January 2018

HAMMOND REEF GOLD PROJECT

Hydrogeology Technical Support Document

VERSION 3

Submitted to:
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Distribution:
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Note: This Version 3 Technical Supporting Document is identical to the Version 2 Technical Supporting Document as provided herein.

December 2013

HAMMOND REEF GOLD PROJECT

Hydrogeology Technical Support Document

VERSION 2

Submitted to:
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Project Number: 13-1118-0010
Document Number: DOC017
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PART A

Introduction

HYDROGEOLOGY TECHNICAL SUPPORT DOCUMENT
VERSION 2
PART A: INTRODUCTION

Version 1 of the Hydrogeology Technical Support Document (TSD) was published on February 15, 2013 as part of Osisko Hammond Reef Gold's (OHRG) Draft Environmental Impact Statement/Environmental Assessment (EIS/EA) Report.

The Draft EIS/EA Report underwent a seven week public review comment period after which, on April 5, 2013, OHRG received comments from the public, Aboriginal groups and the Government Review Team (GRT) seeking clarification and requesting new information.

Approximately 30 comments regarding the Hydrogeology TSD and component of the EIS/EA Report were received from the GRT. Written responses have been prepared for each comment and are provided in Appendix 1.IV of the EIS/EA Report.

Version 1 of the Hydrogeology TSD has not been revised. The methods used to define baseline hydrogeological conditions and predict potential changes to the groundwater levels and seepage flows have not changed, are technically defensible and appropriately conservative. The conclusions and results presented in the Hydrogeology TSD are sound and have remained the same after consideration of comments received. Additional clarifications on some aspects are however provided as part of this Version 2 of the Hydrogeology TSD.

The EIS/EA Report has been revised and updated based on comments received. Version 2 of the Hydrogeology TSD is comprised of the following:

- Part A: Introduction
- Part B: Supplemental Information Package (attached) that provides additional detail on new work undertaken related to the Hydrogeology component and some clarification of the information presented in the Hydrogeology TSD.
- Part C: Version 1 of the Hydrogeology TSD. Part C was issued in February 2013, and is available online on OHRG's website; it has not been re-printed as part of this Version 2 of the Hydrogeology TSD. The Version 1 document should be reviewed within the context of this Version 2 document, and associated updated information as presented in Part A or Part B should be considered as correct should it differ from the information presented in Version 1.

A summary of the information found in Part B is provided below. Throughout the EIS/EA Report, unless otherwise noted, all references made to the Hydrogeology TSD are to Part C.

Groundwater-Surface Water Modelling Approach

Several information requests received form the GRT recommended that a more sophisticated modelling approach be used to quantify groundwater releases to surface water receptors from the TMF and other stockpiles. In the assessment completed, a conservative water balance approach was used to evaluate potential for near surface vs. groundwater water quality influence, whereby all water reporting to the pile is assigned an expected leachate water quality based on geochemical testing and is assumed to be released. This approach is considered to contain less uncertainty than a hydrogeological modelling approach due to the inherent uncertainty and heterogeneity in expected hydraulic conductivity values and/or boundary conditions. Further justification of this approach is provided in the responses to information requests (IRs) MOE-NR-GW-16 and MNDM-18 in the attached Supplemental Information Package.

Conceptual Design Details of Water Management Systems

In consultation with the GRT, OHRG was advised that the provided details on the design of the water management systems (i.e., seepage and runoff collection systems) for the TMF and other stockpiles did not meet the requirements of the EIS Guidelines. In response, a technical memorandum was prepared to provide conceptual level details on the design criteria and approach that will be followed for these systems during subsequent phases of engineering design. This memorandum is provided in the attached Supplemental Information Package.

Differences between Worst Case Predictions and Anticipated Operations Conditions

As described in response to IR MNDM-18, for Waste rock, Ore Stockpile, and Overburden the total annual precipitation is assigned a value of 758 mm. Mass load values are assigned to 85% of the precipitation, whereas the remaining 15% is assumed to be lost to the system due to evaporation and reduction in snow accumulation due to the height of the pile. This is considered a reasonable and conservative assumption given that the measured evaporation rates from rock piles at other Canadian Shield mine sites (Macroline, 2008 as cited in Areva, 2011) indicate that evaporation from the top of the pile can be as high as 60% of rainfall, and that evaporation in other natural areas of the Canadian Shield is several hundred mm (>20% of rainfall) (Singer and Cheng (2002).

It is considered that the mass load assigned to the waste rock (both for surface water and groundwater) is reasonably represented within the current system as modelled, and is appropriately conservative. All of this mass is represented in the collection system, and is thus accounted for in the final discharge values. At closure, mass continues to be assigned to 85% of precipitation falling on the waste rock pile.

Geochemical testing indicates that the waste rock (all lithologies encountered) is non-acid generating with excess neutralization potential and low potential for metal leaching over the long-term, based on both static and kinetic testing. Should groundwater flow occur, additional attenuation reactions including adsorption and chemical precipitation would also be expected to improve water quality.

Based on the above discussion it is reasonably considered that the data as modelled and presented in Tables 4-6 and Table 7-4 (Part B of the Lake Water Quality TSD) represents a worst case. When compared to the average operating conditions, as presented in Table 4-5 and 7-3 (Part B of the Lake Water Quality TSD), the values in Table 4-6 and 7-7 are slightly elevated for some parameters; however, only copper occurs at values slightly above CCME CWQG guidelines, depending on hardness. Further discussion is provided in MNDM-18 and MOE-NR-GW-16 regarding expected concentrations for each facility and implications should the water bypass the collection system. All values including the worst case values are carried forward in the Environmental Assessment when evaluating potential for impacts.

Supplemental Information

Other information requests received formally or during consultation meeting with the GRT requested that more detail and information be provided on aspects of the hydrogeological assessment. In response to these information requests, additional information was prepared and has been provided in the attached Supplemental Information Package. The table below provides a summary of the additional information requested and the corresponding documents in the Supplemental Information Package in which the information is provided.

Additional Information Requested	Location of Information in the Supplemental Information Package or Other Documents
Discuss attenuation influence on groundwater-surface water interaction	MNDM-18, MOE-NR-GW-16
Discuss differences between worst case predictions and anticipated operations conditions	MNDM-18, MOE-NR-GW-16, Table 4-6 and 7-4 (Part B of the Lake Water Quality TSD) and Summary discussion in Part A, above
Compare groundwater quality predictions to GW3 criteria as developed by MOE under O.Reg 153/04	Included in MOE-NR-GW-16 and MNDM-18
Conceptual Design Details of Water Management Systems	Technical Memorandum: Design Basis for Runoff and Seepage Collection Systems (Rev 0, December 3, 2013
Revise Figure 2-10 to include groundwater elevation contours	Revised Figure 2-10A

Supplemental Information Provided in Part B

- Response to Information Request MOE-NR-GW-16
- Response to Information Request MNDM-18
- Technical Memorandum: Design Basis for Runoff and Seepage Collection Systems (Rev 0, December 3, 2013)
- Revised Fig 2-10A (from Response to Information Request MNDM-15)

HYDROGEOLOGY TECHNICAL SUPPORT DOCUMENT
VERSION 2

PART B

Supplemental Information Package

December 2013
Project No. 13-1118-0010
Hammond Reef Gold Project

INFORMATION REQUEST – MOE-NR-GW-16

Source: Ministry of Environment

Summary of Comment

Indicates that ditches will be excavated around the TMF to collect "seepage", which will then be directed to the reclaim pond for re-use, or to the pit upon closure. How deep are these ditches? Are they intended to intercept "all" of the seepage? Has the effectiveness of the ditches to intercept all of the seepage been modelled? The TMF lies in an area of deep overburden deposits which are far less likely to inhibit groundwater movement, and could result in seepage moving at depth (model?). The water table in the TMF area is at depths of 2 to 3 metres in the area of BRH-0021. The head in the pond could induce fairly steep vertical gradients that could result in significant downwards migration of seepage.

Potential Environmental Effects

Leachate seepage and the quality of that leachate represents a significant risk to the environment, with the potential for leachate to transport contaminants to the Marmion Reservoir.

Proposed Action

The proposed seepage collection measures need to be more clearly defined and modelled to demonstrate if they will be suitably effective. Seepage needs to be quantified, and the consequent quantities that will be intercepted and/or lost need to be estimated. The potential impact of seepage losses on receptors needs to be estimated and assessed with respect to suitable criteria.

Reference to EIS

Sec 3.1, 3rd paragraph

Response

A water balance approach was used to evaluate the potential for near surface vs. groundwater water quality influence. All precipitation (minus evaporation) and process water entering the TMF is assigned a water quality and based on the geochemical testing results the resulting mass is accounted for and tracked in the model. As such, the mass load assigned to the TMF water (both for surface water and groundwater) is reasonably represented within the current system as modelled, and is appropriately conservative. All of this mass is represented in the collection system thus is accounted for in the final discharge values. At closure all precipitation (less evaporation) continues to be applied a water quality based on the TMF process water chemistry and is thus conservative. This approach is considered to contain less uncertainty than a hydrogeological modelling approach due to the inherent uncertainty and heterogeneity in expected hydraulic conductivity values and/or boundary conditions.

The seepage collection system is an engineered system which will require detailed design as part of the detailed design phase of the project. At the detailed design phase the depth of ditching, slopes, sump dimensions and pumping system will be developed into construction level drawings following EIS/EA approval. In the water balance model all runoff and seepage is captured and the mass is therefore included in the final discharge water quality, thus the predicted Marmion Basin water quality accounts for all surface water and groundwater flow.

Furthermore, looking specifically at the concentrations expected in the TMF water, Table 4-10 of the Version 2 Site Water Quality TSD presents predicted concentrations of the steady state TMF groundwater quality during the Operation Phase. The predicted TMF groundwater concentrations of cyanide, cobalt, copper, molybdenum and uranium are greater than the PWQO protection for aquatic life regulatory guidelines (PWQO).

Seepage from the all site facilities including the TMF to Lizard Lake during operations will be managed through a seepage collection system that will direct seepage from the TMF back to the TMF. In the event that some seepage bypasses the system, the evaluation conservatively considered the implications assuming 10% of the seepage bypassed the collection system and migrated to Lizard Lake. Predictions of worst case conditions resulted in free cyanide concentrations in Lizard Lake of up to 0.0011 mg/L. Since the predicted concentration is below the guideline of 0.005 mg/L and below a Site Specific Water Quality Objective (SSWQO) of 0.01 mg/L, there are no predicted adverse effects due to free cyanide.

For Waste Rock and Ore, the predicted worst case groundwater concentrations of aluminum (0.25 mg/L), arsenic (0.03 mg/L), copper (0.009 mg/L), and uranium (0.007 mg/L) are greater than the PWQO protection of aquatic life guidelines (PWQO) as presented in the Version 2 Site Water Quality TSD, Table 4-8 and Table 4-9. These values, while above the PWQO values are below the GW3 criteria as developed by MOE under O.Reg 153/04 (with the exception of aluminum for which there is no GW3 criteria). When accounting for a 10 times dilution or attenuation along the flow path (similar to the rationale used in developing the GW3 criteria) it is considered that there is no anticipated adverse effect on aquatic life due to these concentrations. Attenuation along groundwater flow pathways has the potential to substantially reduce concentrations of many parameters (U.S. EPA 2007).

Since PWQOs do not provide acute guidelines, concentrations of the above parameters were compared to the U.S. EPA Ambient Water Quality Criteria CMC (Freshwater Acute) values. These represent acute concentrations to which aquatic life should only be exposed to for short periods of time.

Aluminum – no guideline available

Arsenic – 0.34 mg/L

Copper – 0.013 mg/L

Uranium – no guideline available.

Based on comparison with the above guidelines, the undiluted groundwater concentrations expressing to surface waters would not be considered as acutely toxic.

Given the current accounting of flows and mass load, and the geochemical conditions of the materials on site, it is considered that the groundwater component from stockpiles including the Ore and Waste Rock is negligible with respect to influencing the overall results or conclusions of the EIS/EA with respect to potential for water quality impacts from the site.

In order to assess whether groundwater could affect aquatic life, the MOE under O. Reg 153/04 has developed groundwater concentrations that would be protective of aquatic life based on aquatic protection values (APVs). The APVs are based on the U.S. EPA Ambient Water Quality Criteria (AWQC) for protection of aquatic life and therefore are considered to provide suitable protection for aquatic life. The MOE based the development of the

groundwater protection values (GW3) on the APVs. In developing the GW3, the MOE has assumed that there will be a minimum of a 10x reduction in concentration due to dilution within the receiving waterbody (MOE 2011). With this minimum dilution, all parameters, with the exception of copper for the predicted TMF water quality will be below the PWQO guidelines. Under the assumed conditions, the predicted concentration of copper entering downstream waters could be 0.11 mg/L compared to a GW3 value of 0.069 mg/L (MOE 2009).

These values, while above the PWQO values are below the GW3 criteria as developed by MOE under O.Reg 153/04 (with the exception of aluminum for which there is no GW3 criteria). When accounting for a 10 times dilution along the flow path (similar to the rationale used in developing the GW3 criteria) it is considered that there is no anticipated adverse effect on aquatic life due to these concentrations. Attenuation of these values along groundwater flow pathways has the potential to further, substantially reduce concentrations of many parameters (U.S. EPA 2007).

A abridged version of Table 4-10 is provided below which presents only parameters that are higher than the PWQO. This table also presents the GW3 criteria. The predicted TMF seepage water quality is formatted to indicate values that are higher than applicable guidelines (see Table 4-10 notes).

Based on the assumptions in MOE (2011) the mixed concentration in the downstream waters would be predicted to be 0.011 mg/L. The SSWQO for copper developed for lakes in the Project area was 0.0079 mg/L. Therefore, copper concentrations in downstream receiving waters could be slightly higher than the SSWQO should water from the TMF enter receiving waters through groundwater flow paths. As a result of copper concentrations potentially higher than SSWQO, the potential effects of copper at 0.011 mg/L on aquatic life that could be present in the receiving waters were considered with respect to published toxicity data to determine whether there could be an adverse effect on aquatic life should groundwater with this concentration enter receiving waters. The U.S. EPA ECOTOX database was accessed to obtain toxicity data for copper. The Aquatic Ecology TSD has noted that the fish fauna of this pond is characterized by small-bodied forage fish. Therefore, toxicity data for fathead minnow, a typical test species in toxicity tests, was used to predict the potential for adverse effects on fish species. The potential effects on invertebrates were also assessed through a review of the available toxicity data.

The lowest reported effects concentration for the fathead minnow reported in the database was a MATC (calculated as the geometric mean of the NOEC and LOEC) of 0.016 mg/L during a 7 day exposure (Norberg and Mount 1985, cited in ECOTOX 2013). Reported no effects concentrations (NOECs) for the amphipod *Hyalella azteca* ranged from 0.013 mg/L to 0.05 mg/L. The results indicate that should water at the predicted TMF concentration reach the downstream waters, there would be no anticipated adverse effect on aquatic life.

It should be noted that the above prediction of copper in groundwater is considered conservative in that it does not provide for attenuation of copper concentrations along the flow path nor for dilution in the receiving water. Since the TMF is located more than 100 m from downstream water bodies, attenuation of copper concentrations in groundwater would be expected, particularly where flow may occur through soil layers.

Parameter	Units	Guidelines				Groundwater Quality reporting from TMF
		CCME CWQG[a]	PWQO[b]	MISA[c]	GW3[d]	
Total Cyanide	**mg/L**	0.005	-	-	0.05	***0.03***[f]
Al [e]	**mg/L**	0.1	0.075	-	-	0.02
As	**mg/L**	0.005	0.005	1	1.5	0.0001
Co	**mg/L**	-	0.0009	-	0.052	**0.003**
Cr	**mg/L**	0.001	0.001	-	0.64	0.0002
Cu	**mg/L**	0.002	0.001	0.6	0.069	***0.11***
Mo	**mg/L**	-	0.04	-	**-**	**0.08**
U	**mg/L**	-	0.005	-	0.33	**0.007**

Notes:

(a) Canadian Council of Ministers of the Environment, Canadian Water Quality Guidelines (CCME CWQG) for the protection of freshwater aquatic life. Values greater than the CCME CWQG are in *italic font*.

(b) Provincial Water Quality Objectives (PWQO). Values greater than the PWQO are in **bold font**.

(c) Municipal/Industrial Strategy for Abatement (MISA). Values greater than the MISA are underlined.

(d) MOE (Ontario Ministry of the Environment). 2011. Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Standards Development Branch, MOE. April 2011. Appendix A3(18), Table 9 (GW3 Values). Values greater than the GW3 are in red font.

(e) A 10 times dilution or attenuation along the groundwater flow path would result in aluminum concentration lower than the PWQO values.

(f Assuming treatment efficiency of 5 ppm and natural degradation of cyanide as described in Section 4.2.3.

References

MOE (Ontario Ministry of the Environment). 2011. Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Standards Development Branch, MOE. April 2011.

U.S. Environmental Protection Agency (USEPA). 2007. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water. Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium. October 2007. U.S. Environmental Protection Agency Report EPA/600/R-07/140 http://www.epa.gov/ada/gw/mna.html. Cincinnati, Ohio 45268.

U.S. EPA ECOTOX database. http://cfpub.epa.gov/ecotox/ Accessed July 2013.

OSISKO HAMMOND REEF GOLD PROJECT EIS/EA
INFORMATION REQUEST RESPONSES

INFORMATION REQUEST – MNDM-18

Source: Ministry of Northern Development and Mines

Summary of Comment

The discussion of simulated effects does not appear to include potential groundwater mounding within the waste rock pile and the effect this could have on groundwater flow.

Potential Environmental Effects

Due to the metal leaching potential of the waste rock, subsurface flow from the waste rock pile could potentially impact pit lake water quality and/or result in impacts to surface water receivers.

Proposed Action

Account for the influence of the waste rock pile on the local hydrodynamics.

Reference to EIS

Hydrogeology TSD 2.10.2

Response

The expected high hydraulic conductivity would not support development of a substantial mound within the waste rock pile, furthermore the difference in hydraulic conductivity between waste rock and the underlying bedrock will be several orders of magnitude, thus the local hydrodynamics are not expected to change substantially (i.e. water flow will follow the existing bedrock contours and catchment areas). Regardless of mounding or minor hydrodynamic changes, to account for water entering the pile and in order to provide a conservative impact assessment a water balance approach was used to evaluate potential for near surface vs. groundwater water quality influence, whereby all water reporting to the pile is assigned an expected leachate water quality based on geochemical testing and is assumed to be released. This approach is considered to contain less uncertainty than a hydrogeological modelling approach due to the inherent uncertainty and heterogeneity in expected hydraulic conductivity values and/or boundary conditions.

For Waste rock, Ore Stockpile, and Overburden the total annual precipitation is assigned a value of 758 mm. Mass load values are assigned to 85% of the precipitation, whereas the remaining 15 % is assumed to be lost to the system due to evaporation and reduction in snow accumulation due to the height of the pile. This is considered a reasonable and conservative assumption given that the measured evaporation rates from rock piles at other Canadian Shield mine sites (Macroline, 2008 as cited in Areva, 2011) indicate that evaporation from the top of the pile can be as high as 60% of rainfall, and that evaporation in other natural areas of the Canadian Shield is several hundred mm (>20 % of rainfall) (Singer and Cheng (2002).

It is considered that the mass load assigned to the waste rock (both for surface water and groundwater) is reasonably represented within the current system as modelled, and is appropriately conservative. All of this mass is represented in the collection system thus is accounted for in the final discharge values. At closure mass continues to be assigned to 85% of precipitation falling on the waste rock pile.

Geochemical testing indicates that the waste rock (all lithologies encountered) is non-acid generating with excess neutralization potential and low potential for metal leaching over the long-term, based on both static and

kinetic testing. Should groundwater flow occur, additional attenuation reactions including adsorption and chemical precipitation would also be expected to improve water quality.

For Waste Rock and Ore, the predicted worst case groundwater concentrations of aluminum (0.25 mg/L), arsenic (0.03 mg/L), copper (0.009 mg/L), and uranium (0.007 mg/L) are greater than the PWQO protection of aquatic life guidelines (PWQO) as presented in the Site Water Quality TSD, Table 4-8 and Table 4-9. These values, while above the PWQO values are below the GW3 criteria as developed by MOE under O. Reg 153/04 (with the exception of aluminum for which there is no GW3 criteria). When accounting for a 10 times dilution along the flow path (similar to the rationale used in developing the GW3 criteria) it is considered that there is no anticipated adverse effect on aquatic life due to these concentrations (i.e. aluminum would be below the PWQO at the point of discharge).

Since PWQOs do not provide acute guidelines, concentrations of the above parameters were compared to the U.S. EPA Ambient Water Quality Criteria CMC (Freshwater Acute) values. These represent acute concentrations to which aquatic life should only be exposed to for short periods of time.

Aluminum – no guideline available

Arsenic – 0.34 mg/L

Copper – 0.013 mg/L

Uranium – no guideline available.

Based on comparison with the above guidelines, the undiluted groundwater concentrations expressing to surface waters would not be considered as acutely toxic.

Given the current accounting of flows and mass load, and the geochemical conditions of the materials on site, it is considered that the groundwater component is negligible with respect to influencing the overall results or conclusions of the EIS/EA with respect to potential for water quality impacts from the site.

Parameter	Units	Guidelines		Waste Rock Run Off [a]	Ore Run Off [b]	
		PWQO [c]	GW3 [d]	Maximum ALL[f]	Steady State	Worst Case
Al [e]	mg/L	0.075	-	*0.25*	0.04	*0.25*
As	mg/L	0.005	1.5	*0.03*	0.0002	*0.03*
Cu	mg/L	0.001	0.069	*0.009*	0.0005	*0.009*
U	mg/L	0.005	0.33	*0.007*	0.0002	*0.007*

Notes:

a) Presented in Table 4-8, Site Water Quality TSD.

b) Presented in Table 4-9, Site Water Quality TSD.

c) MOEE (Ministry of Environment and Energy). 1999. Provincial Water Quality Objectives (PWQO), PIBS 3303E, Queen's Printer for Ontario. July 1994, reprinted February 1999. Values greater than the PWQO are in *italic font*.

d) MOE (Ontario Ministry of the Environment). 2011. Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Standards Development Branch, MOE. April 2011. Appendix A3(18), Table 9 (GW3 Values). Values greater than the GW3 are in red font.

e) A 10 times dilution or attenuation along the groundwater flow path would result in aluminum concentration lower than the PWQO values.

f) Maximum Runoff for all Rock Types.

MOE, under O. Reg 153/04 has developed groundwater protection values (GW3) that would be protective of aquatic life based on aquatic protection values (APVs). The APVs are based on the U.S. EPA Ambient Water Quality Criteria (AWQC) for protection of aquatic life and therefore are considered to provide suitable protection for aquatic life.

Prediction of copper in groundwater is considered very conservative in that it does not provide for attenuation of copper concentrations along the flow path. Attenuation of copper concentrations in groundwater would be expected, particularly where flow may occur through soil layers. "Under most conditions, copper is present in aqueous solution as the divalent cation, Cu2+, or as Cu(II) hydroxide or carbonate complexes. However, copper is not especially mobile in aquatic environments due to the relatively low solubility of Cu(II)-bearing solids and high affinity of copper for mineral and organic surfaces." (U.S. EPA, 2007).

References:

Areva, 2011; Hydrology of Waste Rock Piles in Cold Climates; Technical Appendix 5I of the Kiggavik Project Environmental Impact Statement. December 2011.

Macroline, J., 2008. Investigations of water and tracer movement in covered and uncovered unsaturated waste rock, PhD. Dissertation, University of British Columbia, Vancouver, Canada.

MOE (Ontario Ministry of the Environment). 2011. Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Standards Development Branch, MOE. April 2011.

Singer, S.N., and Cheng, C.K. 2002. An Assessment of the Groundwater Resources of Northern Ontario. Hydrogeology of Ontario Series (Report 2). Ministry of the Environment. Toronto. Canada.

U.S. Environmental Protection Agency (USEPA). 2007. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water. Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium. October 2007. U.S. Environmental Protection Agency Report EPA/600/R-07/140 http://www.epa.gov/ada/gw/mna.html. Cincinnati, Ohio 45268.

TECHNICAL MEMORANDUM

DATE December 3, 2013

PROJECT No. 13-1118-0010 (2010)

TO Alexandra Drapack
Osisko Hammond Reef Gold Ltd.

Doc No. 011 (Rev 0)

CC Ken DeVos

FROM Adam Auckland, Adriana Parada and Ken Bocking

EMAIL Adam_Auckland@golder.com

DESIGN BASIS FOR RUNOFF AND SEEPAGE COLLECTION SYSTEMS – HAMMOND REEF GOLD PROJECT

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Osisko Hammond Reef Gold Ltd. (Osisko) to complete the Environmental Impact Assessment (EIA) and Feasibility Study level design of the Tailings Management Facility (TMF), Waste Stockpiles and associated water management systems for the Hammond Reef Gold Project (Project) located northeast of Atikokan, Ontario.

This technical memorandum has been prepared in response to a request received from Environment Canada to provide conceptual design information on the runoff and seepage collection systems for the Tailings Management Facility (TMF) and other stockpiles (i.e. waste rock, overburden and low grade ore).

This memorandum outlines the conceptual design approach and criteria that will serve as a basis for the feasibility level and detailed engineering designs. The design approach and criteria are based on standard engineering practices, project information provided by Osisko, and assumptions based on Golder's experience with similar projects.

2.0 BACKGROUND

Figure 1 shows the layout of the proposed TMF and stockpiles, as well as the associated seepage/runoff collection systems.

The TMF is proposed to store 165 M-m^3 of thickened tailings over a footprint of approximately 800 ha using a central discharge point and a conical deposition method throughout five stages of tailings deposition and progressive dam raise construction. The details of the deposition plan will be developed at the detailed design stage. The TMF will comprise a combination of low permeability zoned earthfill embankment dams with upstream liner, and rockfill dam raises. All runoff and water released from the tailings due to consolidation/settlement will be collected in the TMF reclaim pond (located south of the TMF).

The configuration of the Waste Rock Management Facility (WRMF) and overburden stockpiles include bench heights of 10 m and overall slopes of 2.5H:1V and 2.9H:1V, respectively. The waste rock stockpile will cover an area of about 166 ha with a maximum height of about 120 m and will contain approximately 199 Mt of waste

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rock. The overburden stockpile will be contiguous to the WRMF and will cover an area of about 37 ha with a maximum height of about 40 m and will contain approximately 12.5 Mt of overburden.

The low grade ore stockpile is a temporary stockpile that will exist during operations only. The low grade ore stockpile will not exist after closure because all of the ore will be processed before operations cease. At a maximum height of 70 m, the low grade ore stockpile will contain 21 Mt of ore.

The TMF and stockpile seepage collection systems will consist of the runoff/seepage collection ditches, seepage collection ponds and seepage collection pumping stations, which in turn will pump all collected flows to the TMF reclaim pond or the Process Plant Collection Pond (PPCP).

Runoff/seepage Collection Ditches and Ponds

Runoff/seepage collection ditches will be placed along the downstream toe of each of the TMF dams (north, northeast, east, southwest and west of the TMF), as well as the TMF reclaim pond dam (south of the TMF), to collect toe seepage and local runoff. Water will accumulate in a total of five collection ponds located at topographical low points. A pumping station will be installed in each of the TMF collection ponds and will pump water inside the TMF, where it will flow to the TMF reclaim pond.

Runoff/seepage collection ditches will also be constructed along the perimeter of the three stockpiles: the overburden stockpile, the WRMF and the low grade ore stockpile. Collected water will be rerouted to a total of 9 collection ponds located at topographical low points. A pumping station will be located at each collection pond to recycle accumulated water back into the site water management system.

Each of the seepage collection ponds will be equipped with an emergency spillway to prevent the pond dyke from being overtopped should an extreme storm event occur. Overtopping of a dyke could result in a complete failure of the dyke resulting in a release of all contained water, so it is important to protect against this occurrence.

Management of Collected Water

Water collected within the TMF collection ponds will be pumped within the TMF and will drain to the TMF reclaim pond. Water collected within the stockpile collection ponds will be recycled to the PPCP via an Intermediate Collection Pond. Water collected in the TMF reclaim pond and PPCP will either be used by the Processing Plant for ore processing or released to Marmion Reservoir through an effluent treatment plant, if necessary. An overview of the mine site water management system is provided in Figure 1.

3.0 DESIGN CRITERIA

When the Hammond Reef project enters the detailed design stage, all components of the seepage/runoff collection systems will be designed following standard engineering practice. Table 1 presents the conceptual design criteria for the TMF and stockpile runoff/seepage collection ditches and collection ponds that will be used for the design.

Table 1: Design Criteria for collection ditches and seepage collection ponds

Item	Design Criteria
Collection Ditches	Design flow return period for hydraulic capacity (i.e., ditch size): 25 year peak
	Channel side slopes: 2H:1V (or flatter as required for geotechnical stability)
	Minimum freeboard: 0.3 m

Item	Design Criteria
Collection Ponds	Design return period for storage capacity: 25-year
	Minimum Freeboard (above spillway invert elevation): 0.5 m
	Design flow return period of emergency spillway (IDF): 100 year peak[3]
TMF Reclaim Pond	Environmental Design Flood (EDF)[1]: 100 year rainfall and snowmelt event with a duration of 30 days
	Inflow Design Flood (IDF)[2]: 24 hour, 1:10,000 year rainfall event (Probable Maximum Flood – PMF)
	Minimum Freeboard: 2 m above the maximum tailings surface and/or emergency spillway invert
PPCP	EDF: 24 hour, 1:100 year
	IDF: 24 hour, 1,000 year peak[3]
ICP	EDF: 24 hour, 1:100 year
	IDF: 24 hour, 1,000 year peak[3]

Notes:

1. The Environmental Design Flood is used to determine the volume of water that needs to be retained without resulting in a discharge.
2. The Inflow Design Flood is the runoff resulting from a storm event that can be safely routed through the emergency spillway without overtopping the dam.
3. The IDF for the spillway design corresponds to the recommended minimum for a "significant" hazard dam in Canadian Dam Association (2007)[1].

4.0 DESIGN APPROACH

4.1 Runoff/Seepage Collection Ditches

Collection ditches will be sized to convey seepage and runoff. Runoff design flows will be calculated using an appropriate and accepted hydrologic approach such as the Rational Method. This method is commonly used to calculate peak flows from small watersheds. The flow calculation will consider input parameters such as drainage area, design precipitation event intensity, and runoff coefficient. Seepage rates will be estimated using standard hydrogeological modelling approaches and will consider the TMF dam and stockpile geometry and hydraulic conductivity.

The hydraulic capacity of the collection ditches will be determined using Manning's equation and sized to convey the peak flow from the 25-yr rainfall event with a freeboard of minimum 0.3 m to safely pass the 100-yr rainfall event.

The ditches will have a trapezoidal cross-section and will typically be excavated through the native soil. If required, the ditches will be lined with rip rap to prevent erosion. The thickness of the rip rap will be a minimum of two times the D_{50} of the rip rap size required to withstand the predicted water velocities in each collection ditch section requiring erosion protection. The rip rap will be placed on non-woven geotextile, as required, to prevent erosion of the soils beneath the layer of erosion protection.

A typical collection ditch cross-section is shown in Figure 2.

[1] Canadian Dam Association (2007), "Dam Safety Guidelines". 2007.

4.2 Collection Ponds

The seepage collection ponds will be located at topographic lows and will be designed to be contained by natural topography wherever possible. Excavation and/or the construction of containment berms may be required where natural topography is insufficient for containment. If containment berms are required, the berms will be designed in accordance with the Canadian Dam Association (CDA 2007) and Ministry of Natural Resources (MNR 2011) [2],[3] guidelines.

The seepage collection ponds will be designed to have a storage capacity for the 25-year wet condition. Emergency overflow spillways will be provided for each collection pond to convey storm flows in excess of the design capacity in a controlled manner to the environment. The emergency spillways will be sized to safely convey the peak flow from the 100-yr rainfall event. A minimum allowance for freeboard of 0.5 m will be considered between the berm crest and the maximum operating water level in each pond.

4.3 TMF Reclaim Pond

All runoff and water released from the tailings due to consolidation/settlement will be collected in the TMF reclaim pond which will be located to the south of the TMF.

The TMF reclaim pond will be sized to safely contain the EDF resulting from the 100 year rainfall and snowmelt event with a duration of 30 days.

In accordance with CDA (CDA, 2007), the dam hazard classification of the containment dams is assessed as "high". Based on this classification, the spillways should be designed to safely pass routed flows resulting from the IDF of 1/3 between the 1:1,000 year flood and the Probable maximum Flood (PMF). However, the TMF will be provided with an emergency spillway designed to handle the IDF resulting from the 24 hour, 1:10,000 year rainfall event above the spillway invert (Golder, 2013a). This event is defined as the Probable Maximum Flood (PMF) (Golder, 2013a)[4].

The emergency spillway will comprise a reinforced concrete sill to be constructed across the spillway invert to control outflows and an outlet spillway channel excavated in bedrock and lined with rip rap (sized to withstand the predicted peak water velocities) (Figure 3).

The Hydrological Engineering Center Hydrologic Modeling System software (HEC-HMS) will be used for flood routing of the EDf and IDF during detailed design to determine the spillway invert elevation, the spillway width and the dam crest elevation. The SCS curve number method will be adopted to calculate the infiltration and the SCS unit hydrograph method will be implemented to perform the actual runoff calculations. Input data will include watershed areas, CN numbers, lag time and storage capacity curves among others.

4.4 Process Plant Collection Pond

The PPCP will be divided into two cells by an interior dyke with one cell designed for spill containment (i.e. leach tank rupture and/or thickener failure) and the other cell designed to receive surface water runoff (Golder, 2013b)[5]. As shown on the cross-section of Figure 4, the spill containment will be lined so there will be no seepage through the internal dyke.

[2] Ontario Ministry of Natural Resources, (2011), "Classification on Inflow Design Flood Criteria", Technical Bulletin, August 2011.

[3] Ontario Ministry of Natural Resources, (2011), "Structural Design and Factors of Safety", Technical Bulletin, August 2011.

[4] Golder Associates Ltd. (2013a), "Tailings Management Facility – Feasibility Study Design", Draft Report, April 2013.

[5] Golder Associates Ltd. (2013b), "Process Plant Collection Pond (PPCP) Conceptual Design", Technical Memorandum DOC0005, July 2013.

The proposed side slopes of the PPCP excavation are 2H:1V to allow a geomembrane liner to be placed on the slope, if required. However, it is expected that the majority of the pond excavation will be in rock and therefore steeper side slopes could be considered during detailed design. The Spill Cell will require a low-permeability compacted soil liner, geomembrane liner and/or grouted/sealed bedrock surface to provide containment of spilled process fluids and/or tailings (Golder, 2013b)[4]. Excavated overburden and bedrock may have sufficiently low hydraulic conductivity to minimize seepage from the Runoff Cell (to be confirmed by groundwater modeling during detailed design), which would effectively provide containment and prevent discharge to the environment.

An emergency spillway will be provided on the south side of the Runoff Cell in order to discharge flows in excess of the Environmental Design Storm (EDS) into the West Pit (Golder, 2013b)[4]. The emergency spillway will be sized to safely convey the peak flow from the 24-hr 1,000-yr rainfall event. A stop log control structure will be provided through the interior dyke separating the Spill and Runoff cells. The stop log structure will allow volumes exceeding the capacity of the Spill Cell to be spilled into the Runoff Cell, if necessary.

The HEC-HMS model will be used for flood routing during detailed design. The SCS curve number method will be adopted to calculate the infiltration and the SCS unit hydrograph method will be implemented to perform the actual runoff calculations. Input data will include watershed areas, CN numbers, lag time and storage capacity curves among other.

4.5 Intermediate Collection Pond

The water collected in the ICP from local runoff and other seepage collection ponds will be pumped to the PPCP. The proposed side slopes of the ICP excavation are 2H:1V to allow a geomembrane liner to be placed on the slope, if required. However, it is expected that the majority of the pond excavation will be in rock and therefore steeper side slopes could be considered during detailed design. An emergency spillway will be provided on the southwestern side of the ICP in order to discharge flows in excess of the Environmental Design Storm (EDS). The emergency spillway will be sized to safely convey the peak flow from the 24-hr 1,000-yr rainfall event.

The HEC-HMS model will be used for flood routing during detailed design. The SCS curve number method will be adopted to calculate the infiltration and the SCS unit hydrograph method will be implemented to perform the actual runoff calculations. Input data will include watershed areas, CN numbers, lag time and storage capacity curves among other.

<Original signed by>

<Original signed by>

Adriana Parada, P.Eng.
Water Resources Engineer

Ken Bocking, P.Eng..
Principal

AP/AA/KAB/sp

Attachments:
Figure 1: Surface Water Drainage Plan
Figure 2: Runoff/Seepage Collection Ditch Typical Cross-Section
Figure 3: Reclaim Pond Dam Spillway Profiles and Details
Figure 4: Process Plant Collection Pond Cross-Section and Detail

n:\active\2013\1118\13-1118-0010 osisko-hammond reef - ea support\006 environmental\2010 hydrogeology\doc011_design basis for runoff and seepage collection systems\rev 0\13-1118-0010_doc011_design basis for runoff and seepage_rev 0_3dec13 .docx

610000 612000 614000 616000 618000 620000

5430000 5428000 5426000 5424000 5422000

N

LIVE ORE STOCKPILE
PARKING
SECURITY STATION
TRUCK SHOP
EFFLUENT DISCHARGE POINT
CRUSHED ORE STOCKPILE
FUEL BAY
INTERMEDIATE COLLECTION POND
WASTE ROCK STOCKPILE
EAST PIT
LOW-GRADE ORE STOCKPILE
OVERBURDEN STOCKPILE
100 0 100 200 300
METRES

ACCOMODATION CAMP
PUMPING STATION
TAILINGS MANAGEMENT FACILITY
FRESHWATER INTAKE - CAMP SITE POTABLE
CAMP SITE EFFLUENT DISCHARGE POINT
PUMPING STATION
EMULSION PLANT
DETONATOR STORAGE
PARKING
SECURITY STATION
PARKING
PEBBLE CRUSHING STATION
FRESHWATER INTAKE - PROCESS AND PLANT POTABLE
Sawbill Bay
LIVE ORE STOCKPILE
INTERMEDIATE COLLECTION POND
PROPANE FARM
SUBSTATION
PROCESSING PLANT
PROCESS PLANT COLLECTION POND
TRUCK SHOP
FUEL BAY
EFFLUENT DISCHARGE POINT
EAST PIT
Mitta Lake
GYRATORY CRUSHER PAD
WEST PIT
WASTE ROCK STOCKPILE
DISCHARGE LOCATION
OVERBURDEN STOCKPILE
LOW-GRADE ORE STOCKPILE
Lynxhead Bay

LEGEND

- Freshwater Intake - Camp Site Potable
- Freshwater Intake - Process and Plant Potable
- Effluent Discharge Point
- Discharge Location
- Pumping Station
- Proposed Ditch
- Index Contour (5m interval)
- Ditch
- Marsh/Swamp
- River/Stream
- Road
- Trail
- Intermediate Collection Pond
- Watershed Boundary
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Tailings Management Facility
- Pumping Station
- Processing Plant Collection Pond
- Office and Truck Shop, Explosives Storage and Processing Plant
- Accommodation Camp
- Open Pits
- Waste Rock Stockpile
- Overburden Stockpile
- Low-Grade Ore Stockpile
- Tailings Management Facility Reclaim Pond
- Laydown Area

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

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SCALE 1:40,000 METRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SURFACE WATER DRAINAGE PLAN

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	8 Nov. 2013		
CHECK	SP	8 Nov. 2013		
REVIEW	SP	8 Nov. 2013		

FIGURE: 1

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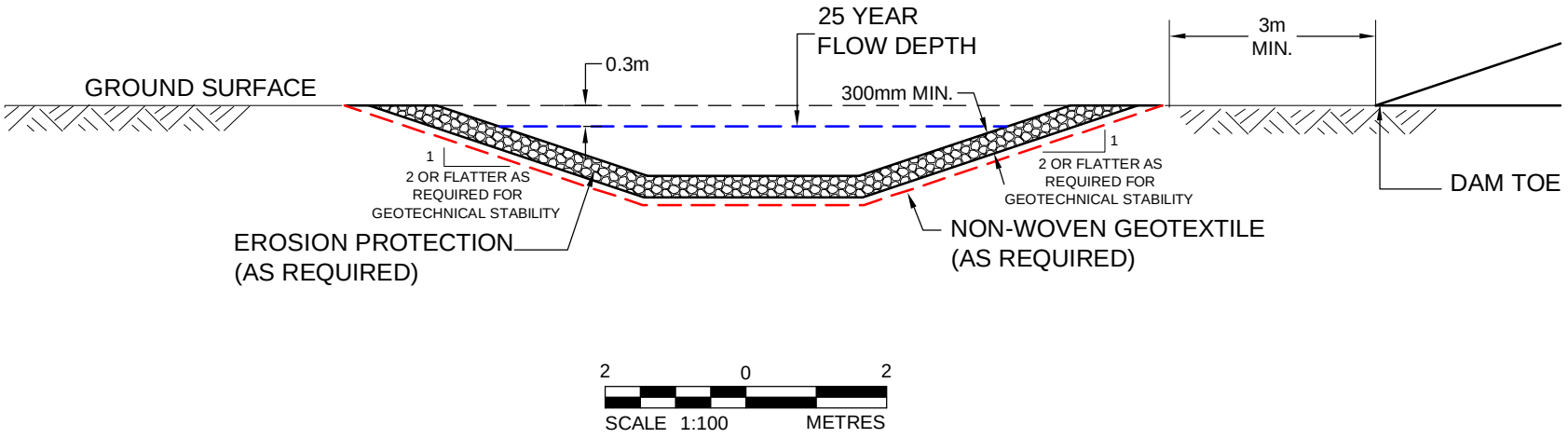
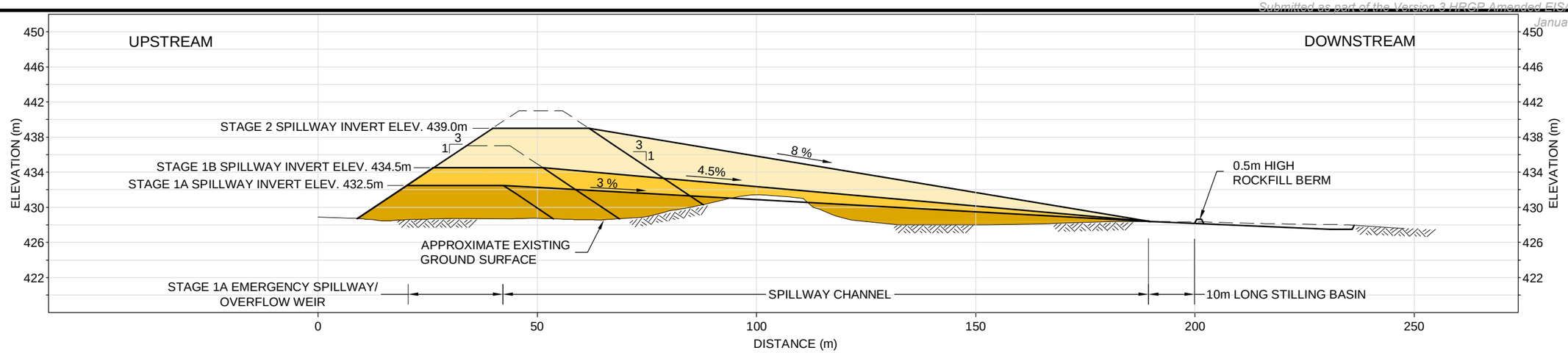
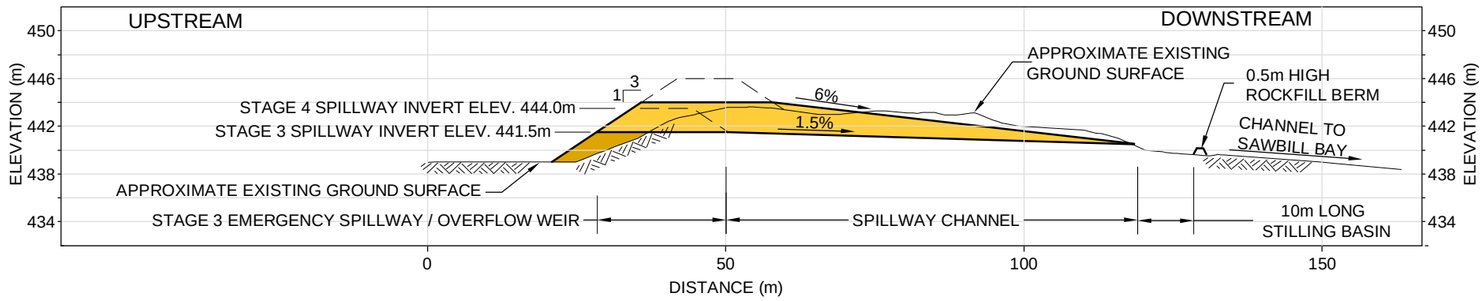
Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263



Golder Associates Mississauga, Ontario, Canada	SCALE AS SHOWN	TITLE	**RUNOFF / SEEPAGE COLLECTION DITCH TYPICAL CROSS-SECTION**
	DATE Nov. 7, 2013		
	DESIGN AP		
	CAD TDR		
FILE No. 1311180010AA002.dwg	CHECK AA	HAMMOND REEF GOLD PROJECT	FIGURE **2**
PROJECT No. 13-1118-0010(2010) REV. A	REVIEW KDV		



PROFILE ALONG RECLAIM POND DAM SPILLWAY AND SPILLWAY CHANNEL - STAGES 1A, 1B AND 2



PROFILE ALONG RECLAIM POND DAM SPILLWAY AND SPILLWAY CHANNEL - STAGES 3 AND 4

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VERTICAL (2X)
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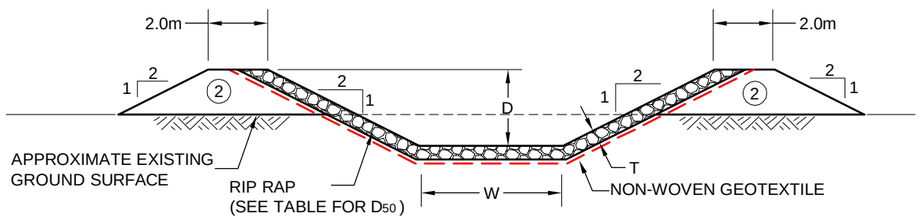
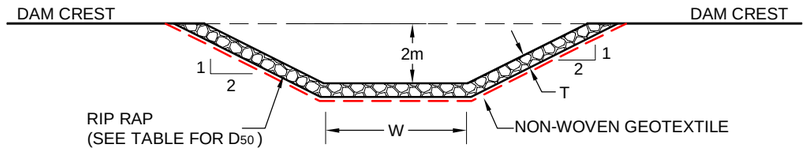
SCALE 1:500 METRES



CROSS-SECTION OF SPILLWAY CHANNEL, STILLING BASIN AND CHANNEL TO SAWBILL BAY



CROSS-SECTION OF OVERFLOW WEIR

4 0 4
SCALE 1:200 METRES

LEGEND:

- NON-WOVEN GEOTEXTILE
- (2) TRANSITION ZONE (150mm MINUS)
- RIP RAP

SPILLWAY CHANNEL DIMENSIONS, SLOPE AND RIP RAP SIZE

Stages	Structure	W (m)	D (m)	Rip Rap D_{50} (m)	T (m)	Channel Slope	Channel Length (m)
Stage 1A	Overflow Weir	5	2	0.3	0.6	0%	22
	Spillway Channel	3	2	0.3	0.6	3.0%	160
	Stilling Basin	3	3	0.3	0.6	0%	10
Stage 1B	Overflow Weir	5	2	0.3	0.6	0%	22
	Spillway Channel	3	2	0.3	0.6	4.5%	150
Stage 2	Overflow Weir	10	2	0.3	0.6	0%	22
	Spillway Channel	5	2	0.5	1	8.0%	140
Stage 3	Overflow Weir	10	2	0.3	0.6	0%	22
	Spillway Channel	3	2	0.3	0.6	1.5%	70
	Stilling Basin	3	3	0.3	0.6	0%	10
	Channel to Sawbill Bay	3	2	0.3	0.6	Varies	850
Stage 4	Overflow Weir	10	2	0.3	0.6	0%	22
	Spillway Channel	3	2	0.5	1	6%	60

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Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	NOV. 2013
DESIGN	SR
CAD	TDR
CHECK	DCJ
REVIEW	JKB

FILE No. 1311180070BA003.dwg
PROJECT No. 13-1118-0010 REV. A

TITLE
RECLAIM POND DAM SPILLWAY PROFILES AND DETAILS

HAMMOND REEF GOLD PROJECT

FIGURE 3

PLOT DATE: November 19, 2013
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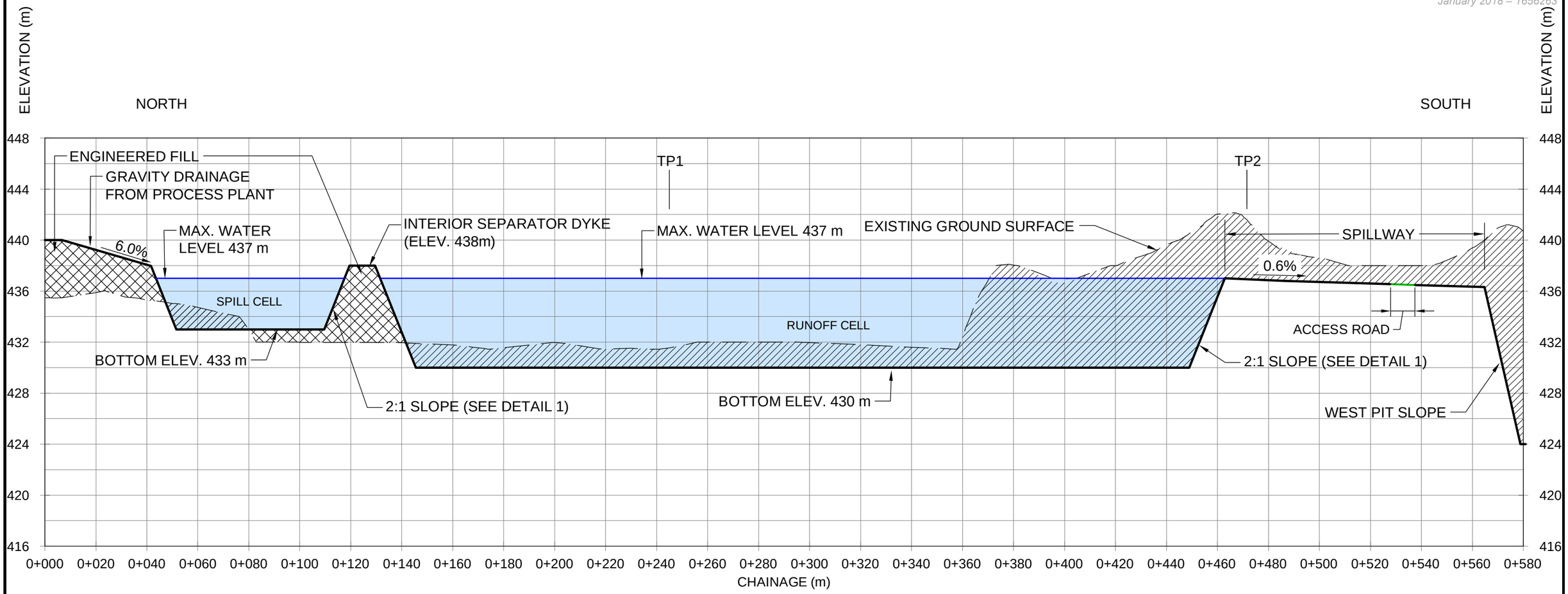

CROSS - SECTION A - A'

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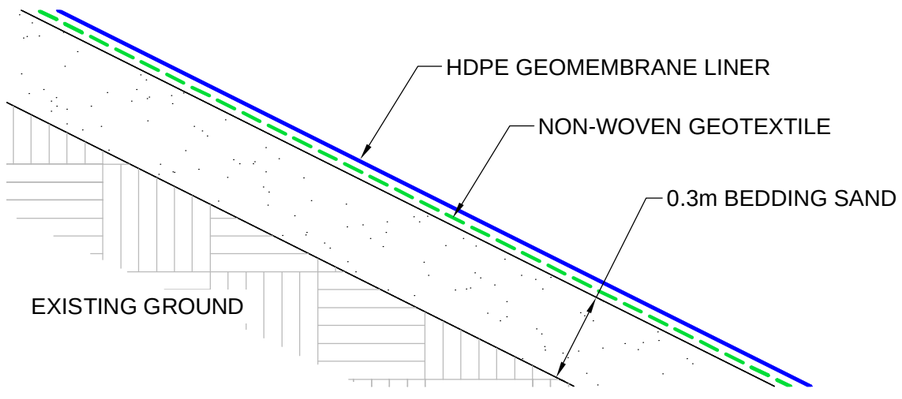
6 0 6 12
SCALE (VERTICAL) 1:300 METRES



DETAIL 1 - CONTAINMENT LINER

NOT TO SCALE

LEGEND:

- ENGINEERED FILL
- EXCAVATION
- HDPE GEOMEMBRANE LINER
- NON-WOVEN GEOTEXTILE

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Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	NOV. 2013
DESIGN	RW
CAD	MY
CHECK	DCJ
REVIEW	JKB

FILE No. 1311180070BA004.dwg
PROJECT No. 13-1118-0010 REV. A

TITLE
PROCESS PLANT COLLECTION POND CROSS-SECTION AND DETAIL

HAMMOND REEF GOLD PROJECT

FIGURE 4

PLOT DATE: November 19, 2013
FILENAME: I:\Projects\2013\13-1118-0010 (OHGH, Atikokan)\-BA-\1311180070BA004.dwg

611500 612000 612500 613000

5422000 5421500 5421000 5420500

Mitta Lake
431.01

Marmion Lake
415

BRH-0005B 439.605
BRH-0001B 428.247
BR-6241 439.1
BR-6030 439.1
BR-6203 432.322
BR-6144 431.63
BR-6051 434.56
BR-6210 431.829
BR-0325 434.6
BR-6224 431.5
BR-6037 433.62
BR-6267 437.85
BR-6221 437.45
BR-6270 435.87
BR-6021 434.53
BR-6192 438.141
BR-0442 440.23
BR-0390 434.73
BR-1012 433.78
BR-1290 445.59
BR-1162 436.09
BR-1249 428.55
BR-6103A 436.25
BR-1112 428.82
BR-1278 430
BR-1283 432.34
BR-1102 429.13
BR-1095 435.68
BR-1093 435.02
BR-6223 433.72
BR-0115 434
BR-6004 433.8
BR-1214 435.32
BR-1280 435.06
BR-1207 428.1
BR-6213 433.649
BR-6190 433.97
BR-0384 428.37
BR-1237 438.17
BR-1229 436.71
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BR-0090 434.29
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BR-6106 432.46
BR-0401 418.6
BR-1198 423.46
BR-1248 426.763
BR-1227 426.61
BR-1050 447.673
BR-6113 433.56
BRH-0003 416.5
BR-1188 416.638
BR-0073 419.991
BR-1042 432.88
BR-0058 436.12
BR-0408 416.53
BR-0413 415.96
BR-1048 434.06
BR-0246 434.05
BR-1159 431.79
BR-1272 418.923
BR-0226 432.82
BR-0216 434.61
BR-1003 434.75
BRH-0008B 419.534
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BR-1151 425.42
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BR-0433 421.556
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BR-1223 426.45
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BR-0437 426.13
BR-1144 421.14
BR-1267 420.95
BR-1161 432.2
BR-1153A 432.66
BR-1261 419.63
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BRH-0002B 422.339
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BR-1083 418.12

LEGEND

434.61 Groundwater Elevation (masl)
Monitoring Well
Inferred Direction of Shallow Groundwater Flow
Inferred Groundwater Divide
Groundwater Elevation Contour (masl)
Mapped Faults
Intermediate Contour (5m interval)
Ditch
Marsh/Swamp
Road
Trail
River/Stream
Lake

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

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SCALE 1:7,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
GROUNDWATER ELEVATIONS AND INFERRED FLOW DIRECTIONS - WEST PIT AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			SCALE AS SHOWN	VERSION 2
DESIGN	CGE	14 Nov. 2008		
GIS	JO	26 Jun. 2013		
CHECK	MSO	26 Jun. 2013		
REVIEW	JMP	26 Jun. 2013		

FIGURE: 2-10A

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PART C

Hydrogeology Technical Support Document, Version 1

December 2013
Project No. 13-1118-0010
Hammond Reef Gold Project

February 2013

HAMMOND REEF GOLD PROJECT
Hydrogeology
Technical Support Document

VERSION 1

Submitted to:
Osisko Hammond Reef Gold Ltd.
155 University Avenue, Suite 1440
Toronto, Ontario M5H 3B7

Project Number: 10-1118-0020
Document Number: 2012-067
Distribution:

Alexandra Drapack, Director Sustainable Development
Cathryn Moffett, Project Manager Sustainable Development

Golder Associates

Hammond Reef Gold Project
Hydrogeology Technical Support Document

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Golder Associates Ltd.

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1.0 INTRODUCTION

Osisko Hammond Reef Gold Ltd. (OHRG) proposes the development of an open pit gold mine in north-western Ontario, herein referred to as the Hammond Reef Gold Project (Project). This Technical Support Document (TSD) is one of a series of reports in support of the Project's Environmental Impact Statement/Environmental Assessment Report (EIS/EA Report).

The following reports have been prepared to support the EIS/EA Report:

- Atmospheric Environment TSD.
- Geochemistry, Geology and Soil TSD.
- **Hydrogeology TSD.**
- Hydrology TSD.
- Water and Sediment Quality TSD.
- Site Water Quality TSD.
- Lake Water Quality TSD.
- Aquatic Environment TSD.
- Terrestrial Ecology TSD.
- Aboriginal Interests TSD.
- Cultural Heritage Resources TSD.
- Human Health and Ecological Risk Assessment TSD.
- Socio-economic Environment TSD.
- Alternatives Assessment Report.
- Conceptual Closure and Rehabilitation Plan.

The EIS/EA Report will summarize the findings of this TSD and of the above-listed supporting reports.

1.1 Purpose and Scope

The purpose of this TSD is to fulfill the assessment scope outlined in the Project's Terms of Reference (ToR) approved by the Ontario Minister of the Environment (July 2012), and in the Environmental Impact Statement Guidelines (EIS Guidelines) published by the Canadian Environmental Assessment Agency (CEA Agency) (December 2011).

This TSD provides a description of the existing conditions of the hydrogeology environment including environmental processes, interrelations and interactions of hydrogeological subcomponents, and their predicted

variability over Project phases. The assessment of hydrogeology is broken down into the following subcomponents:

- Groundwater quantity.
- Groundwater quality.

The overall objective of the hydrogeology assessment described in this TSD is to provide specific information at a level sufficient for inclusion in the EIS/EA Report in order to guide decision making regarding the potential for environmental effects of the Project, or to allow for further analyses as part of other TSDs or work related to the environmental assessment. The information and findings developed from this assessment of hydrogeology will be considered in other TSDs including the Site Water Quality TSD, the Aquatic Environment TSD, the Terrestrial Ecology TSD, and the Hydrology TSD. It should be noted that prediction of changes in groundwater quality are considered in the Site Water Quality TSD. This Hydrogeology TSD provides the existing groundwater quality only. The assessment of environmental effects, the determination of significance of these effects, and the proposed mitigation measures will be addressed in the EIS/EA Report and the Human Health and Ecological Risk Assessment TSD. An explanation of this approach is provided in Section 1.4 of this report.

1.2 Report Organization

This TSD is structured as follows:

- Section 1 presents the purpose and scope of the TSD, an overview of the Project, the general assessment approach, Valued Ecosystem Components, assessment boundaries of the TSD.
- Section 2 describes the existing conditions and predicted potential changes to groundwater quantity.
- Section 3 describes the existing conditions for groundwater quality.
- Section 4 outlines the requirements for the monitoring of groundwater quantity during the Project's life cycle.
- Section 5 summarizes the findings of this report.

1.3 Project Overview

The Project overview and Project description is provided in Chapter 5 of the EIS/EA Report. Project aspects that influence the hydrogeological evaluation are described in Sections 1.3 to 1.8.

1.3.1 Project Location

The Project is located within the Thunder Bay Mining District in north-western Ontario, approximately 170 kilometres (km) west of Thunder Bay and 23 km northeast of the town of Atikokan (Figure 1-1).

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

100 0 100 200 300 400
SCALE 1:10,000,000 KILOMETRES

Golder Associates
Mississauga, Ontario

PROJECT No.	10-1118-0020
SCALE	AS SHOWN
VERSION	1
DATE	February 2013
DESIGN	JO
GIS	JO
CHECK	MSO
REVIEW	JMP

TITLE

PROJECT LOCATION

PROJECT HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

FIGURE: 1-1

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Road access to the Hammond Reef property is presently via two routes: the Premier Lake Road, a gravel road that intersects Highway 623, near Sapawe, and the Hardtack-Sawbill Road, a gravel road that intersects Highway 622 northwest of the Town of Atikokan. The Project Site is also accessible by water from the southwest end of the Upper Marmion Reservoir at its access point from Highway 622. The existing Hardtack-Sawbill Road located to the north of Finlayson Lake has been upgraded to provide an improved and more direct linkage to the Project Site in support of the expanded exploration program. Access routes to the Hammond Reef property are shown on Figure 1-2.

The Hammond Reef deposit is located mainly on a peninsula of land extending into the north end of the Upper Marmion Reservoir (Figure 1-2). The peninsula containing the deposit is surrounded by the Upper Marmion Reservoir on three sides with Sawbill Bay to the northwest and Lynxhead Bay to the southeast. The property also contains a number of smaller lakes. Mitta Lake is a small, steep-sided waterbody located atop mineralized zones of the deposit. Due to its location, the open pit mining activities require the draining of Mitta Lake.

1.3.2 Climate

The Project is located in a typical boreal climate region, which is characterized by long, usually very cold winters, and short, cool to mild summers. The annual temperature average is 1.6 degrees Celsius (°C) for Atikokan with a seasonal maximum of 16.2°C (average) for summer and a minimum of minus 15.4°C (average) for winter. Temperatures lower than minus 37°C have been recorded during the fall and winter. The annual normal total for precipitation is 788 millimetres (mm) (568 mm of rainfall and 220 mm of snowfall) for Atikokan with a seasonal maximum of 299 mm for the summer period.

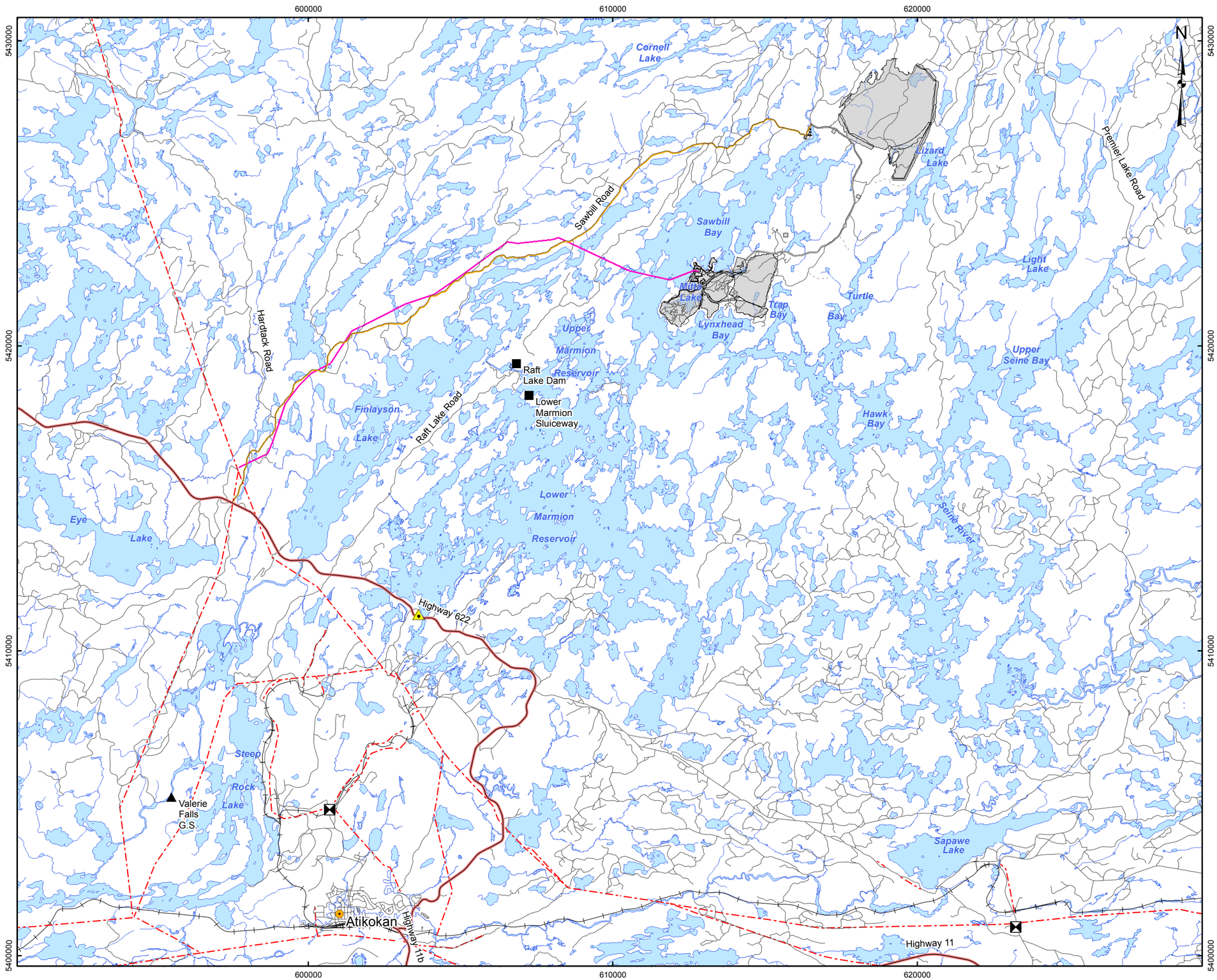
1.3.3 Project Phases

The Project comprises four phases: construction, operations, closure and post-closure. With regards to the hydrogeological assessment, the most relevant is the operations phase given continuous pumping of groundwater inflow to the Mine. The greatest drawdown of groundwater levels will occur at the end of mining.

Activities expected to have the greatest influence on the hydrogeological environment include:

- Dewatering operations at the Mine through to the end of mining.
- Rise in groundwater levels associated with flooding of the Mine during post-closure.
- Seepage collection structures at the perimeter of stockpiles (waste rock, low-grade ore and overburden) and the Tailings Management Facility.

Additional details regarding activities expected to take place in each phase of the Project are provided in Chapter 5 of the EIS/EA Report.



LEGEND

- City/Town
- Boat Launch
- Waterpower Facility
- Water Control Dam Location
- Existing Power Transmission Station
- Provincial Highway
- Road
- Trail
- Existing Railway
- Power Transmission Line
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities

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

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SCALE 1:125,000 METRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
PROJECT LOCATION - LOCAL SCALE

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	FIGURE: 1-2	
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

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1.3.4 Project Components

The Project consists of eight main components:

- Mine, including two open pits (east pit and west pit).
- Waste Rock Management Facility (WRMF).
- Ore Processing Facility.
- Tailings Management Facility (TMF).
- Support and Ancillary Infrastructure.
- Water Management System.
- Linear Infrastructure.
- Borrow Sites.

Of these, the key components related to hydrogeology are the Mine, WRMF, TMF and Water Management Systems. Seepage from the WRMF and TMF will be captured as described in the Site Water Quality TSD. Project components are shown in Figure 1-3. A detailed description of Project components is provided in Chapter 5 of the EIS/EA Report.

1.4 General Assessment Approach

The Project has the potential to affect the hydrogeological environment. The approach for this TSD follows six key steps:

- Step 1: Screening of Project activities to determine which activities have the potential to produce changes to the hydrogeological environment.
- Step 2: Identify temporal and spatial boundaries within which potential changes to the hydrogeological environment may occur.
- Step 3: Identify parameters used to characterize these potential changes.
- Step 4: Design and carry out field studies and/or background research to characterize the existing hydrogeological environment, and to support the prediction of changes on the hydrogeological environment as a result of the Project.
- Step 5: Carry out predictive modelling of potential changes to the hydrogeological environment during Project phases identified as bounding scenarios.
- Step 6: Outline the monitoring requirements for each Project phase to confirm if predicted changes to the hydrogeological environment have occurred.

This TSD is intended to support the EIS/EA Report and as such does not assess the significance of potential effects on the hydrogeological environment, nor does it identify mitigation measures. These topics are addressed in the EIS/EA Report and in other TSDs, including the Site Water Quality TSD, the Aquatic Environment TSD, the Terrestrial Ecology TSD and the Hydrology TSD.

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N

Serpent Lake
Cornell Lake
Long Hike Lake
PREMIER ROAD
TAILINGS MANAGEMENT FACILITY
ACCOMMODATION CAMP
PUMPING STATION
SAWBILL ROAD
Vista Lake
Lizard Lake
PUMPING STATION
DETONATOR STORAGE
EMULSION PLANT
Sawbill Bay
PEBBLE CRUSHING STATION
CONCENTRATOR
POWER SUBSTATION
PROPANE FARM
EFFLUENT TREATMENT PLANT
PROCESS PLANT COLLECTION POND
GYRATORY CRUSHER PAD
LIVE ORE STOCKPILE
PARKING LOT
SECURITY STATION
TRUCK SHOP / MINE OFFICE
PARKING LOT
FUEL BAY
EAST PIT
WEST PIT
WASTE ROCK STOCKPILE
Trap Bay
Turtle Bay
Light Lake
Marmion Reservoir
LOW-GRADE ORE STOCKPILE
OVERBURDEN STOCKPILE
Lynxhead Bay
Upper Seine Bay

LEGEND

- Road
- Trail
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Accommodation Camp
- Laydown Area
- Office and Truck Shop, Explosives Storage and Processing Plant
- Open Pits
- Low-Grade Ore Stockpile
- Overburden Stockpile
- Process Plant Collection Pond
- Pumping Station
- Tailings Management Facility
- Tailings Management Facility Reclaim Pond
- Waste Rock Stockpile
- Mine Area
- Tailings Management Facility Area
- Hydrogeology Local Study Area

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

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SCALE 1:50,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SITE LAYOUT AND HYDROGEOLOGY STUDY AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	FIGURE: 1-3	
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

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1.5 Incorporation of Traditional Knowledge

Traditional knowledge in combination with other information sources is valuable in achieving a better understanding of the Project's potential effects on the biophysical and socio-economic environment. It also contributes to the description of the existing biophysical and human environment, natural cycles, resource distribution and abundance, and the use of land and water resources. Those aspects of traditional knowledge related to water quantity and water quality will be important when considering the results of the hydrogeological assessment in the context of the overall site water discharge and water quality during operations and at closure. A detailed discussion on traditional knowledge is included in the Aboriginal Interests TSD.

1.6 Selection of Valued Ecosystem Components

The Valued Ecosystem Components (VECs) selected are groundwater quantity and groundwater quality. This Hydrogeology TSD addresses groundwater quantity only and the rationale for the selection of this VEC is provided in Table 1-2 along with proposed indicators and measures. The rationale for the selection of groundwater quality as a VEC is provided in the Site Water Quality TSD.

Table 1-2: Valued Ecosystem Component Selected for the Hydrogeological Environment

VEC	Rationale for Selection	Indicators	Measures
Groundwater Quantity	Potential for change to groundwater flow system within the Project footprint as a result of Project activities.	■ Changes in vertical and/or horizontal gradients ■ Changes in flow direction ■ Changes in groundwater contribution to baseflow	■ Groundwater levels

1.6.1 Groundwater Quantity

This Hydrogeology TSD addresses the existing conditions and predicted changes in groundwater levels associated with the development, operation and closure of the Project. No water supply wells are present in the Local Study Area (LSA) and so predicted changes in groundwater levels are not a concern for their operation. Predicted changes in groundwater levels and reductions in groundwater discharge to local streams (baseflow) are quantified herein. The significance of these changes is assessed in the Hydrology TSD, the Terrestrial Ecology TSD and the Aquatic Environment TSD.

1.6.2 Groundwater Quality

This Hydrogeology TSD addresses existing conditions only for groundwater quality. Predictions of changes in groundwater quality associated with the development, operation and closure of the Project are addressed in the Site Water Quality TSD. The Site Water Quality TSD addresses both surface water and groundwater quality as predicted changes in groundwater quality will result in predicted changes in surface water quality.

1.7 Effects Assessment

There are no groundwater users (i.e., domestic, municipal, commercial or industrial water wells) in the vicinity of the Project that could potentially be affected by changes in groundwater levels from Project activities. Therefore while changes to groundwater levels may lead to or influence the assessment of effects of the Project, such changes are not in and of themselves endpoints of the assessment. The assessment of effects developed from changes in hydrogeology will be considered in other TSDs including the Site Water Quality TSD, the Terrestrial Ecology TSD and the Hydrology TSD.

1.8 Temporal and Spatial Boundaries

1.8.1 Temporal Boundaries

Temporal boundaries define the temporal extents within which changes to the environment resulting from Project activities are considered. The Project's hydrogeology temporal boundaries are directly related to Project phases and the duration of these phases, namely: During operations, groundwater levels will decline with the excavation of and pumping from the Mine. Groundwater levels will decline on a continuous basis as the pits are progressively deepened throughout the operations phase. Groundwater level decline will reach a maximum at the end of mining. Therefore, the point at which dewatering ceases (end of mining) has been identified as the only temporal boundary in the assessment of hydrogeology for the Project.

A minor rise in groundwater levels may occur in the immediate vicinity of the stockpiles (waste rock, low-grade ore, and overburden), TMF and process plant collection pond (PPCP) during operations. Engineered controls at these facilities have been designed to limit seepage losses to the adjacent surface water receptors. Predicted seepage losses from these facilities including consideration of any change in groundwater levels, is assessed in the Site Water Quality TSD.

Changes in groundwater levels that may occur during the construction phase will be associated with development of infrastructure. These changes, if any, will be minor and encompassed by changes expected during operations. As such, a temporal boundary for the construction phase has not been established for hydrogeology.

At closure, pumping from the open pits will cease and groundwater levels will begin to rise. As discussed in the Conceptual Closure and Rehabilitation Plan for the EIS/EA Report, it is expected that it will take approximately 78 years for pit water levels to rise to an elevation of 420 masl, the proposed spill-over elevation from the pits to the environment. Groundwater levels will rise progressively along with pit water levels and approach pre-mining elevations over much of the area that experienced changes during operations. It is expected that any residual changes in groundwater levels will be minor and evident only in the immediate vicinity of the open pits. As such, a temporal boundary for post-closure, when groundwater levels recover to an equilibrium level, has not been established for hydrogeology. The effects of closure on the stockpiles (waste rock, low-grade ore, overburden), TMF and PPCP are addressed in the Site Water Quality TSD.

1.8.2 Spatial Boundaries

Spatial boundaries define the geographical extents within which potential environmental changes may occur. As such, spatial boundaries become the hydrogeological study area for the Project. The study area for the hydrogeological assessment was selected based on the following factors:

- General geological conditions.
- Location and depth of the Mine and the location of other mine infrastructure.
- Location of major lakes, streams and watershed divides.

This TSD has one study area, as described in the following section.

1.8.3 Local Study Area

The hydrogeology local study area (LSA) has been developed from the general geological and hydrogeological conditions on the Project Site, the location and depth of the Mine along with other mine infrastructure, and the immediate proximity of the bounding Upper Marmion Reservoir and other surface water features. Experience from other open pit mines developed on the Canadian Shield shows that changes (lowering) in groundwater levels are typically limited to the immediate vicinity of the Mine.

As shown in Figure 1-3, the LSA encompasses the Mine, the WRMF and the TMF. The LSA is bounded by the shoreline of Sawbill Bay, Lynxhead Bay and Trap Bay of Upper Marmion Reservoir on the west and south sides respectively. The LSA is bounded to the east by the shoreline of Turtle Bay (Upper Marmion Reservoir) and Lizard Lake and encompasses the TMF to the north.

2.0 GROUNDWATER QUANTITY

2.1 Parameters

The following parameters were investigated to characterise groundwater quantity within the LSA:

- Groundwater levels.
- Hydraulic gradients.
- Hydraulic conductivity.
- Groundwater flow system.

This discussion of groundwater quantity within the LSA focuses primarily on the area surrounding the Mine where groundwater levels are likely to be affected (i.e., lowered) by mining and pit dewatering activities. Groundwater level changes in the vicinity of the TMF will be affected to a much lesser degree by construction of the TMF and deposition of tailings. As a result, for the purposes of this discussion, the key Project components within the LSA are discussed in the context of two separate areas:

1) The Mine Area which includes the east and west pits, the WRMF, low-grade ore and overburden stockpiles, the PPCP and the Ore Processing Facility.
2) The TMF Area.

The boundaries of the Mine Area and TMF Area are shown in Figure 1-3.

2.2 Field Studies

2.2.1 Previous Investigations

A geotechnical program was conducted to support the design of the pit slopes for the Feasibility Pit Slope Design study of the Project (Golder 2012). The program included the following field investigations:

- Drilling of six HQ-3 size diamond core geotechnical holes (denoted GT01 to GT06) with core orientation.
- Detailed geotechnical core logging including description and orientation of discontinuities.
- Point load strength testing.
- Downstage hydraulic conductivity testing (packer testing) at varying depth intervals to determine bedrock hydraulic conductivity profiles.
- Collection of rock samples for laboratory testing.
- Acoustic televiewer survey of five boreholes (Holes GT01, GT03 to GT05, and Exploration Hole BR366).
- Installation of four grouted-in-place vibrating wire piezometers in boreholes GT01, GT03, GT04, and GT05 to monitor groundwater levels.

Boreholes were inclined to assess bedrock structure in the vicinity of the slopes of the proposed open pits. Borehole drilling locations were selected based on the geological model developed by OHRG from their extensive exploration drilling program.

Select results from this geotechnical investigation program are provided in Appendix 2.I.

2.2.2 Existing Conditions Field Program

The investigation of existing hydrogeological conditions focused on near surface (shallow bedrock and overburden where present) conditions in the Mine Area and in the TMF. In addition, some investigations were directed to characterising the hydraulic properties of deep bedrock in the Mine Area. OHRG has conducted extensive exploration drilling at the Project Site and developed a geological model of bedrock structure and lithology. The results of the exploration drilling program and the geological model guided the development of this hydrogeology drilling program.

The following field activities were conducted:

- Project Site walkover for selection of locations for borehole drilling, observation of areas of groundwater seepage and low flow conditions in nearby streams, and areas of exposed bedrock.
- Drilling of 49 boreholes and installation of 47 monitoring wells (single and nested wells) at 34 locations throughout the LSA.
- Drilling of 5 boreholes and installation of 5 monitoring wells (single and nested) in the vicinity of the proposed accommodation camp (Appendix 2.II).
- Monitoring of groundwater levels at 45 monitoring wells including the use of 16 data logging pressure transducers (data loggers) to obtain continuous records of water level fluctuations.
- In-situ hydraulic conductivity tests at groundwater monitoring wells.
- Grain size analysis of overburden soils.
- Geophysical logging of two exploration boreholes.
- Short-term step drawdown pumping tests at 46 exploration boreholes.
- Passive thermal profile testing, heat pulse flow profiling and constant rate pumping of exploration borehole BR-0433.
- Depth to water measurements at 126 exploration boreholes including the use of data loggers at 16 locations to obtain continuous water level records.
- Three constant rate pumping test events at two exploration boreholes.

A summary of hydrogeological field investigations completed for the Project is provided in Table 2-1.

Table 2-1: Summary of Hydrogeological Field Investigation Dates

Tasks – Shallow Groundwater Investigation	2011	2012
Site walkover	February 1 to 3	—
Borehole drilling and monitoring well installation	Mar 17 to May 2	August 8 to 21
Soil grain size analyses	May/June	September/October
Hydraulic conductivity tests (slug tests)	May 3 to May 7	—
Groundwater level monitoring including installation/downloading of data loggers	May 31 to June 2 August 24 to 29 October 26 to 30	April 21 to 25 August 27 to 31

Tasks – Deep Groundwater Investigation	2011	2012
Hydraulic conductivity tests:		
■ Short-term pumping tests	October 18 to 28	—
■ Constant-rate pumping tests at BR-0220	September 9 to 11	March 10 to 14
■ Constant-rate pumping test at BR-0231	September 11 to 13	March 14 to 16
Geophysical borehole logging	September 11 to 15	—
Groundwater level monitoring	October 26 to March 9	

Notes:
— = Field investigations not conducted in this period.

2.3 Existing Conditions

2.3.1 General Setting

The Project is located within the Thunder Bay Mining District in north-western Ontario, approximately 170 km west of Thunder Bay and 23 km northeast of the town of Atikokan. This area forms part of the physiographic region known as the Severn Uplands (Thurston 1991), a broadly rolling surface of Canadian Shield bedrock that occupies most of north-western Ontario. The bedrock throughout the area is typically either exposed at surface or covered by a thin blanket of Quaternary glacial deposits.

Geological mapping of the area began in the 19th century coinciding with increased prospecting/mining activity including the development of the Hammond Reef and Sawbill mines in the late 1890s in the vicinity of the currently proposed east pit. More detailed geological mapping was initiated in the 1930s by the Ontario Department of Mines and has continued to present. Stone (2010) summarizes work on geochronology and the structural evolution of the area and additional site-specific geological, and structural descriptions are provided in Atomic Energy of Canada Ltd.'s research on brittle rock fracture at the Eye–Dashwa granite (located 30 km north of Atikokan and about 15 km west of the Marmion Fault).

The Mine Area, which includes the open pits, various stockpiles and the Ore Processing Facility, is located generally on a peninsula extending into the north end of the Upper Marmion Reservoir. As shown in Figure 1-3, this peninsula is surrounded by the Upper Marmion Reservoir on three sides with Sawbill Bay to the west and northwest, Lynxhead Bay to the south and Trap Bay to the southeast. The TMF is located to the northeast of the Mine Area and is surrounded by lakes on three sides; Long Hike Lake to the north and Lizard Lake to the east, both of which drain to the Upper Marmion Reservoir which borders the TMF to the southwest. The Upper Marmion Reservoir, which forms part of the Seine River basin, drains to the southwest.

There are a number of small lakes located within the LSA. Mitta Lake is located in the centre of the proposed west pit approximately 20 m above the elevation of Upper Marmion Reservoir. The shoreline of Mitta Lake is generally steep and surrounded by exposed bedrock. A number of other aquatic features exist within the LSA including small lakes, streams, bogs, swamps, fens and marshes. Some small intermittent/ephemeral steams occur within the hydrology Mine Study Area (Hydrology TSD). Some of these streams were observed dry in the summer 2012, and others are expected to freeze during the winter based on channel cross-section and the expected maximum ice thickness (Hydrology TSD, Section 5.1.2.1.1 and Appendix A).

The forest communities of the area are dominated by black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*).

The land surface ranges in elevation from about 415 to 460 masl with the lower elevation being the approximate elevation of Upper Marmion Reservoir. The area is dominated by steep knobs and ridges of exposed bedrock with the intervening lows covered by a discontinuous veneer of glacial till overlain with organic topsoil or swampy organic deposits. Photo 2-1 depicts the typical land cover and topography within the Mine Area, and the topography of the LSA is shown in Figures 2-1 and 2-2.

Topographic lows in the southwest portion of the LSA are typically infilled with glacial till overlain by glaciofluvial deposits and recent alluvium and organic soils. The till is comprised mainly of silt, sand and boulders and rarely exceeds two metres in depth. Bedrock, which is situated at or near the ground surface throughout much of the area, controls the topography and surface drainage conditions.

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Sawbill Bay

PEBBLE CRUSHING STATION
PROPANE FARM
POWER SUBSTATION
CONCENTRATOR
EFFLUENT TREATMENT PLANT
PROCESS PLANT COLLECTION POND
GYRATORY CRUSHER PAD
WEST PIT
Mesa Cave
LOW-GRADE ORE STOCKPILE
EAST PIT
PARKING LOT
LIVE ORE STOCKPILE
FUEL BAY
DETONATOR STORAGE
EMULSION PLANT
SECURITY STATION
TRUCK SHOP / MINE OFFICE
PARKING LOT
WASTE ROCK STOCKPILE
OVERBURDEN STOCKPILE

Lynxhead Bay

LEGEND

- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Process Plant Collection Pond
- Office and Truck Shop, Explosives Storage and Processing Plant
- Open Pits
- Waste Rock Stockpile
- Overburden Stockpile
- Low-Grade Ore Stockpile
- Laydown Area
- Hydrogeology Local Study Area

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

250 0 250 500 750 1,000 1,250
SCALE 1:25,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

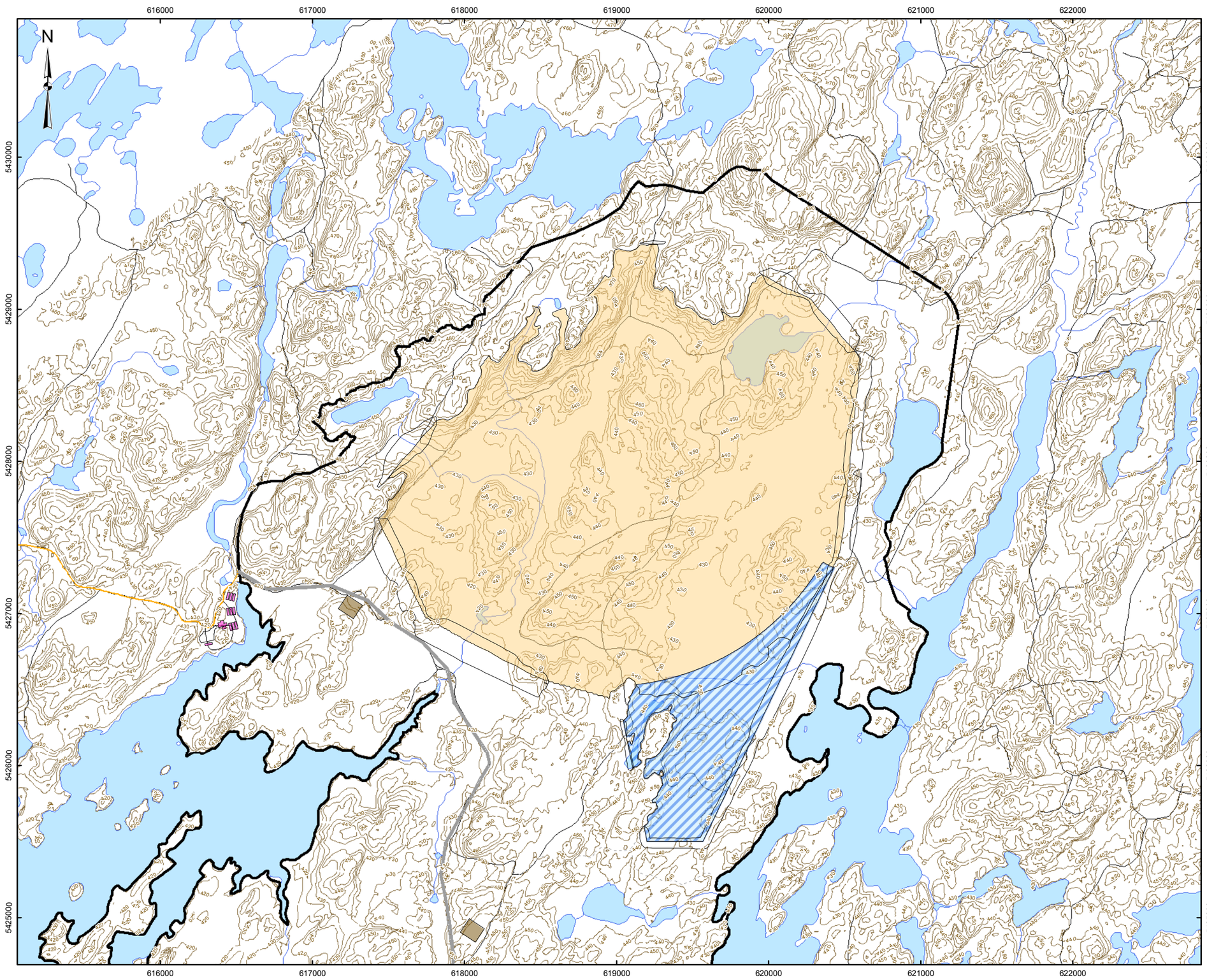
TITLE
TOPOGRAPHY - MINE AND WASTE ROCK MANAGEMENT FACILITY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-1

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\ProposedMineArea_Topo_v3.mxd



LEGEND

- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Accomodation Camp
- Pumping Station
- Tailings Management Facility
- Tailings Management Facility Reclaim Pond
- Hydrogeology Local Study Area

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

250 0 250 500 750 1,000 1,250
SCALE 1:25,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TOPOGRAPHY -
TAILINGS MANAGEMENT FACILITY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-2

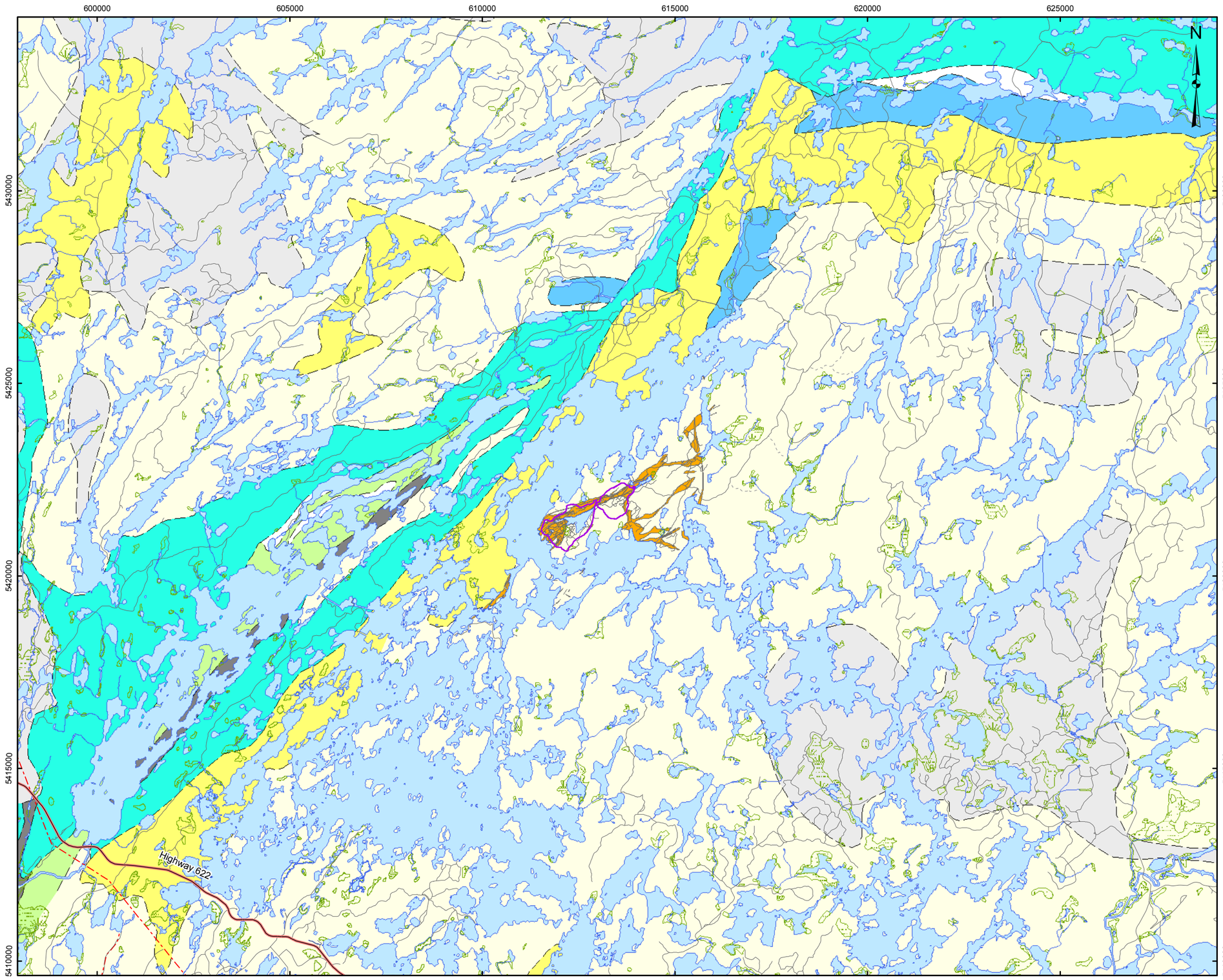
G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXD\sIDraft\HydrogeologyTSD\ProposedTMF_Topo.mxd

Photo 2-1: Typical Topography of the Mine Area

The Project Site is underlain by 2.6 billion to 3 billion year old bedrock of the Superior Province of the Canadian Shield, a stable craton that forms the core of the North American continent. The Superior Province has been divided into various regionally extensive east-northeast-trending subprovinces based on lithology, age, genesis, and metamorphism. The Project Site is situated in the Marmion Batholith of the Central Wabigoon Subprovince.

The central Wabigoon province is a granite-greenstone assemblage consisting of thin, anastomosed greenstone belts separated by large, commonly oval felsic intrusive rocks. The greenstone belts comprise metamorphosed and highly deformed packages of mafic volcanic rocks with lesser components of intermediate to felsic volcanic rocks, intrusive rocks and sedimentary rocks (Stone and Davis, 2006).

The Marmion Lake batholith comprises a diverse assemblage of felsic intrusive rocks, varying from granite to tonalite (quartz diorite) with a gneissic tonalite predominating, and including late stage pegmatite dykes. The western margin of the Marmion Lake batholith is in fault contact with Finlayson Group volcanics (Figure 2-3).



LEGEND

- Road
- Trail
- River/Stream
- Lake
- Wetland
- Open Pits
- Altered Granitoid

Regional Geology

OGS Map P2229

- Finlayson metasediments
- Finlayson mafic volcanics
- Finlayson mafic-ultramafic
- Marmion mafic intrusive
- Marmion hnb tonalite-granite
- Marmion tonalite
- Marmion gneiss

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
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

1,000 0 1,000 2,000 3,000 4,000 5,000
SCALE 1:100,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
REGIONAL BEDROCK GEOLOGY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
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REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-3

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\HydrogeologyTSD\RegionaGeologyI.mxd

The Marmion Batholith is transected by a major structural feature, the 1 to 6 km wide Marmion Deformation Corridor (MDC) (also known as Marmion Lake Fault) that trends northeast to southwest through the area (Figure 2-4). In the LSA, the MDC is variably sheared and altered, and occurs as a broad zone of transcurrent ductile to ductile-brittle deformation (Stone and Halle 1999) having a complex braided structure of brecciated and veined granitoid and tonalite rock. The MDC displays numerous characteristics of brittle-ductile deformation, including moderately to strongly sheared rocks, brecciation, veining and stockwork.

The results of exploration drilling show the mineralized bedrock is largely bounded by two shear zones and splays associated with the MDC. The shear zones dip steeply eastward and extend northeast to southwest through the Mine Area with the intervening rock characterized as foliated, extensively quartz veined with some local faulting, fracturing and jointing. These shears are identified as the Upper Shear and Lower Shear and generally bound the mineralized rock. The upper shear zone is about 1 to 5 m wide, comprised generally of cataclastite with few fracture zones. While the shear zones are traceable as continuous structural features, they generally have been infilled/sealed by vein minerals or clay/gouge materials.

Gold occurs within the mineralized zone as free grains on mineral surfaces concentrated along microfractures and quartz veins within the altered granitic rock. The boundary of the ore zone is defined by grade which roughly corresponds to the degree of brecciation and quartz stockwork veining within the altered granitoid.

The youngest geologic materials regionally comprise a thin veneer of organic soils and recent alluvium as well as glacial deposits that accumulated with the progressive retreat of the ice sheet during the end of the Wisconsinan glaciations. Figure 2-5 provides the overburden geology in the area of the Project. It is likely that any earlier deposits have been largely or entirely removed by glacial erosion, which stripped away the pre-existing overburden and eroded the crystalline bedrock in the area. The northward retreat of the ice sheet started approximately 12,000 years ago and the area became ice-free approximately 10,500 years ago (Dyke et al. 2003).

2.3.2 Hydrogeological Conditions

2.3.2.1 Borehole Drilling

A total of 49 boreholes were drilled in overburden and shallow bedrock at 34 locations within the LSA between March 17, 2011 and August 21, 2012. Borehole and monitoring well locations are shown on Figures 2-6 and 2-7. Borehole depths ranged from 1.5 to 28.9 m with an average drilled depth of 8.7 m. At most locations, a borehole was advanced some metres into the bedrock and a second (adjacent) borehole advanced to the overburden/bedrock contact or into the uppermost section of the bedrock where no overburden was present. Monitoring wells were installed in 47 of the 49 boreholes drilled. Boreholes BRH-0020C and BRH-0025 were drilled for additional geotechnical sampling, therefore, monitoring wells were not installed in these holes. Monitoring well nests were installed with the shallow screen set at a depth of less than 10 m and the deeper screen set at a depth between 15 m to 20 m generally corresponding to the overburden bedrock interface.

Borehole stratigraphy and well installation details are provided in the Record of Borehole and Record of Drillhole logs in Appendix 2.III. Boreholes drilled by OHRG (or Brett Resources Inc.) for the exploration program are generally oriented to the northwest at an inclination of approximately 60 degrees and are identified with a "BR" prefix. Boreholes drilled for the hydrogeological program are vertical and identified with a "BRH" prefix. For nested monitoring wells, the piezometers are identified with an "A" (deep) or "B" (shallow) suffix. Boreholes drilled for the geotechnical investigation of the open pits are identified with a "GT" prefix (Golder 2012).

607500 610000 612500 615000 617500

5425000 5422500 5420000 5417500

N

Sawbill Bay

Mitta Lake

Lynxhead Bay

Trap Bay

Turtle Bay

Hawk Bay

Marmion Reservoir

LEGEND

- Interpreted Fault, Dip unknown
- Low-Angle Thrust Fault
- Underwater Fault
- Road
- Trail
- River/Stream
- Lake
- Wetland
- Open Pits
- High Strain Zone
- High Strain Zone (Underwater)

Lithology

- Quartz Vein Zone
- Sheared Mafic Rock
- Sheared Granitoid
- Altered Granitoid
- Mafic Dyke; Ankeritized
- Pegmatite
- Mafic Dyke
- Amphibolitic Migmatite
- Diorite
- Tonalite
- Gneissic tonalite

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 2,500
SCALE 1:40,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
BEDROCK STRUCTURAL GEOLOGY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-4

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\BedrockStructuralGeology.mxd

610000 615000 620000

5425000

5420000

N

LEGEND

- Road
- Trail
- River/Stream
- Lake
- Wetland
- Open Pits
- Rock drumlin
- Organic Terrain
- Outwash Deltas/Channels
- Till Veneer
- Scoured Bedrock

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 2,500
SCALE 1:50,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
OVERBURDEN GEOLOGY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-5

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\OverburdenGeology.mxd

612000 613000 614000 615000 616000 617000 618000

5426000 5425000 5424000 5423000 5422000 5421000

N

BRH-0016A/B
BH12-10
BRH-0010
BRH-0015A/B
BH12-9
BRH-0013
Sawbill Bay
BRH-0006
BRH-0012A/B
BRH-0014A/B
BRH-0011
GT-06
BRH-0005A/B
BRH-0001A/B
GT-05
BR-0366
BRH-0004
GT-01
Mitta Lake
BR-0371
BRH-0009
BR-0220
GT-02
BR-0231
GT-04
BRH-0003
BRH-0008A/B
GT-03
BR-0433
BRH-0007A/B
Lynxhead Bay
BRH-0002A/B

LEGEND

- Monitoring Well
- Exploration Borehole
- Geotechnical Borehole - Deep Bedrock
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities

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

250 0 250 500 750 1,000 1,250
SCALE 1:25,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
BOREHOLE AND MONITORING WELL LOCATIONS - MINE AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-6

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\HydrogeologyTSD\ProposedMineArea_Borehole_MW_Locations.mxd

617500 620000 622500

5430000

5427500

5425000

N

BRH-0025
BRH-0023
BH12-5A/B
BRH-0024
BH12-1
BRH-0022
BRH-0021A/B
BH12-2
BRH-0019
BRH-0020A/B
BRH-0020C
BH12-3A/B
BH12-4
BRH-0018
BRH-0027
BRH-0017A/B

LEGEND

- Monitoring Well
- Geotechnical Borehole - Overburden
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Facilities

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

250 0 250 500 750 1,000 1,250
SCALE 1:25,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
BOREHOLE AND MONITORING WELL LOCATIONS - TAILINGS MANAGEMENT FACILITY AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-7

G:\Projects\2010\10-1118-0020_BrettResources_HammondReefGIS\MXDs\Draft\Hydrogeology\TSD\ProposedTMF_Borehole_MW_Locations.mxd

2.3.2.2 Geology

Overburden

Overburden materials are comprised of a thin veneer of glacial till or waterlain outwash deposits overlain by organic peat with typical thickness of up to about 2 m encountered in the topographic lows. A bedrock trough infilled with about 8 m of unconsolidated material that includes layered deposits of clay, silt and sand extends beyond the northeast end of the Upper Marmion Reservoir in to the TMF Area where as much as 25 m of unconsolidated material was encountered. At borehole location BRH-0020, these materials comprise layered deposits of clay, silt and sand to approximately 15 m and bouldery sand and gravel to bedrock at a depth of 25 m. The bedrock lows near the perimeter of the TMF Area are typically infilled with organic topsoil overlying layered till deposits comprised of clay, silt, sand and gravel that are generally less than 4 m thick.

Bedrock

The Hammond Reef property occurs within the western margin of the approximately 3 billion year old Marmion batholith which is composed of zones of granitic to tonalitic rock with occasional gneissic fabrics, mafic xenoliths, and late pegmatite dykes. The west margin of the batholith coincides with the northeast-trending Finlayson-Marmion Fault zone which occurs as a broad zone of transcurrent ductile to ductile-brittle deformation. The fault is a complex braided structure with bifurcations and splays occurring in both the horizontal and vertical planes. Two of these splays constitute the dominant structural features of Hammond Reef property. The s dip steeply eastward and extend northeast-southwest through the Mine Area with the intervening rock characterized as foliated, extensively quartz veined with some local faulting, fracturing and jointing. These shears are identified as the Upper Shear and Lower Shear and generally bound the mineralized rock (Ore Zone). The upper shear zone is about 1 to 5 m wide, comprised generally of brecciated rock with few fracture zones. The lower shear contains zones of intense foliation, quartz veining, and clay/gouge layers up to 35 mm thick. Figure 2-8 provides a representative cross-section through the area of the pit showing the steeply dipping shear zones and the angled exploration and geotechnical boreholes.

While the shear zones are traceable as continuous structural features, they generally have been infilled/sealed by vein minerals or clay/gouge materials and may differ little from the surrounding rock in terms of their hydraulic conductivity. However, open, hydraulically transmissive, fractures are locally present along the shear zones. Exploration drillers report that circulation was frequently lost while drilling through these structural features (Golder 2012) and geotechnical borehole GT-04 that intersected a 0.5 m thick sand seam within the upper shear zone.

Geophysical borehole logging of exploration borehole BR-0220 showed multiple partially open fractures throughout the logged portion of the borehole, as shown in Table 4-1 of Appendix 2.IV and in Attachment 2.IV.1. The frequency and/or aperture width of partially open joints and fractures did not appear to increase with proximity to the intersection of the upper shear zone (155.5 m true depth). Heat-pulse flow meter data indicated upward flow under pumping conditions but no flow under static conditions. The source of the upward flow was from fractures below the accessible bottom of the borehole (210 m along hole depth) that likely include the lower shear zone intersected at 340 m along hole depth at this location.

NORTH

SOUTH

GT705

BR-18

BR-138

BR371

GT702

BR-163

BR-103

ELEV. 400

ELEV. 300

ELEV. 200

ELEV. 100

PROJECTED
UPPER SLAY 2

PROJECTED
FOOTWALL
SHEAR

PROJECTED
UPPER SHEAR

5421500 N

5421250 N

GENERAL LEGEND:

- EXISTING GROUND SURFACE
- 2012 PLANNED PIT OUTLINE
- FOOTWALL SHEAR
- UPPER SLAY 2
- UPPER SHEAR

LITHOLOGY:

- TONALITE
- CHLORITIC GRANITE
- ALTERED GRANITOID
- FINE GRAINED GRANITE
- SHEARED ROCK UNITS
- PEGMATITE
- OVERBURDEN
- MAFIC DYKE
- INTERMEDIATE DYKE
- QUARTZ VEIN ZONE
- OTHER

FRACTURE FREQUENCY:

- 0 TO 5
- 5 TO 10
- 10 TO 15
- 15 TO 20
- 20 TO 25

ROCK MASS RATING:

- 0 TO 20
- 20 TO 40
- 40 TO 60
- 60 TO 80
- 80 TO 100

REFERENCES:

PLAN LOCATION OF CROSS SECTION SHOWN IN FIGURE 2.

40 0 40 80
SCALE 1:2000 METRES

Golder Associates
Mississauga, Ontario, Canada

FILE No.	1011180020KA002-8.dwg
PROJECT No.	10-1118-0020
REV.	
SCALE	AS SHOWN
DATE	Jan. 31, 2013
DESIGN	JS
CAD	JS
CHECK	MS
REVIEW	LC

TITLE

STRUCTURAL GEOLOGY CROSS-SECTION THROUGH THE PIT SHOWING SHEAR ZONES

OSISKO HAMMOND REEF PROJECT

FIGURE 2-8

PLOT DATE: January 31, 2013
FILENAME: T:\Projects\2010\10-1118-0020 (BR, Atikokan)\-KA- Hydrogeology TSD\1011180020KA002-8.dwg

Exploration borehole BR-0231 showed six major open fractures with aperture widths ranging from 7 to 65 mm and many partially open fractures, as shown in Table 4-2 of Appendix 2.IV and in Attachment 2.IV.2. BR-0231 intersects the upper shear zone at a true (angled) depth of approximately 72 m at this location. An open joint/fracture with an aperture width of 57.9 mm was observed at a depth of 70.9 m with numerous infilled or healed joints/fractures observed from 72 to 73 m depth. The borehole intersects the lower shear zone at a true depth of approximately 217 m at this location. There were no open joints/fractures observed at this depth although a number of partially open joints/fractures were observed around 210 and 222 m depth. It should be noted that a blockage was encountered in BR-0231 at 260 m preventing the lower portion of the borehole from being logged.

2.4 Groundwater Levels

Depth to groundwater level measurements and groundwater elevations for monitoring wells and exploration boreholes in the LSA are presented in Tables 3-1, 3-2 and 3-3 of Appendix 2.V. Tables 3-1 and 3-2 of Appendix 2.V, provide groundwater levels observed in the Mine and TMF Areas during quarterly monitoring events at 47 groundwater monitoring locations from March 2011 to August 2012. Table 3-3 of Appendix 2.V provides the October 2011 groundwater levels observed at 126 exploration boreholes located in the southwest portion of the Mine Area.

Hydrographs of continuous groundwater level records obtained from monitoring wells and exploration boreholes instrumented with data logging pressure transducers are provided in Figures 3-1 to 3-13 of Appendix 2.V.

The depth to groundwater throughout the LSA averages approximately four metres below ground surface (mbgs) and ranges from 32.93 mbgs at areas of higher elevation to flowing conditions (above ground level). Artesian conditions, as evident by flowing monitoring wells, were encountered at seven monitoring wells generally located at the base of steep slopes.

Groundwater elevations observed in the Mine Area range from a high of 447.7 masl at exploration borehole BR-1050 to a low of 415.96 masl at exploration borehole BR-0413. The collar of Borehole BR-1050 is located on a high elevation bedrock knob approximately 300 m southwest of Mitta Lake while the collar of borehole BR-0413 is located approximately 75 m from the shoreline of the Upper Marmion Reservoir (Elevation: 415 masl).

Figure 2-9 provides directions of inferred groundwater flow in the Mine Area based on October 2011 monitoring data. Groundwater levels measured in the exploration holes are similar to nearby shallow monitoring wells and thus thought to be representative of shallow bedrock conditions. Groundwater flows outward towards Upper Marmion Reservoir with the exception of the southwest portion of the Mine Area where locally groundwater flow converges on Mitta Lake. Figure 2-10 shows inferred groundwater flow directions and groundwater divide between Mitta Lake and Upper Marmion Reservoir in the vicinity of the proposed west pit. The pattern of groundwater flow provides a subdued reflection of the topography with flow from recharge areas at higher elevation to discharge to Mitta Lake and Upper Marmion Reservoir.

612000 613000 614000 615000 616000 617000 618000

5426000 5425000 5424000 5423000 5422000 5421000

N

REFER TO FIGURE 2-10

Sawbill Bay
Mitta Lake
Lynxhead Bay

BRH-0010 435.262
BRH-0013 416.878
BRH-0006 416.751
BRH-0016A 443.433
BRH-0016B 443.653
BH12-10
BH12-9
BRH-0015A 416.856
BRH-0015B 416.793
BRH-0012A 415.940
BRH-0012B 415.960
BRH-0014A 416.944
BRH-0014B 416.952
BRH-0005A 425.425
BRH-0005B 439.605
BRH-0001A 425.738
BRH-0001B 428.247
GT-06
BRH-0004 429.507
BRH-0011 430.747
BR-0366
GT-05
GT-01
BR-0371
BR-0220
BR-0231
GT-02
GT-04
GT-03
BRH-0003 416.500
BRH-0009 415.319
BRH-0008A
BRH-0008B 419.534
BR-0433
BRH-0007A 418.511
BRH-0007B 422.758
BRH-0002A 423.393
BRH-0002B 422.339

LEGEND

- 415.940 Groundwater Elevation (October 2011)
- Monitoring Well
- Exploration Borehole
- Geotechnical Borehole - Deep Bedrock
- Inferred Direction of Shallow Groundwater Flow
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities

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
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

250 0 250 500 750 1,000 1,250
SCALE 1:25,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
GROUNDWATER ELEVATIONS AND INFERRED FLOW DIRECTIONS - MINE AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-9

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\HydrogeologyTSD\MineArea_GW_Elevations_InferredGW_Flow.mxd

611500 612000 612500 613000

5422000 5421500 5421000 5420500

Mitta Lake
431.013

Marmion Lake
415

LEGEND

- 434.61 Groundwater Elevation
- Monitoring Well
- Inferred Direction of Shallow Groundwater Flow
- Inferred Groundwater Divide
- Mapped Faults
- Intermediate Contour (5m interval)
- Ditch
- Marsh/Swamp
- Road
- Trail
- River/Stream
- Lake
- Project Facilities

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
Base Data - MNR NRVIS, obtained 2004
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

100 0 100 200 300 400
SCALE 1:7,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
GROUNDWATER ELEVATIONS AND INFERRED FLOW DIRECTIONS - WEST PIT AREA

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-10

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Groundwater elevations observed in the TMF Area range from a high of 460.1 masl at monitoring well BRH-0026 to a low of 417.1 masl at monitoring well BRH-0020A. Groundwater elevations and flow directions reflect local topography and decrease with proximity to nearby lakes (Upper Marmion Reservoir and Lizard Lake) as shown in Figure 2-11. Groundwater is recharged at the higher elevation areas and discharges directly to Upper Marmion Reservoir or to other nearby surface water bodies.

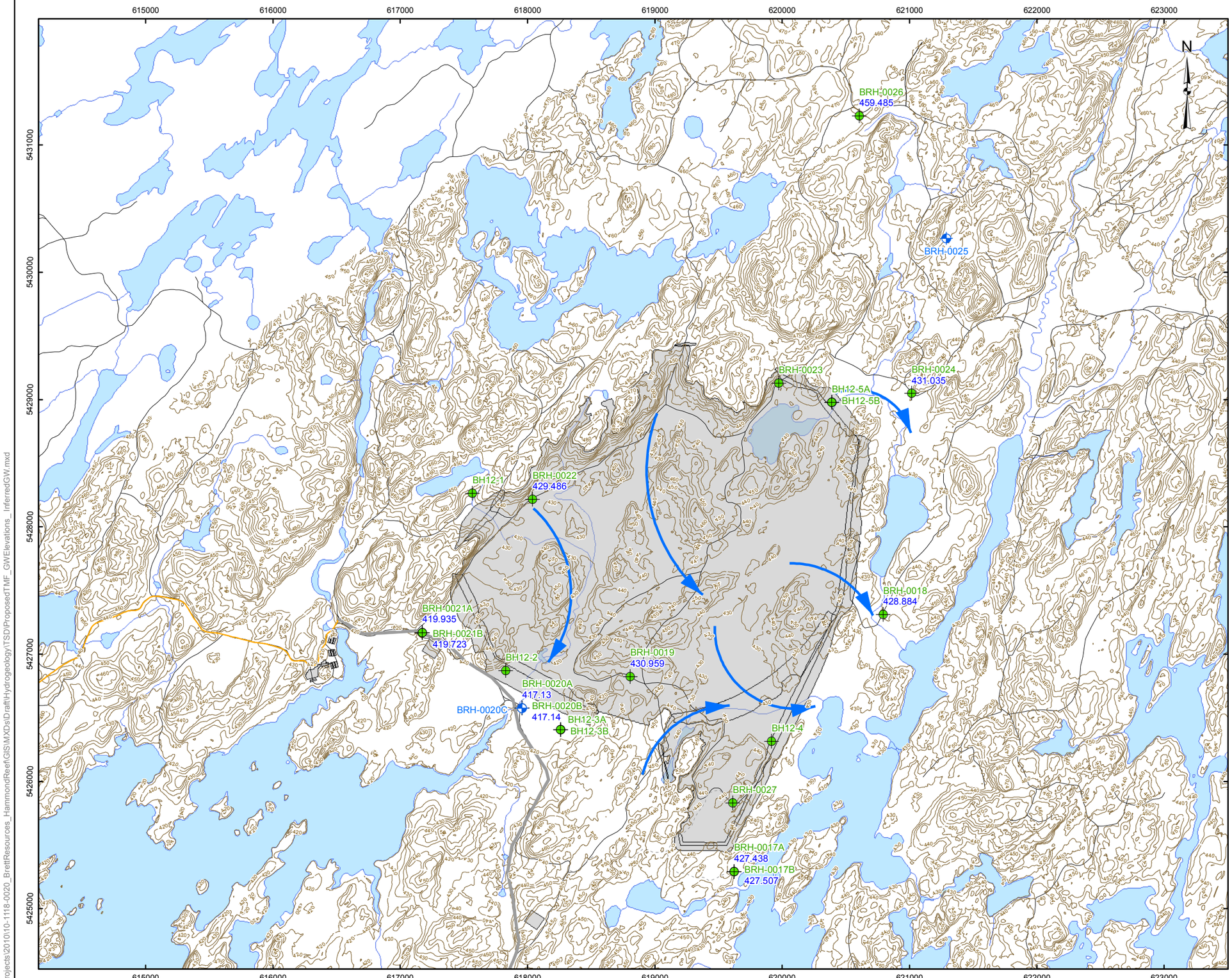
The water level in Upper Marmion Reservoir is lowered during the winter to provide for storage of the spring freshet. Groundwater level data have been reviewed to assess the extent to which changes in the level of Upper Marmion Reservoir influence groundwater levels within the LSA.

Figure 2-12 shows the water level record in Upper Marmion Reservoir and hydrographs for three monitoring wells situated at lower elevations in the Mine Area. Monitoring wells BRH-0003B and BRH-0009 are located within 100 m of the reservoir, while monitoring well BRH-0013 is located in a low lying area approximately 800 m from the reservoir. Water levels in Upper Marmion Reservoir were maintained at or above 415 masl during the summer and fall of 2011. Beginning in late November 2011, reservoir water levels were progressively lowered by nearly 1.7 m (415.17 to 413.49 masl) through to mid-March 2012, when the reservoir and groundwater levels rose with the onset of the spring freshet.

The hydrograph for BRH-0009 (Figure 2-12) shows a near parallel decline in groundwater and reservoir levels after mid-November 2011, with a separation of about 0.15 m, while for the preceding period, groundwater levels were typically about 0.5 m above those of the reservoir with a similar pattern of fluctuations. The near parallel water level trend after mid-November suggests a direct hydraulic connection with the reservoir located at a distance of approximately 91 m from this monitoring well. The similarity of water levels suggests the hydraulic connection between the monitoring well and Upper Marmion Reservoir is relatively permeable.

At BRH-0003B, located only 27 m from the reservoir, groundwater levels are about 1 to 2 m above those of the reservoir and follow a generally similar pattern of decline through most of the winter months. However, groundwater levels did not decline for a period of about four weeks during January/February 2012 while reservoir levels continued to decline and thereafter through to the freshet, groundwater levels declined at a less steep rate and reservoir levels at a steeper rate relative to the period before January. That the rate of decline of groundwater and reservoir levels diverges through January to the freshet suggests an indirect hydraulic connection, if any, between shallow bedrock and the reservoir at this location. At BRH-0013, groundwater levels show only a marginal decline from mid-December through to mid-March while reservoir levels declined nearly 1.7 m. A direct hydraulic connection with the shallow bedrock and the reservoir is not evident at BRH-0013.

Groundwater levels at higher elevations and ranging in distances from 57 m (BRH-0001) to more than 550 m (BRH-0004) from the reservoir show no indication of a hydraulic connection between the upper bedrock and the reservoir. Figure 2-13 provides hydrographs of groundwater elevations from four monitoring wells situated at higher elevations in the Mine Area (BRH-0001, BRH-005, BRH-006 and BRH-0011) along with the reservoir water level. Groundwater elevations at these monitoring locations range from 416.41 to 440.51 masl (approximately 1 to 25 m above reservoir level). As evident on the hydrographs, groundwater levels in the upper bedrock at these monitoring locations are not affected by fluctuating lake levels associated with reservoir operation.



LEGEND

- 417.14 Groundwater Elevation (October 2011)
- Monitoring Well
- Geotechnical Borehole - Overburden
- Inferred Direction of Shallow Groundwater Flow
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Facilities

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
SCALE 1:30,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
GROUNDWATER ELEVATIONS AND INFERRED FLOW DIRECTIONS - TAILINGS MANAGEMENT FACILITY

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
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REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-11

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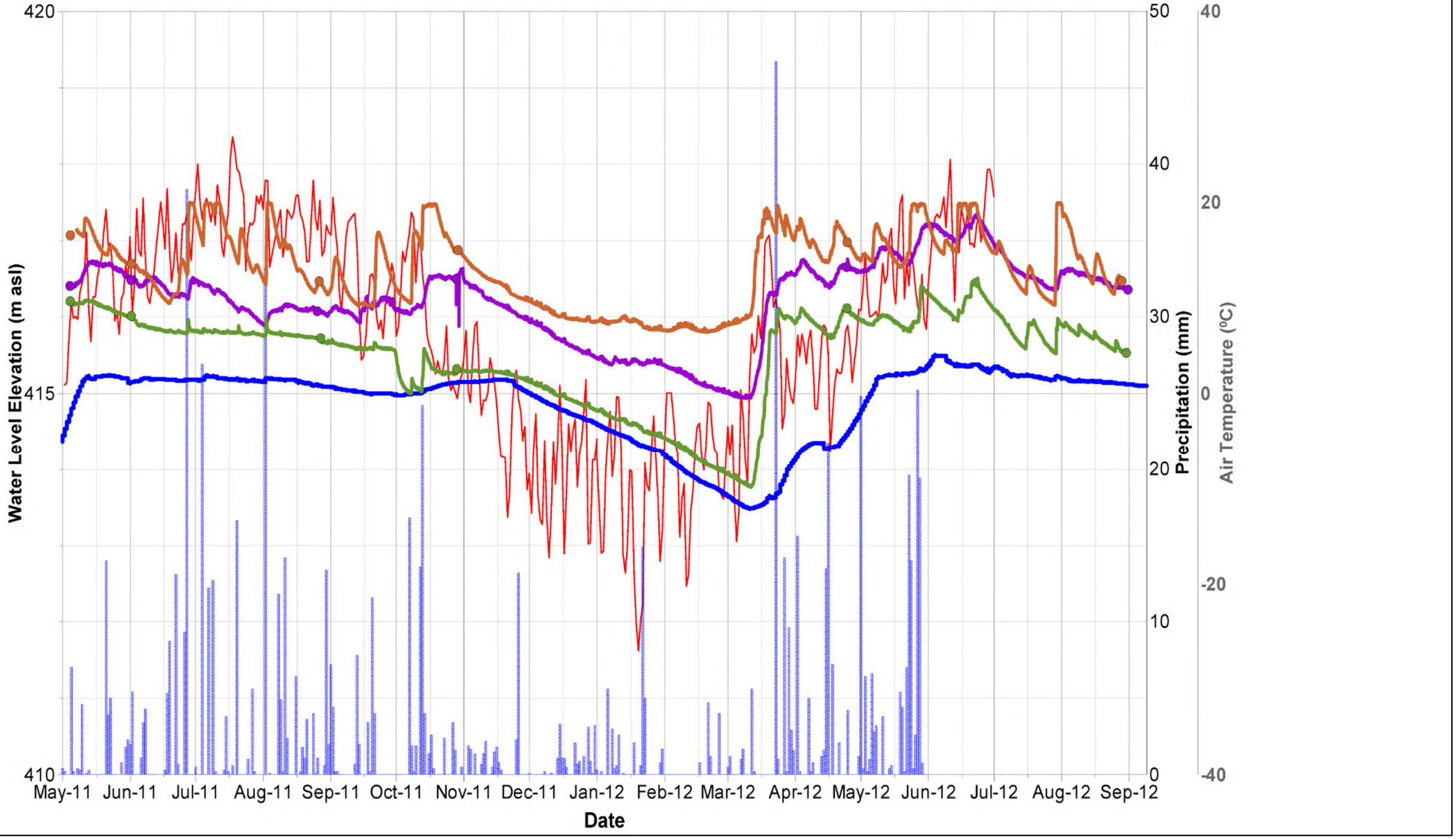


LEGEND

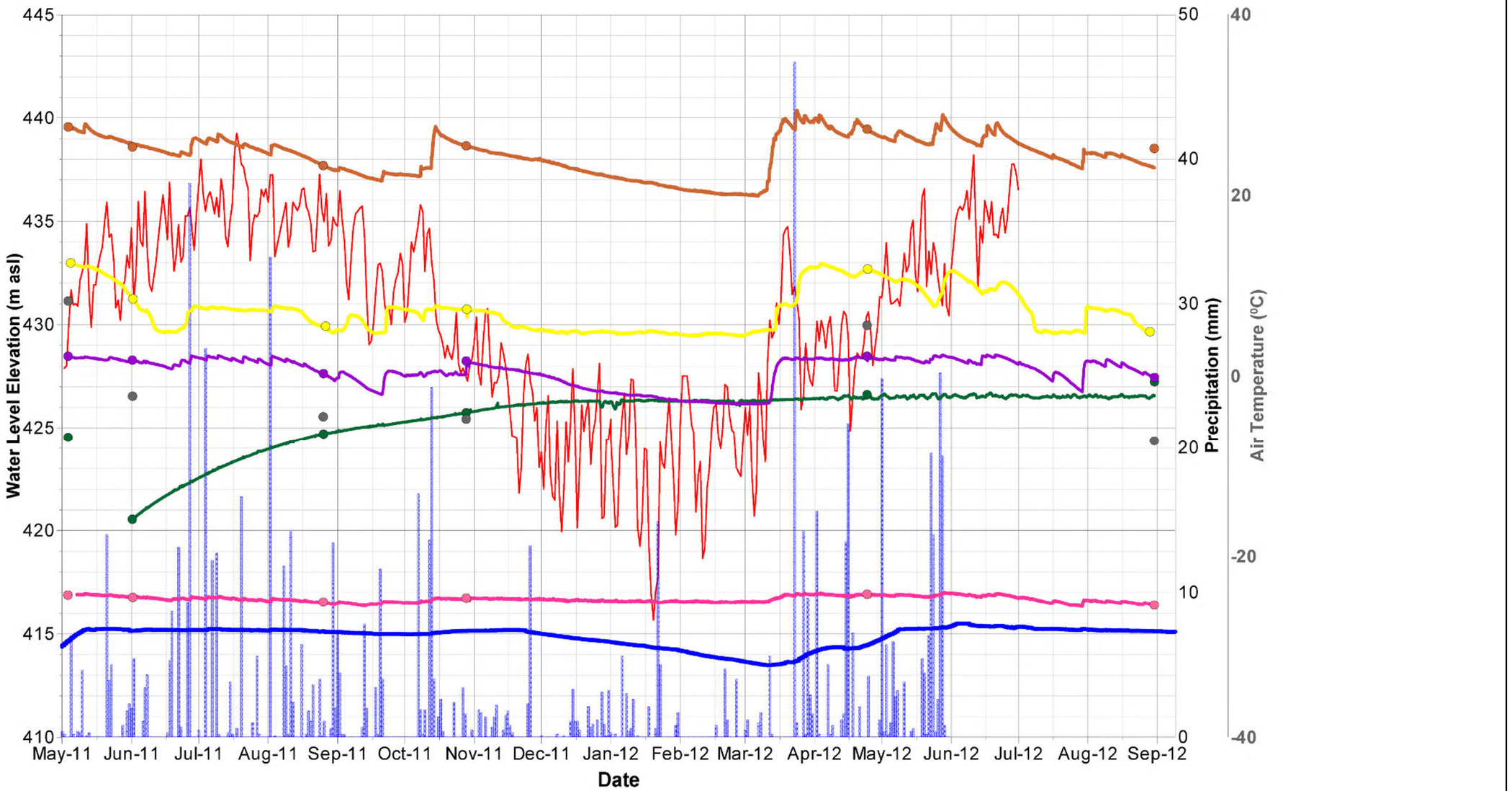
- BRH-0003B
- BRH-0009
- BHR-00013
- Upper Marmion Reservoir
- Average Daily Air Temperature
- Total Daily Precipitation

NOTES:

Colored circles represent manual water level measurements.

PROJECT	HAMMOND REEF GOLD PROJECT ATIKOKAN, ONTARIO, CANADA		
TITLE	**MARMION RESERVOIR AND NEARBY GROUNDWATER LEVELS**		
Golder Associates Mississauga, Ontario	PROJECT NO. 10-1118-0020		VERSION 1
	DESIGN	CGE	14 Nov. 2008
	GIS	JO	4 Feb. 2013
	CHECK	MSO	4 Feb. 2013
	REVIEW	JMP	4 Feb. 2013
	FIGURE: 2-12		

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\Marmion Reservoir and nearby gw levels.mxd



LEGEND

- BRH-0001A
- BRH-0001B
- BRH-0005A
- BRH-0005B
- BRH-0006
- BRH-0011
- Upper Marmion Reservoir
- Average Daily Air Temperature
- Total Daily Precipitation

NOTES:

Colored circles represent manual water level measurements.

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
TYPICAL GROUNDWATER LEVEL FLUCTUATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			VERSION 1
DESIGN	CGE	14 Nov. 2008	
GIS	JO	4 Feb. 2013	
CHECK	MSO	4 Feb. 2013	
REVIEW	JMP	4 Feb. 2013	

FIGURE: 2-13

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These data indicate that a relatively permeable direct hydraulic connection between the bedrock and the reservoir is observable at one location only (BRH-0009), located at a distance of approximately 91 m from the shoreline of Upper Marmion Reservoir. Elsewhere, including at monitoring wells located closer to the reservoir, a direct hydraulic connection was not observed. The seasonal lowering of the reservoir has only a limited influence on nearby groundwater levels within the shallow bedrock at some locations.

At some monitoring locations within the TMF Area, groundwater elevations are within about 1 m above nearby surface water elevations, such as at monitoring well BRH-0017B, which is located within 100 m of the west shoreline of Lizard Lake (Figure 2-7). Although similar, the seasonal decline in groundwater levels through July and August and again during the winter months (December through March) at this monitoring well nest is not reflected in the surface water elevation of the adjacent Lizard Lake (Figure 3-11 of Appendix 2.V). This hydrograph suggests that any surface water influence on groundwater levels is localized to the vicinity of the lake.

At the southwest section of the TMF Area, a trough of granular material was encountered to depths of approximately 25 m at BRH-0020. Groundwater elevations at this monitoring well nest (Figure 2-7) are about 2 m above those of the nearby surface water (Upper Marmion Reservoir) and exhibit similar fluctuations. This suggests that overburden groundwater in this area readily discharges to Upper Marmion Reservoir through a permeable pathway in granular materials.

Due to the undulating topography and numerous bedrock outcrops to the northeast of BRH-0020, it is our interpretation that the bedrock trough observed in the vicinity of BRH-0020 likely extends to Upper Marmion Reservoir to the southeast but does not likely extend further than approximately 500 m northeast of BRH-0020.

2.5 Vertical Hydraulic Gradients/Seepage Areas

Vertical hydraulic gradients have been established at the 15 monitoring well nests using depth to water measurements obtained during quarterly monitoring events. Groundwater level data for monitoring well locations are provided in Tables 3-1 and 3-2 of Appendix 2.V, and a summary of the vertical hydraulic gradients observed at nested monitoring locations is provided in Table 3-4 of Appendix 2.V. Table 2-2 provides the direction of hydraulic gradient at those monitoring nests where a difference in groundwater levels of 0.4 m or greater is observed. The 0.4 m difference was selected to clearly distinguish between areas of groundwater recharge and discharge. Moderate and variable vertical gradients indicate generally lateral groundwater flow.

Table 2-2: Vertical Hydraulic Gradients at Nested Groundwater Monitoring Locations

Project Component	Monitoring Nest	March-May 2011	June 2011	August 2011	October 2011	April 2012	August 2012
		Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)
Mine Area	BRH-0001	-3.93	-7.74	-2.92	-2.51	-1.86	-0.21
	BRH-0002	1.35	1.57	1.25	1.05	1.11	1.20
	BRH-0005	-9.37	-13.01	-13.10	-14.18	-10.45	-14.17
	BRH-0007	-1.08	-1.50	-3.17	-4.25	-1.47	-3.19

Table 2-2: Vertical Hydraulic Gradients at Nested Groundwater Monitoring Location (Continued)

Project Component	Monitoring Nest	March-May 2011	June 2011	August 2011	October 2011	April 2012	August 2012
		Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)	Head Difference (m)
	BRH-0008	2.30	0.79	n/a[(a)]	n/a[(a)]	0.68	1.20
	BRH-0016	-0.43	n/a[(b)]	n/a[(b)]	n/a[(b)]	-0.46	n/a[(b)]

Notes:
Negative head difference indicates a downward (recharge) vertical gradient.
Positive head difference indicates an upward (discharge) vertical gradient.
n/a[(a)] = Unable to establish vertical gradient due to artesian conditions encountered in bedrock monitoring well (BRH-0008A).
n/a[(b)] = Unable to establish vertical gradient due to dry well conditions in overburden monitoring well (BRH-0016B).

Consistent downward (recharge) hydraulic gradients were observed at four locations: at BRH-0001, BRH-0005, BRH-0007 and BRH-0016. As shown in Figure 2-6, these monitoring nests are located at relatively high elevations and adjacent to steeply sloping land and reflect conditions in areas of groundwater recharge.

Consistent upward (discharge) hydraulic gradients were observed at two nested monitoring wells in the Mine Area (BRH-0002 and BRH-0008). Artesian conditions (where groundwater flows out from the top of the well pipe) were observed in the deeper monitoring wells at each of these locations (BRH-0002A and BRH-0008A). Similarly, artesian conditions were observed at a number of exploration boreholes.

Swampy areas and seeps are observed generally near the base of some sloped areas. These features are indicative of groundwater discharge. Figure 2-14 shows groundwater discharge areas as inferred from seepage and swampy areas, flowing boreholes and monitoring wells, as well as locally steeper sloped lands.

2.6 Hydraulic Conductivity

Estimates of hydraulic conductivity (K) values of the overburden materials and bedrock have been developed from the following:

- Grain size distribution of overburden materials.
- Single well response tests in monitoring wells.
- Packer testing of deep bedrock in the area of the proposed open pits.

The range and geomean for estimates of the hydraulic conductivity of overburden materials and bedrock have been developed for the Mine and TMF Areas and summarized in Tables 2-3 and 2-4. Estimates of hydraulic conductivity for select samples of granular overburden materials were derived using the Hazen method and are summarized in Table 3-1 of Appendix 2.VI. Estimates of hydraulic conductivity from single well response tests carried out in monitoring wells screened in overburden and shallow bedrock are provided in Appendix 2.VI, Table 3-2. Estimates of hydraulic conductivity from packer tests completed during the 2010 geotechnical investigation are provided in Appendix 2.I (Tables 3-1 to 3-8 and Figures C1 to C8).

611000 612000 613000 614000 615000

5423000 5422000 5421000 5420000

Sawbill Bay

Mitta Lake

Lynxhead Bay

BRH-0006
BRH-0005A/B
BRH-0001A/B
GT-05
BR-0366
GT-06
BRH-0004
BRH-0011
GT-01
BR-0371
BR-0220
GT-02
BR-0231
GT-04
GT-03
BRH-0003
BRH-0009
BRH-0008A/B
BR-0433
BRH-0007A/B
BRH-0002A/B

N

LEGEND

- BR-0433 Areas of Observed Groundwater Seepage
- Monitoring Well
- Exploration Borehole
- Geotechnical Borehole - Deep Bedrock
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Areas of Inferred Groundwater Discharge
- Project Transmission Line
- Project Facilities

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

200 0 200 400 600 800
SCALE 1:15,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
AREAS OF OBSERVED GROUNDWATER SEEPAGE AND INFERRED GROUNDWATER DISCHARGE

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
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FIGURE: 2-14

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Table 2-3: Summary of Hydraulic Conductivity Estimates for Overburden and Bedrock in Mine Area

Material	Number of Tests	Hydraulic Conductivity (m/s)	
		Range	Geomean
Overburden (Coarse Grained[(a)])	3	1×10^{-5} to 5×10^{-5}	1.8×10^{-5}
Bedrock (Upper 30 m)	40	7×10^{-10} to 7×10^{-5}	1.7×10^{-7}
Bedrock (Below 30 m)	87	7×10^{-10} to 2×10^{-5}	3.6×10^{-8}
Shear Zones	19	1×10^{-9} to 1×10^{-5}	1.9×10^{-7}

Notes:
(a) Coarse Grained refers to soil material with less than 50% material less than 75 micrometres in diameter.

Table 2-4: Summary of Hydraulic Conductivity Estimates for Overburden and Shallow Bedrock in Tailings Management Facility Area

Material	Number of Tests	Hydraulic Conductivity (m/s)	
		Range	Geomean
Overburden (Fine Grained[(a)])	3	3×10^{-7} to 6×10^{-7}	4.4×10^{-7}
Overburden (Coarse Grained[(b)])	8	2×10^{-7} to 5×10^{-5}	6.3×10^{-6}
Bedrock (Upper 30 m)	5	3×10^{-7} to 8×10^{-5}	2.2×10^{-6}

Notes:
(a) Fine Grained refers to soil material with more than 50% material less than 75 micrometres in diameter.
(b) Coarse Grained refers to soil material with less than 50% material less than 75 micrometres in diameter.

Limited test data is available for overburden materials at the Mine and TMF Areas due to the general lack of continuous overburden in these areas.

At the Mine Area a wide range of bedrock hydraulic conductivity values have been measured within the upper 30 m of bedrock, with values ranging from 10^{-10} up to 10^{-5} metres per second (m/s). Below a depth of about 30 m, test data with a geomean of 10^{-8} and 10^{-7} m/s have been developed. Similar hydraulic conductivities of between 10^{-8} and 10^{-7} m/s have also been interpreted for the shear zones. Within the TMF Area, high hydraulic conductivity values for the bedrock were measured, and range from 10^{-7} m/s up to 10^{-5} m/s within the upper 30 m. Boreholes have not been drilled below a depth of 30 m at the TMF Area.

Figure 2-15 provides a summary of hydraulic conductivity estimates of the bedrock developed during the 2010 geotechnical investigation conducted in the vicinity of the proposed west pit. This figure suggests a trend to declining hydraulic conductivity estimates with depth.

Given the variable frequency, orientation and hydraulic interconnectivity of local-scale fracturing and the overall northwesterly incline to the main structural elements, the hydraulic conductivity of the rock has no obvious lateral or vertical bias. As such, the hydraulic conductivity of the rock is assumed to be isotropic.

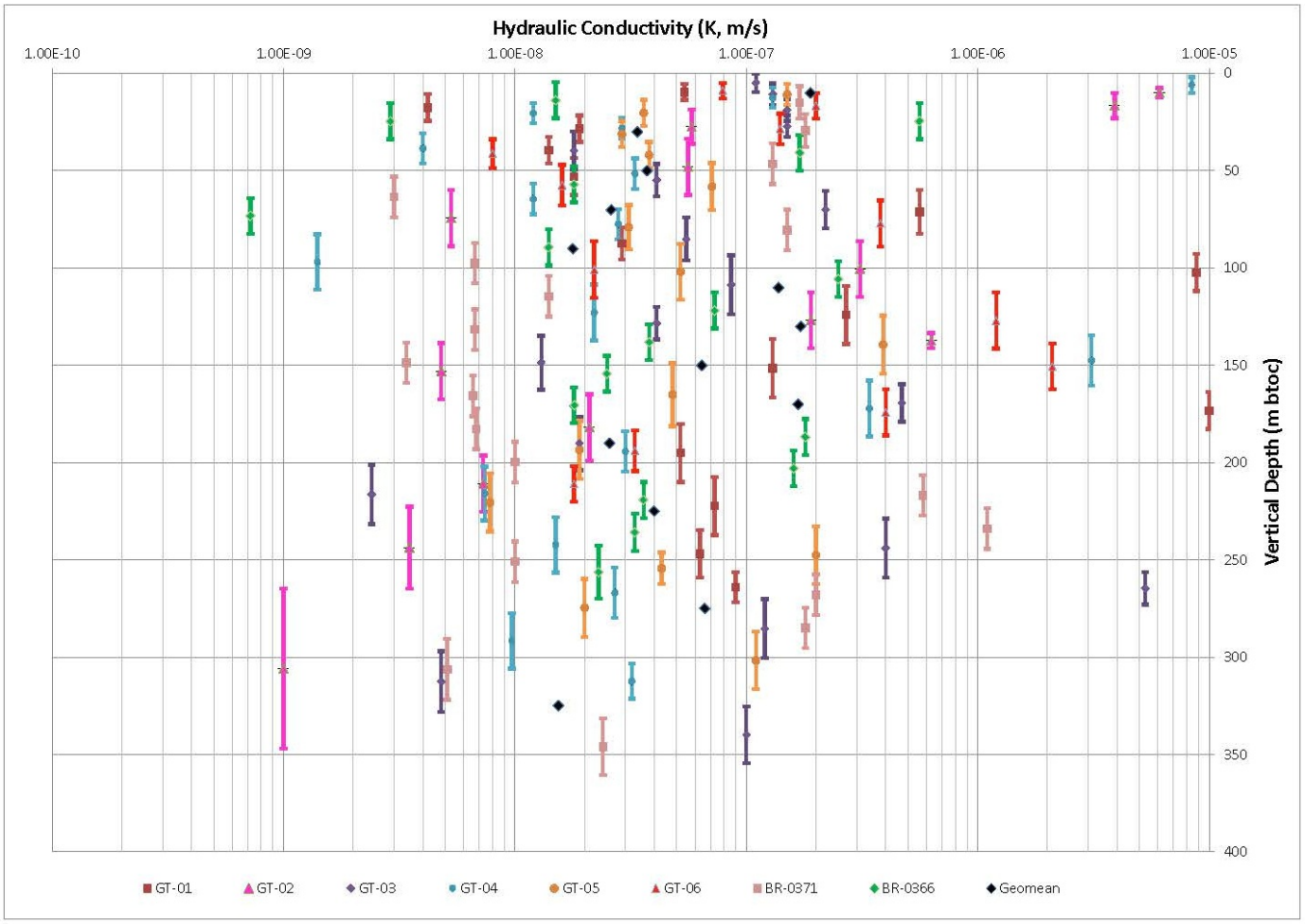


Figure 2-15: Hydraulic Conductivity (K) Estimates from Packer Testing Program in West Pit Area

2.7 Exploration Borehole Testing

Short term and constant rate pumping tests were conducted at a number of exploration boreholes to provide an indication of the water yield characteristics of fractured rock in the south-western end of the west pit adjacent to Upper Marmion Reservoir. Boreholes that intersected and did not intersect the shear zones were selected to provide a good coverage of this area. Boreholes located in low lying wet areas were not selected because of the potential for cross connection between the borehole and adjacent wet areas.

2.7.1 Short-Term Pumping Tests

Short-term pumping tests were conducted in 46 angled exploration boreholes to assess if those holes intersecting the shear zones had a higher hydraulic capacity (could sustain pumping with very little drawdown in the pumped water level) than boreholes that did not intersect the shear zones. The boreholes tested were selected to provide coverage of the area primarily at the southwest end of the west pit where the major structure, the Mitta Lake fault and associated splays and shear zones, extends beneath the adjacent Upper Marmion Reservoir. These exploration holes were drilled using NQ diameter coring equipment (borehole diameter 76 mm) and thus only a small diameter low yield pump (less than 30 litres per minute [L/m]) could be used for testing. The test procedure consisted of pumping at an initial low rate (first step) and then at a higher rate (second step) for a total pumping duration of approximately 30 minutes. The pumping rate at the end of the test was divided by the total drawdown at the end of the test to provide an indication of the specific capacity of the exploration borehole. Boreholes with a low specific capacity reflect bedrock that will yield low to moderate quantities of groundwater during excavation of the open pit. The results of the short term pumping tests are tabulated in Table 2-5.

