during the tests, and the zero time represents the time of the first water level measurement in the recovery period. Although this method is not consistent with the instantaneous initial displacement assumption on which most analytical methods are based, the analysis employed is consistent with the Pandit and Miner (1986) translation method as recommended by Butler (1998) for non-instantaneous test initiation. The theoretical initial drawdown shown in the analysis sheets (Appendix A) is the point where the line of best fit through the data intercepts with the zero elapsed time line. Although this theoretical drawdown does not always match with the first measurement of drawdown, this match is not required for the analysis method chosen.

2.3.3 Results

Test results are summarized in Table 3. The following text discusses the results in the context of screened units, as this interpretation has bearing on hydraulic conductivity assignments in the conceptual model (Section 3).

Overburden: The hydraulic conductivity of the overburden materials was estimated to range from 3E-7 m/s to 1E-4 m/s. The hydraulic conductivity measured at BH12-6B (1E-5 m/s) is likely associated with fill materials, and may not be representative of natural overburden. It is noted that (with the exception of BH12-6B) the results for tests conducted in the silty or silty clay (fine-grained) units did not yield significantly lower hydraulic conductivities than sand and gravel (coarse-grained) units. It could be that the presence of silt layers within the clayey host are controlling lateral permeability around the screened interval. Meanwhile, drilling blow counts suggested that the sand and gravel material was very dense. It is worth noting; however, that in the context of the entire dataset (Table 2), a clearer distinction between the average hydraulic conductivity of fine (3E-7 m/s) and coarse grained units (1E-5 m/s) is present.

Bedrock: Based on the results of the hydraulic testing at BH12-1 and BH12-3A, the hydraulic conductivity of the fresh (competent) bedrock was estimated to range from 4E-8 m/s to 9E-7 m/s, whereas the single weathered bedrock test of this group, which had an immeasurably rapid response, is assumed to have a hydraulic conductivity of 1E-4 m/s.

3.0 CONCEPTUAL MODEL

A conceptual model synthesizes the available data into a description of the hydrogeologic system and thus serves as the foundation or guide for the subsequent numerical model construction. This section describes key conceptual model components including model domain, hydrologic boundaries, overburden thickness, hydrostratigraphic units, hydraulic conductivities, recharge and flow directions.

3.1 Model Domain and Hydrologic Boundaries

The proposed model domain is illustrated in Figure 1. The model area is somewhat centred on the TMF and is regional in scale (22 km^2). The perimeter is delineated based on major hydrologic boundaries including Sawbill Bay to the south and its associated tributary to the west, a large lake to the north and Lizard Lake to the east. These regional features are considered groundwater discharge zones and would be the eventual receptors of TMF seepage, should any seepage bypass the collection system. Elsewhere, the model perimeter is coincident with subwatershed boundaries or topographic highs. The water table is known to roughly follow topographic trends (Section 3.5); as such, these topographic highs are likely synonymous with groundwater flow divides. Internal to the model are several smaller lakes and streams; these are also considered local groundwater discharge zones.

3.2 Overburden Thickness

An overburden thickness map is inferred based on the combined information contained in consultant borehole logs, condemnation holes, and Stea (2010) trenches and surficial geology mapping (Figure 3). The geostatistical routine kriging is used to interpolate the overburden isopach over a uniform 20 m x 20 m grid. The interpolated thickness ranges from 0 m to 31 m with an average thickness of 5 m. As a check, a secondary grid is created using triangulation with linear interpolation. It is found that the two grids are typically within +/- 1 m of each other.

Several prominent "overburden troughs" exist throughout the model domain (Figure 3). It is important to note that the undulating bedrock relief will tend to isolate one trough from another ("pinch outs"). As such, an "aquifer" in one trough may not be hydraulically connected to another in an adjacent trough and potential seepage pathways through overburden could be limited by virtue of bedrock topography. Conversely, there are instances where overburden appears to be laterally continuous from underneath the TMF area to the external environment (for example, see the trough in the vicinity of BH13-4 in the southwest of the proposed TMF footprint).

Because of the preponderance of bedrock outcrops throughout the domain (Figure 2), potential overburden-filled bedrock valleys lacking data constraints may be obscured during the interpolation process. Thus, to overcome this issue, in areas where overburden is mapped as present at surface but no proximal thickness information exists, overburden is assumed to be a maximum of 10 m thick along the approximate centre of the presumed bedrock valley using "dummy points" (Figure 3). In the interest of conservatism, a focus is given towards promoting lateral continuity within the overburden, especially along the perimeter of the TMF. However, actual data points must be honoured and the use of dummy points is used with some restraint around areas with known overburden thicknesses. Approximately 850 dummy points are used as additional constraints in the interpolation process (Figure 3). The assumed value of 10 m is twice the observed average and represents the 85^{th} percentile of logged thicknesses. A result of this approach is that significant lateral continuity between some overburden deposits is established which may not exist in reality. As such, this assignment represents a conservative approach in the context of facilitating TMF seepage.

3.3 Hydrostratigraphy

The conceptual hydrostratigraphy is summarized in Table 4. Supporting discussion for the geologic layering, unit thickness and hydraulic conductivity assignments is provided in the following sub-sections.

3.3.1 Geologic Layering

Where overburden is present in significant quantities a "coarsening downwards" trend is typically observed in the borehole logs. For the conceptual model, we have adopted the following generalized geologic layering which acknowledges the major transitions in material types but is also structured to facilitate discrete hydraulic properties (from ground surface down):

1) Surficial Deposit Layer (peat/muck or sand/gravel as per Figure 2)

2) Fine-Grained Layer (predominately silt and/or clay)

3) Coarse-Grained Layer (predominately sand and/or gravel)

4) Weathered Bedrock Layer

5) Competent Bedrock Layer

An example of this layering is illustrated in cross-sections along the southwestern flank of the TMF (Figure 4).

3.3.2 Unit Thickness

The Surficial Deposit Layer is typically less than 3 m thick (see Golder, 2016, Table 1). However, for the purposes of the conceptual model we have assumed a uniform 3 m thickness across the model domain wherever overburden exists. This assignment is expected to provide a reasonably sufficient depth for the layer to remain largely saturated during numerical simulations and avoid model non-convergence. Using a value at the greater end of the thickness range further increases transmissivity and is thus conservative relative to promoting TMF seepage.

Below the initial Surficial Deposit Layer resides a Fine-Grained Layer and then a Coarse-Grained Layer. Fine-Grained Layer materials (silt and/or clay based) are ubiquitous in boreholes that have overburden thickness extend beyond 3 m in depth (21 of 25 boreholes in or around the model domain). Whereas the Stea (2010) trenching indicate a general absence of finer-grained materials at their respective locations, these test pits are relatively shallow and terminate on bedrock at depths of about 1.5 m to 4.9 m and are thus considered reflective of the aforementioned Surficial Layer. The transition from fine- to coarse-grained material types is often gradual and varies widely from log to log. Furthermore, a continuous, seamless layering of these units is not possible because so much of the overburden is isolated within discrete troughs bounded by rock. Nonetheless, we note that basal coarse-grained materials typically comprise less than 50% of a given overburden sequence. Thus, for the conceptual model, in the interest of simplicity and conservatism, we assume that the Coarse- Grained and Fine-Grained Layers have equally proportional thicknesses (Figure 4). For example, if a given overburden section is 10 m thick, 3 m would be allocated to the Surficial Layer whereas 3.5 m would be allocated to the Fine-Grained Layer and 3.5 m to the Coarse-Grained Layer.

A mix of fresh or weathered conditions is observed within shallow bedrock. Where present, the depth of weathering averages approximately 3 m (Table 5). Again, for the sake of simplicity and conservatism, we have assumed that weathered bedrock is prevalent everywhere within the model domain at a uniform 3 m thickness (Figure 4). The underlying competent rock is assumed to extend to the bottom of the model (to be determined during the numerical model construction, but likely 50 m or more thick).

3.3.3 Hydraulic Conductivity

Hydraulic conductivity (K) is correlated to geologic unit and is assigned in accordance with the geometric mean of that unit's respective hydraulic conductivity dataset (Table 2 and Table 4). As such the Surficial Deposit K = 1E-5 m/s, Fine-Grained K = 3E-7 m/s, Coarse-Grained K = 1E-5 m/s, Weathered Bedrock K = 2E-6 m/s, and Competent Rock K = 2E-7 m/s. (Note: the Surficial Deposit data is based on testing of the first major unit within the upper 3 m of soil).

Almost all material hydraulic conductivities are assumed to be isotropic (K_H:K_V = 1:1); this assignment will tend to promote vertical seepage from the TMF relative to an anisotropy that reduces vertical hydraulic conductivity. The one exception is specific portions of the Fine-Grained layer: wherever deposits of overburden are on the order of 10 m or greater a significant clay presence is logged within the Fine-Grained strata (Golder, 2016). This clay will likely have some influence on vertical permeability and lead to anisotropy. We propose to make the ratio of horizontal to vertical hydraulic conductivity in the Fine-Grained layer K_H:K_V = 1:0.1, except where overburden thins to less than 10 m, whereupon the layer will become isotropic. The effect of the applied anisotropy on TMF seepage will be examined during a sensitivity analysis (Section 4).

Note that the hydraulic conductivities introduced herein are an initial base-case estimate. The final hydraulic conductivity inputs used in the numerical model, while expected to be close to those listed in Table 4, will be refined through the model calibration process and tested in a sensitivity analysis (Section 4).

3.4 Recharge

We have consulted literature sources to provide a conceptual basis for recharge rates. Singer and Cheng (2002) calculate annual bulk groundwater recharge to six major river basins in northern Ontario as being less than 100 mm/yr; this relatively low rate is a function of climate, topography, vertical soil/fracture permeability and soil moisture conditions particular to the northern environment. However, estimated recharge rates for discrete zones can vary according to surficial geology types (Table 6).

The mapped surficial materials are divided into four groupings (Figure 2): 1) bedrock; 2) sand and gravel; 3) till veneer; or 4) peat / muck. At this stage in model development, we propose to *initially* assign recharge rates in according to mapped surficial materials (Figure 2) in concert with Table 3 as follows: bedrock = 5 mm/yr, till veneer = 25 mm/yr, sand and gravel = 300 mm/yr and peat / muck = 5 mm/yr. Some refinement of recharge rate inputs will occur during the calibration stage (Section 4). Ultimately, however, we expect the total recharge rate over the model domain to be less than 100 mm/yr.

3.5 Groundwater Levels

3.5.1 Depth to Water

There are 21 monitoring wells in the vicinity of the model domain (Figure 5). Based on a review of water levels at shallow wells within this group (Golder, 2013[1] and measurements taken thereafter) the depth to water table ranges from 0 m to 4.4 m with most water levels being within 1.5 m of ground surface. These relatively shallow water table depths are partly indicative of many of the wells being located in valley areas or close to discharge features, where groundwater would be expected to be close to ground surface.

3.5.2 Flow Directions

An inferred water table map (Figure 5) is developed using average water levels in shallow wells and surface water elevations taken from the topographic DEM (Figure 1). Where water level data exists, it is observed that groundwater flow patterns roughly mimic topographic trends; that is, groundwater highs coincide with ridges or hills whereas groundwater lows coincide with valley areas. However, this pattern is not shown everywhere throughout the model domain in part because several of the hilly areas do not have a groundwater level measurement to constrain (i.e. likely raise) the water table locally around them. Overall, there is a general regional trend of southwesterly flow towards Sawbill Bay or southeasterly flow towards Lizard Lake with localized divides occurring within the model domain.

In terms of vertical gradients, at nested locations the majority of well pairs exhibit an upward flow. This correlates to the position of many of the wells in low-lying valley areas and/or close to groundwater discharge zones, where groundwater upwelling is to be expected.

3.6 Assumptions

A summary of key assumptions employed in the development of the conceptual model is as follows:

- The groundwater flow system may be modelled on a steady-state basis considering average conditions.
- Lakes, streams and wetlands are considered potential discharge zones.
- Groundwater divides are approximately coincident with topographic highs.
- Groundwater flow, including that in the bedrock system, may be simulated as an equivalent porous medium (EPM). In this setting, groundwater flow is a function of the hydraulic gradient and the hydraulic conductivity of the medium. This assumption also implies that the hydraulic response in the overburden may be transmitted to the underlying bedrock and vice versa. An EPM assumption is deemed sufficient for characterizing groundwater flow at the scale of this analysis.
- Overburden is assumed to be a maximum of 10 m thick in areas where overburden is mapped as present at surface but no proximal thickness information exists to fully characterize the area.
- Bedrock surface is weathered at a uniform thickness of 3 m across the model domain.
- Below a 3 m layer of surficial material. For a given overburden section of significant thickness, a 3 m layer of surficial deposit layer exists followed by a fine-grained layer and coarse-grained layer, the latter two having equally proportional thicknesses.

4.0 NEXT STEPS

Provided the conceptual model detailed herein is acceptable to the GRT, the following next steps are proposed:

1. Numerical Model Construction and Calibration:
   a. A MODFLOW groundwater model will be constructed using the conceptual model outlined herein as the basis.
   b. The model will be calibrated using steady-state, average conditions. Calibration targets will include the average water level recorded at wells within the model domain and the flow patterns as inferred in Section 3.5.
   c. A sensitivity analysis will be performed to assess the influence of hydraulic conductivity and recharge inputs on the calibration result. Through this work an “optimal” base case set of parameters will be finalized.
   d. A technical memorandum summarizing the above will be provided for the GRT’s interim review prior to initiating the next step in modelling (Simulation of TMF). In addition, a more detailed description of proposed next steps in the Simulation of TMF (below) will be provided.

2. Simulation of TMF:
   a. The TMF will be implemented within the numerical model framework for all project phases (operation, closure and post-closure) including the application of conceptual design details of seepage collection system (location, typical dimensions, materials/apparatus, operating parameters, etc.).

b. Seepage quantities and environmental fate will be evaluated using zone budgeting and particle tracking in MODFLOW. This analysis will provide a base case estimate of capture efficiency, potential seepage bypass rates and the amount of discharge reporting to discrete receptors external to the TMF (for example, Lizard Lake, Sawbill Bay, etc.).
c. A sensitivity analysis will be performed to assess the potential upper and lower bounds of seepage / rates and bypass by targeting key parameters within the model and adjusting them within a reasonable range of values.
d. A technical memorandum summarizing the above will be provided for the GRT's review.

5.0 REVIEW COMMENT ADDRESS

The following lists and provides initial address to outstanding GRT comments. Note that this address is not a final response to GRT comments but rather seeks to describe how the ongoing modelling work will serve to eventually resolve these issues.

5.1 Information Request #3

From *Information Request #3 from the Technical Review of the Responses to Information Request #2 for the Hammond Reef Gold Project Environmental Assessment, T3-08 (CEAA, January 29 2016)*:

1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint.

> **Response:** We first ask the reader to consider the new information conveyed in Section 2 and Section 3 of this memorandum. With reference to these sections:
>
> Subsequent to GRT providing this comment in January 2016, Golder has supplemented the already substantial historic dataset (Golder, 2013[1]) with the inclusion of detailed surficial geology mapping covering the entirety of the TMF footprint, 64 condemnation boreholes, and 10 additional single-well response tests in overburden and bedrock units. In areas where data may be considered relatively limited, the conceptual model has employed conservative assumptions for unit thicknesses, hydraulic conductivity and anisotropy that will tend to promote tailings seepage. Furthermore, uncertainty in model parameters and their effect on TMF seepage will be tested during model sensitivity analysis. As such, Golder feels the approach to characterizing hydrogeologic conditions within the TMF footprint is adequate and additional drilling and hydraulic testing are not necessary.

2. *If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7.*

> **Response:** We acknowledge that materials at the base of the TMF may include permeable units and these are considered in the conceptual model (refer to Section 2 and Section 3).

3. *Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint.*

Response: See Golder response to comment #1.

4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model.

Response: The entire TMF and regional surrounds will be included in a 3D numerical groundwater model (refer to Section 3 and Section 4).

5. Re-run the 3D model based on the following:

a) Perform a more robust calibration using additional monitoring well data;

b) Presenting a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions;

c) Model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment);

d) As described in 2., include information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and to determine if the assumption Khorizontal:Kvertical = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the Khorizontal:Kvertical relationship; and

e) Provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity.

Response: A conceptual model has been provided in this memorandum (refer to Section 3). The forthcoming numerical model will be calibrated to monitoring well data to form the “baseline” or “pre-TMF” condition (Section 4). All subsequent project phases, including TMF operation, closure and post-closure, will be simulated thereafter (Section 4). Sensitivity analyses will be conducted for both calibration and predictive (TMF in-place) scenarios (Section 4). In terms of the request for additional monitoring wells and hydraulic testing please refer to Golder’s response to Comment #1.

6. Provide the methodology, analysis and model results.

Response: Subsequent to GRT’s review and approval of the information contained within this conceptual model memorandum, Golder will undertake the next phase of modelling – namely base case (pre-TMF) numerical model construction and calibration. An interim numerical model construction and calibration memorandum will be provided for the GRT’s review and will describe implementation of the conceptual model (Section 3) into the MODFLOW framework, including approach, assumptions, boundary conditions, layer structure, hydraulic inputs, calibration results, flow budget and head outputs and sensitivity analysis.

Subsequent to the numerical model construction and calibration memorandum’s approval, the TMF in-place predictive scenarios will be undertaken and a final memorandum will be submitted documenting, amongst other information, implementation of the TMF phases and seepage collection system within the model framework and simulated seepage rates and pathways for both base case and sensitivity analysis scenarios.

7. Based on the results from question 1-6 above, provide a detailed description of the mitigation measures proposed to intercept seepage and contingency plans in the event seepage beneath the TMF would be greater than predicted.

Response: Mitigation measures and contingency plans will be described within the final memorandum described in Golder's response to Comment #6.

8. Describe the residual effects on water quality; the significance of those residual effects based on the Agency's methodology for assessing significance (including the criteria of magnitude, geographic extent, duration, frequency, reversibility, ecological/social/cultural context); and the follow-up program, including any monitoring measures, which will be implemented to evaluate the predictions of effects and the effectiveness of the proposed mitigation.

Response: The hydrodynamic mixing models (i.e., box models) of Upper Marmion Reservoir and Lizard Lake (see Lake Water Quality TSD) will be updated to include the predicted seepage bypass discharge. TMF Reclaim Pond water quality will be assigned to the seepage bypass to assess the potential residual effects of TMF seepage on water quality in the receiving water bodies. Water quality effects on smaller receiving water bodies upstream of Upper Marmion Reservoir and Lizard Lake or to the north of the TMF will also be assessed. The significance of the residual effects will be described based on the Agency's methodology for assessing significance. Monitoring measures will be described as required to evaluate the predictions of effects and the effectiveness of the proposed mitigation. The results of this effects assessment will be summarized in a technical memorandum that will be provided to the GRT in response to this comment.

5.2 Table of Federal Review Findings

The following addresses *Federal Comments on the June 15, 2016 Supplementary Memorandum on the Scope of Work for the 3D Groundwater Modeling for the Federal Environmental Assessment of the Hammond Reef Gold Project* (CEAA, July 29 2016), specifically the unresolved recommendations listed in *Table of Federal Review Findings on the Proposed Scope of Work for the 3D Groundwater Modeling*.

1. Prior to executing any model runs, the proponent should provide the Government Review Team (GRT) a written submission on the model assumptions and inputs to verify that the proposed approach is reasonable to the GRT.

Response: This current memorandum describes conceptual model development, including key assumptions (refer to Section 3 of this memorandum).

2. The stratigraphy in the groundwater model should be based on a conceptual geological model that incorporates both the existing stratigraphy as presented in the Technical Memo and the sedimentological and mapping results by Stea (2010). The possibility that coarse sediment in filled valleys may be pathways for flow under the TMF should be assessed in the modelling.

Response: The current model stratigraphy considers consultant logs, condemnation holes, and the sedimentological and mapping results documented by Stea (2010) (refer to Section 2 and Section 3). A result of this work is that coarse sediment in filled bedrock valleys (Coarse-Grained Layer) are present in the model.

3. The groundwater model should include separate model layers for distinct hydrostratigraphic units where these may be important to the interpretation of groundwater flow (e.g., filled valleys and beneath the TMF dams).

Response: The model considers the main hydrostratigraphic units in the area including surficial deposit, fine-grained deposit, coarse-grained deposit, weathered bedrock and competent bedrock layers (Section 3). The Coarse-Grained Layer is present in filled bedrock valleys.

4. The groundwater model should include areas where the tailings are in direct contact with the bedrock (e.g., current bedrock ridges) where sediment is thin or absent. This could be a direct pathway for water to flow from the tailings to more permeable units beneath the silt and clay layer.

Response: The model will include the entirety of the TMF, including areas where it is in direct contact with bedrock (Section 2 and Section 3).

5. The preference would be to ensure that each hydrostratigraphic unit is adequately sampled for hydraulic conductivity using field measurements. In the absence of adequate field hydraulic conductivity data for any particular hydrostratigraphic unit, conservative estimates of hydraulic conductivity should be assumed in the groundwater model (i.e. that would tend to favor seepage).

Response: Sufficient hydraulic testing and/or grain size data has been collected to characterize the hydraulic conductivity of surficial deposit, fine-grained (silts and clays), coarse-grained (sands and gravels), weathered bedrock and competent bedrock units (Table 2); the respective geometric mean of measured hydraulic conductivities for each of these units is applied in the model (Section 3). Shallow soils (surficial deposit) as mapped in Stea (2010) are assigned an isotropic hydraulic conductivity of 1E-5 m/s; this relatively high permeability would tend to favour seepage (Section 3).

6. The groundwater model should consider whether the seepage collection system will perform adequately in the presence of possible layering of low hydraulic conductivity silt and clay with higher hydraulic conductivity sand and gravel beneath portions of the seepage collection system.

Response: The current conceptual model (Section 3) allows for this possibility. The performance of the collection system will be assessed in subsequent work (Section 4).

7. The proponent response to Information Request T(3)-08 should clearly indicate which parts of the modeling report and the subsequent analysis are linked to each part of the response to T(3)-08.

Response: Acknowledged. Note that the above comment address is not a final response to GRT comments but rather describe how the ongoing modelling work will serve to eventually resolve these issues. A final response, including clear linkages to the T(3)08 document, will be provided when the modelling analysis is completed.

6.0 CLOSURE

We thank CMC for retaining Golder on this project and look forward to the GRT's review of this current work. If you have any questions, please do not hesitate to contact the undersigned.

Adam Auckland
Project Manager

Devin Hannan, P.Eng.
Associate, Environmental Engineer

DH/KB/AA/sk

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Attachments:
Table 1: Condemnation Holes
Table 2: Hydraulic Conductivity Data Summary
Table 3: Recent Slug Test Summary
Table 4: Hydrostratigraphic Unit Summary
Table 5: Bedrock Weathering Depth

Table 6: Recharge Rates (Singer and Cheng, 2002)
Figure 1: Study Area and Model Domain
Figure 2: Surficial Geology (STEA, 2010)
Figure 3: Inferred Overburden Thickness
Figure 4: Cross-Section 1 (NW to SE)
Figure 5: Inferred Shallow Groundwater Elevation
Appendix A: Borehole Logs
Appendix B: Hydraulic Response Testing

TABLES

Table 1: Condemnation Holes

ID	Easting NAD83	Northing NAD83	Overburden Thickness (m)
BCN-069	617,676	5,428,031	0.6
BCN-070	617,677	5,427,754	10.2
BCN-071	617,673	5,427,444	5.6
BCN-072	617,975	5,427,472	1.1
BCN-073	617,983	5,427,156	10.1
BCN-074	618,280	5,427,155	6.1
BCN-075	618,268	5,427,455	0.6
BCN-076	618,268	5,427,753	1.9
BCN-077	617,976	5,427,747	1.2
BCN-078	617,678	5,427,155	1.4
BCN-079	618,282	5,426,853	19.3
BCN-080	618,279	5,426,563	11.8
BCN-081	618,570	5,426,528	1.1
BCN-082	618,583	5,426,858	3.6
BCN-083	618,880	5,426,857	2.4
BCN-084	618,875	5,426,559	0.8
BCN-085	619,178	5,426,553	0.6
BCN-086	619,177	5,426,850	0.9
BCN-087	618,880	5,427,160	0.8
BCN-088	618,575	5,427,152	6.3
BCN-089	619,178	5,427,151	1.8
BCN-090	619,480	5,426,859	1.6
BCN-091	619,213	5,427,419	1.4
BCN-092	619,474	5,427,458	4.4
BCN-093	618,569	5,427,463	0.5
BCN-094	618,875	5,427,450	0.6
BCN-095	618,872	5,427,754	1.1
BCN-096	618,605	5,427,779	6.0
BCN-097	618,581	5,428,068	19.7
BCN-098	618,876	5,428,058	1.2
BCN-099	618,575	5,428,361	4.7
BCN-100	618,281	5,428,351	8.0
BCN-101	617,972	5,428,052	25.0
BCN-102	618,299	5,428,041	3.8
BCN-103	618,287	5,428,651	2.8
BCN-104	618,592	5,428,591	3.3

ID	Easting NAD83	Northing NAD83	Overburden Thickness (m)
BCN-105	618,616	5,428,955	1.9
BCN-106	618,865	5,428,665	5.4
BCN-107	618,960	5,428,863	0.9
BCN-108	619,183	5,428,950	2.1
BCN-109	619,178	5,429,255	1.7
BCN-110	619,431	5,428,886	3.1
BCN-111	619,472	5,428,657	5.8
BCN-112	619,198	5,428,618	1.8
BCN-113	619,487	5,428,367	3.0
BCN-114	619,193	5,428,343	2.4
BCN-115	618,965	5,428,354	0.9
BCN-116	619,464	5,428,056	2.0
BCN-117	618,494	5,425,134	1.4
BCN-118	619,484	5,427,753	4.6
BCN-119	619,284	5,427,726	0.6
BCN-120	619,800	5,428,060	4.7
BCN-121	620,082	5,428,059	30.6
BCN-125	619,776	5,427,754	3.0
BCN-126	619,765	5,427,451	4.2
BCN-129	620,382	5,427,148	9.8
BCN-130	620,100	5,427,153	1.2
BCN-131	619,783	5,427,149	2.4
BCN-132	619,476	5,427,149	24.3
BCN-135	619,775	5,426,855	12.8
BCN-136	620,075	5,426,855	0.5
BCN-148	617,967	5,425,351	2.7
BCN-149	618,273	5,425,369	5.8
BCN-152	618,275	5,425,056	3.4

TABLE 2: HYDRAULIC CONDUCTIVITY DATA SUMMARY

Borehole ID	Site Area	Easting NAD83	Northing NAD83	Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Screen Interval or Sample Depth (mbgs)	Depth to Rock (mbgs)	Material Description Summary (refer to borehole logs for full description)	Test Method	Conceptual Model Unit Classification	K (m/s)
BH12-10	TMF	617,850	5,425,008	433.1	3.15	1.52-3.05	3.2	Silty Sand	Slug Test	1. Surficial	6.E-06
BH12-6B	TMF	616,523	5,426,942	416.2	3.35	1.52-3.05	9.9	Silty Sand (fill)	Slug Test	1. Surficial	1.E-05
BRH-0012B	Mine	615,588	5,422,185	416.9	5.70	1.5-2.4	3.4	Gravelly Sand, Some Clay, Trace Silt	Slug Test	1. Surficial	1.E-05
BRH-0016B	Mine	618,407	5,425,303	444.8	1.52	0.8-1.5	1.5	Sandy, Clayey Silt	Slug Test	1. Surficial	7.E-06
BRH-0023	TMF	619,973	5,429,127	434.9	3.60	1.8-3.4	3.6	Sand and Gravel	Slug Test	1. Surficial	7.E-06
BRH-0034B	Mine	621,906	5,424,427	444.4	2.70	1.5-3.0	4.6	Peat	Slug Test	1. Surficial	3.E-06
BH12-1	TMF	617,568	5,428,261	436.8	4.19	0.10-0.61	1.2	Silt and Sand	Grain Size	1. Surficial	(2E-8)
BH12-2	TMF	617,830	5,426,870	418.4	18.29	2.29-2.74	15.1	Sandy Silt	Grain Size	1. Surficial	2.E-06
BH12-5	TMF	620,391	5,428,975	433.0	10.69	2.29-2.74	7.8	Silty Sand	Grain Size	1. Surficial	2.E-03
BH12-6	TMF	616,523	5,426,941	416.2	9.91	2.29-2.74	9.9	Silty Sand	Grain Size	1. Surficial	5.E-06
BRH-0012A	Mine	615,588	5,422,185	416.9	5.70	1.5-2.1	3.4	Gravelly Sand, Some Clay, Trace Silt	Grain Size	1. Surficial	1.E-05
BRH-0013	Mine	615,631	5,422,933	416.6	4.37	0.8-1.3	1.3	Gravelly Sand, Some Clay, Trace Silt	Grain Size	1. Surficial	5.E-05
BRH-0016A	Mine	618,407	5,425,303	444.8	5.73	0.8-1.4	1.5	Gravelly, Silty Sand, Some Clay	Grain Size	1. Surficial	1.E-05
BRH-0018	TMF	620,794	5,427,311	430.6	8.69	0-0.6	1.8	Clayey Sand and Silt	Grain Size	1. Surficial	(7E-7)
BRH-0023	TMF	619,973	5,429,127	434.9	3.58	1.8-3.4	3.6	Sand and Gravel, Some Clay, Trace Silt	Grain Size	1. Surficial	3.E-05
BRH-0023	TMF	619,973	5,429,127	434.9	3.60	1.5-2.1	3.6	Silt and Sand	Grain Size	1. Surficial	3.E-05
BRH-0026	TMF	620,607	5,431,227	460.9	8.70	0.7-1.3	1.5	Sand and Gravel	Grain Size	1. Surficial	9.E-06
BRH-0027	TMF	619,614	5,425,831	434.8	2.36	0.8-2.4	2.4	Silty Sand, Some Gravel, Some Clay	Grain Size	1. Surficial	1.E-05
BRH-0029A	Mine	619,343	5,420,385	387.1	11.90	1.5-2.1	5.6	Gravelly Sand	Grain Size	1. Surficial	4.E-06
										Surficial Geomean:	**1.E-05**
BH12-3B	TMF	618,259	5,426,406	419.7	11.58	10.06-11.58	13.4	Silt	Slug Test	2. Fine-Grained	7.E-07
BH12-6A	TMF	616,523	5,426,941	416.2	9.91	8.38-9.91	9.9	Silt	Slug Test	2. Fine-Grained	*1.E-04*
BH12-7A	TMF	616,444	5,426,813	415.8	8.08	5.79-7.31	8.1	Silt / Gravel and Sand	Slug Test	2. Fine-Grained	3.E-07
BH12-7B	TMF	616,444	5,426,814	415.8	4.00	2.13-3.66	8.1	Silty Clay	Slug Test	2. Fine-Grained	2.E-06
BRH-0005B	Mine	612,361	5,421,894	441.8	8.53	7.0-8.5	0.9	Cobbles and Clay	Slug Test	2. Fine-Grained	8.E-07
BRH-0015B	Mine	617,875	5,423,186	417.3	5.50	4.0-5.8	5.8	Clay, Some Silt	Slug Test	2. Fine-Grained	7.E-07
BRH-0028B	Mine	618,741	5,421,296	383.6	3.60	2.1-3.7	3.8	Silty Clay, Trace Gravel	Slug Test	2. Fine-Grained	1.E-06
BRH-0030B	Mine	620,493	5,420,832	415.8	3.00	1.5-3.0	3.3	Silt, Trace Clay	Slug Test	2. Fine-Grained	6.E-06
BRH-0032B	Mine	620,345	5,423,914	427.9	3.50	2.3-3.7	4.0	Silty Clay, Some Sand	Slug Test	2. Fine-Grained	3.E-06
BH12-2	TMF	617,830	5,426,870	418.4	18.29	10.66-11.12	15.1	Silt	Grain Size	2. Fine-Grained	6.E-08
BH12-3	TMF	618,260	5,426,405	419.7	16.46	3.10-3.51	13.4	Silt	Grain Size	2. Fine-Grained	3.E-08
BH12-3	TMF	618,260	5,426,405	419.7	16.46	2.29-2.74	13.4	Silt	Grain Size	2. Fine-Grained	1.E-07
BH12-3	TMF	618,260	5,426,405	419.7	16.46	1.52-1.98	13.4	Silt and Sand	Grain Size	2. Fine-Grained	7.E-07
BH12-3	TMF	618,260	5,426,405	419.7	16.46	9.14-9.60	13.4	Silt	Grain Size	2. Fine-Grained	2.E-08
BH12-3	TMF	618,260	5,426,405	419.7	16.46	12.19-12.65	13.4	Silt and Sand	Grain Size	2. Fine-Grained	4.E-08
BH12-6	TMF	616,523	5,426,941	416.2	9.91	3.05-3.35	9.9	Silt	Grain Size	2. Fine-Grained	1.E-07
BH12-6	TMF	616,523	5,426,941	416.2	9.91	9.14-9.60	9.9	Silt	Grain Size	2. Fine-Grained	4.E-08
BH12-7	TMF	616,444	5,426,813	415.8	8.08	4.57-5.03	8.1	Silt	Grain Size	2. Fine-Grained	6.E-08
BH12-8	TMF	616,371	5,427,060	418.5	4.42	2.29-2.74	4.4	Silt	Grain Size	2. Fine-Grained	3.E-07
BH12-9	Mine	616,268	5,422,990	383.1	9.22	3.05-3.51	9.2	Clayey Silt	Grain Size	2. Fine-Grained	3.E-08
BH12-9	Mine	616,268	5,422,990	383.1	9.22	1.52-1.98	9.2	Silt	Grain Size	2. Fine-Grained	7.E-08
BH12-9	Mine	616,268	5,422,990	383.1	9.22	4.57-5.03	9.2	Clayey Silt	Grain Size	2. Fine-Grained	2.E-08
BH13-2	TMF	620,519	5,427,627	431.1	5.49	2.3-2.9	5.5	Silt	Grain Size	2. Fine-Grained	1.E-06
BH13-3	TMF	620,205	5,426,739	427.0	13.26	9.9-10.5	13.3	Silt	Grain Size	2. Fine-Grained	6.E-07
BH13-3	TMF	620,205	5,426,739	427.0	13.26	5.5-5.9	13.3	Silty Clay	Grain Size	2. Fine-Grained	3.E-08
BH13-4	TMF	618,128	5,426,804	418.5	17.68	0.8-1.4	17.7	Sandy Silt	Grain Size	2. Fine-Grained	5.E-08
BH13-4	TMF	618,128	5,426,804	418.5	17.68	6.1-6.7	17.7	Sandy Silt	Grain Size	2. Fine-Grained	2.E-06
BH13-4	TMF	618,128	5,426,804	418.5	17.68	4.6-5.2	17.7	Silt	Grain Size	2. Fine-Grained	9.E-08
BRH-0021	TMF	617,175	5,427,168	420.4	5.90	1.6-2.1	3.0	Sandy, Clayey Silt	Grain Size	2. Fine-Grained	4.E-07
										Fine-Grained Geomean:	**3.E-07**
BH12-2	TMF	617,830	5,426,870	418.4	18.29	13.11-14.63	15.1	Silty Sand and Gravel	Slug Test	3. Coarse-Grained	6.E-07
BH12-4	TMF	619,918	5,426,313	428.8	10.16	5.49-7.01	7.0	Silt / Silty Sand	Slug Test	3. Coarse-Grained	2.E-06
BH12-5B	TMF	620,390	5,428,976	433.0	6.50	5.33-6.86	7.8	Sand	Slug Test	3. Coarse-Grained	6.E-06
BRH-0014B	Mine	617,147	5,422,218	416.9	4.88	3.4-4.9	5.1	Silty Sand, Some Gravel	Slug Test	3. Coarse-Grained	6.E-07
BRH-0019	TMF	617,958	5,426,576	430.6	8.41	5.0-8.0	8.4	Silty Clay	Slug Test	3. Coarse-Grained	6.E-06
BRH-0020A	TMF	617,958	5,426,576	416.5	28.86	26.3-28.9	25.6	Sand	Slug Test	3. Coarse-Grained	*1.E-04*
BRH-0029B	Mine	619,343	5,420,385	387.1	5.60	2.6-5.6	5.6	Gravelly Sand, Some Silt	Slug Test	3. Coarse-Grained	1.E-06
BRH-0033	Mine	621,181	5,423,647	440.2	7.30	3.0-6.1	7.3	Coarse Sand, Some Clay	Slug Test	3. Coarse-Grained	8.E-06
BH12-4	TMF	619,918	5,426,313	428.8	10.16	6.10-6.55	7.0	Silty Sand	Grain Size	3. Coarse-Grained	2.E-03
BH12-5	TMF	620,391	5,428,975	433.0	10.69	3.35-3.51	7.8	Silty Sand	Grain Size	3. Coarse-Grained	2.E-06
BH12-5	TMF	620,391	5,428,975	433.0	10.69	7.62-7.75	7.8	Gravelly Silty Sand	Grain Size	3. Coarse-Grained	6.E-06
BH12-5	TMF	620,391	5,428,975	433.0	10.69	6.10-6.55	7.8	Sand	Grain Size	3. Coarse-Grained	1.E-04
BH12-7	TMF	616,444	5,426,813	415.8	8.08	7.62-8.08	8.1	Sand and Gravel	Grain Size	3. Coarse-Grained	3.E-05
BH12-9	Mine	616,268	5,422,990	383.1	9.22	9.14-9.22	9.2	Gravelly Silty Sand	Grain Size	3. Coarse-Grained	6.E-06
BH13-1	TMF	620,562	5,428,046	431.0	7.01	3.0-3.6	7.0	Silty Sand	Grain Size	3. Coarse-Grained	6.E-06
BH13-4	TMF	618,128	5,426,804	418.5	17.68	N/A	17.7	Sand	Grain Size	3. Coarse-Grained	9.E-05
BH13-4	TMF	618,128	5,426,804	418.5	17.68	N/A	17.7	Sand	Grain Size	3. Coarse-Grained	4.E-05
BRH-0014	Mine	617,147	5,422,218	416.9	8.78	4.6-5.1	5.1	Sand and Gravel, Some Clay, Trace Silt	Grain Size	3. Coarse-Grained	2.E-05
BRH-0017	TMF	619,624	5,425,289	427.7	7.16	5.6-7.2	3.1	Sand, Some Silt, Some Clay, Trace Gravel	Grain Size	3. Coarse-Grained	2.E-06
BRH-0023	TMF	619,973	5,429,127	434.9	3.60	3.1-3.5	3.6	Gravelly Sand, Some Silt, Trace Clay	Grain Size	3. Coarse-Grained	5.E-05
BRH-0029A	Mine	619,343	5,420,385	387.1	11.90	3.8-4.4	5.6	Gravelly Sand	Grain Size	3. Coarse-Grained	3.E-05
BRH-0029A	Mine	619,343	5,420,385	387.1	11.90	5.3-5.6	5.6	Sand Some Gravel	Grain Size	3. Coarse-Grained	2.E-04
BRH-0029A	Mine	619,343	5,420,385	387.1	11.90	8.8-11.9	5.6	Gravelly Sand, Some Silt, Some Clay	Grain Size	3. Coarse-Grained	1.E-05
BRH-0032A	Mine	620,345	5,423,914	424.0	7.30	5.7-7.3	4.0	Gravelly Sand, Some Clay, Trace Silt	Grain Size	3. Coarse-Grained	5.E-05
BRH-0033	Mine	621,181	5,423,647	440.2	7.30	3.8-4.4	7.3	Sand, Trace Gravel, Trace Silt, Trace Clay	Grain Size	3. Coarse-Grained	1.E-04
BRH-0033	Mine	621,181	5,423,647	440.2	7.30	3.0-6.1	4.0	Sand, Some Clay, Trace Silt, Trace Gravel	Grain Size	3. Coarse-Grained	6.E-05
BRH-0034A	Mine	621,906	5,424,427	439.7	7.30	4.3-4.6	4.6	Gravelly Sand, Some Silt, Some Clay	Grain Size	3. Coarse-Grained	3.E-06
										Coarse-Grained Geomean:	**1.E-05**
BH12-3A	TMF	618,260	5,426,405	419.7	16.46	14.93-16.46	13.4	Bedrock	Slug Test	4. Weathered Bedrock	9.E-07
BH12-5A	TMF	620,391	5,428,975	433.0	10.69	9.14-10.67	7.8	Bedrock	Slug Test	4. Weathered Bedrock	*1.E-04*
BRH-0001B	Mine	611,909	5,421,761	429.1	7.16	4.1-7.2	0.0	Bedrock	Slug Test	4. Weathered Bedrock	3.E-08
BRH-0002B	Mine	612,177	5,420,589	422.6	5.78	4.2-5.7	1.2	Bedrock	Slug Test	5. Competent Bedrock	5.E-06
BRH-0003	Mine	612,744	5,421,086	420.6	5.89	4.4-5.9	0.0	Bedrock	Slug Test	4. Weathered Bedrock	1.E-07
BRH-0004	Mine	613,473	5,421,807	429.6	4.27	2.6-4.1	0.0	Bedrock	Slug Test	4. Weathered Bedrock	3.E-07
BRH-0006	Mine	613,857	5,422,544	417.0	3.88	2.1-3.6	0.9	Bedrock	Slug Test	4. Weathered Bedrock	3.E-07
BRH-0007A	Mine	614,656	5,420,825	427.1	18.44	16.9-18.4	0.7	Bedrock	Slug Test	4. Weathered Bedrock	2.E-06
BRH-0007B	Mine	614,656	5,420,826	427.0	6.86	5.3-6.8	0.7	Bedrock	Slug Test	4. Weathered Bedrock	1.E-06
BRH-0008B	Mine	611,682	5,421,026	420.6	5.74	3.8-5.7	0.5	Bedrock	Slug Test	4. Weathered Bedrock	(4E-9)
BRH-0009	Mine	613,878	5,421,290	416.3	7.77	6.1-7.6	2.7	Bedrock	Slug Test	4. Weathered Bedrock	2.E-05
BRH-0010	Mine	615,227	5,423,654	436.1	2.67	0.7-2.7	0.0	Bedrock	Slug Test	4. Weathered Bedrock	6.E-07
BRH-0011	Mine	615,105	5,421,919	434.2	5.64	3.6-5.5	1.1	Bedrock	Slug Test	4. Weathered Bedrock	3.E-07
BRH-0012A	Mine	615,588	5,422,185	416.9	5.70	4.1-5.7	3.4	Bedrock	Slug Test	4. Weathered Bedrock	3.E-05
BRH-0013	Mine	615,631	5,422,933	416.6	4.37	2.7-4.3	1.3	Bedrock	Slug Test	4. Weathered Bedrock	2.E-07
BRH-0014A	Mine	617,147	5,422,218	416.9	8.78	7.3-8.8	5.1	Bedrock	Slug Test	4. Weathered Bedrock	6.E-06
BRH-0015A	Mine	617,875	5,423,186	417.3	8.74	7.2-8.7	5.8	Bedrock	Slug Test	4. Weathered Bedrock	2.E-07
BRH-0016A	Mine	618,407	5,425,303	444.8	5.73	2.7-5.7	1.5	Bedrock	Slug Test	4. Weathered Bedrock	3.E-05
BRH-0026	TMF	620,607	5,431,227	460.9	8.75	5.8-8.7	1.5	Bedrock	Slug Test	4. Weathered Bedrock	2.E-06
BRH-0030A	Mine	620,493	5,420,832	415.8	5.60	4.1-5.6	3.3	Bedrock	Slug Test	4. Weathered Bedrock	1.E-05
										Weathered Bedrock Geomean:	**2.E-06**
BH12-1	TMF	617,568	5,428,261	436.8	4.19	2.59-4.11	1.2	Bedrock	Slug Test	5. Competent Bedrock	4.E-08
BRH-0001A	Mine	611,909	5,421,762	429.0	19.22	16.0-19.0	0.0	Bedrock	Slug Test	5. Competent Bedrock	7.E-10
BRH-0002A	Mine	612,178	5,420,590	422.7	19.25	16.2-19.3	1.2	Bedrock	Slug Test	4. Weathered Bedrock	7.E-05
BRH-0005A	Mine	612,360	5,421,894	441.7	19.07	16.0-19.0	0.9	Bedrock	Slug Test	4. Weathered Bedrock	1.E-08
BRH-0008A	Mine	611,682	5,421,030	419.6	19.49	17.9-19.5	0.5	Bedrock	Slug Test	5. Competent Bedrock	2.E-08
BRH-0017A	TMF	619,624	5,425,289	427.7	7.16	5.6-7.2	3.1	Bedrock	Slug Test	5. Competent Bedrock	7.E-07
BRH-0018	TMF	620,794	5,427,311	430.6	8.69	5.5-8.7	1.8	Bedrock	Slug Test	5. Competent Bedrock	3.E-07
BRH-0021A	TMF	617,175	5,427,168	420.4	5.90	4.2-5.9	3.0	Bedrock	Slug Test	5. Competent Bedrock	8.E-05
BRH-0022	TMF	618,040	5,428,215	430.6	5.39	2.1-5.2	0.1	Bedrock	Slug Test	5. Competent Bedrock	2.E-06
BRH-0028A	Mine	618,741	5,421,296	383.6	5.80	4.2-5.8	3.8	Bedrock	Slug Test	5. Competent Bedrock	3.E-06
BRH-0029A	Mine	619,343	5,420,385	387.1	11.90	8.8-11.9	5.6	Bedrock	Slug Test	5. Competent Bedrock	1.E-07
BRH-0032A	Mine	620,345	5,423,914	424.0	7.30	5.7-7.3	4.0	Bedrock	Slug Test	5. Competent Bedrock	2.E-08
BRH-0034A	Mine	621,906	5,424,427	439.7	7.30	5.8-7.3	4.6	Bedrock	Slug Test	5. Competent Bedrock	3.E-07
										Competent Bedrock Geomean:	**2.E-07**

Notes:
-masl is metres above sea level.
-mbgs is metres below ground surface.
-m/s is metres per second.
-K is hydraulic conductivity.
-Parenthesis ( ) indicate data is considered an outlier and not used in geomean calculations.
-*Italicized font* indicates an assumed value.

Table 3: Recent Slug Test Summary (August 2016)

Monitoring Well	Screened Unit(s)	Screened Interval (mbgs)	Static Water Level (mbgs)	Hydraulic Conductivity (m/s)
BH12-1	Fresh Bedrock	2.59 to 4.11	0.80	4E-8
BH12-2	Silty Sand and Gravel	13.11 to 14.63	0.78	6E-7
BH12-3A	Fresh Bedrock	14.93 to 16.46	0.09	9E-7
BH12-3B	Silt	10.06 to 11.58	0.16	7E-7
BH12-4	Silt / Silty Sand	5.49 to 7.01	0.38	2E-6
BH12-5A	Weathered Bedrock	9.14 to 10.67	0.36	Assumed 1E-4
BH12-5B	Sand	5.33 to 6.86	0.33	6E-6
BH12-6A	Silt	8.38 to 9.91	0.83	Assumed 1E-4
BH12-6B	Silty Sand (Fill)	1.52 to 3.05	0.98	1E-5
BH12-7A	Silt / Gravel and Sand	5.79 to 7.31	0.51	3E-7
BH12-7B	Silty Clay	2.13 to 3.66	1.16	2E-6
BH12-8	Silt	2.29 to 3.81	3.25	N/A
BH12-9	Silty Clay / Silty Sand	7.62 to 9.14	Damaged	Damaged
BH12-10	Silty Sand	1.52 to 3.05	0.46	6E-6

Table 4: Hydrostratigraphic Unit Summary

Layer (Ground Downwards)	Unit Description	Thickness (m)	Horizontal Hydraulic Conductivity Geomean (m/s)
1	Surficial Deposit	3	1E-5
2	Fine-Grained	50% of Layer 2+3	3E-7
3	Coarse-Grained	50% of Layer 2+3	1E-5
4	Weathered Bedrock	3	2E-6
5	Competent Bedrock	50+	2E-7

Table 5: Bedrock Weathering Depth

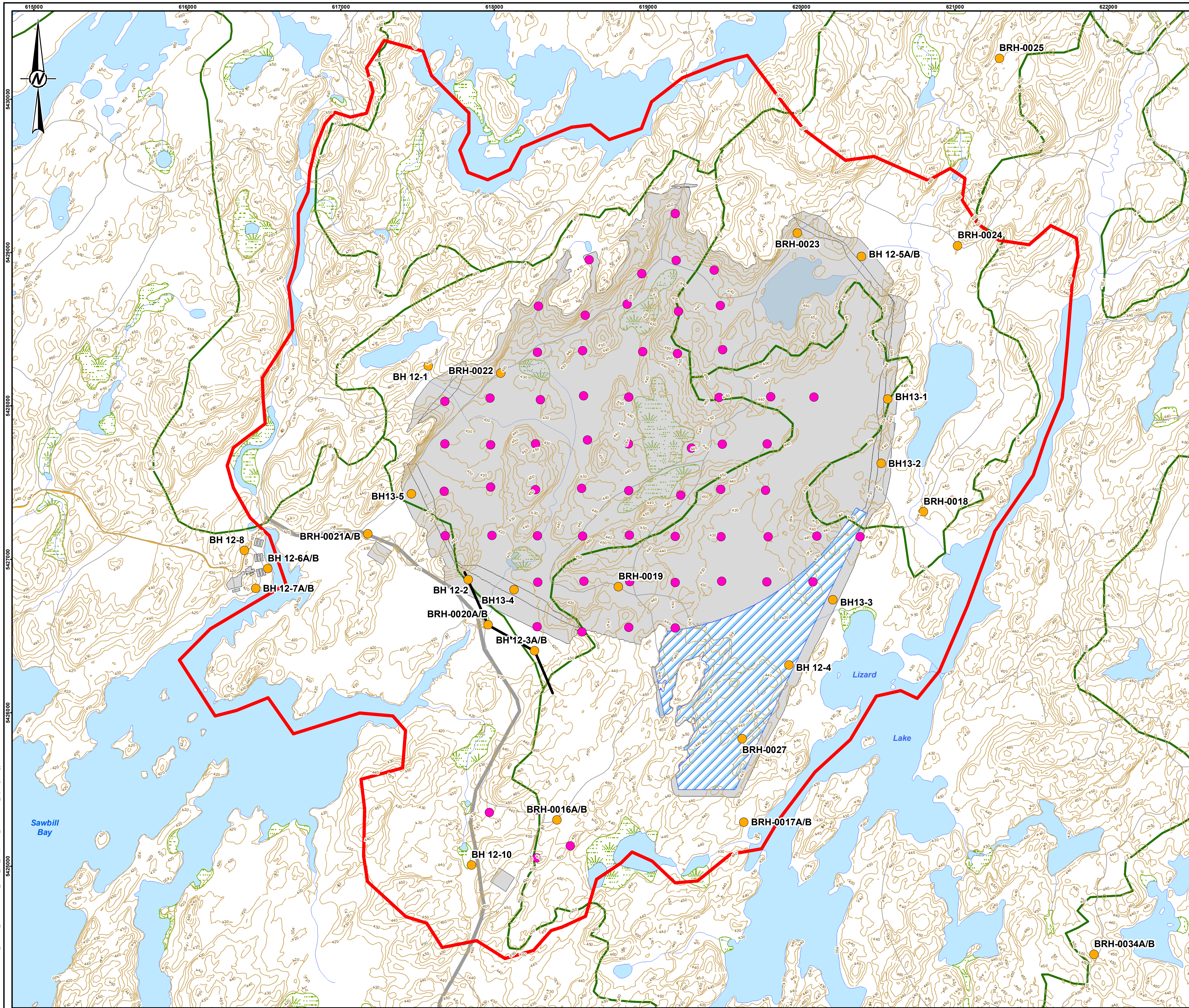
Borehole ID	Easting NAD83	Northing NAD83	Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Depth to Rock (mbgs)	Depth of Weathering (mbtor)
BH12-1	617,568	5,428,261	436.8	4.19	1.2	0.0
BH12-3	618,260	5,426,405	419.7	16.46	13.4	N/A
BH12-5	620,391	5,428,975	433.0	10.69	7.8	2.9
BRH-0001	611,909	5,421,761	429.1	7.16	0.0	9.0
BRH-0002	612,177	5,420,589	422.6	5.78	1.2	N/A
BRH-0003	612,744	5,421,086	420.6	5.89	0.0	2.7
BRH-0004	613,473	5,421,807	429.6	4.27	0.0	4.1
BRH-0005	612,360	5,421,894	441.7	19.07	0.9	16.0
BRH-0006	613,857	5,422,544	417.0	3.88	0.9	N/A
BRH-0007	614,656	5,420,826	427.0	6.86	0.7	2.3
BRH-0008	611,682	5,421,026	420.6	5.74	0.5	13.2
BRH-0009	613,878	5,421,290	416.3	7.77	2.7	2.5
BRH-0010	615,227	5,423,654	436.1	2.67	0.0	N/A
BRH-0011	615,105	5,421,919	434.2	5.64	1.1	3.4
BRH-0012	615,588	5,422,185	416.9	5.70	3.4	N/A
BRH-0013	615,631	5,422,933	416.6	4.37	1.3	N/A
BRH-0014	617,147	5,422,218	416.9	8.78	5.1	N/A
BRH-0015	617,875	5,423,186	417.3	8.74	5.8	N/A
BRH-0016	618,407	5,425,303	444.8	5.73	1.5	*4.2*
BRH-0017	619,624	5,425,289	427.7	7.16	3.1	0.0
BRH-0018	620,794	5,427,311	430.6	8.69	1.8	0.0
BRH-0021	617,175	5,427,168	420.4	5.90	3.0	0.0
BRH-0022	618,040	5,428,215	430.6	5.39	0.1	0.0
BRH-0024	621,017	5,429,046	435.4	7.20	1.0	0.0
BRH-0026	620,607	5,431,227	460.9	8.75	1.5	*7.2*
BRH-0028A	618,741	5,421,296	383.6	5.80	3.8	0.0
BRH-0029A	619,343	5,420,385	387.1	11.90	5.6	0.0
BRH-0030A	620,493	5,420,832	415.8	5.60	3.3	1.3
BRH-0032A	620,345	5,423,914	424.0	7.30	4.0	0.0
BRH-0034A	621,906	5,424,427	439.7	7.30	4.6	0.0
					Average:	**3.1**

Notes:
-masl is metres above sea level.
-mbgs is metres below ground surface.
-m/s is metres per second.
-mbtor is metres below top of rock.
-N/A means full depth of weathering is unknown but logged depth is less than avg. and thus ignored.
-Italicized font indicates minimum depth of weathering (to bottom of hole).

Table 6: Recharge Rates (Singer and Cheng, 2002)

Geologic Deposit	Recharge Rate (mm/yr)
Precambrian Rock	3 – 5
Silty Clay Till	10 – 25
Sand to Silty Sand Till	50 – 75
Silt and Clay	5 – 10
Peat, muck and marl	2 – 5
Sands and Gravels	300 – 350

FIGURES



LEGEND

- Contour (10 m interval)
- Road
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Consultant Boreholes
- Condemnation Holes
- Cross-section
- Model Domain

0 500 1,000

1:25,000 Metres

REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
STUDY AREA AND MODEL DOMAIN

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-09-13
DESIGNED	SO
PREPARED	SO
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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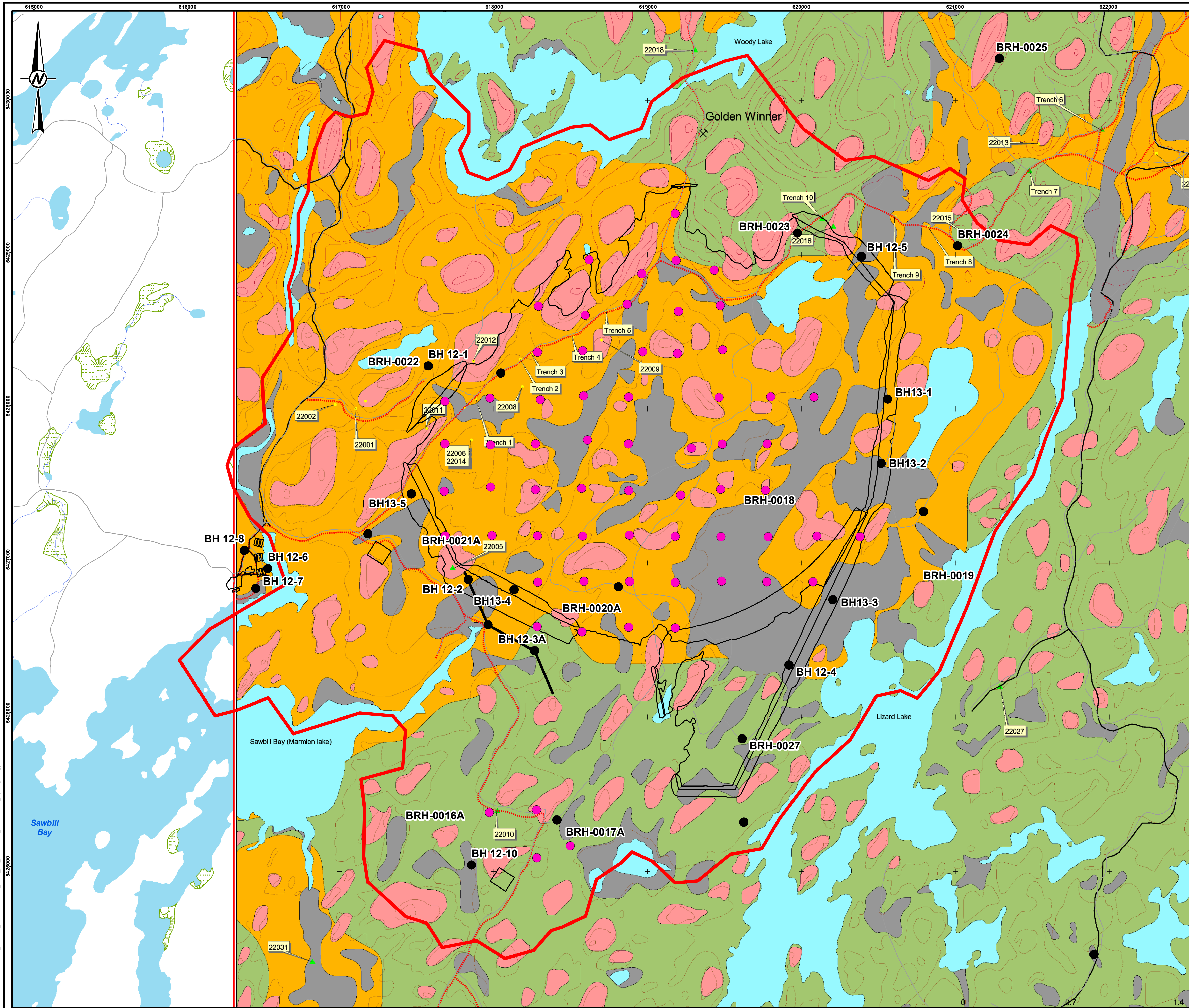
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm



LEGEND

- Road
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Consultant Boreholes
- Condemnation Holes
- Cross-section
- Model Domain

HOLOCENE NONGLACIAL ENVIRONMENT

Terrain Unit and Significance to Mineral Exploration

Organic Terrain:
(deposits of peat laid down in areas of high water table)

Areas where peat and muck are greater than 1m, constituting bogs and muskeg, low-lying floodplains (peat underlain by sand) and lake shore swamps. Significant detriment to exploration due to masking effect of thick organic material and creation of false anomalies by spurious concentration of metals.

PLEISTOCENE GLACIAL ENVIRONMENT

Subaqueous outwash and associated glacio-lacustrine facies:
(deposits of sand and gravel formed at a glacier margin where subglacial meltwater streams empty into glacial lakes).

Sand and gravel deposits are found in broad valleys at the head of Marmion and Finlayson Lakes. Thicknesses vary widely from >10m to less than 1m and bedrock is exposed sporadically. These deposits consist of subaqueously deposited, parallel-laminated, graded beds of coarse/fine sand and coarse open-work gravels interbedded with high energy bouldery, gravel deposits. Deposits are considered detrimental to geochemical prospecting because of far-travelled material diluting a local bedrock signature. Sand deposits are probably more extensive than mapped.

Till Veneer-Discontinuous:
(unsorted deposits of boulders/gravel/mud deposited directly by a glacier;
basal facies formed near base of glacier, ablation facies from debris higher in the ice)

Bedrock outcrop interspersed with deposits of till, 10-80% outcrop. Topography controlled by bedrock. Till is divisible into two facies: Unit 1- silty-sandy, locally -derived basal facies; Unit 2: Bouldery sandy ablation facies with high erratic content. Terrain is suitable for prospecting and geochemical/geophysical surveys as local bedrock is either at surface or within 1m, buried by a locally-derived till. Soil may be too thin for sampling. Occasional deposits of thick ablation till may mask local bedrock.

Bedrock with sediment veneer:
(bedrock scoured by ice and meltwater action, remnants of till and glaciolacustrine silt in hollows between bedrock knobs.

Bedrock outcrop or moss/boulder covered outcrop, with a thin, discontinuous cover of till and glaciolacustrine sediment . A period of intense meltwater flow may be indicated and may account for the lack of sediment cover. Terrain suitable for prospecting because bedrock is ubiquitous. Soils may be thin or absent.

