TECHNICAL MEMORANDUM

DATE May 27, 2014 **PROJECT No.** 13-1118-0010 (5008)

TO Alexandra Drapack
Osisko Hammond Reef Gold Ltd. **DOC No.** 0033 (Rev 1)

FROM Devin Hannan, P.Eng. **EMAIL** dhannan@golder.com

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

1.0 INTRODUCTION

The purpose of this technical memorandum is to report on three-dimensional (3D) groundwater modelling of the eastern portion of the proposed Tailings Management Facility (TMF) for the Hammond Reef Gold Project and the adjacent Lizard Lake catchment area (Figure 1). The objectives of the modelling analysis are as follows:

- Simulate groundwater flow within and around the eastern portion of the TMF; and
- Evaluate applicability of the design concept for seepage collection.

The seepage collection system design is currently at a conceptual level and includes perimeter ditches and collection ponds. As such, a rigorous modelling analysis is not required at this time. Instead, the model described herein is used to evaluate the applicability of the conceptual design in terms of seepage collection such that it may be considered a practical basis for future designs. This modelling will be updated in the future for the purposes of detailed engineering design and regulatory permitting as new hydrogeological data is collected following approval of the Hammond Reef Gold Project Environmental Impact Statement/Environmental Assessment (Osisko, 2013).

2.0 TAILINGS MANAGEMENT FACILITY 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]). The TMF is proposed to store 165 Mm^3 of thickened tailings over a footprint of approximately 800 ha throughout five stages of tailings deposition and progressive dam raise construction. The modelling focusses on the TMF at the ultimate extent, as this configuration would produce the greatest amount of groundwater flow.

The conceptual design for the TMF containment system includes rockfill dams with upstream geomembrane liners. The reclaim pond dams will be fully lined, whereas the upstream rockfill dam shells will be lined on the lower (approximate) half of their upstream flank. Runoff and water released from the tailings due to consolidation/settlement will be collected in the TMF reclaim pond (located south of the TMF). Groundwater seepage will be collected by perimeter collection ditches and conveyed to collection ponds where it will be pumped back to the TMF reclaim pond.

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, Canada L5N 7K2
Tel: +1 (905) 567 4444 Fax: +1 (905) 567 6561 www.golder.com
Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

3.0 HYDROGEOLOGICAL DATA

The primary source of hydrogeological data for model construction is *Hydrogeology Technical Support Document (Version 2)* (Golder, 2013[2]). This TSD includes site borehole logs, hydraulic testing, and grain size analysis summaries. The following information from the TSD is pertinent to the model construction:

- The average overburden depth within the model domain is 5 m;
- Bedrock weathering is not typically observed in borehole logs within the model domain; however, where present, the weathered thickness is less than 3 m;
- The geometric mean hydraulic conductivity of the coarse grained material in the TMF area is 6E-6 m/s; and
- The geometric mean hydraulic conductivity of the upper bedrock zone in the TMF area is 2E-6 m/s.

Figure 1 shows the location of site boreholes and their respective overburden depths. The borehole logs within the model domain (and BRH-0019, which lies slightly outside of the model domain but is included in this analysis) are provided in Appendix A of this memorandum.

4.0 MODEL CONSTRUCTION

A summary of model input parameters and boundary conditions are provided in Table 1. Additional information is as follows:

- **Code:** MODFLOW-2005 (Harbaugh, 2005) is the code used to simulate groundwater flow at the site. 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. MODFLOW has been recognized as an industry standard for general purpose groundwater flow modelling and has gained wide acceptance from academia, consultants and regulatory agencies worldwide. Visual MODFLOW® (Version 2011.1) is used as the pre and post-processor for the simulations presented in this report. SAMG (Algebraic Multigrid Methods for Systems) is used to solve the groundwater flow equations.
- **Domain:** The groundwater model domain is shown on Figure 1. The domain is limited to the eastern TMF as this is the area where seepage would be directed towards Lizard Lake; the remaining western TMF area would discharge towards Sawbill Bay. As such, the western flank of the model is ascribed according to the future topographic divide created by the tailings mound. The eastern boundary of the model is represented by Lizard Lake. The remaining model outline is delineated according to subcatchment divides.
- **Layout:** The MODFLOW representation of the TMF and surrounds is displayed on Figure 2 (model layer 1 shown).
- **Layers:** The nominal model layering is as follows: 1) Tailings and lake bathymetry (Lizard Lake depth taken from Golder, 2013[3]); 2) Dam Materials (Upper); 3) Dam Materials (Lower); 4) Overburden; 5) Weathered Bedrock; 6) Competent Bedrock. Note that it is necessary to subdivide the dam geometry as the tailings dams only have liner on the approximate lower half of their upstream shell, whereas the reclaim pond dam has liner along its entire upstream shell. For a given layer, where the nominal material is not present, the numerical layer thins out to 1 m and the underlying material property is input in its stead.
- **Hydraulic Conductivity:** A “bulk” approach to assigning hydraulic conductivities to each unit is utilized. Spatial differentiation of hydraulic conductivities within units is not considered warranted given the scope of

this model analysis. Isotropic conditions are assumed at each material with the exception of the overburden, which is assigned a K_H:K_Z of 1:0.1. This anisotropy is selected due to the presence of clayey lenses within the overburden material that would tend to impede vertical flow.