Table 2-5: Summary of Specific Capacities Observed During Short-Term Pumping Tests

Borehole	Pumping Rate (Q= L/min)	Time Pumped (min)	Drawdown (m)	Specific Capacity (L/min/m)
BR-0061	5.5	33	11	0.5
BR-0073	11	40	5.5	2.0
BR-0081	6	38	1	6.0
BR-0155	7.5	8	6	1.2
BR-0216	15	35	1.9	7.9
BR-0246	6.5	3	20	0.3
BR-0272	14	42	1.4	10.0
BR-0325	7.9	8	17	0.5
BR-0390	6	23	10	0.6
BR-0413	12	43	6.8	1.8
BR-0433	16	45	0.4	40.0
BR-0437	10	8	15	0.7
BR-1011	13	45	4.5	2.9
BR-1042	8	50	4.5	1.8
BR-1051	5	33	7.5	0.7

Table 2-5: Summary of Specific Capacities Observed During Short-Term Pumping Tests (Continued)

Borehole	Pumping Rate (Q= L/min)	Time Pumped (min)	Drawdown (m)	Specific Capacity (L/min/m)
BR-1054	15	24	2	7.5
BR-1056	13	27	3.5	3.7
BR-1061	12	40	1.8	6.7
BR-1064	15	19	2.7	5.6
BR-1070	15	35	8	1.9
BR-1080	7.5	17	12	0.6
BR-1095	12	21	10	1.2
BR-1128A	4	13	14	0.3
BR-1150	15	32	7.3	2.0
BR-1154	6	13	2.7	2.2
BR-1161	10	30	9	1.1
BR-1168A	11	38	6	1.8
BR-1174	11	32	6.5	1.7
BR-1176	4	13	14	0.3
BR-1188	12	50	6.5	1.8
BR-1194A	8	12	11	0.7
BR-1199	5.5	25	11	0.5
BR-1207	5	27	10	0.5
BR-1223	15	18	7.5	2.0
BR-1229	5	23	20	0.2
BR-1238	15	20	8	1.9
BR-1272	9	23	1	9.0
BR-1278	9	27	8.3	1.1
BR-4301	6.3	41	3.4	1.8
BR-6051	10	38	1.7	5.9
BR-6113	7.5	10	8.8	0.8
BR-6213	14	23	3.7	3.8
BR-6217	15	38	1.2	12.5
BR-6221	10	25	3	3.3
BR-6224	6	25	6.5	0.9
BR-6241	9	30	8	1.1

Notes:
(a) Shear zone intersection depths based on geology model provided by OHRG in July 2011

Calculated specific capacities ranged from 0.3 to a high of 40 litres per minute per metre (L/min/m) of drawdown, averaging 3.5 L/min/m of drawdown. Only two of the test results yielded a specific capacity greater than 10 L/min/m of drawdown; values of 12.5 and 40 L/min/m of drawdown were obtained from boreholes BR-6217 and BR-0433 respectively. Figure 2-16 provides a histogram of the calculated specific capacity results along with the numbers of these exploration holes that intersected shear zones. Figure 2-18 provides the distribution of these results in the area of the proposed west pit. It should be noted that the results are mapped to the borehole collar location whereas for angled boreholes, the main shear/fractures making water may have been intersected at some depth down the borehole to the west and thus not directly below the borehole collar.

With the exception of one higher value, the specific capacities are consistently moderate to low across the area of the proposed west pit and are consistent with the moderate to low hydraulic conductivity values for the bedrock (generally less than 10^{-6} m/s) determined from packer testing.

The highest specific capacity (40 L/min/m of drawdown) was encountered at borehole BR-0433, the collar for which is located within approximately 100 m of the shoreline of Upper Marmion Reservoir. BR-0433 has a total length of 405 m, is angled at 60 degrees below the horizontal, and intersected the lower shear zone at 250 m down the length of the borehole. Further testing was conducted at BR-0433 as discussed below.

Flow Testing of BR-0433

Further testing of BR-0433 was conducted to assess whether the inflow was derived predominantly from the deep shear zone(s) or fractures in the upper section of the borehole. An inflatable packer was set in the borehole at approximately 95 metres below top of casing (along the borehole) and a short open-hole test pumping event was conducted and then repeated following inflation of the packer to isolate the upper portion of the borehole. The results of this additional testing are provided in Appendix 2.VII. Similar pumping rates were achieved for the two pumping events with about 40% more drawdown observed with the packer inflated as shown in Figure 2-17. The results indicated that about 60% of the yield was derived from the lower portion (below 95 m) of the borehole. Thus, while the higher specific capacity in part reflects hydraulic conditions in the lower shear zone, this result indicates that the upper section of the borehole is similarly permeable.

While it is noted that the three highest specific conductivity values were obtained from boreholes with reported shear intersections, elsewhere shear intersections do not appear to influence the test results. While these results generally suggest the main shear zones and splays are not obviously more conductive than the enclosing rock mass, locally transmissive zones may be encountered such as at BR-0433. The amount of drawdown achieved during pumping averaged less than 7.5 m with maximum values of 20 m, which is substantially less than will occur during excavation of the open pit mine to depths of about 300 m below the level of Upper Marmion Reservoir. Fractures that are in-filled with un-cemented material (clay/gouge) may not have yielded much water during testing but could become open and more conductive at the higher hydraulic gradients that will persist through pit operations.

2.7.2 Constant-Rate Pumping Tests

Constant-rate pumping tests of up to 94 hours duration were conducted at two angled PQ diameter exploration boreholes; BR-0220 and BR-0231. These two boreholes are located at the southwest end of the west pit as shown in Figure 2-6. Test procedures and results are provided in Appendix 2.VIII.

These boreholes were selected for testing primarily because they both intersect the upper and lower shear zones, and the larger diameter permitted installation of a submersible pump capable of yielding greater than 200 L/min from depths of 60 m.

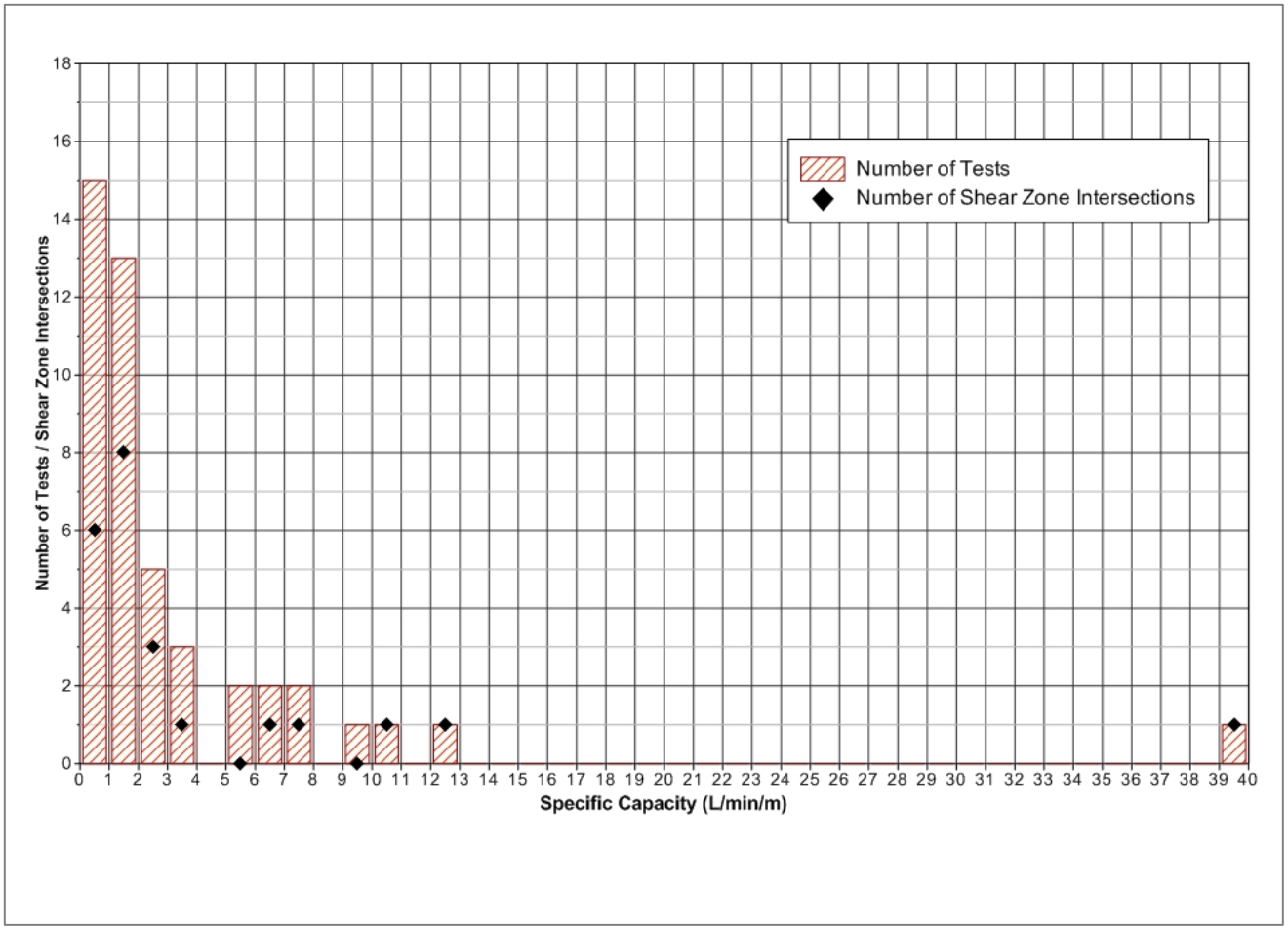


Figure 2-16: Distribution of Specific Capacities from Short Term Pumping Tests

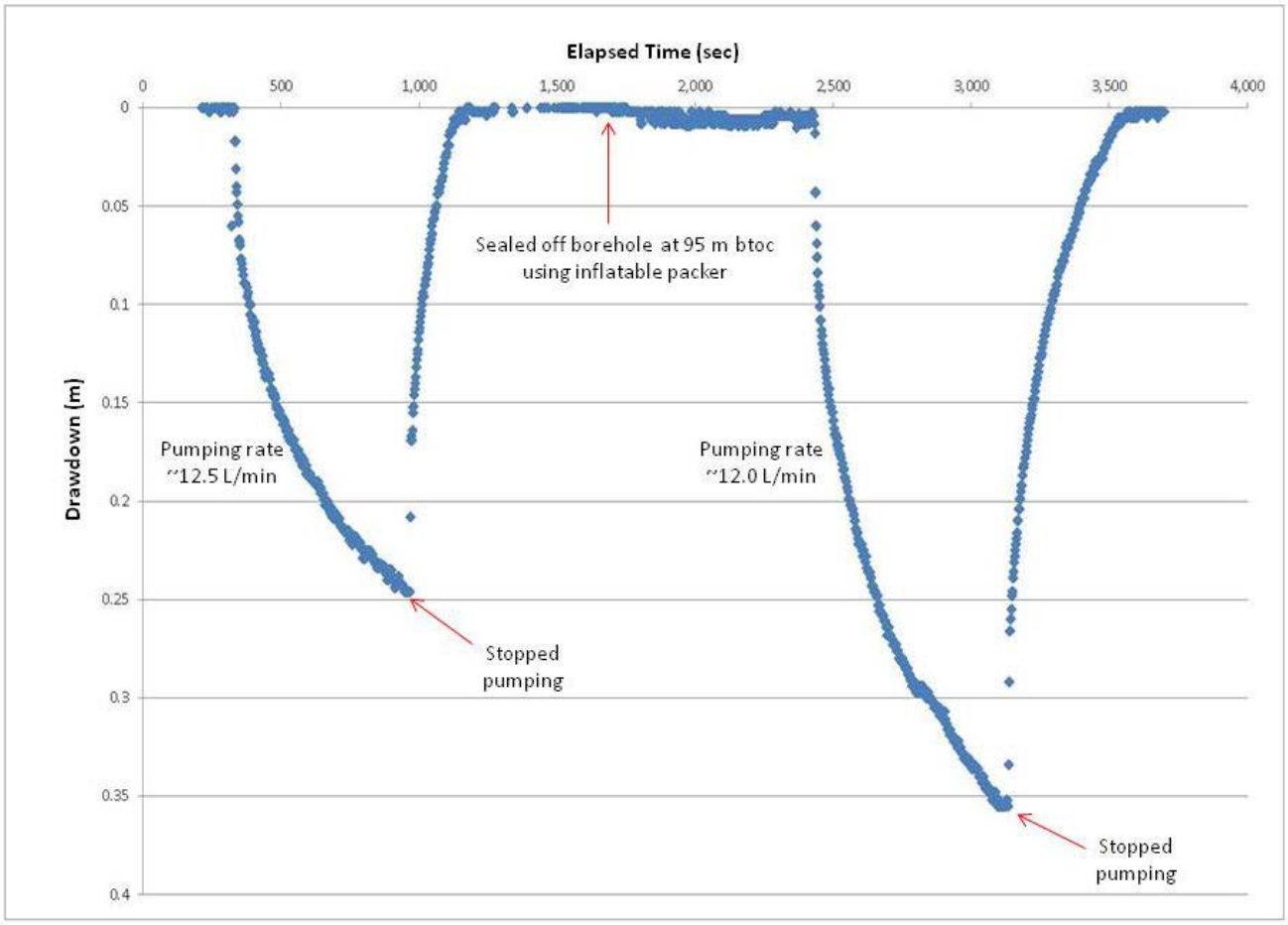


Figure 2-17: Results of Test Pumping at BR-0433 Using Inflatable Packer to Isolate Upper Portion of Borehole

611250 611500 611750 612000 612250 612500 612750 613000 613250 613500

5422000 5421750 5421500 5421250 5421000 5420750 5420500 5420250

BR-4301
BR-6241
BR-6051
BR-0325
BR-6224
BR-6221
BR-0390
Mitta Lake
BR-1278
BR-1095
BR-6213
BR-1207
BR-1229
BR-1174
BR-1128A
BR-1061
BR-6217
BR-1199
BR 1176
BR-1056
BR-0155
BR-1188
BR-0073
BR-1042
BR-6113
BR-1272
BR-0246
BR-0413
BR-0216
BR-0061
BR-1051
BR-1168A
BR-1054
BR-0081
BR-1154
BR-1161
BR-0437
Marmion Reservior
BR-0433
BR-1150
BR-1238
BR-1011
BR-0272
BR-1064
BR-1194A
BR-1070
BR-1080
Lynxhead Bay

N

LEGEND

Specific Capacity at 3 log cycles (L/min/m - Area Proportional)

- 0.00 - 0.99
- 1.00 - 4.99
- 5.00 - 9.99
- 10.00 - 40.00
- Ditch
- Marsh/Swamp
- River/Stream
- Road
- Trail
- Mapped Faults

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Image Provided by OSISKO Hammond Reef Gold Project Ltd (July 2010)
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

100 0 100 200 300 400
SCALE 1:8,000 METRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SPATIAL DISTRIBUTION OF CALCULATED SPECIFIC CAPACITY OF EXPLORATION BOREHOLES

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-18

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\Distribution of Calculated Specific Capacity Results.mxd

The results for the 12-hour pumping test carried out at BR-0220 in September 2011 are provided in Appendix 2.VIII. Table 2-6 provides a summary of the total drawdown and recovery observed at monitoring locations established for this pumping test.

Table 2-6: Drawdown and Recovery Observed During 12 Hour Pumping Test at BR 0220

Observation Well	Radial Distance	Max Drawdown	% Recovery[a]	Upper Shear Zone Intersection		Lower Shear Zone Intersection	
	(m)	(m)		Yes/ No	Depth (m) [b]	Yes/ No	Depth (m) [b]
BR-0220 (pumping well)	0	11.68	100	Yes	155	Yes	340
BR-0216	58	5.5	98	No	–	Yes	287
BR-0089	60	2.16	77	No	–	Yes	281
BR-0226	63	6.91	92	Yes	50	Yes	295
BR-0057	65	2.36	38	Yes	122	Yes	297
BR-0081	73	8.46	89	No	–	Yes	347
BR-1044	75	4.14	83	Yes	105	Yes	265
BR-1048	89	4.11	100	Yes	110	Yes	264
BR-1003	118	1.04	n/a	Yes	140	Yes	337
BR-1053	120	4.74	98	No	–	No	–
BR-0275	134	1.39	90	No	–	Yes	284
BR-1013	149	0.84	83	No	–	Yes	298
BR-1185	153	1.8	n/a	No	–	No	–
BR-1056	153	3.26	69	Yes	67	Yes	211
BR-1223	159	5.09	97	No	–	No	–
BR-1002	236	3.33	n/a	No	–	Yes	261
BR-1204	264	1.56	n/a	No	–	No	–

Notes:
Shear zone intersection depths based on geology model provided by OHRG (July 2011).
(a) % Recovery represents the percentage of water level recovery after a recovery period equivalent to the duration of pumping.
(b) Depth (m) represents true depth along angled borehole.
n/a = Observation wells where water levels were monitored manually and insufficient data were collected to calculate % Recovery.
— = Depth not provided because borehole does not intersect shear zone.

As shown on the hydrographs in Figure 3-1 of Appendix 2.VIII, water levels in most of the observation wells responded nearly instantaneously to pumping. The water level in BR-0220 was lowered by 11.68 m during the testing period and drawdown ranged from over five metres at some of the closer observation wells to less than one metre at the more distant wells. The total drawdown at the end of test pumping has been plotted in plan view for all boreholes monitored in Figure 2-1 of Appendix 2.VIII. The five-metre drawdown contour shows a general northeast-southwest elongation parallel with the bedrock structure. It should be noted that because these holes are angled generally to the northwest and that fracture connections between boreholes occurs at different depth intervals, the drawdown contour drawn around the borehole collars is not an ideal representation of the response to test pumping.

Details for the 24-hour pumping test carried out at BR-0231 in September 2011 are provided in Appendix 2.VIII. Table 2-7 provides a summary of the drawdown and recovery observed within the observation well array during this pumping test.

Table 2-7: Drawdown and Recovery Observed During 24 Hour Pumping Test at BR-0231

Observation Well	Radial Distance	Max Drawdown	% Recovery[(a)]	Upper Shear Zone Intersection		Lower Shear Zone Intersection	
	(m)	(m)		Yes/ No	Depth (m)[(b)]	Yes/ No	Depth (m)[(b)]
BR-0231 (pumping well)	0	8.62	100	Yes	72	Yes	217
BR-0081	262	0.74	85	No	–	Yes	347
BR-0226	127	1.31	70	Yes	50	Yes	295
BR-1040	79	1.88	88	Yes	91	Yes	255
BR-1042	169	1.88	88	No	–	Yes	226
BR-1044	82	1.93	84	Yes	105	Yes	265
BR-1048	87	0.1	100	Yes	110	Yes	264
BR-1056	24	2.11	95	Yes	67	Yes	211
BR-1061	90	1.12	90	Yes	52	Yes	224
BR-1062	93	2.48	90	Yes	50	Yes	192
BR-1229	164	0.23	100	Yes	1	Yes	105
BR-0057	176	1.64	n/a	Yes	122	Yes	297
BR-0089	161	2.27	n/a	No	–	Yes	281
BR-0275	189	0.19	n/a	No	–	Yes	284
BR-1013	191	0.2	n/a	No	–	Yes	298
BR-1053	225	0.77	n/a	No	–	No	–
BR-1223	266	0.51	n/a	No	–	No	–

Notes:
Shear zone intersection depths based on geology model provided by OHRG (July 2011).
(a) % Recovery represents the percentage of water level recovery after a recovery period equivalent to the duration of pumping.
(b) Depth (m) represents true depth along angled borehole.
n/a = Observation wells where water levels were monitored manually and insufficient data were collected to calculate % Recovery.
— = Depth not provided because borehole does not intersect shear zone.

As shown on the hydrographs in Figure 3-1 of Appendix 2.VIII, water levels in most observation wells responded nearly instantaneously to pumping. The water level in BR-0231 was lowered by 8.62 m during the testing period and drawdown ranged from over two metres at some of the closer observation wells to less than 0.20 m at the more distant wells. The total drawdown at the end of test pumping has been plotted in plan view for all boreholes monitored in Figure 2-2 of Appendix 2.VIII. The 2 m drawdown contour shows a weak northeast-southwest elongation parallel with the bedrock structure. As with the test of BR-0220, the boreholes are generally inclined to the northwest and fracture connections between boreholes occur at different depth intervals. Plotting drawdown contours relative to the borehole collars is therefore an imperfect representation in two dimensions of a more complex three-dimensional response.

It is noteworthy that drawdown was greater at boreholes BR-1053 and BR-1223, which do not intersect either shear zone and are located further from the pumping well (225 and 266 m) than boreholes BR-1048, BR-0275 and BR-1013, which intersect the lower shear zone. It is also noteworthy that very little drawdown (0.10 m) was observed at one of the closest boreholes, BR-1048. Water level drawdown varied throughout the observation well array and the level of response to pumping does not appear to be well correlated to distance from the pumping well or shear zone intersections. Such heterogeneity in hydraulic response is typical of fracture-dominated flow in competent rock. A distant borehole may intersect the same fracture system as the pumping well and exhibit a pronounced hydraulic response while a much closer borehole may share few fractures with the pumping well and show only a muted response. The weak correlation between shear zone intersection and hydraulic response suggests that the shear zones are not uniformly transmissive over the scale represented by the monitoring locations.

The results for the 94-hour pumping test carried out at BR-0220 in March 2012 are provided in Appendix 2.VIII. Groundwater levels began to rise after about 40 hours of pumping because of unseasonably warm temperatures that resulted in an extensive snow melt event. Thus only the data collected from the first 24 hours of pumping have been considered in this discussion.

As shown on the hydrographs in Figure 3-2 of Appendix 2.VIII, the water level in the pumping well (BR-0220) was drawn almost ten metres below the level of Upper Marmion Reservoir after 40 hours of pumping at a constant rate of approximately 85 L/m. Water levels in observation wells BR-0433, BR-1056 and BR-1061 responded nearly instantaneously to pumping, whereas the remaining wells showed little or no response. The lack of response to pumping at most observation well locations was likely due, in large part, to the steady recharge of snow melt water rather than a lack of hydraulic connection through the fracture network.

To assess the hydraulic characteristics of the fractured bedrock mass influenced by test pumping, composite drawdown plots are presented in Figures 2-19, 2-20 and 2-21 for the September 2011 test results at BR-0220 and BR-0231, and the March 2012 test results at BR-0220 respectively. These plots show drawdown on the Y-axis plotted against the log of time divided by the square of the radial distance from the pumping well. For an ideal fractured bedrock aquifer, with numerous fractures that are uniformly well interconnected over the area influenced by pumping, the drawdown data for all monitoring wells would plot along the same line, the slope of which reflects the transmissivity of the bedrock mass. As expected for a variably fractured bedrock mass, there is some spread in the data, both with respect to the slope of the drawdown plot and the time at which response to pumping is first evident. The range of transmissivity values presented on these plots is relatively narrow while there is some spread in the time at which response to pumping is first evident.

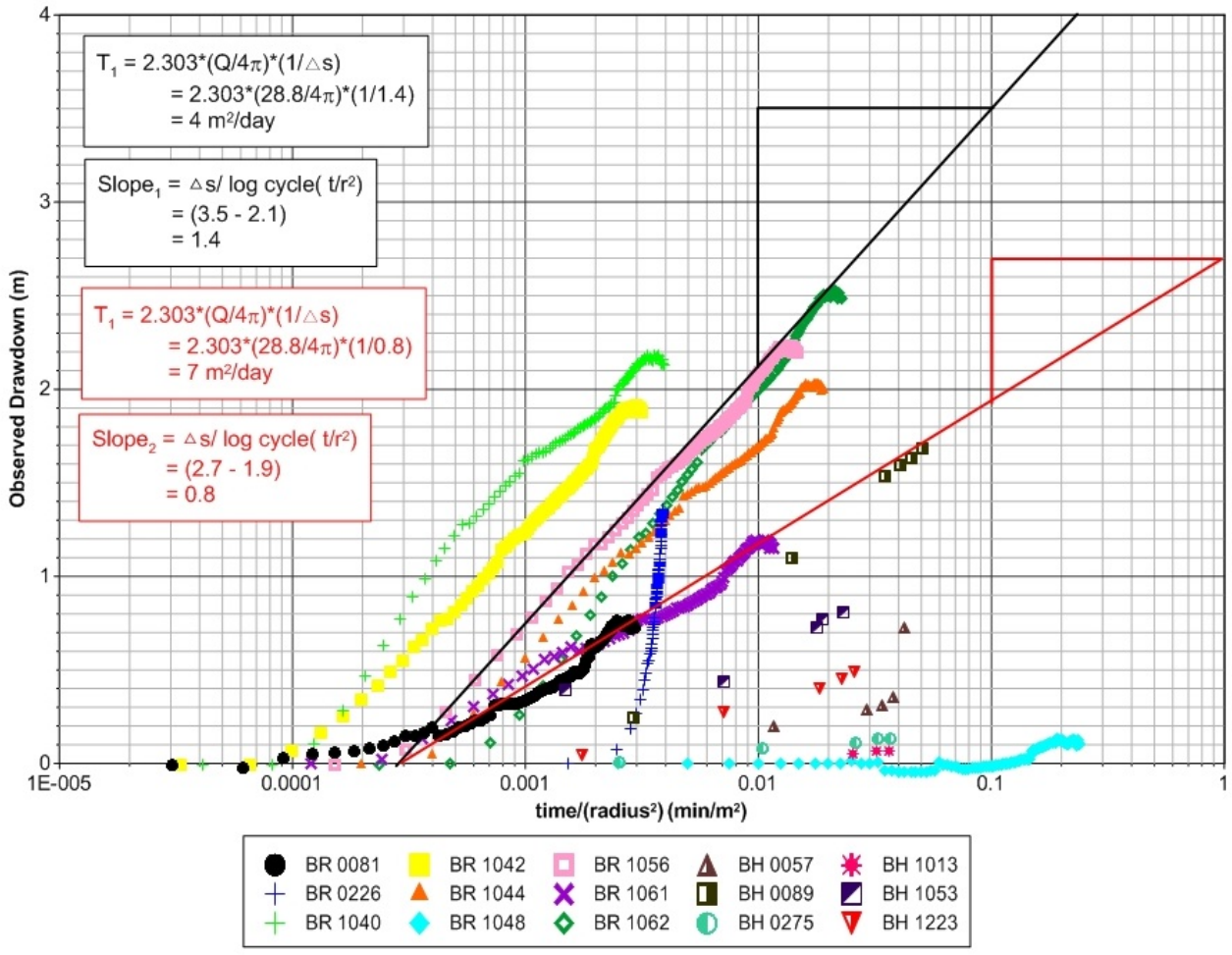


Figure 2-19: BR-0220 September 2011 Pumping Test Composite Drawdown Plot

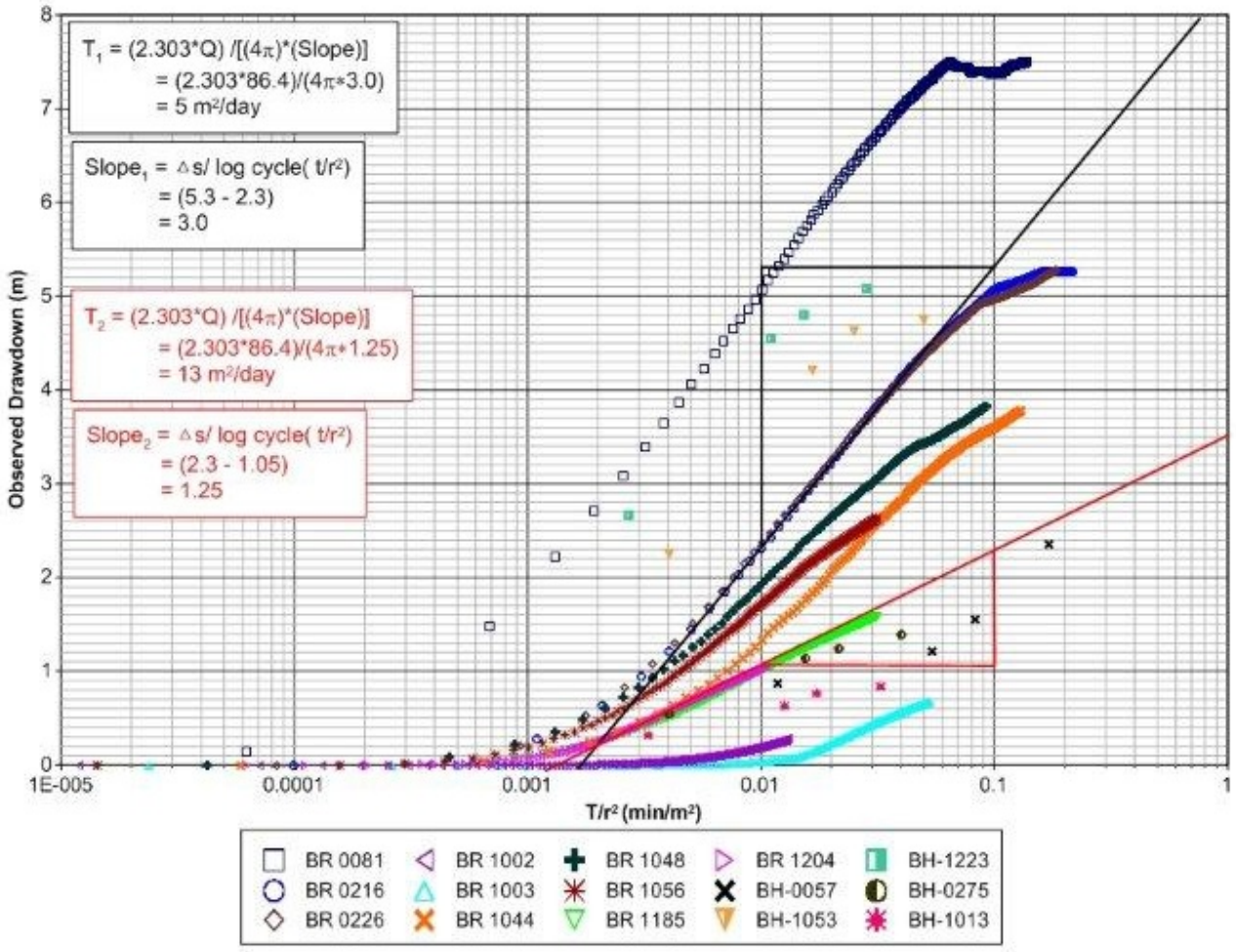


Figure 2-20: BR-0231 September 2011 Pumping Test Composite Drawdown Plot

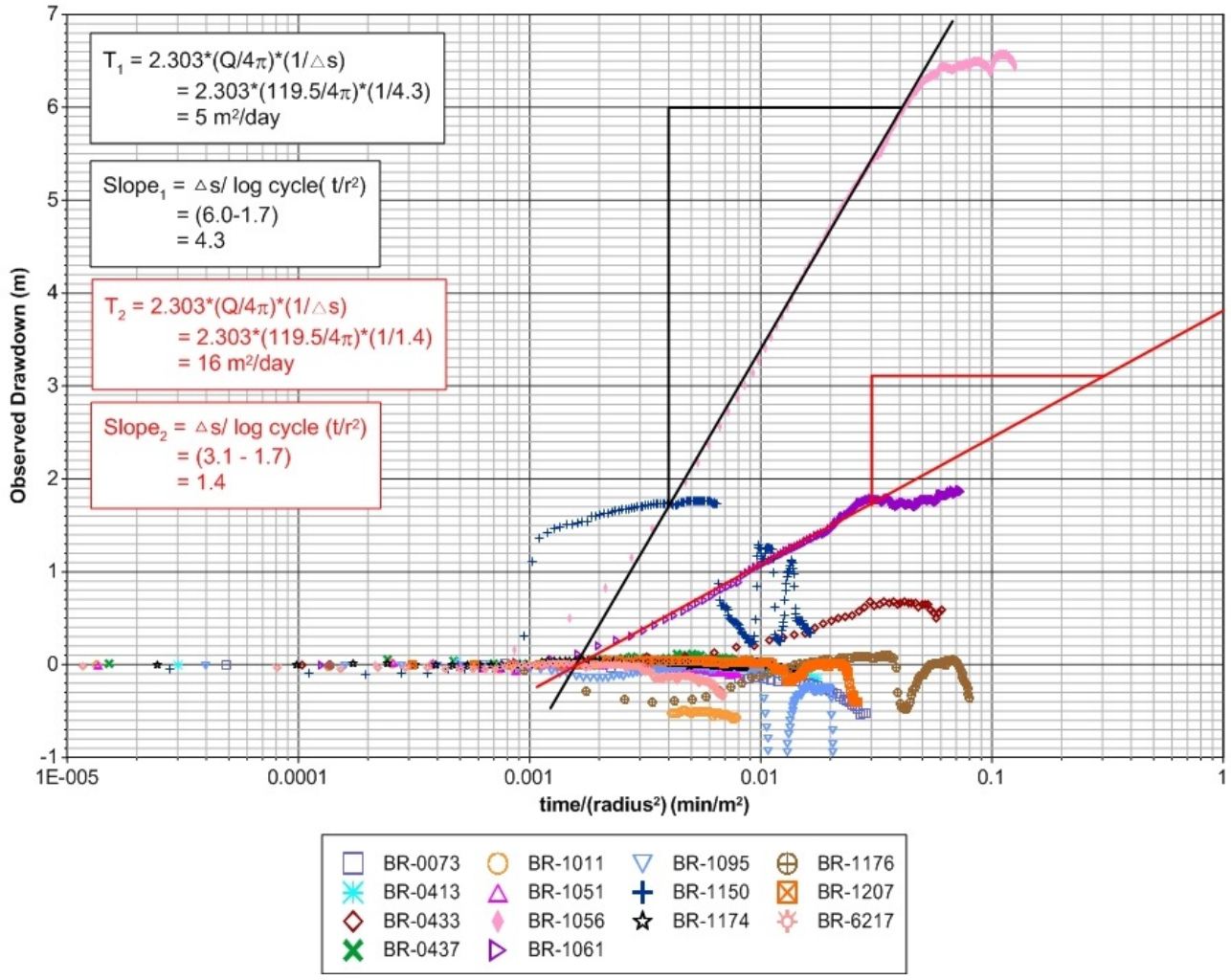


Figure 2-21: BR-0220 March 2012 Pumping Test Composite Drawdown Plot

The drawdown slopes indicate a low transmissivity for the fractured bedrock, with values ranging from 4 m^2/d to 16 m^2/d. Assuming that groundwater inflow to the pumping well was contributed over the full length of the borehole (371 m for BR-0220; 265 m for BR-0231) the bulk hydraulic conductivity of the fractured rock mass is about 1 to 5 x10^{-7} m/s.

With respect to the time at which response to pumping is first evident, the nature of the fracture connection between the pumping well and individual monitoring wells varies, independent of the radial distance. It appears that some fractures are 'open' and form a direct hydraulic connection between the pumping and observation wells. The effects of pumping are readily transmitted through such fractures and pumping influences are observed essentially at the time pumping is initiated. Other fractures may be partially infilled and/or form a much less direct hydraulic connection to the observation well and so the influence of pumping is observed some minutes after pumping starts (independent of radial distance from the pumping well). Consistent with the range in transmissivity values, the response to pumping suggests a variable and moderately well interconnected fracture network in the bedrock.

2.8 Groundwater Flow System

The groundwater flow system at the Project Site comprises:

- Shallow active flow zone.
- Deep bedrock flow zone.

2.8.1 Shallow Active Flow Zone

The upper section of the bedrock is variably fractured and comprises the shallow active flow zone. This zone includes the overburden materials where present and is inferred to extend laterally across the Project Site to a depth of up to 30 m below ground surface. Hydraulic conductivity test data for the shallow bedrock in the Mine Area yielded values ranging from 7 x 10^{-10} to 7 x 10^{-5} m/s with a geometric mean of 2 x 10^{-7} m/s, while values range from 3 x 10^{-7} to 8 x 10^{-5} m/s with a geometric mean of 2.2 x 10^{-6} m/s in the TMF Area (Tables 2-3 and 2-4). Where unfractured, bedrock hydraulic conductivity values of less than 10^{-10} m/s are expected.

Groundwater levels in this flow zone respond readily to rainfall and most noticeably to snow melt events as evident from the continuous hydrograph records obtained (Figures 2-12 and 2-13, and Figures 3-1 to 3-13 of Appendix 2.V). Flow occurs through a well interconnected fracture network within the upper bedrock (where such fractures are present) with flow directions reflecting local topography. Groundwater discharges locally to Mitta Lake and as seepage at the base of steep slopes, with Upper Marmion Reservoir comprising the ultimate discharge area for the shallow active flow system at the Project Site.

Water level measurements collected at about 126 exploration boreholes indicate a relatively uniform pattern of groundwater flow that reflects local topography. There is no evidence of a linear bias that could be attributable to the dominant northeast-southwest structure in the bedrock.

The short-term tests conducted at 46 exploration boreholes indicate moderate to low permeable bedrock across the area of the planned open pit. This is supported by the generally isotropic pattern of groundwater level drawdown observed around the two exploration holes at which longer term pumping tests were conducted.

These results indicate the upper fractured bedrock zone is characterised by a moderately well interconnected fracture network.

Recharge across the LSA is variable depending on surficial geology conditions. In the Mine Area, thin overburden materials locally may comprise a source of seasonal recharge. In the vicinity of the TMF, thicker overburden deposits provide for lateral flow locally with discharge to nearby surface water as well as providing a source of recharge to the underlying fractured bedrock. Groundwater levels respond quickly to recharge and snow melt events, however, the volume of storage available in the upper fractured rock is low. Given the extent of exposed bedrock, and the limited extent of fine grained overburden materials with high water tables, recharge to the groundwater system is expected to be low. Preliminary estimates of baseflows in streams in the LSA suggest a recharge rate of between 50 to 100 mm per year (Hydrology TSD).

2.8.2 Deep Bedrock Flow Zone

Groundwater flow in the deep bedrock occurs through a network of joints and fractures that are present primarily between the shear zones, including the ore zone, and along the shear zones where these have not been sealed by vein mineralisation and/or clay/gouge material.

Hydraulic conductivity values for the deeper bedrock ranged from 7×10^{-10} to 2×10^{-5} m/s with a geometric mean of 3.6×10^{-8} m/s (Table 2-3). The country rock (outside the shear zones) appears to display a weak trend to decreasing fracture permeability with increasing depth which is consistent with similar granitic bodies elsewhere in northern Ontario. Where unfractured, the deep bedrock is expected to have a hydraulic conductivity on the order of 10^{-10} m/s. The transmissivity varying between 4 and 16 m^2/d determined from test pumping likely reflects hydraulic conditions over the full depth of the borehole rather than the upper section of the bedrock only. This is evident at the one exploration borehole location (BR-0433) where testing was conducted over the full depth of the borehole and then over the upper 95 m only. Thus the transmissivity determined from test pumping suggests an average hydraulic conductivity of about 1×10^{-7} to 5×10^{-7} m/s for the thickness of rock tested (371 m at BR-0220; 265 m at BR-0231).

2.9 Numerical Modelling of Existing Conditions

A 3-D groundwater flow model of the Mine Area has been constructed using the MODFLOW-2005 (Harbaugh 2005) code. 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.

The model domain extends into Upper Marmion Reservoir on three sides and to a distance of about 5.5 km northeast of the Mine area with a maximum vertical extent of 470 m.

A key consideration for the simulation of groundwater flow is the presence of fractured rock extending to below the base of the planned open pit mine adjacent to Upper Marmion Reservoir. Typically in the Canadian Shield, fracture frequency and the hydraulic conductivity of fractured rock is observed to decrease with depth. However the shear zones that bound the ore zone extend to a depth below that planned for the open pit. To reflect this condition, the ore zone, which will comprise much of the pit wall at the southwest end of the pit, was conservatively assigned a hydraulic conductivity similar to the shear zone to a depth of 200 m. The hydraulic conductivity distribution shown in Table 2-8 was incorporated into the flow model.

Table 2-8: Hydraulic Conductivity Distribution

	Shallow Flow Zone (m/s)			Deep Flow Zone (m/s)	
Depth below ground	0 – 10 m	10 – 20 m	20 – 30 m	30 – 200 m	Below 200 m
Shear Zones	1×10^{-6}	1×10^{-7}	1×10^{-7}	5×10^{-8}	5×10^{-8}
Ore Zone	1×10^{-6}	1×10^{-7}	1×10^{-7}	5×10^{-8}	2×10^{-8}
Country Rock	1×10^{-6}	1×10^{-7}	1×10^{-8}	1×10^{-8}	1×10^{-8}

Notes: The hydraulic conductivity distribution is isotropic Kx = Ky = Kz

The model was calibrated to existing flow conditions reflecting groundwater level measurements at monitoring wells and exploration holes, as well as spot measurements of flows in nearby streams.

Further details on model construction, boundary conditions and results are provided in Appendix 2.IX.

2.10 Prediction of Potential Changes

Predictions of changes in groundwater levels associated with steady state pit dewatering were developed using the calibrated flow model. This model was modified to incorporate the fully excavated Mine along with adjustments to the infiltration rate at the adjacent stockpiles. As discussed in Section 1.8, the temporal boundary for hydrogeology at the end of mine operations was the only phase of the Project considered for predictions of the change in groundwater quantity as this represents the phase of the Project when groundwater level declines associated with mining will be at their greatest lateral extent.

2.10.1 Predictive Modelling

2.10.1.1 End of Operations

The calibrated 3-D groundwater flow model developed for simulation of the existing conditions was modified to incorporate the topographic representation of the fully developed Mine (both the west and east pits) at the end of mining operations. The adjacent stockpiles (WRMF, low-grade ore and overburden stockpiles) were incorporated as seepage flux boundaries and the PPCP as a constant head boundary. For the stockpiles, the estimated infiltration expected to by-pass the perimeter engineered collection system was input as a modified infiltration over the footprint of each stockpile. The estimated efficiency of the perimeter collection system is provided in the Site Water Quality TSD.

Steady state model simulations were performed to develop predictions of groundwater inflow to the completed open pit for a base case with the hydraulic conductivity of the shear zones ranging from 1×10^{-6} to 5×10^{-8} m/s (Table 2-8). Additional predictive runs were performed to develop a range of inflow estimates with higher hydraulic conductivity values assigned to the shear zones (10^{-6} and 10^{-5} m/s).

Groundwater seepage into the completed open pit under steady state conditions at the end of mining is estimated at 740 cubic metres per day (m^3/d). As indicated in Table 2-9, the bulk of this inflow originates from the ore zone and the relatively narrow shears at depths below 30 m. About one third of this inflow is sourced from the Upper Marmion Reservoir with the balance originating as seepage from the adjacent stockpiles as is discussed further below.

Table 2-9: Predicted Steady State Groundwater Inflow to Open Pit

Unit	Steady State Pit Inflow (m^3/d)	% Of Inflow
0 to 30 mbgs	0	0
Shear Zones (30+ mbgs)	268	36%
Ore Zone (30+ mbgs)	370	50%
Host Rock Zone (30+ mbgs)	102	14%
Total	**740**	**100%**

Notes: mbgs = Metres below ground surface.

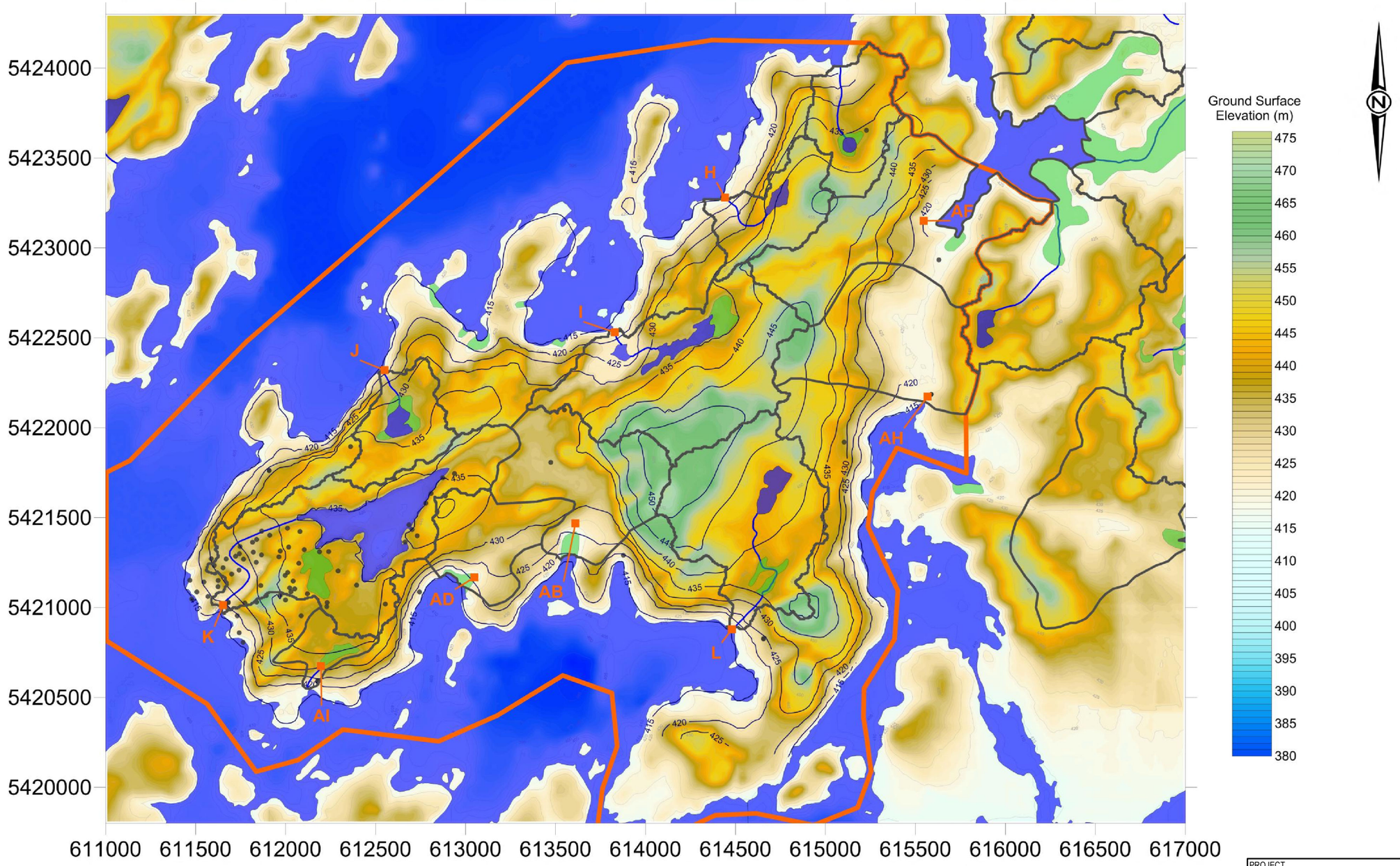
Simulated pre-mining groundwater elevations and surface water subwatersheds are shown in Figure 2-22 while simulated end of mining groundwater elevations are shown in Figure 2-23. The simulated groundwater drawdown extends to the shoreline of Upper Marmion Reservoir on three sides of the open pit, except for a localized area in the vicinity of the PPCP. To the north and northeast, the cone of depression (as defined by the 1 m drawdown contour) extends about 700 m from the pit perimeter and underlies a portion of the WRMF and overburden stockpiles (Figure 2-24). A portion of the seepage losses from each of these stockpiles will discharge to the Mine with the balance reporting to the nearby Upper Marmion Reservoir (Lynxhead Bay and/or Trap Bay) as shown in Table 2-10.

Table 2-10: Predicted Seepage Losses from Stockpiles

Stockpile	Total Seepage (m^3/d)	Receptor	Receiving Discharge (m^3/d)
Waste Rock	241	East Pit	133
		Upper Marmion Reservoir	108
Ore	32	West and East pits	32
Overburden	52	East pit	16
		Upper Marmion Reservoir	36
PPCP	37	Primarily West Pit	36
		Upper Marmion Reservoir	1
Total	**362**		

Of the estimated 362 m^3/d total seepage from the adjacent stockpiles, 217 m^3/d reports to the open pit with the balance (145 m^3/d) reporting to the perimeter collection system or adjacent surface water bodies. Thus of the estimated 740 m^3/d steady state inflow to the pit at the end of mining, a total of about 523 m^3/d (740-217 m^3/d) originates as seepage inflows from the adjacent Upper Marmion Reservoir.

Inflows during early mining will be variable reflecting drainage from the overburden and shallow fractured rock at the pit perimeter that will gradually decline. The lateral extent of groundwater level decline during early mining will be limited. Thereafter flows will progressively increase as the pit is deepened and approximate the steady state inflow of 740 m^3/d at the end of mining. Seepage losses from the adjacent stockpiles and PPCP will initially report primarily to the adjacent Upper Marmion Reservoir. As dewatering progresses and groundwater levels beneath these stockpiles progressively decline, a greater percentage of the seepage losses will report to the open pit.



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. The contour lines shown reflect the simulated water table elevations under Pre-Pit (current) conditions (5m contour interval).

Legend

- Model Extent
- Active Model Domain
- Simulated Water Table Elevation (m)
- Lakes
- Wetlands
- SW Flow Stations
- Streams/Rivers
- Surface Water Subwatersheds
- GW Head Calibration Point

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SIMULATED PRE-MINING REGIONAL GROUNDWATER ELEVATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-22

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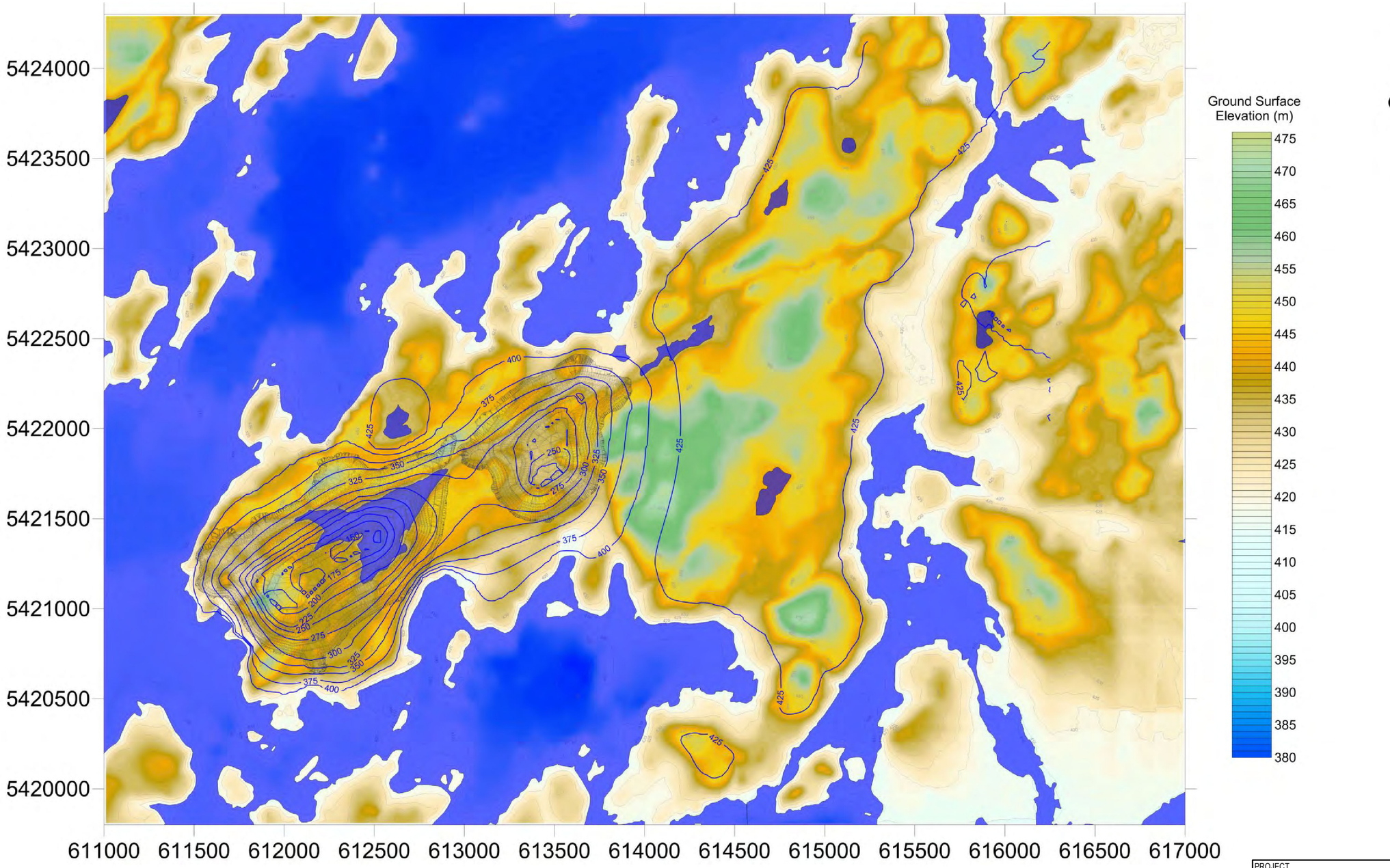

LEGEND

Simulated Groundwater Elevation

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SIMULATED END OF MINING GROUNDWATER ELEVATION

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-23

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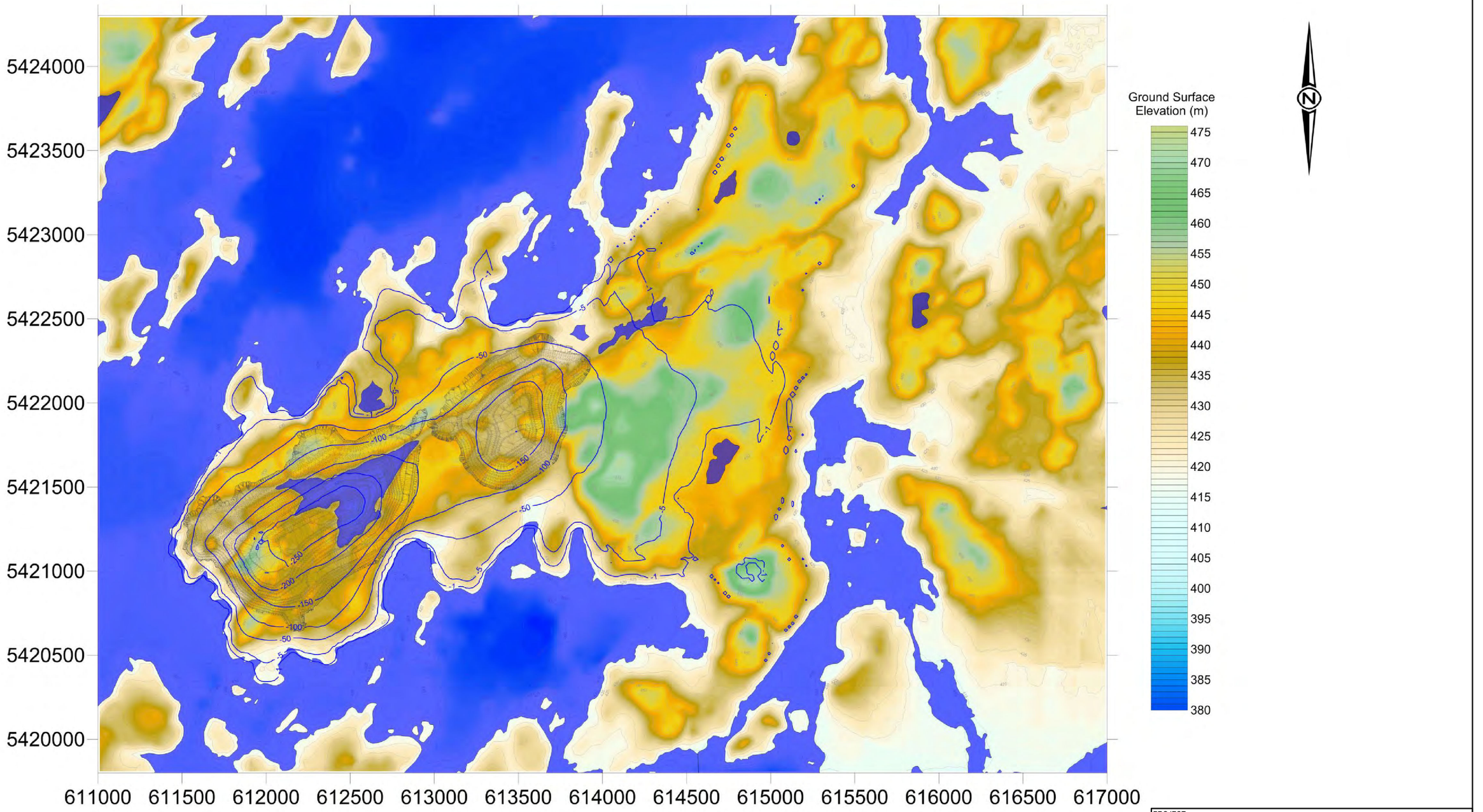

LEGEND

Simulated Groundwater Elevation

NOTES:

1.The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (Contour Interval -1. -5, -50, -100, -150, -200, -250, and -300m).

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SIMULATED END OF MINING GROUNDWATER DRAWDOWN

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	4 Feb. 2013		
CHECK	MSO	4 Feb. 2013		
REVIEW	JMP	4 Feb. 2013		

FIGURE: 2-24

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It should be noted that additional investigations are to be conducted in the area of the PPCP to refine the understanding of subsurface conditions locally. The flow estimates presented above will be refined to support the design of this pond.

2.10.1.2 Uncertainty Analyses

Uncertainty analyses were performed to develop range of possible but less likely estimates of pit inflows relative to the inflow simulation completed above. The uncertainly analyses were completed as follows:

- **Uncertainty 1:** Increase the shear's hydraulic conductivity to $1x10^{-6}$ m/s.
- **Uncertainty 2:** Increase the shear's hydraulic conductivity to $1 x10^{-5}$ m/s.
- **Uncertainty 3:** Increase the hydraulic conductivity of the lower 20 m of the upper fractured zone to equal that of the upper 10 m.
- **Uncertainty 4:** Reduce the ore zone hydraulic conductivity distribution to that of the host rock.
- **Uncertainty 5:** Increase recharge by 25% to account for uncertainty in the infiltration estimate.
- **Uncertainty 6:** Decrease recharge by 25% to account for uncertainty in the infiltration estimate.
- **Uncertainty 7:** Set all layer types to "Type 0 Confined" to account for the possibility that perched conditions may develop at the perimeter of the dewatered pit.

Estimated pit inflows for these steady-state simulations range from 632 m^3/d to 1,814 m^3/d as shown in Table 2-11.

Table 2-11: Uncertainty Analysis Steady-State Pit Inflows

Uncertainty Scenario	Pit Inflows (m^3/d)	% Change
1	958	+29%
2	1,814	+145%
3	901	+21%
4	632	-15%
5	773	4%
6	717	-3%
7	1,055	+42%

Notes: % change is relative to the base case inflow estimate of 740 m^3/d.

Model results are most sensitive to increasing the hydraulic conductivity of the shear zone, as this increase is transmitted over the full depth of the pit and the length of the model domain. The highest estimated inflow (1,814 m^3/d), results from the increase in hydraulic conductivity of the shear zone to 10^{-5} m/s. About three-quarters of this inflow originates from Upper Marmion Reservoir with the shear zones comprising the primary inflow zone. This simulation reflects the potential that shear infill materials (clay and/or gouge) could be compromised by the hydraulic gradients that will progressively increase as the pit is deepened. This simulation does not include the unlikely scenario of the complete flushing of unconsolidated fracture infill resulting in an

extensive wide open fracture providing a direct hydraulic connection between the open pit and Upper Marmion Reservoir.

Slightly increased inflows are predicted if perched groundwater conditions develop above otherwise dewatered rock around the perimeter of the open pit. Assuming (unreasonably for fractured rock) that the pit is completely surrounded by perched groundwater, inflows of 1,055 m^3/d could result.

The lowest estimated inflow results from decreasing the hydraulic conductivity of the ore zone to that of the host rock. In this scenario, the shear zones provide bulk of the inflow to the pit.

2.10.1.3 Transient Analyses

An analysis of the initial stages of pit development was conducted to estimate inflows as excavation progresses below the water table and into the upper fractured rock. Drainage of rock exposed at the pit perimeter will release a significant volume of water (described as storage), during early mining primarily because of the higher volume of water stored in the upper fractured rock relative to the less fractured rock at greater depth. For this run, a uniform 30 m deep, "instantaneous" excavation is assumed to occur across the Mine footprint with simulated inflows developed for the following 90 days as shown in Table 2-12.

Table 2-12: Transient Early Mine Pit Inflows

Time Period	Pit Inflows (m^3/d)
Day 5 to Day 10	1,260
Day 10 to Day 20	861
Day 20 to Day 30	700
Day 30 to Day 60	503
Day 60 to Day 90	422
Steady State	212

These results suggest that during early mining, inflows of about 1,200 m^3/d are possible; and that these inflows will decrease over time as the perimeter overburden and shallow bedrock are drained.

2.10.2 Discussion of Simulated Effects

At the end of mining, the simulated cone of depression (as defined by the 1 m drawdown contour) extends about 700 m from the pit perimeter and underlies a portion of the WRMF and overburden stockpiles (Figure 2-24). As a result, some baseflow loss occurs at hillside seeps (a total decrease from 152 m^3/d to 82 m^3/d) and wetlands and streams (a total decrease from 68 m^3/d to 37 m^3/d) within this area. However, additional seepage emanating from the stockpiles ultimately results in greater discharge to some nearby surface water features. Table 2-13 details changes to groundwater baseflow on a subwatershed level.

Table 2-13: Simulated Subwatershed Groundwater Discharge to Seeps, Wetlands and Streams

Subwatershed	Pre-Pit Discharge (m^3/d)	Ultimate Pit In-Place Discharge (m^3/d)	% Change
AB	32	0	-100%
AD	7	0	-100%
AF	17	25	+47%
AH	38	55	+45%
AI	1	0	-100%
G	8	8	0%
H	0	0	0%
I	41	25	-39%
J	13	1	-92%
K	42	0	-100%
L	21	0	-100%

Figure 2-22 provides the location of these sub-watersheds. It should be noted that in general, local streams in the vicinity of the Mine and stockpiles are intermittent and have been observed to be dry at times during the summer months. With the reduction or even elimination of baseflows in some streams, the period of time when any stream is seasonally dry will increase. Flow will still occur in these streams during the spring freshet and storm events. Further discussion of these effects is contained in the Hydrology TSD, the Terrestrial Ecology TSD and the Aquatic Environment TSD.

3.0 GROUNDWATER QUALITY

This section addresses the existing conditions for groundwater quality (as noted previously in Section 1.6). Prediction of project related effects on groundwater quality are contained in the Site Water Quality TSD.

3.1 Parameters

The following parameters were investigated to characterise groundwater quality within the LSA:

- Concentrations of select chemical parameters.

For the discussion of these results, the key project components within the LSA have been grouped into two separate areas as follows:

- The Mine Area which includes the east and west pits, the WRMF, low-grade ore and overburden stockpiles, the PPCP and the Ore Processing Facility.
- The TMF Area.

The boundaries of the Mine Area and TMF Area are shown in Figure 1-3.

3.2 Field Studies

The investigation of existing groundwater quality at the Project Site is based primarily on the following field activities (Table 3-1):

- Quarterly collection of water quality samples from select groundwater monitoring wells.
- Collection of five groundwater quality samples during 12-hour pumping test at BR-0220.
- Collection of four groundwater quality samples during 24-hour pumping test at BR-0231.
- Collection of three groundwater quality samples during 94-hour pumping test at BR-0220.

Table 3-1: Summary of Field Investigation Dates

Tasks – Groundwater Quality Investigation	2011	2012
Quarterly water quality sampling at monitoring wells	May 31 to June 2 August 24 to 29 October 26 to 30	April 21 to 25 August 27 to 31
Water quality sampling during 12 hour pumping test at BR-0220	September 9 to 11	n/a
Water quality sampling during 24 hour pumping test at BR-0231	September 11 to 13	n/a
Water quality sampling during 94 hour pumping test at BR-0220	n/a	March 10 to 14

Notes:
n/a = No groundwater quality sampling completed.

3.2.1 Quarterly Water Quality Sampling

Groundwater samples were collected from select monitoring wells throughout the LSA on three occasions in 2011 and two occasions in 2012 (Table 3-1). Monitoring locations were selected based on proximity to the proposed Project infrastructure shown on Figure 1-3. Table 3-2 provides a summary of the wells that were sampled routinely during this monitoring program. Monitoring well locations are shown on Figures 2-6 and 2-7.

Table 3-2: Summary of Groundwater Monitoring Wells Sampled in 2011 and 2012

	Date				
Monitoring Well	**May/June 2011**	**August 2011**	**October 2011**	**April 2012**	**August 2012**
BRH-0001B	✓	✓	✓	✓	✓
BRH-0002A	✓	✓	✓	✓	✓
BRH-0002B	✓	✓	✓	✓	✓
BRH-0003	✓	✓	✓	✓	✓
BRH-0004	✓	✓	✓	✓	✓
BRH-0005B	✓	✓	✓	✓	✓
BRH-0006	✓	✓	✓	✓	✓
BRH-0007A	✓	✓	✓	✓	✓
BRH-0007B	✓	n/a[(a)]	✓	✓	n/a[(a)]
BRH-0008A	✓	✓	✓	✓	✓
BRH-0009	✓	✓	✓	✓	✓
BRH-00012A	✓	✓	✓	✓	✓
BRH-00012B	✓	✓	✓	✓	✓
BRH-00013	✓	✓	✓	✓	✓
BRH-00014A	✓	✓	✓	✓	✓
BRH-00014B	✓	✓	✓	✓	✓
BRH-00017A	✓	n/a[(b)]	✓	✓	✓
BRH-00017B	✓	n/a[(b)]	✓	✓	✓
BRH-00020A	✓	✓	✓	✓	✓
BRH-00020B	✓	✓	✓	✓	✓
BRH-00024	✓	✓	✓	✓	✓
BH12-4	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	✓

Notes:

n/a[(a)] = Groundwater table too low to obtain a sample during this monitoring event.

n/a[(b)] = Unable to access monitoring location due to difficult trail conditions.

n/a[(c)] = Monitoring well not installed until August 2012.

Groundwater sampling was performed consistent with recognized standard field sampling methods. The following sample collection protocols were followed:

- **Calibration** – Field parameters were measured with a handheld meter calibrated in the field with calibration solutions provided by the supplier. Calibration for pH (two points: 4 and 7), and electrical conductivity was carried out daily before sampling began and documented in the field notes.
- **Sampling Equipment and Handling** – Sterile gloves were worn during sample collection. Sample bottles were provided by the contract analytical laboratory. Sample bottles were pre-charged with the appropriate preservatives at the analytical laboratory. Samples were stored in a cooler with ice and maintained in a cool state until shipped to the laboratories. As much as possible, samples were shipped in time to meet the required holding times. However, this was not always possible for nitrate, nitrite, and ortho-phosphate (each with holding times of 48 hours) given the remote location.
- **Sample Filtration** – Samples for metals and organic carbon were collected as follows:
  - Unfiltered (total organic carbon).
  - Field filtered (dissolved metals and dissolved organic carbon) using a 0.45 µm Waterra^{TM} filter into the appropriate bottles.
- **Field staff labelled samples with unique sample numbers**. Field observations (e.g., clarity, colour, odour, etc.), as well as the sample collection procedures and techniques were documented.
- **Well Purging** – A minimum of three well volumes were purged, or until the well ran dry. In cases where a well could only be drained dry due to low recovery rates, a minimum of one well volume was purged. Water levels were allowed to recover.
- **Sampling Equipment and Handling** – Dedicated Waterra™ tubing and footvalves were used for every piezometer to avoid cross-contamination between sample locations. Tubing was stored within each well between sampling events or discarded after sampling and replaced in the following field event if it was not able to be stored in the well.
- **Field Parameter Measurement** – Measurements of pH, temperature and electrical conductivity were taken during the collection of groundwater samples.

3.2.1.1 Quality Assurance and Quality Control

QA/QC samples were collected during each groundwater sampling campaign. Duplicate samples were collected for approximately every 10% of samples during each sample collection campaign. In addition to the duplicate samples, the laboratory provided a field blank (de-ionized water decanted into sample bottles at the site) and a travel blank (de-ionized, filled sample bottles that travel from the laboratory to the site and back) for the June sampling program. These QA/QC procedures were in addition to the internal QA/QC requirements and programs of the analytical laboratory.

3.3 Existing Conditions

Groundwater quality data are reported in Appendix 3.I. Major ion chemistry for groundwater samples collected from monitoring wells and exploration boreholes within the Mine Area is depicted on a Piper trilinear diagram in Figure 3-1.

Bedrock groundwater within the LSA has as a calcium-bicarbonate type composition and is typified by low major ion concentrations. Concentrations of bicarbonate, the dominant anion, generally range from about 100 to 180 milligrams per litre (mg/L) and average 140 mg/L, while concentrations of calcium, the dominant cation, generally vary between 7.4 to 84 mg/L and average about 40 mg/L. The pH of the groundwater is weakly acidic to near-neutral, ranging from 5.9 to 8.1. Overburden groundwater is generally similar in composition to bedrock groundwater, although higher dissolved and total concentrations of parameters were reported for some samples collected from monitoring wells screened in overburden.

To provide some context for the review of groundwater quality data within the LSA, results have been compared to Ontario Drinking Water Quality Standards (ODWS) and Provincial Water Quality Objectives (PWQO). It should be noted that PWQOs are applicable to surface waters. Groundwater quality has been compared herein to PWQOs recognizing the immediate proximity of surface waters to the LSA. These comparisons should not be interpreted as an assessment of regularity compliance. It should be noted that no groundwater supply wells are present in the LSA and groundwater is not used locally as a source of drinking water.

Generally, pH values were within the ranges specified by the ODWS and PWQOs (6.5 to 8.5).

Manganese concentrations were typically greater than the ODWS (0.05 mg/L) in most samples, ranging from less than 0.001 to 7.6 mg/L. Concentrations of dissolved organic carbon (less than 1.0 to 47 mg/L), aluminum (less than 0.05 to 2.7 mg/L) and iron (less than 0.02 to 88 mg/L) were greater than ODWS values (5.0, 0.1 and 0.3 mg/L, respectively) in several of the groundwater samples.

Several parameters, including iron (less than 0.02 to 88 mg/L), tungsten (less than 0.01 to 0.5 mg/L), cobalt (less than 0.0005 to 0.061 mg/) and copper (less than 0.001 to 0.03 mg/L) reported concentrations greater than the PWQO values (0.3, 0.03, 0.0009 and 0.005 mg/L, respectively) in several of the groundwater samples. Other parameters exceeding PWQO values in less than ten samples include aluminum, arsenic, zinc, cadmium, uranium, silver and vanadium.

Water quality data obtained during the pumping tests are considered most representative of bedrock groundwater within the LSA, as these samples are representative of a larger volume of groundwater. Pumped water quality reported slightly higher magnesium concentrations (12 to 19 mg/L) and slightly lower concentrations of calcium (41 to 50 mg/L) compared to the total suite of groundwater results (less than 5.0 to 15 mg/L and 7.4 to 84 mg/L, respectively). The Piper trilinear diagram shown in Figure 3-1 shows the similarity of water chemistry from the shallow groundwater (sampled from monitoring wells) and pumped groundwater sampled from exploration holes during test pumping. Pumping test wells generally reported neutral pH values, ranging from 7.6 to 7.8. With the exception of the initial sample obtained during testing at BR-0220 (March 2012) and BR-0231 (September 2011), no obvious trends in parameter concentrations over time were apparent.

As discussed in Section 2.7, groundwater pumped from the exploration boreholes is expected to be sourced from both shallow and deep fractures. Similar to the full groundwater suite, pumped groundwater sample

parameters, including hardness (157 to 217 mg/L) and manganese (0.22 to 0.71 mg/L), were greater than the ODWS in all samples. Concentrations of dissolved organic carbon (4.3 to 6.4 mg/L) and iron (less than 0.02 to 1.4 mg/L) were greater than the ODWS values in several samples.

Generally, trace metal concentrations were lower in pumping test wells than those reported for samples collected from monitoring wells. The only parameter exceeding PWQO values in pumping test wells in one or more samples is iron (less than 0.02 to 1.4 mg/L).

Predicted changes to groundwater quality are provided in the Site Water Quality TSD.

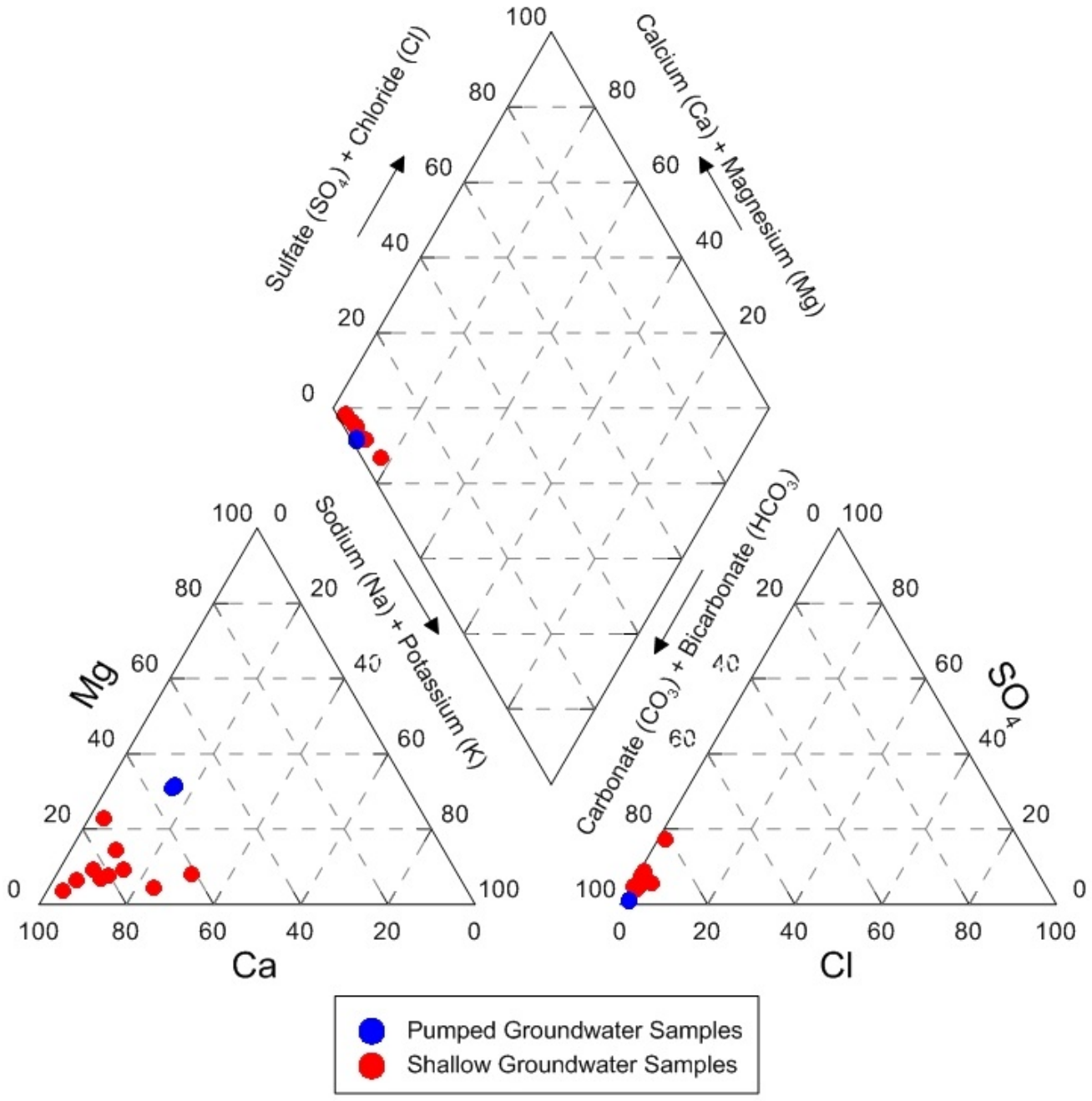

Figure 3-1: Piper Trilinear Diagram of Groundwater Chemistry for Shallow and Pumped Groundwater Samples

4.0 MONITORING PROGRAM

This section provides considerations for the design of the groundwater monitoring program for the Project Site. Detailed monitoring design is provided in the Environmental and Social Management Plan of the EIS/EA Report. The program to monitor groundwater quantity will comprise the measurement of groundwater levels (or water pressures) at a number of locations within the Project Site. Pressure transducers and data loggers will be used to obtain a continuous record of groundwater level fluctuations that will be supported by quarterly manual depth to water measurements. Groundwater level/pressure monitors will be located within and adjacent to the open pits and integrated with the program to monitor pit slopes during excavation. As a minimum, four groundwater level monitoring nests will be established adjacent to the shoreline of Upper Marmion Reservoir for life of mine monitoring around the open pits, including two at the southwest end of the west pit. As a minimum, these nests will be completed with screens set to depths of 10 m and 30 m below the elevation of Upper Marmion Reservoir (415 masl). Within the east and west pits, sump water levels will be regularly monitored along with groundwater pressures on pit slopes. The location, design of and monitoring frequency at locations to be established will be developed as part of pit slope stability monitoring program.

For the remainder of the Project Site, groundwater quantity monitoring will be integrated with a comprehensive water monitoring program that will include groundwater quality, surface water quality, levels and flows along with meteorology and flow metering of all pumped water. With the exception of the area of open pit mining, monitoring locations will be selected primarily based on water quality considerations; and will likely include monitoring at the following general areas:

- Perimeter monitoring at the WRMF, PPCP, low-grade ore stockpile and the TMF.
- Adjacent to areas of chemical/fuel storage and maintenance facilities.

It is expected that a minimum of 20 monitoring well nests will be established at the Project Site (including existing well nests where these can be retained) as part of a comprehensive water monitoring program to monitor groundwater quality at these facilities. Groundwater level measurements will be obtained on a regular basis at any observation well installed for the purpose of monitoring groundwater quality.

Similarly, up to five groundwater monitoring wells (including existing wells where these can be retained) are expected to be established in the immediate proximity of surface water level and flow monitoring stations (where access allows for monitoring well installation) to assess the relationship between groundwater and surface waters.

5.0 SUMMARY OF FINDINGS

The following presents the key findings developed:

- Overburden deposits are of limited lateral and vertical extent at the Project Site. In the Mine Area, discontinuous overburden materials are generally fine grained, have a shallow water table and are typically less than two metres thick. Greater thicknesses (of up to 25 m) of granular materials with a greater lateral extent occur in the vicinity of the TMF Area. Recharge provides for lateral flow within these granular materials with discharge as baseflow to nearby streams or directly to nearby lakes.
- The upper 30 m of bedrock (the upper fractured bedrock) appears more fractured than the underlying rock. Test data indicates moderate to low hydraulic conductivities (on the order of 10^{-6} to 10^{-7} m/s) for the upper bedrock where fractured and much lower values in unfractured bedrock.
- Groundwater hydrographs show that the bedrock is readily recharged where fractured. Most notably in the Mine Area, groundwater discharge is evident from flowing wells and the numerous swampy wet areas at the base of sloped lands. The seasonal raising and lowering of the Upper Marmion Reservoir is reflected in the groundwater hydrograph from only one monitoring location (BRH-0009) suggesting that direct hydraulic connections between the Reservoir and the upper fractured rock are limited.
- The dominant structural features in bedrock at the Mine Area comprise the upper and lower shears and associated splays. Test pumping of 47 exploration boreholes, many of which intersected these structures suggests that, for the most part, these features are not obviously more permeable than the bulk rock mass between the shears (i.e. the ore zone) although indications of potential structurally controlled flow within these shear zones have been observed.
- Groundwater flow occurs primarily through a moderately well interconnected fracture network in the area of the open pit. This fracture network extends at least to 350 m below ground (the base of the open pit) although fracture frequency shows a general decrease with depth. Test data suggest hydraulic conductivity values range between 10^{-8} and 10^{-7} m/s with higher values encountered in the upper fractured zone and occasionally in the deeper rock. Where unfractured, hydraulic conductivity values of less than 10^{-10} m/s are expected.
- Numerical modelling of the Mine Area indicates that steady state groundwater inflows of about 740 m^3/d are expected at the end of mining. About two thirds inflow (523 m^3/d) is derived from the adjacent Upper Marmion Reservoir with the remainder from naturally occurring recharge or seepage that by-passes the engineered collection systems at the adjacent stockpiles. The majority of flow occurs at depth greater than 30 m through the shear zones and ore zone, with a smaller percentage derived from the remaining country rock.
- At steady state at the end of mining, the simulated cone of depression extends to the shoreline of Upper Marmion Reservoir except in the area of the PPCP. To the northeast, the cone of depression extends approximately 700 m from the pit perimeter and underlies portions of the adjacent stockpiles. Steady state seepage losses from the stockpiles report to the open pit (about two-thirds of the estimated total seepage losses of 344 m^3/d) and also to adjacent surface waters (about one-third).

- Drawdown from pit dewatering results in a reduced or eliminated flows at some streams. Conversely, seepage losses from the stockpiles result in an increase in flows at other streams locally. These effects are addressed in the Hydrology TSD, the Terrestrial Ecology TSD, and the Aquatic Environment TSD.
- Greater inflows of about 1200 m^3/d are expected during early mining reflecting the removal of stored water at the perimeter of the pit in the upper fractured zone. These inflows are expected to decrease as the excavation into the upper bedrock progresses.
- More permeable fracture connections to Upper Marmion Reservoir could develop as mining progresses given the lateral continuity of the shear zones beneath the adjacent Upper Marmion Reservoir and the high hydraulic gradients that will develop around the pit. Computer simulations suggest that steady state inflows of about 1,800 m^3/d could occur where more permeable shear zones develop. Inflows in excess of this amount would occur in the unlikely situation that unconsolidated fracture infill material was completely flushed (because of the progressive increase in hydraulic gradients) forming an extensive open fracture connection between the pit and Upper Marmion Reservoir.
- Groundwater has a calcium-bicarbonate type composition and is typified by low major ion concentrations and weakly acidic to near-neutral pH. Water quality from pumped exploration boreholes is similar to the quality of water obtained from shallow monitoring wells. Project effects on groundwater quality are addressed in the Site Water Quality TSD.
- Monitoring of seepage and pore water pressures on the pit slopes will be required to ensure that pit slopes are adequately depressurized during mining.
- Monitoring of groundwater levels will be conducted to verify impact predictions and results integrated within the overall water monitoring and management program for the Project.

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7.0 GLOSSARY OF TERMS

Table 7-1: Glossary of Terms

Term	Definition
Discharge	The release or extraction of water from an aquifer. Typical mechanisms of natural discharge are evapotranspiration by phreatophytes, springs, and drains to surface water bodies. Pumping is a man-caused discharge. (University of Idaho 2012)
Drawdown	The change in potentiometric head caused by the pumping of groundwater. (University of Idaho 2012)
Hydraulic conductivity	The capacity of a porous medium to transmit water through a unit cross-sectional area. Hydraulic conductivity is dependent upon the physical properties of the porous medium and the viscosity of the water and is expressed in units of length/time. (University of Idaho 2012)
MODFLOW	Numerical ground water flow model code developed by the U.S. Geological Survey. (University of Idaho 2012)
Precipitation	As used in hydrology, precipitation is the discharge of water, in a liquid or solid state, out of the atmosphere, generally onto a land or water surface. It is the common process by which atmospheric water becomes surface, or subsurface water. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated. Precipitation includes rainfall, snow, hail, and sleet, and is therefore a more general term than rainfall. (NOAA 2012)
Recharge	Mechanisms of inflow to the aquifer. Typical sources of recharge are precipitation, applied irrigation water, underflow from tributary basins and seepage from surface water bodies. (University of Idaho 2012)
Reservoir	A man-made facility for the storage, regulation and controlled release of water. (NOAA 2012)
Seepage	The interstitial movement of water that may take place through a dam, its foundation, or abutments. (NOAA 2012)
Surface water	Water that flows in streams and rivers and in natural lakes, in wetlands, and in reservoirs constructed by humans. (NOAA 2012)
Transmissivity	The rate of flow of water through a vertical strip of aquifer which is one unit wide and which extends the full saturated depth of the aquifer. (University of Idaho 2012)
Water table	The level below the earth's surface at which the ground becomes saturated with water. The water table is set where hydrostatic pressure equals atmospheric pressure. (NOAA 2012)

8.0 ABBREVIATIONS, ACRONYMS AND INITIALISMS

Table 8-1: List of Abbreviations, Acronyms and Initialisms

Acronym	Definition
3-D	Three-dimensional
BH	Borehole
BR	Borehole drilled for the exploration program
BRG	Groundwater hydrograph monitoring location
BRH	Boreholes drilled for the hydrogeological program
CEA Agency	Canadian Environmental Assessment Agency
EIS/EA	Environmental Impact Statement/Environmental Assessment Report
EIS Guidelines	Environmental Impact Statement Guidelines
Golder	Golder Associates Ltd.
GT	Boreholes drilled for the geotechnical investigation of the pit area
LSA	Local Study Area
MDC	Marmion Deformation Corridor
MSA	Mine Study Area
ODWS	Ontario Drinking Water Quality Standards
OHRG	Osisko Hammond Reef Gold Ltd.
PWQO	Provincial Water Quality Objectives
TMF	Tailings Management Facility
ToR	Terms of Reference
TSD	Technical Support Document
VEC	Valued Ecosystem Component
WRMF	Waste Rock Management Facility

9.0 UNITS

Table 9-1: List of Units

Abbreviation	Unit
°C	degrees Celsius
K	hydraulic conductivity
km	kilometre
L/min/m	litres per minute per metre
L/s	litres per second
m	metre
m/s	metres per second
m^2/d	square metres per day
m^3/d	cubic metres per day
mags	metres above ground surface
masl	metres above sea level
mbgs	metres below ground surface
mg/L	milligrams per litre
mm	millimetre

APPENDIX 2.I

2010 Geotechnical Investigation for Feasibility Level Pit Slope Design

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

A geotechnical site investigation was carried out by Golder Associates Ltd. (Golder) in 2010 as part of the geotechnical investigation to support the Feasibility Pit Slope Design study for the Hammond Reef Gold Project (Project). The results of this study are presented in the Golder report on "Feasibility Pit Slope Design", dated September 2012 (Golder 2012). The following appendix summarizes select results from this report. The investigation included:

- Drilling of six inclined HQ-3 size diamond cored geotechnical holes (denoted GT01 to GT06) with core orientation.
- Geotechnical core logging including description and orientation of discontinuities.
- Point load strength testing.
- Downstage hydraulic conductivity testing (packer testing) at varying intervals.
- Isolated stage hydraulic conductivity testing (packer testing) of two exploration boreholes (denoted BR366 and BR371).
- Collection of rock samples for laboratory testing.
- The installation of four grouted-in-place vibrating wire piezometers in boreholes GT01, GT03, GT04, and GT05.

This appendix presents the results from geotechnical core logging and borehole packer testing as both of these components relate to the discussion of hydrogeology provided in the Hydrogeology Technical Support Document (TSD). The data should be read in conjunction with the Golder report on "Feasibility Pit Slope Design", dated September 2012.

2.0 METHODS

Detailed descriptions of the methodologies for each component of this investigation are provided in the Golder report on "Feasibility Pit Slope Design", dated September 2012.

3.0 RESULTS

3.1 Geotechnical Borehole Logs

The following geotechnical parameters were routinely recorded as part of the geotechnical logging:

- Rock type and geotechnical description.
- Total core recovery (TCR).
- Rock quality designation (RQD).
- Fractures per 0.25 m.
- Strength of intact rock (rock hardness).
- Weathering.
- Major structures.
- Discontinuity type.
- Discontinuity orientation.
- Discontinuity condition and roughness.

The geotechnical data collected during logging of boreholes GT-01 to GT-06, BR-366, BR-371 and BR-375 are presented as one page strip-log histograms of geotechnical data versus depth overlain by the lithologies identified by the Osisko Hammond Reef Gold Ltd. (OHRG) exploration geologists. These histogram summary plots are presented in Figures B1 to B9. The geotechnical borehole locations are shown on Figure 2-6 in the Hydrogeology TSD.

3.2 Packer Testing

A total of 213 packer tested intervals were performed over the course of this investigation. In general, the packer test procedures involved falling head, rising head and/or constant head hydraulic conductivity testing to evaluate the hydraulic conductivity of the isolated packer interval. Testing interval depths and packer testing results have been summarised in Tables 1 to 8 below and are also presented in relation to available geologic information on Figures C1 to C8 in Golder (2012). The geotechnical borehole locations are shown on Figure 2-6 in the Hydrogeology TSD.

Table 1: Packer Testing Results for Geotechnical Borehole GT-01

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-01	1	9	6.00	15.00	5.4×10^{-8}	—	—	5.4×10^{-8}	Slug Recovery
	2	15	11.75	26.75	4.2×10^{-9}	—	—	4.2×10^{-9}	Slug Recovery
	3	15	23.75	38.75	4.8×10^{-9}	1.9×10^{-8}	—	1.9×10^{-8}	Slug Recovery
	4	15	35.75	50.75	1.4×10^{-8}	—	—	1.4×10^{-8}	Slug Recovery
	5	21	47.75	68.75	1.8×10^{-8}	—	—	1.8×10^{-8}	Slug Recovery
	6	25	65.75	90.75	6.0×10^{-7}	—	5.6×10^{-7}	5.6×10^{-7}	Constant Injection
	7	18	87.00	105.00	2.9×10^{-8}	1.6×10^{-8}	—	2.9×10^{-8}	Slug Recovery
	8	21	102.00	123.00	2.1×10^{-6}	—	8.8×10^{-6}	8.8×10^{-6}	Constant Injection
	9	33	120.00	153.00	3.8×10^{-7}	4.9×10^{-7}	2.7×10^{-7}	2.7×10^{-7}	Constant Injection
	10	33	150.00	183.00	2.3×10^{-7}	—	1.3×10^{-7}	1.3×10^{-7}	Constant Injection
	11	21	180.00	201.00	2.6×10^{-6}	—	1.0×10^{-5}	1.0×10^{-5}	Constant Injection
	12	33	198.00	231.00	2.7×10^{-8}	5.2×10^{-8}	—	5.2×10^{-8}	Slug Recovery
	13	33	228.00	261.00	1.0×10^{-7}	9.2×10^{-8}	7.3×10^{-8}	7.3×10^{-8}	Constant Injection
	14	27	258.00	285.00	6.3×10^{-8}	6.1×10^{-8}	—	6.3×10^{-8}	Slug Recovery
	15	17	282.00	299.00	9.0×10^{-8}	3.1×10^{-8}	—	9.0×10^{-8}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-01 is 65.4°.

K = Interval Hydraulic Conductivity.

— = Test not performed.

Table 2: Packer Testing Results for Geotechnical Borehole GT-02

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-02	1	6	8.60	14.30	6.1×10^{-6}	—	—	6.1×10^{-6}	Slug Recovery
	2	15	11.35	26.35	7.3×10^{-6}	—	3.9×10^{-6}	3.9×10^{-6}	Constant Injection
	3	20	21.30	41.30	9.7×10^{-8}	—	5.8×10^{-8}	5.8×10^{-8}	Constant Injection
	4	33	38.40	71.40	—	5.6×10^{-8}	—	5.6×10^{-8}	Slug Recovery
	5	33	68.40	101.40	—	5.3×10^{-9}	—	5.3×10^{-9}	Slug Recovery
	6	33	98.40	131.40	6.7×10^{-7}	—	3.1×10^{-7}	3.1×10^{-7}	Constant Injection
	7	33	128.50	161.50	4.0×10^{-7}	—	1.9×10^{-7}	1.9×10^{-7}	Constant Injection
	8	9	152.50	161.50	—	1.8×10^{-6}	6.3×10^{-7}	6.3×10^{-7}	Constant Injection
	9	33	158.50	191.50	1.2×10^{-9}	4.8×10^{-9}	—	4.8×10^{-9}	Slug Recovery
	10	39	188.50	227.50	2.1×10^{-8}	1.4×10^{-8}	—	2.1×10^{-8}	Slug Recovery
	11	33	224.50	257.50	6.5×10^{-9}	7.3×10^{-9}	—	7.3×10^{-9}	Slug Recovery
	12	48	254.50	302.50	—	3.5×10^{-9}	—	3.5×10^{-9}	Slug Recovery
	13	94	302.60	396.60	1.0×10^{-9}	5.9×10^{-10}	—	1.0×10^{-9}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-02 is 61°.

K = Interval Hydraulic Conductivity.

— = Test not performed.

Table 3: Packer Testing Results for Geotechnical Borehole GT-03

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-03	1	11	0.00	10.50	1.1×10^{-7}	—	—	1.1×10^{-7}	Slug Recovery
	2	12	5.50	17.50	3.1×10^{-7}	—	1.3×10^{-7}	1.3×10^{-7}	Constant Injection
	3	12	14.50	26.50	2.1×10^{-7}	—	1.5×10^{-7}	1.5×10^{-7}	Constant Injection
	4	12	23.50	35.50	2.4×10^{-7}	—	1.5×10^{-7}	1.5×10^{-7}	Constant Injection
	5	21	32.50	53.50	1.8×10^{-8}	—	—	1.8×10^{-8}	Slug Recovery
	6	18	50.50	68.50	4.1×10^{-8}	2.2×10^{-8}	—	4.1×10^{-8}	Slug Recovery
	7	21	65.50	86.50	1.7×10^{-7}	—	2.2×10^{-7}	2.2×10^{-7}	Constant Injection
	8	24	80.50	104.50	5.5×10^{-8}	—	—	5.5×10^{-8}	Slug Recovery
	9	33	101.50	134.50	7.0×10^{-8}	—	8.6×10^{-8}	8.6×10^{-8}	Constant Injection
	10	18	130.50	148.50	4.1×10^{-8}	1.2×10^{-8}	—	4.1×10^{-8}	Slug Recovery
	11	30	146.50	176.50	—	7.7×10^{-9}	1.3×10^{-8}	1.3×10^{-8}	Constant Injection
	12	21	173.50	194.50	5.0×10^{-7}	—	4.7×10^{-7}	4.7×10^{-7}	Constant Injection
	13	30	191.50	221.50	—	1.9×10^{-8}	—	1.9×10^{-8}	Slug Recovery
	14	33	218.50	251.50	—	2.4×10^{-9}	—	2.4×10^{-9}	Slug Recovery
	15	33	248.50	281.50	5.8×10^{-7}	—	4.0×10^{-7}	4.0×10^{-7}	Constant Injection
	16	18	278.50	296.50	1.1×10^{-6}	—	5.3×10^{-6}	5.3×10^{-6}	Constant Injection
	17	33	293.50	326.50	1.9×10^{-7}	—	1.2×10^{-7}	1.2×10^{-7}	Constant Injection
	18	34	322.50	356.50	4.8×10^{-9}	—	—	4.8×10^{-9}	Slug Recovery
	19	32	353.50	385.00	1.0×10^{-7}	—	—	1.0×10^{-7}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-03 is 67°

K = Interval Hydraulic Conductivity

— = Test not performed.

Table 4: Packer Testing Results for Geotechnical Borehole GT-04

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-04	1	9	2.14	11.50	8.4×10^{-6}	—	—	8.4×10^{-6}	Slug Recovery
	2	12	8.50	20.50	8.4×10^{-8}	—	1.3×10^{-7}	1.3×10^{-7}	Constant Injection
	3	12	17.50	29.50	1.2×10^{-8}	—	—	1.2×10^{-8}	Slug Recovery
	4	12	26.50	38.50	2.3×10^{-9}	—	2.9×10^{-8}	2.9×10^{-8}	Constant Injection
	5	18	35.50	53.50	—	4.0×10^{-9}	—	4.0×10^{-9}	Slug Recovery
	6	18	50.50	68.50	—	3.3×10^{-8}	—	3.3×10^{-8}	Slug Recovery
	7	18	65.50	83.50	—	1.2×10^{-8}	—	1.2×10^{-8}	Slug Recovery
	8	18	80.50	98.50	—	2.8×10^{-8}	—	2.8×10^{-8}	Slug Recovery
	9	33	95.50	128.50	—	1.4×10^{-9}	—	1.4×10^{-9}	Slug Recovery
	10	33	125.50	158.50	1.4×10^{-8}	2.2×10^{-8}	—	2.2×10^{-8}	Slug Recovery
	11	30	155.50	185.50	—	3.0×10^{-6}	3.1×10^{-6}	3.1×10^{-6}	Constant Injection
	12	33	182.50	215.50	—	6.0×10^{-7}	3.4×10^{-7}	3.4×10^{-7}	Constant Injection
	13	24	212.50	236.50	—	3.0×10^{-8}	—	3.0×10^{-8}	Slug Recovery
	14	32.00	233.50	265.50	—	7.4×10^{-9}	—	7.4×10^{-9}	Slug Recovery
	15	33	263.50	296.50	—	1.5×10^{-8}	—	1.5×10^{-8}	Slug Recovery
	16	30.00	293.50	323.50	—	2.7×10^{-8}	—	2.7×10^{-8}	Slug Recovery
	17	33	320.50	353.50	—	9.7×10^{-9}	—	9.7×10^{-9}	Slug Recovery
	18	21.00	350.50	371.50	—	3.2×10^{-8}	—	3.2×10^{-8}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-04 is 59.9°

K = Interval Hydraulic Conductivity

— = Test not performed.

Table 5: Packer Testing Results for Geotechnical Borehole GT-05

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-05	1	12	6.00	18.00	1.5×10^{-7}	1.8×10^{-8}	—	1.5×10^{-7}	Slug Recovery
	2	15.00	15.00	30.00	2.4×10^{-8}	3.6×10^{-8}	—	3.6×10^{-8}	Slug Recovery
	3	15	27.00	42.00	2.9×10^{-8}	2.0×10^{-8}	—	2.9×10^{-8}	Slug Recovery
	4	15.00	39.00	54.00	3.3×10^{-8}	3.8×10^{-8}	—	3.8×10^{-8}	Slug Recovery
	5	27	51.00	78.00	8.4×10^{-8}	—	7.1×10^{-8}	7.1×10^{-8}	Constant Injection
	6	25.30	75.00	100.30	3.1×10^{-8}	—	—	3.1×10^{-8}	Slug Recovery
	7	32	97.00	129.00	5.2×10^{-8}	—	—	5.2×10^{-8}	Slug Recovery
	8	15.00	126.00	141.00	—	—	1.5×10^{-5}	1.5×10^{-5}	Constant Injection
	9	33	138.00	171.00	5.1×10^{-7}	1.0×10^{-6}	3.9×10^{-7}	3.9×10^{-7}	Constant Injection
	10	36.00	165.00	201.00	4.8×10^{-8}	2.4×10^{-8}	—	4.8×10^{-8}	Slug Recovery
	11	33	198.00	231.00	—	1.9×10^{-8}	—	1.9×10^{-8}	Slug Recovery
	12	33.00	228.00	261.00	—	7.8×10^{-9}	—	7.8×10^{-9}	Slug Recovery
	13	33	258.00	291.00	—	4.3×10^{-7}	2.0×10^{-7}	2.0×10^{-7}	Constant Injection
	14	18.00	273.00	291.00	—	4.3×10^{-8}	—	4.3×10^{-8}	Slug Recovery
	15	33	288.00	321.00	—	2.0×10^{-8}	—	2.0×10^{-8}	Slug Recovery
	16	33.00	318.00	351.00	1.1×10^{-7}	4.9×10^{-8}	—	1.1×10^{-7}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-05 is 64.4°

K = Interval Hydraulic Conductivity

— = Test not performed.

Table 6: Packer Testing Results for Geotechnical Borehole GT-06

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
GT-06	1	9	5.60	14.60	7.9×10^{-8}	—	—	7.9×10^{-8}	Slug Recovery
	2	15.00	11.60	26.60	2.0×10^{-7}	—	—	2.0×10^{-7}	Slug Recovery
	3	18	23.60	41.60	1.4×10^{-7}	1.4×10^{-7}	—	1.4×10^{-7}	Slug Recovery
	4	17.00	38.60	55.60	—	8.0×10^{-9}	—	8.0×10^{-9}	Slug Recovery
	5	24	53.70	77.70	—	1.6×10^{-8}	—	1.6×10^{-8}	Slug Recovery
	6	27.00	74.70	101.70	1.5×10^{-7}	2.1×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	Constant Injection
	7	33	98.70	131.70	—	2.2×10^{-8}	—	2.2×10^{-8}	Slug Recovery
	8	33.00	128.70	161.70	—	1.6×10^{-6}	1.2×10^{-6}	1.2×10^{-6}	Constant Injection
	9	27	158.70	185.70	—	3.3×10^{-6}	2.1×10^{-6}	2.1×10^{-6}	Constant Injection
	11	27.00	185.70	212.70	—	4.7×10^{-7}	4.0×10^{-7}	4.0×10^{-7}	Constant Injection
	12	24	209.70	233.70	—	3.3×10^{-8}	—	3.3×10^{-8}	Slug Recovery
	13	21.00	230.70	251.70	—	1.8×10^{-8}	—	1.8×10^{-8}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for GT-06 is 61°

K = Interval Hydraulic Conductivity

— = Test not performed.

Table 7: Packer Testing Results for Geotechnical Borehole BR-0366

Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
BR-0366	1	30	269.40	299.40	2.3×10^{-8}	—	—	2.3×10^{-8}	Slug Recovery
	2	22	251.00	272.50	3.3×10^{-8}	1.7×10^{-8}	—	3.3×10^{-8}	Slug Recovery
	3	21	233.00	253.50	3.6×10^{-8}	2.2×10^{-8}	—	3.6×10^{-8}	Slug Recovery
	4	21	215.00	235.50	1.6×10^{-7}	4.2×10^{-8}	—	1.6×10^{-7}	Slug Recovery
	5	21	197.00	217.50	1.8×10^{-7}	1.7×10^{-7}	—	1.8×10^{-7}	Slug Recovery
	6	21	179.00	199.50	1.8×10^{-8}	—	—	1.8×10^{-8}	Slug Recovery
	7	21	5.00	25.50	1.5×10^{-8}	—	—	1.5×10^{-8}	Slug Recovery
	8	21	17.00	37.50	8.2×10^{-7}	—	5.6×10^{-7}	5.6×10^{-7}	Constant Injection
	9	21	17.00	37.50	2.9×10^{-9}	—	—	2.9×10^{-9}	Slug Recovery
	10	21	35.00	55.50	1.7×10^{-7}	—	—	1.7×10^{-7}	Slug Recovery
	11	21	53.00	73.50	1.8×10^{-8}	—	—	1.8×10^{-8}	Slug Recovery
	12	21	71.00	91.50	7.2E-10	—	—	7.2E-10	Slug Recovery
	13	21	89.00	109.50	1.4×10^{-8}	—	—	1.4×10^{-8}	Slug Recovery
	14	21	107.00	127.50	3.4×10^{-7}	7.2×10^{-7}	2.5×10^{-7}	2.5×10^{-7}	Constant Injection
	15	21	125.00	145.50	7.3×10^{-8}	3.7×10^{-8}	—	7.3×10^{-8}	Slug Recovery
	16	21	143.00	163.50	3.7×10^{-8}	3.8×10^{-8}	—	3.8×10^{-8}	Slug Recovery
	17	21	161.00	181.50	2.5×10^{-8}	1.1×10^{-8}	—	2.5×10^{-8}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for BR-0366 is 64.3°

K = Interval Hydraulic Conductivity

— = Test not performed.

Table 8: Packer Testing Results for Geotechnical Borehole BR-0371

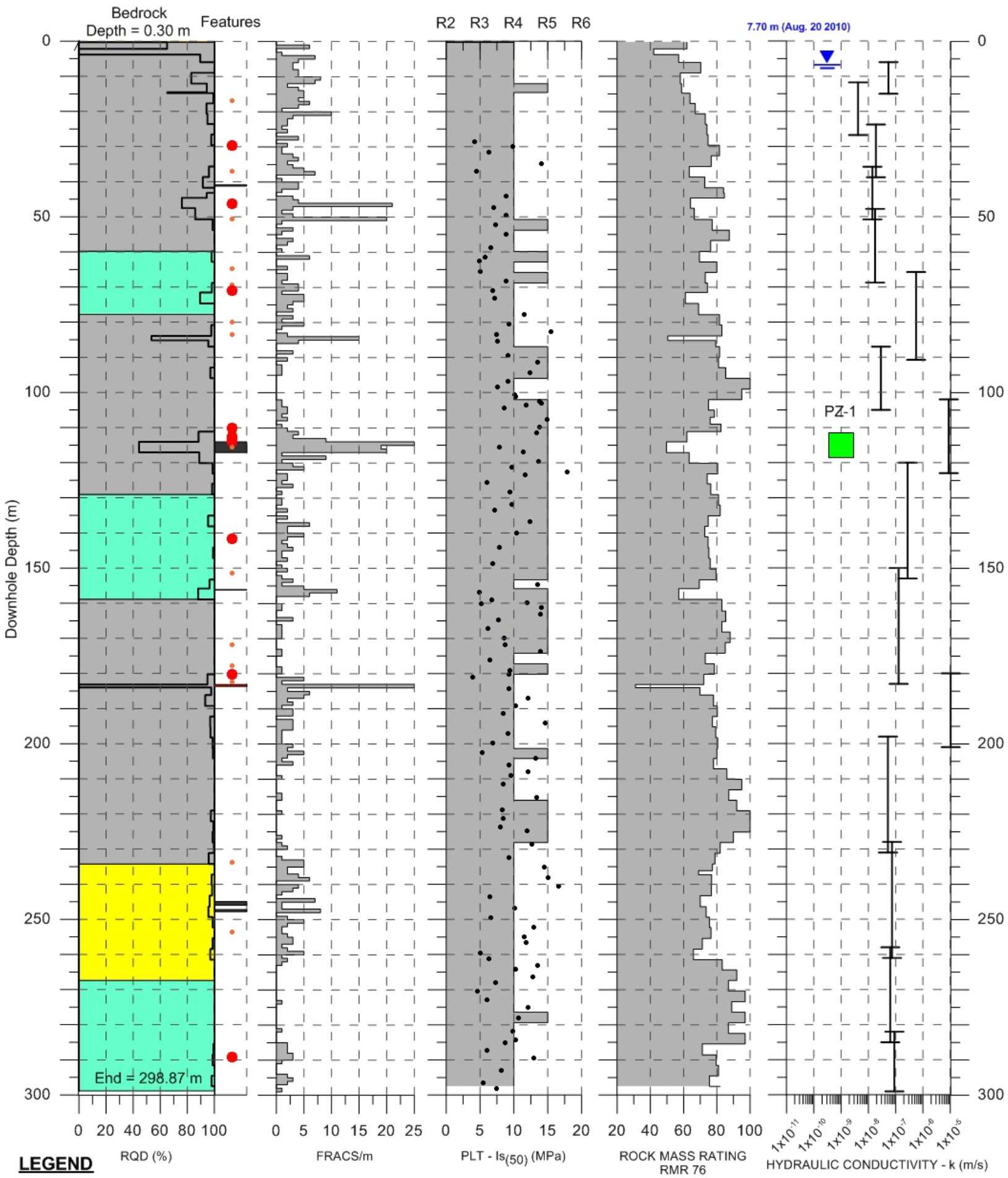
Borehole ID	Interval #	Testing Interval Information			Hydraulic Conductivity (m/s)			Hydraulic Conductivity Analysis	
		Interval (m)	Top (m)	Bottom (m)	Falling Head	Rising Head	Constant Injection	K (m/s)	Test Phase used for Analysis
BR-0371	1	33	307.00	340.00	2.5×10^{-9}	5.1×10^{-9}	—	5.1×10^{-9}	Slug Recovery
	2	31	350.00	381.00	2.4×10^{-8}	5.0×10^{-9}	—	2.4×10^{-8}	Slug Recovery
	3	22	290.00	312.00	—	1.8×10^{-7}	—	1.8×10^{-7}	Slug Recovery
	4	22	272.00	294.00	2.0×10^{-7}	1.1×10^{-7}	—	2.0×10^{-7}	Slug Recovery
	5	22	254.00	276.00	1.0×10^{-8}	6.8×10^{-9}	—	1.0×10^{-8}	Slug Recovery
	6	22	236.00	258.00	1.2×10^{-6}	1.9×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	Constant Injection
	7	22	218.00	240.00	8.6×10^{-7}	8.5×10^{-7}	5.8×10^{-7}	5.8×10^{-7}	Constant Injection
	8	22	200.00	222.00	1.0×10^{-8}	6.8×10^{-9}	—	1.0×10^{-8}	Slug Recovery
	9	22	182.00	204.00	6.8×10^{-9}	3.0×10^{-9}	—	6.8×10^{-9}	Slug Recovery
	10	22	164.00	186.00	6.6×10^{-9}	3.4×10^{-9}	—	6.6×10^{-9}	Slug Recovery
	11	22	146.00	168.00	3.4×10^{-9}	3.4×10^{-9}	—	3.4×10^{-9}	Slug Recovery
	12	22	128.00	150.00	6.7×10^{-9}	3.4×10^{-9}	—	6.7×10^{-9}	Slug Recovery
	13	22	110.00	132.00	1.4×10^{-8}	1.0×10^{-8}	—	1.4×10^{-8}	Slug Recovery
	14	22	92.00	114.00	6.7×10^{-9}	2.0×10^{-9}	—	6.7×10^{-9}	Slug Recovery
	15	22	74.00	96.00	1.5×10^{-7}	9.6×10^{-8}	—	1.5×10^{-7}	Slug Recovery
	16	22	56.00	78.00	3.0×10^{-9}	2.7×10^{-9}	—	3.0×10^{-9}	Slug Recovery
	17	22	38.00	60.00	1.3×10^{-7}	8.0×10^{-8}	—	1.3×10^{-7}	Slug Recovery
	18	18	22.00	40.00	3.0×10^{-7}	—	1.8×10^{-7}	1.8×10^{-7}	Constant Injection
	19	17.5	7.00	24.50	1.7×10^{-7}	—	—	1.7×10^{-7}	Slug Recovery

Notes: Testing interval depths are shown as metres along dip of borehole [mAH]. Dip angle for BR-0371 is 71.2°

K = Interval Hydraulic Conductivity

— = Test not performed.

Northing (m, NAD83):	5421510.8	Azimuth:	186.5°
Easting (m, NAD83):	612773.9	Inclination:	-65.4°
Elevation (m.a.s.l.):	444.2		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- MINOR OPEN JOINT (ATV)
- MAJOR OPEN JOINT (ATV)
- POINT LOAD TEST
- BROKEN CORE
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

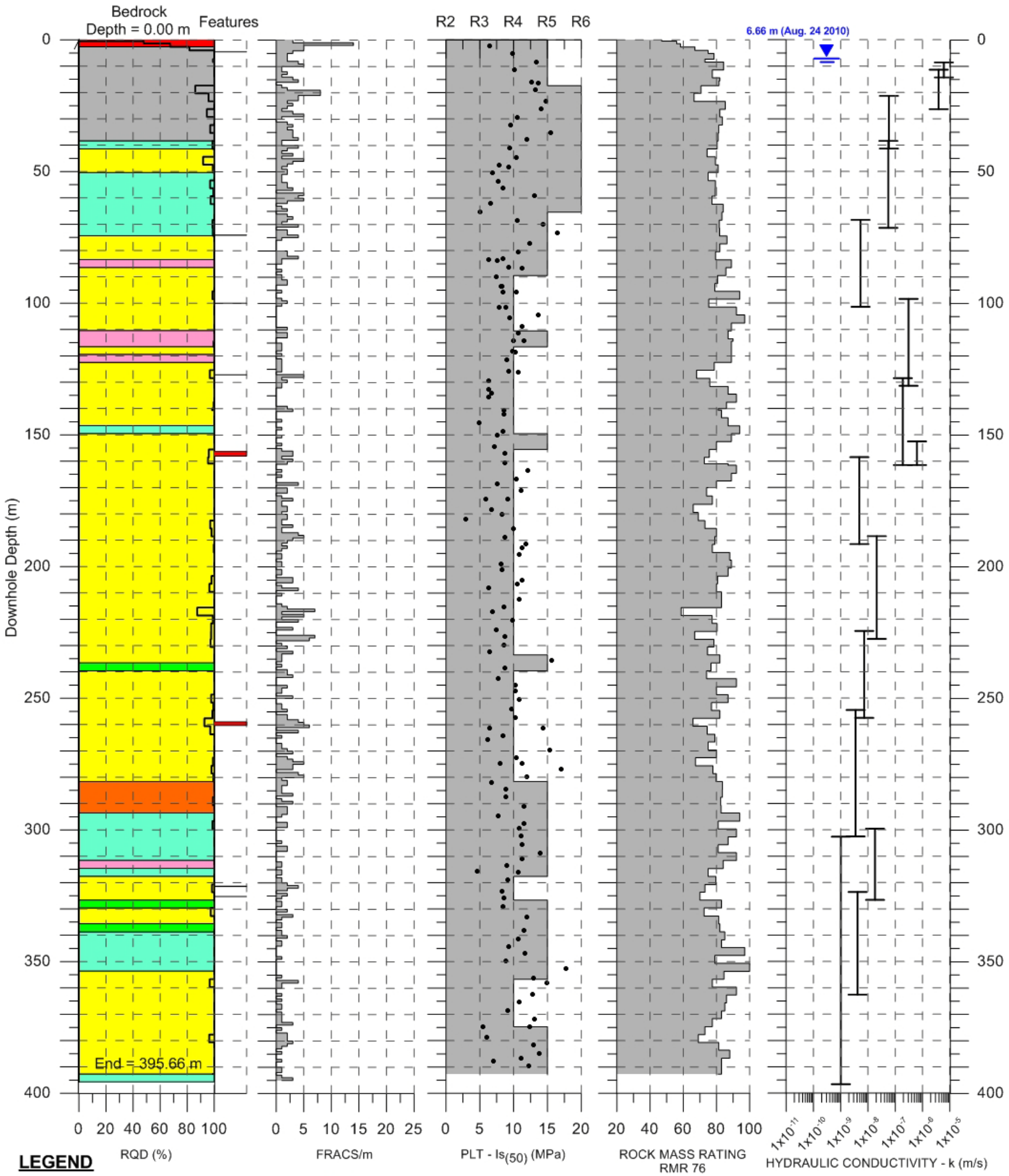
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT01 / BR344

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B1**

Northing (m, NAD83):	5421171.3	Azimuth:	178.8°
Easting (m, NAD83):	612238.8	Inclination:	61.0°
Elevation (m.a.s.l.):	438.1		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- BROKEN CORE
- POINT LOAD TEST
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

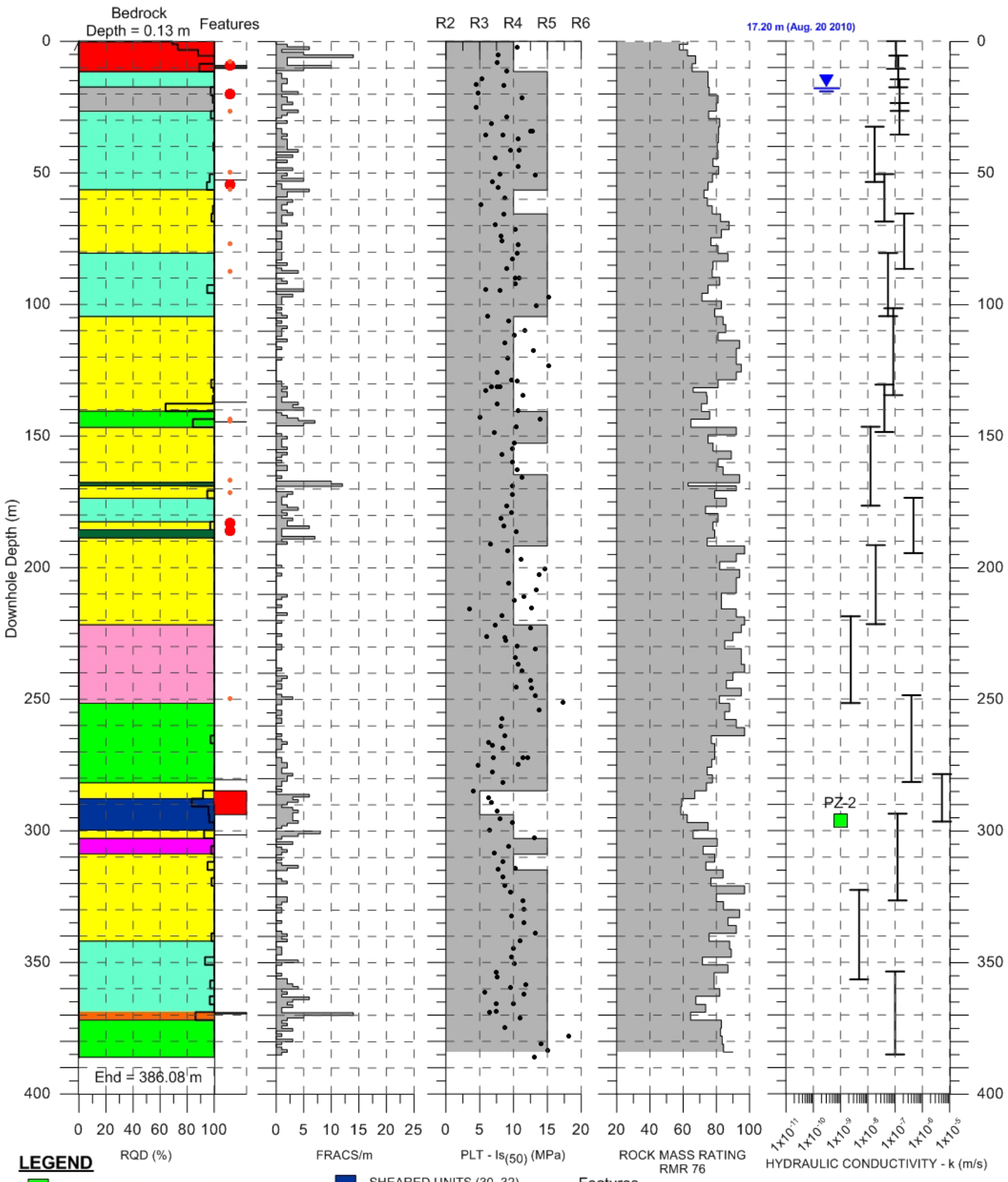
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT02 / BR297

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B2**

Northing (m, NAD83):	5421066.1	Azimuth:	264.3°
Easting (m, NAD83):	612026.1	Inclination:	67.0°
Elevation (m.a.s.l.):	452.1		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- MINOR OPEN JOINT (ATV)
- MAJOR OPEN JOINT (ATV)
- POINT LOAD TEST
- BROKEN CORE
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

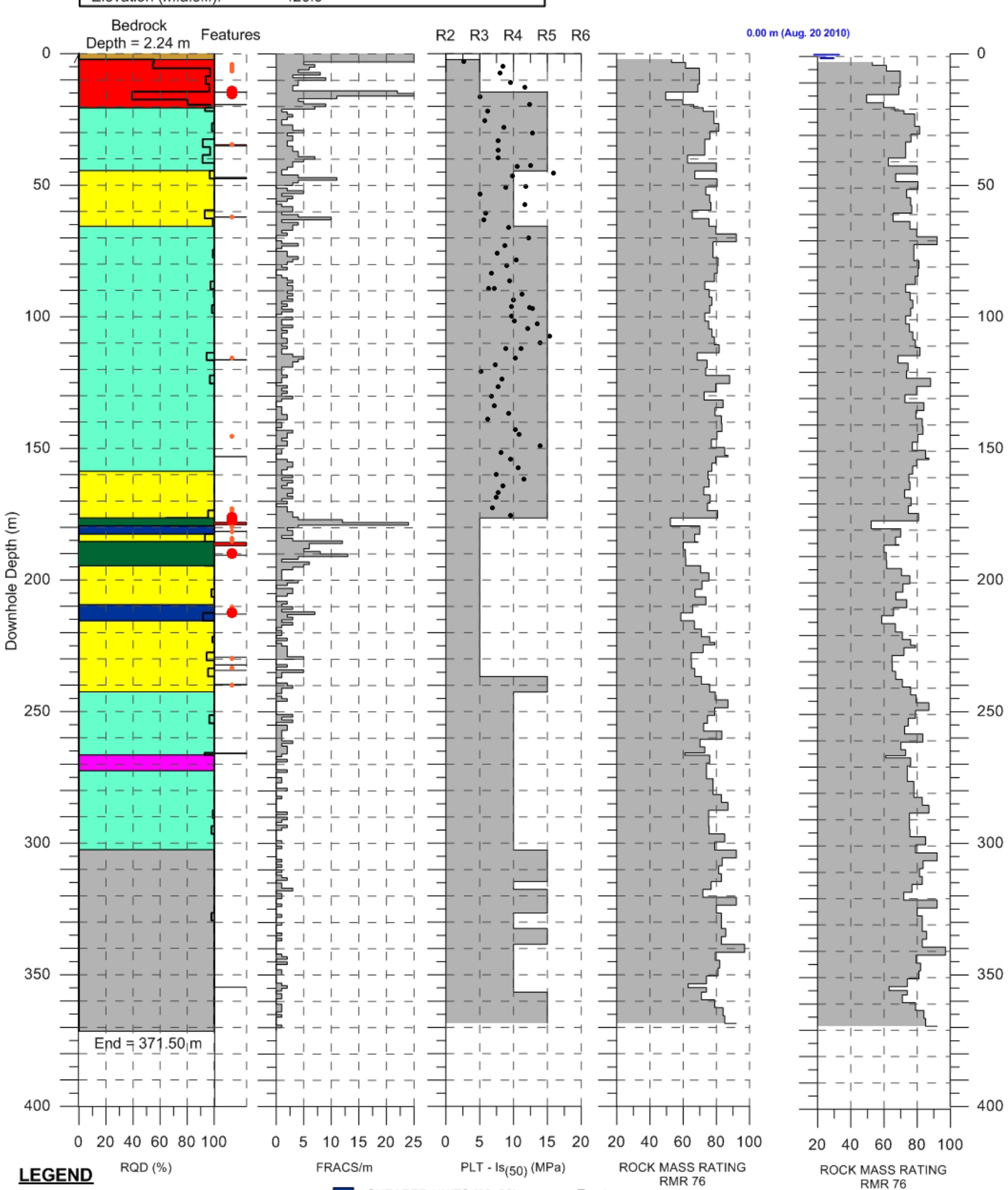
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT03 / BR318

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B3**

Northing (m, NAD83):	5421056.9	Azimuth:	66.5°
Easting (m, NAD83):	611678.5	Inclination:	-59.9°
Elevation (m.a.s.l.):	420.9		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- MINOR OPEN JOINT (ATV)
- MAJOR OPEN JOINT (ATV)
- POINT LOAD TEST
- BROKEN CORE
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

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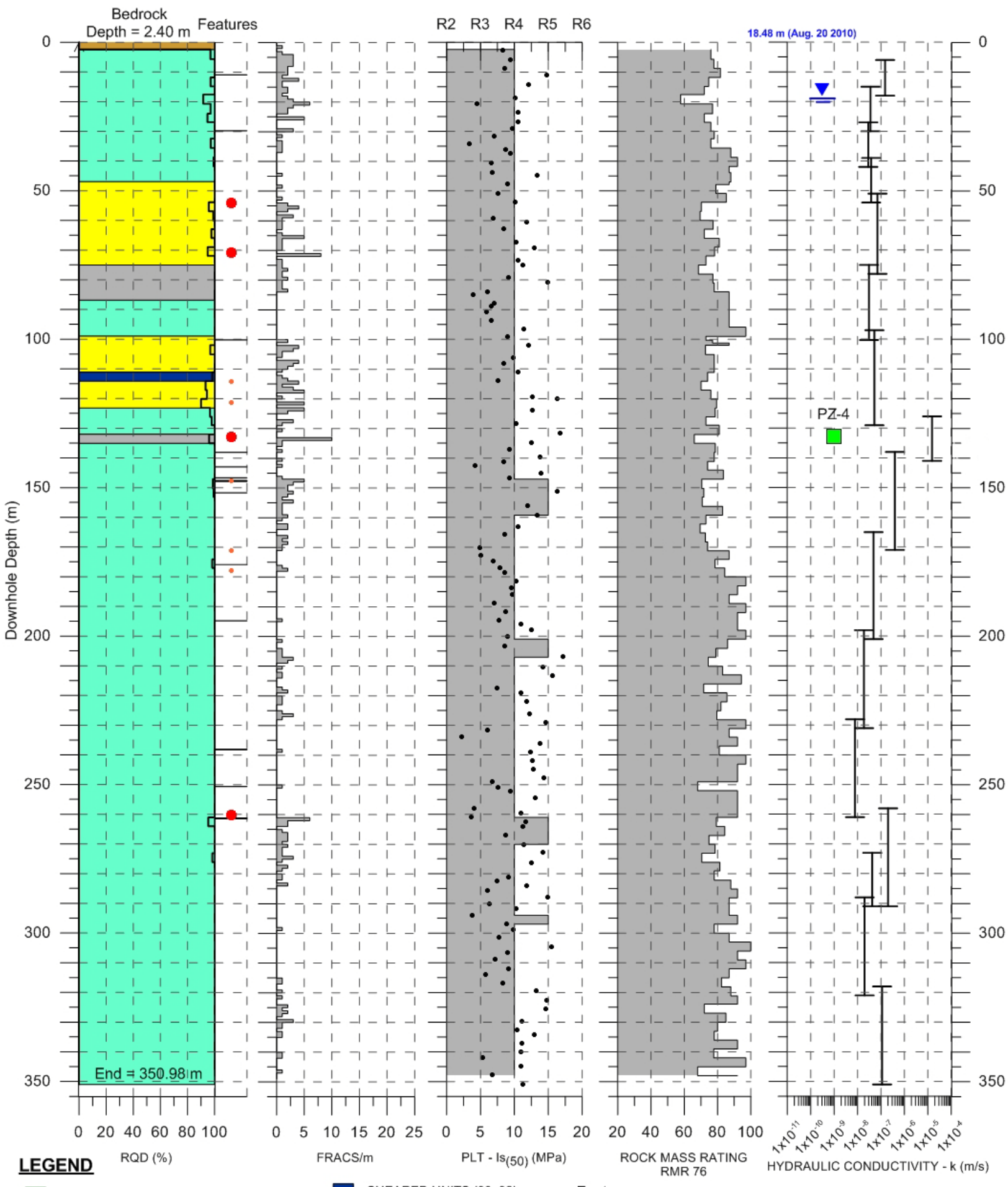
OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT04 / BR331

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B4**

Northing (m, NAD83):	5421697.4	Azimuth:	182.6°
Easting (m, NAD83):	612221.7	Inclination:	-64.4°
Elevation (m.a.s.l.):	456.0		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- MINOR OPEN JOINT (ATV)
- MAJOR OPEN JOINT (ATV)
- POINT LOAD TEST
- BROKEN CORE
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

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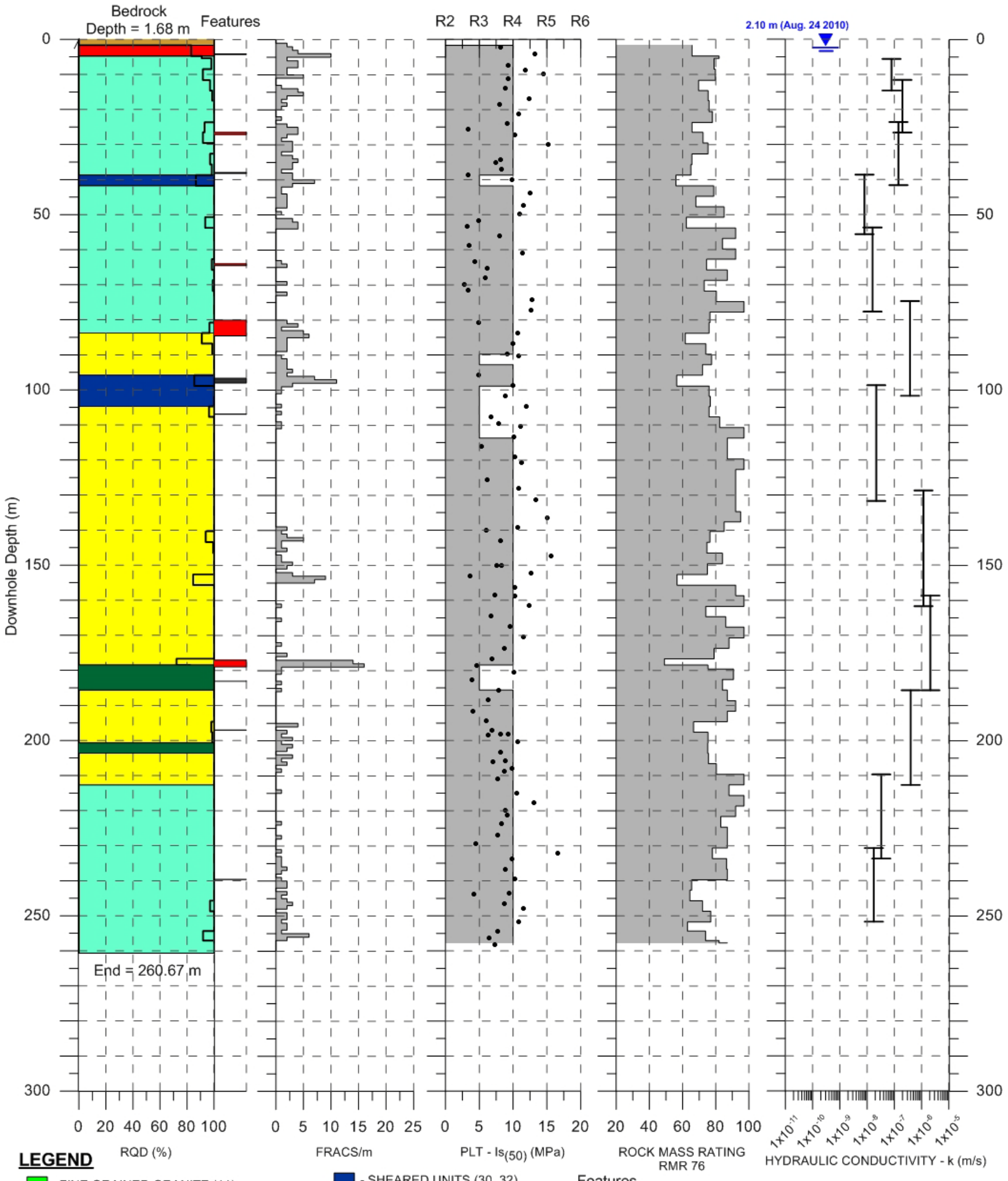
OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT05 / BR358

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B5**

Northing (m, NAD83):	5421962.8	Azimuth:	112.4°
Easting (m, NAD83):	613513.5	Inclination:	-61.0°
Elevation (m.a.s.l.):	434.0		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- BROKEN CORE
- POINT LOAD TEST
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

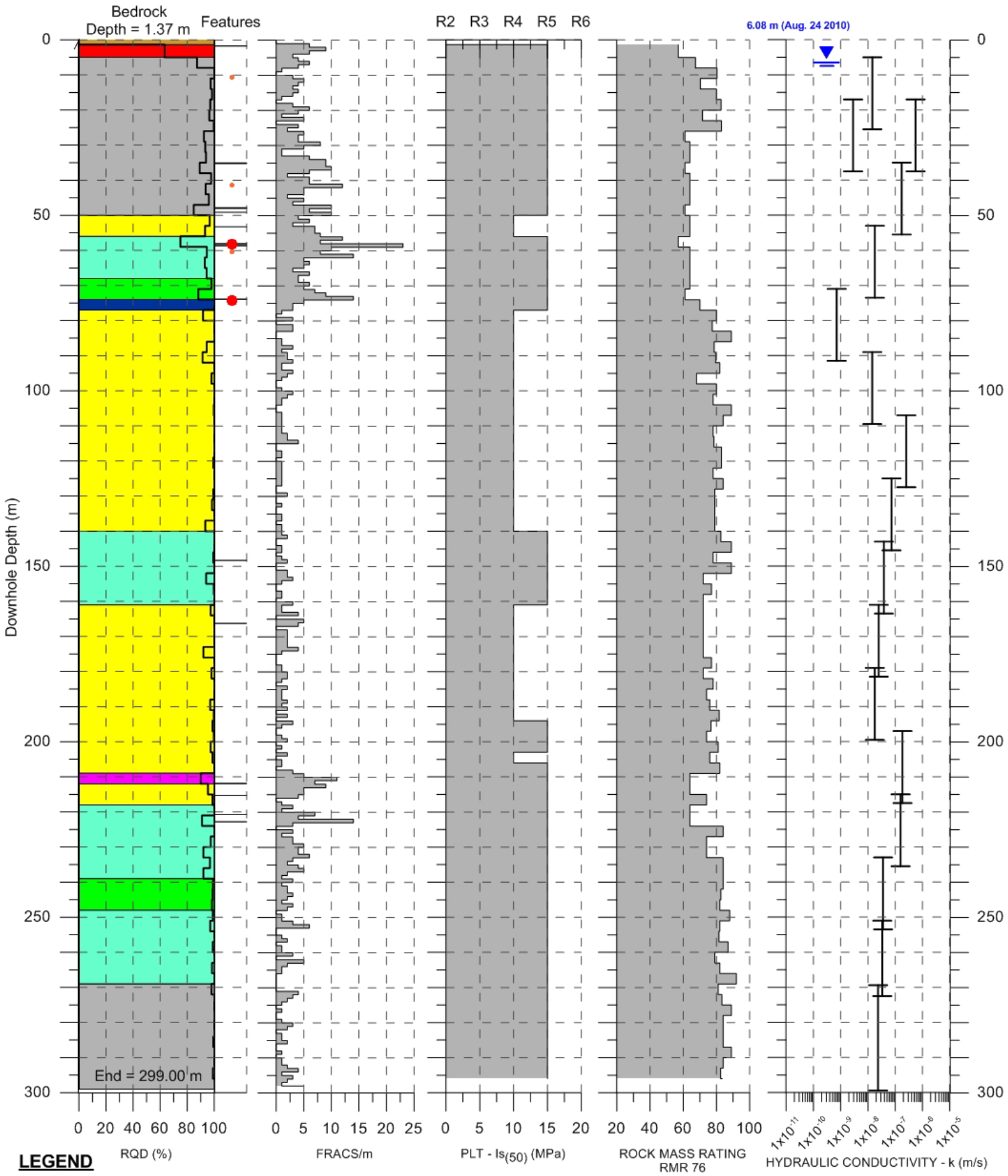
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
GT06 / BR370

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B6**

Northing (m, NAD83):	5421720.4	Azimuth:	323.3°
Easting (m, NAD83):	612941.3	Inclination:	-64.3°
Elevation (m.a.s.l.):	441.3		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- MINOR OPEN JOINT (ATV)
- MAJOR OPEN JOINT (ATV)
- POINT LOAD TEST
- BROKEN CORE
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

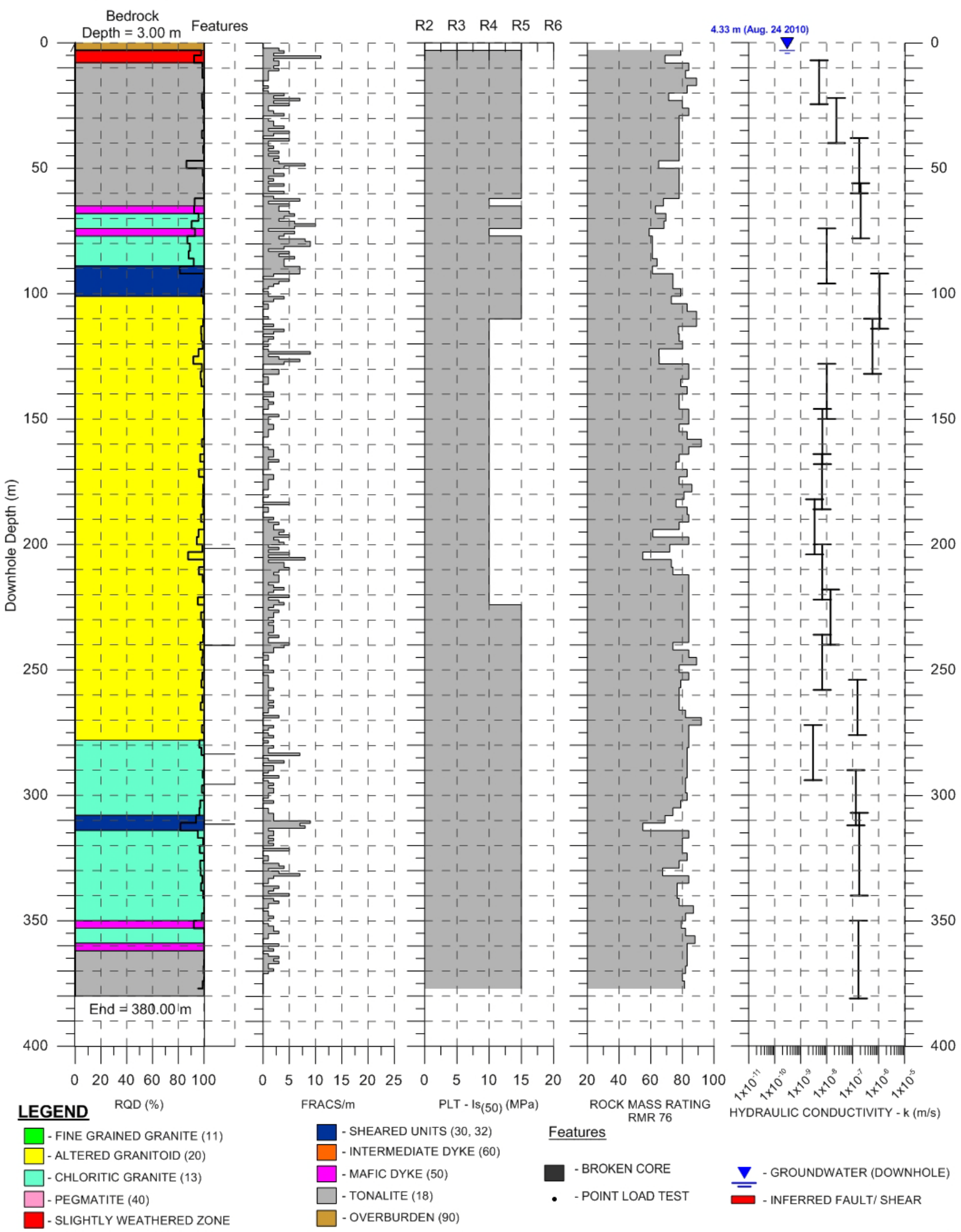
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
BR366

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B7**

Northing (m, NAD83):	5421308.7	Azimuth:	332.5°
Easting (m, NAD83):	612387.9	Inclination:	-71.2°
Elevation (m.a.s.l.):	436.3		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- BROKEN CORE
- POINT LOAD TEST
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

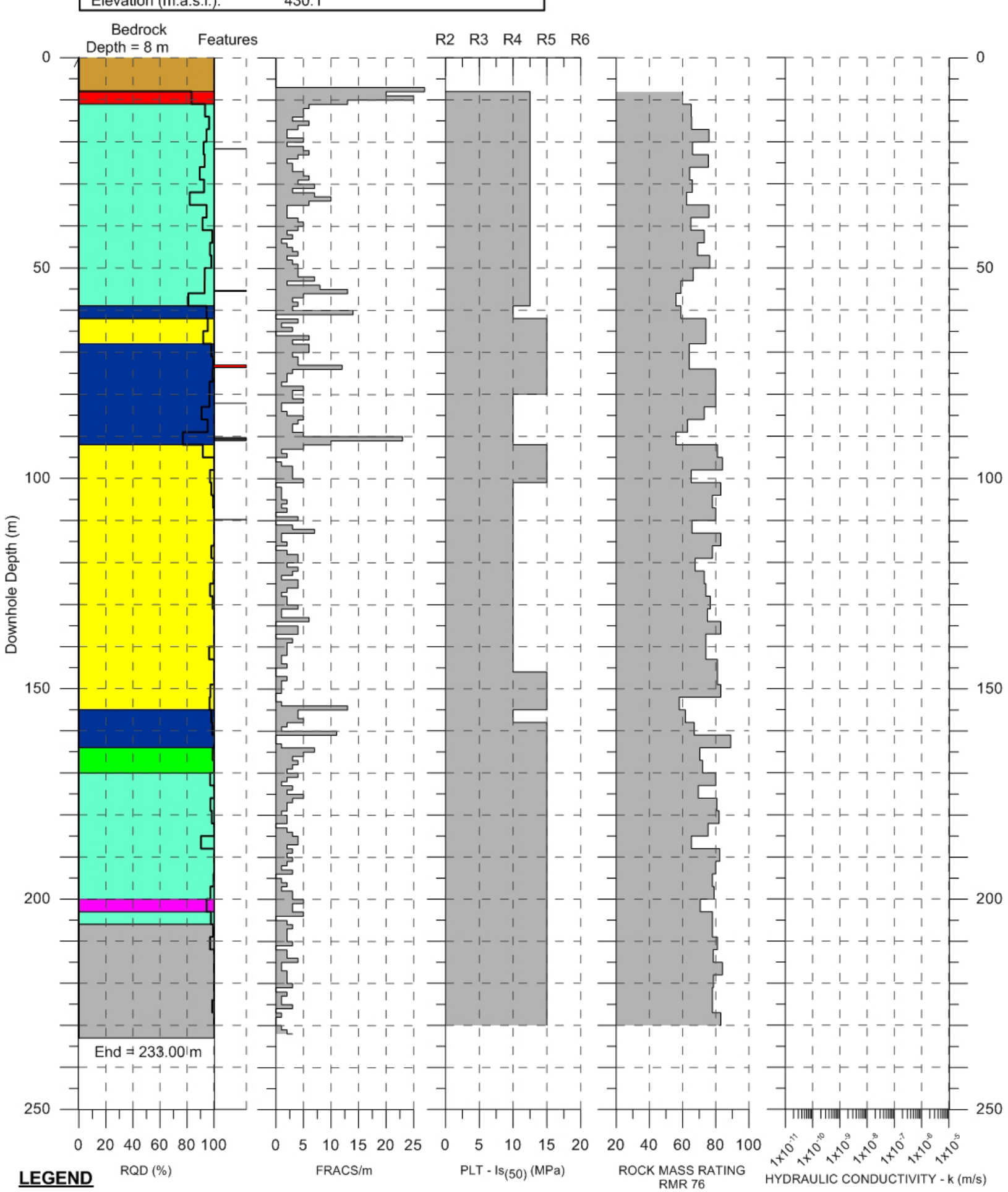
Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
BR371

Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B8**

Northing (m, NAD83):	5421989.6	Azimuth:	325.5°
Easting (m, NAD83):	613405.4	Inclination:	-59.7°
Elevation (m.a.s.l.):	430.1		



LEGEND

- FINE GRAINED GRANITE (11)
- ALTERED GRANITOID (20)
- CHLORITIC GRANITE (13)
- PEGMATITE (40)
- SLIGHTLY WEATHERED ZONE
- QUARTZ VEIN ZONE (45)
- SHEARED UNITS (30, 32)
- INTERMEDIATE DYKE (60)
- MAFIC DYKE (50)
- TONALITE (18)
- OVERBURDEN (90)

Features

- BROKEN CORE
- POINT LOAD TEST
- GROUNDWATER (DOWNHOLE)
- INFERRED FAULT/ SHEAR

Golder Associates

OSISKO HAMMOND REEF PROJECT

HISTOGRAM SUMMARY PLOT
BR375

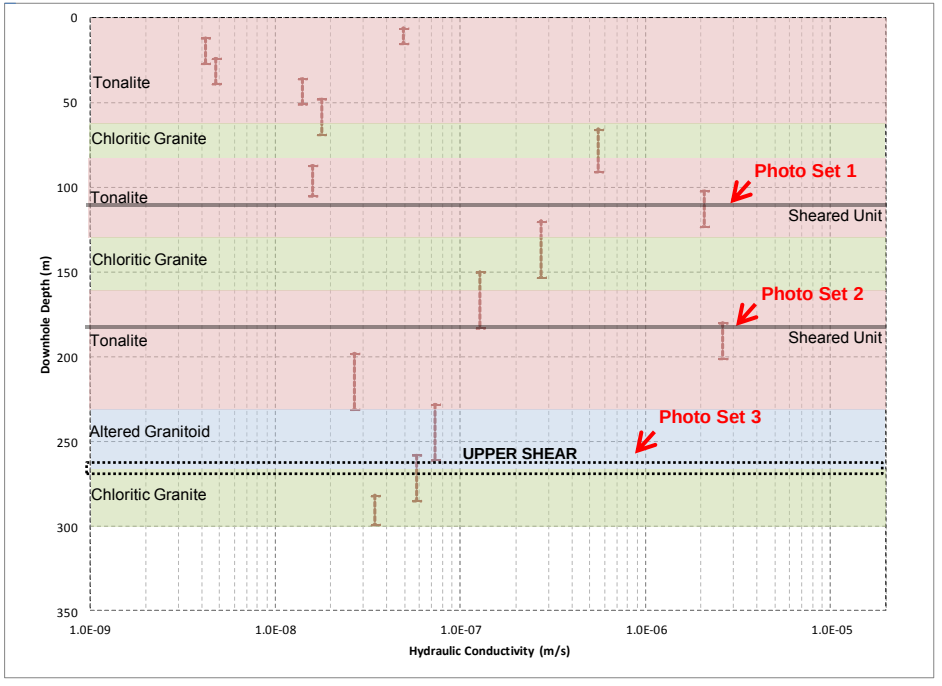
Project No. 10-1118-0020	Date: Nov-10	Drawn: MS	Rev: LC	**FIGURE B9**

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 16552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT01 / BR344

FIGURE C1

a) GT01 Hydraulic Conductivity (K) Results



b) Selected Core Photographs

Photo Set 1 – 108.30 to 116.79 m

Photo Set 2 – 174.52 to 185.67 m

Photo Set 3 – 285.15 to 296.50 m

c) Notes

1. High K values related to fracturing and open joints.
2. High K values related to shear at 183 to 184 m.
3. Low hydraulic conductivity around zone where Upper Shear is expected to intersect.