Symbols

- Trails accessible by ATV
- Truck accesible roads
- Trench 2 — Trench site- 2010 survey glaciofluvial sediments -sample number on accomapnying figure
- 22019 — Sample site- glacial till sample number
- Golden Winner prospect (gold)

0 500 1,000
1:25,000 Metres

REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. SURFICIAL GEOLOGY TAKEN FROM SURFICIAL GEOLOGY UPDATE OF THE GOLDEN WINNER AREA: SEDIMENTOLOGY AND STRATIGRAPHY OF GLACIOFLUVIAL DEPOSITS AND RECOMMENDATIONS FOR RECCE SAMPLING (STEA, 2010).
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
SURFICIAL GEOLOGY (STEA, 2010)

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-09-19
DESIGNED	SO
PREPARED	SO
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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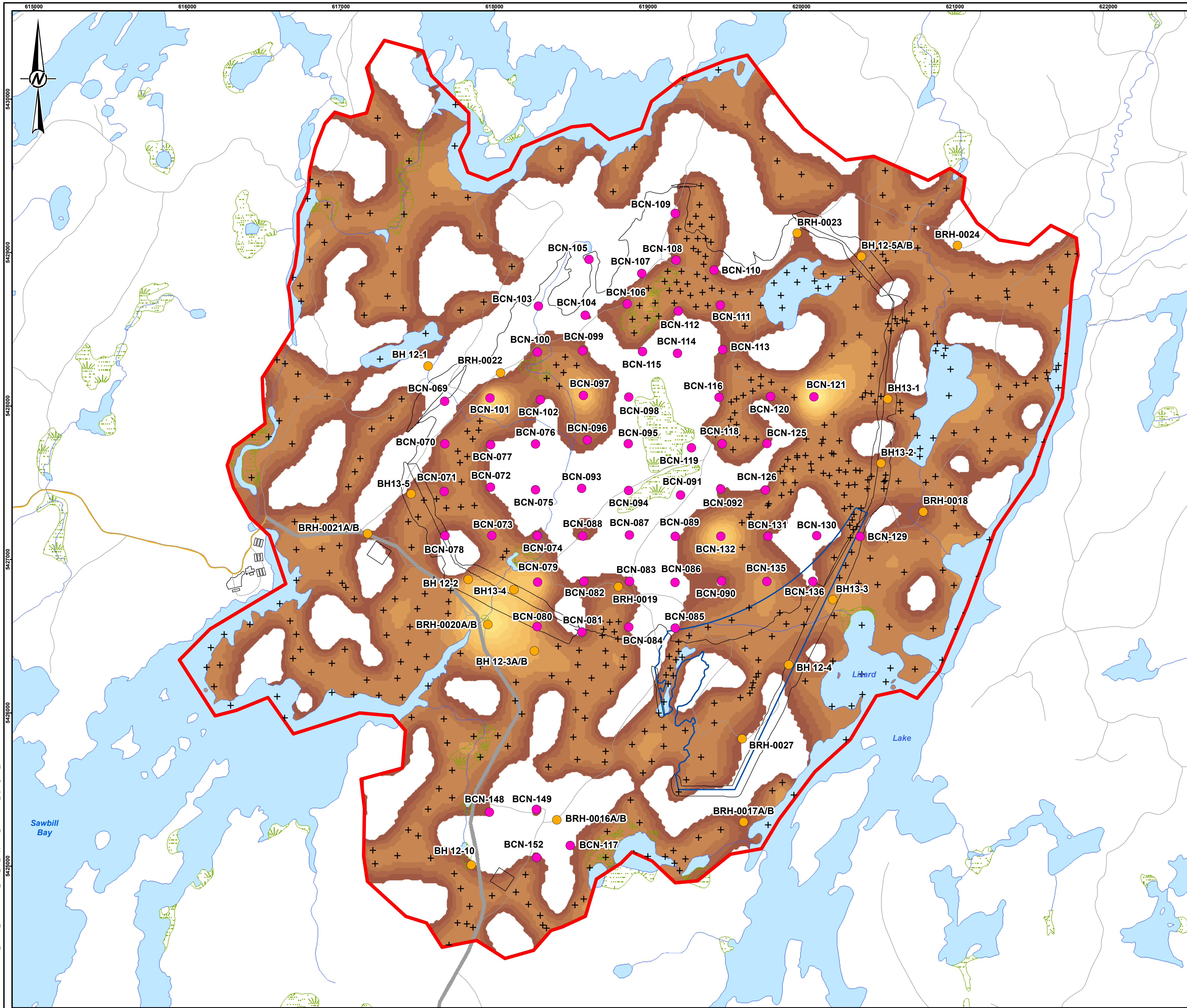

LEGEND

- Road
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Additional Contour Points, Assumed Overburden Thickness = 10 m
- Consultant Boreholes
- Condemnation Holes
- Model Domain

Overburden Thickness (m)

- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
INFERRED OVERBURDEN THICKNESS

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-10-04
DESIGNED	SO
PREPARED	SO
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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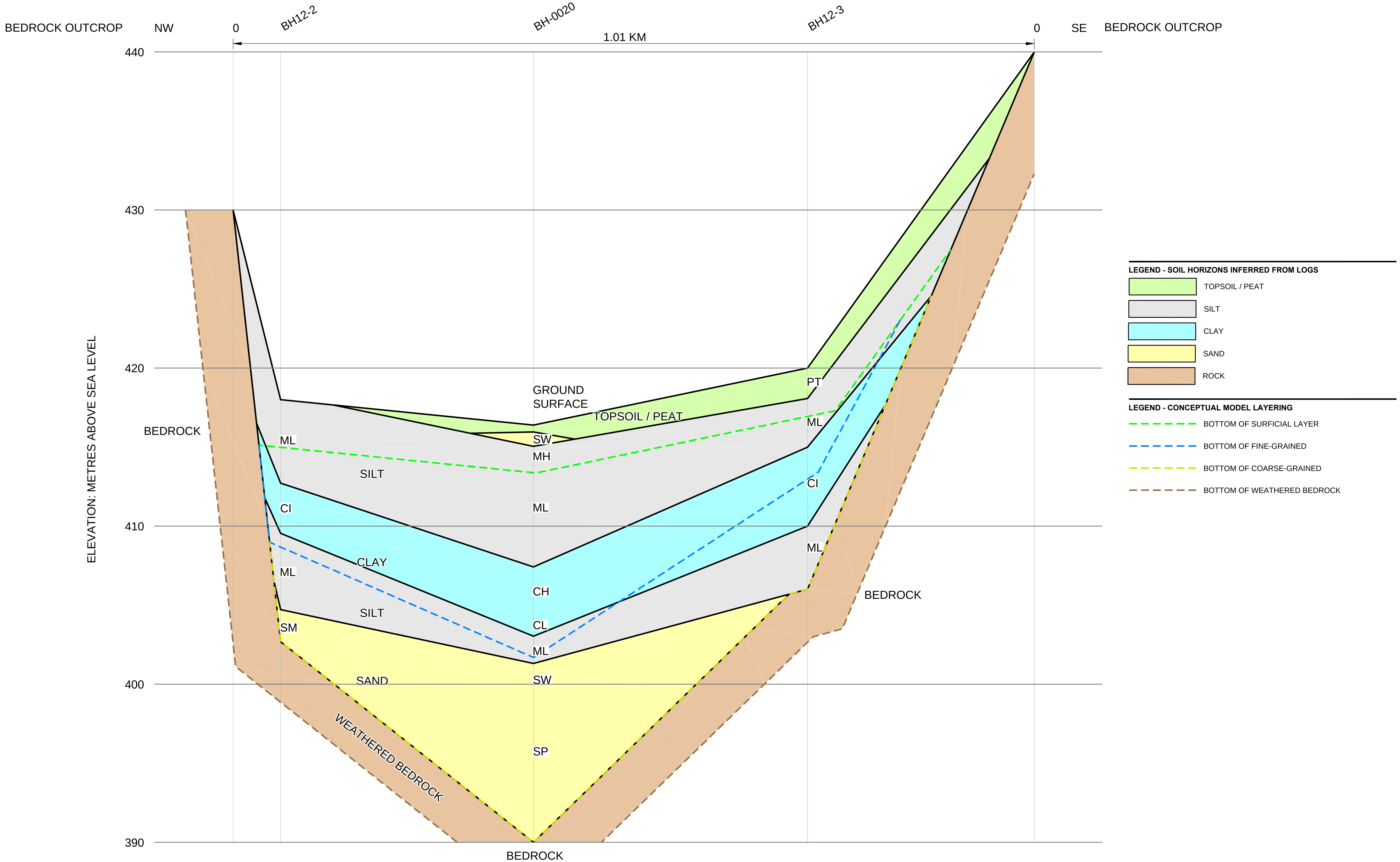

NOTE(S)

1. SEE FIGURE 1 FOR SECTION LOCATION
2. LOCATIONS ARE APPROXIMATE
3. SOIL STRATA AND BEDROCK LOCATIONS BETWEEN BOREHOLE ARE INFERRED
4. SOIL CODES (MH, ML, ETC.) TAKEN FROM USCS GROUP SYMBOLS
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2016

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PROJECT
HAMMOND REEF GOLD PROJECT

CONSULTANT
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YYYY-MM-DD	2016-09-21
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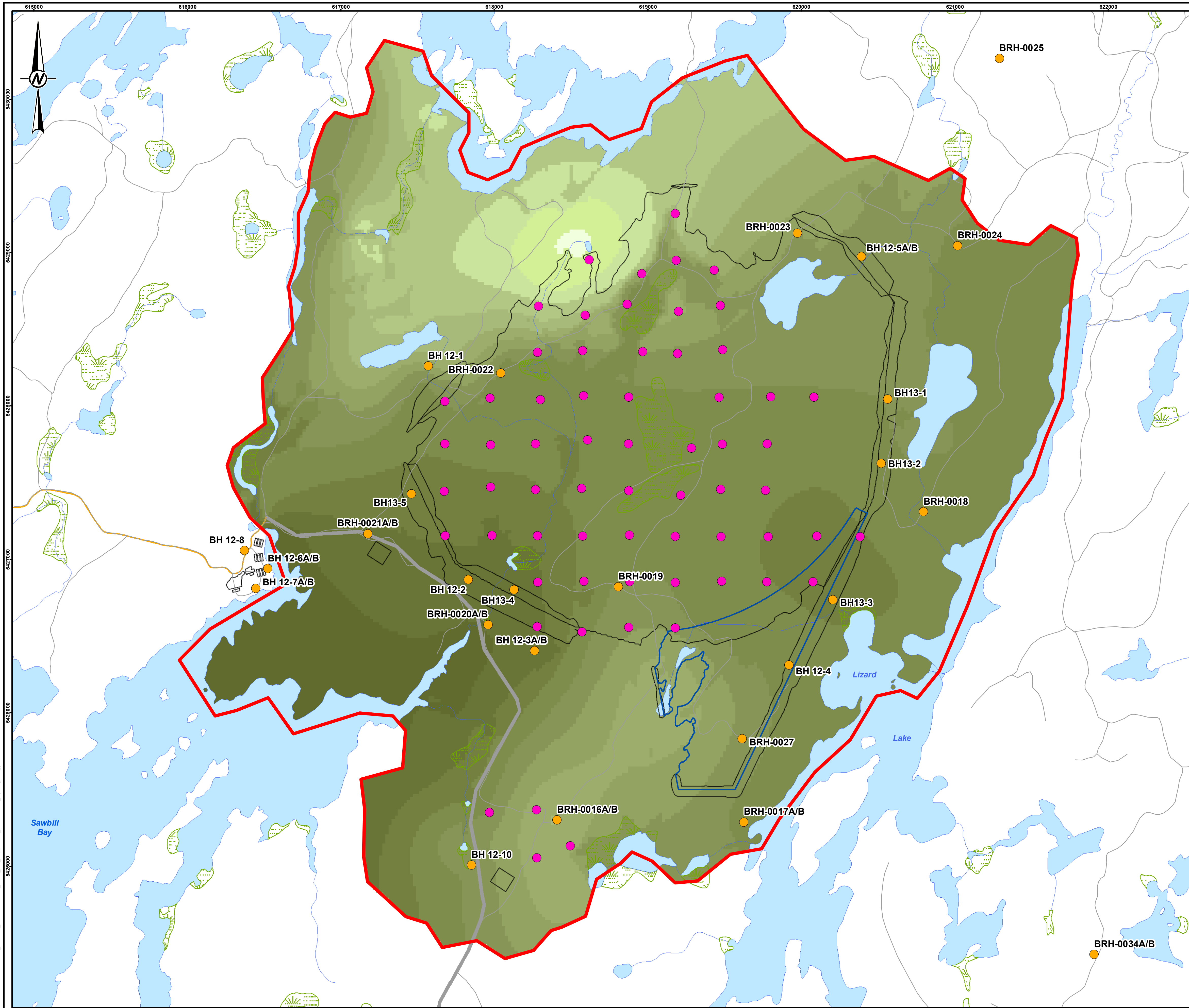
PREPARED	STB
REVIEWED	
APPROVED	

TITLE
CROSS-SECTION 1 (NW TO SE)

PROJECT NO.	Control	REV.	Figure
1656263			4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25 mm



LEGEND

- Road
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Consultant Boreholes
- Condemnation Holes
- Model Domain

Inferred Shallow Groundwater Elevation (m)

- 413 - 415
- 415 - 420
- 420 - 425
- 425 - 430
- 430 - 435
- 435 - 440
- 440 - 445
- 445 - 450
- 450 - 455
- 455 - 460
- 460 - 465
- 465 - 470

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
INFERRED SHALLOW GROUNDWATER ELEVATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-19
DESIGNED	SO
PREPARED	SO
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	5

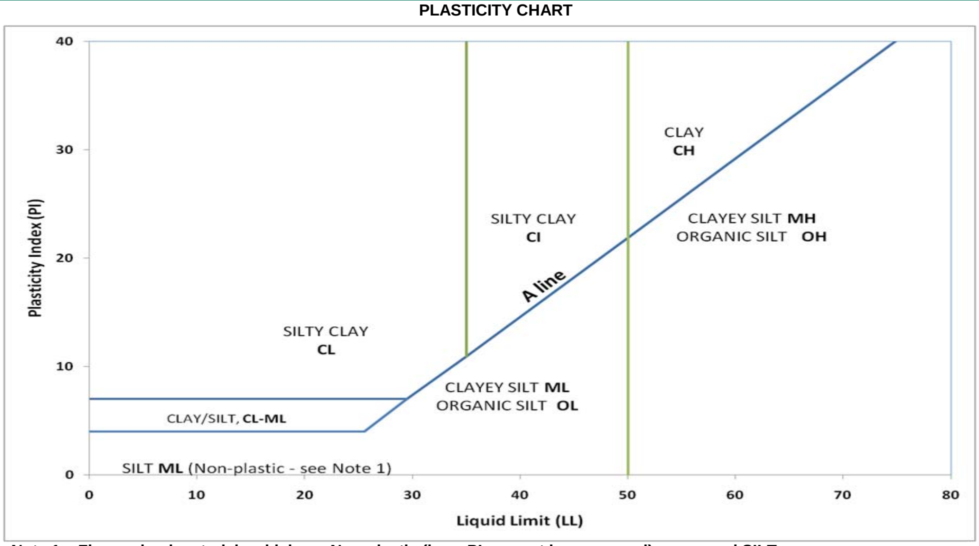
APPENDIX A
Borehole logs

METHOD OF SOIL CLASSIFICATION

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{D_{30}^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content <30% by mass)	COARSE GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass is larger than 4.75 mm)	Gravels with <12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	<30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (>50% by mass is smaller than 4.75 mm)	Sands with <12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators: Dilatancy	Field Indicators: Dry Strength	Field Indicators: Thread Diameter	Field Indicators: Toughness (of 3 mm thread)	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content <30% by mass)	FINE GRAINED SOILS (>50% by mass is smaller than 0.075 mm)	SILTS (PI and LL plot below A-Line on Plasticity Chart)	Liquid Limit <50	Rapid	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit >50	Slow to very slow	Low to medium	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to High	1 mm to 3 mm	Medium to High	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart)	Liquid Limit <35	None	Low to medium	~ 3 mm	Low to medium	0% to 30%	CL	SILTY CLAY
			Liquid Limit 35 to 50	None	Medium to High	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit >50	None	High	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures						30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat						>75%		PEAT

PLASTICITY CHART



Note 1 – Fine grained materials which are Non-plastic (i.e. a PL cannot be measured) are named SILT.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used when the soil has between 5 and 12% fines (*i.e.* between "clean" sand and "dirty" sand) or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

SYMBOLS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
≤ 5	trace
5 to 12	some
12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.).

Piezo-Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

SOIL TESTS

w	water content
PL	plastic limit
LL	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

Note: [1] Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness

Term	SPT 'N' (blows/0.3m) *
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D 1586, uncorrected for overburden pressure effects or energy transfer.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D 1586, uncorrected for overburden pressure effects or energy transfer.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0001A

SHEET 1 OF 2

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 26, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU- Curved; UN- Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN / FLUSH	RECOVERY (TOTAL CORE %, SOLID CORE %)	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA (B Angle; DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jr Ja Jn)	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK												
0	CME 55, NQ Core	Slightly weathered coarse grained grey crystalline rock		0.0	1					JIR; Partially Healed JIR; JIR				
1		Pink intrusive quartz from 0.6 m to 0.9 m depth.			2					JIR; JUSM; JIR; JPLSM; JIR; Broken Core; JIR; MB; JPLSPSM; Broken Core; JIR; JIR				
2					3					JIR; JUR; JIR; MB; Broken Core				
3					4					JUS; JIR; MB; JIR? MB?; JIR; JISM; JIR; Weathered Zone				
4					5					JPLSM; JUSM; MB; JIR; JIR; MB; JRR? MB?				
5–6					6					MB; MB; MB; JIR; JIR; JUR; JUSM; MB				
7					7					JPLSM; Broken Core				
8		Pink coarse grained slightly weathered crystalline rock, quartz crystals. Pink quartz intrusion from 7.6 m to 9.0 m depth.		7.8	8					JIR; JIR; MB; JIR; JIR; JIR; JPLSM; JIR; MB				
9		Coarse grained greenish grey rock with pink quartz in varying amounts		9.0	9	<<				JPLR				∇ 6/1/2011
10														

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0001A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 26, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate; BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage; PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular; PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.3 METRES | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

Drilling record: CME 55, NQ Core

--- CONTINUED FROM PREVIOUS PAGE ---

Depth scale (m)	Description	Elev. / Depth (m)	Run No.
10	Coarse grained greenish grey rock with pink quartz in varying amounts		10
	Pink QUARTZ intrusion	12.2	11
	Coarse grained greenish grey rock with pink quartz in varying amounts	12.7	
13	Medium grained grey from 12.7 m to 13.7 m depth.		
	Coarse grained grey with pink quartz intrusions		12
14	Quartz intrusion coarse grey from 13.9 m to 14.1 m depth.		
15	Quartz interbeded into coarse gravel grey from 14.9 m to 17.6 m depth.		13
			14
	Coarse grained grey from 14.9 m to 17.6 m depth.		15
19	END OF DRILLHOLE	19.1	

Discontinuity type and surface description (top to bottom): MB, JSTR, JPLSM, MB, JPLR, MB, JIR, JIR, JIR, JIR, JIR, JUSM, JUSM, JPLSM, JPLSM, JIR, JIR, Broken Core, JIR, MB, MB, JIR, JPLSM, MB, FPLSM, JPLSM, JIR, JIR, JUSM, MB, JPLSM, JPLSM, JISM, MB

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0001B

LOCATION: N ;E

DRILLING DATE: April 26, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK																		
0	CME 55 NQ Core	FOR CORING DETAILS SEE RECORD OF DRILLHOLE BRH-0001A		0.0																6/1/2011; Bentonite Holeplug; Riser; Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
7		END OF BOREHOLE		7.2																

Scale column headings: 80 60 40 20 (recovery, RQD); 5 10 15 20 (fract. index); 0 90 180 270 (B angle); 0 30 60 90 (dip); 10^{-6} 10^{-5} 10^{-4} 10^{-3} (hydraulic conductivity); 2 4 6 (point load)

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRAFT

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0002A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 30, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

TOP OF BEDROCK

Depth (m)	Description	Elev./Depth (m)	Run No.	Type and Surface Description	Notes
0	Coarse grained grey crystalline rock	0.0	1		6/1/2011
1–2.6			2	Broken Core; Broken Core; MB; JIR; JIR	
2.6–4.1			3	JIR; JIR; JIR; JIR; JPLSM; JIR; JPLR; JIR; JIR; JIR	
4.1–5.6			4	MB; JPLSM; JPLSM; JPLR; JPLR; Broken Core; JUSM; JIR; JPLSM; Broken Core	Bentonite Holeplug Riser
5.6–7.2			5	JIR; JIR; JIR; JPLR; MB	
7.2–8.7			6	JPLSM; JIR; JIR; JPLR; JIR; JPLR; JIR; JIR; JIR; MB	
8.7–10			7	JIR; JIR; JIR; JPLSM; JPLSM	

Drilling record: CME 55, NQ Core

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0002A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 30, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX METRES (5 10 15 20) | DISCONTINUITY DATA: B Angle (0 90 180 270), DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn | HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) | Diametral Point Load Index (MPa) (2 4 6) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: CME 55, NQ Core

Depth (m)	Description	Elev./Depth	Run No.	Discontinuity type	Notes
10	Coarse grained grey crystalline rock		7	JIR; Broken Core; JIR	
11			8	JIR; JIR; MB	
12			9	JIR; JPLR; JIR	Bentonite Holeplug
13				JIR	
14			10	JIR; MB	
15			11	JIR	
16				JIR; JIR; MB	
17			12	JIR; JIR; JIR; JIR; MB	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
18			13	JIR; JIR	
19				JIR; JIR	
	END OF DRILLHOLE	19.3		MB	
20					

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0002A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 30, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---																		
20																				
21													Broken Core							
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0002B

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 1, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH / COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK																		
0	CME 55 NQ Core	FOR CORING DETAILS SEE RECORD OF DRILLHOLE BRH-0002A		0.0																6/1/2011 (water level ~1.6 m); Bentonite Holeplug; Riser; Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5.7		END OF DRILLHOLE		5.7																

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0003

SHEET 1 OF 1

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 28, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
0	CME 55, NQ Core	Coarse grained crystalline rock, slightly weathered pyrite crystals, greenish grey speckled	0.0	1	JIR x 2, JIR, JIR, JIR, JIR, JIR, JIR, JIR, Broken Core, JPLSM	
2				2	JIR, JISM, JPLR, JPLSM, JPLR, JPLR, JPLR, JPLR, JPSTR, Broken Core	Bentonite Holeplug; Riser
3		Coarse grained pink and grey with pyrite crystals.		3	JIR, JUSM, JIR, JISM, JISM, JISM, JISM, JIR, JIR, JIR, JPLSM, JISM, JPLSM, JPLSM, JISM, JPLSM, JPLSM, JPLSM, JPLSM	
5				4	JIR, JIR, JIR, JPLSM, JPLSM, JPLSM, JPLSM, JPLR, JPLSM, JPLSM, JPLSM, JPLSM, JPLSM, JIR, JPLSM, JPLR, JIR, JIR, JIR, JIR, JPLSM, JISM, JISM, JPLR	6/1/2011; Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
6		END OF DRILLHOLE	5.9			

Column headings also include: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 0 to 10 metres.

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

RECORD OF DRILLHOLE: BRH-0004

PROJECT: 10-1118-0020 PH 4000

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 24, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
0	CME 55 NQ Core	Grey coarse grained crystalline rock, slightly weathered	0.0	1	JIR, JIR, JIR, JIR, JIR, JIR? MB?	6/1/2011 (water level); Bentonite Holeplug
1–2				2	JIR, JIR, JIR	Riser
2–4				3	JIR, JIR, JIR, Large clay filled joint, JIR, JIR, JIR, JIR, MB, JIR, JIR, MB	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
4.1		END OF DRILLHOLE	4.1			

Depth scale marks: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0005A

LOCATION: N ;E
BORING DATE: April 25, 2011
DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm
INCLINATION: -90 degrees
PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Boulders, clay and ORGANICS, moist to wet, brown	0.0	1	DO	50/0.2				
1		Moderately weathered, greenish grey, medium grained, crystalline rock	0.9							
2	CME 55, NQ Core						80	43	33	
3		Slightly weathered					100	20	20	
4							92	76	72	
5							100	47	47	Bentonite Holeplug Riser
6							100	80	88	
8							98	87	87	
9		Quartz Intrusion, coarse grained					95	76	69	
10										

Column headings also include: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp W Wl (16, 32, 48, 64); ADDITIONAL LAB. TESTING; STRATA PLOT.

DRAFT

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

RECORD OF BOREHOLE: BRH-0005A

PROJECT: 10-1118-0020 PH 4000

LOCATION: N ;E
BORING DATE: April 25, 2011
DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm
INCLINATION: -90 degrees
PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 55 / NQ Core	Moderately weathered, greenish grey, medium grained, crystalline rock									
11		Slightly weathered, coarse grained, grey and white tonalite									
13											Bentonite Holeplug
16											6/1/2011 (water level)
17											Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
19.1		END OF BOREHOLE		19.1							
		Note:									
		1. For coring details see Record of Drillhole BRH-0005A.									

Core run values (10–19.1 m):

Approx. depth (m)	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
10.0–10.2	95	76	69
10.2–11.7	100	98	98
11.7–13.3	97	95	95
13.3–14.1	103	103	100
14.1–16.3	100	100	100
16.3–17.8	92	38	38
17.8–19.1	122	102	102

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0005A

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 25, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | COLOUR % RETURN / FLUSH | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

Drilling record: CME 55, NQ Core

Depth (m)	Description	Run No.	Discontinuity type and surface description	Notes
	TOP OF BEDROCK			
0.9	Moderately weathered, greenish grey, medium grained, crystalline rock	1	Broken Core; IR? Top of Rock?; JIR; JUSM; JUSM; FOIR; Broken Core; JIR; JIR; Broken Core; Broken Core	
	Slightly weathered	2	MB; JIR; JISM; JIR; JIR; JIR; MB; JUS; JUS; JSTR? MB?	
		3	JIR; JIR; JIR; JIR; MB; JPLSM; JPLSM	Riser (5)
		4	JPLSM; JPLSM; MB; JUSM	
		5	JISM; JIR; JIR; JUR; MB; MB	Bentonite Holeplug
		6	JUSM; JIR; JIR; MB	
	Quartz Intrusion, coarse grained	7	JUS; JSTSM; MB; MB	
		8	JIR; JIR	

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0005A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 25, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

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DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
11	CME 55 NQ Core	Moderately weathered, greenish grey, medium grained, crystalline rock				
		Slightly weathered, coarse grained, grey and white tonalite		8	MB, MB, MB	
12–13				9	JIR	
13–14				10 (<<)		Bentonite Holeplug
14–16				11	MB, MB, JIR, JIR, JIR? MB?	6/1/2011
16–17				12	JISM, JPLSM, JSTSM, JPLSM, JIR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
18–19				13 (<<)	JIR, JIR, MB, MB	
19.1		END OF DRILLHOLE	19.1			
20						

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0005B

LOCATION: N ;E

BORING DATE: April 25, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger; 200 mm Diam. (Hollow Stem Auger)	Clay and ORGANICS, brown, moist to wet		0.0							Riser; Bentonite Holeplug
		Cobbles and CLAY		0.7							6/1/2011 (water level); Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE		8.5							

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0006

LOCATION: N ;E

BORING DATE: April 23, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger; 200 mm Diam. (Hollow Stem Auger)	Firm moist brown clay and ORGANICS		0.0	1	50 DO	34				Bentonite Holeplug; Riser
					2	50 DO	25/0.14				
1	CME 55; NQ Core	Slightly weathered pink coarse grained crystalline rock		0.9				100	100	100	6/1/2011 (water level)
								92	53	14	
2								100	63	43	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
3								100	82	66	
		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0006.		3.6							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 16 32 48 64

ADDITIONAL LAB. TESTING

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF DRILLHOLE: BRH-0006

PROJECT: 10-1118-0020 PH 4000
SHEET 1 OF 1
LOCATION: N ;E
DRILLING DATE: April 23, 2011
DATUM: Geodetic
INCLINATION: -90° AZIMUTH: ---
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
1	CME 55 NQ Core	Slightly weathered pink coarse grained crystalline rock	0.9	1	JIR	Riser
				2	JIR, JIR, Healed Joint, JIR, JIR, Broken Core, JIR, JIR, JIR	Bentonite Holeplug 6/1/2011
2				3	Broken Core, JIR, JIR, Broken Core, JIR	
					FIR, JIR	Silica Sand
3				4	FIR, Broken Core, JIR, JIR, JIR, JIR	31.8 mm Diam. PVC #10 Slot Screen
		END OF DRILLHOLE	3.6			

Column headings also shown: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0007A

LOCATION: N ;E

BORING DATE: April 22, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE										
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Cobbles and clay (FILL)		0.0								
	CME 55, NQ Core	Slightly weathered grey medium graines crystalline rock, lots of healed joints		0.7				100	50	30		
2								98	44	42		
3		QUARTZ, coarse grained, pink		3.0				100	85	64		
4		Quartz coars grained pink from 3.8 m to 4.0 m depth.										
		Brown, highly weathered from 4.3 m to 4.4 m depth. Coarse to medium grained, grey crystalline rock, healed joints/										
5		Pink quartz with occasional grey bands from 4.9 m to 7.5 m depth.						100	82	87		Bentonite Holeplug
6								100	80	90		6/1/2011
8		Green and pink quartz.						100	92	90		
9		Highly weathered zone, brown. Coarse grained, greenish grey, crystalline rock. Quartz, green and pink from 8.8 m to 8.9 m depth. Coarse grained, greenish grey crystalline rock from 8.9 m to 9.6 m depth.						97	78	69		
		Green quartz from 9.6 m from 10.1 m depth.										
10												

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ ; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp —O^W— Wl ; 16 32 48 64

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0007A

SHEET 2 OF 2

LOCATION: N ;E

BORING DATE: April 22, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16, 32, 48, 64) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Boring method: CME 55, NQ Core

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Depth (m)	Description	Elev./Depth (m)	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	Piezometer
10	QUARTZ, coarse grained, pink. Alternating greenish grey and pink green quartz from 10.1 m to 12.0 m depth.		97	78	69	
11			100	87	77	
12	Greenish grey from 12.0 m to 12.4 m depth. Quartz from 12.4 m to 13.0 m depth.		98	98	98	
13	Greenish grey with quartz feldspar bands.					Riser; Bentonite Holeplug
14	Pink qyartz from 14.2 m to 14.4 m depth. Grey coarse grained crystalline rock from 14.4 m to 14.5 m depth. Pink quartz. Brown weathering from 14.6 m to 15.4 m depth.		100	82	80	
15	Quartz and feldspar from 15.4 m to 17.8 m depth		98	75	58	
16–17			98	84	67	Silica Sand
17.5			89	78	78	31.8 mm Diam. PVC #10 Slot Screen
18	Grey with pink viens from 17.8 m to 18.4 m depth.		100	100	100	
	END OF BOREHOLE	18.4				

Note:

1. For coring details see Record of Drillhole BRH-0007A.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0007A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 22, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
1	CME 55, NQ Core	Slightly weathered grey medium graines crystalline rock, lots of healed joints	0.7	1	Broken Core, JCR, Healed Joint, Broken Core	
2				2	Healed Joint, Healed Joint, Broken Core, JIR, JIR, JIR, JIR, JIR, JIR, JIR, Broken Core, Broken Core	
3		QUARTZ, coarse grained, pink	3.0	3	JIR, MB, JIR, MB, JIR, MB, JIR	
4		Quartz coars grained pink from 3.8 m to 4.0 m depth.			JSTR, MB, JIR, MB, Broken Core, Broken Core	
5		Brown, highly weathered from 4.3 m to 4.4 m depth. Coarse to medium grained, grey crystalline rock, healed joints/ Pink quartz with occasional grey bands from 4.9 m to 7.5 m depth.		4	MB, JIR, JIR, JUSM, JISM, JIR, MB	Bentonite Holeplug
6				5	JISM, JSTR	6/1/2011
7					JUR, JIR, JIR	
8		Green and pink quartz.		6	JIR, Broken Core	
9		Highly weathered zone, brown Coarse grained, greenish grey, crystalline rock. Quartz, green and pink from 8.8 m to 8.9 m depth. Coarse grained, greenish grey crystalline rock from 8.9 m to 9.6 m depth.			MB, JIR, JIR	
10		Green quartz from 9.6 m from 10.1 m depth. Alternating greenish grey and pink green quartz from 10.1 m to 12.0 m depth.		7	JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR, MB	
				8		

Column headings also include: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr, Ja, Jn; HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0007A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 22, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA (B Angle; DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

Drilling record: CME 55, NQ Core

--- CONTINUED FROM PREVIOUS PAGE ---

Depth (m)	Description	Run No.	Discontinuity type	Notes / Instrumentation
10.8	QUARTZ, coarse grained, pink	8	JIR, JIR, JIR	
11.8			MB, MB, JIR, JIR	
12.0	Greenish grey from 12.0 m to 12.4 m depth.			
12.4	Quartz from 12.4 m to 13.0 m depth.	9	JIR	
13.0	Greenish grey with quartz feldspar bands.			Riser
13.2		10	MB, JIR, JIR	Bentonite Holeplug
14.2	Pink qyartz from 14.2 m to 14.4 m depth.		JIR	
14.4	Grey coarse grained crystalline rock from 14.4 m to 14.5 m depth. Pink quartz		JIR, MB, MB, JIR	
14.6	Brown weathering from 14.6 m to 15.4 m depth.			
15.4	Quartz and feldspar from 15.4 m to 17.8 m depth	11	JIR, JIR, JIR, JIR, JSTR, JIR, JIR, JUR, JIR, MB	
16.3		12	JIR, JIR, JSTR, JUR, JUR, JSTR, MB	Silica Sand
17.4		13	JIR, Broken Core, JIR, MB	31.8 mm Diam. PVC #10 Slot Screen
17.8	Grey with pink viens from 17.8 m to 18.4 m depth.	14	JIR, MB	
18.4	END OF DRILLHOLE			

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0007B

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 23, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	FOR STRATIGRAPHY DETAILS SEE RECORD OF BOREHOLE BRH-0007.		0.0							Bentonite Holeplug; Riser; 6/1/2011 (water level); Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
6.8		END OF BOREHOLE		6.8							

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0008A

LOCATION: N ;E

BORING DATE: April 29, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE						
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Wet, silty clay ORGANICS		0.0				6/1/2011 (water level)
		Highly weathered, coarse grained, pink and grey crystalline rock		0.5	33	13	0	
2	CME 55, NQ Core				100	70	63	
		TONALITE, grey, coarse grained crystalline rock, slitly weathered.		2.6				
3					98	73	68	
		Coarse grained, grey crystaline rock						
5					100	83	78	Bentonite Holeplug
6					100	88	88	
8					98	97	95	
		Coarse grained, grey rock						
		Pink feldspar and quartz vein						
9		Tonalite, pink grey black, coarse grained			100	93	71	
		Coarse grained, grey crystalline rock with quartz and tonalite intrusions						
10								

Column headings also printed: SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○; 20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp, W, Wl; 16, 32, 48, 64); ADDITIONAL LAB. TESTING.

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0008A

LOCATION: N ;E

BORING DATE: April 29, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

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DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	DEPTH (m)	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
10	CME 55 NQ Core	TONALITE, grey, coarse grained crystalline rock, slitly weathered.		100	93	71	Riser
11				100	85	85	
12				100	98	98	
13		Green, coarse grained crystalline rock with quartz intrusions					Bentonite Holeplug
14				100	73	63	
15				100	90	86	
16							
17		Coarse grained, grey crystalline rock with quartz tonalite		97	82	80	
18				100	64	61	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
19		END OF BOREHOLE	19.5				
		Note:					
20							

Column headers also include: STRATA PLOT; ELEV.; SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp, W, Wl) (16, 32, 48, 64); ADDITIONAL LAB. TESTING.

DRAFT

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0008A

LOCATION: N ;E

BORING DATE: April 29, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT (Wp —○W— Wl) (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20		1. For coring details see Record of Drillhole BRH-0008A.									
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0008A

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 29, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Cleavage

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
Ro - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK			
	CME 55, NQ Core	Highly weathered, coarse grained, pink and grey crystalline rock	0.5	1	
1					
2				2	
		TONALITE, grey, coarse grained crystalline rock, slitly weathered.	2.6		
3				3	
4					
		Coarse grained, grey crystaline rock			
5				4	Bentonite Holeplug
6					
				5	
7					
8				6	
		Coarse grained, grey rock			
		Pink feldspar and quartz vein			
9		Tonalite, pink grey black, coarse grained			
		Coarse grained, grey crystalline rock with quartz and tonalite intrusions		7	
10					Riser
				8	

Column headings: COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %) 80 60 40 20; R.Q.D. % 80 60 40 20; FRACT. INDEX METRES 5 10 15 20; DISCONTINUITY DATA: B Angle 0 90 180 270; DIP w.r.t. CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; Diametral Point Load Index (MPa) 2 4 6; RMC -Q' AVG.

Discontinuity type and surface descriptions (top to bottom): JIR, JIR, JPLSM, JIR, JIR, JIR, JPLR, JIR, JIR, JIR, Broken Core, JISM, JISM, JPLSM, JISM, JPLSM, JIR, JUSM, JPLSM, JIR, JUR, JIR, JISM, JIR, JUSM, JIR, JUR, JIR, JPLSM, JISM, JPLSM, JUSM, JIR, JISM

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0008A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 29, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

Legend: JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU- Curved; UN- Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: CME 55, NQ Core

Depth (m)	Description	Run No.	Discontinuity type and surface description	Notes
~10.4–13.5	TONALITE, grey, coarse grained crystalline rock, slitly weathered.	8, 9	JIR, JIR, JIR, JISM, JIR	
~13.5–17	Green, coarse grained crystalline rock with quartz intrusions	10, 11	JISM, JIR, JIR, JIR, JIR, JIR, JISM, JIR, JIR, JIR, JIR, JUSM, JPLSM, JPLR, JIR, Broken Core	Bentonite Holeplug
~17–19.5	Coarse grained, grey crystalline rock with quartz tonalite	12, 13	JIR, JPLSM, JPLSM, JIR, JIR, JIR, SJRSM, JUSM, JIR, JIR, JIR, JSTR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
19.5	END OF DRILLHOLE			

Depth scale: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0008B

LOCATION: N ;E

BORING DATE: April 30, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	FOR STRATIGRAPHY DETAILS SEE RECORD OF BOREHOLE BRH-0008A.		0.0							6/1/2011 (water level); Bentonite Holeplug; Riser; Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5.7		END OF BOREHOLE		5.7							

Depth scale marks: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRAFT

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0009

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 23, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES – NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, wet, brown clay and ORGANICS, some cobbles	0.0	1	50 DO	9				
		Boulders?	0.5				20	12	0	6/1/2011 (water level)
		Broken core?	2.7							Bentonite Holeplug; Riser
	CME 55, NQ Core	Grey, coarse grained, slightly weathered, porous metamorphozed	4.6				35	28	17	
		Pink, coarse grained, crystalline rock QUARTZ and feldspar, metamorphozed	5.2				100	80	72	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
							100	88	71	
		END OF BOREHOLE	7.6							

Note:

1. For coring details see Record of Drillhole BRH-0009.

Column headings also printed: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp, W, Wl) (16, 32, 48, 64); ADDITIONAL LAB. TESTING; STRATA PLOT.

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0009

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 23, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
5	CME 55 NQ Core	Grey, coarse grained, slightly weathered, porous metamorphozed	4.6	4	JIR, JIR, Broken Core	Bentonite Holeplug
		Pink, coarse grained, crystalline rock QUARTZ and feldspar, metamorphozed	5.2		JIR, JIR, JIR, JIR, JIR	
6				5	JIR, JIR, JIR, JIR	Silica Sand
7					JIR, Broken Core, JIR, JIR, JIR, Broken Core	31.8 mm Diam. PVC #10 Slot Screen
				6	JIR, JIR, JIR	
		END OF DRILLHOLE	7.6			

Depth scale marks: 8, 9, 10, 11, 12, 13, 14

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0010

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 20, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
0	CME 55 NQ Core	Moderately weathered, medium grained, greenish grey crystalline rock	0.0	1	Broken Core, Broken Core, JIR, JIR, JIR, JIR, Broken Core, JIR, Broken Core, JIR, Void, Broken Core	Bentonite Holeplug; Riser
1–2.7				2	JIR, JIR, Broken Core, JIR, JIR, JIR, JIR, Broken Core, FSTSM	31.8 mm Diam. PVC #10 Slot Screen; 6/1/2011; Silica Sand
		END OF DRILLHOLE	2.7			

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Column headings: SYMBOLIC LOG; COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.3 METRES; B Angle; DIP w.r.t. CORE AXIS; Jr Ja Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0011

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 21, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	Wet SAND, some clay, some organics, trace boulder	0.0							
				1	DO	50				
1		GRAVEL and COBBLES	0.9			-				
	CME 55 NQ Core	Slightly weathered, coarse crystalline rock (Tonalite)	1.1				75	63	38	
2							100	97	91	Bentonite Holeplug; Riser
3		Slightly weathered, medium grained crystalline rock, grey					100	63	57	
4										6/1/2011 (water level)
		Pink QUARTZ, coarse grained	4.5				100	93	84	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5										
		END OF BOREHOLE	5.5							

Note:

1. For coring details see Record of Drillhole BRH-0011.

Column headings also include: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa, nat V. + Q - ●, rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT, Wp — W — Wl (16, 32, 48, 64); ADDITIONAL LAB. TESTING; STRATA PLOT.

DRAFT

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0011

SHEET 1 OF 1

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 21, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55, NQ Core	Slightly weathered, coarse crystalline rock (Tonalite)	1.1	1	JIR, JUS, Broken Core	
2				2	JIR, JIR, JIR	Bentonite Holeplug, Riser
3		Slightly weathered, medium grained crystalline rock, grey		3	JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR, JIR	
4						6/1/2011
		Pink QUARTZ, coarse grained	4.5	4	JIR, JIR, JUR, JIR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5		END OF DRILLHOLE	5.5			
6						
7						
8						
9						
10						
11						

Column headings also include: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr Ja Jn; HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0012

LOCATION: N ;E

BORING DATE: April 20, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES – NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE / SHEAR STRENGTH	HYDRAULIC CONDUCTIVITY / WATER CONTENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Compact, wet, brown SAND, some gravel, trace silt		0.0							Bentonite Holeplug
1					1	50 DO	12				Riser; Silica Sand
2					2	50 DO	50				31.8 mm Diam. PVC #10 Slot Screen; water level 6/1/2011
		Gravel, Boulders, Cobbles and Sand		2.5	3	50 DO	71				Bentonite Holeplug
3											
	CME 55, NQ Core	Slightly weathered, coarse grained, greenish grey with pink and white sheared VOLCANICS		3.4				T.C.R. (%) 100; S.C.R. (%) 100; R.Q.D. (%) 100			
4											Silica Sand
5		Slightly weathered, white and pink with grey sheared VOLCANICS, metal pockets		5.0				T.C.R. (%) 100; S.C.R. (%) 72; R.Q.D. (%) 70			31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE		5.7							
6		Note: 1. For coring details see Record of Drillhole BRH-0012.									

Dynamic penetration resistance, blows/0.3m: 20, 40, 60, 80. Shear strength Cu, kPa: nat V. +, Q - ●, rem V. ⊕, U - ○; 20, 40, 60, 80.
Hydraulic conductivity, k, cm/s: 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}. Water content percent: Wp, W, Wl; 16, 32, 48, 64.

DRAFT

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0012

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 20, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage
PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular
PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55 NQ Core	Slightly weathered, coarse grained, greenish grey with pink and white sheared VOLCANICS	3.4	1	BIR, BIR	
4				2	JIR, JIR, JIR, JSTR, JIR, JIR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5		Slightly weathered, white and pink with grey sheared VOLCANICS, metal pockets	5.0		JIR	
		END OF DRILLHOLE	5.7			

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Column headings also include: SYMBOLIC LOG; COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF BOREHOLE: BRH-0013

PROJECT: 10-1118-0020 PH 4000

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 20, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —O W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger; 200 mm Diam. (Hollow Stem Auger)	Dense, wet, brown SAND, little gravel		0.0							Bentonite Holeplug; water level 6/1/2011
1					1	50 DO	37				
	CME 55; NQ Core	Slightly weathered, medium, crystalline rock, pink, feldspar, quartz, pyrite cubes		1.3				T.C.R. (%) 82; S.C.R. (%) 82; R.Q.D. (%) 32			Riser
3		Slightly weathered, medium, crystalline rock, grey / pink, feldspar, quartz		3.0				T.C.R. (%) 100; S.C.R. (%) 98; R.Q.D. (%) 100			Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE		4.3							

Note:

1. For coring details see Record of Drillhole BRH-0013.

DEPTH SCALE 1 : 50	LOGGED: MO
Golder Associates	CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0013

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 20, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55, NQ Core	Slightly weathered, medium, crystalline rock, pink, feldspar, quartz, pyrite cubes	1.3	1	Broken Core; JIR; JIR; JIR; JISTR; JIR Broken Core; JIR; JIR; JIR; JIR; JIR; JIR; Broken Core	Bentonite Holeplug; Riser
		Slightly weathered, medium, crystalline rock, grey / pink, feldspar, quartz	3.0	2	JIR; JIR; JIR; JIR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		END OF DRILLHOLE	4.3			

Other column headings: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

RECORD OF BOREHOLE: BRH-0014

PROJECT: 10-1118-0020 PH 4000
LOCATION: N ;E
SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

BORING DATE: April 8, 2011
INCLINATION: -90 degrees

DATUM: Geodetic
PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, wet, brown PEAT	0.0	1	50 DO	8				
										6/1/2011 (water level)
1		Firm, moist, light brown SILTY CLAY (Varved)	0.8	2	50 DO	5				Bentonite Holeplug
2				3	50 DO	5				Riser
3		Loose, wet, grey SILT and SAND	2.6	4	50 DO	3				Silica Sand
4		Compact, wet, grey SILTY SAND, some gravel	3.8	5	50 DO	21				
		Compact, wet, grey, coarse SILTY SAND, some gravel	4.6	6	50 DO	30				
5	CME 55, NQ Core	Slightly weathered, grey, medium to coarse crystalline medium to strong rock	5.1				100	28	36	Bentonite Holeplug
6–7							100	53	57	Silica Sand
8							100	62	68	31.8 mm Diam. PVC #10 Slot Screen
9		END OF BOREHOLE	8.8							

Note:

1. For coring details see Record of Drillhole BRH-0014.

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ○; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp —○W— Wl; 16 32 48 64
ADDITIONAL LAB. TESTING

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0014

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 8, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

Abbreviations:

- JN - Joint
- FLT - Fault
- SHR - Shear
- VN - Vein
- CJ - Conjugate
- BD - Bedding
- FO - Foliation
- CO - Contact
- OR - Orthogonal
- CL - Cleavage
- PL - Planar
- CU - Curved
- UN - Undulating
- ST - Stepped
- IR - Irregular
- PO - Polished
- K - Slickensided
- SM - Smooth
- Ro - Rough
- MB - Mechanical Break
- BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH / COLOUR % RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX METRES (5 10 15 20) | DISCONTINUITY DATA: B Angle (0 90 180 270), DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn | HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) | Diametral Point Load Index (MPa) (2 4 6) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

Depth (m)	Drilling record	Description	Elev./Depth (m)	Run No.
		TOP OF BEDROCK		
5.1–8.8	CME 55, NQ Core	Slightly weathered, grey, medium to coarse crystalline medium to strong rock	5.1	1, 2, 3
		END OF DRILLHOLE	8.8	

Type and surface description (top to bottom): Crushed with clay in seams; Crushed with clay in seams; JISTR; JIR; Crushed with clay in seams; Crushed with clay in seams; JIR; JPLSM; JPLSM; JPLSM; JPLSM; JPLS; JPLSM; JPLSM; JPLSM; JPLSM; JIR; JPLSM; Intensly Fractured; Intensly Fractured; JPLSM; JPLSM; JPLSM; JPLR; JPLR; JPLR; JPLR; JPLR; JPLR; JPLR; JIR; JPLR; Intensly Fractured; Intensly Fractured

Notes / Water levels / Instrumentation:

- Bentonite Holeplug
- Silica Sand
- 31.8 mm Diam. PVC #10 Slot Screen

Depth scale: 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0015

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 19, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Firm, moist, reddish brown CLAY, trace silt	0.0	1	50 DO	-				
1				2	50 DO	6				6/2/2011 (water level)
				3	50 DO	7				Bentonite Holeplug
				4	50 DO	2				
2–3										Riser
3		Very soft, wet, grey SILT and CLAY	3.0	5	50 DO	WH				
4				6	50 DO	3				Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		Compact, grey, wet, fine to coarse SAND some gravel, trace silt	4.6	7	50 DO	13				
										Bentonite Holeplug
6	CME 55, NQ Core	Slightly weathered, medium crystalline rock	5.8				100	57	100	
		Coarse, white vein					100	62	60	
7		Coarse, white vein Coarse grained, grey, slightly weathered crystalline rock								Silica Sand
8		Pink feldspar and quartz vein, slightly weathered Grey, coarse grained, slightly weathered Pink feldspar and quartz					100	82	72	31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE	8.7							
9		Note: 1. For coring details see Record of Drillhole BRH-0015.								
10										

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp — W — Wl — 16 32 48 64

ADDITIONAL LAB. TESTING

DRAFT

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0015

SHEET 1 OF 1

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 19, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
6	CME 55, NQ Core	Slightly weathered, medium crystalline rock	5.8	1	JIR	
					JIUR	
					FOIR, JIR	
		Coarse, white vein		2	JSTR, JSTR	
7		Coarse, white vein Coarse grained, grey, slightly weathered crystalline rock			JIR, JIR, JIR, JIR, JSTR, JIR, JIR, JIR	Silica Sand
					Broken Core, JIR, JIR, JIR, JIR	
8				3	JIR, FOIR	31.8 mm Diam. PVC #10 Slot Screen
		Pink feldspar and quartz vein, slightly weathered Grey, coarse grained, slightly weathered Pink feldspar and quartz			JIR, JIR, JIR, JIR, JIR	
		END OF BOREHOLE	8.7			
9						
10						
11						
12						
13						
14						
15						

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF BOREHOLE: BRH-0016

PROJECT: 10-1118-0020 PH 4000

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 7, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, moist, brown SILTY SAND, trace organics		0.0	1	50 DO	PL				Bentonite Holeplug
1					2	50 DO	37				Riser; Silica Sand
		Dense, wet, brownish grey, medium to coarse SAND, some gravel, trace silt		1.1							
2	CME 55, NQ Core	Slightly weathered, bedding, grey, coarsely crystalline, medium stron rock (Tonalite)		1.5				T.C.R. (%) 100; S.C.R. (%) 76; R.Q.D. (%) 76			Bentonite Holeplug; ▽ 6/2/2011
3								T.C.R. (%) 100; S.C.R. (%) 47; R.Q.D. (%) 81			
4											Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
5								T.C.R. (%) 100; S.C.R. (%) 100; R.Q.D. (%) 100			
		END OF BOREHOLE		5.7							
6		Note: 1. For coring details see Record of Drillhole BRH-0016.									
7											
8											
9											
10											

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0016

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 7, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55 NQ Core	Slightly weathered, bedding, grey, coarsely crystalline, medium stron rock (Tonalite)	1.5	1	JSTR	
2					JIR	Bentonite Holeplug
					JUR	6/2/2011
					JIR, JPLR, JIR	
3				2	Intensely Fractured, Intensely Fractured, JUR, JIR, JPLR, JIR, JPLR, JPLR	
4					JIR	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
5				3		
		END OF DRILLHOLE	5.7			
6						
7						
8						
9						
10						
11						

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0017

LOCATION: N ;E

BORING DATE: April 7, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, moist to wet, brown SILTY SAND, some organics	0.0	1	50 DO	-				Bentonite Holeplug
1				2	50 DO	55				Riser; 6/2/2011
		Loose to compact, wet, brown SILTY SAND	1.5	3	50 DO	20				Silica Sand
2		Compact, wet, brown, medium to coarse SAND, trace to some gravel, trace silt	2.3	4	50 DO	18				
3				5	50 DO	50/ 0.1				
	CME 55, NQ Core	Fresh bedding, trey, very coarse crystalline strong rock (Tonalite)	3.1				100	87	100	Bentonite Holeplug
5							100	85	95	Silica Sand
6							98	81	85	31.8 mm Diam. PVC #10 Slot Screen
7		END OF BOREHOLE	7.2							

Note:

1. For coring details see Record of Drillhole BRH-0017.

Column headings also printed (no data): DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16, 32, 48, 64); ADDITIONAL LAB. TESTING.

DRAFT

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0017

SHEET 1 OF 1

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 7, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

Abbreviations: JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock. NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25 METRES | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn) | HYDRAULIC CONDUCTIVITY k, cm/s | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION

Depth (m)	Drilling Record	Description	Run No.	Type and Surface Description	Notes / Instrumentation
		TOP OF BEDROCK			
3.1	CME 55, NQ Core	Fresh bedding, trey, very coarse crystalline strong rock (Tonalite)	1	JPLR, JPLR	Silica Sand; Bentonite Holeplug
			2	JPLSM, JPLSM, JPLSM, JPLR, JIR, JIR	Silica Sand
			3	JPLR, JPLR, JPLR, JPLR, JPLR, JPLR, JIR, JIR, JIR, JIR	31.8 mm Diam. PVC #10 Slot Screen
7.2		END OF DRILLHOLE			

Depth scale marks: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0018

LOCATION: N ;E

BORING DATE: March 28, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE										
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, moist, brown SILTY SAND		0.0	1	50 DO	PH					
1					2	50 DO	15					
		Compact, moist, brown to grey SILTY SAND, trace to some gravel		1.4	3	50 DO	50/ 0.28					
2	CME 55, NQ Core	Fresh, grey, very coarse crystalline, strong rock (granite Quartz)		1.8				100	78	69		Bentonite Seal; water level 5/04/2011
3								100	93	100		Riser
5								100	93	100		
6								100	100	100		Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
8								100	81	88		
		END OF BOREHOLE		8.7								

Note:

1. For coring details see Record of Drillhole BRH-0018.

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp —○W— Wl; 16 32 48 64

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0018

SHEET 1 OF 1

LOCATION: N ;E

DRILLING DATE: March 28, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate; BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage; PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular; PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
2	CME 55, NQ Core	Fresh, grey, very coarse crystalline, strong rock (granite Quartz)	1.8	1	JIR	
					Closely Fractured	5/31/2011
					Closely Fractured	
3				2	JIR	
					Healed Joint JPLR	
					JIR	Bentonite Holeplug Riser
4				3	JIR	
					JIR	
5					JIR	
					JIR	
6				4		
7						Silica Sand
					JPLR	31.8 mm Diam. PVC #10 Slot Screen
					JIR	
				5	JSTR	
8					JIR	
					JIR	
		END OF BOREHOLE	8.7			
9						
10						
11						

Column headers also include: SYMBOLIC LOG; COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0019

LOCATION: N ;E

BORING DATE: March 19, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem Auger)

DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
GROUND SURFACE					
Dark brown peat (ORGANICS)	0.0	1	50 DO	3	Silica Sand
Dark brown sandy silt and organics (TOPSOIL)	0.3				Hole Plug; 6/2/2011 (water level)
Grey brown to brown, layered SILTY SAND, trace to little clay, oxidized mottling	0.6	2	50 DO	5	Riser
Brown, layered CLAYEY SILT, trace to some sand, oxidized mottling	1.5	3	50 DO	25	Cuttings
		4	50 DO	28	
Grey, layered SILT, little to some clay, trace sand	3.0	5	50 DO	26	
		6	50 DO	22	Hole Plug
		7	50 DO	27	
		8	50 DO	15	
		9	50 DO	15	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		10	50 DO	11	
		11	50 DO	2	Cave
END OF BOREHOLE PROBABLE BEDROCK REFUSAL	8.4				

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

RECORD OF BOREHOLE: BRH-0020

PROJECT: 10-1118-0020 PH 4000

LOCATION: N ;E

BORING DATE: March 19, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem Auger)

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE					
0	TOPSOIL	0.0				Cement 6/2/2011
	Reddish brown SAND, little silt, trace organics	0.2	1	50 DO	4	
1	Layered, greyish brown CLAYEY SILT, trace sand	0.8	2	50 DO	5	Hole Plug
			3	50 DO	4	
2						Riser
	Layered, greyish SILTY CLAY, trace sand	2.3	4	50 DO	3	
3			5	50 DO	4	
4			6	50 DO	3	
5			7	50 DO	2	
			8	50 DO	2	Backfill Cuttings
6			9	50 DO	3	
7			10	50 DO	3	
8			11	50 DO	3	
9	Reddish brown CLAY, some silty clay layers, trace to little sand	9.1	12	50 DO	WH	
10						

Chart columns: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp ⊢—○W—⊣ Wl) (16, 32, 48, 64); ADDITIONAL LAB. TESTING

DRAFT

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0020

LOCATION: N ;E

BORING DATE: March 19, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem Auger)

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	PIEZOMETER OR STANDPIPE INSTALLATION
10	Reddish brown CLAY, some silty clay layers, trace to little sand		13	50 DO	PH		Backfill Cuttings
11						nat V. +, rem V. ⊕	
12	Layered, grey SILTY CLAY, trace sand	11.8	14	50 DO	1		
13	Layered, grey SILT, some clay, trace sand	13.3	15	50 DO	WH		
15	Grey brown GRAVELLY SAND, little silt, trace to little clay	14.8	16	50 DO	20		
16	Bouldery SAND	15.8					Hole Plug
18							Silica Sand
19							31.8 mm Diam. PVC #10 Slot Screen
20							

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DRAFT

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0020

LOCATION: N ;E

BORING DATE: March 19, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp W Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Bouldery SAND									Cave
25.6	CME 55, NQ Core	Greyish green, fresh, porphrite TONALITE, with quartz / feldspar veins		25.6				T.C.R. (%) 100, S.C.R. (%) 67, R.Q.D. (%) 78			
								T.C.R. (%) 100, S.C.R. (%) 93, R.Q.D. (%) 96			
								T.C.R. (%) 100, S.C.R. (%) 95, R.Q.D. (%) 100			
28.9		END OF BOREHOLE		28.9							

Depth scale marks: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

DRAFT

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0020

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 19, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

Legend: JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU- Curved; UN- Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55 / NQ Core	Greyish green, fresh, porphrite TONALITE, with quartz / feldspar veins	25.6		JUER	
26				1	JPLR	
					JPLR	
					JPLR	
					JNPLR	
27						
				2	JPLR	
28					Broken Core	
					Broken Core	
					JPLR	
				3	JPLR	
29		END OF DRILLHOLE	28.9			
30						
31						
32						
33						
34						
35						

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0020C

LOCATION: N ;E

BORING DATE: May 2, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger / Nicone Vane Push			0.0							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

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DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0020C

LOCATION: N ;E

BORING DATE: May 2, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger										
		END OF BOREHOLE		10.7							
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF BOREHOLE: BRH-0021

PROJECT: 10-1118-0020 PH 4000

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: March 17, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Topsoil (HUMUS/ORGANICS)		0.0							Cement; Hole Plug
		SILTY SAND and ORGANICS		0.6	1	50 DO	13				Cuttings; ▽ 6/2/2011
1		Layered sandy SILT and silty sand, oxidization throughout		1.2	2	50 DO	29				Riser
2		Grey brown SILT, trace sand		2.3							Hole Plug
		SAND, some gravel, little silt, trace cobbles		2.6	3	50 DO	48				
3	CME 55, NQ Core	Light to dark green and grey, fresh porphyritic TONALITE, pinkish alteration zones (hematite) and quartz / feldspar veins throughout		3.0				100	60	60	Silica Sand
4–5								93	66	60	Cave; 31.8 mm Diam. PVC #10 Slot Screen
6		END OF BOREHOLE BEDROCK REFUSAL		5.9							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20, 40, 60, 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ○: 20, 40, 60, 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}
WATER CONTENT PERCENT: Wp —○W— Wl: 16, 32, 48, 64
ADDITIONAL LAB. TESTING

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0021

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 17, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
3	CME 55 NQ Core	Light to dark green and grey, fresh porphyritic TONALITE, pinkish alteration zones (hematite) and quartz / feldspar veins throughout	3.0	1	JUER JPLSM JPLSM JPLSM JPLSM	Hole Plug Silica Sand
4–5				2	JPLSM JPLSM JPLSM Broken Core JUER JPLSM JPLSM JCSM	Cave 31.8 mm Diam. PVC #10 Slot Screen
6		END OF BOREHOLE BEDROCK REFUSAL	5.9			

Depth scale marks: 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

RECORD OF BOREHOLE: BRH-0022

PROJECT: 10-1118-0020 PH 4000
SHEET 1 OF 1

LOCATION: N ;E
BORING DATE: March 17, 2011
DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm
INCLINATION: -90 degrees
PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Brown GRAVELLY SAND, some cobbles / boulders, trace silt		0.0	1	DO	50/0.1				Silica Sand
	CME 55, NQ Core	Greyish green, fresh porphyritic TONALITE, with pinkish alteration zones (hematite) throughout and trace quartz / feldspar veins		0.1				98	70	77	
1								100	75	83	Riser; Hole Plug
2											6/2/2011 (water level)
3								100	47	82	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
4								100	81	78	
5		END OF BOREHOLE BEDROCK REFUSAL		5.4							

Chart axes: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp W Wl (16, 32, 48, 64); ADDITIONAL LAB. TESTING

DRAFT

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0022

SHEET 1 OF 1

LOCATION: N ;E

DRILLING DATE: March 17, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE				
0–5.4	CME 55 NQ Core	Greyish green, fresh porphyritic TONALITE, with pinkish alteration zones (hematite) throughout and trace quartz / feldspar veins	0.1	1	JSMPL, JRW, JSMPL, JUER, JSMPL	Silica Sand
				2	JSMPL, JUER, JPLSM, JPLSM, JPLSM	Riser; Hole Plug; water level 6/2/2011
				3	JUER, JSMPL, JPLR, UNPLR, Broken Core, JPLSM, JPLSM, JUER, JPLSM	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				4	JPLSM, JUER, JUER, JPLSM	
		END OF BOREHOLE BEDROCK REFUSAL	5.4			

Column headings: COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.; SYMBOLIC LOG

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF BOREHOLE: BRH-0023

PROJECT: 10-1118-0020 PH 4000
SHEET 1 OF 1
LOCATION: N ;E
BORING DATE: March 26, 2011
DATUM: Geodetic
SAMPLER HAMMER, 63.5 kg; DROP, 760 mm
INCLINATION: -90 degrees
PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem Auger)

Description	Elev. Depth (m)	Sample Number	Type	Blows/0.3m	Piezometer or Standpipe Installation
GROUND SURFACE					
Boulders and TOPSOIL	0.0				
SILT and SAND, trace organics	0.5	1	50 DO	11	Hole Plug; Riser; water level 5/31/2011
Gravelly SILT and SAND	1.3				
SAND and BOULDERS, some gravel, trace silt	1.5	2	50 DO	21	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		3	50 DO	32	
Gravelly SILT and SAND, some boulders, some cobbles, trace clay	2.7	4	50 DO	8	Cave In
END OF BOREHOLE PROBABLE BEDROCK REFUSAL	3.6				

Other column headings (no data entered): DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. +, Q - ●, rem V. ⊕, U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp — W — Wl (16, 32, 48, 64); ADDITIONAL LAB. TESTING.