- **Geomembrane Liner:** The geomembrane liner is considered impermeable (inactive cells) in the model. However, there is the potential that future "wear and tear" of the liner may increase the effective permeability the material. This could result in some shallow seepage crossing the rockfill dams; however, this seepage would ultimately report to the perimeter seepage collection ditches and be captured.
- **Perimeter Seepage Collection Ditches:** The seepage collection ditches are represented by drain cells at a depth of 7 m below existing ground surface.
- **Cross-Section**: A west-east cross-section through the model domain is shown on Figure 3.

5.0 MODEL RESULTS

Figure 4 displays the simulated water table surface. Groundwater flows from a high at the tailings radially outward, eventually discharging to either the perimeter seepage collection ditching, drainage features upstream of Lizard Lake or to Lizard Lake itself.

Table 2 lists the model flow budget. The term "in" means into the *groundwater* system, whereas "out" means out of the *groundwater* system. The total amount of water entering and leaving the modelled groundwater system is 1,954 m^3/d.

Inflows: Most of the inflow to the model is provided by the tailings (712 m^3/d) and reclaim pond (1,240 m^3/d). Some flow occurs within the tailings themselves, a result of constant head cells at higher elevations "feeding" adjacent cells at lower elevations – this is a normal and expected numerical outcome given the representation of the tailings water table surface as sloped constant heads. It follows that the net groundwater flow emanating from the TMF is 712 m^3/d – 395 m^3/d = 317 m^3/d. Note that a small portion of inflow, 2 m^3/d, occurs from the Lizard Lake upstream drainage to Lizard Lake itself. This is a result of the drainage feature having a higher head elevation than the downstream Lizard Lake.

Outflows: For this given conceptual design the majority of the outflow reports to the perimeter collection ditches (1,409 m^3/d). The remainder of outflow reports to the Lizard Lake catchment (146 m^3/d total).

Seepage Collection: Also provided in Table 2 is a breakdown of flows as they pertain to collection ditch efficiency for the conceptual design. A total of 1,409 m^3/d of the 1,553 m^3/d of groundwater emanating from the TMF is retained. These results reflect a capture efficiency of 91%. This is consistent with the treatment efficiency used in the EIS/EA (Osisko, 2013).

6.0 CONCLUSIONS

A 3D MODFLOW groundwater model is constructed to simulate flow in and around the eastern portion of the TMF and Lizard Lake and to estimate the capture efficiency of the proposed seepage collection system conceptual design. The modelling analysis suggests that a capture efficiency of greater than 90% is achievable using a perimeter seepage collection ditch of 7 m or greater. It follows that the seepage collection system conceptualization forms a reasonable basis for future detailed design, and that values used in the EIS/EA evaluation is reasonable and appropriate.

7.0 RECOMMENDATIONS

It is recommended that, as the conceptual design is advanced during pre- construction stages, the model should in turn be refined to provide more exacting estimates of seepage and continue to assist in the design finalization. With a more refined model, a sensitivity analysis may be performed to determine an upper and lower bound on results.

8.0 REFERENCES

Golder, 2013[1]. *Design Basis for Runoff and Seepage Collection Systems – Hammond Reef Gold Project.* Document No. 011 (Rev 0). Project No. 13-1118-0010 (2010). Submitted to Osisko Hammond Reef Gold Ltd. December 3, 2013.

Golder, 2013[2]. *Hammond Reef Gold Project, Hydrogeology Technical Support Document, Version 2.* Document No. DOC017. Project No. 13-1118-0010. Submitted to Osisko Hammond Reef Gold Ltd. December 2013.

Golder, 2013[3]. *Hammond Reef Gold Project, Aquatic Environment Technical Support Document, Version 2.* Document No. DOC013. Project No. 13-1118-0010. Submitted to Osisko Hammond Reef Gold Ltd. December 2013.

Harbaugh, A.W., 2005. *MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model - the Ground-Water Flow Process.* U.S. Geologic Survey Techniques and Methods 6-A16.

Osisko (Osisko Hammond Reef Gold Ltd.), 2013. *Hammond Reef Gold Project, Environmental Impact Statement/Environmental Assessment Report. Version 2.* Submitted to Canadian Environmental Assessment Agency and Ontario Ministry of the Environment. December 2013. Toronto, ON.

9.0 CLOSURE

We trust this meets your current requirements. If you have any questions please do not hesitate to contact the undersigned.