DATE: November 2010

PROJECT: 10-1118-0020

Golder Associates

DOC: JS

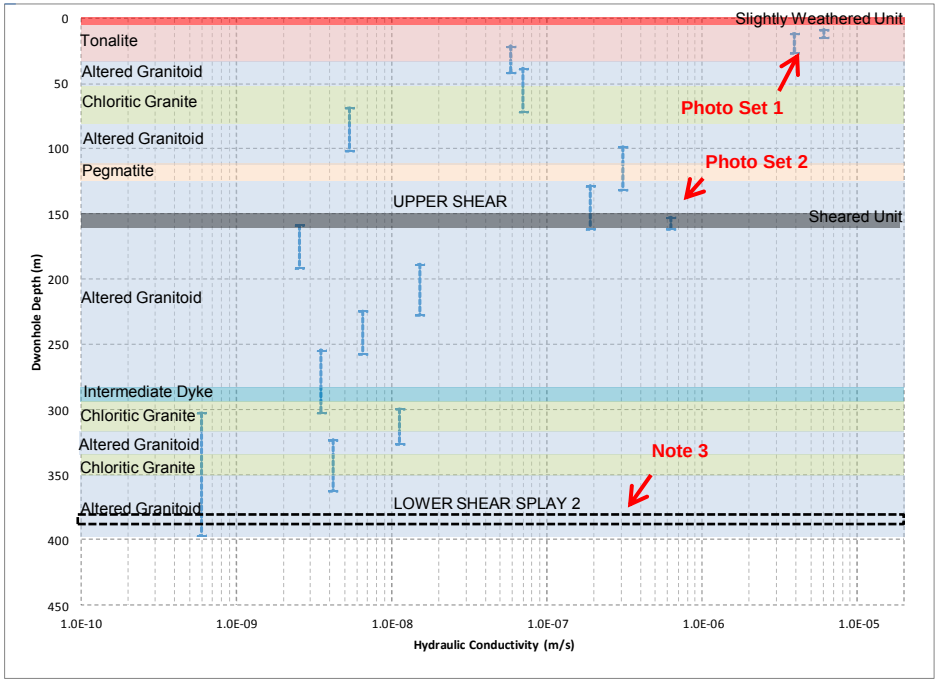
CHK: AN APD: LC

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 16552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT02 / BR297

FIGURE C2

a) GT02 Hydraulic Conductivity (K) Results



b) Selected Core Photographs

Photo Set 1 – 0.00 to 11.00 m

Photo Set 2 – 147.17 to 154.50 m

Photo Set 2 – 154.50 to 169.80 m

c) Notes

1. High K values at shallow depths near weathered zone related to fracturing and open joints.
2. Moderate to high K values at Upper Shear (150 to 161 m), relating to fracturing and several open joints with high oxidation and gouge.
3. Low hydraulic conductivity around zone where Lower Shear Splay 2 is expected to intersect. (Shear Splay is not clearly observed in core photos)

DATE: November 2010

PROJECT: 10-1118-0020

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DOC: JS

CHK: AN APD: LC

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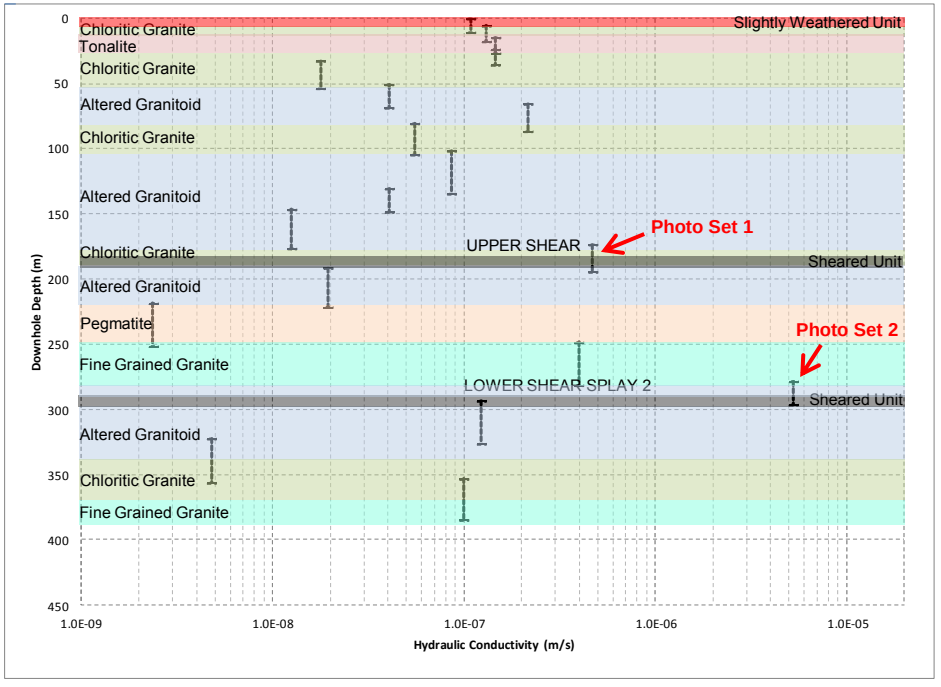
January 2013 – 10552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT03 / BR318

FIGURE C3

a) GT03 Hydraulic Conductivity (K) Results



b) Selected Core Photographs

Photo Set 1 – 182.50 to 194.10 m

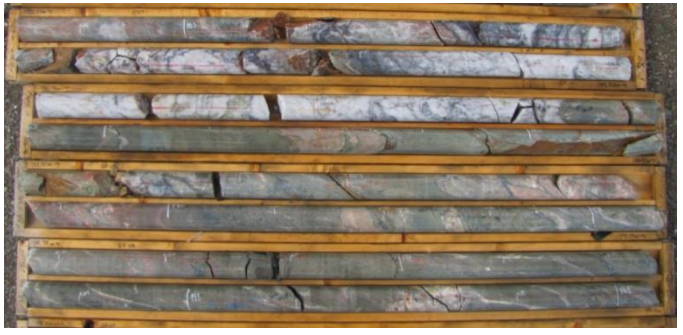


Photo Set 1 – 277.51 to 288.60 m

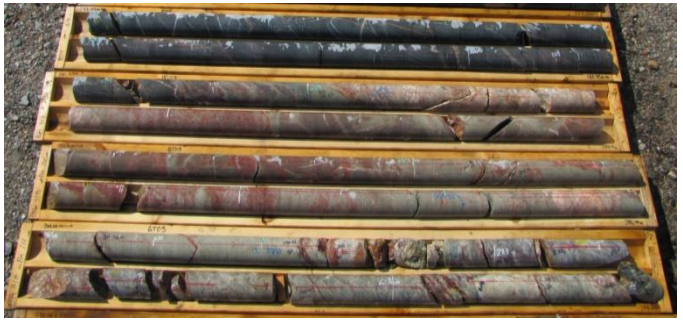


Photo Set 2 – 288.60 to 299.50 m

c) Notes

1. Moderate to high K values at Upper Shear (182 to189 m), relating to fracturing and several open joints with high oxidation.
2. High K values at Lower Shear Splay 2 (281 to 295 m), relating to high fracturing and several open joints with high oxidation and gouge.

DATE: November 2010

PROJECT: 10-1118-0020

Golder Associates

DOC: JS

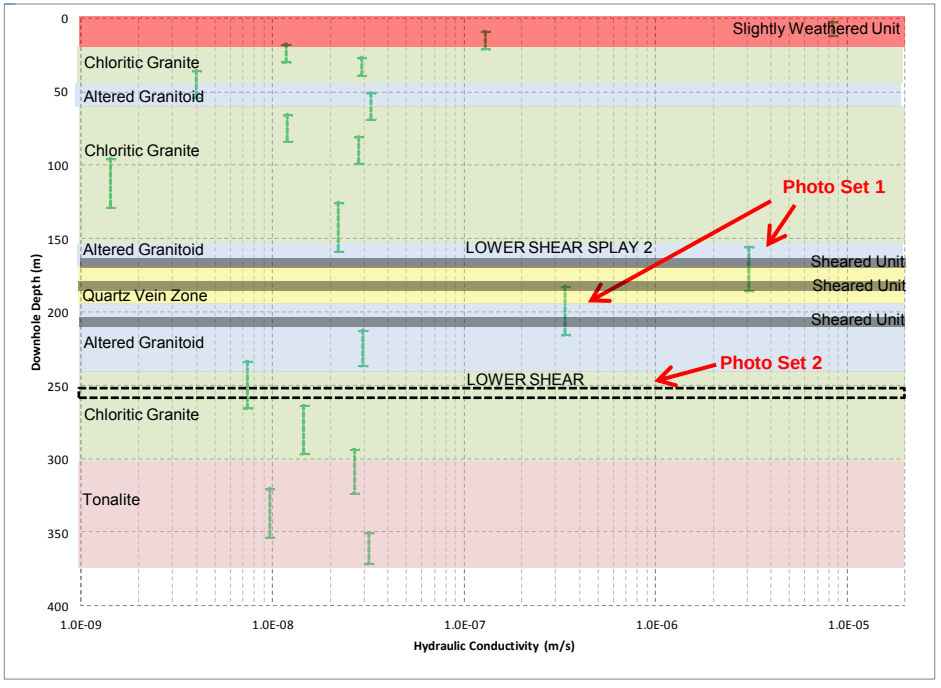
CHK: AN APD: LC

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2013 – 10552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT04 / BR331

FIGURE C4

a) GT04 Hydraulic Conductivity Results



b) Selected Core Photographs

Photo Set 1 – 170.50 to 180.80 m

Photo Set 1 – 180.80 to 191.97 m

Photo Set 2 – 242.55 to 253.75 m

c) Notes

1. Moderate to high K values at Lower Shear Splay 2 (177 to 178 m), relating sheared rock with sand layer. Heat pulse testing also indicate upwards flow through this structure.
2. Low hydraulic conductivity and low fracturing around zone where Lower Shear is expected to intersect.

DATE: November 2010

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DOC: JS

CHK: AN APD: LC

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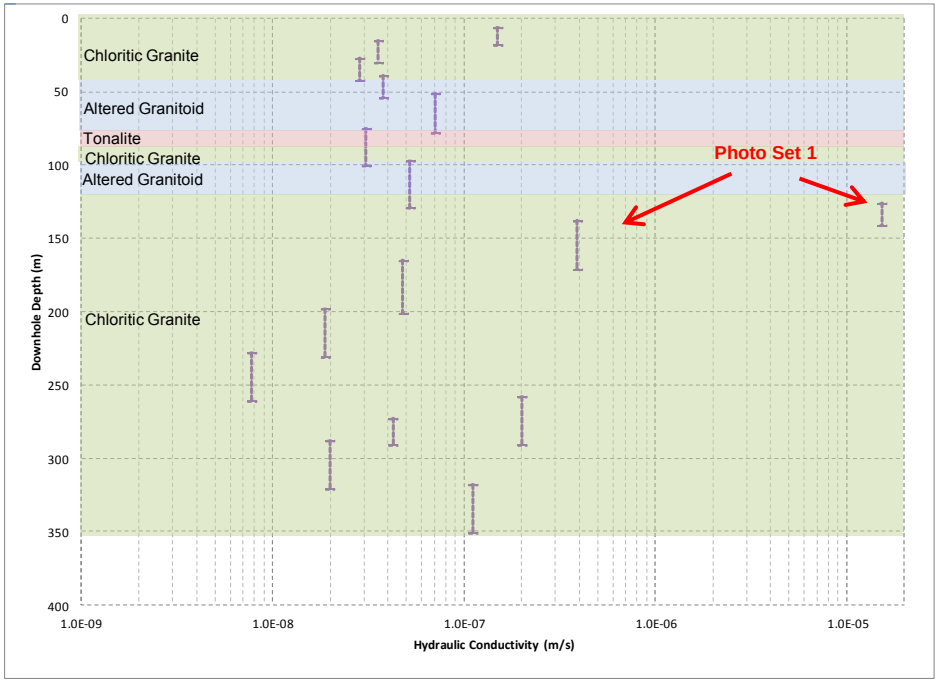
January 2013 – 10552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT05 / BR358

FIGURE C5

a) GT05 Hydraulic Conductivity Results

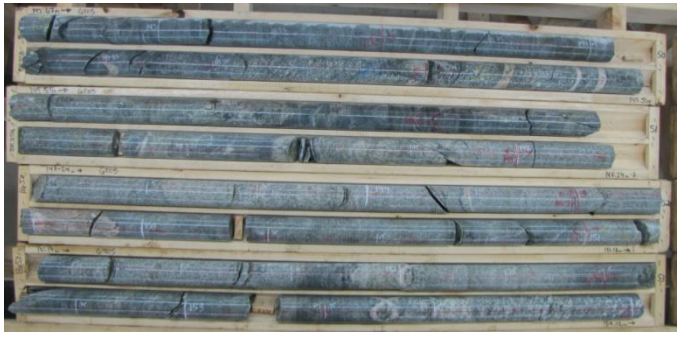


b) Selected Core Photographs

Photo Set 1 – 119.54 to 131.08 m

Photo Set 1 - 131.08 to 142.67 m

Photo Set 1 – 142.67 to 154.02 m



c) Notes

1. High K values due to open clay infilled joints from 133.55 to 133.67 m and nearby fracturing

DATE: November 2010

PROJECT: 10-1118-0020

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CHK: AN APD: LC

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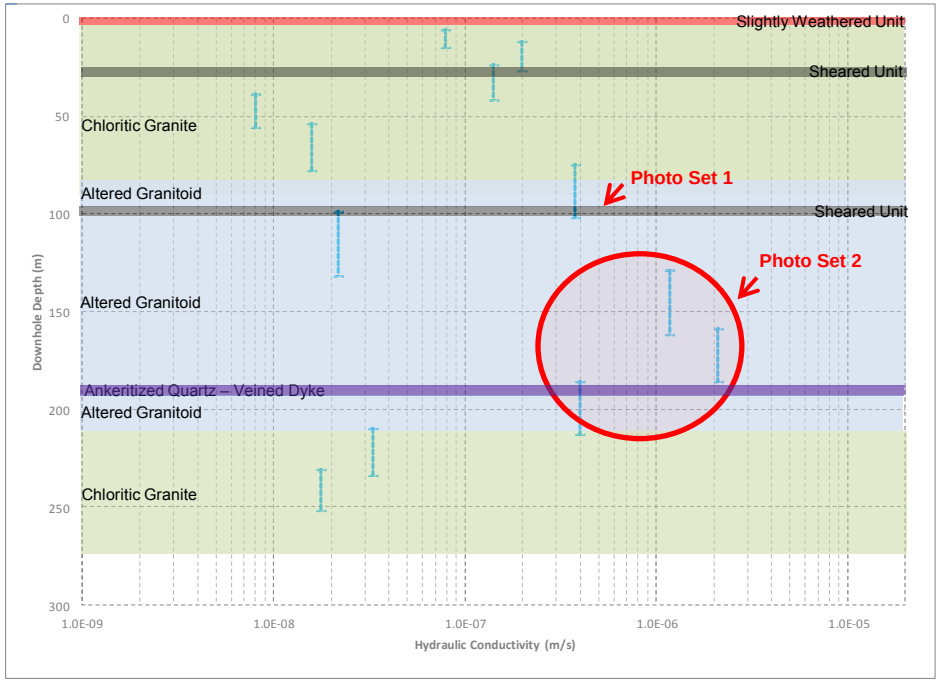
January 2013 – 10552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – GT06 / BR370

FIGURE C6

a) GT06 Hydraulic Conductivity Results



b) Selected Core Photographs

Photo Set 1 – 93.09 to 104.48 m

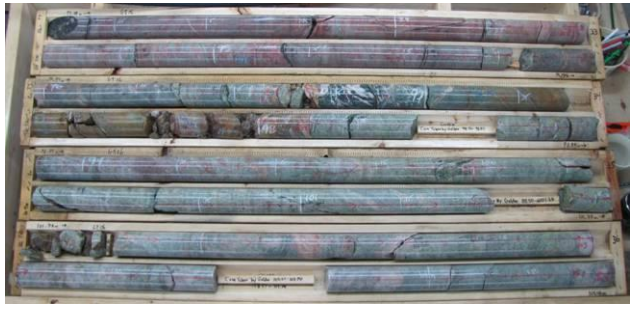


Photo Set 2 - 162.33 to 173.95 m

Photo Set 2 – 173.95 to 185.48 m

c) Notes

1. Moderate to high K values related to shear zone (177 to 183 m), relating to high fracturing and several open joints with clay and hematite gouge material.
2. Moderate to high K values related to some open joints and a small shear zone at 178 m.

DATE: November 2010

PROJECT: 10-1118-0020

Golder Associates

DOC: JS

CHK: AN APD: LC

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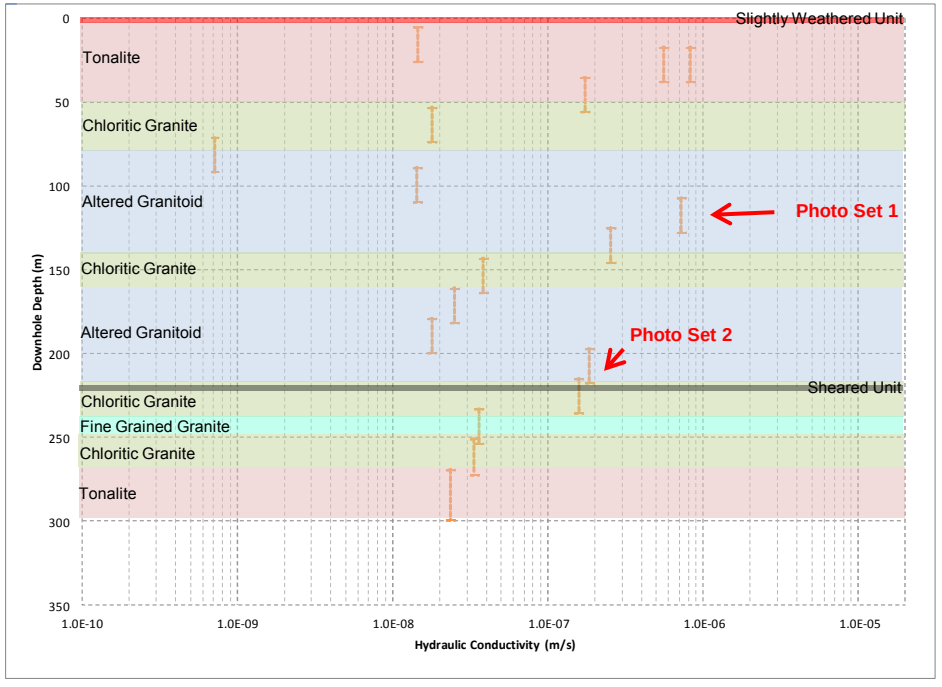
January 2018 – 16552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – BR366

FIGURE C7

a) BR366 Hydraulic Conductivity Results



b) Selected Core Photographs

Photo Set 1 – 118.63 to 135.73 m

Photo Set 2 – 204.70 to 221.08 m

c) Notes

1. Moderate to high K values is likely due to an open fracture within the interval.
2. Moderate to high K is related to sheared rock / high fracturing at 215 m; Joint surfaces appeared to be mostly clean.

DATE: November 2010

PROJECT: 10-1118-0020

Golder Associates

DOC: JS

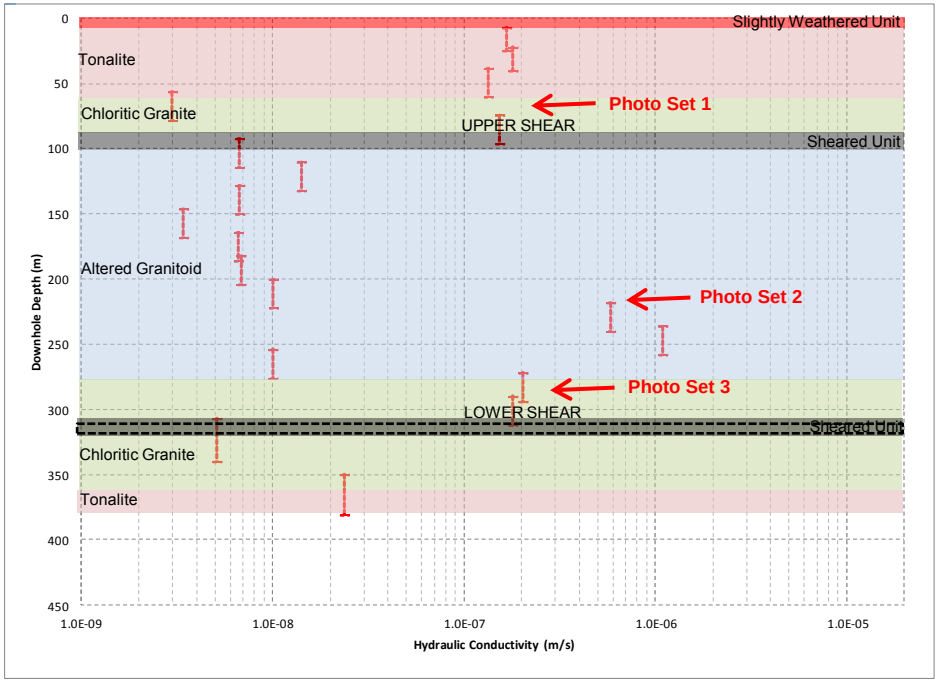
CHK: AN APD: LC

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2013 – 13552253

OSISKO Hammond Reef Project
HYDROGEOLOGY TESTING
PACKER TEST RESULTS – BR371

FIGURE C8

a) BR371 Hydraulic Conductivity Results

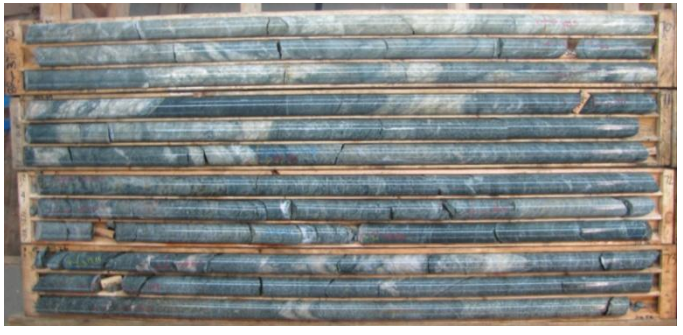


b) Selected Core Photographs

Photo Set 1 – 76.00 to 92.00 m

Photo Set 2 – 230.49 to 247.70 m

Photo Set 3 – 299.34 to 316.58 m



c) Notes

1. Moderate K values related to Upper Shear (72 to 90 m) showing high fracturing and open joints with high oxidation and some clay gouge.
2. Moderate to high K values related to open joints at 240 m.
3. Moderate to high K values is likely related to high fracturing around 283 m. Although there was no clear shear zone, the high conductivity zone is around the zone where Lower Shear is expected to intersect the borehole.

DATE: November 2010

PROJECT: 10-1118-0020

Golder Associates

DOC: JS

CHK: AN APD: LC

HYDROGEOLOGY TSD
VERSION 1

APPENDIX 2.II

Existing Hydrogeological Conditions Investigation at Accommodation Camp

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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ATTACHMENTS

Attachment 2.II.1
Record of Borehole and Record of Drillhole Logs for 2012 Drilling Program

Attachment 2.II.2
Grain Size Distribution Plots

1.0 INTRODUCTION

In July 2012, Osisko Hammond Reef Gold Ltd. (OHRG) notified Golder Associates Ltd. (Golder) that OHRG was considering establishing an accommodation camp with capacity for 800 people at the Hammond Reef Gold Project (Project) Site. Monitoring wells were installed at two downgradient locations and one upgradient location to establish subsurface conditions and provide for the collection of baseline groundwater elevation and quality data.

2.0 METHODS

2.1 Borehole Drilling and Monitoring Well Installations

Borehole drilling and monitoring well installations during the 2012 drilling program were carried out by TBT Engineering Ltd. (TBT) from Thunder Bay, Ontario, under the supervision of a Golder technician. Drilling and monitoring well installations were conducted by an Ontario Ministry of Environment (MOE) licensed well technician/contractor in accordance with the *Water Resources Act*, Ontario Regulation 903 (O. Reg. 903). Drilling was conducted at three locations in the vicinity of the proposed accommodation camp and a total of five monitoring wells (nested and single) were installed. The locations of boreholes and monitoring wells completed in the vicinity of the proposed camp are shown in Figure 1.

Boreholes were advanced using a track-mounted CME 55 drill rig equipped with standard 200 mm diameter hollow-stem augers. Boreholes were advanced by auger drilling and sampling with in situ Standard Penetration Tests (SPTs) at continuous depth intervals of approximately 0.75 m to refusal. SPTs and sampling were carried out using a hydraulic hammer and conventional 35 mm internal diameter split spoon sampling equipment. Split spoon samples were collected, photographed, logged and placed in plastic bags (double bagged), sealed and labeled during drilling. At locations where multiple boreholes were advanced for the installation of nested monitoring wells, SPT sampling and logging was typically only completed during drilling of the first (deepest) borehole for efficiency. Borehole stratigraphy is provided in the Record of Borehole logs in Attachment 2.II.1.

Monitoring wells were constructed using 52.5 mm ID Schedule 40 PVC screen and risers installed in 1.52 m sections. Each well typically had a screened interval of 1.52 m or 3.05 m in length. Clean silica sand was used to form a filter pack from the well bottoms to on average 0.5 m above the top of screen. Bentonite chips (Holeplug) were used to form low-permeability seals around the riser pipe from the top of the filter pack to surface. PVC risers were cut leaving approximately 0.9 m of stickup above the ground surface, vented and sealed with a J-plug or PVC slip cap. Following installation, the wells were completed with lockable above ground protective casings and developed using dedicated polyethylene tubing and inertial foot valves.

Monitoring wells were generally installed with screened intervals in separate stratigraphic units (referred to as nested wells) positioned to intersect zones of higher permeability and to characterize and sample discrete overburden units. At each location, a monitoring well was installed within the overburden immediately overlying inferred bedrock (boreholes were advanced to auger refusal but bedrock was not confirmed by coring) and an offset monitoring well was completed in the shallower overburden soils if a sufficient thickness of saturated overburden was present. For nested monitoring wells, the deeper wells are denoted with the suffix ‘A’ and the

shallower wells are denoted with the suffix 'B'. Monitoring well installation details are provided in the Record of Borehole logs in Attachment 2.II.1.

Upon completion of the drilling and well installation program, OHRG conducted an elevation survey to establish the ground surface and top of well pipe elevations at each monitoring location.

Table 1 below provides a summary of borehole and monitoring well installation details, including ground surface and top of well pipe elevations, and Universal Transverse Mercator (UTM) co-ordinates. Monitoring well locations are shown in Figure 1.

Table 1: Summary of Details for Boreholes and Monitoring Wells in Proposed Accommodation Camp

General Information					Geologic Information		Monitoring Well Information					
Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden Thickness (m)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
	Easting	Northing								from	to	
BH12-6A	616523	5426941	416.18	9.91	9.91[(a)]	Topsoil, Silty Sand, Silt, Clayey Silt, Silty Clay, Silt	BH12-6A	Nested	417.06	8.38	9.91	Silt, trace sand
BH12-6B	616523	5426942	416.16	3.05			BH12-6B		417.12	1.52	3.05	Silty Sand
BH12-7A	616444	5426813	415.84	8.08	8.08[(a)]	Topsoil, Silt, Clayey Silt, Silty Clay, Silt, Gravel and Sand	BH12-7A	Nested	416.69	5.79	7.31	Silt, trace sand; Gravel and Sand
BH12-7B	616444	5426814	415.80	3.66			BH12-7B		416.76	2.13	3.66	Silty Clay, trace sand
BH12-8	616371	5427060	418.49	3.96	3.96[(a)]	Silty Sand, Silt	BH12-8	Single	419.55	2.29	3.81	Silt, trace sand

Notes:

masl = Metres above mean sea level.

mbgs = Metres below ground surface.

[(a)] Auger refusal encountered at this depth (probable bedrock) but bedrock was not confirmed by rock coring.

616000

617000

5427000

BH12-8
415.26

ACCOMMODATION BUILDINGS

MAIN CAMP

PARKING LOT

BH12-6B
415.35

BH12-6A
415.45

BH12-7B
414.9

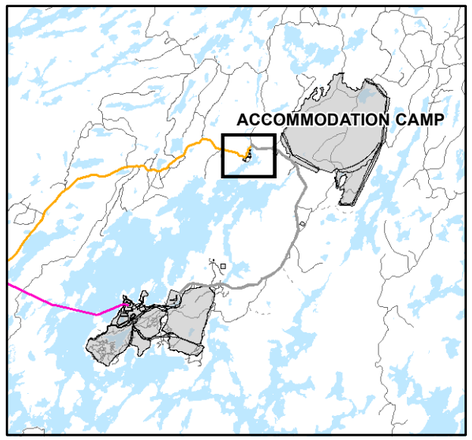
BH12-7A
415.33

Marmion Reservoir

N

LEGEND

- 414.9 Groundwater Elevation (August 2012)
- Monitoring Well
- Road
- Trail
- Index Contour (5m interval)
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities



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

100 0 100 200 300
SCALE 1:5,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
MONITORING WELL LOCATIONS AND GROUNDWATER ELEVATIONS – ACCOMMODATION CAMP

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	5 Feb. 2013		
CHECK	MSO	5 Feb. 2013		
REVIEW	JP	5 Feb. 2013		

FIGURE: 1

G:\Projects\2010\10-1118-0020_BrettResources_HammondReefGIS\MXDs\Draft\HydrogeologyTSDAppendixExplorationCamp_GWElevations_InferredGW.mxd

2.2 Soil Laboratory Testing

Select samples of overburden soil obtained from boreholes BH12-6, BH12-7 and BH12-8 were submitted for laboratory testing to confirm general characterization and classification of the samples for hydrogeological purposes. Laboratory testing included:

- Natural Moisture Content (ASTM D2216).
- Particle Size Analysis of Soils using Sieve and Hydrometer (ASTM D422).
- Atterberg Limits (ASTM D4318).

2.3 Hydraulic Conductivity Testing

Estimates of hydraulic conductivity (K) values of the overburden materials encountered during drilling have been developed from the following:

- Grain size distribution of overburden materials.
- Single well response tests (slug tests) in monitoring wells.

Particle size analysis was conducted (sieve and hydrometer) on select samples of overburden material collected from boreholes during drilling. Samples were selected to represent the various stratigraphic units encountered within the proposed accommodation camp. For samples of granular overburden materials where the grain size was appropriate (i.e., d10 greater than 0.01 mm), the results of the grain size analyses were used to estimate the hydraulic conductivity of the material using the Hazen method.

Slug tests were completed in monitoring wells BH12-6A/B and BH12-7A/B following drilling in order to estimate the hydraulic conductivity of the overburden formations in which the monitoring well screens were installed. The water level in monitoring well BH12-8 was too low to conduct a slug test at this location.

Wells were developed prior to conducting slug tests. The physical testing involved measuring the static water level depth and then removing a known volume of water using dedicated Waterra™ tubing and foot valves. Recovering water levels were measured using Schlumberger *Diver*™ data logging pressure transducers (data loggers) set to record time, pressure and temperature at a time interval selected based on the rate of recovery during well development. Water levels were measured manually to determine the end of the test and the data logger removed and downloaded.

Slug test data were analyzed using the Hvorslev method. This method is based on the formula for hydraulic conductivity (K) in a variable head scenario:

$$K = \frac{d^2 \times \ln\frac{2L}{D}}{8 \times L \times (t_2 - t_1)} \times \ln(H_2 - H_1)$$

Where:

d = well pipe diameter

L = screen length

D = Screen/filter pack diameter

t = time, seconds

H = head

2.4 Groundwater Level Monitoring

Following completion of the borehole drilling and monitoring well installations, manual depth to water measurements were recorded at each monitoring well. During the quarterly groundwater monitoring event carried out at the Project Site in August 2012 (Appendices 2.V and 3.I), depth to water measurements were recorded at monitoring wells BH12-6A/B, BH12-7A/B and BH12-8. Water levels were measured using a portable electronic water level meter. The top of each well pipe was used as the reference elevation for the water level measurements.

2.5 Groundwater Quality Sampling

Groundwater samples were collected from monitoring wells BH12-6A/B and BH12-7A/B during the quarterly groundwater monitoring event conducted in August 2012. Monitoring wells BH12-6A and BH12-6B were sampled on August 27 and monitoring wells BH12-7A and BH12-7B were sampled on August 31.

Monitoring well BH12-8 was not sampled for groundwater quality during the quarterly groundwater monitoring event conducted in August 2012 due to insufficient well yield.

Groundwater sampling was performed consistent with recognized standard field sampling methods. The following sample collection protocols were followed:

- **Calibration** – Field parameters were measured with a handheld meter calibrated in the field with calibration solutions provided by the supplier. Calibration for pH (two points: 4 and 7), and electrical conductivity was carried out daily before sampling began and documented in the field notes.
- **Sampling Equipment and Handling** – Sterile gloves were worn during sample collection. Sample bottles were provided by the contract analytical laboratory. Sample bottles were pre-charged with the appropriate preservatives at the analytical laboratory. Samples were stored in a cooler with ice and maintained in a cool state until shipped to the laboratories. As much as possible, samples were shipped in time to meet the

required holding times. However, this was not always possible for nitrate, nitrite, and ortho-phosphate (each with holding times of 48 hours) given the remote location.

- **Sample Filtration** – Samples for metals and organic carbon were collected as follows:
  - Unfiltered (total organic carbon).
  - Field filtered (dissolved metals and dissolved organic carbon) using a 0.45 µm Waterra™ filter into the appropriate bottles.
- **Field staff labelled samples with unique sample numbers**. Field observations (e.g., clarity, colour, odour, etc.), as well as the sample collection procedures and techniques were documented.
- **Well Purging** – A minimum of three well volumes were purged, or until the well ran dry. In cases where a well could only be drained dry due to low recovery rates, a minimum of one well volume was purged. Water levels were allowed to recover.
- **Sampling Equipment and Handling** – Dedicated Waterra™ tubing and footvalves were used for every piezometer to avoid cross-contamination between sample locations. Tubing was stored within each well between sampling events or discarded after sampling and replaced in the following field event if it was not able to be stored in the well.
- **Field Parameter Measurement** – Measurements of pH, temperature and electrical conductivity were taken during the collection of groundwater samples.

2.5.1 Analytes

Baseline groundwater quality samples were submitted under chain of custody to an accredited environmental laboratory (ALS Laboratories) in Thunder Bay, Ontario, for analysis of Volatile Organic Compounds, Petroleum Hydrocarbons and the following water quality parameters outlined in the Ontario *Mining Act* (O. Reg. 240/00):

- **General parameters** – pH, alkalinity, acidity, conductivity, total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC).
- **Major ions** – Calcium, magnesium, potassium, sodium, sulphate, chloride, fluoride, carbonate (CO_3^-), bicarbonate (CO_3^{2-}) and free cyanide. Hardness was calculated based on major ions.
- **Nutrients** – Nitrate (NO_3-N), nitrite (NO_2-N), total ammonia (NH_3-N), phosphorus, and ortho-phosphates. Un-ionized ammonia (NH_3) was calculated based on the NH_3-N concentration, and the field pH and temperature.
- **Organics** – phenols.
- **Metals** – dissolved.

3.0 RESULTS

3.1 Overburden Stratigraphy

Where it exists, overburden in the Mine Area and along the mine site road to the northeast is generally less than 9 m thick and typically consists of a thin layer of topsoil (generally less than 0.2 m) overlying discontinuous layers of clayey silt, silty clay and silt. At borehole BH12-7, a 1.37 m thick layer of gravel and sand was encountered at depth overlying inferred bedrock.

It should be noted that boreholes were terminated upon refusal on probable bedrock. It is possible that the maximum thickness of the overburden is greater than recorded.

Borehole stratigraphy is provided in the Record of Borehole logs in Attachment 2.II.1. The results of laboratory testing are provided on the Record of Borehole logs in Attachment 2.II.1. Grain size distribution plots for select samples are provided in Attachment 2.II.2.

3.2 Groundwater Levels and Vertical Hydraulic Gradients

Depth to groundwater level measurements and groundwater elevations observed in August 2012 at monitoring wells BH12-6A/B, BH12-7A/B and BH12-8 are provided in Table 2. Groundwater elevations are also shown in Figure 1.

Table 2: Depth to Groundwater Levels and Groundwater Elevations Observed in August 2012

Monitoring Well ID	Depth to Groundwater (mbtp)	Top of Pipe Elevation (masl)	Groundwater Elevation (masl)
BH12-6A	1.61	417.06	415.45
BH12-6B	1.77	417.12	415.35
BH12-7A	1.36	416.69	415.33
BH12-7B	1.87	416.77	414.90
BH12-8	4.30	419.56	415.26

Notes:
(mbtp) = metres below top of well pipe
(masl) = metres above sea level

Groundwater elevations observed in monitoring wells throughout the proposed accommodation camp area range from a high of 415.45 masl at BH12-6A to a low of 414.90 masl at BH12-7B.

At locations with nested wells (BH12-6 and BH12-7), the water levels at the pair of wells were compared to assess vertical hydraulic gradients. Table 3 provides the direction of hydraulic gradient observed at nested monitoring locations in the vicinity of the proposed accommodation camp observed in August 2012.

Table 3: Vertical Hydraulic Gradients at Nested Groundwater Monitoring Locations

Monitoring Well Nest	Head Difference (m)
BH12-6	0.10
BH12-7	0.43

Notes:
Negative head difference indicates a downward vertical gradient.
Positive head difference indicates an upward vertical gradient.

Slight upward hydraulic gradients were observed at both nested monitoring locations with flow towards Marmion Reservoir.

3.3 Hydraulic Conductivity

Estimates of the hydraulic conductivity of overburden soils were derived by conducting rising head tests, and analysis of grain size. Grain size distribution curves are provided in Attachment 2.II.2. Table 4 provides a summary of the hydraulic conductivity estimates.

Table 4: Hydraulic Conductivity Estimates of Overburden at Proposed Accommodation Camp

Monitoring Location	Sample ID	Material Description	Hydraulic Conductivity (m/s)	Testing Type	Analytical Method
BH12-6	4	Silty Sand	1.0×10^{-5}	Grain size	Hazen
BH12-6B	n/a	Silty Sand	2.8×10^{-6}	Slug Test	Hvorslev
BH12-7	8	Sand and Gravel	2.8×10^{-5}	Grain size	Hazen
BH12-7A	n/a	Silt, trace sand; Sand and Gravel	8.0×10^{-8}	Slug Test	Hvorslev
BH12-7B	n/a	Silty Clay, trace sand	5.8×10^{-7}	Slug Test	Hvorslev

Notes:
n/a = Hydraulic conductivity estimate reflects screened interval of monitoring well at this location.

The results of the analyses indicate that the hydraulic conductivity of the overburden in the vicinity of the accommodation camp is variable, but generally on the order of 10^{-5} to 10^{-7} m/s.

3.4 Groundwater Quality

The groundwater quality results were compared to criteria listed in the Ontario Provincial Water Quality Objectives (PWQO 1999[1]), Ontario Drinking Water Quality Standards (ODWS 2006[2]) and Canadian Council of

[1] PWQO. 1999. Provincial Water Quality Objectives. Ministry of Environment and Energy (February 1999).

[2] ODWS. 2006. Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines. Dated June 2003 and revised June 2006 (PIBS 4449e01).

Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 2007[3]). The analytical results for the groundwater samples collected in August 2012 are presented in Table 5. Parameters that exceed ODWS, PWQO and/or CCME are highlighted in Table 5 and summarized below.

[3] CCME. 2007. Canadian Water Quality Guidelines for the Protection of Aquatic Life, Canadian Council of Ministers of the Environment, Update 7.1 (December 2007). Updated as per CCME publications at www.http://ceqg-rcqe.ccme.ca/, visited 29 September, 2012.

Table 5: Groundwater Quality

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BH12-6A	BH12-6B	BH12-7A	BH12-7B
						Aug-12	Aug-12	Aug-12	Aug-12
Physical Tests									
Conductivity (EC)	uS/cm	3.0	—	—	—	390	1490	320	206
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	164	124	157	65.8
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.3	***5.87***	7.96	6.54
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	26800	48500	79100	1820
Total Dissolved Solids	mg/L	10	—	—	500[q]	416	998	197	158
Anions and Nutrients									
Acidity (as CaCO3)	mg/L	2.0	—	—	—	11.2	209	3	23.6
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	159	50.4	143	62.6
Ammonia-N, Total	mg/L	0.020	0.019[t]	0.02[u]	—	0.27	1.88	0.224	0.039
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	159	50.4	143	62.6
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5	<5
Chloride (Cl)	mg/L	0.10	120	—	250[q]	24.6	424	5.71	19.1
Fluoride	mg/L	0.030	—	—	1.5	0.04	<0.030	0.172	<0.030
Nitrate-N (NO3-N)	mg/L	0.030	13	—	10	0.209	<0.030	<0.030	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	0.06	—	1	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.0050	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	0.004-0.1[v]	0.02[f]	—	18.7	39.6	13.2	0.732
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	4.29	10.9	11.6	6.02
Cyanides									
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon									
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	2.9	11.4	2.6	1.3
Total Organic Carbon	mg/L	1.0	—	—	—	2.9	39.4	2.6	1.5
Dissolved Metals [s]									
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.0194	0.0955	0.0358	0.0186
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	0.0014	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	0.078	0.162	0.022	0.12
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000017	***0.000019***	***0.00005***	***0.000025***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	55.5	33.3	42.5	16.9
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010

Table 5: Groundwater Quality (Continued)

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BH12-6A	BH12-6B	BH12-7A	BH12-7B
						Aug-12	Aug-12	Aug-12	Aug-12
Dissolved Metals (Continued)									
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	0.00058	0.0609	<0.00050	0.00058
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[l]	0.001-0.005[f][m]	1[q]	<0.0010	<0.0010	0.0013	0.001
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	<0.020	***87.7***	<0.020	<0.020
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.050	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	6.17	9.91	12.4	5.73
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.369	7.63	0.152	0.0559
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0014	<0.0010	0.0066	<0.0010
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	0.0034	<0.0020	0.0023
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	1.33	4.99	1.76	1.3
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0010	<0.0010	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	8.48	163	5.35	15.6
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.127	0.517	0.0461	0.0897
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	0.0041	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	0.0116	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	0.0042	0.002	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	<0.0030	0.0119	0.0067	0.0083
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics									
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	<0.0010	0.0025	<0.0010	0.0038

Notes:

Values in bold italics exceed the CCME guidelines.

Values underlined exceed the PWQO guidelines.

Values shaded in grey exceed the ODWQS guidelines.

— = No guideline available for analyte.

[a] Total concentrations are assumed, unless stated otherwise.

[b] Canadian Council of Ministers of the Environment, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Update 7.1 (December 2007).

[c] Provincial Water Quality Objectives, Ministry of Environment and Energy (February 1999).

[d] Ontario Drinking Water Standards, Objectives and Guidelines, Ministry of the Environment (June 2003)

Table 5: Groundwater Quality (Continued)

(e) Under clear flow: + 25 mg/L from background levels for any short-term exposure (e.g., 24-h period).
Average + 5 mg/L-1 from background levels for longer term exposures (24 h<discharge<30 d).
Under high flow: + 25 mg/L-1 from background levels at any time when background levels between 25 and 250 mg/L-1.
+ 10% of background levels when background is >250 mg/L-1.

(f) Interim Guideline.

(g) Aluminum guideline
= 15 µg.L-1 at 4.5<pH<5.5
=+10% at 5.5<pH<6.5
=75 µg/L-1 at 6.5<pH<9

(h) Beryllium guideline
= 11 µg/L-1 at hardness<75 mgCaCO3/L
= 1100 µg/L-1 at hardness>75 mgCaCO3/L

(i) Respectively for long term and short term exposure

(j) Guideline based on Cd=10^{0.86[log(hardness)]-3.2}

(k) Cadmium guideline
= 0.1 µg/L-1 at hardness<100 mgCaCO3/L
= 0.5 µg/L-1 at hardness>100 mgCaCO3/L

(l) Copper guideline
= 2 µg/L-1 at a water hardness of 0–120 mg/L-1 (soft to medium) as CaCO3
= 3 µg/L-1 at a water harness of 120–180 mg/L-1 (hard) as CaCO3
= 4 µg/L-1 at a water harness >180 mg/L-1 (very hard) as CaCO3

(m) Copper guideline
= 1 µg/L-1 at hardness<20 mg CaCO3/L
= 5 µg/L-1 at hardness>20 mg CaCO3/L

(n) Lead guideline
= 1 µg/L-1 at a water harness of 0–60 mg/L-1 (soft) as CaCO3
= 2 µg/L-1 at a water harness of 60–120 mg/L-1 (medium) as CaCO3
= 4 µg/L-1 at a water harness of 120–180 mg/L-1 (hard) as CaCO3
= 7 µg/L-1 at a water harness >180 mg/L-1 (very hard) as CaCO3

(o) Lead guideline
= 1 µg/L-1 at hardness<30 mg CaCO3/L
= 3 µg/L-1 at 30<hardness<80 mg CaCO3/L
= 5 µg/L-1 at hardness>80 mg CaCO3/L

(p) Nickel guideline
= 25 µg/L-1 at a water harness of 0–60 mg/L-1 (soft) as CaCO3
= 65 µg/L-1 at a water harness of 60–120 mg/L-1 (medium) as CaCO3
= 110 µg/L-1 at a water harness of 120–180 mg/L-1 (hard) as CaCO3
= 150 µg/L-1 at a water harness >180 mg/L-1 (very hard) as CaCO3

Table 5: Groundwater Quality (Continued)

(q) Aesthetic Objective.

(r) Interim Maximum Acceptable Concentration.

(s) Guidelines for CCME and PWQO apply to total metal concentrations. Groundwater samples were be analyzed for dissolved metals only and the CCME and PWQO guidelines are provided for comparison purposes only.

(t) Un-ionized ammonia. Total ammonia:

Temp (°C)	pH							
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	10
0	231	73.0	23.1	7.32	2.33	0.749	0.250	0.042
5	153	48.3	15.3	4.84	1.54	0.502	0.172	0.034
10	102	32.4	10.3	3.26	1.04	0.343	0.121	0.029
15	69.7	22.0	6.98	2.22	0.715	0.239	0.089	0.026
20	48.0	15.2	4.82	1.54	0.499	0.171	0.067	0.024
25	33.5	10.6	3.37	1.08	0.354	0.125	0.053	0.022
30	23.7	7.50	2.39	0.767	0.256	0.094	0.043	0.021

(u) f = 1/(10pKa-pH +1), where f is the fraction of NH3; pKa = 0.09018 + 2729.92/T; T = ambient water temperature in Kelvin (K = °C + 273.16)

(v) Ultra-oligotrophic <4 µg·.L-1; oligotrophic 4-10 µg·.L-1; mesotrophic 10-20 µg·.L-1; meso-eutrophic 20-35 µg·.L-1; eutrophic 35-100 µg·.L-1; hyper-eutrophic >100 µg·.L-1

To provide some context for the review of groundwater quality data within the proposed accommodation camp area, results have been compared to Ontario Drinking Water Quality Standards (ODWS) and Provincial Water Quality Objectives (PWQO). It should be noted that PWQOs are applicable to surface waters. Groundwater quality has been compared herein to PWQOs recognizing the immediate proximity of surface waters to the proposed accommodation camp. These comparisons should not be interpreted as an assessment of regularity compliance.

Generally, groundwater quality in the shallow and deep overburden at monitoring locations BH12-7A and BH12-7B was similar to the deep overburden at monitoring location BH12-6A. The quality of groundwater in the shallow overburden at monitoring location BH12-6B had notably higher concentrations of select parameters in comparison to the other monitoring locations and is not interpreted to be representative of natural (baseline) conditions.

The following parameters did not meet the CCME, PWQO and/or ODWS:

- pH values ranged from 5.87 to 7.96, ranging from slightly acidic to slightly alkaline. The pH of groundwater obtained from monitoring well BH12-6B was below the lower value range of the CCME, PWQO and ODWS criteria (6.5).
- The concentration of chloride (424 mg/L) in groundwater obtained from monitoring well BH12-6B was greater than the CCME long-term exposure criteria (120 mg/L).

4.0 REFERENCES

Golder (Golder Associates Ltd.). 2012. *Osisko Hammond Reef Gold (OHRG) Proposed Camp Implications on Hydrogeological Studies for Environmental Assessment and Potable Water Supply.* Technical Memorandum. Document Number 2012-042. Submitted to Osisko Hammond Reef Gold Ltd.. July 25, 2012.

HYDROGEOLOGY TSD
APPENDIX 2.II
VERSION 1

Attachment 2.II.1

Record of Borehole and Record of Drillhole Logs for 2012 Drilling Program

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m
0		GROUND SURFACE		416.18			
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	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
1					2	50 DO	WH
2					3	50 DO	2
					4	50 DO	3
				413.28			
3		(ML) SILT, trace fine sand, zone of clayey silt; brown; wet, very loose		2.90	5A	50 DO	3
				412.83			
		(ML) CLAYEY SILT, trace sand; brown; Wn>PL, soft to stiff		3.35	5B		
4				411.91			
		(CI) SILTY CLAY, trace to some sand; low to medium plasticity; brown to grey; cohesive, Wn>PL, firm		4.27	6	50 DO	2
5					7	75 TO	-
6							
7				409.09			
		(ML) SILT, trace sand; grey; moist to wet, compact		7.09	8	50 DO	11
8							
9					9	50 DO	11
				406.27			
10		END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK		9.91			
11							
12							
13							

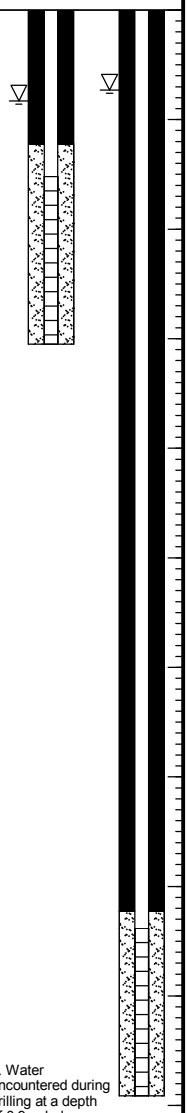
SAMPLES

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
MH
MH/NP
MH
MH/NP

PIEZOMETER OR STANDPIPE INSTALLATION



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:

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

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

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. +, 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) (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		415.84							B A
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	TOPSOIL (50 mm)		0.00							
		(ML) SILT, some sand; brown; moist; compact		0.05 / 415.15	1	50 DO	12			MH	
1		(ML) CLAYEY SILT; trace to some sand; brown; Wn<PL, firm to stiff		0.69 / 414.47	2	50 DO	8				
2		(CI) SILTY CLAY, trace sand; red brown to brown; cohesive, medium plasticity; Wn>PL, soft to very soft		1.37	3	50 DO	3			MH	
					4	50 DO	3				
3					5	50 DO	1				
4		(ML) SILT, trace sand; grey; wet, compact to loose		411.80 / 4.04							
					6	50 DO	13			MH/NP	
5											
6					7	50 DO	7				
		(GW) GRAVEL and SAND, some fines; brown; wet, dense		409.13 / 6.71							
7					8	50 DO	47			MH	
8		END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK		407.76 / 8.08							
9											
10											
11											
12											

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:

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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

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. +, 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) (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		418.49							
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(SM/ML) SILTY SAND; dark brown to grey, organically stained; moist, loose		0.00	1	50 DO	9				50 mm Diameter Monitoring Well
				417.80							
1		(ML) SILT, trace sand; grey; damp to wet, dense to compact		0.69	2	50 DO	20				Bentonite Seal
2					3	50 DO	37				
					4	50 DO	20			MH	
3					5	50 DO	20				Silica Sand Filter
				414.07							
4		END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK		4.42							
5											
6											
7											
8											
9											
10											

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:

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

HYDROGEOLOGY TSD
APPENDIX 2.II
VERSION 1

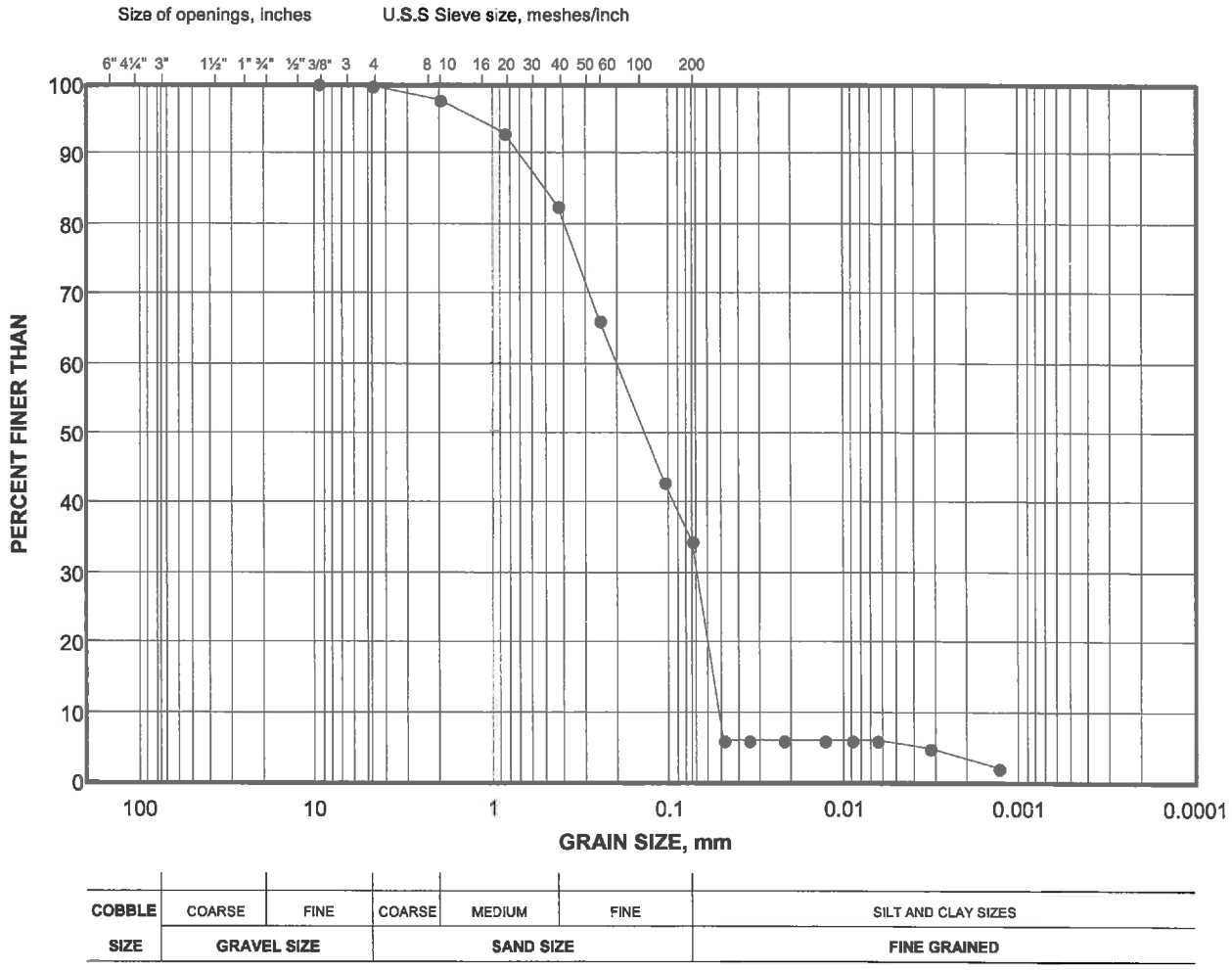
Attachment 2.II.2

Grain Size Distribution Plots

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-6	4	

Project Number: 11-1118-0074

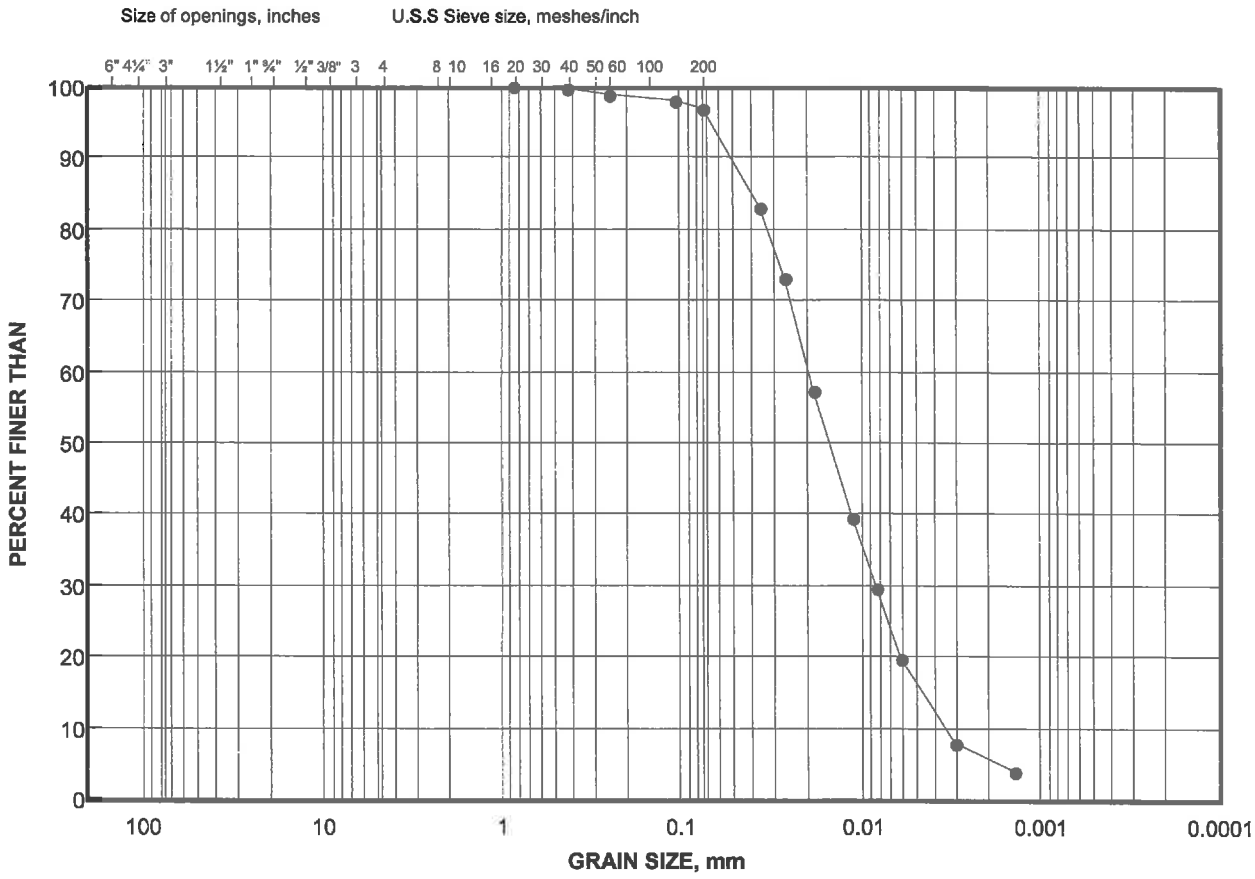
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-6	5A	

Project Number: 11-1118-0074

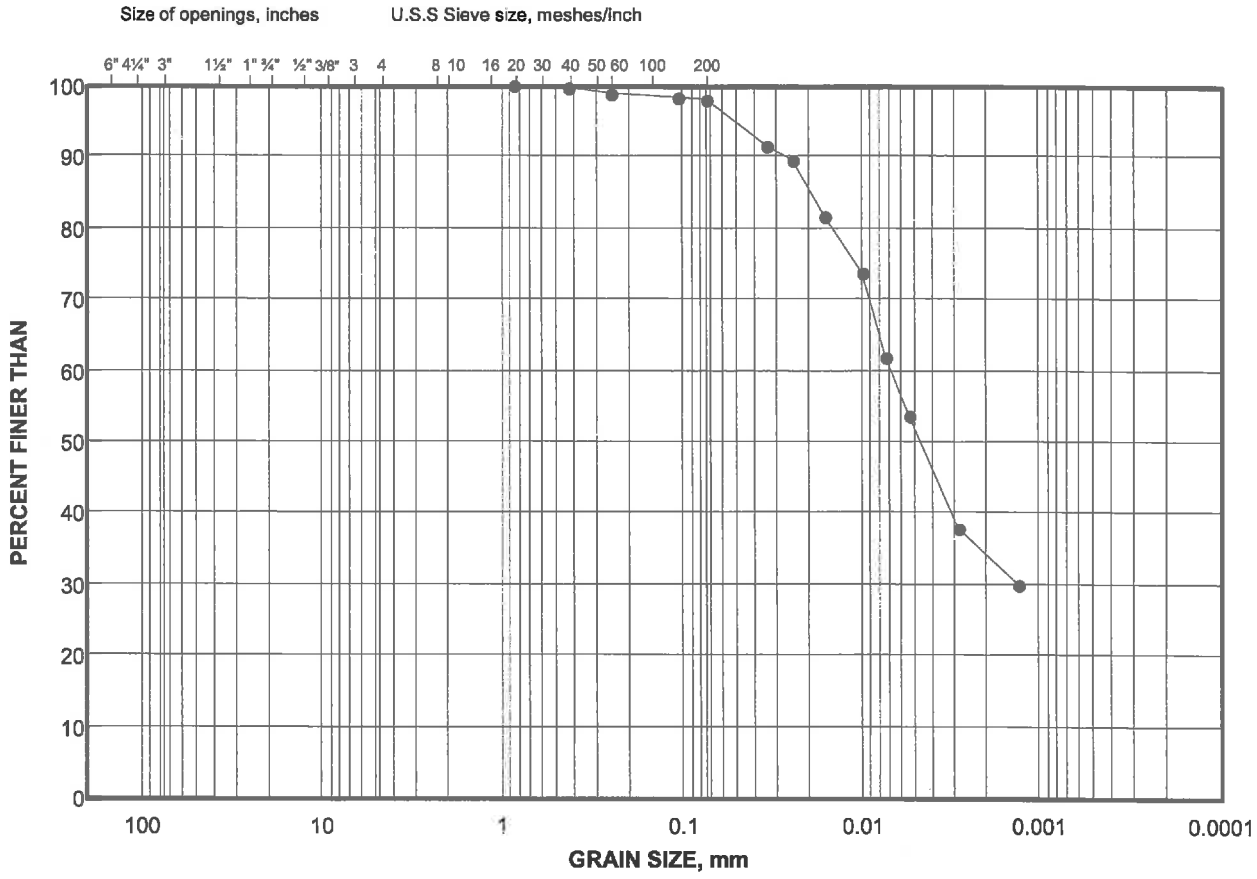
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-6	6	

Project Number: 11-1118-0074

Checked By: _____

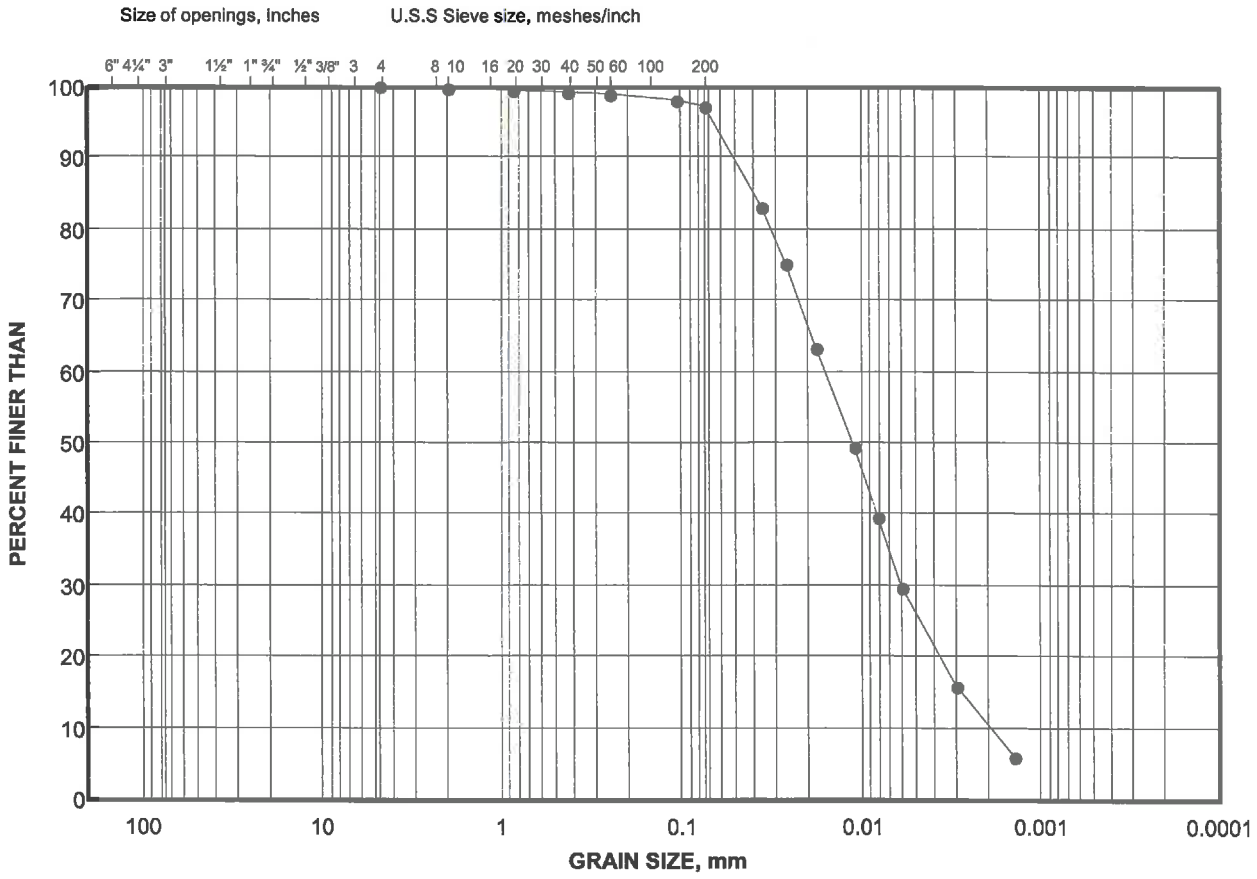
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-6	9	

Project Number: 11-1118-0074

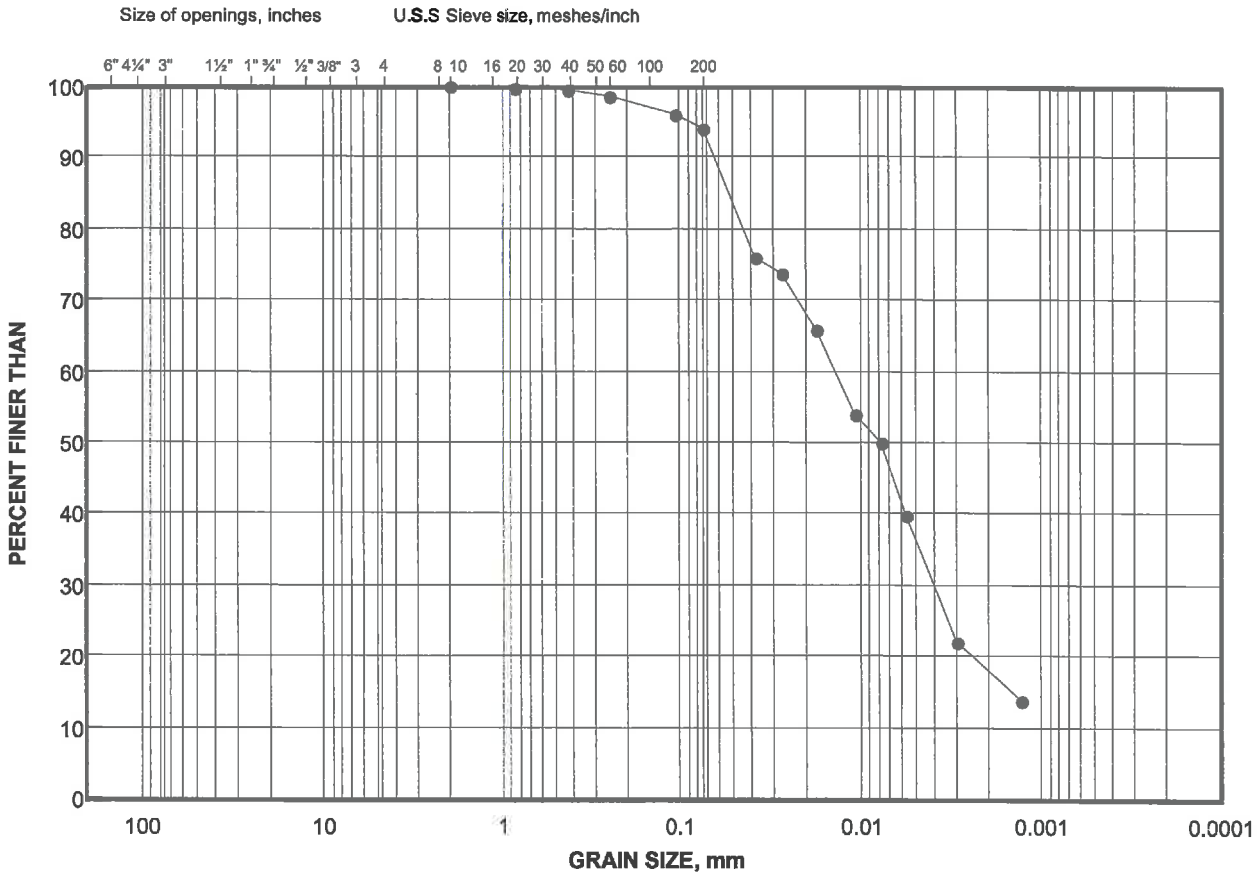
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-7	1	

Project Number: 11-1118-0074

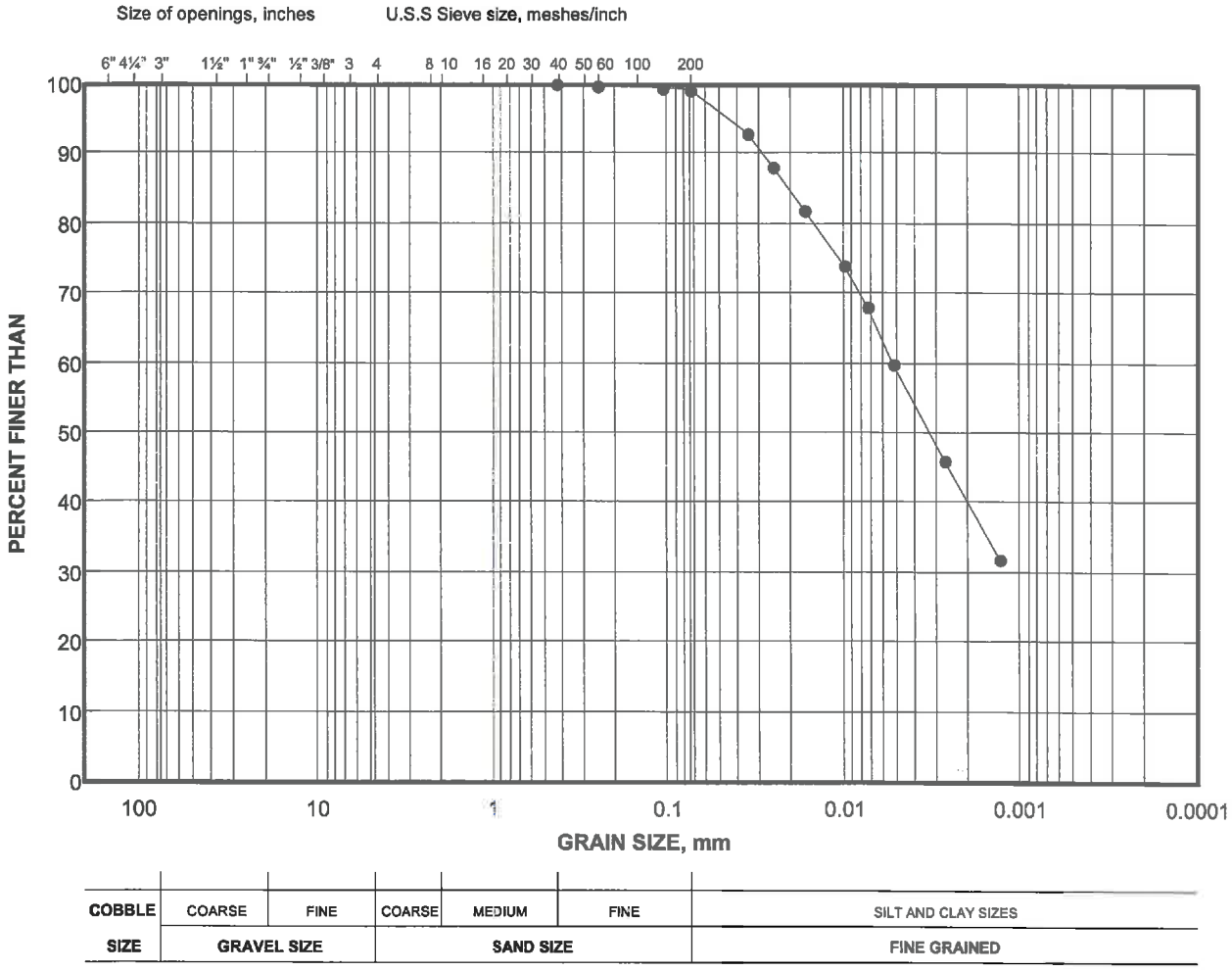
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-7	3	

Project Number: 11-1118-0074

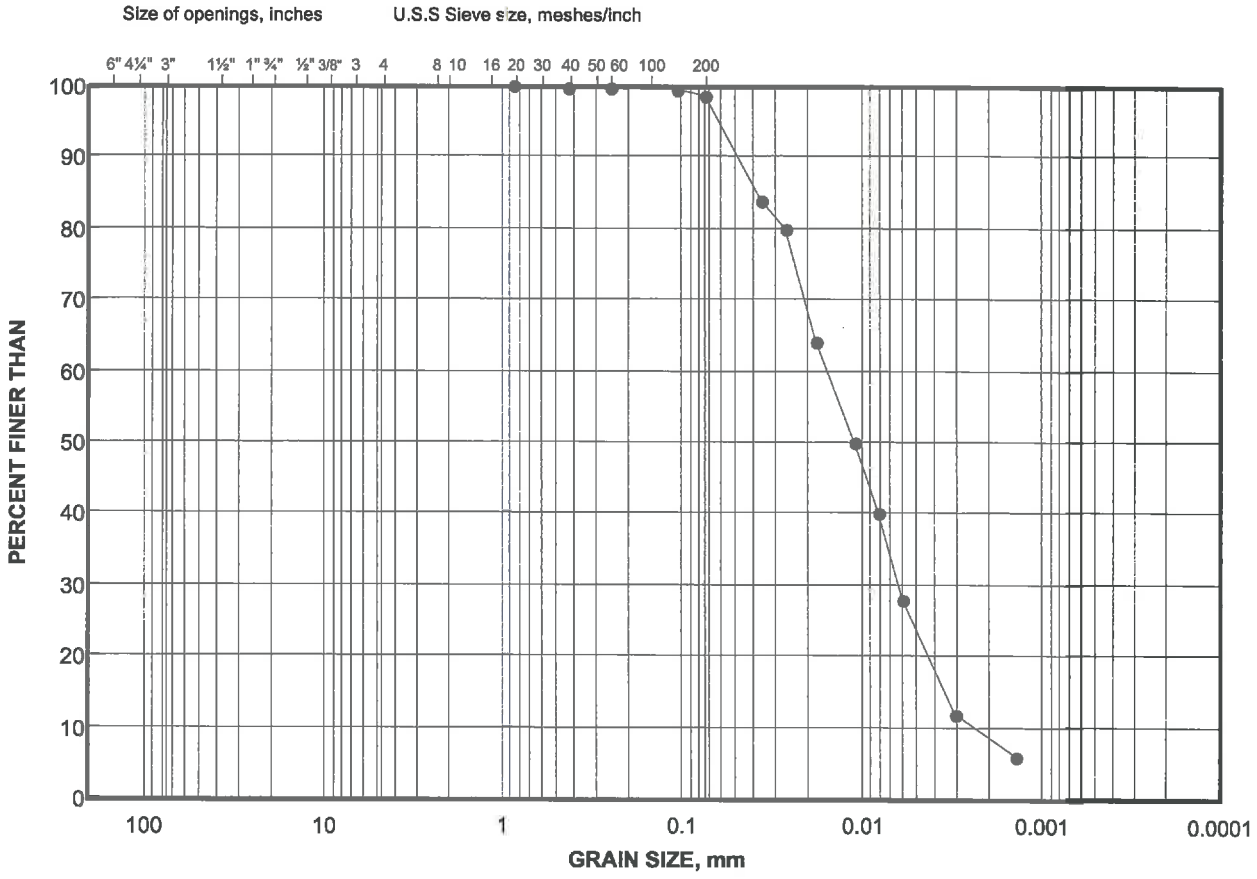
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-7	6	

Project Number: 11-1118-0074

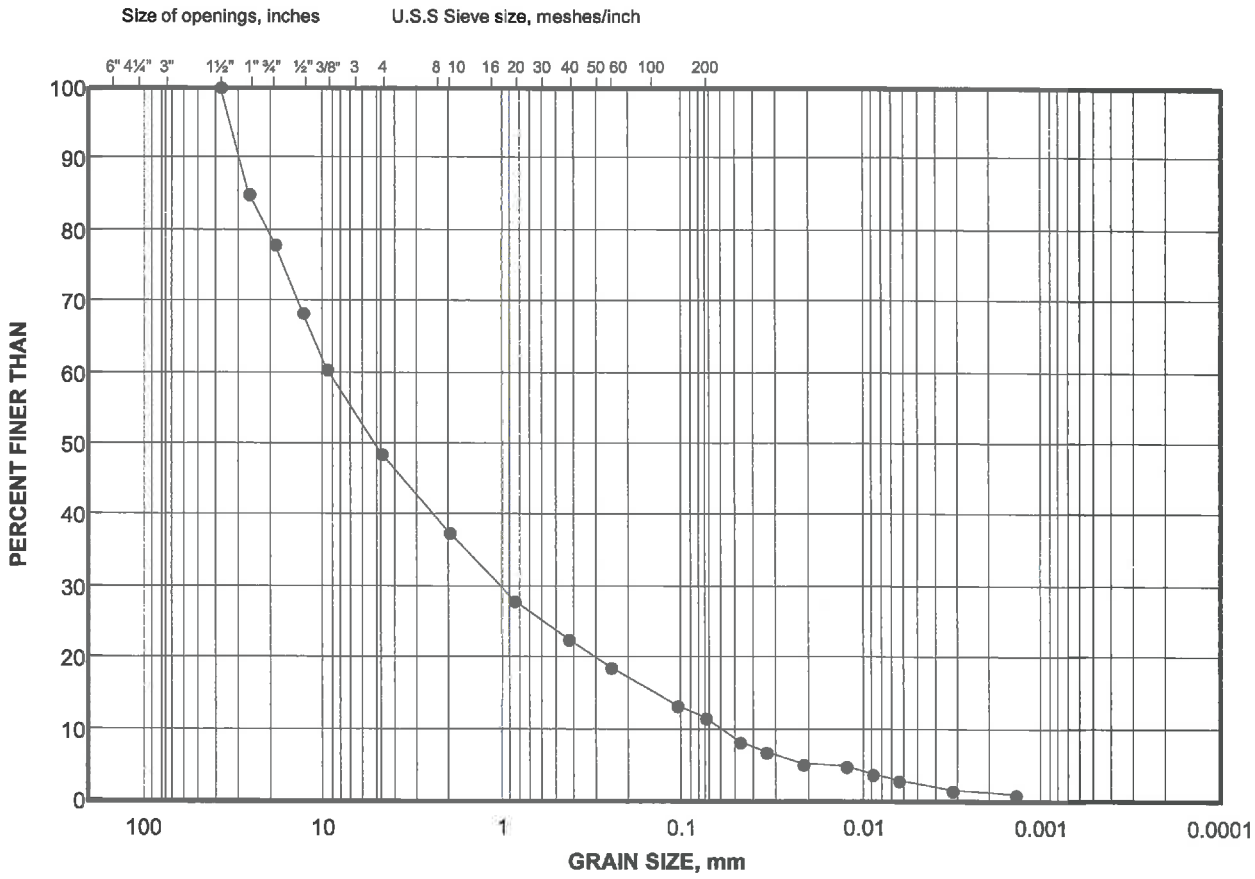
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-7	8	

Project Number: 11-1118-0074

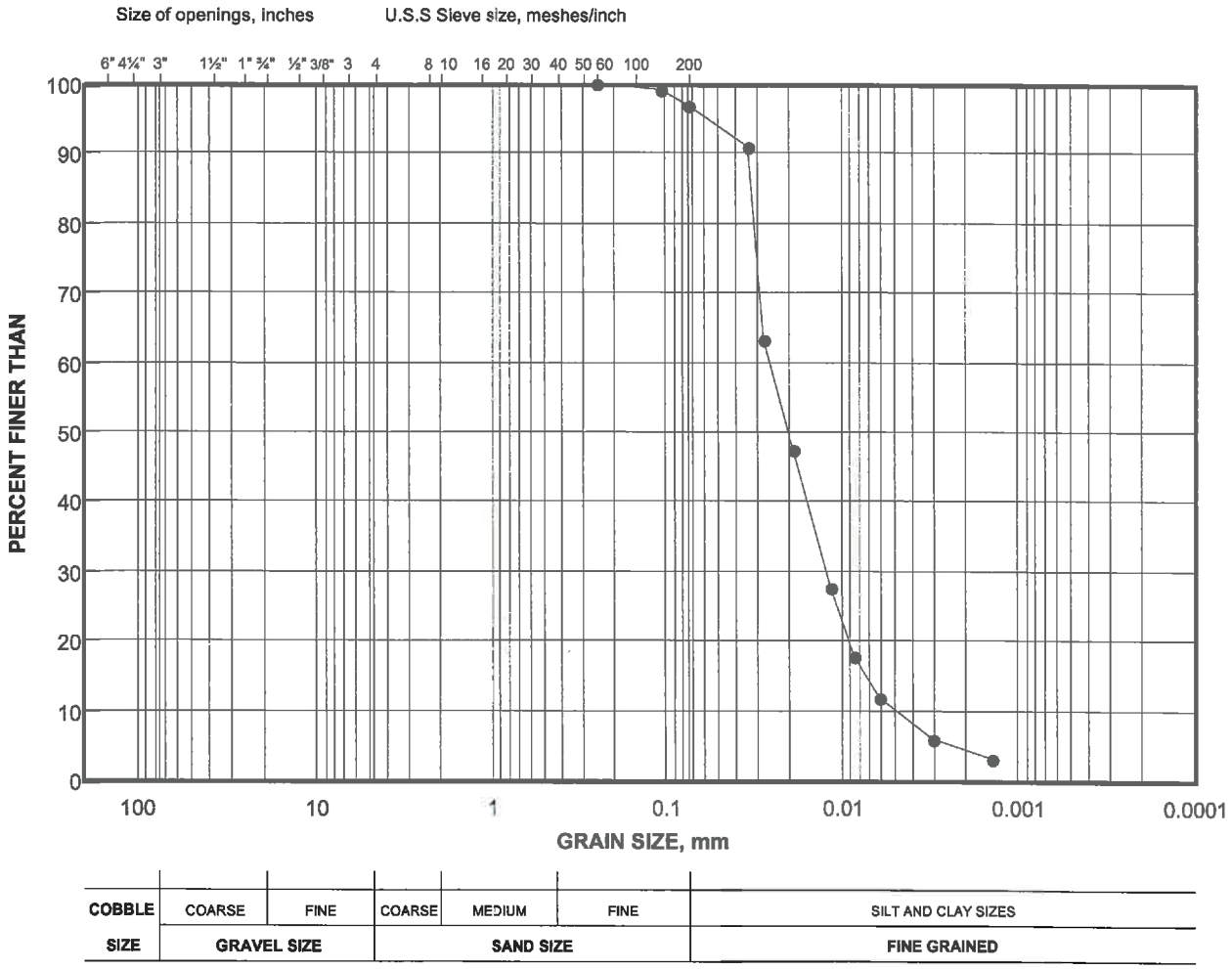
Checked By: AG

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-8	4	

Project Number: 11-1118-0074

Checked By: AS

Golder Associates

Date: 17-Sep-12

APPENDIX 2.III

Borehole Drilling and Monitoring Well Installations

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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Figure 3: Typical Particle Size Distribution for Fine Grained (>50% material <75um) Soils in the TMF Area. 10

Figure 4: Typical Particle Size Distribution for Coarse Grained (<50% material <75um) Soils in TMF Area 10

ATTACHMENTS

Attachment 2.III.1
Record of Borehole and Record of Drillhole Logs for 2011 Drilling Program

Attachment 2.III.2
Record of Borehole and Record of Drillhole Logs for 2012 Drilling Program

Attachment 2.III.3
Grain Size Distribution Plots

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) carried out two borehole drilling programs at the Hammond Reef Gold Project (Project) Site in 2011 and 2012 for the purposes of collecting information about the subsurface material and to facilitate the installation of monitoring wells for hydrogeological monitoring.

A borehole drilling and monitoring well installation program was completed from March 17 to May 2, 2011, as part of the baseline hydrogeological and geotechnical investigations for the Project. The primary objectives of the 2011 borehole drilling program were:

- Characterize the general stratigraphy of overburden soils and shallow bedrock within the Local Study Area (LSA).
- Characterize geotechnical foundation conditions within the proposed Mine, Waste Rock and Tailings Management Facilities.
- Install monitoring wells to facilitate hydraulic conductivity testing, groundwater level monitoring and water quality sampling.

A second borehole drilling and monitoring well installation program was completed from August 8 to 21, 2012, as part of the geotechnical and hydrogeological investigations for the Project. The primary objectives of the 2012 borehole drilling program were:

- Characterize the stratigraphy and geotechnical foundation conditions of the overburden soils and shallow bedrock at select locations along recently modified boundaries of the Tailings Management Facility (TMF), Support and Ancillary Infrastructure (mine site road alignments) and Accommodation Camp.
- Install monitoring wells to facilitate hydraulic conductivity testing, groundwater level monitoring and water quality sampling.

2.0 METHODS

2.1 Borehole Drilling and Monitoring Well Installations

Borehole drilling and monitoring well installations during the 2011 drilling program were carried out by George Downing Estate Drilling Ltd. (Downing) from Grenville-sur-la-Rouge, Quebec, under the supervision of a Golder technician. Drilling and monitoring well installations were conducted by an Ontario Ministry of Environment (MOE) licensed well technician/contractor in accordance with the *Water Resources Act* Ontario Regulation 903 (O. Reg. 903). Drilling was conducted at 34 locations and a total of 51 monitoring wells (nested and single) were installed. Borehole depths varied from 1.70 m (BRH-0025) to 28.86 m (BRH-0020A) with an average drilled depth of 8.84 m. Boreholes BRH-0020C and BRH-0025 were drilled specifically for geotechnical purposes and monitoring wells were not installed at these locations. Shelby tube samples were obtained and shear vane testing was carried out in relatively soft clayey soils at borehole BRH-0020C. The locations of boreholes and monitoring wells completed during this drilling program are shown in Figures 2-6 and 2-7 of the Hydrogeology TSD.

Borehole drilling and monitoring well installations during the 2012 drilling program were carried out by TBT Engineering Ltd. (TBT) from Thunder Bay, Ontario, under the supervision of a Golder technician. Drilling and monitoring well installations were conducted by an Ontario Ministry of Environment (MOE) licensed well technician/contractor in accordance with O. Reg. 903. Drilling was conducted at 10 locations and a total of 14 monitoring wells (nested and single) were installed. The locations of boreholes and monitoring wells completed during this drilling program are shown in Figures 2-6 and 2-7 of the Hydrogeology TSD.

During both drilling programs, boreholes were advanced using a track-mounted CME 55 drill rig equipped with standard 200 mm diameter hollow-stem augers and NQ diameter rock coring equipment. Boreholes were advanced by auger drilling and sampling with in-situ Standard Penetration Tests (SPTs) at continuous depth intervals of approximately 0.75 m to refusal followed by bedrock coring to target depths. SPTs and sampling were carried out using a hydraulic hammer and conventional 35 mm internal diameter split spoon sampling equipment. Split spoon samples were collected, photographed, logged and placed in plastic bags (double bagged), sealed and labeled during drilling. Shelby tube samples were obtained and shear vane testing was carried out in clayey soil conditions at select borehole locations. At locations where multiple boreholes were advanced for the installation of nested monitoring wells, SPT sampling and logging was typically only completed during drilling of the first (deepest) borehole for efficiency. Bedrock coring was completed to confirm bedrock (approximately 3 m into rock) or to greater depths based on well installation requirements. Bedrock coring was completed using NQ diameter wire line rock coring equipment with run lengths of 1.5 m. Core samples were logged during drilling then placed sequentially into labelled core boxes and secured for delivery to OHRG personnel. Borehole stratigraphy is provided in the Record of Borehole and Record of Drillhole logs in Attachments 2.III.1 and 2.III.2.

Monitoring wells installed during the 2011 drilling program were constructed using threaded 31.75 mm ID Schedule 40 PVC riser pipe and no. 10 machine slotted screen installed in 1.52 m sections. Wells installed during the 2012 drilling program were constructed using 52.5 mm ID Schedule 40 PVC screen and risers installed in 1.52 m sections. Each well typically had a screened interval of 1.52 m or 3.05 m in length. Clean silica sand was used to form a filter pack from the well bottoms to on average 0.5 m above the top of screen.

Coated bentonite pellets (Pel-Plug) or bentonite chips (Holeplug) were used to form seals above the filter packs around the risers. PVC risers were cut leaving approximately 0.9 m of stickup above the ground surface, vented and sealed with a J-plug or PVC slip cap. Following installation, the wells were completed with lockable above ground protective casings and developed using dedicated polyethylene tubing and inertial foot valves.

Monitoring wells were generally installed with screened intervals in separate stratigraphic units (referred to as nested wells) positioned to intersect zones of higher permeability and to characterize and sample discrete overburden and bedrock stratigraphic units. At most locations, a monitoring well was installed within the upper fractured bedrock and an offset monitoring well was completed in the overburden soils if a sufficient thickness of saturated overburden was present. Several monitoring well nests were installed with screened intervals in shallow (<10 m) and deeper bedrock (15-20 m). Monitoring well installation details are provided in the Record of Borehole and Record of Drillhole logs in Attachments 2.III.1 and 2.III.2. Tables 1 and 2 provide summaries of borehole and monitoring well installation details, including ground surface elevation, top of well pipe elevation, and Universal Transverse Mercator (UTM) co-ordinates for boreholes and monitoring wells within the Mine, TMF and Support and Ancillary Infrastructure areas. The locations of these boreholes and monitoring wells are shown in Figures 2-6 and 2-7 of the Hydrogeology TSD.

Table 1: Summary of Details for Boreholes and Monitoring Wells in the Mine Area

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden Thickness (m)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Mine Area	BRH-0001A	611909	5421762	428.97	19.22	0.00	No overburden	BRH-0001A	Nested	429.70	16.17	19.22	Bedrock
	BRH-0001B	611909	5421761	429.10	7.16	0.00	No overburden	BRH-0001B		429.69	3.92	6.97	Bedrock
	BRH-0002A	612178	5420590	422.67	19.25	0.00	No overburden	BRH-0002A	Nested	423.59	16.12	19.17	Bedrock
	BRH-0002B	612177	5420589	422.62	5.78	0.00	No overburden	BRH-0002B		423.67	2.73	5.78	Bedrock
	BRH-0003	612744	5421086	420.59	5.89	0.00	No overburden	BRH-0003	Single	421.08	4.21	5.73	Bedrock
	BRH-0004	613473	5421807	429.63	4.27	0.00	No overburden	BRH-0004	Single	430.40	2.75	4.27	Bedrock
	BRH-0005A	612360	5421894	441.74	19.07	0.97	Boulders, Clay and Organics	BRH-0005A	Nested	442.73	15.99	19.04	Bedrock
	BRH-0005B	612361	5421894	441.80	8.53	1.17		BRH-0005B		442.75	5.40	6.92	Bedrock
	BRH-0006	613857	5422544	416.97	3.88	0.86	Gravelly, silty, clayey sand, trace organics	BRH-0006	Single	418.10	2.36	3.88	Bedrock
	BRH-0007A	614656	5420825	427.07	18.44	0.66	Cobbles and Clay	BRH-0007A	Nested	427.82	16.91	18.43	Bedrock
	BRH-0007B	614656	5420826	427.05	6.86	1.22		BRH-0007B		427.79	5.34	6.86	Bedrock
	BRH-0008A	611682	5421030	419.57	19.49	0.48	Organics and Silty Clay	BRH-0008A	Nested	420.40	17.86	19.38	Bedrock
	BRH-0008B	611682	5421026	420.55	5.74	0.33		BRH-0008B		419.71	4.18	5.70	Bedrock
	BRH-0009	613878	5421290	416.27	7.77	0.53	Clay and Organics, some cobbles	BRH-0009	Single	417.13	6.25	7.77	Bedrock
	BRH-0011	615105	5421919	434.22	5.64	1.07	Sand, some clay, some organics, trace boulders	BRH-0011	Single	435.26	4.12	5.64	Bedrock
	BRH-0012A	615588	5422185	416.87	5.66	3.38	Gravelly Sand, some clay, trace silt	BRH-0012A	Nested	417.87	4.13	5.65	Bedrock
	BRH-0012B	615588	5422185	416.87	2.40			BRH-0012B		417.87	0.88	2.40	Gravelly Sand
	BRH-0013	615631	5422933	416.57	4.37	1.32	Gravelly Sand, some clay, trace silt	BRH-0013	Single	417.41	2.85	4.37	Bedrock
	BRH-0010	615227	5423654	436.10	2.67	0.00	None	BRH-0010	Single	436.86	0.76	2.28	Bedrock
	BRH-0014A	617147	5422218	416.86	8.78	5.11	Peat, Clay, Silty Sand, some gravel, Sand and Gravel	BRH-0014A	Nested	417.86	7.25	8.78	Bedrock
	BRH-0014B	617147	5422218	416.86	4.88			BRH-0014B		417.86	3.35	4.88	Clay, Silty Sand, some gravel, Sand and Gravel
	BRH-0015A	617875	5423186	417.30	8.74	5.81	Clay, Clay, some silt, Sand, some gravel	BRH-0015A	Nested	418.23	7.21	8.73	Bedrock
	BRH-0015B	617875	5423186	417.30	5.50			BRH-0015B		418.23	3.98	5.50	Clay, some silt, Sand, some gravel

Table 1: Summary of Details for Boreholes and Monitoring Wells in the Mine Area (Continued)

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden Thickness (m)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Mine Area	BRH-0016A	618407	5425303	444.80	5.73	1.52	Sandy, clayey Silt, Gravelly, silty Sand	BRH-0016A	Nested	445.59	2.68	5.73	Bedrock
	BRH-0016B	618407	5425303	444.80	1.52			BRH-0016B		445.59	0.76	1.52	Sandy, clayey Silt, Gravelly, silty Sand
	BH12-9	616268	5422990	383.12	9.22	9.22	Peat, Silty Clay, Silt, Clayey Silt to Silt, Silty Clay, Silty Sand	BH12-9	Single	383.94	7.62	9.14	Silty Clay, Silty Sand and Gravel
	BH12-10	617850	5425008	433.11	3.15	3.28	Peat and Topsoil, Silty Sand Silty Clay, Silty Sand	BH12-10	Single	433.94	1.52	3.05	Silty Sand

Notes:
masl = Metres above mean sea level.
mbgs = Metres below ground surface.

Table 2: Summary of Details for Boreholes and Monitoring Wells in the Tailings Management Facility Area

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden Thickness (m)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Tailings Management Facility Area	BRH-0017A	619624	5425289	427.70	7.16	3.08	Silty Sand, Sand	BRH-0017A	Nested	428.55	5.64	7.16	Bedrock
	BRH-0017B	619624	5425289	427.70	3.05			BRH-0017B		428.55	1.52	3.05	Sand
	BRH-0018	620794	5427311	430.60	8.69	1.75	Clayey Sand and Silt, Silty Sand	BRH-0018	Single	431.64	5.49	8.53	Bedrock
	BRH-0019	618808	5426822	430.56	8.41	8.41	Topsoil, Silt, Silty Clayey Sand, Clayey Silt, Silty Clay, Clay, Sand	BRH-0019	Single	431.56	5.05	8.10	Silty Clay, Clay, Sand
	BRH-0020A	617958	5426576	416.51	28.86	25.55	Topsoil, Sand, Clay and Silt, Clayey Silt, Clay, Silty Clay, Sand	BRH-0020A	Nested	417.47	26.34	28.86	Bedrock
	BRH-0020B	617955	5426575	416.49	20.68			BRH-0020B		417.33	17.63	20.68	Bouldery Sand
	BRH-0020C	617955	5426575	416.49	14.48			n/a	Single	n/a	n/a	n/a	n/a
	BRH-0021A	617175	5427168	420.41	5.90	3.05	Topsoil, Sand, Sandy clayey Silt, Silt, Sand	BRH-0021A	Nested	421.42	4.18	5.70	Bedrock
	BRH-0021B	617175	5427168	420.41	2.82			BRH-0021B		421.42	1.30	2.82	Sandy clayey Silt, Silt, Sand
	BRH-0022	618040	5428215	430.63	5.39	0.10	Gravelly Sand, some cobbles, some boulders, trace silt	BRH-0022	Single	431.56	2.13	5.18	Bedrock
	BRH-0023	619973	5429127	434.90	3.58	3.58	Topsoil and Boulders, Silt and Sand, Sand and Gravel, Bouldery Sand and Gravel	BRH-0023	Single	435.80	1.83	3.35	Bouldery Sand and Gravel
	BRH-0024	621017	5429046	435.36	7.19	0.96	Gravelly Sand and Boulders, trace silt	BRH-0024	Single	436.36	5.61	7.14	Bedrock
	BRH-0025	621289	5430267	443.34	1.70	1.70	Peat, Organics and silty Sand, Silty Sand and Cobbles	n/a	n/a	n/a	n/a	n/a	n/a
	BRH-0026	620607	5431227	460.88	8.75	1.52	Topsoil / Sand and Gravel, some silt, some cobbles, some boulders, trace clay	BRH-0026	Single	461.98	5.70	8.75	Bedrock
	BRH-0027	619614	5425831	434.80	2.36	2.36	Peat, some sand, some silt, Sandy silty Clay, Silty Sand, some gravel, some clay	BRH-0027	Single	435.98	0.84	2.36	Sandy silty Clay, Silty Sand, some gravel, some clay
	BH12-1	617568	5428261	436.84	4.17	1.22	Peat, Silt and Sand, Silty Sand, Sand	BH12-1	Single	437.76	2.59	4.11	Bedrock
	BH12-2	617830	5426870	418.40	18.36	15.14	Silt, Sandy Silt, Clayey Silt, Silty Clay, Silt, Silty Sand and Gravel	BH12-2	Single	419.28	13.11	14.63	Silty Sand and Gravel
	BH12-3A	618260	5426405	419.49	16.46	13.41	Peat, Silt and Sand, trace gravel, Silt, some sand, Silty Clay, trace sand, Silt trace sand, Silt and Sand, some gravel	BH12-3A	Nested	420.38	14.93	16.46	Bedrock
	BH12-3B	618259	5426406	419.53				BH12-3B		420.32	10.06	11.58	Silt
	BH12-4	619918	5426313	428.57	10.16	7.01	Peat, Clayey Silt, Silty Clay, Silt, Silty Sand	BH12-4	Single	429.53	5.49	7.01	Silt, Silty Sand
	BH12-5A	620391	5428975	433.03	10.69	7.85	Sand Fill, Peat, Sand, Silty Sand	BH12-5A	Nested	433.95	9.14	10.67	Bedrock
	BH12-5B	620390	5428976	433.03				BH12-5B		433.96	5.33	6.86	Silt, Sand, Silty Sand and Gravel

Notes:

masl = Metres above mean sea level.

mbgs = Metres below ground surface.

n/a = Borehole drilled for geotechnical purposes only; no monitoring well installed at this location.

3.0 SOIL LABORATORY TESTING

Overburden soil samples obtained from select boreholes during the 2011 and 2012 drilling programs were submitted for laboratory testing to confirm general characterization and classification of the samples for hydrogeological and geotechnical purposes. Laboratory testing included:

- Natural Moisture Content (ASTM D2216).
- Particle Size Analysis of Soils using Sieve and Hydrometer (ASTM D422).
- Atterberg Limits (ASTM D4318).
- Specific Gravity of Soil (ASTM D854-06).
- Organic Content (ASTM D5268).

The results of laboratory testing are provided on the Record of Borehole and Record of Drillhole logs in Attachments 2.III.1 and 2.III.2. Grain size distribution plots for select samples are provided in Attachment 2.III.3.

4.0 OVERBURDEN STRATIGRAPHY

Where it exists, overburden in the Mine Area and along the mine road to the northeast is generally less than nine metres thick and typically consists of thin, discontinuous sandy to clayey till overlain by topsoil or peat. Overburden deposits in wet, low-lying areas are usually overlain with peat. Typical grain size distribution curves for soil samples collected from boreholes drilled in low-lying areas within the Mine Area are combined in Figures 1 and 2. Detailed overburden stratigraphy is provided on the Record of Borehole logs in Attachments 2.III.1 and 2.III.2 and has been summarized in Tables 1 and 2. Borehole locations are shown in Figure 2-6 of the Hydrogeology TSD.

Overburden in the TMF Area generally ranges from not present to less than eight metres thick along the perimeter of the proposed TMF, with thicker deposits of up to 25.5 m occurring in a bedrock trough in the southwest portion of the TMF near Marmion Reservoir. The overburden observed at boreholes BRH-00019, BRH-0020, BH12-2 and BH12-3 in the southwest portion of the TMF generally comprised fine grained waterlain deposits overlying coarser grained glacial till, while the overburden throughout the remainder of the TMF Area was similar to the Mine Area generally consisting of thin, discontinuous sandy to clayey till overlain by topsoil or peat. Typical grain size distribution curves for soil samples collected from boreholes in the TMF Area are combined in Figures 3 and 4. Detailed overburden stratigraphy encountered at borehole locations in the TMF Area is provided on the Record of Borehole logs in Attachments 2.III.1 and 2.III.2 and has also been summarized in Table 2. Borehole locations are shown in Figure 2-7 of the Hydrogeology TSD.

Overburden cover throughout the LSA, and particularly within the Mine Area, is typically discontinuous and stratigraphy is often inconsistent from one location to the next. Likewise, when similar stratigraphy was observed at neighboring borehole locations, it was often found that similar soil horizons were not connected from one location to the next.

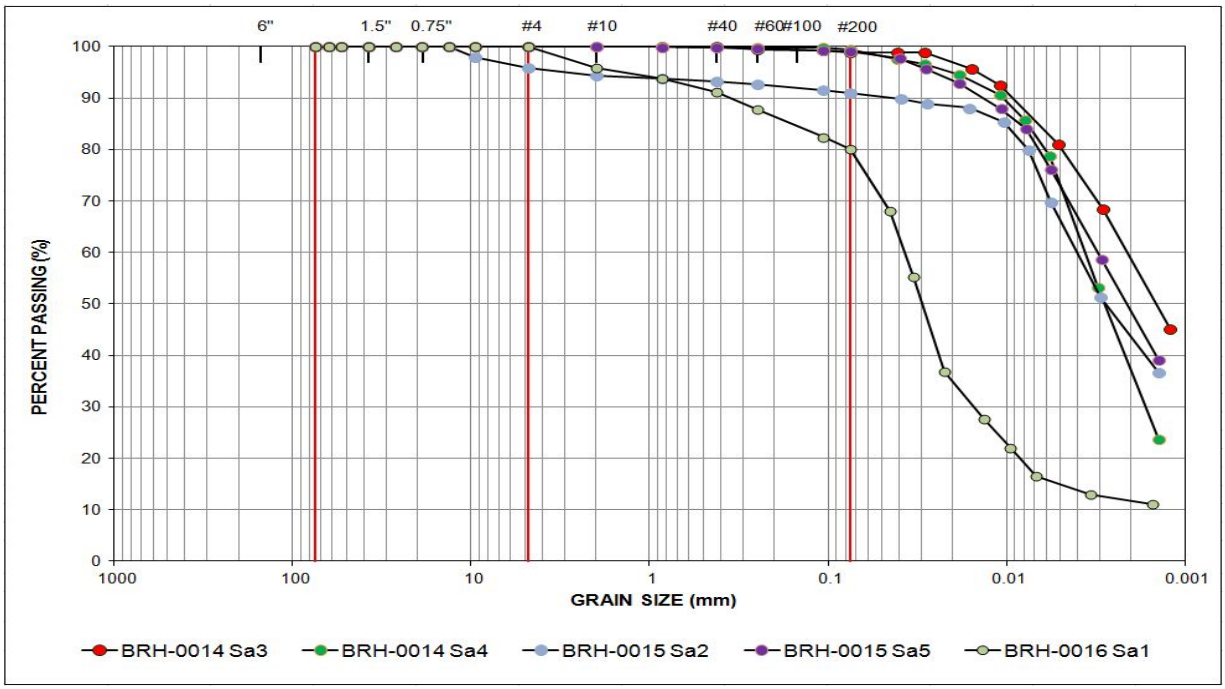

Figure 1: Particle Size Distribution for Fine Grained (>50% material <75um) Soils in the Mine Area.

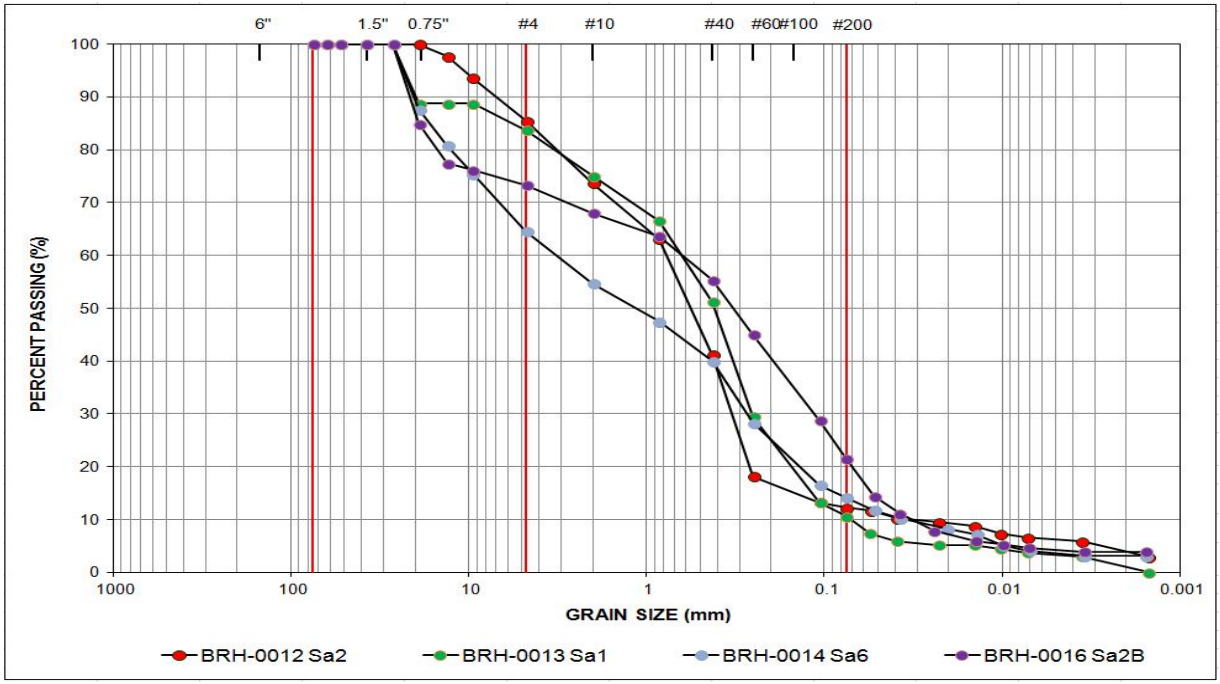

Figure 2: Particle Size Distribution for Coarse Grained (<50% material <75um) Soils in the Mine Area.

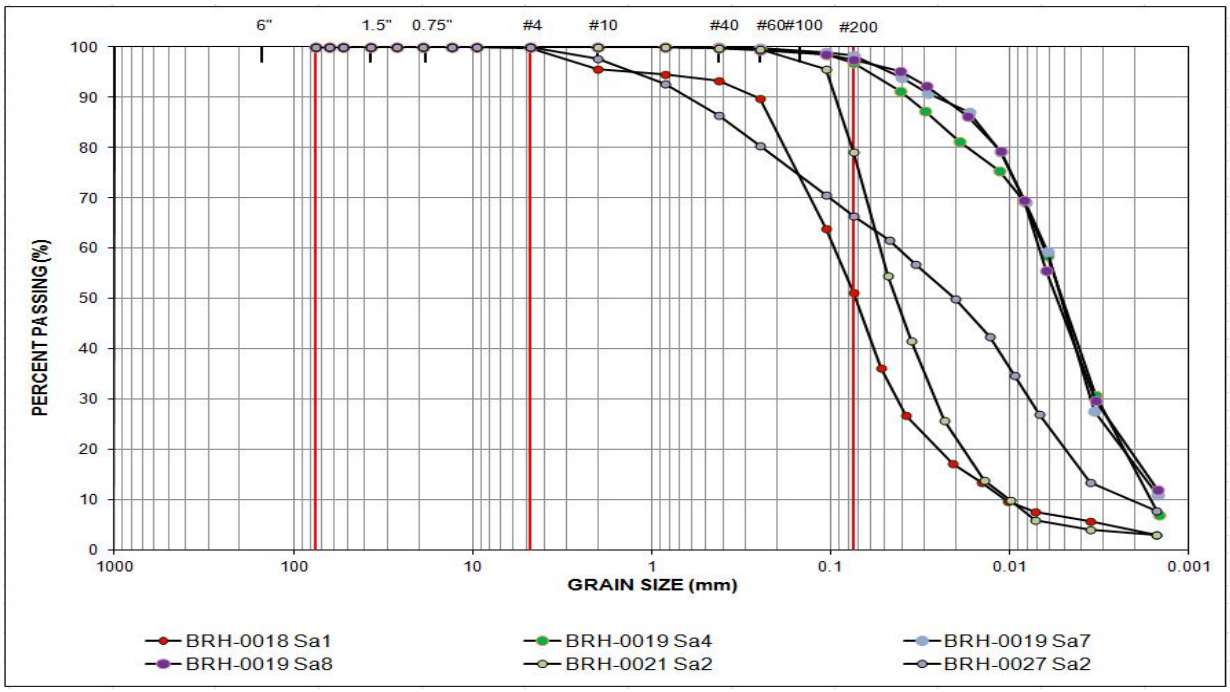

Figure 3: Typical Particle Size Distribution for Fine Grained (>50% material <75um) Soils in the TMF Area.

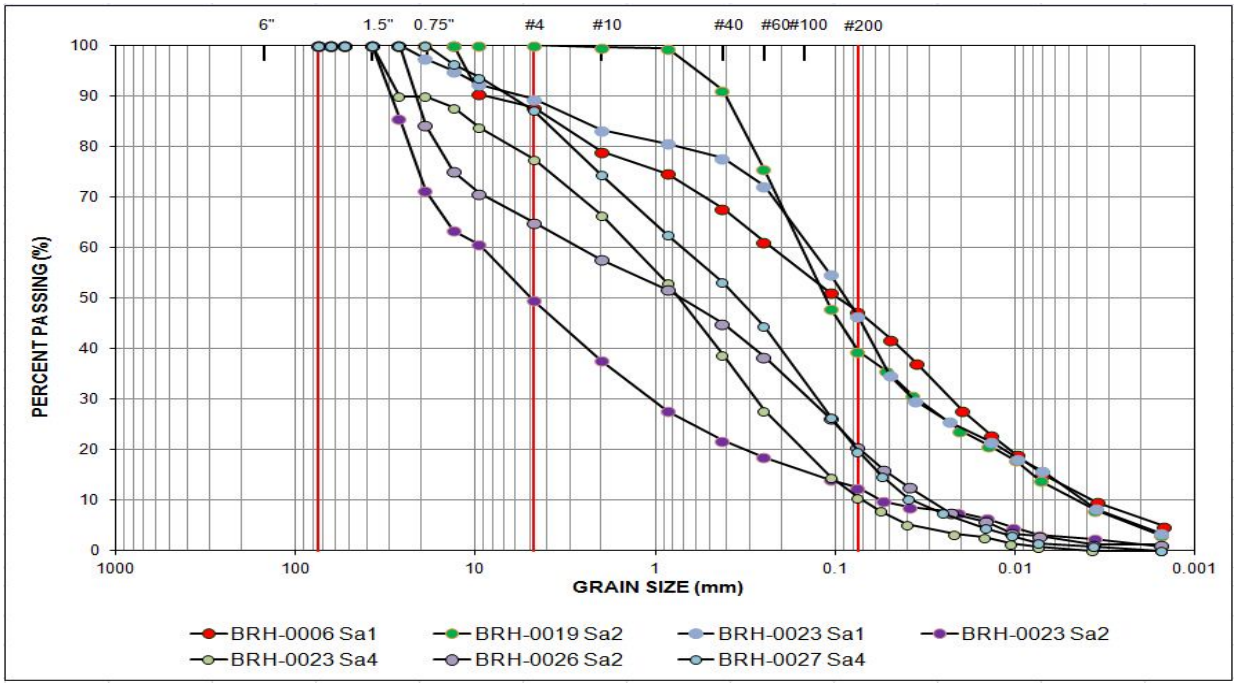

Figure 4: Typical Particle Size Distribution for Coarse Grained (<50% material <75um) Soils in TMF Area

HYDROGEOLOGY TSD
APPENDIX 2.III
VERSION 1

Attachment 2.III.1

Record of Borehole and Record of Drillhole Logs for 2011 Drilling Program

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0001A

SHEET 1 OF 2

LOCATION: N 5421761.9 ;E 611909.1

DRILLING DATE: April 26, 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	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.
		TOP OF BEDROCK		428.97															
0	CME 55 NQ Core	Slightly weathered, coarse-grained, grey, crystalline rock.		0.00	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						
2					3								JPLSPSM; Broken Core; JIR; JIR						
3					4								JIR; JUR; JIR; MB; Broken Core; JUS; JIR						
4					5								MB; JIR MB; JIR JISM; JIR Weathered Zone; JPLSM JUSM; MB						
5					6								JIR; MB; MB JRR; MB; MB; MB; JIR						
6					7								JIR; JUR; JUSM; MB; JPLSM Broken Core						
7				421.2	8								JIR; JIR						
8		Pink, coarse-grained, slightly weathered, crystalline rock, quartz, pyrite crystals.		7.8	9	<<							MB; JIR; JIR; JIR; JPLSM; JIR; MB						
9		Coarse-grained, greenish-grey rock, with pink quartz in varying amounts.		420.0 9.0									JPLR						
10		*CONTINUED NEXT PAGE*																	

28/10/11

Bentonite Holeplug

Riser

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0001A

SHEET 2 OF 2

LOCATION: N 5421761.9 ;E 611909.1

DRILLING DATE: April 26, 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.	
10		--- *CONTINUED FROM PREVIOUS PAGE* ---																		
10	CME 55 NQ Core	Coarse-grained, greenish-grey rock, with pink quartz in varying amounts.			10								MB JSTR JPLSM MB							
11																				
12				416.8									JPLR MB JIR							
		Pink quartz intrusion.		12.2	11								JIR							Bentonite Holeplug
				416.3									JIR JIR JIR							
13		Coarse-grained, greenish-grey rock, with pink quartz.		12.7									JUSM							
		Medium-grained, grey, from 12.7 m to 13.7 m depth.											JUSM JPLSM JPLSM							
14		Coarse-grained, grey, with pink quartz intrusions. Quartz intrusion, coarse-grained, grey from 13.9 m to 14.1 m depth.			12								JIR JIR Broken Core JIR							
15		Coarse-grained, grey, with quartz intrusions from 14.9 m to 17.6 m depth.			13								MB MB JIR JPLSM							
16													MB FPLSM							
17					14								JPLSM JIR							Silica Sand
													JIR JUSM							31.8 mm Diam. PVC #10 Slot Screen
18		Coarse-grained, grey, from 14.9 m to 17.6 m depth.											MB							
19					15								JPLSM JPLSM JISM							
				409.9									MB							
		END OF DRILLHOLE		19.1																0.6 m Riser Stickup.
20																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0001B

SHEET 1 OF 1

LOCATION: N 5421761.0 ;E 611908.6

DRILLING DATE: April 26, 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		429.10																
0	CME 55 NQ Core	Refer to Drillhole BRH-0001A for Rock description.		0.00																
7				421.9																
		END OF BOREHOLE		7.2																0.5 m Riser Stickup.

28/10/11

Bentonite Holeplug

Riser

Silica Sand

31.8 mm Diam. PVC #10 Slot Screen

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0002A

SHEET 1 OF 2

LOCATION: N 5420590.1 ;E 612177.9

DRILLING DATE: April 30, 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.

28/10/11

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	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.	
		GROUND SURFACE		422.67																
0	CME 55 NQ Core	Boulders, clay, organics.		0.00	1															
1				421.5																
		Coarse-grained, grey, crystalline rock.		1.2																
2					2								Broken Core Broken Core MB JIR							
													JIR JIR JIR JIR JIR JPLSM JIR							
3					3								JPLR JIR JIR JIR							
4					4								MB JPLSM JPLSM JPLR JPLR							Riser
5													Broken Core JUSM JIR JPLSM Broken Core JIR							Bentonite Holeplug
6					5								JIR JIR							
7													JPLR MB JPLSM							
8					6								JIR JIR JPLR JIR JPLR JIR JIR JIR MB							
9					7								JIR JIR JIR JPLSM JPLSM							
10		*CONTINUED NEXT PAGE*																		

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

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

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0002A

SHEET 2 OF 2

LOCATION: N 5420590.1 ;E 612177.9

DRILLING DATE: April 30, 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.	
		--- CONTINUED FROM PREVIOUS PAGE ---																		
10	CME 55 NQ Core	Coarse-grained, grey, crystalline rock.			7								JIR; Broken Core; JIR							
				412.3																
		White alteration.		10.4																
11					8															
				411.3																
		Medium-grained, white and grey, (TONALITE) with quartz veins.		11.4									JIR; JIR; MB							
12					9								JIR; JPLR							Bentonite Holeplug
13													JIR; JIR							
14					10								JIR; MB							
15																				
16					11								JIR; JIR; MB							
17					12								JIR; JIR							Silica Sand
18													JIR; JIR; MB							31.8 mm Diam. PVC #10 Slot Screen
					13								JIR; JIR							
19													JIR; MB							
				403.4																
		END OF DRILLHOLE		19.3																0.83 m Riser Stickup.
20																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0002B

SHEET 1 OF 1

LOCATION: N 5420588.6 ;E 612177.3

DRILLING DATE: May 1, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING 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		422.62																
0	CME 55 / NQ Core	Refer to Drillhole BRH-0002A for Rock description.		0.00																28/10/11
1																				
2																				Bentonite Holeplug
3																				Riser
4																				
5				416.9																Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
6		END OF DRILLHOLE		5.7																0.78 m Riser Stickup.
7																				
8																				
9																				
10																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0003

SHEET 1 OF 1

LOCATION: N 5421086.0 ;E 612744.1

DRILLING DATE: April 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		420.59																
0	CME 55 NQ Core	Coarse-grained, crystalline rock, slightly weathered, pyrite crystals, greenish-grey.		0.00	1								JIR x 2 JIR JIR JIR JIR							
1													JIR JIR JIR Broken Core JPLSM							
2					2								JIR JISM JPLR JPLSM							Bentonite Holeplug
				417.9									JPLR JPLR JPLR JPLR JPSTR							Riser
3		Coarse-grained, pink and grey with pyrite crystals.		2.7	3								Broken Core JIR JUSM JIR JISM JISM JISM JISM JIR JIR JIR JPLSM JISM JPLSM JPLSM JISM JPLSM JPLSM JPLSM JPLSM							
4					4								JIR JIR JIR JPLSM JPLSM JPLSM JPLR JPLSM JPLSM JPLSM JPLSM JIR JPLSM JPLR JIR							28/10/11 Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				414.7									JIR							
5		END OF DRILLHOLE		5.9									JIR JPLSM JISM JISM JPLR							0.5 m Riser Stickup.
6																				
7																				
8																				
9																				
10																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0004

SHEET 1 OF 1

LOCATION: N 5421807.5 ;E 613473.5

DRILLING DATE: April 24, 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		429.63																
0	CME 55 NQ Core	Coarse-grained, grey, crystalline rock, slightly weathered.		0.00	1								JIR JIR JIR							28/10/11
													JIR JIR							
1													JIR, MB							Bentonite Holeplug
					2								JIR							
2													JIR							Riser
													JIR JIR							
3					3								JIR							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
													Large clay-filled joint JIR JIR JIR JIR MB JIR JIR							
4				425.5									MB							
		END OF DRILLHOLE		4.1																0.52 m Riser Stickup.
5																				
6																				
7																				
8																				
9																				
10																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0005A

SHEET 1 OF 2

LOCATION: N 5421894.3 ;E 612359.7

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	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		441.7							
0	CME 55 (Hollow Stem Auger)	Moist to wet, brown, BOULDERS, CLAY and ORGANICS.		0.0							
				440.8	1	50 DO	50/ 0.2				
1	CME 55 (200 mm Diam. Hollow Stem Auger)	Moderately weathered, greenish-grey, medium-grained, crystalline rock.		0.9							
2											
		Slightly weathered.									
3											
4											Riser
5	CME 55 (NQ Core)										Bentonite Holeplug
6											
7											
8											
9		Quartz Intrusion, coarse-grained.									
10		*CONTINUED NEXT PAGE*									

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0005A

SHEET 2 OF 2

LOCATION: N 5421894.3 ;E 612359.7

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	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
		--- 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.									
12											
13											Bentonite Holeplug
14											
15											
16											28/10/11
17											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
18											
19				422.6							
		END OF BOREHOLE		19.1							0.9 m Riser Stickup.
20		Note: 1. For coring details see Record of Drillhole BRH-0005A.									

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0005A

SHEET 1 OF 2

LOCATION: N 5421894.3 ;E 612359.7

DRILLING DATE: April 25, 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	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN / FLUSH	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.	
		TOP OF BEDROCK	440.84																
1	CME 55 NQ Core	Moderately weathered, greenish-grey, medium-grained, crystalline rock.	0.90									Broken Core IR? Top of Rock							
												JIR							
												JUSM							
				1								JUSM							
2												FOIR							
												Broken Core							
												JIR							
												JIR							
												Broken Core							
												Broken Core							
		Slightly weathered.										MB							
3												JIR							
												JISM							
				2								JIR							
												JIR							
												JIR							
												MB							
												JUS							
												JUS							
												JSTR MB							
4												JIR							
												JIR							
												JIR							
				3								JIR							
												MB							
												JPLSM							
												JPLSM							Riser
5																			
												JPLSM							
				4								JPLSM							
												MB							
												JUSM							
6																			Bentonite Holeplug
												JISM							
												JIR							
				5								JIR							
												JUR							
7												MB							
												MB							
												JUSM							
8				6								JIR							
												JIR							
												MB							
9		Quartz Intrusion, coarse-grained.										JUS							
				7								JSTSM							
10												MB							
												MB							
				8								JIR							
												JIR							

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0005A

SHEET 2 OF 2

LOCATION: N 5421894.3 ;E 612359.7

DRILLING DATE: April 25, 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	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.	
		--- CONTINUED FROM PREVIOUS PAGE ---																		
11	CME 55 NQ Core	Moderately weathered, greenish-grey, medium-grained, crystalline rock.			8								MB							
		Slightly weathered, coarse-grained, grey and white (TONALITE).											MB							
12													MB							
					9								JIR							
13																				
					10															Bentonite Holeplug
14													MB							
													MB							
15					11															
													JIR							
16													JIR							28/10/11
													JIR? MB?							
					12								JISM							
17													JPLSM							Silica Sand
													JSTSM							31.8 mm Diam. PVC #10 Slot Screen
													JPLSM							
18					13								JIR							
													JIR							
19				422.6									MB							
		END OF DRILLHOLE		19.1									MB							0.9 m Riser Stickup.
20																				

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0005B

SHEET 1 OF 1

LOCATION: N 5421894.0 ;E 612361.4

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	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		441.8							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0005A for stratigraphy details.		0.0							
				440.9							
1				0.9							
2											Riser; 28/10/11
3											Bentonite Holeplug
4											
5											
6											
7											Silica Sand
8											31.8 mm Diam. PVC #10 Slot Screen
				433.3							
		END OF BOREHOLE		8.5							0.86 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: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0006

SHEET 1 OF 1

LOCATION: N 5422543.6 ;E 613856.8

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	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		417.0							
	CME 55 200 mm Diam. (Hollow Stem Auger)	Firm to hard, moist, brown, Gravelly, SILTY, CLAYEY SAND, trace organics.		0.0	1	50 DO	34			MH	28/10/11 ▽
				416.1	2	50 DO	25/ 0.14				Bentonite Holeplug
1	CME 55 NQ Core	Slightly weathered, pink, coarse-grained, crystalline rock.		0.9							Riser
2											Silica Sand
3				413.4							31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE		3.6							0.82 m Riser Stickup.
4		Note:									
		1. For coring details see Record of Drillhole BRH-0006.									
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: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0006

SHEET 1 OF 1

LOCATION: N 5422543.6 ;E 613856.8

DRILLING DATE: April 23, 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	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.	
		TOP OF BEDROCK		416.07																
1	CME 55 NQ Core	Slightly weathered, pink, coarse-grained, crystalline rock.		0.90	1								JIR JIR JIR Healed Joint JIR JIR Broken Core JIR JIR JIR Broken Core JIR JIR Broken Core JIR							Riser Bentonite Holeplug
2		Pink and grey.			2															
3		Grey.			3								FIR JIR FIR Broken Core							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		Pink.			4								JIR JIR JIR JIR							
		END OF DRILLHOLE		413.4 3.6																0.82 m Riser Stickup.

DEPTH SCALE
1 : 50

LOGGED: DA
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-0007A

SHEET 1 OF 2

LOCATION: N 5420824.6 ;E 614656.1

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	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		427.1							
0	CME 55	Cobbles and clay (FILL).		0.0							
				426.4							
1	200 mm Diam. (Hollow Stem Auger)	Slightly weathered, grey, medium-grained, crystalline rock, lots of healed joints.		0.7							
2											
3				424.1							
		Quartz, coarse-grained, pink.		3.0							
4		Quartz, coarse-grained, pink, from 3.8 m to 4.0 m depth.									
		Highly weathered, brown, from 4.3 m to 4.4 m depth. Coarse to medium-grained, grey crystalline rock, healed joints.									Bentonite Holeplug
5	CME 55 NQ Core	Quartz, pink, with occasional grey bands, from 4.9 m to 7.5 m depth.									
6											
7											
8		Green and pink quartz.									
		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.									28/10/11
9		Quartz, green, from 9.6 m from 10.1 m depth.									
10											

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0007A

SHEET 2 OF 2

LOCATION: N 5420824.6 ;E 614656.1

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	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
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 55 NQ Core	Quartz, coarse-grained, pink. Alternating greenish-grey and pink green quartz, from 10.1 m to 12.0 m depth.									
11											
12		Greenish-grey from 12.0 m to 12.4 m depth. Quartz, from 12.4 m to 13.0 m depth.									
13		Greenish-grey, with quartz and feldspar bands.									Riser
14		Pink quartz, from 14.2 m to 14.4 m depth. Coarse grained, grey crystalline rock, from 14.4 m to 14.5 m depth. Pink quartz. Brown weathering, from 14.6 m to 15.4 m depth.									
15		Quartz and feldspar from 15.4 m to 17.8 m depth.									
16											
17											Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
18		Grey, with pink veins from 17.8 m to 18.4 m depth.		408.7							
		END OF BOREHOLE		18.4							0.59 m Riser Stickup.
19		Note: 1. For coring details see Record of Drillhole BRH-0007A.									
20											

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0007A

SHEET 1 OF 2

LOCATION: N 5420824.6 ;E 614656.1

DRILLING DATE: April 22, 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		426.37																
1	CME 55 NQ Core	Slightly weathered, grey, medium-grained, crystalline rock, lots of healed joints.		0.70	1								Broken Core JCR Healed Joint Broken Core							
2					2								Healed Joint Healed Joint Broken Core JIR JIR JIR JIR JIR JIR Broken Core Broken Core							
3		Quartz, coarse-grained, pink.		424.1 3.0	3								JIR MB JIR MB JIR MB JIR							
4		Quartz, coarse-grained, pink, from 3.8 m to 4.0 m depth.											JSTR MB JIR MB							
5		Highly weathered, brown, from 4.3 m to 4.4 m depth. Coarse to medium-grained, grey crystalline rock, healed joints. Quartz, pink, with occasional grey bands, from 4.9 m to 7.5 m depth.			4								Broken Core Broken Core MB JIR JIR JUSM JISM JIR MB							Bentonite Holeplug
6					5								JISM JSTR							
7													JUR							
8		Green and pink quartz.			6								JIR JIR Broken Core							28/10/11
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		Quartz, green, 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															
		CONTINUED NEXT PAGE																		

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0007A

SHEET 2 OF 2

LOCATION: N 5420824.6 ;E 614656.1

DRILLING DATE: April 22, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING 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.	
		--- CONTINUED FROM PREVIOUS PAGE ---																		
11	CME 55 NQ Core	Quartz, coarse-grained, pink.			8								JIR JIR JIR MB MB JIR							
12		Greenish-grey from 12.0 m to 12.4 m depth. Quartz, from 12.4 m to 13.0 m depth.			9								JIR JIR							Riser
13		Greenish-grey, with quartz and feldspar bands.											MB JIR							
14		Pink quartz, from 14.2 m to 14.4 m depth. Coarse-grained, grey crystalline rock, from 14.4 m to 14.5 m depth. Pink quartz.			10								JIR JIR MB MB JIR							
15		Brown weathering, from 14.6 m to 15.4 m depth.																		
16		Quartz and feldspar from 15.4 m to 17.8 m depth.			11								JIR JIR JIR JIR JSTR JIR JIR JUR JIR MB							
17					12								JIR JIR JSTR JUR JUR JSTR MB							Silica Sand
18		Grey, with pink veins from 17.8 m to 18.4 m depth.			13 14								JIR Broken Core JIR MB JIR							31.8 mm Diam. PVC #10 Slot Screen
				408.7									MB							
		END OF DRILLHOLE		18.4																0.59 m Riser Stickup.
19																				
20																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0007B

SHEET 1 OF 1

LOCATION: N 5420825.8 ;E 614655.8

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	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		427.0							
0	CME 55	Refer to Borehole BRH-0007A for stratigraphy details.		0.0							
	200 mm Diam. (Hollow Stem Auger)			426.3							
1				0.7							
2											Riser Bentonite Holeplug
3				424.0							
	CME 55			3.0							
4	NQ Core										28/10/11
5											
6											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREOLE		420.2 6.8							0.53 m Riser Stickup.
7											
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0008A

SHEET 1 OF 2

LOCATION: N 5421030.0 ;E 611682.5

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	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 6/1/2011
		GROUND SURFACE		419.6							
0	CME 55	Wet, silty CLAY and ORGANICS.		0.0							
	200 mm Diam. (Hollow Stem Auger)			419.1							
		Highly weathered, coarse-grained, pink and grey crystalline rock.		0.5							
1											
2				417.0							
		Coarse-grained, grey, crystalline rock, slightly weathered (TONALITE).		2.6							
3											
4											
5	CME 55 NQ Core										Bentonite Holeplug
6											
7											
8											
		Pink feldspar and quartz vein.									
9		Tonalite, pink, grey, black, coarse-grained.									
		Coarse-grained, grey, crystalline rock with quartz and tonalite intrusions.									
10											

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0008A

SHEET 2 OF 2

LOCATION: N 5421030.0 ;E 611682.5

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	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
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 55 NQ Core	Coarse-grained, grey, crystalline rock, slightly weathered (TONALITE).									Riser
11											
12											
13											
14		Coarse-grained, green, crystalline rock, with quartz intrusions.									Bentonite Holeplug
15											
16											
17		Coarse-grained, grey, crystalline rock with quartz (TONALITE).									
18											
19				400.1							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
20		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0008A.		19.5							- 0.5 m Riser Stickup. - Artesian well

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0008A

SHEET 1 OF 2

LOCATION: N 5421030.0 ;E 611682.5

DRILLING DATE: April 29, 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		419.07																
1	CME 55 NQ Core	Highly weathered, coarse-grained, pink and grey crystalline rock.		0.50	1								JIR JIR JPLSM JIR JIR							
2					2								JIR JPLR							
				417.0									JIR JIR JIR Broken Core							
3		Coarse-grained, grey, crystalline rock, slightly weathered (TONALITE).		2.6	3								JISM JISM JPLSM JISM JPLSM JIR							
4													JUSM JPLSM							
5					4								JIR JUR JIR JISM							Bentonite Holeplug
6													JIR							
7					5								JUSM JIR JUR JIR							
8					6															
9		Pink feldspar and quartz vein. Tonalite, pink, grey, black, coarse-grained.																		
10		Coarse-grained, grey, crystalline rock with quartz and tonalite intrusions.			7								JPLSM JISM JPLSM JUSM JIR JISM							Riser
		CONTINUED NEXT PAGE			8															

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0008A

SHEET 2 OF 2

LOCATION: N 5421030.0 ;E 611682.5

DRILLING DATE: April 29, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING 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.	
		--- CONTINUED FROM PREVIOUS PAGE ---																		
11	CME 55 NQ Core	Coarse-grained, grey, crystalline rock, slightly weathered (TONALITE).			8								JIR JIR JIR JISM							
12					9															
13													JIR							
14		Coarse-grained, green, crystalline rock, with quartz intrusions.			10								JISM JIR JIR JIR JIR JIR JISM JIR JIR							Bentonite Holeplug
15													JIR JIR JUSM							
16					11								JPLSM JPLR JIR							
17		Coarse-grained, grey, crystalline rock with quartz (TONALITE).			12								Broken Core JIR JPLSM JPLSM JIR							
18													JIR							
19					13								JIR SJRSM JUSM JIR JIR JIR JSTR							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				400.1																
20		END OF DRILLHOLE		19.5																- 0.5 m Riser Stickup. - Artesian well

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0008B

SHEET 1 OF 1

LOCATION: N 5421026.1 ;E 611682.4

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	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		420.6							
0	CME 55 Stem Auger	Refer to Borehole BRH-0008A for stratigraphy details.		0.0							
				420.1							
	200 mm Diam. (Hollow			0.5							
1											28/10/11 ▽
2											Bentonite Holeplug
				418.0							Riser
				2.6							
3	CME 55 NQ Core										
4											
											Silica Sand
5											31.8 mm Diam. PVC #10 Slot Screen
				414.9							
		END OF BOREHOLE		5.7							0.67 m Riser Stickup.
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: DA

CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0009

SHEET 1 OF 1

LOCATION: N 5421289.5 ;E 613877.5

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	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		416.3							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose, wet, brown CLAY and ORGANICS, some cobbles.		0.0 / 415.8	1	50 DO	9				
1	CME 55 200 mm Diam. (Hollow Stem Auger)	BOULDERS.		0.5 / 413.6							28/10/11 ▽
3	CME 55 NQ Core	Highly weathered and fractured, (BEDROCK).		2.7 / 411.7							Bentonite Holeplug Riser
4	CME 55 NQ Core	Coarse-grained, grey, slightly weathered, porous.		4.6 / 411.1							
5	CME 55 NQ Core	Pink, coarse-grained, crystalline rock.		5.2 / 408.7							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0009.		7.6							0.7 m Riser Stickup.