Depth scale (metres): 0 1 2 3 4 5 6 7 8 9 10

DRAFT

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0024

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: March 26, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	GRAVELLY SAND and boulders, trace silt		0.0	1	50 DO	50/ 0.2				Concrete
1	CME 55 NQ Core	Slightly weathered, greenish grey porphyritic TONALITE, hematite and fledspar veins throughout		1.0				T.C.R. (%) 81, S.C.R. (%) 30, R.Q.D. (%) 30			Riser
2											Hole Plug
3								T.C.R. (%) 100, S.C.R. (%) 69, R.Q.D. (%) 76			
4											
5								T.C.R. (%) 85, S.C.R. (%) 50, R.Q.D. (%) 60			5/31/2011 (water level)
6								T.C.R. (%) 75, S.C.R. (%) 41, R.Q.D. (%) 44			Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7		END OF BOREHOLE		7.2							
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE (SOIL CORE) 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0024

SHEET 1 OF 1

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 26, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

Legend: JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
1	CME 55 NQ Core	Slightly weathered, greenish grey porphyritic TONALITE, hematite and fledspar veins throughout	1.0	1		Riser
2						
3				2	JPLR, JPLR, JPLR, JPLR, JUER, JPLR	Hole Plug
4					JPLR	
5				3	Void, Void, JPLR, Void, Void, Void, JUER, JUER, JPLR, Broken Core	5/31/2011
6				4	JPLR, JWR, JPLR, Void	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7						
		END OF DRILLHOLE	7.2			
8–11						

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0025

LOCATION: N ;E

BORING DATE: March 27, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	Peat (ORGANICS)		0.0							
1					1	50 DO	3				
		ORGANICS, and silty SAND, little gravel		1.2							
		Silty SAND and COBBLES		1.5	2	50 DO	50				
		END OF BOREHOLE PROBABLE BEDROCK REFUSAL		1.7							
2											
3											
4											
5											
6											
7											
8											
9											
10											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0026

LOCATION: N ;E

BORING DATE: March 29, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp ⊢ ⊖W ⊣ Wl) (16, 32, 48, 64) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Boring method: 0–1.5 m: Power Auger, 200 mm Diam. (Hollow Stem Auger); 1.5–8.7 m: CME 55, NQ Core

Description	Elev. Depth (m)
GROUND SURFACE	
ORGANICS	0.0
Loose to compact, moist, light brown SILTY SAND, trace organics	0.2
Cobbles and Boulders	1.2
Slightly weathered, grey, fine crystalline, weak rock	1.5
Slightly weathered, grey, fine crystalline, medium strong rock Sheared volcanics	2.2
Note: 1. For coring details see Record of Drillhole BRH-0026.	8.7

Samples

Number	Type	Blows/0.3m
1	50 DO	11
2	50 DO	28

Core runs

T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
98	48	38
102	77	90
100	51	83
100	63	58
100	63	98

Piezometer or standpipe installation: Silica Sand; Riser; Bentonite Holeplug; water level 5/31/2011; Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0026

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 29, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55 NQ Core	Slightly weathered, grey, fine crystalline, weak rock	1.5	1	Closely Fractured; Closely Fractured; Closely Fractured; Closely Fractured; Closely Fractured	
2		Slightly weathered, grey, fine crystalline, medium strong rock Sheared volcanics	2.2			Bentonite Holeplug 5/31/2011
3				2	Closely Fractured; JIR; JIR; JIR; JIR	
4					JIR; JIR; JIR; JIR	
5				3	JIR; JIR; JIR; JIR; JUSM; JISM; JIR; JIR; JIR	
6				4	JIR; JIR; JIR; JIR; JIR; JIR; JIR; JUSM; JUSM	Silica Sand
7					JIR; JIR; JIR	31.8 mm Diam. PVC #10 Slot Screen
8				5	JUR; JIR; JIR; JIR; JIR; JIR; JIR; JIR; JIR; JIR	
		END OF DRILLHOLE	8.7			
9						
10						
11						

FLUSH: <<

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0027

LOCATION: N ;E

BORING DATE: April 8, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE					
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	PEAT	0.0				
		Loose, wet, dark brown PEAT, some sand, some silt	0.2	1	50 DO	PL	Bentonite Holeplug; Riser
1		Loose to compact, wet, grey, SITLY SAND, trace gravel	0.6	2	50 DO	8	
		Compact, wet, grey coarse SAND and GRAVEL, trace silt	1.7	3	50 DO	13	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
2				4	50 DO	50/0.12	
		END OF BOREHOLE	2.4				

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp —○W— Wl 16 32 48 64
ADDITIONAL LAB. TESTING

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0028

LOCATION: N ;E

BORING DATE: April 3, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	PEAT	0.0							
		Loose, wet SANDY SILT, trace clay	0.2	1	50 DO	PL				
1				2	50 DO	10				Bentonite Holeplug; 5/31/2011
				3	50 DO	5				Riser
3		Compact to dense, wet, light brown SILTY SAND, trace clay, trace gravel	2.9	4	50 DO	37				Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
4	CME 55, NQ Core	Fresh, grey, coarsely grained crystalline, strong rock (Tonalite)	3.8				T.C.R. (%) 100, 97; S.C.R. (%) 94, 57; R.Q.D. (%) 100, 60			Bentonite Holeplug; Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		Note: 1. For coring details see Record of Drillhole BRH-0028.	5.7							

Dynamic penetration scale: 20, 40, 60, 80. Shear strength: nat V. + Q - ●; rem V. ⊕ U - ○; scale 20, 40, 60, 80.

Hydraulic conductivity scale: 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}. Water content percent: Wp — W — Wl; scale 16, 32, 48, 64.

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF DRILLHOLE: BRH-0028

PROJECT: 10-1118-0020 PH 4000

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 3, 2011

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
4	CME 55 / NQ Core	Fresh, grey, coarsely grained crystalline, strong rock (Tonalite)	3.8	1	JIR	Bentonite Holeplug
5				2	JUR; Closely Fractured; JSTR; JPLR; JPLR; JIR; JPLSM; JIR; Intensley Fractured	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		END OF DRILLHOLE	5.7		Intensley Fractured	

Other column headings: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0029A

LOCATION: N ;E

BORING DATE: April 1, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	PEAT (Organics)	0.0							
		Very loose, wet, dark brown SILTY SAND, some orgnics, some gravel	0.1	1	50 DO	PL				5/31/2011 (water level)
1		Loose to compact, wet, brown, coarse SAND, some gravel, trace silt	0.8	2	50 DO	14				Bentonite Holeplug
2				3	50 DO	12				Riser
				4	50 DO	11				
3				5	50 DO	20				
4				6	50 DO	26				Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
5				7	50 DO	10				
				8	50 DO	50/0.27				
6	CME 55, NQ Core	Slightly weathered, grey, coarse to very coarse crystalline, medium strong rock (Tonalite)	5.6				98	67	72	
7		Fresh, grey, coarsely crystalline, strong rock	6.8							Bentonite Holeplug
8							100	100	100	
9							100	97	100	Silica Sand
10										

CONTINUED NEXT PAGE

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 16 32 48 64
ADDITIONAL LAB. TESTING

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0029A

LOCATION: N ;E

BORING DATE: April 1, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10–11	CME 55 NQ Core	Fresh, grey, coarsely crystalline, strong rock						T.C.R. (%) 100 / 97; S.C.R. (%) 97 / 63; R.Q.D. (%) 100 / 75			Silica Sand 31.8 mm Diam. PVC #10 Slot Screen 31.8 mm Diam. PVC #10 Slot Screen
12		Note: 1. For coring details see Record of Drillhole BRH-0029A.		11.9							

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF DRILLHOLE: BRH-0029A

PROJECT: 10-1118-0020 PH 4000

SHEET 1 OF 1

LOCATION: N ;E

DRILLING DATE: April 1, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Drilling record: CME 55, NQ Core

Depth (m)	Description	Elev./Depth (m)	Run No.	Discontinuity type and surface description	Notes / Water levels / Instrumentation
	TOP OF BEDROCK				
5.6–6.8	Slightly weathered, grey, coarse to very coarse crystalline, medium strong rock (Tonalite)	5.6	1	JIR, JUSM, JISM, JIR, JPL, JIR, JIR	Silica Sand
6.8–11.9	Fresh, grey, coarsely crystalline, strong rock	6.8	1	JIR, JIR	Bentonite Holeplug
			2		
			3	JIR, JIR	Silica Sand
			4	JSTSM, Intensely Fractured, JIR, JIR, JSTSM, JSTSM, JSTSM, JIR	31.8 mm Diam. PVC #10 Slot Screen
11.9	END OF DRILLHOLE	11.9			

Depth scale: 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0030A

LOCATION: N ;E

BORING DATE: April 2, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE					
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	PEAT (Organics)	0.0				Bentonite Holeplug
		Loose, wet, dark brown SILTY SAND, trace organics	0.2	1	50 DO	PL	
1		Loose to compact, wet, brown SILT, some sand, trace clay	0.8	2	50 DO	14	Riser; water level 5/31/2011
		Loose to compact, wet, brown to grey SILT, trace clay	1.5	3	50 DO	14	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
2				4	50 DO	21	
3		Loose, wet, coarse SAND, some gravel ,trace silt, cobbles	3.0	5	50 DO	50/ 0.25	
	CME 55, NQ Core	Slightly weathered, medium crystalline, grey strong rock (sheared volcanics)	3.3				Bentonite Holeplug
4		5mm silt seam in joint					
		Fresh, coarse grained crystalline, grey strong rock (Tonalite)	4.6				Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
5							
		Note: 1. For coring details see Record of Drillhole BRH-0030A.	5.6				

Rock core results (3.3–4.6 m): T.C.R. (%) 100, S.C.R. (%) 81, R.Q.D. (%) 84

Rock core results (4.6–5.6 m): T.C.R. (%) 98, S.C.R. (%) 75, R.Q.D. (%) 83

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ ; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp — W — Wl ; 16 32 48 64
ADDITIONAL LAB. TESTING

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0030A

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 2, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU- Curved; UN- Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK			
4	CME 55 / NQ Core	Slightly weathered, medium crystalline, grey strong rock (sheared volcanics)	3.3	1	Bentonite Holeplug
5		Fresh, coarse grained crystalline, grey strong rock (Tonalite)	4.6	2	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		END OF DRILLHOLE	5.6		
6					
7					
8					
9					
10					
11					
12					
13					

Column headings also include: SYMBOLIC LOG; COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

JPLK

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0030A

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 2, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---																		
													JIR							
													JPLR							
14													JIR							
													JIR							
													JIR							
15													JSTMS							
16																				
17													JPLSM							
18													JIR							
													JPLR							
													JIR							
19																				
20																				
21																				
22																				
23																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0031

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 2, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger 200 mm Diam. (Hollow Stem Auger)	PEAT (Native)		0.0	1	50 DO	1				
1					2	50 DO	1				5/31/2011 (water level)
		Loose, wet, grey SILT, trace sand		1.7	3	50 DO	8				
2		SAND, dense		2.0							
		Compact, wet, grey CLAYEY SILT, trace sand		2.1	4	50 DO	18				Bentonite Holeplug
3		Very loose, wet, grey medium to coarse SAND		3.0							
		Compact, wet, CLAYEY SILT, trace sand		3.2	5	50 DO	12				
4					-	50 DO	3				Riser
5					6	50 DO	17				31.8 mm Diam. PVC #10 Slot Screen Silica Sand
6					7	50 DO	50/ 0.1				
		END OF BOREHOLE		6.2							
7											
8											
9											
10											

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0032

LOCATION: N ;E

BORING DATE: April 3, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE					
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, moist, brown PEAT, trace cobble, trace gravel	0.0	1	50 DO	PL	Bentonite Holeplug
1				2	50 DO	11	Riser; water level 5/31/2011
		Loose to compact, wet, grey SILT, trace sand	1.5	3	50 DO	16	
2		Compact, wet, grey SILTY SAND	2.4	4	50 DO	22	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
3		Loose, wet, grey, coarse SAND and GRAVEL, trace silt	3.0	5	50 DO	11	
				6	50 DO	50/ 0.2	
4	CME 55, NQ Core	Fresh, grey, coarsley grained crystalline, strong rock (Tonalite)	4.0				Bentonite Holeplug
5–7							Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		Note: 1. For coring details see Record of Drillhole BRH-0032.	7.3				

Core recovery (4.0 m to 7.3 m):

T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
100	100	0
100	92	93
100	68	82

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ○; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp — W — Wl; 16 32 48 64
ADDITIONAL LAB. TESTING

DRAFT

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0032

SHEET 1 OF 1

LOCATION: N ;E

DRILLING DATE: April 3, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR:

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
4	CME 55 / NQ Core	Fresh, grey, coarsley grained crystalline, strong rock (Tonalite)	4.0	1		Bentonite Holeplug
5				2	MB	
6				3	JSTR, JPLSM, JIR, JPLSM, JIR, JPLSM, JIR, JPLSM, JIR, JIR, JPLSM, JIR, JPLSM, JIR, JIR	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
7		END OF DRILLHOLE	7.3			
8						
9						
10						
11						
12						
13						
14						

Column headers also include: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

DRAFT

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 22/06/11 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0032C

LOCATION: N ;E

BORING DATE: April 4, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE										
0	Power Auger; 200 mm Diam. (Hollow Stem Auger)	FOR STRATIGRAPHY DETAILS SEE RECORD OF BOREHOLE BRH-0032.		0.0								Cuttings; water level 5/31/2011
3.4		Cobbles and Boulders		3.4								
3.6	CME 55; NQ Core	Slightly weathered, coarsely grained crystalline, strong rock		3.6				100	72	94		Bentonite Holeplug; Riser
								100	48	63		
								100	85	100		Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
								100	76	95		
8.6		Note: 1. For coring details see Record of Drillhole BRH-0032C.		8.6								

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● ; rem V. ⊕ U - ○ ; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl ; 16 32 48 64

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0032C

SHEET 1 OF 1

LOCATION: N ;E

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 4, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK					
		Cobbles and Boulders		3.4			Cuttings
4	CME 55 NQ Core	Slightly weathered, coarsely grained crystalline, strong rock		3.6	1	JPLSM, JIR	
5					2	JIR, JPLR, Intensely Fractured, Intensely Fractured, JPLSM, JPLSM, JSTSM, JPLSM, JIR, JIR	Bentonite Holeplug; Riser
6					3	JPLSM, JSTR, JPLSM	
7–8					4	JPLSM, JPLSM, JPLSM	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
		END OF DRILLHOLE		8.6			

Other column headings: COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0033

LOCATION: N ;E

BORING DATE: April 4, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem Auger)

Description	Elev. Depth (m)	Sample Number	Type	Blows/0.3m	Piezometer or Standpipe Installation
GROUND SURFACE					
Loose, wet, dark brown PEAT (Fibrous)	0.0	1	50 DO	PL	
		2	50 DO	12	Bentonite Holeplug
					5/31/2011
		3	50 DO	6	Riser
Loose, wet, grey, coarse SAND, trace gravel	2.0	4	50 DO	10	
		5	50 DO	7	
		6	50 DO	3	Silica Sand
					31.8 mm Diam. PVC #10 Slot Screen
		7a	50 DO	7	
Compact, wet, grey SILT, trace sand	5.0	7b			
		8	50 DO	25	Cave-In
END OF BOREHOLE SPOON REFUSAL	7.3				

Column headings: DEPTH SCALE METRES (0–10); BORING METHOD; SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)); SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp, W, Wl) (16, 32, 48, 64); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

RECORD OF BOREHOLE: BRH-0034A

PROJECT: 10-1118-0020 PH 4000

SHEET 1 OF 1

LOCATION: N ;E

BORING DATE: April 5, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE								
Power Auger, 200 mm Diam. (Hollow Stem Auger)	Loose, wet, dark brown, PEAT, trace sand	0.0	1	50 DO	3				
	Boulder	0.5	2	RC	-				5/31/2011 (water level)
	Loose, wet, dark brown PEAT, trace sand	1.0	3	50 DO	1				
	Loose, wet, grey, SILT, trace sand	2.4	4	50 DO	5				Bentonite Holeplug
	Cobbles and Boulders	2.7							
	Compact, wet, grey, coarse, SAND and GRAVEL	4.3	5	50 DO	50/ 0.3				Riser
CME 55, NQ Core	Fresh, grey, coarsely grained, crystalline, strong rock	4.6				100	91	100	
						100	72	93	Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
	Note: 1. For coring details see Record of Drillhole BRH-0034A.	7.3							

DEPTH SCALE 1 : 50

LOGGED: MO

CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF DRILLHOLE: BRH-0034A

LOCATION: N ;E
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 5, 2011
DRILL RIG: CME 55 Trackmount
DRILLING CONTRACTOR:

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES / WATER LEVELS / INSTRUMENTATION
		TOP OF BEDROCK				
	CME 55 / NQ Core	Fresh, grey, coarsely grained, crystalline, strong rock	4.6			Riser
5				1	JIR	Bentonite Holeplug
6				2	SPLR JIR MB JPLSM JPLSM Intensely Fractured Intensely Fractured JPLSM JPLSM	Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7						
		END OF DRILLHOLE	7.3			
8						
9						
10						
11						
12						
13						
14						

Column headings also printed: SYMBOLIC LOG; FLUSH; COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

PROJECT: 10-1118-0020 PH 4000

RECORD OF BOREHOLE: BRH-0034B

LOCATION: N ;E

BORING DATE: April 5, 2011

DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

INCLINATION: -90 degrees

PENETRATION TEST HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									
0	Power Auger, 200 mm Diam. (Hollow Stem Auger)	For stratigraphy refer to Borehole BRH-0034A		0.0							Bentonite Holeplug; Riser; 5/31/2011 (water level); Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
3.4	CME 55, NQ Core	To confirm Bedrock cored 0.9 m depth.		3.4		RC					
4.3		END OF BOREHOLE		4.3							

DRAFT

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: BG?

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 22/06/11 DATA INPUT:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-1

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 17 and 19, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT (W)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	436.84						
0	TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers	PEAT (100 mm)	0.00						
		(ML) SILT and SAND, trace gravel, zones of clayey silt; dark brown to brown, organic inclusions; moist, very loose	436.74 / 0.10	1	50 DO	3	~31	MH/NP	50 mm Diameter Monitoring Well
		(SM) SILTY SAND, some gravel; brown; moist, compact	436.15 / 0.69	2A	50 DO	19	~35	MH	
1		(SP) SAND, medium grained, some fines, trace gravel; brown; wet, compact	435.93 / 0.91	2B			~15		Bentonite Seal ▽
	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-1	435.62 / 1.22						Silica Sand Filter
4		END OF BOREHOLE	432.65 / 4.19						

Chart headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa — nat V. +, Q - ●, rem V. ⊕, U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40).

1. Water encountered during drilling at a depth of 1.1 m below ground surface, Aug. 17/12

2. Water level at a depth of 1.1 m below ground surface upon completion of drilling, Aug. 19/12

DEPTH SCALE
1 : 25

Golder Associates

LOGGED: AM
CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF DRILLHOLE: BH 12-1

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 17 and 19, 2012
DRILL RIG: CME 55 TRACK MOUNTED
DRILLING CONTRACTOR: TBT ENGINEERING

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	UNC Index (MPa)	STRAIN ε	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		435.62													
	NQ CORING	Fresh, fine to medium grained unaltered, green TONALITE (BEDROCK)		1.22	1												Bentonite Seal
2																	
3					2												Silica Sand Filter
4				432.65													
		END OF DRILLHOLE		4.19													
5																	
6																	

GTA-RCK 008 1111180074.GPJ GAL-MISS.GDT 2/14/13 GPC AUG. 2012

DEPTH SCALE
1 : 25

Golder Associates

LOGGED: AM
CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-2

LOCATION: SEE FIGURE 2

BORING DATE: August 12 and 13, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Boring method: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

Depth (m)	Description	Elev. / Depth (m)	Sample No.	Type	Blows/0.3m	Additional Lab. Testing	Piezometer or Standpipe Installation
0	GROUND SURFACE	418.40					
	(ML) SILT, some sand; dark brown, organically stained, organic inclusions; moist, loose to compact	0.00	1	50 DO	10		50 mm Diameter Monitoring Well
	(ML) sandy SILT; brown, zones of silt, zones of clayey silt; moist to wet, compact to very loose	417.71 / 0.69	2	50 DO	12		
			3	50 DO	8		
			4	50 DO	2	MH	
	(ML) CLAYEY SILT, trace sand; brown to grey, zones of sandy silt; cohesive, Wn>PL, soft to firm	415.50 / 2.90	5	50 DO	2		
			6	50 DO	2	MH	Bentonite Seal
	(CI) SILTY CLAY, trace fine sand; medium plasticity; red-brown to grey; cohesive, Wn>PL, firm	412.84 / 5.56	7	50 DO	WH	MH	
			8	75 TO	-		
	(ML) SILT, trace to some fine sand; grey; wet, compact to loose	409.79 / 8.61	9	50 DO	12		
10							

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-2

LOCATION: SEE FIGURE 2

BORING DATE: August 12 and 13, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	TRACK MOUNTED POWER AUGER; 200 mm Dia. Hollow Stem Augers	(ML) SILT, trace to some fine sand; grey; wet, compact to loose							
11				10	50 DO	13	○	MH	Bentonite Seal
12				11	50 DO	5	○		
13		(SM) SILTY SAND and GRAVEL, rock fragments; grey; wet, compact	405.22 / 13.18						
14				12	50 DO	14			Silica Sand Filter
15	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-2	403.26 / 15.14						
18		END OF BOREHOLE	400.11 / 18.29						

1. Water encountered during drilling at a depth of 2.1 m below ground surface, Aug. 12/12

2. Water level measured in monitoring well at a depth of 0.91 m (Elev. 417.49 m) below ground surface, Aug. 28/12

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

GTA-BHS 001 1111180074.GPJ GAL-MIS.GDT 2/14/13 GPC AUG. 2012

PROJECT: 11-1118-0074

RECORD OF DRILLHOLE: BH 12-2

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 12 and 13, 2012
DRILL RIG: CME 55 TRACK MOUNTED
DRILLING CONTRACTOR: TBT ENGINEERING

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	UNC Index (MPa)	STRAIN ε	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		403.26													
16–18	NQ CORING	Fine to medium grained, green, weathered to fresh TONALITE BEDROCK with Quartz vains		15.14	1												
					2												
				400.11 / 18.29													
		END OF DRILLHOLE															

Depth scale: 16, 17, 18, 19, 20, 21, 22, 23, 24, 25

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AM
CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-3A

SHEET 1 OF 2

LOCATION: SEE FIGURE 2

BORING DATE: August 9 and 10, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

SOIL PROFILE

ELEV. / DEPTH (m)	DESCRIPTION
419.69 / -0.20	GROUND SURFACE
	(PT) PEAT; black, wood fragments; wet, very loose
418.12 / 1.37	(ML) SILT and SAND, trace gravel; grey; moist, loose
417.36 / 2.13	(ML) SILT, some sand; grey; wet, loose
415.22 / 4.27	(CI) SILTY CLAY, medium plasticity, trace sand; red-brown to grey; cohesive, Wn>PL, soft to firm
410.65 / 8.84	(ML) SILT, trace fine sand; grey; wet, compact to loose

SAMPLES

NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT / NOTES	ADDITIONAL LAB. TESTING
1	50 DO	WH	301	
2	50 DO	1	134.2	
3	50 DO	6		MH
4	50 DO	8		MH
5	50 DO	8		MH/NP
6	50 DO	1		
7	50 DO	WH	55.6	MH
8	50 DO	1	65.9	MH
9	50 DO	16		MH/NP

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp —○W— Wl (10 20 30 40)

PIEZOMETER OR STANDPIPE INSTALLATION: 50 mm Diameter Monitoring Well; Bentonite Seal

DEPTH SCALE METRES: 0 – 9

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

GTA-BHS 001 1111180074.GPJ GAL-MIS.GDT 2/14/13 GPC AUG. 2012

PROJECT: 11-1118-0074

RECORD OF DRILLHOLE: BH 12-3A

LOCATION: SEE FIGURE 2

DRILLING DATE: August 9 and 10, 2012

DATUM: Geodetic

DRILL RIG: CME 55 TRACK MOUNTED

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: TBT ENGINEERING

Abbreviations: JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE	406.08		
14	NQ CORING, 100 mm Dia. Casing	Fine to medium grained, green, slightly weathered to fresh TONALITE BEDROCK	13.41	1	Bentonite Seal
15–16			403.03	2	Silica Sand Filter
		END OF DRILLHOLE	16.46		

Depth scale: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

Other columns (blank or graphical only): SYMBOLIC LOG; PENETRATION RATE (m/min); FLUSH COLOUR % RETURN; RECOVERY TOTAL CORE % / SOLID CORE %; R.Q.D. %; FRACT. INDEX PER 0.3 m; DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION); HYDRAULIC CONDUCTIVITY K, cm/sec; UNC Index (MPa); STRAIN ε

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-3A

LOCATION: SEE FIGURE 2

BORING DATE: August 9 and 10, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers	(ML) SILT, trace fine sand; grey; wet, compact to loose							
11				10	50 DO	7	○ (approx. 21%)		
12		(ML) SILT and SAND, some gravel; grey (TILL-LIKE), compact	407.83 / 11.66	11	50 DO	15	○ (approx. 10%)	MH	Bentonite Seal
13		For bedrock coring details refer to Record of Drillhole BH 12-3A	406.08 / 13.41						
14–16	NQ CORING, 100 mm Dia. Casing								Silica Sand Filter
		END OF BOREHOLE	403.03 / 16.46						

1. Water encountered during drilling at a depth of 2.3 m below ground surface, Aug. 9/12

2. Water level measured in monitoring well A at a height of 0.02 m (Elev. 419.51 m) above ground surface, Aug. 28/12

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-3B

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 14, 2012

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		-0.20							
0	TRACK MOUNTED POWER AUGER; 200 mm Dia. Hollow Stem Augers	For soil details refer to Record of Borehole BH 12-3A									50 mm Diameter Monitoring Well
5											Bentonite Seal
7					1	75 TO	-		53.7 ○		
11											Silica Sand Filter
		END OF BOREHOLE		11.58							1. Water level measured in monitoring well B at a height of 0.03 m (Elev. 419.52 m) above ground surface, Aug. 28/12

DEPTH SCALE

1 : 65

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-4

LOCATION: SEE FIGURE 2

BORING DATE: August 8 and 9, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers (0 to 7.01 m); NQ CORING (7.01 to 10.16 m)

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT / LAB DATA	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
GROUND SURFACE	428.77 / -0.20						
(PT) Fibrous PEAT; black; wet, very loose		1	50 DO	1	406.8		50 mm Diameter Monitoring Well
		2	50 DO	1	401.5		
		3	50 DO	1	320.5		
(ML) CLAYEY SILT, trace fine sand; grey, zones of silt; Wn<PL to Wn~PL, stiff	426.44 / 2.13	4	50 DO	10		MH	Bentonite Seal
(CI) SILTY CLAY, medium plasticity, trace to some fine sand, zones of brown clay, zones of silt; brown to grey; cohesive, Wn>PL to Wn~PL, stiff to very stiff	425.67 / 2.90	5	50 DO	1	72	MH	
		6	50 DO	9			
(ML) SILT, some fine sand; grey; wet, loose	423.39 / 5.18	7	50 DO	9			
(SM) SILTY SAND, trace gravel; brown to grey; wet, loose	422.63 / 5.94	8	50 DO	6		MH	Silica Sand Filter
For bedrock coring details refer to Record of Drillhole BH 12-4	421.56 / 7.01						
END OF BOREHOLE	418.41 / 10.16						

1. Water encountered during drilling at a depth of 0.6 m below ground surface, Aug. 8/12

2. Water level at a depth of 2.7 m below ground surface upon completion of drilling, Aug. 9/12

3. Water level measured in monitoring well at a height of 0.02 m (Elev. 428.59 m) above ground surface, Aug. 28/12

DEPTH SCALE 1 : 63.5

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF DRILLHOLE: BH 12-4

LOCATION: SEE FIGURE 2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 8 and 9, 2012

DRILL RIG: CME 55 TRACK MOUNTED

DRILLING CONTRACTOR: TBT ENGINEERING

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	UNC Index (MPa)	STRAIN ε	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		421.56													
8–10	NQ CORING	Medium grained, fresh TONALITE, dark grey		7.01	1												
					2												
				418.41													
		END OF DRILLHOLE		10.16													

Depth scale: 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

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DEPTH SCALE

1 : 63.5

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-5

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 21, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○) (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp, W, Wl) (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION (B, A)

Boring method: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers (0.00 – 7.75 m); NQ CORING (7.75 – 10.69 m)

Description	Elev. / Depth (m)	Sample No.	Type	Blows/0.3m	Water content / notes	Additional Lab. Testing
GROUND SURFACE	433.03					
(SM) SAND, some fines, trace to some gravel; brown (FILL); moist to wet, very loose	0.00	1A	50 DO	WH	○	
(PT) Fiberos (PEAT); black; wet, very loose	432.73 / 0.30	1B			442.2	
		2	50 DO	WH	389.8	
(SP) SAND, medium grained, trace fines; brown and grey; wet, very loose	431.38 / 1.65	3	50 DO	WH		
(SM) SILTY SAND; grey; wet, loose	430.90 / 2.13	4	50 DO	7	○	MH
		5	50 DO	9	○	MH
(SP) SAND, some fines; grey; wet, very loose	428.99 / 4.04	6A	50 DO	3	○	
(ML) SILT, some sand; grey; wet, very loose	428.15 / 4.88	6B			○	
(SW) SAND, trace gravel, some fines; grey; wet, compact	427.47 / 5.56	7	50 DO	23	○	MH
(SM) gravelly SILTY SAND; grey; wet, very dense	425.94 / 7.09	8	50 DO	50/.13	○	MH
For bedrock coring details refer to Record of Drillhole BH 12-5	425.28 / 7.75					
END OF BOREHOLE	422.34 / 10.69					

1. Water encountered during drilling at a depth of 0.1 m below ground surface, Aug. 21/12

2. Water level at a depth of 0.3 m below ground surface upon completion of drilling, Aug. 21/12

DEPTH SCALE

1 : 62

Golder Associates

LOGGED: AM

CHECKED: DCJ

RECORD OF DRILLHOLE: BH 12-5

PROJECT: 11-1118-0074

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 21, 2012

DRILL RIG: CME 55 TRACK MOUNTED

DRILLING CONTRACTOR: TBT ENGINEERING

DATUM: Geodetic

Abbreviations: JN - Joint; FLT - Fault; SHR - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO - Polished; K - Slickensided; SM - Smooth; Ro - Rough; MB - Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	UNC Index (MPa)	STRAIN ε	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		425.28													B A
8–10	NQ CORING	Weathered to fresh, green, fine to medium grained, TONALITE BEDROCK		7.75	1												
					2												
				422.34													
		END OF DRILLHOLE		10.69													

DEPTH SCALE

1 : 62

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-6

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 20, 2012

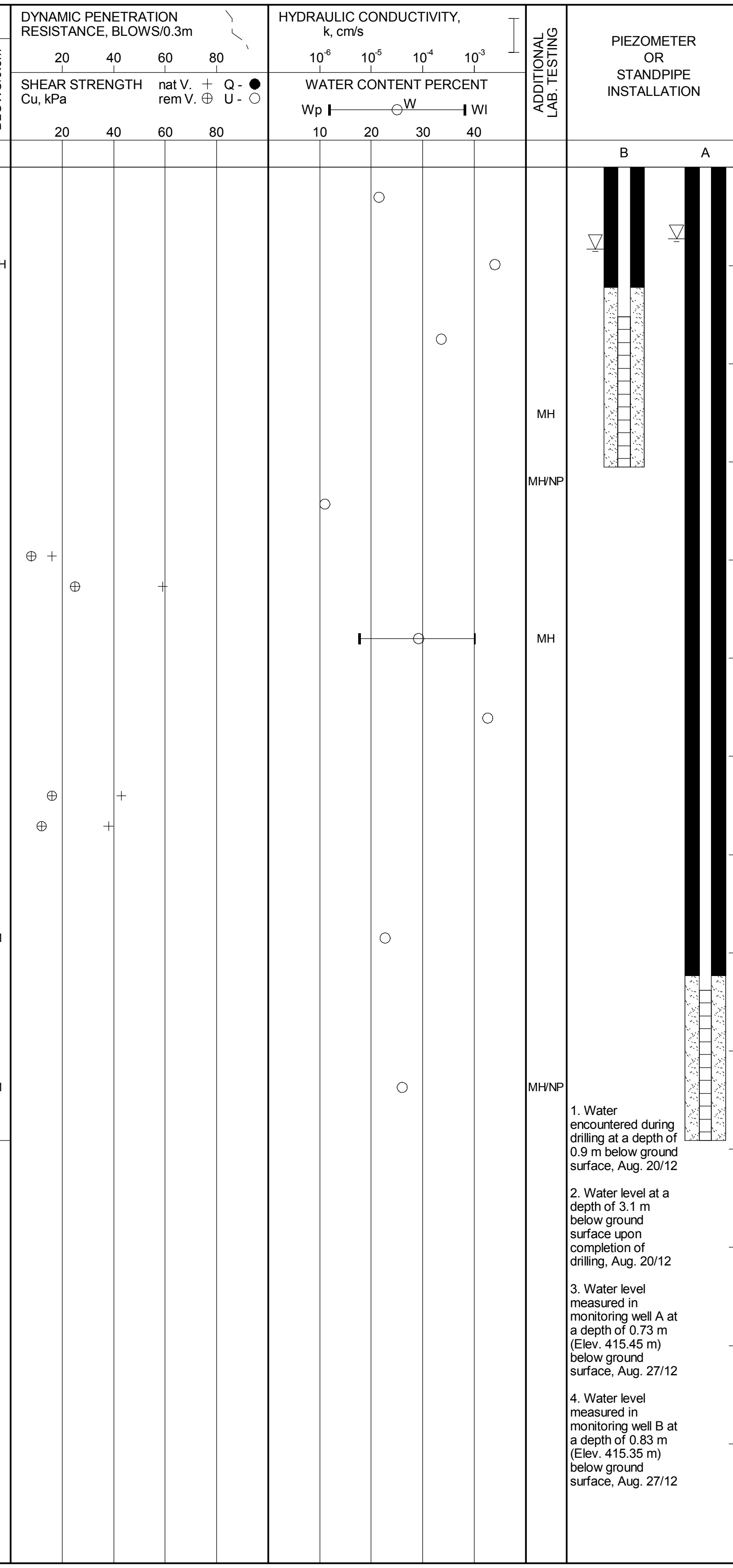
DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Boring method: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
GROUND SURFACE	416.18				
TOPSOIL (180 mm)	0.00				
(SM) SILTY SAND; brown, zones of medium sand (PROBABLE FILL); moist to wet, very loose	0.18	1	50 DO	2	
		2	50 DO	WH	
		3	50 DO	2	
		4	50 DO	3	MH
(ML) SILT, trace fine sand, zone of clayey silt; brown; wet, very loose	413.28 / 2.90	5A	50 DO	3	MH/NP
(ML) CLAYEY SILT, trace sand; brown; Wn>PL, soft to stiff	412.83 / 3.35	5B			
(CI) SILTY CLAY, trace to some sand; low to medium plasticity; brown to grey; cohesive, Wn>PL, firm	411.91 / 4.27	6	50 DO	2	MH
		7	75 TO	-	
(ML) SILT, trace sand; grey; moist to wet, compact	409.09 / 7.09	8	50 DO	11	
		9	50 DO	11	MH/NP
END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK	406.27 / 9.91				



1. Water encountered during drilling at a depth of 0.9 m below ground surface, Aug. 20/12

2. Water level at a depth of 3.1 m below ground surface upon completion of drilling, Aug. 20/12

3. Water level measured in monitoring well A at a depth of 0.73 m (Elev. 415.45 m) below ground surface, Aug. 27/12

4. Water level measured in monitoring well B at a depth of 0.83 m (Elev. 415.35 m) below ground surface, Aug. 27/12

DEPTH SCALE 1 : 69

Golder Associates

LOGGED: AM

CHECKED: DCJ

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PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-7

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 14, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
GROUND SURFACE	415.84				
TOPSOIL (50 mm)	0.00 / 0.05				
(ML) SILT, some sand; brown; moist; compact		1	50 DO	12	MH
(ML) CLAYEY SILT; trace to some sand; brown; Wn<PL, firm to stiff	415.15 / 0.69	2	50 DO	8	
(CI) SILTY CLAY, trace sand; red brown to brown; cohesive, medium plasticity; Wn>PL, soft to very soft	414.47 / 1.37	3	50 DO	3	MH
		4	50 DO	3	
		5	50 DO	1	
(ML) SILT, trace sand; grey; wet, compact to loose	411.80 / 4.04	6	50 DO	13	MH/NP
		7	50 DO	7	
(GW) GRAVEL and SAND, some fines; brown; wet, dense	409.13 / 6.71	8	50 DO	47	MH
END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK	407.76 / 8.08				

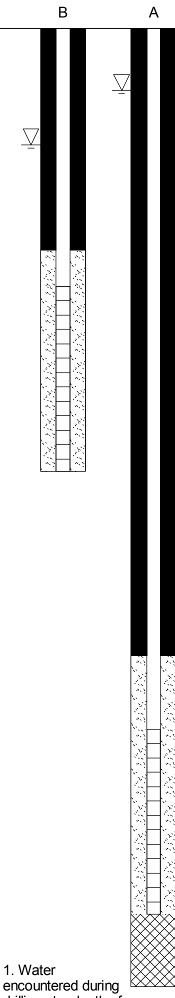
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 10 20 30 40

PIEZOMETER OR STANDPIPE INSTALLATION



1. Water encountered during drilling at a depth of 3.7 m below ground surface, Aug. 14/12

2. Water level at a depth of 2.7 m below ground surface upon completion of drilling, Aug. 14/12

3. Borehole caved to a depth of 7.3 m below ground surface upon completion of drilling, Aug. 14/12

4. Water level measured in monitoring well A at a depth of 0.51 m (Elev. 415.33 m) below ground surface, Aug. 30/12

5. Water level measured in monitoring well B at a depth of 0.94 m (Elev. 414.90 m) below ground surface, Aug. 27/12

DEPTH SCALE 1 : 62.5

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-8

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 15, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Boring method (0 to 4.42 m): TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

Description	Elev. / Depth (m)	Sample No.	Type	Blows/0.3m	Additional Lab. Testing
GROUND SURFACE	418.49				
(SM/ML) SILTY SAND; dark brown to grey, organically stained; moist, loose	0.00	1	50 DO	9	
(ML) SILT, trace sand; grey; damp to wet, dense to compact	417.80 / 0.69	2	50 DO	20	
		3	50 DO	37	
		4	50 DO	20	MH
		5	50 DO	20	
END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK	414.07 / 4.42				

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Piezometer or standpipe installation:

50 mm Diameter Monitoring Well

Bentonite Seal

Silica Sand Filter

1. Water encountered during drilling at a depth of 2.6 m below ground surface, Aug. 15/12

2. Water level at a depth of 3.1 m below ground surface upon completion of drilling, Aug. 15/12

3. Water level measured in monitoring well at a depth of 3.23 m (Elev. 415.26 m) below ground surface, Aug. 27/12

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

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PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-9

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 16, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT / HYDRAULIC CONDUCTIVITY	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	383.12							
0	TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers	(PT) PEAT; black, wood fragments; wet, very loose	0.00	1	50 DO	1		498.1		50 mm Diameter Monitoring Well
1				2A				363.8		
		(CL) SILTY CLAY, trace to some sand; dark brown, organically stained; Wn>PL, very soft to soft	382.05 / 1.07	2B	50 DO	2				
		(ML) SILT, trace sand; brown; wet, compact	381.75 / 1.37	3	50 DO	16			MH/NP	
2		(ML) CLAYEY SILT to SILT, trace sand; brown to grey; cohesive, Wn<PL to Wn~PL, very stiff to stiff	380.82 / 2.30	4	50 DO	19				
3				5	50 DO	12			MH	Bentonite Seal
4–5				6	50 DO	10			MH	
6		(CL) SILTY CLAY, medium plasticity, trace sand; brown to grey; cohesive, Wn>PL, firm	377.56 / 5.56	7	50 DO	2			MH	
7				8	75 TO	-				
8										Silica Sand Filter
		(SM) gravelly SILTY SAND, some fines; grey; wet, very dense	374.51 / 8.61	9	50 DO	50/.08			MH	
9		END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK	373.90 / 9.22							

Notes:

1. Water encountered during drilling at a depth of 0.6 m below ground surface, Aug. 16/12

2. Water level at a depth of 1.0 m below ground surface upon completion of drilling, Aug. 16/12

DEPTH SCALE 1 : 53.5

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-10

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 15, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER, 200 mm Dia. Hollow Stem Augers

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT / HYDRAULIC CONDUCTIVITY NOTES
GROUND SURFACE	433.11				
(PT) PEAT and TOPSOIL	0.00	1A	50 DO	2	787.8
(SM) SILTY SAND; grey (PROBABLE FILL); moist, very loose	432.81 / 0.30	1B			
(CL) SILTY CLAY, some sand, trace gravel, organically stained, peat and organic inclusions, dark brown to brown (PROBABLE FILL); moist, firm	432.42 / 0.69	2	50 DO	6	
(SM) SILTY SAND, trace to some gravel, containing cobbles and boulders, rock fragments; grey; moist, compact	431.74 / 1.37	3	50 DO	19	
		4	50 DO	50/.15	
	429.96	5	50 DO	50/.10	
END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK	3.15				

PIEZOMETER OR STANDPIPE INSTALLATION:

50 mm Diameter Monitoring Well

Bentonite Seal

Silica Sand Filter

1. Water encountered during drilling at a depth of 2.3 m below ground surface, Aug. 15/12

2. Water level at a depth of 1.8 m below ground surface upon completion of drilling, Aug. 15/12

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: AM

CHECKED: DCJ

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-1

SHEET 1 OF 1

LOCATION: East Dam

BORING DATE: MARCH 17, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○) (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp ⊢—○W—⊣ Wl) (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Boring method: POWER AUGER BORING, 108mm I.D. HOLLOW STEMS

Description	Elev. / Depth (m)
GROUND SURFACE	431.00 / 0.00
(PT) PEAT; dark brown, wood fragments; frozen, very loose	428.26 / 2.74
(SM) SILTY SAND, trace gravel; green to grey; wet, loose to compact	426.73 / 4.27
(ML) Sandy CLAYEY SILT; green to brown; wet, loose	425.82 / 5.18
(SM) SILTY SAND; green; wet, very loose	423.99 / 7.01
END OF BOREHOLE AUGER REFUSAL	

Sample Number	Type	Blows/0.3m	Additional Lab. Testing
1	SS	21	
2	SS	1	
3	SS	W.H.	
4	SS	6	
5	SS	11	MH w
6	SS	8	
7	SS	5	MH w A
8	SS	2	
9	SS	2	w M

Piezometer or standpipe installation: ∇ Mar. 17, 2013

NOTE:
1. Water level measured in open borehole at a depth of 0.9 m below ground surface (Elev. 430.1 m) upon completion of drilling.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RM

CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-2

SHEET 1 OF 1

LOCATION: East Dam

BORING DATE: MARCH 12, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

Boring method: 108mm I.D. HOLLOW STEMS, POWER AUGER BORING (0.00 to 5.49 m)

DEPTH (m)	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	431.14						
0	(PT) PEAT; dark brown	0.00	1	SS	W.H.			
	(ML) Sandy SILT, trace organics; brown; moist, very loose	430.53 / 0.61	2	SS	2	70	MH w	
	(ML) SILT, trace sand; green; wet, compact	429.31 / 1.83	3	SS	14			
			4	SS	14	~21	MH w	
			5	SS	17			Mar. 12, 2013 (water level)
			6	SS	23			
	(SM) Gravelly SILTY SAND; green to grey; wet, compact	426.57 / 4.57	7	SS	18	~8	M w	
			8	SS	6			
	END OF BOREHOLE AUGER REFUSAL	425.65 / 5.49						

NOTE:
1. Water level measured in open borehole at a depth of 3.6 m below ground surface (Elev. 427.5 m) upon completion of drilling.

Chart headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. +, Q - ●, rem V. ⊕, U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40)

Depth scale: 0 – 10 metres

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RM
CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-3

LOCATION: Reclaim Pond Dam

BORING DATE: MARCH 17, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE: DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m) | SAMPLES: NUMBER, TYPE, BLOWS/0.3m | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa (nat V. +, Q - ●, rem V. ⊕, U - ○) (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}) | WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Boring method: 108mm I.D. HOLLOW STEMS POWER AUGER BORING

Description	Elev. / Depth (m)
GROUND SURFACE	427.01 / 0.00
(PT) PEAT; dark brown; frozen to moist, very loose	424.42 / 2.59
(CL) SILTY CLAY; green; w>PL, cohesive, very soft	421.45 / 5.56
(CI) SILTY CLAY; green; w>PL, cohesive, soft	420.15 / 6.86
(CH) CLAY; green; cohesive, firm to very stiff	418.17 / 8.84
(ML) SILT, some sand; green; wet, compact	

Number	Type	Blows/0.3m	Other data
1	SS	W.H.	
2	SS	W.H.	
3	SS	W.H.	
4	SS	W.H.	
5	SS		MH, w, A
Vane 1	V		
6A	SS		
6B	SS		64.1; MH, w, A
Vane 2	V		
7	TO		55, 56.4; MH, w, A
Vane 3	V		
8A	SS	16	
8B	SS	12	
9	SS	9	
10	SS	15	

Piezometer: ∇ Mar. 18, 2013

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RM
CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-3

LOCATION: Reclaim Pond Dam

BORING DATE: MARCH 17, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT (Wp–W–Wl)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
10	108mm I.D. HOLLOW STEMS POWER AUGER BORING	(ML) SILT, some sand; green; wet, compact		10	SS	15	~21	MH w	
11				11	SS	13			
				12	SS	11			
12		BOULDER	414.82 / 12.19						
		(SM) SILTY SAND, some gravel; green; wet, compact	12.34	13	SS	20			
		BOULDER	414.36 / 12.65						
13		(SM) SILTY SAND, some gravel; green; wet, very dense	414.01 / 13.00	14	SS	70	~18	M w	
		END OF BOREHOLE AUGER REFUSAL NOTE: 1. Water level measured in open borehole at a depth of 4.4 m below ground surface (Elev. 422.6 m) upon completion of drilling.	413.75 / 13.26						

Column headings also include: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. +, Q - ●, rem V. ⊕, U - ○; 20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp, W, Wl (10, 20, 30, 40); STRATA PLOT.

Depth scale continues: 14, 15, 16, 17, 18, 19, 20

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RM
CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-4

LOCATION: Southwest Dam

BORING DATE: MARCH 18, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: POWER AUGER BORING, 108mm I.D. HOLLOW STEMS

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING
GROUND SURFACE	418.50						
TOPSOIL - (SM) SILTY SAND; brown, some organics (pieces of wood); loose	0.00	1	SS	5			
(ML) Sandy SILT; green; moist, compact	417.97 / 0.53	2	SS	14		○	MH w
(CI) SILTY CLAY, some sand; green to brown; firm to stiff	416.98 / 1.52	3	SS	21			
		4	SS	6		Wp–Wl, w 51.9	MH A w
		Vane 1	V		⊕, +		
(ML) CLAYEY SILT, trace clay; green; moist; soft to stiff	413.93 / 4.57	5	TO		+	○	MH A (NP) w
		Vane 2	V		⊕, +		
(ML) Sandy SILT, some clay; green; wet, very loose to compact	412.40 / 6.10	6	SS	W.H.		○	MH w
		7	SS	14			
(SP) SAND; grey to light brown; moist, very loose	410.88 / 7.62	8	SS	4		○	M w
(SW-SM) SAND, some gravel; light brown to grey; moist, compact	409.36 / 9.14						

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DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RM

CHECKED:

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PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-4

LOCATION: Southwest Dam

BORING DATE: MARCH 18, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING
10	108mm I.D. HOLLOW STEMS POWER AUGER BORING	(SW-SM) SAND, some gravel; light brown to grey; moist, compact						
11				9	SS	11	O	M w
				10	SS	12		
12		(SP-SM) SAND, some gravel; grey to light brown; wet, loose to compact	406.31 / 12.19	11	SS	12	O	M w
13								
14				12	SS	4		
15				13	SS	14		
16								
17				14	SS	24		
18		END OF BOREHOLE AUGER REFUSAL NOTE: 1. Borehole was filled with water during drilling to balance flowing sand therefore water level could not be measured.	400.82 / 17.68					
19								
20								

Column headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - O) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —O^W— Wl (10, 20, 30, 40); STRATA PLOT; PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RM

CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-5

LOCATION: Southwest Dam

BORING DATE: MARCH 21, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

BORING METHOD: 108mm I.D. HOLLOW STEMS POWER AUGER BORING

DEPTH (m)	SOIL PROFILE DESCRIPTION	ELEV. (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING
	GROUND SURFACE	423.25						
0.00	(PT) PEAT, trace gravel; brown, with pieces of wood, frozen; very loose		1	SS	29			
			2	SS	4			
1.68	(CL) SILTY CLAY; green; w>PL, cohesive, soft	421.57	3	SS	4		Wp–W–Wl plotted	MH w A
			Vane 1	V		rem V. ⊕; nat V. 120		
			4	SS	17		○	MH w
			5	SS	3			
4.42	(ML) Sandy SILT; green; wet, very loose	418.83	6	SS	4		○	MH w
			7	SS	7			
			8	SS	1			
7.47	(SM) SILTY SAND; green; wet, very loose	415.78	9	SS	2			
			10	SS	2		○	MH w
9.14	(SM) SILTY SAND, some gravel; green; wet, compact	414.11	11	SS	15			

PIEZOMETER OR STANDPIPE INSTALLATION

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 10 20 30 40

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DRAFT

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RM

CHECKED:

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH13-5

LOCATION: Southwest Dam

BORING DATE: MARCH 21, 2013

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10				413.04							
		END OF BOREHOLE AUGER REFUSAL NOTE: 1. Borehole was filled with water during drilling to balance flowing sand therefore water level could not be measured.		10.21							
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RM
CHECKED:

APPENDIX B
Hydraulic Response Testing

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-1

INTERVAL (metres below ground surface)

Top of Interval =	**2.59**
Bottom of Interval =	**4.11**

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

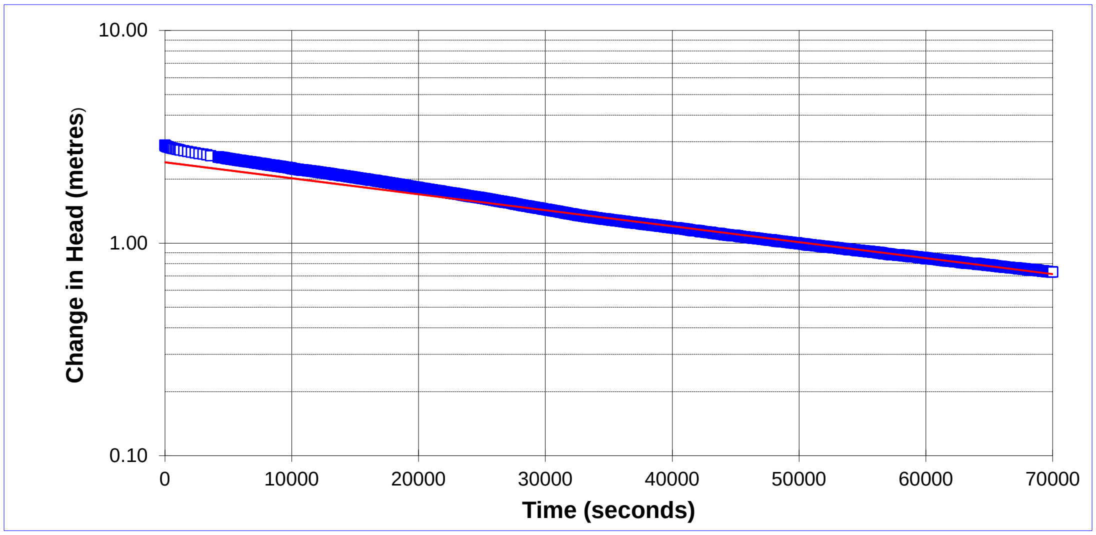
r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^{\,2} - r_c^{\,2})$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	**0.06**
r_w =	**0.10**
L_e =	**1.52**
$ln(R_e/r_w)$	**2.02**
y_0 =	**2.40**
y_t =	**0.85**
t =	**60000.0**

RESULTS

K=	**4E-08**	**m/sec**
K=	**4E-06**	**cm/sec**



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/24/16

Analysis By: MIB
Checked By: ____
Analysis Date: 5/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-2

INTERVAL (metres below ground surface)

Top of Interval = 13.11
Bottom of Interval = 14.63

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

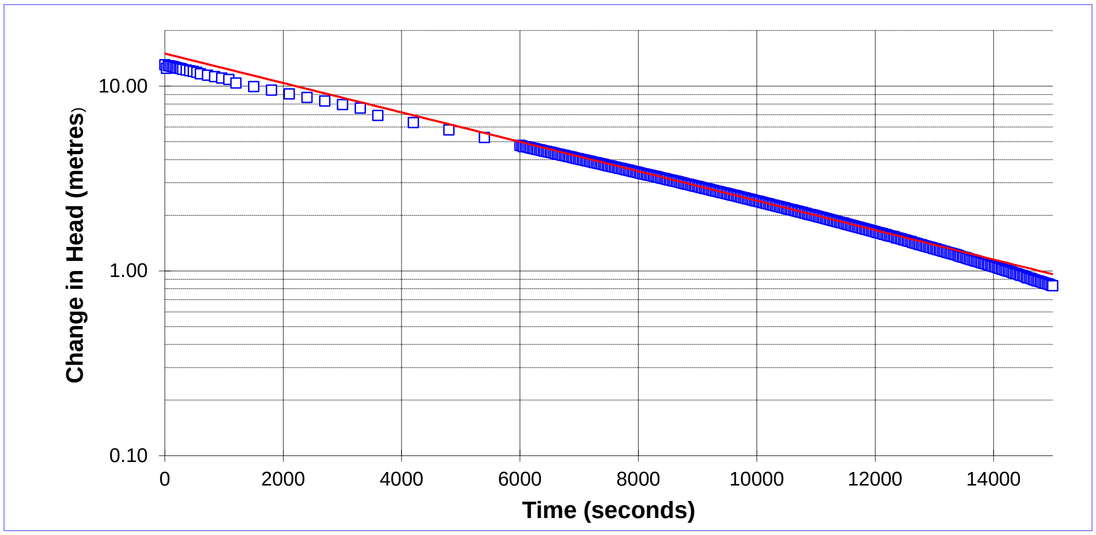
where:

r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_{ce} =	0.06
r_w =	0.10
L_e =	1.52
$\ln(R_e/r_w)$	2.62
y_0 =	15.00
y_t =	2.40
t =	10000.0

RESULTS		
K=	6E-07	m/sec
K=	6E-05	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/23/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-3A

INTERVAL (metres below ground surface)

Top of Interval = **14.93**
Bottom of Interval = **16.46**

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

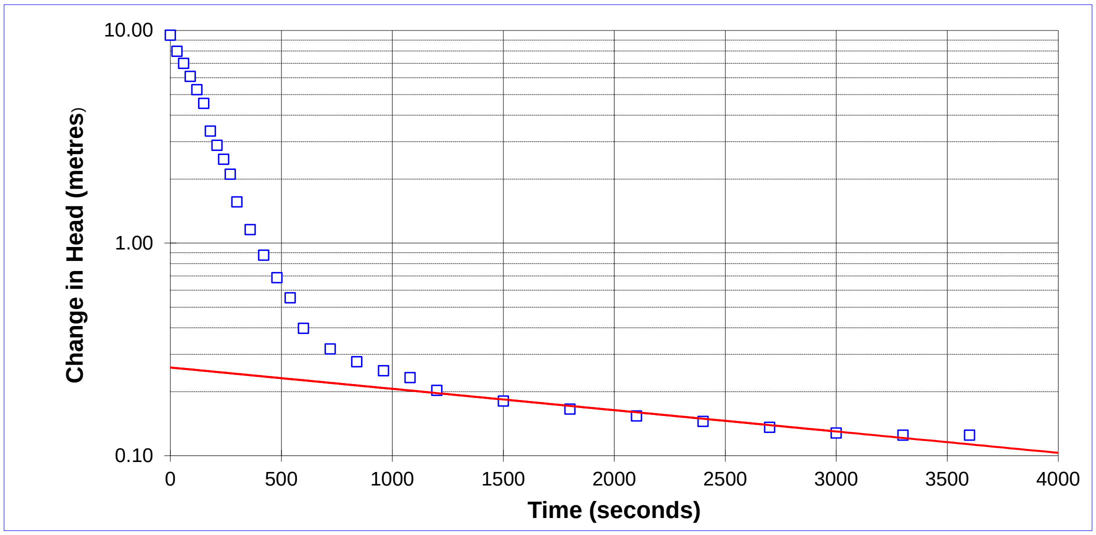
r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	0.06
r_w =	0.10
L_e =	1.53
$\ln(R_e/r_w)$	3.26
y_0 =	0.26
y_t =	0.13
t =	3000.0

RESULTS

K=	9E-07	m/sec
K=	9E-05	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/25/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-3B

INTERVAL (metres below ground surface)

Top of Interval = 10.06
Bottom of Interval = 11.58

$$K = \frac{r_c^{2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$ where K=m/sec

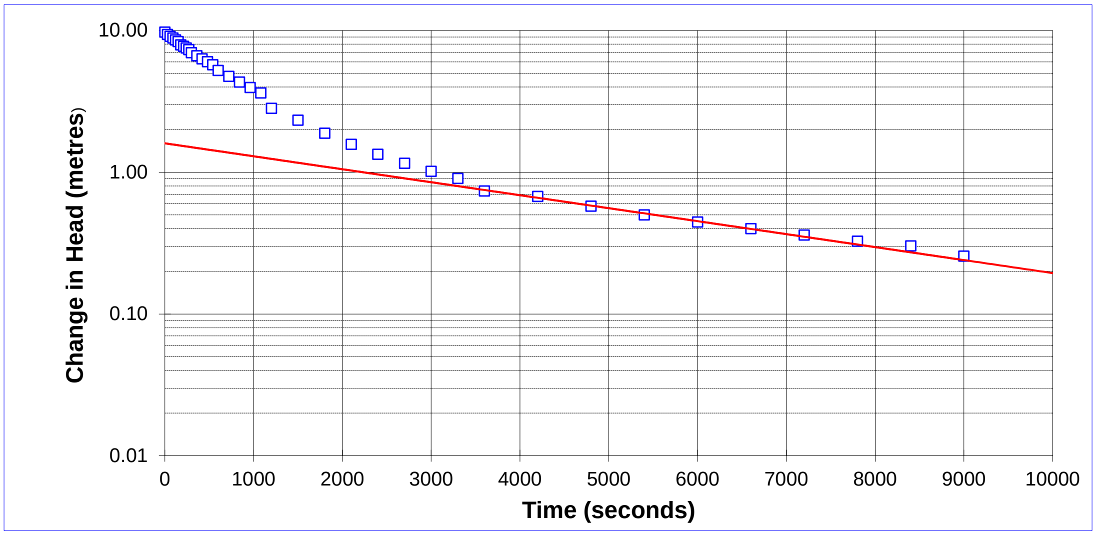
where:

r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^{2} - r_c^{2})$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_{ce} =	0.06
r_w =	0.10
L_e =	1.50
$\ln(R_e/r_w)$	2.64
y_0 =	1.60
y_t =	0.24
t =	9000.0

RESULTS

K=	7E-07	m/sec
K=	7E-05	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/25/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-4

INTERVAL (metres below ground surface)

Top of Interval = 5.44
Bottom of Interval = 7.04

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

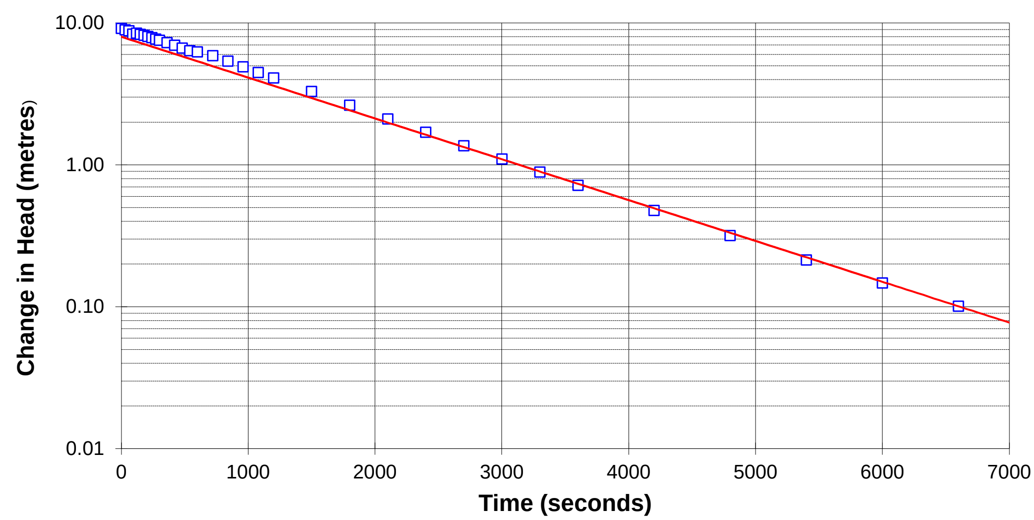
r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_{ce} =	0.06
r_w =	0.10
L_e =	1.60
$\ln(R_e/r_w)$	2.84
y_0 =	8.00
y_t =	0.15
t =	6000.0