<Original signed by>

Devin Hannan, P.Eng.
Associate, Environmental Engineer

<Original signed by>

Ken De Vos, M.Sc., P.Geo.
Principal

DAH/KD/sp

Attachments:
Table 1 – Summary of Model Construction Details
Table 2 – Model Flow Budget
Figure 1 – General Arrangement Plan Tailings Management Facility
Figure 2 – Model Layout (Layer 1)
Figure 3 – Model Cross-section
Figure 4 – Simulated Water Table (masl)
Appendix A – Borehole logs

n:\active\2013\1118\13-1118-0010 osisko-hammond reef - ea support\006 environmental\5008 groundwater\rev 1\13-1118-0010_doc0033 rev1_tmf 3d groundwater modelling_27may2014.docx

TABLES

May 2014

TABLE 1
Summary of Model Construction Details

13-1118-0010 (5008)
DOC0033

General Attributes	
Code	USGS MODFLOW 2000
Software	Visual MODFLOW Version 2011.1
Flow Type	Steady-State
Dimensions	3D

Domain	
Area	10 km^2
Horizontal Extents	2 km wide x 5 km long
Vertical Extents	492 masl to 400 masl
Top of Model	Ground Surface (see Figure 1)
Bottom of Model	400 masl (competent rock layer)

Grid Layout	
Grid Spacing	10 m x 10 m to 20 m x 20 m
Number of Layers	6
Number of Active Cells	538,314

Numerical Layer Details

Layer	Nominal Description	Thickness	Notes
1	Tailings and Lake Bathymetry	62 m to 1 m	
2	Rockfill Dam and Liner (Upper)	14 m to 1 m	Liner ~ 1 m thick.
3	Rockfill Dam and Liner (Lower)	14 m to 1 m	Liner ~ 1 m thick.
4	Overburden	5 m - 7 m	
5	Weathered Bedrock	3 m	
6	Competent Bedrock	80 m to 1 m	

Material Properties

Material	Hydraulic Conductivity K_H (m/s)	K_H:K_Z	Source
Tailings	6E-07	1:1	(Golder, 2012)
Water Bodies	1E-02	1:1	Assumed
Rockfill	1E-04	1:1	Assumed
Geomembrane Liner	Impermeable	1:1	Assumed
Overburden	6E-06	1:0.1	Golder, 2013[2]
Weathered Bedrock	2E-06	1:1	Golder, 2013[2]
Competent Bedrock	2E-08	1:1	Assumed

Boundary Conditions

Feature	Type	Assigned Head	Source
Tailings Phreatic Surface	Constant Head	Ground minus 2 m	Assumed
Reclaim Pond	Constant Head	444.5 masl	Golder, 2013[2]
Seepage Collection Ditch	Drains (Conductance 500 m^2/d)	Ground minus 7 m	Iterative modelling.
Lizard Lake U/S Drainage	Constant Head	430 masl	Golder, 2013[2]
Lizard Lake	Constant Head	426.65 masl	Golder, 2013[3]
External Catchment Areas	Inactive	-	Golder, 2013[2]

May 2014

TABLE 2
Model Flow Budget

13-1118-0010 (5008)
DOC0033

Global Flow Balance				
Feature	**Boundary Type**	**Flow In (m^3/d)**	**Flow Out (m^3/d)**	**Net In (+) / Out (-)**
Tailings	CH	712	395	317
Reclaim Pond	CH	1,240	4	1,236
Northeast Dam Collection Trench	Drains	0	110	-110
East Dam Collection Trench	Drains	0	196	-196
Reclaim Pond Collection Trench	Drains	0	1,103	-1,103
Lizard Lake	CH	0	126	-126
Lizard Lake Upstream Drainage	CH	2	20	-18
	TOTAL:	1,954	1,954	0

TMF Groundwater Flow Details	
Total Groundwater Flow External To TMF (m^3/d)	1,553
Tailings Seepage Collected (m^3/d)	306
Reclaim Pond Seepage Collected (m^3/d)	1,103
Bypass to Lizard Lake and Lizard Lake Drainage (m^3/d)	144
Collection Efficiency (%)	91
Bypass to Lizard Lake Catchment (%)	9

FIGURES

617500 620000 622500

5430000 5427500 5425000

North Dam
Ultimate Crest
Elev. 463 m

BCN-109
1.7m

BRH-0023
3.60m

BH12-5
7.75m

Northeast Dam
Ultimate Crest
Elev. 457 m

West Dam
Ultimate Crest
Elev. 461 m to 463 m

BH12-1
1.22m

Maximum
Elev. 492 m

Lizard Lake
Upstream
Drainage
(430 m)

East Dam
Ultimate Crest
Elev. 459 m

BRH-0018
1.80m

BCN-071
5.6m

BRH-0021A
3.00m

BCN-078
1.35m

BCN-129
9.75m

BH12-2
15.14m

BCN-079
19.28m

BRH-0019
8.40m

BCN-136
0.54m

BRH-0020A
25.60m

BCN-080
11.8m

BCN-081
1.12m

BH12-3
13.41m

Reclaim Pond Dam
Ultimate Crest
Elev. 446.5 m

BH12-4
7.01m

Reclaim Pond
(444.5 m)

Lizard Lake
(426.5 m)

BRH-0027
2.40m

Sawbill Bay

BRH-0017
3.10m

N

LEGEND

- Index Contour (5m interval)
- Ditch
- Marsh/Swamp
- River/Stream
- Road
- Trail
- Lake
- Wetland
- Osisko Exploration Borehole (Overburden Thickness Labelled)
- Hydrogeological Borehole (Overburden Thickness Labelled)
- Geotechnical Borehole (Overburden Thickness Labelled)
- Perimeter Seepage Collection Ditch
- Pit Spillover Point
- Tailings Discharge Location
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Reclaim Pipeline
- Spillway Channel
- Tailings Pipeline
- TMF Access Road
- Model Domain
- Dam
- Tailings Management Facility
- Tailings Management Facility Reclaim Pond