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DA

CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0009

SHEET 1 OF 1

LOCATION: N 5421289.5 ;E 613877.5

DRILLING DATE: April 23, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING 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	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.	
		TOP OF BEDROCK		415.77																
				0.50	1															28/10/11
1																				
					2															
2																				
					3															Riser Bentonite Holeplug
3																				
	CME 55																			
4	NQ Core																			
		Coarse-grained, grey, slightly weathered, porous, metamorphozed.			4								JIR							
5		Large quartz crystals.											JIR							
				411.1									Broken Core							
		Pink, coarse-grained, crystalline rock, QUARTZ and FELDSPAR, metamorphozed.		5.2									JIR							
													JIR							
6													JIR							
					5								JIR							
													JIR							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7													JIR							
													Broken Core							
													JIR							
													JIR							
													JIR							
													Broken Core							
					6								JIR							
				408.7									JIR							
		END OF DRILLHOLE		7.6																0.7 m Riser Stickup.
8																				
9																				
10																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0010

SHEET 1 OF 1

LOCATION: N 5423654.2 ;E 615227.5

DRILLING DATE: April 20, 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		436.10																
0	CME 55 / NQ Core	Moderately weathered, medium-grained, greenish-grey, crystalline rock.		0.00	1								Broken Core							Bentonite Holeplug
													Broken Core							
													JIR							
													JIR							
													JIR							
1													JIR							Riser 29/10/11
													Broken Core							
													JIR							
													Broken Core							
													JIR							
													Void							
													Broken Core							
					2								JIR							Silica Sand
													JIR							
													Broken Core							31.8 mm Diam. PVC #10 Slot Screen
2													JIR							
													JIR							
													JIR							
													Broken Core							
				433.4									FSTSM							
		END OF DRILLHOLE		2.7																0.59 m Riser Stickup.
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0011

SHEET 1 OF 1

LOCATION: N 5421918.9 ;E 615104.5

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	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		434.2							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Wet, brown, SAND, some clay, some organics, trace boulders.		0.0							
		Dense, wet, brown, SAND and GRAVEL.		433.3	1	50 DO	-				
1		GRAVEL and COBBLES.		0.9 433.1							
	CME 55 NQ Core	Slightly weathered, coarse-grained, crystalline rock, (TONALITE).		1.1							Bentonite Holeplug Riser
2											
3											28/10/11
		Slightly weathered, grey, medium-grained, crystalline rock.									
4											Silica Sand
				429.7							
		Pink, coarse-grained, quartz.		4.5							31.8 mm Diam. PVC #10 Slot Screen
5											
				428.7							
		END OF BOREHOLE		5.5							0.85 m Riser Stickup.
		Note:									
6		1. For coring details see Record of Drillhole BRH-0011.									
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: DA

CHECKED: MO

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0011

SHEET 1 OF 1

LOCATION: N 5421918.9 ;E 615104.5

DRILLING DATE: April 21, 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		433.12																
	CME 55 NQ Core	Slightly weathered, coarse-grained, crystalline rock, (TONALITE).		1.10	1								JIR JUS Broken Core							Riser
2					2								JIR							Bentonite Holeplug
													JIR JIR							
3					3								JIR JIR							
		Slightly weathered, grey, medium-grained, crystalline rock.											JIR JIR JIR JIR JIR JIR JIR JIR JIR							28/10/11
4				429.7																Silica Sand
		Pink, coarse-grained, quartz.		4.5	4								JIR JIR JUR							31.8 mm Diam. PVC #10 Slot Screen
5				428.7									JIR							
		END OF DRILLHOLE		5.5																0.85 m Riser Stickup.
6																				
7																				
8																				
9																				
10																				
11																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0012A

SHEET 1 OF 1

LOCATION: N 5422185.1 ;E 615588.5

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	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		416.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Compact to very dense, wet, brown, Gravelly SAND, some clay, trace silt.		0.0							Bentonite Holeplug
1					1	50 DO	12				Riser 29/10/11
2					2	50 DO	50			MH	
				414.4							
		GRAVEL, BOULDERS, COBBLES, and SAND.		2.5	3	50 DO	71				Silica Sand
3				413.5							
4	CME 55 NQ Core	Slightly weathered, coarse-grained, greenish-grey with pink and white, sheared, VOLCANICS (BEDROCK).		3.4							
				411.9							31.8 mm Diam. PVC #10 Slot Screen
5		Slightly weathered, white and pink with grey, sheared, VOLCANICS, metal pockets.		5.0							
				411.2							
		END OF BOREHOLE		5.7							BRH-0012A 0.88 m Riser Stickup.
6		Note:									
		1. For coring details see Record of Drillhole BRH-0012A.									
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: DA

CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0012A

SHEET 1 OF 1

LOCATION: N 5422185.1 ;E 615588.5

DRILLING DATE: April 20, 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		413.47																
4	CME 55 NQ Core	Slightly weathered, coarse-grained, greenish-grey with pink and white, sheared, VOLCANICS (BEDROCK).		3.40	1								BIR BIR							
													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.		411.9 5.0	2								JIR							
		END OF DRILLHOLE		411.2 5.7																BRH-0012A 0.88 m Riser Stickup.
6																				
7																				
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: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0012B

SHEET 1 OF 1

LOCATION: N 5422185.1 ;E 615588.5

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. +, 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		416.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0012A for stratigraphy details.		0.0							Bentonite Holeplug
1					1	50 DO	12				Riser 29/10/11
2					2	50 DO	50				Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
				414.4							
				2.5	3	50 DO	71				
3				413.5							
	CME 55 NQ Core			3.4							
4											
5				411.9							
				5.0							
				411.2							
		END OF BOREHOLE		5.7							BRH-0012B 0.86m Riser Stickup.
6		Note: 1. Monitoring well installation in same Borehole as BRH-0012A.									
7											
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0013

SHEET 1 OF 1

LOCATION: N 5422933.2 ;E 615631.1

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	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 WI) (16 32 48 64)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		416.6							29/10/11 ▽
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Dense, wet, brown, Gravelly SAND, some clay, trace silt.		0.0							
1				415.3	1	50 DO	37			MH	Bentonite Holeplug
2	CME 55 NQ Core	Slightly weathered, medium-grained, pink, crystalline rock, feldspar, quartz, and pyrite cubes (BEDROCK).		1.3							Riser
3				413.6							
4		Slightly weathered, medium-grained, grey and pink, crystalline rock, feldspar, quartz.		3.0							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				412.3							
5		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0013.		4.3							0.7 m Riser Stickup.
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: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0013

SHEET 1 OF 1

LOCATION: N 5422933.2 ;E 615631.1

DRILLING DATE: April 20, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING 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		415.27																
2	CME 55 NQ Core	Slightly weathered, medium-grained, pink, crystalline rock, feldspar, quartz, and pyrite cubes (BEDROCK).		1.30	1								Broken Core JIR JIR JIR JISTR JIR Broken Core JIR JIR JIR JIR JIR Broken Core							Bentonite Holeplug Riser
3				413.6																
	CME 55 NQ Core	Slightly weathered, medium-grained, grey and pink, crystalline rock, feldspar, quartz.		3.0	2								JIR JIR JIR JIR							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
4				412.3																
		END OF DRILLHOLE		4.3																0.7 m Riser Stickup.
5																				
6																				
7																				
8																				
9																				
10																				
11																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0014A

SHEET 1 OF 1

LOCATION: N 5422217.6 ;E 617147.4

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	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		416.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose, wet, brown, fibrous, PEAT.		0.0	1	50 DO	8		1014.5		29/10/11 Cement
				416.1							
1		Firm, moist, light brown, varved, CLAY, trace silt, trace sand.		0.8	2	50 DO	5				
											Bentonite Holeplug
2					3	50 DO	5			MH	
											Riser
3					4	50 DO	3			MH	
				413.1							
4		Compact, wet, grey, silty SAND, some gravel.		3.8	5	50 DO	21				
				412.3							
5		Compact, wet, grey, coarse, SAND and GRAVEL, some clay, trace silt, trace cobbles.		4.6	6	50 DO	30			MH	
				411.8							
	CME 55 NQ Core	Slightly weathered, grey, medium to coarse-grained, crystalline, medium to strong rock, (TONALITE).		5.1							Bentonite Holeplug
6											Silica Sand
7											
8											31.8 mm Diam. PVC #10 Slot Screen
				408.1							
9		END OF BOREHOLE		8.8							0.9 m Riser Stickup.
		Note:									
		1. For coring details see Record of Drillhole BRH-0014A.									
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0014A

SHEET 1 OF 1

LOCATION: N 5422217.6 ;E 617147.4

DRILLING DATE: April 8, 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		411.76																
6	CME 55 NQ Core	Slightly weathered, grey, medium to coarse-grained, crystalline, medium to strong rock, (TONALITE) (BEDROCK).		5.10	1								Crushed with clay in seams Crushed with clay in seams JISTR JIR Crushed with clay in seams Crushed with clay in seams JIR							Bentonite Holeplug
7					2								JPLSM JPLSM JPLSM JPLSM JPLS JPLSM JPLSM JPLSM JPLSM JIR JPLSM Intensly Fractured Intensly Fractured JPLSM							Silica Sand
8					3								JPLSM JPLR JPLR JPLR JPLR JPLR JPLR JPLR JIR JPLR							31.8 mm Diam. PVC #10 Slot Screen
				408.1																
9		END OF DRILLHOLE		8.8									Intensly Fractured Intensly Fractured							0.9 m Riser Stickup.
10																				
11																				
12																				
13																				
14																				
15																				

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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0014B

SHEET 1 OF 1

LOCATION: N 5422217.6 ;E 617147.4

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	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		416.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0014A for stratigraphy details.		0.0							Cement; 29/10/11
				416.1							
1				0.8							Bentonite Holeplug
2											
				414.3							Riser
3				2.6							
				413.1							Silica Sand
4				3.8							31.8 mm Diam. PVC #10 Slot Screen
				412.3							
				4.6							
5				411.8							
	CME 55 NQ Core			5.1							
6											
7											
8				408.1							
		END OF BOREHOLE		8.8							0.9 m Riser Stickup.
9		Note: 1. Monitoring well installation in same Borehole as BRH-0014A.									
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0015A

SHEET 1 OF 1

LOCATION: N 5423186.0 ;E 617874.5

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	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		417.3							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Firm, moist, reddish brown, CLAY, trace silt, trace sand, trace gravel.		0.0	1	50 DO	-				29/10/11
1		Occasional 1-2 mm grey silt seams.			2	50 DO	6			MH	
					3	50 DO	7				Bentonite Holeplug
2					4	50 DO	2				
				414.3							Riser
3		Very soft, wet, grey, Clay, some silt, trace sand		3.0	5	50 DO	WH			MH	
4					6	50 DO	3				
				412.7							Silica Sand
		Compact, grey, wet, fine to coarse, SAND, some gravel, trace silt.		4.6	7	50 DO	13				
5				411.5							
6	CME 55 NQ Core	Slightly weathered, medium-grained, crystalline rock (BEDROCK).		5.8							Bentonite Holeplug
		Coarse, white vein.									
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.		408.6							31.8 mm Diam. PVC #10 Slot Screen
		END OF BOREHOLE		8.7							0.84 m Riser Stickup.
9		Note: 1. For coring details see Record of Drillhole BRH-0015.									
10											

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0015A

SHEET 1 OF 1

LOCATION: N 5423186.0 ;E 617874.5

DRILLING DATE: April 19, 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		411.50																
6	CME 55 NQ Core	Slightly weathered, medium-grained, crystalline rock.		5.80	1								JIR							Bentonite Holeplug
													JIUR							
													FOIR							
													JIR							
		Coarse, white vein.			2								JSTR							
		Coarse, white vein.											JSTR							
7		Coarse grained, grey, slightly weathered crystalline rock.											JIR							
													JIR							
													JIR							
													JIR							
													JSTR							
													JIR							
													JIR							
													JIR							
													Broken Core							
													JIR							Silica Sand
													JIR							
8													JIR							31.8 mm Diam. PVC #10 Slot Screen
													JIR							
													JIR							
													FOIR							
		Pink feldspar and quartz vein, slightly weathered.			3								JIR							
		Grey, coarse grained, slightly weathered. Pink feldspar and quartz.											JIR							
				408.6									JIR							
		END OF BOREHOLE		8.7																0.84 m Riser Stickup.
9																				
10																				
11																				
12																				
13																				
14																				
15																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0015B

SHEET 1 OF 1

LOCATION: N 5423186.0 ;E 617874.5

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	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. +, 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		417.3							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0015A for stratigraphy details.		0.0	1	50 DO	-				29/10/11
1					2	50 DO	6			MH	
					3	50 DO	7				Bentonite Holeplug
2					4	50 DO	2				
				414.3							Riser
3				3.0	5	50 DO	WH			MH	
4					6	50 DO	3				
				412.7							Silica Sand
				4.6	7	50 DO	13				31.8 mm Diam. PVC #10 Slot Screen
5				411.5							
6	CME 55 NQ Core			5.8							
7											
8				408.6							
		END OF BOREHOLE		8.7							0.76 m Riser Stickup.
9		Note:									
		1. Monitoring well installation in same Borehole as BRH-0015A.									
10											

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DA
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0016A

SHEET 1 OF 1

LOCATION: N 5425303.2 ;E 618407.5

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		444.8							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose, moist, brown, SANDY, CLAYEY SILT, trace organics.		0.0	1	50 DO	PL		○	MH	Cement Bentonite Holeplug Silica Sand
1		Dense, wet, brownish grey, medium to coarse, Gravelly, SILTY SAND, some clay.		443.7 1.1 443.3	2	50 DO	37		○	MH	Bentonite Holeplug ▽ 26/10/11
2	CME 55 NQ Core	Slightly weathered, bedding, grey, coarse-grained, crystalline, medium strong rock (TONALITE).		1.5							
3											
4											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
5				439.1							
6		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0016.		5.7							0.77 m Riser Stickup.
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0016A

SHEET 1 OF 1

LOCATION: N 5425303.2 ;E 618407.5

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		443.30																
2	CME 55 NQ Core	Slightly weathered, bedding, grey, coarse-grained, crystalline, medium strong rock (TONALITE).		1.50	1								JSTR JIR JUR JIR JPLR JIR							Bentonite Holeplug
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															
				439.1																
6		END OF DRILLHOLE		5.7																0.77 m Riser Stickup.
7																				
8																				
9																				
10																				
11																				

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0016B

SHEET 1 OF 1

LOCATION: N 5425303.2 ;E 618407.5

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. +, 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		444.8							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0016A for stratigraphy details.		0.0							Cement Bentonite Holeplug
1				443.7							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen 26/10/11
				1.1							
	CME 55 NQ Core			443.3							
2				1.5							
3											
4											
5				439.1							
		END OF BOREHOLE		5.7							0.72 m Riser Stickup.
6		Note: 1. Monitoring well installation in same Borehole as BRH-0016A.									
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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. +, 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		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													
6													Silica Sand; 31.8 mm Diam. PVC #10 Slot Screen
7				417.4									
		END OF BOREHOLE		7.2									0.84 m Riser Stickup.
8		Note: 1. For coring details see Record of Drillhole BRH-0017A.											
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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																				

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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: TDM

CHECKED: MO

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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. +, 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		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						
		Compact, moist, brown to grey, silty SAND, trace to some gravel.		429.2 1.4	3	50 DO	50/ 0.28						27/10/11
2	CME 55 NQ Core	Fresh, grey, very coarse-grained, crystalline, strong rock (quartz GRANITE)		428.8 1.8									Bentonite Holeplug
3													Riser
4													
5													
6													31.8 mm Diam. PVC #10 Slot Screen
7													Silica Sand
8				421.9									
9		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0018.		8.7									0.97 m Riser Stickup.
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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							
6					4															31.8 mm Diam. PVC #10 Slot Screen
																				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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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		W	MH	
				429.1							Riser
		Wet, brown, layered, clayey SILT, some sand, oxidized mottling.		1.5	3	50 DO	25				
2											Cuttings
					4	50 DO	28		W	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		W		Bentonite Holeplug
					7	50 DO	27			MH	
5											
					8	50 DO	15		W	MH	
6											Silica Sand
					9	50 DO	15				31.8 mm Diam. PVC #10 Slot Screen
7					10	50 DO	11		W		
				423.0							
		Wet, brown, medium to coarse, granitic, SAND, trace silt.		7.6							
8					11	50 DO	2				
				422.2							Cave
		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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0020A

SHEET 1 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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		416.5							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	TOPSOIL		0.0 / 416.3							Cement
		Wet, reddish-brown, SAND, little silt, trace organics.		0.2 / 415.7	1	50 DO	4				
1		Moist to wet, layered, greyish-brown, CLAY and SILT.		0.8	2	50 DO	5				Bentonite Holeplug
					3	50 DO	4		229.82		
2				414.2					268.13		Riser
		Wet, layered, greyish, CLAYEY SILT.		2.3	4	50 DO	3				
3					5	50 DO	4		143.64		
									162.79		
4					6	50 DO	3				
					7	50 DO	2		149.39		
5									124.49		
					8	50 DO	2				Backfill Cuttings
6					9	50 DO	3		134.06		
									143.64		
7					10	50 DO	3				
					11	50 DO	3		114.91		
8									114.91		
9				407.4							
		Wet, reddish-brown, CLAY, some silty clay layers, trace to little sand.		9.1	12	50 DO	WH		162.79		
									134.06		
10		*CONTINUED NEXT PAGE*									

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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0020A

SHEET 2 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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
10		*--- CONTINUED FROM PREVIOUS PAGE ---*									
	CME 55 200 mm Diam. (Hollow Stem Auger)	Wet, reddish-brown, CLAY, some silty clay layers, trace to little sand.			13	50 DO	PH				
11											
				404.7							
		Wet, layered, grey, SILTY CLAY.		11.8	14	50 DO	1				Backfill Cuttings
12											
				403.2							
13		Wet, layered, grey, SILT, some clay, trace sand.		13.3	15	50 DO	WH				
14											
				401.7							
		Wet. grey-brown, gravelly SAND, little silt, trace to little clay.		14.8	16	50 DO	20				
15											
				400.7							
		SAND with boulders.		15.8							
16											
17											Cave
18											
19											
20		*CONTINUED NEXT PAGE*									

143.64
153.22
153.22
114.91

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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0020A

SHEET 3 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	CME 55 200 mm Diam. (Hollow Stem Auger)	SAND with boulders.									
21											
22											Cave
23											
24											
25											Bentonite Holeplug
				390.9							
	CME 55 NQ Core	Greyish-green, fresh, porphritic, TONALITE, with quartz / feldspar veins.		25.6							Silica Sand
26											
27											
28											31.8 mm Diam. PVC #10 Slot Screen
				387.6							
29		END OF BOREHOLE		28.9							0.8 m Riser Stickup.
30											

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0020A

SHEET 1 OF 1

LOCATION: N 5426576.0 ;E 617958.1

DRILLING DATE: March 19, 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		390.91																	
26	CME 55 NQ Core	Greyish-green, fresh, porphritic, TONALITE, with quartz / feldspar veins.		25.60	1									JUER JPLR JPLR JPLR JNPLR							Silica Sand
27					2									JPLR							31.8 mm Diam. PVC #10 Slot Screen
28					3									Broken Core Broken Core JPLR JPLR							
				387.6																	
29		END OF DRILLHOLE		28.9																	0.8 m Riser Stickup.
30																					
31																					
32																					
33																					
34																					
35																					

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0020B/C

SHEET 1 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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		416.5							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	TOPSOIL		0.0 / 416.3							Cement
		Wet, reddish-brown, SAND, little silt, trace organics.		0.2 / 415.7	1	50 DO	4				
1		Moist to wet, layered, greyish-brown, clayey SILT, trace sand.		0.8	2	50 DO	5				Bentonite Holeplug
					3	50 DO	4		229.82 / 268.13		
2				414.2							Riser
		Wet, layered, greyish, silty CLAY, trace sand.		2.3	4	50 DO	3				
3					5	50 DO	4		143.64 / 162.79		
4					6	50 DO	3				
					7	50 DO	2		149.39 / 124.49		
5					8	50 DO	2				Backfill Cuttings
6					9	50 DO	3		134.06 / 143.64		
7					10	50 DO	3				
					11	50 DO	3		114.91 / 114.91		
8											
9				407.4							
		Wet, reddish-brown, CLAY, some silty clay layers, trace to little sand.		9.1	12	50 DO	WH		162.79 / 134.06		
10		*CONTINUED NEXT PAGE*									

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-0020B/C

SHEET 2 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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 55 200 mm Diam. (Hollow Stem Auger)	Wet, reddish-brown, CLAY, some silty clay layers, trace to little sand.									
					13	50 DO	PH				
11											
				404.7							
		Wet, layered, grey, silty CLAY, trace sand.		11.8	14	50 DO	1				
12											
				403.2							
13		Wet, layered, grey, SILT, some clay, trace sand.		13.3	15	50 DO	WH				Backfill Cuttings
14											
				401.7							
15		Wet. grey-brown, gravelly SAND, little silt, trace to little clay.		14.8	16	50 DO	20				Bentonite Holeplug
				400.7							
16		SAND with boulders.		15.8							
17											
18											Silica Sand
19											31.8 mm Diam. PVC #10 Slot Screen
20		*CONTINUED NEXT PAGE*									

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0020B/C

SHEET 3 OF 3

LOCATION: N 5426576.0 ;E 617958.1

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	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
20		*--- CONTINUED FROM PREVIOUS PAGE ---*									
	CME 55	SAND with boulders.		395.8							Cave
		END OF BOREHOLE		20.7							
21											
22											
23											
24											
25											
26											
27											
28											
29											0.72 m Riser Stickup.
30											

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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0021A

SHEET 1 OF 1

LOCATION: N 5427168.0 ;E 617175.1

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)	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		420.4							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Topsoil (HUMUS/ORGANICS).		0.0							Cement
				419.8							Cuttings 26/10/11
		Moist to wet, dark brown, silty SAND and ORGANICS.		0.6							
1					1	50 DO	13		○		Bentonite Holeplug
				419.2							
		Moist, brown, layered, SANDY, CLAYEY SILT, oxidization throughout.		1.2							Riser
					2	50 DO	29		○	MH	
2				418.1							Silica Sand
		Wet, compact, grey-brown, SILT, trace sand.		2.3							
				417.8	3	50 DO	48				
		Wet, compact, brown, SAND, some gravel, little silt, trace cobbles.		2.6							
				417.4							
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							
											Bentonite Holeplug
4											
5											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				414.5							
6		END OF BOREHOLE BEDROCK REFUSAL		5.9							0.98 m Riser Stickup.
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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0021A

SHEET 1 OF 1

LOCATION: N 5427168.0 ;E 617175.1

DRILLING DATE: March 17, 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		417.41																
3	CME 55 NQ Core	Light to dark green and grey, fresh, porphyritic, TONALITE, pinkish alteration zones (hematite) and quartz / feldspar veins throughout.		3.00	1								JUER							Silica Sand; Bentonite Holeplug
4													JPLSM; JPLSM; JPLSM; JPLSM							
5					2								JPLSM; JPLSM; JPLSM; Broken Core							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
													JUER; JPLSM; JPLSM							
				414.5									JCSM							
6		END OF BOREHOLE BEDROCK REFUSAL		5.9																0.98 m Riser Stickup.
7																				
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: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0021B

SHEET 1 OF 1

LOCATION: N 5427168.0 ;E 617175.1

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	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		420.4							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Refer to Borehole BRH-0021A for stratigraphy details.		0.0							Cement; Cuttings
				419.8							
1				0.6							26/10/11; Bentonite Holeplug
				419.2							
				1.2							Riser
2				418.1							31.8 mm Diam. PVC #10 Slot Screen; Silica Sand
				2.3							
				417.8							
				2.6							
				417.4							
3				3.0							
	CME 55 NQ Core										Bentonite Holeplug
4											
5											Silica Sand
				414.5							
6		END OF BOREHOLE Note: 1. Monitoring well installation in same Borehole as BRH-0021A.		5.9							0.98 m Riser Stickup.
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: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0022

SHEET 1 OF 1

LOCATION: N 5428214.5 ;E 618039.6

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	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
0	CME 55 200 mm Diam. (Hollow Stem Auger)	GROUND SURFACE		430.6							
		Moist to wet, brown, gravelly SAND, some cobbles / boulders, trace silt.		0.0	1	50 DO	50/ 0.1				Silica Sand
		Greyish-green, fresh, porphyritic, TONALITE, with pinkish alteration zones (hematite) throughout and trace quartz / feldspar veins.		0.1							
1											Riser ▽ 26/10/11
2											Bentonite Holeplug
3	CME 55 NQ Core										
4											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
5				425.2							
		END OF BOREHOLE		5.4							0.79 m Riser Stickup.
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: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0022

SHEET 1 OF 1

LOCATION: N 5428214.5 ;E 618039.6

DRILLING DATE: March 17, 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	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.	
		GROUND SURFACE		430.53																
0	CME 55 / NQ Core	Greyish-green, fresh, porphyritic, TONALITE, with pinkish alteration zones (hematite) throughout and trace quartz / feldspar veins.		0.10	1								JSMPL JRW JSMPL							Silica Sand
1													JUER JSMPL							Riser Bentonite Holeplug 26/10/11
					2								JSMPL JUER							
2													JPLSM JPLSM JPLSM							
					3								JUER JSMPL							
3													JPLR UNPLR Broken Core JPLSM JPLSM							Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
4													JUER JPLSM							
					4								JPLSM							
5				425.2									JUER JUER JPLSM							
		END OF BOREHOLE BEDROCK REFUSAL		5.4																0.79 m Riser Stickup.
6																				
7																				
8																				
9																				
10																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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. + 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		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	1	50 DO	11		○	MH	Bentonite Holeplug; Riser
1				433.6							
		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	2	50 DO	21		○	MH	
2				432.6							
		SAND and BOULDERS, some gravel, trace silt.		2.3	3	50 DO	32				Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
				432.2							
		Gravelly SAND, some silt, trace clay.		2.7							
3					4	50 DO	8		○	MH	
				431.3							Cave In
		END OF BOREHOLE PROBABLE BEDROCK REFUSAL		3.6							0.9 m Riser Stickup.
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: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0024

SHEET 1 OF 1

LOCATION: N 5429045.7 ;E 621017.2

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. + 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		435.4							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Dry, brown, gravelly SAND and BOULDERS, trace silt.		0.0							Concrete
				434.4	1	50 DO	50/ 0.2				
1	CME 55 NQ Core	Fresh to slightly weathered, greenish-grey, porphyritic, TONALITE, hematite and fledspar veins throughout.		1.0							Riser
2											Bentonite Holeplug
3											
4											27/10/11
5											
6											Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
7				428.2							
		END OF BOREHOLE Note: 1. For coring details see Record of Drillhole BRH-0024A.		7.2							0.95 m Riser Stickup.
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: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0024

SHEET 1 OF 1

LOCATION: N 5429045.7 ;E 621017.2

DRILLING DATE: March 26, 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		434.36																
1	CME 55 NQ Core	Fresh to slightly weathered, greenish-grey, porphyritic, TONALITE, hematite and fledspar veins throughout.		1.00	1								JPLR JPLR							Riser
2													JPLR JPLR JUER JPLR							Bentonite Holeplug
3					2								JPLR							
4													Void Void JPLR Void Void							27/10/11
5					3								Void JUER JUER JPLR Broken Core							Silica Sand
6					4								JPLR JWR JPLR Void							31.8 mm Diam. PVC #10 Slot Screen
7				428.2																
		END OF DRILLHOLE		7.2																0.95 m Riser Stickup.
8																				
9																				
10																				
11																				

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0025

SHEET 1 OF 1

LOCATION: N 5430265.1 ;E 621269.2

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	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		443.3							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Wet, dark brown, PEAT (ORGANICS).		0.0							
1				442.1	1	50 DO	3				
		Wet, dark brown, ORGANICS and silty SAND, little gravel.		1.2 / 441.8							▽ 27/10/11
		Wet, greyish, silty SAND and COBBLES.		1.5 / 441.6	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 21/09/12 DATA INPUT:

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MO
CHECKED: MO

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF BOREHOLE: BRH-0026

SHEET 1 OF 1

LOCATION: N 5431226.5 ;E 620606.8

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

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		460.9							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	ORGANICS.		0.0 / 460.7							
0	CME 55 200 mm Diam. (Hollow Stem Auger)	Loose to compact, moist, light brown, SAND and GRAVEL, some silt, trace clay, some cobbles and boulders.		0.2	1	50 DO	11				
1	CME 55 200 mm Diam. (Hollow Stem Auger)				2	50 DO	28			MH	Silica Sand; Riser; 5/31/2011
1	CME 55 200 mm Diam. (Hollow Stem Auger)			459.4							
2	CME 55 NQ Core	Slightly weathered, grey, fine-grained, crystalline, weak rock (BEDROCK).		1.5 / 458.7							Bentonite Holeplug
2	CME 55 NQ Core	Slightly weathered, grey, fine-grained, crystalline, medium-strong rock (BEDORCK). Sheared volcanics.		2.2							
6	CME 55 NQ Core										Silica Sand
7	CME 55 NQ Core										31.8 mm Diam. PVC #10 Slot Screen
8	CME 55 NQ Core			452.2							
9		Note: 1. For coring details see Record of Drillhole BRH-0026.		8.7							0.8 m Riser Stickup.
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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 10-1118-0020 / 4000

RECORD OF DRILLHOLE: BRH-0026

SHEET 1 OF 1

LOCATION: N 5431226.5 ;E 620606.8

DRILLING DATE: March 29, 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		459.38																
	CME 55 NQ Core	Slightly weathered, grey, fine-grained, crystalline, weak rock.		1.50									Closely Fractured							5/31/2011
2				458.7	1								Closely Fractured							Bentonite Holeplug
		Slightly weathered, grey, fine-grained, crystalline, medium-strong rock. Sheared volcanics.		2.2									Closely Fractured							
3					2								Closely Fractured							
													JIR							
													JIR							
													JIR							
4													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
5					3								JIR							
													JIR							
													JIR							
													JUSM							
													JISM							
													JIR							
													JIR							
													JIR							Silica Sand
6					4								JIR							
													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
													JUSM							
7													JUSM							
													JIR							
													JIR							31.8 mm Diam. PVC #10 Slot Screen
													JIR							
					5								JUR							
													JIR							
8													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
													JIR							
				452.2									JIR							
		END OF DRILLHOLE		8.7																0.8 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:

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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 / 433.1	2	50 DO	8		○	MH	Bentonite Holeplug Riser Silica Sand 31.8 mm Diam. PVC #10 Slot Screen
2		Compact, wet, grey, coarse, SILTY SAND, some gravel, some clay.		1.7 / 432.4	3	50 DO	13		○		
					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											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TDM
CHECKED: MO

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

HYDROGEOLOGY TSD
APPENDIX 2.III
VERSION 1

Attachment 2.III.2

Record of Borehole and Record of Drillhole Logs for 2012 Drilling Program

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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	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
0		GROUND SURFACE		436.84							
	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	PEAT (100 mm)		0.00 / 436.74							
		(ML) SILT and SAND, trace gravel, zones of clayey silt; dark brown to brown, organic inclusions; moist, very loose		0.10	1	50 DO	3			MH/NP	50 mm Diameter Monitoring Well
				436.15							
		(SM) SILTY SAND, some gravel; brown; moist, compact		0.69	2A	50 DO	19			MH	
1				435.93							
		(SP) SAND, medium grained, some fines, trace gravel; brown; wet, compact		0.91	2B						Bentonite Seal
				435.62							
	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-1		1.22							
2											
3											Silica Sand Filter
4				432.65							
		END OF BOREHOLE		4.19							
5											

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:

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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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

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		433.11							
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(PT) PEAT and TOPSOIL		0.00 / 432.81	1A	50 DO	2			787.8	50 mm Diameter Monitoring Well
		(SM) SILTY SAND; grey (PROBABLE FILL); moist, very loose		0.30 / 432.42	1B						Bentonite Seal
1		(CL) SILTY CLAY, some sand, trace gravel, organically stained, peat and organic inclusions, dark brown to brown (PROBABLE FILL); moist, firm		0.69 / 431.74	2	50 DO	6				
2		(SM) SILTY SAND, trace to some gravel, containing cobbles and boulders, rock fragments; grey; moist, compact		1.37	3	50 DO	19				Silica Sand Filter
					4	50 DO	50/ .15				
3				429.96	5	50 DO	50/ .10				
		END OF BOREHOLE DUE TO AUGER REFUSAL ON PROBABLE BEDROCK		3.15							
4											
5											
6											
7											
8											
9											
10											

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:

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

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January 2018 – 1656263

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-2

SHEET 1 OF 2

LOCATION: SEE FIGURE 2

BORING DATE: August 12 and 13, 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	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		418.40					
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(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
				417.71					
1		(ML) sandy SILT; brown, zones of silt, zones of clayey silt; moist to wet, compact to very loose		0.69	2	50 DO	12		
					3	50 DO	8		
2					4	50 DO	2	MH	
				415.50					
3		(ML) CLAYEY SILT, trace sand; brown to grey, zones of sandy silt; cohesive, Wn>PL, soft to firm		2.90	5	50 DO	2		
4									
5					6	50 DO	2	MH	Bentonite Seal
				412.84					
6		(CI) SILTY CLAY, trace fine sand; medium plasticity; red-brown to grey; cohesive, Wn>PL, firm		5.56	7	50 DO	WH	MH	
7					8	75 TO	-		
8									
				409.79					
9		(ML) SILT, trace to some fine sand; grey; wet, compact to loose		8.61	9	50 DO	12		
10									

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

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

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January 2018 – 1656263

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-2

SHEET 2 OF 2

LOCATION: SEE FIGURE 2

BORING DATE: August 12 and 13, 2012

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

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

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; 10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10		*--- CONTINUED FROM PREVIOUS PAGE ---*									
10	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(ML) SILT, trace to some fine sand; grey; wet, compact to loose			10	50 DO	13			MH	Bentonite Seal
11											
12					11	50 DO	5				
13				405.22							
		(SM) SILTY SAND and GRAVEL, rock fragments; grey; wet, compact		13.18							
14					12	50 DO	14				Silica Sand Filter
15				403.26							
	NQ CORING	For bedrock coring details refer to Record of Drillhole BH 12-2		15.14							
16											
17											
18				400.11							
		END OF BOREHOLE		18.29							
19											
20											

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:

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

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January 2018 – 1656263

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

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
				419.69							
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	GROUND SURFACE		-0.20							
		(PT) PEAT; black, wood fragments; wet, very loose			1	50 DO	WH		301		50 mm Diameter Monitoring Well
1					2	50 DO	1		134.2		
				418.12							
		(ML) SILT and SAND, trace gravel; grey; moist, loose		1.37	3	50 DO	6			MH	
2				417.36							
		(ML) SILT, some sand; grey; wet, loose		2.13	4	50 DO	8			MH	
3					5	50 DO	8			MH/NP	
4				415.22							
		(Cl) SILTY CLAY, medium plasticity, trace sand; red-brown to grey; cohesive, Wn>PL, soft to firm		4.27	6	50 DO	1				Bentonite Seal
5											
6					7	50 DO	WH		55.6	MH	
7											
8					8	50 DO	1		65.9	MH	
				410.65							
9		(ML) SILT, trace fine sand; grey; wet, compact to loose		8.84	9	50 DO	16			MH/NP	

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AM
CHECKED:

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Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

PROJECT: 11-1118-0074

RECORD OF BOREHOLE: BH 12-3A

SHEET 2 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

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) (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	(ML) SILT, trace fine sand; grey; wet, compact to loose									
					10	50 DO	7				
11				407.83							
		(ML) SILT and SAND, some gravel; grey (TILL-LIKE), compact		11.66							
12											Bentonite Seal
					11	50 DO	15			MH	
13				406.08							
	NQ CORING 100 mm Dia. Casing	For bedrock coring details refer to Record of Drillhole BH 12-3A		13.41							
14											
15											Silica Sand Filter
16				403.03							
		END OF BOREHOLE		16.46							
17											
18											
19											

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:

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

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January 2018 – 1656263

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	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
0	TRACK MOUNTED POWER AUGER 200 mm Dia. Hollow Stem Augers	GROUND SURFACE		-0.20							▽
0		For soil details refer to Record of Borehole BH 12-3A									50 mm Diameter Monitoring Well
1											
2											
3											
4											Bentonite Seal
5											
6											
7					1	75 TO -			53.7		
8											
9											
10											
11											Silica Sand Filter
11		END OF BOREHOLE		11.58							
12											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

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DEPTH SCALE
1 : 65

Golder Associates

LOGGED: AM

CHECKED:

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January 2018 – 1656263

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 - ○)	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

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

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
		(PT) Fiberos (PEAT); black; wet, very loose		0.30	1B		
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			
				425.28	8	50 DO	50/ .13
	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

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

HYDROGEOLOGY TSD
APPENDIX 2.III
VERSION 1

Attachment 2.III.3

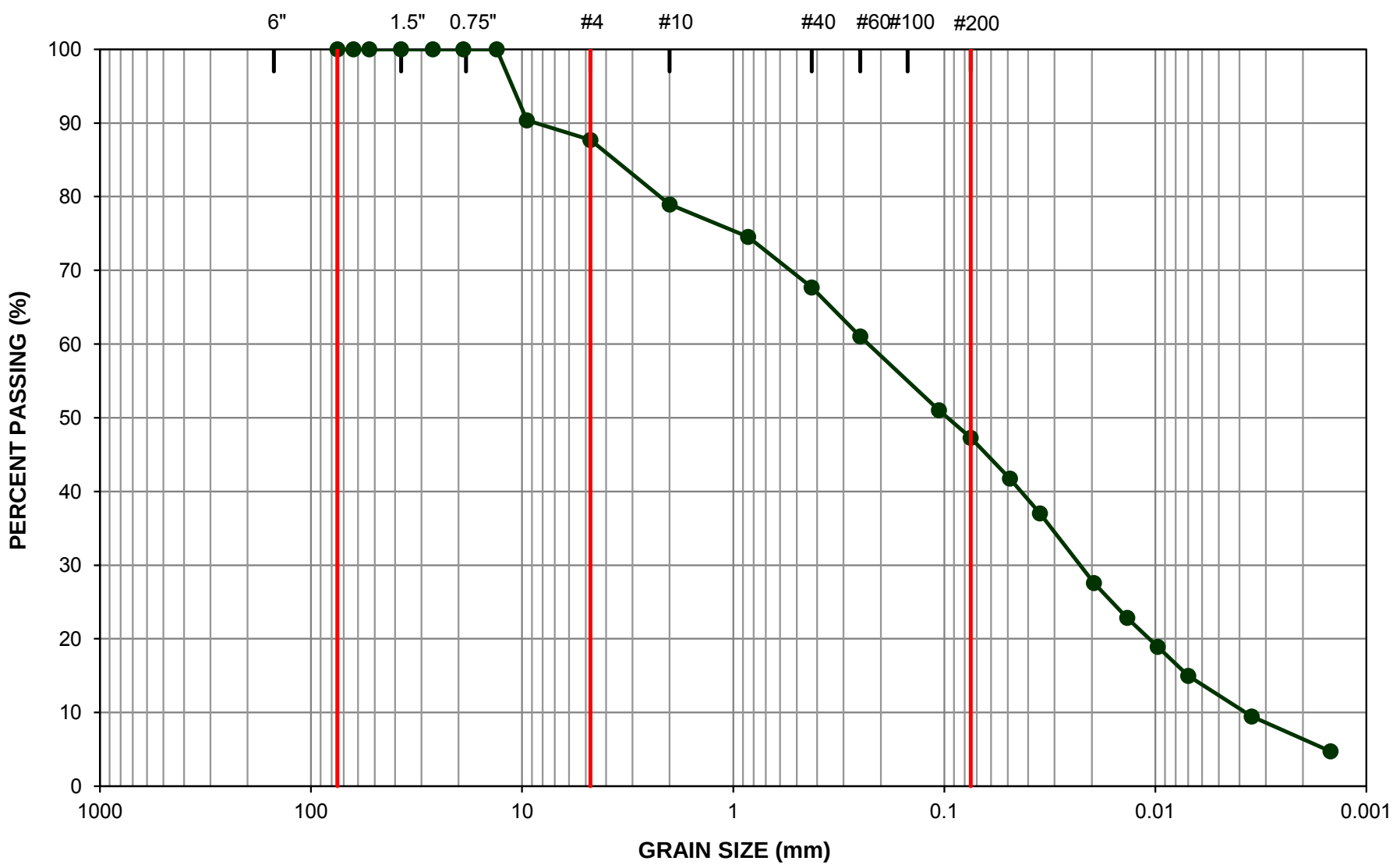
Grain Size Distribution Plots

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



Golder Associates
Sudbury, Ontario

DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0006**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA683**	DEPTH:	**N/A**

Reviewed:

CERTIFIED BY CCIL

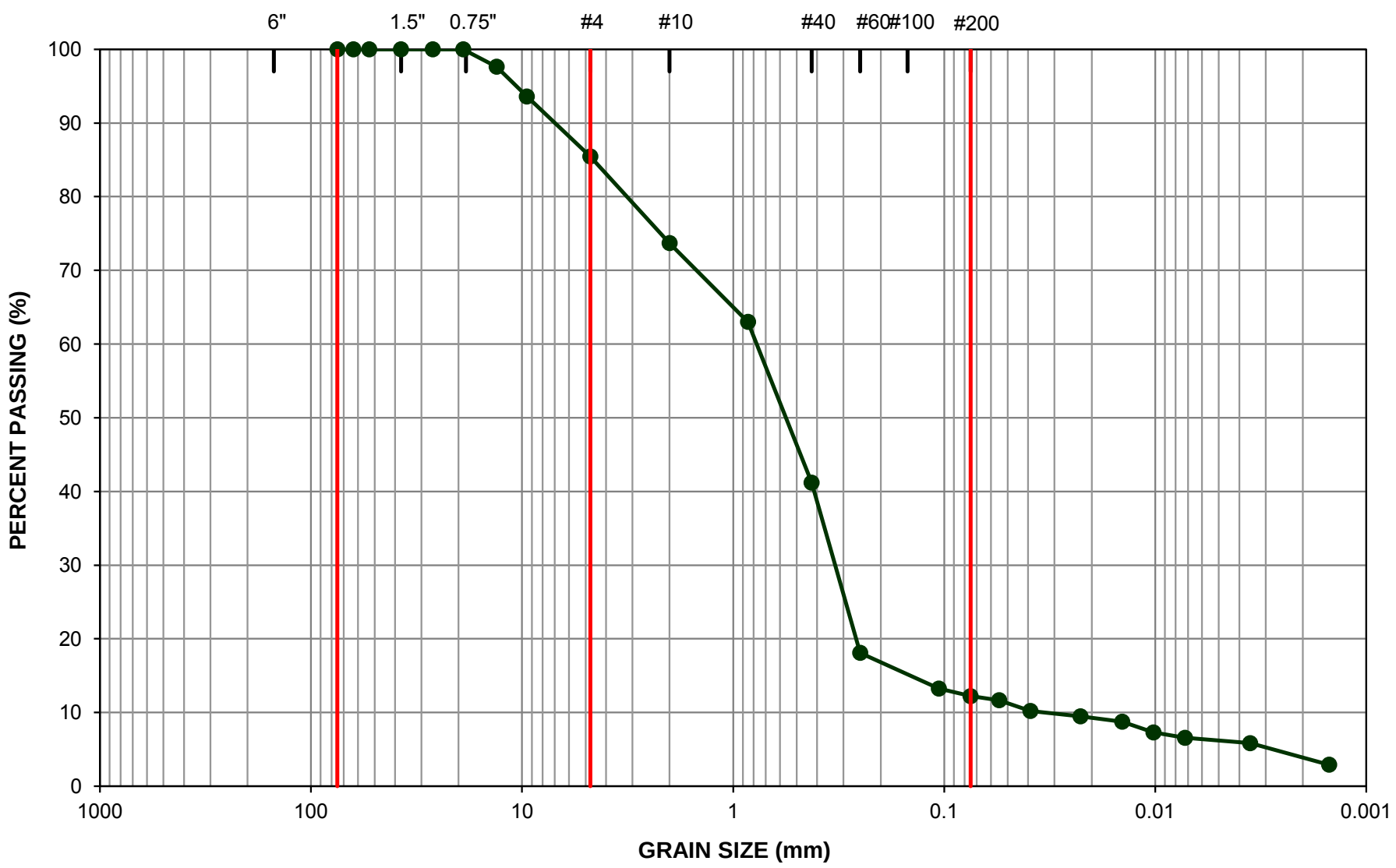
CERTIFIED CONCRETE
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



Golder Associates
Sudbury, Ontario

DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0012**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA684**	DEPTH:	**N/A**

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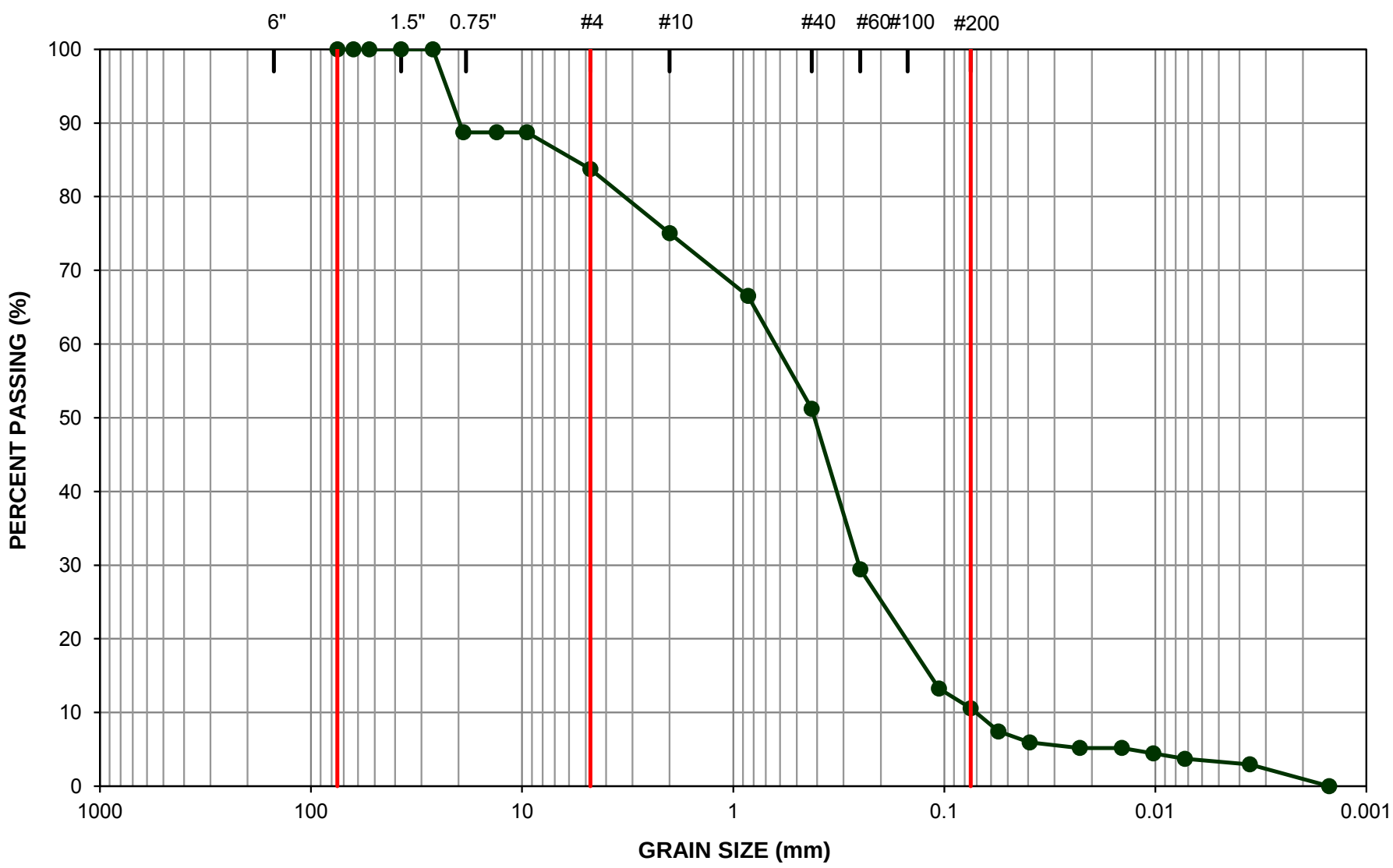
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0013**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA685**	DEPTH:	**N/A**

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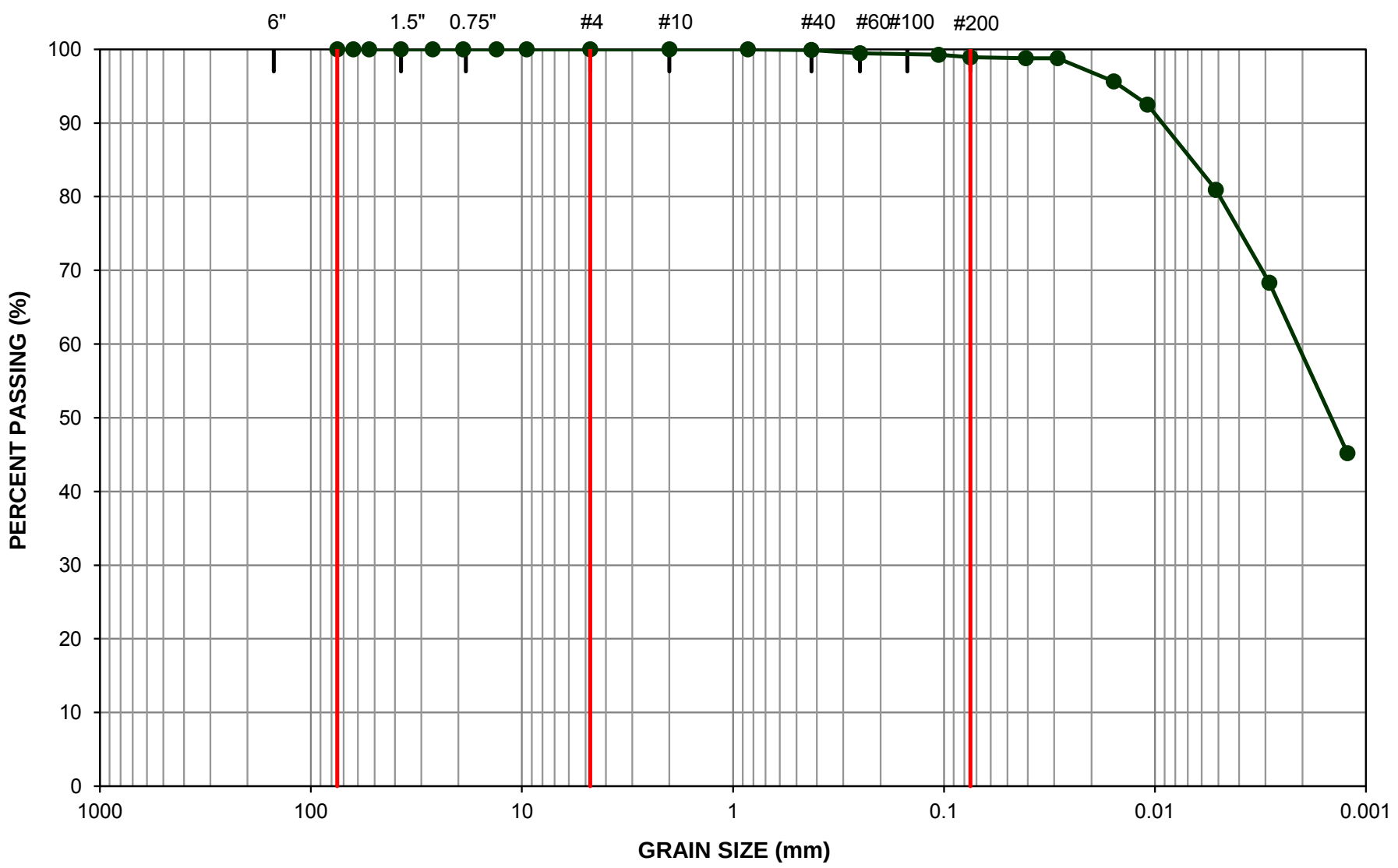
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0014**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**3**
LAB #:	**GA686**	DEPTH:	**N/A**

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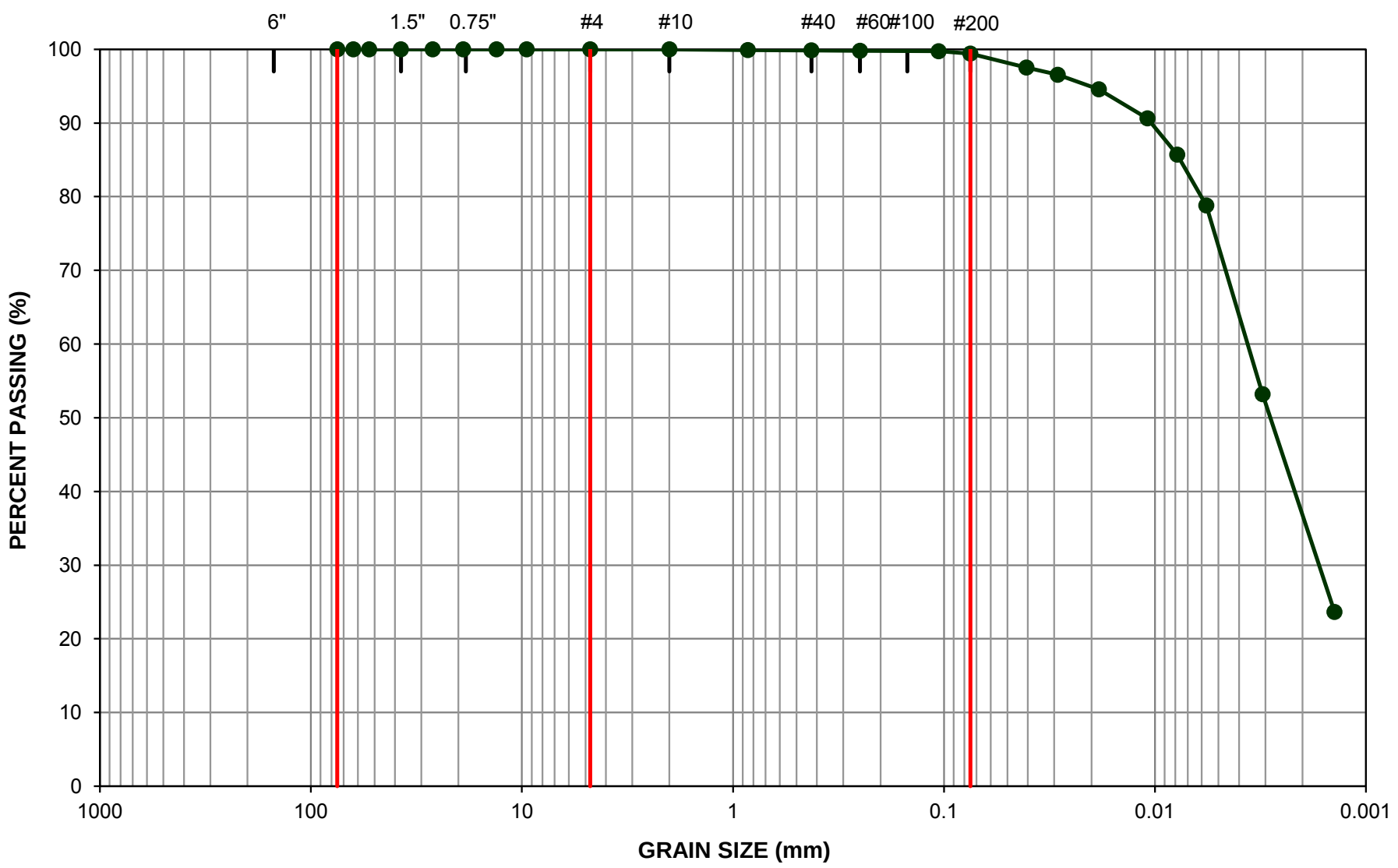
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0014**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA687**	DEPTH:	**N/A**

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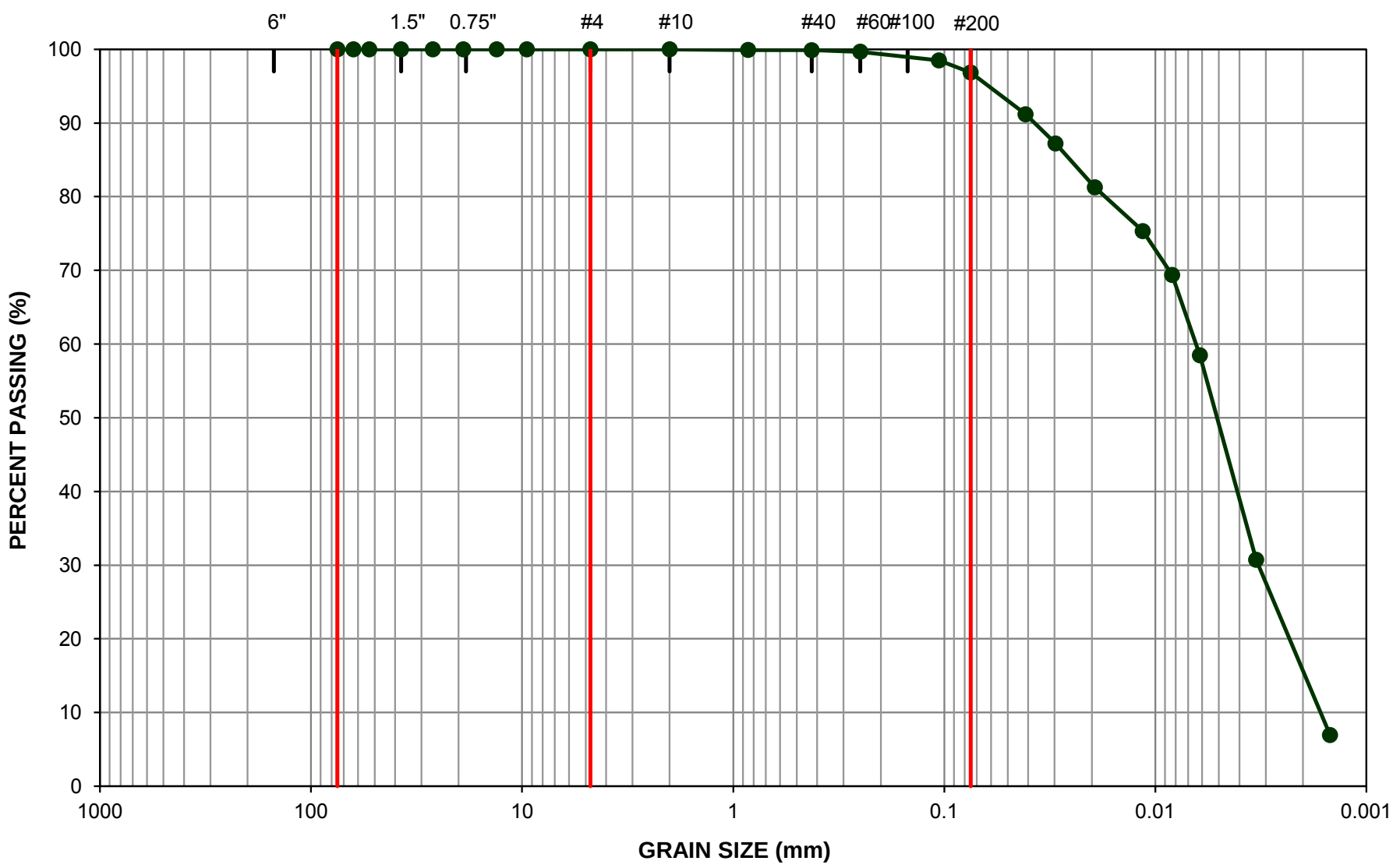
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 19, 2011**	BOREHOLE:	**BRH-0019**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA696**	DEPTH:	**N/A**

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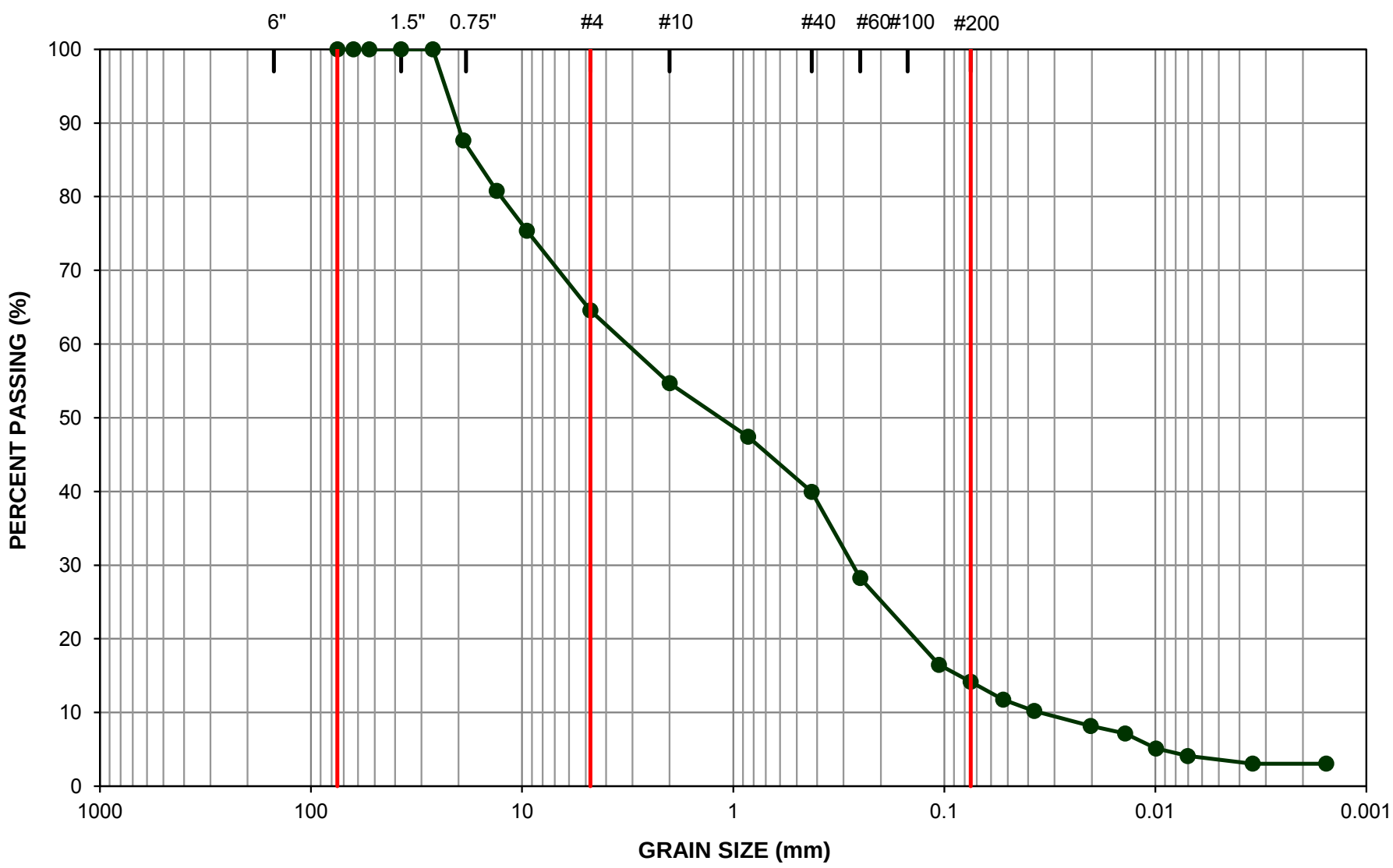
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0014**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**6**
LAB #:	**GA688**	DEPTH:	**N/A**

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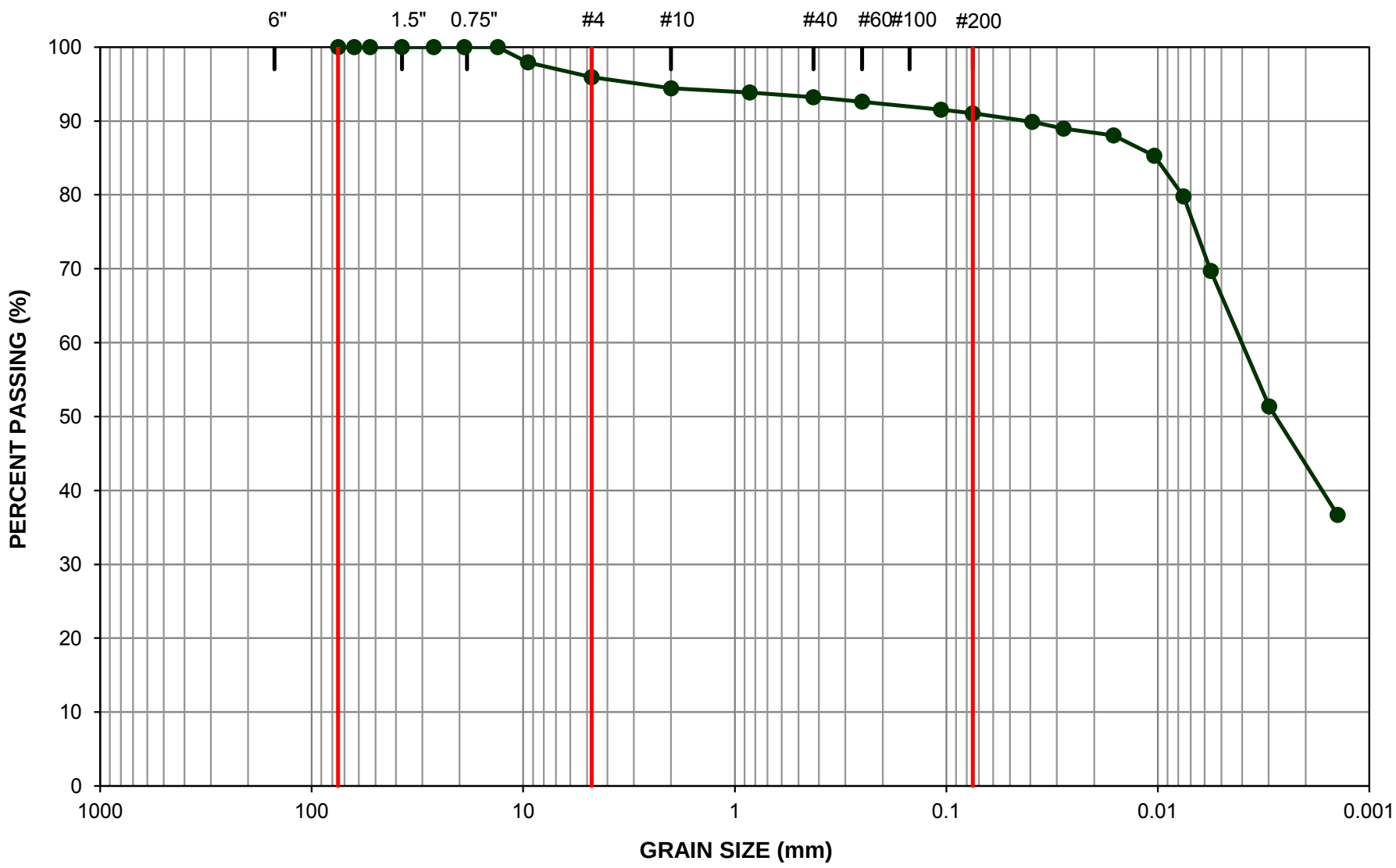
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0015**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA689**	DEPTH:	**N/A**

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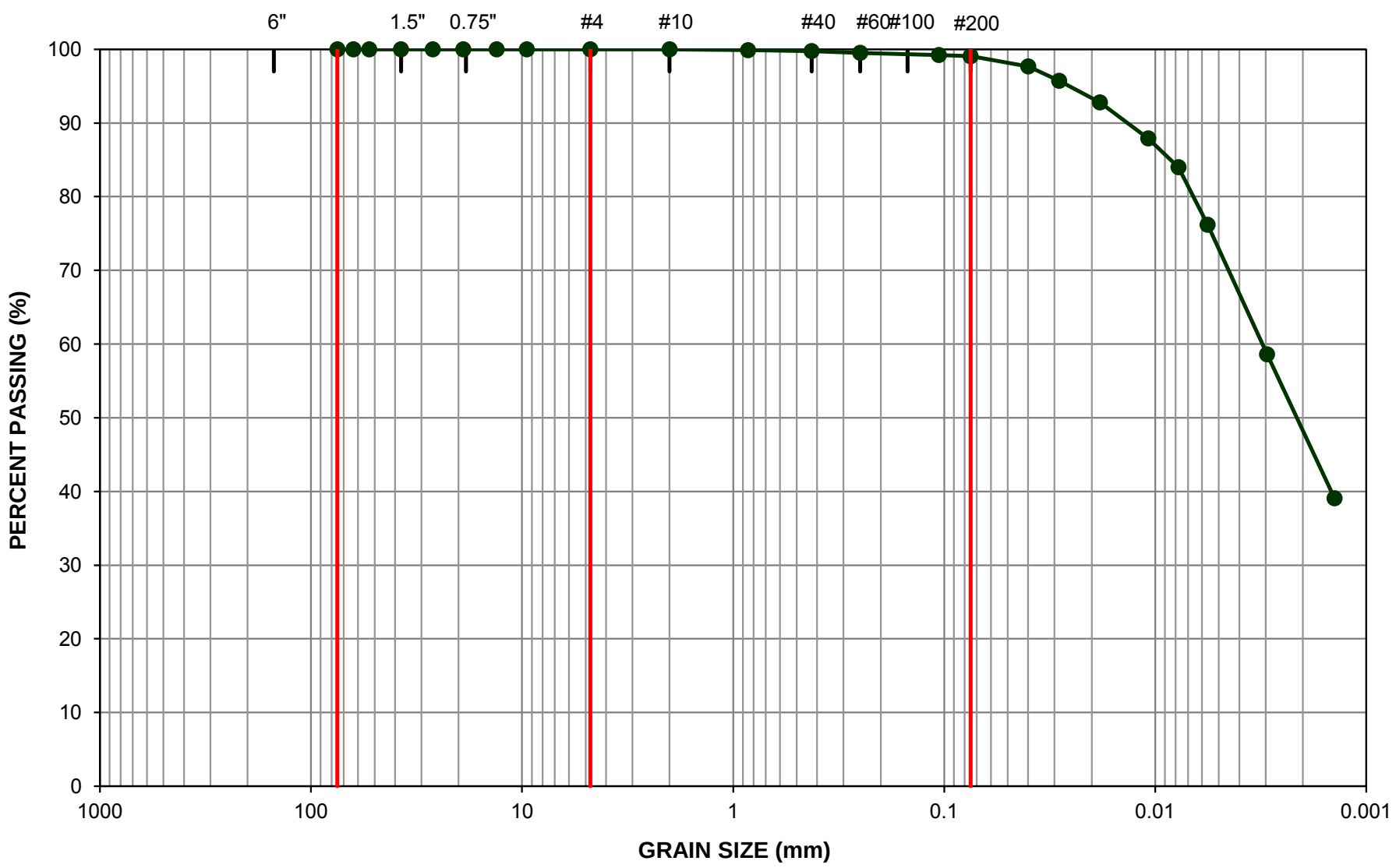
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0015**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**5**
LAB #:	**GA690**	DEPTH:	**N/A**

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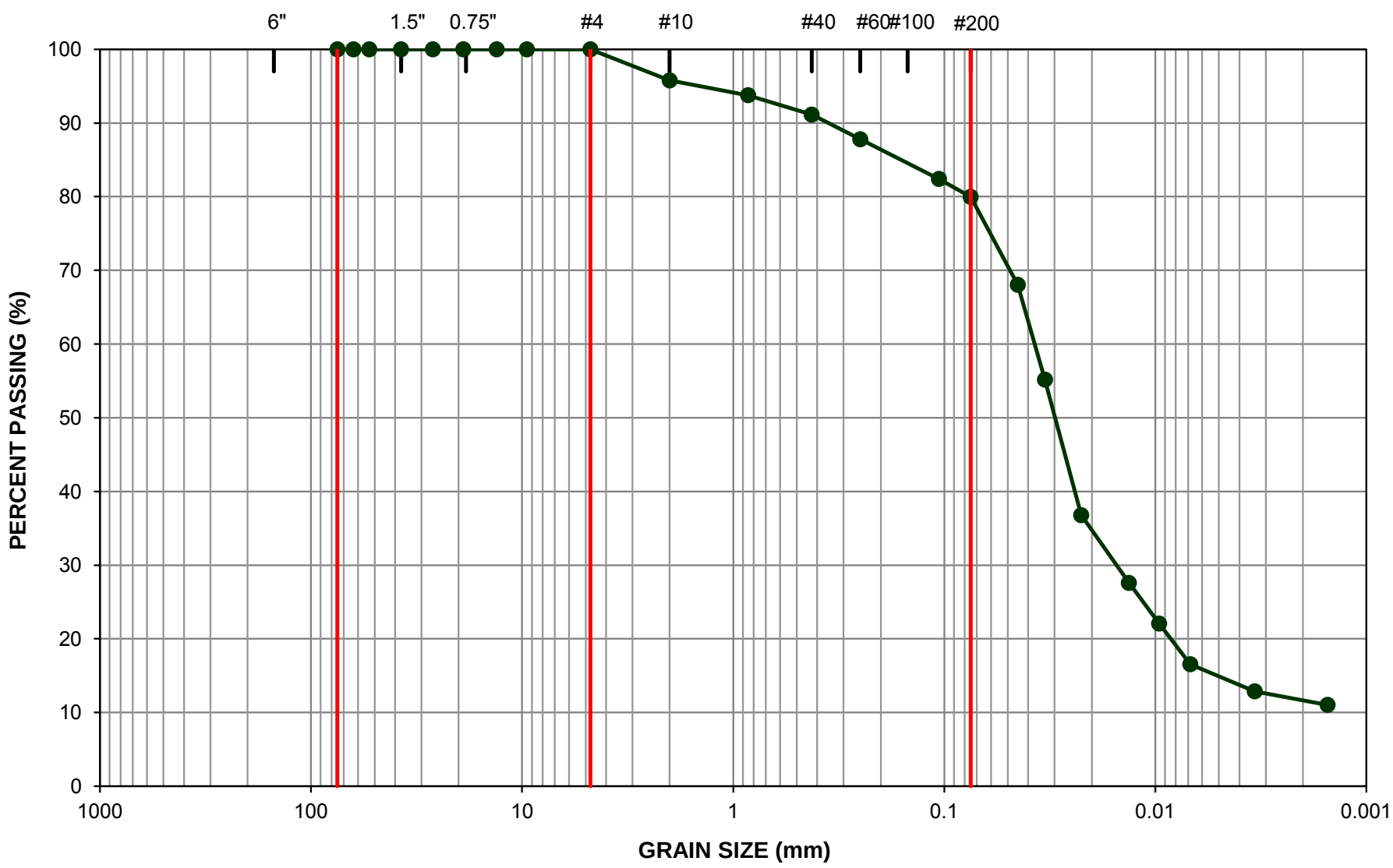
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0016**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA691**	DEPTH:	**N/A**

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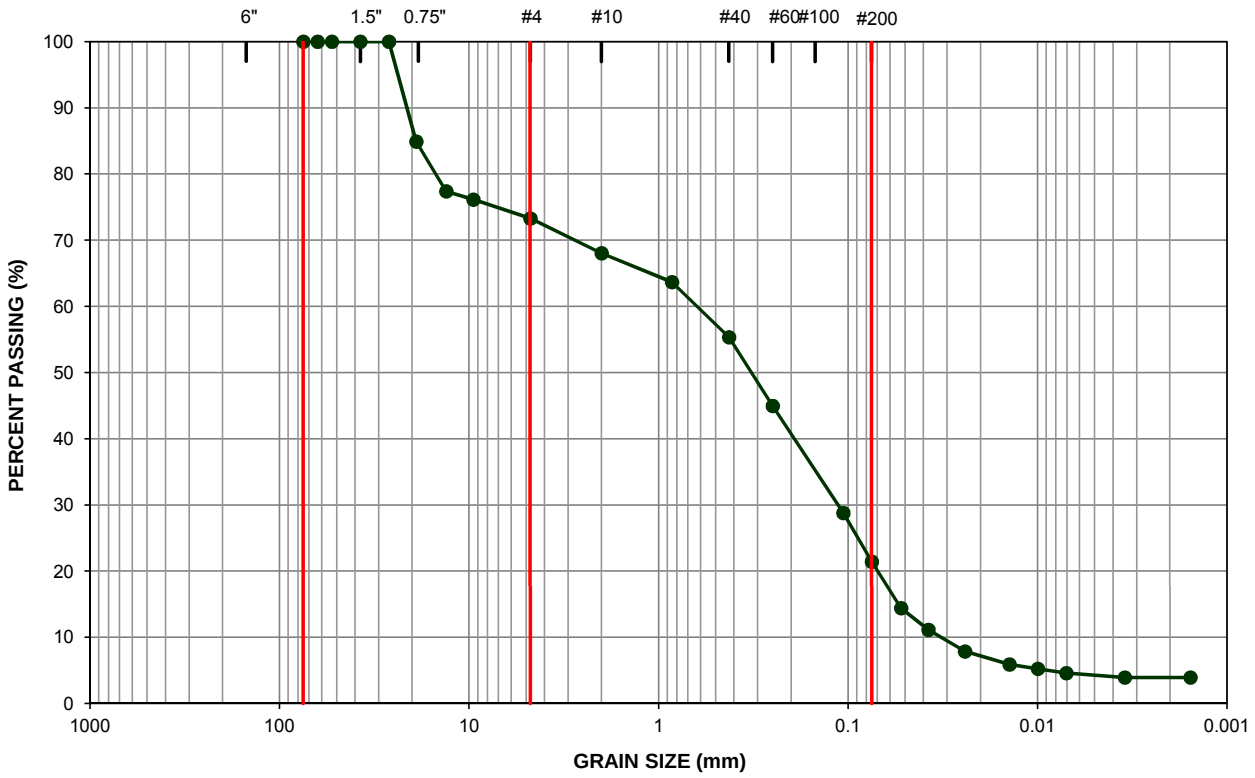
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0016**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2B**
LAB #:	**GA692**	DEPTH:	**N/A**

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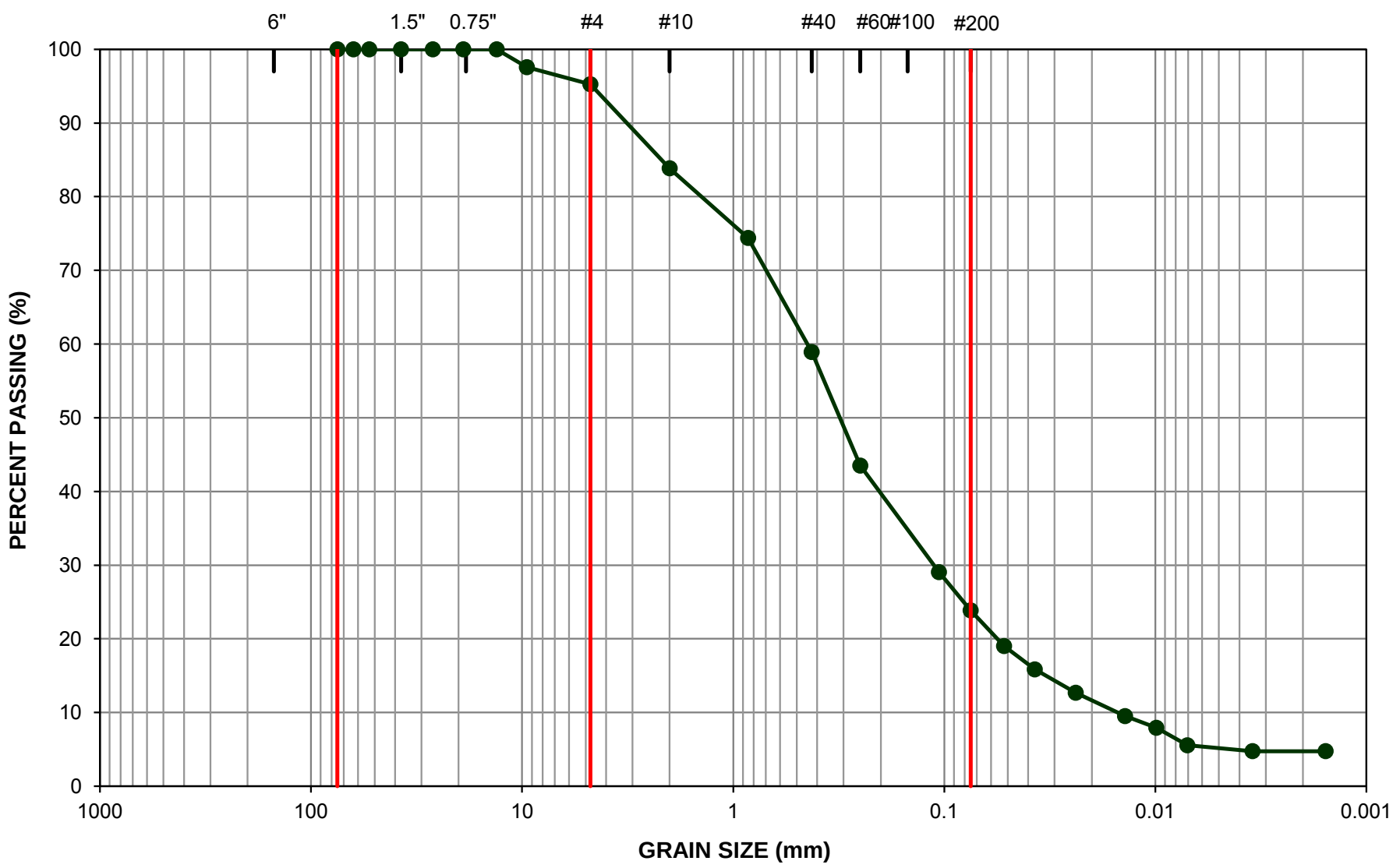
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 20, 2011**	BOREHOLE:	**BRH-0017**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**3**
LAB #:	**GA693**	DEPTH:	**N/A**

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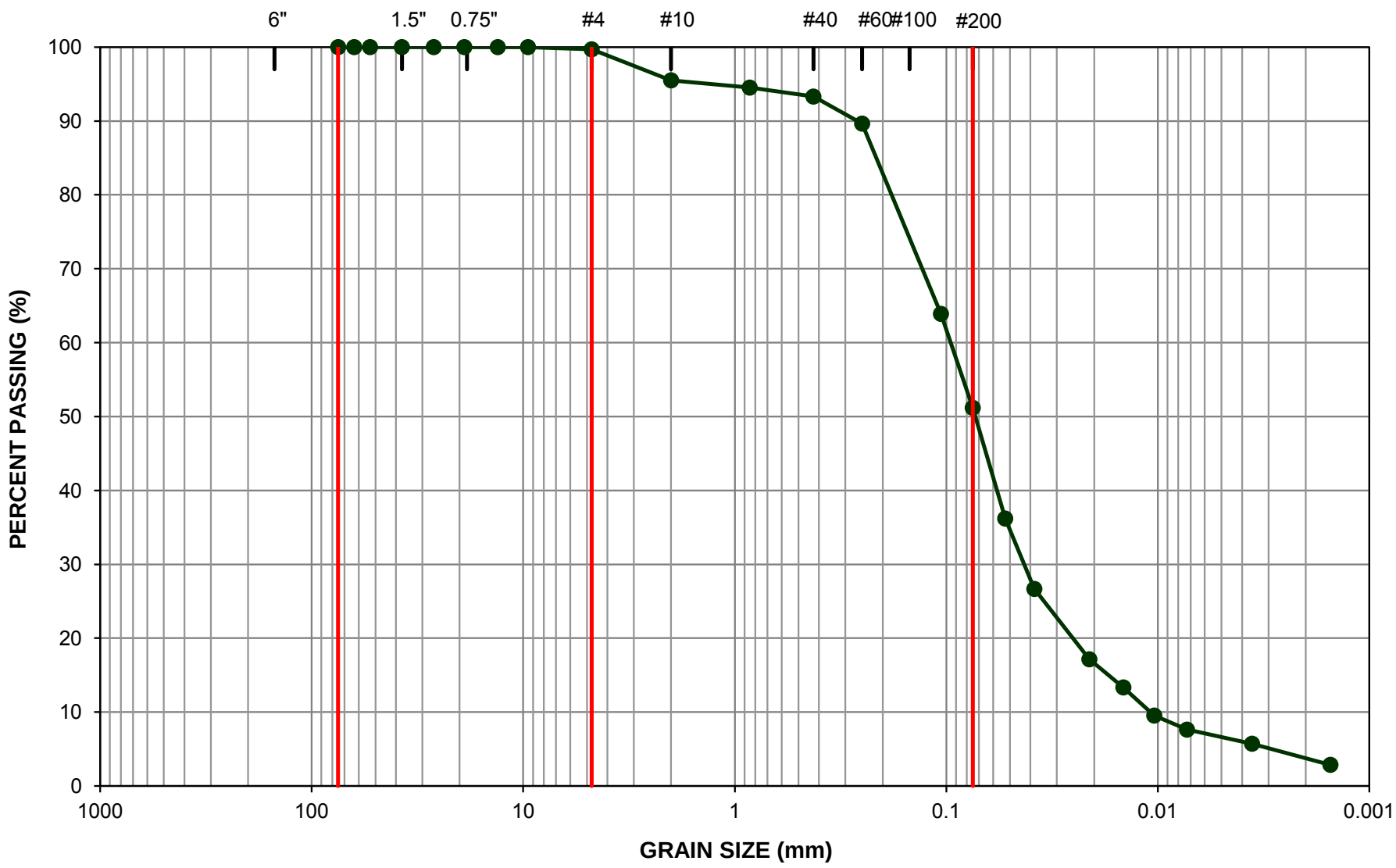
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0018**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA694**	DEPTH:	**N/A**

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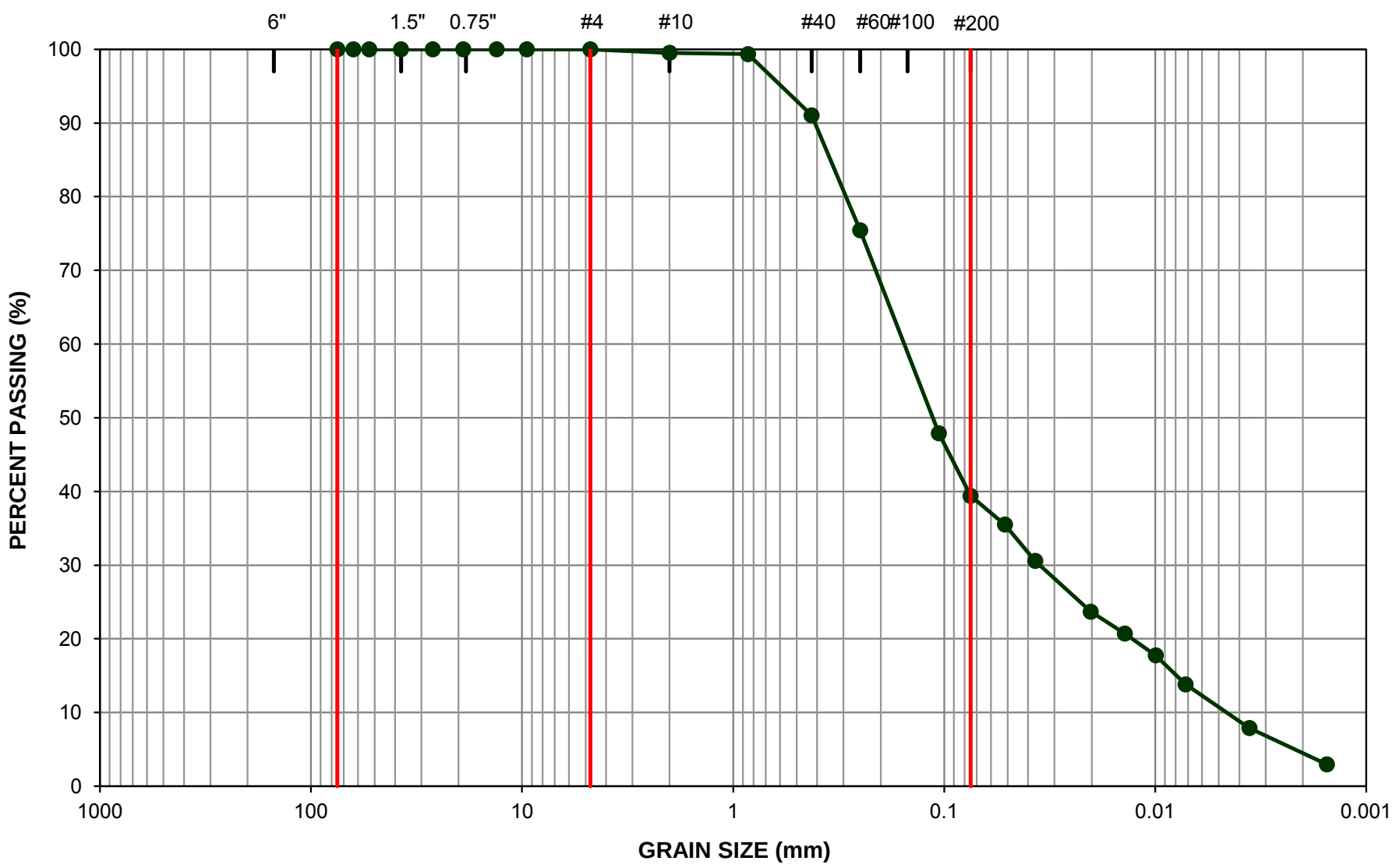
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0019**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA695**	DEPTH:	**N/A**

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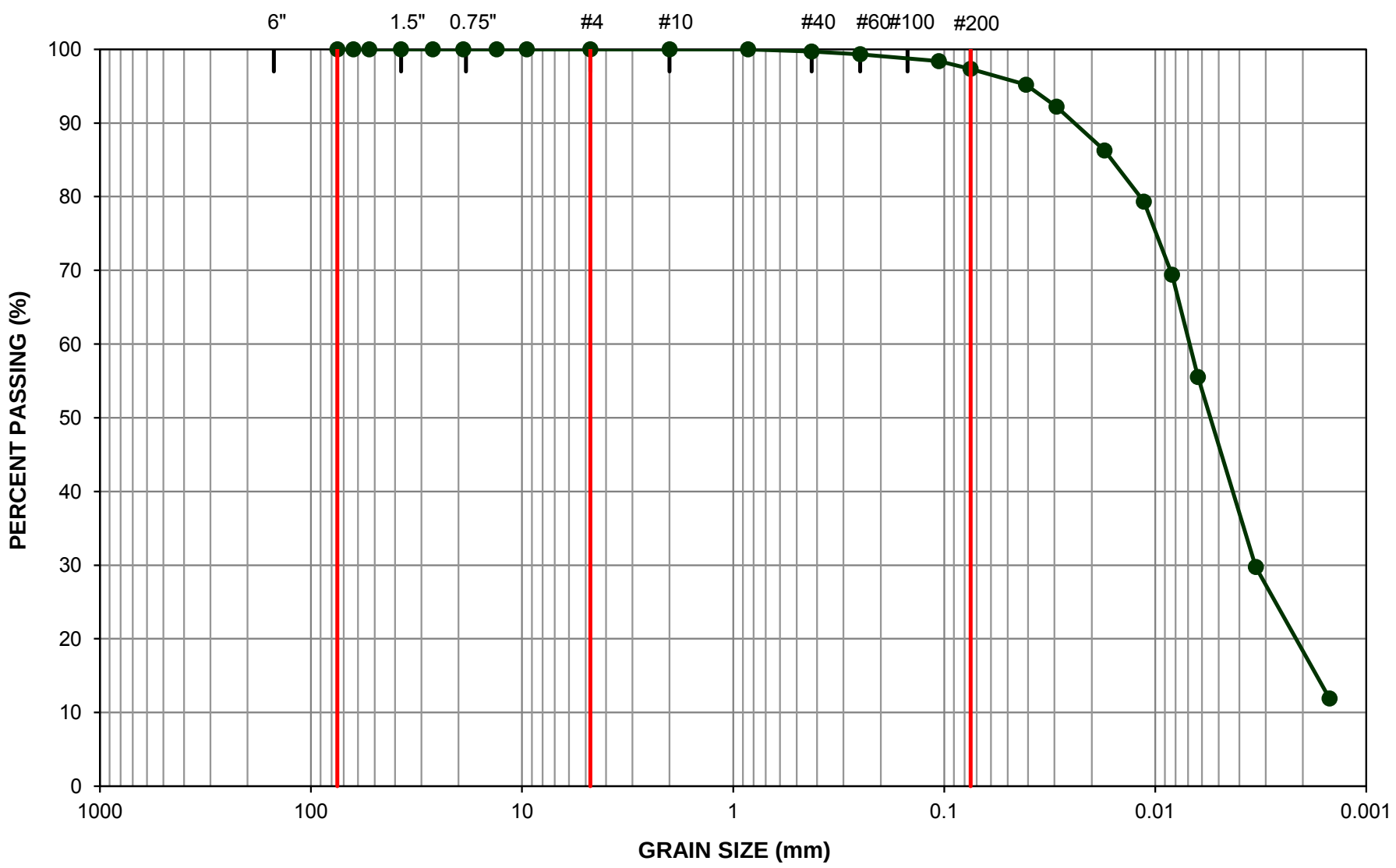
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0019**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**8**
LAB #:	**GA697**	DEPTH:	**N/A**

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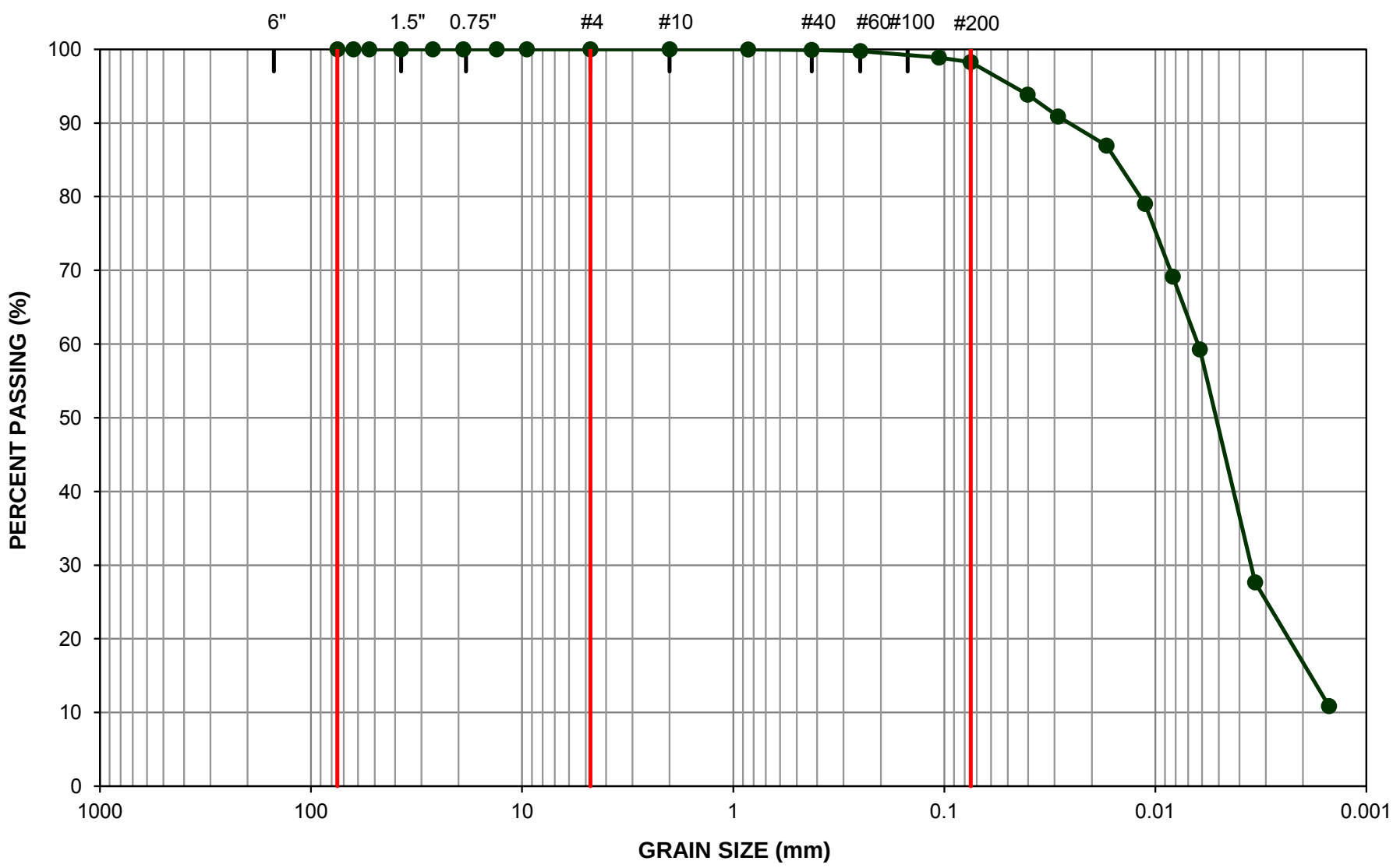
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0019**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**7**
LAB #:	**GA698**	DEPTH:	**N/A**

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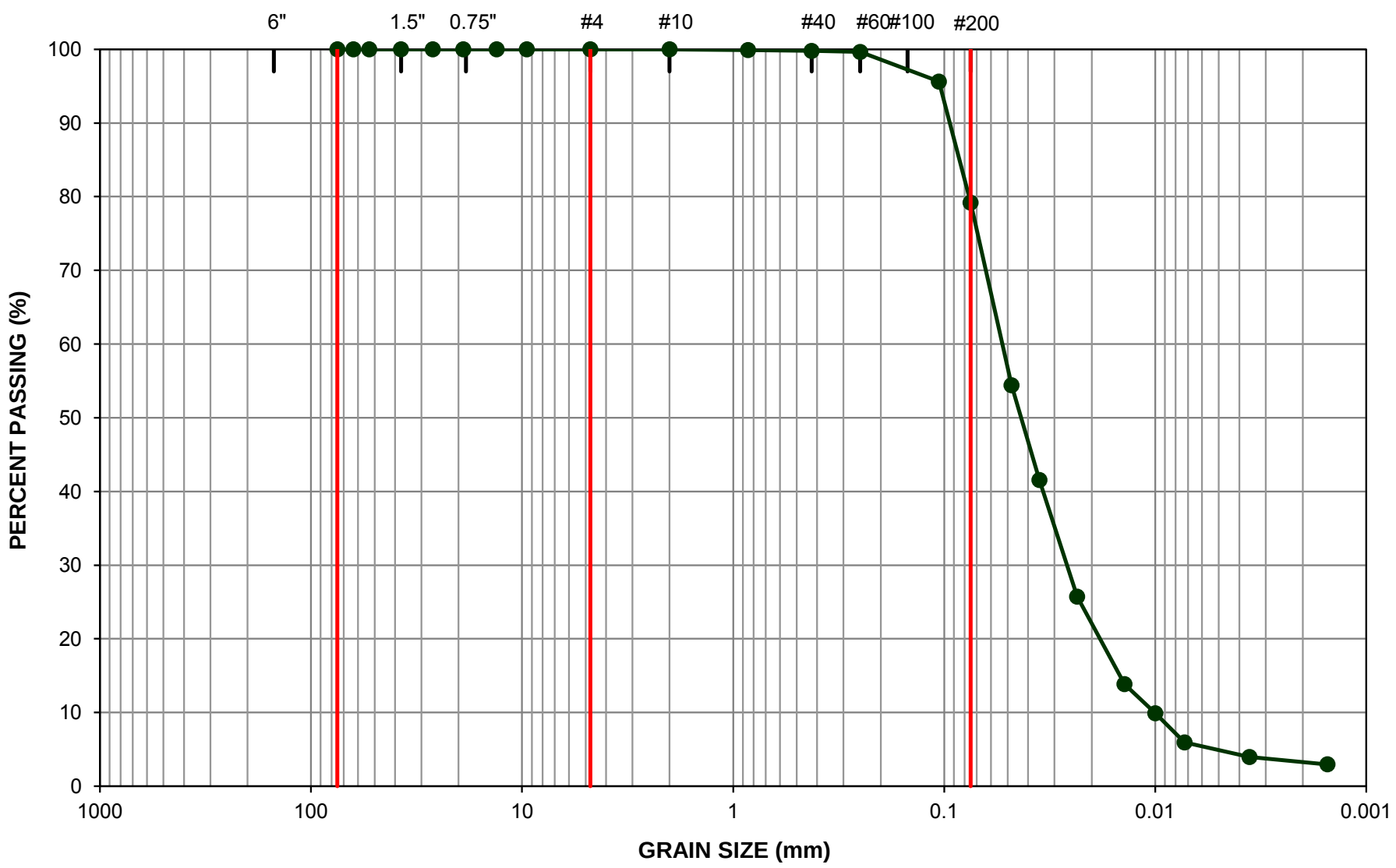
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0021**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA702**	DEPTH:	**N/A**

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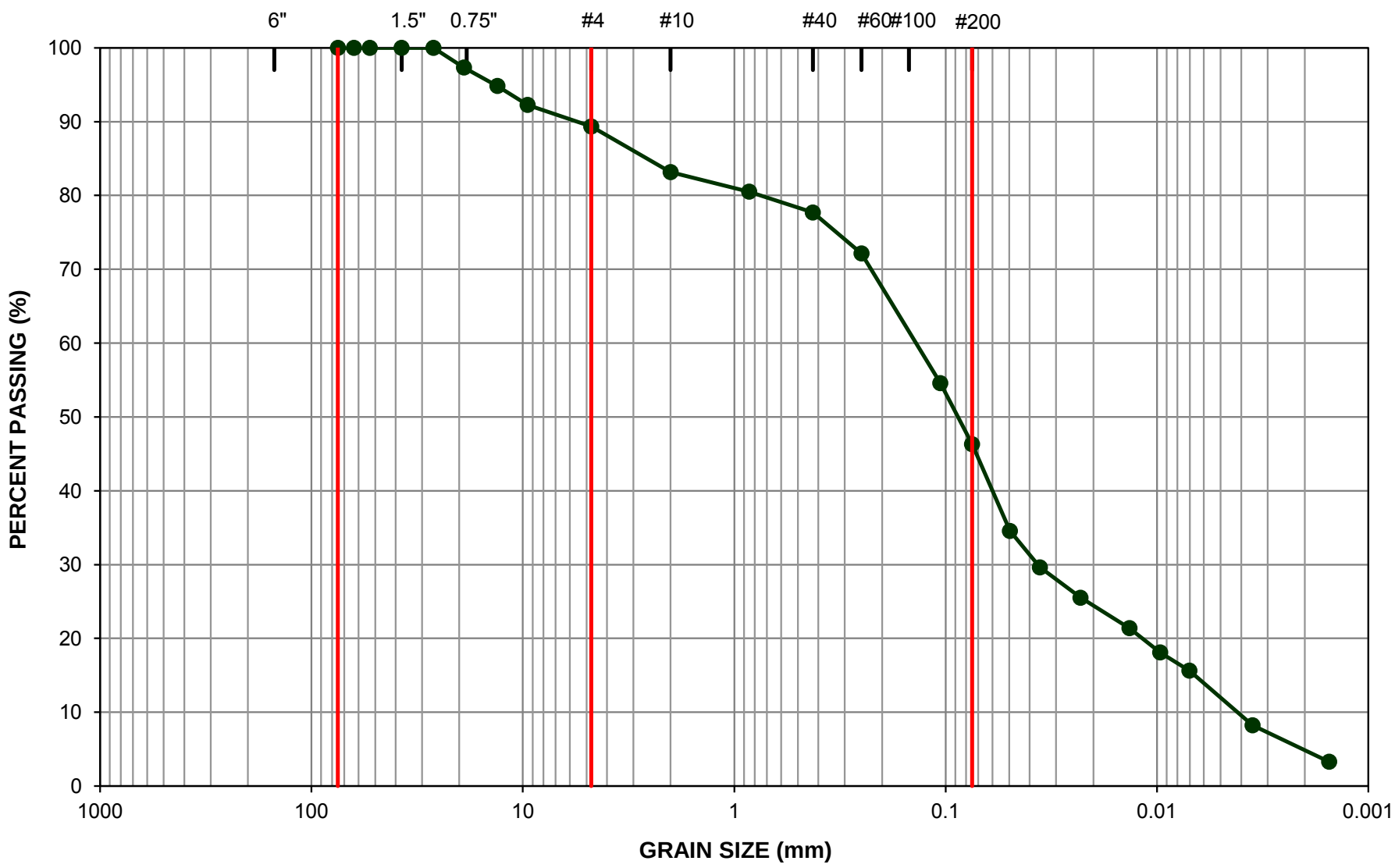
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 21, 2011**	BOREHOLE:	**BRH-0023**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA703**	DEPTH:	**N/A**

Reviewed:

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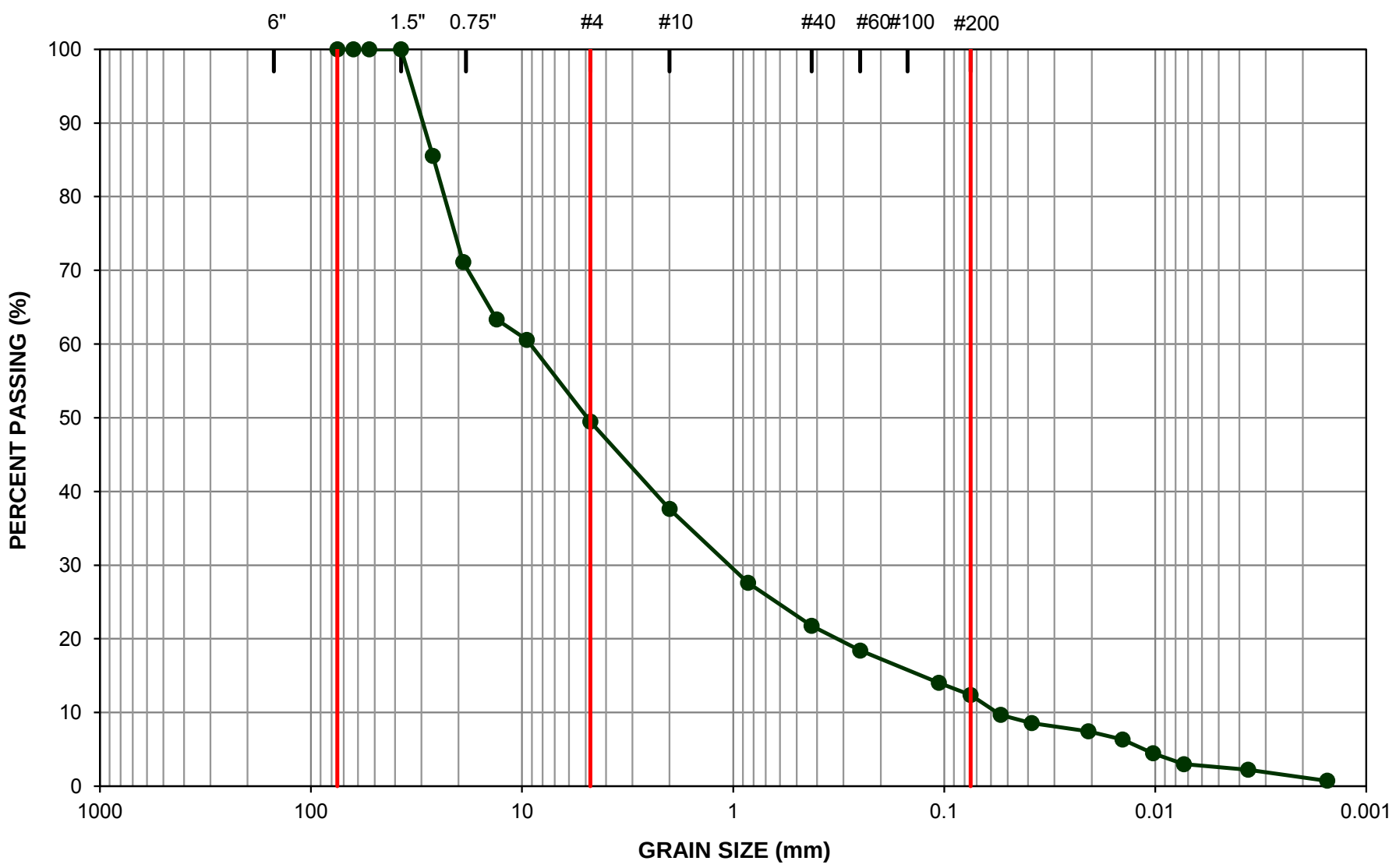
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0023**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA704**	DEPTH:	**N/A**

Reviewed:

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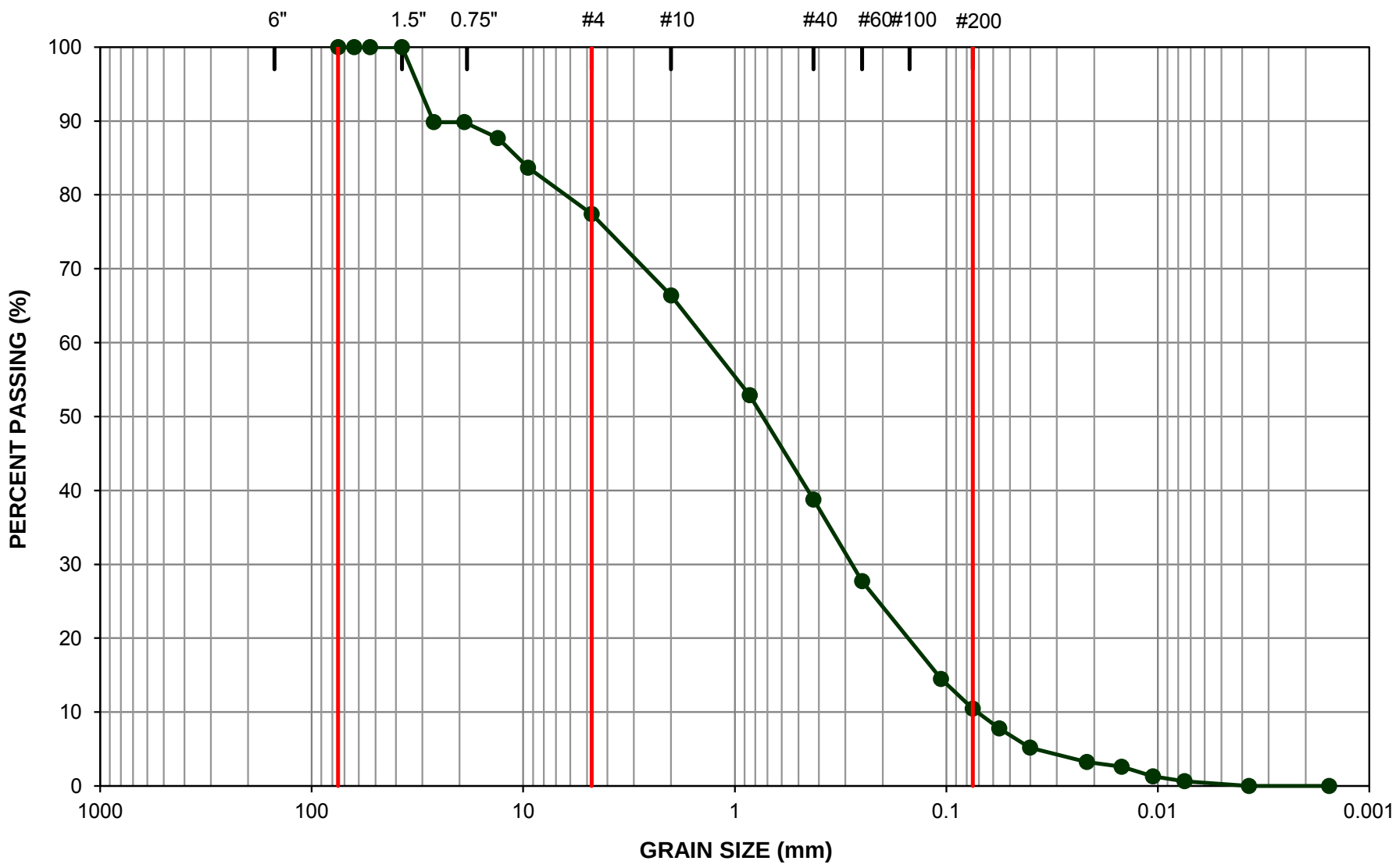
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



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DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0023**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA705**	DEPTH:	**N/A**

Reviewed:

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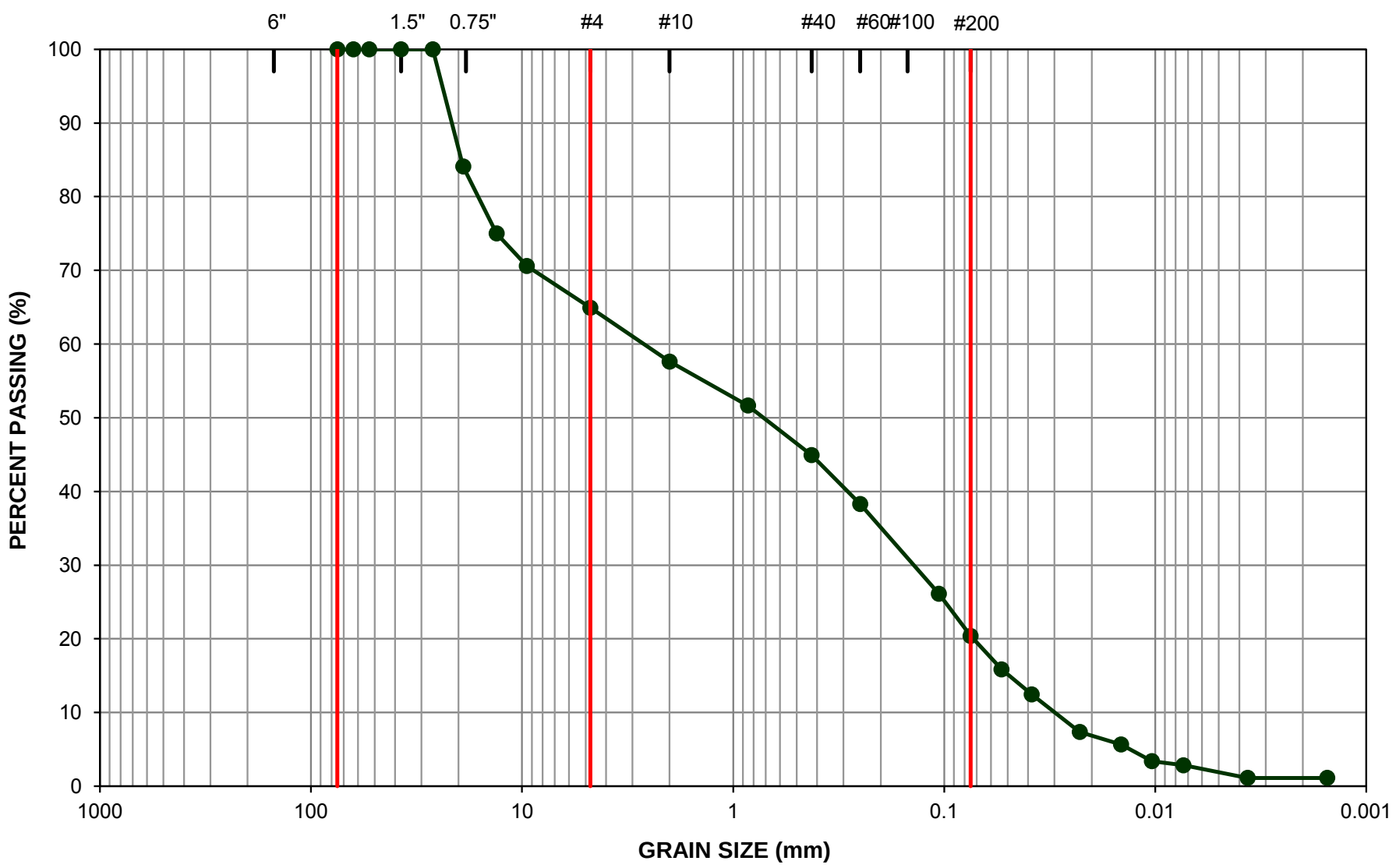
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0026**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA706**	DEPTH:	**N/A**

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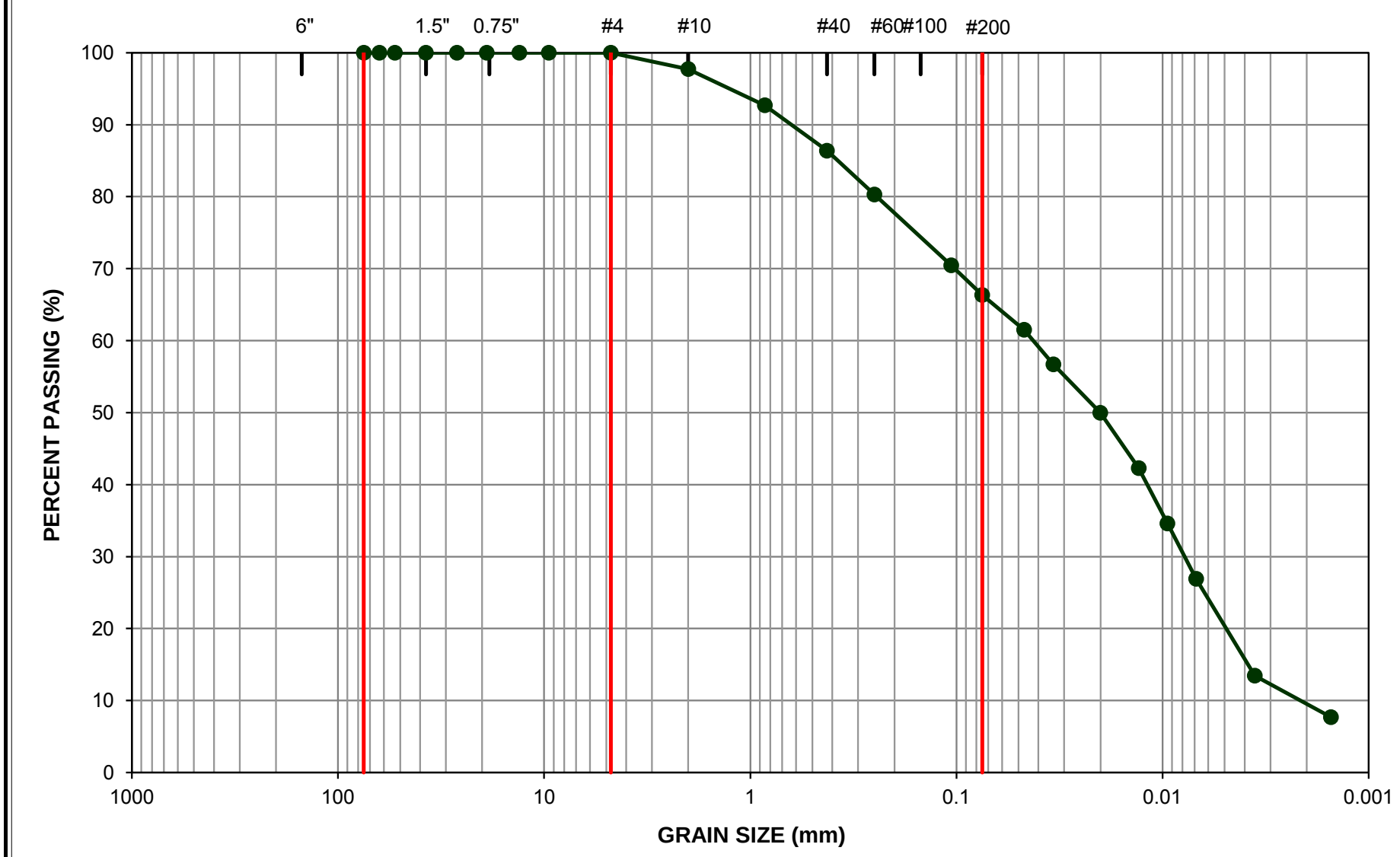
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0027**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA707**	DEPTH:	**N/A**

Reviewed:

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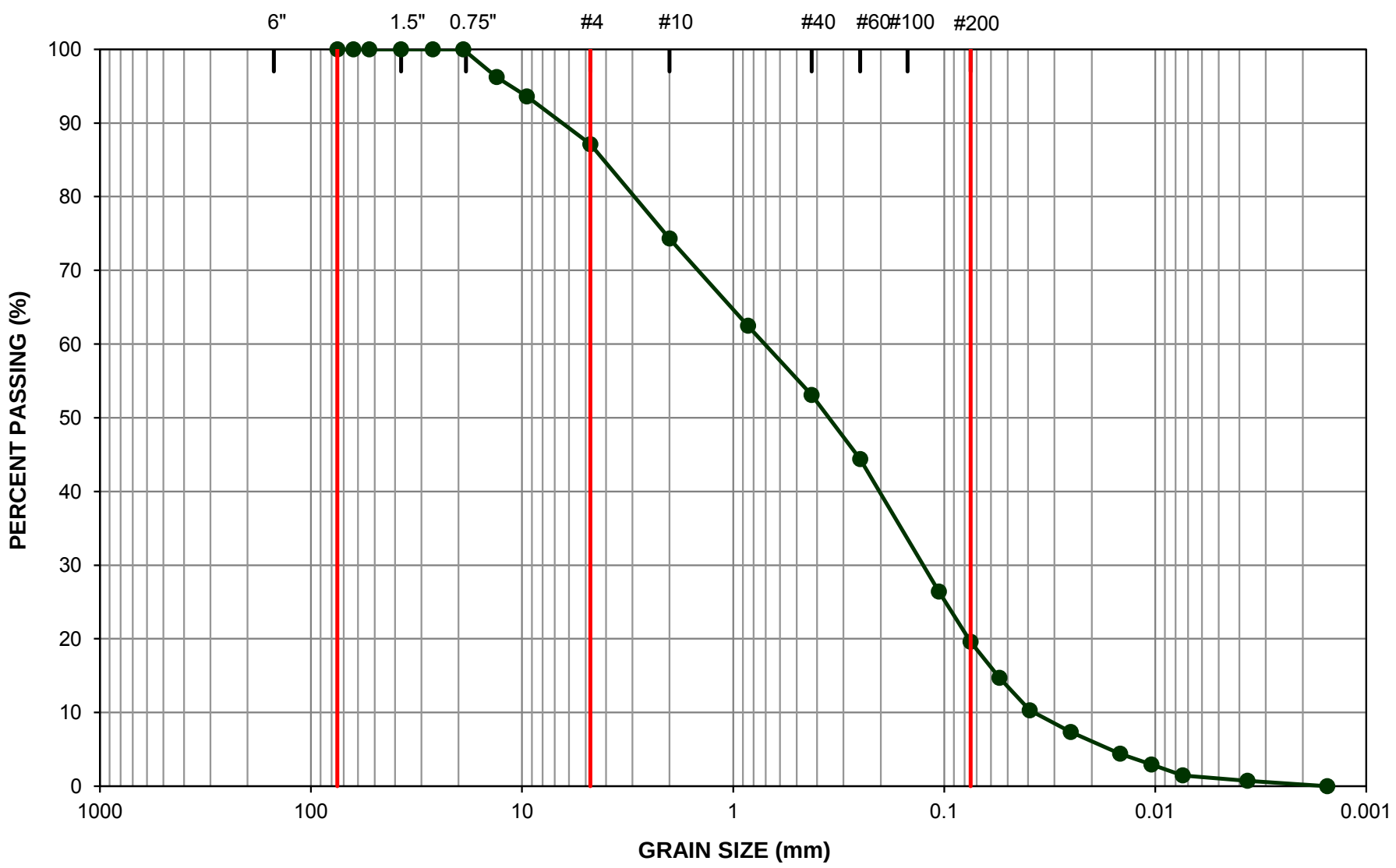
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0027**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA708**	DEPTH:	**N/A**

Reviewed:

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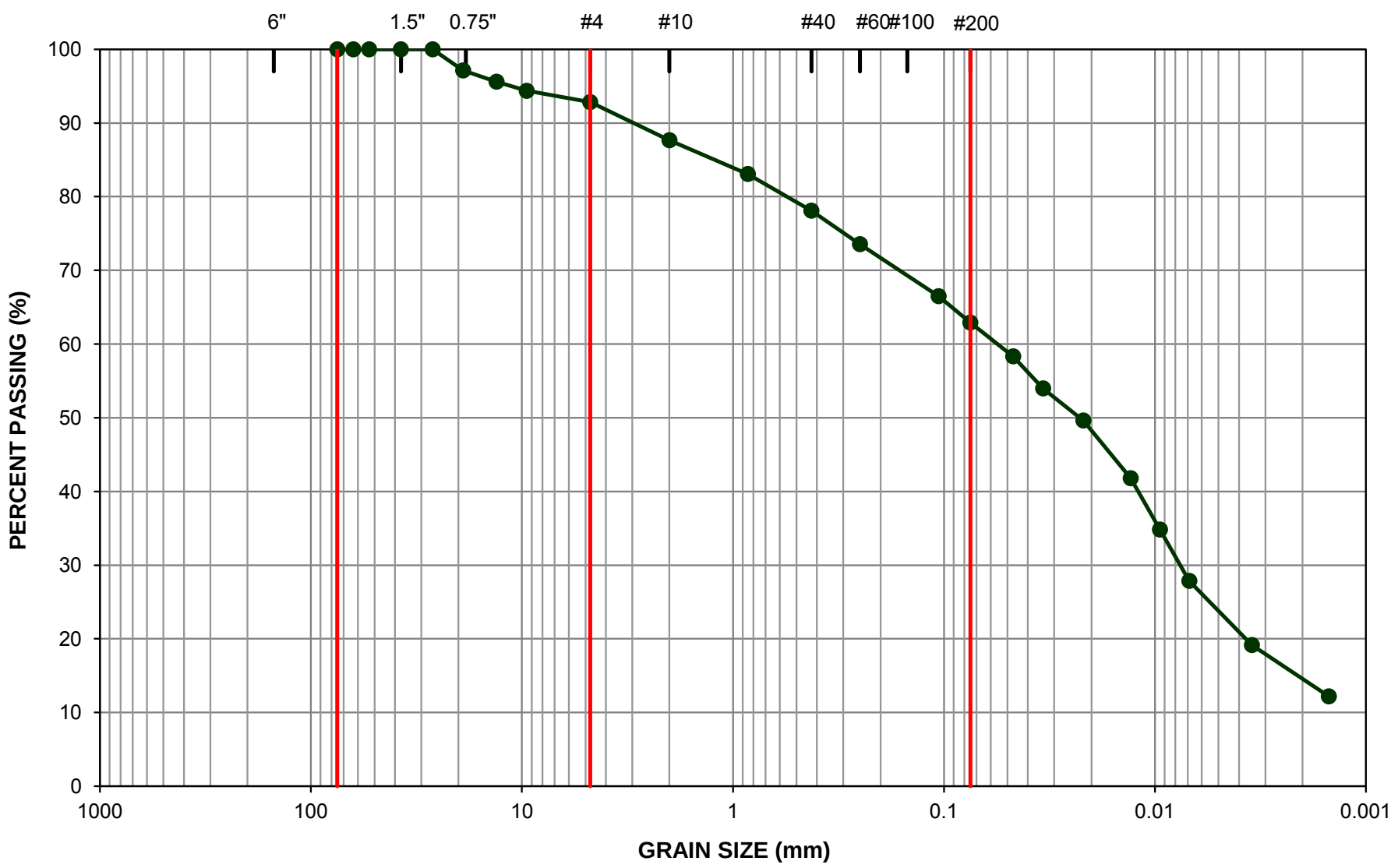
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 22, 2011**	BOREHOLE:	**BRH-0028**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**2**
LAB #:	**GA709**	DEPTH:	**N/A**

Reviewed:

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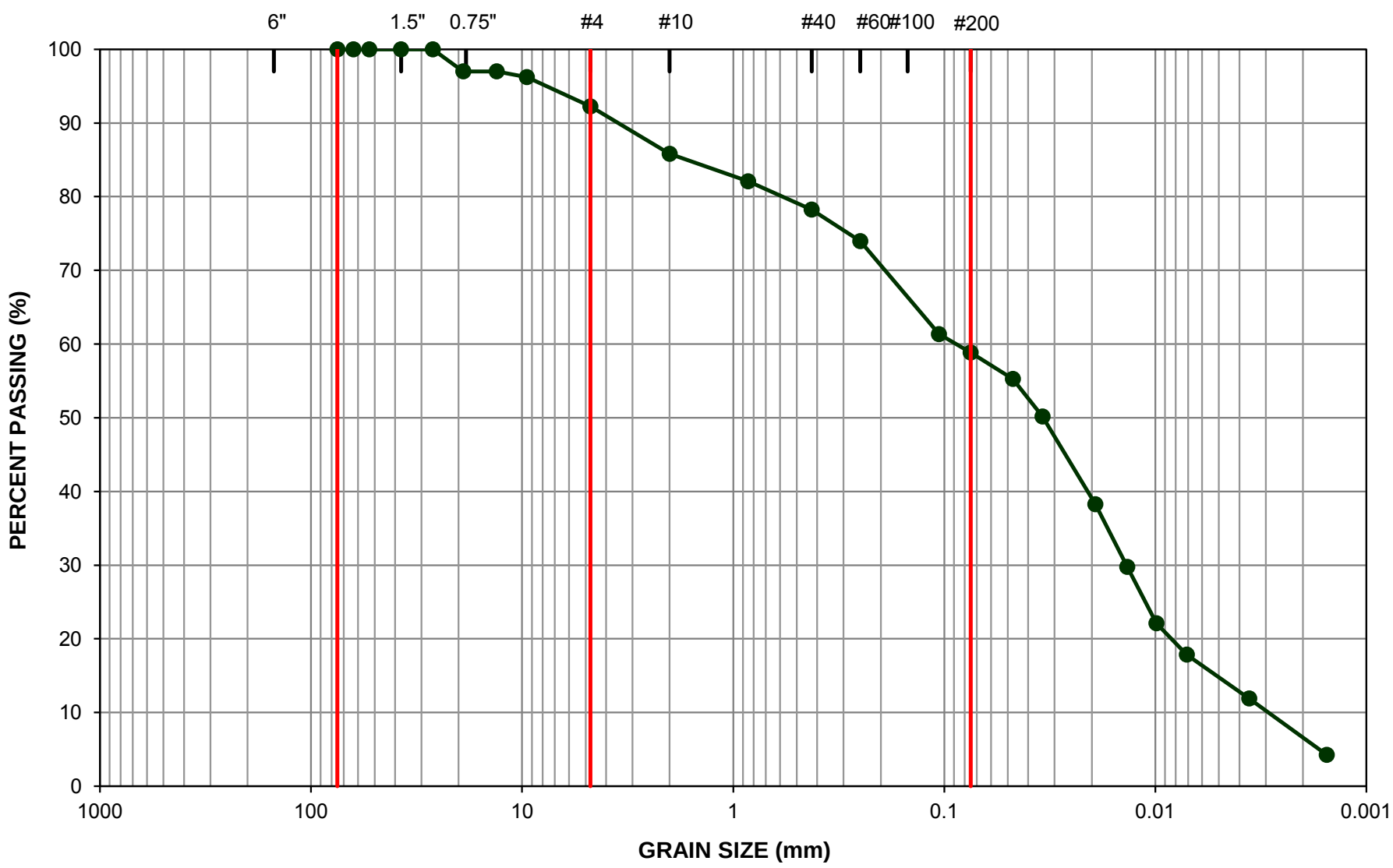
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0028**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA710**	DEPTH:	**N/A**

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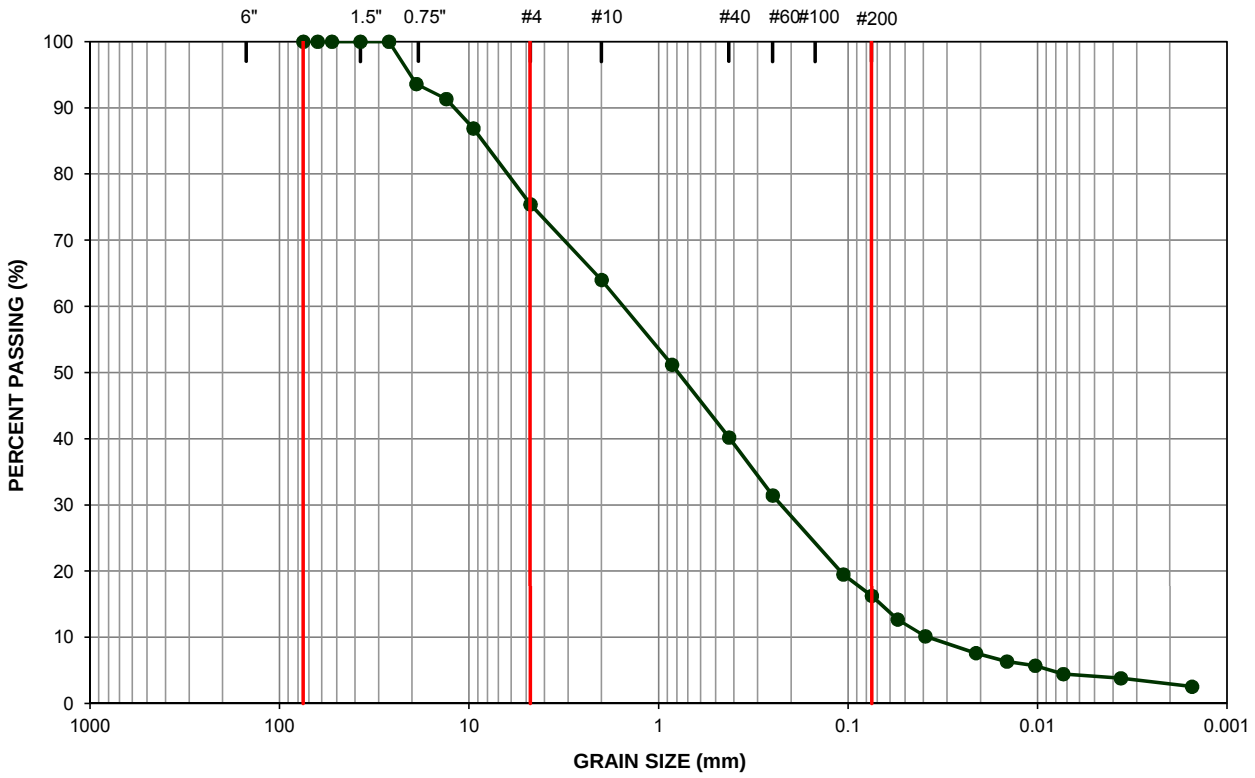
CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Coarse	Fine	Coarse	Medium	Fine	Silt & Clay Sizes
		Gravel Size		Sand Size			



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0029A**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**1**
LAB #:	**GA711**	DEPTH:	**N/A**

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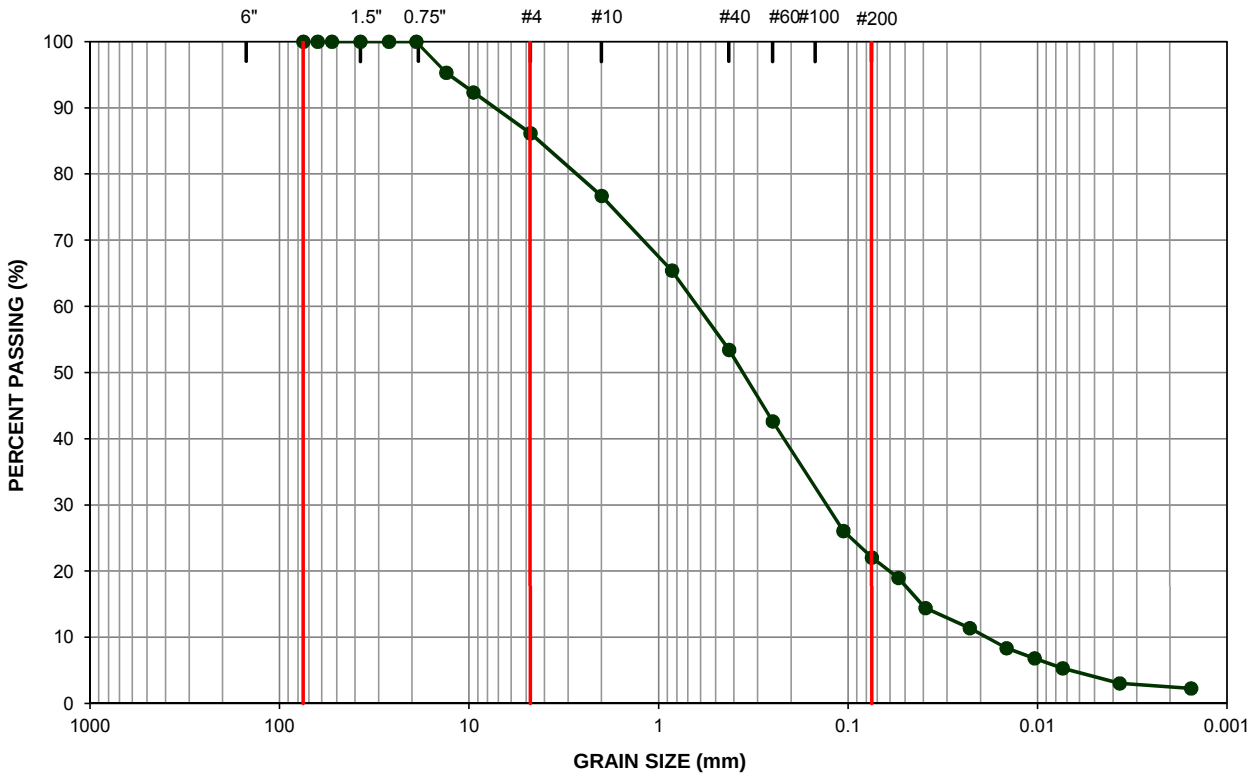
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0029A**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**3**
LAB #:	**GA712**	DEPTH:	**N/A**

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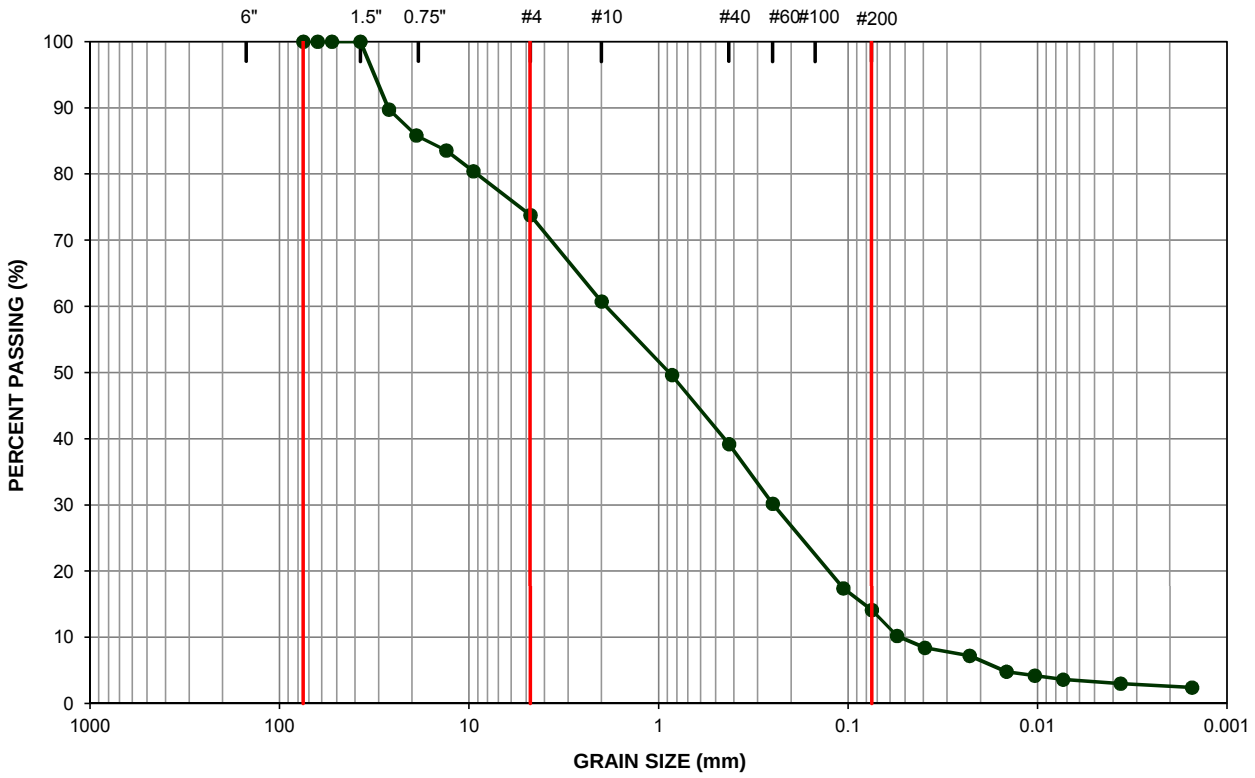
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0029A**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**6**
LAB #:	**GA713**	DEPTH:	**N/A**

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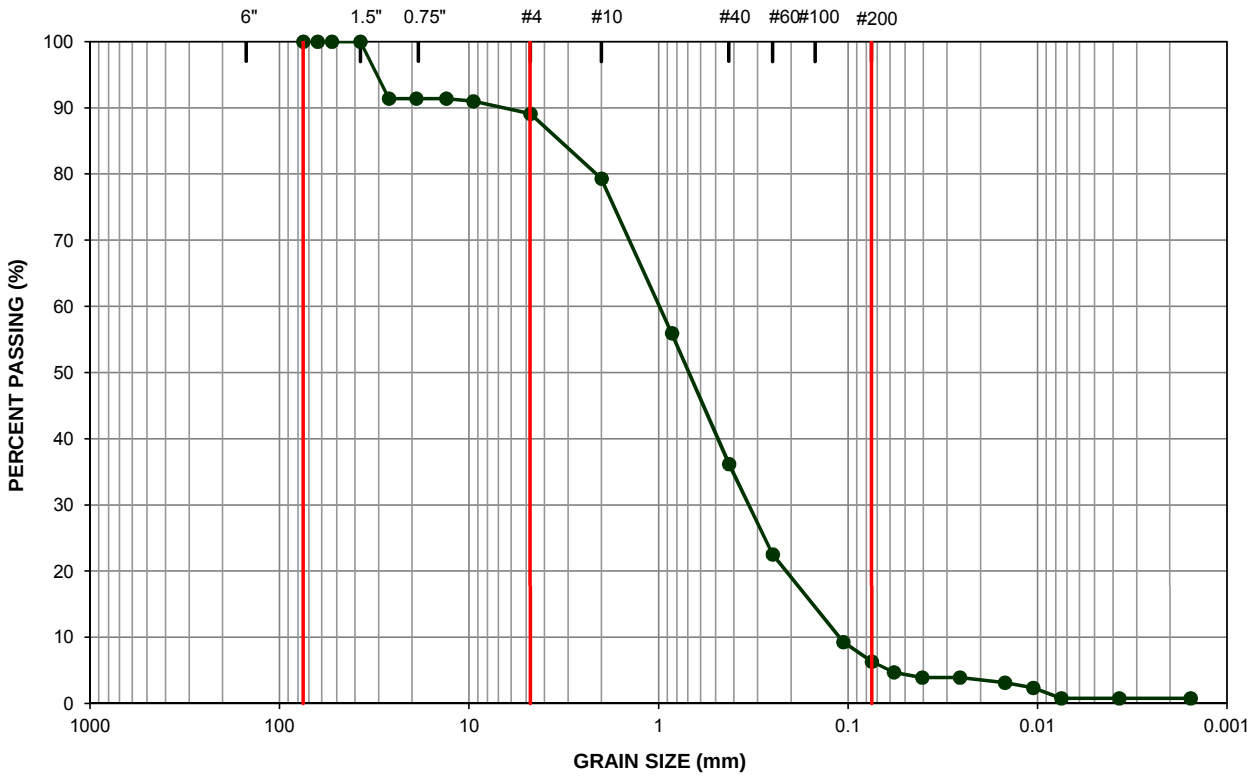
TESTING LABORATORY
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0029A**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**8**
LAB #:	**GA714**	DEPTH:	**N/A**