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/24/16

Analysis By: MIB
Checked By: ____
Analysis Date: 5/9/2016

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-5B

INTERVAL (metres below ground surface)

Top of Interval =	**5.37**
Bottom of Interval =	**6.87**

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}\ln\frac{y_0}{y_t}$$

where K=m/sec

where:

r_{ce} = effective casing radius (metres)

Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = theoretical initial drawdown (metres)

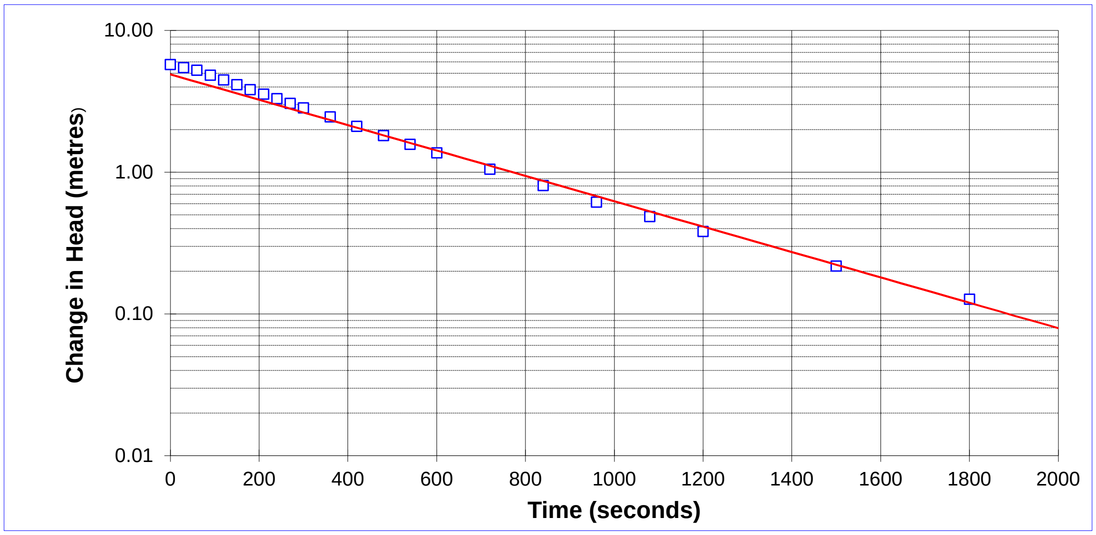
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	**0.06**
r_w =	**0.10**
L_e =	**1.50**
$\ln(R_e/r_w)$	**2.27**
y_0 =	**4.90**
y_t =	**0.12**
t =	**1800.0**

RESULTS

K=	**6E-06**	**m/sec**
K=	**6E-04**	**cm/sec**



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/25/16

Analysis By: MIB
Checked By: ____
Analysis Date: 5/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-6B

INTERVAL (metres below ground surface)

Top of Interval = 1.56
Bottom of Interval = 3.06

$$K = \frac{r_c^{2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

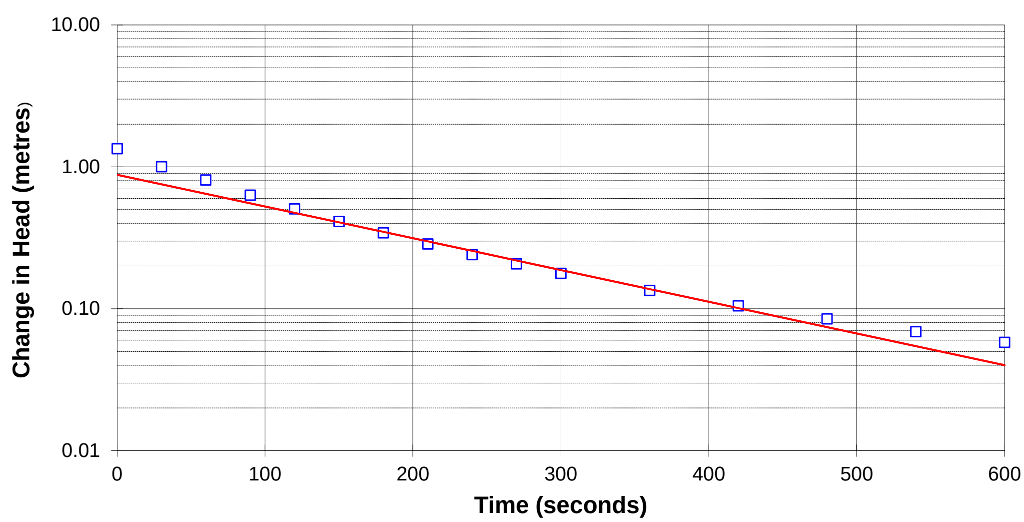
r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^{2}-r_c^{2})$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	0.06
r_w =	0.10
L_e =	1.50
$\ln(R_e/r_w)$	1.75
y_0 =	0.88
y_t =	0.04
t =	600.0

RESULTS

K=	1E-05	m/sec
K=	1E-03	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/25/16

Analysis By: MIB
Checked By: ____
Analysis Date: 5/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-7A

INTERVAL (metres below ground surface)

Top of Interval = 5.79
Bottom of Interval = 7.31

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}\ln\frac{y_0}{y_t}$$

where K=m/sec

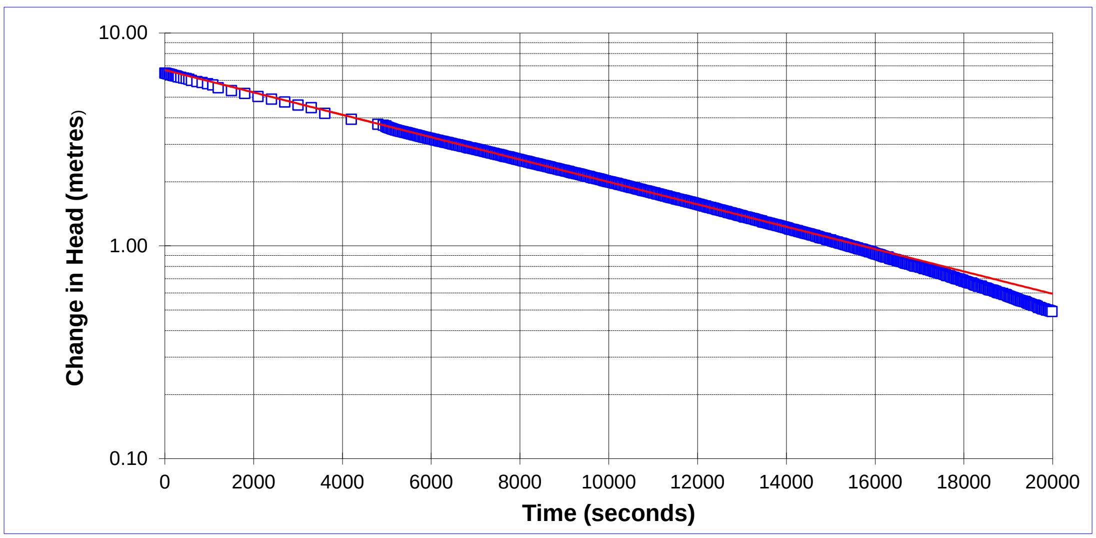
where:

r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_{ce} =	0.06
r_w =	0.10
L_e =	1.52
$\ln(R_e/r_w)$	2.34
y_0 =	6.70
y_t =	1.23
t =	14000.0

RESULTS

K=	3E-07	m/sec
K=	3E-05	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/23/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-7B

INTERVAL (metres below ground surface)

Top of Interval = 2.13
Bottom of Interval = 3.66

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);

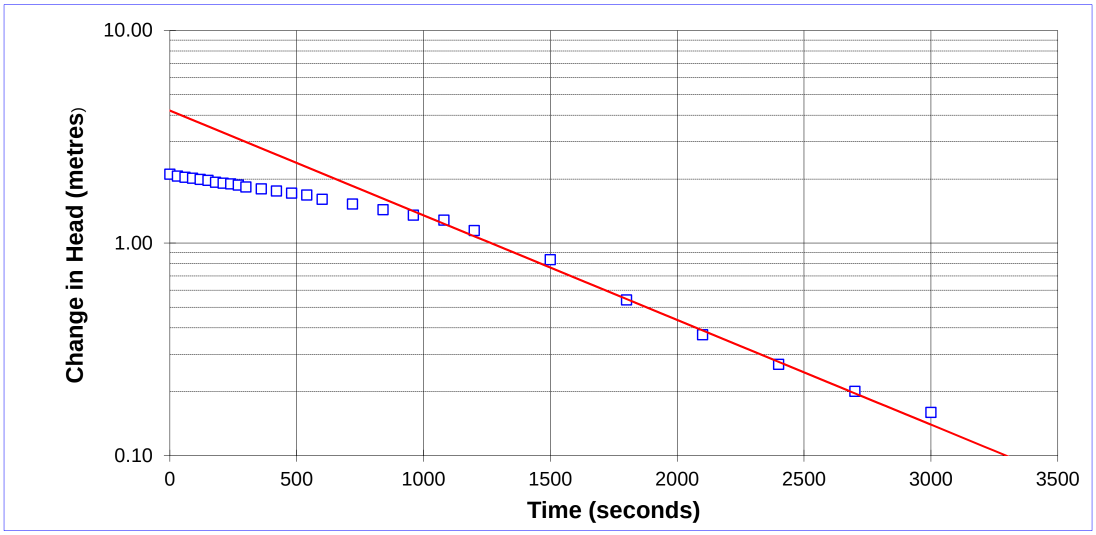
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	0.06
r_w =	0.10
L_e =	1.53
$\ln(R_e/r_w)$	1.85
y_0 =	4.20
y_t =	0.14
t =	3000.0

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/23/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-10

INTERVAL (metres below ground surface)

Top of Interval =	**1.52**
Bottom of Interval =	**3.05**

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_{ce} = effective casing radius (metres)
Given as $r_{ce} = r_c + S_y(r_w^2 - r_c^2)$ (Bouwer, 1989);
R_e = effective radius (metres);
L_e = length of screened interval (metres);

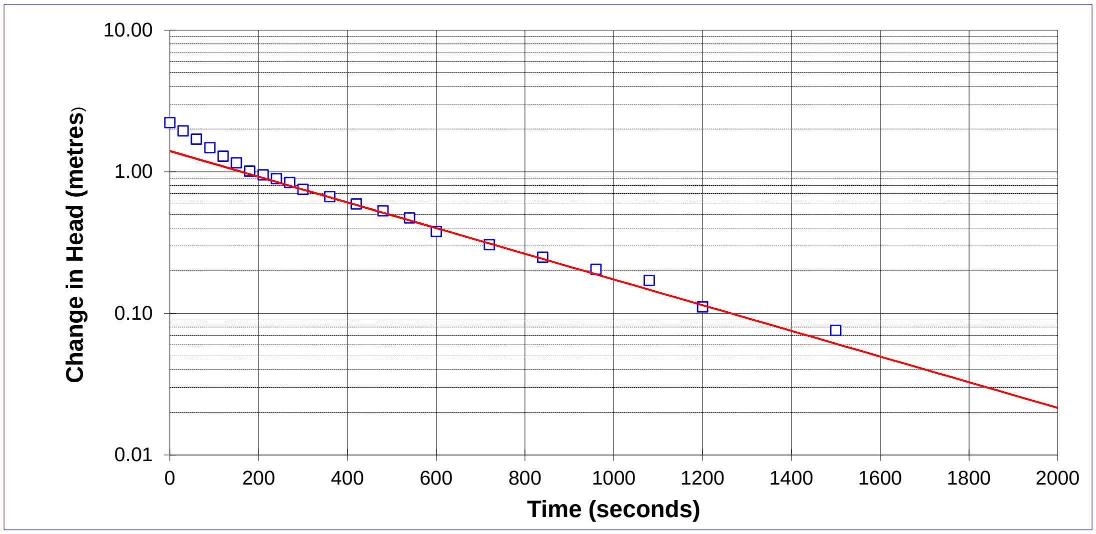
r_w = radial distance to undisturbed aquifer (metres)
y_0 = theoretical initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_{ce} =	0.06
r_w =	0.10
L_e =	1.53
$ln(R_e/r_w)$	2.34
y_0 =	1.40 Theoretical Initial Displacement
y_t =	0.40
t =	600.0

RESULTS

K=	6E-06	m/sec
K=	6E-04	cm/sec



Project Name: CMC EA Support/Hammond Reef
Project No.: 1656263/1000/1001
Test Date: 08/23/16

Analysis By: MIB
Checked By: ____
Analysis Date: 6/9/2016

Golder Associates Ltd.

PART D

CEAA Comments on Conceptual Model Development

Canadian Environmental Assessment Agency | **Agence canadienne d'évaluation environnementale**

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55 St. Clair Avenue East,
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Toronto, ON M4T 1M2

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Toronto (Ontario) M4T 1M2

November 22, 2016

ELECTRONIC MAIL

Ms. Sandra Pouliot, ing.
Project Manager, Environment
Canadian Malartic Corporation
100, chemin du Lac Mourier
Malartic, QC J0Y 1Z0

SUBJECT: Federal Comments on the October 6, 2016 Updated Memorandum on the Tailings Management Facility Hydrogeological Fieldwork and Conceptual Model Development for the Federal Environmental Assessment of the Hammond Reef Gold Project

Dear Ms. Pouliot:

The Canadian Environmental Assessment Agency, along with Environment and Climate Change Canada and Natural Resources Canada, completed the review of the October 6, 2016 updated technical memorandum on the hydrogeological fieldwork and conceptual model development for the 3D groundwater modeling of the tailings management facility for the proposed Hammond Reef Gold Project.

Upon review of the September 21, 2016 memorandum and the October 6, 2016 updated memorandum, the Federal Review Team (FRT) is of the opinion that Canadian Malartic Corporation (CMC) can proceed with construction of the 3D groundwater model as discussed in the updated October 2016 memorandum. The FRT is also in agreement with CMC's proposal for next steps, as described in Section 4.0 of the September 2016 memorandum.

Comments and recommendations from the FRT on the October 2016 memorandum are included as an attachment to this letter. The FRT expects to review and approve the technical memorandum on the baseline modeling done for step one (i.e., model construction and calibration) prior to CMC proceeding with step two (i.e., simulation of tailings management facility). CMC is also expected to describe, in the technical memorandum on the baseline modeling of step one, the rationale behind how FRT comments and recommendations on the October 2016 memorandum are addressed.

.../2

Efforts by CMC and federal reviewers to resolve the issues are recognized by the Agency. The FRT awaits the results of step one of the 3D groundwater modeling for the tailings management facility, to provide further feedback.

Please contact me at (416) 952-1574 or send an email to HammondReef@ceaa-acee.gc.ca if clarification of this letter or its attachments is needed.

Sincerely,
<Original signed by>

Loraine Cox
Project Manager

Attachment:

- Review of Technical Memorandum "Hammond Reef Gold Project: Tailings Management Facility Hydrogeological Fieldwork and Conceptual Model Development" by Golder Associates Ltd., September 21, 2016, updated October 6, 2016 (nine pages)

cc. Sheryl Lusk, Environment and Climate Change Canada
Jennifer Dorr, Natural Resources Canada
Antonia Testa, Ministry of the Environment and Climate Change

Review of Technical Memorandum "Hammond Reef Gold Project: Tailings Management Facility Hydrogeological Field Work and Conceptual Model Development" by Golder Associates Ltd., September 21, 2016, updated October 6, 2016.

October 17, 2016

Background

Golder Associates has provided a Technical Memorandum that builds on the technical correspondence between the proponent Canadian Malarctic Corporation (CMC), their consultant Golder Associates and the Federal Review Team which includes the Canadian Environmental Assessment Agency (CEAA), Environment and Climate Change Canada (ECCC) and Natural Resources Canada (NRCan). CEAA has previously communicated the FRT comments pertaining to hydrogeology in letters dated January 29, May 6 (CEAA, 2016b) and July 29, 2016 (CEAA, 2016a).

An initial Technical Memorandum was prepared by Golder Associates on September 21, 2016 to address the FRT comments and seek approval for the proposed groundwater modelling of baseline conditions. The Technical Memorandum was also presented to the FRT and discussed in a conference telephone call on September 27, 2016. Subsequently, the Technical Memorandum was updated by Golder Associates on October 6, 2016 (Golder Associates, 2016a) based on the feedback received during the teleconference. NRCan can has reviewed both the Technical Memorandum of September 21, 2016 and the updated Technical Memorandum of October 6, 2016 and has provided comments that pertain to its expertise in hydrogeology and groundwater flow.

References

CEAA, 2016a. Federal Comments on the June 15, 2016 Supplementary Memorandum on the Scope of Work for the 3D Groundwater Modelling for the Federal Environmental Assessment of the Hammond Reef Gold Project. Letter from CEAA (Carl Johansson) to CMC (Sandra Pouliot), July 29, 2016.

CEAA, 2016b. Federal Review of the Draft Technical Memorandum on the Additional 3D Groundwater Modelling for the Hammond Reef Gold Project Federal Environmental Assessment. Letter from CEAA (Loraine Cox) to CMC (Sandra Pouliot), May 6, 2016.

Domenico, P.A. and Schwartz, F.W., 1990. Physical and Chemical Hydrogeology. John Wiley & Sons, Toronto, Ont., 824 pages.

Golder Associates, 2016a. Technical Memorandum. Hammond Reef Gold Project: Tailings Management Facility, Hydrogeological Field Work and Conceptual Model Development. October 6, 2016 (updated from September 21, 2016).

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Golder Associates, 2016b. Technical Memorandum. Hammond Reef Gold Project: Tailings Management Facility, Hydrogeological Field Work and Conceptual Model Development. September 21, 2016.

Golder Associates, 2016c. Technical Memorandum. Hammond Reef Gold Project – Tailings Management Facility, Additional stratigraphic information and proposed 3D groundwater modelling. June 15, 2016.

Golder Associates, 2016d. Draft Technical Memorandum. Hammond Reef Gold Project – Tailings Management Facility, Additional 3D Groundwater Modelling. March 1, 2016.

Golder Associates, 2014. Technical Memorandum. Osisko Hammond Reef Gold Project, Tailings Management Facility 3D Groundwater Modelling, May 21, 2014, *in* Hammond Reef Gold Project, Addendum to the Final EIS/EA report, June 2015.

Golder Associates, 2013. Hammond Reef Gold Project, Hydrogeology Technical Support Document, version 2, December 2013. (Note that this document also includes Technical Support Document (TSD) version 1 from February 2013 as Part C).

Stea, R.R., 2010. Surficial Geology update of the Golden Winner area: sedimentology and stratigraphy of the glaciofluvial deposits and recommendations for recce sampling. Stea Geological Services, June 10, 2010 (part of Golder Associates (2016d) draft TM).

Comments on the technical memorandum

The Technical Memorandum is organized under four main headings: field data, conceptual model, proposed next steps and review comments address. NRCan's comments respond to each of these four areas directly.

Field Data

Data and results are presented for 10 new hydraulic tests (bail tests) on existing monitoring wells. In addition, two wells responded too quickly to manually measure the response, one well had a small depth of water in the casing and one well was damaged so there are no results for these four wells. The results were tabulated according to the geologic materials in the screened interval, summarized and combined with previous results at the Tailings Management Facility (TMF).

Comment 1: Wells with no results.

No hydraulic conductivities were reported for wells BH12-5 and BH12-6A in the September 21, 2016 Technical Memorandum because the piezometers recovered too quickly to be measured with a manual water level tape (Golder Associates, 2016b). Therefore, their higher values were not incorporated into the geometric means of the bedrock and silt units. This issue was addressed in the updated Technical Memorandum (Golder Associates, 2016a) by assuming relatively high hydraulic conductivity values of 1E-4 ($1X10^{-4}$) m/s. An assumed value of 1E-4 m/s is provided for BRH-0020A, which suggests that this piezometer may also have had a rapid response. Rapid responses in wells screened in high hydraulic conductivity units can sometimes be measured using solid slugs and data loggers.

Comment 2: Wells not tested.

While reviewing the hydraulic conductivity results from all monitoring wells near the TMF, it appears that some monitoring wells have not been slug/bail tested. A list of potentially untested wells includes BRH-0020A and BRH-0024 in bedrock and BRH-0017B, BRH-0020B, BRH-0021B and BRH-0027 in unconsolidated sediments.

Comment 3: Data for BH13 series boreholes and condemnation boreholes.

Aside from the borehole locations that are shown on map figures, no logs or tabulated data could be found for the BH13 series and the condemnation boreholes in the September 21, 2016 Technical Memorandum. When asked during the September 27, 2016 teleconference whether the BH13 sites had been slug/bail tested, Golder Associates indicated that these boreholes did not have well completions. This comment was addressed in Table 1 and Appendix A of the updated Technical Memorandum (Golder Associates, 2016a) where the data and logs are presented.

Conceptual model

An updated conceptual model was presented including model domain, hydrologic boundaries, overburden thickness, hydrostratigraphic units, hydraulic conductivities, recharge and groundwater flow directions (Golder Associates, 2016a and 2016b).

Comment 4: Model domain and hydrologic boundaries.

The model domain encompasses the entire TMF and extends to the major hydrologic boundaries which are the eventual receiving waters. Between major water features, the model's boundary will correspond to topographic divides (and inferred groundwater divides). NRCan is in general agreement with the proposed model domain.

Comment 5: Sediment (overburden) thickness.

Golder (2016a, 2016b) has consolidated the results from the boreholes (test holes, wells and condemnation holes) with surficial mapping from Stea (2010) to interpolate sediment thickness across the modelling domain. It is also recognized that the bedrock valleys may be obscured by the interpolation process due to the preponderance of data from bedrock outcrops and the dearth of data from bedrock valleys. To overcome this issue, Golder (2016b) used "dummy points" at a depth of 10 m to help maintain the continuity of bedrock valleys.

NRCan recognizes that it is not practical to delineate the continuity of all buried bedrock valleys by drilling. NRCan is generally supportive of the approach used by Golder Associates to characterize sediment thickness. During the September 27, 2016 teleconference, NRCan expressed concern that the interpolated map presented by Golder Associates was not sufficiently conservative. NRCan is of the opinion that the bedrock valleys may be more continuous than suggested in Figure 3 (Golder Associates, 2016b); some of the wider bedrock troughs are more continuous and may be deeper than modeled, as demonstrated by the many NNE-SSW trending valleys and lakes in the area (e.g., Lizard Lake). These buried bedrock troughs are somewhat under-represented in the data set as their wide and flat valley bottoms are less accessible due to the presence of peat bogs (see Figure 2). Also, the delineation of the surficial mapped polygons from Stea's (2010) map would require many more data points than the number of boreholes and therefore would bias the interpolation to that dataset. NRCan proposed that the methodology would provide a more conservative interpolation if more "dummy points" were used to ensure continuity in potentially significant buried valleys.

The sediment thickness was re-interpolated (Figure 3) using more "dummy points" in the updated Technical Memorandum (Golder Associates, 2016a) with the result of having more continuity in potential buried valleys.

Comment 6: Hydrostratigraphy.

Golder Associates (2016a, 2016b, and 2016c) has revised the hydrostratigraphic conceptual model to include three sediment layers, as compared with the Addendum to the final EIS/EA report (Golder, 2014) where only one sediment layer was used. NRCan had previously expressed concern (CEAA, 2016a) that the layering of fine and coarse sediments may be important for the interpretation of groundwater flow and evaluation of the seepage collection system. NRCan is satisfied that the updated conceptual model includes a coarse-grained sediment unit buried beneath a fine-grained sediment unit.

Comment 7: Unit thickness.

The thicknesses of the layers will be generalized across the model domain in the interests of simplicity and conservatism. Where sediment is 3 m thick or less, it will be characterized as a coarse surficial deposit layer. Where it is more than 3 m, the excess will be subdivided equally between fine-grained and coarse-grained units. A uniform thickness of 3 m will be used for weathered bedrock although Golder noted in the conference call and documented in Table 5 (Golder Associates, 2016a) that the bedrock surface is not weathered everywhere. Where sediment is absent, tailings would lie directly on the weathered bedrock unit.

NRCan is generally satisfied that the simplifications used for the model would be generally conservative with respect to groundwater seepage (i.e. overestimating rather than underestimating seepage). A potential exception is where an overestimated permeable surficial deposit could result in more flow through this shallow unit (which would more likely discharge to a perimeter seepage collection system) compared to flow through a deeper confined coarse-grained unit that may be more difficult to capture in a perimeter seepage collection system.

Comment 8: Hydrostratigraphy at lake boundaries.

The model domain extends to major lakes in the area and also includes a few smaller lakes. It is not clear if the bathymetry of the major lakes will be used and how the hydrostratigraphy will be specified along the margins of lakes. Hydrostratigraphy along the margin and beneath lakes could affect the hydraulic connectivity between aquifers and lakes and therefore the flow through the buried coarse grained and bedrock units and ultimately fluxes and flowpaths to the lakes in discharge areas.

Comment 9: Hydraulic conductivity.

At the request of the FRT during the teleconference, Golder Associates (2016a) has compiled the full list of hydraulic conductivity testing results in Table 2, organized according to hydrostratigraphic unit.

Table 2 includes hydraulic conductivity results from slug tests and estimates based on grain size. There appears to be some problems with the hydraulic conductivity estimates using the Hazen method which may be due to calculation errors. For example, the estimated hydraulic conductivity for BH12-4 at a depth of 6.10 to 6.55 m (sample 8) is shown as 2E-3 m/s in Table 2. However, the grain size curve in Appendix 2.III.3 of Golder Associates (2013) indicates a d_{10} of about 0.022 mm which suggests a hydraulic conductivity of approximately 5E-6 m/s which is closer to the slug test value of 2E-6 m/s in the adjacent piezometer. Similarly, the value for BH12-5 at a depth of 2.29 to 2.74 m may be also in error. These erroneous values will slightly affect the geometric mean but more importantly will reduce the range of hydraulic conductivity estimates since these are the largest values in Table 2.

Comment 10: Grain size analyses data.

Hydraulic conductivity estimates are presented in Table 2 (Golder Associates, 2016a) for BH13 series boreholes based on grain size analyses, however, the grain size distributions for these boreholes were not found.

Comment 11: Hazen equation.

The equation for the Hazen method was not presented in the reports. It is generally used in the following form (Domenico and Schwartz, 1990):

$$K = C\, d_{10}^{2}$$

Where K is hydraulic conductivity in cm/s, C is a coefficient generally considered to vary from 100 to 150 $(\text{cm sec})^{-1}$ and d_{10} is the 10^{th} percentile of the grain size distribution (10% finer) in cm. Table 1 in Appendix 2.VI (Golder Associates, 2013) appears to have the incorrect units for C and d_{10} but nonetheless have the correct result for K in that table. However, the values for the coefficient C vary from 40 to 120 without apparent justification. A brief discussion and reference should be provided that justifies the values of the C coefficient.

Comment 12: Groundwater levels.

A map of shallow groundwater elevations has been assembled based on surface water elevations and monitoring wells located mostly within the valleys and along the margins of the proposed TMF (Figure 5, Golder Associates, 2016a and 2016b). The map suggests the presence of a regional groundwater flow pattern radiating outward from a small pond near BCN-105 (with another secondary high near BRH-0016A).

NRCan is of the opinion that Figure 5 may represent the shallow groundwater elevations in the valleys but the absence of data from the bedrock uplands does not allow groundwater levels in the uplands to be included. As a result, the map suggests a different conceptualization of groundwater flow than is likely the case. NRCan believes that groundwater levels in the uplands will also be a subdued replica of surface topography. This appears to be the case in the West Pit Area (e.g., Figure 2-10 in Golder Associates, 2013). Consequently, the map of shallow groundwater levels would resemble that of a muted surface topography; in other words it would resemble Figure 1 more than Figure 5. The result is that groundwater flow in the bedrock uplands is probably much more localized and directed towards the valleys and that groundwater flow in the valleys follows a more regional pattern similar to that of Figure 5. The presence of competent bedrock in the uplands at elevations above that of the valleys may form hydraulic barriers to the regional flow patterns implied in Figure 5 (e.g., bedrock ridges at BCN-076 and BCN-075, at BCN-098, BCN-095 and BCN-093, and at BCN-087, BCN-089 and BCN-092 (and others) have competent bedrock above the ground elevations of the adjacent valleys).

NRCan is not suggesting that additional water level measurements are needed for the bedrock uplands since that would be onerous and may not add significantly to the modelling effort. Rather, NRCan would like to ensure that Golder Associates and the FRT agree on the conceptualization of groundwater flow, and the groundwater modelling should not attempt to replicate the groundwater flow patterns shown in Figure 5 as suggested by section 4.0 (item 1b). A pragmatic approach may be to make some assumptions about the depth of the water table in the uplands based on boreholes in the West Pit area and possibly using “dummy points” in upland areas for map interpolation.

Next steps

Comment 13: Proposed next steps.

Golder Associates (2016a and 2016b) proposed a two part approach to the modelling in which the first step would include a calibrated steady-state model for average background conditions, a sensitivity analysis, and a technical memorandum to summarize the work to date and more detailed plans of the next part for interim review by the FRT. The second part would include simulation of the TMF for all project phases to evaluate seepage, flowpaths, receptors and capture efficiency. NRCan is supportive of the proposed approach. As noted in the previous comment, model calibration to reproduce the flow pattern implied by Figure 5 may be misguided.

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Review comments address

Golder Associates has addressed the comments from Information Request #3 and the table of federal review findings (CEAA, 2016a).

Comment 14: Information request #3.

In response to the request for additional drilling, Golder Associates has indicated the additional information added from condemnation boreholes, surficial geology mapping and additional well tests. Where data is limited, conservative estimates will be used and uncertainty will be tested in the model using a sensitivity analysis. Golder Associates are of the opinion that additional drilling and hydraulic testing are not necessary. They acknowledge there may be permeable units at the base of the TMF. They have updated the model boundaries to include the entire TMF and plan to re-run the model, assess the potential residual impacts (with mitigation) and document the modelling and results in subsequent memorandums.

NRCan accepts that there will be uncertainty in hydraulic parameters and stratigraphy within the TMF footprint due to the variable nature of topography and geological processes. While additional drilling and testing would help characterize some of this variability, it should be possible to estimate of a range of groundwater seepage using conservative estimates of hydraulic parameters and hydrostratigraphic layering. NRCan is generally satisfied with the proposed approach to address issues pertaining to Information Request #3.

Comment 15: Table of Federal Review Findings, items 2, 3, 4, and 6.

Golder Associates (2016a) have updated both the conceptual model and the hydrostratigraphy within the flow model. NRCan is satisfied that the model will include distinct layering within the sediment, coarse sediment within bedrock valleys and tailings in direct contact with bedrock. Golder Associates also indicates that the current conceptual model allows for consideration of the concerns expressed by the FRT with respect to evaluating the effectiveness of the seepage collection system (which would be assessed in subsequent work). NRCan is satisfied the conceptual model allows for this evaluation.

Comment 16: Table of Federal Review Findings, item 5.

Golder Associates (2016a) indicate that they have sufficient data to characterize the hydraulic conductivity of various units. In the updated Technical Memorandum, they have tabulated and summarized their data according to hydrostratigraphic units. Although the number of hydraulic conductivity data from slug tests within the TMF is not extensive, there appears to be sufficient information to proceed with groundwater flow modelling. Sensitivity analysis will be an important component of the modelling to assess the potential implications of uncertainty in hydraulic conductivity.

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Recommendations

1) NRCan is supportive of the progress shown by Golder Associates in the development of a conceptual model and plan for groundwater modelling of the Tailings Management Facility. NRCan is satisfied and agrees that Golder Associates can proceed with numerical groundwater model construction as discussed in the updated Technical Memorandum.

2) Some calculation errors may be present in some of the hydraulic conductivity estimates. Calculations should be reviewed and Tables 2 and 4 (Golder Associates , 2016a) updated if necessary. Grain size data for BH13 boreholes should be reported. The use of the Hazen method and justification of the C coefficient should be documented. These updates need not be communicated back to the FRT prior to submitting the baseline conceptual model and may simply be included in the modelling report as part of the baseline conditions.

3) Although NRCan does not believe that additional hydraulic testing is required to proceed with groundwater modelling, testing of some existing piezometers could provide additional hydraulic conductivity data in strategic locations with relatively low effort. Several piezometers have not been slug tested (Comment 2) and actual measurements may be possible on high hydraulic conductivity piezometers BH12-5, BH12-6A and possibly BRH-0020A using solid slugs and data loggers (Comment 1). NRCan considers this additional data collection to be a suggestion as opposed to a strict requirement and notes that added site specific knowledge of hydraulic conductivities could help better characterize hydraulic conductivities, particularly the high values near the margin of the TMF.

4) In the report on groundwater modelling, it will be necessary to describe the hydrostratigraphic conceptualization near lakes in discharge areas and its implementation within the model. As discussed in Comment 8 above, the hydraulic connections with the lakes could affect flow rates and flowpaths from the TMF into the lakes. If lake sediments are added to the model, the sensitivity analysis should consider the influence of their hydraulic conductivity on the model results.

5) Although assumptions related to hydrostratigraphy are generally conservative with respect to seepage, it will be important, as part of the sensitivity analysis, to consider the potential effects of high hydraulic conductivity values in key locations where they have been measured. For example, the coarse sediments shown buried at depth in Figure 4 have higher hydraulic conductivity (Table 2) than the geometric mean (Table 4, Golder Associates, 2016a) and are strategically located between the TMF and Sawbill Bay.

6) NRCan is not convinced that the current map of inferred shallow groundwater elevations (Figure 5, Golder Associates, 2016a and 2016b) is valid (Comment 12) and therefore it may not be useful for baseline model calibration as suggested in section 4.0 of the Technical Memorandum. The groundwater elevation map could be updated to reflect the lack of data in the uplands and the interior of the TMF. Areas mapped as peat bogs by Stea (2010) could be included as areas where the water table is at or near the ground surface. Water level depths in bedrock uplands could be estimated based on data from borehole or piezometer data in the mine area and then used as “dummy points” in the interpolation. The actual groundwater elevations in the uplands would be of lesser importance than the conceptual

understanding of groundwater flow directions for baseline conditions in which flow is a muted replica of surface topography.

PART E

Baseline Model Construction and Calibration

MEMORANDUM

TO Sandra Pouliot, ing. Canadian Malartic Corporation **DATE** March 30, 2017

CC Karen Besemann (Golder), Adam Auckland (Golder), Ken DeVos (Golder)

PROJECT No 1656263 1000 1001

FROM Devin Hannan, P.Eng.

DOC No. 007 (Rev 1)

HAMMOND REEF GOLD PROJECT: BASELINE GROUNDWATER MODEL CONSTRUCTION AND CALIBRATION – REVISED MEMORANDUM

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to present Canadian Malartic Corporation (CMC) with this revised technical memorandum describing numerical groundwater model construction and calibration pertaining to the proposed Hammond Reef Gold Project Tailings Management Facility (TMF) site near Atikokan, Ontario (Figure 1). The model described herein considers pre-TMF ("baseline") conditions. Golder seeks the Government Review Team's (GRT) approval on the work described herein prior to proceeding with subsequent predictive scenarios which will examine TMF operation, closure, and post-closure conditions.

1.1 Background

This memorandum builds upon prior technical correspondence between CMC, Golder and the GRT concerning the proposed TMF. Most recently, Golder submitted *Hammond Reef Gold Project: Baseline Groundwater Model Construction and Calibration* (Golder, January 25, 2017). Subsequently, the GRT provided feedback in "*Federal Comments on the January 25, 2017 Tailings Management Facility Baseline Groundwater Model Memorandum for the Federal Environmental Assessment of the Hammond Reef Gold Project* (CEAA, March 2, 2017). The work described herein revisits the original model construction and calibration with the intent of addressing GRT's recommendations. This current memorandum supersedes its predecessor dated January 25, 2017.

1.2 Document Structure

This memorandum is organized into four main sections:

1) **Model Construction**. The implementation of the baseline (pre-TMF) conceptual model within a numerical framework is detailed.

2) **Calibration**. A description of the model calibration process and results is provided.

3) **Sensitivity Analysis**. The results of a series of simulations to assess the model sensitivity to input parameters is presented.

4) **Proposed Next Steps**. The groundwork for next steps in model development, including TMF implementation, is set forth.

5) **Review Comment Address**. GRT comments from CEAA, March 2, 2017 are addressed.

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2.0 MODEL CONSTRUCTION

2.1 General Assumptions

The following assumptions have been employed in realizing the conceptual model (Golder, 2016) within a numerical framework.

- Groundwater flow is three-dimensional (3D). The model construct allows for both lateral and vertical flow paths between adjacent hydrostratigraphic units. It follows that groundwater may flow from overburden to bedrock and vice versa within a continuous system.
- Groundwater flow, including that in the bedrock system, may be simulated as an equivalent porous medium (EPM). In this setting, groundwater flow is a function of the hydraulic gradient and the hydraulic conductivity of the medium. An EPM assumption is deemed sufficient for characterizing groundwater flow at the scale of this analysis.
- The groundwater flow system may be modelled on a steady-state basis considering average conditions.
- Lakes, streams and wetlands are considered potential groundwater discharge zones.
- Groundwater divides are approximately coincident with topographic highs.
- For a given overburden section of significant thickness, a 3 metre (m) layer of surficial deposit layer exists followed by a fine-grained layer and coarse-grained layer, the latter two having equally proportional thicknesses.
- Overburden is assumed to be a maximum of 10 m thick in areas where overburden is mapped as present at surface but no proximal thickness information exists to fully characterize the area.
- Bedrock surface is weathered to a minimum thickness of 3 m.

2.2 Code

Modelling is conducted using MODFLOW-NWT, a Newton formulation of MODFLOW-2005 (Niswonger et al., 2011). MODFLOW is a multi-purpose three dimensional groundwater flow code developed by the United States Geological Survey. It is modular in nature and uses the finite difference formulation of the groundwater flow equation in its solution. Visual MODFLOW® (Build 4.6.0.168) is the graphical user interface for the simulations presented in this report.

2.3 Model Domain and Grid

The model domain (Figure 1) is approximately centred on the planned TMF extents and is regional in scale (24 km^2). The perimeter is delineated based on major hydrologic boundaries including Sawbill Bay to the south and its associated tributary to the west, Long Hike Lake to the north and Lizard Lake to the east. These regional features are considered primarily groundwater discharge zones and would be the eventual receptors of TMF seepage, should any seepage bypass the collection system. Elsewhere, the model perimeter is coincident with subwatershed boundaries or topographic highs.

Vertically, the top of the model is bounded by ground surface (Figure 1). The bottom of the model is set within competent bedrock at 335 masl, a depth of 90 m or greater below the base of the proposed TMF (Figure 4A/B).

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The model domain is subdivided laterally using 20 m x 20 m finite-difference grid cells positioned in a north-south / west-east perspective. Vertically, the model grid is comprised of five numerical layers. In total the model is comprised of 301,240 active cells.

2.4 Layer Structure

The model is vertically subdivided into five numerical layers corresponding to the conceptual hydrostratigraphic units (Figures 4A/B), namely:

1) Surficial Deposit Layer (sand/gravel, peat/muck or till as per Figure 2)
2) Fine-Grained Layer (predominately silt and/or clay)
3) Coarse-Grained Layer (predominately sand and/or gravel)
4) Weathered Bedrock Layer
5) Competent Bedrock Layer

The numerical implementation of Layers 1 through 3 are guided through the inferred overburden thickness mapping (Figure 3). The overburden thickness shown in Figure 3 was developed from information obtained from condemnation drillholes, geotechnical and environmental borehole drilling and overburden mapping from Stea, 2010, as discussed in Golder, 2016. The Surficial Deposit Layer is assumed to have a minimum thickness of 3 m across the model domain wherever overburden exists. Where the total overburden thickness extends beyond 4 m, the upper 3 m is parametrized as the Layer 1 Surficial Deposits and the remaining thickness split equally between the underlying Layer 2 Fine-Grained and then Layer 3 Coarse-Grained. Thus, for example, if an overburden section is 10 m thick than Layer 1 would be 3 m thick, Layer 2 would be 3.5 m thick, and Layer 3 would be 3.5 m thick.

Weathered bedrock is prevalent everywhere within the model domain at a minimum thickness of 3 m. In areas of outcropping the total thickness of weathered bedrock in the model increases to a total 4 m as the weathered bedrock parameters are assigned up through the minimally thick ("pinched out" to 0.5 m) overburden layers.

Competent rock extends from beneath the weathered bedrock layer to the bottom of the model and terminates at an elevation of 335 masl (approximately 90 m or greater below the base of the TMF).

2.5 Boundary Conditions

There are three types of boundary condition cells in the model (Figure 5): 1) inactive cells; 2) constant head cells; and 3) drain cells. Note that all of the boundary conditions cells shown in Figure 5 are present from the pre-calibration to final calibration and sensitivity models. That is, in this current work (unlike the prior modelling analysis), all drain cells, including peat drains, remain constant throughout the model analysis.

- *Inactive cells* represent a hydraulic no-flow boundary, such as a groundwater divide at the model perimeter.
- *Constant head cells* have a fixed groundwater elevation and may add or remove water from the system depending on the calculated head of the adjoining active cell(s). Constant head cells are used to represent large lakes, including Lizard Lake, Sawbill Bay, and Long Hike Lake at the perimeter of the model (assigned lakes levels, inferred from the DEM, are noted on Figure 5). Lakes are implemented by assigning constant head cells within the lake volume in a manner that roughly approximates mapped bathymetry (Golder, 2013[1]).

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As illustrated in Figures 4A/B, this approach allows a given lake to be in direct contact with any hydrostratigraphic unit so long as the lake depth intersects the position of the unit's numerical layer. In the case of Long Hike Lake there is no bathymetry mapping; as such the lake depth is assumed to reach the bottom of the overburden for its entire volume within the model.

- *Drains cells* are similar to constant head cells except they are constrained such that they may only remove groundwater from the system. Drain cells are used to represent the small mapped wetlands, streams and peat areas in the model and are assigned head values equivalent to ground surface. The application of drains within the peat unit – in essence implying a groundwater discharge zone – is consistent with the boggy conditions and near-surface water table observed in these areas (Figure 2). As drain cells represent shallow features they are input in the upper layer of the model only.

  Drain cells are assigned a conductance of 1,000 m^2/d. This conductance value allows for an accurate correspondence between assigned versus calculated head within the drain cell while maintaining numerical solver stability. Note that assigning a low drain cell conductance may result in an impedance to outflow and cause the calculated head in the cell to increase above the originally assigned head value.

2.6 Hydraulic Conductivity and Recharge

Hydraulic conductivity and recharge inputs were initially based on the conceptual model (Golder, 2016) and then refined during calibration as described in Section 3. Table 1 summarizes the final calibrated baseline model assignment for each unit. Figure 6A to Figure 6E illustrates the modelled hydraulic conductivity distribution for each layer. Note that weathered bedrock is present in Layers 1 through 3, as well as its nominal Layer 4, as a result of surficial outcropping. Figure 7 illustrates the recharge distribution.

Table 1: Baseline Model Hydraulic Conductivity (K) and Recharge

Nominal Layer	Unit	Material	Modelled K_H (m/s)	Modelled K_Z (m/s)	Recharge (mm/yr)
1	Surficial Deposit	Sand/Gravel	2E-5	2E-5	200
		Till	5E-6	5E-6	50 to 135
		Peat	1E-5	1E-5	5
2	Fine-Grained	Silt and/or Clay	3E-7	3E-7	-
3	Coarse-Grained	Sand and/or Gravel	1E-4	1E-4	-
4	Weathered Bedrock	Bedrock	2E-6	2E-6	50
5	Competent Bedrock	Bedrock	2E-7	2E-7	-

3.0 CALIBRATION

Model calibration may be defined as: "*the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observation of the ground-water flow system*" (ASTM, 2008). For this particular model, the focus of the calibration effort is primarily on finalizing hydraulic conductivity and recharge assignments.

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3.1 General Methodology

Calibration begins with the model incorporating the conceptual inputs as described in Golder, 2016. The subsequent steps involve an iterative, "trial and error" approach to adjusting input parameters until model output satisfactorily matches observed water level data ("calibration targets") as listed in Table 2. Each progressive simulation is thusly referred to as an "iteration". Goodness-of-fit for each iteration is assessed via statistical and other quantitative or qualitative means including:

- *Mean Residual*: This term, expressed in units of metres herein, indicates the average difference between observed and simulated water levels. The mean residual may suggest the degree to which the model is, on average, predicting heads above or below the observed dataset. A mean residual approaching zero is usually desired.

- *Mean Absolute Residual*: This indicator, expressed in units of metres herein, represents the average absolute value of the difference between observed and simulated water levels. A mean absolute residual of 1 m or less is considered optimal given the scale of this analysis and the measured range in water levels (typically within 1 m as indicated in Table 2).

- *RMS Error*: This term reflects the average of the squared differences between observed and simulated water levels. RMS is akin to standard deviation and is a measure of the spread of error about the mean residual. This term must be used with some care as it does not account for the potential range of water levels. However, in a progressively improving calibration process, this value should decrease.

- *NRMS*: This indicator, expressed in percentage, is the RMS divided by (or normalized by) the range of observed values for the dataset multiplied by 100%. NRMS may be considered a better indicator of goodness of fit as it accounts for the scale of the potential range of water levels. In this assessment NRMS magnitude is subjective, and, aside from the expectation of a decreasing NRMS with a calibration improvement, there is not a set target value that may be quantitatively ascribed. Nonetheless, based on Golder's experience, a NRMS target of 10% or less is frequently employed as the minimum target in Ontario.

- *Calibration Plot*: Simulated versus observed head values are compared on a plot with a central 45 degree line. In an idealized result, each point will lie along the 45-degree line. However, this rarely occurs in practice. Instead, the calibration plot is used as a visual inspection tool to determine goodness-of-fit and to detect any simulation bias (too high or too low relative to measured data) in the output. A good calibration outcome will show most points spread somewhat closely and evenly about the 45-degree line.

- *% of Simulated Water Table Above Ground Surface*: In models that simulate a shallow water table it is common/acceptable for a small portion of the calculated heads to slightly breach ground surface. This may occur as a result of minor inaccuracies introduced by numerical approximation and do not indicate a poor calibration. However, large areas with significant head above ground surface may indicate a systemic issue. As such, we have included as a quasi-calibration measure the percent of simulated water table above ground surface.

- *Regional Flow Directions*: Simulated trends are visually compared to regional inferences (as described in Section 3.2).

3.2 Targets

The "calibration targets" are average water levels measured at 22 TMF area wells (see attached Table 2 and Figure 8). For the purposes of model calibration, the target water levels are calculated as DEM elevation minus depth to water as opposed to the actual measured groundwater elevation. This adjustment is undertaken to avoid introducing residual error that might occur as a result of minor discrepancies between the interpolated model DEM versus actual surveyed topography.

In addition to groundwater elevation, the direction of vertical gradients is assessed for nested wells. Gradients are calculated as follows:

Observed Vertical Gradient = $\dfrac{\text{(Avg. Water Level Shallow Well) – (Avg. Water Level Deep Well)}}{\text{Distance between Midpoint of Screens}}$

Model Vertical Gradient = $\dfrac{\text{(Calc. Water Level Shallow Well) – (Calc. Water Level Deep Well)}}{\text{Distance between Midpoint of Model Layers}}$

In this document a negative "-" gradient denotes an upward flow direction.

Note that the *magnitude* of vertical gradients, whereas reported on herein, do not provide a good calibration indicator in this setting because: 1) the observed vertical gradient magnitude is an averaging of water level difference measured over discrete screened intervals; whereas 2) the model calculates hydraulic head at the centroid of each cell which may then be applied across the entirety of the layer thickness. The difference between screen versus layer distances makes direct comparison of gradient magnitude unfeasible (as is often the case in regional scale modelling analysis).

Lastly, during calibration it is also common to compare simulated heads with inferred groundwater patterns based on the measured dataset. In the previous conceptual model development memorandum, an inferred water table map was presented (Golder, 2016 – Figure 5). However, this particular map is of limited value in calibration as a large portion of the mapped domain is not constrained by monitoring data. Nonetheless, the following general trends may be inferred:

- Groundwater flow patterns roughly mimic topographic trends.
- There is a regional trend of southwesterly flow towards Sawbill Bay or southeasterly flow towards Lizard Lake with localized divides occurring within the model domain.
- The water table is frequently at, or close to, ground surface, particularly in low-lying areas.

3.3 Calibration Adjustments and Results

3.3.1 Initial Iteration

Calibration results of the revised initial iteration utilizing the conceptual model inputs (Golder, 2016) are illustrated in Figure 8 and summarized in Table 2 (named "Run 0" for reporting purposes). A key aspect of this revised initial iteration relative to the previous model analysis (Golder, 2017) is that the boundary conditions, in particular the peat drain cells, are consistent with the final calibrated model. Whereas the revised initial iteration is no longer displaying a large bias towards over-estimating heads relative to the initial iteration in Golder, 2016, the results nonetheless still indicate a sub-optimal calibration in each statistical indicator.

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The initial iteration does successfully match vertical gradient directions at five of six well nests, the one exception being BH12-5 which has a very small observed gradient.

3.3.2 Adjustments

In order to achieve a satisfactory calibration the following adjustments are made (these changes ultimately result in the inputs as described in Section 2 – Model Construction of this memorandum):

- The hydraulic conductivity distribution of the surficial deposits is differentiated material-wise as per Figure 2 to allow a more accurate portrayal of hydraulic properties and to align with the recharge rate distribution.
- The surficial sand hydraulic conductivity is slightly increased from 1E-5 m/s to 2E-5 m/s. This adjustment remains within the measured range of values for the surficial sand materials (Golder, 2016). In addition, the surficial sand recharge rate is reduced from 300 mm/yr to 200 mm/yr. This reduction in recharge is considered reasonable owing to the presence of fines in these sandy materials (i.e. the surficial sand is typically not a high-permeability, uniformly graded coarse sand or gravel which would be more conducive to a relatively high recharge rates of 300 mm/yr). These changes assist in depressurizing areas with an over-estimation of hydraulic head.
- The surficial till hydraulic conductivity is slightly decreased from 1E-5 m/s to 5E-6 m/s. This update is considered a more reasonable reflection of the relatively lower hydraulic conductivities typically associated with till materials. Furthermore, the surficial till recharge was increased from 25 mm/yr to 50 mm/yr. These changes were required to raise water levels in the till closer to ground surface as observed in the monitoring data.
- A discrete recharge zone with a rate of 135 mm/yr is applied in the valley wherein BRH-0016B is situated to better match water levels at that monitor. This small, largely enclosed "basin" feature likely allows for a greater concentration of recharge than in other surficial till areas.
- The fine-grained unit hydraulic conductivity 10:1 anisotropy (in areas where overburden is greater than 10 m thick) is made isotropic. This adjustment further assists in depressurizing areas with an over-estimation of hydraulic head. In addition, we note that this update would promote vertical seepage to the underlying coarse-grained unit (the most transmissive unit in the model). This parameter adjustment is revisited during sensitivity analysis (Section 4).
- The coarse-grained unit hydraulic conductivity is increased from 1E-5 m/s to 1E-4 m/s. This adjustment remains within the measured range of values for the coarse-grained materials (Golder, 2016). The increase in coarse-grained hydraulic conductivity results in a beneficial near-global decrease in target water levels and mounding. In addition, we note that this update is conservative (relative to the conceptual inputs) in terms of seepage rates that may emanate from the TMF.
- The weathered bedrock recharge rate (where rock outcrops at surface) was increased from 5 mm/yr to 50 mm/yr to produce a local head increase to the surrounding surficial materials where water levels are observed to be close to ground surface.

3.3.3 Final Calibration Results

Calibration results of the final calibration iteration using the inputs described in Section 2 are illustrated in Figure 9 and summarized in Table 2 (named "Run 1" for reporting purposes). The results indicate a satisfactory calibration in each statistical indicator and no undue bias in global trends.

The calibrated model successfully matches vertical gradient directions at five of six well nests, the one exception being BH12-5 which has a very small observed gradient (Table 2).

Simulated groundwater patterns compare reasonably well with our understanding of shallow groundwater behaviour and display a subdued reflection of topographic trends – groundwater highs (divides) occur along topographic ridges whereas groundwater lows (discharge areas) occur within valleys and adjacent to drainage features. There is a groundwater divide running somewhat centrally through the model domain; groundwater west of this area reports to Sawbill Bay whereas groundwater east of this area reports to Lizard Lake drainage. Another groundwater divide occurs in the north of the model domain; groundwater north of this area discharges to Long Hike Lake whereas groundwater south of this area reports to either Sawbill Bay or Lizard Lake.

A map of simulated depth to water table is provided in Figure 10. Depth to water is greatest in the upland areas to the north and along topographic highs. Elsewhere, in the valley areas, depth to water is relatively shallow with a large portion of the valley areas having the water table within 1 m of ground surface. There are a few discrete areas where the groundwater table is above ground surface; this is a minor occurrence (under 2% of the total model area) and acceptable given the regional scale of the model.

3.4 Groundwater Flow Budgets

Flow budgeting for the pre-calibration and final (baseline) calibration models is provided in Table 3. A typical global flow budget is provided that accounts for total inflow and outflow through recharge and the hydrologic boundaries implemented in the model (Figure 5). Also provided is the flow through the coarse-grained unit. The purpose of this flow accounting is not only to report on the model water budget but also to gain further insight into the effect of sensitivity analysis permutations (Section 4).

With respect to the final (baseline) calibration model the following is noted:

- Total flow through the model is 5,271 m^3/d.
- Recharge provides the majority of inflow (5,068 m^3/d or 96%). A small amount of water (203 m^3/d or 4%) enters the model from the lakes (mostly Long Hike Lake, owing to its higher water level elevation).
- The peat and internal wetland / stream features receive the majority of outflow (a combined 3,783 m^3/d or 72%). The remainder of outflow (1,488 m^3/d, or 28%) reports directly to the lakes.
- The coarse-grained layer receives a significant amount of flow-through (4,087 m^3/d, or 77% of the model flow).

4.0 SENSITIVITY ANALYSIS

An additional set of simulations are performed to determine the model sensitivity to key input parameters. Sensitivity in this particular analysis is quantified on the basis of calibration statistics and changes to flow budgets. Whereas the approach at this stage is quantifying the effect on calibration, parameters expected to play a role in future TMF seepage rates are examined.

The sensitivity analysis scenarios involve varying recharge rates and hydraulic conductivity values within a reasonable range as follows (Table 4):

- Run 2: Recharge rates increased by 50%.
- Run 3: Recharge rates decreased by 50%.
- Run 4: Fine-grained material hydraulic conductivity multiplied by 10.
- Run 5: Fine-grained material hydraulic conductivity divided by 10.
- Run 6: Fine-grained material anisotropy changed to 1:0.1 (where overburden is greater than 10 m thick).
- Run 7: Coarse-grained material hydraulic conductivity multiplied by 10.
- Run 8: Coarse-grained material hydraulic conductivity divided by 10.
- Run 9: Weathered bedrock material hydraulic conductivity multiplied by 10.
- Run 10: Weathered bedrock material hydraulic conductivity divided by 10.

From a calibration statistics perspective, the model appears to be most sensitive to the applied changes in recharge and least sensitive to changes in the fine-grained unit hydraulic conductivity. Almost every permutation indicates a worsening in calibration relative to baseline. These sub-optimal outcomes suggest that the sensitivity scenarios are less likely to occur relative to the baseline inputs. One possible exception is Run 4, where the sensitivity results are practically the same as the baseline; as mentioned, the model exhibits a low sensitivity to changes in fine-grained unit hydraulic conductivity. In the face of a wide range of potential fine-grained unit hydraulic conductivity values providing similar outcomes, we have chosen a calibration value that reflects the central tendency of the measured dataset (3E-7 m/s).

5.0 PARAMETER INPUTS SCENARIOS FOR FUTURE TMF SEEPAGE ANALYSIS

The calibration results indicate that the baseline model provides a defensible set of input parameters to use in the forthcoming predictive modelling of TMF seepage.

However, the sensitivity analysis suggests that other credible input sets may exist. With the purview of establishing a conservative upper limit on potential seepage, we propose to utilize Run 11 (Fine-grained material hydraulic conductivity multiplied by 10 and Coarse-grained material hydraulic conductivity multiplied by 10) alongside the baseline model inputs in the evaluation of TMF seepage. Run 11, while providing slightly inferior calibration statistics relative to the baseline, is nonetheless a plausible variant and, importantly, is the scenario tested that is most likely to promote seepage external to the TMF (for example this Run provides the greatest coarse-grained unit flow-through as per Table 4). In our view this two-model approach will allow for a practical understanding of potential seepage ranges and will enforce a conservative seepage collection system design.

6.0 NEXT STEPS

Provided the model construction and calibration detailed herein is acceptable to the GRT, the next step of the model process will be simulation of the TMF, including:

1. The TMF will be implemented within the numerical model framework for the operation, closure and post-closure project phases including the application of conceptual design details of seepage collection system.
2. Seepage quantities and environmental fate will be evaluated using zone budgeting and particle tracking in MODFLOW. This analysis will provide a base case estimate of capture efficiency, potential seepage bypass rates and the amount of discharge reporting to discrete receptors external to the TMF (for example, Lizard Lake, Sawbill Bay).
3. Both baseline (Run 1) and Run 11 inputs will be tested.
4. A report or technical memorandum summarizing the above will be provided for the GRT's review. This memorandum, amongst other items, will include conceptual details of seepage interception systems and contingency plans and an assessment of the residual impacts to the downstream receptors, thereby addressing Parts 7 and 8 of the Information Request T(3)-08.

7.0 REVIEW COMMENT ADDRESS

The following lists and provides initial address to GRT comments from CEAA., 2017. This address is not a final response to all GRT comments but rather seeks to resolve current modelling concerns so as to allow Golder to proceed to the next stage of modelling (TMF Simulation). We cannot fully address all of the GRTs concerns until the predictive TMF Simulation modelling is complete.

7.1 "Recommendations" from CEAA, 2017

1. *Model details and results should be fully reported, in order to evaluate the validity of the model calibration and sensitivity analysis. Comments 2-5 identify minor corrections or additions that are requested to ensure accuracy of reporting that will assist with the evaluation of model results, including:*

   a. *Reporting of cell conductance for drain cells, and identification of any cells that were specified as drain cells for the pre-calibration model;*

   b. *Verification and correction of the identified "Screened Unit" in Table 2 that is incorrectly labelled for several wells;*

   c. *Tabulation and summary of water level data for the model calibration, and the average depth to water in each monitoring well, the range (and standard deviation if enough data are available) of measured water depths, and the DEM elevation of each well should also be reported. The range and standard deviations of water levels can then be compared with the magnitude of the residuals in the model calibration and sensitivity analysis.*

   d. *If data are available for monitoring well BRH-0020B, they should be added to the water level data summary requested above and then used to ensure all available data are incorporated into model calibration and sensitivity analysis.*

Response:

- Recommendation 1a has been addressed in Section 2.5.
- Recommendations 1b, 1c and 1d have been addressed in Table 2.

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2*. To demonstrate the actual improvement in model calibration due to the adjustments in K and recharge values, the pre-calibration model should also include the drain cell boundary conditions as implemented for the calibrated model.*

> **Response:** The pre-calibration model now includes the peat drain cell boundary conditions (as per Section 2.5 and Section 3.3.1).

3*. Anisotropy of the fine-grained unit should be included as a scenario in the sensitivity analysis as it may influence the assessment of the effectiveness of the perimeter seepage collection ditches.*

> **Response:** Anisotropy of the fine-grained unit is now included as scenario in the sensitivity analysis (Section 4). Please note that the baseline model considers the fine-grained unit as isotropic, which not only yields a superior calibration result but also better facilitates vertical flow to the underlying coarse-grained layer and thus increases the potential for seepage bypass underneath the collection ditches.

4*. Vertical hydraulic gradients could be used as either a calibration target or for evaluation of results. Either way, matching hydraulic gradients in the model to measured gradients may help to constrain the model's parameters. At a minimum, the report should compare measured and modelled vertical hydraulic gradients.*

> **Response:** Vertical hydraulic gradients between observed and simulated water levels at calibration wells are compared in Table 2 and discussed in Section 3.

5. *The report should present the results of the final calibrated model and their implications in more detail:*

   a. *First, a map of depth to the water table (i.e. below ground surface) would be helpful to evaluate water levels (also showing areas where the water table is above ground surface).*

   b. *Second, a map indicating boundary conditions (i.e. also indicating active drain cells) and boundary fluxes would provide insight into the distribution of groundwater discharge under baseline conditions.*

   c. Third, a summary of baseline seepage fluxes to various boundaries/receptors (Lizard Lake, Sawbill Bay, Sawbill Creek, Long Hike and Woody Lakes, and the drain cell boundaries) should be tabulated..

Response:

- Recommendation 5a is addressed in Section 3.3.3 (Figure 10).
- Recommendation 5b is addressed in Figure 5.
- Recommendation 5c is addressed in Table 3.