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

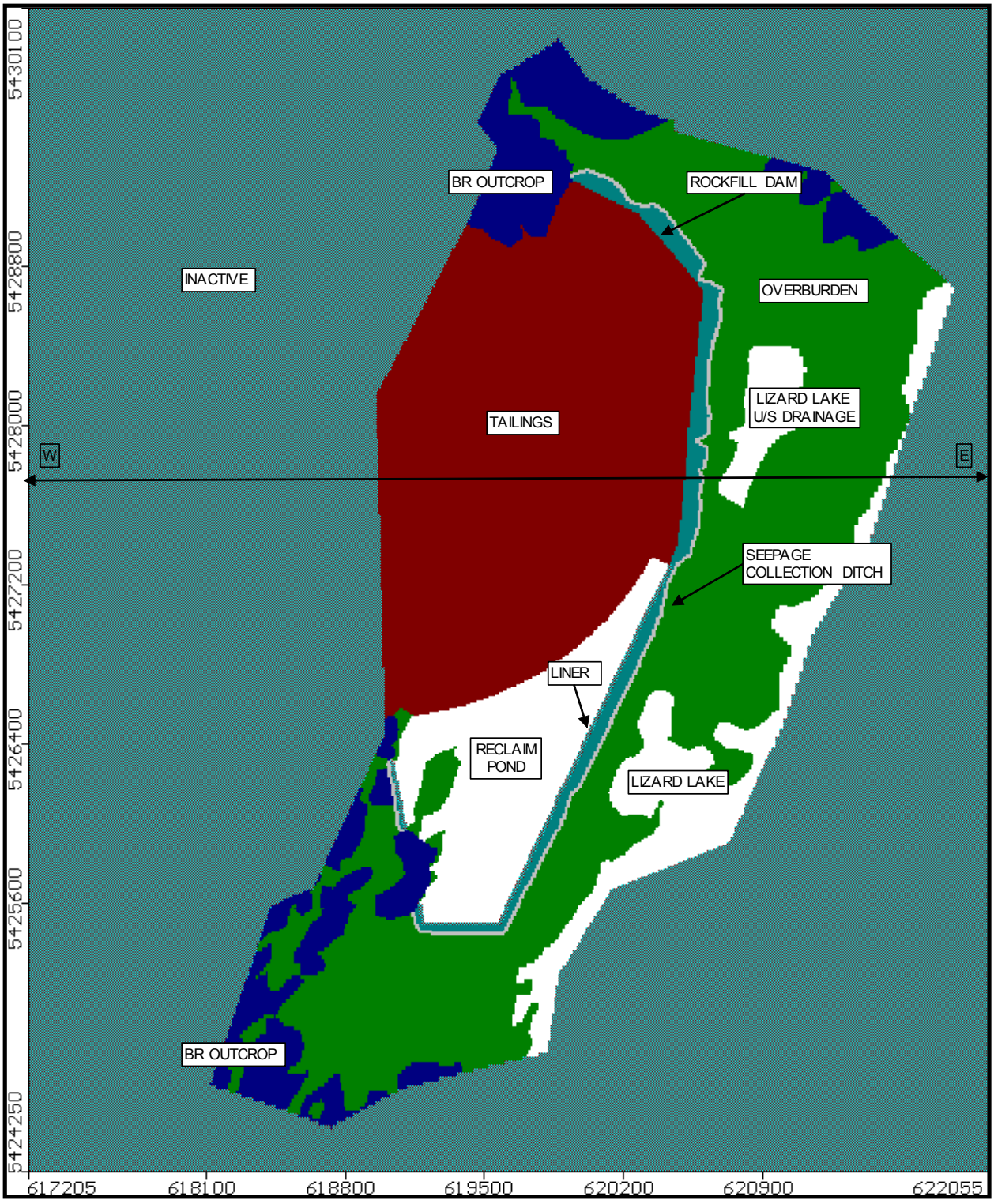
TITLE
GENERAL ARRANGEMENT PLAN
TAILINGS MANAGEMENT FACILITY (ULTIMATE)

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			SCALE AS SHOWN	REV. ION 2
DESIGN	CGE	14 Nov. 2008		
GIS	SC	20 May. 2014		
CHECK	DH	20 May. 2014		
REVIEW	DH	20 May. 2014		

FIGURE: 1

G:\Projects\2013\13-1118-0010_Osisko_Hammond_ReefGIS\MXDs\ReportingHydrogeologyTMF_Modelling\GeneralArrangement_TMF.mxd



LEGEND

UNIT	DESCRIPTION
	WATER BODY
	TAILINGS
	ROCKFILL DAM
	OVERBURDEN
	WEATHERED BEDROCK
	COLLECTION DITCH
	INACTIVE / NO FLOW