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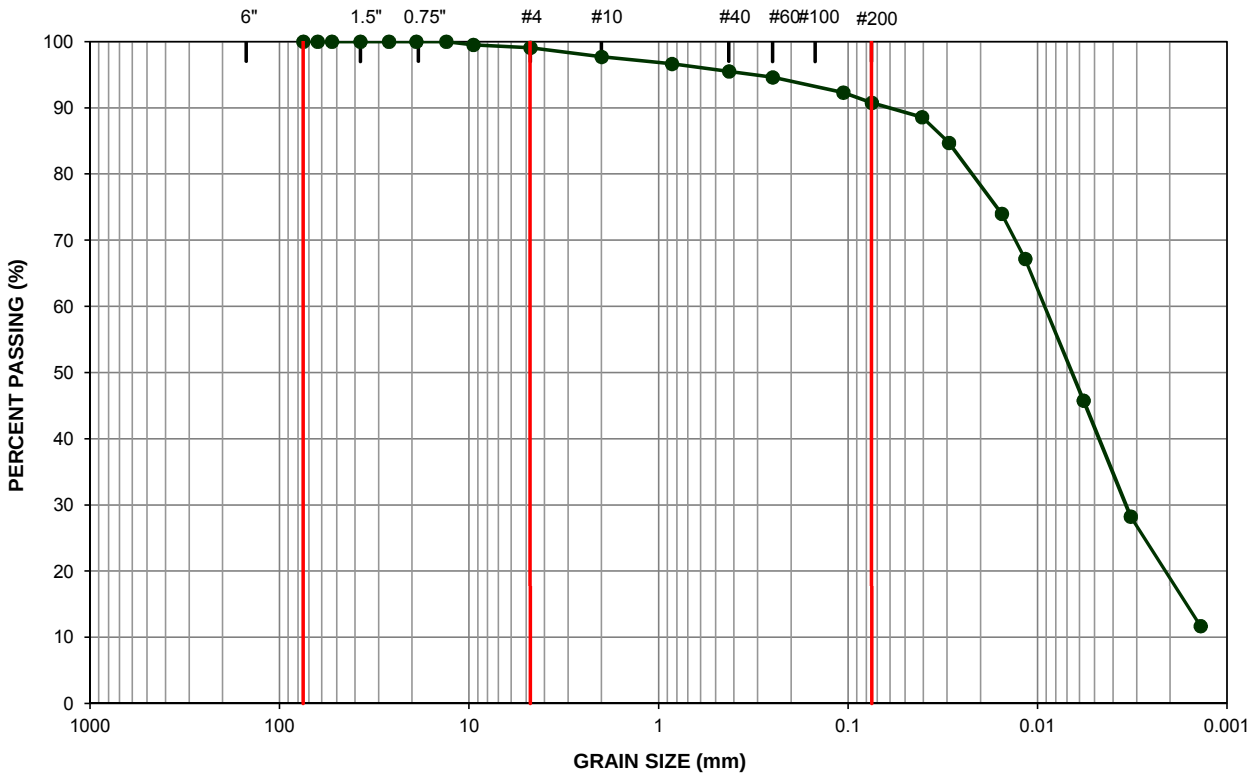
TESTING LABORATORY
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0030A**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**3**
LAB #:	**GA715**	DEPTH:	**N/A**

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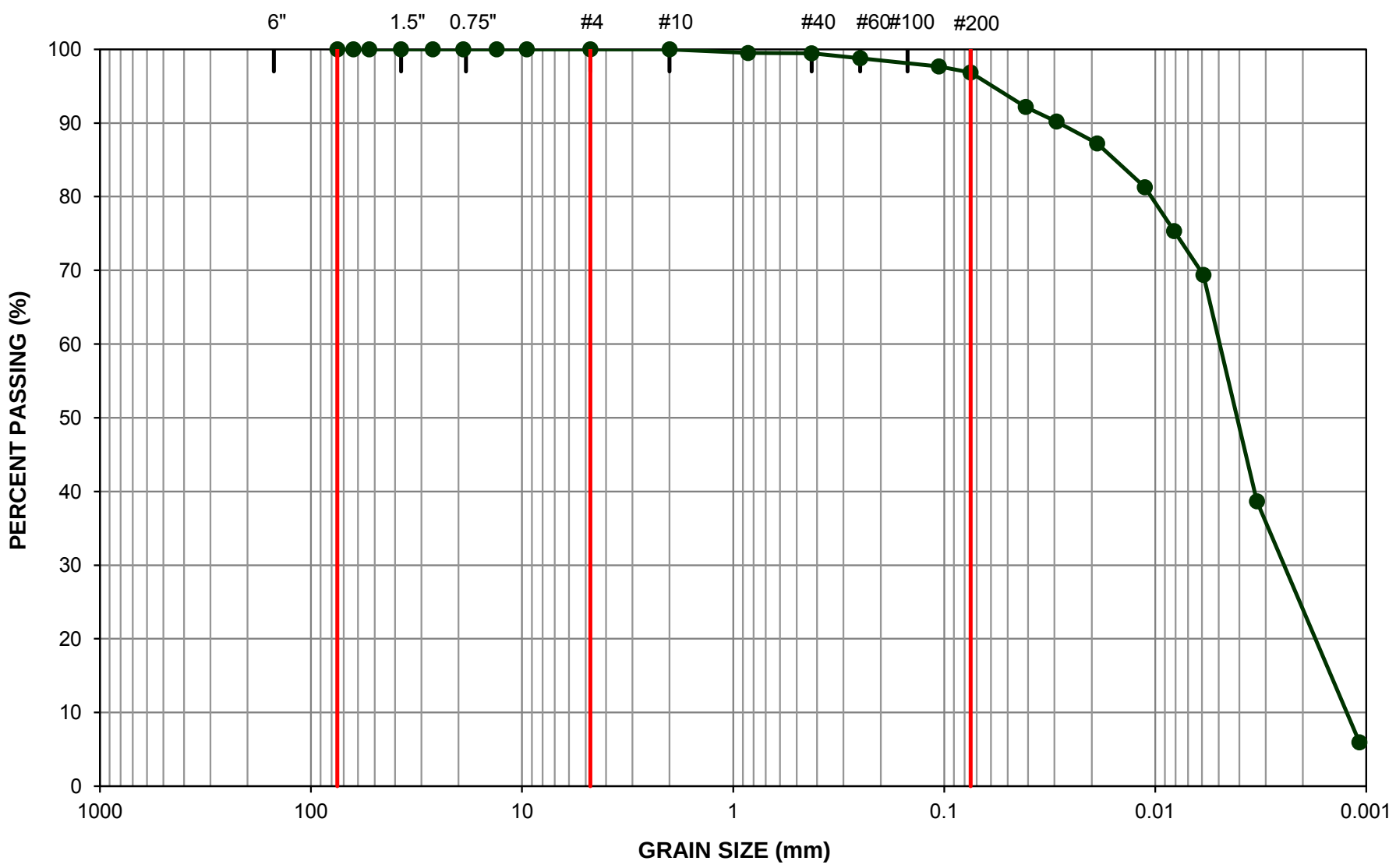
TESTING LABORATORY
CSA Standard A283

50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0031**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA716**	DEPTH:	**N/A**

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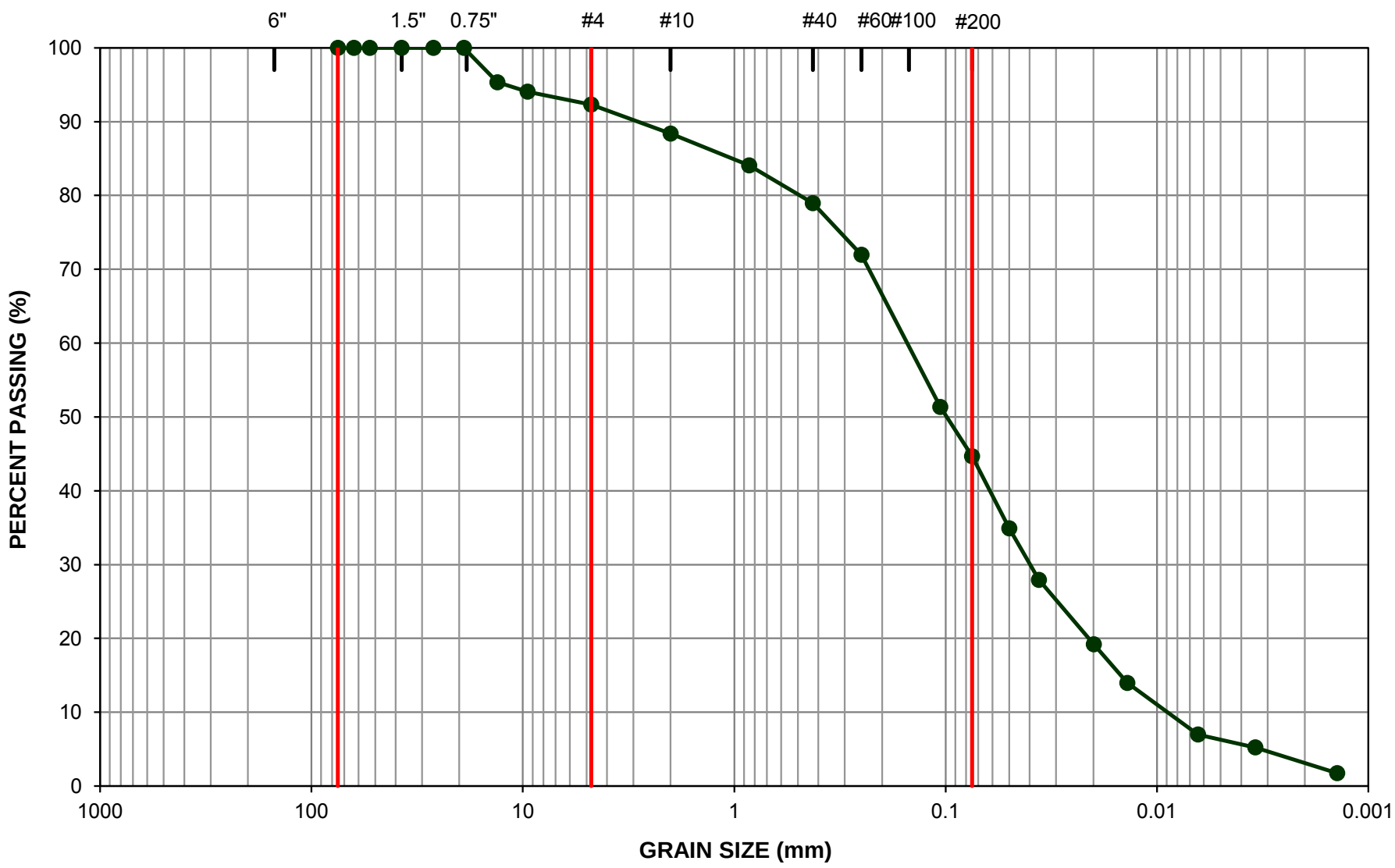
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 23, 2011**	BOREHOLE:	**BRH-0031**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**6**
LAB #:	**GA717**	DEPTH:	**N/A**

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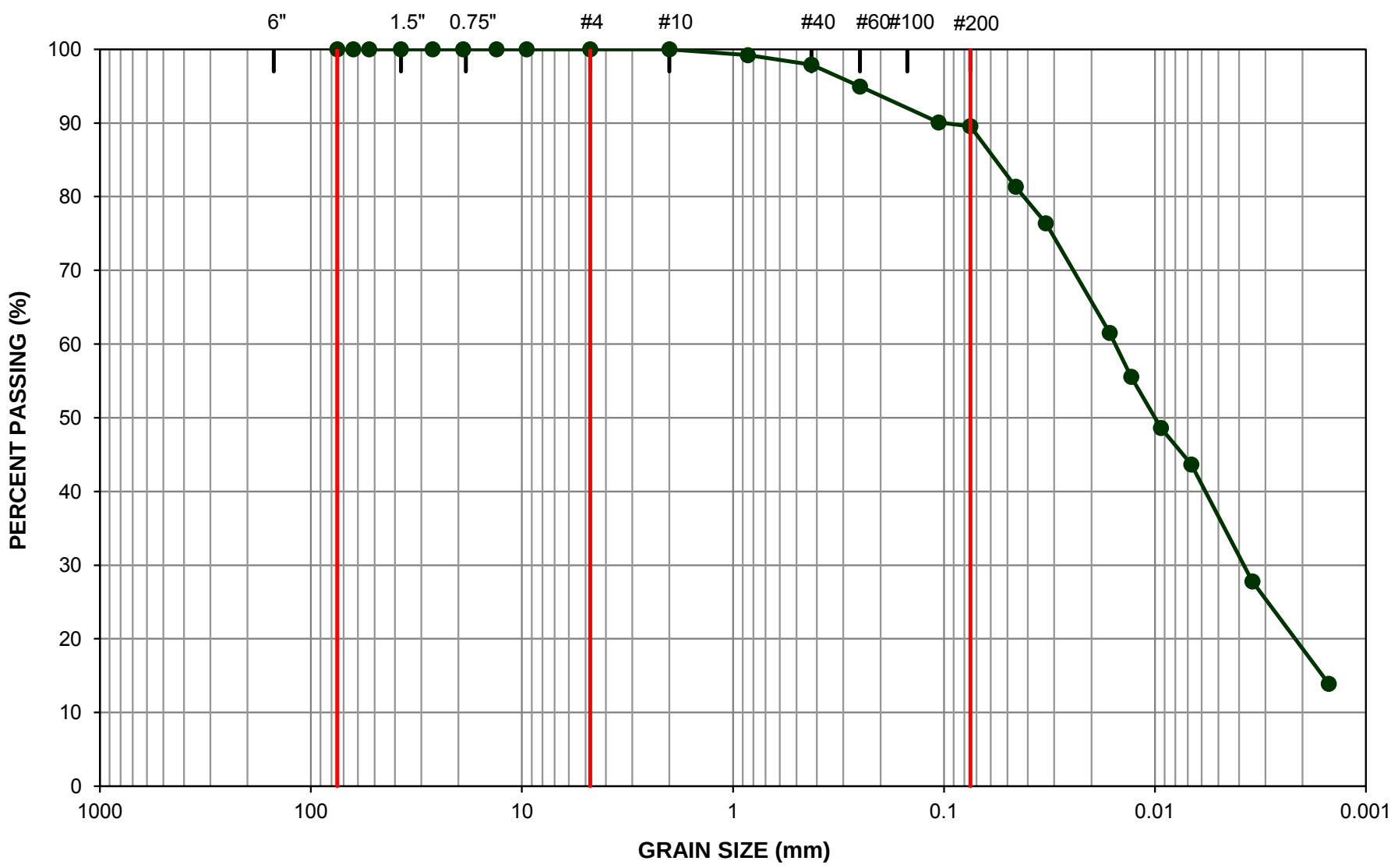
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0032**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**3**
LAB #:	**GA718**	DEPTH:	**N/A**

Reviewed:

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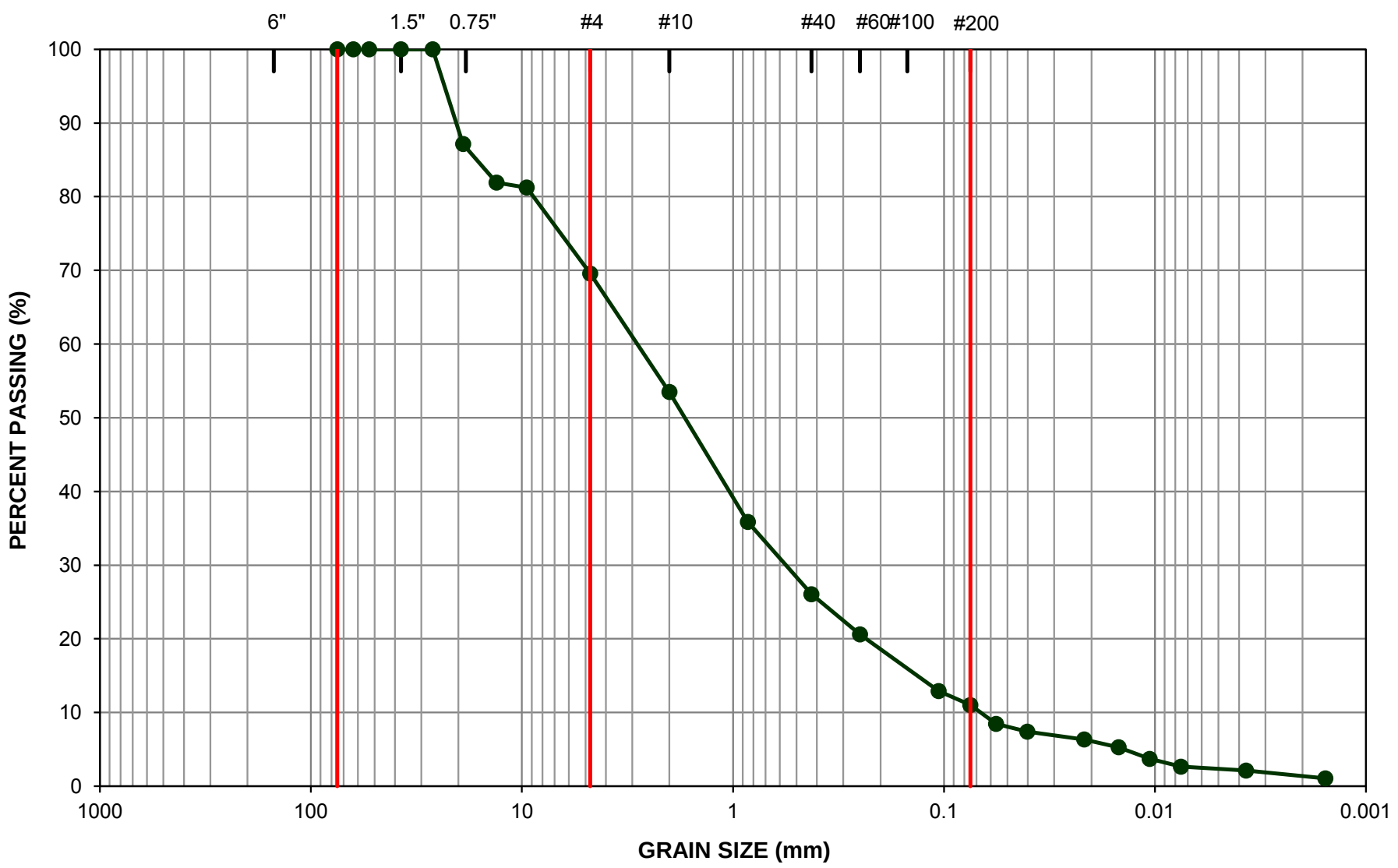
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



Golder Associates
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DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0032**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**5**
LAB #:	**GA719**	DEPTH:	**N/A**

Reviewed:

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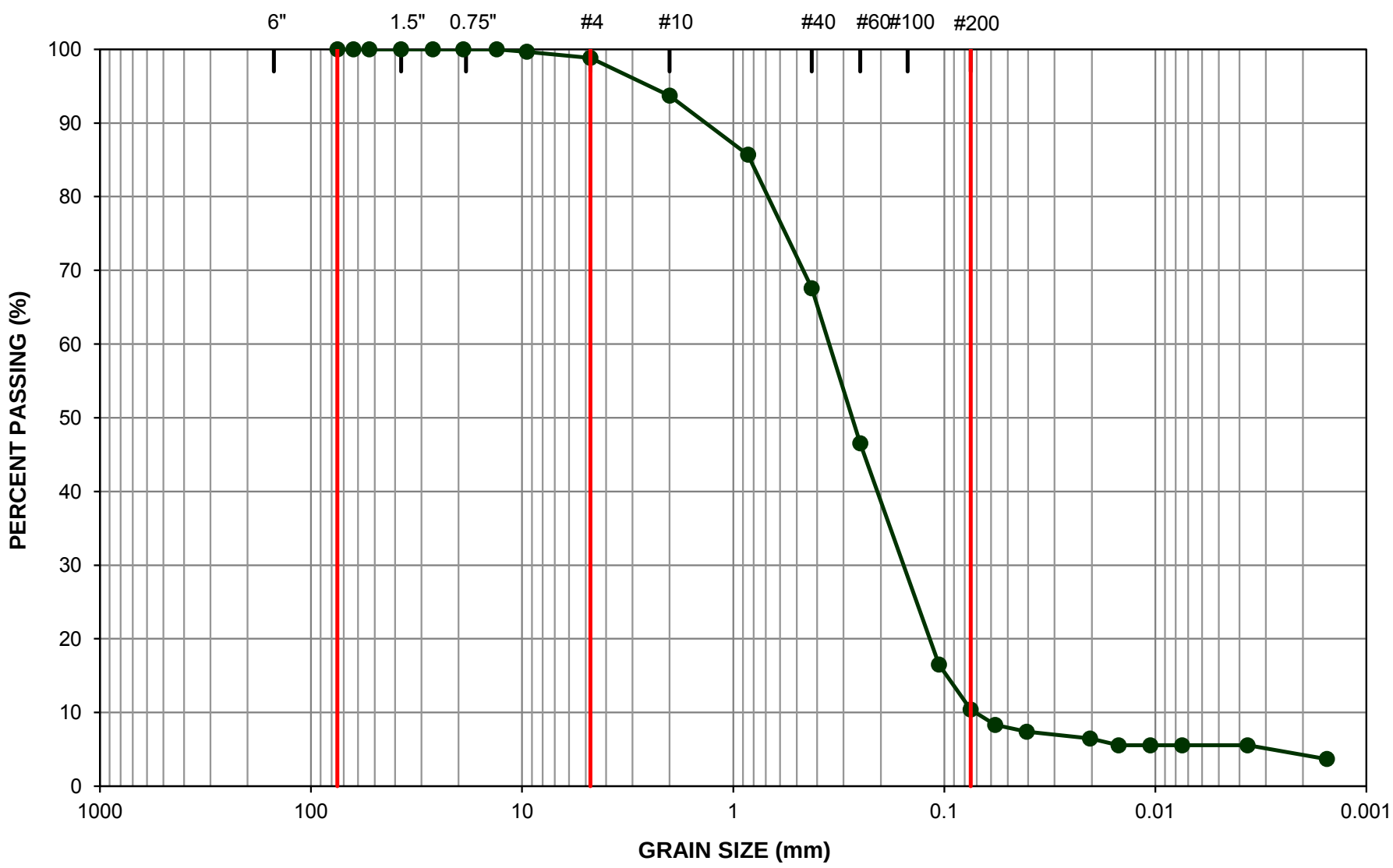
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0033**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4**
LAB #:	**GA720**	DEPTH:	**N/A**

Reviewed:

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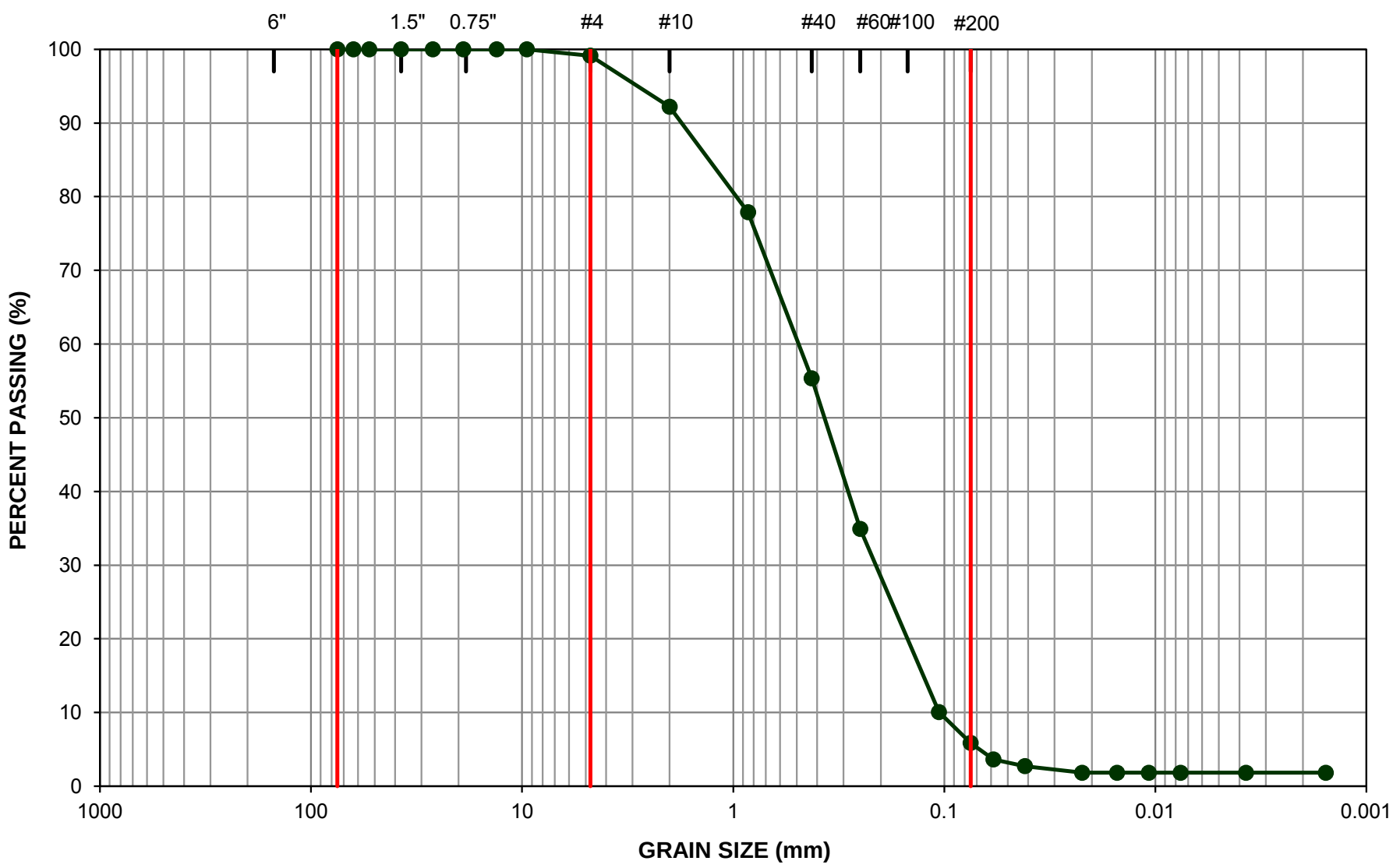
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0033**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**6**
LAB #:	**GA721**	DEPTH:	**N/A**

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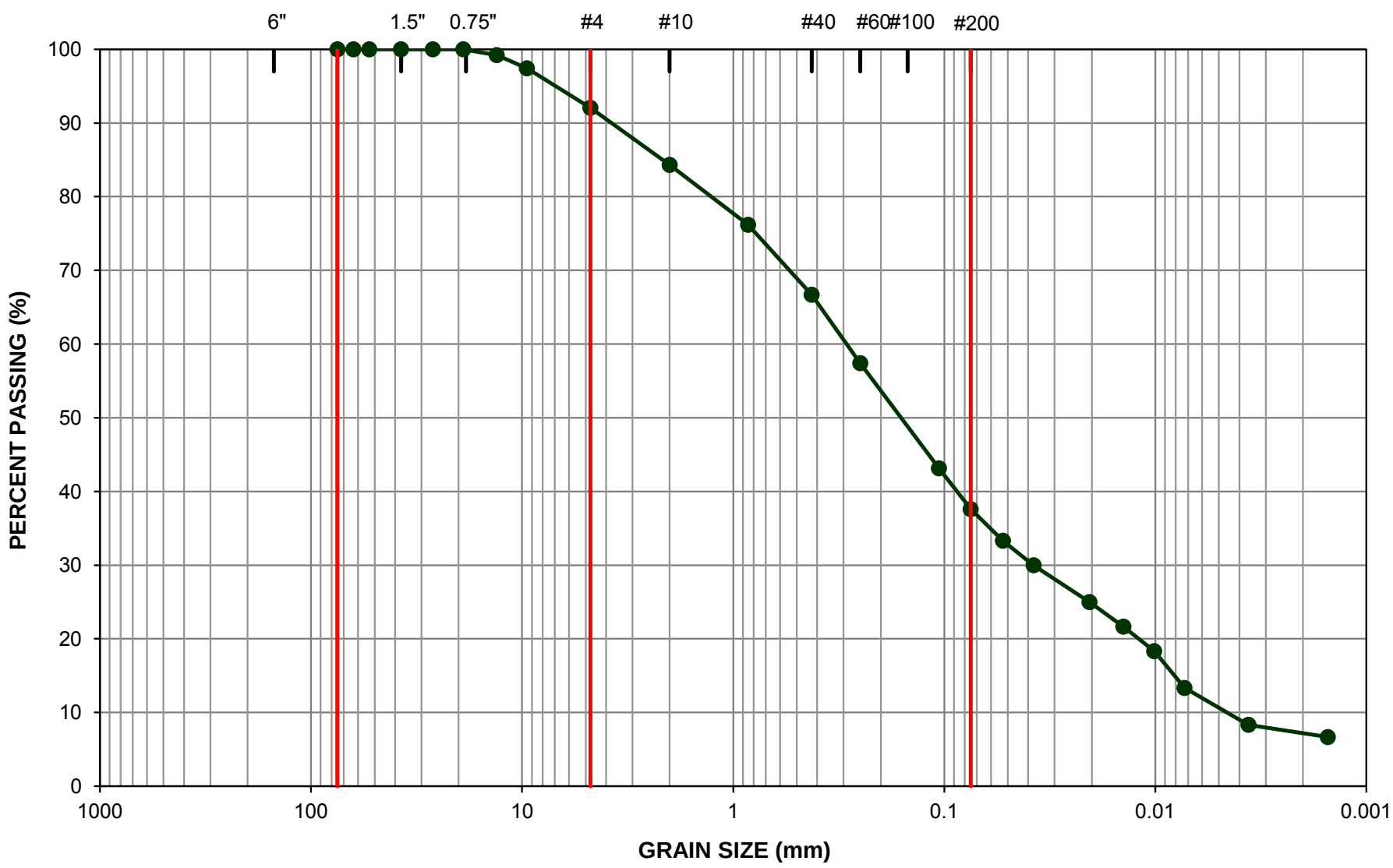
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size		Sand Size			Silt & Clay Sizes
		Coarse	Fine	Coarse	Medium	Fine	



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DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0033**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**8**
LAB #:	**GA722**	DEPTH:	**N/A**

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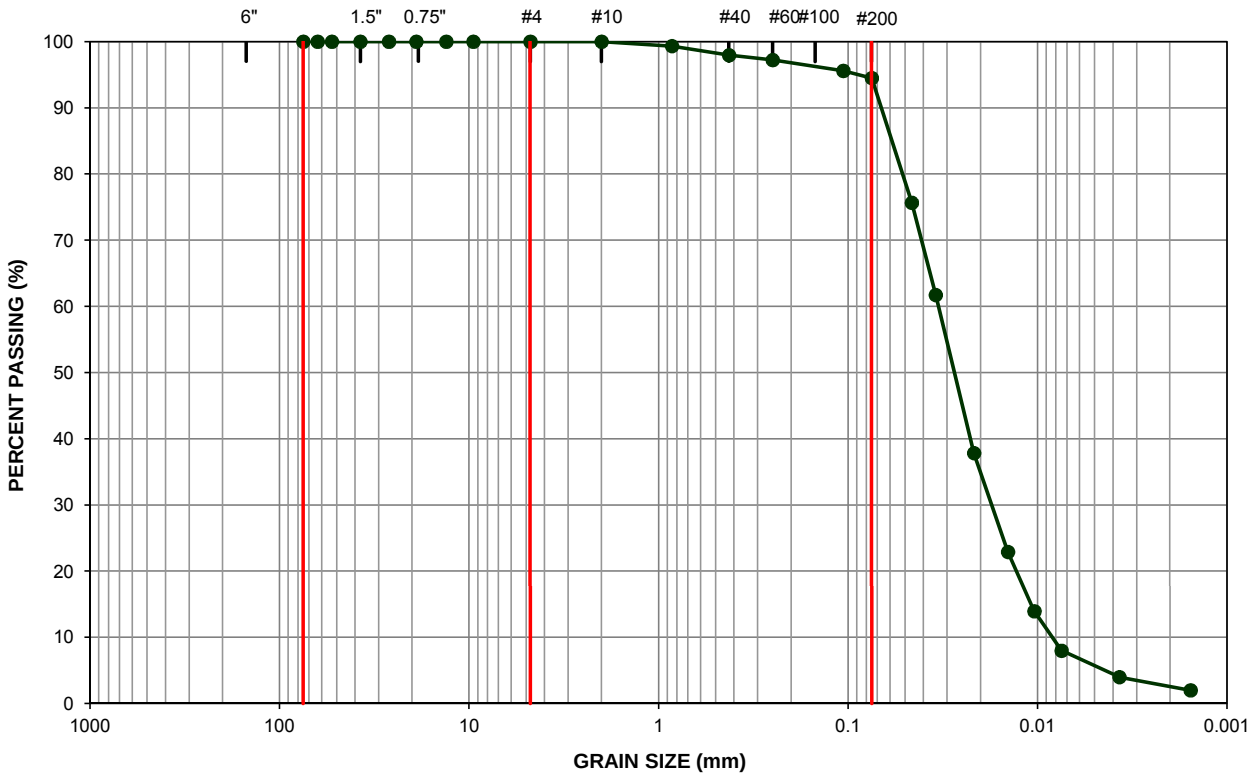
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0034**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**4B**
LAB #:	**GA723B**	DEPTH:	**N/A**

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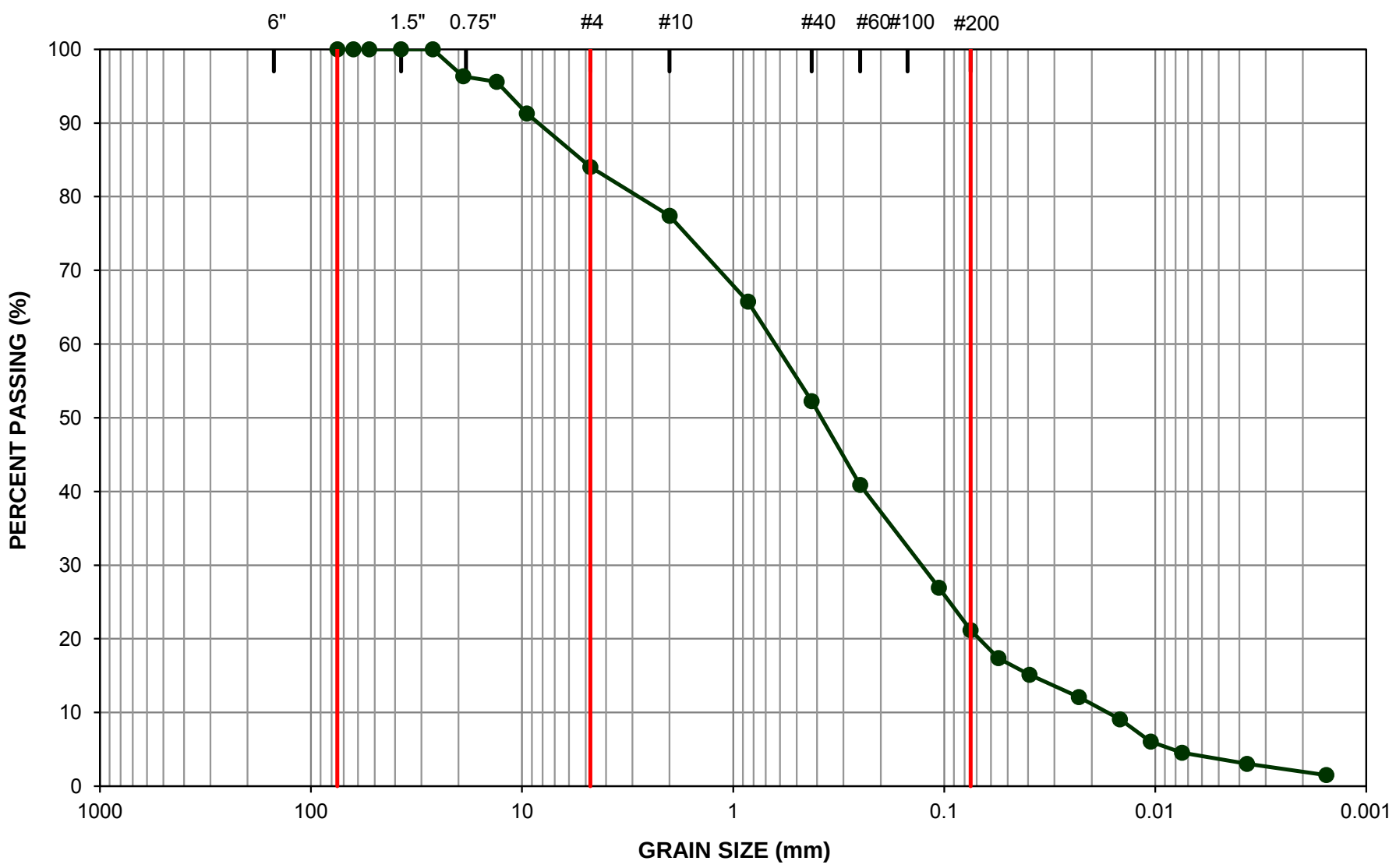
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

PARTICLE SIZE DISTRIBUTION

Hammond Reef

Boulder Size	Cobble Size	Gravel Size: Coarse	Gravel Size: Fine	Sand Size: Coarse	Sand Size: Medium	Sand Size: Fine	Silt & Clay Sizes



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DATE:	**September 26, 2011**	BOREHOLE:	**BRH-0034**
PROJECT #:	**10-1118-0020 ph 4000**	SAMPLE:	**6**
LAB #:	**GA724**	DEPTH:	**N/A**

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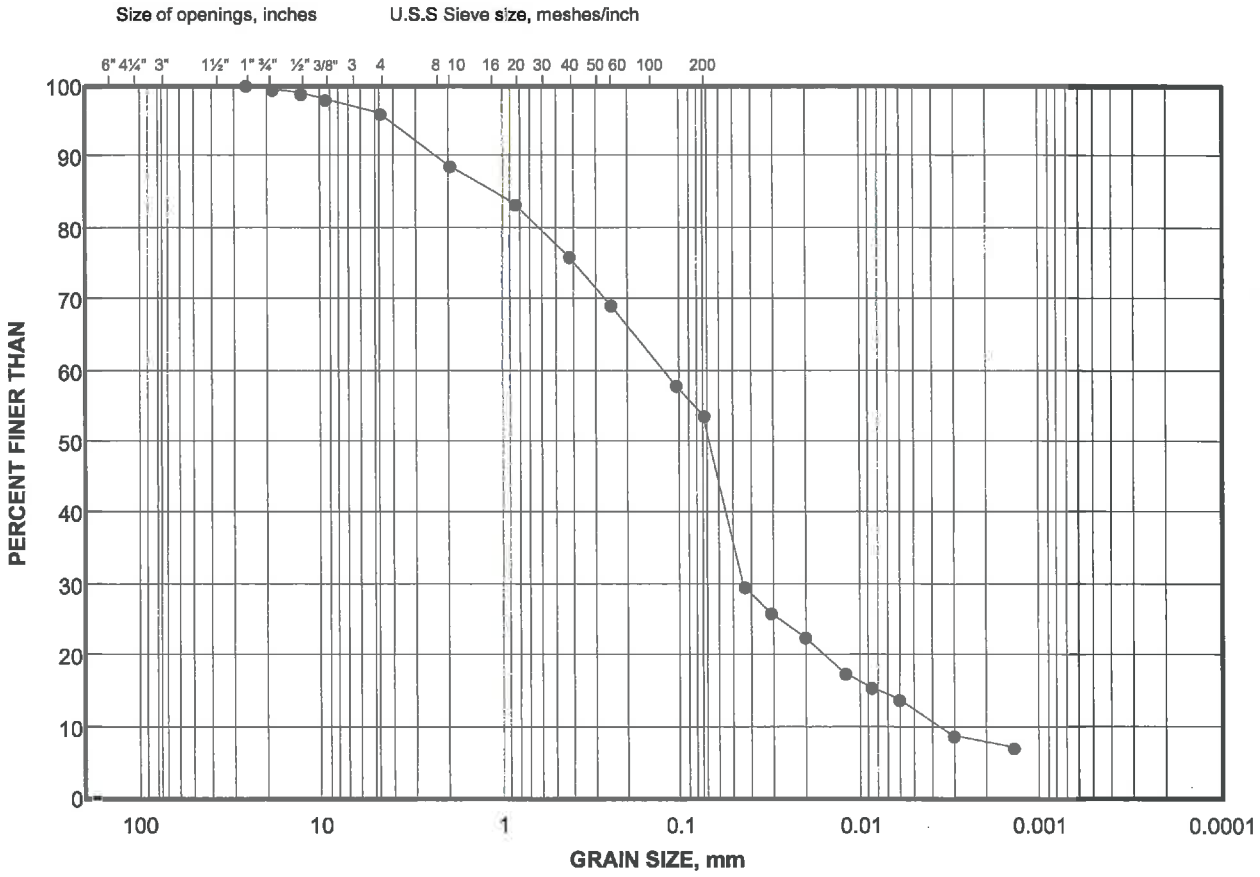
TESTING LABORATORY
CSA Standard A283

CANADA'S 50 BEST MANAGED COMPANIES

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-1	1	

Project Number: 11-1118-0074

Checked By: _____

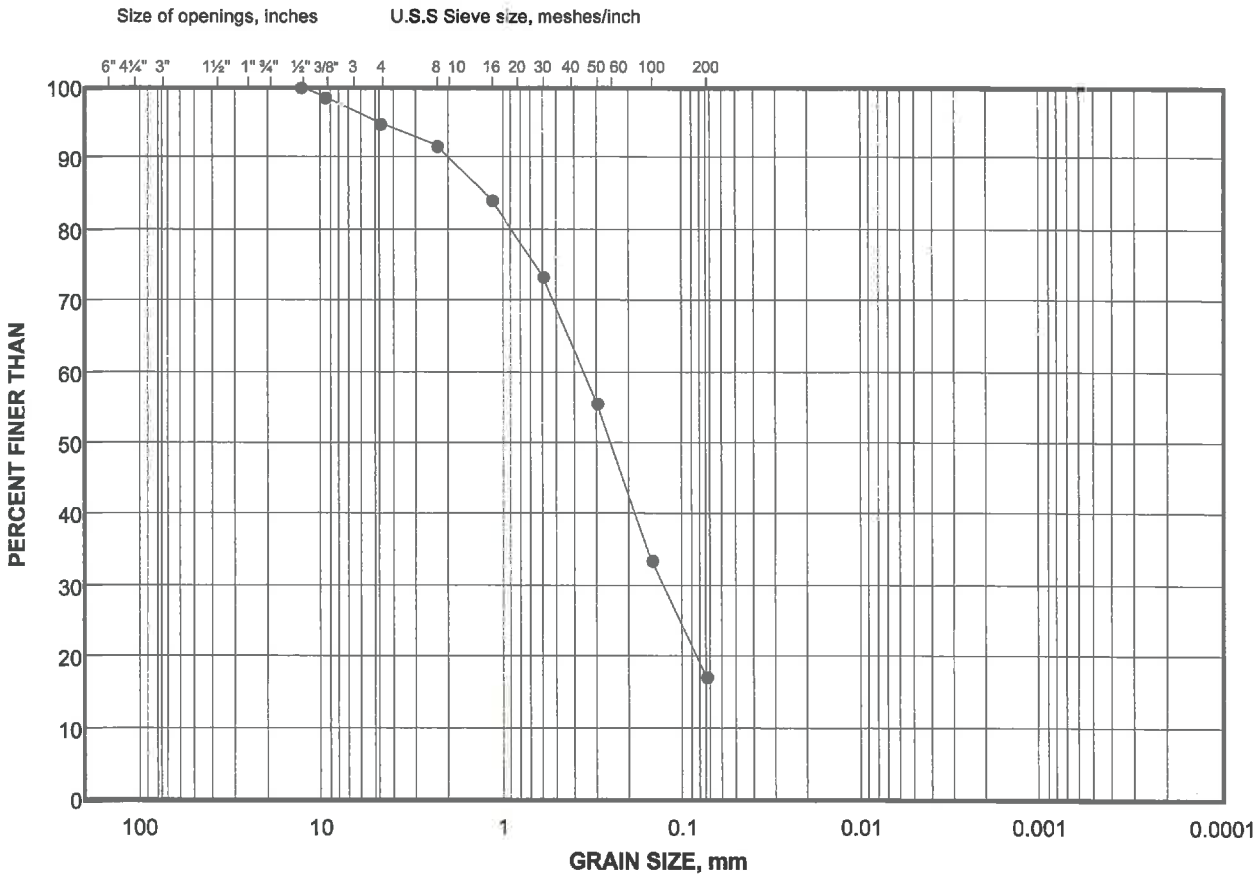
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-1	2B	

Project Number: 11-1118-0074

Checked By: AG

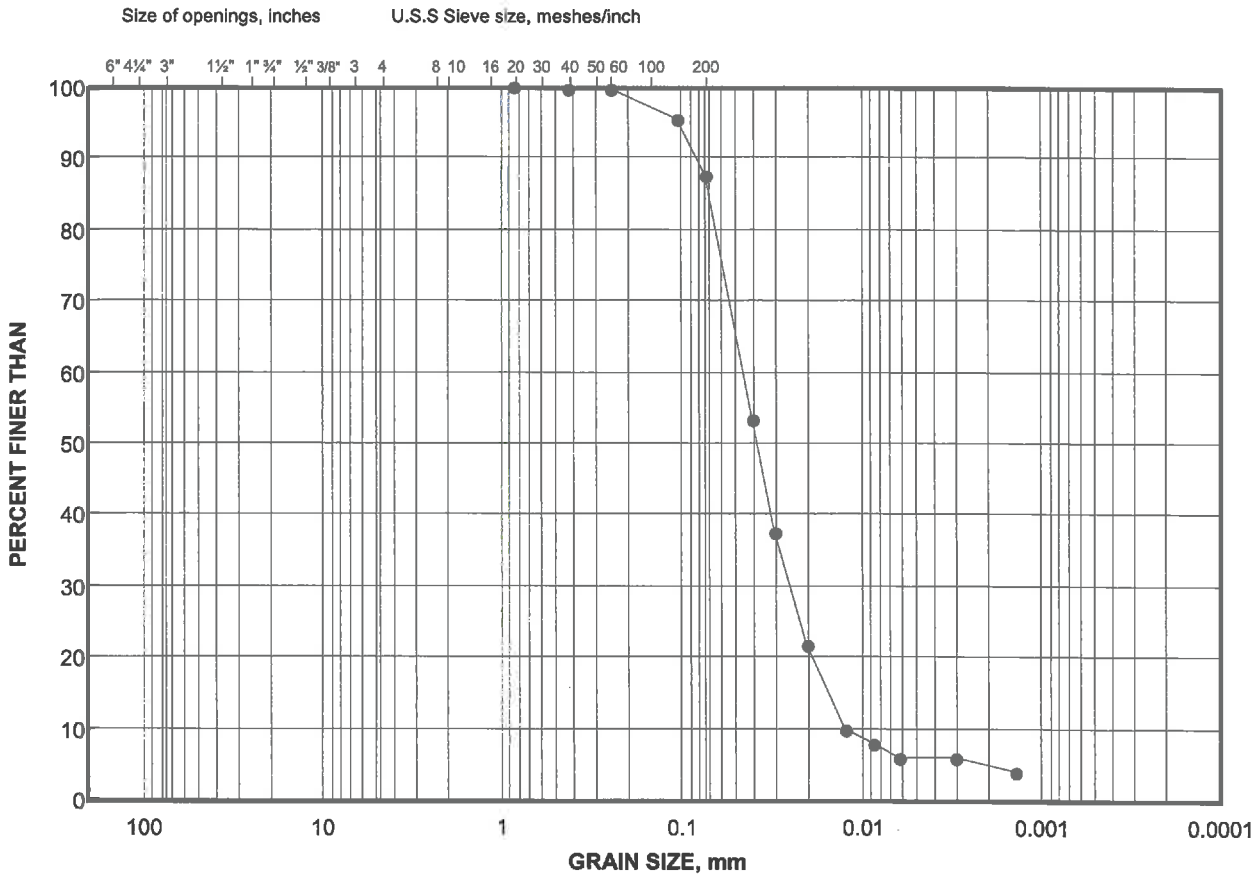
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-2	4	

Project Number: 11-1118-0074

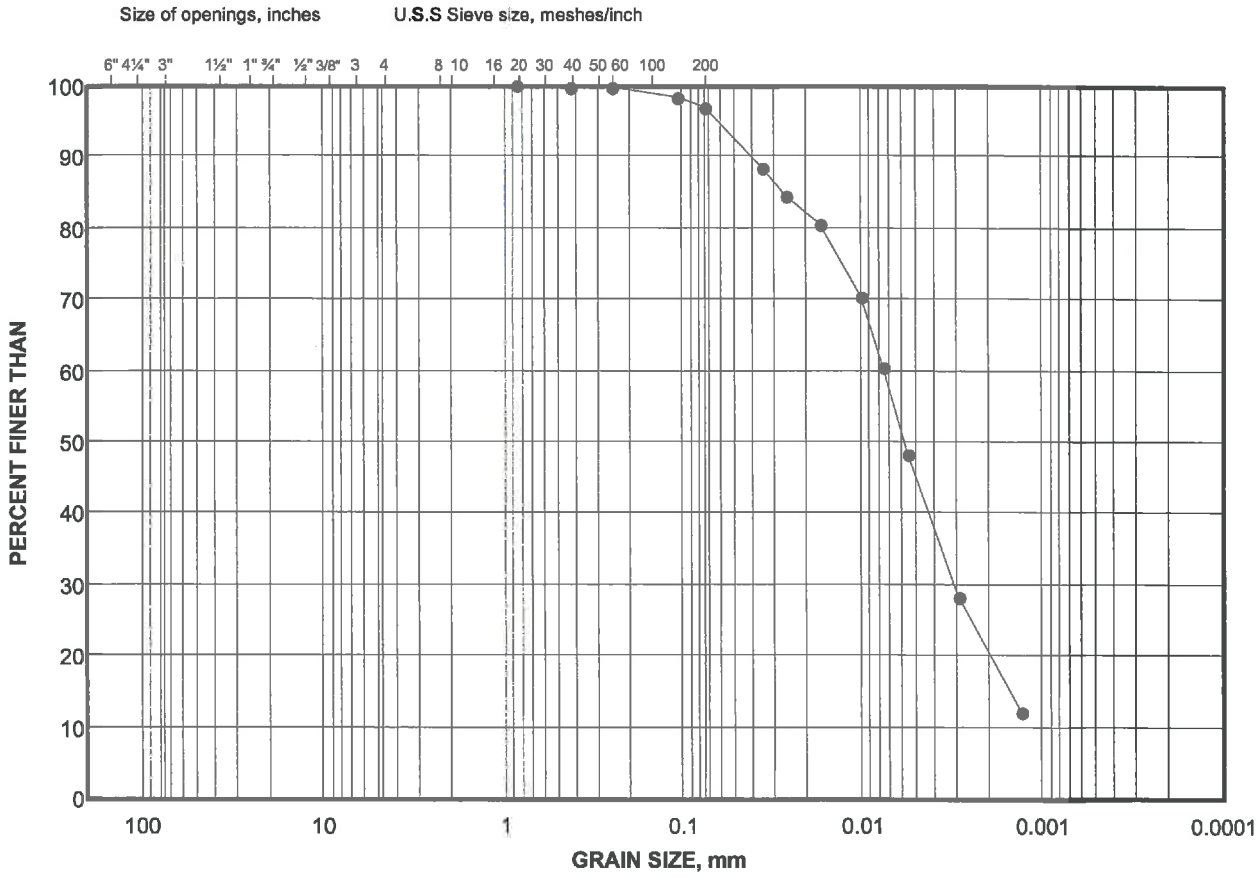
Checked By: AS

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-2	6	

Project Number: 11-1118-0074

Checked By: AS

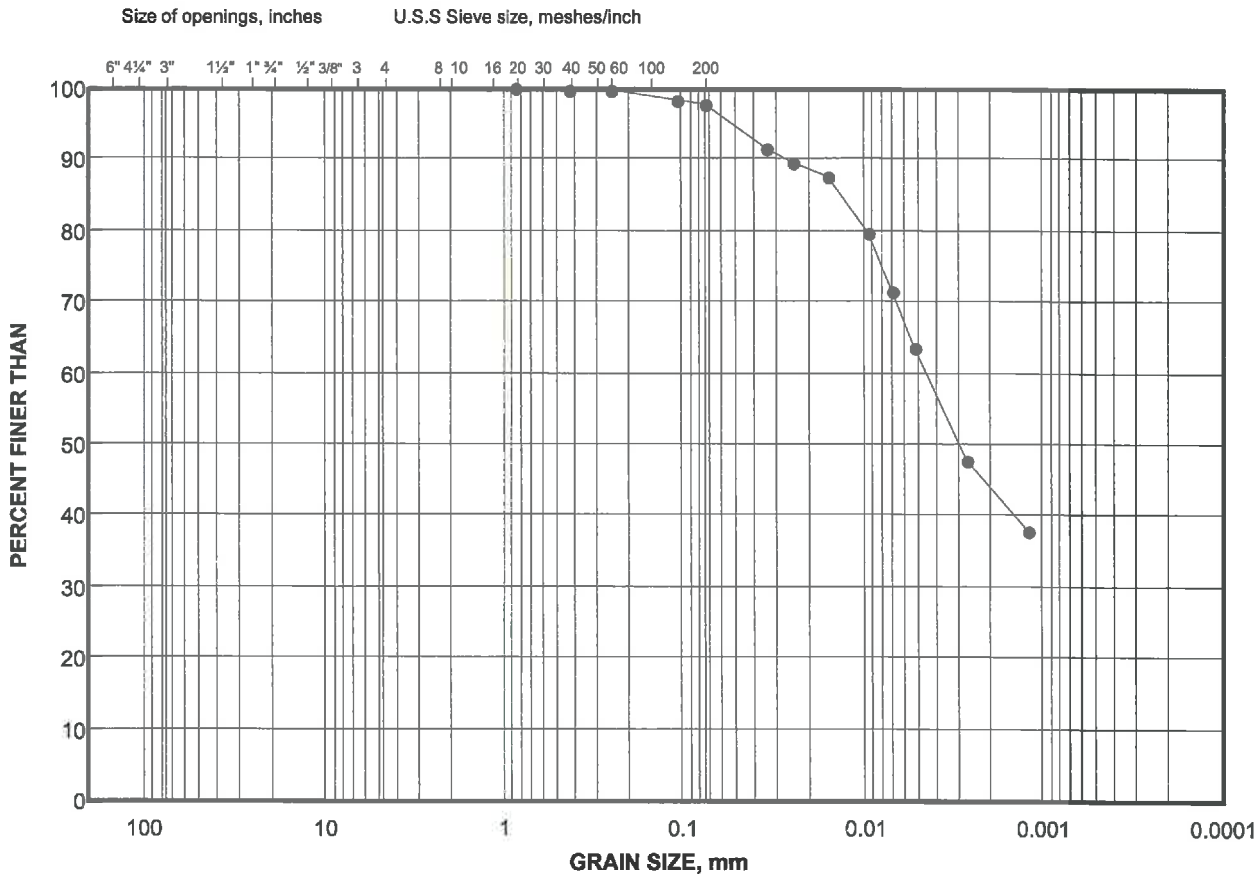
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-2	7	

Project Number: 11-1118-0074

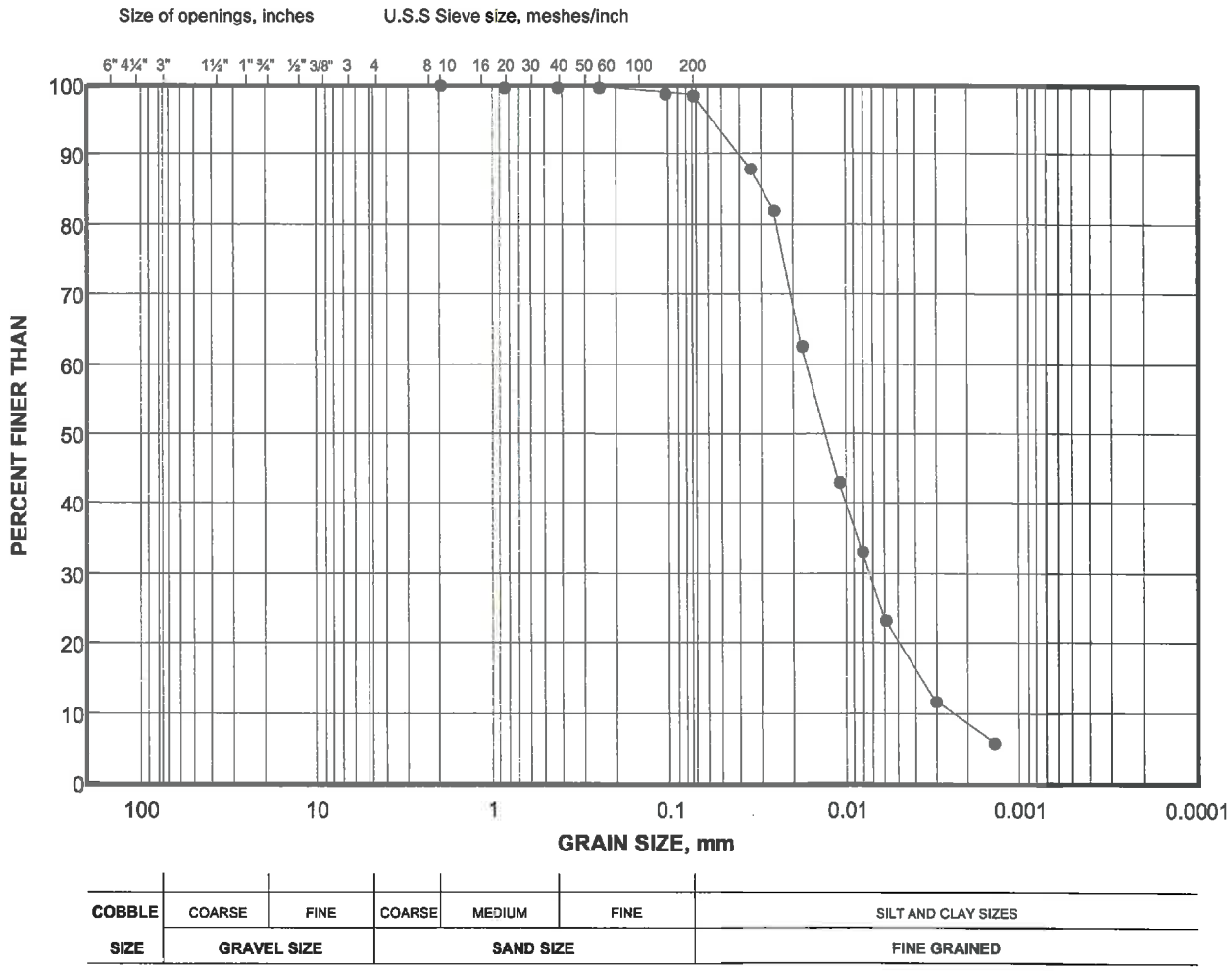
Checked By: AG

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-2	10	

Project Number: 11-1118-0074

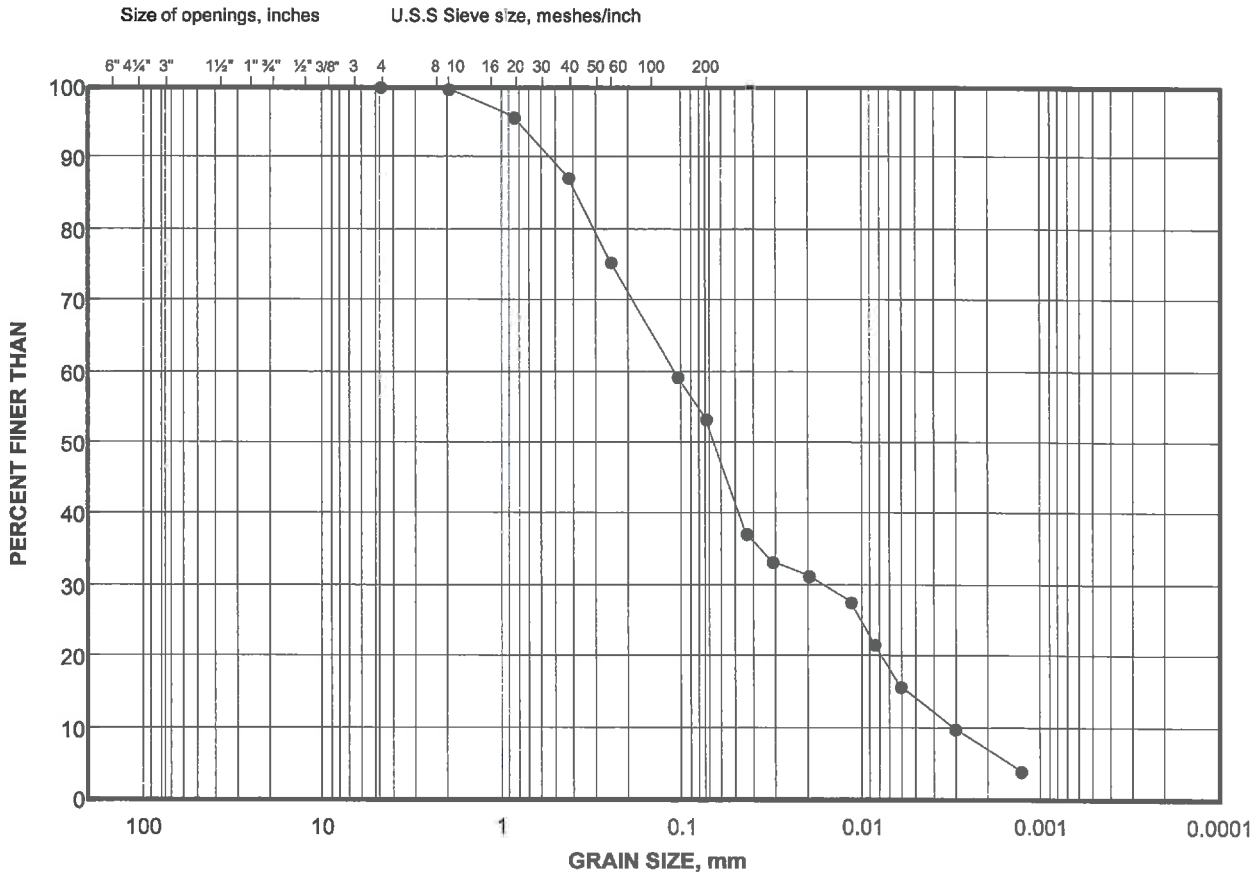
Checked By: AV

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	3	

Project Number: 11-1118-0074

Checked By: AS

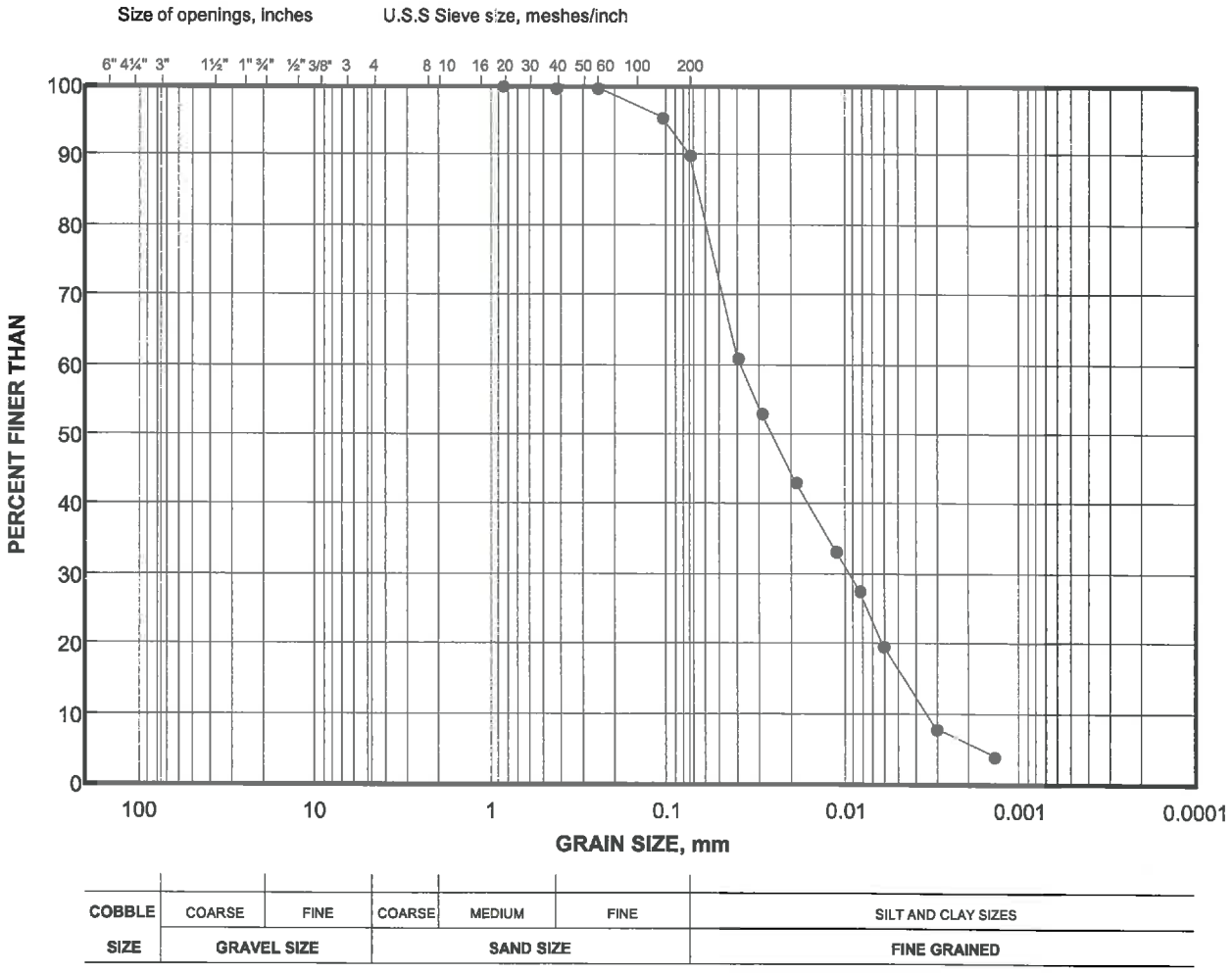
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	4	

Project Number: 11-1118-0074

Checked By: MJ

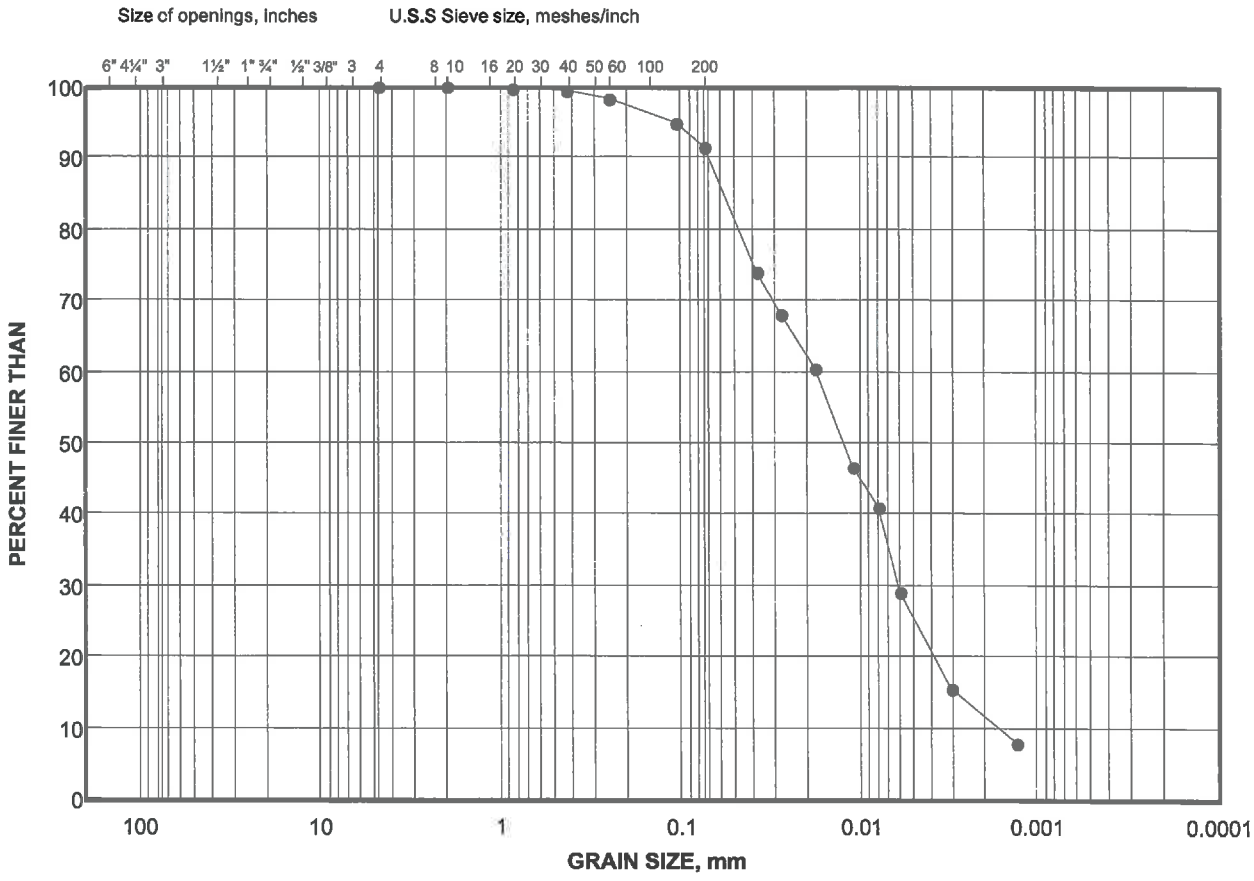
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	5	

Project Number: 11-1118-0074

Checked By: _____

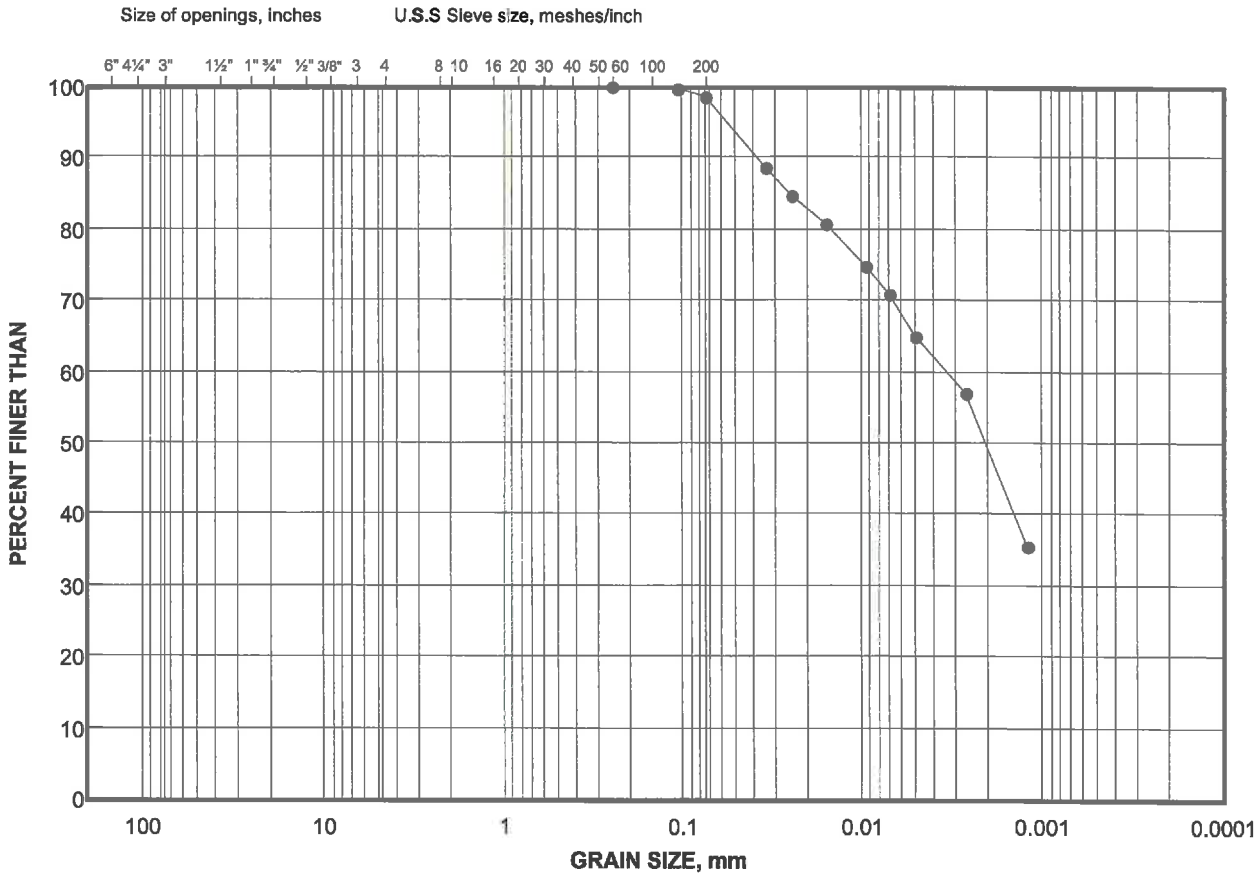
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	7	

Project Number: 11-1118-0074

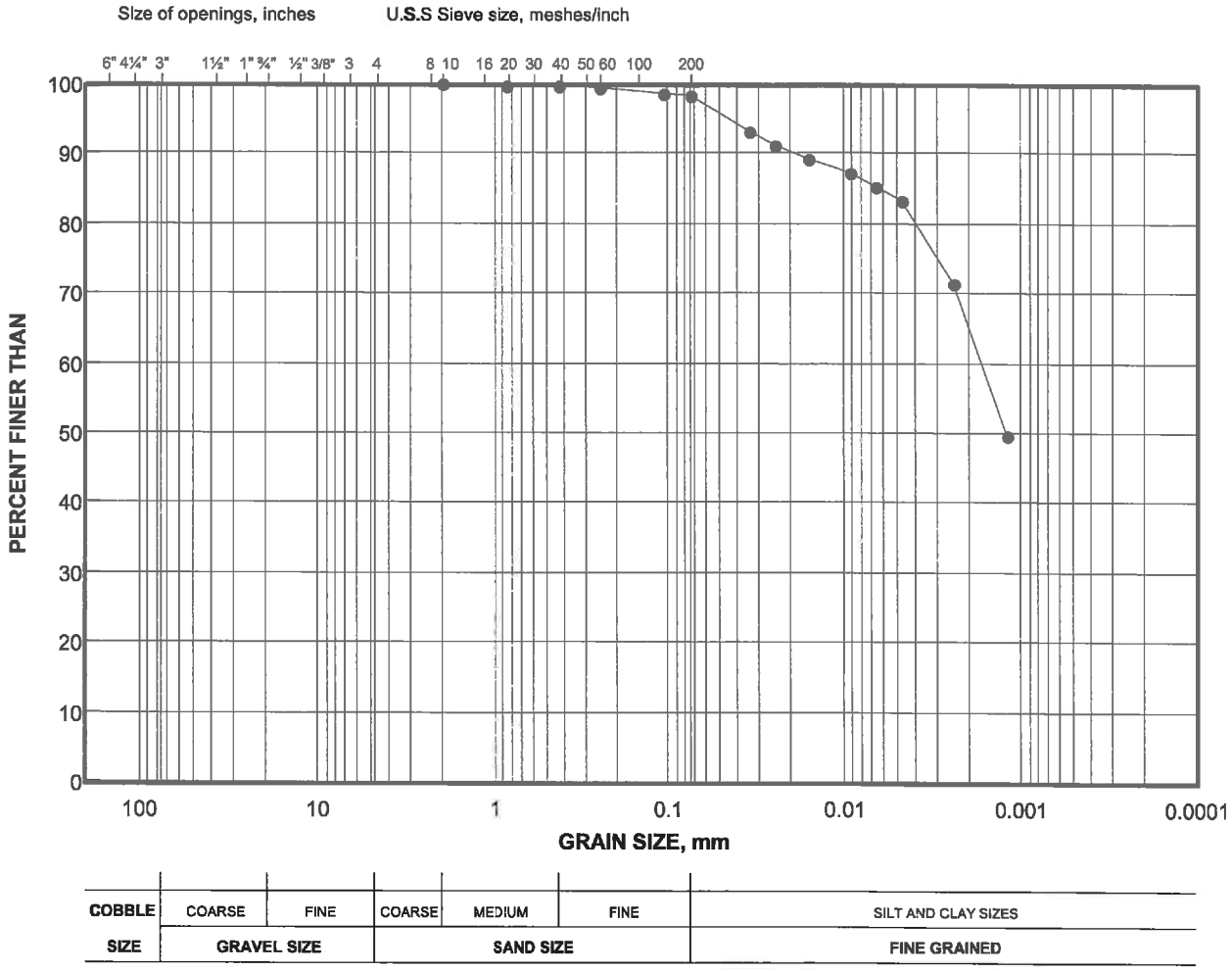
Checked By: AG

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	8	

Project Number: 11-1118-0074

Checked By: _____

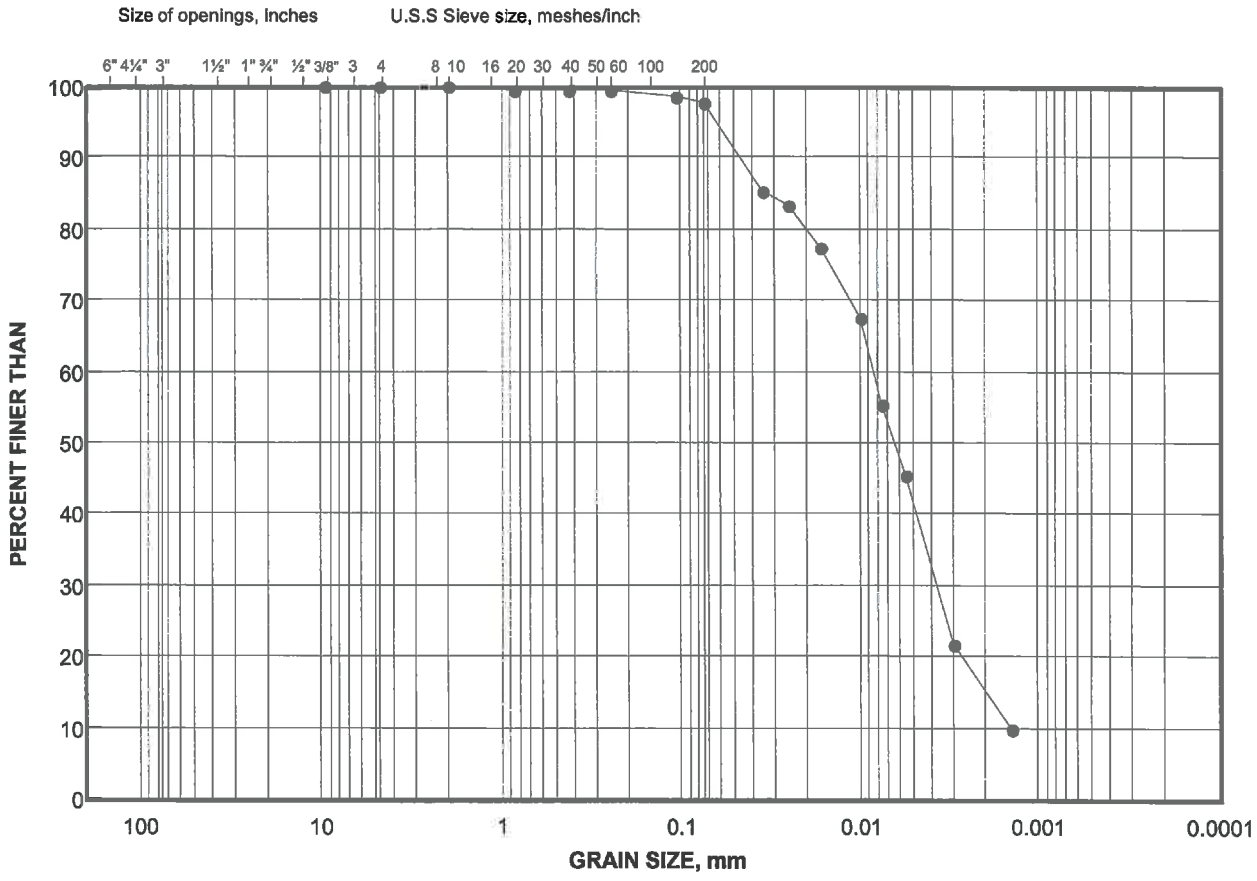
Golder Associates

Date: 17-Sep-12

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 – 1656263

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	9	

Project Number: 11-1118-0074

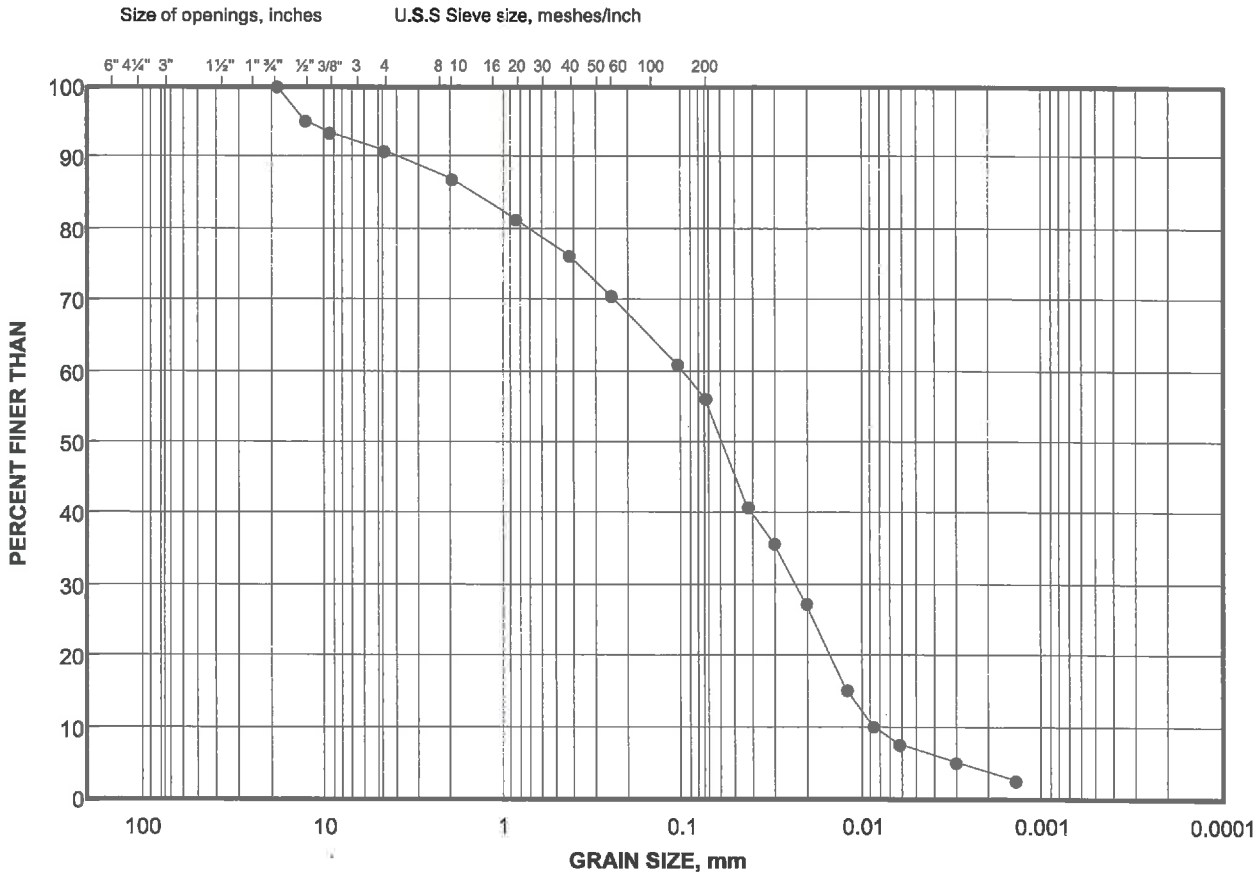
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-3	11	

Project Number: 11-1118-0074

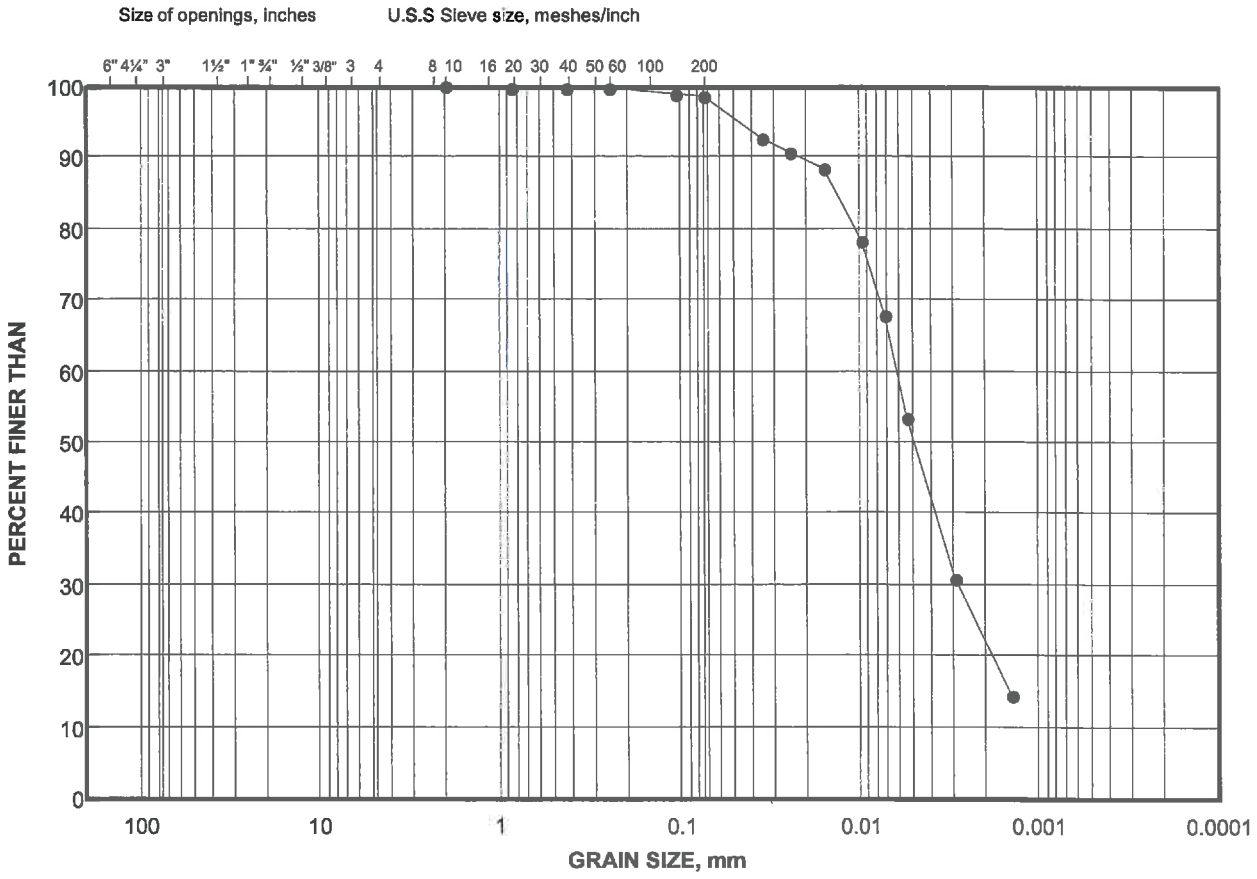
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-4	4	

Project Number: 11-1118-0074

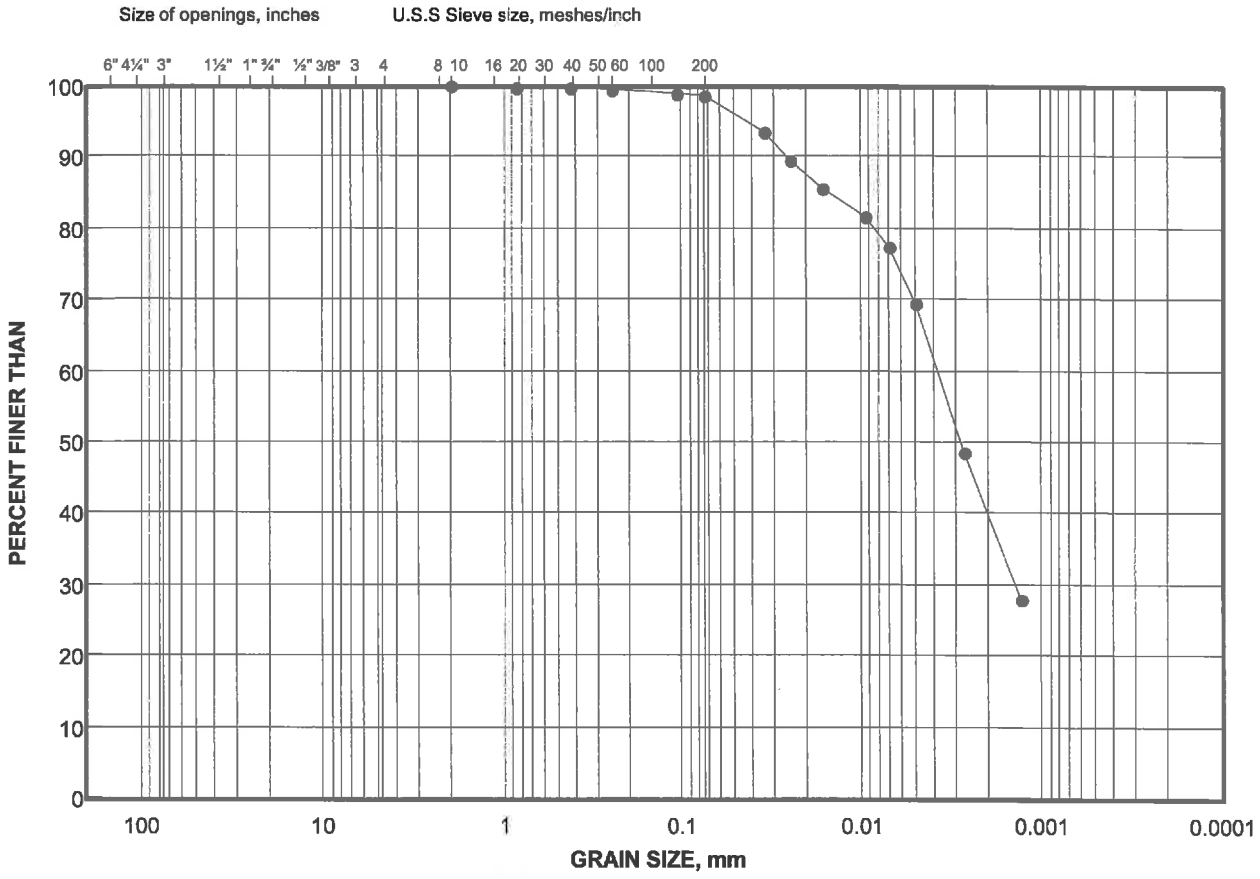
Checked By: AG

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-4	5	

Project Number: 11-1118-0074

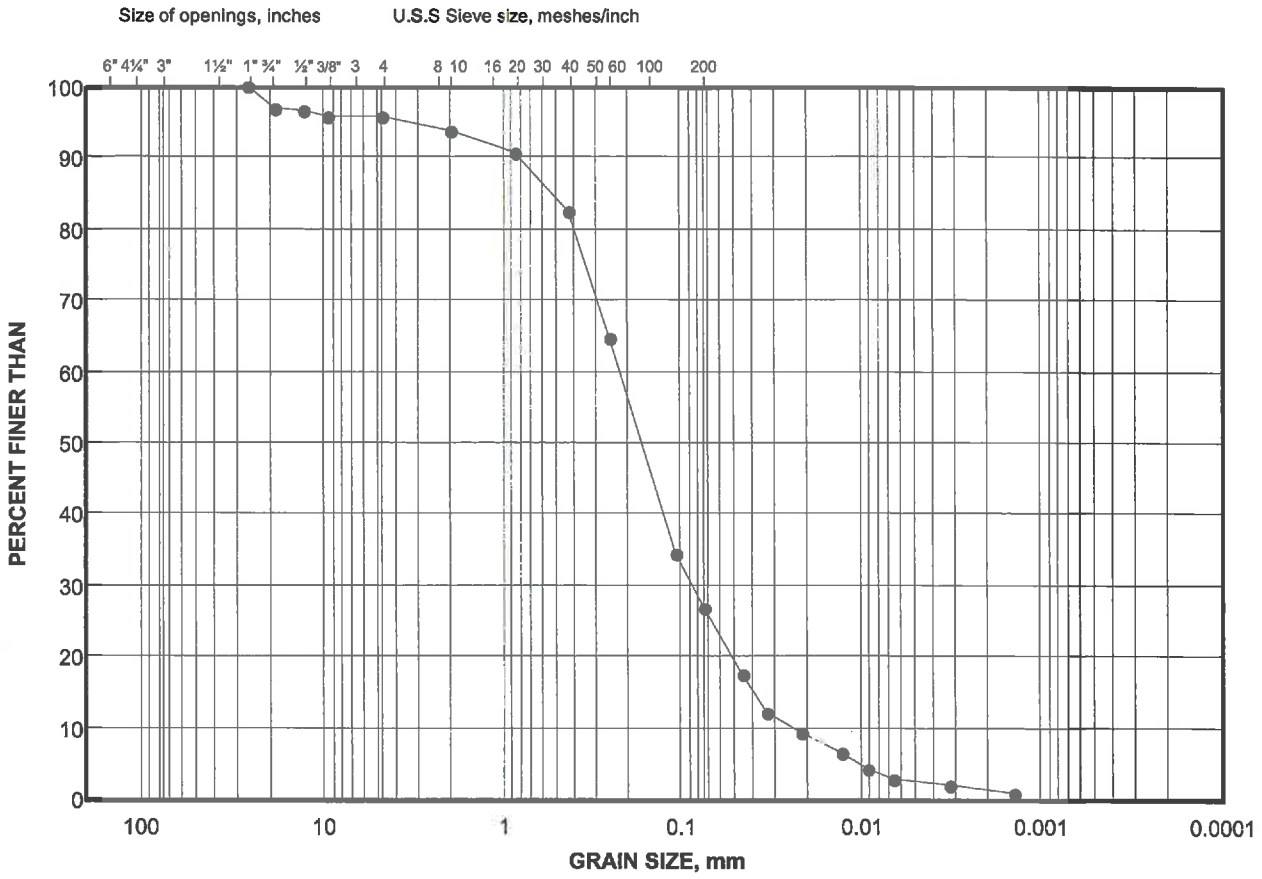
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12-4	8	

Project Number: 11-1118-0074

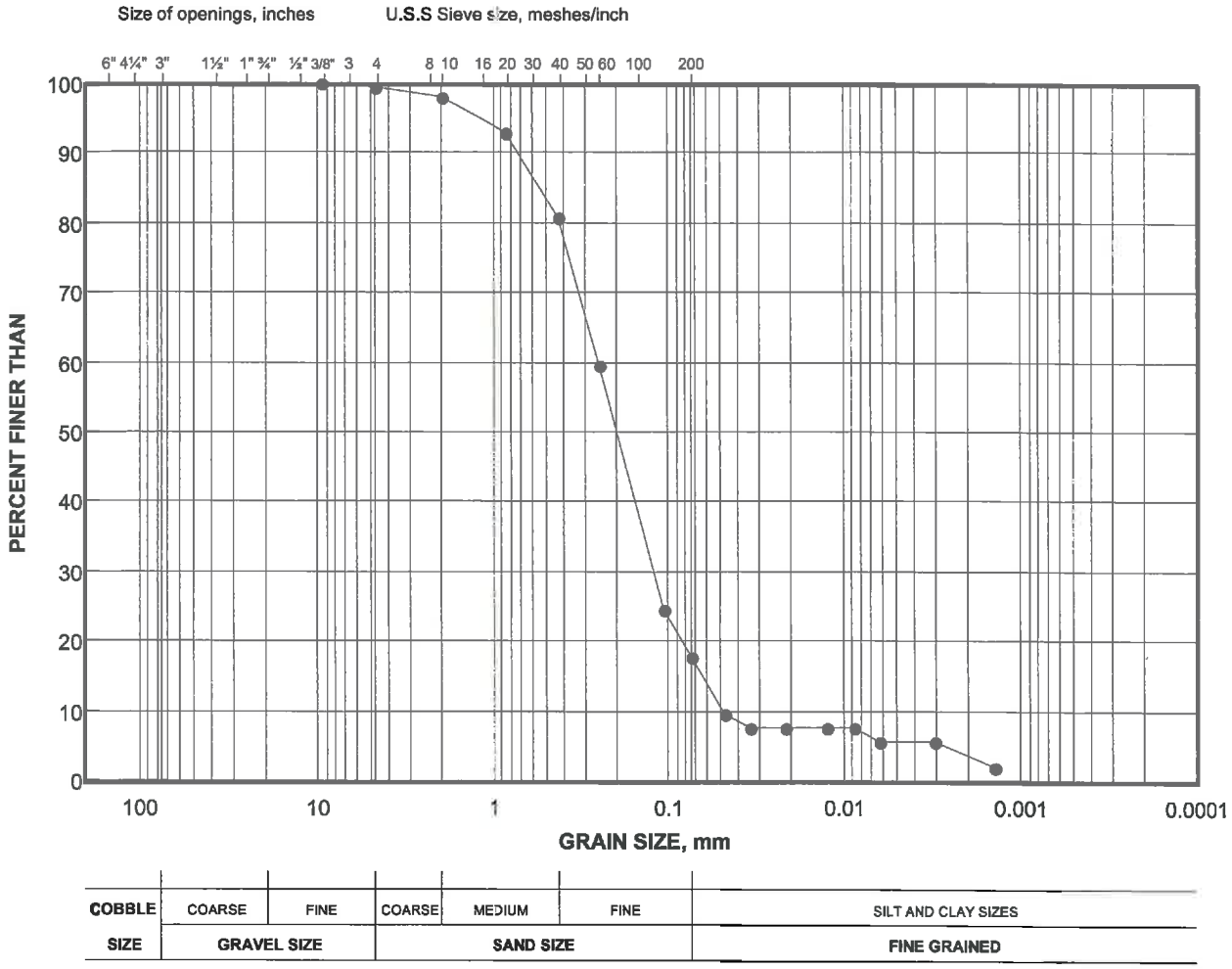
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
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Project Number: 11-1118-0074

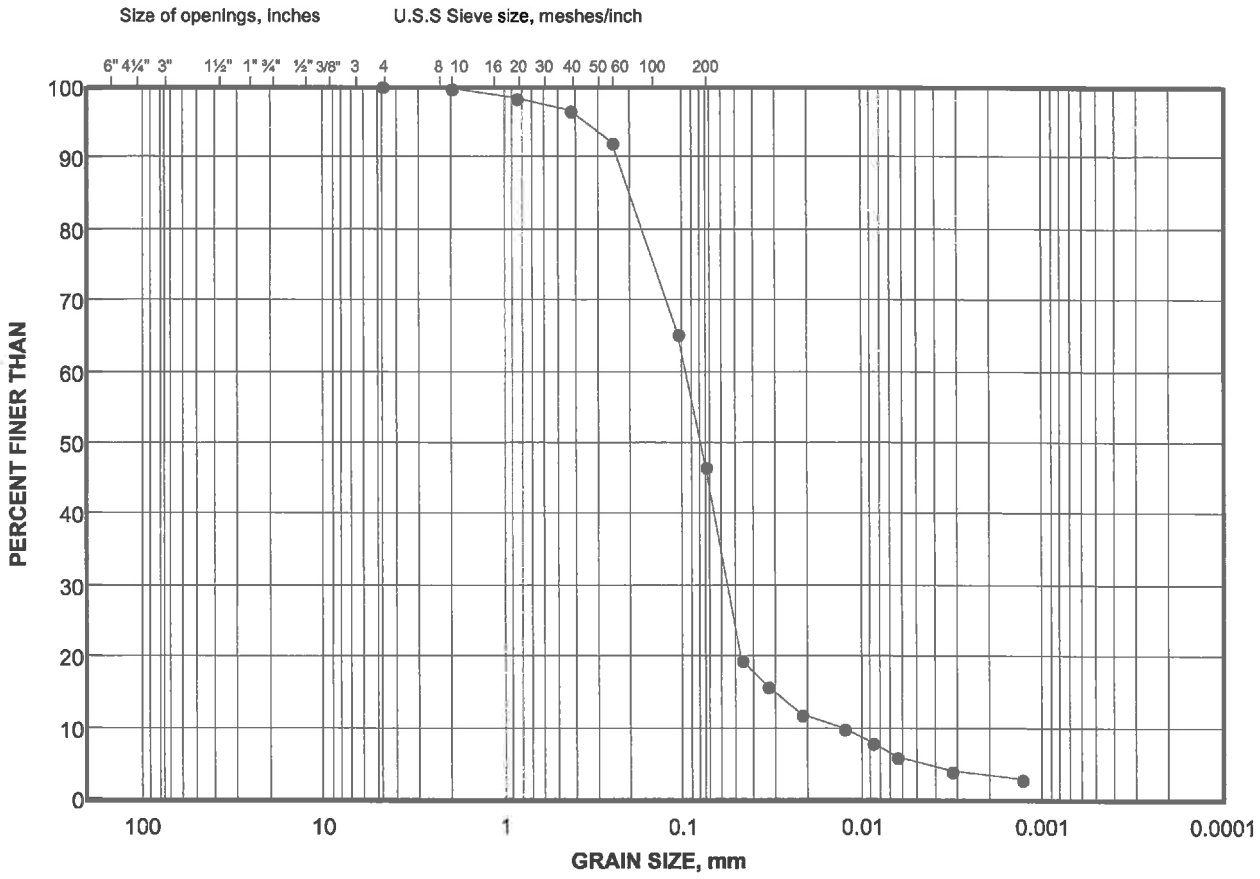
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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Project Number: 11-1118-0074

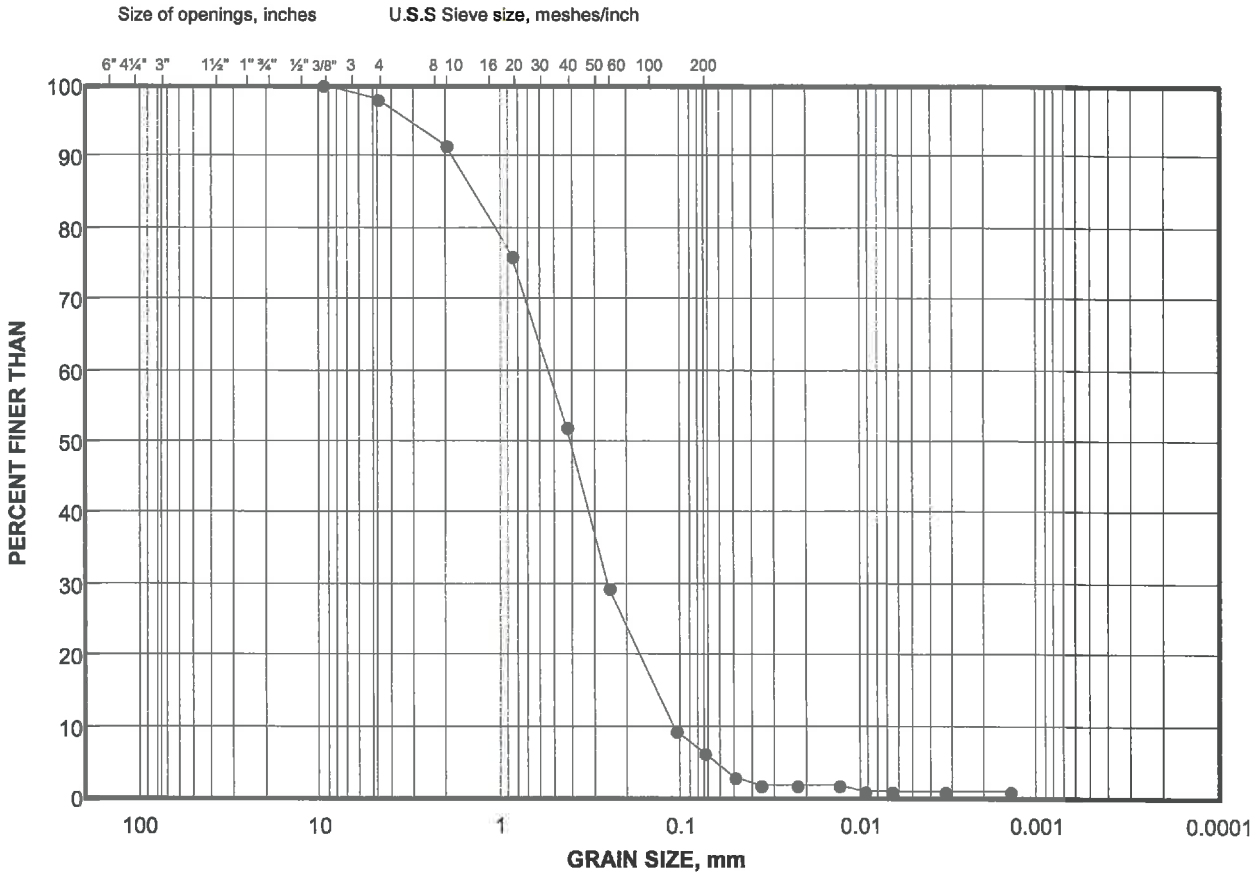
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
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Project Number: 11-1118-0074

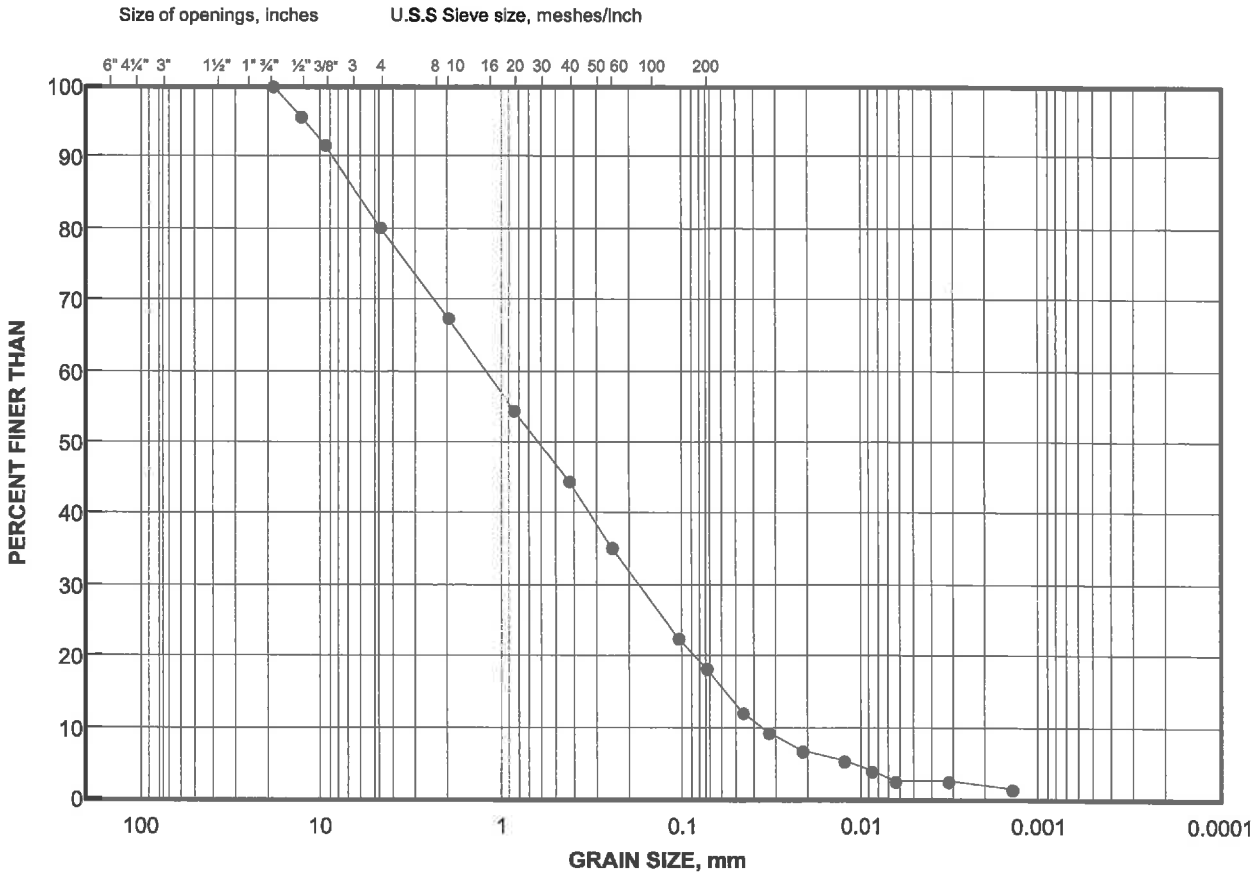
Checked By: AS

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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●	12-5	8	

Project Number: 11-1118-0074

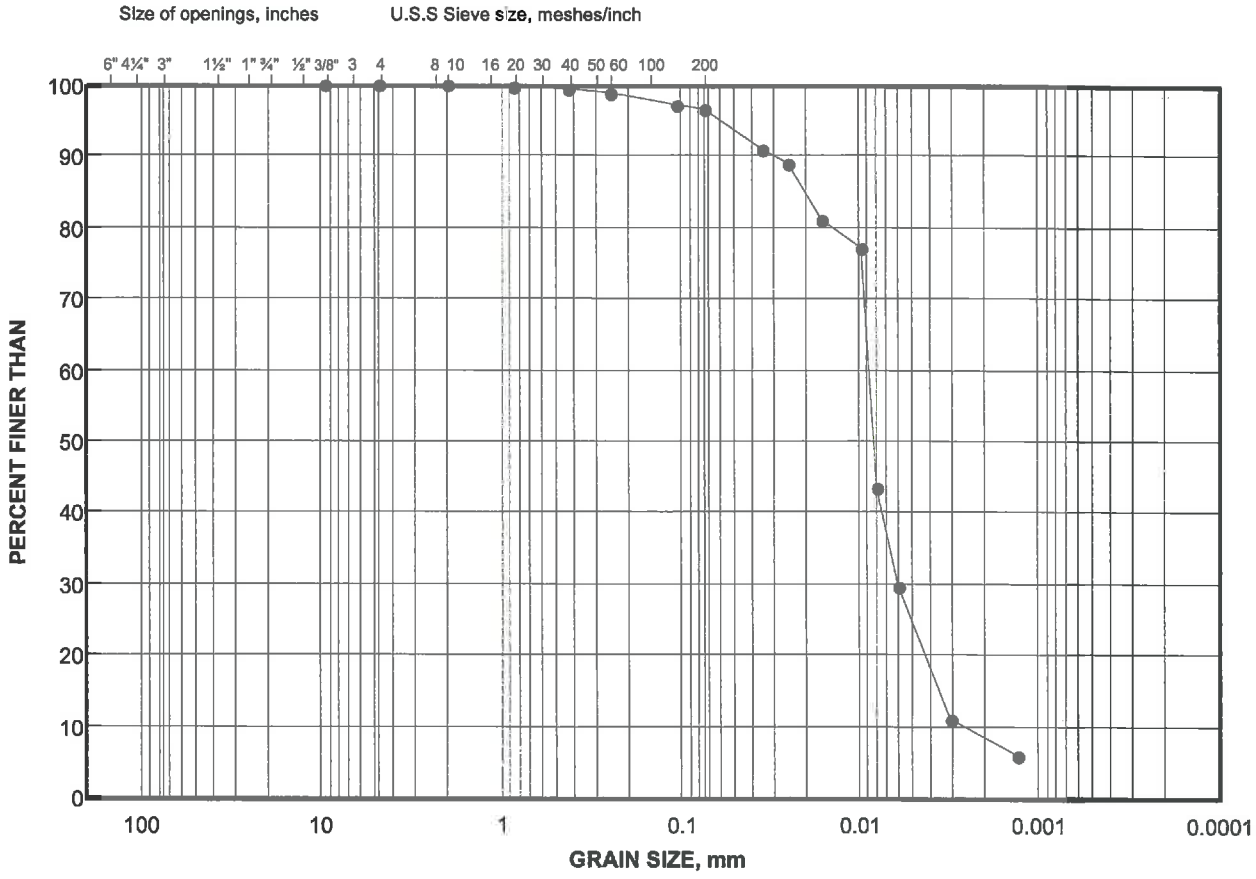
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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Project Number: 11-1118-0074

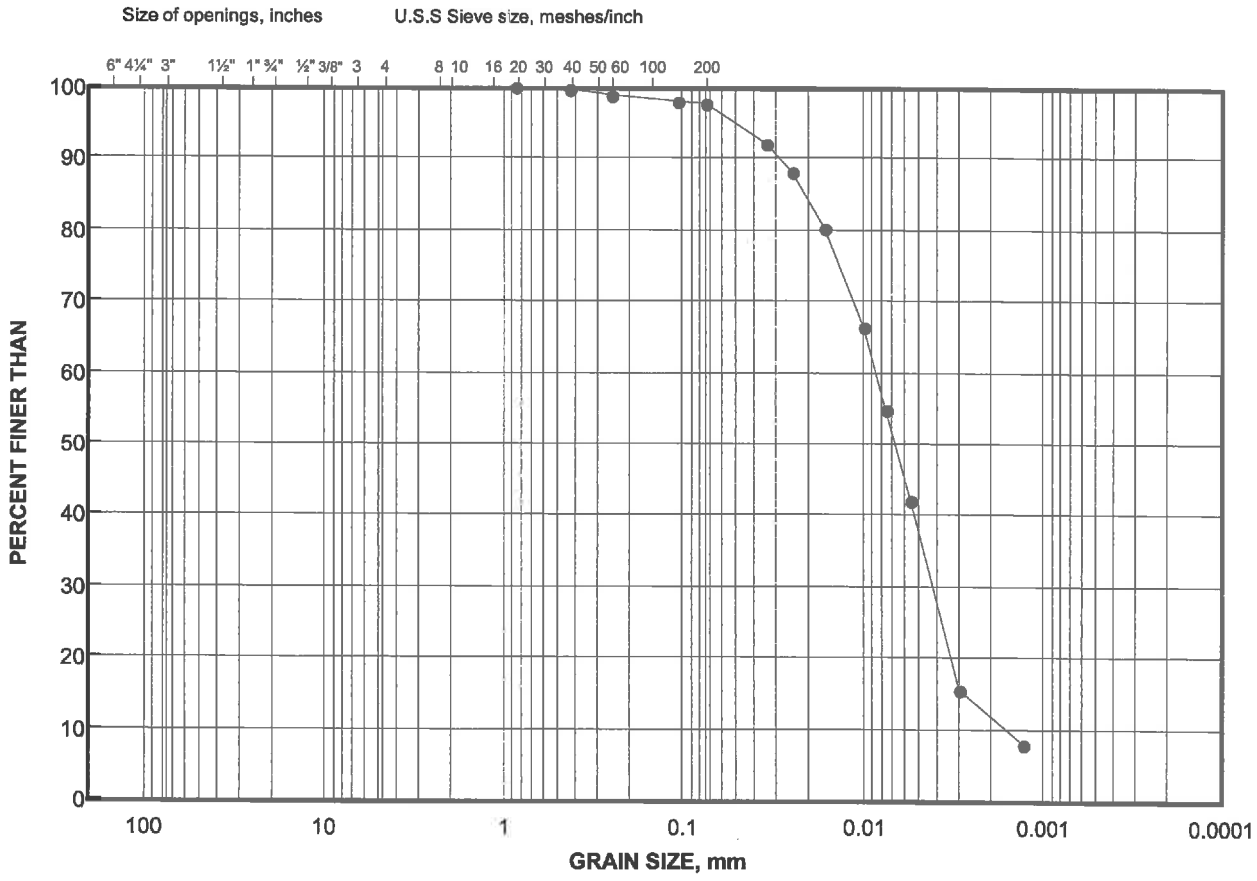
Checked By: A

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
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Project Number: 11-1118-0074

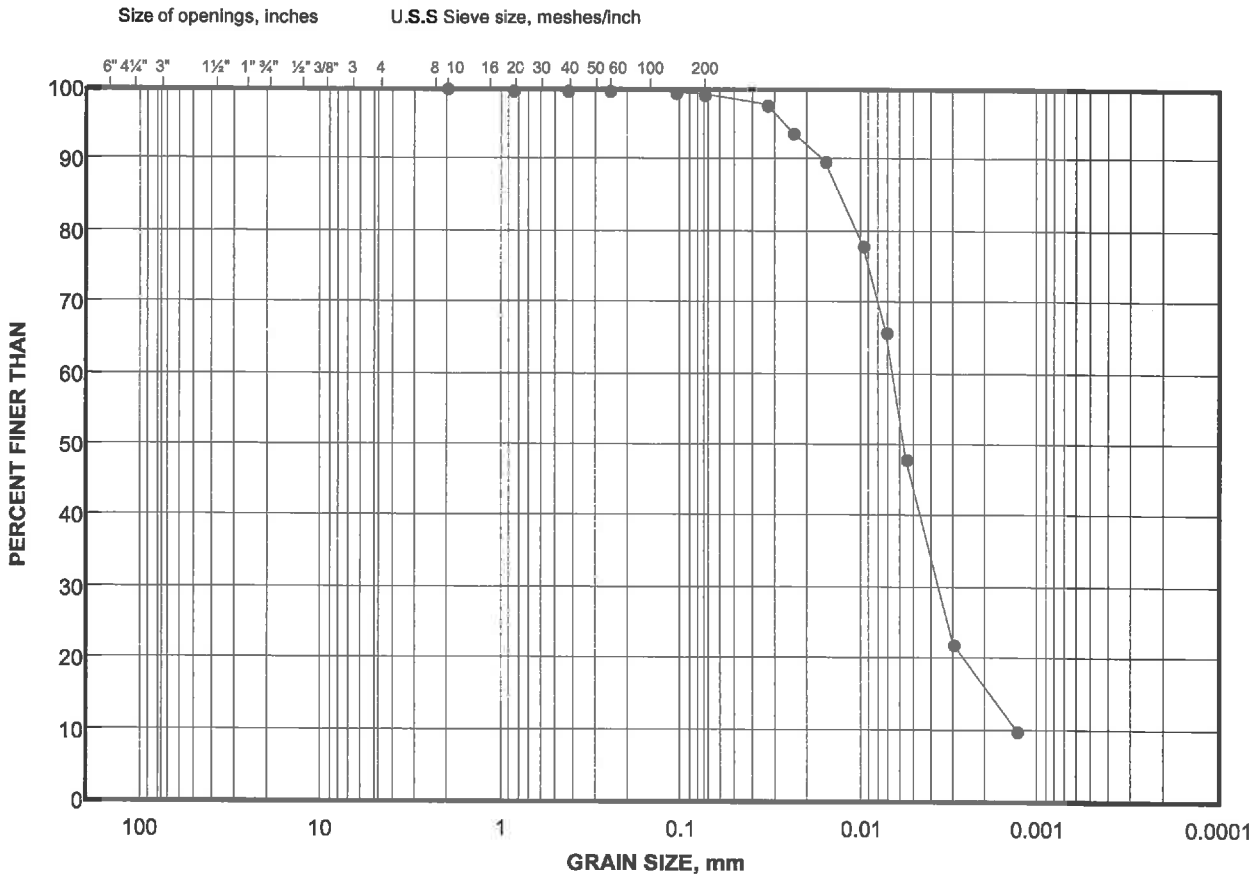
Checked By: ___

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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Project Number: 11-1118-0074

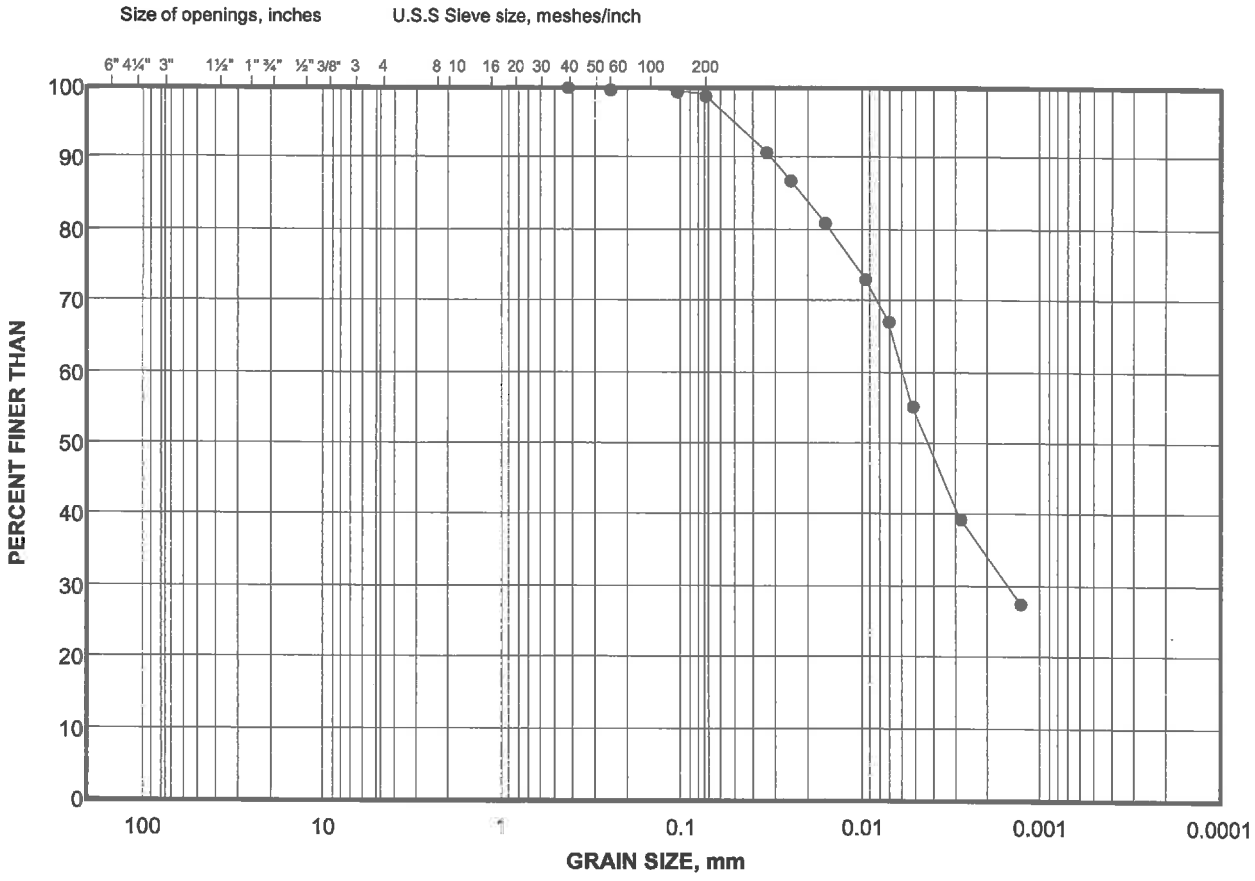
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



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Project Number: 11-1118-0074

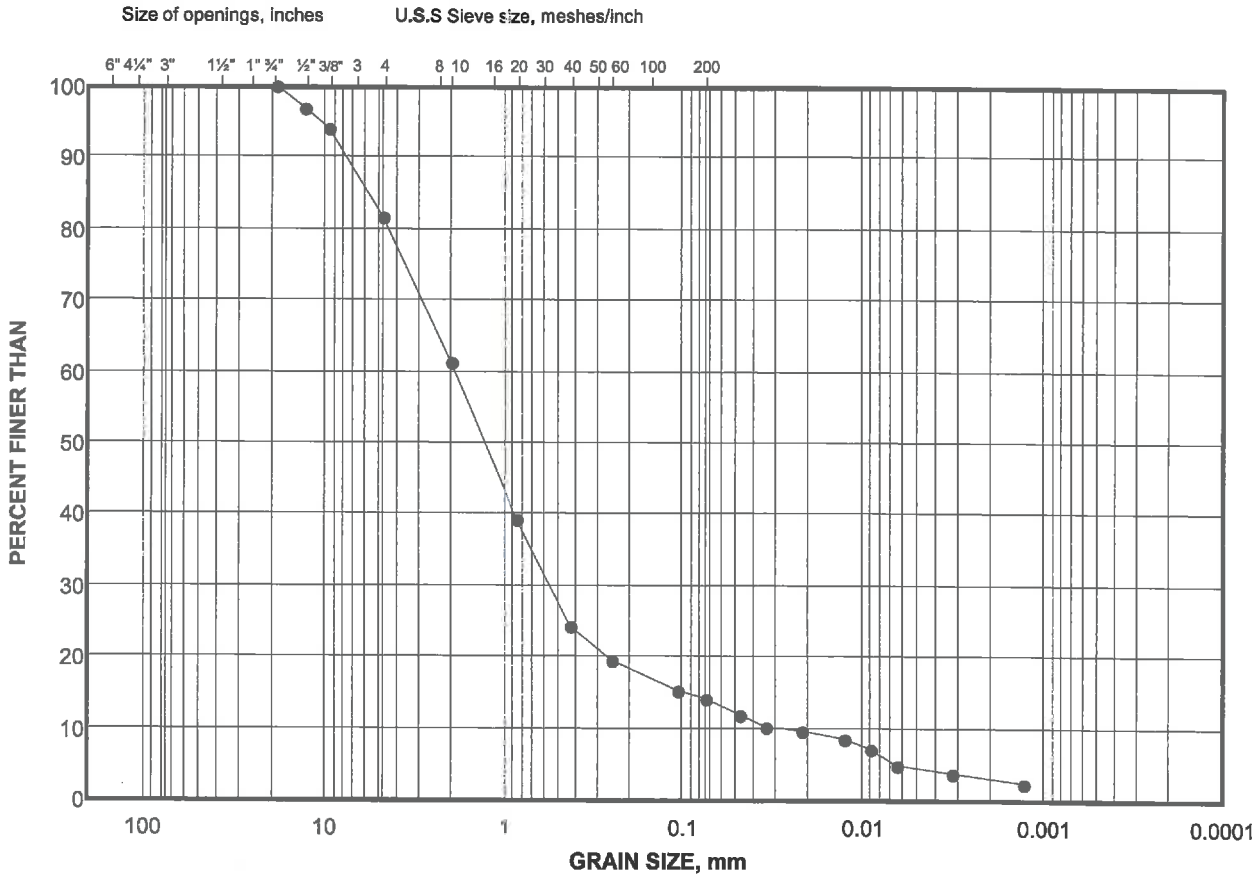
Checked By: _____

Golder Associates

Date: 17-Sep-12

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
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Project Number: 11-1118-0074

Checked By: _____

Golder Associates

Date: 17-Sep-12

APPENDIX 2.IV

Geophysical Borehole Logging

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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ATTACHMENTS

Attachment 2.IV.1
Geophysical Record of Borehole for Exploration Borehole BR-0220

Attachment 2.IV.2
Geophysical Record of Borehole for Exploration Borehole BR-0231

1.0 INTRODUCTION

This appendix presents the methodology and results from borehole geophysical surveys carried out in PQ size exploration boreholes BR-0220 and BR-0231 as part of the hydrogeological investigation program for the Hammond Reef Gold Project (Project). Golder Associates Ltd. (Golder) carried out the geophysical logging to obtain further information regarding the hydraulic properties and potential connectivity of the main structural features (Upper Shear Zone, FW Splay 2, and/or the intersection zone of FW Splay 2 with the Lower Shear Zone) in the southwest portion of the west pit area.

2.0 INSTRUMENTATION

Geophysical logging methods included the use of a heat pulse flow meter (HPFM) to detect and quantify upward or downward groundwater flow from open, water-producing features within the boreholes and televiewer logging tools (optical and acoustic) to obtain continuous, orientated images of select portions of the boreholes, identifying the depths and physical properties of any fractures/joints/faults joints or voids in the bedrock. The HPFM and televiewer probes were lowered on a wireline through the open portion of each borehole to measure different properties of the bedrock and water column. The probes and methodology that were used for this investigation are discussed in the following subsections.

2.1 Heat Pulse Flow Meter

This borehole probe records the vertical flow of water at a given depth in the borehole where the probe is held stationary long enough for all effects of probe movement on the fluid column to have faded away. The probe measures the time required for vertical flow to move a thermally tagged parcel of water a distance of 2 cm up or down borehole after heating by capacitor discharge onto an electrical grid. The probe measures flow through a cylindrical measurement section where the borehole annulus surrounding this cylinder is blocked by a flexible disk (the diverter). Flow meter response times are converted to flow rates using calibration formulas provided by the probe manufacturer. Two flow profiles are made, under ambient conditions first, and then under steady pumping conditions. The HPFM has a low flow detection limit of approximately 0.038 L/min. The device also has an upper flow detection limit associated with the thermal inertia of the thermistors, which is not capable of detecting flows in excess of approximately 5.68 L/min in either direction (up or down).

2.2 Optical and Acoustic Televiewers

The optical televiewer produces a continuous oriented 360° image of the inside of the borehole wall with detail for resolving fractures as narrow as 0.1 millimetre (mm) and with a radial resolution of 1 degree using an optical imaging system as the logging probe is slowly pulled upwards (see below). The televiewer probe is magnetically orientated so that the azimuth of the scan and the deviation of the borehole can be measured during logging.

The acoustic televiewer, which requires a fluid-filled borehole, produces an image of the borehole wall based on the amplitude and travel time of acoustic beams reflected from the formation wall. When an acoustic beam is transmitted, part of the energy is lost in voids or fractures, producing dark bands on the amplitude log. Travel time measurements allow a reconstruction of the borehole shape, essentially producing a three-dimensional caliper representation of the borehole. The problem of data acquisition in holes with murky drill fluid (or for holes in poor ground where mud has been used for drill support) can be overcome by use of an acoustic televiewer, as the fluid does not need to be flushed prior to logging.

Images acquired by televiewers are oriented by collecting simultaneous data from a 3-component fluxgate magnetometer and a 3-component tilt meter incorporated into the tools. Prior to interpretation, the image is rotated to a common reference direction, either magnetic north or the high-side of the borehole. Planar features which intersect the borehole wall produce sinusoidal traces in the “unwrapped” televiewer image. Using the reference direction recorded during logging, sinusoids can be analyzed to produce dip and dip directions of structural features.

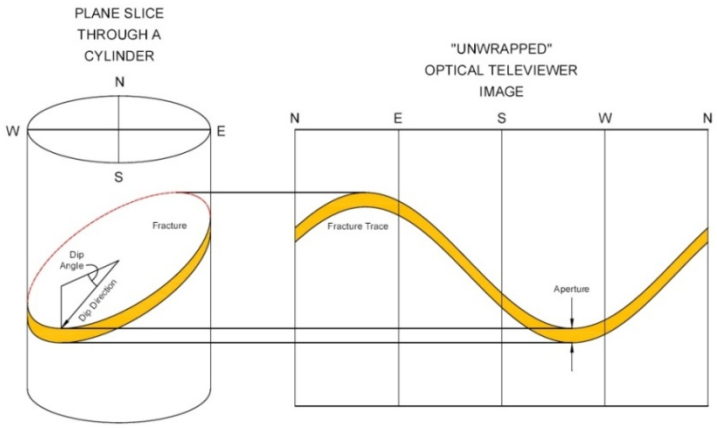


Figure 1: Three-Dimensional Schematic of a Fracture with Aperture and the Appearance of the Same Fracture in a Televiewer Image. Interpretation Software Allows for the Calculation of Dip and Dip Direction by Fitting a Sinusoid to the Structure in the Televiewer Image.

The example below (unwrapped image of the inside of a borehole) shows televiewer data acquired from BR-0231 at 2 mm and 3 mm intervals for the optical and acoustic televiewers, respectively.

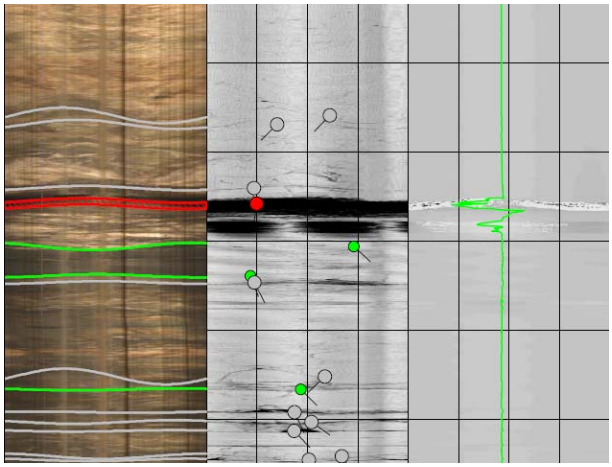


Figure 2: Example Optical and Acoustic Televiewer Log from Borehole BR-0231

The optical and acoustic televiewer logs are interpreted to map the orientation and extent of fractures within a borehole. While fractures can be observed within the optical televiewer log, it is difficult to determine whether a fracture is open or infilled based on the optical televiewer alone. The amplitude response from a fracture feature in the acoustic televiewer log helps to determine whether the fracture is open, infilled, or healed. A low amplitude response indicates that the fracture is open, as energy is lost within the fracture and is not reflected back to the probe, whereas a high amplitude response indicates it is infilled or healed.

3.0 METHODS

3.1 Fieldwork

Geophysical logging of exploration boreholes BR-0220 and BR-0231 was carried out by a Golder geophysicist from September 8 to 14, 2011.

Prior to lowering the HPFM and televiewer probes into either borehole, a dummy probe was deployed in each borehole using a winch controlled wire line system to identify blockages or unstable borehole wall conditions.

After retrieving the dummy probe, the open portion of each borehole was logged using the HPFM and televiewer probes by lowering each probe on the winch controlled wire line system.

A *Mount Sopris*™ borehole logging system was used to undertake the borehole geophysical investigation. The data was checked in the field for quality control purposes prior to demobilizing from the site. Borehole casing stickup and probe lengths were measured in the field so they could be corrected for in the dataset when processing.

In borehole BR-0220, an impassable obstruction was encountered with the dummy probe at 211 m and no data were gathered below that point. Additionally, borehole fluid in BR-0220 was too murky for use of the optical borehole imaging probe.

In borehole BR-0231, an impassable obstruction was encountered with the dummy probe at 262.8 m and no data were gathered below that point. Additionally, ambient flow of water in BR-0231 was too high to measure with the heat-pulse flow meter or to be affected by low-flow pumping.

3.2 Data Processing

The geophysical data was processed using WellCAD (Advanced Logic Technology, Luxembourg). For each borehole a composite geophysical logs were compiled to allow for data interpretation. Borehole logs were depth corrected based on field measurements. Structure (specifically fractures) was picked using available optical and acoustic televiewer logs, and is presented relative to borehole images and relative to true dip and dip direction.

The geophysical data are combined onto borehole logs that provide “Amplitude-HS”, the amplitude of the reflected acoustic signal, presented in image form, oriented to the high-side of the borehole; “TravelTime-HS”, the travel time of the reflected acoustic signal, presented in image form, oriented to the high-side of the borehole; “Acoustic Caliper”, showing the calculated diameter of the borehole based on the travel time of the acoustic signal; “Structure”, showing the interpreted structural features relative to the high-side of the borehole; “Tadpole TN”, showing the same interpreted structural features relative to true dip and dip direction; “ABI Roll”, showing the rotation of the acoustic borehole imaging probe with depth, measured mechanically; “ABI MRoll”, showing the rotation of the acoustic borehole imaging probe with depth, measured magnetically; “Tilt”, showing the degree of inclination of the acoustic borehole imaging probe from vertical and; “Azimuth TN”, showing the direction of dip, corrected to True North. BR-0220 also includes the logs “HPFM – Static” and “HPFM – Dynamic” which show the flow of water measured using the heat-pulse flow meter under static and pumping

conditions, respectively. The heat pulse results for BR-0220 show that fractures which produce water during pumping conditions exist below 210 m, below the bottom depth of geophysical measurement. BR-0231 also includes the log “Image-HS” which shows the optical borehole image oriented to the high-side of the borehole.

4.0 RESULTS

Table 1 provides a summary of the depth, azimuth, dip and aperture thickness for all interpreted joint and fracture features identified in borehole BR-0220. The geophysical data are provided in greater detail on the geophysical borehole log provided on Attachment 2.IV.1.

Analysis of BR-0220 shows that the tilt of the borehole increases with depth from 29.3 deg from vertical to 33 deg from vertical. The dip direction of the hole remained constant at approximately 326 deg relative to True North. Structural analysis of BR-0220 showed multiple partially open fractures according to the acoustic image, summarized in Table 1 below, as well as many bedding planes. No major open fractures, filled fractures or veins were observed in the section of the hole logged. Heat-pulse flow meter data was gathered under static and dynamic (pumping) conditions. Static data indicated no ambient flow in the borehole, while dynamic data measured upward flow under pumping conditions originating from below the accessible bottom of the borehole (211 m).

Table 1: Interpreted fractures of BR-0220, relative to true dip and dip direction

Depth (m)	Azimuth (deg from True North)	Dip (deg from horizontal)	Aperture (mm)	Type
15.18	256.89	10.83	<1	Partially Open
42.34	188.7	18.58	<1	Partially Open
51.37	218.86	25.64	<1	Partially Open
68.39	109.53	6.71	<1	Partially Open
71.67	69.82	4.35	<1	Partially Open
104.69	55.35	20.84	<1	Partially Open
125.83	298.71	30.13	<1	Partially Open
127.36	293.98	29.93	<1	Partially Open
130.91	181.77	76.24	<1	Partially Open
131.75	155.49	59.86	<1	Partially Open
141.44	192.12	70.98	<1	Partially Open
159.35	82.16	14.13	<1	Partially Open
183.38	158.48	51.64	<1	Partially Open
185.24	202.48	29.07	<1	Partially Open

Table 2 provides a summary of the depth, azimuth, dip and aperture thickness for all interpreted joint and fracture features identified in borehole BR-0220. The geophysical data are provided in greater detail on the geophysical borehole log provided on Attachment 2.IV.2.

Analysis of BR-0231 shows that the tilt of the borehole increases with depth from 33 deg from vertical to 35 deg from vertical. The dip direction changes with depth from 294 deg to 305 deg relative to True North. Structural analysis shows five major open fractures and many partially open fractures according to both acoustic and optical images, summarized in Table 2 below, as well as multiple bedding planes and filled fractures and veins.

The major open fractures have aperture widths ranging from seven to 65 mm. No heat-pulse flow meter data could be gathered from this borehole due to malfunctioning equipment.