6*. The most important issue is how to deal with the model's relative insensitivity to hydraulic conductivity (and to a lesser extent recharge). Table 3 indicates that other parameter sets may provide comparable calibrations to the final calibrated model. However, these parameter sets may not produce similar seepage results or respond similarly to the TMF and the perimeter seepage collection ditches. Therefore, NRCan recommends that Golder identify a few credible scenarios (i.e. sets of calibrated model parameters) that would represent the full range of possible seepage. Each of these credible scenarios would then be implemented for the TMF modelling to provide a potential range of results (e.g., seepage bypass rates and seepage collection capture efficiencies). Selection of* *credible sets of model parameters should be based on more than just the calibration criteria based on hydraulic head in Table 3. It should consider some measure of seepage flux (e.g., total seepage from layer 3) that would indicate variable levels of confinement and permeability of the coarse-grained layer. Therefore, Table 3 should also report a relevant measure of seepage to allow comparison of the influence of parameters on both calibration and seepage.*

> **Response:** Model flow budgets, including baseline and sensitivity scenario flow-through within the coarse-grained unit, are provided in Table 4. Golder has proposed two credible scenarios that represent the expected and upper bound of possible seepage as described in Section 5.

8.0 CLOSURE

We thank CMC for retaining Golder on this project and look forward to the GRT's review of this current work. If you have any questions, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Adam Auckland
Project Manager

Devin Hannan, P.Eng.
Associate, Environmental Engineer

MEMORANDUM

9.0 REFERENCES

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Attachments:

Table 2: Water Level and Calibration Results
Table 3: Groundwater Flow Budgets
Table 4: Sensitivity Analysis Results
Figure 1: Study Area and Model Domain
Figure 2: Surficial Geology (STEA, 2010)
Figure 3: Inferred Overburden Thickness
Figure 4A: Model Cross Section A-A'
Figure 4B: Model Cross Section B-B'
Figure 5: Boundary Conditions
Figure 6A: Hydraulic Conductivity Distribution Layer 1
Figure 6B: Hydraulic Conductivity Distribution Layer 2
Figure 6C: Hydraulic Conductivity Distribution Layer 3

MEMORANDUM

N:\Active\2016\3 Proj\1656263 CMC_EA Support_Hammond Reef\3. Environment\1. TMF Seepage Assessment\Model Construction Calibration\Rev 1\1656263_DOC007_Rev 1_TMF Model Construction and Calibration_30Mar2017.docx

MEMORANDUM

TABLE

Date: March 30, 2017
Project No. 1656263 1000 1001
To: Sandra Pouliot, ing. Canadian Malartic Corporation

Golder Associates

TABLE 2
Water Levels and Calibration Results

Well ID	Log Screened Unit	Model Screened Unit	DEM Elevation (masl)	Field Measurements							Pre-Calibration Model (Run 0)			Baseline Calibrated Model (Run 1)		
				Depth to Water Avg. (mbgs)	Depth to Water Min (mbgs)	Depth to Water Max (mbgs)	Depth to Water Range (m)	Depth to Water Std. Dev. (m)	Avg. GW Elevation [Calib. Target] (masl)	Avg. Vertical Gradient (m/m)	GW Elevation (masl)	Residual (m)	Vertical Gradient (m/m)	GW Elevation (masl)	Residual (m)	Vertical Gradient (m/m)
BH 12-1	Bedrock	Weathered Bedrock	439.6	0.49	0.18	0.80	0.62	0.44	439.1	-	440.0	0.9	-	440.0	0.9	-
BH 12-10	Silty Sand (immediately below peat)	Peat	433.5	0.71	0.46	0.97	0.52	0.36	432.8	-	430.8	-2.0	-	433.1	0.3	-
BH 12-2	Silt, Silty Sand and Gravel	Fine-Grained	418.4	0.40	0.03	0.78	0.75	0.53	418.0	-	418.8	0.8	-	417.7	-0.2	-
BH 12-3A	Bedrock	Weathered Bedrock	418.8	-0.19	-0.67	0.29	0.96	0.68	419.0	-0.01	421.4	2.3	-0.001	419.1	0.0	-0.01
BH 12-3B	Silt	Fine-Grained	418.8	-0.14	-0.60	0.32	0.92	0.65	419.0		421.4	2.4		419.0	0.1	
BH 12-4	Silt, Silty Sand	Fine-Grained	428.2	-0.08	-0.74	0.58	1.31	0.93	428.2	-	428.0	-0.3	-	427.9	-0.4	-
BH 12-5A	Bedrock	Weathered Bedrock	432.9	-0.13	-0.62	0.36	0.98	0.69	433.0	0.005	433.0	-0.1	-0.002	433.0	0.0	-0.001
BH 12-5B	Sand	Coarse-Grained	432.9	-0.15	-0.63	0.33	0.97	0.68	433.1		433.0	-0.1		433.0	0.0	
BRH-0016A	Bedrock	Weathered Bedrock	446.3	1.37	1.19	1.57	0.38	0.16	444.9	0.13	431.9	-13.1	0.0	444.1	-0.8	0.01
BRH-0016B	Sandy Clayey Silt (at bedrock contact)	Weathered Bedrock	446.3	0.95	0.77	1.14	0.38	0.27	445.3		431.9	-13.5		444.2	-1.2	
BRH-0017A	Bedrock	Weathered Bedrock	428.8	0.10	-0.08	0.26	0.34	0.17	428.7	-0.004	427.6	-1.1	-0.001	428.7	0.0	-0.001
BRH-0017B	Compact Silty Sand / Sand (Till)	Till	428.8	0.12	0.02	0.19	0.17	0.09	428.7		427.6	-1.1		428.7	0.0	
BRH-0018	Bedrock	Weathered Bedrock	429.8	0.87	-1.04	1.93	2.97	1.23	428.9	-	429.7	0.8	-	428.7	-0.2	-
BRH-0019	Silty Clay to Clay	Fine-Grained	430.8	0.03	-0.40	0.59	0.99	0.50	430.8	-	430.9	0.1	-	431.0	0.2	-
BRH-0020A	Bedrock	Weathered Bedrock	415.9	-0.70	-0.87	-0.62	0.25	0.14	416.6	-0.08	418.4	1.8	-0.01	417.2	0.7	-0.004
BRH-0020B	Sand with Boulders	Coarse-Grained	415.9	-0.65	-0.65	-0.65	0.01	0.00	416.5		418.4	1.9		417.2	0.7	
BRH-0021A	Bedrock	Weathered Bedrock	420.5	0.73	0.09	1.40	1.31	0.57	419.8	-0.08	420.5	0.7	-0.004	420.5	0.7	-0.001
BRH-0021B	Organics, Sand, Sandy Clayey Silt	Peat	420.5	0.97	0.30	1.72	1.43	0.62	419.5		420.5	1.0		420.5	0.9	
BRH-0022	Bedrock	Weathered Bedrock	431.7	1.21	1.06	1.38	0.33	0.14	430.5	-	432.6	2.1	-	431.4	0.9	-
BRH-0023	Sand and Gravel, Boulders, Some Clay	Till	438.3	0.42	0.32	0.51	0.19	0.08	437.9	-	436.8	-1.1	-	439.8	1.9	-
BRH-0024	Bedrock	Weathered Bedrock	433.6	4.39	4.18	4.54	0.36	0.17	429.2	-	433.2	4.0	-	432.0	2.7	-
BRH-0027	Compact Sandy Silty Clay, Silty Sand	Till	437.0	0.08	0.08	0.08	0.00	n/a	437.0	-	431.4	-5.5	-	434.5	-2.5	-

Calibration Statistics	Pre-Calibration Model (Run 0)	Baseline Calibrated Model (Run 1)
Residual Mean (m):	-0.9	0.2
Absolute Residual Mean (m):	2.6	0.7
Normalized Root Mean Square (%):	15.4%	3.6%
% of Model Domain with Heads Above Ground Surface:	8%	2%

Note: A negative "-" depth to water denotes a water level above ground surface.

TABLE 3
Groundwater Flow Budgets

		Pre-Calibration (Run 0)			Baseline Calibration (Run 1)		
Feature	**Boundary Type**	**In (m3/d)**	**Out (m3/d)**	**Net (m3/d)**	**In (m3/d)**	**Out (m3/d)**	**Net (m3/d)**
Recharge	Recharge	5,513	0	5,513	5,068	0	5,068
Sawbill Bay	Constant Head	4	665	-661	7	739	-732
Long Hike Lake	Constant Head	63	201	-138	177	173	4
Lizard Lake	Constant Head	0	242	-242	0	404	-404
North Pond	Constant Head	7	224	-217	19	172	-153
Internal Wetland / Streams	Drains	0	1,617	-1,617	0	1,752	-1,752
Peat	Drains	0	2,639	-2,639	0	2,031	-2,031
	Total:	5,587	5,587	0	5,271	5,271	0

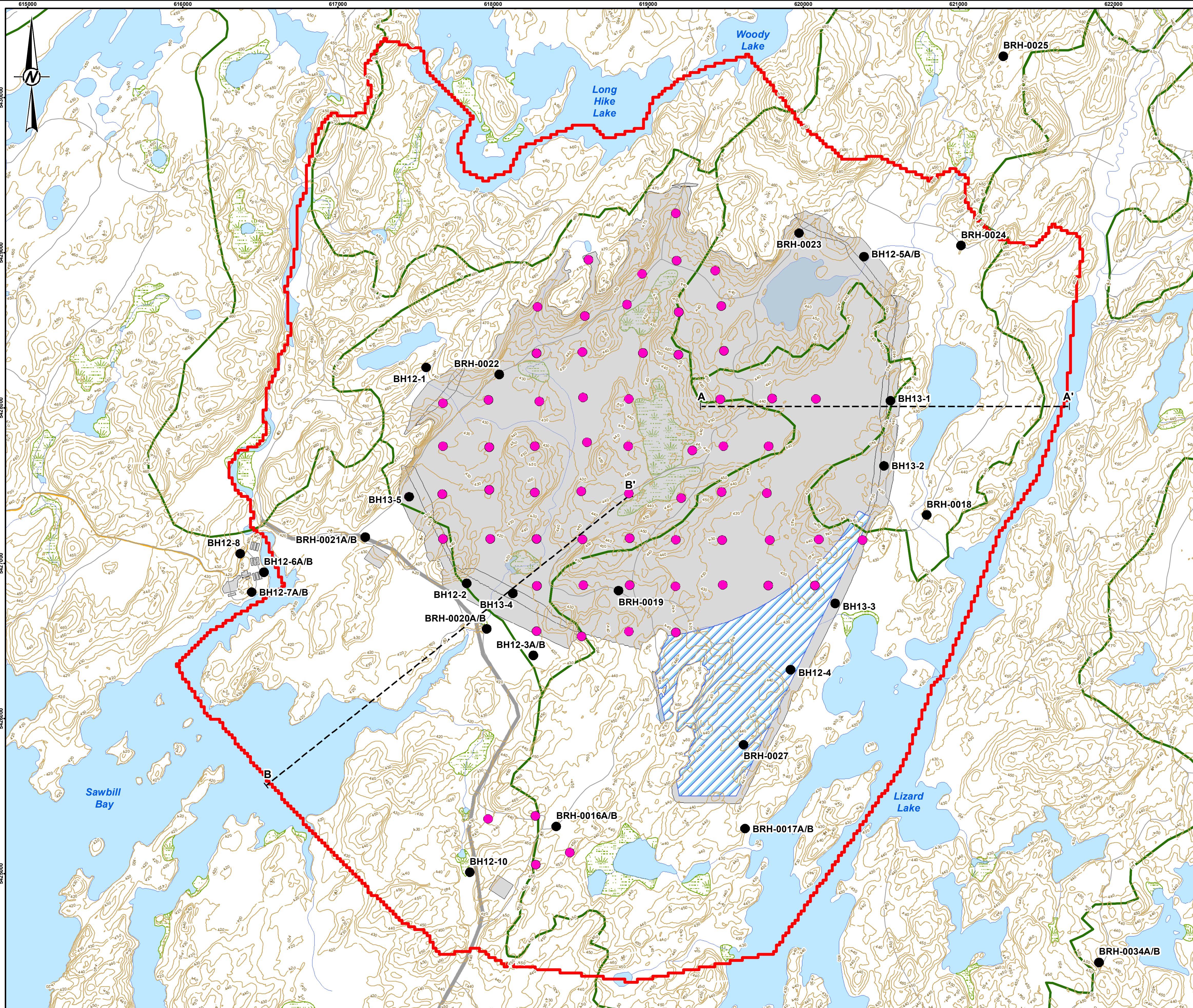
Flow Through Coarse-Grained Unit:	3,217	3,217	0	4,087	4,087	0

TABLE 4
Sensitivity Analysis Results

	Run 1		**Run 2**		**Run 3**		**Run 4**		**Run 5**		**Run 6**		**Run 7**		**Run 8**		**Run 9**		**Run 10**		**Run 11**	
Description	Baseline Calibration		Increase Recharge 50%		Decrease Recharge 50%		Fine-Grained K x 10		Fine-Grained K / 10		Fine-Grained $K_H : K_V = 1 : 0.1$		Coarse-Grained K x 10		Coarse-Grained K / 10		W. Bedrock K x 10		W. Bedrock K / 10		Fine-Grained and Coarse-Grained K x	
Calibration Statistics																						
Res. Mean (m)	0.2		0.9		-1.0		0.0		0.6		0.4		-0.4		0.5		-0.3		0.6		-0.8	
Abs. Res. Mean (m)	0.7		1.1		1.3		0.7		1.0		0.9		1.0		0.7		0.8		0.9		1.2	
Normalized RMS (%)	3.6		5.5		8.5		3.5		4.5		4.1		5.0		3.6		4.3		4.8		5.6	
% Model Domain with Head Above Ground	2%		4%		1%		2%		3%		3%		1%		4%		1%		3%		1%	
Groundwater Flow Budget																						
	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)	In (m^3/d)	Out (m^3/d)
Recharge	5,068	0	7,601	0	2,534	0	5,068	0	5,068	0	5,068	0	5,068	0	5,068	0	5,068	0	5,068	0	5,068	0
Sawbill Bay Const. Heads	7	739	7	999	7	457	10	735	7	719	7	736	7	1,206	7	578	8	784	7	732	13	1,224
Long Hike Lake Const. Heads	177	173	150	322	216	35	204	169	132	186	171	176	823	151	81	192	260	155	133	180	1,287	142
Lizard Lake Const. Heads	0	404	0	498	0	293	0	410	0	388	0	385	0	971	0	287	0	477	0	390	0	1,042
North Pond Const. Heads	19	172	14	265	27	80	47	174	10	174	14	170	52	141	12	171	21	168	18	173	210	156
Internal Wetland/Stream Drains	0	1,752	0	2,545	0	951	0	1,895	0	1,624	0	1,719	0	2,112	0	1,711	0	1,757	0	1,748	0	2,907
Peat Drains	0	2,031	0	3,144	0	967	0	1,947	0	2,127	0	2,074	0	1,369	0	2,229	0	2,016	0	2,004	0	1,106
Total	*5,271*	*5,271*	*7,772*	*7,773*	*2,784*	*2,784*	*5,329*	*5,329*	*5,217*	*5,218*	*5,260*	*5,260*	*5,950*	*5,949*	*5,169*	*5,169*	*5,357*	*5,357*	*5,227*	*5,227*	*6,577*	*6,577*
Flow Through Coarse-Grained Unit	4,087	4,087	5,588	5,588	2,433	2,433	4,539	4,539	3,177	3,177	3,845	3,845	5,335	5,335	2,950	2,950	4,704	4,704	3,925	3,925	6,561	6,561

MEMORANDUM

FIGURES



LEGEND

- Consultant Boreholes
- Condemnation Holes
- Model Cross-Section
- Road
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Contour (10 m interval)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Model Domain

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
STUDY AREA AND MODEL DOMAIN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

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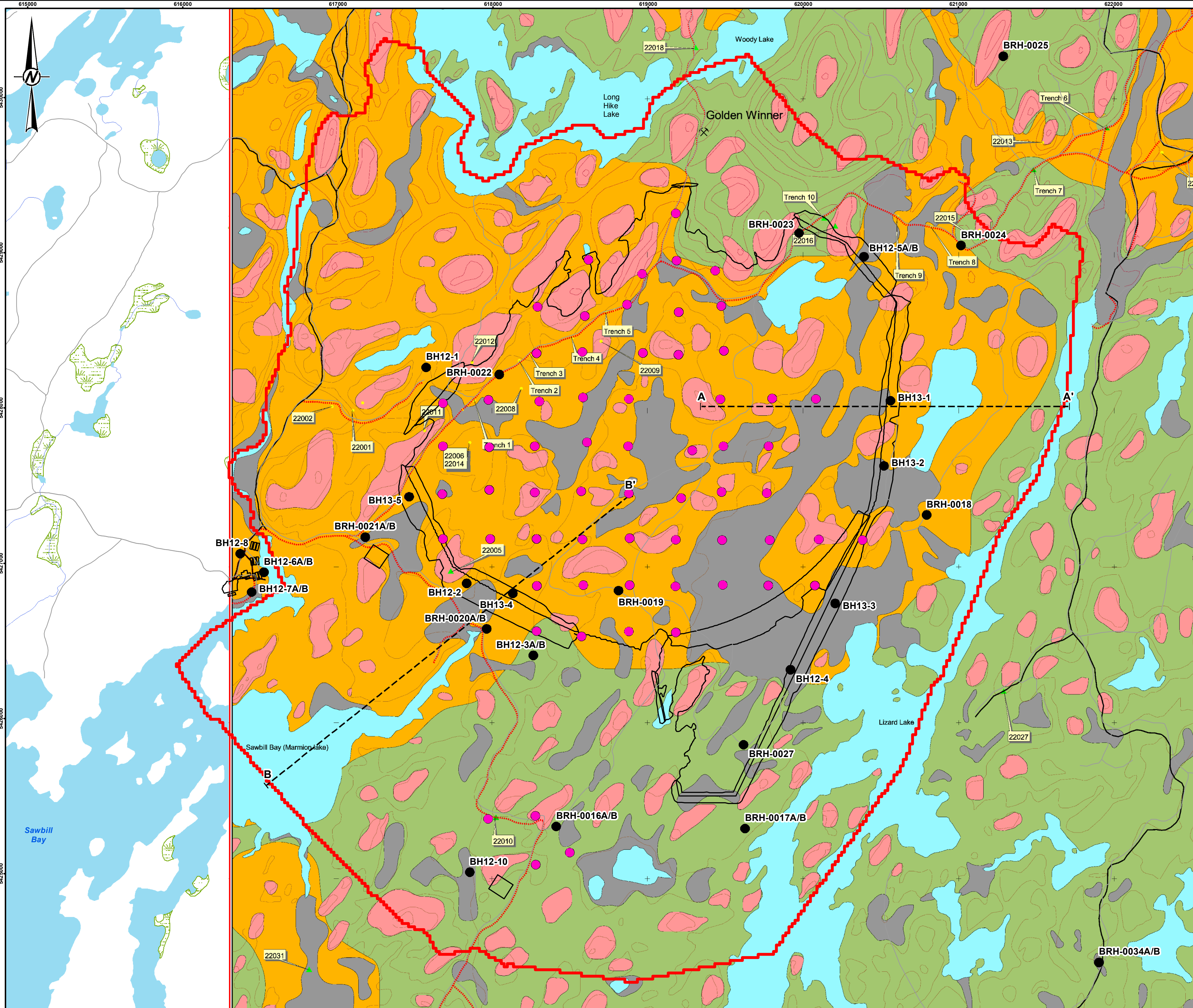

LEGEND

- Road
- River/Stream
- Lake
- Wetland
- Consultant Boreholes
- Condemnation Holes
- Model Cross-Section
- Proposed Tailings Management Facility
- Model Domain

HOLOCENE NONGLACIAL ENVIRONMENT

Terrain Unit and Significance to Mineral Exploration

Organic Terrain:
(deposits of peat laid down in areas of high water table)

Areas where peat and muck are greater than 1m, constituting bogs and muskeg, low-lying floodplains (peat underlain by sand) and lake shore swamps. Significant detriment to exploration due to masking effect of thick organic material and creation of false anomalies by spurious concentration of metals.

PLEISTOCENE GLACIAL ENVIRONMENT

Subaqueous outwash and associated glacio-lacustrine facies:
(deposits of sand and gravel formed at a glacier margin where subglacial meltwater streams empty into glacial lakes).

Sand and gravel deposits are found in broad valleys at the head of Marmion and Finlayson Lakes. Thicknesses vary widely from >10m to less than 1m and bedrock is exposed sporadically. These deposits consist of subaqueously deposited, parallel-laminated, graded beds of coarse/fine sand and coarse open-work gravels interbedded with high energy bouldery. gravel deposits. Deposits are considered detrimental to geochemical prospecting because of far-travelled material diluting a local bedrock signature. Sand deposits are probably more extensive than mapped.

Till Veneer-Discontinuous:
(unsorted deposits of boulders/gravel/mud deposited directly by a glacier;
basal facies formed near base of glacier, ablation facies from debris higher in the ice)

Bedrock outcrop interspersed with deposits of till, 10-80% outcrop. Topography controlled by bedrock. Till is divisible into two facies: Unit 1- silty-sandy, locally -derived basal facies; Unit 2: Bouldery sandy ablation facies with high erratic content. Terrain is suitable for prospecting and geochemical/geophysical surveys as local bedrock is either at surface or within 1m, buried by a locally-derived till. Soil may be too thin for sampling. Occasional deposits of thick ablation till may mask local bedrock.

Bedrock with sediment veneer:
(bedrock scoured by ice and meltwater action, remnants of till and glaciolacustine silt in hollows between bedrock knobs.

Bedrock outcrop or moss/boulder covered outcrop, with a thin, discontinuous cover of till and glaciolacustrine sediment . A period of intense meltwater flow may be indicated and may account for the lack of sediment cover. Terrain suitable for prospecting because bedrock is ubiquitous. Soils may be thin or absent.

Symbols

- Trails accessible by ATV
- Truck accesible roads
- Trench 2 — Trench site- 2010 survey glaciofluvial sediments -sample number on accomapnying figure
- 22019 — Sample site- glacial till sample number
- Golden Winner prospect (gold)

0 500 1,000

1:25,000 Metres

REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. SURFICIAL GEOLOGY TAKEN FROM SURFICIAL GEOLOGY UPDATE OF THE GOLDEN WINNER AREA: SEDIMENTOLOGY AND STRATIGRAPHY OF GLACIOFLUVIAL DEPOSITS AND RECOMMENDATIONS FOR RECCE SAMPLING (STEA, 2010).
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
SURFICIAL GEOLOGY (STEA, 2010)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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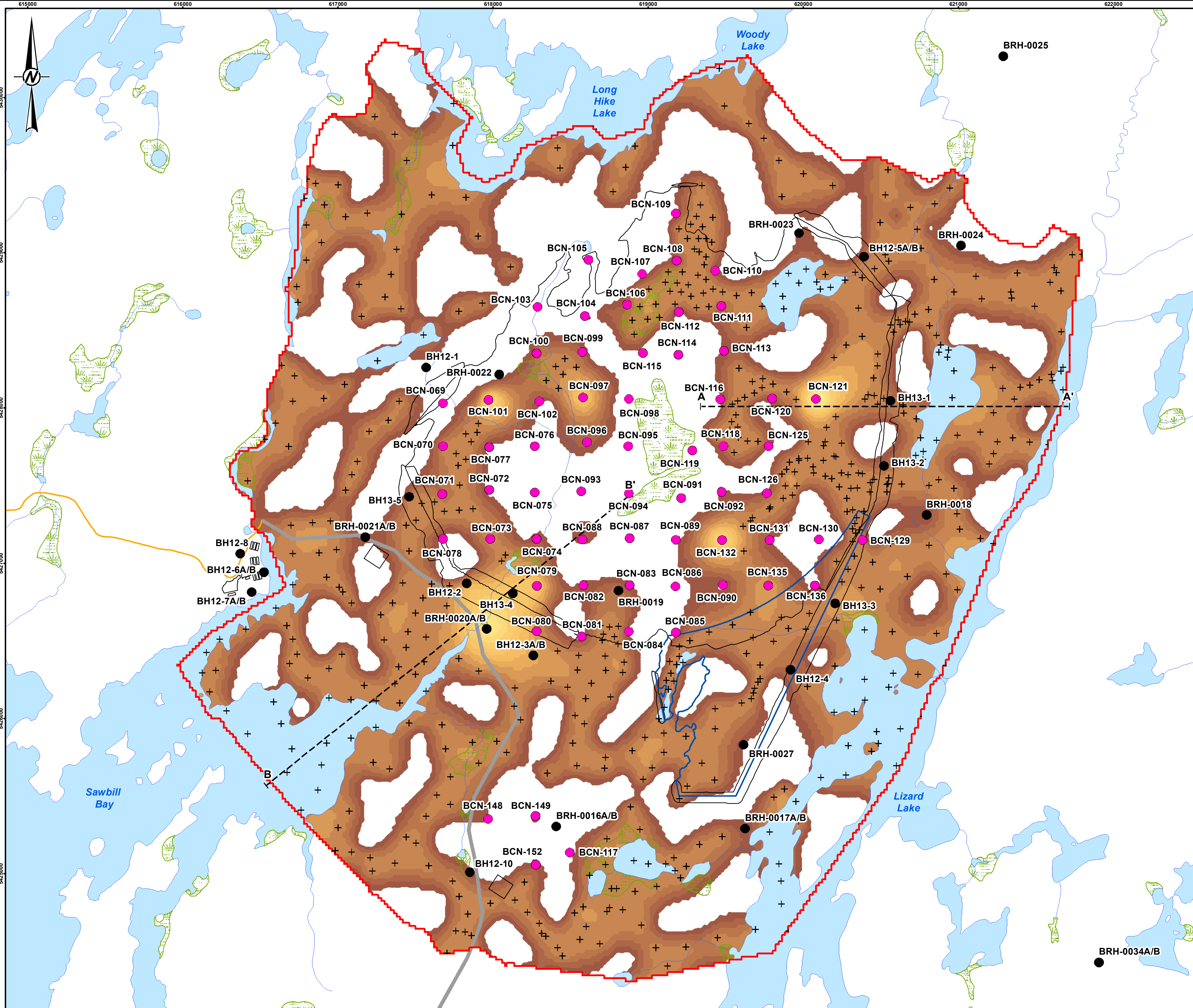


LEGEND

- Additional Contour Points, Assumed Overburden Thickness = 10 m
- Consultant Boreholes
- Condemnation Holes
- Model Cross-Section
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Model Domain

Overburden Thickness (m)

- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

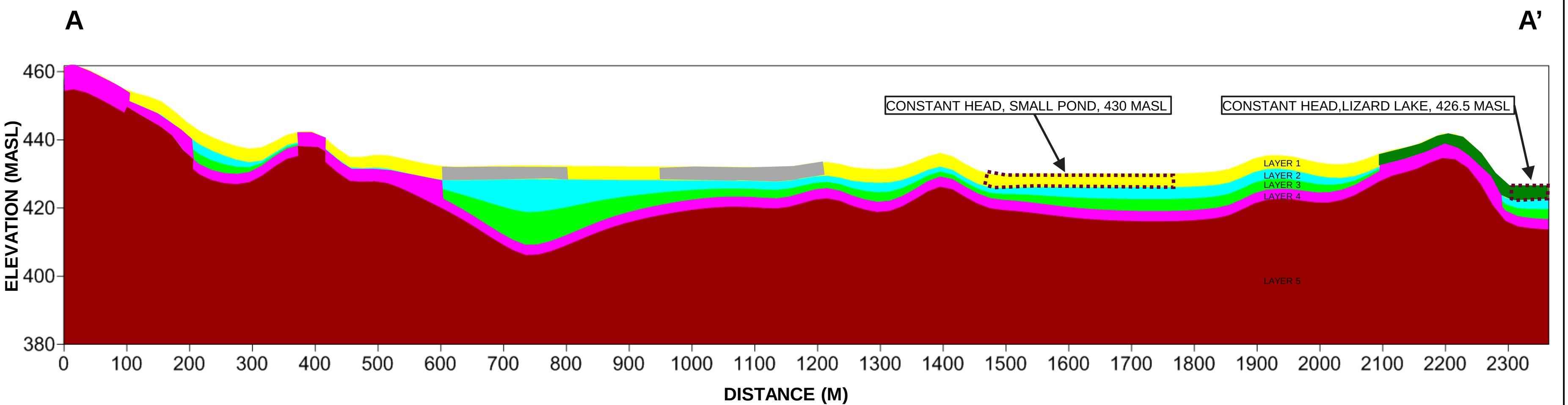
TITLE
INFERRED OVERBURDEN THICKNESS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



HYDROSTRATIGRAPHIC UNIT SUMMARY

- SURFICIAL SAND, K = 2E-5 M/S
- SURFICIAL TILL, K = 5E-6 M/S
- SURFICIAL PEAT. K = 1E-5 M/S
- WEATHERED BEDROCK, K = 2E-6 M/S
- FINE-GRAINED, K = 3E-7 M/S
- COARSE-GRAINED, K = 1E-4 M/S
- COMPETENT BEDROCK, K = 2E-7 M/S

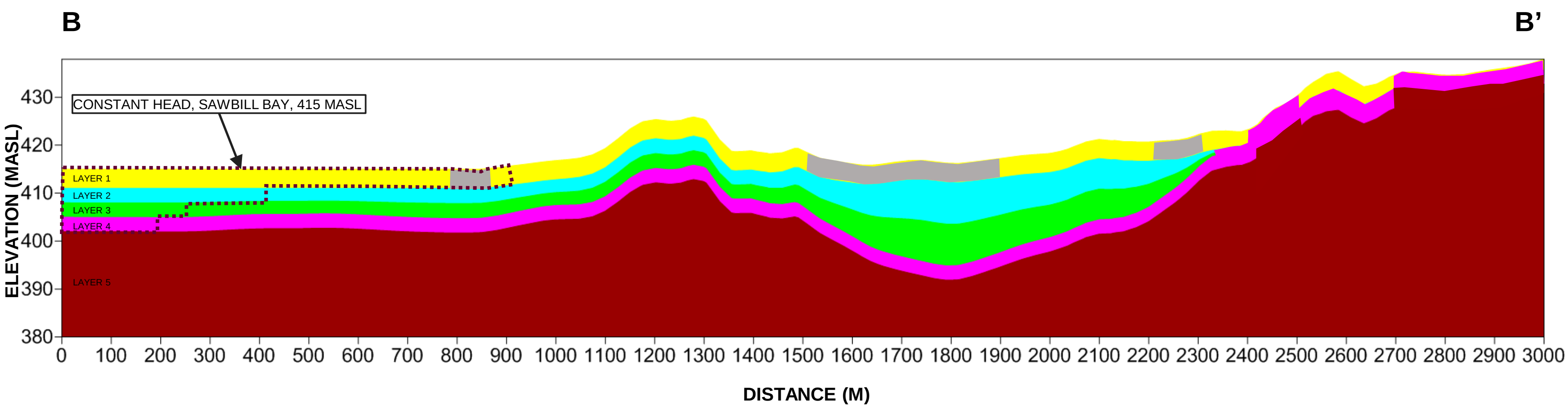
NOTES:
-REFER TO FIGURE 1 FOR CROSS-SECTION LOCATION IN PLAN VIEW.

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

MODEL CROSS SECTION A – A'

JANUARY 2017	PROJECT: 1656263	FIGURE 4A



HYDROSTRATIGRAPHIC UNIT SUMMARY

- SURFICIAL SAND, K = 2E-5 M/S
- SURFICIAL TILL, K = 5E-6 M/S
- SURFICIAL PEAT, K = 1E-5 M/S
- WEATHERED BEDROCK, K = 2E-6 M/S
- FINE-GRAINED, K = 3E-7 M/S
- COARSE-GRAINED, K = 1E-4 M/S
- COMPETENT BEDROCK, K = 2E-7 M/S

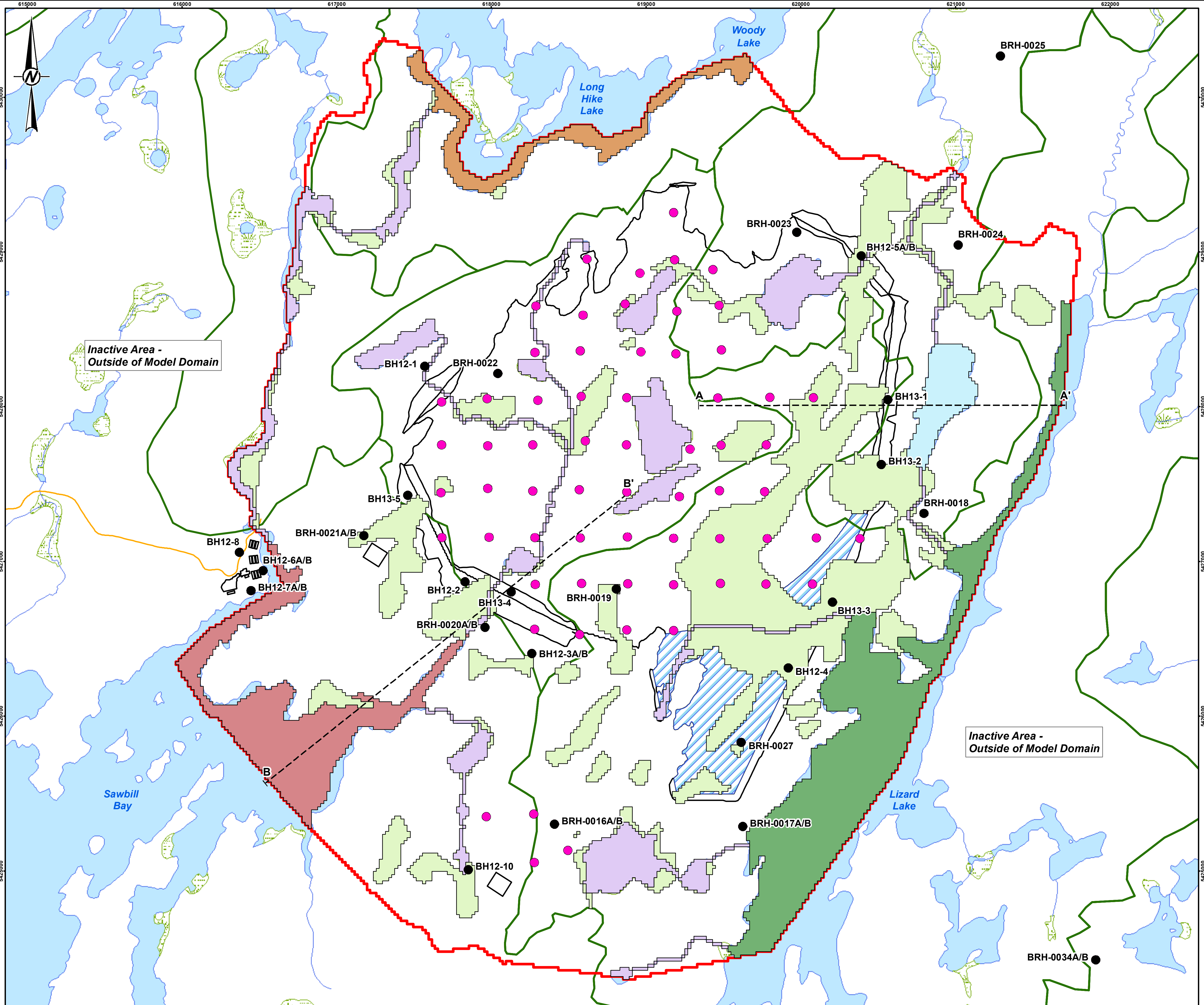
NOTES:
-REFER TO FIGURE 1 FOR CROSS-SECTION LOCATION IN PLAN VIEW.

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

MODEL CROSS SECTION B – B'

JANUARY 2017	PROJECT: 1656263	FIGURE 4B



LEGEND

- Consultant Borehole
- Condemnation Hole
- Model Cross-Section
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Model Domain
- Sawbill Bay - Constant Head Boundary Condition
- Lizard Lake - Constant Head Boundary Condition
- Long Hike Lake - Constant Head Boundary Condition
- North Pond - Constant Head Boundary Condition
- Internal Wetlands and Streams - Drain Boundary Condition
- Peat - Drain Boundary Condition

0 500 1,000
1:25,000 Metres

NOTE(S)

1. BOUNDARY CONDITIONS FOR LAYER 1 SHOWN

REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
BOUNDARY CONDITIONS

CONSULTANT

YYYY-MM-DD	2017-03-28
DESIGNED	SO
PREPARED	PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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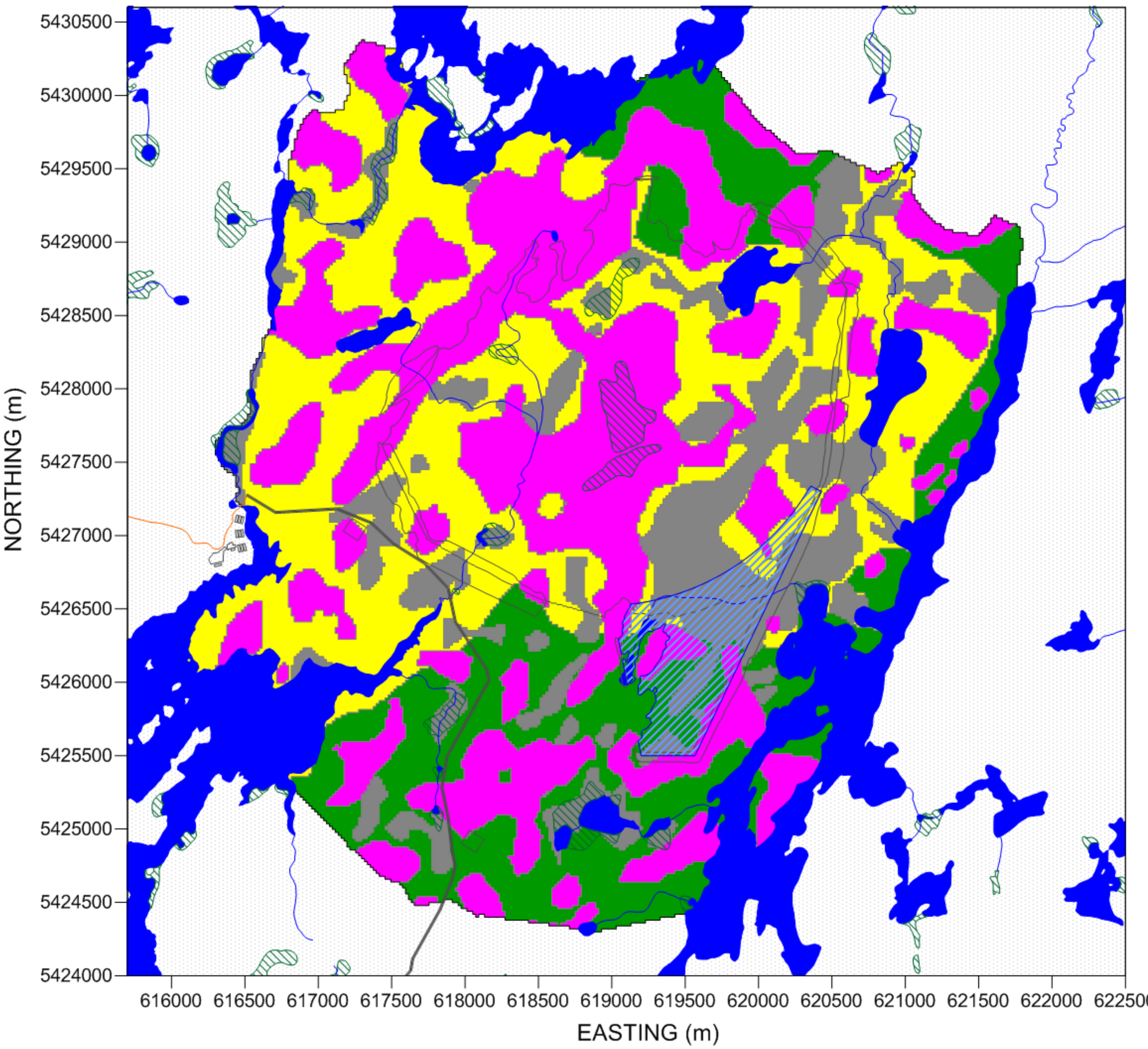
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



HYDRAULIC CONDUCTIVITY

- SURFICIAL SAND (2E-5 m/s)
- SURFICIAL TILL (5E-6 m/s)
- SURFICIAL PEAT (1E-5 m/s)
- WEATHERED BEDROCK (2E-6 m/s)

NOTE:

- ALL MATERIALS ISOTROPIC

REFERENCE(S)

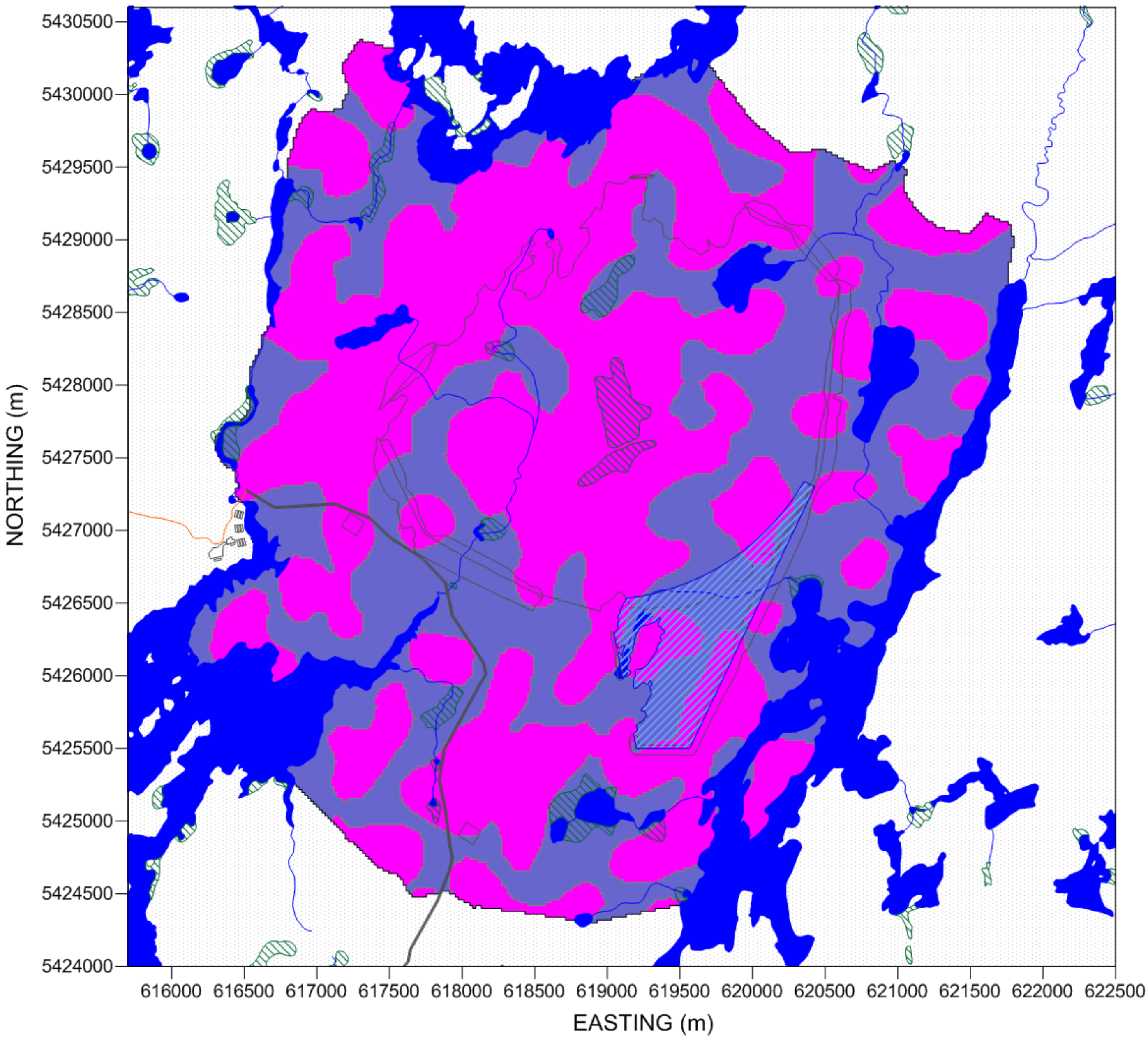
1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 1

JANUARY 2017	PROJECT: 1656263	FIGURE 6A



HYDRAULIC CONDUCTIVITY

FINE-GRAINED (3E-7 m/s)
WEATHERED BEDROCK (2E-6 m/s)

NOTE:
- ALL MATERIALS ISOTROPIC

REFERENCE(S)

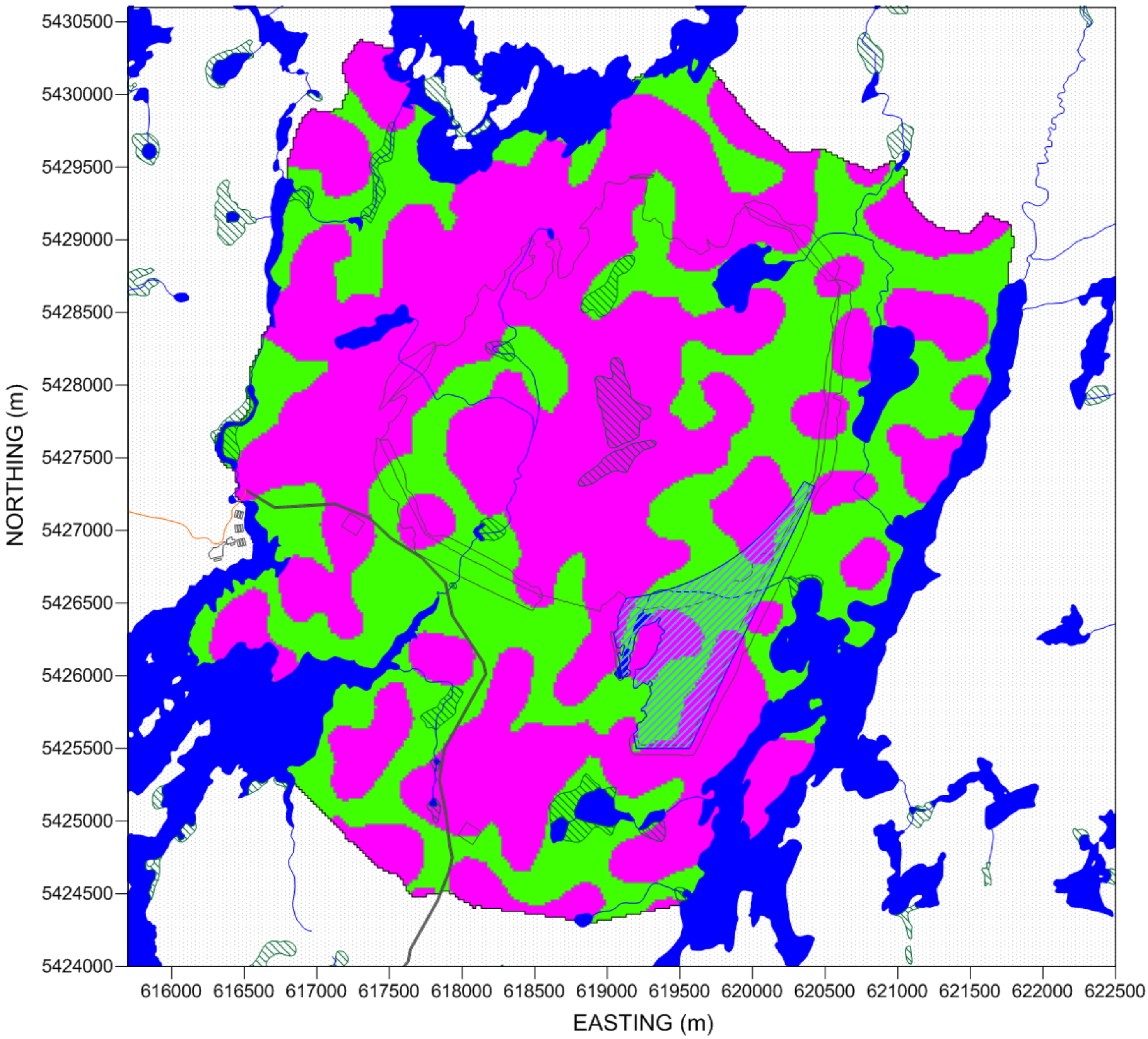
1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 2

JANUARY 2017	PROJECT: 1656263	FIGURE 6B



HYDRAULIC CONDUCTIVITY

- COARSE-GRAINED (1E-4 m/s)
- WEATHERED BEDROCK (2E-6 m/s)

NOTE:

- ALL MATERIALS ISOTROPIC

REFERENCE(S)

1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CANADIAN MALARTIC CORPORATION
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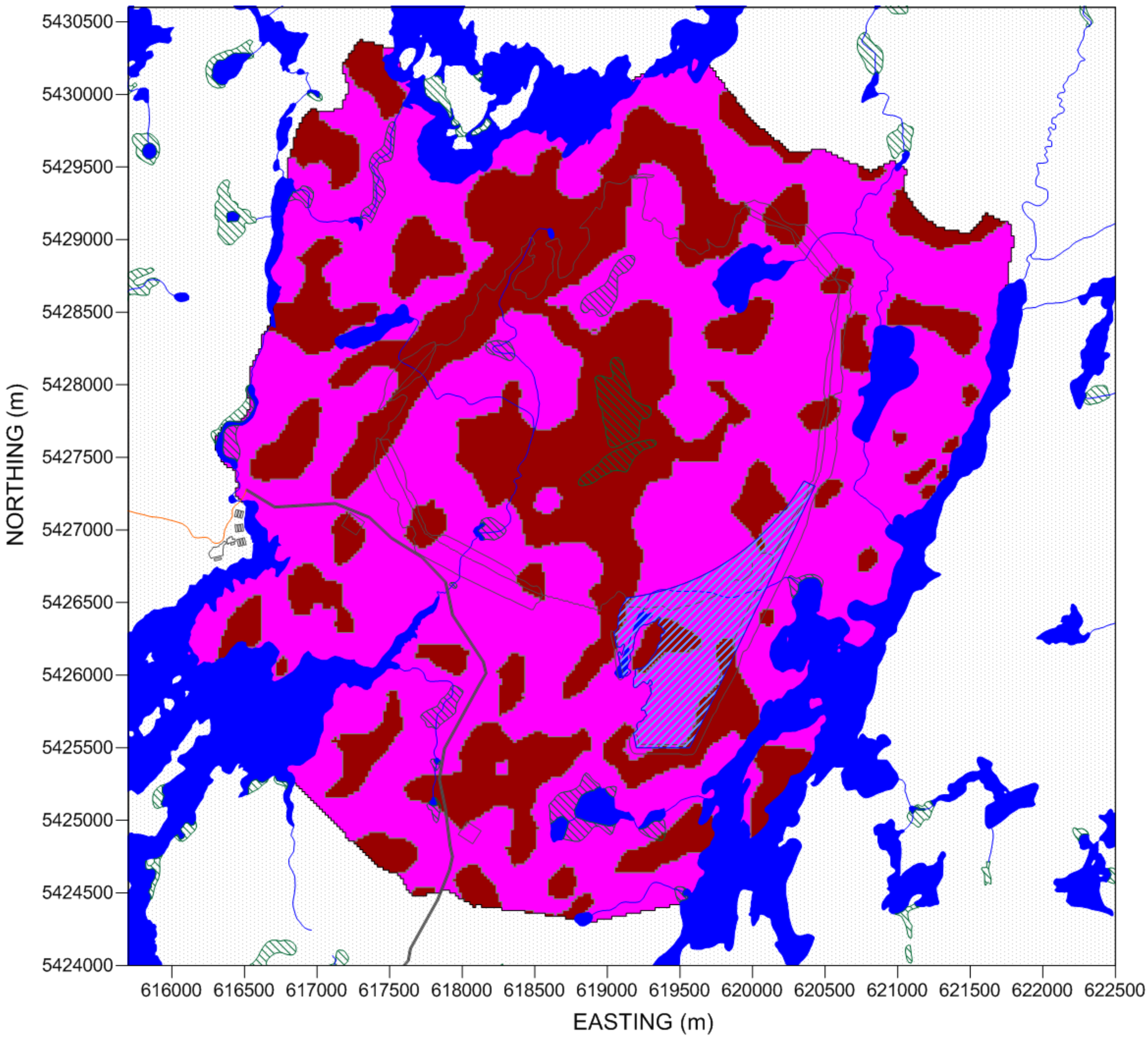
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 3

JANUARY 2017	PROJECT: 1656263	FIGURE 6C



HYDRAULIC CONDUCTIVITY

- WEATHERED BEDROCK (2E-6 m/s)
- COMPETENT BEDROCK (2E-7 m/s)

NOTE:
- ALL MATERIALS ISOTROPIC

REFERENCE(S)

1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CANADIAN MALARTIC CORPORATION
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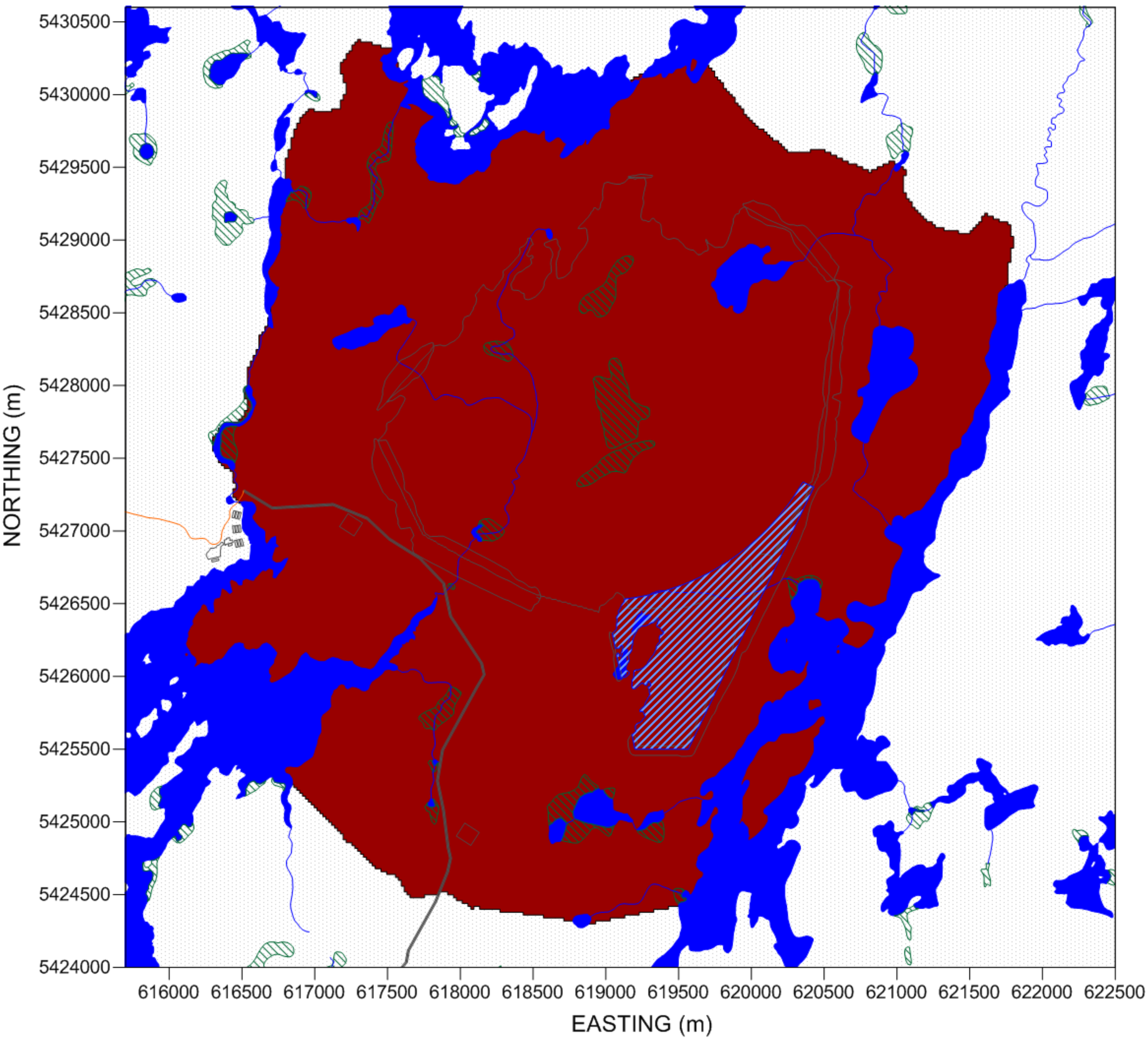
HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 4

JANUARY 2017	PROJECT: 1656263	FIGURE 6D



HYDRAULIC CONDUCTIVITY

COMPETENT BEDROCK (2E-7 m/s)

NOTE:

- ALL MATERIALS ISOTROPIC

REFERENCE(S)

1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

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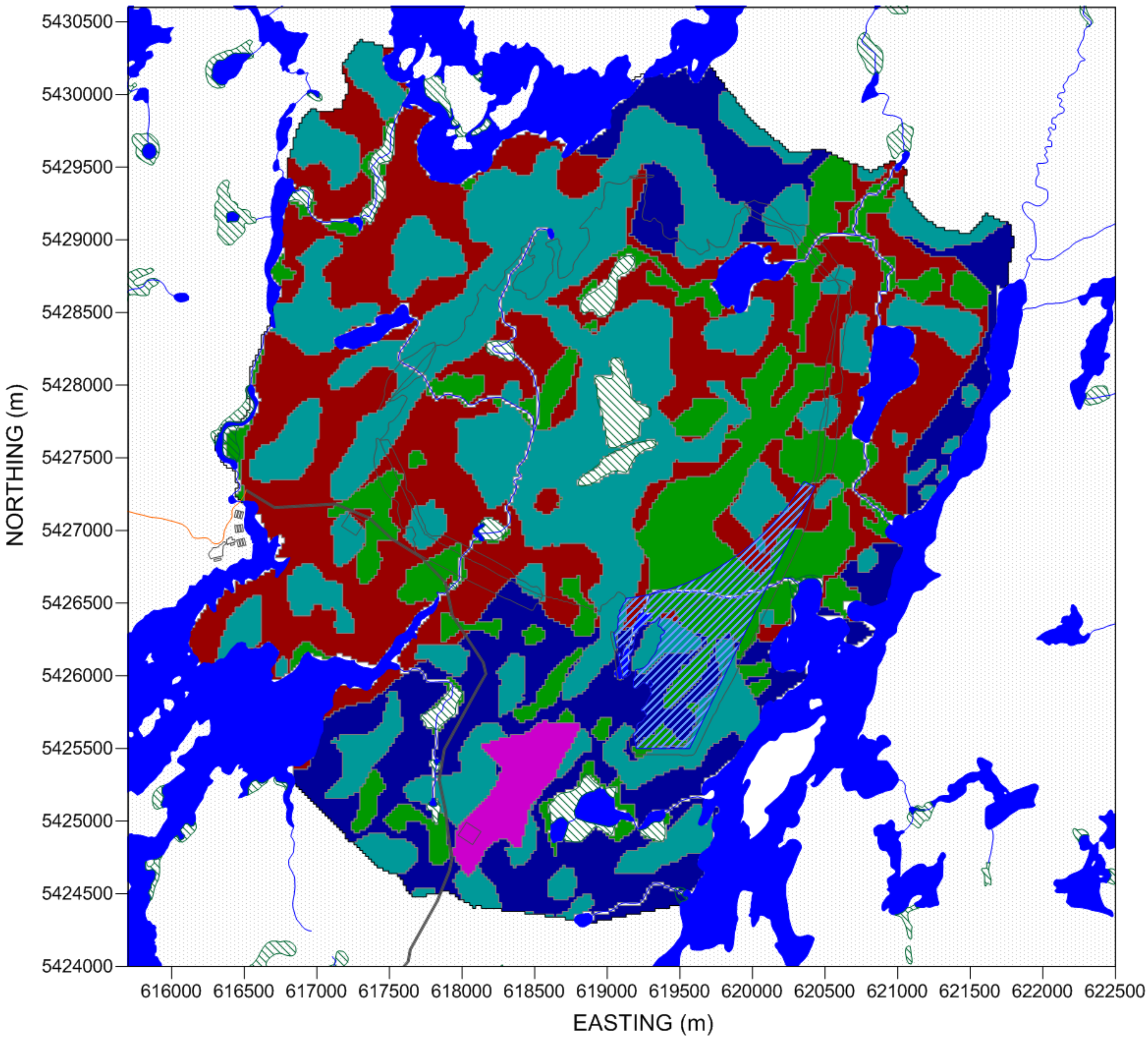
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 5

JANUARY 2017	PROJECT: 1656263	FIGURE 6E



RECHARGE

- SURFICIAL SAND (200 mm/yr)
- SURFICIAL TILL (50 mm/yr)
- SURFICIAL PEAT (5 mm/yr)
- WEATHERED BEDROCK (50 mm/yr)
- RECHARGE VALLEY (135 mm/yr)
- LAKES/ RIVERS/ WETLANDS (0 mm/yr)

REFERENCE(S)