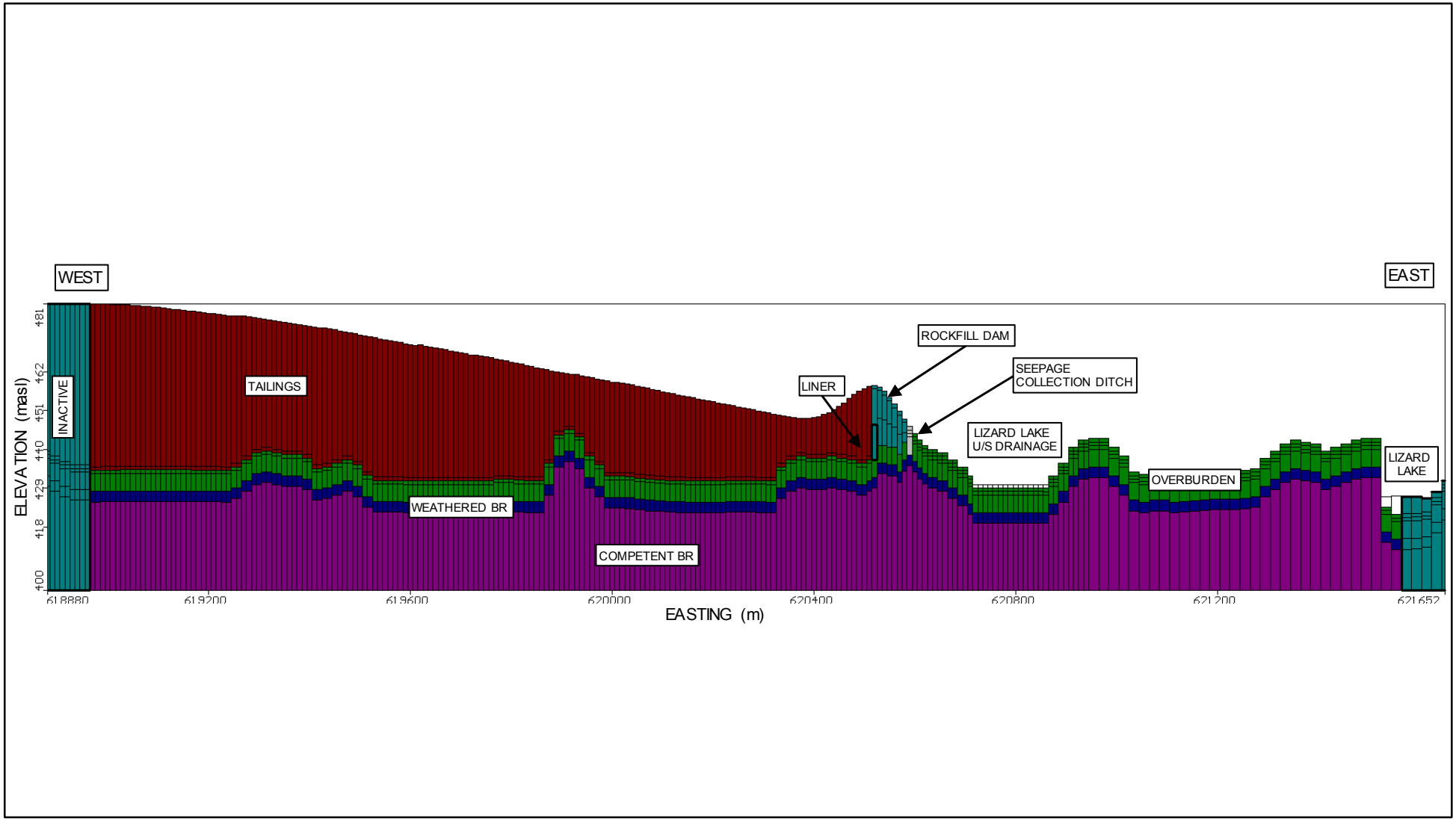
PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
MODEL LAYOUT (LAYER 1)

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			REV. 0.0
DESIGN	SC	5 May. 2014	FIGURE: 2
GIS	SC	21 May. 2014	
CHECK	DH	21 May. 2014	
REVIEW	DH	21 May. 2014	

G:\Projects\2013\13-1118-0010_Osisko_Hammond_Reef\GIS\MXDs\Reporting\Hydrogeology\TMF_Modelling\ModelLayout.mxd



LEGEND

UNIT	DESCRIPTION
	WATER BODY
	TAILINGS
	ROCKFILL DAM
	OVERBURDEN
	WEATHERED BEDROCK
	COLLECTION DITCH
	INACTIVE / NO FLOW