Table 2: Interpreted fractures of BR-0231, relative to true dip and dip direction

Depth (m)	Azimuth (deg from True North)	Dip (deg from horizontal)	Aperture (mm)	Type
11.99	224.37	9.05	<1	Partially Open
30.59	285.12	25.34	<1	Partially Open
32.79	199.53	76.07	<1	Partially Open
44.22	259.53	23.11	<1	Partially Open
70.91	157.21	22.16	57.93	Major Open
95.66	258.5	36.78	<1	Partially Open
125.5	151.44	36.13	31.93	Major Open
126.76	110.25	13.67	<1	Partially Open
127.04	288.46	34.56	<1	Partially Open
127.49	267.3	23.01	15.93	Major Open
130.75	162.72	61.24	<1	Partially Open
130.78	174.37	80.86	<1	Partially Open
152.19	274.95	24.25	<1	Partially Open
161.7	155.78	72	<1	Partially Open
170.81	209.72	33.15	19.75	Major Open
190.93	169.47	75.46	7.1	Major Open
199.58	187.26	22.29	65.06	Major Open
205.26	142.73	63.91	<1	Partially Open
208.45	159.09	51.98	<1	Partially Open
208.48	147.14	58.52	<1	Partially Open
208.68	147.14	56.99	<1	Partially Open
209.63	215	18.35	30.7	Partially Open
209.69	144.71	51.14	<1	Partially Open
210.03	154.63	46.96	14.6	Partially Open
211.42	143.81	68.34	<1	Partially Open
211.58	137.31	54.67	<1	Partially Open
222.17	151.27	49.69	55.54	Partially Open
244.66	166.11	60.24	<1	Partially Open

HYDROGEOLOGY TSD
APPENDIX 2.IV
VERSION 1

Attachment 2.IV.1

Geophysical Record of Borehole for Exploration Borehole BR-0220

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

GEOPHYSICAL RECORD OF BOREHOLE: BR-220

Project Name: Hammond Reef

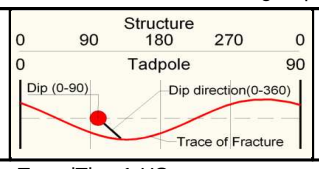
Client: Osisko

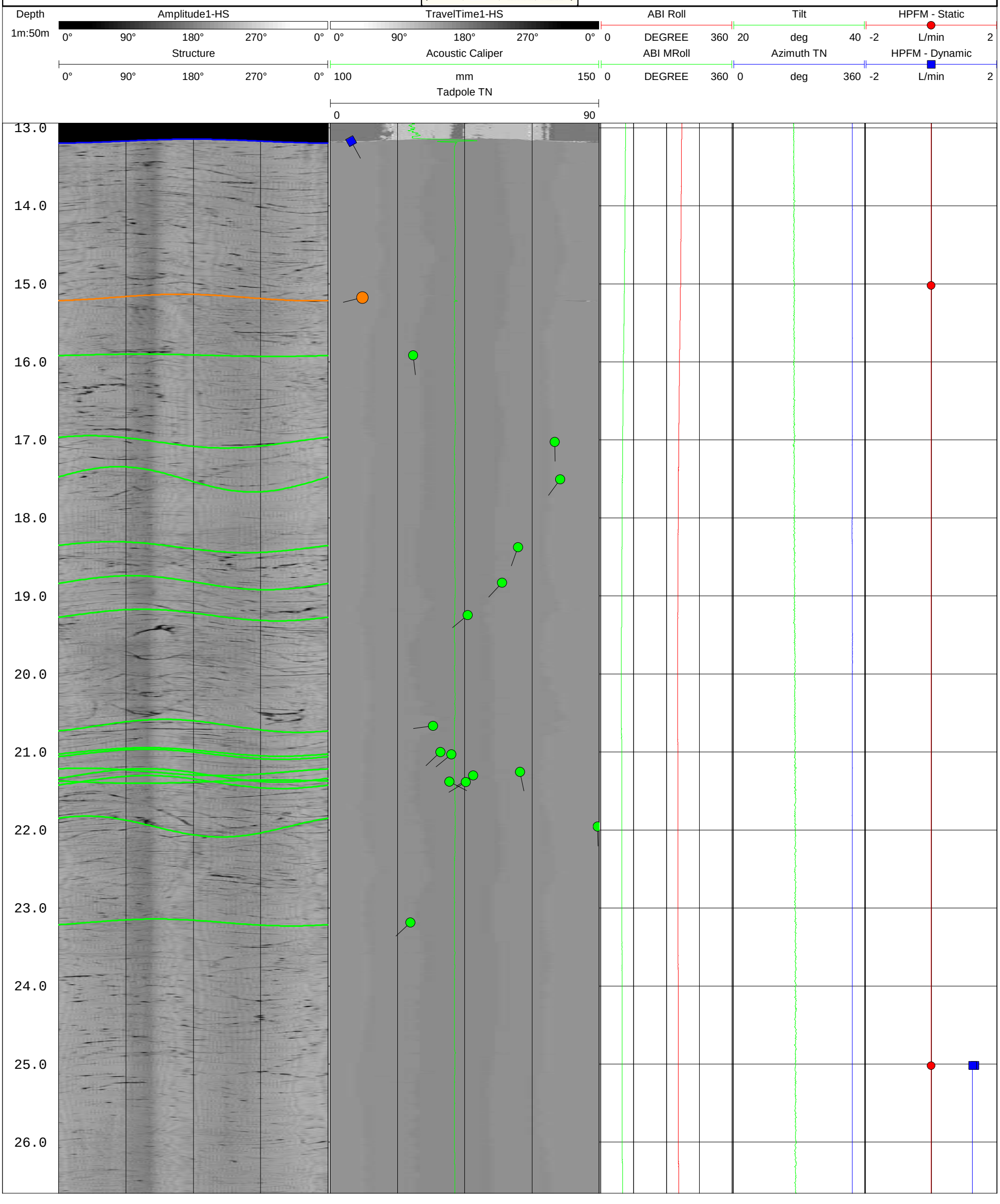
Project Number: 11-1118-0079

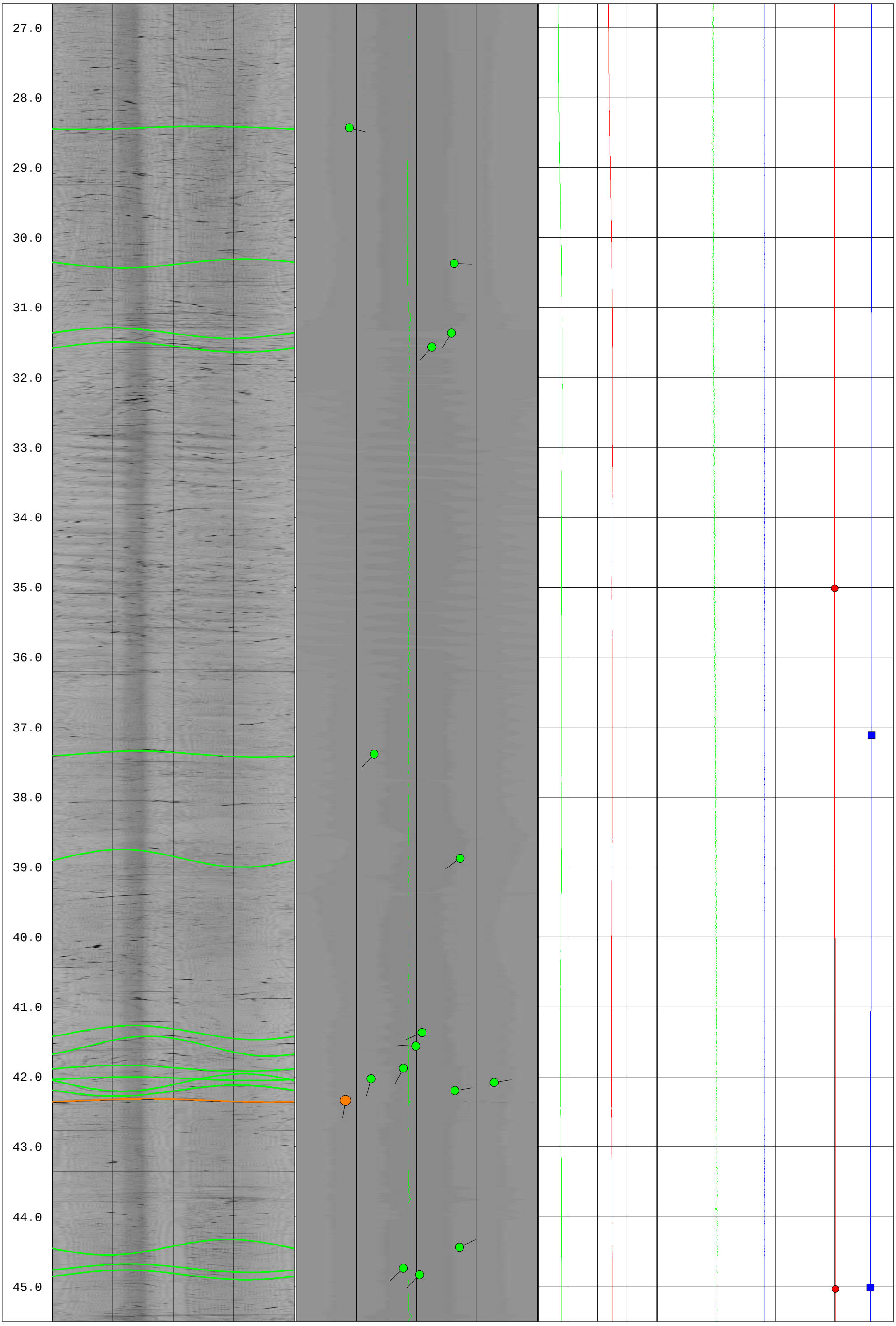
Date: September 2011

Datum:	??						
Easting:	??	Depth Reference:	'0' at Ground Surface	Borehole Diameter:	PQ - 122 mm	Location:	Atikokan, Ontario
Northing:	??	Drilling Method:		Borehole Inclination:	-90 deg (vertical)	Log Date:	Sept 8, 2011
Elevation:	??	Drilled Depth:	300m	Casing Depth:	3m	Logged By:	AR

Partially Open Joint / Fracture Bedding / Banding / Foliation Water Table



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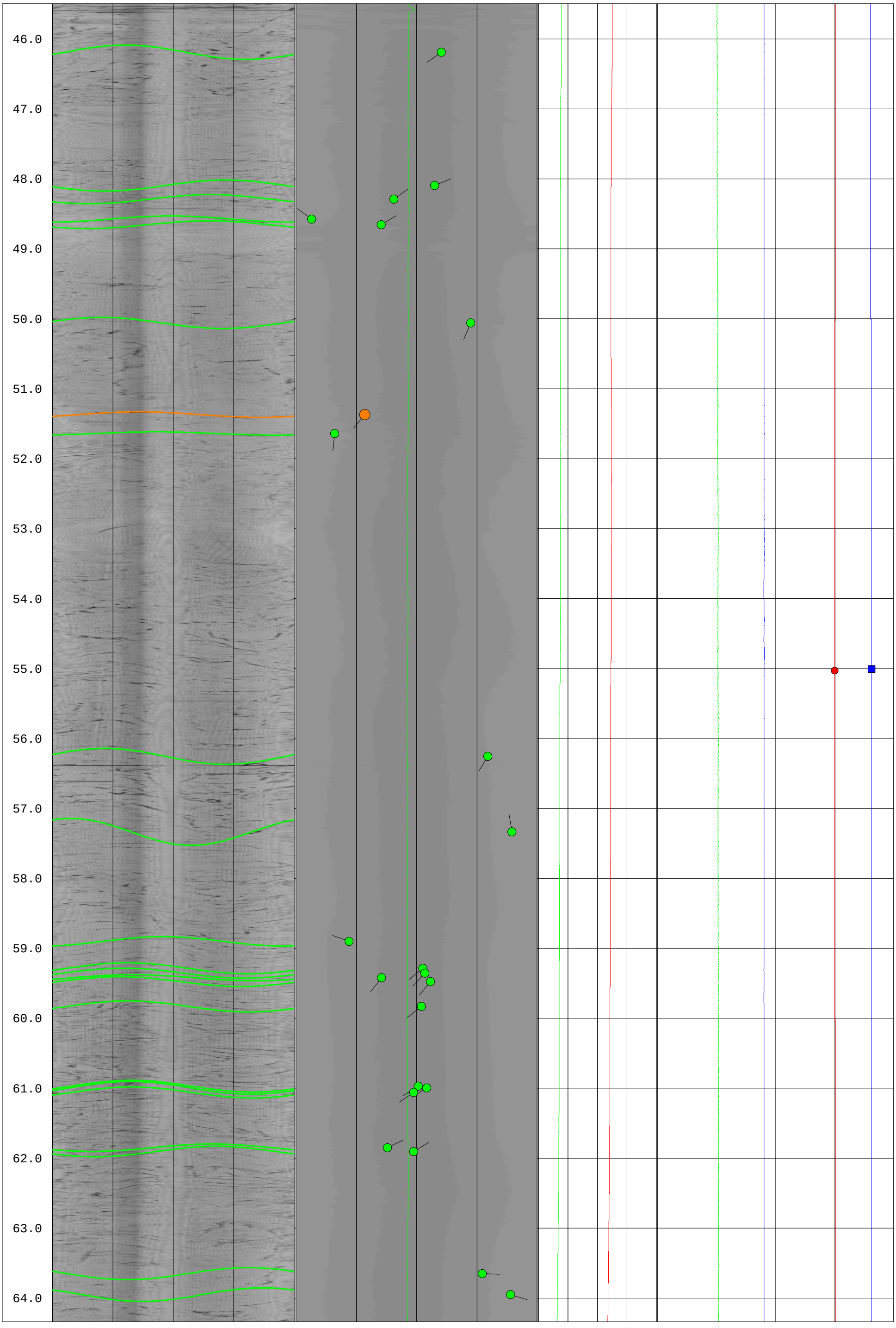
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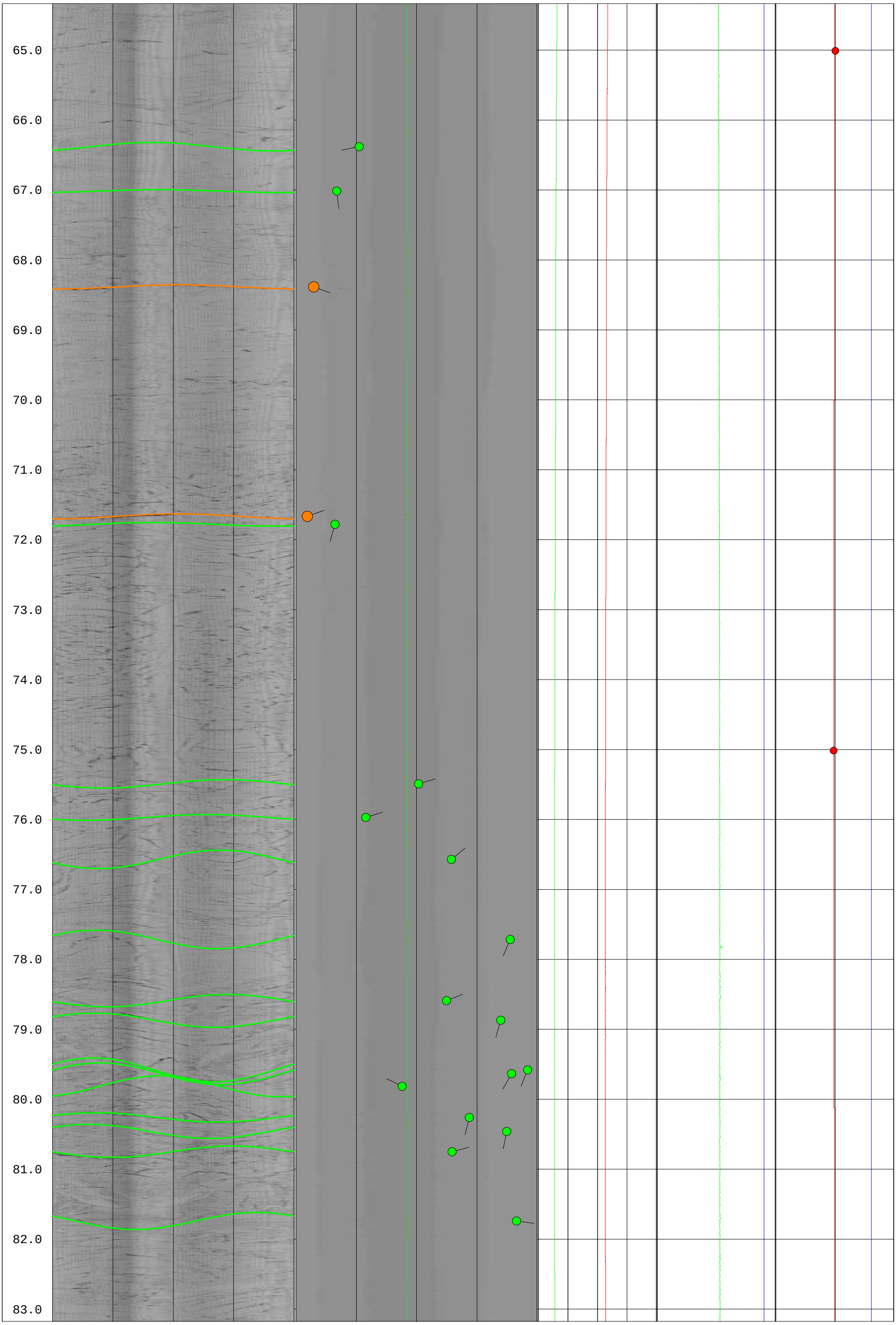
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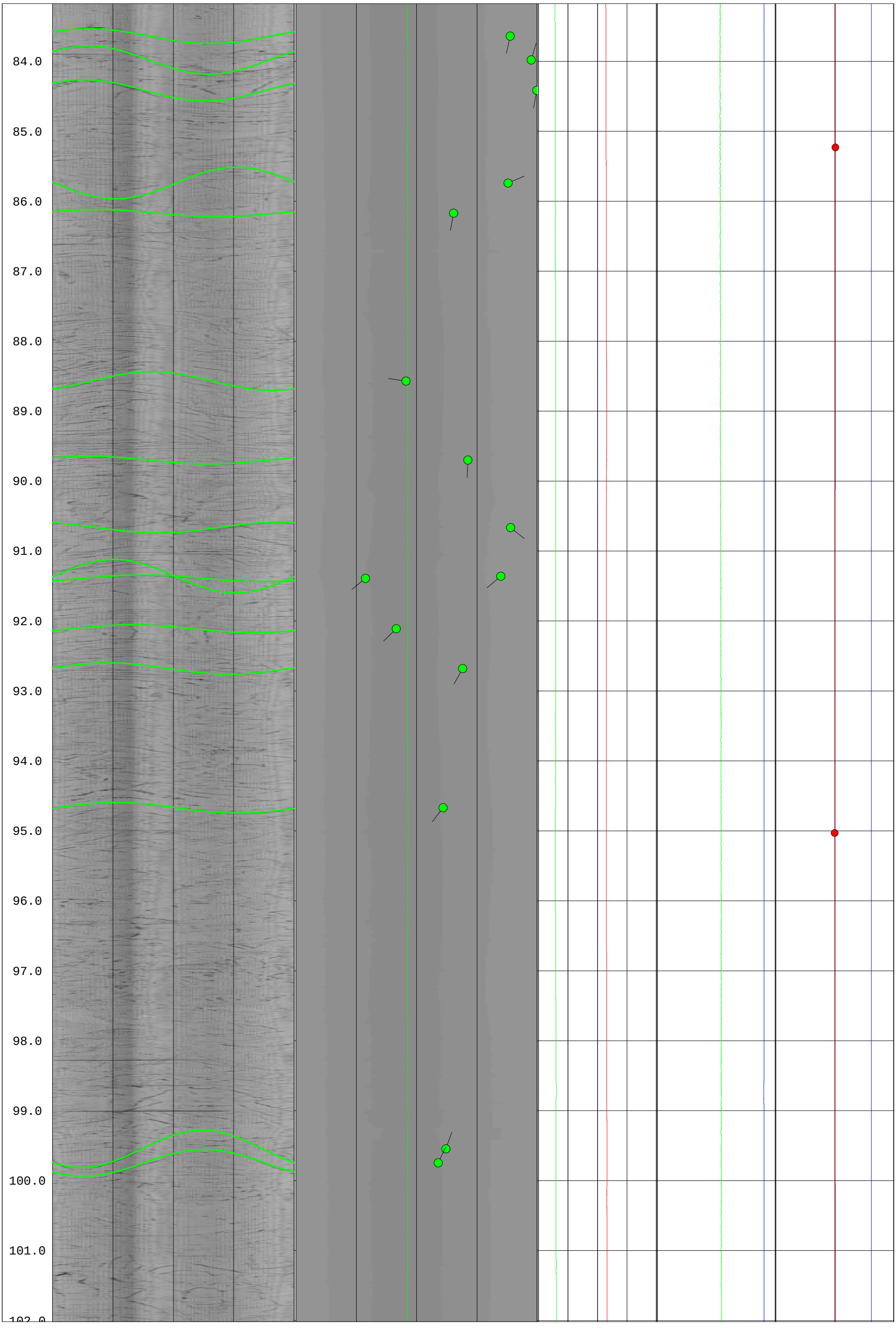
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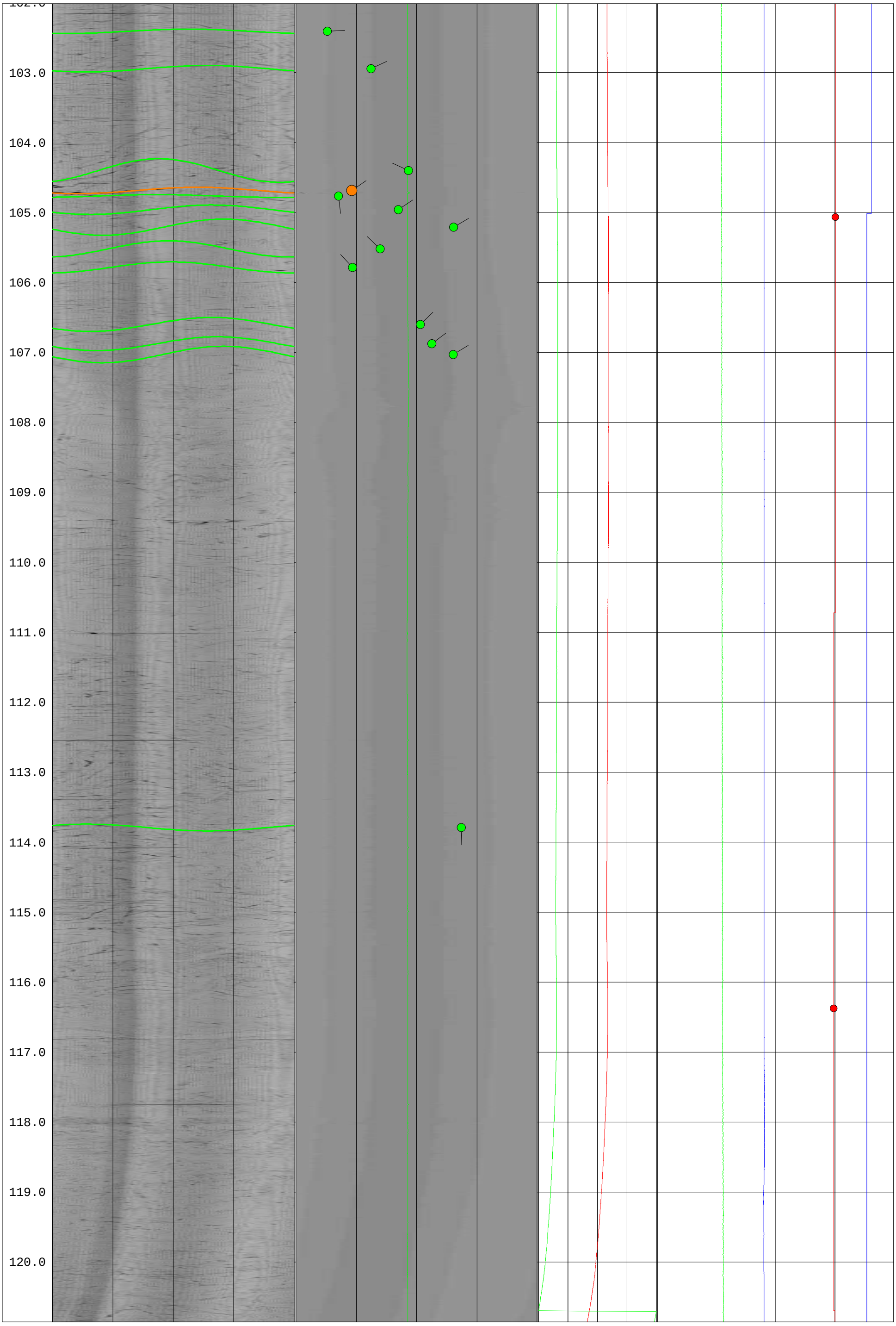
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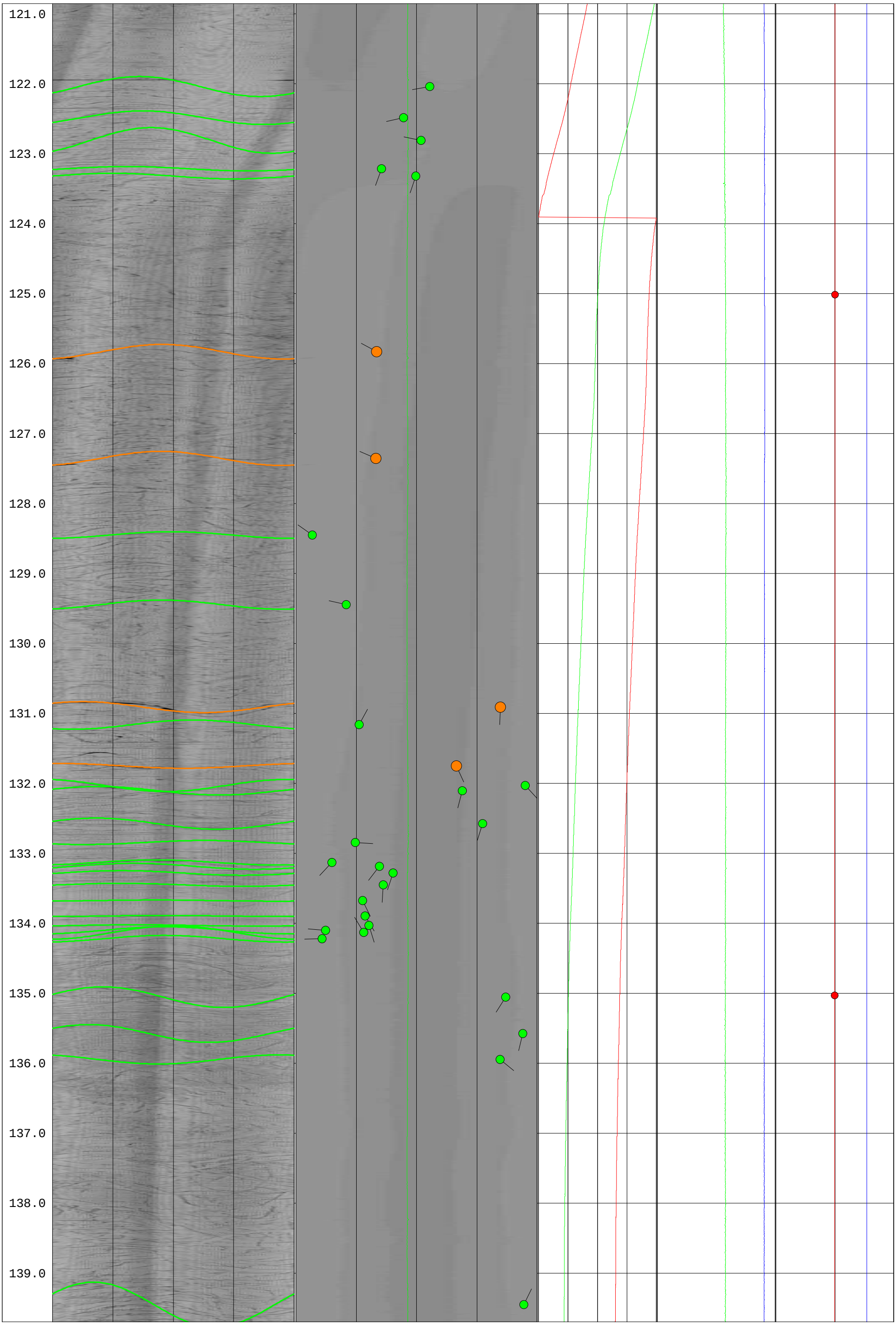
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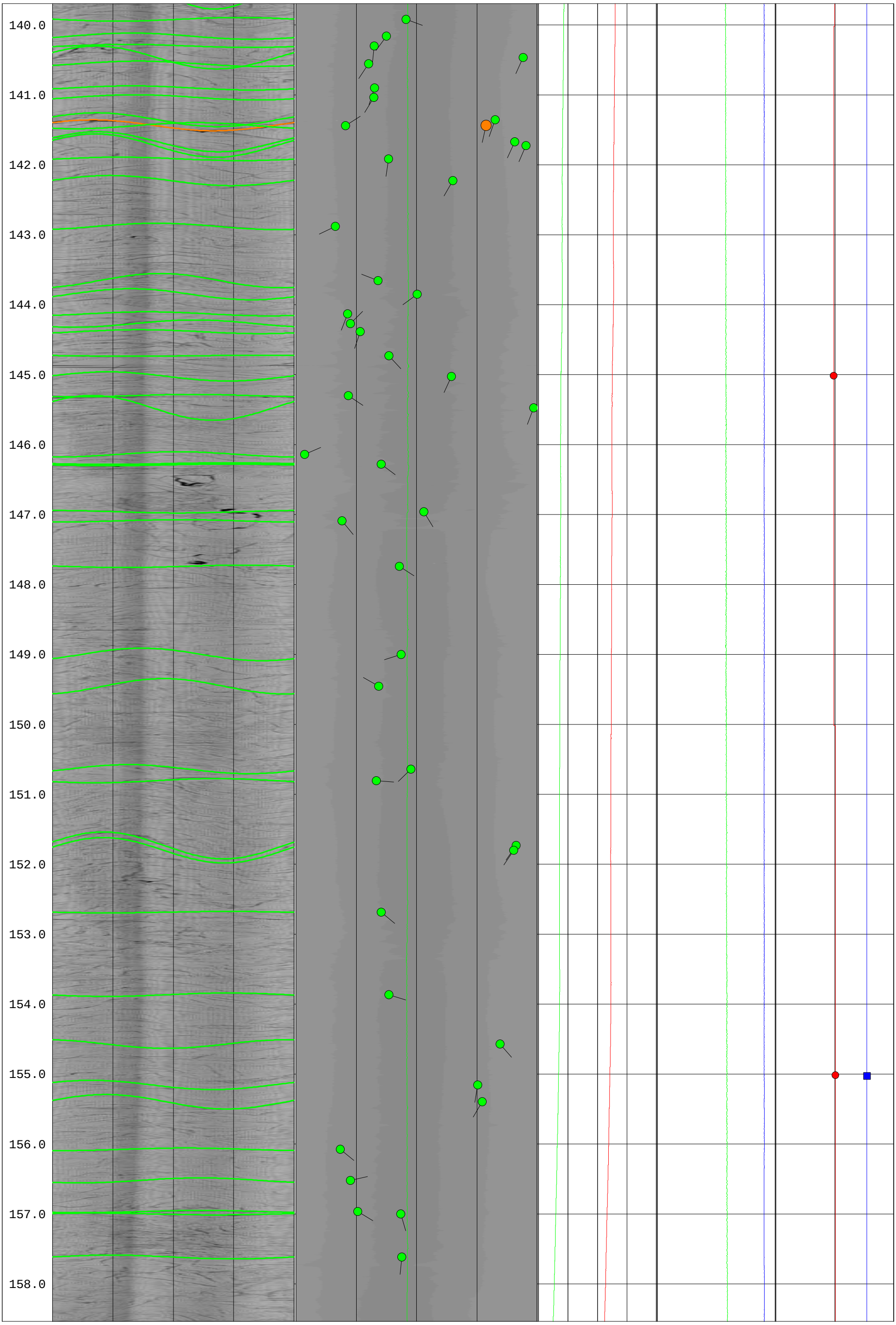
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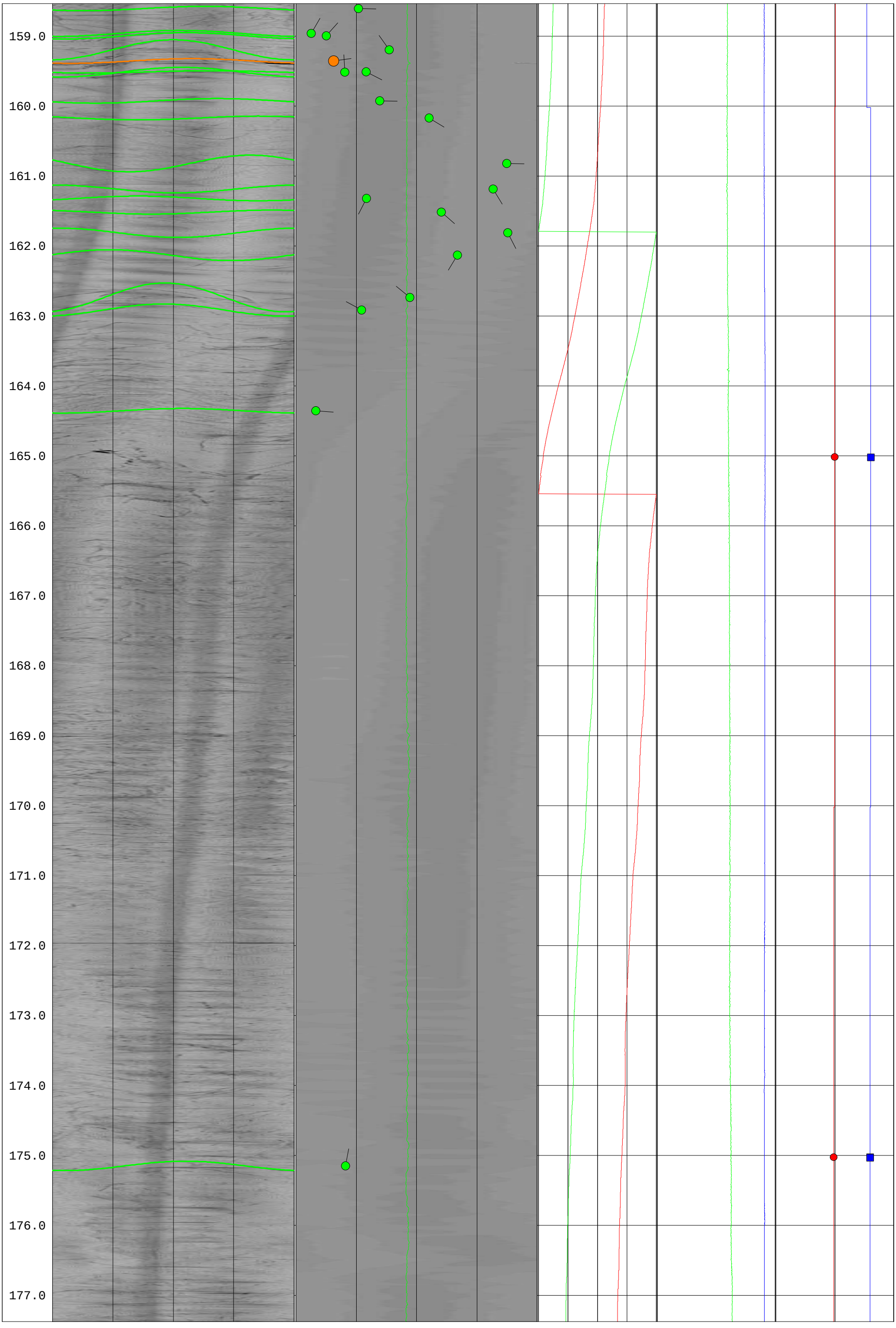
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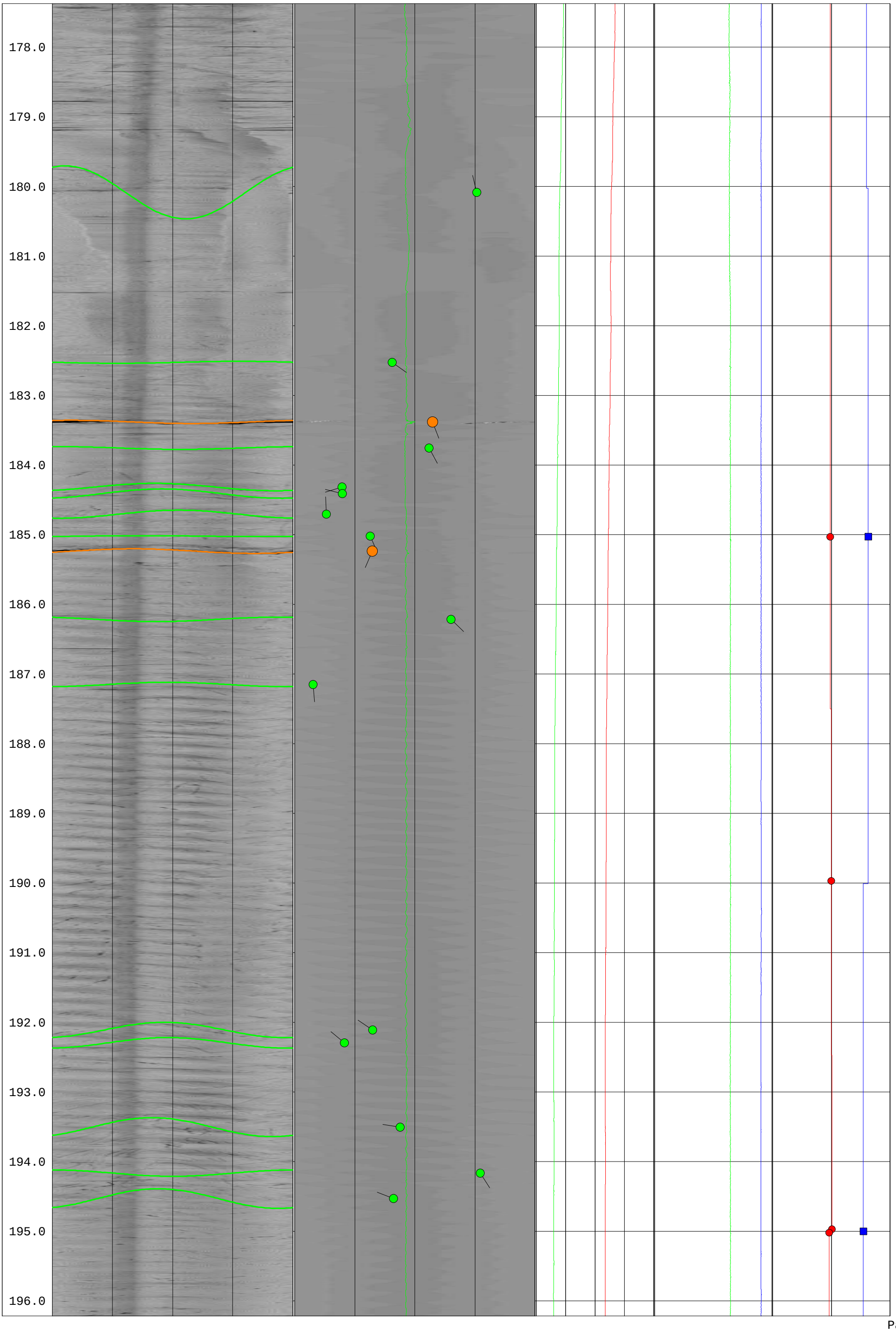
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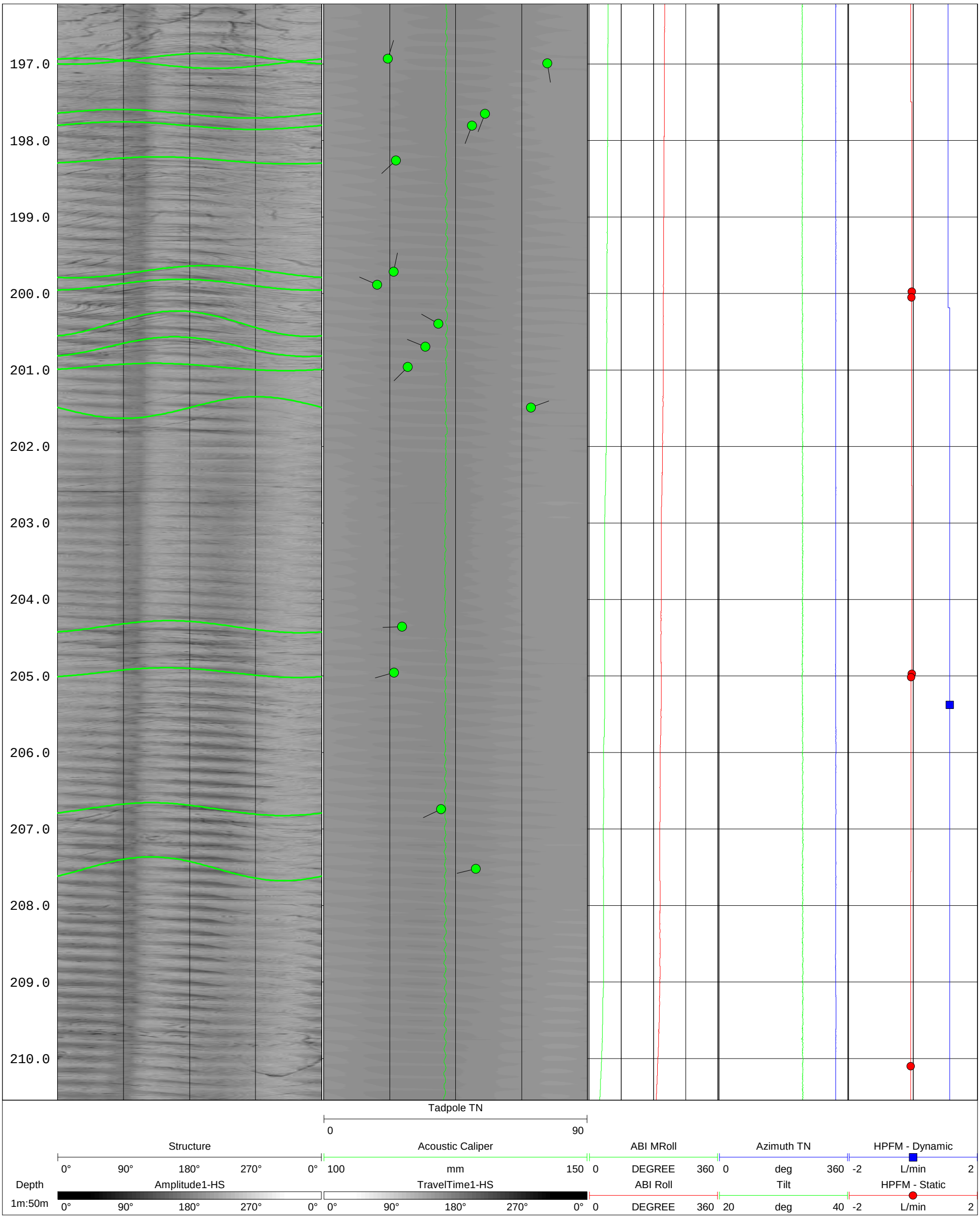
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HPFM - Dynamic
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Depth
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Amplitude1-HS
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TravelTime1-HS
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ABI Roll
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DEGREE
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Tilt
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deg
40
HPFM - Static
-2
L/min
2

HYDROGEOLOGY TSD
APPENDIX 2.IV
VERSION 1

Attachment 2.IV.2

Geophysical Record of Borehole for Exploration Borehole BR-0231

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

GEOPHYSICAL RECORD OF BOREHOLE: BR-231

Project Name: Hammond Reef

Client: Osisko

Project Number: 11-1118-0079

Date: September 2011

Datum:

Easting:

Northing:

Elevation:

Depth Reference:

Drilling Method:

Drilled Depth: 300m

Borehole Diameter:

Borehole Inclination: -90 deg (vertical)

Casing Depth: 3m

Location:

Log Date: Sept 9, 2011

Logged By: AR

Major Open Joint / Fracture

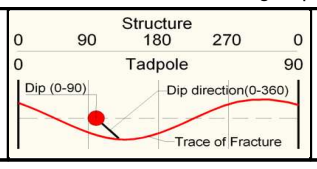
Minor Open Joint / Fracture

Partially Open Joint / Fracture

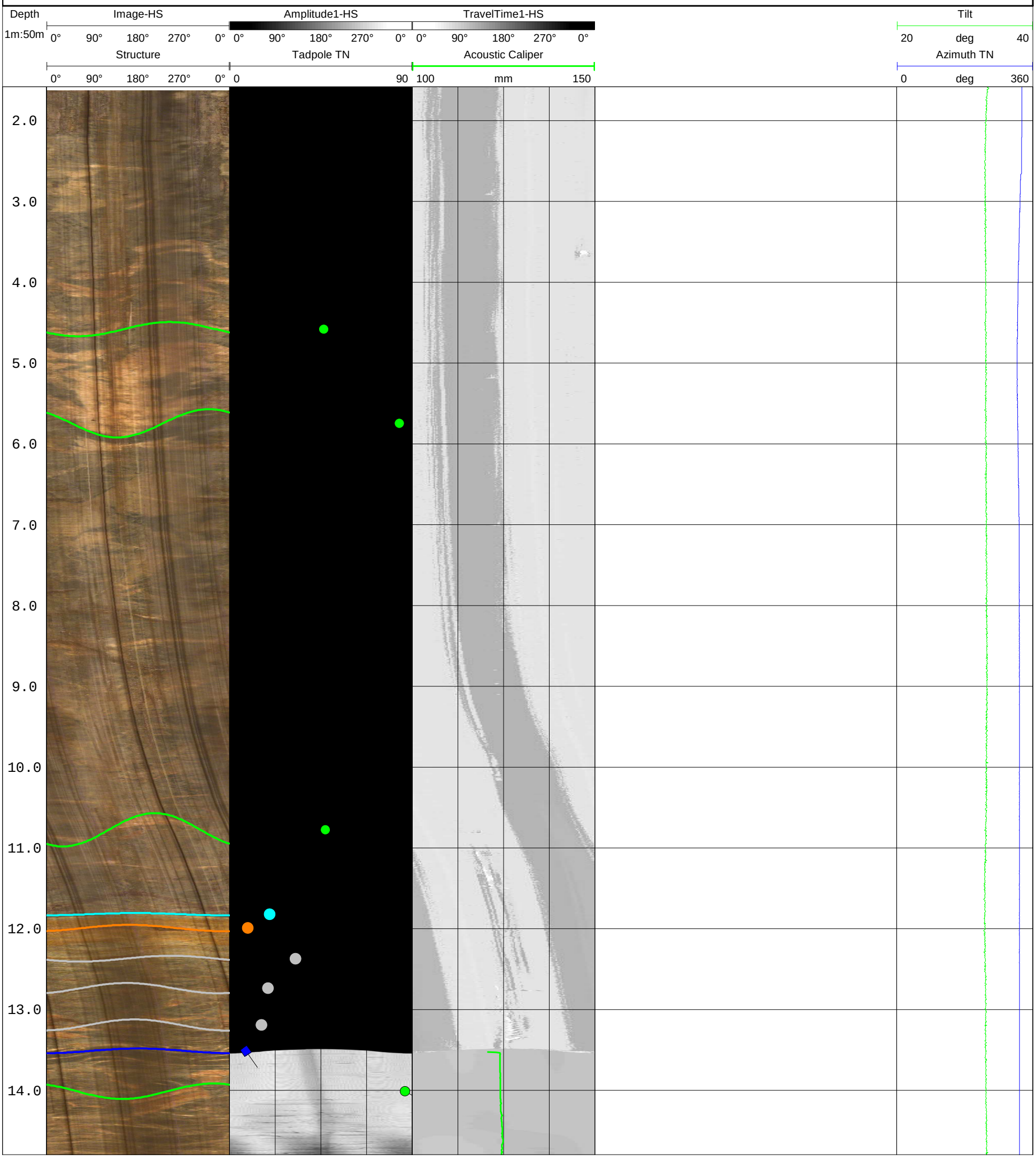
Filled Fracture / Joint

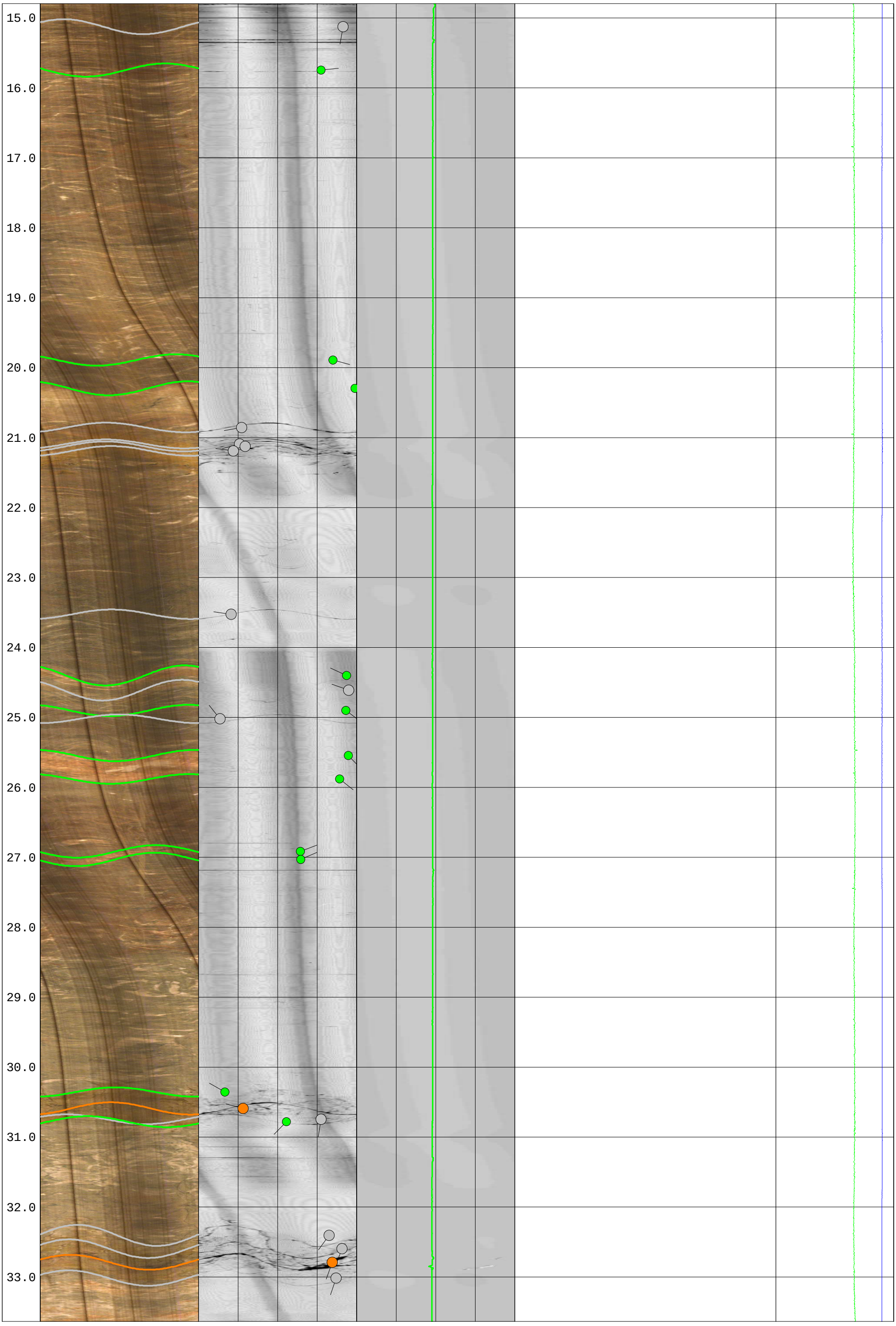
Bedding / Banding / Foliation

Water Table



Notes: Downward flow too high to be measured with Heat-Pulse Flow Meter.

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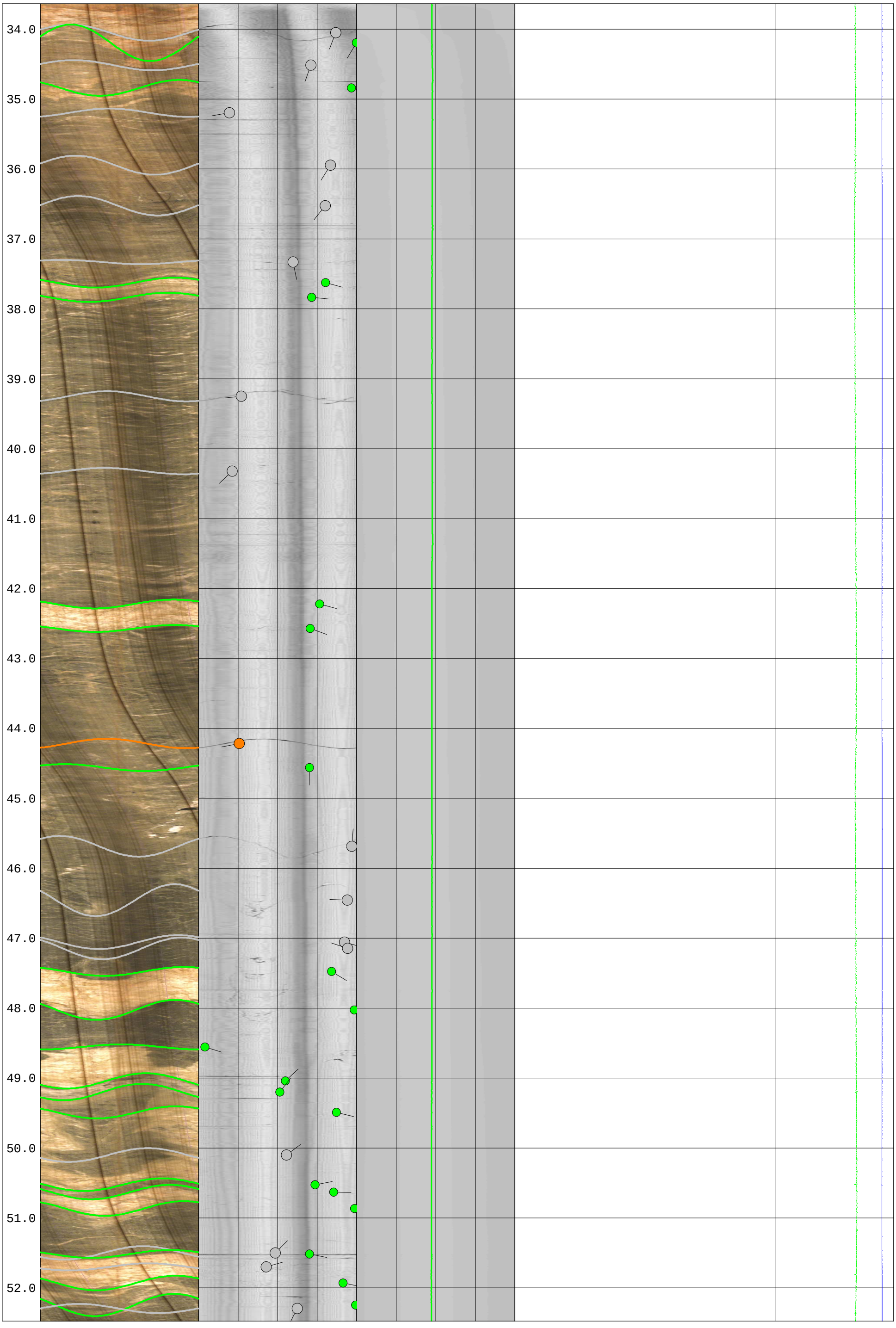
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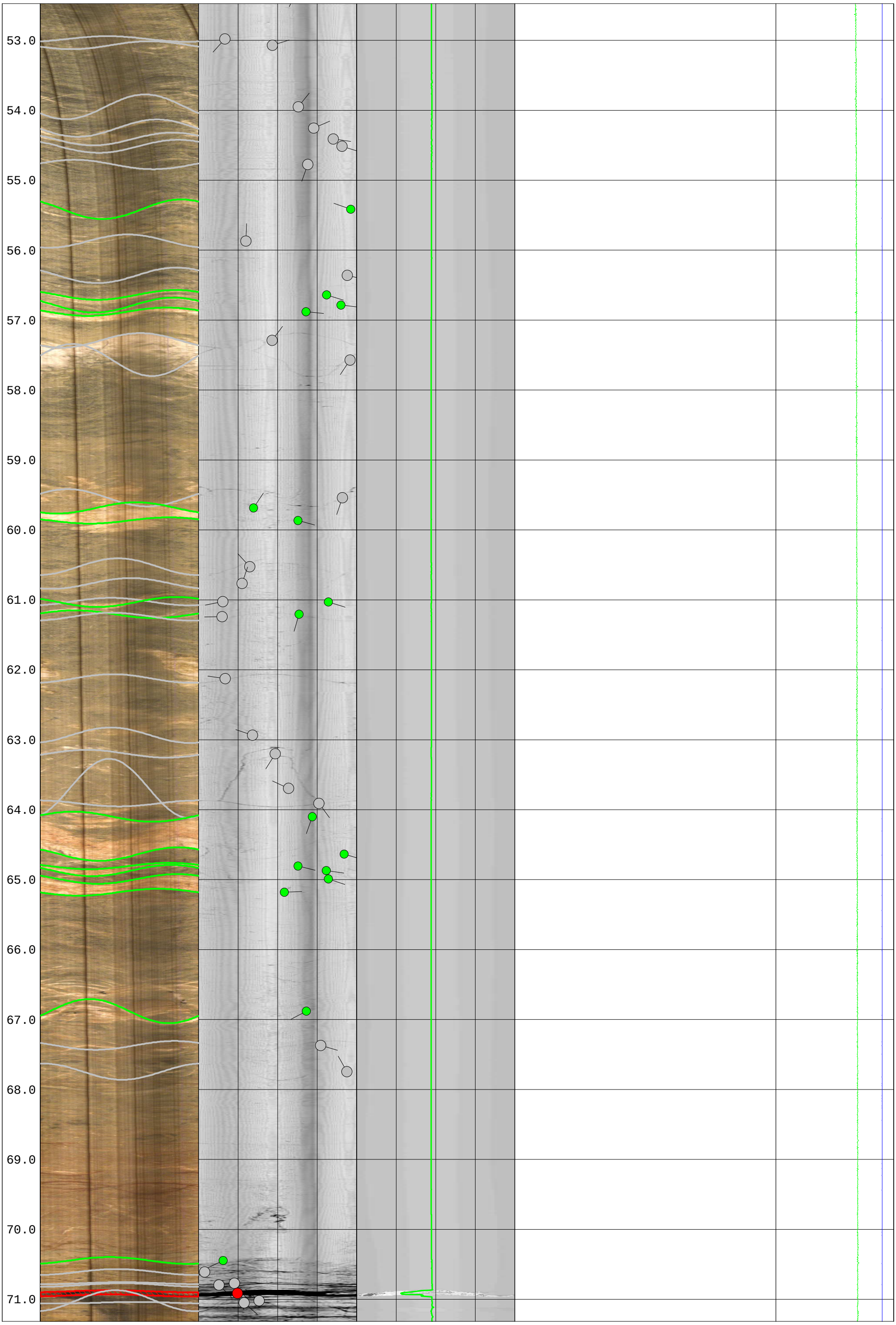
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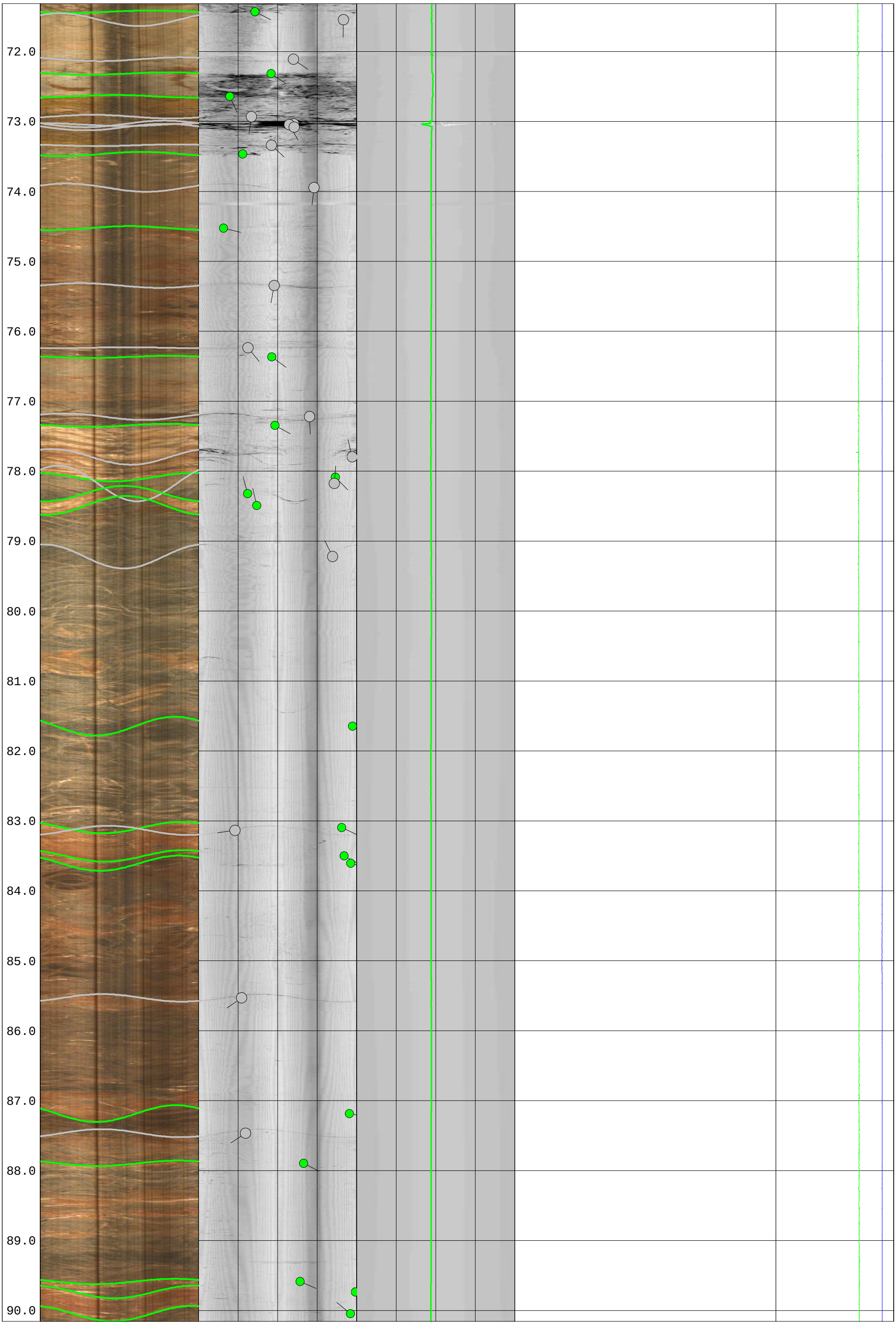
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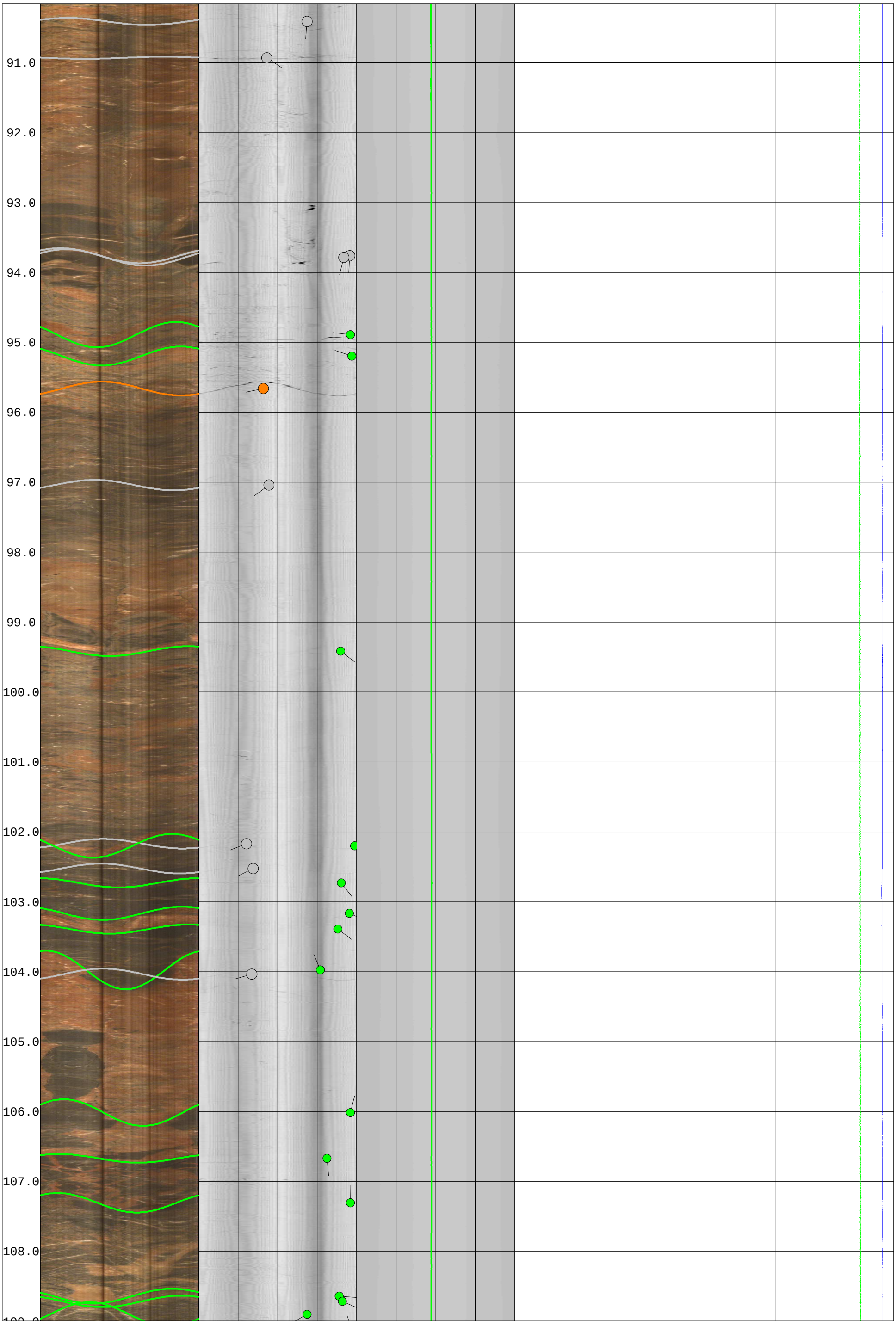
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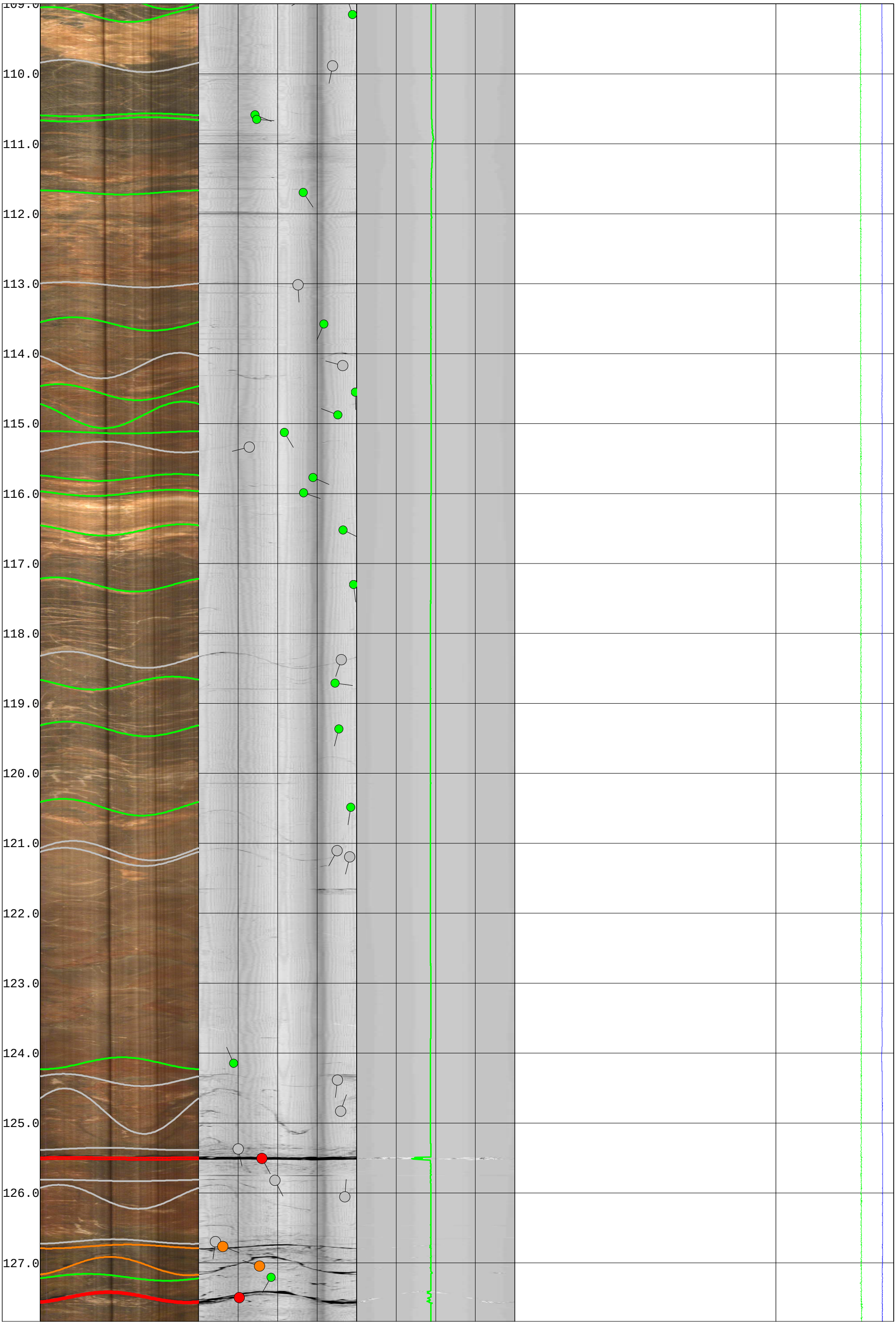
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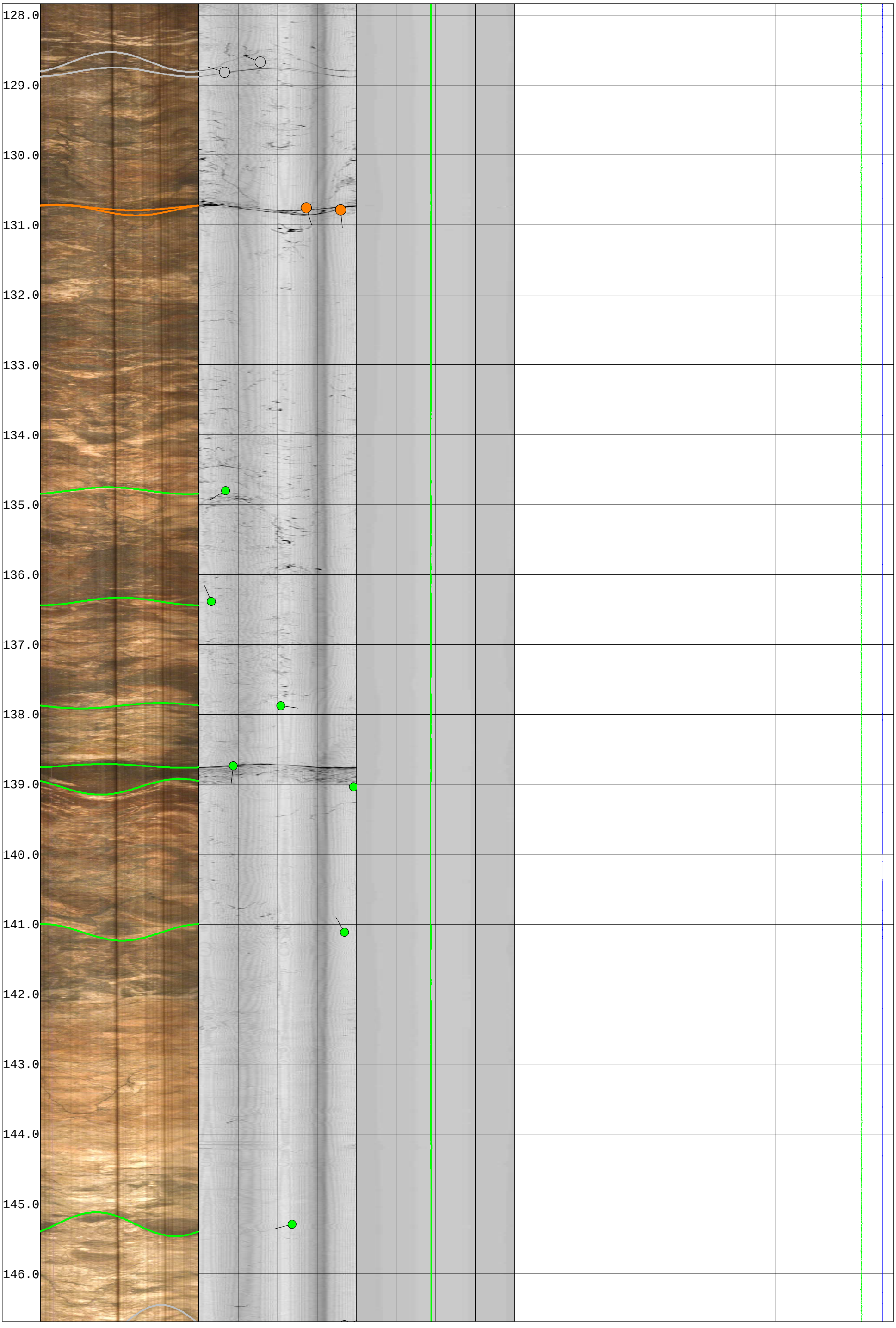
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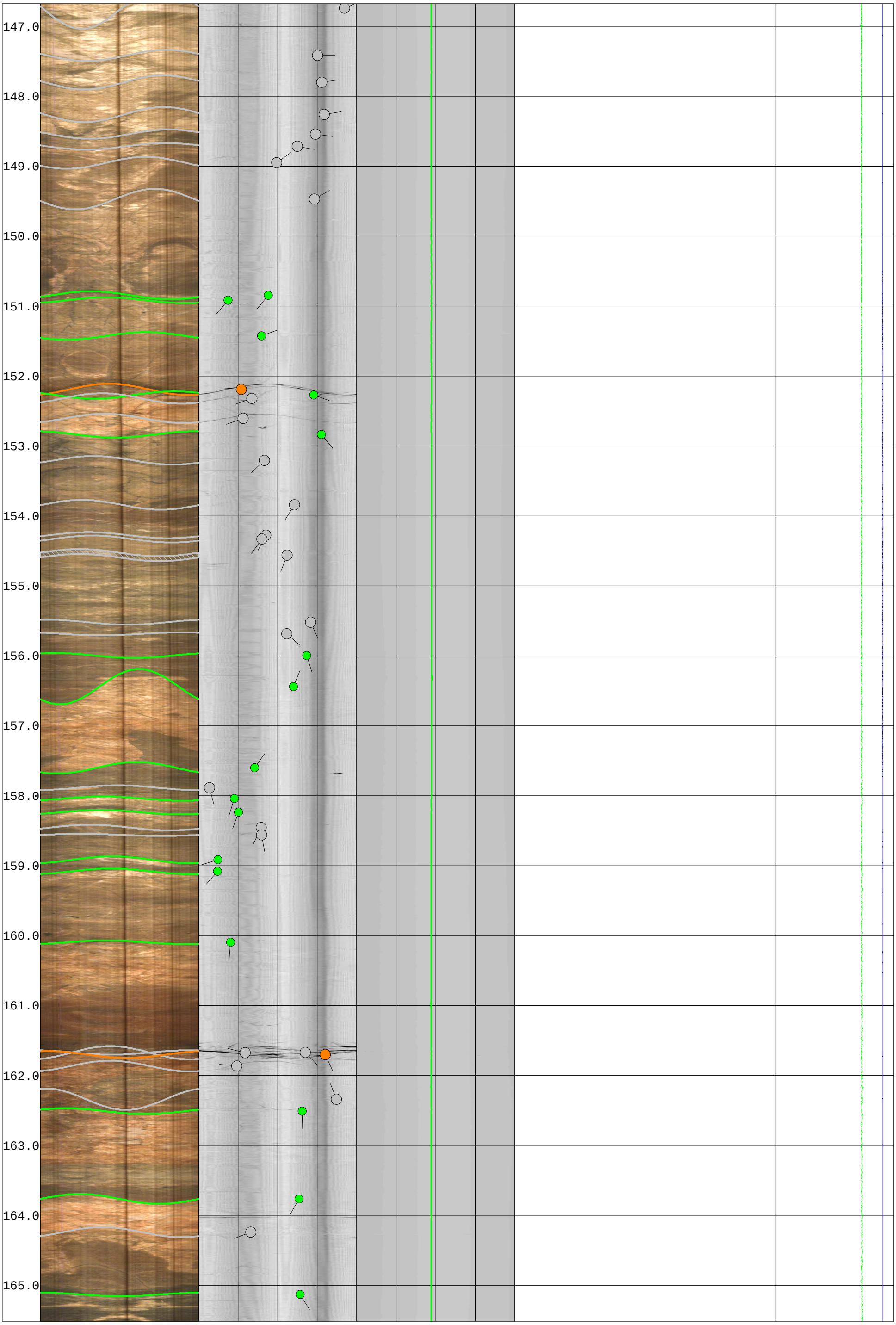
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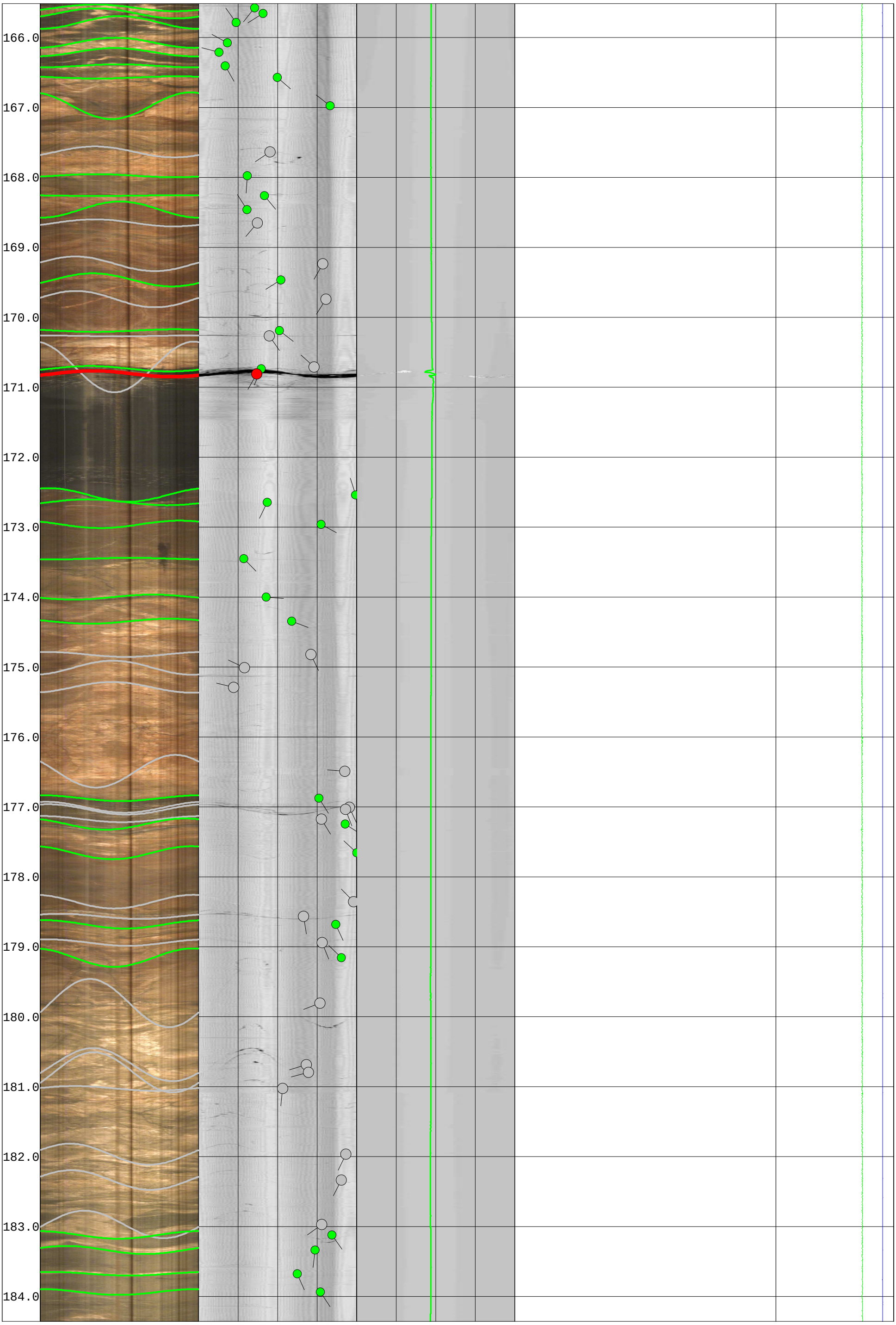
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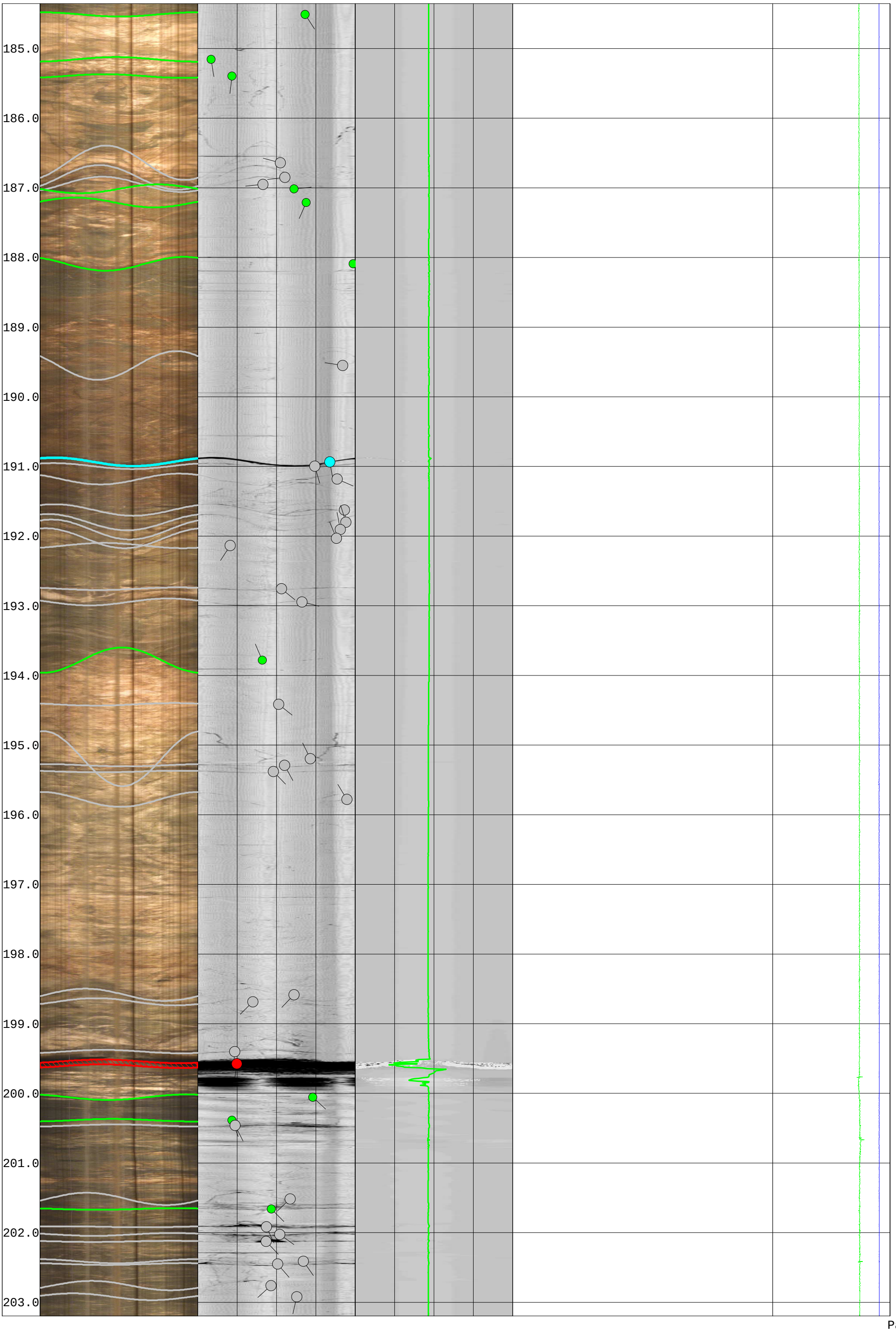
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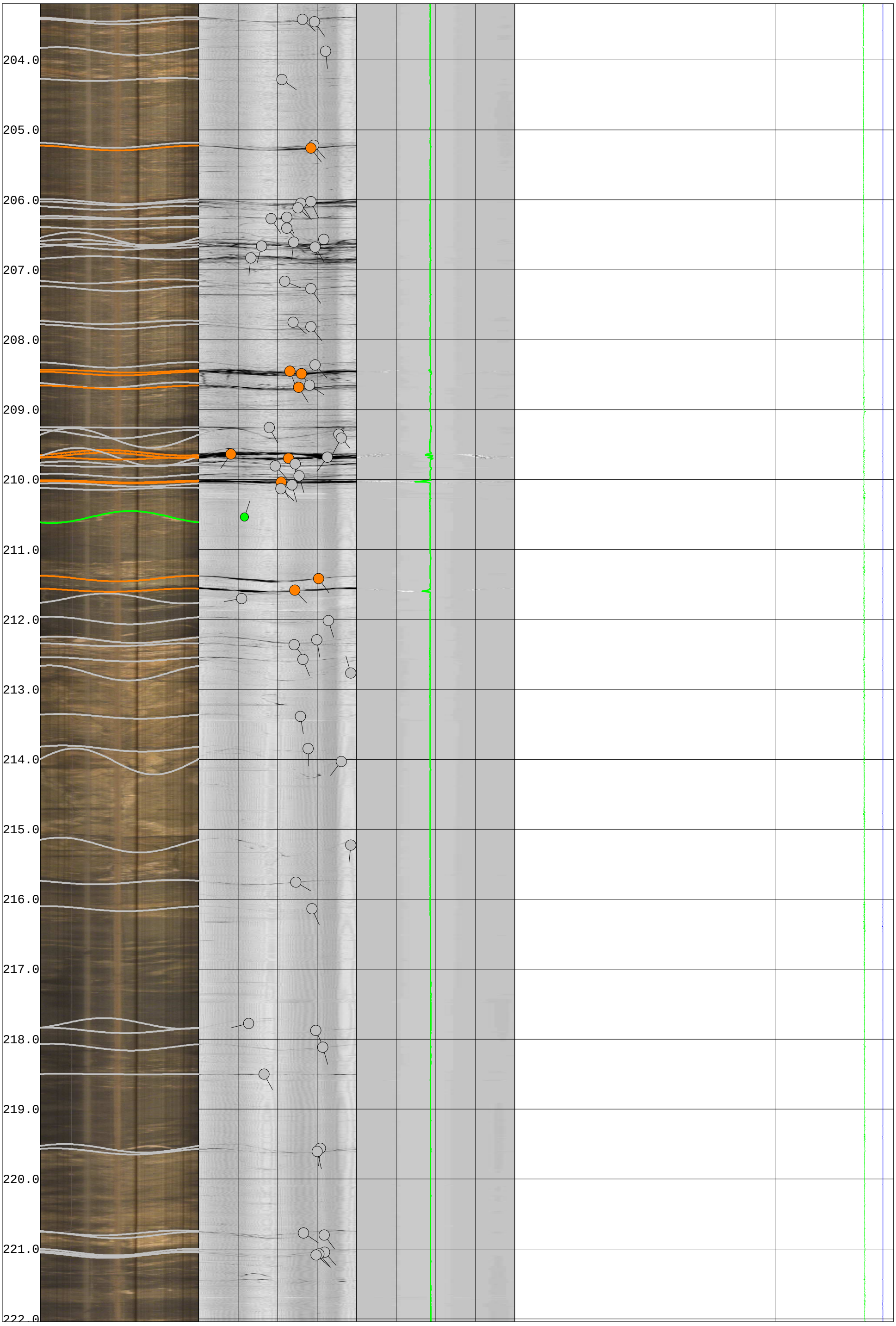
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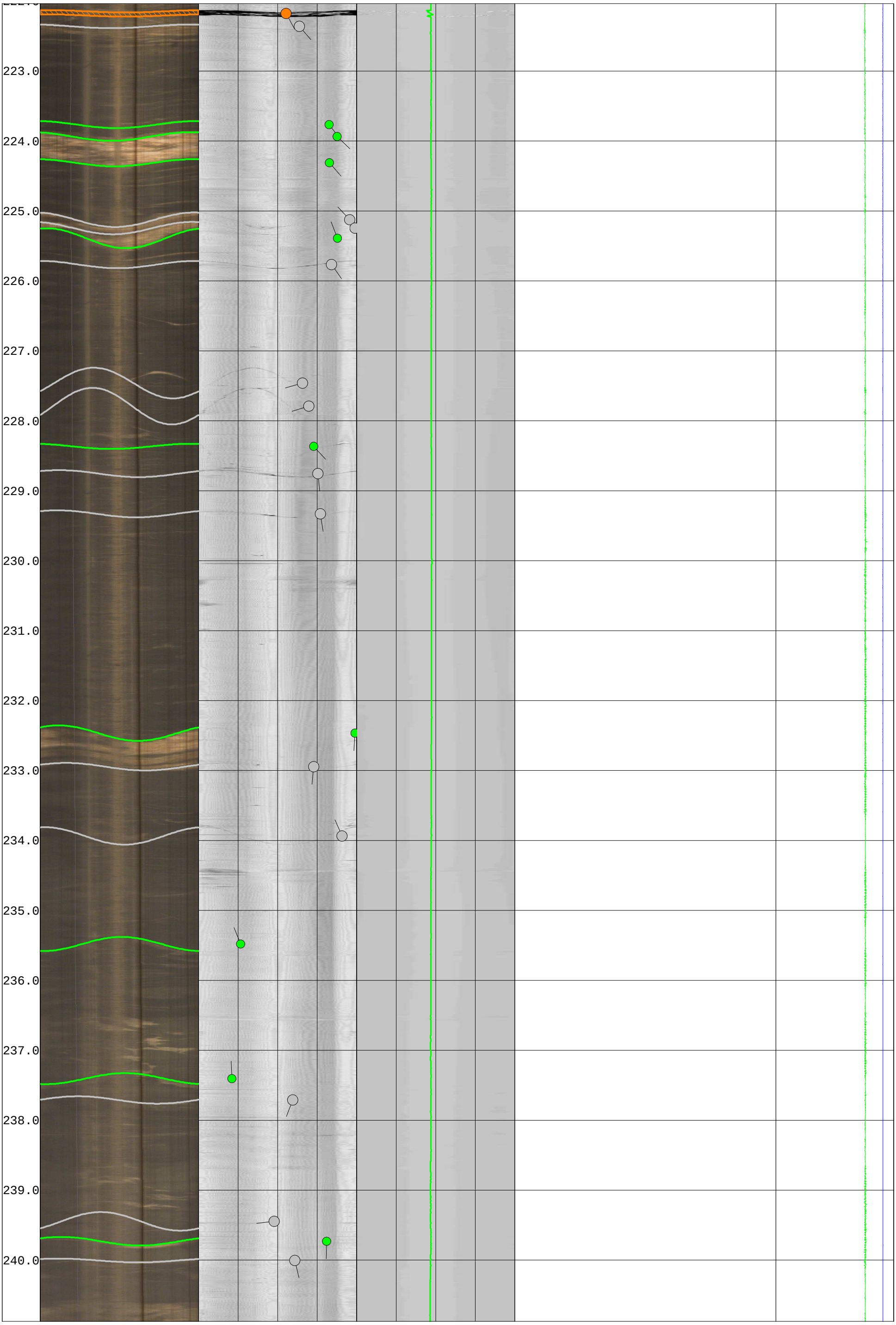
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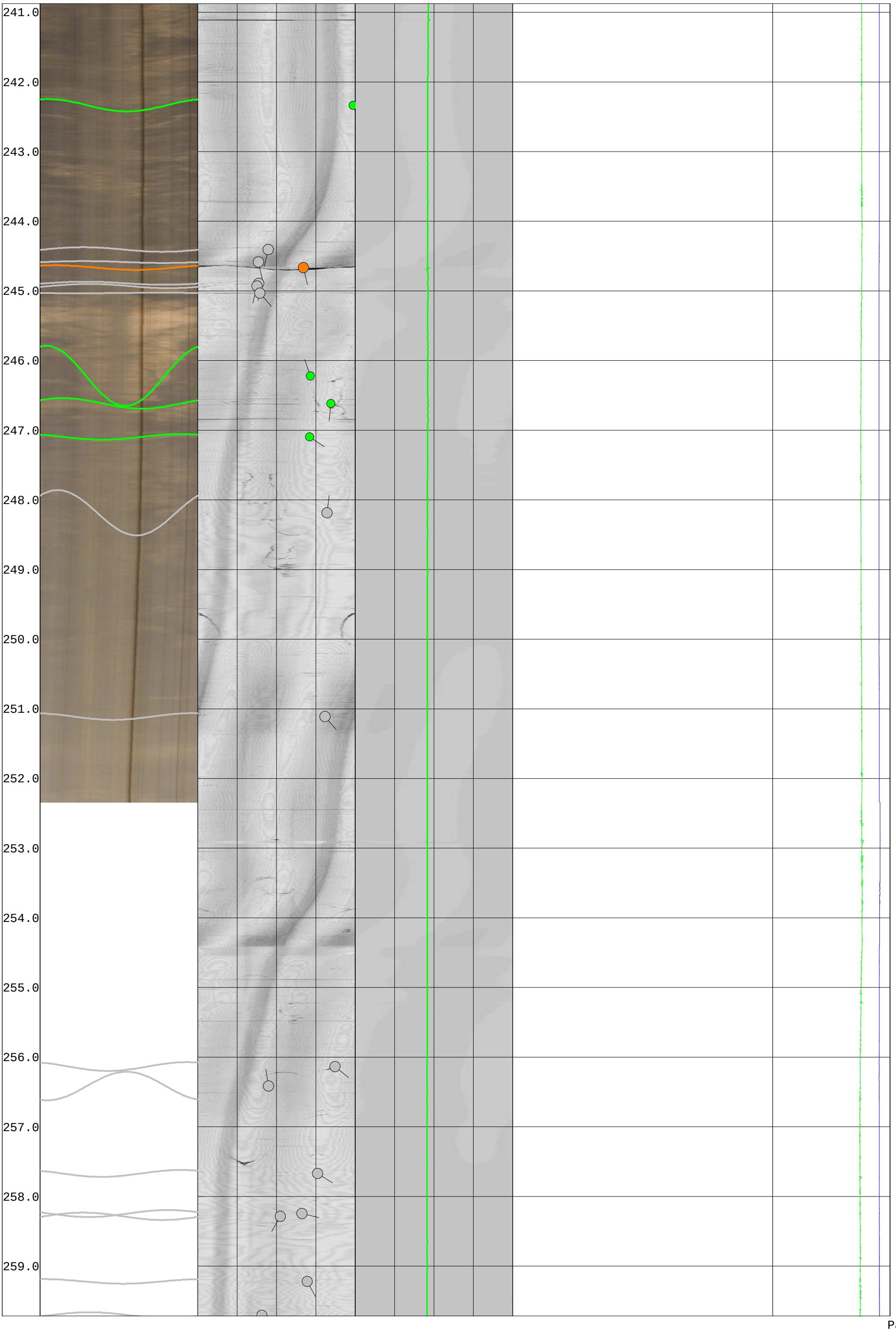
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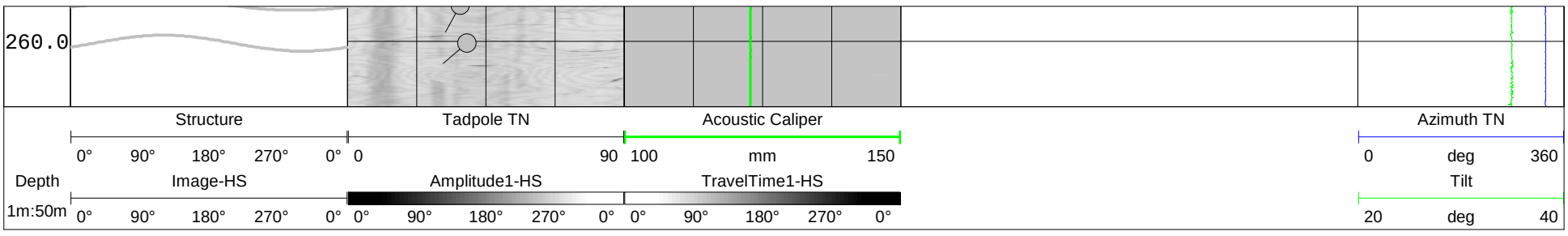
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Tilt
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APPENDIX 2.V

Groundwater Level Monitoring

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

To establish baseline groundwater levels and vertical hydraulic gradients throughout the Local Study Area (LSA) of the Hammond Reef Gold Project (Project), and to identify zones of lower water levels that could potentially be related to permeable bedrock structural features, Golder Associates Ltd. (Golder) monitored static water levels in monitoring wells and exploration boreholes from May 2011 through August 2012. To obtain a continuous record of water level fluctuations at select locations, data logging pressure transducers were installed in select monitoring wells and exploration boreholes throughout the LSA.

2.0 METHODS

2.1 Water Level Monitoring in Shallow Wells

Following completion of the borehole drilling and monitoring well installation program in 2011, manual depth to water measurements were recorded at each monitoring well during three groundwater monitoring events in 2011 (May/June, August and October) and two groundwater monitoring events in 2012 (April and August). Water levels were measured using a portable electronic water level meter. The top of each well pipe was used as the reference point for the water level measurements.

During the August 2012 monitoring event, depth to water measurements were also recorded at monitoring wells BH12-2, BH12-3A/B, BH12-4, BH12-6A/B, BH12-7A/B and BH12-8, which had recently been installed during the 2012 borehole drilling program.

In May 2011, data logging pressure transducers (Schlumberger *Mini-Divers*™) were installed to obtain continuous (hourly) water level records at the following monitoring well locations:

- BRH-0001A/B.
- BRH-0002A/B.
- BRH-0003.
- BRH-0005B.
- BRH-0006.
- BRH-0008A/B.
- BRH-0009.
- BRH-0011.
- BRH-0013.
- BRH-0015B.
- BRH-0020B.

Two barometric pressure data loggers (Schlumberger *Baro-Divers*™) were also installed at the site to obtain continuous hourly records of barometric pressure for water level data compensation. Schlumberger *Baro-Divers*™ were installed approximately two metres below the top of pipe (above the high water mark) in monitoring wells BRH-0003 and BRH-0026.

During the August 2012 monitoring event, Schlumberger *Mini-Divers*™ were installed in monitoring wells BH12-3B and BH12-4 to obtain continuous (hourly) water level records.

2.2 Water Level Monitoring in Exploration Boreholes

From October 19 to 28, 2011, Golder obtained manual measurements of static water levels in 126 existing exploration boreholes in the vicinity of the proposed west pit area to obtain a better understanding of the natural water table and to identify anomalous zones that could potentially be related to permeable bedrock structural features. This work was carried out in conjunction with the short-term pumping tests described in Section 2.7.1 of the Hydrogeology TSD. Upon completion of the short-term pumping tests, Schlumberger *Mini-Diver*™ transducers were installed in 27 boreholes throughout the west pit area and programmed to record groundwater levels continuously (hourly) from October 28, 2011, to March 10, 2012.

A Schlumberger *Baro-Diver*™ was installed near BR-0220 to obtain a continuous hourly record of barometric pressure from October 28, 2011, to March 10, 2012, for water level data compensation.

It should be noted that the steel casings/collars for five boreholes were damaged by heavy equipment throughout the winter and, as a result, only 22 of the 27 Schlumberger *Mini-Diver*™ transducers were recovered in March 2012.

3.0 RESULTS

3.1 Groundwater Levels

Groundwater levels observed in 2011 and 2012 at monitoring wells located within the Mine and TMF Areas are summarized in Tables 3-1 and 3-2. The locations of these monitoring wells are shown in Figures 2-6 and 2-7 of the Hydrogeology TSD. Continuous water level hydrographs for monitoring wells instrumented with Schlumberger *Mini-Divers*™ are presented in Figures 3-1 to 3-12. The water level elevations and inferred groundwater flow directions observed at monitoring wells in October 2011 are displayed in Figures 2-9 and 2-11 in the Hydrogeology TSD.

Table 3-1: Groundwater Elevations Observed at Monitoring Wells in 2011

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden / Bedrock Contact Depth (mbgs)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Mine Area	BRH-0001A	611909	5421762	428.97	19.22	0.00	No overburden	BRH-0001A	Nested	429.70	16.17	19.22	Bedrock
	BRH-0001B	611909	5421761	429.10	7.16	0.00	No overburden	BRH-0001B		429.69	3.92	6.97	Bedrock
	BRH-0002A	612178	5420590	422.67	19.25	0.00	No overburden	BRH-0002A	Nested	423.59	16.12	19.17	Bedrock
	BRH-0002B	612177	5420589	422.62	5.78	0.00	No overburden	BRH-0002B		423.67	2.73	5.78	Bedrock
	BRH-0003	612744	5421086	420.59	5.89	0.00	No overburden	BRH-0003	Single	421.08	4.21	5.73	Bedrock
	BRH-0004	613473	5421807	429.63	4.27	0.00	No overburden	BRH-0004	Single	430.40	2.75	4.27	Bedrock
	BRH-0005A	612360	5421894	441.74	19.07	0.97	Boulders, Clay and Organics	BRH-0005A	Nested	442.73	15.99	19.04	Bedrock
	BRH-0005B	612361	5421894	441.80	8.53	1.17		BRH-0005B		442.75	5.40	6.92	Bedrock
	BRH-0006	613857	5422544	416.97	3.88	0.86	Gravelly, silty, clayey sand, trace organics	BRH-0006	Single	418.10	2.36	3.88	Bedrock
	BRH-0007A	614656	5420825	427.07	18.44	0.66	Cobbles and Clay	BRH-0007A	Nested	427.82	16.91	18.43	Bedrock
	BRH-0007B	614656	5420826	427.05	6.86	1.22		BRH-0007B		427.79	5.34	6.86	Bedrock
	BRH-0008A	611682	5421030	419.57	19.49	0.48	Organics and Silty Clay	BRH-0008A	Nested	420.40	17.86	19.38	Bedrock
	BRH-0008B	611682	5421026	420.55	5.74	0.33		BRH-0008B		419.71	4.18	5.70	Bedrock
	BRH-0009	613878	5421290	416.27	7.77	0.53	Clay and Organics, some cobbles	BRH-0009	Single	417.13	6.25	7.77	Bedrock
	BRH-0010	615227	5423654	436.10	2.67	0.00	None	BRH-0010	Single	436.86	0.76	2.28	Bedrock
	BRH-0011	615105	5421919	434.22	5.64	1.07	Sand, some clay, some organics, trace boulders	BRH-0011	Single	435.26	4.12	5.64	Bedrock
	BRH-0012A	615588	5422185	416.87	5.66	3.38	Gravelly Sand, some clay, trace silt	BRH-0012A	Nested	417.87	4.13	5.65	Bedrock
	BRH-0012B	615588	5422185	416.87	2.40			BRH-0012B		417.87	0.88	2.40	Gravelly Sand
	BRH-0013	615631	5422933	416.57	4.37	1.32	Gravelly Sand, some clay, trace silt	BRH-0013	Single	417.41	2.85	4.37	Bedrock
	BRH-0014A	617147	5422218	416.86	8.78	5.11	Peat / Clay / Silty Sand, some gravel / Sand and Gravel	BRH-0014A	Nested	417.86	7.25	8.78	Bedrock
	BRH-0014B	617147	5422218	416.86	4.88			BRH-0014B		417.86	3.35	4.88	Clay / Silty Sand, some gravel / Sand and Gravel
	BRH-0015A	617875	5423186	417.30	8.74	5.81	Clay / Clay, some silt / Sand, some gravel	BRH-0015A	Nested	418.23	7.21	8.73	Bedrock
	BRH-0015B	617875	5423186	417.30	5.50			BRH-0015B		418.23	3.98	5.50	Clay, some silt / Sand, some gravel
	BRH-0016A	618407	5425303	444.80	5.73	1.52	Sandy, clayey Silt / Gravelly, silty Sand	BRH-0016A	Nested	445.59	2.68	5.73	Bedrock
	BRH-0016B	618407	5425303	444.80	1.52			BRH-0016B		445.59	0.76	1.52	Sandy, clayey Silt / Gravelly, silty Sand

Table 3-1: Groundwater Elevations Observed at Monitoring Wells in 2011 (Continued)

Project Component	Groundwater Levels and Elevations												
	Borehole ID	Date of WL Measurement (Spring 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Spring 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Summer 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Fall 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)
Mine Area	BRH-0001A	March 5, 2011	5.17	424.54	June 1, 2011	9.16	420.55	August 25, 2011	5.00	424.70	October 28, 2011	3.964	425.738
	BRH-0001B	March 5, 2011	1.22	428.47	June 1, 2011	1.41	428.28	August 25, 2011	2.06	427.63	October 28, 2011	1.440	428.247
	BRH-0002A	April 5, 2011	-0.02	423.61	June 1, 2011	-0.01	423.60	August 25, 2011	0.58	423.01	October 28, 2011	0.200	423.393
	BRH-0002B	April 5, 2011	1.40	422.27	June 1, 2011	1.63	422.04	August 25, 2011	1.90	421.77	October 28, 2011	1.326	422.339
	BRH-0003	April 5, 2011	4.67	416.41	June 1, 2011	4.59	416.49	August 25, 2011	5.00	416.07	October 28, 2011	4.575	416.500
	BRH-0004	March 5, 2011	0.78	429.62	June 1, 2011	0.87	429.53	August 25, 2011	0.92	429.48	October 28, 2011	0.888	429.507
	BRH-0005A	March 5, 2011	11.59	431.14	June 1, 2011	16.19	426.54	August 25, 2011	17.19	425.54	October 28, 2011	17.306	425.425
	BRH-0005B	March 5, 2011	2.24	440.51	June 1, 2011	3.20	439.55	August 25, 2011	4.11	438.64	October 28, 2011	3.145	439.605
	BRH-0006	March 5, 2011	1.20	416.90	June 1, 2011	1.32	416.78	August 25, 2011	1.55	416.55	October 28, 2011	1.345	416.751
	BRH-0007A	April 5, 2011	4.36	423.47	June 1, 2011	6.29	421.53	August 26, 2011	9.39	418.44	October 28, 2011	9.31	418.51
	BRH-0007B	April 5, 2011	3.25	424.55	June 1, 2011	4.76	423.03	August 26, 2011	6.19	421.61	October 28, 2011	5.04	422.76
	BRH-0008A	April 5, 2011	-0.01	420.41	June 1, 2011	-0.01	420.40	August 26, 2011	artesian	n/a	October 28, 2011	artesian	n/a
	BRH-0008B	April 5, 2011	1.61	418.10	June 1, 2011	0.10	419.61	August 26, 2011	0.05	419.66	October 28, 2011	0.175	419.534
	BRH-0009	April 5, 2011	0.93	416.20	June 1, 2011	1.12	416.01	August 27, 2011	1.41	415.72	October 28, 2011	1.81	415.32
	BRH-0010	April 5, 2011	1.31	435.55	June 1, 2011	1.60	435.26	August 26, 2011	1.81	435.05	October 29, 2011	1.595	435.262
	BRH-0011	April 5, 2011	2.28	432.99	June 1, 2011	4.02	431.24	August 26, 2011	5.34	429.92	October 28, 2011	4.52	430.75
	BRH-0012A	April 20, 2011	1.51	416.37	June 1, 2011	1.83	416.04	August 27, 2011	2.02	415.85	October 29, 2011	1.93	415.94
	BRH-0012B	April 20, 2011	1.51	416.37	June 1, 2011	1.81	416.06	August 27, 2011	2.00	415.87	October 29, 2011	1.91	415.96
	BRH-0013	April 5, 2011	0.34	417.07	June 1, 2011	0.71	416.70	August 26, 2011	0.95	416.46	October 29, 2011	0.53	416.88
	BRH-0014A	April 5, 2011	0.61	417.25	June 1, 2011	0.79	417.07	August 27, 2011	1.10	416.76	October 29, 2011	0.914	416.944
	BRH-0014B	April 5, 2011	0.60	417.26	June 1, 2011	0.78	417.08	August 27, 2011	1.09	416.77	October 29, 2011	0.906	416.952
	BRH-0015A	May 5, 2011	1.13	417.10	June 2, 2011	1.30	416.94	August 27, 2011	1.68	416.56	October 29, 2011	1.377	416.856
	BRH-0015B	May 5, 2011	1.21	417.03	June 2, 2011	1.33	416.90	August 27, 2011	1.75	416.48	October 29, 2011	1.440	416.793
	BRH-0016A	March 5, 2011	1.99	443.60	June 2, 2011	2.13	443.46	August 27, 2011	2.37	443.22	October 26, 2011	2.156	443.433
	BRH-0016B	March 5, 2011	1.56	444.03	June 2, 2011	dry	n/a[(a)]	August 27, 2011	dry	n/a[(a)]	October 26, 2011	1.936	443.653

Table 3-1: Groundwater Elevations Observed at Monitoring Wells in 2011 (Continued)

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden / Bedrock Contact Depth (mbgs)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Tailings Management Facility Area	BRH-0017A	619624	5425289	427.70	7.16	3.08	Silty Sand / Sand	BRH-0017A	Nested	428.55	5.64	7.16	Bedrock
	BRH-0017B	619624	5425289	427.70	3.05			BRH-0017B		428.55	1.52	3.05	Sand
	BRH-0018	620794	5427311	430.60	8.69	1.75	Clayey Sand and Silt / Silty Sand	BRH-0018	Single	431.64	5.49	8.53	Bedrock
	BRH-0019	618808	5426822	430.56	8.41	8.41	Topsoil / Silt / Silty Clayey Sand / Clayey Silt / Silty Clay / Clay / Sand	BRH-0019	Single	431.56	5.05	8.10	Silty Clay / Clay / Sand
	BRH-0020A	617958	5426576	416.51	28.86	25.55	Topsoil / Sand / Clay and Silt / Clayey Silt / Clay / Silty Clay / Bouldery Sand	BRH-0020A	Nested	417.47	26.34	28.86	Bedrock
	BRH-0020B	617955	5426575	416.49	20.68			BRH-0020B		417.33	17.63	20.68	Bouldery Sand
	BRH-0020C	617955	5426575	416.49	14.48			n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
	BRH-0021A	617175	5427168	420.41	5.90	3.05	Topsoil / Sand / Sandy clayey Silt / Silt / Sand	BRH-0021A	Nested	421.42	4.18	5.70	Bedrock
	BRH-0021B	617175	5427168	420.41	2.82			BRH-0021B		421.42	1.30	2.82	Sandy clayey Silt / Silt / Sand
	BRH-0022	618040	5428215	430.63	5.39	0.10	Gravelly Sand, some cobbles, some boulders, trace silt	BRH-0022	Single	431.56	2.13	5.18	Bedrock
	BRH-0023	619973	5429127	434.90	3.58	3.58	Topsoil and Boulders / Silt and Sand / Sand and Gravel / Bouldery Sand and Gravel	BRH-0023	Single	435.80	1.83	3.35	Bouldery Sand and Gravel
	BRH-0024	621017	5429046	435.36	7.19	0.96	Gravelly Sand and Boulders, trace silt	BRH-0024	Single	436.36	5.61	7.14	Bedrock
	BRH-0025	621289	5430267	443.34	1.70	1.70	Peat / Organics and silty Sand / Silty Sand and Cobbles	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
	BRH-0026	620607	5431227	460.88	8.75	1.52	Topsoil / Sand and Gravel, some silt, some cobbles, some boulders, trace clay	BRH-0026	Single	461.98	5.70	8.75	Bedrock
	BRH-0027	619614	5425831	434.80	2.36	2.36	Peat, some sand, some silt / Sandy silty Clay / Silty Sand, some gravel, some clay	BRH-0027	Single	435.98	0.84	2.36	Sandy silty Clay / Silty Sand, some gravel, some clay

Table 3-1: Groundwater Elevations Observed at Monitoring Wells in 2011 (Continued)

Project Component	Groundwater Levels and Elevations												
	Borehole ID	Date of WL Measurement (Spring 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Spring 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Summer 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Fall 2011)	Groundwater Level (mbtp)	Groundwater Elevation (masl)
Tailings Management Facility Area	BRH-0017A	May 5, 2011	0.77	427.78	June 2, 2011	0.98	427.57	n/a[b]	n/a[b]	n/a[b]	October 29, 2011	1.114	427.438
	BRH-0017B	May 5, 2011	0.87	427.68	June 2, 2011	1.00	427.55	n/a[b]	n/a[b]	n/a[b]	October 29, 2011	1.045	427.507
	BRH-0018	March 29, 2011	1.39	430.25	May 31, 2011	2.43	429.21	August 28, 2011	2.97	428.67	October 27, 2011	2.755	428.884
	BRH-0019	March 20, 2011	1.59	429.97	June 2, 2011	0.60	430.96	August 29, 2011	1.31	430.25	October 26, 2011	0.601	430.959
	BRH-0020A	March 5, 2011	0.09	417.38	June 2, 2011	0.000 (artesian)	n/a	August 27, 2011	0.34	417.13	October 26, 2011	0.342	417.130
	BRH-0020B	March 5, 2011	0.00 (artesian)	n/a	June 2, 2011	0.000 (artesian)	n/a	August 27, 2011	0.19	417.13	October 26, 2011	0.185	417.140
	BRH-0020C	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]
	BRH-0021A	March 23, 2011	2.41	419.02	June 2, 2011	1.09	420.33	August 29, 2011	1.97	419.45	October 26, 2011	1.485	419.935
	BRH-0021B	March 23, 2011	2.73	418.69	June 2, 2011	1.31	420.12	August 29, 2011	2.19	419.23	October 26, 2011	1.697	419.723
	BRH-0022	March 24, 2011	2.31	429.25	June 2, 2011	1.98	429.57	August 29, 2011	2.19	429.37	October 26, 2011	2.070	429.486
	BRH-0023	March 28, 2011	1.33	434.47	May 31, 2011	1.22	434.58	August 28, 2011	1.41	434.39	October 27, 2011	1.308	434.493
	BRH-0024	March 28, 2011	5.52	430.84	May 31, 2011	5.18	431.18	August 28, 2011	5.53	430.83	October 27, 2011	5.320	431.035
	BRH-0025	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]
	BRH-0026	March 31, 2011	2.90	459.08	May 31, 2011	2.47	459.51	August 28, 2011	3.13	458.85	October 27, 2011	2.493	459.485
	BRH-0027	April 8, 2011	1.26	434.72	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]

Notes:
masl = Metres above mean sea level.
mbgs = Metres below ground surface. Negative values indicate static water levels above top of pipe.
mbtp = Metres below top of pipe.
n/a[a] = Groundwater elevation lower than bottom of monitoring well.
n/a[b] = Field crew unable to access monitoring location.
n/a[c] = No monitoring well installed at this location.

Table 3-2: Groundwater Elevations Observed at Monitoring Wells in 2012

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden/ Bedrock Contact Depth (mbgs)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Mine Area	BRH-0001A	611909	5421762	428.97	19.22	0.00	No overburden	BRH-0001A	Nested	429.70	16.17	19.22	Bedrock
	BRH-0001B	611909	5421761	429.10	7.16	0.00	No overburden	BRH-0001B		429.69	3.92	6.97	Bedrock
	BRH-0002A	612178	5420590	422.67	19.25	0.00	No overburden	BRH-0002A	Nested	423.59	16.12	19.17	Bedrock
	BRH-0002B	612177	5420589	422.62	5.78	0.00	No overburden	BRH-0002B		423.67	2.73	5.78	Bedrock
	BRH-0003	612744	5421086	420.59	5.89	0.00	No overburden	BRH-0003	Single	421.08	4.21	5.73	Bedrock
	BRH-0004	613473	5421807	429.63	4.27	0.00	No overburden	BRH-0004	Single	430.40	2.75	4.27	Bedrock
	BRH-0005A	612360	5421894	441.74	19.07	0.97	Boulders, Clay and Organics	BRH-0005A	Nested	442.73	15.99	19.04	Bedrock
	BRH-0005B	612361	5421894	441.80	8.53	1.17		BRH-0005B		442.75	5.40	6.92	Bedrock
	BRH-0006	613857	5422544	416.97	3.88	0.86	Gravelly, silty, clayey sand, trace organics	BRH-0006	Single	418.10	2.36	3.88	Bedrock
	BRH-0007A	614656	5420825	427.07	18.44	0.66	Cobbles and Clay	BRH-0007A	Nested	427.82	16.91	18.43	Bedrock
	BRH-0007B	614656	5420826	427.05	6.86	1.22		BRH-0007B		427.79	5.34	6.86	Bedrock
	BRH-0008A	611682	5421030	419.57	19.49	0.48	Organics and Silty Clay	BRH-0008A	Nested	420.40	17.86	19.38	Bedrock
	BRH-0008B	611682	5421026	420.55	5.74	0.33		BRH-0008B		419.71	4.18	5.70	Bedrock
	BRH-0009	613878	5421290	416.27	7.77	0.53	Clay and Organics, some cobbles	BRH-0009	Single	417.13	6.25	7.77	Bedrock
	BRH-0010	615227	5423654	436.10	2.67	0.00	None	BRH-0010	Single	436.86	0.76	2.28	Bedrock
	BRH-0011	615105	5421919	434.22	5.64	1.07	Sand, some clay, some organics, trace boulders	BRH-0011	Single	435.26	4.12	5.64	Bedrock
	BRH-0012A	615588	5422185	416.87	5.66	3.38	Gravelly Sand, some clay, trace silt	BRH-0012A	Nested	417.87	4.13	5.65	Bedrock
	BRH-0012B	615588	5422185	416.87	2.40			BRH-0012B		417.87	0.88	2.40	Gravelly Sand
	BRH-0013	615631	5422933	416.57	4.37	1.32	Gravelly Sand, some clay, trace silt	BRH-0013	Single	417.41	2.85	4.37	Bedrock
	BRH-0014A	617147	5422218	416.86	8.78	5.11	Peat / Clay / Silty Sand, some gravel / Sand and Gravel	BRH-0014A	Nested	417.86	7.25	8.78	Bedrock
	BRH-0014B	617147	5422218	416.86	4.88			BRH-0014B		417.86	3.35	4.88	Clay / Silty Sand, some gravel / Sand and Gravel
	BRH-0015A	617875	5423186	417.30	8.74	5.81	Clay / Clay, some silt / Sand, some gravel	BRH-0015A	Nested	418.23	7.21	8.73	Bedrock
	BRH-0015B	617875	5423186	417.30	5.50			BRH-0015B		418.23	3.98	5.50	Clay, some silt / Sand, some gravel
	BRH-0016A	618407	5425303	444.80	5.73	1.52	Sandy, clayey Silt / Gravelly, silty Sand	BRH-0016A	Nested	445.59	2.68	5.73	Bedrock
	BRH-0016B	618407	5425303	444.80	1.52			BRH-0016B		445.59	0.76	1.52	Sandy, clayey Silt / Gravelly, silty Sand

Table 3-2: Groundwater Elevations Observed at Monitoring Wells in 2012 (Continued)

Project Component	Groundwater Levels and Elevations						
	Borehole ID	Date of WL Measurement (Spring 2012)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Summer 2012)	Groundwater Level (mbtp)	Groundwater Elevation (masl)
Mine Area	BRH-0001A	April 24, 2012	3.095	426.607	August 30, 2012	2.468	427.23
	BRH-0001B	April 24, 2012	1.220	428.467	August 30, 2012	2.240	427.45
	BRH-0002A	April 24, 2012	-0.006	423.599	August 31, 2012	0.922	422.67
	BRH-0002B	April 24, 2012	1.180	422.485	August 31, 2012	2.191	421.47
	BRH-0003	April 24, 2012	4.422	416.653	August 31, 2012	4.714	416.36
	BRH-0004	April 24, 2012	0.815	429.580	August 30, 2012	0.951	429.44
	BRH-0005A	April 24, 2012	12.766	429.965	August 30, 2012	18.375	424.36
	BRH-0005B	April 24, 2012	2.335	440.415	August 30, 2012	4.229	438.52
	BRH-0006	April 24, 2012	1.164	416.932	August 30, 2012	1.691	416.41
	BRH-0007A	April 24, 2012	4.64	423.18	August 28, 2012	9.468	418.35
	BRH-0007B	April 24, 2012	3.15	424.64	August 28, 2012	6.249	421.54
	BRH-0008A	April 24, 2012	-0.010	420.407	August 31, 2012	-0.002	420.40
	BRH-0008B	April 24, 2012	-0.015	419.724	August 31, 2012	0.508	419.20
	BRH-0009	April 24, 2012	1.02	416.11	August 30, 2012	1.599	415.53
	BRH-0010	April 24, 2012	1.27	435.59	August 28, 2012	1.658	435.20
	BRH-0011	April 24, 2012	2.56	432.70	August 28, 2012	5.605	429.66
	BRH-0012A	April 22, 2012	1.74	416.14	August 30, 2012	2.055	415.82
	BRH-0012B	April 22, 2012	1.71	416.16	August 30, 2012	2.045	415.83
	BRH-0013	April 24, 2012	0.43	416.98	August 28, 2012	0.938	416.47
	BRH-0014A	April 25, 2012	0.647	417.211	August 28, 2012	1.141	416.72
	BRH-0014B	April 25, 2012	0.633	417.225	August 28, 2012	1.138	416.72
	BRH-0015A	April 25, 2012	1.167	417.066	August 28, 2012	1.61	416.62
	BRH-0015B	April 25, 2012	1.198	417.035	August 28, 2012	1.77	416.46
	BRH-0016A	April 22, 2012	1.975	443.614	August 28, 2012	2.346	443.24
	BRH-0016B	April 22, 2012	1.513	444.076	August 28, 2012	dry	n/a[(a)]

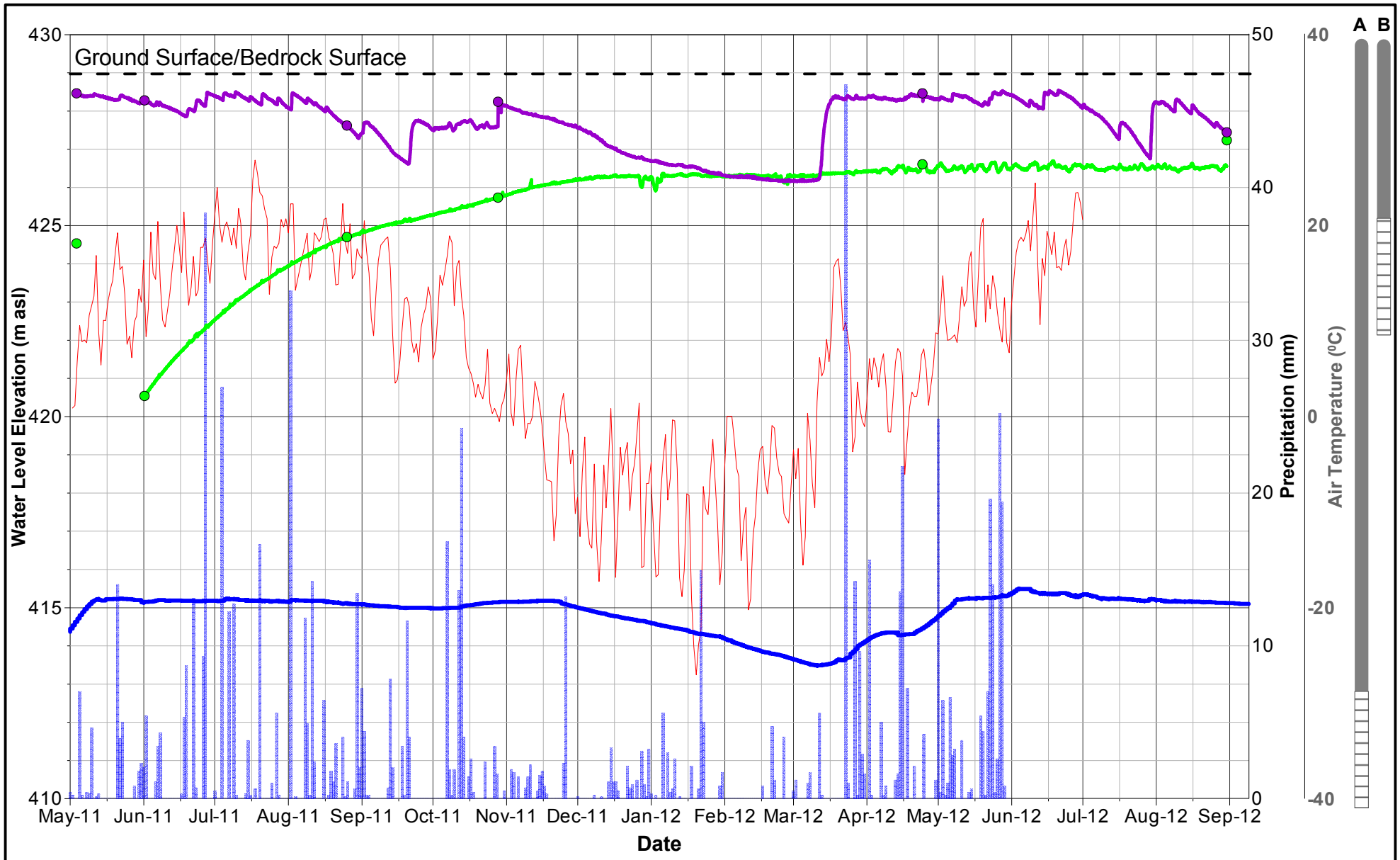
Table 3-2: Groundwater Elevations Observed at Monitoring Wells in 2012 (Continued)

Project Component	General Information					Geologic Information		Monitoring Well Information					
	Borehole ID	UTM Location (NAD 83 Zone 15U)		Ground Surface Elevation (masl)	Total Borehole Depth (mbgs)	Overburden/ Bedrock Contact Depth (mbgs)	General Overburden Description	Monitoring Well ID	Monitoring Well Type	Top of Pipe Elevation (masl)	Screened Interval (mbgs)		Screened Material
		Easting	Northing								from	to	
Tailings Management Facility Area	BRH-0017A	619624	5425289	427.70	7.16	3.08	Silty Sand / Sand	BRH-0017A	Nested	428.55	5.64	7.16	Bedrock
	BRH-0017B	619624	5425289	427.70	3.05			BRH-0017B		428.55	1.52	3.05	Sand
	BRH-0018	620794	5427311	430.60	8.69	1.75	Clayey Sand and Silt / Silty Sand	BRH-0018	Single	431.64	5.49	8.53	Bedrock
	BRH-0019	618808	5426822	430.56	8.41	8.41	Topsoil / Silt / Silty Clayey Sand / Clayey Silt / Silty Clay / Clay / Sand	BRH-0019	Single	431.56	5.05	8.10	Silty Clay / Clay / Sand
	BRH-0020A	617958	5426576	416.51	28.86	25.55	Topsoil / Sand / Clay and Silt / Clayey Silt / Clay / Silty Clay / Bouldery Sand	BRH-0020A	Nested	417.47	26.34	28.86	Bedrock
	BRH-0020B	617955	5426575	416.49	20.68			BRH-0020B		417.33	17.63	20.68	Bouldery Sand
	BRH-0020C	617955	5426575	416.49	14.48			n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]
	BRH-0021A	617175	5427168	420.41	5.90	3.05	Topsoil / Sand / Sandy clayey Silt / Silt / Sand	BRH-0021A	Nested	421.42	4.18	5.70	Bedrock
	BRH-0021B	617175	5427168	420.41	2.82			BRH-0021B		421.42	1.30	2.82	Sandy clayey Silt / Silt / Sand
	BRH-0022	618040	5428215	430.63	5.39	0.10	Gravelly Sand, some cobbles, some boulders, trace silt	BRH-0022	Single	431.56	2.13	5.18	Bedrock
	BRH-0023	619973	5429127	434.90	3.58	3.58	Topsoil and Boulders / Silt and Sand / Sand and Gravel / Bouldery Sand and Gravel	BRH-0023	Single	435.80	1.83	3.35	Bouldery Sand and Gravel
	BRH-0024	621017	5429046	435.36	7.19	0.96	Gravelly Sand and Boulders, trace silt	BRH-0024	Single	436.36	5.61	7.14	Bedrock
	BRH-0025	621289	5430267	443.34	1.70	1.70	Peat / Organics and silty Sand / Silty Sand and Cobbles	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]
	BRH-0026	620607	5431227	460.88	8.75	1.52	Topsoil / Sand and Gravel, some silt, some cobbles, some boulders, trace clay	BRH-0026	Single	461.98	5.70	8.75	Bedrock
	BRH-0027	619614	5425831	434.80	2.36	2.36	Peat, some sand, some silt / Sandy silty Clay / Silty Sand, some gravel, some clay	BRH-0027	Single	435.98	0.84	2.36	Sandy silty Clay / Silty Sand, some gravel, some clay
	BH12-1	617568	5428261	436.84	4.17	1.22	Peat / Silt and Sand / Silty Sand / Sand	BH12-1	Single	437.76	2.59	4.11	Bedrock
	BH12-2	617830	5426870	418.40	18.36	15.14	Silt / Sandy Silt / Clayey Silt / Silty Clay / Silt / Silty Sand and Gravel	BH12-2	Single	419.28	13.11	14.63	Silty Sand and Gravel
	BH12-3A	618260	5426405	419.49	16.46	13.41	Peat / Silt and Sand, trace gravel / Silt, some sand / Silty Clay, trace sand / Silt, trace sand / Silt and Sand, some gravel	BH12-3A	Nested	420.38	14.93	16.46	Bedrock
	BH12-3B	618259	5426406	419.53				BH12-3B		420.32	10.06	11.58	Silt
	BH12-4	619918	5426313	428.57	10.16	7.01	Peat / Clayey Silt / Silty Clay / Silt / Silty Sand	BH12-4	Single	429.53	5.49	7.01	Silt / Silty Sand
	BH12-5A	620391	5428975	433.03	10.69	7.85	Sand Fill / Peat / Sand / Silty Sand	BH12-5A	Nested	433.95	9.14	10.67	Bedrock
	BH12-5B	620390	5428976	433.03				BH12-5B		433.96	5.33	6.86	Silt / Sand / Silty Sand and Gravel

Table 3-2: Groundwater Elevations Observed at Monitoring Wells in 2012 (Continued)

Project Component	Groundwater Levels and Elevations						
	Borehole ID	Date of WL Measurement (Spring 2012)	Groundwater Level (mbtp)	Groundwater Elevation (masl)	Date of WL Measurement (Summer 2012)	Groundwater Level (mbtp)	Groundwater Elevation (masl)
Tailings Management Facility Area	BRH-0017A	April 22, 2012	1.805	426.747	August 28, 2012	1.307	427.25
	BRH-0017B	April 22, 2012	0.930	427.622	August 28, 2012	1.341	427.21
	BRH-0018	April 23, 2012	2.176	429.463	August 29, 2012	2.938	428.70
	BRH-0019	April 22, 2012	0.443	431.117	August 27, 2012	1.13	430.43
	BRH-0020A	April 22, 2012	0.110	417.362	August 27, 2012	0.213	417.26
	BRH-0020B	April 22, 2012	0.040	417.285	August 27, 2012	0.145	417.18
	BRH-0020C	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]
	BRH-0021A	April 22, 2012	0.946	420.474	August 27, 2012	1.821	419.60
	BRH-0021B	April 22, 2012	1.212	420.208	August 27, 2012	2.054	419.37
	BRH-0022	April 22, 2012	1.890	429.666	August 27, 2012	2.114	429.44
	BRH-0023	April 23, 2012	0.906	434.895	August 29, 2012	1.423	434.38
	BRH-0024	April 23, 2012	5.050	431.305	August 29, 2012	5.469	430.89
	BRH-0025	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]
	BRH-0026	April 23, 2012	1.927	460.051	August 29, 2012	3.172	458.81
	BRH-0027	April 22, 2012	0.687	435.292	n/a[(c)]	n/a[(c)]	n/a[(c)]
	BH12-1	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(e)]	n/a[(e)]	n/a[(e)]
	BH12-2	n/a[(d)]	n/a[(d)]	n/a[(d)]	August 28, 2012	1.786	417.49
	BH12-3A	n/a[(d)]	n/a[(d)]	n/a[(d)]	August 28, 2012	0.869	419.51
	BH12-3B	n/a[(d)]	n/a[(d)]	n/a[(d)]	August 28, 2012	0.798	419.52
	BH12-4	n/a[(d)]	n/a[(d)]	n/a[(d)]	August 28, 2012	0.935	428.59
	BH12-5A	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(e)]	n/a[(e)]	n/a[(e)]
	BH12-5B	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(e)]	n/a[(e)]	n/a[(e)]

Notes:
masl = Metres above mean sea level.
mbgs = Metres below ground surface. Negative values indicate static water levels above top of pipe.
mbtp = Metres below top of pipe.
n/a[(a)] Groundwater elevation lower than bottom of monitoring well.
n/a[(b)] No monitoring well installed at this location.
n/a[(c)] Field crew unable to access monitoring location.
n/a[(d)] Monitoring well not installed at this location until August 2012.
n/a[(e)] Water level data not required at this location.