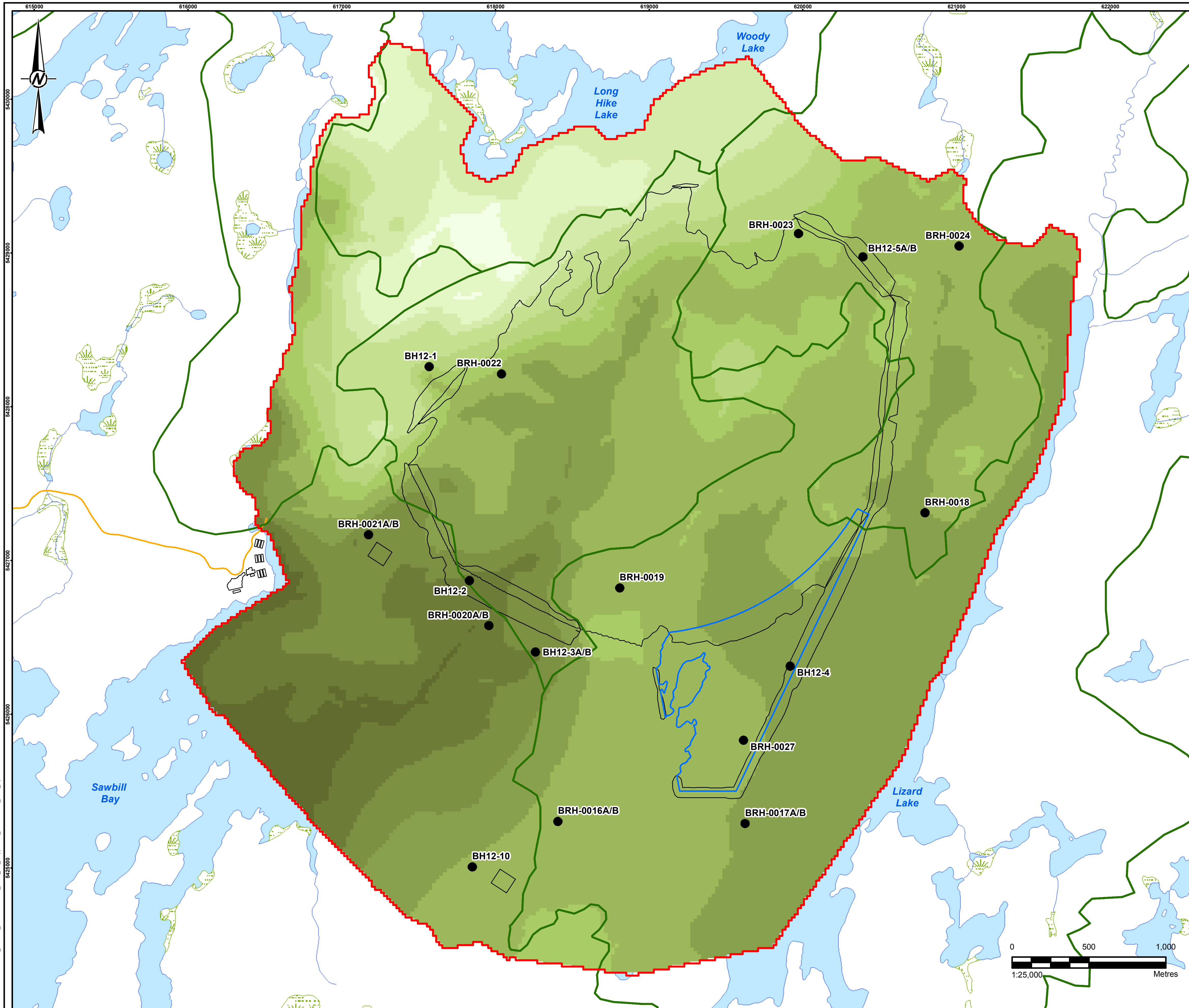
1. BASE DATA – PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

RECHARGE DISTRIBUTION

JANUARY 2017	PROJECT: 1656263	FIGURE 7



LEGEND

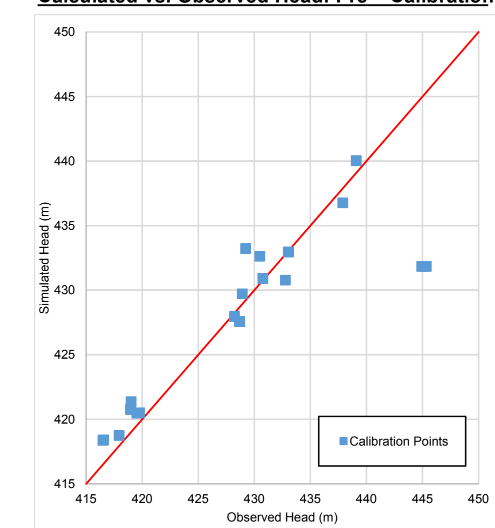
- Calibration Wells
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Model Domain

Pre-Calibration Simulated Water Table (m)

- 410 - 415
- 415 - 420
- 420 - 425
- 425 - 430
- 430 - 435
- 435- 440
- 440 - 445
- 445 - 450
- 450 - 455
- 455 - 460
- 460 - 465

Description	Residual Mean (m)	Absolute Residual Mean (m)	RMS (m)	Normalized nRMS (%)	% of Water Table Above Ground Surface
Pre-Calibration Results	-0.86	2.59	4.44	15.4	8%

Calculated vs. Observed Head: Pre – Calibration



REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

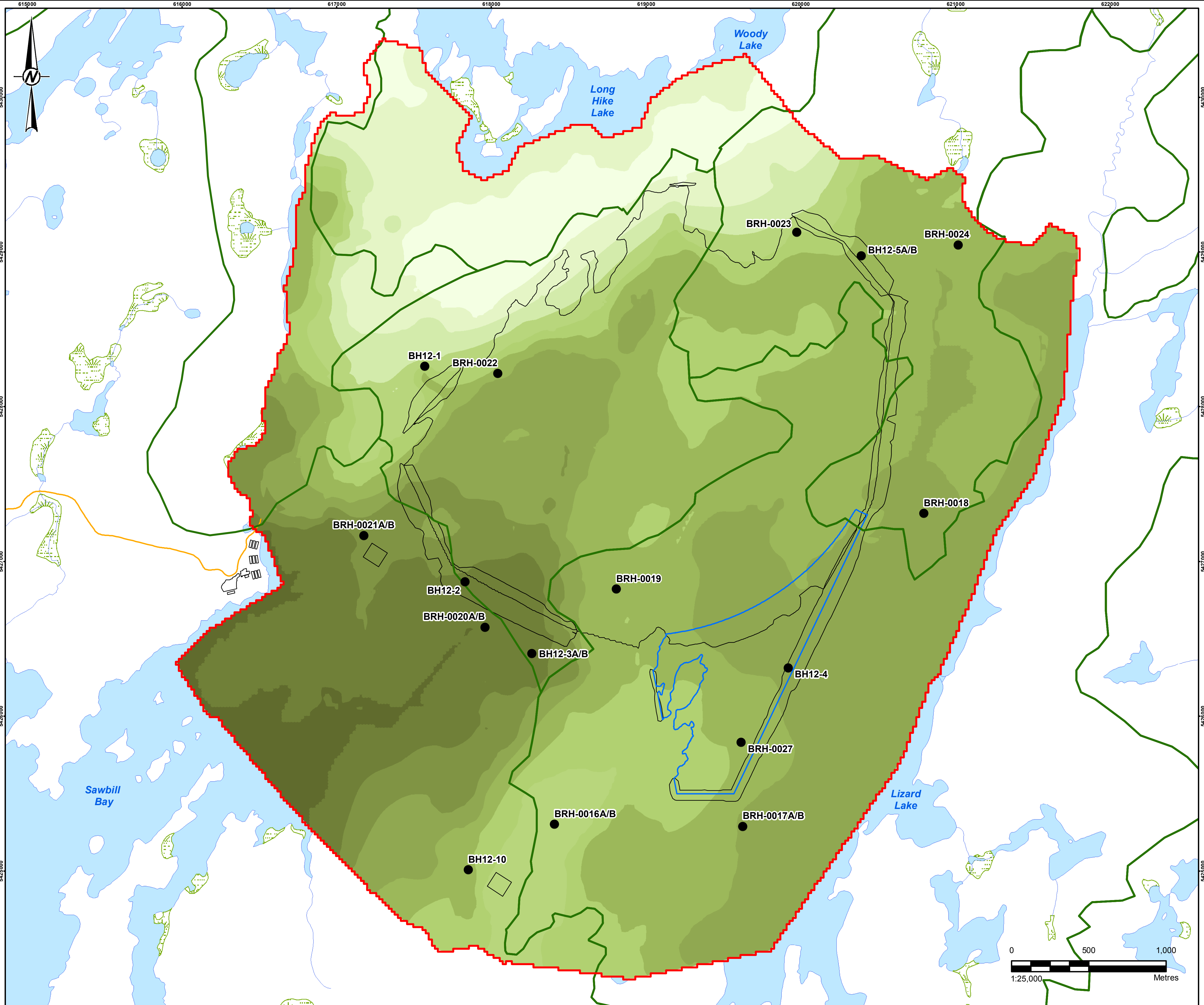
TITLE
PRE-CALIBRATION SIMULATED WATER TABLE AND CALIBRATION RESULTS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	SO
PREPARED	PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	8



LEGEND

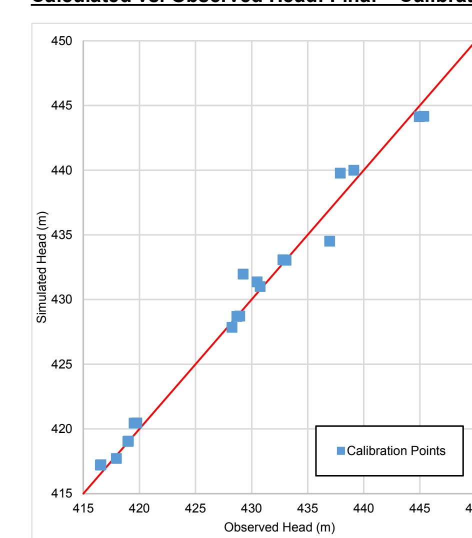
- Calibration Wells
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Model Domain

Final Calibration Simulated Water Table (m)

- 410 - 415
- 415 - 420
- 420 - 425
- 425 - 430
- 430 - 435
- 435 - 440
- 440 - 445
- 445 - 450
- 450 - 455
- 455 - 460

Description	Residual Mean (m)	Absolute Residual Mean (m)	RMS (m)	Normalized nRMS (%)	% of Water Table Above Ground Surface
Final Calibration Results	0.22	0.70	1.03	3.6	2%

Calculated vs. Observed Head: Final – Calibration



REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

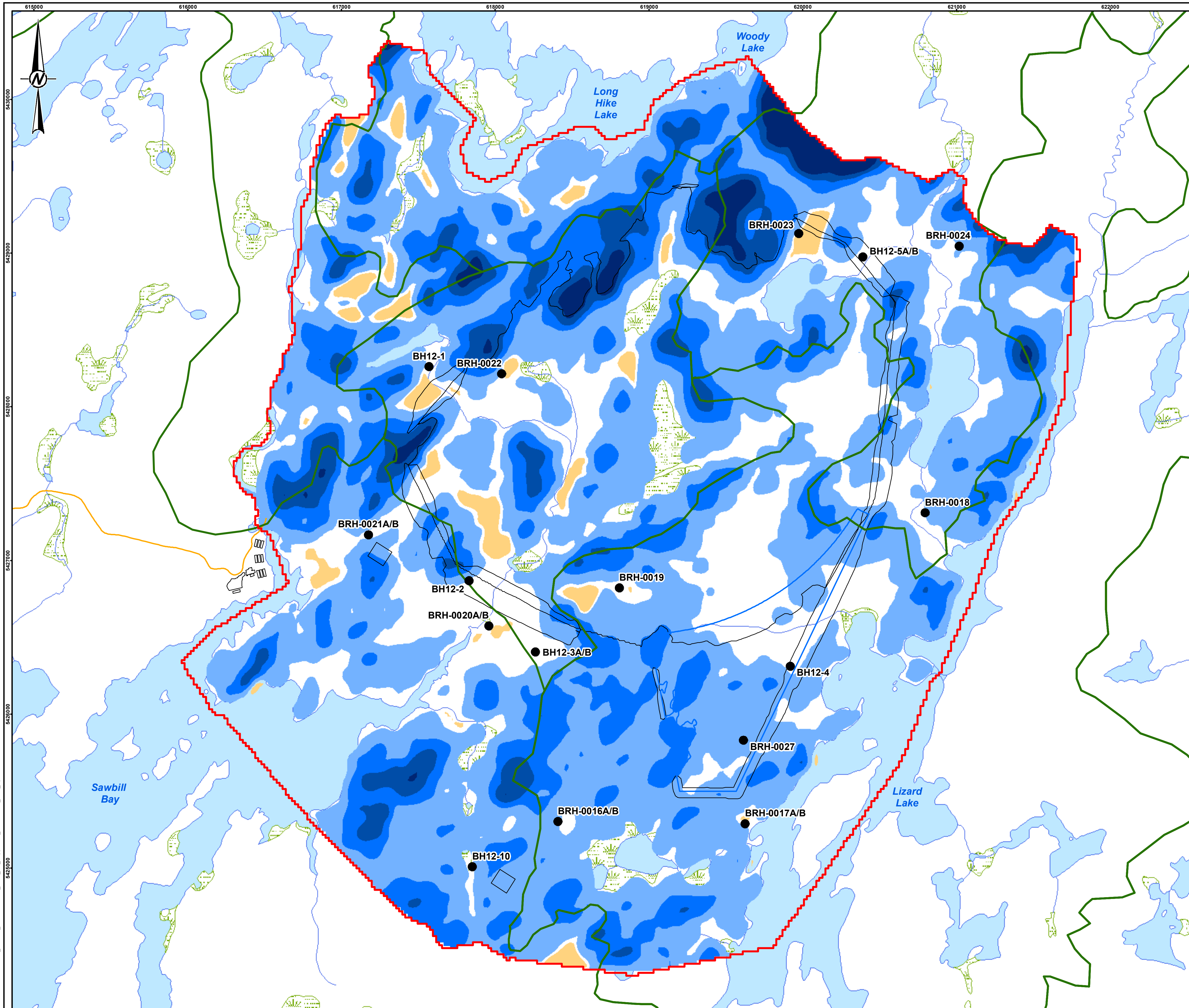
TITLE
FINAL CALIBRATION SIMULATED WATER TABLE AND CALIBRATION RESULTS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	SO
PREPARED	PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm



LEGEND

- ● Calibration Wells
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Proposed Tailings Management Facility
- Proposed Reclaim Pond
- Local Watershed Boundary
- Model Domain

Depth to Water Table (m)

- -10 to -1
- 1 to 10
- 10 to 20
- 20 to 30
- 30 to 40

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
FINAL CALIBRATION DEPTH TO WATER TABLE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-29
DESIGNED	SO
PREPARED	PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0001	0.0	10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

PART F

CEAA Comments on Baseline Model Construction and Calibration

Canadian Environmental Assessment Agency
Agence canadienne d'évaluation environnementale

Ontario Regional Office
55 St. Clair Avenue East,
Room 907
Toronto, ON M4T 1M2

Bureau régional de l'Ontario
55, avenue St-Clair est,
bureau 907
Toronto (Ontario) M4T 1M2

April 27, 2017

ELECTRONIC MAIL

Ms. Sandra Pouliot, ing.
Environment Project Leader
Canadian Malartic Corporation
100, chemin du Lac Mourier
Malartic, QC J0Y 1Z0

SUBJECT: Federal Comments on the March 30, 2017 Hammond Reef Gold Project Baseline Groundwater Model Construction and Calibration – Revised Memorandum

Dear Ms. Pouliot:

The Canadian Environmental Assessment Agency and Natural Resources Canada completed the review of the March 30, 2017 revised memorandum on the groundwater baseline model construction and calibration for the proposed tailings management facility of the Hammond Reef Gold Project.

Upon review of the revised memorandum, the Federal Review Team (FRT) recommends proceeding to the next stage of the process, as briefly described in Section 6.0 of the memorandum. The stage two report is expected to have content that duly responds to all parts of Information Request T(3)-08.

The FRT recognizes the efforts by Canadian Malartic Corporation to resolve the issues and looks forward to receiving the stage two report for review.

Sincerely,

<Original signed by>

Loraine Cox
Project Manager

cc. Sheryl Lusk, Environment and Climate Change Canada
Jennifer Dorr, Natural Resources Canada
Sasha McLeod, Ministry of the Environment and Climate Change

PART G

Groundwater Modelling of TMF and Seepage Impact Assessment

MEMORANDUM

TO	Sandra Pouliot, ing. Canadian Malartic Corporation	**DATE**	August 18, 2017
CC	Karen Besemann (Golder), Ken DeVos (Golder)	**PROJECT No**	1656263 1000 1001
FROM	Devin Hannan, P.Eng., and Adam Auckland, P. Eng.	**DOC No.**	010 (Rev 1)

HAMMOND REEF GOLD PROJECT: GROUNDWATER MODELLING OF TAILINGS MANAGEMENT FACILITY AND SEEPAGE IMPACT ASSESSMENT

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to present Canadian Malartic Corporation (CMC) with this updated technical memorandum describing numerical groundwater modelling of the proposed Hammond Reef Gold Project Tailings Management Facility (TMF) site near Atikokan, Ontario (Figure 1). The model described herein considers TMF Operations, Closure, and Post-Closure phases and evaluates seepage rates to the TMF seepage collection system as well as bypass to receptors external to the TMF. This memorandum is provided to support and complete the response to Federal Information Request T(3)-08.

1.1 Background

This memorandum builds upon prior communications between CMC, Golder and the joint Federal-Provincial government review team (GRT) concerning the proposed TMF. Recent correspondence includes:

- *Hammond Reef Gold Project: Baseline Groundwater Model Construction and Calibration – Revised Memorandum* (Golder, March 30 2017). In this memorandum Golder describes the baseline pre-TMF model construction and calibration to existing conditions.
- *Federal Comments on the March 30, 2017 Hammond Reef Gold Project Baseline Groundwater Model Construction and Calibration – Revised Memorandum* (CEAA, April 27 2017). In this memorandum the GRT indicates they are satisfied with the model conceptualization and calibration described in Golder, March 30 2017, and recommends proceeding to the TMF simulation stage described herein.
- *Hammond Reef Gold Project: Groundwater Modelling of Tailings Management Facility and Seepage Impact Assessment* (Golder, June 16 2017). In this memorandum Golder describes TMF model construction and simulated groundwater impacts under Operations, Closure and Post-Closure conditions.
- *Federal Comments on the June 16, 2017 Technical Memorandum (Hammond Reef Gold Project: Groundwater Modeling of Tailings Management Facility and Seepage Impact Assessment) to address Information Request T(3)-08* (CEAA, July 21 2017). In this memorandum the GRT requests clarification of the TMF model parameters, mitigation and contingency measures, effects on Long Hike Lake, effects to Indigenous peoples, and proposed monitoring.

This current (Rev 1) memorandum supersedes the previous (Rev 0) Golder memorandum of the same title, dated June 16 2017, and is updated to address the review comments described in CEAA, July 21 2017.

MEMORANDUM

2.0 TMF CONCEPTUAL DESIGN

The modelled TMF layout is based on the design framework put forth in the technical memorandum *Design Basis for Runoff and Seepage Collection Systems – Hammond Reef Gold Project* (Golder, 2013[1]) included in the *Hydrogeology Technical Support Document (Version 2)* (Golder, 2013[2]). Figure 1 illustrates the conceptual design of the TMF at ultimate extents.

The TMF is proposed to store 165 Mm^3 of thickened tailings over a footprint of approximately 800 hectares using a central slurry discharge point and a conical deposition method throughout five stages of tailings deposition and progressive dam raise construction.

The TMF containment system design includes a combination of naturally-occurring bedrock highs and rockfill dams with upstream geomembrane liners. The upstream rockfill dam shells will be lined on the lower (approximate) half of their upstream flank. The reclaim pond dams will be fully lined.

Surface water runoff and water released from the tailings due to consolidation/settlement will be collected in the reclaim pond. The majority of groundwater seepage emanating from the TMF will discharge to either the reclaim pond or a system of perimeter seepage collection ditches (Figure 2). During Operations, water collected in the ditches will be pumped back into the reclaim pond and recycled to the mill. During Closure, tailing deposition will cease and water collected in the ditches will continue to be pumped back into the reclaim pond until such time that water quality within the reclaim pond is acceptable for release to the external environment. During Post-Closure, after water quality has been determined to be acceptable for release, water collected in the perimeter ditches will be discharged to the external environment, the reclaim pond overflow spillway will be lowered and runoff will be conveyed from the reclaim pond eastward toward Sawbill Bay. A small amount of water will be permanently retained below the invert of the closure spillway.

3.0 TMF IMPLEMENTATION IN MODEL

The following subsections describe the model augmentation required to model the TMF. Unless otherwise specified, general comments regarding "the model" include reference to Operations, Closure, and Post-Closure phase models. The model parameterization described within this section is considered the Base Case scenario. Additional Sensitivity Analysis scenarios use modified parameters as described in Section 5.

3.1 General Approach

The TMF modelling builds upon the pre-TMF "baseline" calibrated groundwater model described in *Hammond Reef Gold Project: Baseline Groundwater Model Construction and Calibration – Revised Memorandum* (Golder, 2017). Hydraulic parameters and boundary conditions external to the TMF remain the same as previously described and are not revisited in detail herein.

The TMF is implemented in the pre-existing model by adjusting layering, boundary conditions and hydraulic properties to mimic the basic structure and hydraulic behaviour of the TMF as envisioned in the conceptual design. Three successive and separate models are used to simulate the major phases of the TMF lifespan, namely:

1. Operations
2. Closure
3. Post-Closure

MEMORANDUM

A note regarding Construction phase:

During Construction, prior to Operations, no tailings placement will occur. At the end of the Construction phase, the reclaim pond will be filled with fresh water from Marmion Reservoir. Any seepage from the reclaim pond during construction will be fresh water (i.e., not impacted by mill processes) and will not result in adverse effects to water quality in the receiving environment.

The general approach to modelling Operations, Closure and Post-Closure phases is differentiated as follows:

- **Operations:** The TMF at its ultimate extents is considered as this configuration would produce the most seepage. During Operations, tailings slurry is actively deposited from the perimeter dams and to the centre of the tailings mound. Naturally-occurring precipitation provides a second source water entering the tailings deposit as potential recharge. As such, it is conservatively assumed that the tailings are fully saturated during this phase (i.e. the phreatic surface is coincident with the tailings surface), thus promoting the greatest amount of seepage. Groundwater seepage is intercepted by perimeter seepage collection ditches and pumped back to the reclaim pond (the pump back process is not explicitly simulated within the groundwater model). The reclaim pond water elevation is conservatively implemented at its maximum Operations design elevation of 444.5 masl.

- **Closure:** The end of Operations forms the initial conditions for the Closure phase. The primary difference between Operations and Closure is that tailings slurry is no longer deposited and thus naturally-occurring precipitation is the only source of potential recharge to the tailings deposit. As such, the phreatic surface within the tailings will decline over time and seepage will gradually reduce. In order to capture this process, the Closure phase is modelled transiently. Groundwater seepage continues to be intercepted by perimeter seepage collection ditches and pumped back to the reclaim pond. The reclaim pond water elevation continues to be held at its maximum of 444.5 masl.

- **Post-Closure:** The end of the Closure phase forms the initial condition for the Post-Closure phase. For the purpose of this modelling assessment, Post-Closure is defined as the period after the TMF groundwater level and flow conditions have reached a state of quasi-equilibrium, or in other words, are no longer affected but the preceding tailings deposition activities. During Post-Closure, the phreatic surface within the tailings has stabilized. As such, a steady-state approach may be utilized. Groundwater seepage continues to be intercepted by perimeter seepage collection ditches; however, this water is no longer pumped back to the reclaim pond but instead is released to the external environment. The reclaim pond water elevation is lowered to the elevation of the closure spillway at 440 masl.

3.2 Code

Flow modelling is conducted using MODFLOW-2005 (Harbaugh, 2005) with particle tracking (seepage pathway delineation) simulated using the companion code MODPATH (Pollock, 1989). MODFLOW is a multi-purpose three dimensional groundwater flow code developed by the United States Geological Survey. It is modular in nature and uses the finite difference formulation of the groundwater flow equation in its solution. Visual MODFLOW® (Build 4.6.0.168) is the graphical user interface for the simulations presented in this report. For the TMF scenarios, MODFLOW-2005 with the SAMG solver is selected instead of the previously utilized MODFLOW-NWT formulation (Golder, 2017). During testing the two approaches provided similar results; however, the SAMG solver was found to be more computationally efficient for this current analysis.

3.3 Temporal Setting

The temporal setting for each TMF phase is as follows:

- **Operations**: The continual application of both slurry and natural precipitation to the tailings mound provides for the (conservative) assumption that the tailings will remain entirely saturated for the duration of Operations. As such, water levels and groundwater flow within and external to the TMF will remain constant. A steady-state approach is appropriate to model these conditions.

- **Closure:** The application of slurry will cease during Closure leaving precipitation as the only source of recharge to the tailings deposit. As such, the phreatic surface within the tailings and associated seepage rates will decline over time. A transient approach is utilized to model this behaviour. A 100-year simulation is run in order to capture the amount of time required to reach a quasi-steady state condition. The stabilization of water levels is considered, within the context of this assessment, to be the beginning of the Post-Closure phase. Water collected within the perimeter seepage collection ditches will be pumped back to the reclaim pond until TMF reclaim pond water reaches a satisfactory quality for discharge to the external environment.

- **Post-Closure:** Water levels and flow rates within and external to the TMF will be relatively stable during Post-Closure and will continue as such long-term. A steady-state approach is appropriate to model these conditions.

3.4 Model Domain and Grid

The model domain (Figure 1) remains unchanged from the baseline calibrated model (Golder, 2017). The domain is approximately centred on the planned TMF extents and is regional in scale (24 km^2). The perimeter is delineated based on major hydrologic boundaries including Sawbill Bay to the south and its associated tributary to the west, Long Hike Lake to the north and Lizard Lake to the east. These regional features are considered primarily groundwater discharge zones and would be the eventual receptors of TMF seepage should any seepage bypass the collection system. Elsewhere, the model perimeter is coincident with subwatershed boundaries or topographic highs.

Vertically, the top of the model is bounded by ground surface (Figure 1). Ground surface in the area of the TMF is dictated by the tailings mound, dams, and reclaim pond. The maximum elevation of the model coincides with the top of the tailings mound (492 masl). The bottom of the model is set within competent bedrock at 335 masl, a depth of 90 m or greater below the base of the TMF.

The model domain is subdivided laterally using finite-difference grid cells positioned in a north-south / west-east perspective. Regional cell size remains at 20 m x 20 m. However, for the current analysis, cell resolution in the area of the TMF is increased to 10 m x 10 m to allow for greater detail in implementing TMF features.

The current work includes five additional numerical layers posited on top of the prior five (Golder, 2017) for a total of 10 model layers.

In total the model is comprised of approximately 1,374,000 active cells.

MEMORANDUM

3.5 Layer Structure

The model is vertically subdivided into ten numerical layers (Figures 3A/B). Layers 1 through 5 have been added in this current analysis in order to implement the TMF structures. Layers 6 through 10, previously Layers 1 through 5 in the pre-TMF baseline model, remain the same as previously modelled (Golder, 2017).

The nominal designation / purpose of each layer is as follows:

TMF Layers:

1) Top of Tailings. This thin (0.1 m) layer allows implementation of constant heads atop the tailing deposit, as described in Section 3.6, as well as the top surface of the reclaim pond.
2) Upper Tailings. This layer encompasses the approximate upper half of the tailings deposit. The tailings is subdivided to allow for greater hydraulic head resolution. The vertical thickness of this layer depends on the location within the tailings deposit. The maximum thickness of this layer is 30.5 m which coincides with the thickest portion of the tailings (a total of 61 m). The layer thins to 0.2 m where tailings are not present.
3) Lower Tailings. This layer encompasses the approximate lower half of the tailings deposit. The vertical thickness of this layer depends on the location within the tailings deposit. The maximum thickness of this layer is 30.5 m which coincides with the thickest portion of the tailings (a total of 61 m). The layer thins to 0.2 m where tailings are not present.
4) Upper Dam. This layer encompasses the approximate upper half of the rockfill dam. The vertical thickness of this layer depends on the location along the dam. The maximum thickness of this layer is 18.9 m which occurs within the maximum height of the dam (a total of 37.8 m). The layer thins to 0.5 m where the rockfill dam is not present.
5) Lower Dam. This layer encompasses the approximate lower half of the rockfill dam and allows for the implementation of the liner on the lower upstream flank of the dam. The vertical thickness of this layer depends on the location along the dam. The maximum thickness of this layer is 18.9 m which occurs within the maximum height of the dam (a total of 37.8 m). The layer thins to 0.5 m where the rockfill dam is not present.

Hydrostratigraphic Layers:

6) Surficial Deposit Layer (sand/gravel, peat/muck or till)
7) Fine-Grained Layer (predominately silt and/or clay)
8) Coarse-Grained Layer (predominately sand and/or gravel)
9) Weathered Bedrock Layer
10) Competent Bedrock Layer

MODFLOW requires each numerical layer to be continuous throughout the model domain; in other words, a layer cannot “pinch-out” to a zero thickness. In the case of the five new TMF layers:

- Inside the TMF: where a material is not present its nominal layer thins to a minimum thickness and the appropriate material properties are assigned within this minimum thickness. For example, the rockfill dam material does not exist within the tailings deposit. As such, upstream of the dam footprint Layer 4 Upper Dam thins to 0.5 m underneath Layer 3 Lower Tailings. This minimally thick area is assigned the hydraulic properties of the overlying tailings.

MEMORANDUM

- Outside of the TMF: the layers thin to a minimum thickness of 0.5 m or less and are made inactive. Thus, the first instance of active cells external to the TMF is in Layer 6 (the Surficial Deposit Layer).

3.6 Boundary Conditions

A general illustration of model boundary conditions are shown in plan view on Figure 4 with additional cross-section illustration provided on Figure 3A/B/C. For illustration purposes, the Operations model boundary conditions are shown with Closure and Post-Closure variations noted where applicable. External to the TMF, model boundary conditions remain as previously described (Golder, 2017). The following subsections describe additional boundary conditions utilized to implement key TMF features during Operations, Closure and Post-Closure.

3.6.1 Tailings

- **Operations:** The Top of Tailings (Layer 1) is assigned constant head cells within the tailings footprint with values set coincident to the tailings surface elevation (as per Figure 1, tailings mound elevation ranges from 492 masl to just under 445 masl). This assignment is intended to conservatively simulate the water contributing to the tailings deposit via slurry application and, in effect, assumes that the tailings are fully saturated and the water table is coincident with the top of the tailings. This boundary condition is applied without consideration of actual precipitation and process water inflows and, particularly with the Sensitivity Scenarios, can result in an equivalent pseudo-recharge in excess of what would be physically possible. As such, this assumption is considered to be conservative with respect to potential seepage rates. Note that the underlying tailings layers, in effect almost the entirety of the tailings deposit thickness, do not have a boundary condition assignment and MODFLOW is free to calculate a resultant hydraulic head based on the surrounding gradient and material properties.

- **Closure and Post-Closure:** The tailings constant head cells are removed during Closure as tailings slurry is no longer being deposited. A recharge rate based on naturally-occurring precipitation is applied (Section 3.8.2).

3.6.2 Reclaim Pond

- **Operations and Closure:** The reclaim pond water is assigned constant head cells with a value of 444.5 masl according to the design water level. The reclaim pond exists in Layers 1 through 5 (the bottom of the reclaim pond is bound by pre-TMF topography, which is delineated by the top of Layer 6 – see Figure 3C).

- **Post-Closure**: The reclaim pond water is assigned constant head cells with a value of 440 masl in accordance with the Post-Closure spillway elevation.

3.6.3 Liners

A geomembrane liner is modelled in two locations:

- **Tailings Dams:** A liner is modelled along the lower half of the upstream flank of the tailings dams (Figure 3A/B and Figure 4). The liner is implemented as a vertical “wall” of no-flow cells in Layer 5 Lower Dam, directly abutting the dam material. The height of the liner depends on the height of the dam at a given location; its maximum height is 18.9 m, which is half of the greatest total dam height (37.8 m).

- **Reclaim Pond:** A liner is modelled along the entire upstream flank of the reclaim pond dam (Figure 3C and Figure 4). The liner is implemented as a vertical “wall” of no-flow cells in Layers 1 through 5, directly abutting the dam material.

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Additional notes on the modelled liner:

- In reality, the liner would be placed sub-vertically along the slope of the upstream dam shell; however, for the regional modelling purposes considered herein, a vertical approximation is considered reasonable.
- Horizontally (i.e. in plan view) the liner dimensions are 10 m x 10 m – the minimum horizontal cell size in the model. Note that, "in reality", the liner would be much thinner. However, from a regional modelling perspective such as currently being examined, the 10 m thickness is acceptable as it does not introduce a significant amount of error in the seepage calculations to receptors. Also note that, whether the liner is modelled as, for instance, 0.01 m or 10 m, it would still act as a no-flow boundary with no gradient being calculated within the cell itself (in other words an increased thickness in liner does not result in a proportional increase in its efficacy – the liner has zero transmissivity irrespective of its thickness).

3.6.4 Seepage Collection Ditches

The seepage collection ditching is implemented as a series of drain cells at the perimeter of the TMF (where they exist as per Figure 1) with drainage head values set at 5 m below ground surface. The ditch depth of 5 m is based on preliminary model testing that indicated suitable seepage capture efficiency could be achieved at this depth. The drain cells exist in Layer 6 (ground surface external to the TMF) down to Layer 9 depending on the thickness of the layering at their location. The drain cells are assigned a conductance of 1,000 m^2/d. This conductance value allows for an accurate correspondence between assigned versus calculated head within the drain cell while maintaining numerical solver stability.

The approach to modelling drains is the same Operations, Closure and Post-Closure conditions. However, a distinction is made in how water reporting to these drains is accounted for in the seepage analysis. In Operations and Closure, all water reporting to the drains is assumed to be routed to the reclaim pond. During Post-Closure, water reporting to the drains is assumed to be routed to the ultimate receptor in the adjacent watershed. Thus, for example, Post-Closure seepage reporting to seepage collection ditches along the eastern flank of the TMF will be discharged towards Lizard Lake.

3.7 Hydraulic Parameters

Hydraulic parameters considered in the current work include hydraulic conductivity (K), specific yield (S_y), specific storage (S_s) and effective porosity (n_e) (Table 1). The hydraulic conductivity of native materials remain the same as previously modelled (Golder, 2017). Specific yield and specific storage are required input for the Closure transient simulation.

Several new materials are introduced as part of the TMF implementation:

- **Tailings:** Tailings hydraulic conductivity and porosity are derived from bench scale laboratory testing for the Hammond Reef project as described in Johnson et al., 2013. Specific yield and effective porosity are assumed to be equivalent to the tailings porosity. Specific storage is assumed to be equivalent to that of a fine sand.
- **Rockfill:** Rockfill dam properties are assumed to be equivalent to that of a coarse granular material.
- **Liner:** The liner is assumed to be impermeable (implemented using no-flow cells).

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- **Reclaim Pond:** In reality, the body of the reclaim pond consists solely of water (i.e. no porous media). However, the presence of water within the pond is implied in the model by assigning the pond cells with large hydraulic conductivity and storage values (care was taken to avoid numerical instability by assigning too large a hydraulic conductivity). As mentioned previously, the pond cells are also assigned as constant heads, so the hydraulic parameters within the pond will not alter the calculated head within the cell. However, as the MODFLOW package uses a block-centred approach to calculate flow between cells, there may be a minor influence of the reclaim pond parameter assignment on the head calculation in cells immediately external to the pond.

Table 1: Hydraulic Parameters

Nominal Layer	Unit	Material	K (m/s)	S_y	S_s (1/m)	n_e
1 – 3	Tailings	Tailings	6E-7(1)	0.42(1)	5E-4(4)	0.42(1)
4 – 5	Dam	Rockfill	1E-4(7)	0.3(2)	5E-4(4)	0.25(2)
	Dam	Liner	Impermeable	-	-	-
1 – 5	Reclaim Pond	"Water"	1E-2	0.99	1E-4	0.99
6	Surficial Deposit	Sand/Gravel	2E-5	0.3(2)	5E-4(4)	0.25(2)
		Till	5E-6	0.16(2)	2E-4(4)	0.15(5)
		Peat	1E-5	0.44(2)	1E-4	0.5(6)
7	Fine-Grained	Silt and/or Clay	3E-7	0.20(2)	5E-4(4)	0.34(2)
8	Coarse-Grained	Sand and/or Gravel	1E-4	0.28(2)	5E-4(4)	0.24(2)
9	Weathered Bedrock	Bedrock	2E-6	1E-3(3)	5E-6(4)	0.05(7)
10	Competent Bedrock	Bedrock	2E-7	9E-4(3)	1E-6(4)	0.01(7)

1. Value derived from Johnson et al., 2013.
2. Value derived from Morris and Johnson, 1967.
3. Value derived from Heath, 1983.
4. Value derived from Batu, 1998.
5. Value derived from Fetter, 2003.
6. Value derived from Rezanezhad et al., 2016.
7. Value derived from Freeze and Cherry, 1979.

3.8 Recharge

The recharge distribution external to the TMF remains as previously modelled (Golder, 2017). Within the TMF only two materials are present at surface to receive recharge: the rockfill dams and the tailings; no recharge is applied over the reclaim pond or seepage collection ditches.

Rockfill dam recharge is assumed to be 250 mm/yr for all TMF phases; this recharge rate is chosen as it is moderately higher than the 200 mm/yr recharge applied to the native sand material at surface (Golder, 2017).

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The approach to tailings recharge varies according to TMF phase as described below.

3.8.1 Operations Phase Tailings Recharge

Recharge water to the tailings during Operations is sourced via the tailings slurry application and naturally occurring precipitation, with the former providing the majority of water. However, strictly speaking, a recharge rate is not applied over the tailings during Operations modelling. Instead, the constant heads capping the top of the tailings provide a pseudo-recharge by applying enough water into the tailings to maintain a phreatic surface coincident with the tailings surface. On average, this results in a pseudo-recharge rate of approximately 574 mm/yr over the tailings footprint under Base Case conditions (Section 4.2.1).

However, it is important to note that there is no limit to the amount of water potentially generated by the constant head cells. This is a conservative approach, particularly in the Sensitivity Analyses (Section 5), where the amount of water generated within the TMF may exceed the amount of water actually available to the tailings "in reality".

Lastly, the amount of water applied by a given constant head cell (or cluster of cells) can vary considerably and is largely dependent on the native material that underlies (or underdrains) the tailings. For example, flow budget testing of the Base Case model indicates that the tailings area underlain by weathered bedrock outcropping comprises approximately 40% of the tailings footprint but receives only 20% of the total inflow from the constant head cells. This is a result of the weathered bedrock's relatively low hydraulic conductivity limiting potential underdrainage relative to the surrounding overburden.

3.8.2 Closure and Post-Closure Phase Tailings Recharge

Recharge water to the tailings during Closure and Post-Closure is sourced solely from precipitation. A considerable amount of this water is expected to either evaporate or runoff as surface water into the collection system. Thus, in order to estimate the proportion of precipitation that actually infiltrates the tailings, a water budget analysis has been conducted using the monthly precipitation and evaporation data presented in the Hydrology TSD (Golder 2013[3]) and the Environment Canada method (Johnstone and Louie, 1983). Based on this method the estimated tailings recharge is 85 mm/yr. This rate is applied to the tailings in both Closure and Post-Closure phase models.

4.0 SEEPAGE MODELLING

4.1 Approach

The general approach to evaluating TMF seepage rates is as follows:

1. Prior to running the TMF model:
    a. Use MODFLOW's zone budget utility to define discrete flow budgets zones at the following sources/sinks: tailings constant head cells, reclaim pond constant head cells, seepage collection ditch drain cells, and Sawbill Bay, Lizard Lake, Long Hike Lake constant head cells and drains within their respective watershed areas external to the TMF and seepage collection system (Figure 4).
    b. Input particles within the tailings and reclaim pond cells to allow for forward-tracking seepage pathway delineation from the TMF.

2. Run each TMF model phase successively and compile output heads, flow budgets, and forward-tracked particles from the TMF.
3. Seepage pathways are assessed by viewing the forward tracked particle pathlines.
4. Quantify Total TMF seepage. Total TMF seepage is the combined net inflow from both tailings constant heads and reclaim pond constant heads.
5. Determine the proportion of Total TMF seepage that discharges to:
    a. Sawbill Bay watershed constant head and drain cells within the Sawbill Bay drainage area external to the TMF.
    b. Lizard Lake watershed constant head and drain cells within the Lizard Lake drainage area external to the TMF.
    c. Long Hike Lake watershed constant head and drain cells within the Long Hike Lake watershed external to the TMF.

    The partitioning of Total TMF seepage to 5a and 5c is conducted by comparing pre-TMF to TMF model flows external to the TMF. As the model cells are not altered external to the TMF these model flows may be directly compared in this area.

    The majority of flow increase within areas external to the TMF, where it occurs, is a result of TMF seepage that bypasses the collection system. An extremely small amount of water (less than 0.5% relative to seepage inflow) may leak from lake constant head cells as a result of the downgradient drawdown imposed by the collection ditches; however, this is considered insignificant in this analysis. As such, any increase in flow to features external to the TMF relative to pre-TMF conditions is attributed to tailings seepage and tallied as such in the seepage rate summary (Section 4.2).

    In some instances flow at certain receptors external to the TMF has been reduced relative to pre-TMF conditions because the seepage collection drains now capture a portion of flow that would otherwise report to the receptor. However, TMF seepage may nonetheless contribute to this receptor (for example via deep bypass). In these cases, particle tracking pathways are closely examined alongside zone budgeting. Where a particle path from the TMF terminates at a given cell, the total inflow at that cell is assumed to originate from (or at least be impacted by) TMF seepage and is tallied as such in the seepage rate summary (Section 4.2).

6. After the flows in step 5 are accounted for, any remaining TMF seepage (i.e. the Total TMF seepage calculated in step 4 minus the “bypass” flows calculated in step 5) must be intercepted by the seepage collection drains as these cells are the only remaining point of TMF seepage discharge. Nonetheless, inflow to the seepage collection drains is independently determined via zone budget. Typically, a check will reveal that the total collection system discharge is close to the total amount of seepage minus the aforementioned bypass. Usually collection drain discharge is slightly greater because the collection drains will also capture some groundwater downgradient of the TMF.

7. A similar process as the above is repeated for the Sensitivity Analysis scenario, although the focus is primarily on Operations (as this phase provides the maximal upper bound on seepage rates).

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4.2 Results

4.2.1 Operations

The Operations phase simulated water table and seepage pathlines are illustrated on Figure 5. As anticipated, the groundwater flow pattern is dominated by mounding within the tailings deposit. Flow within and from the TMF is radial; however, far-field regional flow patterns remain similar to those simulated for pre-TMF conditions (Golder, 2017).

The seepage pathlines travel radially from the TMF and indicate that bypass seepage may enter the Sawbill Bay, Lizard Lake and Long Hike Lake watersheds. Note that the number of pathlines exiting the TMF does not correlate to the magnitude of seepage.

A summary of the Operations phase TMF seepage rates is provided in Table 2.

Table 2: Operations TMF Seepage Rate Summary

Feature	Tailings Seepage (m^3/d)
Net In	
Tailings	10,109
Reclaim Pond	10,292
TOTAL	*20,401*
Net Out	
Collection Ditches (pumped back to reclaim pond)	19,131
Sawbill Bay Watershed External to TMF	608
Lizard Lake Watershed External to TMF	505
Long Hike Lake Watershed External to TMF	157
TOTAL	*20,401*

Based on the simulated results the conceptual collection system provides a capture efficiency of approximately 94%.

In addition, a "global" groundwater flow budget is provided in Appendix A. The purpose of this flow budget is to demonstrate that numerical error is acceptable (less than 1%) and to provide a general understanding of the flow distribution at the principal boundary conditions.

4.2.2 Closure

The Closure phase simulation is run transiently for 100 years with output generated every 10 years. Operations (Section 4.2.1) and Post-Closure (Section 4.2.3) provide the upper and lower bounds on groundwater levels and seepage rates; as such, model-wide water levels and seepage rates for every time step during Closure have not been reported. Instead, hydrographs demonstrating the decline in water level within select locations within the tailings deposit over time is provided (Figure 6). In the early years following the end of Operations a relatively rapid drop in water levels is observed. As time progresses, this decline becomes less dramatic.

The time required for water levels required to reach a quasi-equilibrium depends on the location within the tailings (Figure 6). Water levels near the edge of the tailings deposit stabilize relatively rapidly (within 10 years) whereas

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water levels within the deep, central portion of the tailings may still be in slow decline after 100 years (although the majority of drawdown has occurred long before this period). The slow rate of depressurization within the central bulk of the tailings is in part because of their low hydraulic conductivity (6E-7 m/s), but also because they are assumed to be fully saturated during Operations and there is over 25 m of head available for potential drawdown.

4.2.3 Post-Closure

The Post-Closure phase simulated water table and seepage pathlines are illustrated on Figure 7. The reduction in head within the tailings is substantial – towards the centre of the mound more than 25 m of water level decline has occurred. Nonetheless, a small water table mound persists within the tailings and flow within and from the TMF continues to be roughly radial.

The seepage pathlines travel radially from the TMF and continue to indicate that some bypass seepage may enter Sawbill Bay, and Lizard Lake. No pathlines entered Long Hike Lake but the zone budgeting indicates that a small amount of seepage continues to report to this location.

A summary of the Post-Closure phase TMF seepage rates is provided in Table 3.

Table 3: Post-Closure TMF Seepage Rate Summary

Feature	Tailings Seepage (m^3/d)
Net In	
Tailings	1,450
Reclaim Pond	7,245
TOTAL	*8,695*
Net Out	
Sawbill Bay Collection Ditches	989
Sawbill Bay External Watershed External to TMF	33
Lizard Lake Collection Ditches	7,531
Lizard Lake Watershed External to TMF	46
Long Hike Lake Watershed	96
TOTAL	*8,695*

Total seepage production under Post-Closure is less than half of that under Operations owing to the exchange of constant heads at tailings surface with a relatively small fixed recharge rate and a reduction in the reclaim pond water level.

In addition, a “global” groundwater flow budget is provided in Appendix A. The purpose of this flow budget is to demonstrate that numerical error is acceptable (less than 1%) and to provide a general understanding of the flow distribution at the principal boundary conditions.

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5.0 SENSITIVITY ANALYSIS

A sensitivity analysis is performed to put an upper bound on potential seepage rates. Two scenarios are examined as described below. As the purpose of the sensitivity scenarios is to define maximum potential seepage rates, only the Operations phase model is considered (as this model would produce the most seepage).

5.1 Scenario 1: Native Material Hydraulic Conductivity Increase

As first proposed in Golder, 2017, the first sensitivity scenario involves multiplying the modelled fine-grained material hydraulic conductivity by 10 and the coarse-grained material hydraulic conductivity by 10, running the model and re-assessing seepage.

A summary of the Operations phase, Sensitivity Analysis Scenario 1 seepage rates is provided in Table 4.

Table 4: Sensitivity Analysis Scenario 1 – Fine-Grained and Coarse-Grained Hydraulic Conductivity x 10 – Seepage Rates (Operations)

Feature	**Tailings Seepage (m^3/d)**
Net In	
Tailings	30,538
Reclaim Pond	31,009
TOTAL	*61,548*
Net Out	
Collection Ditches (pumped back to reclaim pond)	57,991
Sawbill Bay Watershed	2,294
Lizard Lake Watershed	1,088
Long Hike Lake Watershed	175
TOTAL	*61,548*

Based on the simulated results the conceptual collection system provides a capture efficiency of approximately 95%.

In addition, a "global" groundwater flow budget is provided in Appendix A. The purpose of this flow budget is to demonstrate that numerical error is acceptable (less than 1%) and to provide a general understanding of the flow distribution at the principal boundary conditions.

5.2 Scenario 2: Tailings Material Hydraulic Conductivity Increase

As recommended by the GRT (CEAA, 2017), a second sensitivity scenario that examines increasing tailings hydraulic conductivity is conducted. For this assessment, the original tailings hydraulic conductivity (6E-7 m/s) is multiplied by an order of magnitude (6E-6 m/s). Note that this variant is not combined with Scenario 1 as the combined increases in both tailings and native material hydraulic conductivities would result in a tailings pseudo-recharge far in excess of what would be physically possible during Operations.

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A summary of the Operations phase, Sensitivity Analysis Scenario 2 seepage rates is provided in Table 5.

Table 5: Sensitivity Analysis Scenario 2 – Tailings Hydraulic Conductivity x 10 – Seepage Rates (Operations)

Feature	Tailings Seepage (m^3/d)
Net In	
Tailings	20,327
Reclaim Pond	10,329
TOTAL	*30,656*
Net Out	
Collection Ditches (pumped back to reclaim pond)	27,903
Sawbill Bay Watershed	1,732
Lizard Lake Watershed	863
Long Hike Lake Watershed	158
TOTAL	*30,656*

Based on the simulated results the conceptual collection system provides a capture efficiency of approximately 91%.

In addition, a "global" groundwater flow budget is provided in Appendix A. The purpose of this flow budget is to demonstrate that numerical error is acceptable (less than 1%) and to provide a general understanding of the flow distribution at the principal boundary conditions.

6.0 SEEPAGE IMPACT ASSESSMENT

A water quality evaluation was completed to assess the potential residual effects due to seepage to the downstream environment. This assessment focused on the following primary receivers:

- Upper Marmion Reservoir;
- Lizard Lake; and,
- Long Hike Lake.

Smaller streams and waterbodies located upstream of these primary receivers have been determined to be impacted through the Aquatic Environment assessment due to loss of watershed area and the associated reduction of inflow or loss of connectivity to larger bodies of water. Compensation for these smaller streams and waterbodies has been included in the No Net Loss/Habitat Offsetting Plan for the Project (see Part B of the Aquatic Environment TSD [Golder 2013[4]]) which has been approved in principal by Fisheries and Oceans Canada (DFO). No further assessment of potential for impact to these smaller streams and waterbodies is considered necessary because adequate compensation will be provided.

Water quality in Marmion Reservoir and Lizard Lake was evaluated using the lake-wide mixing models (i.e., box-model) developed and presented in the Lake Water Quality TSD (see Section 2.1 and 3.0 of the Lake Water

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Quality TSD [Golder 2013[5]]). This hydrodynamic modelling assessment provides predictions of potential mixed lake water concentrations at key locations within Upper Marmion Reservoir and Lizard Lake based on the general flow distributions, volumes and mixing characteristics of the lakes. Within each lake, internal divisions were established based on lake bathymetry and were positioned at locations where shallow depths would tend to hydraulically separate the lake compartments. Each basin (or compartment) within in the model was assumed to be well-mixed with no vertical stratification. Upper Marmion Reservoir was divided into 13 compartments as shown on Figure 8. Lizard Lake was divided into three compartment as shown on Figure 9.

Potential lake water concentrations were calculated by mixing TMF seepage and mine effluent (for Upper Marmion Reservoir only) with the baseline concentrations in each receiver. Input baseline values were calculated using the average of the baseline data (see Water and Sediment Quality TSD [Golder 2013[6]]). Operational TMF seepage and mine effluent discharge input values were based on steady-state (average) water quality predictions as determined and presented in Appendix 4.II of the Site Water Quality TSD (Golder 2013[7]). Post-closure TMF seepage concentrations were based on post-closure water quality predictions as determined and presented in Table 4-14 of the Site Water Quality TSD (Golder 2013[7]). Table 6 provides the TMF seepage and mine effluent discharge input concentrations assumed. Tables 7 through 13 provide the baseline input data for the relevant receivers.

Baseline water quality data was not available for Long Hike Lake. To assess potential mixed concentrations in Long Hike Lake, a hydrologic assessment was completed to estimate the mean annual natural outflow from the lake and baseline water quality in Lizard Lake was assumed to be representative of water quality in Long Hike Lake. This assumption was considered reasonable because both Lizard Lake and Long Hike Lake are naturally occurring lakes, are of similar size and are located within the same geologic setting. Long Hike Lake has a drainage area of approximately 5 km^2 at its outlet and an estimated mean annual outflow of 0.036 m^3/s (or 3,110 m^3/day) based on the linear regression relationship between mean flow and drainage area established from regional flow data and described in Section 5.1.2.2.2 of the Hydrology TSD (Golder 2013[3]).

6.1 Construction Phase

As identified in Section 3.1, no tailings placement will occur during construction and only fresh water will be stored in the reclaim pond towards the end of construction. Factors that influence seepage discharge will be similar to pre-development conditions. Any seepage from the reclaim pond towards the end of the construction phase will be fresh water (i.e., not impacted by mill processes) and will have limited potential to result in adverse effects to water quality in the receiving environment.

6.2 Operations

During operations, a system of seepage collection ditches will be constructed as described in Section 3.6.4. Operation of this collection system is predicted to capture 94% of the seepage emanating from the TMF. Captured water will be pumped back to the reclaim pond and recycled to the mill. Water quality in the downstream receivers was assessed by mixing the seepage predicted to bypass the collection system (i.e., the remaining 6% or less that flows beneath the collection ditches) with the receiving water bodies. This assessment was completed using seepage bypass rates predicted by the Base Case (Table 2) and the Sensitivity (Tables 4 and 5) modelling scenarios. For Marmion Reservoir and Lizard Lake, the Base Case water quality assessment assumed average mixing proportions and is considered to be representative of typical expected conditions. The Sensitivity Scenarios conservatively assumed maximum mixing proportions within the receiver (i.e., maximum predicted concentrations of mine effluent and seepage) based on a 28-year time series (see Section 3.0 of the Lake Water Quality TSD [Golder 2013[5] for details). Sensitivity Scenario 1 provides an upper bound for potential impact to water quality due to seepage. The water quality assessment for Long Hike Lake considered only average conditions and assumed full mixing within the lake, due to the limited data available.

With reference to Figure 8, the Upper Marmion Reservoir assessment assumed seepage discharge to basin 7C, and mine effluent discharge to basin 6. Results are reported for basins 7C, 6 and 11, the downstream most basin above the Raft Lake Dam. With reference to Figure 9, seepage discharge was proportioned to basins 1, 2 and 3 (i.e., North, Central and South) of Lizard Lake based on the length of dam occurring within each subwatershed.

The results of the Operations phase water quality assessment are presented in Tables 7 through 13. No exceedances of Provincial Water Quality Objectives (PWQO) or Site Specific Water Quality Objectives (SSWQO) are predicted.

6.3 Closure

At Closure, the closure construction activities identified in the Conceptual Closure and Rehabilitation Plan TSD (Golder 2013[8]) will be implemented. During this time, tailings deposition will have ceased resulting in reduced inflow to the tailings deposit. The phreatic surface within the tailings will gradually lower and the seepage rate from the tailings deposit will gradually reduce towards Post-Closure conditions. For the purpose of this assessment, the Closure phase is considered to be the period in which the groundwater level and flow conditions are transitioning between Operations, which results in the highest seepage discharge rates, to Post-Closure, when the groundwater level and flow conditions have reached a state of quasi-equilibrium. As demonstrated in Tables 2 and 3, seepage rates will gradually decrease during the Closure phase and, as shown in Table 6 and explained in Section 6.4, the quality of the seepage emanating from the TMF will improve with time during Closure. Therefore, the potential impacts to water quality within the receivers will be bound by the Operations and Post-Closure phases with the Closure phase representing the period of transition. As no residual impacts are identified for the Operations and Post-Closure phases (see Section 6.4), a detailed, transient assessment of water quality during Closure is not considered necessary.

6.4 Post-Closure

At Post-Closure, natural precipitation is the only source of recharge to the TMF and groundwater level and flow conditions will have stabilized. Table 3 provide estimated seepage discharge rates for the Post-Closure phase. Compared to Operations, Post-Closure seepage is reduced by about 60%.

Seepage will continue to be collected and pumped back to the TMF reclaim pond until water quality has been determined through monitoring to be acceptable for discharge. The ultimate release of captured seepage will be subject to the requirements of the Environmental Compliance Approval (ECA) for the Project, issued by the Ontario Ministry of Environment and Climate Change (MOECC) and the Certified Closure Plan, submitted to and approved by the Ministry of Northern Development and Mines (MNDM). Release of captured seepage will only occur once it is determined that doing so will not impose unacceptable impact the receiving waterbodies.

As demonstrated by Table 6, TMF seepage water quality is predicted to improve at Post-Closure because discharge of process water will have ceased. Cyanide will not be discharged and residual cyanide within the TMF will have degraded. Nitrate and ammonia have also been excluded as it is assumed these soluble compounds will not remain on surfaces after prolonged weathering and exposure.

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In consideration of the following factors, it can be concluded that there will be no residual impacts to water quality during Post-Closure:

- No exceedances of guideline values have been predicted for the Operations phase under the Base Case and Sensitivity Scenarios;
- Seepage discharge rates are predicted to reduce between Operations and Post-Closure by about 60%, as demonstrated by Tables 2 and ;
- Collected seepage will be retained until it is suitable for discharge (i.e., until it is determined that it will not cause unacceptable impacts to the receivers);
- Tailings deposition will have long ceased and seepage water quality will improve with time, as demonstrated by Table 5; and,
- Discharge of mine effluent, which is the primary mass load to Upper Marmion Reservoir, will have long ceased at Post-Closure.

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Table 6: Steady State (Average) TMF Seepage and Mine Effluent Water Quality – Operations and Post-Closure

Parameter	Unit	Mine Effluent (Reclaim Pond)	TMF Seepage (Operations)	TMF Seepage (Post-closure)
Physical-Chemical				
pH	—	7.8	7.8	7.3
Acidity	mg/L	—	—	—
Alkalinity	mg($CaCO_3$)/L	104	—	—
Conductivity	µS/cm	—	—	—
Total Suspended Solids	mg/L	—	—	—
Total Dissolved Solids	mg/L	—	—	—
Major Ions				
Calcium	mg/L	21	28	5.8
Chloride	mg/L	21	31	—
Fluoride	mg/L	—	—	—
Magnesium	mg/L	11	16	3.1
Potassium	mg/L	28	40	2.5
Sodium	mg/L	73	106	0.32
Sulphate	mg/L	168	242	—
Hardness[(a)]	mg($CaCO_3$)/L	100	136	—
Cyanide (free) [(b)]	mg/L	0.19	0.028	—
Cyanide (total)	mg/L	0.19	0.028	—
Nutrients				
Nitrate-N	mg/L	1.5	0.00004	—
Ammonia-N	mg/L	15.0	20	—
Un-ionized ammonia	mg/L	0.173	0.25	—
Phosphorus	mg/L	0.019	0.02	0.008
Dissolved Metals				
Aluminum	mg/L	0.013	0.02	0.01
Antimony	mg/L	0.0017	0.002	0.0002
Arsenic	mg/L	0.000041	0.0001	0.0002
Barium	mg/L	0.012	—	—
Beryllium	mg/L	—	—	—
Bismuth	mg/L	—	—	—
Boron	mg/L	0.0012	0.00002	0.0008
Cadmium	mg/L	0.000017	0.000017	0.00001
Chromium	mg/L	0.0002	0.0002	0.0005
Cobalt	mg/L	0.002	0.003	0.0001
Copper	mg/L	0.075	0.11	0.0007
Iron	mg/L	0.000067	0.0001	0.003
Lead	mg/L	0.00012	0.0002	0.00003
Manganese	mg/L	0.037	—	—
Mercury	mg/L	0.000009	0.00001	0.00001
Molybdenum	mg/L	0.056	0.08	0.002
Nickel	mg/L	0.0077	0.01	0.0003
Selenium	mg/L	0.0007	0.0008	0.0005
Silver	mg/L	0.000016	0.00001	0.00001
Strontium	mg/L	0.22	—	—
Thallium	mg/L	0.00015	—	—
Tin	mg/L	0.023	—	—
Titanium	mg/L	—	—	—
Tungsten	mg/L	—	—	—
Uranium	mg/L	0.0051	0.007	0.0008
Vanadium	mg/L	0.000037	0.00004	0.00003
Zinc	mg/L	0.0019	0.002	0.002
Zirconium	mg/L	—	—	—

Notes:
— Site water quality data was not modeled for this parameter.
(a) Hardness was calculated using the formula: Hardness, mg equivalent/L CaCO3 = ([Ca,mg/l]*2.497) + ([Mg,mg.l]*4.116). (REF: USEPA)
(b) Free cyanide was modeled using PHREEQC based on solution chemistry and the concentration of total cyanide.