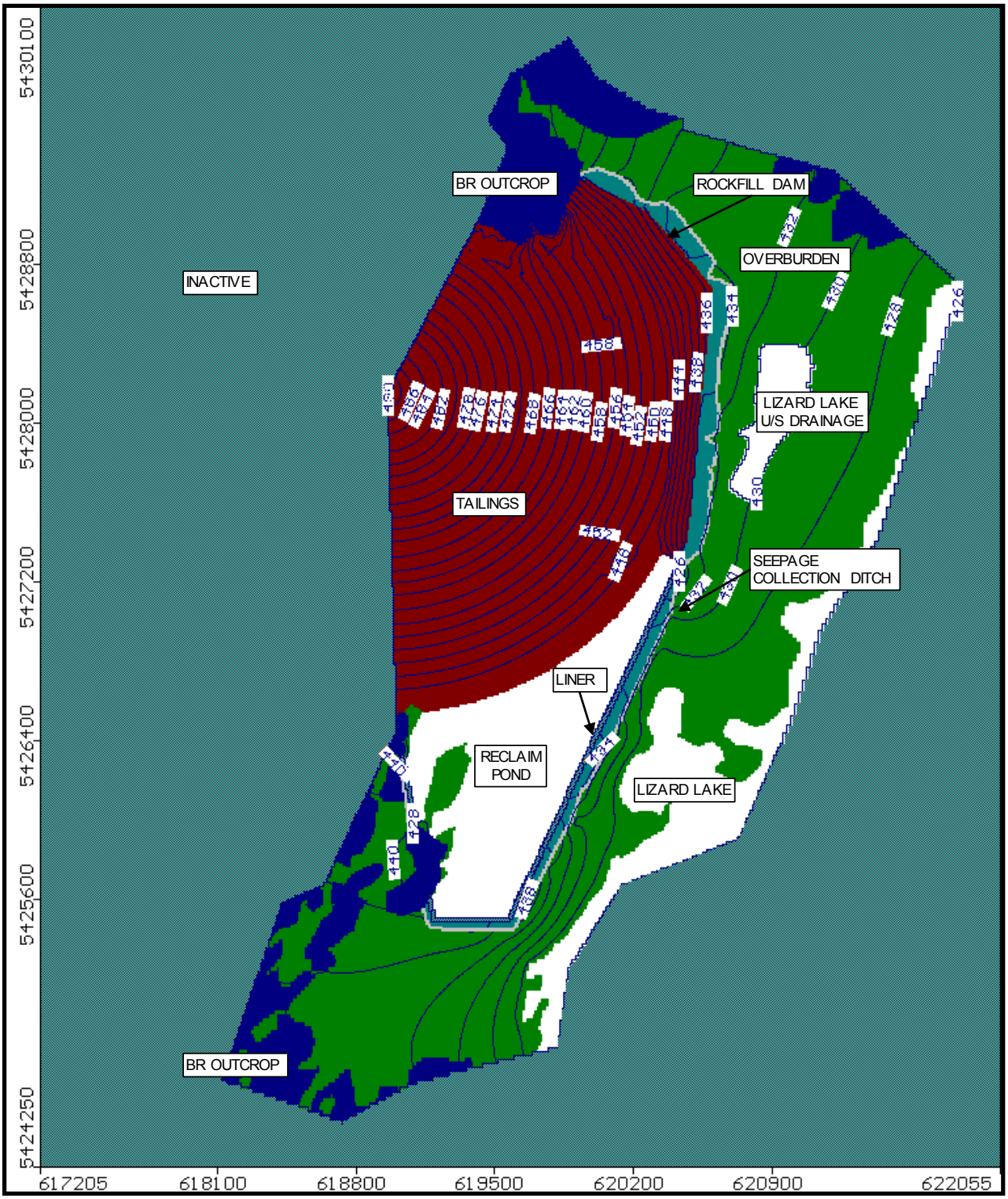
PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
MODEL CROSS-SECTION

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			REV. 0.0
DESIGN	SC	5 May. 2014	FIGURE: 3
GIS	SC	21 May. 2014	
CHECK	DH	21 May. 2014	
REVIEW	DG	21 May. 2014	

G:\Projects\2013\13-1118-0010_Osisko_Hammond_Reef\GIS\MXDs\Reporting\Hydrogeology\TMF_ModellingModelCrossSection.mxd



LEGEND

UNIT	DESCRIPTION
	WATER BODY
	TAILINGS
	ROCKFILL DAM
	OVERBURDEN
	WEATHERED BEDROCK
	COLLECTION DITCH
	INACTIVE / NO FLOW

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SIMULATED WATER TABLE (masl)

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			REV. 0.0
DESIGN	SC	5 May. 2014	FIGURE: 4
GIS	SC	21 May. 2014	
CHECK	DH	21 May. 2014	
REVIEW	DH	21 May. 2014	

G:\Projects\2013\13-1118-0010_Osisko_Hammond_Reef\GIS\MXDs\Reporting\HydrogeologyTMF_Modelling\SimulatedWaterTable.mxd

APPENDIX A

Borehole logs

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0017A

SHEET 1 OF 1

LOCATION: N 5425289.5 ;E 619623.7

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	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		424.6									
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose, moist to wet, brown, silty SAND, some organics.		0.0	1	50 DO	-						Cement; 29/10/11; Bentonite Holeplug; Riser
1					2	50 DO	55						
				423.1									
		Loose to compact, wet, brown, SAND, some silt, some clay, trace gravel.		1.5	3	50 DO	20					MH	
2				422.3									Silica Sand
		Compact, wet, brown, medium to coarse, SAND, trace to some gravel, trace silt.		2.3	4	50 DO	18						
3				421.5	5	50 DO	50/ 0.1						
	CME 55 NQ Core	Fresh bedding, grey, very coarse-grained, crystalline, strong rock (TONALITE).		3.1									Bentonite Holeplug
4													
5													
													Silica Sand
6													31.8 mm Diam. PVC #10 Slot Screen
7				417.4									
		END OF BOREHOLE		7.2									0.84 m Riser Stickup.
		Note:											
		1. For coring details see Record of Drillhole BRH-0017A.											
8													
9													
10													