LEGEND

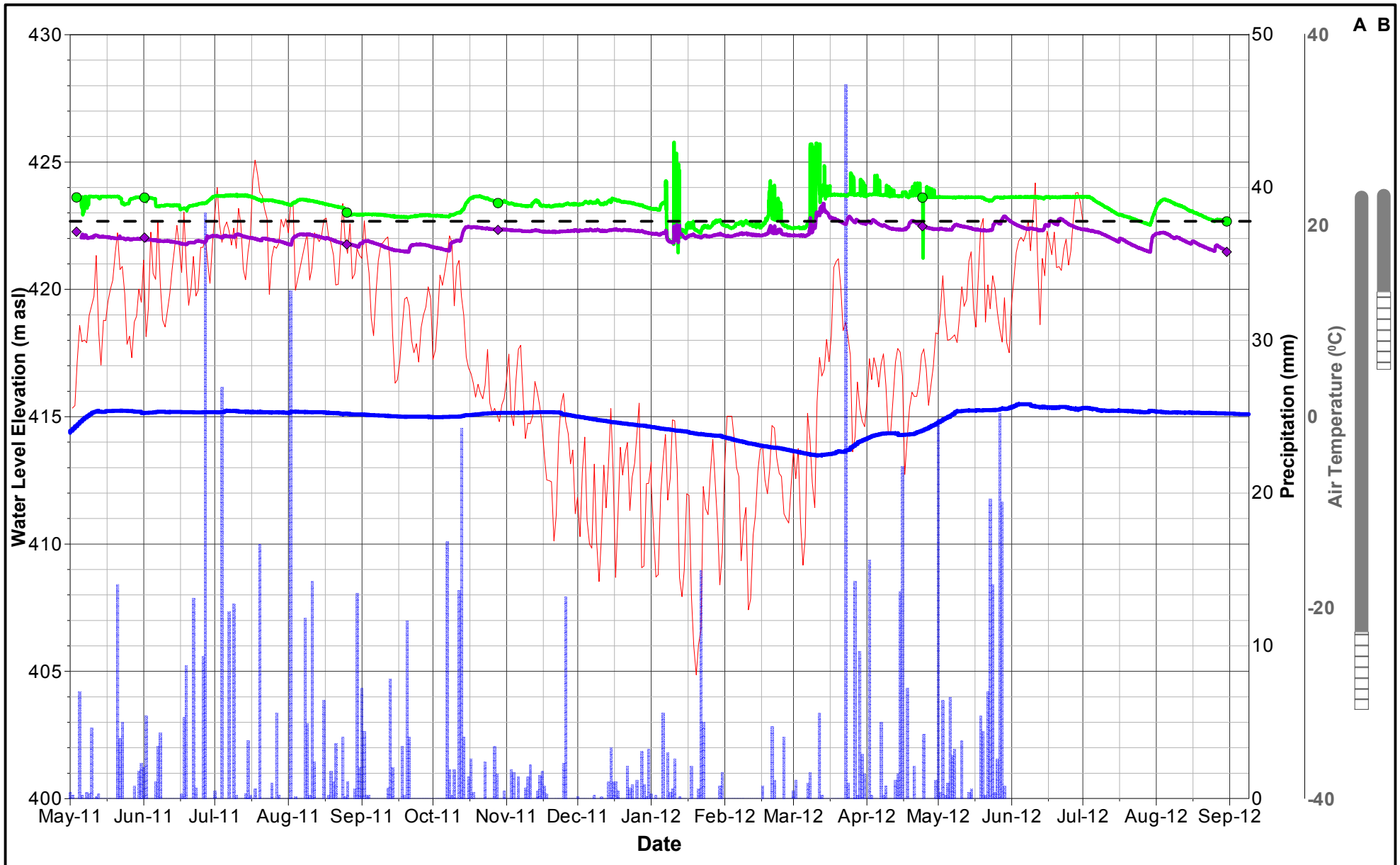
- BRH-0001A
- BRH-0001B
- Upper Marmion Reservoir
- Total Daily Precipitation
- Ground Surface/Bedrock Surface
- Average Daily Air Temperature

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0001

FIGURE: 3-1	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

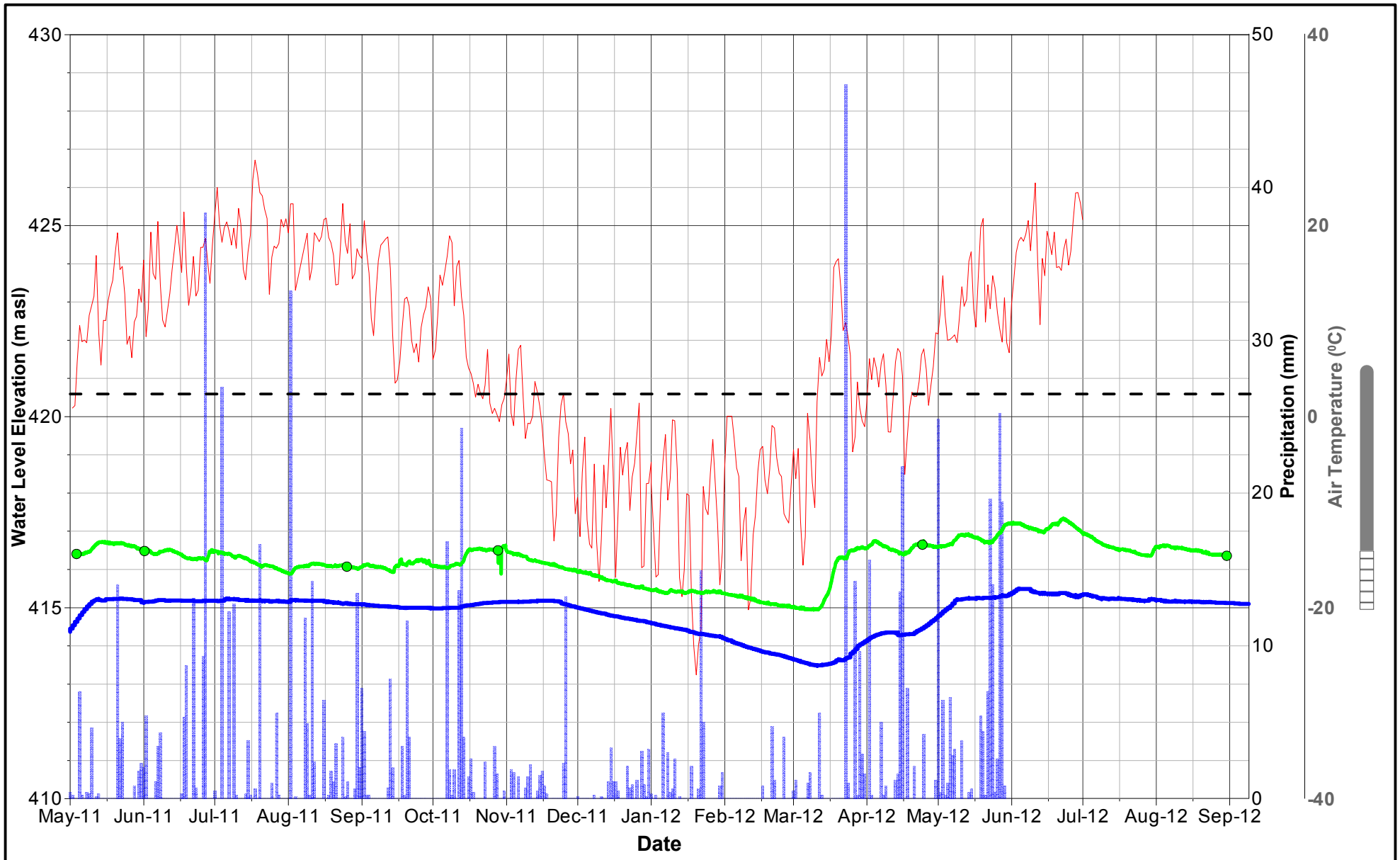
- BRH-0002A
- BRH-0002B
- Upper Marmion Reservoir
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface (No Overburden)

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0002

FIGURE: 3-2	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

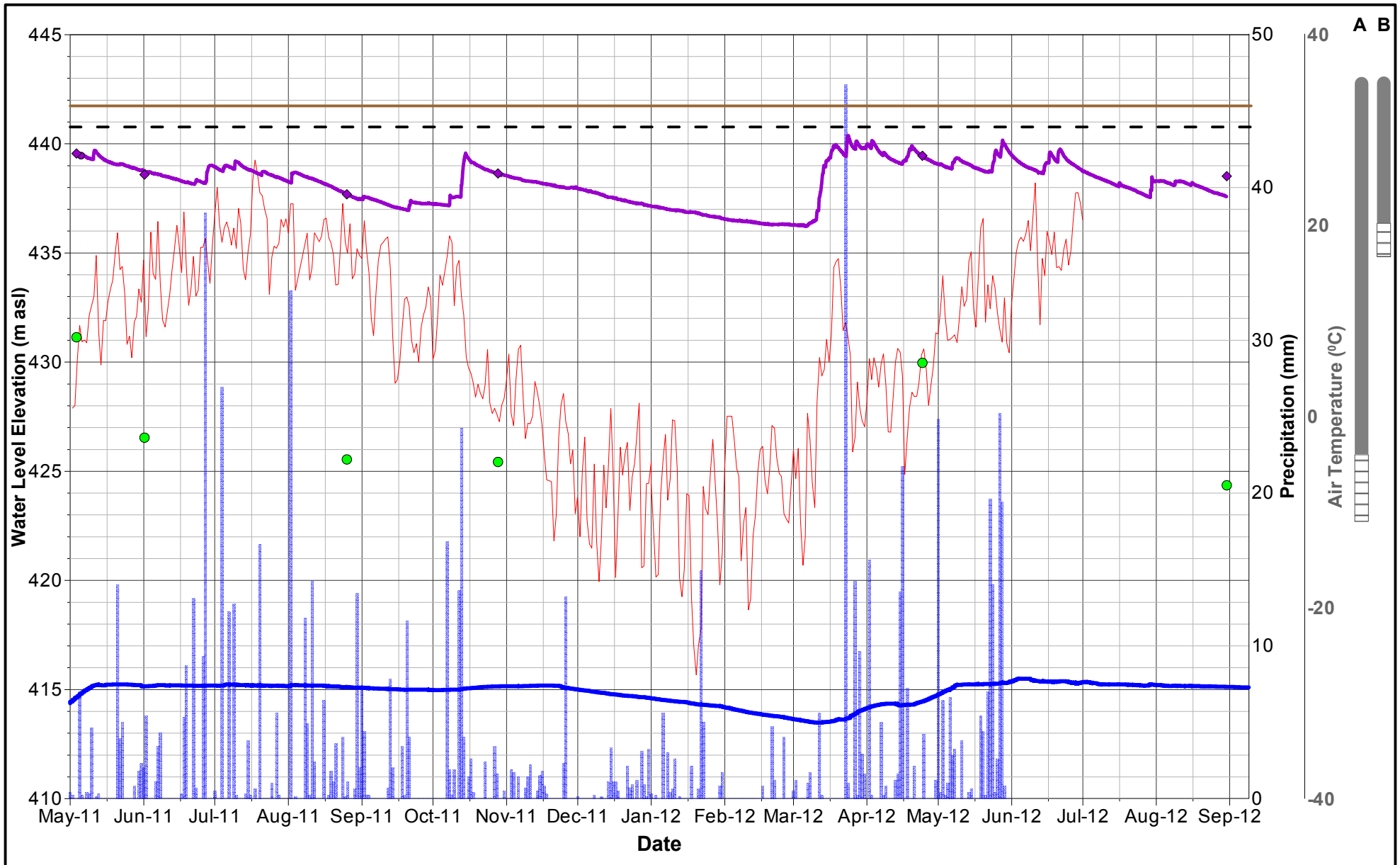
- BRH-0003
- Upper Marmion Reservoir
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface (no Overburden)

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0003

FIGURE: 3-3	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

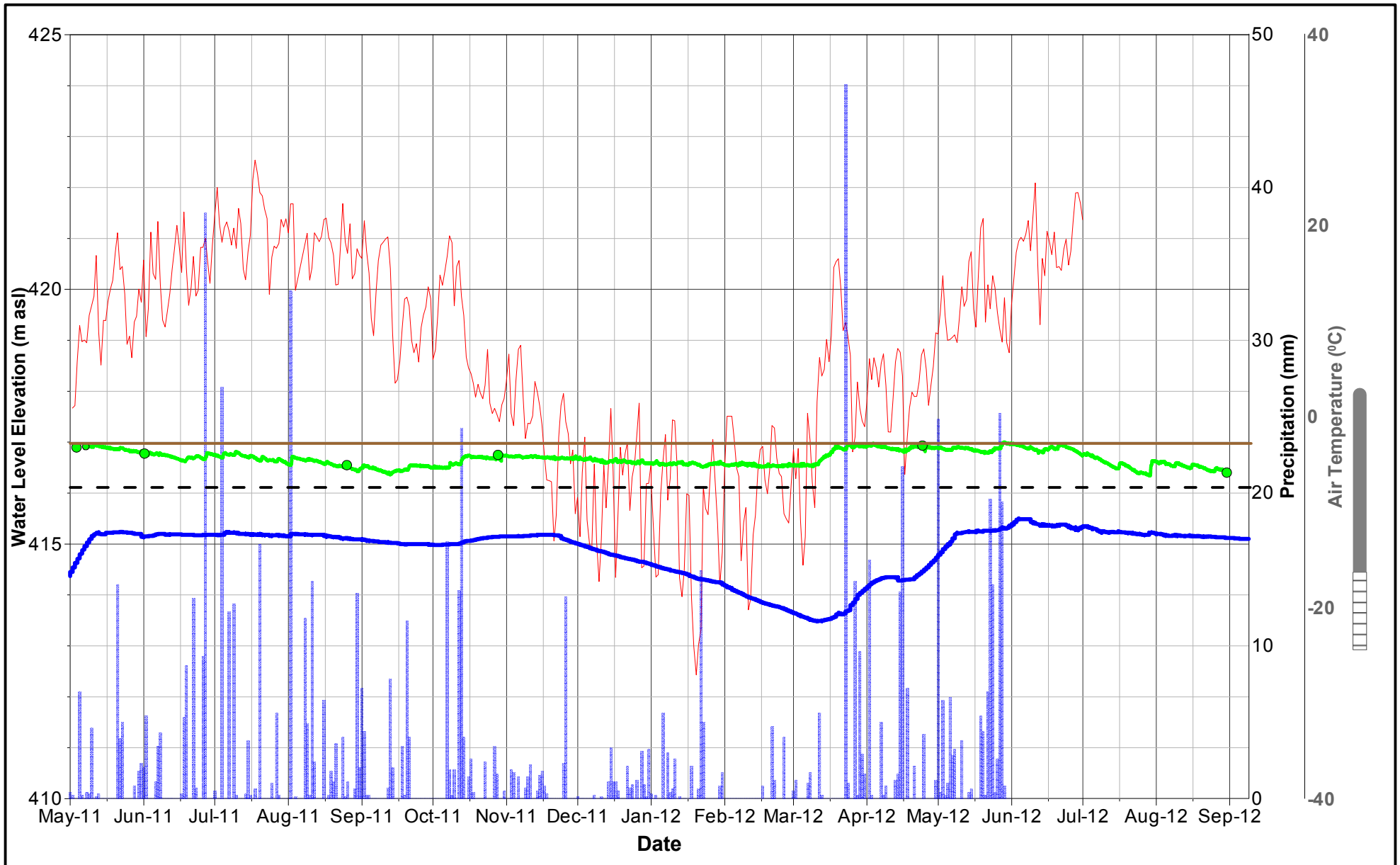
- BRH-0005A
- BRH-005B
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Averaga Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0005

FIGURE: 3-4	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

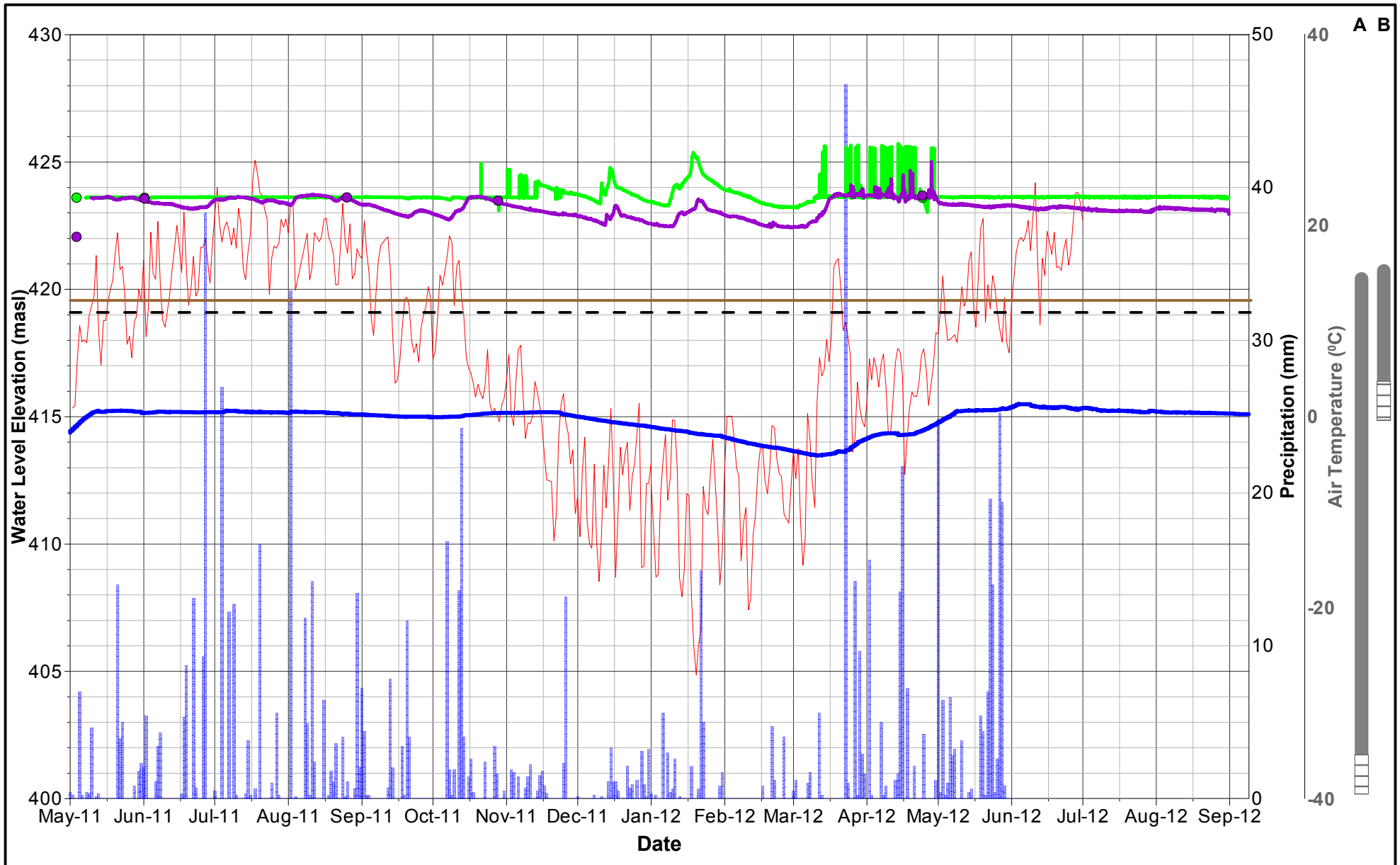
- BRH-0006
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0006

FIGURE: 3-5	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

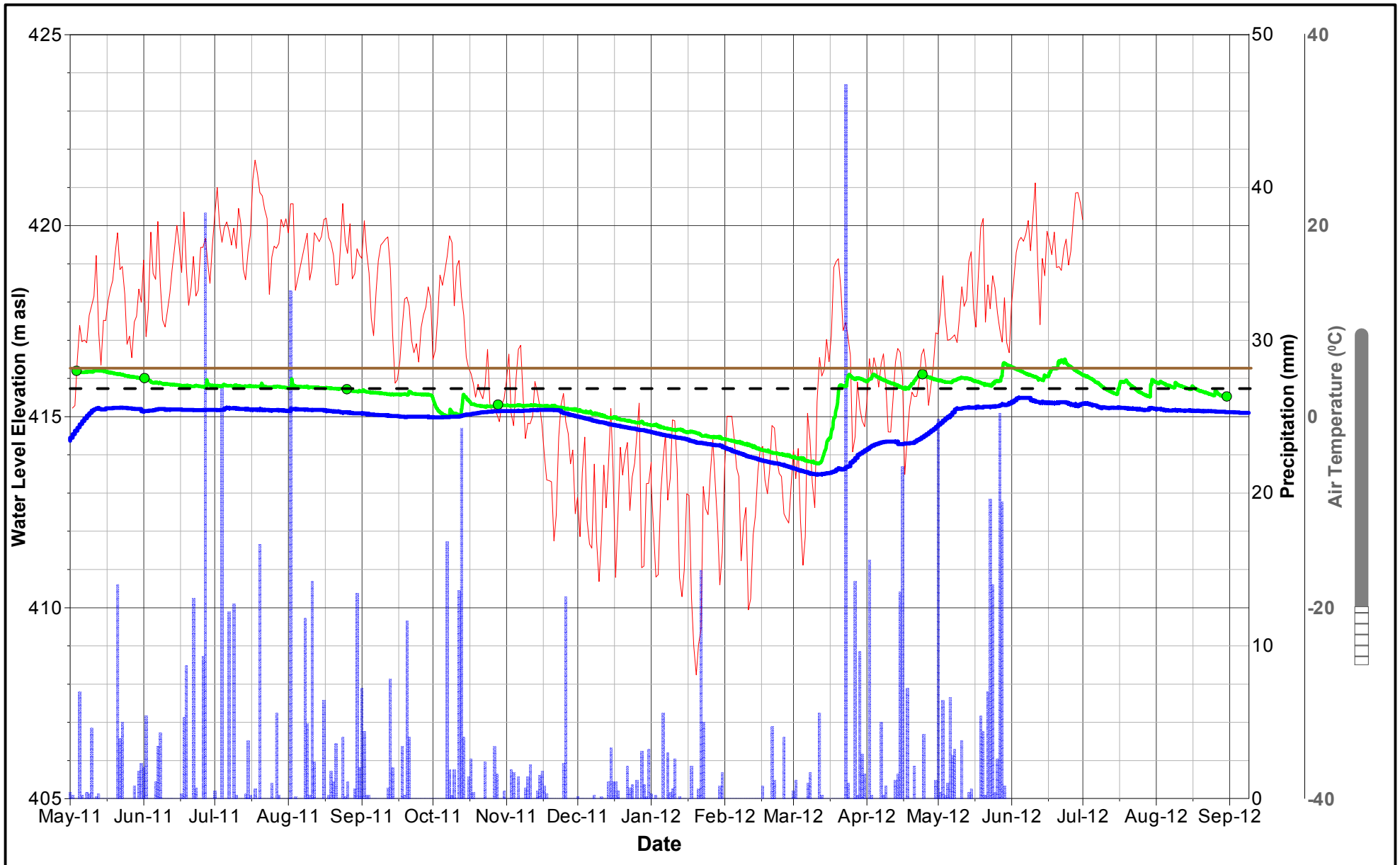
- BRH-008A
- BRH-008B
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Level at BRH-0008

FIGURE: 3-6	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: LB	REVIEW: MO



LEGEND

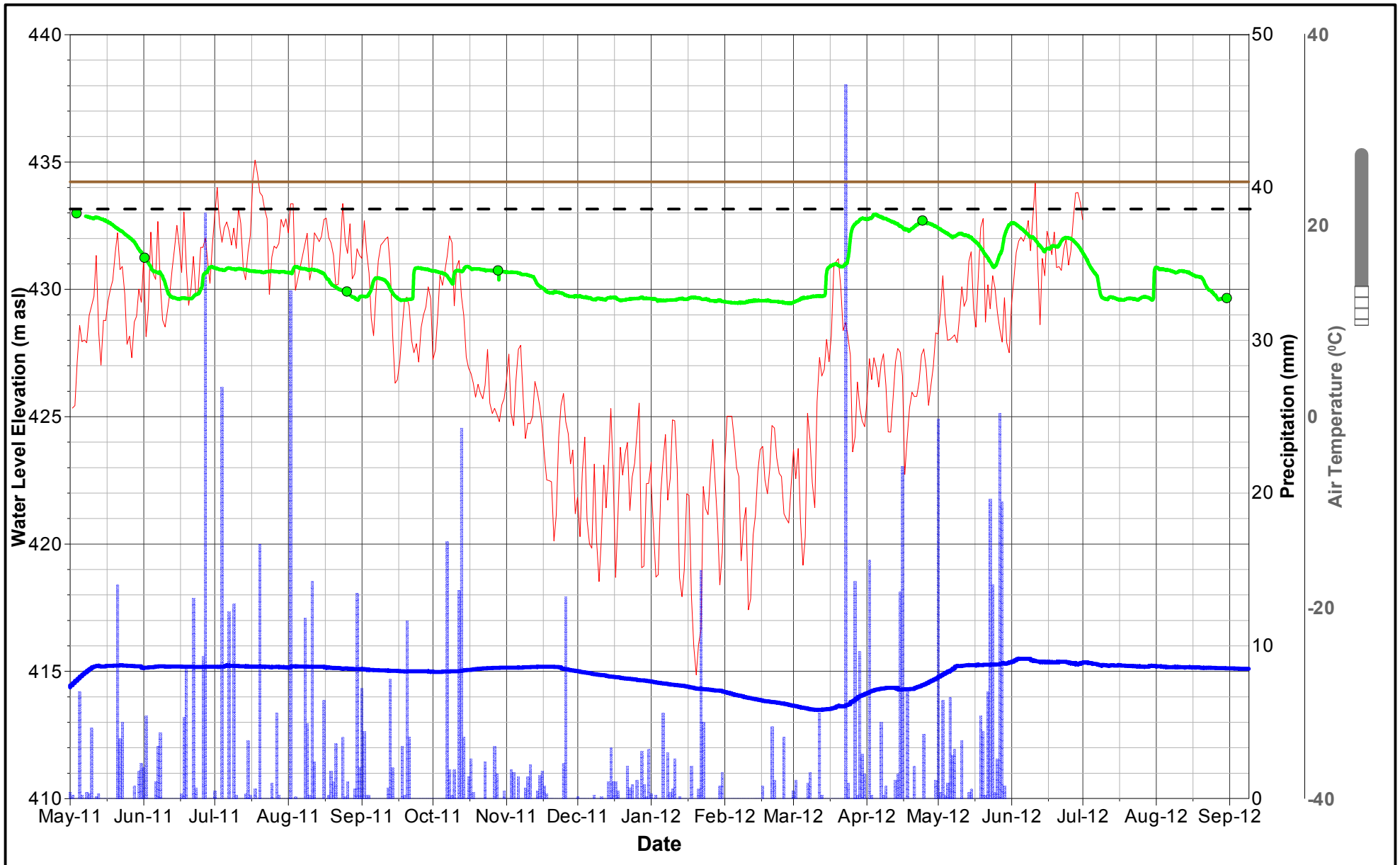
- BRH-0009
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater levels at BRH-0009

FIGURE: 3-7	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: LB	REVIEW: MO



LEGEND

- BRH-0011
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

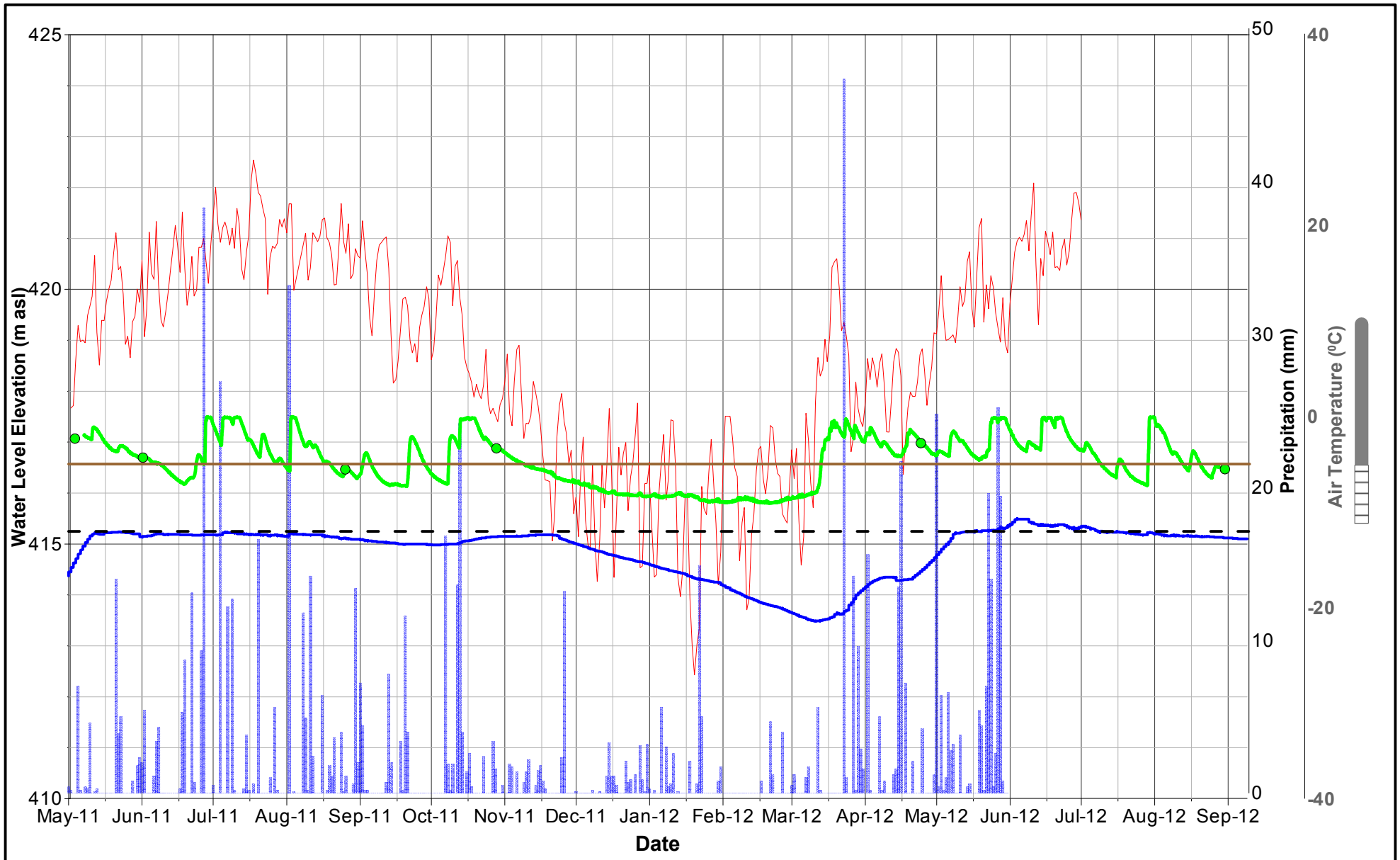
Groundwater Levels at BRH-0011

FIGURE: 3-8

DATE: SEPTEMBER 2012

PROJECT NO: 11-1118-0079

DRAWN: LB | REVIEW: MO



LEGEND

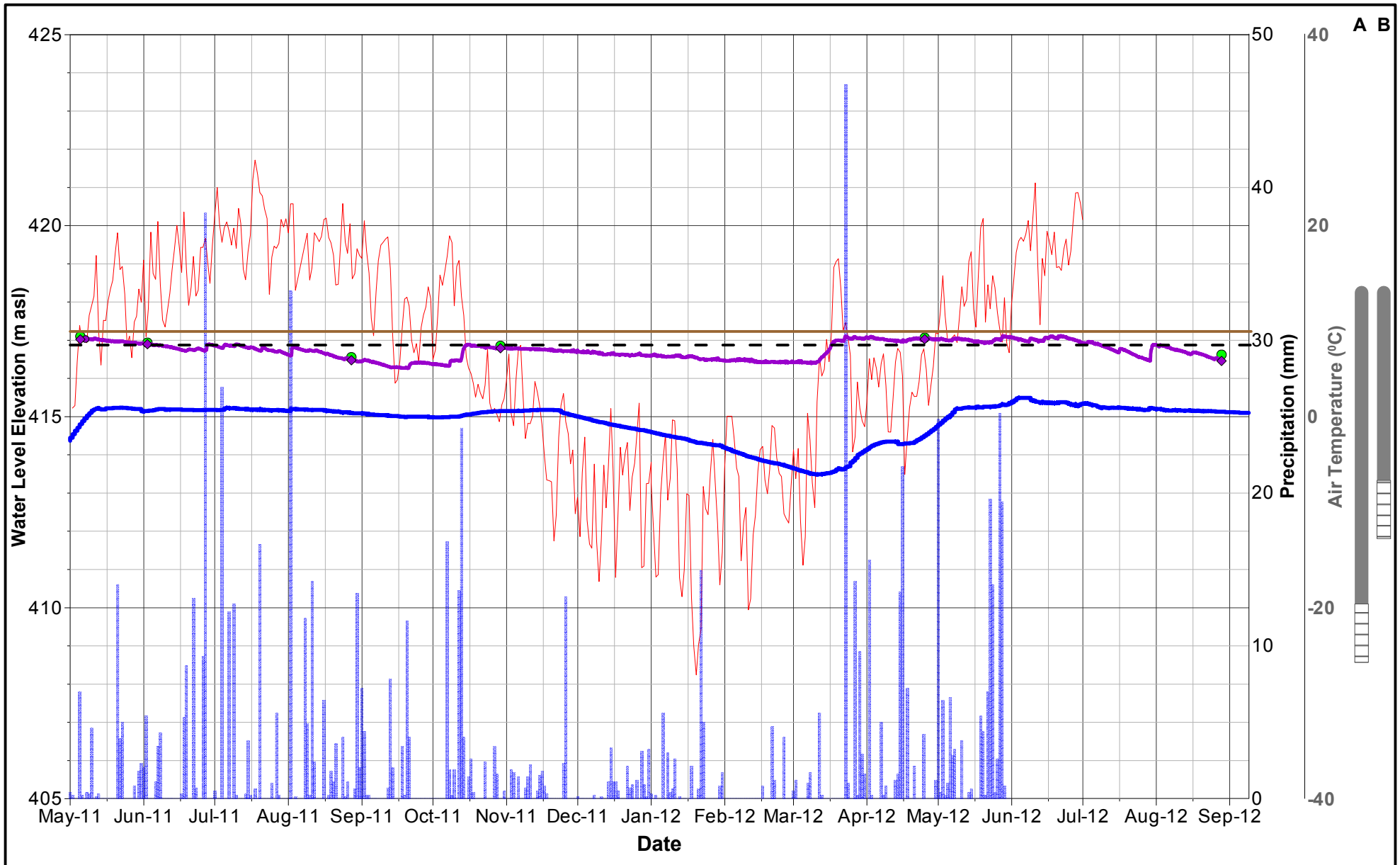
- BRH-00013
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Average Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0013

FIGURE: 3-9	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: LB	REVIEW: MO



LEGEND

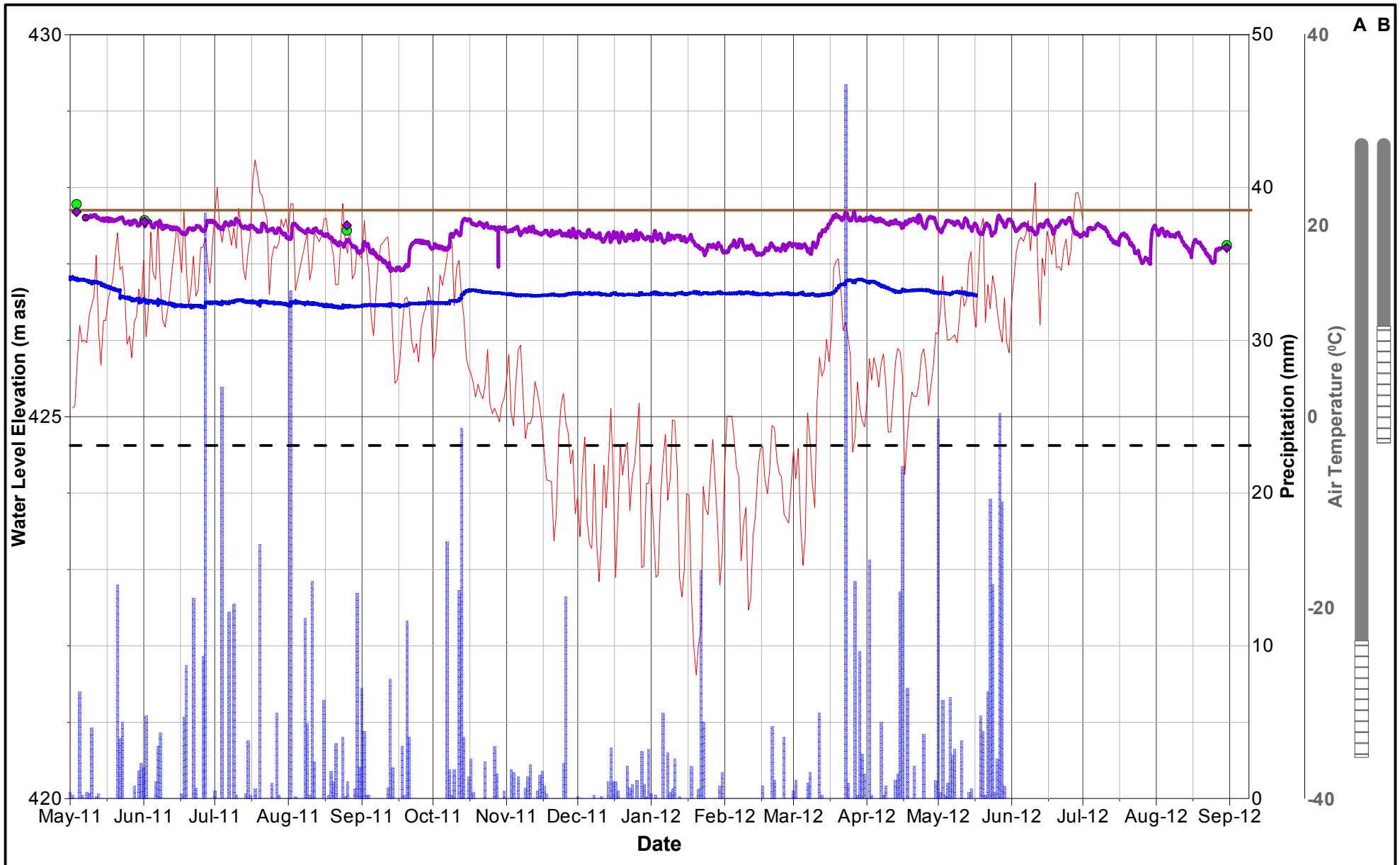
- BRH-0015A
- BRH-0015B
- Upper Marmion Reservoir
- Total Daily Precipitation
- Average Daily Air Temperature
- Ground Surface/Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0015

FIGURE: 3-10	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

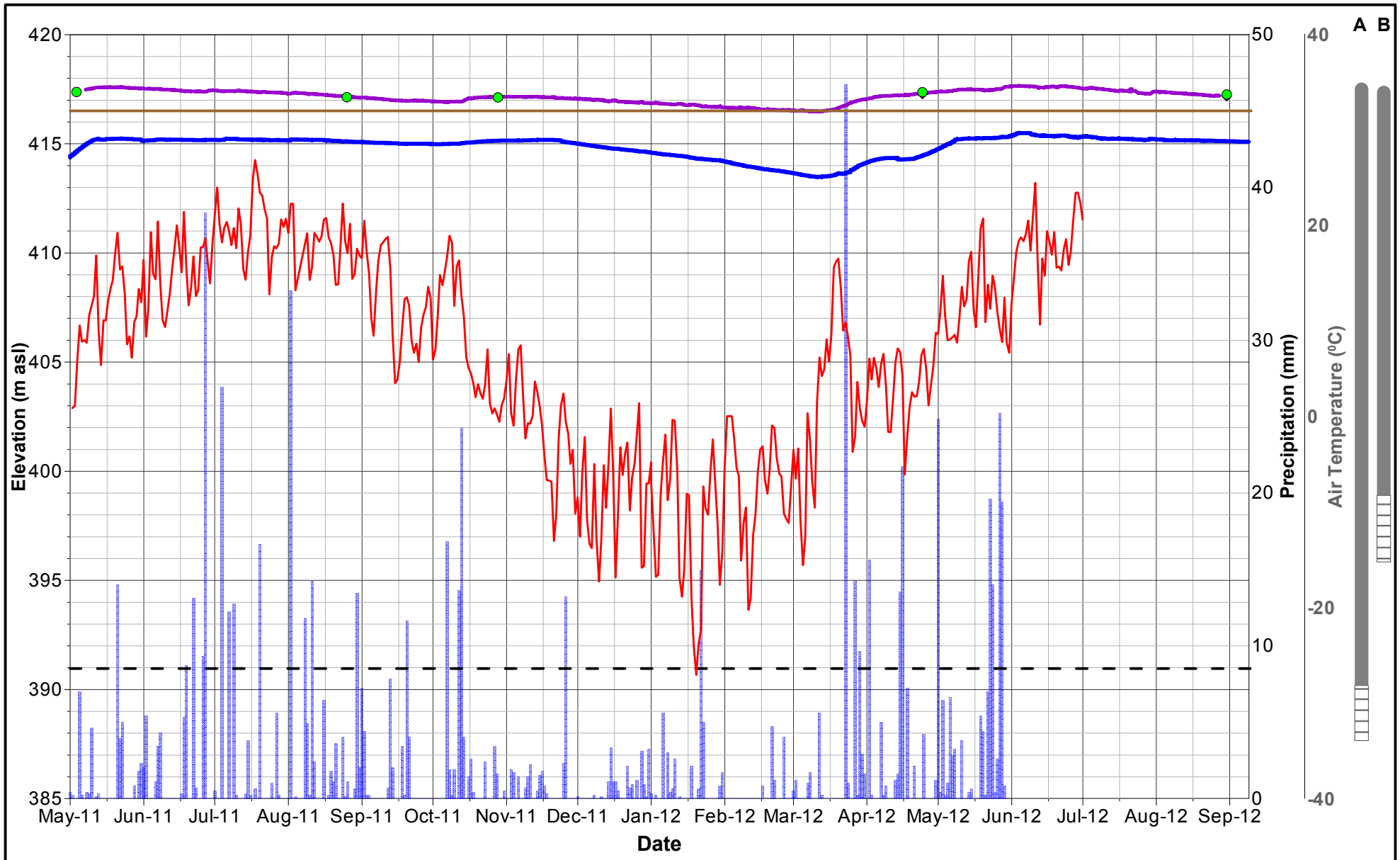
- BRH-0017A
- BRH-0017B
- Upper Marmion Reservoir
- Ground Surface
- Total Daily Precipitation
- Averaga Daily Air Temperature
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0017

FIGURE: 3-11	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO



LEGEND

- BRH-0020A
- BRH-0020B
- Upper Marmion Reservoir
- Average Daily Air Temperature
- Total Daily Precipitation
- Ground Surface
- Bedrock Surface

OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels at BRH-0020

FIGURE: 3-12	
DATE: SEPTEMBER 2012	
PROJECT NO: 10-1118-0020	
DRAWN: LB	REVIEW: MO

Groundwater levels observed at exploration boreholes in the vicinity of the west pit in October 2011 are summarized in Table 3-3. The borehole locations and corresponding groundwater elevations, along with inferred flow directions, are shown in Figure 7-10 of the Hydrogeology TSD. Continuous water level hydrographs for exploration boreholes instrumented with Schlumberger *Mini-Divers*™ are presented in Figure 3-13. The water level elevations and inferred groundwater flow directions observed at these exploration boreholes are displayed in Figure 7-10 in the Hydrogeology TSD.

Table 3-3: Groundwater Elevations Observed at Exploration Boreholes in West Pit Area

Borehole ID	Date	UTM Coordinates (NAD 83, Zone 15U)		Groundwater Elevation (masl)
		Easting	Northing	
BR-0090	19-Oct-11	612320	5421165	434.68
BR-0115	19-Oct-11	612715	5421403	434.07
BR-0246	19-Oct-11	612359	5421044	434.09
BR-0325	19-Oct-11	612895	5421681	437.16
BR-0390	19-Oct-11	612797	5421554	435.14
BR-0437	19-Oct-11	612529	5420863	427.49
BR-0442	19-Oct-11	612897	5421592	441.00
BR-1011	19-Oct-11	612507	5420734	420.99
BR-1012	19-Oct-11	612925	5421547	434.91
BR-1028A	19-Oct-11	612751	5421358	434.22
BR-1051	19-Oct-11	612591	5420965	426.70
BR-1063	19-Oct-11	612524	5420791	424.38
BR-1064	19-Oct-11	612347	5420696	427.64
BR-1073	19-Oct-11	612262	5420645	431.52
BR-1078	19-Oct-11	612402	5420611	426.57
BR-1093	19-Oct-11	612082	5421418	436.96
BR-1094	19-Oct-11	612482	5420670	421.39
BR-1095	19-Oct-11	612031	5421411	437.45
BR-1102	19-Oct-11	611873	5421414	429.14
BR-1112	19-Oct-11	611929	5421467	428.86
BR-1144	19-Oct-11	612603	5420851	423.13
BR-1150	19-Oct-11	612334	5420808	432.49
BR-1151	19-Oct-11	612548	5420923	426.94
BR-1153A	19-Oct-11	612379	5420828	432.78
BR-1159	19-Oct-11	612433	5421064	432.01
BR-1162	19-Oct-11	612019	5421530	438.32
BR-1163	19-Oct-11	611839	5421275	428.60
BR-1197A	19-Oct-11	611821	5421356	428.45

Table 3-3: Groundwater Elevations Observed at Exploration Boreholes in West Pit Area (Continued)

Borehole ID	Date	UTM Coordinates (NAD 83, Zone 15U)		Groundwater Elevation (masl)
		Easting	Northing	
BR-1207	19-Oct-11	611849	5421363	428.80
BR-1214	19-Oct-11	611931	5421375	436.14
BR-1229	19-Oct-11	611971	5421312	438.28
BR-1237	19-Oct-11	612017	5421336	438.56
BR-1249	19-Oct-11	611929	5421515	432.74
BR-1278	19-Oct-11	612153	5421455	432.83
BR-1280	19-Oct-11	612155	5421400	435.11
BR-1283	19-Oct-11	611775	5421432	432.38
BR-1290	19-Oct-11	611984	5421567	446.62
BR-6004	19-Oct-11	612747	5421364	434.16
BR-6021	19-Oct-11	612830	5421598	435.98
BR-6030	19-Oct-11	612252	5421706	439.76
BR-6037	19-Oct-11	612180	5421633	435.46
BR-6051	19-Oct-11	612612	5421704	434.77
BR-6057	19-Oct-11	612702	5421297	433.93
BR-6072	19-Oct-11	612657	5421265	433.18
BR-6103A	19-Oct-11	612869	5421494	436.41
BR-6106	19-Oct-11	612583	5421159	433.06
BR-6113	19-Oct-11	612555	5421110	434.31
BR-6126A	19-Oct-11	612717	5421233	434.44
BR-6129	19-Oct-11	612535	5421136	436.40
BR-6144	19-Oct-11	612950	5421723	432.12
BR-6190	19-Oct-11	612940	5421340	434.07
BR-6191	19-Oct-11	612784	5421263	433.88
BR-6192	19-Oct-11	612904	5421626	438.76
BR-6203	19-Oct-11	612611	5421705	432.74
BR-6210	19-Oct-11	612540	5421681	432.73
BR-6213	19-Oct-11	612857	5421378	433.99
BR-6217	19-Oct-11	612627	5421214	432.72
BR-6221	19-Oct-11	612408	5421604	437.52
BR-6223	19-Oct-11	612884	5421427	434.27
BR-6241	19-Oct-11	612310	5421754	441.88
BR-6267	19-Oct-11	612255	5421612	437.98

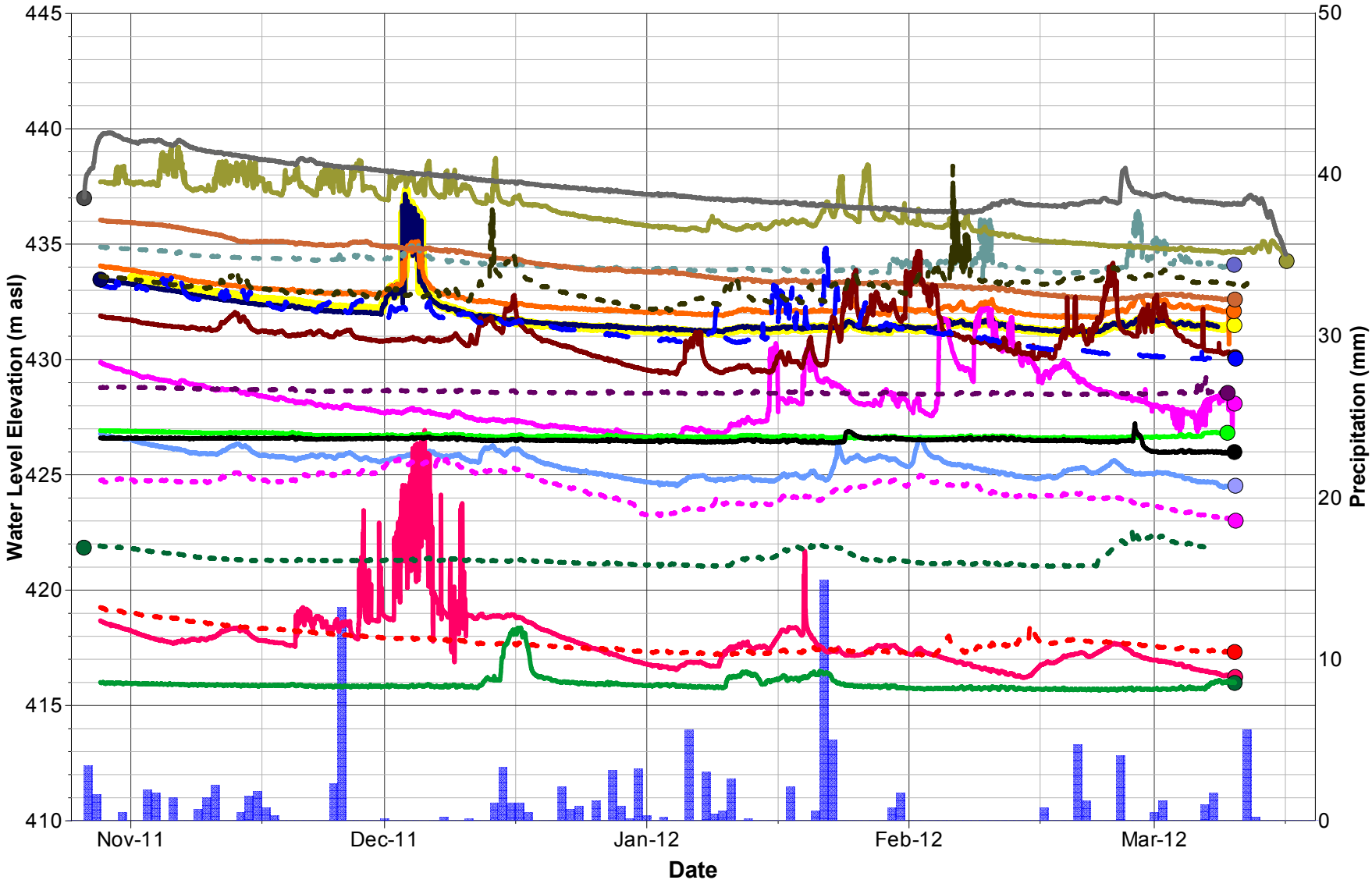
Table 3-3: Groundwater Elevations Observed at Exploration Boreholes in West Pit Area (Continued)

Borehole ID	Date	UTM Coordinates (NAD 83, Zone 15U)		Groundwater Elevation (masl)
		Easting	Northing	
BR-6270	19-Oct-11	612255	5421612	437.54
BR-0046	20-Oct-11	611696	5420961	419.09
BR-0058	20-Oct-11	612075	5421101	438.00
BR-0061	20-Oct-11	611862	5420985	425.25
BR-0081	20-Oct-11	612031	5420899	434.32
BR-0216	20-Oct-11	612085	5421005	434.67
BR-0220	20-Oct-11	612040	5420973	434.00
BR-0226	20-Oct-11	612062	5421037	434.32
BR-0231	20-Oct-11	612033	5421161	435.31
BR-0384	20-Oct-11	611751	5421332	428.43
BR-0401	20-Oct-11	611479	5421140	418.87
BR-0408	20-Oct-11	611536	5421043	416.54
BR-0413	20-Oct-11	611584	5421039	416.16
BR-1003	20-Oct-11	612167	5421015	434.88
BR-1042	20-Oct-11	611875	5421103	433.23
BR-1048	20-Oct-11	612066	5421080	434.56
BR-1056	20-Oct-11	612009	5421163	434.67
BR-1060	20-Oct-11	611967	5420960	431.26
BR-1061	20-Oct-11	612078	5421239	435.11
BR-1069	20-Oct-11	611963	5421281	433.93
BR-1070	20-Oct-11	612037	5420624	430.44
BR-1080	20-Oct-11	611954	5420567	420.89
BR-1109	20-Oct-11	612151	5420718	431.42
BR-1129	20-Oct-11	611743	5421261	429.57
BR-1135	20-Oct-11	611769	5420895	422.61
BR-1146	20-Oct-11	611752	5421192	425.05
BR-1154	20-Oct-11	612132	5420876	433.69
BR-1157	20-Oct-11	612088	5420654	430.55
BR-1161	20-Oct-11	612286	5420877	432.30
BR-1168A	20-Oct-11	612286	5420927	433.91
BR-1174	20-Oct-11	611590	5421268	426.93
BR-1187	20-Oct-11	611608	5421228	428.04
BR-1190	20-Oct-11	611882	5421269	430.10

Table 3-3: Groundwater Elevations Observed at Exploration Boreholes in West Pit Area (Continued)

Borehole ID	Date	UTM Coordinates (NAD 83, Zone 15U)		Groundwater Elevation (masl)
		Easting	Northing	
BR-1193	20-Oct-11	612257	5420970	434.20
BR-1194A	20-Oct-11	612003	5420672	434.49
BR-1198	20-Oct-11	611564	5421114	423.47
BR-1199	20-Oct-11	611546	5421192	431.85
BR-1216	20-Oct-11	611683	5421251	427.69
BR-1223	20-Oct-11	611973	5420901	426.61
BR-1227	20-Oct-11	611731	5421133	426.77
BR-1228	20-Oct-11	611782	5421246	429.04
BR-1238	20-Oct-11	612099	5420756	432.20
BR-1246	20-Oct-11	612036	5420725	433.64
BR-1261	20-Oct-11	611827	5420805	419.64
BR-1263	20-Oct-11	611779	5420925	424.36
BR-1267	20-Oct-11	611843	5420875	420.96
BR-1128A	24-Oct-11	611752	5421285	432.98
BR-1176	24-Oct-11	611864	5421204	426.34
BR-0073	25-Oct-11	611672	5421085	421.84
BR-1188	25-Oct-11	611639	5421091	416.88
BR-0092	26-Oct-11	612266	5421275	433.95
BR-0097	26-Oct-11	612195	5421298	434.64
BR-0169	26-Oct-11	613559	5422084	438.27
BR-0189	26-Oct-11	612693	5421627	428.07
BR-0433	26-Oct-11	611849	5420891	421.85
BR-1177	26-Oct-11	611824	5420729	419.98
BR-1225	26-Oct-11	611909	5420789	423.70
BR-1251A	26-Oct-11	611867	5420637	425.85
BR-1272	26-Oct-11	611804	5421023	423.37
BR-6224	26-Oct-11	612145	5421641	437.02
BR-0377	28-Oct-11	612651	5420690	419.55
BR-1050	28-Oct-11	611972	5421132	447.81
BR-1077	28-Oct-11	612595	5420727	419.53
BR-1083	28-Oct-11	612312	5420564	418.47
BR-1248	28-Oct-11	611675	5421175	429.47

Notes:
masl = Metres above mean sea level.



OSISKO HAMMOND REEF GOLD

Golder Associates

Groundwater Levels in Exploration Boreholes

FIGURE: 3-13	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: LB	REVIEW: MO

3.2 Vertical Hydraulic Gradients

At locations with nested monitoring wells, the water levels in adjacent wells were compared to assess vertical gradients. Table 3-4 summarizes the vertical hydraulic gradients observed at the nested well locations.

Table 3-4: Vertical Hydraulic Gradients at Nested Monitoring Well Locations

Project Component	Monitoring Location	March to May 2011		June 2011		August 2011		October 2011		April 2012		August 2012	
		Groundwater Elevation (masl)	Vertical Gradient (m)	Groundwater Elevation (masl)	Vertical Gradient (m)	Groundwater Elevation (masl)	Vertical Gradient (m)	Groundwater Elevation (masl)	Vertical Gradient (m)	Groundwater Elevation (masl)	Vertical Gradient (m)	Groundwater Elevation (masl)	Vertical Gradient (m)
Mine Area	BRH-0001	424.54	-3.93	420.55	-7.74	424.70	-2.92	425.74	-2.51	426.61	-1.86	427.23	-0.21
	BRH-0002	423.61	1.35	423.60	1.57	423.01	1.25	423.39	1.05	423.60	1.11	422.67	1.20
	BRH-0005	431.14	-9.37	426.54	-13.01	425.54	-13.10	425.43	-14.18	429.97	-10.45	424.36	-14.17
	BRH-0007	423.47	-1.08	421.53	-1.50	418.44	-3.17	418.51	-4.25	423.18	-1.47	418.35	-3.19
	BRH-0008	420.41	2.30	420.40	0.79	n/a[(a)]	n/a[(a)]	n/a[(a)]	n/a[(a)]	420.41	0.68	420.40	1.20
	BRH-0012	416.37	0.00	416.04	-0.02	415.85	-0.02	415.94	-0.02	416.14	-0.02	415.82	-0.01
	BRH-0014	417.25	-0.01	417.07	-0.01	416.76	-0.01	416.94	-0.01	417.21	-0.01	416.72	-0.00
	BRH-0015	417.10	0.08	416.94	0.04	416.56	0.08	416.86	0.06	417.07	0.03	416.62	0.16
	BRH-0016	443.60	-0.43	n/a[(b)]	n/a[(b)]	n/a[(b)]	n/a[(b)]	443.43	-0.22	443.61	-0.46	n/a[(b)]	n/a[(b)]
Tailings Management Facility Area	BRH-0017	427.78	0.10	427.57	0.02	n/a[(c)]	n/a[(c)]	427.44	-0.07	426.75	-0.88	427.25	0.03
	BRH-0020	n/a[(d)]	n/a[(d)]	n/a[(e)]	n/a[(e)]	417.13	0.00	417.13	-0.01	417.36	0.08	417.26	0.08
	BRH-0021	419.02	0.33	420.33	0.21	419.45	0.22	419.94	0.21	420.47	0.27	419.60	0.23
	BH12-3	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	n/a[(f)]	419.51	-0.02

Notes:

masl = Metres above mean sea level.

n/a[(a)] Unable to establish vertical gradient due to artesian conditions encountered in bedrock monitoring well (BRH-0008A).

n/a[(b)] Unable to establish vertical gradient due to dry well conditions encountered at overburden monitoring well (BRH-0016B).

n/a[(c)] Field crew unable to measure water levels due to inaccessible trail conditions.

n/a[(d)] Unable to establish vertical gradient due to artesian conditions encountered in overburden monitoring well (BRH-0020B).

n/a[(e)] Unable to establish vertical gradient due to artesian conditions encountered in overburden and bedrock monitoring wells (BRH-0020A/B).

n/a[(f)] Monitoring wells not installed until August 2012.

APPENDIX 2.VI

Hydraulic Conductivity

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) carried out two borehole drilling programs at the Hammond Reef Gold Project (Project) site in 2011 and 2012 for the purposes of collecting information about the subsurface material and to facilitate the installation of monitoring wells for hydrogeological monitoring. Upon completion of drilling, the hydraulic conductivity of the overburden and shallow bedrock were estimated by conducting in-situ single well response tests (slug tests) and analysis of grain size.

2.0 METHODS

During both drilling programs, boreholes were advanced using a track-mounted CME 55 drill rig equipped with standard 200 mm diameter hollow-stem augers and NQ diameter rock coring equipment. Boreholes were advanced by auger drilling and sampling with in-situ Standard Penetration Tests (SPTs) at continuous depth intervals of approximately 0.75 m to refusal followed by bedrock coring to target depths. SPTs and sampling were carried out using a hydraulic hammer and conventional 35 mm internal diameter split spoon sampling equipment. Monitoring wells installed during the 2011 drilling program were constructed using Schedule 40 PVC riser pipe and no. 10 machine slotted screen installed in 1.52 m sections. Each well typically had a screened interval of 1.52 m or 3.05 m in length. Further detail on drilling and well installation methods are provided in Appendix 2.III.

2.1 Soil Laboratory Testing

Grain size analysis was conducted (sieve and hydrometer) on select samples of overburden material collected from boreholes during drilling. Samples were selected to represent the various stratigraphic units encountered throughout the Local Study Area (LSA). Where the grain size was appropriate, the results of the grain size analysis were used to estimate the hydraulic conductivity of the material using the Hazen method.

2.2 Slug Tests

Slug tests were completed following drilling in order to estimate the hydraulic conductivity of the overburden and shallow bedrock (<30 m from top of bedrock surface) throughout the LSA.

Wells were developed prior to conducting slug tests. Physical testing involved measuring the static water level depth and then removing a known volume of water using dedicated Waterra™ tubing and foot valves. Recovering water levels were measured using Diver groundwater data loggers set to record time, pressure and temperature at a time interval selected based on the rate of recovery during well development. Water levels were measured manually to determine the end of the test and the data logger removed and downloaded.

Slug test data were analyzed using the Hvorslev method. This method is based on the formula for hydraulic conductivity (K) in a variable head scenario:

$$K = \frac{d^2 \times \ln\frac{2L}{D}}{8 \times L \times (t_2 - t_1)} \times \ln(H_2 - H_1)$$

Where:

d = well pipe diameter

L = screen length

D = Screen/filter pack diameter

t = time, seconds

H = head

2.3 Packer Testing

During the geotechnical field investigation carried out by Golder in 2010 to support of the Feasibility Pit Slope Design Study, a total of 213 packer tests were carried out in six angled geotechnical boreholes and two select exploration boreholes. In general, the packer test procedures involved falling head, rising head and/or constant head hydraulic conductivity testing to evaluate the hydraulic conductivity of the bedrock in the vicinity of the west pit at depths ranging from about 10 to 500 m from surface.

3.0 RESULTS

The hydraulic conductivity of the subsurface materials was estimated by conducting analysis of grain size, slug tests and packer tests.

Hydraulic conductivity estimates developed from grain size data using the Hazen method are provided in Table 1. A summary of hydraulic conductivity estimates developed from grain size data using the Hazen method and from slug tests is provided on Table 2. Table 2 presents the average hydraulic conductivity for shallow bedrock (<30 m depth) and coarse/fine grained overburden samples by taking the geometric mean of the values, which gives a normalized average given the different orders of magnitude of the values.

Grain size distribution curves for all overburden samples collected during drilling are presented in Appendix 2.III, Attachment 2.III.3. Borehole locations are shown on Figures 2-6 and 2-7 of the Hydrogeology TSD. Borehole stratigraphy and sample interval depths are provided on the Record of Borehole and Record of Drillhole logs in Appendix 2.III, Attachments 2.III.1 and 2.III.2.

Table 1: Hydraulic Conductivity Estimates of Overburden Samples – Hazen Method

Project Component	Borehole No.	Sample No.	Soil Classification	d_{10} (mm)	C (cm/mm^2s)	K (m/s)
Mine Area	BRH-0012	2	gravelly sand, some clay, trace silt	0.035	100	1.23×10^{-5}
	BRH-0013	1	gravelly sand, some clay, trace silt	0.071	100	5.04×10^{-5}
	BRH-0014	6	sand and gravel, some clay, trace silt	0.037	120	1.64×10^{-5}
	BRH-0016	2B	gravelly, silty sand, some clay	0.031	100	9.61×10^{-6}
	BH12-9	9	silty sand	0.03	80	7.20×10^{-6}
Tailings Management Facility Area	BRH-0017	3	sand, some silt, some clay, trace gravel	0.014	100	1.96×10^{-6}
	BRH-0018	1	clayey sand and silt	0.0105	60	6.62×10^{-7}
	BRH-0021	2	sandy, clayey silt	0.01	40	4.00×10^{-7}
	BRH-0023	2	sand and gravel, some clay, trace silt	0.056	100	3.14×10^{-5}
	BRH-0023	4	gravelly sand, some silt, trace clay	0.071	100	5.04×10^{-5}
	BRH-0026	2	sand and gravel, some silt, trace clay	0.03	100	9.00×10^{-6}
	BRH-0027	4	silty sand, some gravel, some clay	0.038	80	1.16×10^{-5}
	BH12-2	4	sandy silt	0.013	40	6.76×10^{-7}
	BH12-4	8	silty sand, trace gravel	0.025	80	5.00×10^{-6}
	BH12-5	4	silty sand	0.048	80	1.84×10^{-5}
	BH12-5	5B	silty sand	0.013	80	1.35×10^{-6}
	BH12-5	7	sand, trace gravel	0.15	100	2.25×10^{-4}
	BH12-5	8	gravelly, silty sand	0.037	80	1.10×10^{-5}

Table 2: Summary of Hydraulic Conductivity Estimates for Overburden and Shallow Bedrock

Project Component	Monitoring Well and Sample ID	Screened/Tested Material	Hydraulic Conductivity K (m/s)	Method of Analysis	
Mine Area	BRH-0001A	bedrock	7.1×10^{-10}	Hvorslev	Slug test
	BRH-0001B	bedrock	2.5×10^{-8}	Hvorslev	Slug test
	BRH-0002A	bedrock	6.8×10^{-5}	Hvorslev	Slug test
	BRH-0002B	bedrock	4.5×10^{-6}	Hvorslev	Slug test
	BRH-0003	bedrock	1.4×10^{-7}	Hvorslev	Slug test
	BRH-0004	bedrock	3.0×10^{-7}	Hvorslev	Slug test
	BRH-0005A	bedrock	1.4×10^{-8}	Hvorslev	Slug test
	BRH-0005B	bedrock	8.0×10^{-7}	Hvorslev	Slug test
	BRH-0006	bedrock	3.2×10^{-7}	Hvorslev	Slug test
	BRH-0008A	bedrock	1.8×10^{-8}	Hvorslev	Slug test
	BRH-0008B	bedrock	3.8×10^{-9}	Hvorslev	Slug test
	BRH-0007A	bedrock	1.9×10^{-6}	Hvorslev	Slug test
	BRH-0007B	bedrock	1.0×10^{-6}	Hvorslev	Slug test
	BRH-0009	bedrock	1.8×10^{-5}	Hvorslev	Slug test
	BRH-0011	bedrock	2.8×10^{-7}	Hvorslev	Slug test
	BRH-0012A	bedrock	3.0×10^{-5}	Hvorslev	Slug test
	BRH-0013	bedrock	2.1×10^{-7}	Hvorslev	Slug test
	BRH-0010	bedrock	6.1×10^{-7}	Hvorslev	Slug test
	BRH-0014A	bedrock	6.1×10^{-6}	Hvorslev	Slug test
	BRH-0015A	bedrock	2.7×10^{-7}	Hvorslev	Slug test
	BRH-0016A	bedrock	3.0×10^{-5}	Hvorslev	Slug test
	Minimum	bedrock	7.1×10^{-10}		
	Maximum	bedrock	6.8×10^{-5}		
	Geomean	bedrock	4.6×10^{-7}		
	BRH-0012 SA#2	gravelly sand, some clay, trace silt	1.2×10^{-5}	Hazen	Grain Size
	BRH-0012B	sand, trace to some gravel, trace silt	9.8×10^{-6}	Hvorslev	Slug test
	BRH-0013 SA#1	gravelly sand, some clay, trace silt	5.0×10^{-5}	Hazen	Grain Size

Table 2: Summary of Hydraulic Conductivity Estimates for Overburden and Shallow Bedrock (Continued)

Project Component	Monitoring Well and Sample ID	Screened/Tested Material	Hydraulic Conductivity K (m/s)	Method of Analysis	
	BRH-0014 SA#6	sand and gravel, some clay, trace silt	1.6×10^{-5}	Hazen	Grain Size
	BRH-0014B	silt, trace sand/silty sand, some gravel	5.9×10^{-7}	Hvorslev	Slug test
	BRH-0015B	silt and clay/sand, some gravel, trace silt	7.3×10^{-7}	Hvorslev	Slug test
	BRH-0016 SA#2B	gravelly, silty sand, some clay	9.6×10^{-6}	Hazen	Grain Size
	BH12-9 SA#9	silty sand	7.2×10^{-6}	Hazen	Grain Size
	Minimum	coarse grained [(a)] soil	9.8×10^{-6}		
	Maximum	coarse grained soil	5.0×10^{-5}		
	Geomean	coarse grained soil	1.8×10^{-5}		
	BRH-0016B	silty sand, trace org/sand, some gravel, trace silt	6.9×10^{-6}	Hvorslev	Slug test
	Minimum	fine grained [(b)] soil	6.9×10^{-6}		
	Maximum	fine grained soil	6.9×10^{-6}		
	Geomean	fine grained soil	6.9×10^{-6}		
Tailings Management Facility Area	BRH-0017A	bedrock	6.6×10^{-7}	Hvorslev	Slug test
	BRH-0018	bedrock	3.4×10^{-7}	Hvorslev	Slug test
	BRH-0021A	bedrock	8.3×10^{-5}	Hvorslev	Slug test
	BRH-0022	bedrock	1.5×10^{-6}	Hvorslev	Slug test
	BRH-0026	bedrock	1.7×10^{-6}	Hvorslev	Slug test
	Minimum	bedrock	3.4×10^{-7}		
	Maximum	bedrock	8.3×10^{-5}		
	Geomean	bedrock	2.2×10^{-6}		
	BRH-0017 SA#3	sand, some silt, some clay, trace gravel	2.0×10^{-6}	Hazen	Grain Size
	BRH-0019	silt, little to some clay, trace sand/sand, trace silt	5.8×10^{-6}	Hvorslev	Slug test
	BRH-0023	sand, gravel and boulders	6.6×10^{-6}	Hvorslev	Slug test
	BRH-0023 SA#2	sand and gravel, some clay, trace silt	3.1×10^{-5}	Hazen	Grain Size
	BRH-0023 SA#4	gravelly sand, some silt, trace clay	5.0×10^{-5}	Hazen	Grain Size
	BRH-0026 SA#2	sand and gravel, some silt, trace clay	9.0×10^{-6}	Hazen	Grain Size
	BRH-0027 SA#4	silty sand, some gravel, some clay	1.2×10^{-5}	Hazen	Grain Size

Table 2: Summary of Hydraulic Conductivity Estimates for Overburden and Shallow Bedrock (Continued)

Project Component	Monitoring Well and Sample ID	Screened/Tested Material	Hydraulic Conductivity K (m/s)	Method of Analysis	
	BH12-4	silty sand, trace gravel	2.0×10^{-7}	Hvorslev	Slug test
	BH12-4 SA#8	silty sand, trace gravel	5.0×10^{-6}	Hazen	Grain Size
	BH12-5 SA#4	silty sand	1.8×10^{-5}	Hazen	Grain Size
	BH12-5 SA#5B	silty sand	1.4×10^{-6}	Hazen	Grain Size
	BH12-5 SA#7	sand, trace gravel	2.3×10^{-4}	Hazen	Grain Size
	BH12-5 SA#8	gravelly, silty sand	1.1×10^{-5}	Hazen	Grain Size
	Minimum	coarse grained soil	2.0×10^{-7}		
	Maximum	coarse grained soil	5.0×10^{-5}		
	Geomean	coarse grained soil	6.3×10^{-6}		
	BRH-0018 SA#1	clayey sand and silt	6.6×10^{-7}	Hazen	Grain Size
	BRH-0021 SA#2	sandy, clayey silt	4.0×10^{-7}	Hazen	Grain Size
	BH12-3B	silt, trace fine sand	3.3×10^{-7}	Hvorslev	Slug test
	BH12-2 SA#4	sandy silt	6.8×10^{-7}	Hazen	Grain Size
	Minimum	fine grained soil	3.3×10^{-7}		
	Maximum	fine grained soil	6.6×10^{-7}		
	Geomean	fine grained soil	4.4×10^{-7}		

Notes:

(a) Coarse Grained refers to soil material with less than 50% material less than 75 micrometres in diameter.

(b) Fine Grained refers to soil material with more than 50% material less than 75 micrometres in diameter.

The results indicate that the hydraulic conductivity of the overburden throughout the LSA is variable. In the Mine Area, there were not many borehole locations with overburden present. Where present, the overburden was general coarse grained (less than 50% material less than 75 micrometres in diameter) with a hydraulic conductivity of approximately 2×10^{-5} m/s.

In the TMF Area, overburden was more commonly encountered at borehole locations. The material was generally coarse grained with some fine grained (more than 50% material less than 75 micrometres in diameter) deposits overlying the coarser material in the vicinity of the bedrock trough at the northeast end of Marmion Reservoir. Hydraulic conductivity of the overburden ranges from about 3×10^{-7} to 5×10^{-5} in the TMF Area.

The hydraulic conductivity of shallow bedrock in the Mine and TMF Areas averages about 5×10^{-7} to 2×10^{-6} m/s.

The packer testing results from the 2010 geotechnical investigation are provided in Appendix 2.I.

APPENDIX 2.VII

Short Term Pumping Tests

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

From October 20 to 28, 2011, a series of short-term step drawdown pumping tests were carried out in 46 existing angled NQ-size exploration boreholes to estimate the specific capacity of the bedrock at each location to obtain a general understanding of the hydraulic properties of the permeable structural features in the bedrock mass and identify potential zones of higher permeability throughout the proposed open pits area. This program focused primarily on testing exploration boreholes that intersect the Upper and/or Lower Shear Zones although a number of holes that do not intersect either Shear Zone were also tested for comparison purposes.

The short-term step drawdown pumping tests carried out in October 2011, indicated a generally low permeability rock mass consistent with what would be expected for a sparsely fractured granitic plutonic environment. The quartz stockwork overprints all phases of the Hammond Reef deposit appears to be entirely filled and non-transmissive from a hydrogeological perspective. Experience from other areas in the Canadian Shield has shown that active groundwater flow in granitic bedrock is typically confined to shallow brittle fracture systems, and is dependent on the secondary permeability associated with the fracture networks. Hydraulic conductivity tends to decrease with depth as fractures become less common and less interconnected (Stevenson et al. 1996; McMurry et al. 2003) although geotechnical testing (Golder 2012) identified transmissive fractures (7×10^{-6} m/s) at a depth of 290 m in geotechnical borehole GT-03 and between 170 and 180 m depth (7×10^{-6} m/s) in GT-04.

An exception to the generally low specific capacities observed in most exploration boreholes was BR-0433 – a 405 m-long exploration borehole dipping approximately 60 degrees to the west and located along the south boundary of the west pit bordering the Marmion Reservoir. Borehole BR-0433 intersects the lower shear zone at a depth of 250 m (along hole depth). At this location, apparent specific capacity of 40 L/min/m was markedly higher than that measured at any of the other tested locations.

Hydraulic testing of BR-0433 was carried out in March 2012 to compare the degree of contribution to the observed yield from the shallow fracture network in comparison to the deeper structures. Testing involved passive thermal profiling, heat pulse flow profiling, and constant rate withdrawal testing using an inflatable borehole packer to isolate the portion of the borehole.

2.0 METHODS

2.1 Short-Term Pumping Tests

Short-term step drawdown pumping tests were carried out in 46 existing angled NQ-size exploration boreholes using two inch diameter Grundfos RediFlo-2™ submersible pumps powered with gas generators. The boreholes tested were selected to provide coverage of the area primarily at the southwest end of the west pit where the major structure, the Mitta Lake fault and associated splays and Shear Zones, extends beneath the adjacent Marmion Reservoir. Tested borehole locations are shown on Figure 2-18 in the Hydrogeology Technical Support Document (TSD).

Due to the rugged terrain and limited road network at the site, the pumping equipment was hauled around the site in trailers towed behind all-terrain vehicles (ATVs). Figure 1 shows the field equipment used for the short-term pumping tests and provides an example of a typical groundwater drawdown plot for the step drawdown pumping tests.

Schlumberger Mini-Diver™ data logging pressure transducers connected to direct read cables were attached to the water hose just above the pump and the cables were extended to surface to allow for real-time monitoring of water levels in the borehole at surface during pumping. The pumps were lowered into the boreholes to a depth of approximately 15 m below the water table and the water level was allowed to stabilize prior to pumping. Pumping was generally carried out in one or two steps with pumping rates being increased during successive steps. Pumping rates during the first step ranged from 2 L/min to 11 L/min and pumping rates during the second step ranged from 8 L/min to 16 L/min. The final step of each test was typically carried out at the maximum achievable pumping rate. The flow rate and borehole water level were monitored routinely throughout each test. Pumping steps were carried out until the water level in the borehole began to stabilize, then pumping rates were either increased or pumping was stopped. Upon completion of pumping, the water level was allowed to partially recover prior to removal of the pump in order to obtain estimates of recovery rates for each borehole. Figure 1 shows a typical drawdown plot for the specific capacity tests carried out during this investigation.

It should be noted that the pumping rates achieved with the Grundfos RediFlo-2™ submersible pumps averaged 9.4 L/min and did not exceed 16 L/min (even at full power in shallow groundwater conditions). Pumping rates were dependent on depth to the water table from surface and the maximum achievable flow rates generally decreased with increasing depth to water. As a result, the pumping rates were generally inconsistent for the duration each test, typically decreasing throughout each test as water levels decreased.

2.2 Additional Hydraulic Testing of BR-0433

Hydraulic testing of BR-0433 was carried out in March 2012 to compare the degree of contribution to the observed yield from the shallow fracture network in comparison to the deeper structures. Testing involved passive thermal profiling, heat pulse flow profiling, and constant rate withdrawal testing using an inflatable borehole packer to isolate the upper portion of the borehole.

Passive thermal profiling of the upper 80 m water column was carried using a Schlumberger Mini-Diver™ data logging pressure transducer with an accuracy of 0.1°C and a resolution of 0.01°C. The pressure transducer was

suspended from a steel braided wire rope and lowered through the water column at 10 m depth increments pausing for approximately five minutes at each increment. The pressure transducer was set to log the temperature of the water every five seconds for the duration of each profile. Three passive thermal profiles of the water column in BR-0433 were completed in March. The first profile was carried out prior to initiating the 94-hour pumping test at BR-0220 (see Appendix 2.VIII), the second profile was carried out during the 94-hour pumping test at BR-0220, and the third profile was carried out following completion of the 94-hour pumping test at BR-0220.

The heat pulse flow profiling was carried out on March 15, 2012, using a 500 Watt resistance heater and a series of Schlumberger Mini-Diver™ data logging pressure transducers attached to the power supply cable at distances of two metres and five metres from the heat source. The heater was suspended from an insulated power supply cable and lowered into the borehole manually from surface. Electricity was supplied to the heater from surface using a gas generator. A two-inch submersible purge pump (100-Watt Proactive Typhoon™) was used to initiate steady upward flow in the borehole (BR-0433) during the thermal pulse testing. The outflow from the pump was routed through a graduated bucket to allow for accurate measurements of flow rate.

To evaluate the degree of contribution to the observed yield from the shallow fracture network in comparison to the deeper bedrock, the heat pulse flow profiling was carried out at four depth intervals: 8 m, 25 m, 50 m and 60 m (the maximum depth range for the equipment). At each depth interval, the heater was turned on for approximately 30 seconds and then turned off to create a slug of heated water. The data loggers suspended above the heater were set log the water temperature at one second intervals and, thus, logged the change in temperature as the slug of heated water flowed upward past the two data loggers. The total time required for the slug of heated water to travel three metres from the lower data logger to the upper data logger was converted into an approximate flow rate, which allowed for a comparison of flow rates at each depth interval under constant rate pumping conditions.

Constant rate withdrawal testing was carried out in borehole BR-0433 using a two-inch submersible purge pump (100-Watt Proactive Typhoon™) and an inflatable borehole packer to isolate the upper portion (95 m) of the borehole. A single NQ-diameter inflatable borehole packer was manually lowered to a depth of approximately 95 m below ground surface. A Schlumberger Mini-Diver™ data logging pressure transducer was set to log water level measurements at two second intervals. The pump was lowered into the borehole to a depth of approximately three metres below the upper water level and pumping was initiated at a flow rate of approximately 12.5 L/min (the maximum achievable flow rate). Pumping was carried out for approximately ten minutes until the water level in the borehole began to stabilize. The packer was inflated to seal off the lower portion of the borehole and the test was repeated, pumping at a constant rate of approximately 12 L/min and logging water level drawdown for approximately ten minutes.

It should be noted that flowing artesian conditions were observed at BR-0433 at the time of testing.

Figure 1: Pumping Equipment and Typical Drawdown Plot for Specific Capacity Testing

3.0 RESULTS

3.1 Short-Term Pumping Tests

Table 1 provides a summary of the step drawdown test results and the observed specific capacities. Figures 2 to 47 present the time-drawdown plots for the 46 short-term step drawdown pumping tests. Figure 2-18 in the Hydrogeology TSD shows the location of the tested boreholes and relative specific capacities observed at each location. Figure 2-16 in the Hydrogeology TSD presents a histogram of the distribution of specific capacity estimates in relation to shear zone interceptions.

Table 1: Specific Capacity Estimates from Short-Term Pumping Tests

Borehole ID	UTM (NAD 83 Zone 15U)		Top of Casing Elevation (masl)	Depth (m)	Dip	Azimuth	Intersecting Shear Zone(s)	Upper Shear Intersection Depth (m)	Lower Shear Intersection Depth (m)	Number of Pumping Steps	Pumping Rate During Final Step (L/min)	Pumping Rate During Final Step (L/sec)	Total Pumping Time (min)	Total Pumping Time (sec)	Total Drawdown (m)	Specific Capacity (L/min/m)
	Easting	Northing														
BR-0061	611862	5420985	451.8	351.0	-65.0	333.0	None	n/a[(a)]	n/a[(a)]	1	5.5	0.092	33.33	2000	11.0	0.5
BR-0073	611672	5421085	427.9	216.0	-50.0	327.0	Lower	n/a[(a)]	n/a[(a)]	2	11.0	0.183	40.00	2400	5.5	2.0
BR-0081	612031	5420899	437.9	387.0	-60.0	327.0	Lower	n/a[(a)]	n/a[(a)]	2	6.0	0.100	38.33	2300	1.0	6.0
BR-0155	612248	5421158	438.2	329.0	-53.0	328.0	Upper/Lower	n/a[(a)]	n/a[(a)]	1	7.5	0.125	8.33	500	6.0	1.3
BR-0216	612085	5421005	435.3	338.0	-67.0	327.4	Lower	n/a[(a)]	n/a[(a)]	1	15.0	0.250	35.00	2100	1.9	7.9
BR-0246	612359	5421044	435.2	338.0	-76.3	320.0	None	n/a[(a)]	n/a[(a)]	1	6.5	0.108	2.50	150	20.0	0.3
BR-0272	612305	5420680	434.6	437.0	-80.0	333.4	Lower	n/a[(a)]	n/a[(a)]	2	14.0	0.233	41.67	2500	1.4	10.0
BR-0325	612895	5421681	446.1	269.0	-51.0	332.5	None	n/a[(a)]	n/a[(a)]	1	7.9	0.132	8.33	500	17.0	0.5
BR-0390	612797	5421554	445.4	368.0	-75.0	323.0	None	n/a[(a)]	n/a[(a)]	1	6.0	0.100	23.33	1400	10.0	0.6
BR-0413	611584	5421039	426.8	291.0	-79.0	324.7	Lower	n/a[(a)]	n/a[(a)]	2	12.0	0.200	43.33	2600	6.8	1.8
BR-0433	611849	5420891	424.1	405.0	-59.2	330.0	Lower	n/a[(a)]	n/a[(a)]	2	16.0	0.267	45.00	2700	0.4	40.0
BR-0437	612529	5420863	448.7	753.0	-82.0	333.0	Lower	n/a[(a)]	446.7	1	10.0	0.167	8.33	500	15.0	0.7
BR-1011	612507	5420734	442.5	567.1	-81.0	328.3	Upper/Lower	256.2	241.8	2	13.0	0.217	45.00	2700	4.5	2.9
BR-1042	611875	5421103	455.8	450.4	-70.0	325.8	None	n/a[(a)]	n/a[(a)]	1	8.0	0.133	50.00	3000	4.5	1.8
BR-1051	612591	5420965	440.5	576.0	-80.3	319.7	Upper	n/a[(a)]	n/a[(a)]	1	5.0	0.083	33.33	2000	7.5	0.7
BR-1054	612443	5420915	436.9	480.0	-78.0	329.2	None	n/a[(a)]	n/a[(a)]	2	15.0	0.250	24.17	1450	2.0	7.5
BR-1056	612009	5421163	448.1	387.0	-74.0	323.5	Upper/Lower	n/a[(a)]	n/a[(a)]	3	13.0	0.217	26.67	1600	3.5	3.7
BR-1061	612078	5421239	443.2	279.0	-82.0	321.8	None	n/a[(a)]	n/a[(a)]	3	12.0	0.200	40.00	2400	1.8	6.7
BR-1064	612347	5420696	435.8	483.0	-68.0	327.0	None	n/a[(a)]	n/a[(a)]	1	15.0	0.250	19.2	1150	2.7	5.6
BR-1070	612037	5420624	431.9	612.5	-60.0	328.8	Upper/Lower	384	394.8	2	15.0	0.250	35.0	2100	8.0	1.9
BR-1080	611954	5420567	425.9	594.0	-79.5	325.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	1	7.5	0.125	16.7	1000	12.0	0.6
BR-1095	612031	5421411	445.5	159.0	-56.6	324.3	Lower	n/a[(a)]	n/a[(a)]	2	12.0	0.200	20.8	1250	10.0	1.2
BR-1128A	611752	5421285	433.9	144.0	-69.0	332.6	Lower	n/a[(a)]	n/a[(a)]	1	4.0	0.067	13.3	800	14.0	0.3
BR-1150	612335	5420806	438.0	503.0	-80.9	328.3	None	n/a[(a)]	n/a[(a)]	1	15.0	0.250	31.7	1900	7.3	2.1
BR-1154	612132	5420876	437.4	495.2	-76.0	331.5	Lower	n/a[(a)]	n/a[(a)]	3	6.0	0.100	12.9	775	2.7	2.2
BR-1161	612286	5420877	438.7	417.0	-80.0	320.8	Lower	n/a[(a)]	n/a[(a)]	2	10.0	0.167	30.0	1800	9.0	1.1
BR-1168A	612285	5420929	439.0	383.0	-74.0	320.3	Lower	n/a[(a)]	n/a[(a)]	2	11.0	0.183	38.3	2300	6.0	1.8
BR-1174	611590	5421268	430.2	138.0	-70.3	317.5	Lower	n/a[(a)]	n/a[(a)]	2	11.0	0.183	31.7	1900	6.5	1.7
BR 1176	611864	5421204	427.4	275.0	-64.0	330.1	Lower	n/a[(a)]	n/a[(a)]	1	4.0	0.067	13.3	800	14.0	0.3
BR-1188	611639	5421091	427.8	250.0	-78.0	327.4	Lower	n/a[(a)]	n/a[(a)]	2	12.0	0.200	50.0	3000	6.5	1.8
BR-1194A	612003	5420672	436.8	449.0	-49.0	328.0	None	n/a[(a)]	n/a[(a)]	1	8.0	0.133	11.7	700	11.0	0.7
BR-1199	611546	5421192	434.7	104.5	-60.5	328.6	None	n/a[(a)]	n/a[(a)]	1	5.5	0.092	25.0	1500	11.0	0.5
BR-1207	611849	5421363	433.6	79.0	-61.1	328.1	Lower	n/a[(a)]	32.4	1	5.0	0.083	26.7	1600	10.0	0.5
BR-1223	611973	5420901	433.5	344.0	-61.4	325.6	None	n/a[(a)]	n/a[(a)]	2	15.0	0.250	18.3	1100	7.5	2.0
BR-1229	611971	5421312	443.1	154.9	-50.3	327.0	Upper/Lower	n/a[(a)]	n/a[(a)]	1	5.0	0.083	23.3	1400	20.0	0.3
BR-1238	612099	5420756	434.4	389.0	-69.6	324.4	None	n/a[(a)]	n/a[(a)]	2	15.0	0.250	20.0	1200	8.0	1.9

Table 1: Specific Capacity Estimates from Short-Term Pumping Tests (Continued)

Borehole ID	UTM (NAD 83 Zone 15U)		Top of Casing Elevation (masl)	Depth (m)	Dip	Azimuth	Intersecting Shear Zone(s)	Upper Shear Intersection Depth (m)	Lower Shear Intersection Depth (m)	Number of Pumping Steps	Pumping Rate During Final Step (L/min)	Pumping Rate During Final Step (L/sec)	Total Pumping Time (min)	Total Pumping Time (sec)	Total Drawdown (m)	Specific Capacity (L/min/m)
	Easting	Northing														
BR-1272	611804	5421023	452.2	296.0	-59.2	326.5	n/a[(a)]	n/a[(a)]	n/a[(a)]	1	9.0	0.150	23.3	1400	1.0	9.0
BR-1278	612152	5421456	441.2	169.4	-48.0	352.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	9.0	0.150	26.7	1600	8.3	1.1
BR-4301	613219	5421875	436.0	141.4	-47.0	327.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	6.0	0.100	87.2	5232	3.4	1.8
BR-6051	612613	5421703	446.0	278.0	-79.9	327.9	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	10.0	0.167	38.3	2300	1.7	5.9
BR-6113	612555	5421110	441.5	476.0	-65.0	325.2	n/a[(a)]	n/a[(a)]	n/a[(a)]	1	7.5	0.125	10.0	600	8.8	0.9
BR-6213	612857	5421378	442.9	470.0	-80.0	327.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	14.0	0.233	23.3	1400	3.7	3.8
BR-6217	612627	5421214	438.7	407.5	-81.6	324.8	Upper/Lower	319.59	357.58	2	15.0	0.250	38.3	2300	1.2	12.5
BR-6221	612409	5421604	440.9	185.0	-80.8	334.2	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	10.0	0.167	25.0	1500	3.0	3.3
BR-6224	612145	5421640	452.6	101.0	-47.8	329.6	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	6.0	0.100	25.0	1500	6.5	0.9
BR-6241	612309	5421754	453.2	117.0	-50.0	327.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	2	9.0	0.150	30.0	1800	8.0	1.1

Notes: Shear Zone intersection depths based on geology model provided by OHRG (July 2011).
n/a[(a)] = Represents data that was unavailable.