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Table 7: Base Case Water Quality Predictions for Upper Marmion Reservoir - Operations Scenario

Parameter	Unit	Receiving WQ Guidelines[(a)]				Marmion Reservoir Baseline	Basin 6 (near mine discharge)	Basin 7c (downstream of TMF)	Basin 11 (near Raft Lake Dam)
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	6.5	6.5	6.5	6.5
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg($CaCO_3$)/L	—	-25%	—	—	19	-	-	-
Conductivity	µS/cm	—	—	—	—	49	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	4.5	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	53	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	6.4	6.46	6.45	6.45
Chloride	mg/L	—	—	—	—	1.1	1.08	1.06	1.07
Fluoride	mg/L	—	—	—	—	0.031	-	-	-
Magnesium	mg/L	—	—	—	—	1.3	1.28	1.27	1.28
Potassium	mg/L	—	—	—	—	0.68	0.71	0.68	0.7
Sodium	mg/L	—	—	—	—	1.3	1.4	1.3	1.3
Sulphate	mg/L	—	—	—	—	1.6	1.8	1.7	1.7
Hardness	mg($CaCO_3$)/L	—	—	—	—	21	21	21	21
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.001	0.001	0.001
Nutrients									
Nitrate-N[(a)]	mg/L	13	—	—	—	0.063	0.065	0.063	0.064
Ammonia-N	mg/L	—	—	—	—	0.023	0.041	0.028	0.036
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000067	0.00027	0.00012	0.00022
Phosphorus	mg/L	—	0.02	—	—	0.013	0.013	0.013	0.013
Dissolved Metals									
Aluminum [(b)]	mg/L	0.005-0.1	0.015-0.075	—	—	0.03	0.03	0.03	0.03
Antimony	mg/L	—	0.02	—	—	0.00078	0.00078	0.00078	0.00078
Arsenic	mg/L	0.005	0.1	1	—	0.00049	0.00049	0.00049	0.00049
Barium	mg/L	—	—	—	—	0.0071	-	-	-
Beryllium [(d)]	mg/L	—	0.011-1.1	—	—	0.00028	-	-	-
Bismuth	mg/L	—	—	—	—	0.00054	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.014	0.014	0.014	0.014
Cadmium [(c)]	mg/L	see notes	0.0001-0.0005	—	—	0.000036	0.000036	0.000036	0.000036
Chromium (total)	mg/L	0.01	0.01	—	—	0.00048	0.00048	0.00048	0.00048
Cobalt	mg/L	—	0.0009	—	—	0.00017	0.00017	0.00017	0.00017
Copper [(d)]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.0011	0.0012	0.0012	0.0012
Iron (total)	mg/L	0.3	0.3	—	—	0.24	0.24	0.24	0.24
Lead [(d)]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00029	0.00029	0.00029	0.00029
Manganese	mg/L	—	—	—	—	0.024	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.000005	0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—	—	0.00036	0.00043	0.00038	0.00041
Nickel [(d)]	mg/L	0.025-0.15	0.025	1	—	0.00099	0.0010	0.00099	0.00099
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.000087	0.000087	0.000087	0.000087
Strontium	mg/L	—	—	—	—	0.013	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000084	-	-	-
Tin	mg/L	—	—	—	—	0.00071	-	-	-
Titanium	mg/L	—	—	—	—	0.0012	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.0045	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0022	0.0022	0.0022	0.0022
Vanadium	mg/L	—	0.006	—	—	0.0005	0.0005	0.0005	0.0005
Zinc	mg/L	0.03	0.02	1	—	0.0052	0.0052	0.0052	0.0052
Zirconium	mg/L	—	0.004	—	—	0.0015	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details

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Table 8: Sensitivity Analysis Scenario 1 – Fine-Grained and Coarse-Grained Hydraulic Conductivity x 10 – Water Quality Predictions for Upper Marmion Reservoir – (Operations)

Parameter	Unit	Receiving WQ Guidelines[(a)]				Marmion Reservoir Baseline	Basin 6 (near mine discharge)	Basin 7c (downstream of TMF)	Basin 11 (near Raft Lake Dam)
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	6.5	6.5	6.5	6.5
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg($CaCO_3$)/L	—	-25%	—	—	19	-	-	-
Conductivity	µS/cm	—	—	—	—	49	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	4.5	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	53	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	6.4	6.66	6.49	6.58
Chloride	mg/L	—	—	—	—	1.1	1.79	1.16	1.52
Fluoride	mg/L	—	—	—	—	0.031	-	-	-
Magnesium	mg/L	—	—	—	—	1.3	1.41	1.30	1.36
Potassium	mg/L	—	—	—	—	0.68	1.23	0.75	1.03
Sodium	mg/L	—	—	—	—	1.3	2.7	1.5	2.2
Sulphate	mg/L	—	—	—	—	1.6	4.9	2.0	3.7
Hardness	mg($CaCO_3$)/L	—	—	—	—	21	22	22	22
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.004	0.001	0.003
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.004	0.001	0.003
Nutrients									
Nitrate-N[(a)]	mg/L	13	—	—	—	0.063	0.084	0.063	0.077
Ammonia-N	mg/L	—	—	—	—	0.023	0.255	0.054	0.171
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000067	0.01	0.0005	0.0061
Phosphorus	mg/L	—	0.02	—	—	0.013	0.013	0.013	0.013
Dissolved Metals									
Aluminum [(b)]	mg/L	0.005-0.1	0.015-0.075	—	—	0.03	0.03	0.03	0.03
Antimony	mg/L	—	0.02	—	—	0.00078	0.0008	0.00078	0.00079
Arsenic	mg/L	0.005	0.1	1	—	0.00049	0.00048	0.00049	0.00048
Barium	mg/L	—	—	—	—	0.0071	-	-	-
Beryllium [(d)]	mg/L	—	0.011-1.1	—	—	0.00028	-	-	-
Bismuth	mg/L	—	—	—	—	0.00054	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.014	0.014	0.014	0.014
Cadmium [(c)]	mg/L	see notes	0.0001-0.0005	—	—	0.000036	0.000038	0.000036	0.000038
Chromium (total)	mg/L	0.01	0.01	—	—	0.00048	0.00048	0.00048	0.00048
Cobalt	mg/L	—	0.0009	—	—	0.00017	0.0002	0.00017	0.00019
Copper [(d)]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.0011	0.0028	0.0014	0.0022
Iron (total)	mg/L	0.3	0.3	—	—	0.24	0.23	0.24	0.23
Lead [(d)]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00029	0.00029	0.00029	0.00029
Manganese	mg/L	—	—	—	—	0.024	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.000005	0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—	—	0.00036	0.0014	0.0005	0.0010
Nickel [(d)]	mg/L	0.025-0.15	0.025	1	—	0.00099	0.0011	0.0010	0.0011
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.000087	0.000086	0.000087	0.000086
Strontium	mg/L	—	—	—	—	0.013	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000084	-	-	-
Tin	mg/L	—	—	—	—	0.00071	-	-	-
Titanium	mg/L	—	—	—	—	0.0012	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.0045	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0022	0.0023	0.0022	0.0023
Vanadium	mg/L	—	0.006	—	—	0.0005	0.00049	0.0005	0.00049
Zinc	mg/L	0.03	0.02	1	—	0.0052	0.0053	0.0052	0.0052
Zirconium	mg/L	—	0.004	—	—	0.0015	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.
"—" = Receiving water quality guidelines do not exist for this parameter.
(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.
(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.
(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.
(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

Table 9: Sensitivity Analysis Scenario 2 – Tailings Hydraulic Conductivity x 10 – Water Quality Predictions for Upper Marmion Reservoir – (Operations)

Parameter	Unit	Receiving WQ Guidelines[a]				Marmion Reservoir Baseline	Basin 6 (near mine discharge)	Basin 7c (downstream of TMF)	Basin 11 (near Raft Lake Dam)
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	6.5	6.5	6.5	6.5
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg($CaCO_3$)/L	—	-25%	—	—	19	-	-	-
Conductivity	µS/cm	—	—	—	—	49	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	4.5	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	53	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	6.4	6.7	6.48	6.58
Chloride	mg/L	—	—	—	—	1.1	1.8	1.14	1.52
Fluoride	mg/L	—	—	—	—	0.031	-	-	-
Magnesium	mg/L	—	—	—	—	1.3	1.4	1.29	1.36
Potassium	mg/L	—	—	—	—	0.68	1.23	0.73	1.03
Sodium	mg/L	—	—	—	—	1.3	2.7	1.4	2.2
Sulphate	mg/L	—	—	—	—	1.6	4.9	2.0	3.7
Hardness	mg($CaCO_3$)/L	—	—	—	—	21	22	22	22
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.0038	0.001	0.003
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.0038	0.001	0.003
Nutrients									
Nitrate-N[a]	mg/L	13	—	—	—	0.063	0.084	0.063	0.077
Ammonia-N	mg/L	—	—	—	—	0.023	0.254	0.048	0.17
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000067	0.0096	0.00044	0.0061
Phosphorus	mg/L	—	0.02	—	—	0.013	0.013	0.013	0.013
Dissolved Metals									
Aluminum [b]	mg/L	0.005-0.1	0.015-0.075	—	—	0.03	0.03	0.03	0.03
Antimony	mg/L	—	0.02	—	—	0.00078	0.0008	0.00078	0.00079
Arsenic	mg/L	0.005	0.1	1	—	0.00049	0.00048	0.00049	0.00048
Barium	mg/L	—	—	—	—	0.0071	-	-	-
Beryllium [d]	mg/L	—	0.011-1.1	—	—	0.00028	-	-	-
Bismuth	mg/L	—	—	—	—	0.00054	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.014	0.014	0.014	0.014
Cadmium [c]	mg/L	see notes	0.0001-0.0005	—	—	0.000036	0.000039	0.000036	0.000038
Chromium (total)	mg/L	0.01	0.01	—	—	0.00048	0.00048	0.00048	0.00048
Cobalt	mg/L	—	0.0009	—	—	0.00017	0.0002	0.00017	0.00019
Copper [d]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.0011	0.0028	0.0013	0.0022
Iron (total)	mg/L	0.3	0.3	—	—	0.24	0.23	0.24	0.23
Lead [d]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00029	0.00029	0.00029	0.00029
Manganese	mg/L	—	—	—	—	0.024	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.000005	0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—	—	0.00036	0.00137	0.00047	0.0010
Nickel [d]	mg/L	0.025-0.15	0.025	1	—	0.00099	0.00111	0.0010	0.00107
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.000087	0.000086	0.000087	0.000086
Strontium	mg/L	—	—	—	—	0.013	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000084	-	-	-
Tin	mg/L	—	—	—	—	0.00071	-	-	-
Titanium	mg/L	—	—	—	—	0.0012	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.0045	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0022	0.0023	0.0022	0.0023
Vanadium	mg/L	—	0.006	—	—	0.0005	0.00049	0.0005	0.00049
Zinc	mg/L	0.03	0.02	1	—	0.0052	0.0053	0.0052	0.0052
Zirconium	mg/L	—	0.004	—	—	0.0015	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

[a] See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

[b] Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

[c] Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

[d] Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

MEMORANDUM

Table 10: Base Case Water Quality Predictions for Lizard Lake - Operations Scenario

Parameter	Unit	Receiving WQ Guidelines[a]				Lizard Lake Baseline	Northern	Central	Southern
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	7.0	7.0	7.0	7.0
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg($CaCO_3$)/L	—	-25%	—	—	27	-	-	-
Conductivity	µS/cm	—	—	—	—	63	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	2.1	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	55	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	10	10.32	10.32	10.32
Chloride	mg/L	—	—	—	—	0.25	0.26	0.26	0.26
Fluoride	mg/L	—	—	—	—	0.03	-	-	-
Magnesium	mg/L	—	—	—	—	0.9	0.90	0.90	0.90
Potassium	mg/L	—	—	—	—	0.65	0.66	0.66	0.66
Sodium	mg/L	—	—	—	—	0.67	0.69	0.7	0.7
Sulphate	mg/L	—	—	—	—	1.9	1.9	1.9	1.9
Hardness	mg($CaCO_3$)/L	—	—	—	—	30	30	30	30
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.001	0.001	0.001
Nutrients									
Nitrate-N[a]	mg/L	13	—	—	—	0.034	0.034	0.034	0.034
Ammonia-N	mg/L	—	—	—	—	0.022	0.025	0.026	0.027
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000047	0.00009	0.00011	0.0001
Phosphorus	mg/L	—	0.02	—	—	0.0082	0.008	0.008	0.008
Dissolved Metals									
Aluminum [b]	mg/L	0.005-0.1	0.015-0.075	—	—	0.018	0.018	0.018	0.018
Antimony	mg/L	—	0.02	—	—	0.00097	0.00097	0.00097	0.00097
Arsenic	mg/L	0.005	0.1	1	—	0.00043	0.00043	0.00043	0.00043
Barium	mg/L	—	—	—	—	0.0069	-	-	-
Beryllium [d]	mg/L	—	0.011-1.1	—	—	0.00023	-	-	-
Bismuth	mg/L	—	—	—	—	0.00058	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.011	0.011	0.011	0.011
Cadmium [c]	mg/L	see notes	0.0001-0.0005	—	—	0.00003	0.00003	0.00003	0.00003
Chromium (total)	mg/L	0.01	0.01	—	—	0.00049	0.00049	0.00049	0.00049
Cobalt	mg/L	—	0.0009	—	—	0.00012	0.00012	0.00012	0.00012
Copper [d]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.00087	0.00089	0.0009	0.0009
Iron (total)	mg/L	0.3	0.3	—	—	0.053	0.05	0.05	0.05
Lead [d]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00024	0.00024	0.00024	0.00024
Manganese	mg/L	—	—	—	—	0.0094	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.000005	0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—	—	0.00032	0.00033	0.00034	0.00034
Nickel [d]	mg/L	0.025-0.15	0.025	1	—	0.0008	0.0008	0.0008	0.0008
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.0001	0.0001	0.0001	0.0001
Strontium	mg/L	—	—	—	—	0.015	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000068	-	-	-
Tin	mg/L	—	—	—	—	0.00055	-	-	-
Titanium	mg/L	—	—	—	—	0.0013	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.005	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0025	0.0025	0.0025	0.0025
Vanadium	mg/L	—	0.006	—	—	0.00037	0.00037	0.00037	0.00037
Zinc	mg/L	0.03	0.02	1	—	0.0055	0.0055	0.0055	0.0055
Zirconium	mg/L	—	0.004	—	—	0.002	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

Table 11: Sensitivity Analysis Scenario 1 – Fine-Grained and Coarse-Grained Hydraulic Conductivity x 10 – Water Quality Predictions for Lizard Lake – (Operations)

Parameter	Unit	Receiving WQ Guidelines[(a)]				Lizard Lake Baseline	Northern	Central	Southern
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	7.0	7.0	7.0	7.0
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg($CaCO_3$)/L	—	-25%	—	—	27	-	-	-
Conductivity	µS/cm	—	—	—	—	63	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	2.1	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	55	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	10	10.35	10.35	10.34
Chloride	mg/L	—	—	—	—	0.25	0.30	0.31	0.30
Fluoride	mg/L	—	—	—	—	0.03	-	-	-
Magnesium	mg/L	—	—	—	—	0.9	0.92	0.93	0.92
Potassium	mg/L	—	—	—	—	0.65	0.72	0.73	0.71
Sodium	mg/L	—	—	—	—	0.67	0.8	0.9	0.8
Sulphate	mg/L	—	—	—	—	1.9	2.3	2.3	2.2
Hardness	mg($CaCO_3$)/L	—	—	—	—	30	31	31	31
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.001	0.001	0.001
Nutrients									
Nitrate-N[(a)]	mg/L	13	—	—	—	0.034	0.034	0.034	0.034
Ammonia-N	mg/L	—	—	—	—	0.022	0.055	0.06	0.05
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000047	0.00046	0.00053	0.00041
Phosphorus	mg/L	—	0.02	—	—	0.0082	0.008	0.008	0.008
Dissolved Metals									
Aluminum [(b)]	mg/L	0.005-0.1	0.015-0.075	—	—	0.018	0.018	0.018	0.018
Antimony	mg/L	—	0.02	—	—	0.00097	0.00097	0.00097	0.00097
Arsenic	mg/L	0.005	0.1	1	—	0.00043	0.00043	0.00043	0.00043
Barium	mg/L	—	—	—	—	0.0069	-	-	-
Beryllium [(d)]	mg/L	—	0.011-1.1	—	—	0.00023	-	-	-
Bismuth	mg/L	—	—	—	—	0.00058	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.011	0.011	0.011	0.011
Cadmium [(c)]	mg/L	see notes	0.0001-0.0005	—	—	0.00003	0.00003	0.00003	0.00003
Chromium (total)	mg/L	0.01	0.01	—	—	0.00049	0.00049	0.00049	0.00049
Cobalt	mg/L	—	0.0009	—	—	0.00012	0.00013	0.00013	0.00013
Copper [(d)]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.00087	0.0011	0.0011	0.001
Iron (total)	mg/L	0.3	0.3	—	—	0.053	0.05	0.05	0.05
Lead [(d)]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00024	0.00024	0.00024	0.00024
Manganese	mg/L	—	—	—	—	0.0094	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.000005	0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—	—	0.00032	0.00045	0.00047	0.00043
Nickel [(d)]	mg/L	0.025-0.15	0.025	1	—	0.0008	0.00082	0.00082	0.00081
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.0001	0.0001	0.0001	0.0001
Strontium	mg/L	—	—	—	—	0.015	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000068	-	-	-
Tin	mg/L	—	—	—	—	0.00055	-	-	-
Titanium	mg/L	—	—	—	—	0.0013	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.005	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0025	0.0025	0.0025	0.0025
Vanadium	mg/L	—	0.006	—	—	0.00037	0.00037	0.00037	0.00037
Zinc	mg/L	0.03	0.02	1	—	0.0055	0.0055	0.0055	0.0055
Zirconium	mg/L	—	0.004	—	—	0.002	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

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Table 12: Sensitivity Analysis Scenario 2 – Tailings Hydraulic Conductivity x 10 – Water Quality Predictions for Lizard Lake – (Operations)

Parameter	Unit	Receiving WQ Guidelines[(a)]				Lizard Lake Baseline	Northern	Central	Southern
		CCME	PWQO	MISA	SSWQO				
Physical-Chemical									
pH	—	6.5-9	6.5-8.5	—	—	7.0	7.0	7.0	7.0
Acidity	mg/L	—	—	—	—	2.9	-	-	-
Alkalinity	mg(CaCO$_3$)/L	—	-25%	—	—	27	-	-	-
Conductivity	µS/cm	—	—	—	—	63	-	-	-
Total Suspended Solids	mg/L	+5-25	—	—	—	2.1	-	-	-
Total Dissolved Solids	mg/L	—	—	—	—	55	-	-	-
Major Ions									
Calcium	mg/L	—	—	—	—	10	10.34	10.35	10.34
Chloride	mg/L	—	—	—	—	0.25	0.30	0.31	0.29
Fluoride	mg/L	—	—	—	—	0.03	-	-	-
Magnesium	mg/L	—	—	—	—	0.9	0.92	0.93	0.92
Potassium	mg/L	—	—	—	—	0.65	0.71	0.73	0.71
Sodium	mg/L	—	—	—	—	0.67	0.8	0.9	0.8
Sulphate	mg/L	—	—	—	—	1.9	2.3	2.3	2.2
Hardness	mg(CaCO$_3$)/L	—	—	—	—	30	31	31	31
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.001	0.001	0.001
Nutrients									
Nitrate-N[(a)]	mg/L	13	—	—	—	0.034	0.034	0.034	0.034
Ammonia-N	mg/L	—	—	—	—	0.022	0.053	0.058	0.049
Un-ionized ammonia	mg/L	0.019	0.02	—	—	0.000047	0.000	0.001	0.000
Phosphorus	mg/L	—	0.02	—	—	0.0082	0.008	0.008	0.008
Dissolved Metals									
Aluminum [(b)]	mg/L	0.005-0.1	0.015-0.075	—	—	0.018	0.018	0.018	0.018
Antimony	mg/L	—	0.02	—	—	0.00097	0.00097	0.00097	0.00097
Arsenic	mg/L	0.005	0.1	1	—	0.00043	0.000	0.000	0.000
Barium	mg/L	—	—	—	—	0.0069	-	-	-
Beryllium [(d)]	mg/L	—	0.011-1.1	—	—	0.00023	-	-	-
Bismuth	mg/L	—	—	—	—	0.00058	-	-	-
Boron	mg/L	1.5	0.2	—	—	0.011	0.011	0.011	0.011
Cadmium [(c)]	mg/L	see notes	0.0001-0.0005	—	—	0.00003	0.00003	0.00003	0.00003
Chromium (total)	mg/L	0.01	0.01	—	—	0.00049	0.000	0.000	0.000
Cobalt	mg/L	—	0.0009	—	—	0.00012	0.00013	0.00013	0.00013
Copper [(d)]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.00087	0.001	0.001	0.001
Iron (total)	mg/L	0.3	0.3	—	—	0.053	0.05	0.05	0.05
Lead [(d)]	mg/L	0.001-0.007	0.001-0.005	0.4	—	0.00024	0.0002	0.00024	0.00024
Manganese	mg/L	—	—	—	—	0.0094	-	-	-
Mercury	mg/L	0.000026	0.0002	—	—	0.000005	0.00001	0.00001	0.00001
Molybdenum	mg/L	0.073	0.04	—	—	0.00032	0.00044	0.00046	0.00043
Nickel [(d)]	mg/L	0.025-0.15	0.025	1	—	0.0008	0.00081	0.00082	0.00081
Selenium	mg/L	0.001	0.1	—	—	0.0005	0.0005	0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—	—	0.0001	0.0001	0.0001	0.0001
Strontium	mg/L	—	—	—	—	0.015	-	-	-
Thallium	mg/L	0.0008	0.0003	—	—	0.000068	-	-	-
Tin	mg/L	—	—	—	—	0.00055	-	-	-
Titanium	mg/L	—	—	—	—	0.0013	-	-	-
Tungsten	mg/L	—	0.03	—	—	0.005	-	-	-
Uranium	mg/L	—	0.005	—	—	0.0025	0.0025	0.0025	0.0025
Vanadium	mg/L	—	0.006	—	—	0.00037	0.00037	0.00037	0.00037
Zinc	mg/L	0.03	0.02	1	—	0.0055	0.0055	0.0055	0.0055
Zirconium	mg/L	—	0.004	—	—	0.002	-	-	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

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Table 13: Upper Bound Water Quality Predictions for Long Hike Lake - Operations Scenario

Parameter	Unit	Receiving WQ Guidelines[a]				Baseline Water Quality[e]	Long Hike Lake Mixed Concentration
		CCME	PWQO	MISA	SSWQO		
Physical-Chemical							
pH	—	6.5-9	6.5-8.5	6.0–9.5		6.9	6.9
Acidity	mg/L	—	—	—		2.9	-
Alkalinity	mg(CaCO3)/L	—	-25%	—		27	-
Conductivity	µS/cm	—	—	—		63	-
Total Suspended Solids	mg/L	+5-25	—	—		2.1	-
Total Dissolved Solids	mg/L	—	—	—		54.7	-
Major Ions						-	
Calcium	mg/L	—	—	—		10.3	11
Chloride	mg/L	120	—	—		0.25	1.9
Fluoride	mg/L	—	—	—		0.03	-
Magnesium	mg/L	—	—	—		0.90	1.7
Potassium	mg/L	—	—	—		0.65	2.8
Sodium	mg/L	—	—	—		0.67	6.3
Sulphate	mg/L	—	—	—		1.9	15
Hardness	mg(CaCO3)/L	—	—	—		30	36
Cyanide (free)	mg/L	0.005	0.005	—	0.01	0.001	0.002
Cyanide (total)	mg/L	—	—	—	0.01	0.001	0.002
Nutrients						-	
Nitrate-N	mg/L	13	—	—		0.034	0.032
Ammonia-N	mg/L	—	—	—		0.022	1.1
Un-ionized ammonia	mg/L	0.019	0.02	—		5E-05	0.013
Phosphorus	mg/L	—	0.02	—		0.008	0.009
Dissolved Metals						-	
Aluminum [b]	mg/L	0.005-0.1	0.015-0.075	—		0.018	0.018
Antimony	mg/L	—	0.02	—		0.001	0.001
Arsenic	mg/L	0.005	0.1	1		0.0004	0.0004
Barium	mg/L	—	—	—		0.007	-
Beryllium [d]	mg/L	—	0.011-1.1	—		0.0002	-
Bismuth	mg/L	—	—	—		0.0006	-
Boron	mg/L	1.5	0.2	—		0.011	0.011
Cadmium [c]	mg/L	see notes	0.0001-0.0005	—		0.00003	0.000029
Chromium (total)	mg/L	0.01	0.01	—		0.0005	0.00048
Cobalt	mg/L	—	0.0009	—		0.0001	0.00028
Copper [d]	mg/L	0.002-0.004	0.001-0.005	0.6	0.0079	0.0009	0.0067
Iron (total)	mg/L	0.3	0.3	—		0.053	0.05
Lead [d]	mg/L	0.001-0.007	0.001-0.005	0.4		0.0002	0.00024
Manganese	mg/L	—	—	—		0.009	-
Mercury	mg/L	0.000026	0.0002	—		0.000005	0.000005
Molybdenum	mg/L	0.073	0.04	—		0.0003	0.0046
Selenium	mg/L	0.001	0.1	—		0.0005	0.0005
Silver	mg/L	0.0001	0.0001	—		0.0001	0.000097
Strontium	mg/L	—	—	—		0.015	-
Thallium	mg/L	0.0008	0.0003	—		7E-05	-
Tin	mg/L	—	—	—		0.001	-
Titanium	mg/L	—	—	—		0.001	-
Tungsten	mg/L	—	0.03	—		0.005	-
Uranium	mg/L	—	0.005	—		0.003	0.0028
Vanadium	mg/L	—	0.006	—		0.0004	0.00035
Zinc	mg/L	0.03	0.02	1		0.006	0.0053
Zirconium	mg/L	—	0.004	—		0.002	-

Notes:

Underlined values exceed PWQO guidelines. **Bold** values exceed CCME CWQG. Grey shaded value exceed MISA guidelines. Double underlined values exceed SSWQO.

"-" = Site water quality data was not modelled for this parameter.

"—" = Receiving water quality guidelines do not exist for this parameter.

(a) See Appendix 2.IV of Lake Water Quality TSD for the list of all parameters, guidelines and notes.

(b) Aluminum CCME CWQG and PWQO guidelines range is pH dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(c) Cadmium CCME CWQG is calculated using a formula (See Appendix 2.IV of Lake Water Quality TSD) that is hardness-dependent.

(d) Beryllium, copper, lead and nickel guidelines are hardness dependent. See Appendix 2.IV of Lake Water Quality TSD for details.

(e) Baseline water quality of Lizard Lake assumed to be representative of baseline water quality of Long Hike Lake

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6.5 Conclusions and Contingency Measures

Seepage collection measures, as described in Section 3.6.4, will be implemented to mitigate impacts to the surrounding environment. The groundwater modelling and water quality assessment presented herein have demonstrated that there are no predicted exceedances of PWQO or SWWQO within the receivers as a result of seepage bypass. At present, the design of the collection system is conceptual. During detailed design, additional field data will be collected and the modeling of the TMF facility will be updated to support the design of both the TMF and the external seepage collection system. The final design of the collection ditches will be completed to allow for the capture efficiency required to mitigate adverse impacts to the downstream receiving environment. The modelling analysis presented in this memorandum indicates that implementation of a collection system with a capture efficiency of greater the 94% is technically feasible.

Monitoring wells will be installed between the seepage collection system and the downstream receivers to monitor both seepage flow and water quality to confirm predictions and the effectiveness of the seepage collection system. This monitoring system will be designed during the detailed design phase of the project and will adhere to the requirements of the applicable permits. Water quality in the receiving environment will also be monitored as part of the Environmental Effects Monitoring (EEM) program for the project. Should seepage bypass be greater than predicted and/or water quality be worse than predicted such that adverse impacts to the downstream environment are possible, appropriate contingency measures will be implemented. Available contingency measures include process adjustments (e.g., cyanide destruction efficacy), deepening the seepage collection ditches, installation of active pumping wells or construction of subsurface low permeability cut-off walls within the deeper overburden valleys. Should implementation of contingency measures be required, the appropriate measures will be evaluated and identified based on the conditions encountered.

Although the preliminary analysis presented in this memorandum suggests there will be no impacts to water quality, some uncertainty exists with respect to seepage release to Long Hike Lake. As a condition of EA approval, CMC will commit to collect additional subsurface data between the TMF and Long Hike Lake to re-evaluate and confirm the model results with respect to seepage discharge to Long Hike Lake. If required based on the results of this subsequent confirmatory analysis, CMC will collect the appropriate data to characterize baseline conditions in Long Hike Lake, including water quality, sediment quality, and hydrology data, and Long Hike Lake will be included in the EEM program for the project.

7.0 RESPONSES TO GRT COMMENTS

This section provides responses to the most recent set of comments made by the GRT in CEAA, July 2017. The comments are addressed sequentially as they appear in CEAA, July 2017. In some instances we have subdivided the original comment to allow for more direct response.

GRT Comment 1: Tailings Management Facility (TMF) Model Layers

GRT Comment 1a. *Explain why separate model layers were implemented for the rockfill dam (layers 4 and 5) and the tailings (layers 1-3). It appears that layers 4 and 5 are only used for the dam and result in the distortion of tailings layers (layers 1-3) over the rockfill dams. Why not use different properties within the same layers to avoid layer distortion?*

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Response:

The current layer structure is the outcome of importing and updating an earlier TMF model construction (Golder, 2014) into the current work. In our 2014 analyses, the TMF structure consisted of three layers, namely:

Layer 1: Tailings (i.e. the tailings were represented by a single bulk layer)

Layer 2: Upper Dam (no liner)

Layer 3: Lower Dam (liner on upstream flank)

The 2014 layer structure and associated grids were used as the initial input for constructing the TMF within the current model. However, several modifications were eventually imposed to refine groundwater conditions within the TMF, including:

- A thin upper layer was introduced to posit the constant heads at the very top of the tailings mound (i.e. the current Layer 1), as opposed to applying a constant head through the entirety of the bulk tailings;
- The underlying bulk tailings were subdivided to more accurately characterize the vertical head distribution within the tailings (i.e. the current Layer 2 and 3).

The addition of current Layers 1, 2 and 3 were created by simply subdividing the aforementioned pre-existing layer structure within Visual MODFLOW itself (this process takes seconds).

We acknowledge the GRTs suggestion of having continuous tailings-to-dam layers as another valid layer construction approach. However, this method would have required the development of a new set of layers in an external pre-processor and hence would have been considerably more time consuming. Nonetheless, for the purpose of this response, we tested this suggested approach (i.e. in effect combined Layer 2 and Layer 4 into a new Layer 2, and Layer 3 and Layer 5 into a new Layer 3) and found that the model flow budget and TMF seepage rates were within 2% of the current model.

Lastly, please consider that the layers do not “distort” but instead simply thin to a minimal thickness where the nominal material is not present. This is a common approach to assigning numerical layer thicknesses in MODFLOW.

Based on the above arguments we do not consider it necessary to revise our current model approach and our reported method does not require further justification within this updated memorandum.

GRT Comment 1b. *Report the properties and thickness of layers 4 and 5 under the tailings.*

Response:

Please see revised Section 3.5.

GRT Comment 1c. *Please clarify where the liner is implemented in the model. Since the liner is implemented as no flow cells, it implies that the liner height corresponds to the thickness (i.e. height) of these cells. Clearly state in which layer the liner on the rockfill dam has been implemented and specify liner thickness.*

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Response:

Please see revised Section 3.6.3.

GRT Comment 2: Reclaim Pond Hydraulic Parameters

Please specify how the reclaim pond is implemented in the model, in particular its hydraulic parameters and which cells are specified as no-flow cells.

Response:

Please see revised Sections 3.6.2, 3.6.3, and 3.7.

GRT Comment 3: Operations Phase Tailings Recharge

Please note that provided the hydraulic conductivity (K) of the tailings is appropriate, the constant head boundary condition at the tailings surface for the operations phase is accepted as a conservative approach that results in a high recharge rate to the tailings and therefore a high seepage rate.

Response:

Acknowledged.

GRT Comment 4: Seepage Proportioning to Receptors

The proportioning of seepage to the various receptors (section 4.1, bullet 4) is not clearly described and the comparison between pre-TMF and TMF models may not be appropriate. Changes in flow to external receptors (bullet 4a) can only be compared if the cells used to compile the fluxes for pre-TMF and TMF models are the same (since discharge from cells within the TMF boundary in the pre-TMF model are essentially meaningless for comparison to the TMF models). Based on the statement in bullet 4b, it appears that the cells that are included in the "Sawbill Bay drainages" and to the "Lizard Lake drainages" (Table A1) have changed between the pre-TMF (baseline) model and the TMF models. In order to compare pre-TMF and TMF models, the pre-TMF model discharges should use the same cells as the TMF models (i.e. compile discharge for cells outside the eventual TMF and collection ditches).

As a result of the proportioning of seepage to the various receptors, it is difficult to reconcile the summary values presented in Tables 2, 3 and 4 with the values presented in the Appendix A in Table A1. It is not apparent where the values for flow to the collection ditches and to the watersheds "External to the TMF" came from.

Describe how the values in Tables 2 through 4 were determined in a manner that clarifies the issues raised about seepage proportioning.

Response:

Section 4, and in particular sub-Section 4.1, have been revised to provide more clarity on the approach to determining TMF seepage rates and proportioning amongst receptors. We further emphasize the following:

- Pre-TMF and TMF model flows to receptors are compared on the basis of zone budgeting external to the TMF. The two model results may be directly compared as they use the same zone budget cells.

- The above notwithstanding, the flow rates tallied in Table 2 through 5 cannot be calculated solely on the basis of zone budget partitioning – additional steps, including particle tracking, are required to differentiate seepage-impacted flow versus non-impacted flow (Section 4.1). As such, there is not a straightforward way to link conventional zone budget (i.e. direct source / sink) reporting such as in Appendix A versus the more complex partitioning required to produce Tables 2 through 5.

- The intent of Appendix A was to demonstrate that the modelled numerical error was acceptable and to provide a general understanding of flow distribution through the entire model domain. In other words, Appendix A was a peripheral flow budget provided for reporting completeness. There was not, nor was there intended to be, a direct correspondence between Table 2 through 4 (and now Table 5), which isolate and tallies flow related solely to TMF seepage, versus Appendix A, which tallies the entire flow in the model (irrespective of tailings impact).

- The Appendix A reporting of global pre-TMF model flows alongside TMF model flows was simply for ease of reference and was not meant to engender direct comparison between the two. In fact, there cannot be a direct comparison between the global flow budgets of the two sets of models because the boundary conditions have substantially changed in the area of the TMF. We acknowledge that the inclusion of the pre-TMF flow budgets alongside the TMF flow budgets in Table A1 may have caused confusion and have thus removed the pre-TMF global flow budgets as they are not directly relevant to the current work (note the pre-TMF flow budgets may still be reviewed in Golder, 2017).

GRT Comment 5: Sensitivity Analysis

The sensitivity analysis considered the effect of 10-fold increases in K in coarse- and fine-grained material. These increases resulted in an approximately 3-fold increase in overall recharge and seepage rates and also to seepage flow bypassing the collector system to external receptors. One variable not considered was the K of the tailings. Although increasing the K of the tailings would most certainly increase the recharge rate (due to the constant head boundary condition), it is not clear what would be the effect on the seepage flow bypassing the collector system.

GRT Comment 5a. *Explain the effect increasing the K of the tailings would have on the seepage flow bypassing the collection system, as well as the potential environmental effect on the water quality of the receiving waterbodies.*

Response:

An additional sensitivity analysis scenario that examines a ten-fold increase in tailings hydraulic conductivity (Sensitivity Scenario 2) has been conducted as part of this updated memorandum (Section 5.2). This sensitivity scenario was imposed upon the base case model rather than combining it with Sensitivity Scenario 1 because the combined increases in both tailings and native material hydraulic conductivities together with the constant head boundary assumption would result in a tailings pseudo-recharge far in excess of what actual inflows to the TMF would be during Operations if precipitation and tailings discharge were added together. The predicted seepage bypass rates are provided in Table 5 and are less than the predicted seepage bypass rates for Sensitivity Scenario 1 (Table 4). It follows that the potential impacts to water quality would be less when compared to Sensitivity Scenario 1. Regardless, Sensitivity Scenario 2 water quality predictions are provided in Tables 9 and 12, respectively, for Upper Marmion reservoir and Lizard Lake. No exceedances of PWQO or SWWQO are predicted.

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GRT Comment 5b. *Describe the contingency measures that would be applied to address the change in seepage bypass flow and any potential environmental effect on the receiving waterbodies.*

Response:

As Sensitivity Scenario 2 did not result in seepage bypass rates beyond what had already been predicted for Sensitivity Scenario 1 and presented in the previous version of this memorandum, the mitigation and contingency measures identified in Section 6.5 remain valid and are considered appropriate.

GRT Comment 6: Mitigation and Contingency Measures

GRT Comment 6a. *Section 6.2 of the report states no exceedances of the Provincial Water Quality Objectives or Site Specific Water Quality Objectives are predicted. However, there is no indication that Site Specific Water Quality Objectives are applicable to this project.*

Response:

Site Specific Water Quality Objectives (SSWQO) of 0.0079 mg/L for copper and 0.01 mg/L for cyanide are identified in Section 5.2.1.1.2 of the Human Health and Ecological Risk Assessment TSD (HHERA) (Golder 2013[9]). The HHERA explains the appropriateness and technical rationale for the application of these SSWQO to the surface waters in the Project area. These SSWQO are protective of aquatic life in the receiving waters downstream of the TMF.

GRT Comment 6b. *The report indicates that the predicted concentration of copper in Long Hike Lake would exceed both the Canadian Water Quality Guideline for the Protection of Aquatic Life and the Provincial Water Quality Objective, yet no mitigation has been identified for segments of the northern perimeter of the TMF (i.e., area south of Long Hike Lake), as well as a segment of the perimeter immediately west of the reclaim pond. (Please see the figure on page 4 of this attachment.) Appropriate mitigation and contingency measures are expected, along with commitments to implement them. Further the report lists potential options as contingency measures for evaluation, if such measures are deemed necessary. It is unclear whether the mitigation, contingency and monitoring measures could be implemented based on the suitable geographic area available between the tailings management facility and the receiving waterbodies.*

Describe appropriate mitigation and contingency measures for the segments shown in the attached figure (appearing as Sections A, B and C); otherwise, provide justification for not identifying measures. Include commitments to implement the appropriate mitigation and contingency measures around the perimeter of the tailings management facility in the Commitments Registry.

Response:

CMC has committed to implementing mitigation in the form seepage collection ditches. CMC will further commit to ensuring water quality guidelines/objectives (i.e., PWQO, CCME or SSWQO, where applicable) are not exceeded in Upper Marmion Reservoir, Lizard Lake and Long Hike Lake as a result of the Project. These commitments will be included in the Commitments Registry. The modelling presenting in this memorandum has demonstrated that seepage collection and compliance with the appropriate water quality guidelines/objectives can be achieved. Therefore, the mitigation measure presented in this memorandum (i.e., seepage collection ditches) are appropriate and sufficient. Further data collection and additional modelling analysis will be required to support the detailed design of the TMF and the associated mitigation measures. During the detailed design process the TMF will be designed such that the receiving waters are protected and that commitments with respect to water quality are met.

The predicted upper bound copper concentration in Long Hike Lake is below the SSWQO of 0.079 mg/L for copper. This SSWQO has been determined through the HHERA to be protective of aquatic life in the surface waters in the Project area. Therefore, additional mitigation measures are not considered to be necessary at this time. As noted in Section 6.5, CMC will commit to confirmatory investigations to confirm the results presented in this evaluation with respect to seepage flow to Long Hike Lake. If required based on the results of this subsequent confirmatory analysis, CMC will collect the appropriate data to characterize baseline conditions in Long Hike Lake, including water quality, sediment quality, and hydrology data, and Long Hike Lake will be included in the EEM program for the Project. The applicability of the SSWQOs will also be confirmed for Long Hike Lake based on the baseline data characterization.

Contingency measures, by definition, are measures to be implemented in the event of unforeseen circumstances. Contingency measures would be considered necessary if, based on monitoring results, it is found that seepage bypass rates and/or reclaim pond water quality are beyond what was anticipated following detailed design and the potential exists for concentrations in Upper Marmion Reservoir, Lizard Lake or Long Hike Lake to exceed the above referenced water quality guidelines/objectives. It would not be appropriate for CMC to commit to specific contingency measures as part of the EIS/EA without fully understanding the final design of the facility, the mechanisms/processes that are causing in the potential water quality exceedances and the specific parameters of concern (e.g., copper, cyanide, etc.). Regardless, for sake of demonstration and to fulfill the request of the GRT, descriptions of feasible mitigation and contingency measures are provided below, with reference to Section A, B and C as shown in page 4 of the attachment to CEAA June 2017.

Section A

- Extend the seepage collection ditch flowing west towards Sawbill Bay to approximately the toe of the TMF Reclaim Pond dam (see Figure 1). The depth of the ditch can be increased if necessary to increase capture efficiency.

Section C

- Extend the seepage collection ditch flowing eastward within valley between bedrock outcrops to the Lizard Lake-Long Hike Lake sub-watershed divide. The depth of the ditch can be increased if necessary to increase capture efficiency.

All Sections (A, B, C)

- Identify and grout zones of higher permeability (e.g., coarser grained soils or fractured rock) between the TMF and the downstream receiving environment to reduce transmissivity of the subsurface.
- Install active pumping wells into overburden areas to intercept seepage flows and reduce seepage discharge to the downstream receiving environment.
- Modify mill processes, implement additional water treatment measures or modify existing water treatment measures (e.g., cyanide destruction) to improve TMF water quality.

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Potential mitigation and contingency measures would be similar in terms of performance objectives (e.g., to either reduce seepage rates or improve seepage water quality) but differ in when they would be implemented. For clarity, mitigation measures would be incorporated into the design of the TMF (i.e. proactive measures). As the current predicted water quality in the receiving waters is protective of aquatic life, the presently planned mitigation in the form of seepage collection ditches is considered adequate. Further mitigation would only be required if through further engineering design and associated investigations, it becomes apparent that water quality may be adversely affected. Contingency measures would be implemented after construction if unforeseen circumstances arise and through monitoring it is determined that water quality in the receivers may be adversely impacted (i.e., reactive measures).

GRT Comment 7: Effects on Long Hike Lake

Prior to this report, the environmental impact statement documentation indicated that the water quality of Long Hike Lake would not be affected by the Hammond Reef Gold Project. As a result, Indigenous groups were advised as such (see Appendix 7.V of the EIS documentation). Given the report now predicts for Long Hike Lake copper concentrations that exceed both the Canadian Water Quality Guideline for the Protection of Aquatic Life and the Provincial Water Quality Objective, as well as elevated sulphate levels, effects on the use and access to the lake by Indigenous groups (which in part could relate to the physical presence of mitigation, contingency and monitoring measures in the area) are unclear.

For each Indigenous group, describe how the effects on the water quality of Long Hike Lake, including the implementation of any proposed mitigation, contingency and monitoring measures would affect the traditional use of and access to the lake. Please specify the traditional use(s), including timing and duration, as appropriate. Describe the mitigation measures to address the effects to access and on traditional use. Include the mitigation measures in the Commitments Registry, along with a commitment to seek and incorporate input from the Indigenous groups.

Response

With respect to predicted copper concentrations, please refer to the response to Comment 6 above. The predicted upper bound copper concentration in Long Hike Lake is below the SSWQO for copper that protective of aquatic life in the surface waters around the Project area and mitigation is not necessary at this time.

With respect to predicted sulphate concentrations, please refer to the technical memorandum *Response to Comment related to Sulphate Influence on Methylmercury Generation and Wild Rice Harvesting - Hammond Reef Gold Project* (Golder 2017). Wild rice harvesting is not known to occur in Long Hike Lake.

Direct access to Long Hike Lake is provided by the Premier Lake Road. Should the need for mitigation or contingency measures arise resulting from CMC's commitment to maintain water quality below PWQO and CCME guidelines or SSWQO where applicable, the measures will be designed and implemented such that access is not effected. Use of Long Hike Lake for fishing is primarily used by commercially guided trips for non-Aboriginal fishermen. Aboriginal communities are not known to frequent Long Hike Lake for fishing as there are productive lakes that are much easier to access (i.e., Upper Marmion Reservoir and Lizard Lake) (Pers. Comm., Bud Dickson, Aug. 2, 2017). At this time, no mitigation for Project related effects to Aboriginal access or use of Long Hike Lake are necessary.

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GRT Comment 8: Monitoring

Section 6.5 of the report indicates monitoring wells would be installed between the seepage collection systems and downgradient receptors. Demonstrate that this concept could work appropriately, given the available land between the TMF and the receiving waterbodies. Describe any limitations to the installation and implementation of the proposed monitoring program, and explain how the limitations would be addressed.

It is implied that the water quality monitoring would include all parameters listed in Tables 5 through 10. However, the report does not specify. Add as commitments to the Commitments Registry, the inclusion of all parameters listed in Tables 5 through 10 in both the groundwater and surface water quality monitoring programs.

Response

The TMF seepage monitoring program will be selected based on more advanced groundwater modelling that includes additional subsurface investigation data to be collected in support of the detailed design of the TMF and on information obtained during construction. Monitoring wells will be located in areas where seepage flows are expected to be high (e.g., coarse grained overburden units). Shallow and deep wells will be installed where overburden units are deep. Water quality in surface creeks and streams around the perimeter of the TMF will be monitored regularly and the volumes and quality of seepage captured in the seepage collection ditches will be monitored.

The minimum offset from the toe of the TMF dams to the downstream receptors (i.e., Sawbill Bay and Lizard Lake) is about 100 m. This minimum offset is sufficient to install a seepage collection ditch and monitoring well(s) on the downstream side of the ditch to assess seepage bypass with.

Limitations would include the difficulty associated with monitoring seepage flow through deep bedrock and the impracticality of monitoring the entire perimeter of the TMF. The monitoring program will be developed such data collected can be used to confirm or refine the predictions of the updated groundwater model to be developed during detailed design. The operational groundwater model will be periodically refined and re-calibrated as necessary throughout the project and will be used to estimate and assess seepage bypass rates in areas where monitoring is either problematic or impractical.

The water quality monitoring program will include all parameters listed in Tables 6 through 13 (formerly Tables 5 through 10) and a commitment to this effect will be included in the Commitments Registry, however as chemical stability is demonstrated for certain parameters, the list of parameter may be refined through discussion and agreement by the appropriate regulatory agencies.

GRT Comment 9: Unclear References within the Report

Within the report, certain references to content from technical supporting documents appear incorrect. For example, the first paragraph on page 12 refers to Appendix 2.II of the Site Water Quality Technical Supporting Document (TSD); however the TSD does not have the appendix. Also, there is a reference to Figure 11 on page 12, as well as a reference to Figure 12 on page 13. These references appear to be typographic errors, where the correct figures are likely Figures 8 and 9, respectively.

Please clarify the referencing and make the appropriate amendments to the report.

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Response

References have been corrected throughout this updated memorandum.

8.0 RESPONSES TO INFORMATION REQUEST T(3)-08

Building on the results presented in this memorandum, the following provides a comprehensive address of Information Request T(3)-08.

From *Information Request #3 from the Technical Review of the Responses to Information Request #2 for the Hammond Reef Gold Project Environmental Assessment, T3-08 (CEAA, January 29 2016)*:

1. Drill additional boreholes to obtain borehole and stratigraphic logs to characterize the permeability of the base of the entire TMF. Perform additional single-well response tests and consider performing a pump test to better characterize hydraulic conductivity values and isotropy/anisotropy. Develop a plan for the additional boreholes and stratigraphic logs in discussion with relevant government agencies to ensure adequate characterization of baseline conditions within the proposed TMF footprint.

Response:

Subsequent to GRT providing this comment in January 2016, Golder has supplemented the already substantial historic dataset (Golder, 2013[7]) with the inclusion of detailed surficial geology mapping covering the entirety of the TMF footprint, 64 condemnation boreholes, and 10 additional single-well response tests within the overburden and bedrock units. In areas where data may be considered relatively limited, the conceptual model has employed conservative assumptions for unit thicknesses, hydraulic conductivity and anisotropy that will tend to promote tailings seepage. Uncertainty in model parameters and their effect on TMF seepage has been tested during model sensitivity analysis and upper bound estimates of seepage release have been assessed for impacts. CMC has worked closely with the GRT during the development of the TMF groundwater model construction and calibration and has received and incorporated review comments and input from the GRT technical reviewers to ensure that GRT expectations are met. As such, Golder feels the adopted approach to characterizing hydrogeologic conditions within the TMF footprint is adequate for this EA stage of the project and additional drilling and hydraulic testing are not necessary to support a decision with respect to potential environmental impacts.

2. *If the results indicate that the base of the TMF is permeable (as compared to thick sequences of laterally continuous clay), provide responses to and action on questions 3-7.*

Response:

We acknowledge that materials at the base of the TMF may include permeable units and these have been considered in the conceptual model where supported by the geological data (refer to Section 2 and Section 3 of the Conceptual Model Development memorandum [Golder 2016]).

3. *Drill additional monitoring wells to obtain sufficient information to determine the groundwater flow paths and the fate of chemical constituents in the TMF seepage water. Develop a plan for the additional monitoring wells in*

MEMORANDUM

discussion with relevant government departments to ensure baseline information is gathered in regions where units with higher hydraulic conductivities are found within the proposed TMF footprint.

Response:

Please refer to the response to comment #1 above.

4. Using the data from the additional monitoring wells, model the entire TMF using the 3D numerical groundwater model.

Response:

The entire TMF and regional surrounds have been included in the 3D numerical groundwater model (refer to Section 3 and Section 4 of the Conceptual Model Development memorandum [Golder 2016]).

5. Re-run the 3D model based on the following:

a) Perform a more robust calibration using additional monitoring well data;

b) Presenting a detailed conceptual model using visual depictions to describe the baseline hydrogeological conditions;

c) Model all project phases including baseline, operations phase, closure (decommissioning), and post-closure (abandonment);

d) As described in 2., include information from the additional boreholes and stratigraphic logs for the entire TMF to determine if the overburden is isotropic or anisotropic, based on the absence or presence of laterally continuous horizontally bedded sedimentary deposits, and to determine if the assumption Khorizontal:Kvertical = 1:0.1 is valid. If it is not, update the model assumption for isotropy/anisotropy. The installation of additional monitoring wells and hydraulic testing will also help better define the Khorizontal:Kvertical relationship; and

e) Provide a sensitivity analysis for the model that considers possible extremes in such parameters as recharge and hydraulic conductivity.

Response:

a) The numerical model has been calibrated to monitoring well data to form the “baseline” or “pre-TMF” condition, as documented in Golder 2017. The model calibration process included review of the calibration results by the GRT and revision of the model in response to comments and recommendations received. Subsequent to the final revision to the calibration of the baseline model, CMC received recommendation form the GRT to proceed to the predictive simulation stage of the modelling process, implying that they were adequately satisfied with the model calibration.
b) The detailed conceptual model (Golder 2016), model calibration (Golder 2017) and predictive simulation memoranda have presented the model and relevant results using visual depictions.
c) All project phases, including baseline, TMF operation, closure and post-closure, have been simulated. The baseline model results are provided in Golder 2017. TMF operation, closure and post-closure results have been provided in this memorandum.

d) Please refer to the response to comment #1 above regarding collection of additional data. Overburden anisotropy has been selected through model calibration and evaluated through sensitivity analysis (Golder 2017)

e) Sensitivity analyses has been conducted for both calibration and predictive simulations. During calibration (Golder 2017), 10 additional sensitivity scenarios were evaluated and consider possible extremes in recharge, anisotropy and hydraulic conductivity. Almost every permutation resulted in a worsening in calibration relative to baseline. Sensitivity Run 11, (Fine-grained material hydraulic conductivity multiplied by 10 and Coarse-grained material hydraulic conductivity multiplied by 10) has been carried through to predictive simulations to evaluate a baseline condition that is more conductive to seepage. Run 11, while providing slightly inferior calibration statistics relative to the baseline, is nonetheless a plausible variant and, importantly, is the scenario tested that is most likely to promote seepage external to the TMF. This two-model approach allows for a reasonable understanding of potential seepage ranges. Furthermore, in response to the recommendation of the GRT, a second sensitivity scenario has been simulated in which the hydraulic conductivity of the tailings is multiplied by 10.

6. Provide the methodology, analysis and model results.

Response:

The numerical modelling methodology, analysis and results have been documented and provided in Golder 2016, Golder 2017 and this memorandum.

7. Based on the results from question 1-6 above, provide a detailed description of the mitigation measures proposed to intercept seepage and contingency plans in the event seepage beneath the TMF would be greater than predicted.

Response:

Mitigation measures and contingency plans are described in Section 3.6.3, 3.6.4, Section 6.5 and Section 7.0 of this memorandum.

8. Describe the residual effects on water quality; the significance of those residual effects based on the Agency's methodology for assessing significance (including the criteria of magnitude, geographic extent, duration, frequency, reversibility, ecological/social/cultural context); and the follow-up program, including any monitoring measures, which will be implemented to evaluate the predictions of effects and the effectiveness of the proposed mitigation.

Response:

Section 6 of this memorandum provides an assessment of residual impacts due to seepage bypass and discharge to the downstream environment. No residual effects have been identified for the Operations, Closure or Post-Closure phases. The follow-up program, mitigation measures and contingency plans are described in Section 6.5 and Section 7.0 and are considered to be sufficient and adequate for the EA stage of the Project.

MEMORANDUM

9.0 CLOSURE

We thank CMC for retaining Golder on this project and look forward to the GRT's review of this current work. If you have any questions, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

<Original signed by>

Adam Auckland, M.Sc., P.Eng.
Water Resources Engineer, Project Manager

Devin Hannan, P.Eng.
Associate, Environmental Engineer

MEMORANDUM

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Attachments:

Figure 1: Tailings Management Facility – General Arrangement Plan and Model Domain
Figure 2: Runoff / Seepage Collection Ditch Typical Cross-Section
Figure 3A: Model Cross Section A-A'
Figure 3B: Model Cross Section B-B'
Figure 3C: Model Cross Section C-C'
Figure 4: Boundary Conditions
Figure 5: Operations Phase: Simulated Water Table and Pathlines from the TMF (Base Case)
Figure 6: Closure Phase: Simulated Tailings Water Levels
Figure 7: Post-closure Phase: Simulated Water Table and Pathlines from the TMF (Base Case)
Figure 8: Model Compartments – Upper Marmion Reservoir
Figure 9: Model Compartments – Lizard Lake

Appendix A: Groundwater Model Flow Budgets

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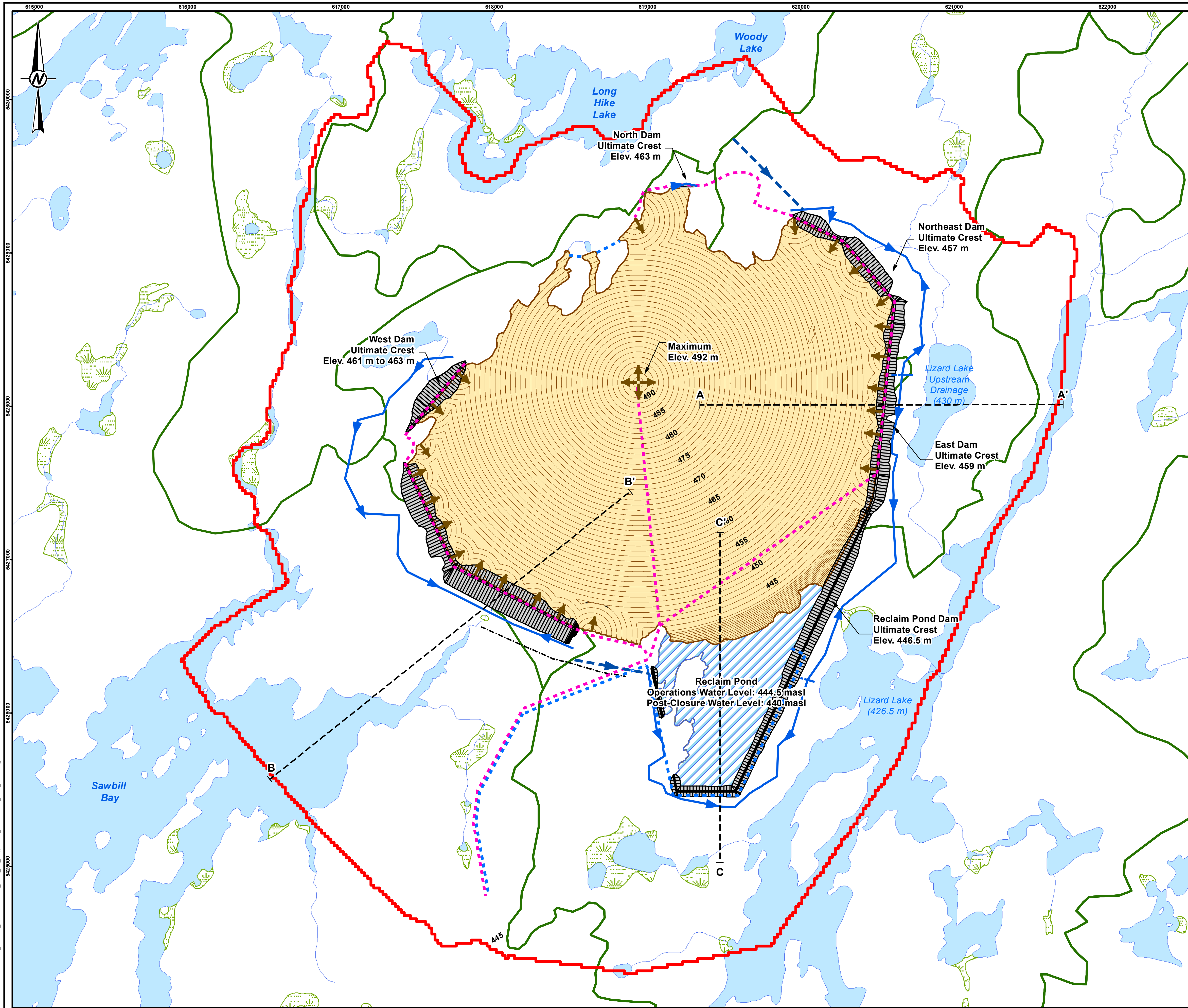
MEMORANDUM

FIGURES



REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
TAILINGS MANAGEMENT FACILITY – GENERAL ARRANGEMENT PLAN AND MODEL DOMAIN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-06-14
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	-

PROJECT NO.	CONTROL	REV.	FIGURE
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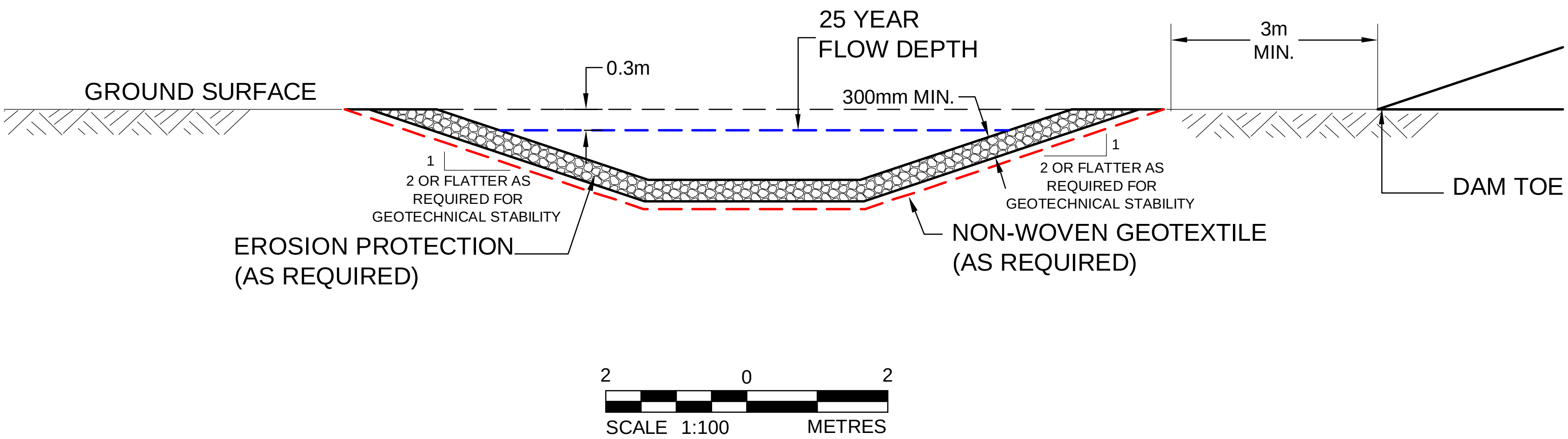

Golder Associates
Mississauga, Ontario, Canada

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CAD	TDR		
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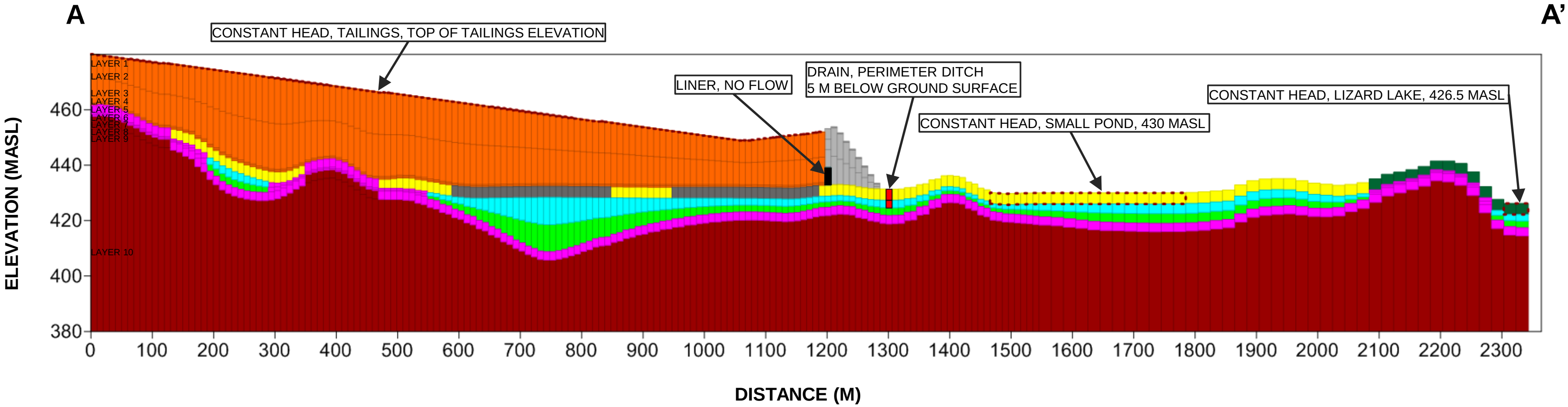

HYDROSTRATIGRAPHIC UNIT SUMMARY

- TAILINGS, K = 6E-7 M/S, Ss = 1E-4 1/M, Sy = 0.42
- DAMS, K = 1E-4 M/S, Ss = 5E-4 1/M, Sy = 0.3
- LINER, NO FLOW
- SURFICIAL SAND, K = 2E-5 M/S, Ss = 5E-4 1/M, Sy = 0.3
- SURFICIAL TILL, K = 5E-6 M/S, Ss = 2E-4 1/M, Sy = 0.16
- SURFICIAL PEAT, K = 1E-5 M/S, Ss = 1E-4 1/M, Sy = 0.44
- WEATHERED BEDROCK, K = 2E-6 M/S, Ss = 5E-6 1/M, Sy = 1E-3
- FINE-GRAINED, K = 3E-7 M/S, Ss = 5E-4 1/M, Sy = 0.20
- COARSE-GRAINED, K = 1E-4 M/S, Ss = 5E-4 1/M, Sy = 0.28
- COMPETENT BEDROCK, K = 2E-7 M/S, Ss = 1E-6 1/M, Sy = 9E-4

NOTES:
-REFER TO FIGURE 1 FOR CROSS-SECTION LOCATION IN PLAN VIEW.