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0017A

SHEET 1 OF 1

LOCATION: N 5425289.5 ;E 619623.7

DRILLING DATE: April 7, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

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 %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	
		TOP OF BEDROCK		421.50																
4	CME 55 NQ Core	Fresh, bedding, grey, very coarse-grained, crystalline, strong rock (TONALITE).		3.10	1								JPLR JPLR							Silica Sand Bentonite Holeplug
5					2								JPLSM JPLSM JPLSM JPLR JIR JIR							Silica Sand
6					3								JPLR JPLR JPLR JPLR JPLR JIR JIR							31.8 mm Diam. PVC #10 Slot Screen
7				417.4									JIR JIR							
		END OF DRILLHOLE		7.2																0.84 m Riser Stickup.
8																				
9																				
10																				
11																				
12																				
13																				

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0017B

SHEET 1 OF 1

LOCATION: N 5425289.5 ;E 619623.7

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	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		427.7							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0017A for stratigraphy details.		0.0							Cement 29/10/11; Bentonite Holeplug; Riser
1				426.2							
				1.5							
2				425.4							Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
				2.3							
3				424.6							
	CME 55 NQ Core			3.1							
4											
5											
6											
7				420.5							
		END OF BOREHOLE		7.2							0.81 m Riser Stickup.
		Note:									
		1. Monitoring well installation in same Borehole as BRH-0017A.									
8											
9											
10											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0018

SHEET 1 OF 1

LOCATION: N 5427310.9 ;E 620793.8

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	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
0		GROUND SURFACE		430.6							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose, moist, brown, CLAYEY SAND and SILT		0.0	1	50 DO	PH		○	MH	
1					2	50 DO	15				
				429.2							
		Compact, moist, brown to grey, silty SAND, trace to some gravel.		1.4	3	50 DO	50/ 0.28		○		27/10/11
2				428.8							Bentonite Holeplug
	CME 55 NQ Core	Fresh, grey, very coarse-grained, crystalline, strong rock (quartz GRANITE)		1.8							Riser
6											31.8 mm Diam. PVC #10 Slot Screen
7											Silica Sand
8				421.9							
9		END OF BOREHOLE		8.7							0.97 m Riser Stickup.
		Note:									
		1. For coring details see Record of Drillhole BRH-0018.									
10											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: TDM

CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0018

SHEET 1 OF 1

LOCATION: N 5427310.9 ;E 620793.8

DRILLING DATE: March 28, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Trackmount

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

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 %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	
		TOP OF BEDROCK		428.80																
2	CME 55 NQ Core	Fresh, grey, very coarse-grained, crystalline, strong rock (quartz GRANITE)		1.80	1								JIR							Bentonite Holeplug
													Closely Fractured							
													Closely Fractured							
3					2								JIR							
													Healed Joint JPLR							Riser
													JIR							
4																				
					3								JIR							
													JIR							
5																				
													JIR							
													JIR							
																				31.8 mm Diam. PVC #10 Slot Screen
6					4															
																				Silica Sand
7																				
													JPLR							
					5								JIR							
													JSTR							
8													JIR							
				421.9									JIR							
		END OF BOREHOLE		8.7																0.97 m Riser Stickup.
9																				
10																				
11																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM
CHECKED: MO

SUD-RCK 10-1118-0020 (4000).GPJ GAL-MISS.GDT 21/09/12 DATA INPUT:

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0019

SHEET 1 OF 1

LOCATION: N 5426821.6 ;E 618808.1

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	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 ▽ 26/10/11
		GROUND SURFACE		430.6							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Wet, dark brown, PEAT (ORGANICS).		0.0 / 430.3	1	50 DO	3				Silica Sand
		Wet, dark brown, sandy SILT and ORGANICS (TOPSOIL).		0.3 / 430.0							Bentonite Holeplug
		Grey-brown to brown, layered, SILTY, CLAYEY SAND, oxidized mottling.		0.6							
1					2	50 DO	5			MH	
				429.1							Riser
		Wet, brown, layered, clayey SILT, some sand, oxidized mottling.		1.5							
2					3	50 DO	25				Cuttings
					4	50 DO	28			MH	
				427.6							
3		Moist to wet, grey, layered, SILTY CLAY, trace sand to CLAY, some silt, trace sand		3.0	5	50 DO	26				
4					6	50 DO	22				Bentonite Holeplug
					7	50 DO	27			MH	
5					8	50 DO	15			MH	
6					9	50 DO	15				Silica Sand
											31.8 mm Diam. PVC #10 Slot Screen
7					10	50 DO	11				
				423.0							
		Wet, brown, medium to coarse, granitic, SAND, trace silt.		7.6	11	50 DO	2				
8											Cave
				422.2							
		END OF BOREHOLE PROBABLE BEDROCK REFUSAL		8.4							0.83 m Riser Stickup.
9											
10											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0023