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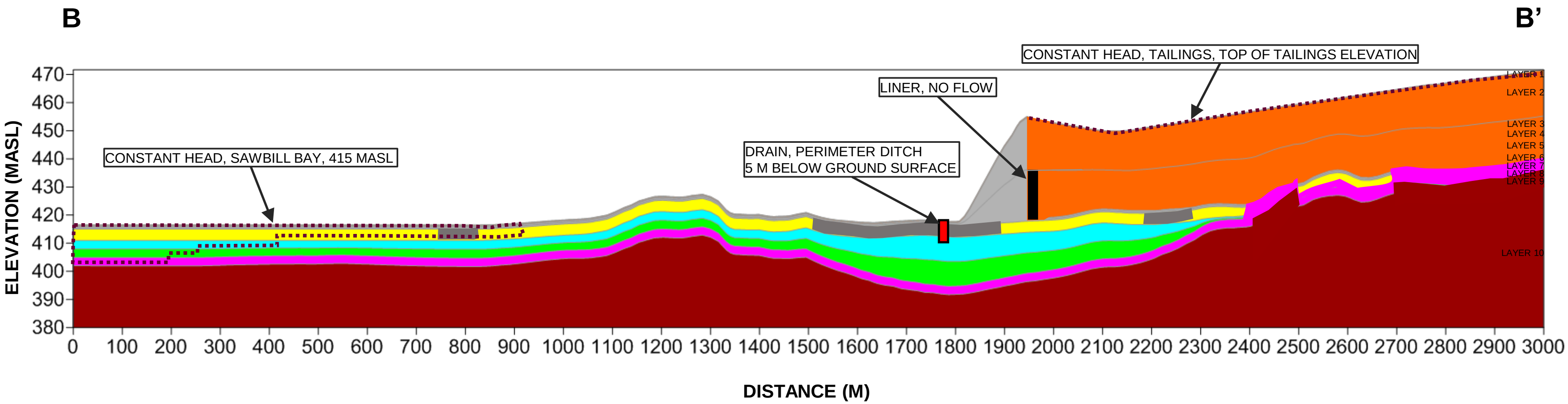
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

MODEL CROSS SECTION A – A'

AUGUST 2017	PROJECT: 1656263	FIGURE 3A



HYDROSTRATIGRAPHIC UNIT SUMMARY

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- SURFICIAL TILL, K = 5E-6 M/S, Ss = 2E-4 1/M, Sy = 0.16
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- COARSE-GRAINED, K = 1E-4 M/S, Ss = 5E-4 1/M, Sy = 0.28
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NOTES:
-REFER TO FIGURE 1 FOR CROSS-SECTION LOCATION IN PLAN VIEW.

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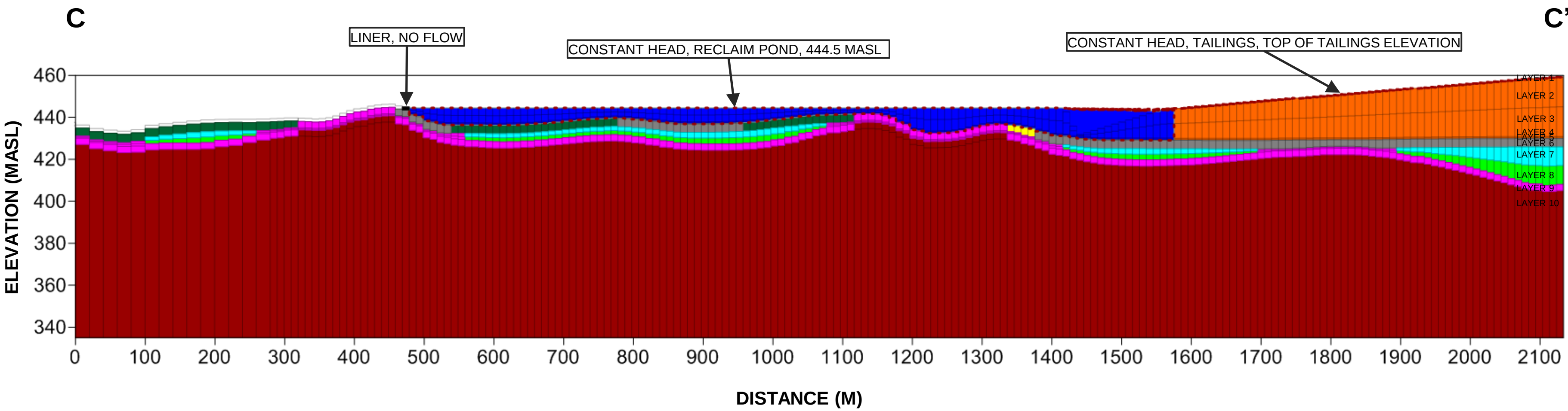
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

OPERATIONS MODEL CROSS SECTION B – B'

AUGUST 2017	PROJECT: 1656263	FIGURE 3B



HYDROSTRATIGRAPHIC UNIT SUMMARY

- RECLAIM POND, K = 0.01 M/S, Ss = 1E-4 1/M, Sy = 0.99
- TAILINGS, K = 6E-7 M/S, Ss = 1E-4 1/M, Sy = 0.42
- DAMS, K = 1E-4 M/S, Ss = 5E-4 1/M, Sy = 0.3
- LINER, NO FLOW
- SURFICIAL SAND, K = 2E-5 M/S, Ss = 5E-4 1/M, Sy = 0.3
- SURFICIAL TILL, K = 5E-6 M/S, Ss = 2E-4 1/M, Sy = 0.16
- SURFICIAL PEAT, K = 1E-5 M/S, Ss = 1E-4 1/M, Sy = 0.44
- WEATHERED BEDROCK, K = 2E-6 M/S, Ss = 5E-6 1/M, Sy = 1E-3
- FINE-GRAINED, K = 3E-7 M/S, Ss = 5E-4 1/M, Sy = 0.20
- COARSE-GRAINED, K = 1E-4 M/S, Ss = 5E-4 1/M, Sy = 0.28
- COMPETENT BEDROCK, K = 2E-7 M/S, Ss = 1E-6 1/M, Sy = 9E-4

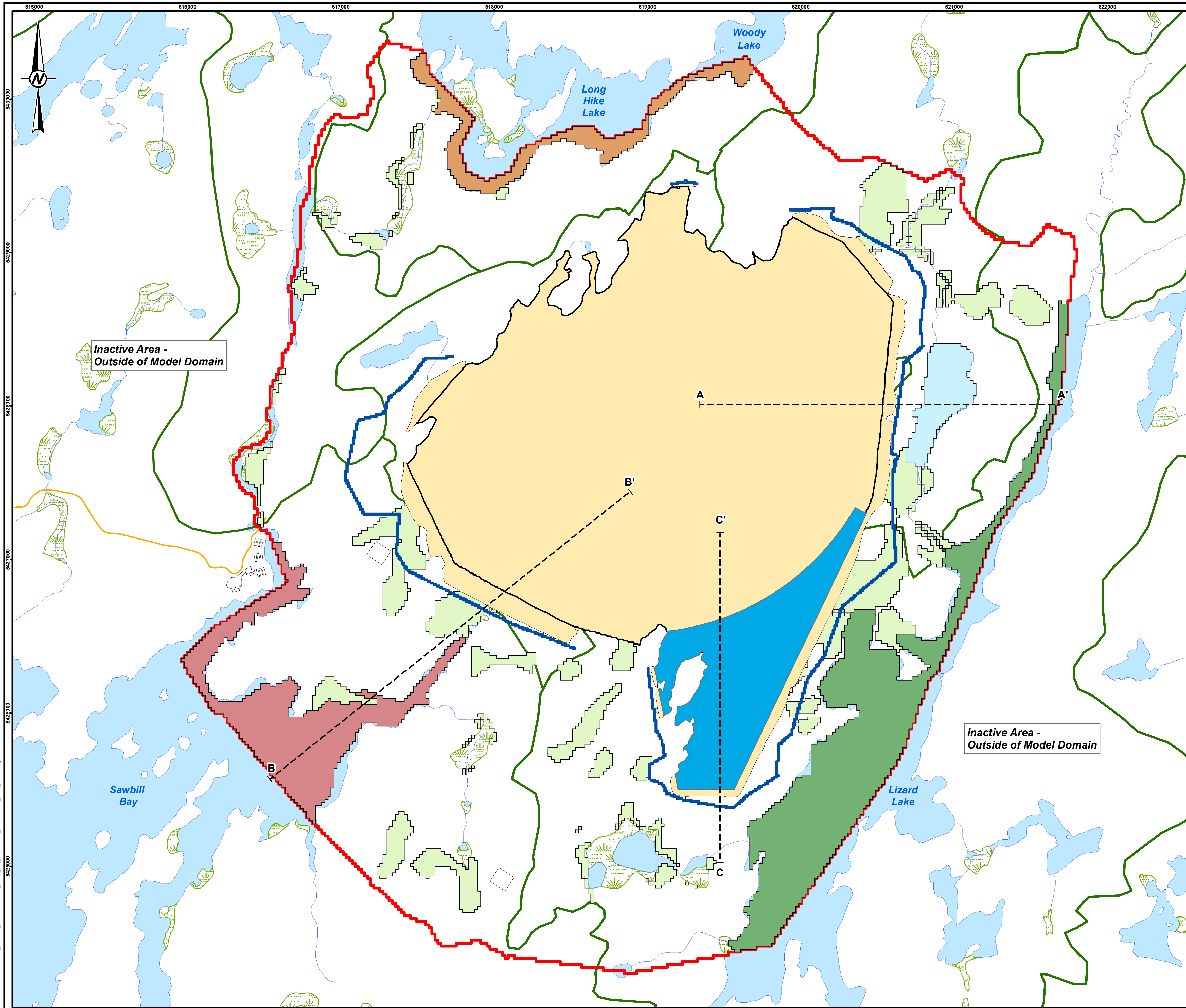
NOTES:
-REFER TO FIGURE 1 FOR CROSS-SECTION LOCATION IN PLAN VIEW.

CANADIAN MALARTIC CORPORATION
HAMMOND REEF GOLD PROJECT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

MODEL CROSS SECTION C – C'

AUGUST 2017	PROJECT: 1656263	FIGURE 3C



LEGEND

- Model Cross-Section
- Access Road (Hardtack / Sawbill)
- River/Stream
- Lake
- Wetland
- Local Watershed Boundary
- Model Domain
- Sawbill Bay – Constant Head – Layers 6 through 9
- Lizard Lake – Constant Head – Layers 6 through 9
- Long Hike Lake – Constant Head – Layers 6 through 8
- North Pond – Constant Head – Layer 6
- Peat – Drain – Layer 6
- Tailings – Constant Head – Layer 1
- Reclaim Pond – Constant Head – Layers 1 through 5
- Seepage Collection Ditch – Drain – Layers 6 through 9

0 500 1,000
1:25,000 Metres

NOTE(S)

1. OPERATIONS PHASE MODEL SHOWN FOR ILLUSTRATION.
2. TAILINGS CONSTANT HEAD ELEVATION SET AT TAILINGS SURFACE ELEVATION. CONSTANT HEAD CELLS ONLY PRESENT DURING OPERATIONS AND REMOVED DURING CLOSURE / POST-CLOSURE.
3. RECLAIM POND CONSTANT HEAD ELEVATION SET AT 444.5 masl DURING OPERATIONS / CLOSURE AND 440 masl DURING POST-CLOSURE.
4. SEEPAGE COLLECTION DITCH DRAIN ELEVATION SET AT GROUND SURFACE MINUS 5 m.
5. EXTERNAL TO THE TAILINGS AND RECLAIM POND CELLS ARE INACTIVE IN LAYERS 1 THROUGH 5. THE FIRST INSTANCE OF ACTIVE CELLS EXTERNAL TO THE TAILINGS AND RECLAIM POND OCCURS IN LAYER 6.

REFERENCE(S)

1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

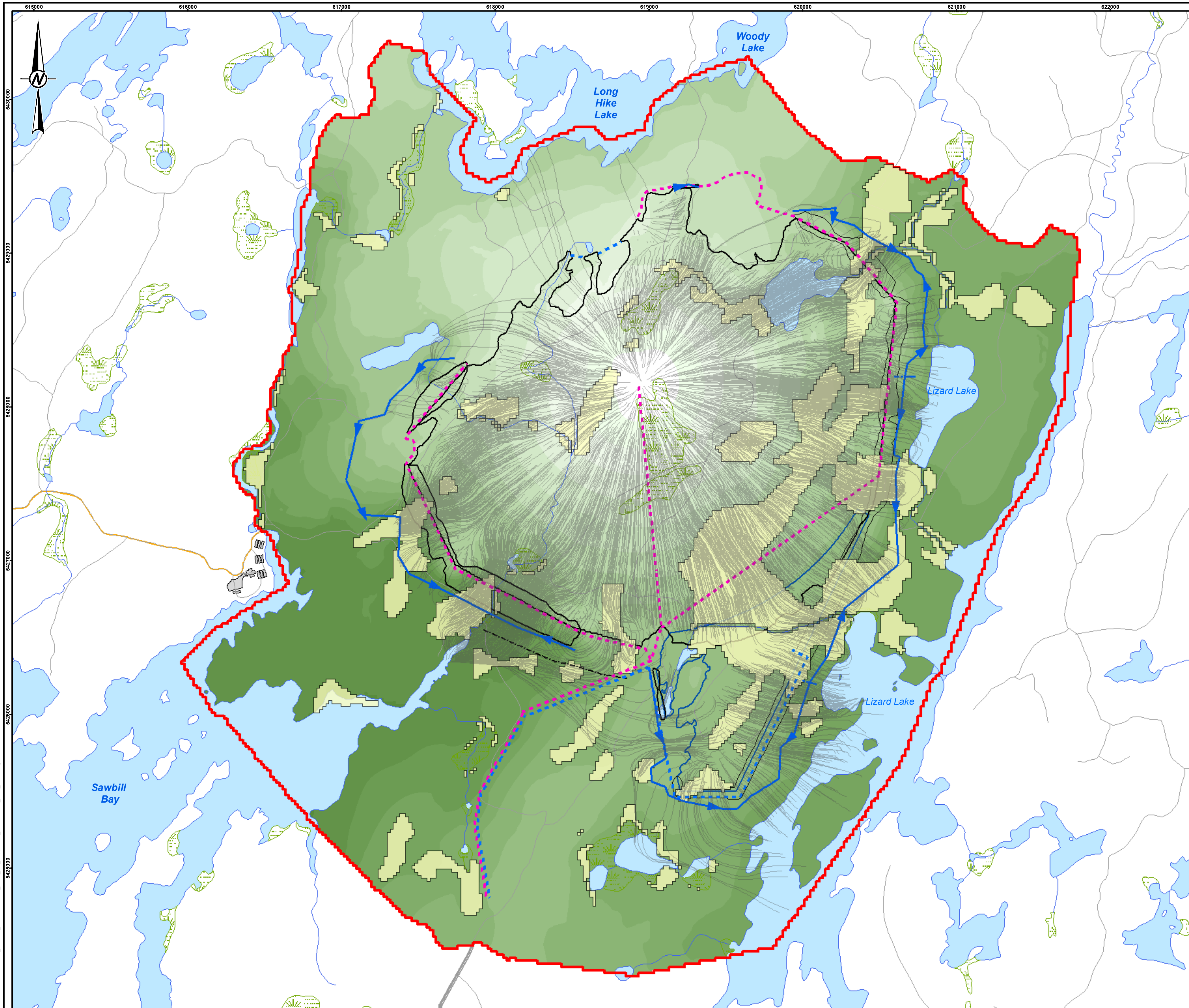
TITLE
BOUNDARY CONDITIONS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-08-18
DESIGNED	SO
PREPARED	PR
REVIEWED	DH
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0005	0.0	4



LEGEND

- Road
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- River/Stream
- Reclaim Pipeline
- Spillway Channel
- Tailings Pipeline
- Pit Spillover Point
- Pathline
- Lake
- Wetland
- Proposed Reclaim Pond
- Model Domain
- Peat – Drain Boundary Condition

Base Case Operations Water Level (m)

- 410 - 415
- 415 - 420
- 420 - 425
- 425 - 430
- 430 - 435
- 435 - 440
- 440 - 445
- 445 - 450
- 450 - 455
- 455 - 460
- 460 - 465
- 465 - 470
- 470 - 475
- 475 - 480
- 480 - 485
- 485 - 490

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
OPERATIONS PHASE: SIMULATED WATER TABLE AND PATHLINES FROM THE TMF (BASE CASE)

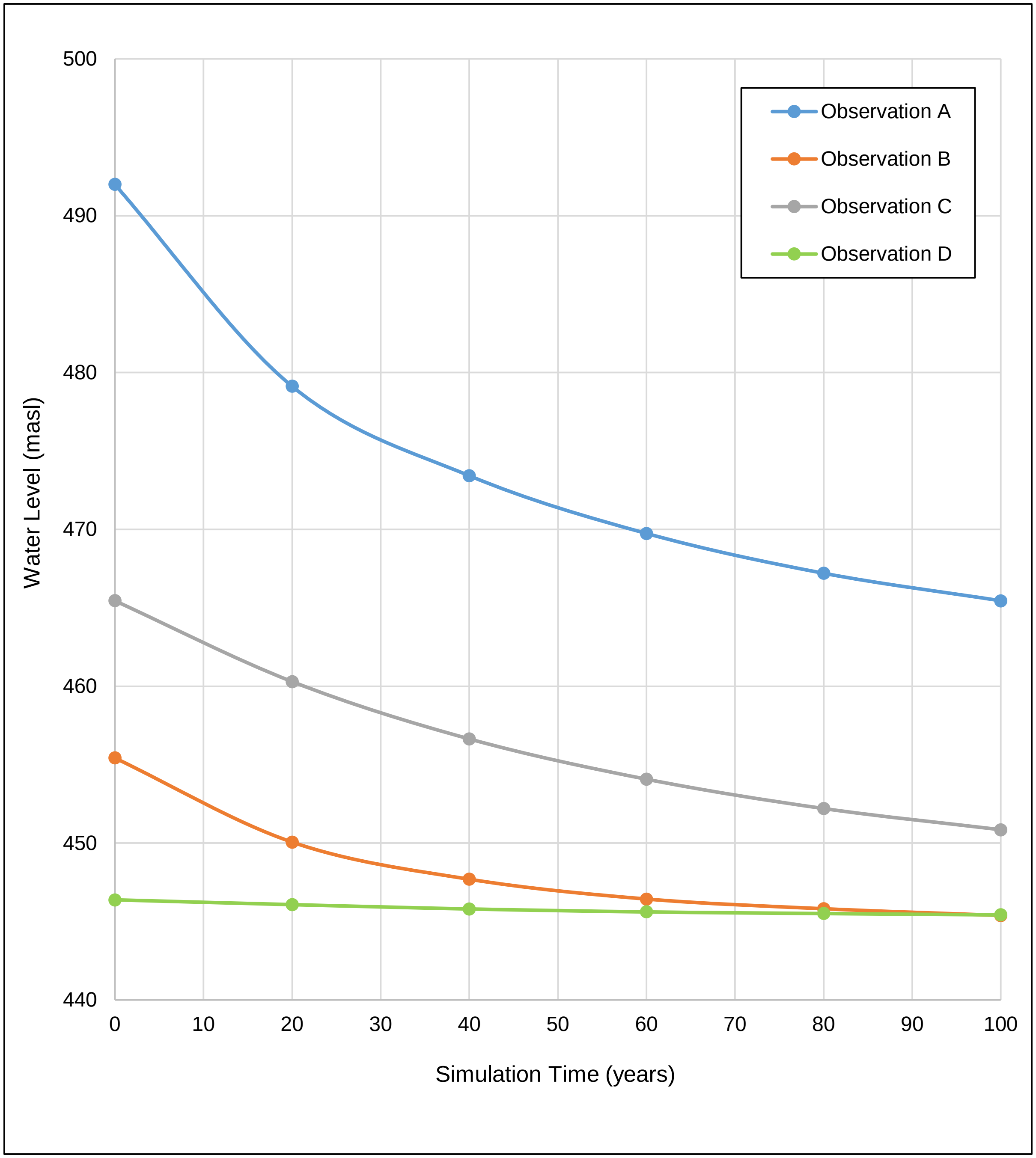
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-08-14
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	-

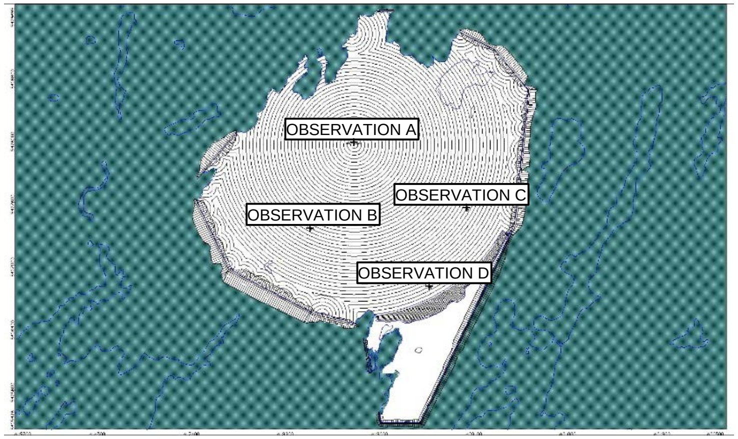
PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0005	0.0	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

Panel A: Simulated Water Levels



Panel B: Observation Locations

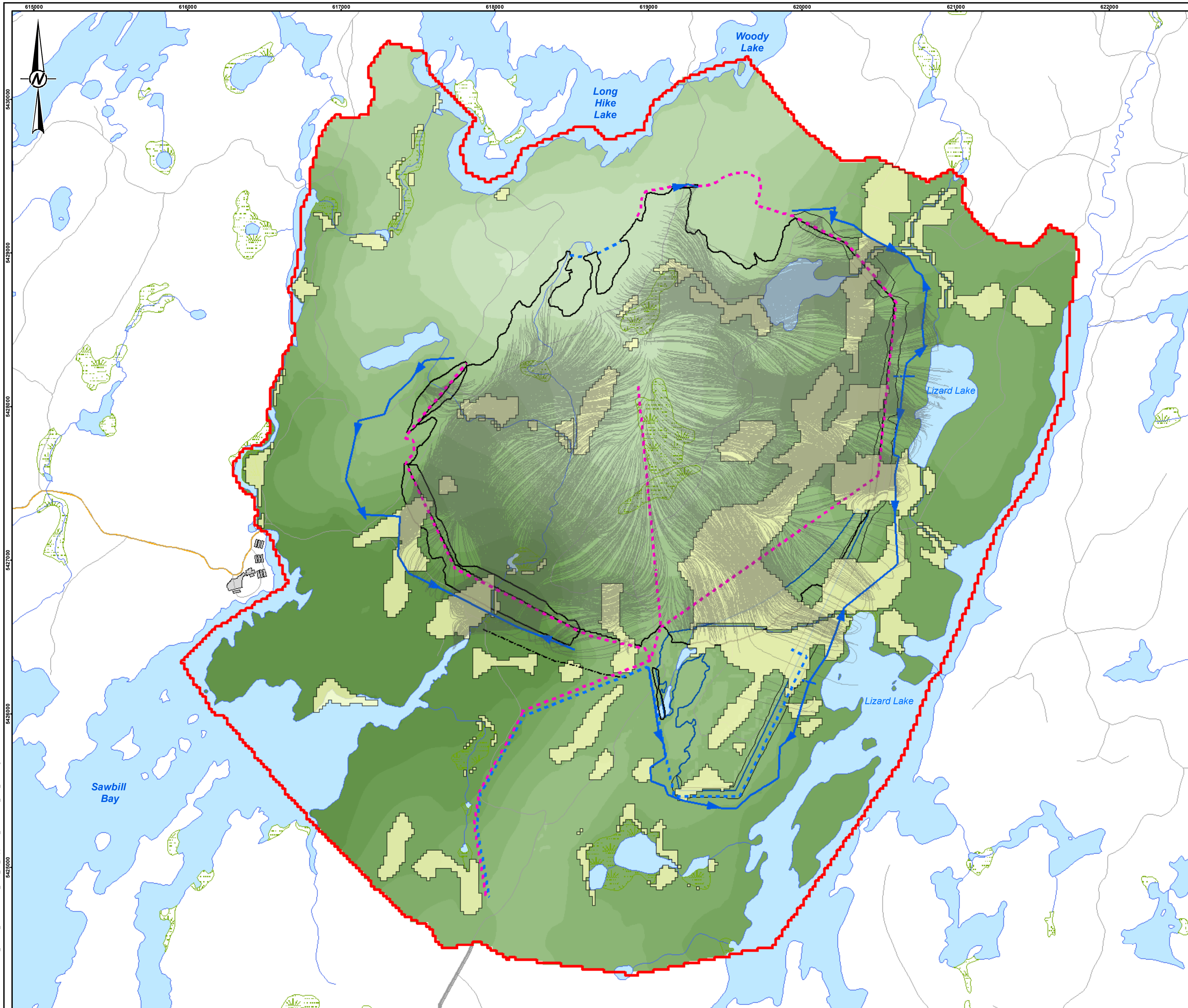


PROJECT
CANADIAN MALARTIC CORPORATION
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
CLOSURE PHASE:
SIMULATED TAILINGS WATER LEVELS

Golder Associates

PROJECT No.		1656263	FILE No. ----
DESIGN	AM	16-JUN-17	SCALE NTS REV.
CADD	AM	16-JUN-17	**FIGURE 6**
CHECK	DH	16-JUN-17	
REVIEW			



LEGEND

- Road
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- River/Stream
- Reclaim Pipeline
- Spillway Channel
- Tailings Pipeline
- Pit Spillover Point
- Pathline
- Lake
- Wetland
- Tailings Management Facility
- Proposed Reclaim Pond
- Model Domain
- Peat – Drain Boundary Condition

Base Case Post-Closure Water Level (m)

- 410 - 415
- 415 - 420
- 420 - 425
- 425 - 430
- 430 - 435
- 435 - 440
- 440 - 445
- 445 - 450
- 450 - 455
- 455 - 460
- 460 - 465
- 465 - 470

0 500 1,000
1:25,000 Metres

REFERENCE(S)
1. BASE DATA - PROVIDED BY OSISKO HAMMOND REEF GOLD PROJECT LTD.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 15N

CLIENT
CANADIAN MALARTIC CORPORATION

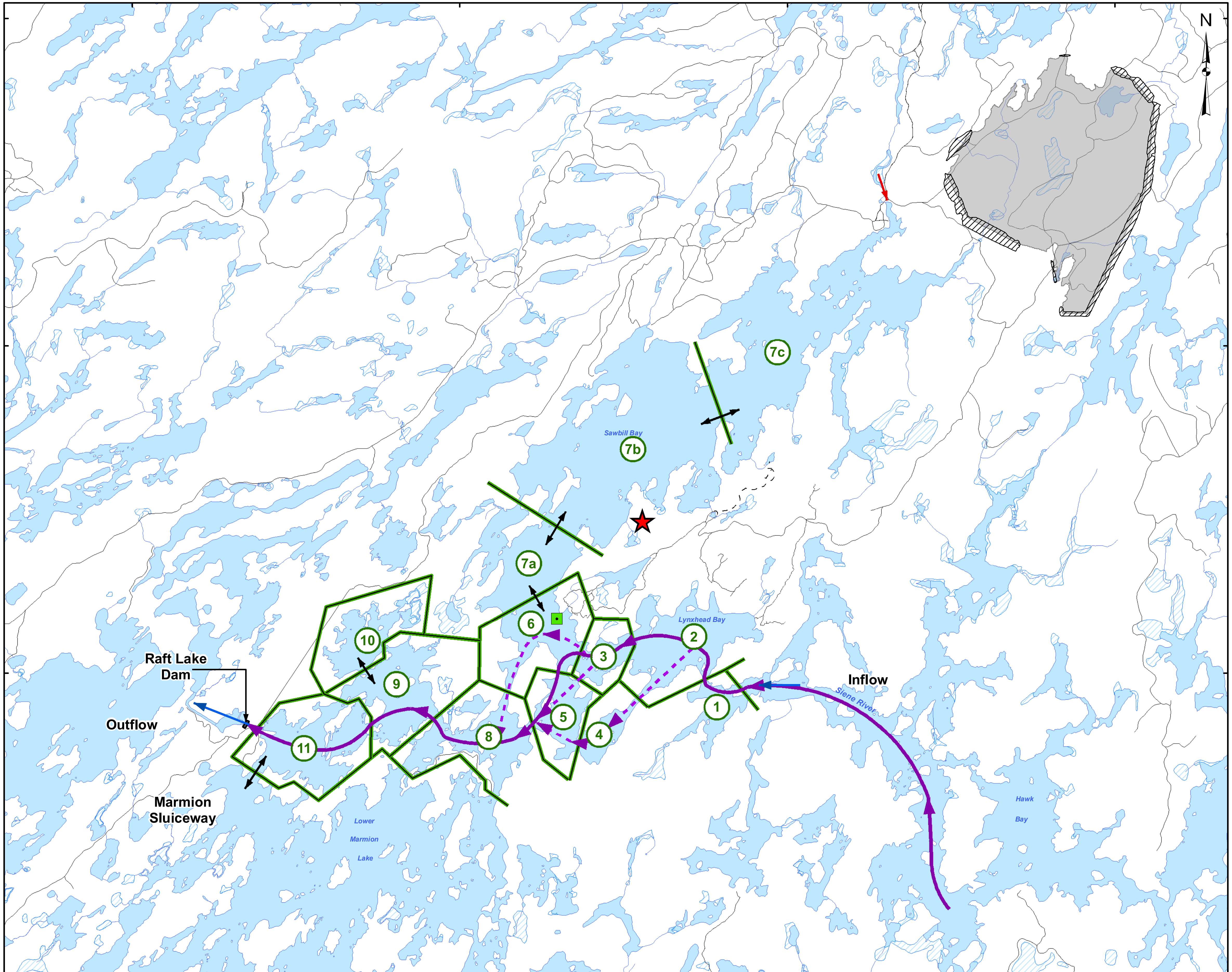
PROJECT
TAILINGS MANAGEMENT FACILITY MODELLING

TITLE
POST-CLOSURE PHASE: SIMULATED WATER TABLE AND PATHLINES FROM THE TMF (BASE CASE)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-08-14
DESIGNED	SO
PREPARED	SO/PR
REVIEWED	DH
APPROVED	-

PROJECT NO.	CONTROL	REV.	FIGURE
1656263	0005	0.0	7



LEGEND

- Discharge Location
- Main River Flow
- Secondary Flow Path
- Water Level Drive Exchange Flow
- Major Tributaries
- Road
- River/Stream
- Lake
- Wetland
- Model Compartment
- Tailings Management Facility
- Tailings Management Facility Dam

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

500 0 500 1,000 1,500 2,000
SCALE 1:60,000 METRES

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

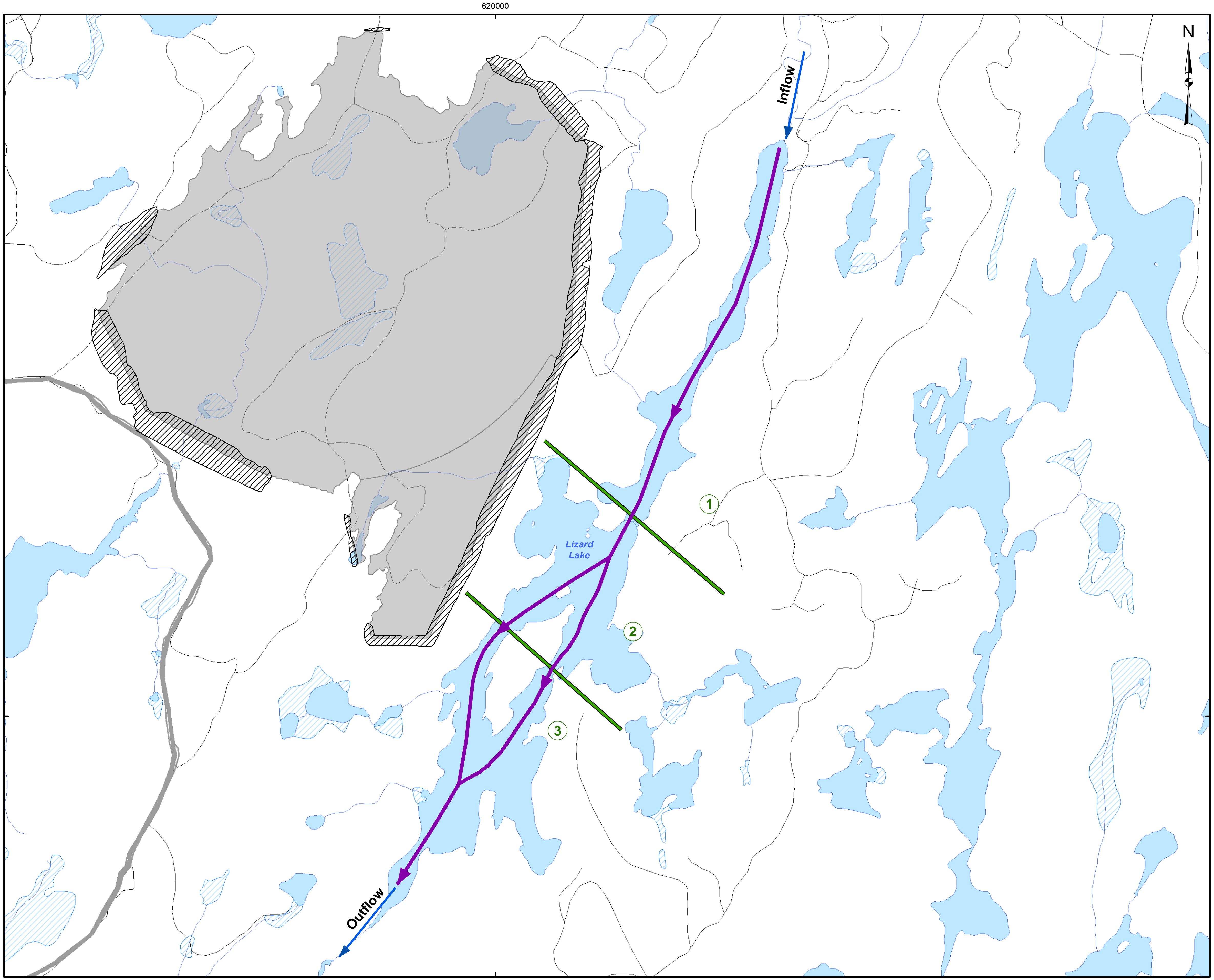
MODEL COMPARTMENTS
UPPER MARMION RESERVOIR

PROJECT NO. 1656263			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO/PR	16 Jun. 2017		
CHECK	AA	16 Jun. 2017		
REVIEW	AA	16 Jun. 2017		

Golder Associates
Mississauga, Ontario

FIGURE: 8

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\LakeWaterQuality\1656263_TMF_Modelling\ModelCompartments_UpperMarmionReservoir.mxd



LEGEND

- Main River Flow
- Model Compartment Boundary
- Road
- River/Stream
- Lake
- Wetland
- Tailings Management Facility
- Tailings Management Facility Dam

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

500 0 500 1,000
SCALE 1:25,000 METRES

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

MODEL COMPARTMENTS
LIZARD LAKE

Golder Associates
Mississauga, Ontario

PROJECT NO. 1656263			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	**FIGURE: 9**	
GIS	JO/PR	16 Jun. 2017		
CHECK	AA	16 Jun. 2017		
REVIEW	AA	16 Jun. 2017		

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\LakeWaterQuality\1656263_TMF_Modelling\ModelCompartments_LizardLake.mxd

APPENDIX A

TABLE A1
Groundwater Model Flow Budgets

	Feature	Boundary Type	Operations (Base Case)			Post-Closure (Base Case)			Operations (Sensitivity Scenario 1)			Operations (Sensitivity Scenario 2)		
			In (m^3/d)	Out (m^3/d)	Net (m^3/d)	In (m^3/d)	Out (m^3/d)	Net (m^3/d)	In (m^3/d)	Out (m^3/d)	Net (m^3/d)	In (m^3/d)	Out (m^3/d)	Net (m^3/d)
Internal to TMF	Tailings	Constant Head	12,778	2,669	10,109	0	0	0	32,481	1,943	30,538	32,549	12,222	20,327
	Tailings	Recharge	-	-	-	1,450	0	1,450	0	0	0	0	0	0
	Reclaim Pond	Constant Head	10,893	601	10,292	7,418	173	7,245	32,626	1,617	31,009	10,982	653	10,329
	Dams	Recharge	272	0	272	272	0	272	272	0	272	272	0	272
	Collection Ditches	Drain	0	19,978	-19,978	0	9,650	-9,650	0	58,450	-58,450	0	28,590	-28,590
External to TMF	Recharge External to TMF	Recharge	3,345	0	3,345	3,351	0	3,351	3,345	0	3,345	3,345	0	3,345
	Sawbill Bay	Constant Head	9	790	-781	9	654	-645	15	1,660	-1,645	9	879	-871
	Sawbill Bay Drainages	Drain	0	1,500	-1,500	0	701	-701	0	2,794	-2,794	0	2,534	-2,534
	Lizard Lake/Small Pond	Constant Head	51	593	-542	48	533	-485	371	1,372	-1,001	35	652	-617
	Lizard Lake Drainages	Drain	0	564	-564	0	256	-256	0	587	-587	0	1,007	-1,007
	Long Hike Lake	Constant Head	184	301	-117	183	246	-63	1,305	269	1,036	184	302	-118
	Long Hike Lake Drainages	Drain	0	536	-536	0	530	-530	0	1,722	-1,722	0	536	-536
		Total:	***27,532***	***27,532***	***0***	***12,731***	***12,743***	***-12***	***70,415***	***70,414***	***1***	***47,375***	***47,376***	***-1***
		Global Flow Budget Discrepancy (%):	***-0.002***			***-0.093***			***0.001***			***-0.002***		

Note:

1. "Drainages" include upstream feeder creeks, ponds, wetlands and peat areas.

PART H

CEAA and MOECC Comments on Groundwater Modelling of TMF and Seepage Impact Assessment

Canadian Environmental Assessment Agency
Agence canadienne d'évaluation environnementale

Ontario Regional Office
55 St. Clair Avenue East,
Room 907
Toronto, ON M4T 1M2

Bureau régional de l'Ontario
55, avenue St-Clair est,
bureau 907
Toronto (Ontario) M4T 1M2

November 8, 2017

ELECTRONIC MAIL

Ms. Sandra Pouliot, ing.
Environment Project Leader
Canadian Malartic Corporation
100, chemin du Lac Mourier
Malartic, QC J0Y 1Z0

SUBJECT: Federal Comments on the August 18, 2017 Technical Memorandum to address Information Request T(3)-08 of the Federal Environmental Assessment

Dear Ms. Pouliot:

The Federal Review Team (FRT) has reviewed the August 18, 2017 technical memorandum entitled "Groundwater Modelling of Tailings Management Facility and Seepage Impact Assessment" (the Stage Two Report). The review findings are summarized in the attachment to this letter.

The FRT agrees to close Information Request T(3)-08, provided the Commitments Registry indicates that Canadian Malartic Corporation would:

- Implement the proposed mitigation and contingency measures described in the Stage Two Report to ensure compliance with federal guidelines or provincial objectives to protect aquatic life, as applicable;
- Collect baseline data on Long Hike Lake (water and sediment quality, fish and fish habitat, and hydrology data) for inclusion in a comprehensive, aquatic effects monitoring plan that includes all receiving waterbodies (Upper Marmion Reservoir, Lizard Lake and Long Hike Lake); and
- Submit the comprehensive aquatic effects monitoring plan reports in accordance with the requirements of the federal environmental assessment follow up and monitoring program.

Please contact me at (647) 262-8051 or HammondReef@ceaa-acee.gc.ca if you have questions about this letter or the attached review findings.

Sincerely,
<Original signed by>

Loraine Cox
Project Manager

Attachment: Results from the Federal Review of the August 18, 2017 Technical Memorandum (two pages)

cc. Sheryl Lusk, Environment and Climate Change Canada
Angelique Magee, Natural Resources Canada
Sasha McLeod, Ministry of the Environment and Climate Change

Attachment: Results from the Federal Review of the August 18, 2017 Technical Memorandum

Comments 1 to 5 (Groundwater Modeling Report)
[Linked to IR T(3)-08, Parts 1 through 6]
The Federal Review Team (FRT) notes that the Stage Two Report, which includes the August 18, 2017 technical memorandum, documents the groundwater modeling and provides the requested clarifications.

Conclusion: The FRT is satisfied with the groundwater modeling as documented in the Stage Two Report.

Comments 6a and 6b (Surface Water Quality Mitigation and Contingency Measures)
[Linked to IR T(3)-08, Parts 7 and 8]
The modeling results indicate that copper concentrations could exceed both the federal guideline and the provincial objective to protect aquatic life. However, the FRT notes that Canadian Malartic Corporation (CMC) has committed to implement mitigation (i.e., seepage collection ditches). CMC has also committed to ensure water quality in Upper Marmion Reservoir, Lizard Lake and Long Hike Lake would comply with federal guidelines or provincial objectives, where applicable, through implementation of contingency measures (e.g., deepening and extending collection ditches, using active pumping wells, and modifying mill processes and water treatment measures), as necessary.

Conclusion: Based on the groundwater modeling results, the FRT is satisfied that the proposed mitigation and contingency measures are appropriate. The FRT expects CMC to include a commitment to implementing these mitigation and contingency measures as appropriate in the Commitments Registry.

Comment 7 (Effects on Long Hike Lake)
[Linked to IR T(3)-08, Part 8]
The FRT notes that CMC would monitor water quality in Long Hike Lake and take corrective action to ensure compliance with federal or provincial water quality requirements, as applicable. Further, CMC indicated that implementation of mitigation and contingency measures would not affect access to Long Hike Lake for use by Indigenous peoples or the public.

Conclusion: The FRT expects CMC to include commitments within the Commitments Registry to collect baseline data (water and sediment quality, fish and fish habitat, as well as hydrology data) for Long Hike Lake and monitor water quality within all potential receiving waterbodies (i.e., Upper Marmion Reservoir, Lizard Lake, and Long Hike Lake) as part of a comprehensive, aquatic effects monitoring plan to ensure the water quality within the waterbodies remain protective of aquatic life. A commitment to submit aquatic effects monitoring plan reports in accordance with the requirements of the federal environmental assessment follow up monitoring program is also required.

Comment 8 (Monitoring)
[Linked to IR T(3)-08, Part 8]
As requested, CMC committed to include all parameters listed in Tables 6 through 13 in the water quality monitoring program, and indicated the commitment would be added to the Commitments Registry.

Conclusion: The FRT is satisfied with this response to Comment 8.

Comment 9 (Unclear References within the Report)
[Linked to IR T(3)-08, Part 6]
As requested, CMC made the corrections to the references for the updated, August 18, 2017 technical memorandum.

Conclusion: The FRT is satisfied with this response to Comment 9.

Ministry of the Environment and Climate Change

199 Larch Street
Suite 1201
Sudbury ON P3E 5P9
Tel.: (705) 564-3060
Fax: (705) 564-4180

Ministère de l'Environnement et de l'Action en matière de changement climatique

199, rue Larch
Bureau 1201
Sudbury ON P3E 5P9
Tél. : (705) 564-3060
Téléc.: (705) 564-4180

October 20, 2017

M E M O R A N D U M

TO: Sasha McLeod
Special Project Officer
Environmental Approvals Branch

FROM: Debra Abbott
Hydrogeologist
Technical Support, Northern Region

RE: Hammond Reef Gold Project, Groundwater Modelling of TMF and Seepage Impact Assessment, Atikokan, Ontario

As requested, I have reviewed the report *Hammond Reef Gold Project: Groundwater Modelling of Tailings Management Facility and Seepage Impact Assessment,* dated August 18, 2017, prepared by Golder Associates. I understand that this report was produced in response to comments from federal reviewers regarding the seepage potential from the proposed tailings management facility (TMF). The previous MOECC reviewer had identified shortcomings with the previous model, but had accepted that these could be addressed in future permitting.

The current model builds on the previous model that was developed for baseline conditions at the site, adding the TMF; thus, addressing the question of quantity and fate of the seepage from the TMF expected during operations and closure. This review focussed only on the TMF modelling and no review of the baseline model was undertaken.

The updated modelling indicates that the majority of the seepage from the TMF will be captured by the planned seepage collection ditches. The seepage that escapes is shown to report to Lizard Lake, Marmion Reservoir and Long Hike Lake. Seepage capture of 94% is modelled, which is integral to the impact assessment to the three lakes. This capture rate is very high and the final design of the collection trenches will need to meet this capture efficiency to mitigate adverse effects to the three receiving lakes. Monitoring and contingency measures are discussed and are acceptable at this stage.

I am satisfied with the updated groundwater modelling report. Additional field investigations and design work will be required to support future permitting. Modifications to the seepage collection system may be required should geological conditions be found to be different than modelled. I concur with the previous MOECC hydrogeological reviewer that the seepage and loading rates reported in the EA should be considered as commitments that could be recognized as limits in the future ECA. Monitoring of the groundwater between the seepage collection system and the lakes, as described in this memorandum, will be required by the ECA to demonstrate seepage capture and determine the quality and estimate the quantity of the seepage that bypasses the collection system. Failure of the collection system to meet required performance will necessitate contingency measures to be implemented.

If you require further information or clarification, or if you wish to discuss any of these comments, please do not hesitate to contact me.

<Original signed by>

D.E. Abbott, M.Sc., P.Geo.

cc GW RR no township 05 05 Hammond Reef Gold EA
(U\ABBOTTDE\Debra\REVIEWS\Mines|Hammond Reef EA TMF modelling.doc)

Ministry of the Environment and Climate Change

435 James Street South
Suite 331
Thunder Bay ON P7E 6S7
Tel.: (807) 475-1794
Fax: (807) 475-1754

Ministère de l'Environnement et de l'Action en matière de changement climatique

435, rue James sud
Bureau 331
Thunder Bay ON P7E 6S7
Tél. : (807) 475-1794
Téléc.: (807) 475-1754

October 20, 2017

M E M O R A N D U M

TO: Sasha McLeod
Special Project Officer
Environmental Approvals Branch

FROM: Amy Godwin
Surface Water Specialist
Technical Support, Northern Region

RE: Hammond Reef Gold Project: Updated TMF Groundwater Modelling and Seepage Assessment, Atikokan, Ontario

INTRODUCTION

As requested, I have reviewed the surface water related sections of the memo prepared by Golder Associates entitled *Hammond Reef Gold Project: Groundwater modelling of tailings management facility and seepage impact assessment*, dated August 18, 2017.

The purpose of my review was to assess the potential affects to surface water features in consideration of the new seepage and groundwater modelling results presented in the memo. The adequacy of the models used and the confidence in the model results is beyond the scope of my review.

DISCUSSION

The report indicates that water quality in Marmion Reservoir and Lizard Lake was evaluated using the lake-wide mixing models (i.e. boxmodel) which were developed and presented in the Lake Water Quality TSD. Baseline values used as model inputs were calculated using the average of the baseline data Operational period TMF seepage model input values and mine effluent discharge input values were based on steady-state (average) water quality predictions. MOECC guidance recommends that 75^{th} percentile values be used for water quality modelling, rather than average values since average values may underestimate potential impacts. The use of 75^{th} percentile water quality values provides a more conservative approach to predicting effects.

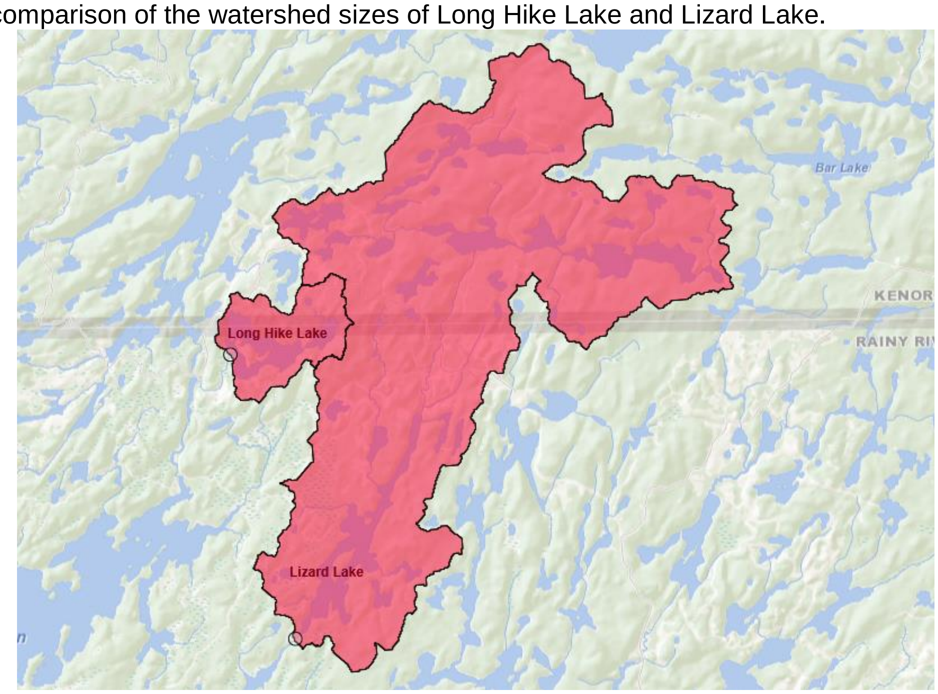
Baseline water quality data was not available for Long Hike Lake. To assess potential mixed concentrations in Long Hike Lake, a hydrologic assessment was completed to estimate the mean annual natural outflow from the lake, though no details were provided. Baseline water quality in Lizard Lake was assumed to be representative of water quality in Long Hike Lake. The proponent suggests that this assumption was considered reasonable because both Lizard Lake and Long Hike Lake are naturally occurring lakes, are of similar size and are located within the same geologic setting. This cannot be confirmed without collecting baseline data for Long Hike

Lake. To further confound these assumptions, the two lakes have quite different watershed characteristics, as shown in table 1 and figure 1 below.

Table 1: Watershed characteristics for Long Hike Lake and Lizard Lake determined with the Ontario Flow Assessment Tool.

Watershed Characteristic	Long Hike Lake	Lizard Lake
Drainage Area (km²)	5.034	61.364
Shape Factor ()	7.632	11.258
Length of Main Channel (km)	6.198	26.286
Area Lakes/Wetlands (km²)	1.247	8.597
Area - Lakes (km²)	1.21	7.851
Area - Wetlands (km²)	0.037	0.746

Figure 1: A comparison of the watershed sizes of Long Hike Lake and Lizard Lake.



The report indicates that water quality in the downstream receivers was assessed by mixing the seepage predicted to bypass the collection system (i.e., the remaining 6% or less that flows beneath the collection ditches) with the receiving water bodies. While the regional hydrogeologist can comment on this, this appears to be a very optimistic estimate of seepage collection and losses. Should this not be achievable and seepage losses actually are greater than 6%, then potential loadings to downstream receivers could be greater than predicted.

Additionally, in table 13 or the report, sulphate concentrations in Long Hike Lake are predicted to increase to 15mg/L, assuming seepage losses to the lake of only 6% (and based on Lizard Lake baseline water quality). This concentration is actually within the range of sulphate concentrations shown to increase mercury methylation rates (10-20mg/L) given the right conditions, and is a concern to the ministry.

As well, the copper concentration presented in this table is predicted to exceed the CCME and PWQO values using the current modelling inputs; copper could be even more elevated should seepage losses be underestimated.

The report indicates that the water quality assessment for Long Hike Lake considered only average conditions and assumed full mixing within the lake, due to the limited data available. It is not clear if this adequately predicts potential impacts to the lake. There is a high level of uncertainty due to the various assumptions being made.

The report continues to reference site specific water quality objectives (SSWQO) which have been discussed previously and will not be considered in this situation.

Table 13 of the report does not include the proper coding as described in the notes below the table. The predicted copper concentration in Long Hike Lake exceeds the CCME CWQG and the PWQO value; the value should be bold and underlined in the table to highlight this expected exceedance of federal and provincial guidelines.

RECOMMENDATIONS

It is recommended that the baseline condition of Long Hike Lake be characterized in terms of water quality, sediment quality, fish, and benthic community prior to any development at the site. Water quality data that is representative of the lake should be used as inputs for water quality modelling to determine potential impacts to the lake due to seepage effects. It is recommended that 75th percentile water quality values be used for modelling as these provide a more conservative approach to predicting effects than the use of average values.

Seepage loss estimates should be based on robust hydrogeological data; the current seepage collection estimates appear to be feasibly unachievable.

Like the other lakes anticipated to be impacted by the development of the proposed mine, a comprehensive monitoring program should be developed for Long Hike Lake to monitor and assess the potential impacts to the lake due to groundwater seepage from the nearby TMF associated with the mine. Trigger values should be established for the receivers and mitigation measures should be developed and employed should monitoring reveal impacts greater than those predicted through modelling. Groundwater wells should be established in order to monitor the seepage quality and quantity in order to confirm the commitments made in the EA in regards to seepage collection are being met.

CLOSURE

If you have any questions regarding the above comments and recommendations, do not hesitate to contact me. The purpose of the preceding review is to provide advice to the Ministry of the Environment and Climate Change about the response provided by CMC/Golder regarding the need for additional groundwater modelling and seepage assessment. The conclusions, opinions and recommendations of the reviewer are based on information provided by others, except where otherwise specifically noted. The ministry cannot guarantee that the information that has been provided by others is accurate or complete. A lack of specific comment by the reviewer is not to be construed as endorsing the content or views expressed in the reviewed material.

<Original signed by>

Amy Godwin
Surface Water Specialist
Technical Support Section, Northern Region

c.c. Todd Kondrat, Surface Water Specialist – Group Leader, Northern Region, Technical Support Section
Carrie Hutchison – A/Water Resources Supervisor, Northern Region, Technical Support Section
Debra Abbott, Hydrogeologist – Ground Water Group Leader, Northern Region, Technical Support Section
Adam Wright, Special Project Officer, Environmental Approvals Branch

PART I

CMC Response Letters to CEAA and MOECC

CANADIAN MALARTIC CORPORATION

November 17th, 2017

Loraine Cox
Project Manager, Ontario Regional Office
Canadian Environmental Assessment Agency / Government of Canada

Subject: Response to Federal Comment on the August 18, 2017 Technical Memorandum to address Information Request T(3)-08 of the Federal Environmental Assessment – Hammond Reef Gold Project

Dear Mrs Cox,

CMC has received comments from the Federal Review Team (FRT) on the response to Information Request T(3)-08 in the form of the November 8, 2017 letter from the Canadian Environmental Assessment Agency (CEAA) entitled '*Federal Comments of the August 18, 2017 Technical Memorandum to address Information Request T(3)-08 of the Federal Environment Assessment*'. The FRT indicated in their letter that the response is sufficient to close the information request, with the condition that additional commitments be added to the Commitments Registry for the Project.

In response, CMC will add the following commitments to the Commitments Registry:

- Implement mitigation measures to capture seepage emanating from the TMF as described in the *Technical Memorandum: Groundwater Modelling of Tailings Management Facility and Seepage Impact Assessment*, dated August 18, 2017 as necessary to mitigate adverse impact to water quality and aquatic health. Appropriate contingency measures, as described in the above referenced memo, will be implemented if it is determined through monitoring that water quality in Upper Marmion Reservoir, Lizard Lake or Long Hike Lake is projected to consistently exceed appropriate guidelines/objectives for the protection of aquatic life as a result of TMF seepage bypass. Appropriate guidelines/objectives include federal guidelines (CCME), provincial objectives (PWQO) or Site Specific Water Quality Objectives (SSWQO) where it can be demonstrated that the SSWQO are protective of aquatic life.
- Prior to the operations phase, collect baseline data on Long Hike Lake, including water and sediment quality, fish and fish habitat, benthic community, and hydrology data for inclusion in a comprehensive aquatic effects monitoring plan that includes all receiving waterbodies (Upper Marmion Reservoir, Lizard Lake or Long Hike Lake).

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- Submit the comprehensive aquatic effects monitoring plan reports in accordance with the requirements of the federal environmental assessment follow up and monitoring program.

With these commitments, CMC now considers this information request closed. This response and the above referenced letter from CEAA will be incorporated into the T(3)-08 response document package. The updated T(3)-08 response document package and Commitments Registry will be submitted as part of the Version 3 Amended EIS/EA Report.

If you have any questions or comments on the above matter, do not hesitate to contact me by email or at (819) 856-9866.

Regards,

<Original signed by>

Sandra Pouliot
Environment specialist
Canadian Malartic Corporation
spouliot@canadianmalartic.com

c. Pascal Lavoie, CMC Director Environment and Sustainability

CANADIAN MALARTIC CORPORATION

November 17th, 2017 (Email only)

Sasha McLeod
Project Officer, Environmental Approvals Branch
Ministry of the Environment and Climate Change

Subject: Response to Comments received on the Groundwater Modelling of the TMF and Seepage Impact Assessment - Hammond Reef Gold Mine Project

Dear Ms. McLeod,

CMC has received two letters from the Ontario Ministry of Environment and Climate Change (MOECC) regarding the response to Federal Information Request T(3)-08. The letters are dated October 20, 2017 and include review comments from a ministry hydrogeologist and surface water specialist. In addition, the MOECC provided a letter dated November 2, 2017 with additional commitments that are requested to be included in the Commitments Registry for the Project.

Review comments from the hydrogeologist indicate the following:

- The hydrogeologist is satisfied with the groundwater modelling;
- Identified monitoring and contingency measures are acceptable at this stage;
- Additional field investigations and design work will be required to support future permitting;
- Modification to the proposed seepage collection system may be required should geological conditions be found to be different than modelled;
- Seepage and loading rates reported in the EA should be considered as commitments that could be recognized as limits in the future ECA;
- Monitoring of the groundwater between the seepage collection system and the lakes will be required by the ECA to demonstrate seepage capture and determine the quality and estimate the quantity of the seepage that bypasses the collection system;
- Failure of the collection system to meet required performance will necessitate contingency measures to be implemented.

Review comments from the surface water specialist recommend the following:

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- The baseline condition of Long Hike Lake should be characterized in terms of water quality, sediment quality, fish, and benthic community prior to any development at the site;
- 75th percentile water quality values be used for future modelling;
- A comprehensive monitoring program should be developed for Long Hike Lake to monitor and assess the potential impacts to the lake due to groundwater seepage from the nearby TMF;
- Trigger values should be established for the receivers and mitigation measures should be developed and employed should monitoring reveal impacts greater than those predicted through modelling;
- Groundwater wells should be established in order to monitor the seepage quality and quantity in order to confirm the commitments made in the EA in regards to seepage collection are being met.

CMC acknowledges that additional field investigations and design work will be required to support permitting. CMC will commit to limit the quantity of seepage bypass to an appropriate level which will mitigate adverse impact to water quality in the receiving environment, as defined through appropriate follow up modelling\evaluation should monitoring trends show that water quality in Upper Marmion Reservoir, Lizard Lake or Long Hike Lake is projected to consistently exceed appropriate guidelines/objectives for the protection of aquatic life as a result of TMF seepage bypass.

CMC will add the commitments listed below to the Commitments Registry.

- Implement mitigation measures to capture seepage emanating from the TMF as described in the *Technical Memorandum: Groundwater Modelling of Tailings Management Facility and Seepage Impact Assessment*, dated August 18, 2017 as necessary to mitigate adverse impact to water quality and aquatic health. Appropriate contingency measures, as described in the above referenced memo, will be implemented if it is determined through monitoring that water quality in Upper Marmion Reservoir, Lizard Lake or Long Hike Lake is projected to consistently exceed appropriate guidelines/objectives for the protection of aquatic life as a result of TMF seepage bypass. Appropriate guidelines/objectives include federal guidelines (CCME), provincial objectives (PWQO) or Site Specific Water Quality Objectives (SSWQO) where it can be demonstrated that the SSWQO are protective of aquatic life.
- Install monitoring wells between the TMF seepage collection system and the downstream receiving lakes to monitoring seepage bypass rate and water quality.

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- Prior to the operations phase, CMC will collect baseline data on Long Hike Lake, including water and sediment quality, fish and fish habitat, benthic community, and hydrology data for inclusion in a comprehensive aquatic effects monitoring plan that includes all receiving waterbodies (Upper Marmion Reservoir, Lizard Lake or Long Hike Lake). CMC will provide a proposed outline of this baseline work to MOECC for review prior to undertaking the work.
- Prior to the operations phase, CMC will re-run the models for predicting seepage water quality at Long Hike Lake using average (steady state), 75th percentile and worst case scenarios. CMC will provide the modelling results to MOECC for review, in support of future permitting and approvals applications.
- Prior to the operations phase, CMC commits to further explore options for reducing the predicted sulphate concentrations in seepage from the site and options for avoiding or minimizing the potential for mercury methylation in any waterbodies expected to receive seepage from the site.

With the commitments as added to the commitments registry, CMC now considers this information request closed. This response and the above referenced letters from MOECC will be incorporated into the T(3)-08 response document package. The updated T(3)-08 response document package and Commitments Registry will be submitted as part of the Version 3 Amended EIS/EA Report.

If you have any questions or comments on the above matter, do not hesitate to contact me by email or at (819) 856-9866.

Regards,

<Original signed by>

Sandra Pouliot
Environment specialist
Canadian Malartic Corporation
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c. Pascal Lavoie, CMC Director Environment and Sustainability