SHEET 1 OF 1

LOCATION: N 5429127.4 ;E 619973.0

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	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. +, rem V. ⊕, Q - ●, 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		434.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Boulders and TOPSOIL.		0.0 / 434.4							27/10/11
		Moist to wet, greyish-brown, SILT and SAND, trace organics.		0.5 / 433.6	1	50 DO	11		○	MH	Bentonite Holeplug; Riser
1		Wet, brown, gravelly SILT and SAND.		1.3 / 433.4							
		Wet, brown, SAND and GRAVEL, some clay, trace silt, trace cobbles and boulders.		1.5 / 432.6	2	50 DO	21		○	MH	
2		SAND and BOULDERS, some gravel, trace silt.		2.3 / 432.2	3	50 DO	32				Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		Gravelly SAND, some silt, trace clay.		2.7 / 431.3	4	50 DO	8		○	MH	Cave In
3		END OF BOREHOLE PROBABLE BEDROCK REFUSAL		3.6							0.9 m Riser Stickup.
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0027

SHEET 1 OF 1

LOCATION: N 5425831.2 ;E 619613.6

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	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
0	CME 55 200 mm Diam. (Hollow Stem Auger)	GROUND SURFACE		434.8							
		Loose, moist, PEAT.		0.0 / 434.6							
		Loose, wet, dark brown, PEAT, some sand, some silt.		0.2 / 434.2	1	50 DO	PL		○		
1		Loose to compact, wet, grey, SANDY, SILTY CLAY		0.6	2	50 DO	8		○	MH	Bentonite Holeplug / Riser / Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				433.1							
2		Compact, wet, grey, coarse, SILTY SAND, some gravel, some clay.		1.7	3	50 DO	13		○		
				432.4	4	50 DO	50/ 0.12		○	MH	
		END OF BOREHOLE PROBABLE BEDROCK REFUSAL		2.4							0.95 m Riser Stickup.
3											
4											
5											
6											
7											
8											
9											
10											

SUD-BOREHOLE 10-1118-0020 (4000).GPJ GLDR_CAN.GDT 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM

CHECKED: MO

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-4

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: August 8 and 9, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

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

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	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
				428.77							
0		GROUND SURFACE		-0.20							
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(PT) Fibrous PEAT; black; wet, very loose			1	50 DO	1		406.8		50 mm Diameter Monitoring Well
1					2	50 DO	1		401.5		
2					3	50 DO	1		320.5		
				426.44							
		(ML) CLAYEY SILT, trace fine sand; grey, zones of silt; Wn<PL to Wn~PL, stiff		2.13	4	50 DO	10			MH	Bentonite Seal
				425.67							
3		(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		2.90	5	50 DO	1		72	MH	
4											
5					6	50 DO	9				
				423.39							
		(ML) SILT, some fine sand; grey; wet, loose		5.18	7	50 DO	9				
				422.63							
6		(SM) SILTY SAND, trace gravel; brown to grey; wet, loose		5.94	8	50 DO	6			MH	Silica Sand Filter
				421.56							
7	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-4		7.01							
8											
9											
10				418.41							
		END OF BOREHOLE		10.16							
11											
12											

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

2. 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:

GTA-BHS 001 1111180074.GPJ GAL-MIS.GDT 11/16/12 GPC AUG. 2012

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

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE		433.03			
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(SM) SAND, some fines, trace to some gravel; brown (FILL); moist to wet, very loose		0.00 / 432.73	1A	50 DO	WH
				0.30	1B		
		(PT) Fiberos (PEAT); black; wet, very loose					
1					2	50 DO	WH
				431.38			
		(SP) SAND, medium grained, trace fines; brown and grey; wet, very loose		1.65 / 430.90	3	50 DO	WH
2		(SM) SILTY SAND; grey; wet, loose		2.13	4	50 DO	7
3					5	50 DO	9
4				428.99			
		(SP) SAND, some fines; grey; wet, very loose		4.04	6A	50 DO	3
				428.15			
5		(ML) SILT, some sand; grey; wet, very loose		4.88	6B		
				427.47			
		(SW) SAND, trace gravel, some fines; grey; wet, compact		5.56	7	50 DO	23
6							
7				425.94			
		(SM) gravelly SILTY SAND; grey; wet, very dense		7.09	8	50 DO	50/ .13
				425.28			
	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-5		7.75			
8							
9							
10							
				422.34			
		END OF BOREHOLE		10.69			
11							
12							

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

SHEAR STRENGTH Cu, kPa: 20, 40, 60, 80

nat V. + Q - ●

rem V. ⊕ U - ○

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

WATER CONTENT PERCENT: 10, 20, 30, 40

Wp W Wl

ADDITIONAL LAB. TESTING
MH
MH
MH
MH

PIEZOMETER OR STANDPIPE INSTALLATION

B A

442.2

389.8

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:

GTA-BHS 001 1111180074.GPJ GAL-MIS.GDT 11/16/12 GPC AUG. 2012