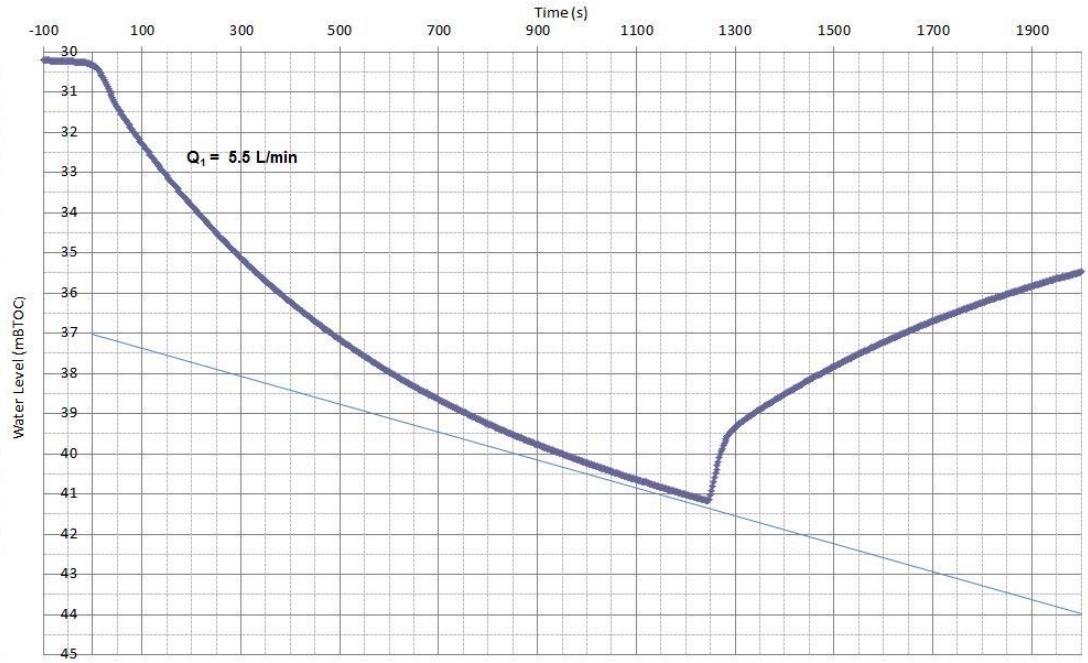

Figure 2: BR-0061 Step Drawdown Test

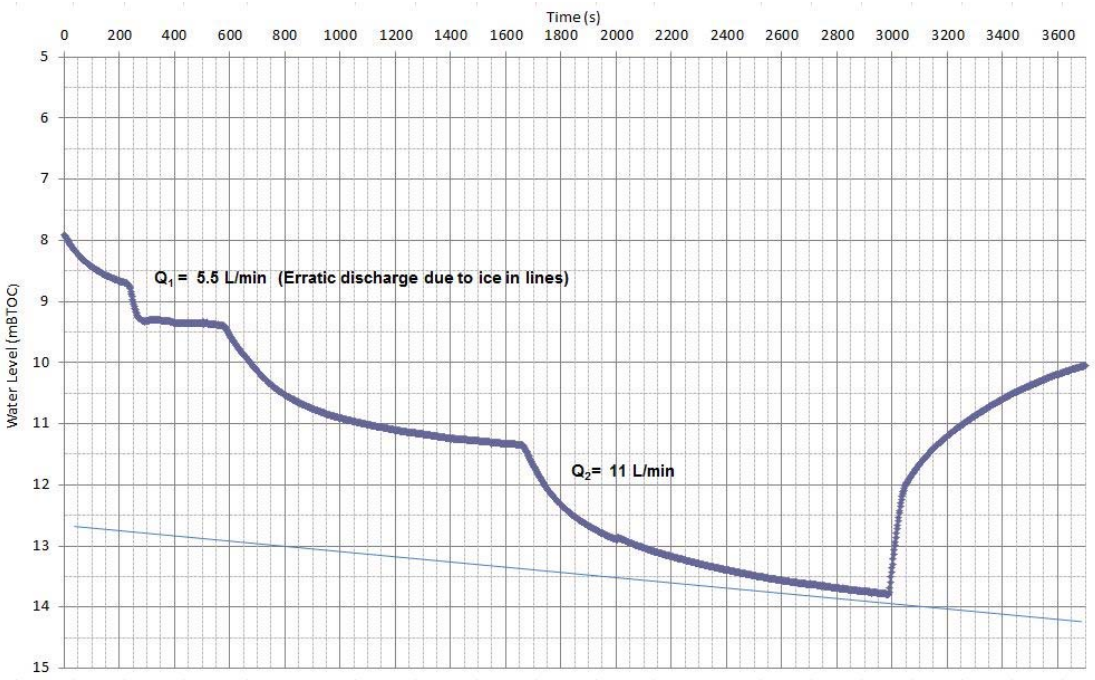

Figure 3: BR-0073 Step Drawdown Test

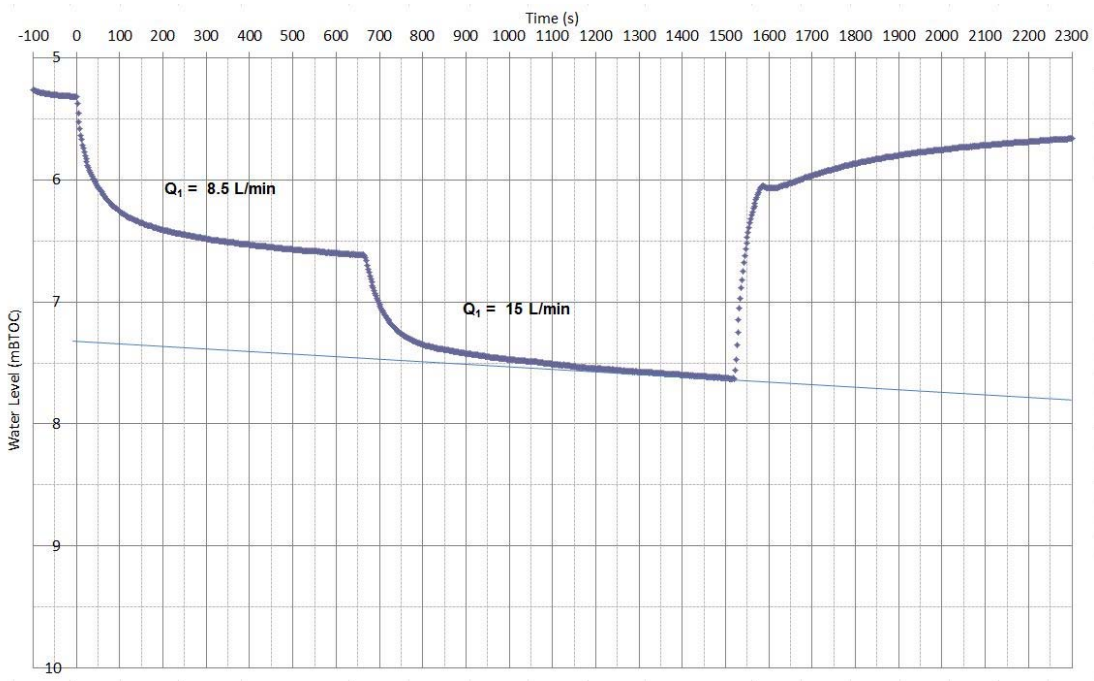

Figure 4: BR-0081 Step Drawdown Test

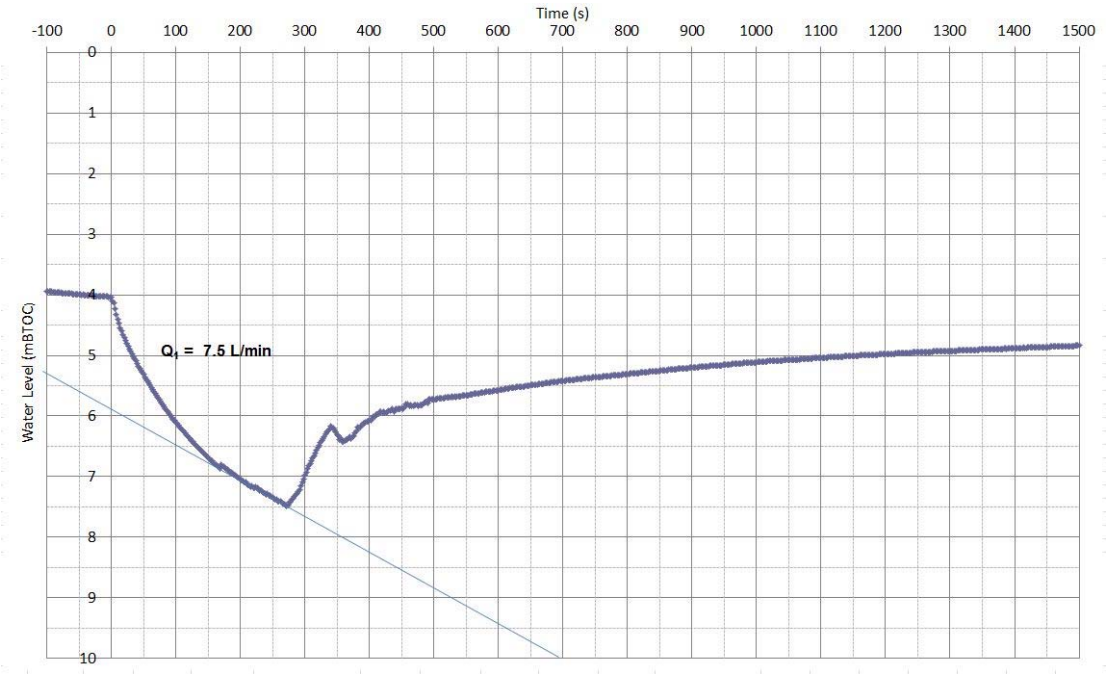

Figure 5: BR-0155 Step Drawdown Test

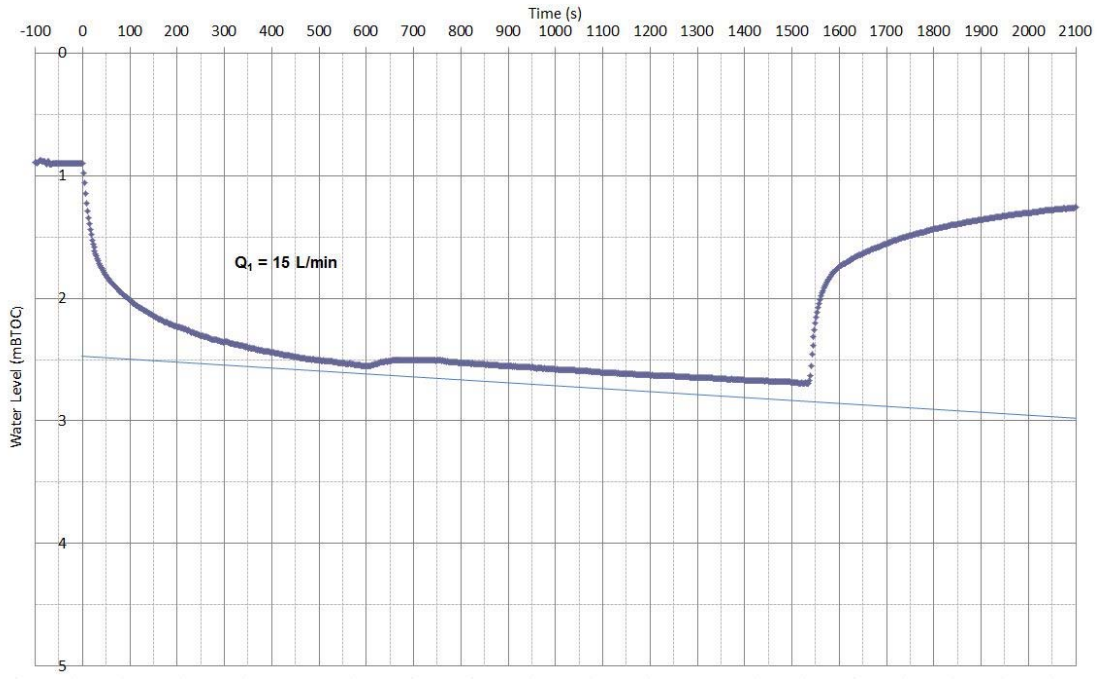

Figure 6: BR-0216 Step Drawdown Test

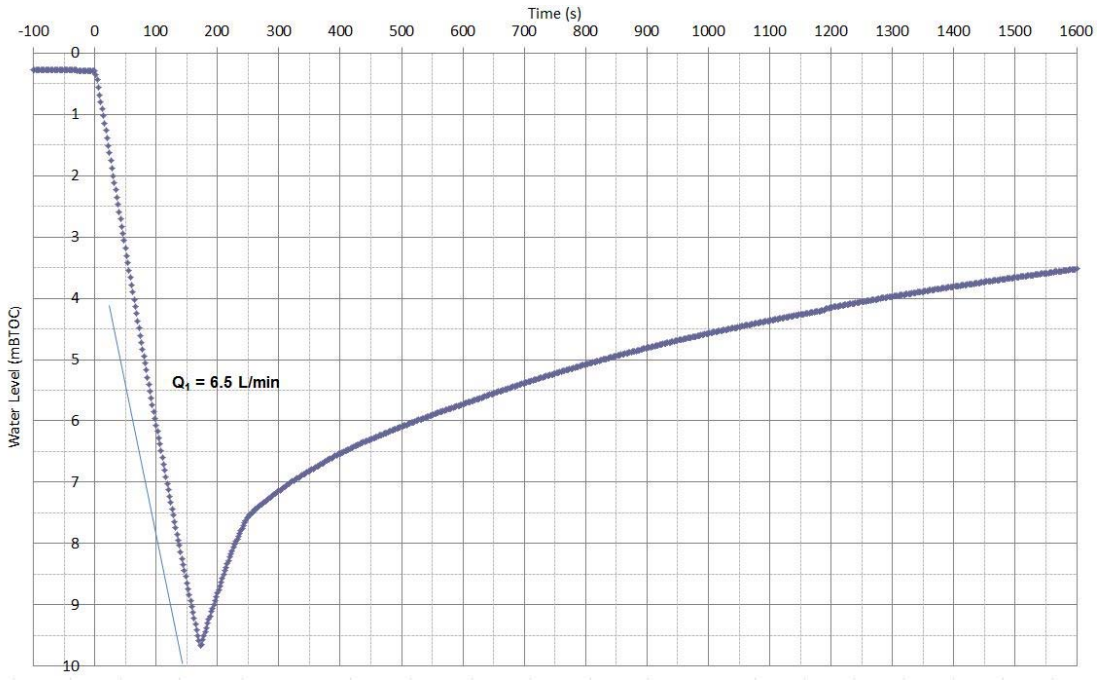

Figure 7: BR-0246 Step Drawdown Test

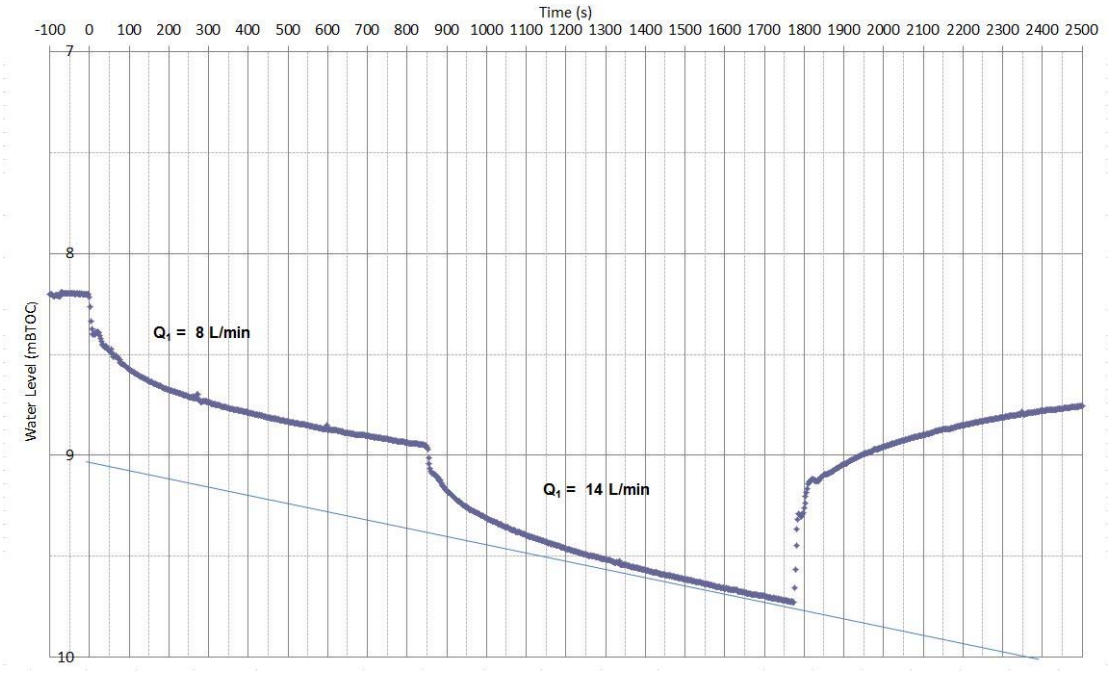

Figure 8: BR-0272 Step Drawdown Test

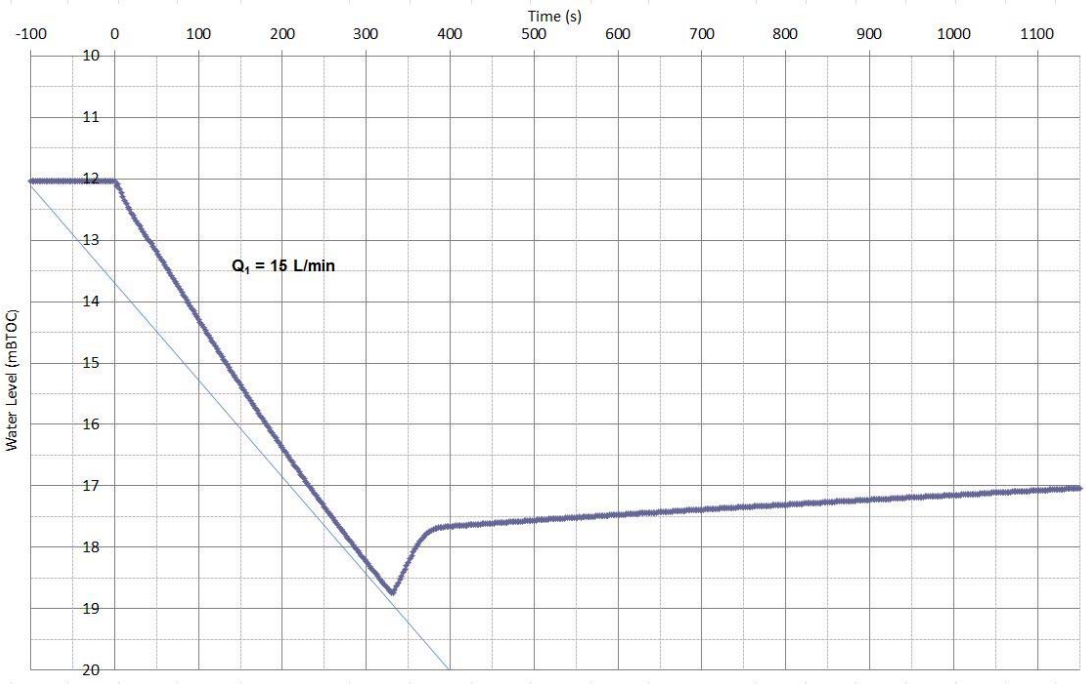

Figure 9: BR-0325 Step Drawdown Test

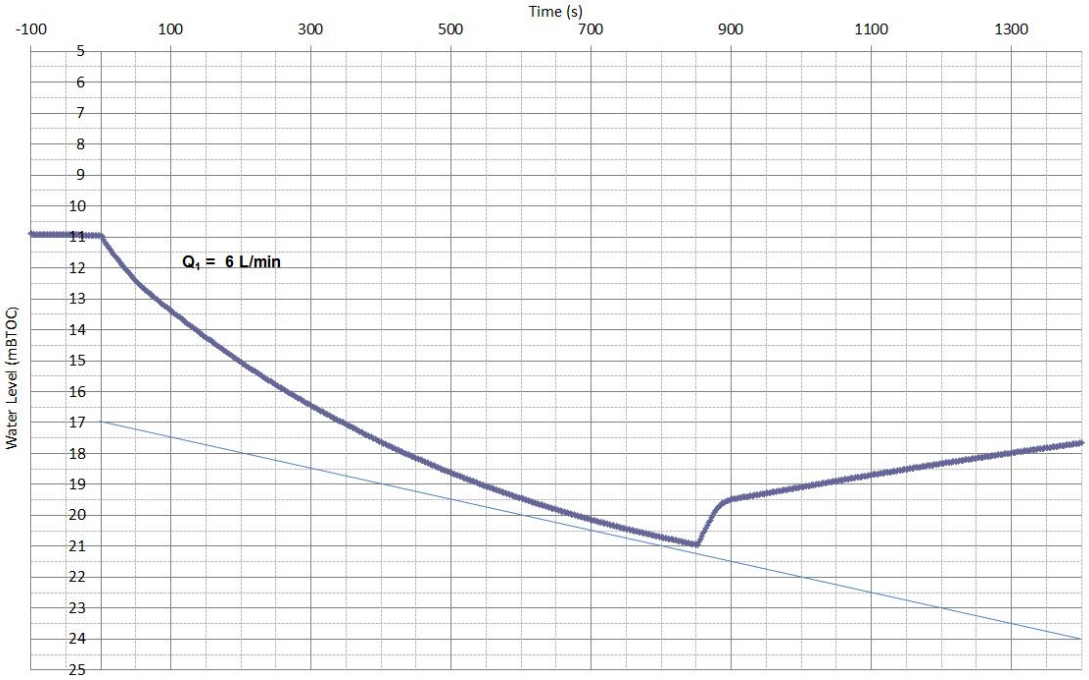

Figure 10: BR-0390 Step Drawdown Test

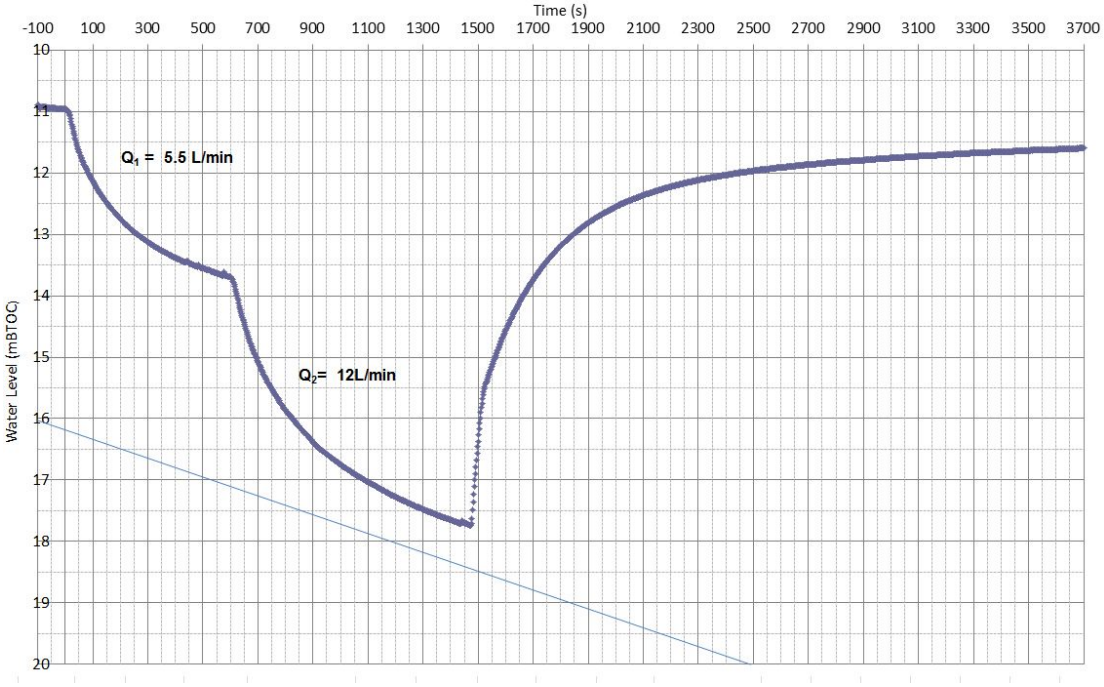

Figure 11: BR-0413 Step Drawdown Test

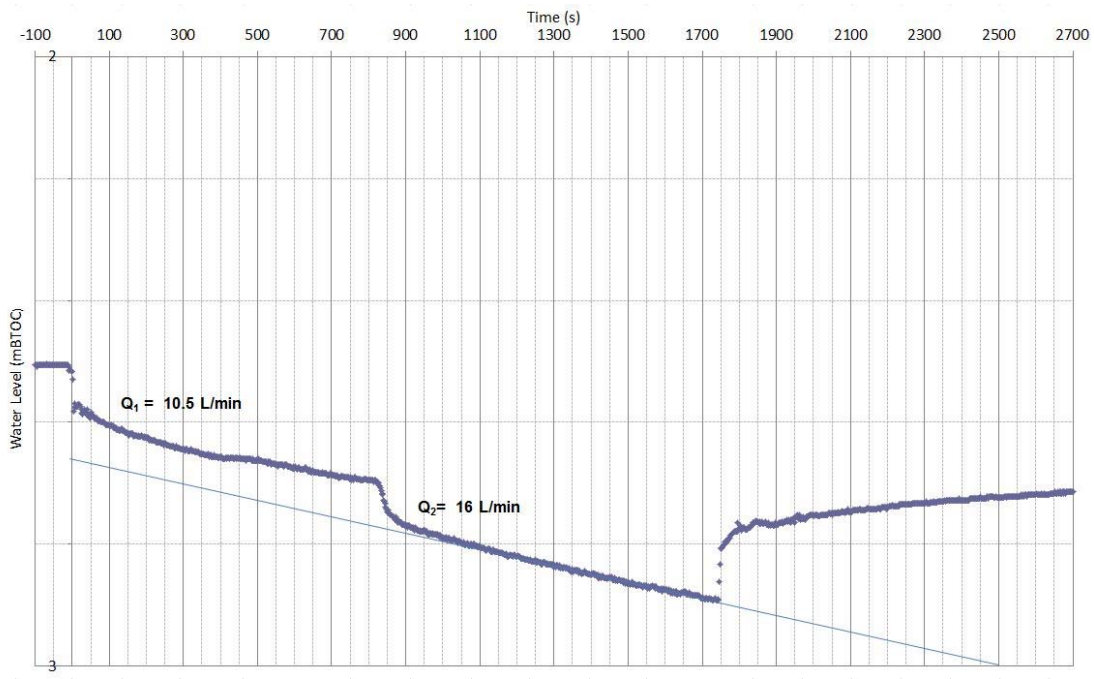

Figure 12: BR-0433 Step Drawdown Test

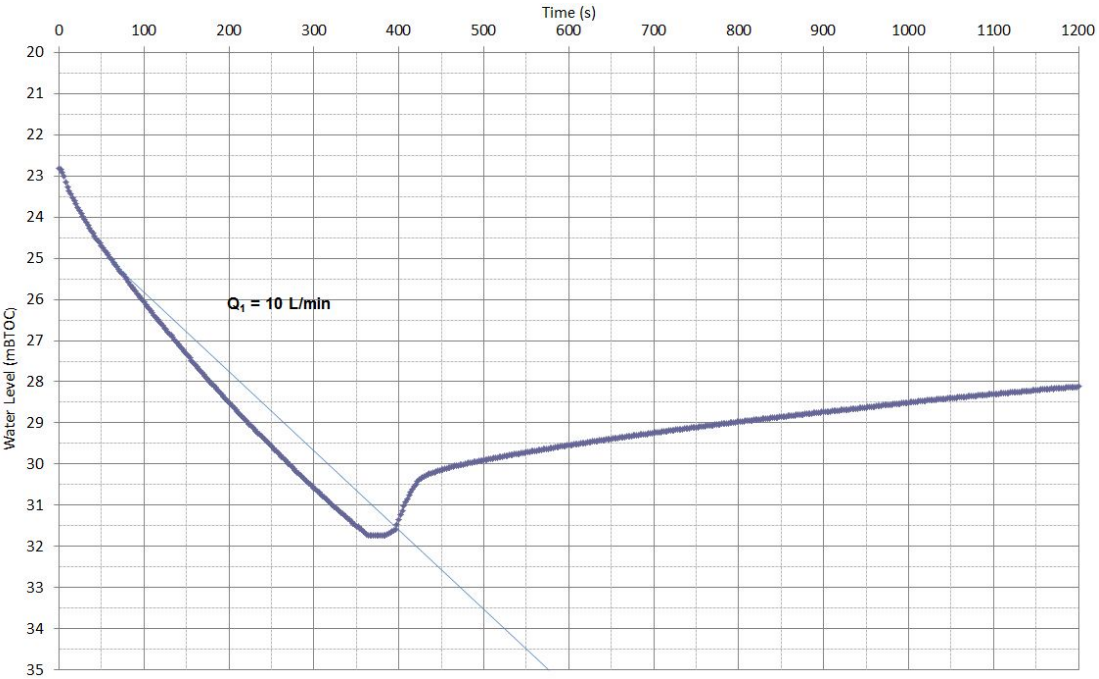

Figure 13: BR-0437 Step Drawdown Test

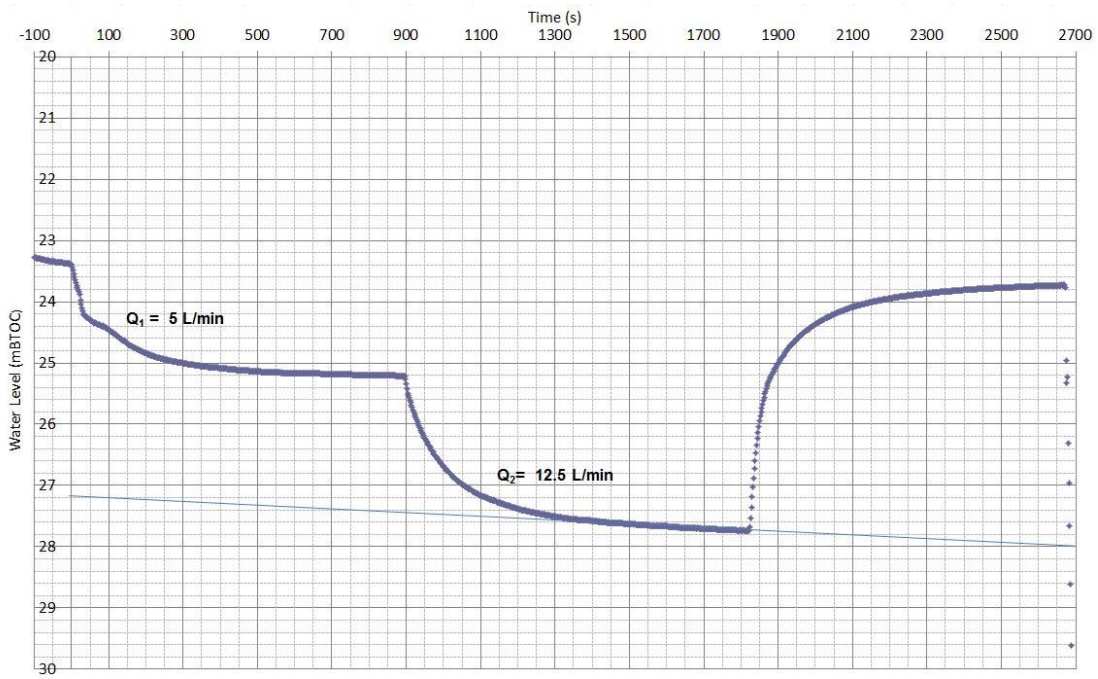

Figure 14: BR-1011 Step Drawdown Test

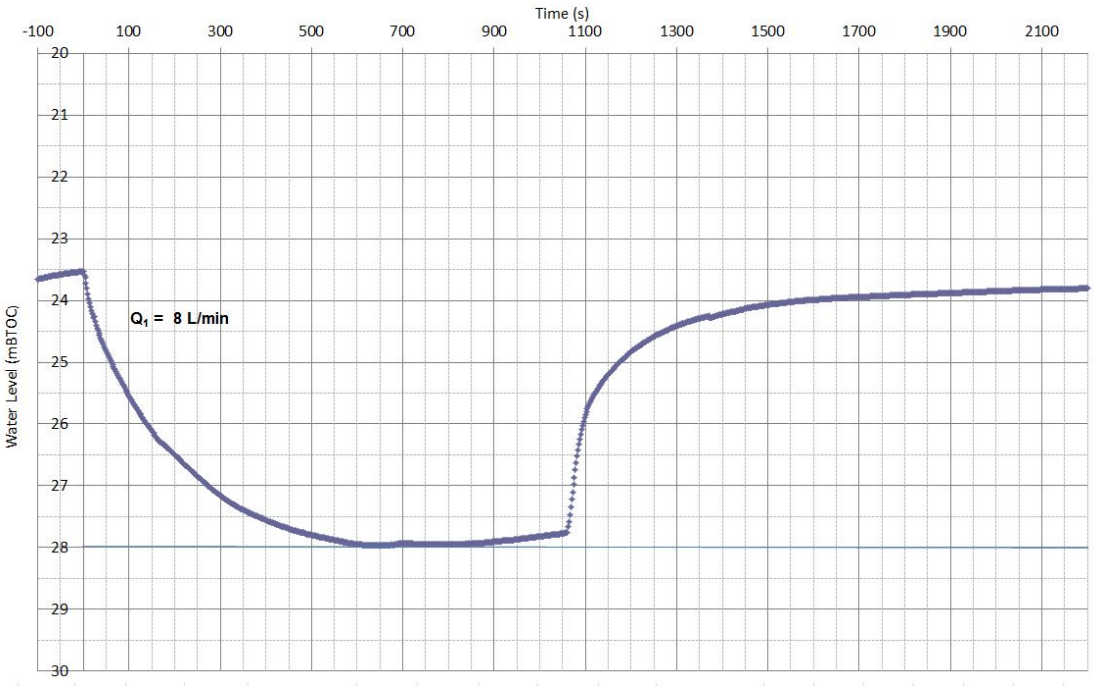

Figure 15: BR-1042 Step Drawdown Test

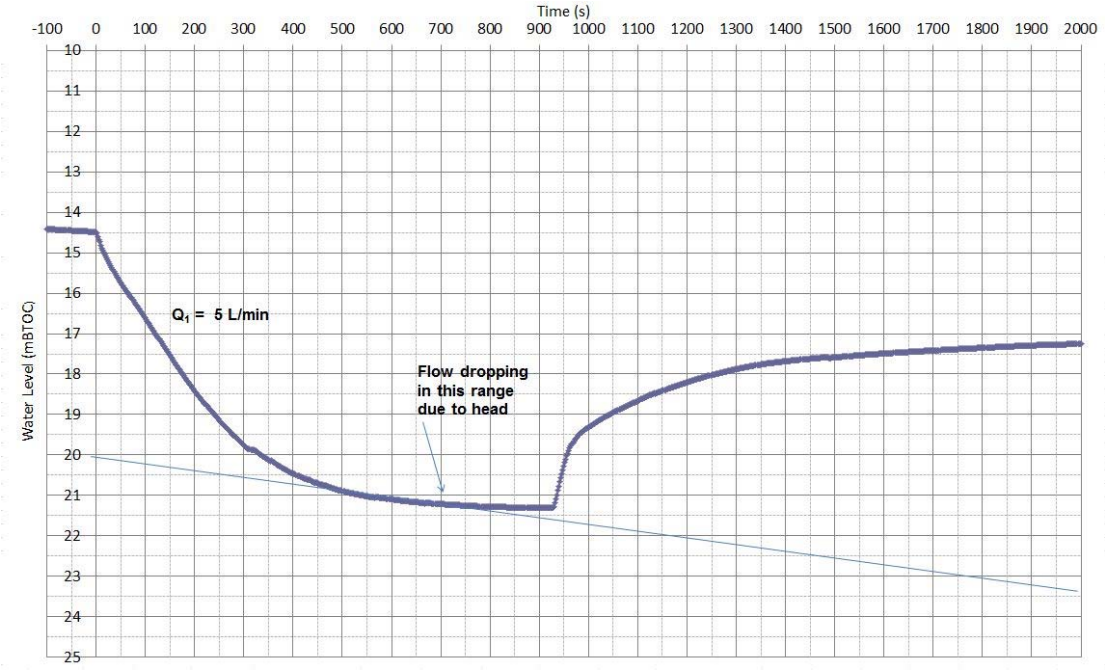

Figure 16: BR-1051 Step Drawdown Test

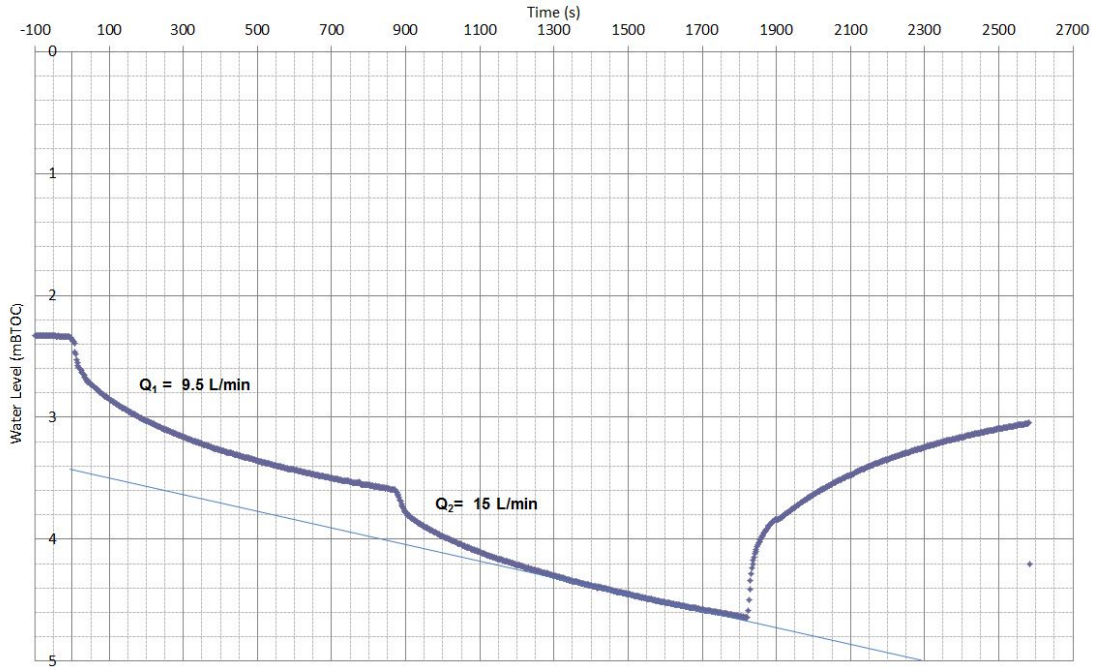

Figure 17: BR-1054 Step Drawdown Test

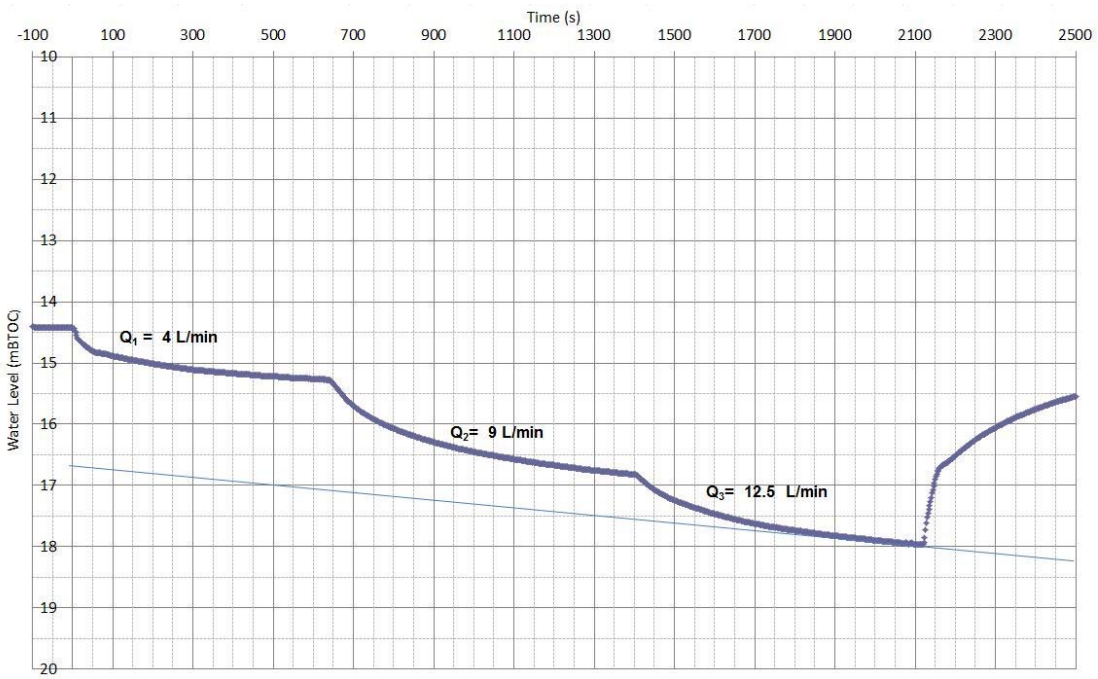

Figure 18: BR-1056 Step Drawdown Test

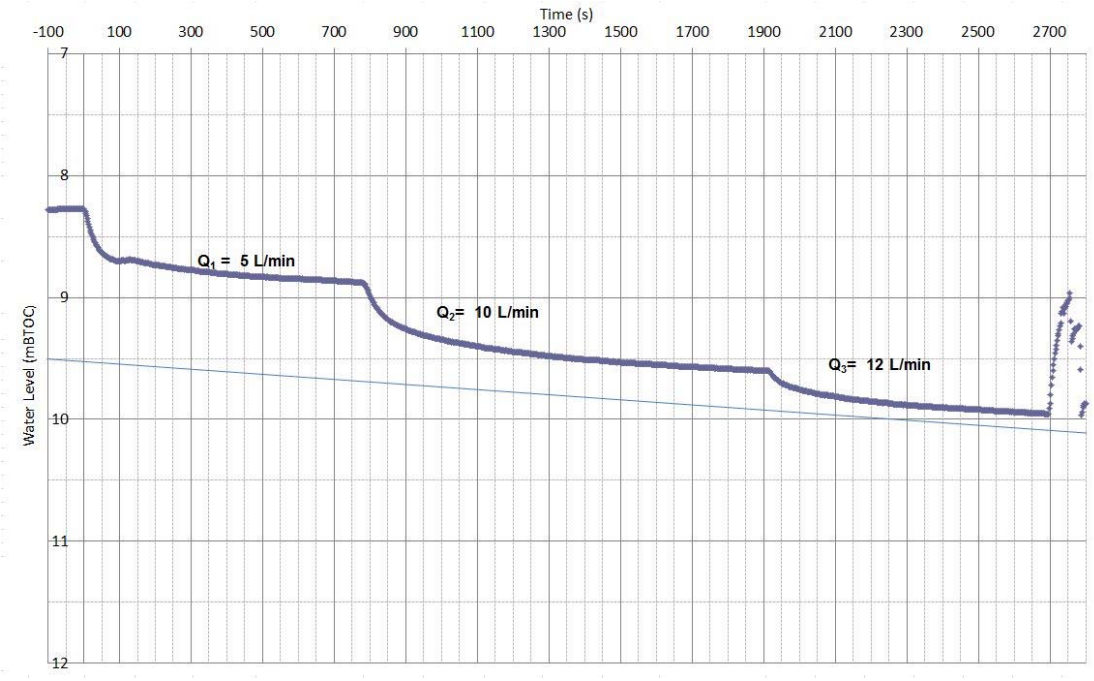

Figure 19: BR-1061 Step Drawdown Test

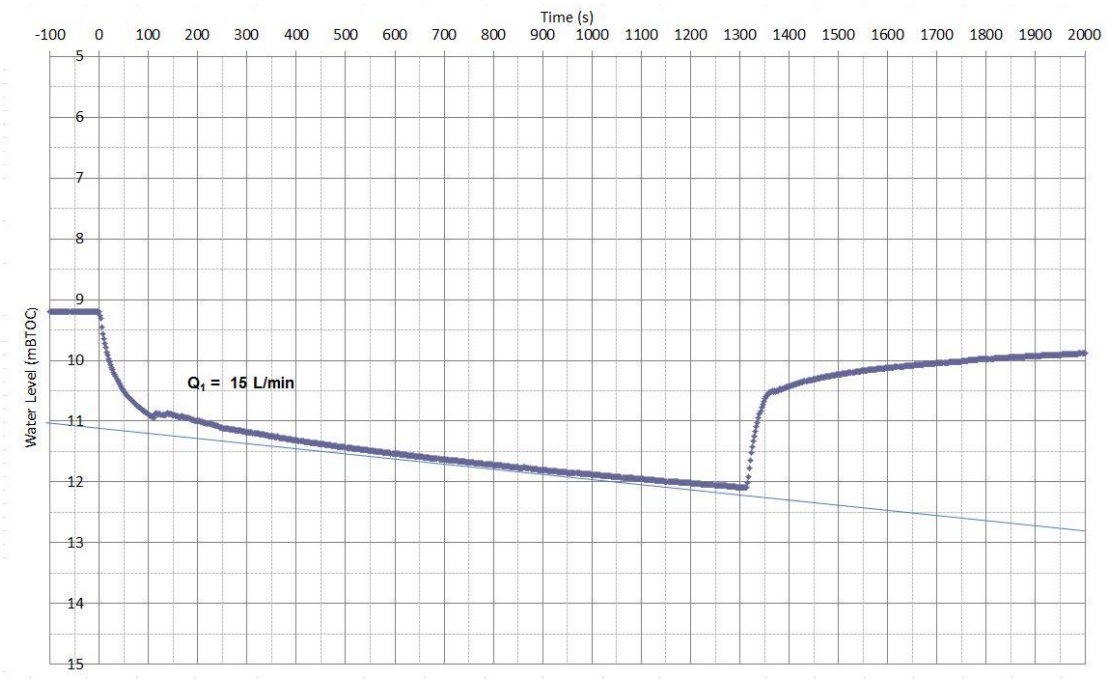

Figure 20: BR-1064 Step Drawdown Test

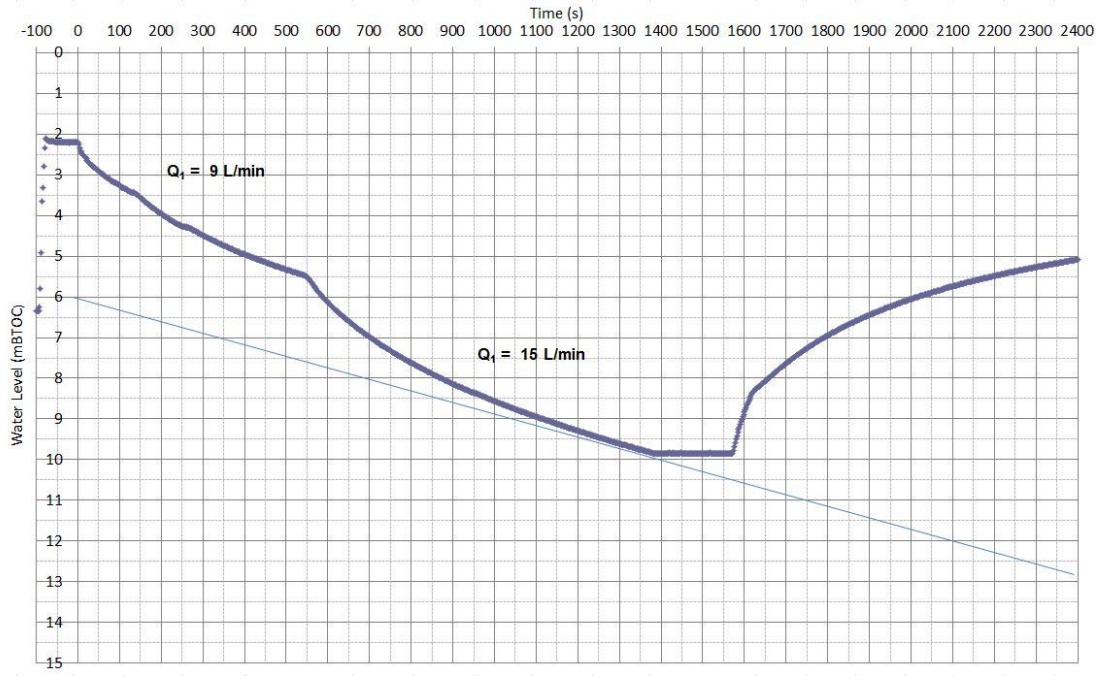

Figure 21: BR-1070 Step Drawdown Test

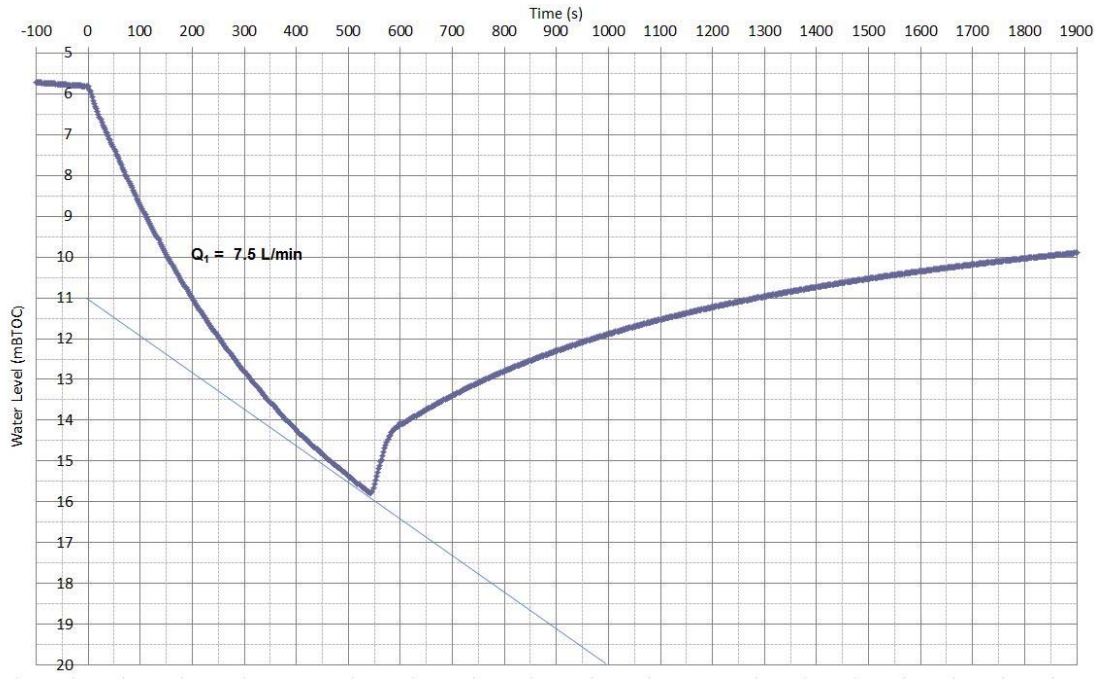

Figure 22: BR-1080 Step Drawdown Test

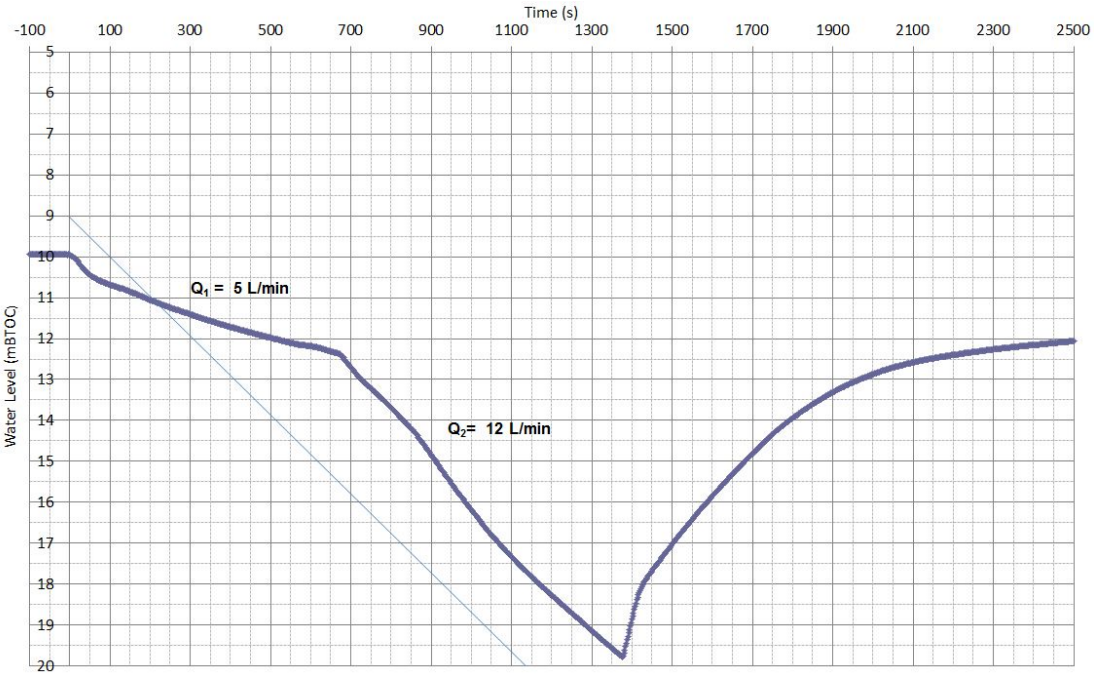

Figure 23: BR-1095 Step Drawdown Test

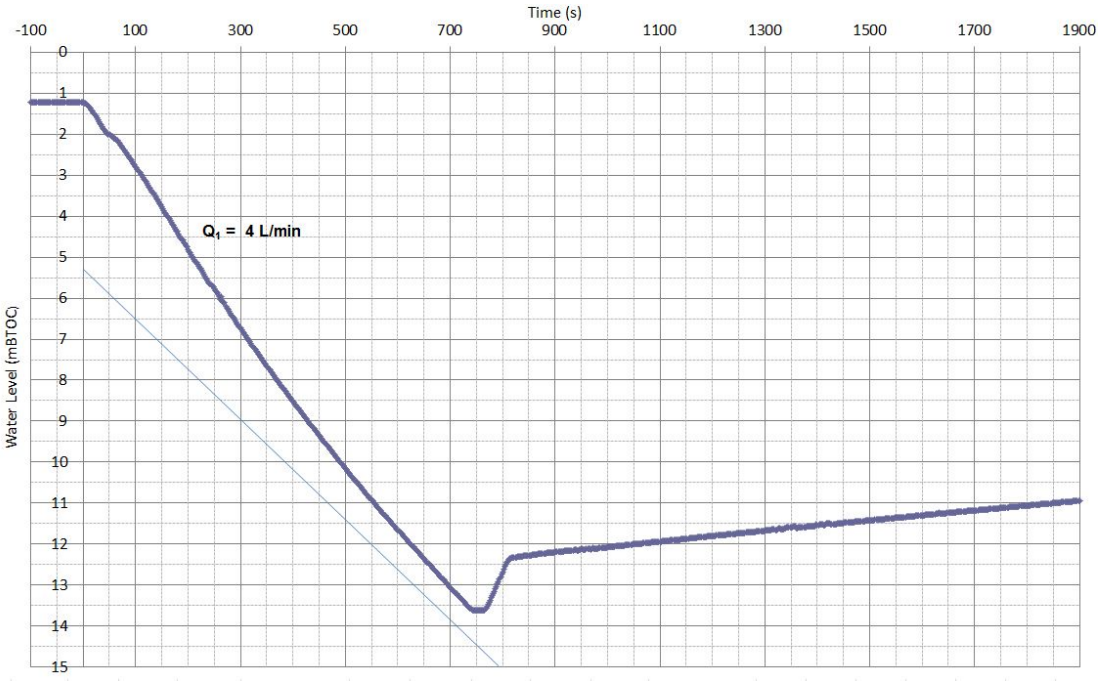

Figure 24: BR-1128A Step Drawdown Test

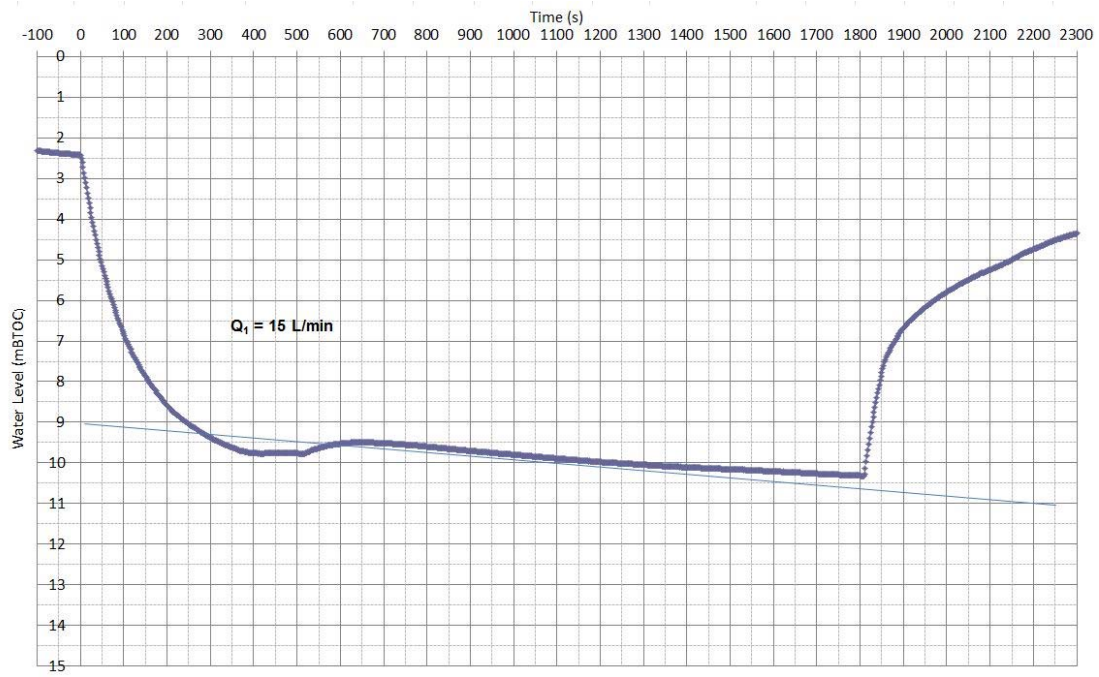

Figure 25: BR-1150 Step Drawdown Test

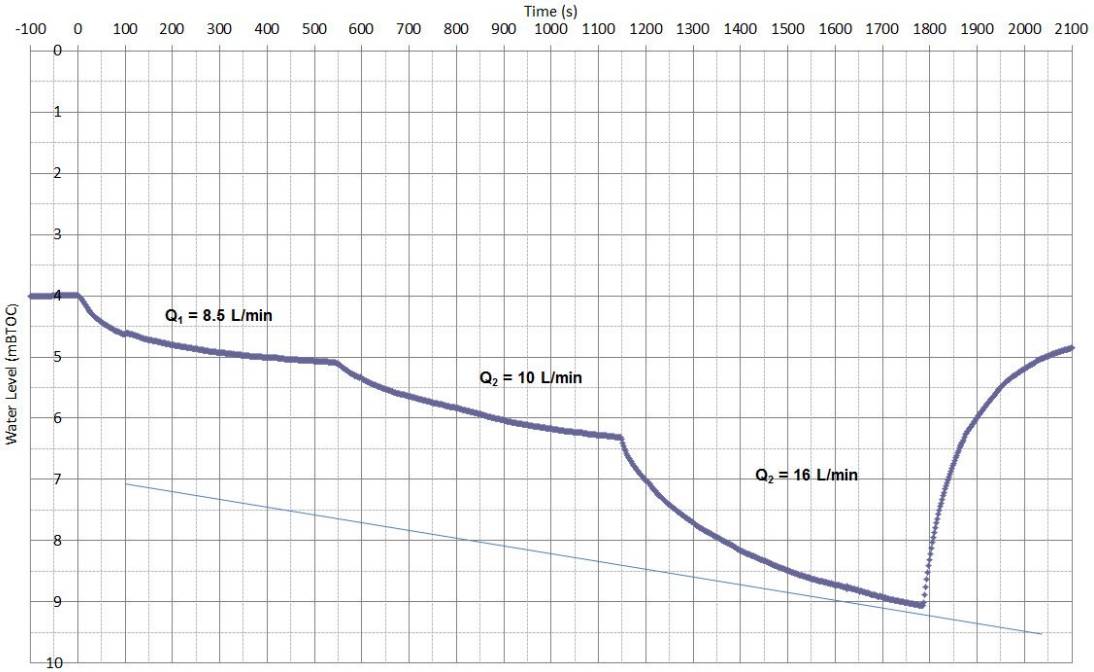

Figure 26: BR-1154 Step Drawdown Test

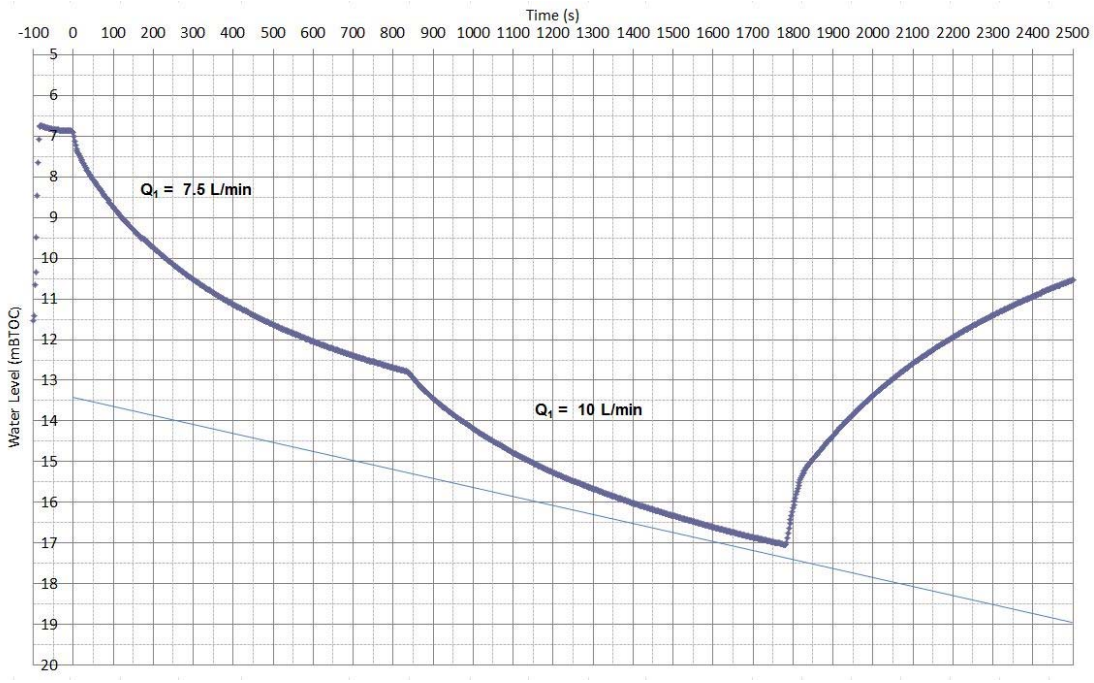

Figure 27: BR-1161 Step Drawdown Test

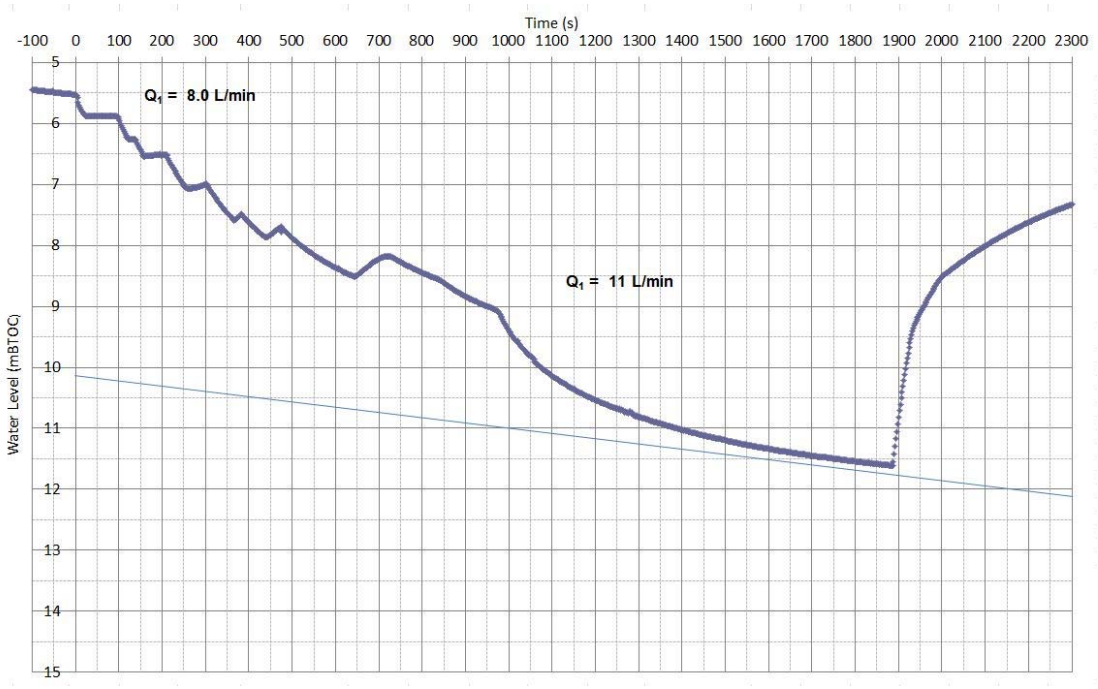

Figure 28: BR-1168A Step Drawdown Test

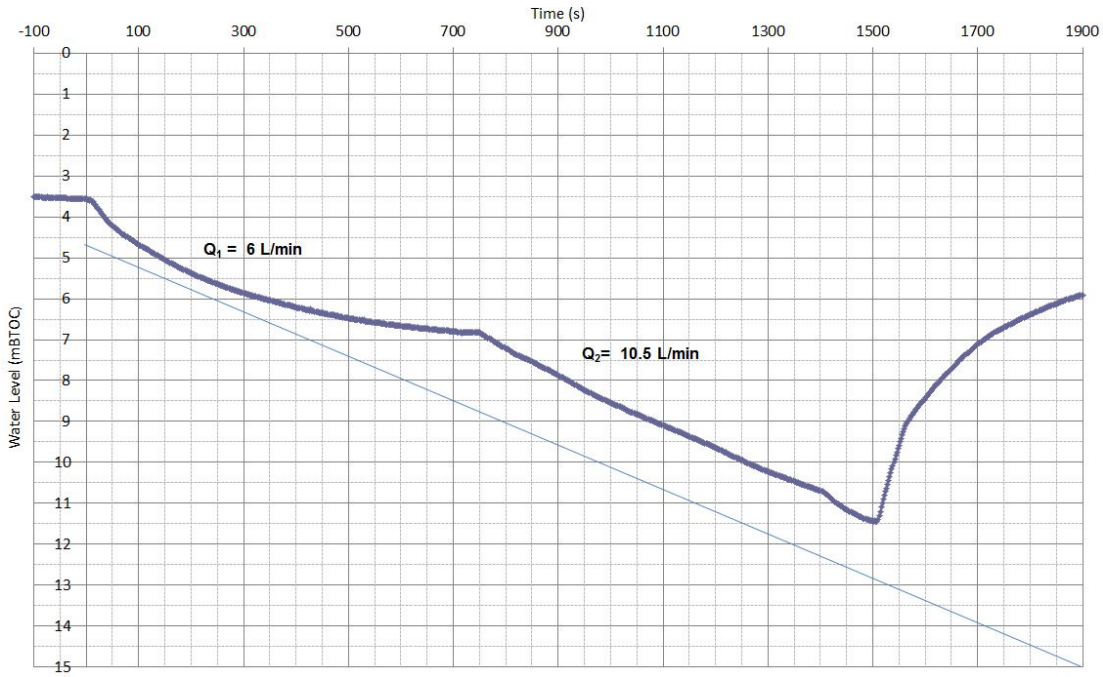

Figure 29: BR-1174 Step Drawdown Test

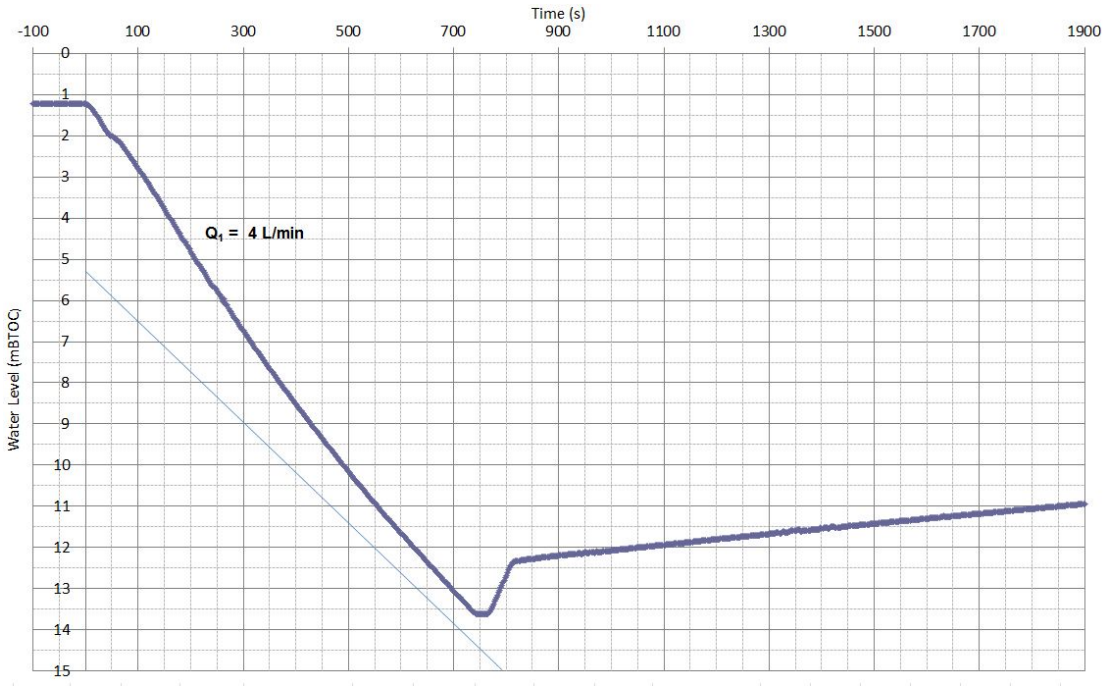

Figure 30: BR-1176 Step Drawdown Test

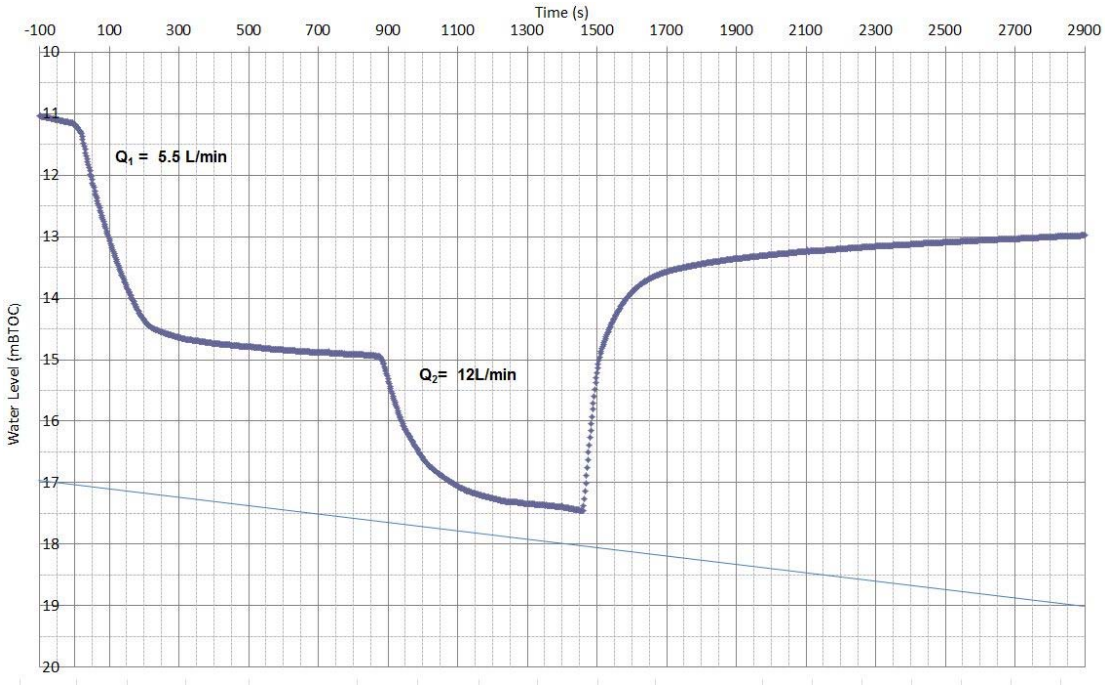

Figure 31: BR-1188 Step Drawdown Test

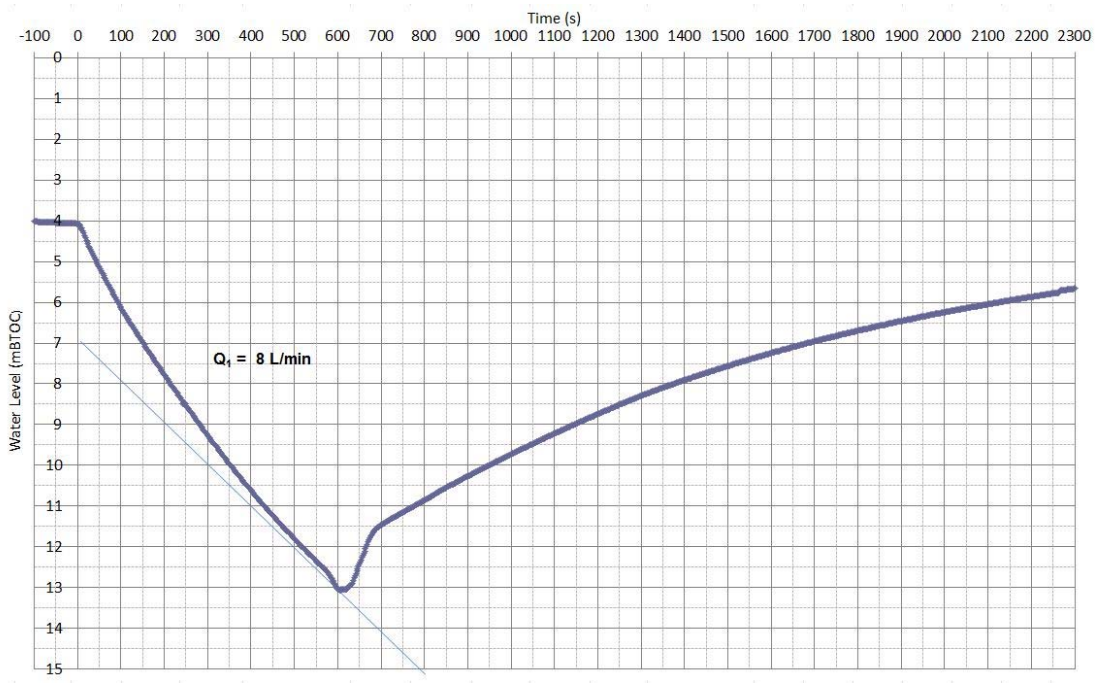

Figure 32: BR-1194A Step Drawdown Test

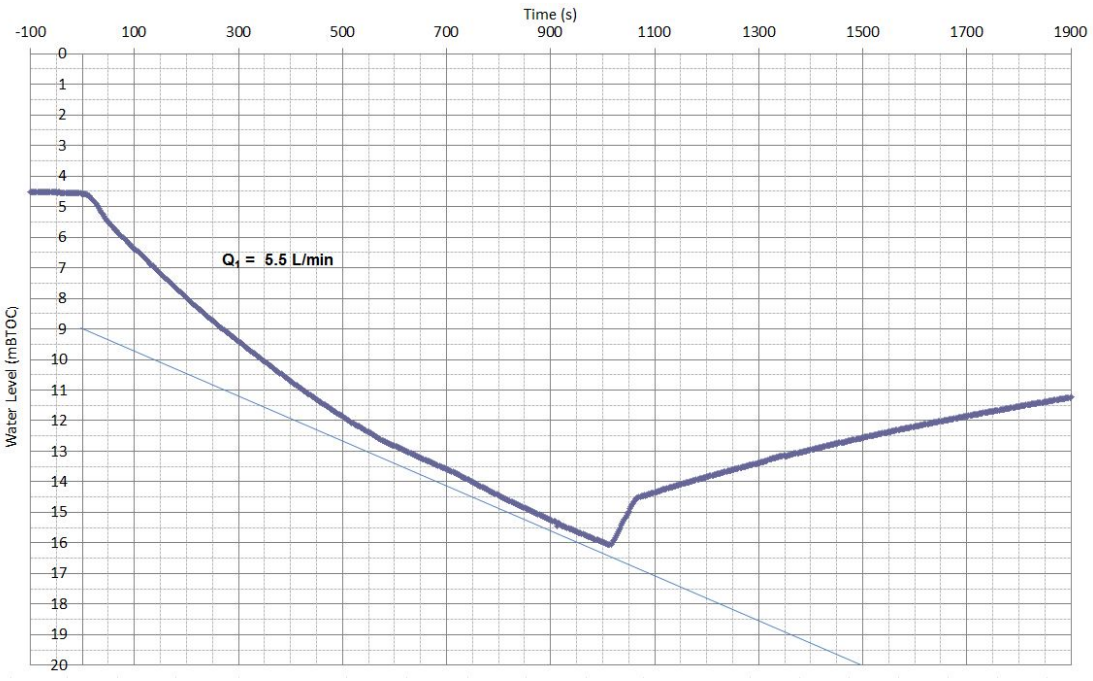

Figure 33: BR-1199 Step Drawdown Test

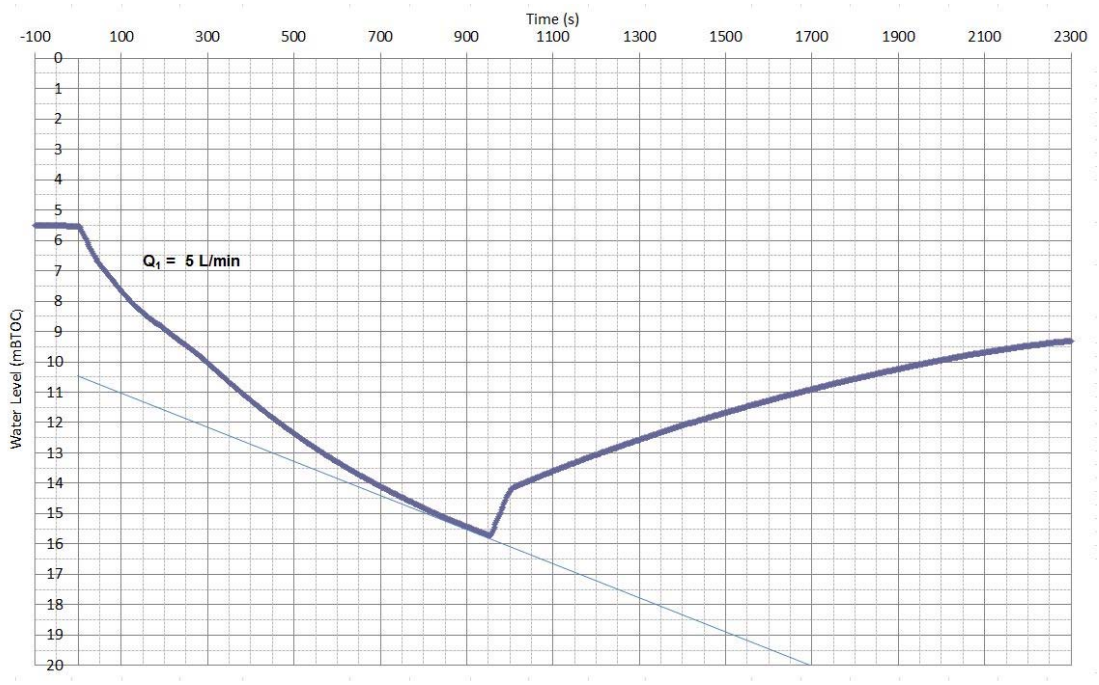

Figure 34: BR-1207 Step Drawdown Test

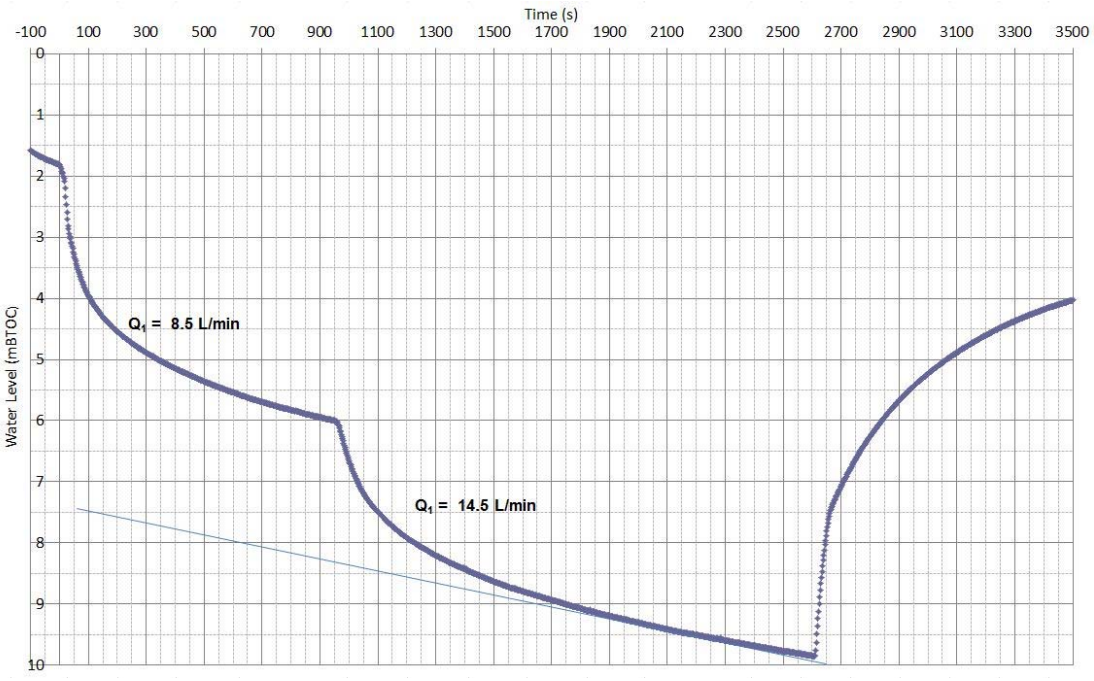

Figure 35: BR-1223 Step Drawdown Test

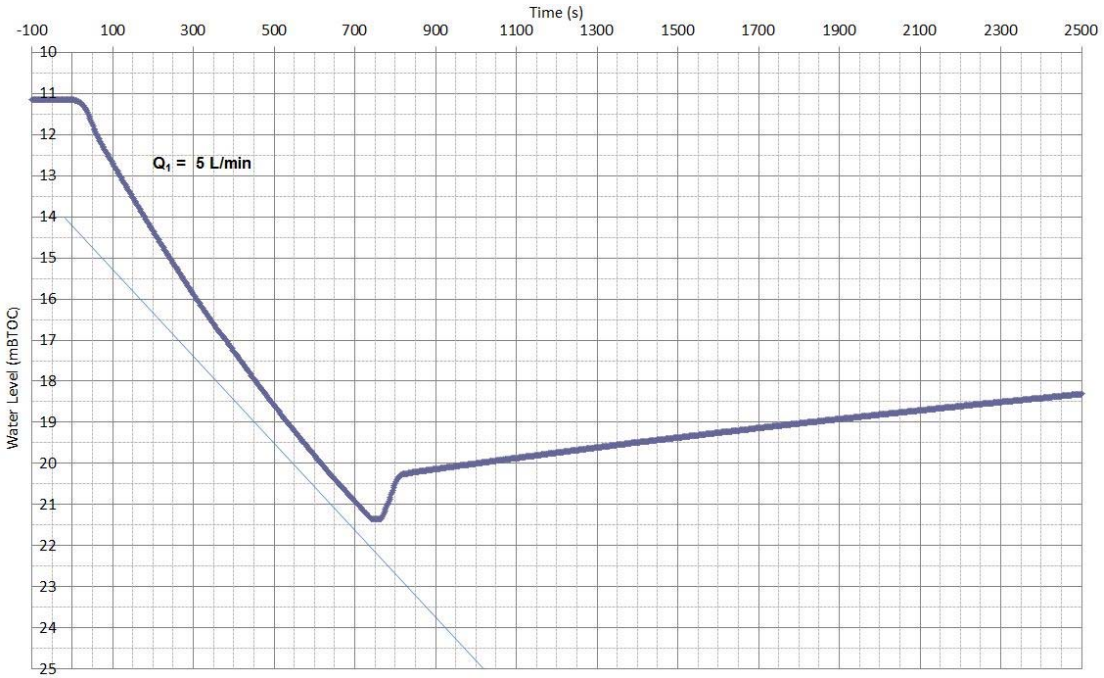

Figure 36: BR-1229 Step Drawdown Test

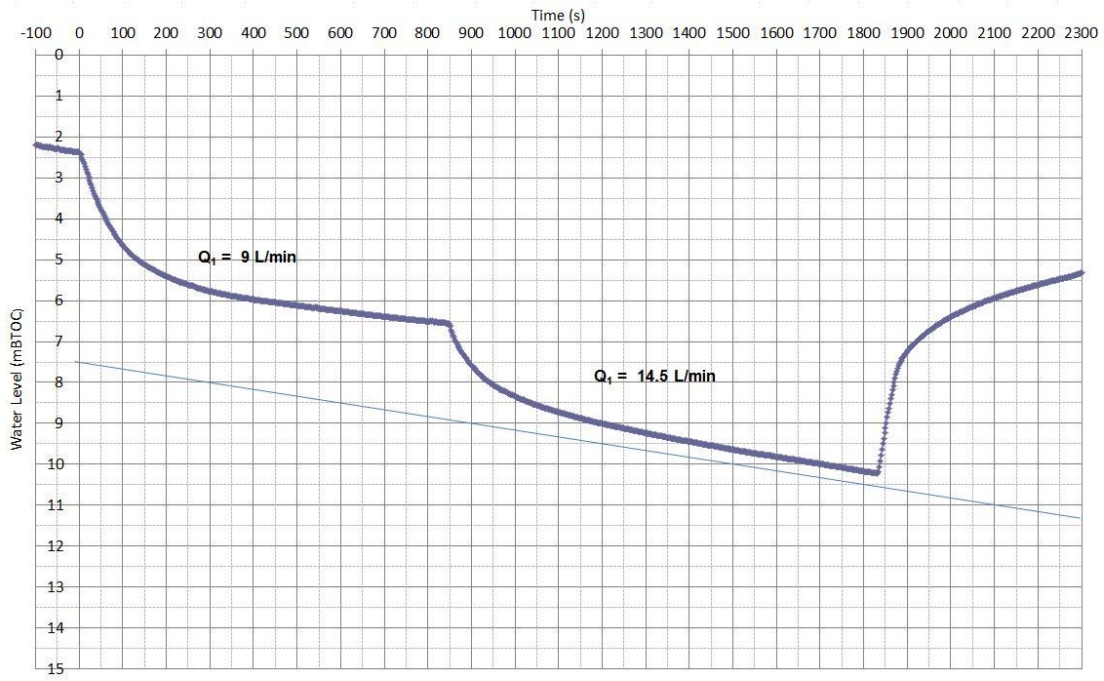

Figure 37: BR-1238 Step Drawdown Test

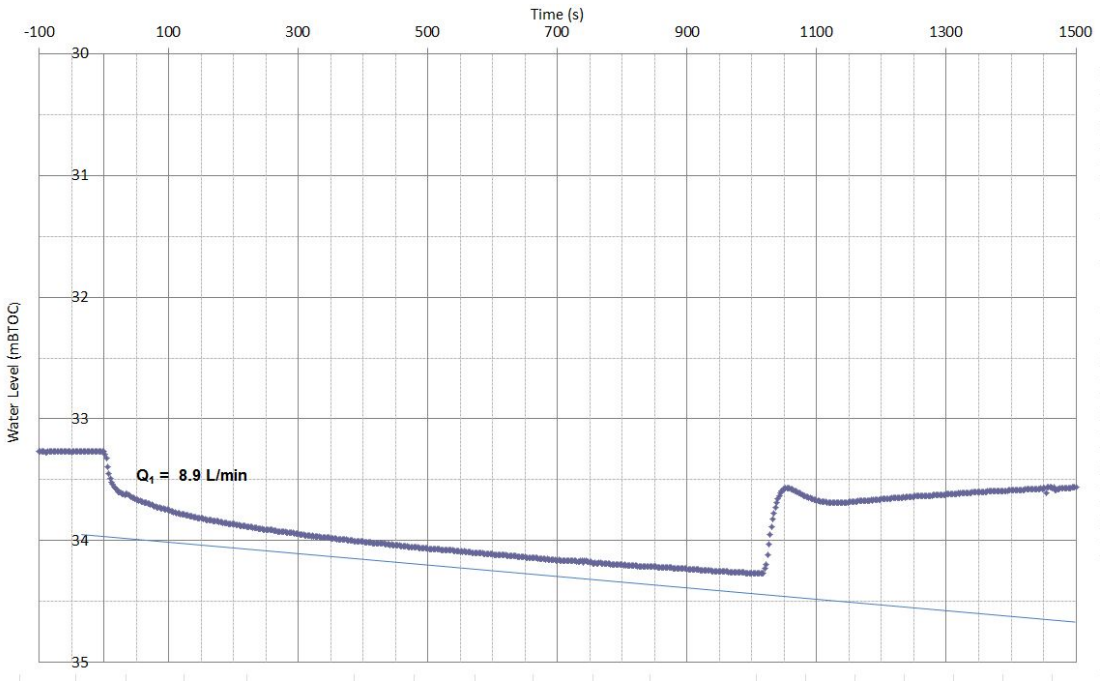

Figure 38: BR-1272 Step Drawdown Test

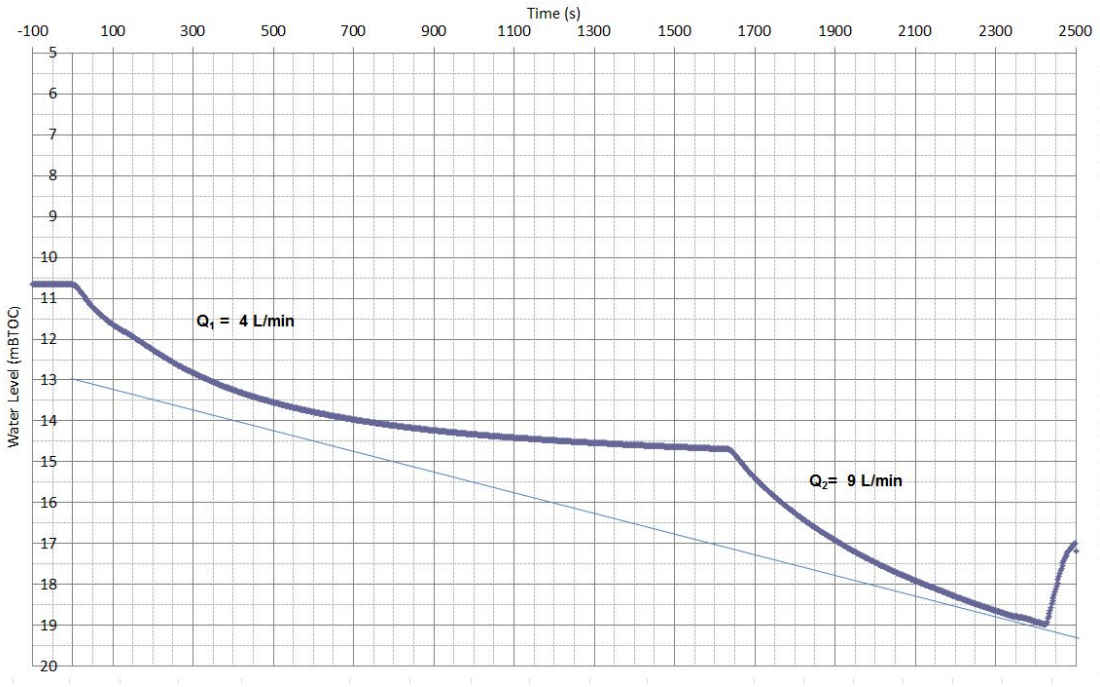

Figure 39: BR-1278 Step Drawdown Test

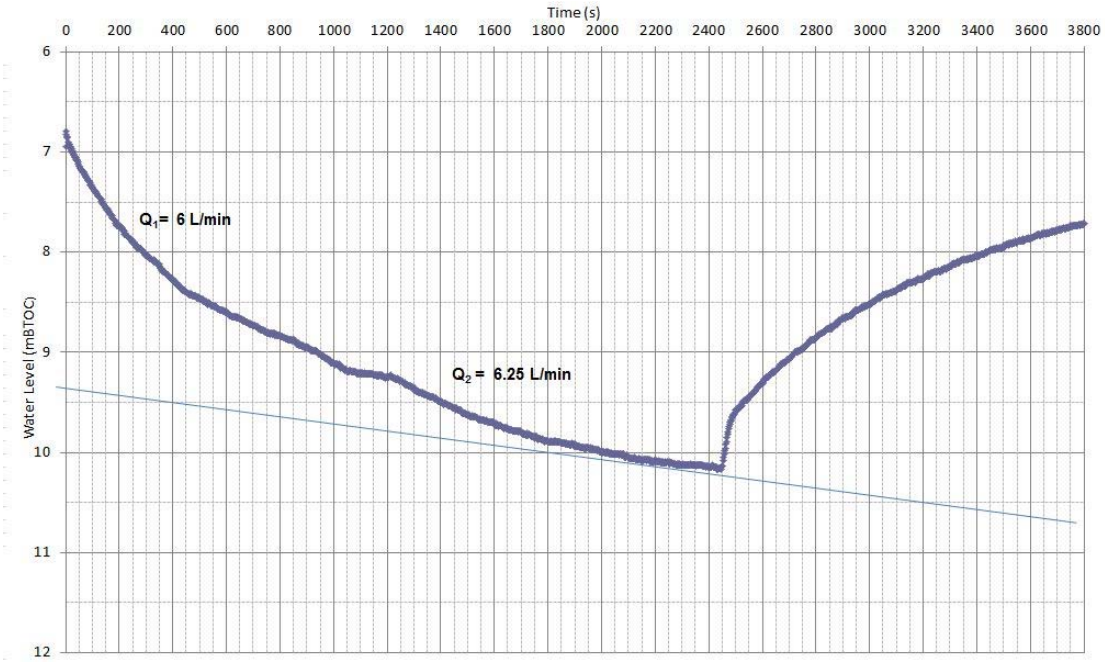

Figure 40: BR-4301 Step Drawdown Test

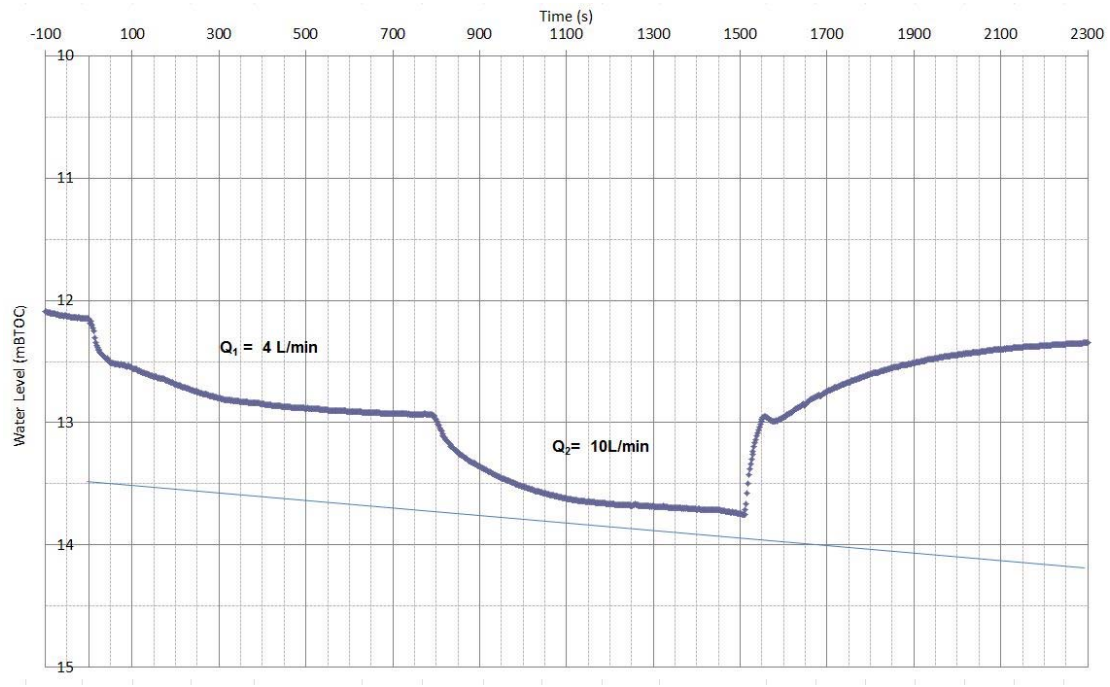

Figure 41: BR-6051 Step Drawdown Test

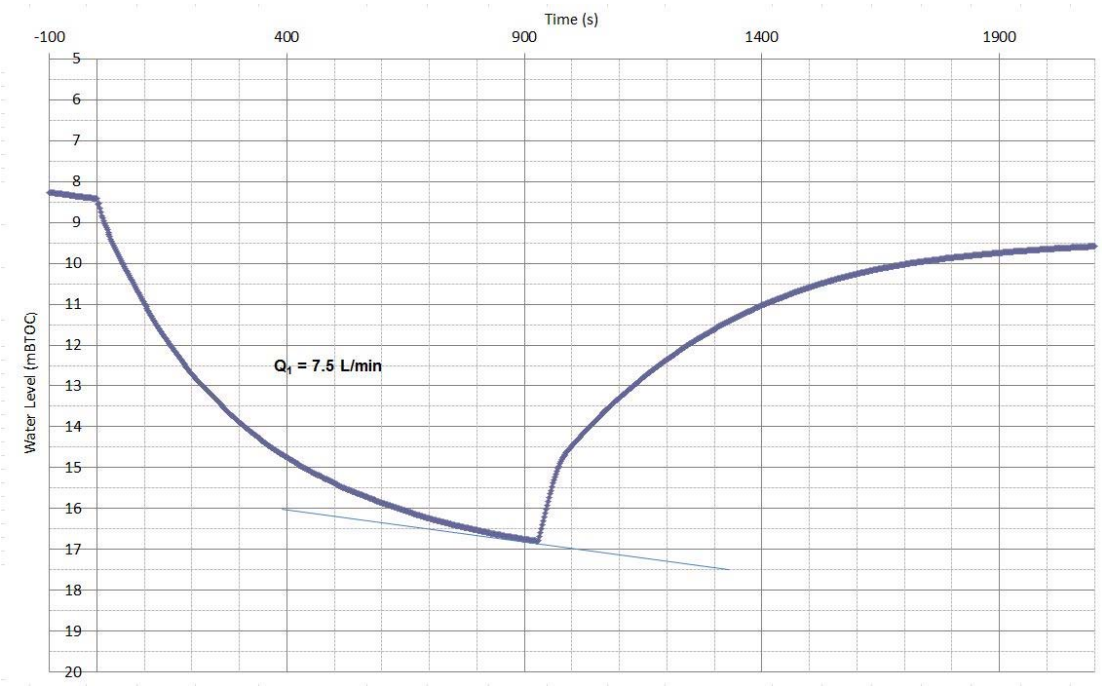

Figure 42: BR-6113 Step Drawdown Test

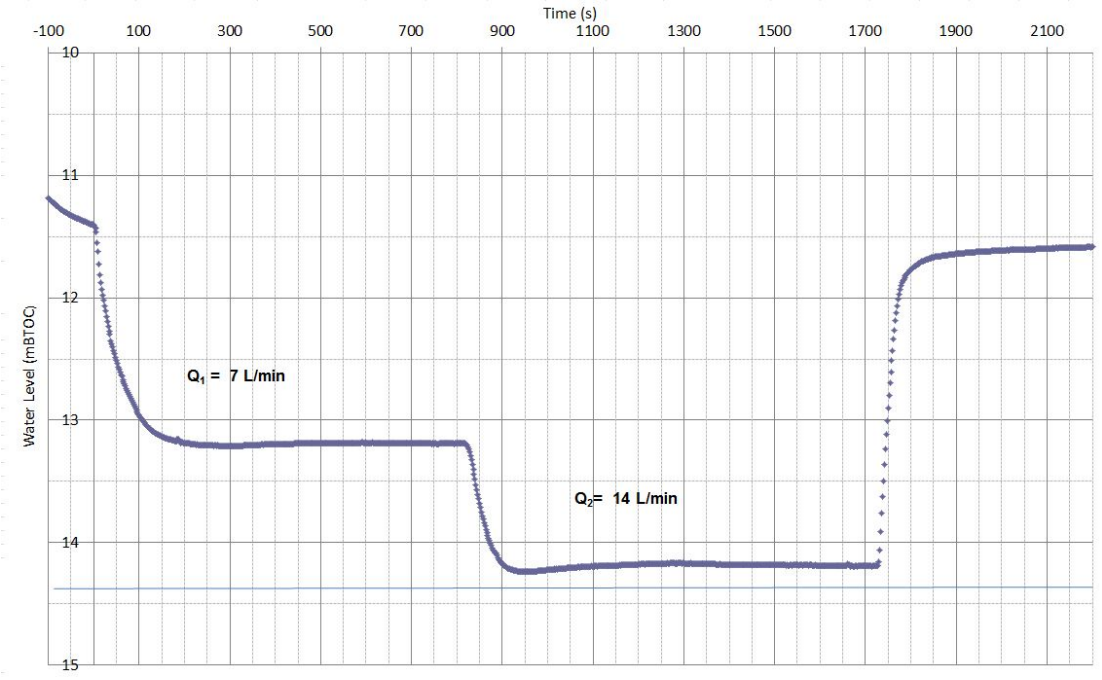

Figure 43: BR-6213 Step Drawdown Test

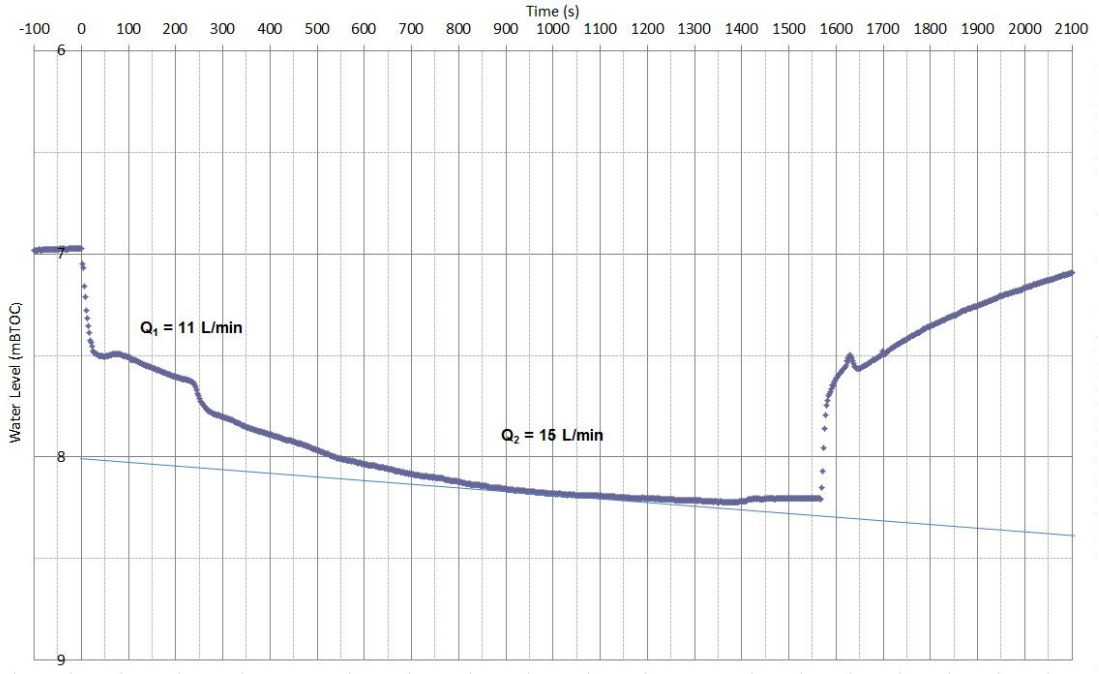

Figure 44: BR-6217 Step Drawdown Test

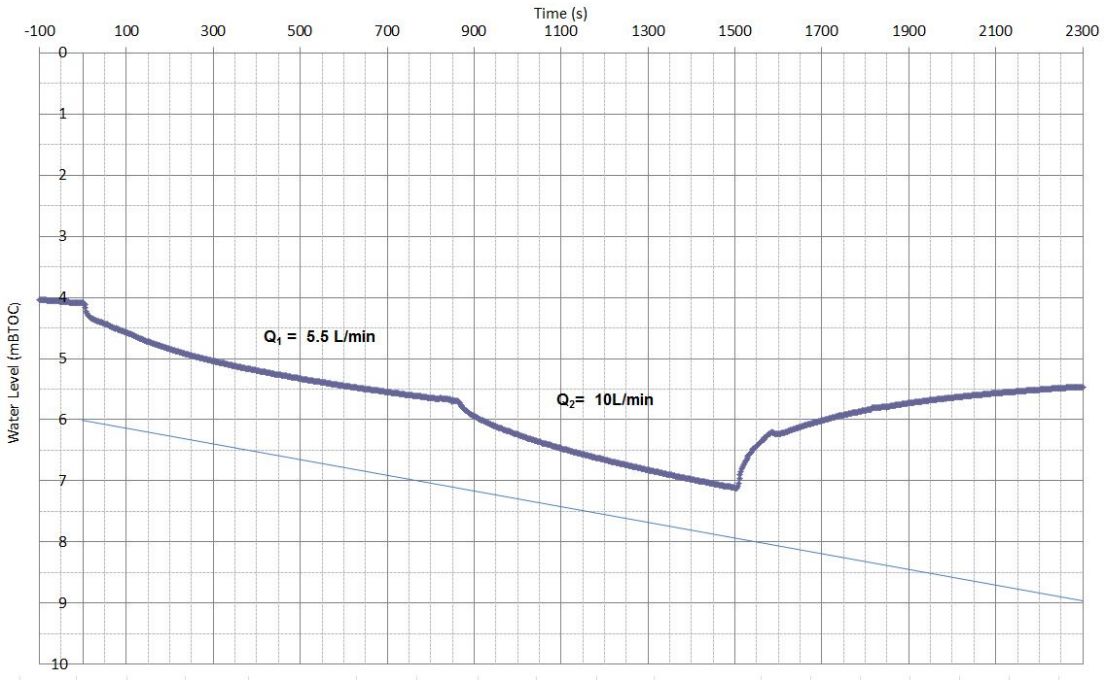

Figure 45: BR-6221 Step Drawdown Test

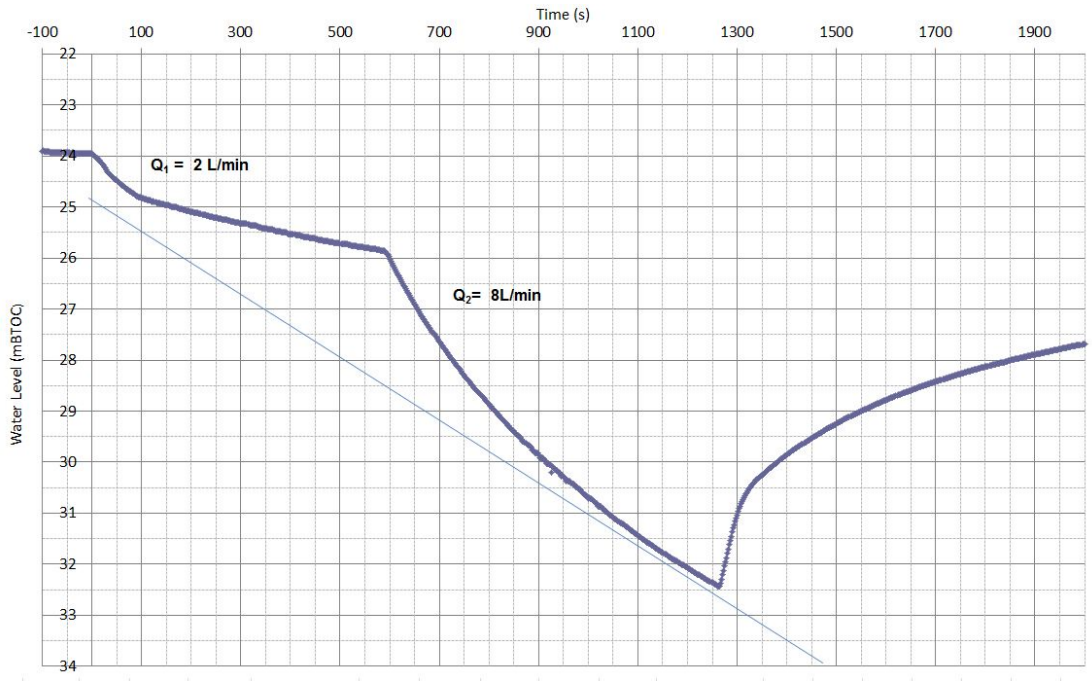

Figure 46: BR-6224 Step Drawdown Test

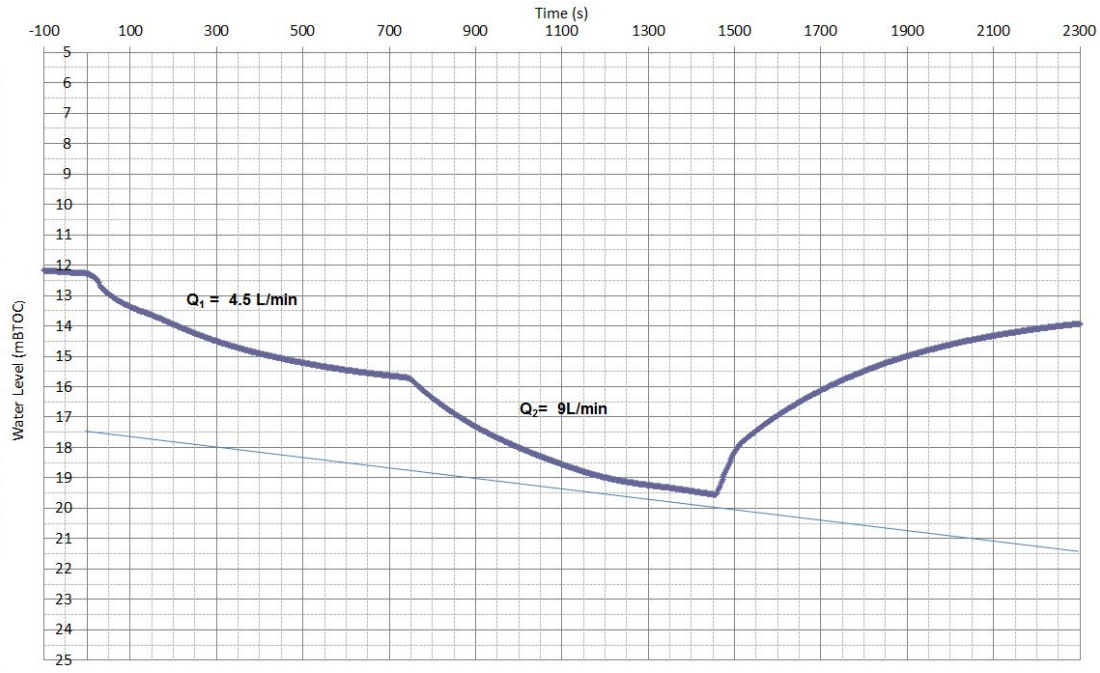

Figure 47: BR-6241 Step Drawdown Test

Calculated specific capacities ranged from less than 0.5 to a high of 40 litres per minute per metre (L/min/m) of drawdown, averaging 3.5 L/min/m of drawdown indicating a generally low permeability rock mass consistent with what would be expected for a sparsely fractured granitic plutonic environment. Only two of the test results yielded a specific capacity greater than 10 L/min/m of drawdown; values of 12.5 and 40 L/min/m of drawdown were obtained from boreholes BR-6217 and BR-0433 respectively. Figure 2-16 in the Hydrogeology TSD provides a histogram of the calculated specific capacity results along with the numbers of these exploration holes that intersected Shear Zones. Figure 2-18 provides the distribution of these results in the area of the proposed west pit. It should be noted that the results are mapped to the borehole collar location whereas for angled boreholes, the main shear/fractures making water may have been intersected at some depth down the borehole to the west and thus not directly below the borehole collar.

3.2 Additional Hydraulic Testing of BR-0433

The results of the passive thermal profile revealed a groundwater temperature of 5.5°C at the water surface declining 0.015°C per metre to a depth of approximately 25 m below which the groundwater temperature slowly began increasing with a measured gradient of approximately 0.008°C /m. Golder interprets this thermal profile as being consistent with a hydraulically active shallow zone 20 to 30 m thick. The results of passive thermal profile testing are presented on Figure 48.

The heat pulse flow testing found an initial flow velocity of 0.0105 m/s at a depth of 8 metres. This fell to 0.011 m/s at 25 m and remained the same at 50 m. At 60 m, the observed velocity fell to 0.0088 m/s. These measurements indicate that more than half the yield (58%) in BR-0433 is entering the borehole below 60 m depth. The results of the heat pulse flow testing are presented on Figure 49.

Generally similar results were obtained comparing the well yield before and after isolating the deeper portions of BR-0433 using an inflatable packer set at a depth of 100 m. For this testing, a representative total hole drawdown of 0.24 m was obtained for Q =12.5 L/min and t = 10,000 s. After packer inflation, a drawdown of 0.37 m was obtained for Q =12.0 L/min and t = 10,000 s indicating that approximately 60% of the total yield in BR-0433 is entering the borehole below 100 m depth. A time-drawdown plot for the constant rate pumping test is shown on Figure 2-17 in the Hydrogeology TSD.

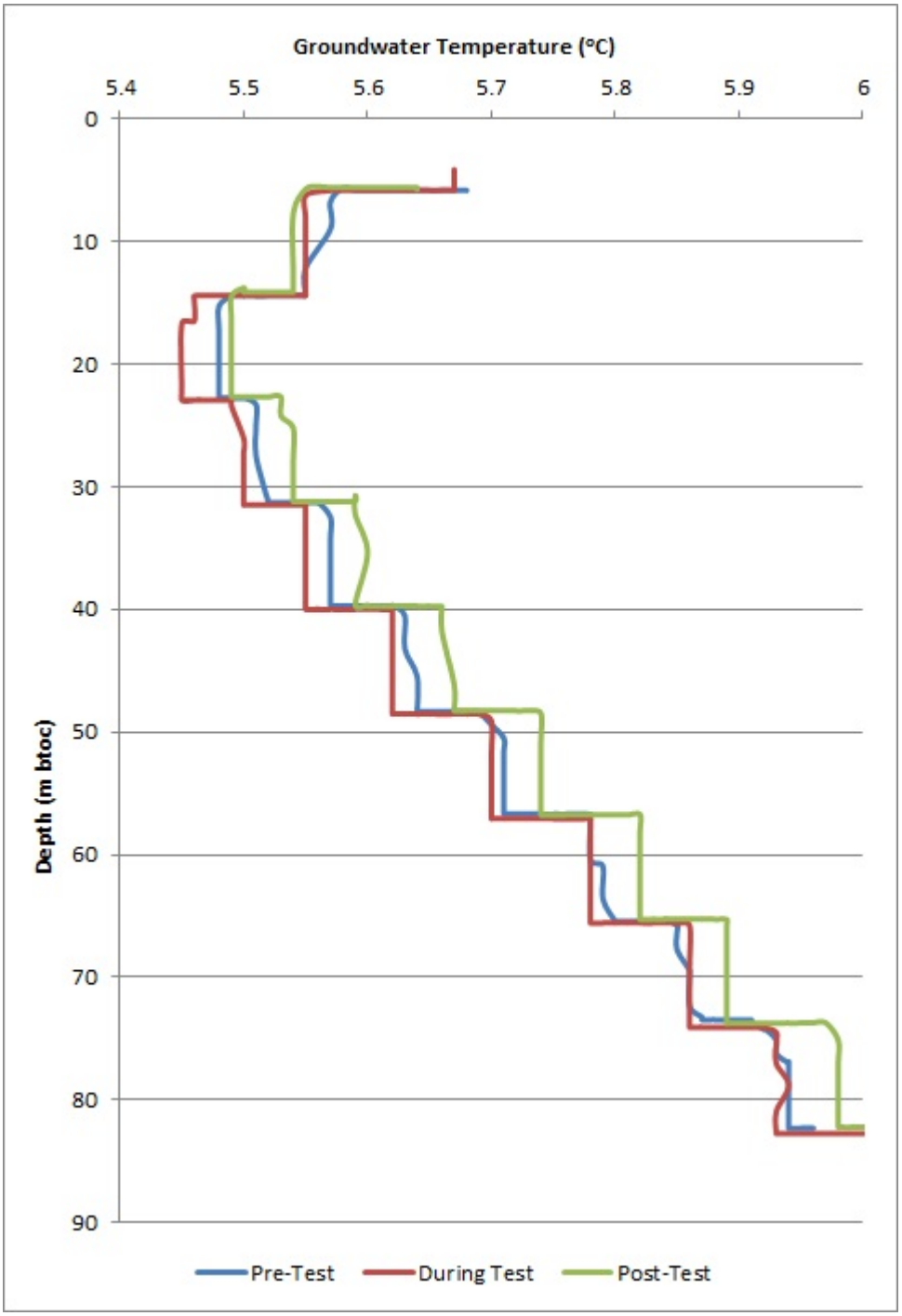

Figure 48: Passive Thermal Profiles of Upper 80 m Water Column

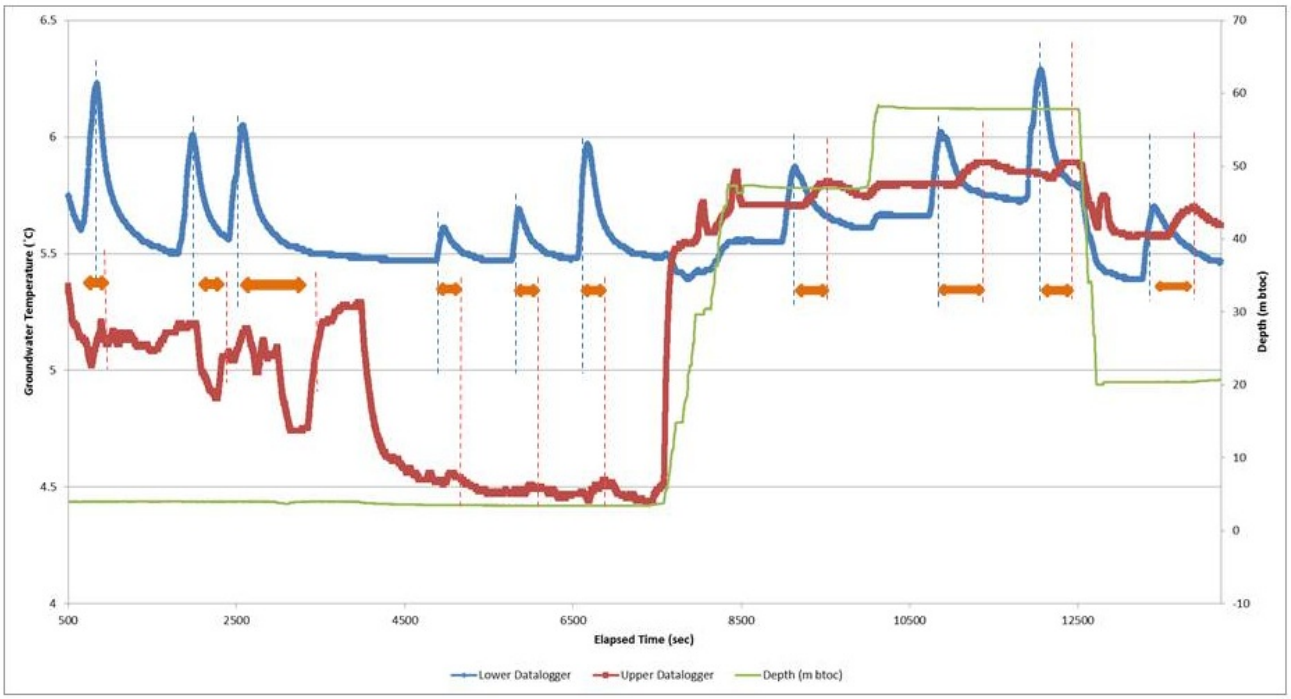

Figure 49: Heat Pulse Flow Testing

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McMurry, J., D.A. Dixon, J.D. Garroni, B.M. Ikeda, S. Stroes-Gascoyne, P. Baumgartner and T.W. Melnyk. 2003. *Evolution of a Canadian deep geologic repository: Base scenario*. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10092-R00. Toronto, Canada.

Stevenson, D.R., E.T. Kozak, C.C. Davison, M. Gascoyne, R.A. Broadfoot. 1996. *Hydrogeologic characterization of domains of sparsely fractured rock in the granitic Lac du Bonnet Batholith, Southeastern Manitoba, Canada*. Atomic Energy of Canada Limited Report, AECL-11558, COG-96-117. Pinawa, Canada.

APPENDIX 2.VIII

Constant Rate Pumping Tests

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

From September 2011 to March 2012, three constant rate pumping tests of up to 94 hours duration were conducted at two angled PQ diameter exploration boreholes; BR-0220 and BR-0231. These two boreholes are located at the southwest end of the west pit as shown in Figure 2-6 in the Hydrogeology Technical Support Document (TSD).

In September 2011 Golder Associates Ltd. (Golder) carried out a screening level hydrogeological field investigation to obtain preliminary information regarding the hydraulic properties and potential connectivity of the primary geologic structural features (Upper Shear Zone, FW Splay 2, and/or the intersection zone of FW Splay 2 with the Lower Shear Zone) in the southwest portion of the west pit. The field investigation included constant rate pumping tests in two existing PQ diameter angled exploration boreholes (BR-0220 and BR-0231). These two boreholes were selected for screening level pumping tests for the following reasons:

- PQ diameter boreholes are wide enough to accept up to a 100 mm diameter submersible well pump capable of yielding greater than 3.5 L/sec from depths of 60 m below top of casing (mbtoc).
- Both boreholes intersect the Upper and Lower Shear Zones.
- These two boreholes were the closest existing PQ diameter boreholes to geotechnical borehole GT-04 in which a sand-filled seam with an aperture width of 550 mm was intercepted at 178 m below ground surface (mbgs) within the Lower Shear Zone. This structural feature exhibited a hydraulic conductivity greater than 10-6 m/s. Given that boreholes BR-0220 and BR-0231 both intersected the Lower Shear Zone, it was possible that similar structural features associated with the Shear Zones may have been intersected by these two boreholes, in which case conducting pumping tests at these locations could potentially provide information regarding the hydraulic characteristics of the Upper and Lower Shear Zones.
- Both boreholes were vehicle-accessible.

The results of the short duration pumping tests carried out in October 2011 (Appendix 2.VI) indicated that the Upper and Lower Shear Zones are generally poorly transmissive throughout the southwest portion of the west pit. The results of the two previous screening level pumping tests at BR-0220 and BR-0231 indicated that the bedrock mass appears to be well connected hydraulically throughout the west pit with the observed hydraulic response not obviously correlated with either the Upper or the Lower Shear Zones. It was noted, at the time, that the 12-hour pumping test at BR-0220 was of a short duration and water levels in the pumping well had not been drawn below the level of Marmion Reservoir. As a result of these findings, Golder carried out a 4-day (94-hour) pumping test at BR-0220 in order to lower the water level in the pumping well below the level of Marmion Reservoir to better assess the hydraulic connection through what is likely a more transmissive fracture zone. The testing program was designed to assess if the hydraulic connection to the reservoir is present in the upper more permeable and slightly weathered rock mass or in the extensive shear zones at depth. It should be noted that Golder, on behalf of Osisko Hammond Reef Gold Ltd. (OHRG), obtained the Ontario Ministry of the Environment (MOE) Permit to Take Water (PTTW) number 0833-8PQMAX prior to initiating this pumping test.

2.0 METHODS

2.1 12-hour Pumping Test at BR-0220

On September 9, 2011, Golder installed a 100 mm diameter ITT Goulds submersible well pump inside borehole BR-0220 to a depth of 39 mbtoc. The static water level observed prior to pump installation was 13.40 mbtoc. The pump was lowered on 50.8 mm diameter steel rods using a manual chain block winch mounted overhead on a steel tripod (Photo 1). Two Solinst *Levelogger*™ data logging pressure transducers (data loggers) connected to direct read cables were attached to the steel pipe section just above the pump and the cables were extended to surface to allow for real-time monitoring of water levels in the pumping well. The flow rate was controlled using a manual gate valve plumbed to the steel rods at the well head. Pumped water was routed through the gate valve and two flow meters prior to being discharged in a nearby low-lying area.

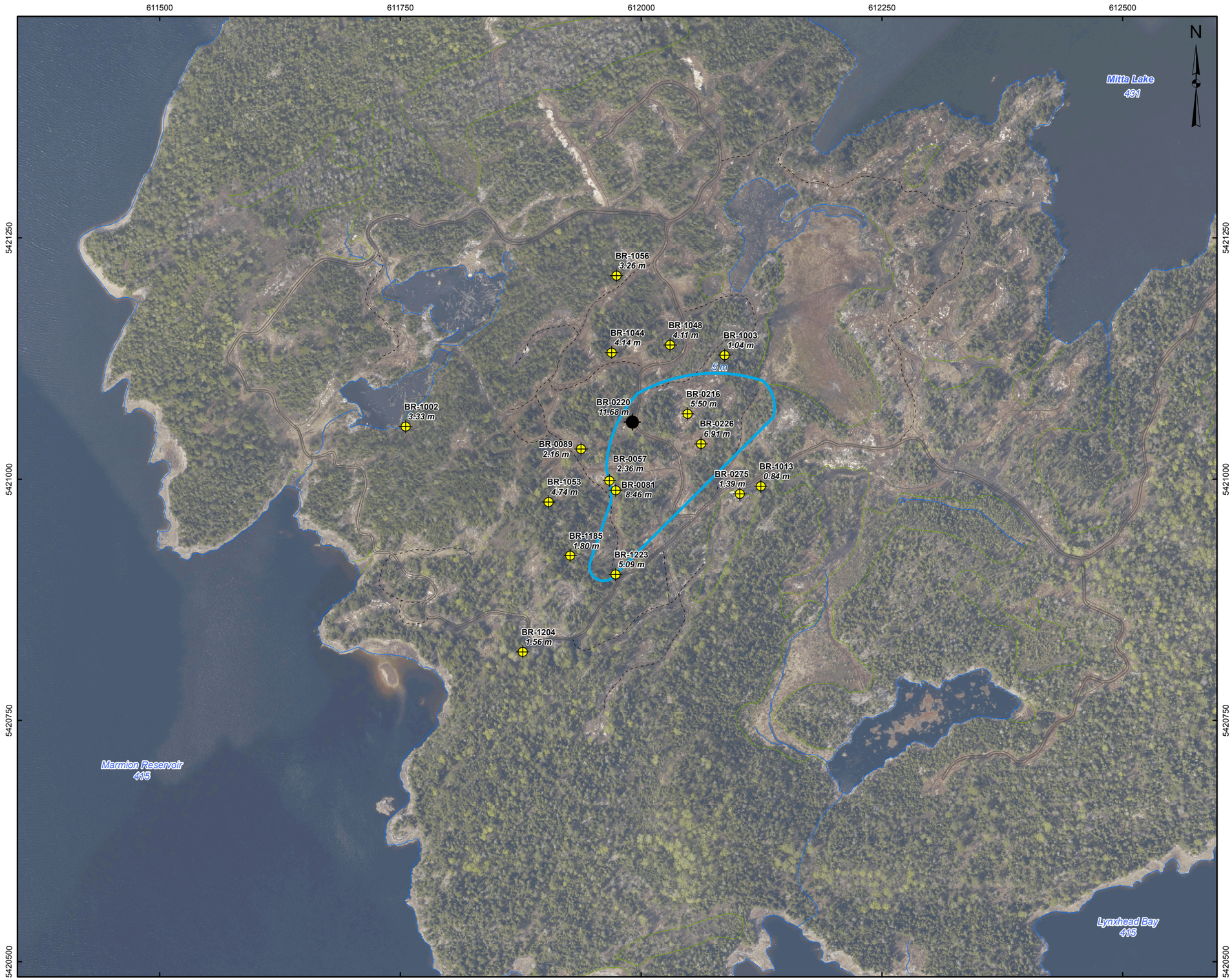
Photo 1: Equipment used for 12-hour pumping test at BR-0220. Photos 1A and 1B show pump being lowered into borehole using chain block and tripod. Photo 1C shows the two flow meters used to monitor flow rate. Photo 1D shows how the discharge water was routed through the flow meters prior to being discharged.

Prior to initiating the pumping test at BR-0220, Golder conducted a brief step drawdown test in order to establish a suitable pumping rate that would achieve maximum drawdown in the pumping well without exceeding 50,000 L/day of discharge water. The pumping test could not exceed a total volume of 50,000 L/day because a MOE PTTW was not obtained for this pumping test and the maximum allowable water taking without a MOE PTTW is 50,000 L/day. Based on the results of the step drawdown test, it was established BR-0220 could be pumped at a rate of approximately 50 L/min for a duration of up to 16 hours without lowering the water level below the pump intake or exceeding the maximum allowable water taking limit of 50,000 L/day.

An array of observation wells was established prior to initiating the pumping test by selecting a number of existing angled exploration boreholes within a 264 m radius of the pumping well (BR-0220) in which water levels would be monitored manually (using an electronic water level meter) or continuously using data loggers. A total of 17 observation wells were established and 11 of these were instrumented with data loggers. The data loggers were suspended within the observation wells from stainless steel cables attached to the exterior of the well casing. Data loggers were generally installed approximately 10 to 15 m below the static water level, although installation depths varied depending on the calibrated depth range of each instrument. Manual water levels were recorded prior to installation of data loggers and at each of the non-instrumented observation wells prior to starting the pump. Observation well locations are shown in Figure 1.

Exploration boreholes that were damaged, inaccessible or located in swampy areas and potentially hydraulically connected to adjacent surface water features (i.e., static water level in borehole was similar to water levels observed in surrounding surface water features) were not used as observation wells.

The exploration boreholes selected as observation wells for this pumping test are listed in Table 1 and locations are also shown in Figure 1. Table 1 also provides Universal Transverse Mercator (UTM) coordinates for BR-0220 and the observation wells, radial distances of observation wells from BR-0220 and methods of water level measurement.



LEGEND

0.68 m Maximum Drawdown

- Observation Well
- Pumping Well
- Inferred Groundwater Drawdown
- Ditch
- Marsh/Swamp
- River/Stream
- Road
- Trail

Radial Distances of Observation Wells from Pumping Well BR-0220

Exploration Borehole	Radial Distance (m)
BR-0216	58
BR-0089	60
BR-0226	63
BR-0057	65
BR-0081	73
BR-1044	75
BR-1048	89
BR-1003	118
BR-1053	120
BR-0275	134
BR-1013	149
BR-1185	153
BR-1056	153
BR-1223	159
BR-1002	236
BR-1204	264

NOTE

Fractures that responded to pumping located variably down angled exploration holes to northwest of borehole collars.

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Image Provided by OSISKO Hammond Reef Gold Project Ltd (July 2010)
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

50 0 50 100 150 200 250
SCALE 1:4,000 METRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
MONITORING LOCATIONS AND WATER LEVEL DRAWDOWN FOR 12-HOUR PUMPING TEST AT BR-0220

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	5 Feb. 2013		
CHECK	MSO	5 Feb. 2013		
REVIEW	JMP	5 Feb. 2013		

FIGURE: 1

G:\Projects\2010\10-1118-0020_BrettResources_HammondReef\GIS\MXDs\Draft\Hydrogeology\TSD\Appendix\Pumping_Test_at_BR-0220.mxd

Table 1: Pumping and Observation Well Details for 12-hour Pumping Test at BR-0220 (September 2011)

	UTM Location (NAD 83, Zone 15U)		Radial Distance from Pumping Well	Method of Water Level Measurement	
	Easting	Northing	(m)	Transducer	Manual
Pumping Well					
BR-0220	611991	5421059	0	Yes	No
Observation Wells					
BR-0081	611973	5420988	73	Yes	No
BR-0216	612048	5421068	58	Yes	No
BR-0226	612009	5421119	63	Yes	No
BR-1002	611755	5421055	236	Yes	No
BR-1003	612087	5421129	118	Yes	No
BR-1044	611969	5421131	75	Yes	No
BR-1048	612030	5421139	89	Yes	No
BR-1056	611974	5421211	153	Yes	No
BR-1185	611926	5420921	153	Yes	No
BR-1204	611877	5420821	264	Yes	No
BR-0057	611967	5420998	65	No	Yes
BR-0089	611937	5421031	60	No	Yes
BR-0275	612102	5420985	134	No	Yes
BR-1013	612124	5420993	149	No	Yes
BR-1053	611904	5420977	120	No	Yes
BR-1223	611973	5420901	159	No	Yes

The pumping test was initiated at 09:45 on September 10, 2011, and borehole BR-0220 was pumped for 12 hours and 15 minutes (a total of 735 minutes) at a constant rate of approximately 50 L/min until the pump was turned off at 22:00 that same day. Data loggers were set to begin monitoring water levels several hours prior to starting the pump in order to establish water levels in the pumping well and observation wells prior to the test and continued monitoring for approximately 12 hours after pumping stopped to record water level recovery at each location. Four manual water level measurements were obtained at each of the non-instrumented observations wells during pumping and three additional water level measurements were obtained during the 12-hour recovery period after pumping had stopped.

During pumping, the rate of discharge (flow rate) was monitored and recorded frequently. The flow rate was measured routinely by recording the volume of water passing through the two flow meters over a fixed time interval (i.e., litres per minute) and verified occasionally by recording the volume of water flowing from the discharge hose over a fixed time interval (using a graduated bucket and a stopwatch).

Samples of the discharge water were collected approximately every three hours for the duration of the pumping test. Sampling was performed consistent with recognized standard field sampling methods.

The following sample collection protocols were followed:

- **Calibration** – field parameters were measured with a handheld meter calibrated in the field with calibration solutions provided by the supplier. Calibration for pH (two points: 4 and 7), and electrical conductivity was carried out daily before sampling began and documented in the field notes.
- **Sampling Equipment and Handling** – Sterile gloves were worn during sample collection. Sample bottles were provided by the contract analytical laboratory. Sample bottles were pre-charged with the appropriate preservatives at the analytical laboratory. Samples were stored in a cooler with ice and maintained in a cool state until shipped to the laboratories. As much as possible, samples were shipped in time to meet the required holding times. However, this was not always possible for nitrate, nitrite, and ortho-phosphate (each with holding times of 48 hours) given the remote location.
- **Sample Filtration** – Samples for metals and organic carbon were collected as follows:
  - Unfiltered (total organic carbon).
  - Field filtered (dissolved metals and dissolved organic carbon) using a 0.45 µm Waterra^{TM} filter into the appropriate bottles.
- **Field staff labelled samples with unique sample numbers**. Field observations (e.g., clarity, colour, odour, etc.), as well as the sample collection procedures and techniques were documented.
- **Field Parameter Measurement** – Measurements of pH, temperature and electrical conductivity were taken during the collection of groundwater samples.

A total of four groundwater samples and one duplicate sample (for QA/QC) were collected and submitted under chain of custody to ALS Laboratories in Thunder Bay, Ontario, for analysis of the following water quality parameters outlined in the Ontario *Mining Act* (Ontario Regulation [O. Reg.] 240/00):

- **General parameters** - pH, alkalinity, acidity, conductivity, total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC).
- **Major ions** – calcium, magnesium, potassium, sodium, sulphate, chloride, fluoride, carbonate (CO_3^-), bicarbonate (CO_3^{2-}) and free cyanide. Hardness was calculated based on major ions.
- **Nutrients** – nitrate (NO_3-N), nitrite (NO_2-N), total ammonia (NH_3-N), phosphorus, and ortho-phosphates. Un-ionized ammonia (NH_3) was calculated based on the NH_3-N concentration, and the field pH and temperature.
- **Organics** – phenols.
- **Metals** – dissolved.

2.2 24-hour Pumping Test at BR-0231

As discussed in Section 1, exploration borehole BR-0231 was also selected as a pumping well for a screening level pumping test to investigate the hydraulic properties and potential connectivity of the primary geologic structural features in the southwest portion of the west pit.

On September 8, 2011, Golder conducted a brief step drawdown test in BR-0231 to determine if a 50 mm diameter Grundfos *RediFlo-2*™ submersible pump would be sufficient to conduct a pumping test in this borehole, or if the larger 100 mm diameter ITT Goulds submersible well pump used for the 12-hour pumping test at BR-0220 would be required to obtain sufficient drawdown. The results of the step test indicated that the maximum achievable flow rate (~20 L/min) using the 50 mm pump would be sufficient to obtain significant drawdown in BR-0231. It was estimated that the maximum daily volume of water taken from the well at this pumping rate would be approximately 29,000 L so a MOE PTTW was not required for this pumping test.

The pump was lowered by hand into borehole BR-0231 to a depth of approximately 30 mbtoc. The static water level observed prior to pump installation was 12.04 mbtoc. Two data loggers connected to direct read cables were attached to the water hose approximately 0.5 m above the pump and the cables were extended to surface to allow for real-time monitoring of water levels in the pumping well. The flow rate was controlled using a Grundfos Variable Frequency Drive to regulate pump speed. Pumped water was routed through a flow meter prior to being discharged in a nearby low-lying area.

An array of observation wells was established prior to initiating the pumping test by selecting a number of existing angled exploration boreholes within a 266 m radius of the pumping well (BR-0231) in which water levels would be monitored manually (using an electronic water level meter) or continuously using data loggers. A total of 16 observation wells were established and 10 of these were instrumented with data loggers. The transducers were suspended within the observation wells from stainless steel cables attached to the exterior of the well casing. Data loggers were generally installed approximately 10 to 15 m below the static water level, although installation depths varied depending on the calibrated depth range of each data logger. Manual water levels were recorded prior to installation of data loggers and at each of the non-instrumented observation wells prior to starting the pump. Observation well locations are shown in Figure 2.

Exploration boreholes that were damaged, inaccessible or located in swampy areas and potentially hydraulically connected to adjacent surface water features (i.e., static water level in borehole was similar to water levels observed in surrounding surface water features) were not used as observation wells.

The exploration boreholes selected as observation wells for this pumping test are listed in Table 1 and locations are also shown on Figure 2. Table 2 also provides UTM coordinates for BR-0231 and the observation wells, radial distances of observation wells from BR-0231 and methods of water level measurement.

611500 611750 612000 612250 612500

5421500 5421250 5421000 5420750

N

Mitta Lake
431.013

Marmion Lake
415

BR-1229
0.23 m

2 m

BR-1061
1.12 m

BR-1056
2.11 m

BR-1062
2.48 m

BR-0231A
8.62 m

BR-1040
1.88 m

BR-1044
1.93 m

BR-1048
0.10 m

BR-1042
1.88 m

BR-0089
2.27 m

BR-0226
1.31 m

BR-0057
1.64 m

BR-1013
0.2 m

BR-1053
0.77 m

BR-0081
0.74 m

BR-0275
0.19 m

BR-1223
0.51 m

LEGEND

1.19 m Maximum Drawdown
Observation Well
Pumping Well
Inferred Groundwater Drawdown
Ditch
Marsh/Swamp
River/Stream
Road
Trail

Radial Distances of Observation Wells from Pumping Well BR-0231

Exploration Borehole	Radial Distance (m)
BR-1056	77
BR-1040	79
BR-1044	70
BR-1048	24
BR-1061	90
BR-1062	93
BR-0226	127
BR-0089	161
BR-1229	164
BR-1042	169
BR-0057	176
BR-0275	189
BR-1013	191
BR-1053	225
BR-0081	183
BR-1223	266

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Image Provided by OSISKO Hammond Reef Gold Project Ltd (July 2010)
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

50 0 50 100 150 200 250
SCALE 1:4,000 METRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
MONITORING LOCATIONS AND WATER LEVEL DRAWDOWN FOR 24-HOUR PUMPING TEST AT BR-0231

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008		
GIS	JO	5 Feb. 2013		
CHECK	MSO	5 Feb. 2013		
REVIEW	JMP	5 Feb. 2013		

FIGURE: 2

G:\Projects\2010\10-1118-0020_BretlResources_HammondReefGIS\MXDs\Draft\HydrogeologyTSD\Appendix\Pumping_Test_at_BR-0231A.mxd

Table 2: Pumping and Observation Well Details for 24-hour pumping test at BR-0231 (September 2011)

	UTM Location (NAD 83, Zone 15U)		Radial Distance from Pumping Well	Method of Water Level Measurement	
	Easting	Northing	(m)	Transducer	Manual
Pumping Well					
BR-0231A	612033	5421161	0	Yes	No
Observation Wells					
BR-0081	612031	5420899	262	Yes	No
BR-0226	612062	5421037	127	Yes	No
BR-1040	612111	5421146	79	Yes	No
BR-1042	611875	5421103	169	Yes	No
BR-1044	612005	5421084	82	Yes	No
BR-1048	612066	5421080	87	Yes	No
BR-1056	612009	5421163	24	Yes	No
BR-1061	612078	5421239	90	Yes	No
BR-1062	611942	5421177	93	Yes	No
BR-1229	611971	5421312	164	Yes	No
BR-0057	611967	5420998	176	No	Yes
BR-0089	611937	5421031	161	No	Yes
BR-0275	612102	5420985	189	No	Yes
BR-1013	612124	5420993	191	No	Yes
BR-1053	611904	5420977	225	No	Yes
BR-1223	611973	5420901	266	No	Yes

The pumping test was initiated at 17:07 on September 11, 2011, and borehole BR-0231 was pumped for 24 hours and 7 minutes (a total of 1,447 minutes) at a rate of approximately 20 L/min until the pump was turned off at 17:14 on September 12, 2011. The data loggers were set to begin monitoring water levels several hours prior to starting the pump in order to establish static water levels in the pumping well and observation wells prior to the test and continued monitoring for approximately 21 hours after pumping stopped to record water level recovery at each location. Six manual water level measurements were obtained at each of the non-instrumented observations wells during pumping and one additional water level measurement was obtained at each location during the recovery period after pumping had stopped.

During pumping, the rate of discharge (flow rate) was monitored and recorded frequently. The flow rate was measured routinely by recording the volume of water passing through the flow meter over a fixed time interval (i.e., litres per minute) and verified occasionally by recording the volume of water flowing from the discharge hose over a fixed time interval (using a graduated bucket and a stopwatch).

Four samples of the discharge water were collected throughout the pumping test. The first sample was collected after three hours of pumping, while subsequent samples were collected after 18, 22 and 24 hours of pumping. Sampling was performed consistent with recognized standard field sampling methods as outlined in Section 2.1.

The samples were submitted under chain of custody to ALS Laboratories in Thunder Bay, Ontario, for analysis of water quality parameters outlined in O. Reg. 240/00, as indicated in Section 2.1.

2.3 94-hour Pumping Test at BR-0220

The results of the specific capacity tests indicated that the Upper and Lower Shear Zones are generally poorly transmissive throughout the southwest portion of the west pit. The results of the two previous screening level pumping tests at BR-0220 and BR-0231 indicated that the bedrock mass appears to be well connected hydraulically throughout the west pit with the observed hydraulic response not obviously correlated with either the Upper or the Lower Shear Zones. It was noted, at the time, that the 12-hour pumping test at BR-0220 was of a short duration and water levels in the pumping well had not been drawn below the level of Marmion Reservoir. As a result of these findings, Golder carried out longer duration pumping test at BR-0220 in order to lower the water level in the pumping well (BR-0220) below the level of Marmion Reservoir to better assess the hydraulic connection through what is likely a more transmissive fracture zone. The testing program was designed to assess if the hydraulic connection to the reservoir is present in the upper more permeable and slightly weathered rock mass or in the extensive shear zones at depth. On behalf of OHRG, Golder obtained MOE PTTW number 0833-8PQMAX prior to initiating this pumping test as the anticipated daily water taking throughout this pumping test was anticipated to be greater than 50,000 L/day.

From March 8 to 9, 2012, Golder installed a 100 mm diameter ITT Goulds submersible well pump inside borehole BR-0220 to a depth of 61 mbtoc. The static water level observed prior to pump installation was 17.85 mbtoc. The pump was lowered on 50.8 mm diameter steel rods using a manual chain block winch mounted overhead on a steel tripod (Photo 1). Two data loggers connected to direct read cables were attached to the steel pipe section just above the pump and the cables were extended to surface to allow for real-time monitoring of water levels in the pumping well. A Schlumberger *BaroDiver*™ barometric pressure transducer was also used to obtain a continuous record of barometric pressure for water level data compensation.

The flow rate during pumping was controlled using a manual gate valve plumbed to the steel rods at the well head. Pumped water was routed through the gate valve, then a flow meter and an orifice weir prior to being discharged into a sediment collection basin then pumped into nearby low-lying areas (Photo 2).

Photo 2: Equipment used for 94-hour pumping test at BR-0220. Photo 2A shows the water being routed from the well head to through the flow meter. Photo 2B shows the water being routed from the flow meter to the orifice weir. Photo 2C shows manometer. Photo 2D shows the orifice weir and pumped water discharging into a sediment collection basin.

Prior to initiating the pumping test at BR-0220, Golder conducted a step drawdown test in order to establish a suitable pumping rate that would lower the water level in BR-0220 below the level of Marmion Reservoir over a 5-day period without lowering the water level below the pump intake. Based on the results of the step drawdown test, it was established that BR-0220 could be pumped at a rate of approximately 85 L/min for up to 5 days to achieve maximum drawdown in BR-0220 without lowering the water level below the pump intake.

An array of observation wells was established prior to initiating the pumping test by selecting a number of existing angled exploration boreholes within a 655 m radius of the pumping well (BR-0220) in which water levels would be monitored using data loggers. Water levels were not monitored manually at any observation wells throughout this pumping test due to access limitations as a result of deep snow cover. A total of 16 accessible observation wells were located and instrumented with data loggers. The data loggers were suspended within

the observation wells from stainless steel cables attached to the exterior of the well casing. Data loggers were generally installed approximately 10 to 15 m below the static water level, although installation depths varied depending on the calibrated depth range of each data logger. Manual water levels were recorded prior to installation and removal of data loggers.

The array of observation wells used for this pumping test were selected primarily based on previous experience at the Project Site. Boreholes that showed water level response to previous pumping tests were targeted. It is noteworthy that the depth of snow cover at the time of the field program limited access to select locations, which limited the number of exploration boreholes that could be used in the observation well array for this pumping test.

The exploration boreholes selected as observation wells for this pumping test are listed in Table 3. Table 3 also provides UTM coordinates for BR-0220 and the observation wells, radial distances of observation wells from BR-0220 and methods of water level measurement.

Table 3: Pumping and Observation Well Details for 94-hour Pumping Test at BR-0220 (March 2012)

	UTM Location (NAD 83, Zone 15U)		Radial Distance from Pumping Well	Method of Water Level Measurement	
	Easting	Northing	(m)	Transducer	Manual
Pumping Well					
BR-0220	611991	5421059	0	Yes	No
Observation Wells					
BR-0073	611672	5421085	320	Yes	No
BR-0413	611584	5421039	408	Yes	No
BR-0433	611849	5420891	220	Yes	No
BR-0437	612529	5420863	573	Yes	No
BR-1011	612507	5420734	610	Yes	No
BR-1051	612591	5420965	607	Yes	No
BR-1056	611974	5421211	153	Yes	No
BR-1061	612078	5421239	200	Yes	No
BR-1070	612037	5420624	438	Yes	No
BR-1095	612031	5421411	354	Yes	No
BR-1150	612334	5420808	425	Yes	No
BR-1168A	612286	5420927	323	Yes	No
BR-1174	611590	5421268	452	Yes	No
BR-1176	611864	5421204	192	Yes	No
BR-1207	611849	5421363	336	Yes	No
BR-6217	612627	5421214	655	Yes	No

The pumping test was initiated at 16:11 on March 10, 2012, and borehole BR-0220 was pumped for 94 hours and 4 minutes (a total of 5,640 minutes) at a constant rate of approximately 85 L/min until the pump was turned off at 14:15 on March 14. Data loggers were set to begin monitoring water levels several hours prior to starting the pump in order to establish static water levels in the pumping well and observation wells prior to the test and continued monitoring for approximately 24 hours after pumping stopped to record water level recovery at each location.

During pumping, the rate of discharge (flow rate) was monitored and recorded frequently. The flow rate was measured routinely by recording the volume of water passing through the flow meter over a fixed time interval (i.e., litres per minute), monitoring the water level in the manometer attached to the orifice weir and occasionally recording the volume of water discharging from the orifice weir over a fixed time interval (using a graduated bucket and a stopwatch).

It should be noted that unseasonably mild weather conditions were encountered during this pumping test and the snow cover melted consistently between March 12 and March 16. A 2 m in the water level in BR-0220 was observed from 11:30 to 18:00 on March 13, suggesting that melt water was influencing groundwater levels throughout the test site. As a result, the pumping test was abandoned on March 14 and water level recovery rates were not measured or recorded.

A total of 488,100 L (488.1 m^3) of water were pumped over the duration of the 4-day pumping test. Discharge water was pumped into two nearby low-lying areas as directed by OHRG environmental staff. The discharge locations were monitored routinely throughout the pumping test and all necessary measures for siltation and erosion control were taken to limit the erosion and sediment transport to receiving surface water. Discharge water was diverted between the two locations as required to minimize overland flow and avoid over-filling either location.

Three samples of the discharge water were collected throughout the pumping test. The first sample was collected after approximately 20 hours of pumping, while subsequent samples were collected after approximately 46 and 94 hours of pumping. Sampling was performed consistent with recognized standard field sampling methods as outlined in Section 2.1.

The samples were submitted under chain of custody to ALS Laboratories in Thunder Bay, Ontario, for analysis of water quality parameters outlined in the Ontario *Mining Act* (Ontario Regulation 240/00) as outlined Section 2.1.

3.0 RESULTS

The test details for pumping tests at BR-0220 and BR-0231 are summarized in Table 4.

Table 4: Summary of Pumping Tests

Pumping Well	Testing Dates	Pumping Duration	Recovery Duration	Total Test Duration	Pumping Rate		Total Volume Pumped		Well Depth	Maximum Drawdown in Pumping Well	Shear Zone Intersections
					L/min	m^3/day	(L)	(m^3)	(m)	(m)	
BR-0220	September 10 to 11, 2011	12.25 hrs (735 mins)	12 hrs (720 mins)	24.25 hrs (1,455 mins)	50.4	72.58	37,044	37.04	370.94	11.68	Upper/Lower
BR-0231	September 11 to 13, 2011	24.1 hours (1,447 mins)	23.9 hours (1,434 mins)	48 hours (2,881 mins)	20	28.8	28,940	28.94	265.18	5.14	Upper/Lower
BR-0220	March 10 to 14, 2012	94 hrs (5,640 mins)	n/a	94 hrs (5,640 mins)	85	122.4	488,100	488.1	370.94	26.06	Upper/Lower

3.1 12-hour Pumping Test at BR-0220

Borehole BR-0220 was pumped for 735 minutes at a constant rate of approximately 50 L/min during which time the water level in the borehole declined a total of 11.68 m. After the pump was turned off, the water level fully recovered within 12 hours. Details of the drawdown and recovery observed in BR-0220 and the observation wells are summarized on Table 2-6 in the Hydrogeology TSD. Hydrographs of the water levels in BR-0220 and the observation wells are shown in Figure 3.

Water levels in nearly all of the observation wells responded to pumping and most responded almost instantaneously. The water level in BR-0220 was lowered by 11.68 m during the testing period and drawdown throughout the observation well array ranged from 0.84 m (BR-1013) to 8.46 m (BR-0081). The pattern of water level drawdown at the end of the pumping period is presented in plan view in Figure 1.

It is noteworthy that a positive boundary that could not be overcome at the established pumping rate (50 L/min) was encountered in BR-0220 at a water level elevation of approximately 418 masl.

3.2 24-hour Pumping Test at BR-0231

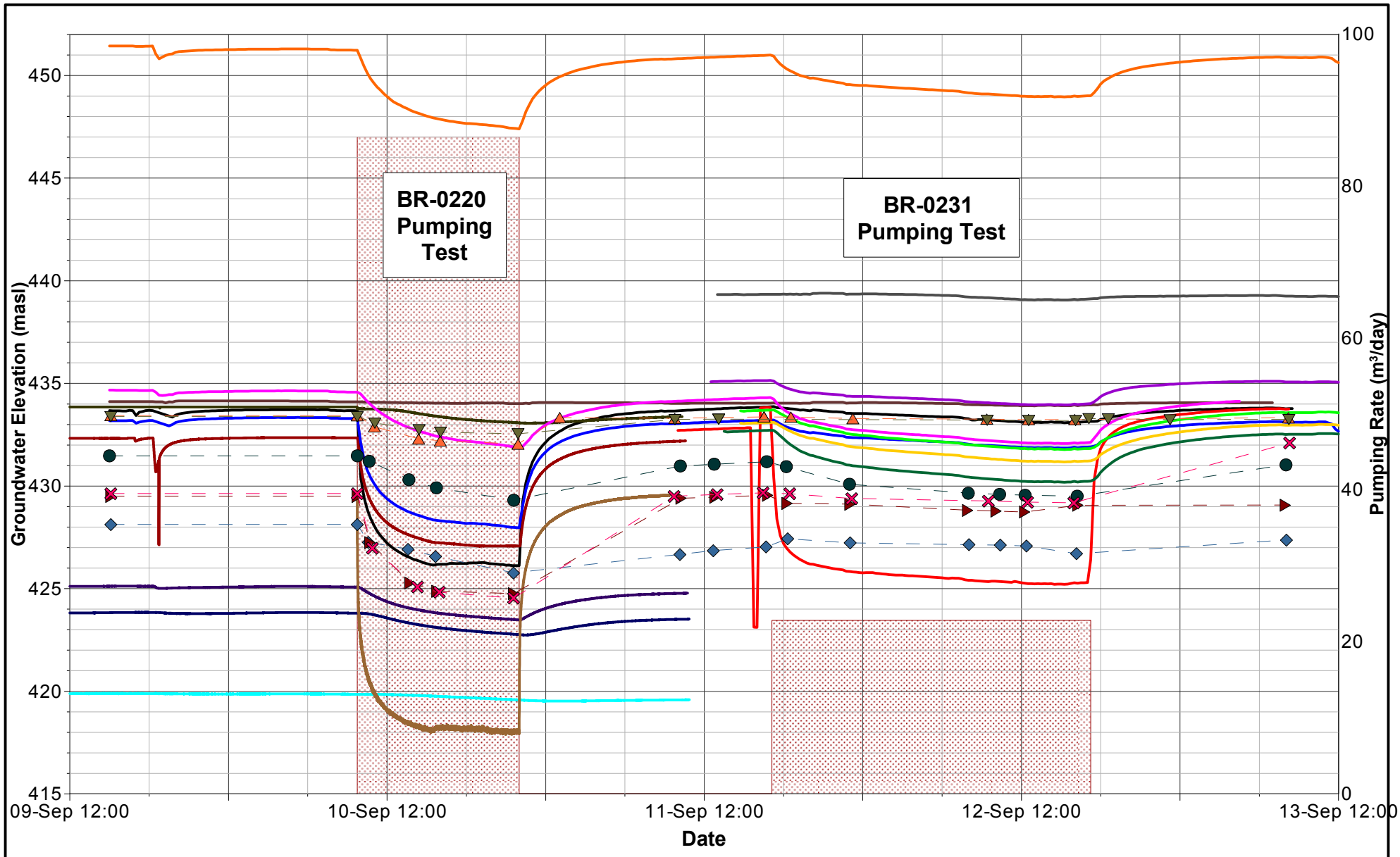
Borehole BR-0231 was pumped for 1,447 minutes at a constant rate of approximately 20 L/min during which time the water level in the borehole declined a total of 8.62 m. After the pump was turned off, the water level fully recovered within 12 hours. Details of the drawdown and recovery observed in BR-0231 and the observation wells are summarized on Table 2-7 in the Hydrogeology TSD. Hydrographs of the water levels in BR-0231 and the observation wells are shown in Figure 3-1.

Water levels in most of the observation wells responded to pumping and many responded nearly instantaneously, although the responses observed throughout the observation well array were generally more subdued than those observed during the previous pumping test at BR-0020, likely due to the lower pumping rate established for this test. The water level in BR-0231 was lowered by 8.62 m during the testing period and drawdown throughout the observation well array ranged from 0.10 m (BR-1048) to 2.48 m (BR-1062). The total drawdown at the end of test pumping for all observation wells is shown in plan view in Figure 2.

3.3 94-hour Pumping Test at BR-0220

Borehole BR-0220 was pumped for 94 hours (5,640 minutes) at a constant rate of approximately 85 L/min during which time the water level in the borehole declined a total of 26.06 m. Decreasing water levels due to pumping were observed in three observation wells (BR-0433, BR-1056 and BR-1061) and drawdown ranged from 0.68 m to 6.48 m. The water levels in each of these observation wells responded nearly instantaneously to pumping. Water levels in the remaining observation wells were influenced by infiltration of snow melt and did not respond to pumping. At many locations the groundwater level actually increased throughout the pumping test. After pumping, the water level in the pumping well (BR-0220) and observation wells BR-0433, BR-1056 and BR-1061 recovered to levels that were up to 3 m greater than the static water level prior to pumping, which further suggests that infiltrating snow melt had raised the overall water table in the area.

Details of the drawdown observed in BR-0220 and the observation wells are shown on the hydrographs in Figure 3-2 and summarized in Table 5.

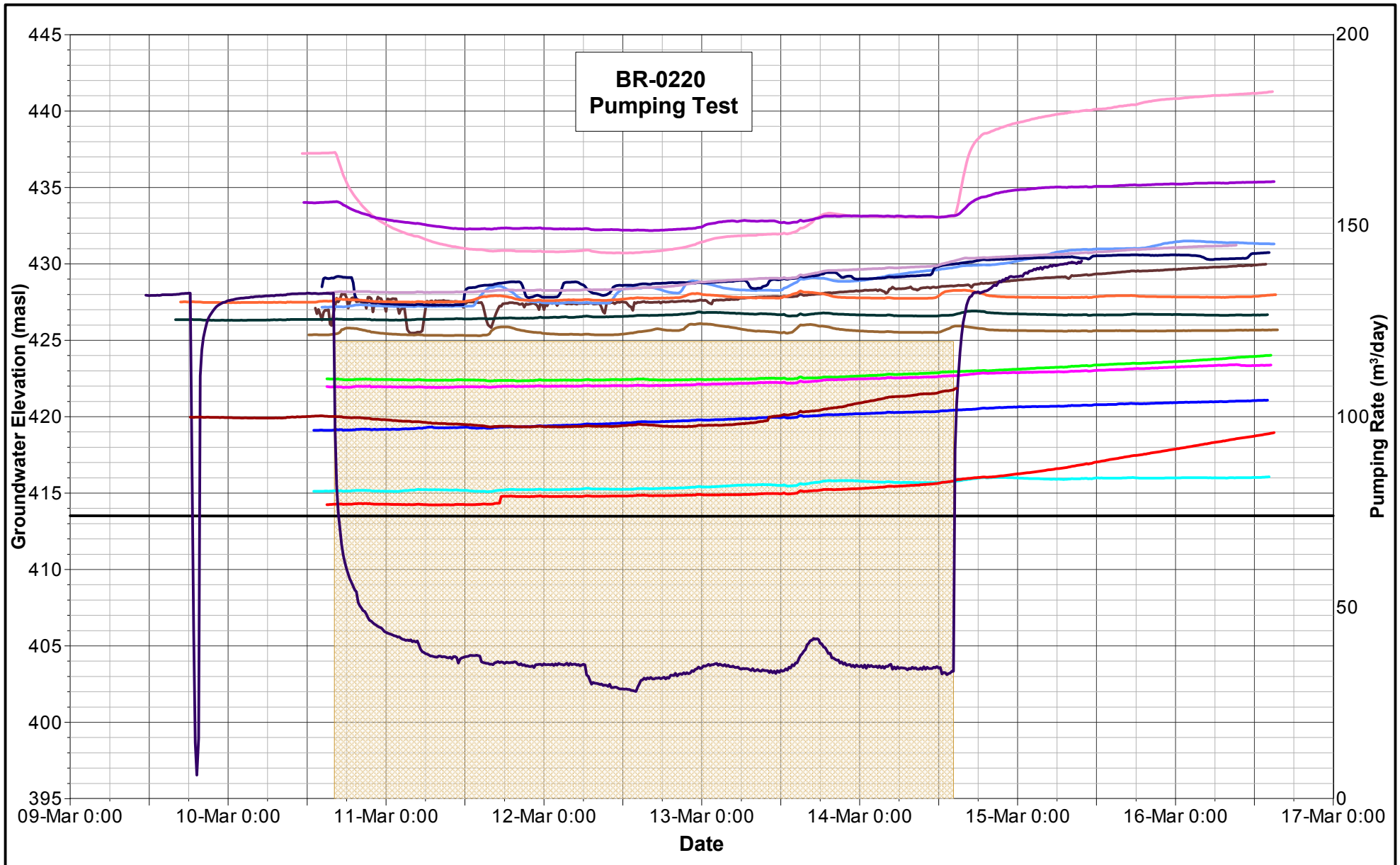


OSISKO HAMMOND REEF GOLD

Golder Associates

September 2011 Pumping Test Hydrographs

FIGURE: 3-1	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: JH	REVIEW: MO



OSISKO HAMMOND REEF GOLD

Golder Associates

March 2012
BR-0220 Pumping Test
Hydrographs

FIGURE: 3-2	
DATE: SEPTEMBER 2012	
PROJECT NO: 11-1118-0079	
DRAWN: JH	REVIEW: MO

Table 5: Summary of Details for Pumping Test at BR-0220 in March 2012

Observation Well	Radial Distance	Max Drawdown	Upper Shear Zone Intersection		Lower Shear Zone Intersection	
	(m)	(m)	Yes / No	Depth[(a)] (m)	Yes / No	Depth[(a)] (m)
BR-0220 (pumping well)	0	11.68	Yes	155	Yes	340
BR-1056	153	6.48	Yes	67	Yes	211
BR-1176	192	n/a[(b)]	No	—	Yes	116
BR-1061	200	1.76	Yes	52	Yes	224
BR-0433	220	0.68	No	—	Yes	285
BR-0073	320	n/a[(b)]	No	—	Yes	125
BR-1168a	323	n/a[(b)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
BR-1207	336	n/a[(b)]	No	—	Yes	31
BR-1095	354	n/a[(b)]	No	—	Yes	65
BR-0413	408	n/a[(b)]	No	—	Yes	142
BR-1150	425	n/a[(b)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
BR-1070	438	n/a[(b)]	No	—	No	—
BR-1174	452	n/a[(b)]	No	—	Yes	17
BR-0437	573	n/a[(b)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
BR-1051	607	n/a[(b)]	No	—	No	—
BR-1011	610	n/a[(b)]	n/a[(c)]	n/a[(c)]	n/a[(c)]	n/a[(c)]
BR-6217	655	n/a[(b)]	Yes	320	Yes	382

Notes:

[(a)] Depth (m) represents true depth along angled borehole.

n/a[(b)] = No measurable drawdown observed at this location.

n/a[(c)] = Geologic information not available.

— = Depth not provided because borehole does not intersect Shear Zone.

Shear Zone intersection depths for boreholes BR-0220, BR-1056, BR-1061 and BR-0433 based on geology model provided by OHRG (July 2011).

Shear Zone intersection depths for boreholes BR-1176, BR-0073 BR-1207, BR-1095, BR-0413, BR-1070, BR-1174, BR-1051 and BR-6217 provided by OHRG (November 2012).

APPENDIX 2.IX

Three-dimensional Groundwater Flow Modelling

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has developed a three-dimensional (3D) groundwater flow model for the mine area of the Osisko Hammond Reef Gold Project (Project). The following model simulations were completed:

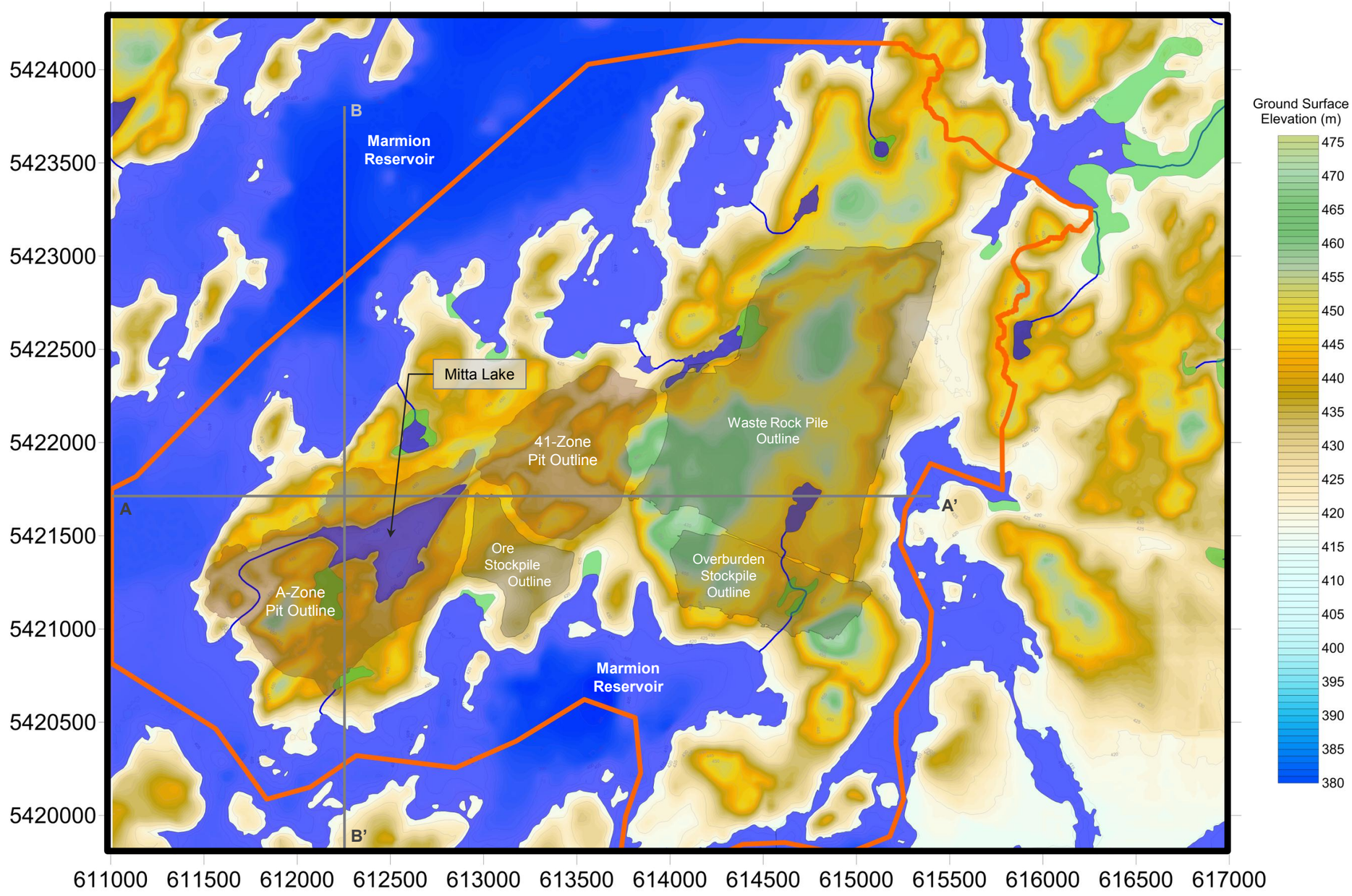
1. **Pre-Pit**. This simulation approximates current site conditions.
2. **Ultimate Pit**. This simulation approximates the full extent of the excavated pit at the end of active mining. It will take about 11 years to reach the Ultimate Pit layout. Groundwater inflows will report to the base of the pit and be removed by pumping (dewatering).

The Project Site is located near Atikokan in north-western Ontario. The mine area, general site features and model domain are shown on Figure 1-1. The Project Site lies within a peninsula extending in Marmion Reservoir. The Project will consist of mining two adjacent open pits corresponding to the main mineralized zones (west pit and east pit). The two pits will have a combined maximum length of about 2,540 m (southwest to northeast direction) and a maximum width of approximately 970 m (southeast to northwest direction) at the pit crest. The maximum depths of the west pit and east pit are about 320 m and 240 m, respectively. Located in close proximity to the pits are waste rock, low-grade ore and overburden stockpiles.

The objectives of the groundwater modelling are as follows:

- Realize the conceptual hydrogeological model within a 3D numerical framework and affirm this conceptualization through calibration to measured field data (the Pre-Pit model).
- Assess potential open pit inflow ranges and drawdown for the base case Ultimate Pit condition and additional uncertainty analysis scenarios.
- Estimate potential groundwater baseflow changes to surface water features due to pit dewatering and stockpile seepage.
- Estimate waste rock, low-grade ore and overburden stockpile and sedimentation pond seepage rates and pathways.

The purpose of this report is to document the construction, calibration, and results of the groundwater modelling. This document serves as an appendix to the Hydrogeology Technical Support Document (TSD). Much of the supporting hydrogeological characterization and conceptual model development that the model is based on are detailed in the TSD and are not repeated herein.



Note

The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.

Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Cross-Section Locations

DRAFT

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

OSISKO

Hammond Reef Project

MODEL DOMAIN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 1-1

1.1 Scope

The following tasks were completed as part of the modelling study:

- Apply the hydrogeological units/layering, boundary conditions, hydraulic conductivities and recharge rates specified in the conceptual model (Section 2 of the Hydrogeology TSD) within a numerical model framework (the Pre-Pit model).
- For the Pre-Pit Model: calibrate to steady state, average pre-pit groundwater levels and stream flows.
- For the Ultimate Pit Model: evaluate steady state pit inflows, drawdown, and potential surface water baseflow changes.
- Partition stockpile seepages and sedimentation pond leakage and identify potential receptors.
- Conduct an uncertainty analysis to determine a range of potential pit inflows and drawdown.

2.0 GENERAL MODEL ASSUMPTIONS

Several assumptions are utilized in order to realize the conceptual model within a practical numerical framework, including:

- The current modelling approach considers average, steady-state, saturated flow conditions. Seasonal or abrupt changes in the groundwater system due to snow melt, summer dry periods, storm events, etc. are not considered in the analysis.
- Unsaturated flow is not modelled in this analysis.
- The groundwater flow system in the study area may be simulated as an equivalent porous media or "EPM". In this setting, groundwater flow is a function of the hydraulic gradient and the hydraulic conductivity of the medium. The Shear Zones are considered the most significant, or potentially transmissive, structural rock features on the Project Site. The fracture flow in these units is implicitly modelled through the discrete EPM zonation of their geometry. Elsewhere, regional fracture flow is not explicitly modelled, and an EPM assumption is deemed sufficient for characterizing groundwater flow at the scale of this analysis.
- 3D mapping of inferred Shear Zone and ore body geometries was obtained from Osisko Hammond Reef Gold (OHRG) during June 2012. This data is in part used to construct the hydrostratigraphic assignments in and closely around the open pit areas. For the model, the Shear Zones are assumed to extend southwest beneath Marmion Reservoir and northeast to end of the model domain, and are as such according to the projected trend in the existing data.
- Overburden, where present on-site, is discontinuous and/or shallow. The overburden material generally consists of lower permeability till with hydraulic conductivity similar to or lower than the underlying shallow rock. As such, the overburden was not explicitly considered in the model as a distinct geologic unit and instead was "lumped" with the shallow rock layering.

3.0 MODEL CONSTRUCTION

3.1 Flow Code

MODFLOW-2005 (Harbaugh 2005) is the code used to simulate groundwater flow at the Project 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. The preconditioned conjugate gradient method (PCG2) is used to solve the groundwater flow equations. MODPATH (Pollock 1989), a companion code to MODFLOW, is used to complete the particle tracking analyses to delineate seepage pathways from the stockpiles.

3.2 Domain and Discretization

The active model area encapsulates the proposed mine and surrounding peninsula, covering an area of approximately 15 km^2 (Figure 1-1). The far-field location of the eastern model extents are chosen in order to avoid artificial boundary effects that might otherwise occur because of pit drawdown.

The 3D model grid is constructed using a “cube” model approach. As such, the model is discretized using small, uniform grid blocks, resulting in a dense 3D grid with constant cell dimensions and layer thickness. The primary advantages of this method are that it increases numerical stability and allows practical input of complex geometric structures such as the Ore Zone and Shears. The model grid has the following dimensions and properties:

- Lower Left Corner (UTM15 NAD83):..... 611,000 ; 5,419,800
- Upper Right Corner (UTM15 NAD83): ..... 617,000 ; 5,424,300
- Top (masl): 480
- Bottom (masl): 0
- Cell Dimensions:..... 20 m wide x 20 m long x 10 m thick
- Number of Layers:..... 48
- Number of Cells Per Layer:..... 67,500
- Total Number of Cells:..... 3,240,000
- Total Number of Active Cells:..... 1,595,640

Topography is shown on Figure 1-1. As the model top elevation is selected to envelope the uppermost topography in the area, a considerable number of cells in upper layers are “air” and thus assigned inactive until the layer containing topographic elevation is reached for a given row and column. In addition, inactive cells are found bordering the active model domain. Half of the total cells in the model are active as a result.

3.3 Model Hydrostratigraphy and Hydraulic Conductivity

The model hydrostratigraphy and hydraulic conductivity are presented in cross-section in Figure 3-1 and Figure 3-2; Figure 1-1 shows the plan view location of the cross-sections. As shown in the cross-sections, the hydrostratigraphic interpretation/thicknesses are draped from topographic elevation (Figure 1-1).

Contained within the aforementioned 48 numerical layers are three overarching hydrostratigraphic groupings:

1) Ore Zone
2) Shear Zones
3) Host Rock Zone

The modelled thickness and hydraulic conductivity of each hydrostratigraphic unit is summarized in Table 1.

Table 1: Model Hydrostratigraphic Units and Hydraulic Conductivity

Unit	Depth Range (mbgs)	Kxyz
Ore	0-10	1×10^{-6}
Ore	10-30	1×10^{-7}
Ore	30-200	5×10^{-8}
Ore	200+	2×10^{-8}
Shear	0-10	1×10^{-6}
Shear	10-30	1×10^{-7}
Shear	30+	5×10^{-8}
Host	0-10	1×10^{-6}
Host	10-20	1×10^{-7}
Host	20+	1×10^{-8}

The Ore Zone exists centrally within the peninsula, incising the Host Rock Zone in a southwest to northeast trend from Marmion Reservoir to about 500 m beyond Mitta Lake. The inferred 3D extents of the Ore Zone were provided by OHRG in July 2012 and approximated in the model. The Ore Zone has a hydraulic conductivity of 1×10^{-6} m/s at surface and, like the Host Rock Zone, demonstrates a trend of reduced hydraulic conductivity with depth; however the decrease is more gradual and reaches a minimum of 2×10^{-8} m/s.

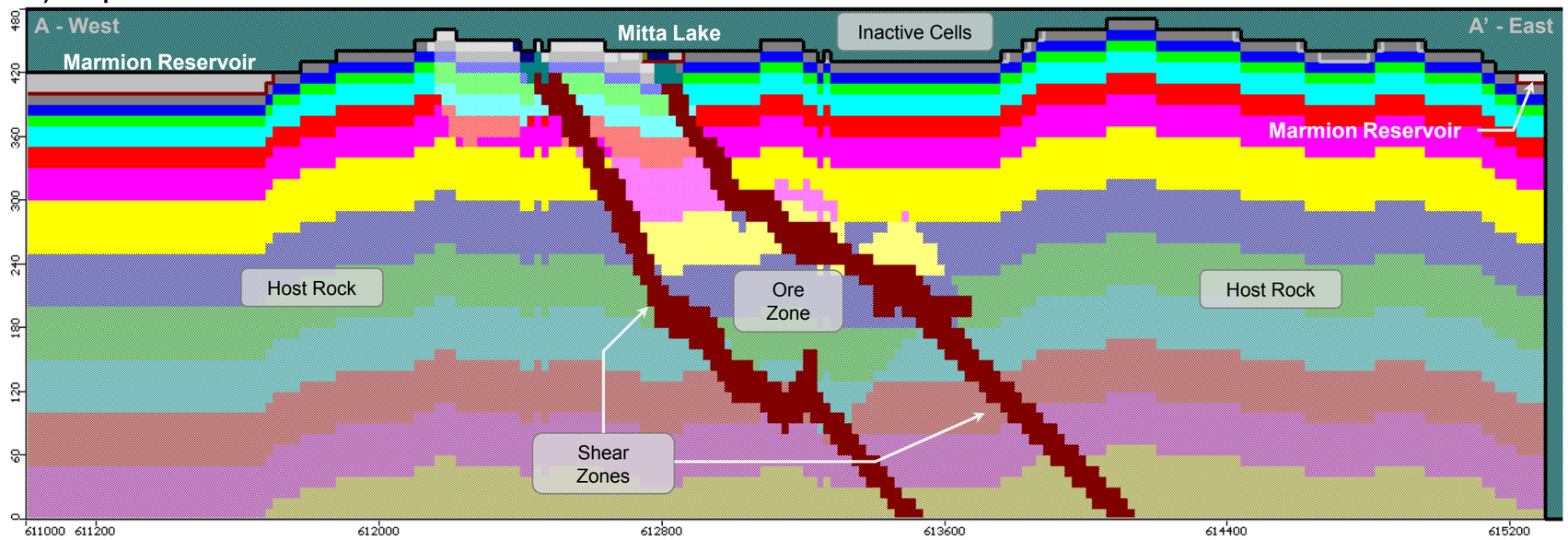
The Shear Zone consists of two quasi-linear planes extending in a southwest to northeast direction centrally through the peninsula at about a -45 degree dip to the southeast. The inferred 3D extents of the Shear Zones were provided by OHRG in July 2012 and approximated in the model. Based on this interpretation, the Shear Zones are extended southwest beneath Marmion Reservoir and northeast to the edge of the model domain. While it is not certain if the shears extend to these areas, it is deemed conservative from an impact assessment to consider them continuous throughout the model domain. The Shear Zones are frequently situated at or near the contact between Host Rock Zone and Ore Zone, where the Ore Zone is present.

The Shears have an estimated hydraulic conductivity of about 1×10^{-7} m/s and an average thickness of about 1 m. As the Shears are thinner than the model cells, an averaging process is required to assign a “bulk”

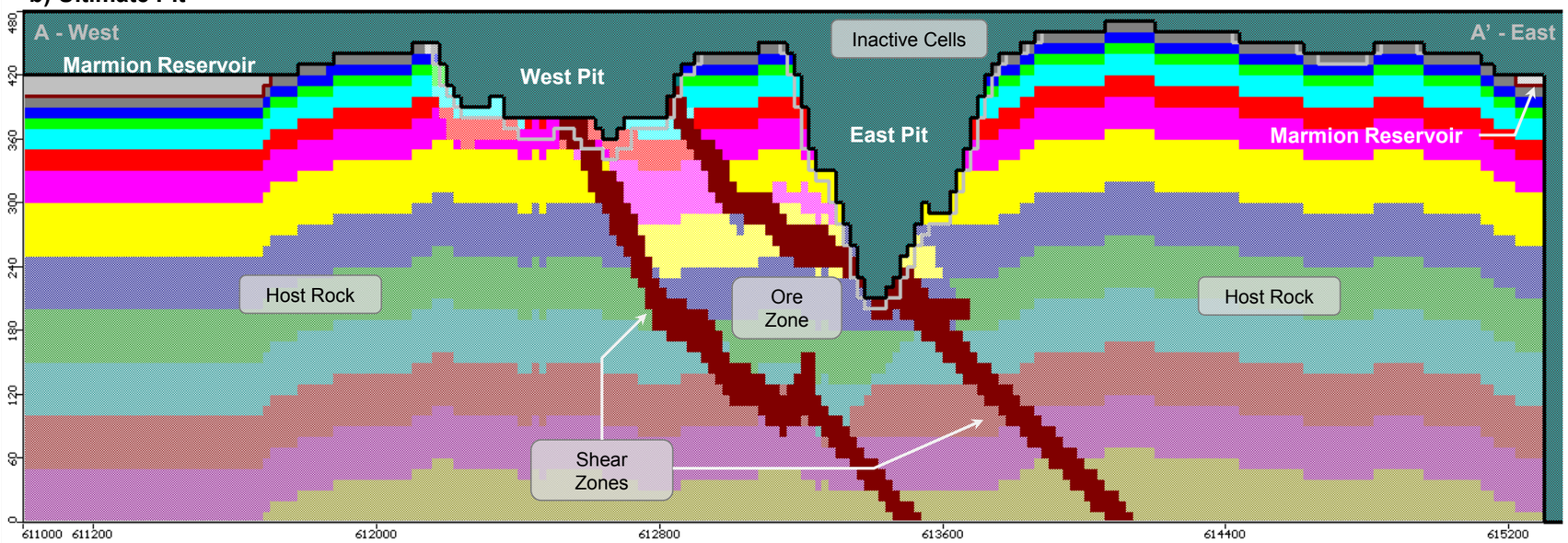
hydraulic conductivity to each of the 20 m x 20 m x 10 m numerical cells they lie within. Thus, for a given Ore Zone or Host Rock cell that the shear intersects, the average hydraulic conductivity of the cell is based on a volume-weighted average of the two units present within the cell. The resulting average values are then grouped in half-order magnitude "bins" in order to streamline the number of material properties required to populate the model. The resulting Shear Zones are thus represented with five hydraulic conductivity zones (or bins) ranging from 1×10^{-6} m/s to 5×10^{-8} m/s.

The Host Rock Zone comprises the majority of the model hydrostratigraphy. The Host Rock Zone hydraulic conductivity displays decreasing hydraulic conductivity with depth, ranging from 1×10^{-6} m/s at surface to 1×10^{-9} m/s at the bottom of the model.

a) Pre-pit



b) Ultimate Pit



Hydraulic Conductivity Summary

Colour	K Zone	K_x (m/s)	K_y (m/s)	K_z (m/s)	Layer Description
	2	1.0E-06	1.0E-06	1.0E-06	Shear Zone
	3	5.0E-07	5.0E-07	5.0E-07	Shear Zone
	4	1.0E-07	1.0E-07	1.0E-07	Shear Zone
	5	5.0E-08	5.0E-08	5.0E-08	Shear Zone
	6	-	-	-	-
	7	-	-	-	-
	8	1.0E-06	1.0E-06	1.0E-06	Lake - CH Zone
	9	1.0E-06	1.0E-06	1.0E-06	Host - 0-10m
	10	1.0E-07	1.0E-07	1.0E-07	Host - 10-20m
	11	1.0E-08	1.0E-08	1.0E-08	Host - 20-30m
	12	1.0E-08	1.0E-08	1.0E-08	Host - 30-50m
	13	1.0E-08	1.0E-08	1.0E-08	Host - 50-70m
	14	1.0E-08	1.0E-08	1.0E-08	Host - 70-100m
	15	1.0E-08	1.0E-08	1.0E-08	Host - 100-150m
	16	1.0E-08	1.0E-08	1.0E-08	Host - 150-200m
	17	1.0E-08	1.0E-08	1.0E-08	Host - 200-250m
	18	1.0E-08	1.0E-08	1.0E-08	Host - 250-300m
	19	1.0E-08	1.0E-08	1.0E-08	Host - 300-350m
	20	1.0E-08	1.0E-08	1.0E-08	Host - 350-400m
	21	1.0E-08	1.0E-08	1.0E-08	Host - 400-500m
	22	1.0E-06	1.0E-06	1.0E-06	Ore - 0-10m
	23	1.0E-07	1.0E-07	1.0E-07	Ore - 10-20m
	24	1.0E-07	1.0E-07	1.0E-07	Ore - 20-30m
	25	5.0E-08	5.0E-08	5.0E-08	Ore - 30-50m
	26	5.0E-08	5.0E-08	5.0E-08	Ore - 50-70m
	27	5.0E-08	5.0E-08	5.0E-08	Ore - 70-100m
	28	5.0E-08	5.0E-08	5.0E-08	Ore - 100-150m
	29	5.0E-08	5.0E-08	5.0E-08	Ore - 150-200m
	30	2.0E-08	2.0E-08	2.0E-08	Ore - 200-250m
	31	2.0E-08	2.0E-08	2.0E-08	Ore - 250-300m
	32	2.0E-08	2.0E-08	2.0E-08	Ore - 300-350m
	33	2.0E-08	2.0E-08	2.0E-08	Ore - 350-400m
	34	2.0E-08	2.0E-08	2.0E-08	Ore - 400-500m

Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. This East-West cross-section is taken from groundwater model Row 130 with 3x vertical exaggeration.

Legend

Constant Head Boundary Outline Drain Boundary Outline

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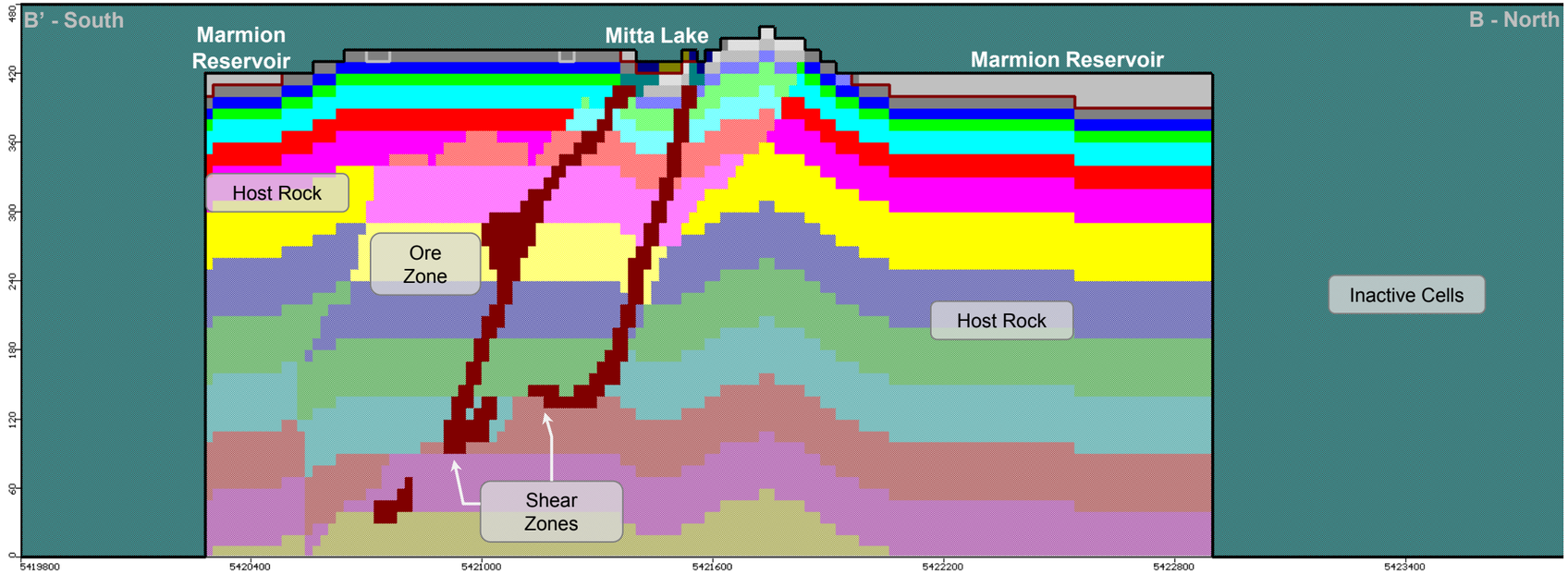
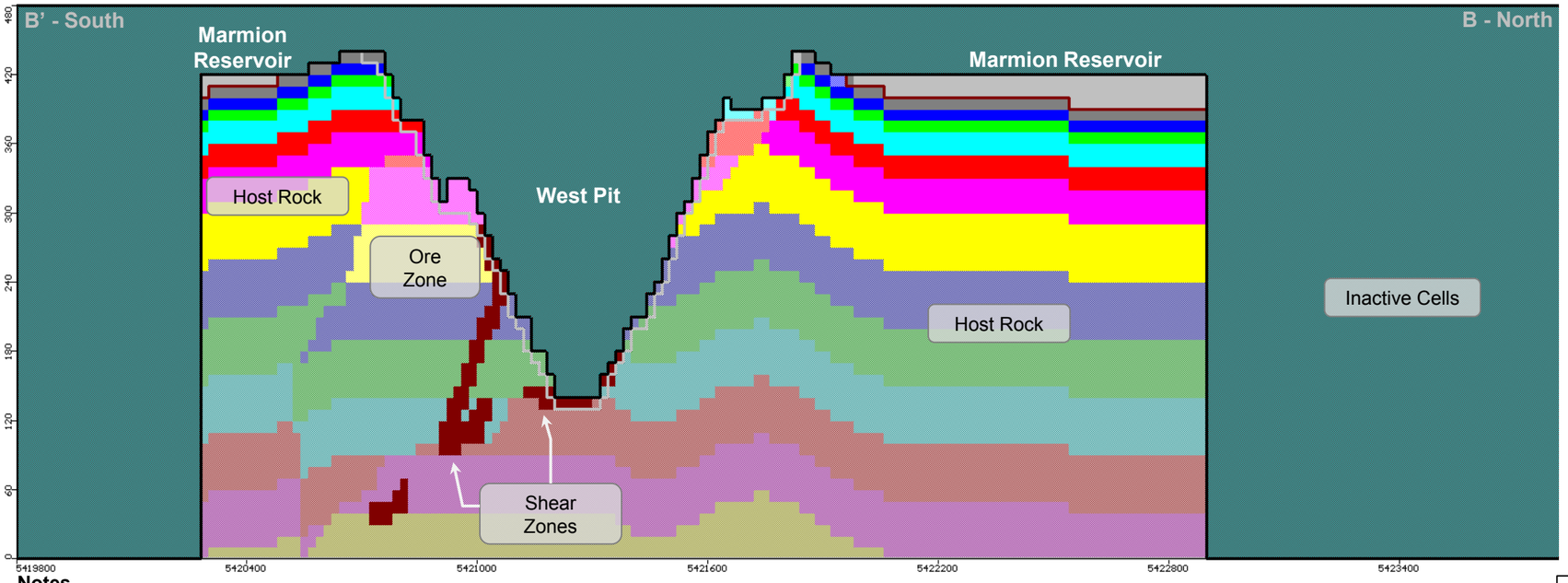
MODEL HYDROSTRATIGRAPHY (SECTION A-A')

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-1

a) Pre-pit



b) Ultimate Pit



Hydraulic Conductivity Summary

Colour	K Zone	K_x (m/s)	K_y (m/s)	K_z (m/s)	Layer Description
	2	1.0E-06	1.0E-06	1.0E-06	Shear Zone
	3	5.0E-07	5.0E-07	5.0E-07	Shear Zone
	4	1.0E-07	1.0E-07	1.0E-07	Shear Zone
	5	5.0E-08	5.0E-08	5.0E-08	Shear Zone
	6	-	-	-	-
	7	-	-	-	-
	8	1.0E-06	1.0E-06	1.0E-06	Lake - CH Zone
	9	1.0E-06	1.0E-06	1.0E-06	Host - 0-10m
	10	1.0E-07	1.0E-07	1.0E-07	Host - 10-20m
	11	1.0E-08	1.0E-08	1.0E-08	Host - 20-30m
	12	1.0E-08	1.0E-08	1.0E-08	Host - 30-50m
	13	1.0E-08	1.0E-08	1.0E-08	Host - 50-70m
	14	1.0E-08	1.0E-08	1.0E-08	Host - 70-100m
	15	1.0E-08	1.0E-08	1.0E-08	Host - 100-150m
	16	1.0E-08	1.0E-08	1.0E-08	Host - 150-200m
	17	1.0E-08	1.0E-08	1.0E-08	Host - 200-250m
	18	1.0E-08	1.0E-08	1.0E-08	Host - 250-300m
	19	1.0E-08	1.0E-08	1.0E-08	Host - 300-350m
	20	1.0E-08	1.0E-08	1.0E-08	Host - 350-400m
	21	1.0E-08	1.0E-08	1.0E-08	Host - 400-500m
	22	1.0E-06	1.0E-06	1.0E-06	Ore - 0-10m
	23	1.0E-07	1.0E-07	1.0E-07	Ore - 10-20m
	24	1.0E-07	1.0E-07	1.0E-07	Ore - 20-30m
	25	5.0E-08	5.0E-08	5.0E-08	Ore - 30-50m
	26	5.0E-08	5.0E-08	5.0E-08	Ore - 50-70m
	27	5.0E-08	5.0E-08	5.0E-08	Ore - 70-100m
	28	5.0E-08	5.0E-08	5.0E-08	Ore - 100-150m
	29	5.0E-08	5.0E-08	5.0E-08	Ore - 150-200m
	30	2.0E-08	2.0E-08	2.0E-08	Ore - 200-250m
	31	2.0E-08	2.0E-08	2.0E-08	Ore - 250-300m
	32	2.0E-08	2.0E-08	2.0E-08	Ore - 300-350m
	33	2.0E-08	2.0E-08	2.0E-08	Ore - 350-400m
	34	2.0E-08	2.0E-08	2.0E-08	Ore - 400-500m

Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. This North-South cross-section is taken from groundwater model Column 63 with 3x vertical exaggeration.

Legend

Constant Head Boundary Outline

Drain Boundary Outline

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MODEL HYDROSTRATIGRAPHY (SECTION B-B')

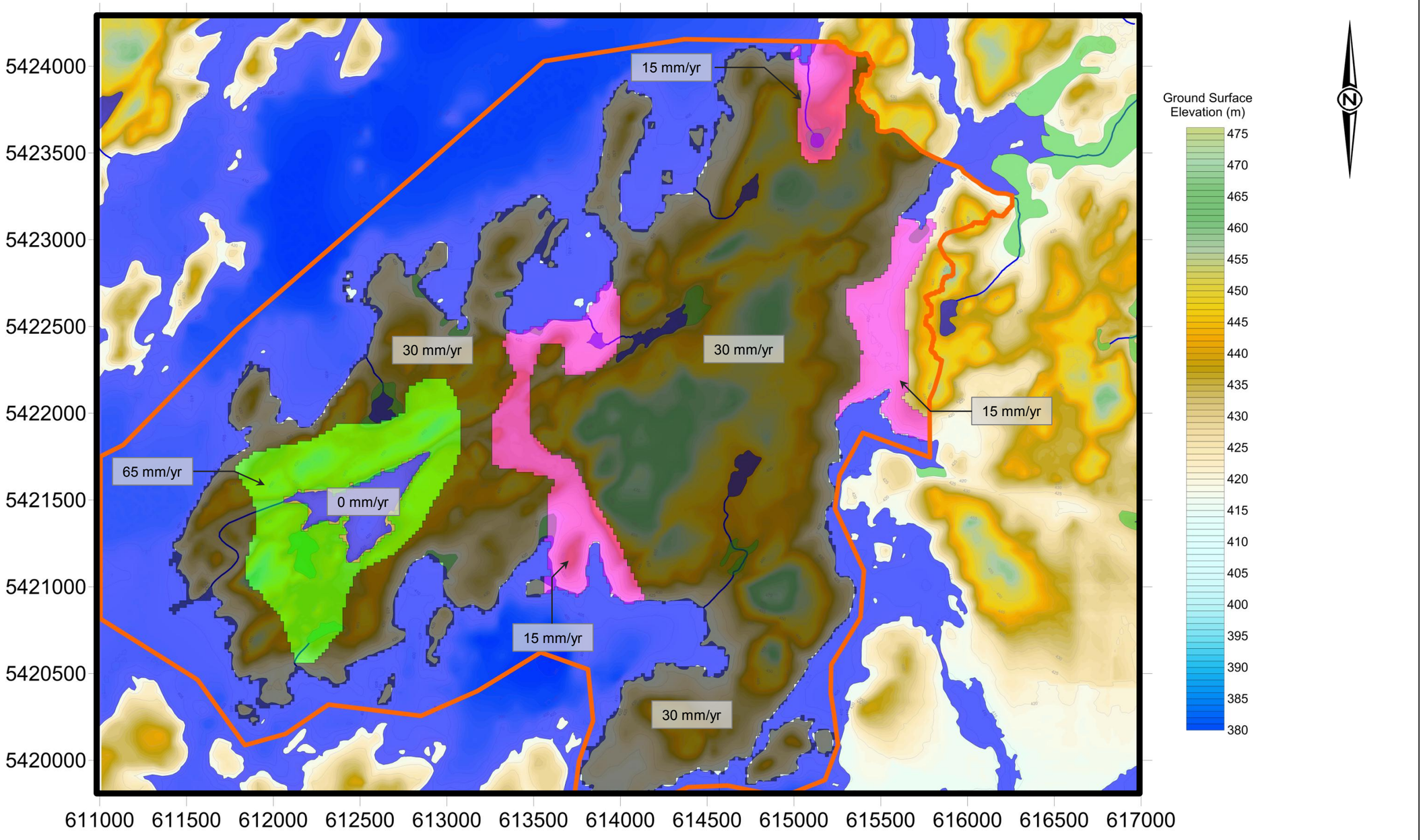
OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-2

3.4 Recharge

Site-specific estimates of recharge developed from an analysis of stream flow hydrographs are not available for the model area. All continuously measured gauges lie outside of the model domain; the closest station is SW3, located approximately 3 km east of the model on Lumby Creek at Turtle Bay (Hydrology TSD, Section 5.1.1.2). Analysis of this hydrograph using baseflow separation techniques provides an estimated recharge ranging from about 50 mm/yr to 150 mm/yr (Hydrology TSD, Section 5.1.2.3). However, it is noted that isolating estimates of true groundwater recharge are difficult at this gauge (and others in the area) as lake storage plays a significant role in the hydrology of the watershed. In addition, interflow may comprise a significant portion of the estimated stream baseflow. As such, it is supposed that actual groundwater recharge is less than that estimated via baseflow separation in this instance. The specific recharge rates applied in the model were principally derived via the calibration process (Section 4) and guided by an estimated rate of infiltration into the rock of about 50 mm/yr.

Figure 3-3 and Figure 3-4 display the recharge distribution for the Pre-Pit and Ultimate Pit models, respectively. The following is noted:

- The recharge rates applied vary from 0 mm/yr to 65 mm/yr, with the majority of the model area receiving 30 mm/yr.
- Areas of groundwater discharge, as observed through visual observation during field reconnaissance or implied during model calibration, are assigned a lower infiltration rate of 15 mm/yr.
- The model calibration process suggests that areas around Mitta Lake receive higher recharge than surrounding areas. As such, a zone around the lake is assigned 65 mm/yr.
- No recharge is applied over Marmion Reservoir and Mitta Lake.
- No recharge is applied over the pit footprint in the Ultimate Pit model. All water reaching the pit is assumed to be captured by the dewatering system, effectively negating any groundwater infiltration.
- An infiltration rate of 50 mm/yr is applied at the base of the stockpile footprints in the Ultimate Pit model. The stockpiles are not lined; as such the recharge rate is similar to the surrounding naturally occurring infiltration, however, the value has been increased to reflect the influence of a constant source of water at the ground surface. Note that this number refers to the amount of stockpile seepage occurring from the stockpile itself vertically down into the saturated groundwater system.
- No recharge is applied over the sedimentation pond as this feature is considered a surface water body boundary condition (Section 3.5). However, leakage may occur underneath this pond into the groundwater system. Further field studies are to be undertaken to ascertain if this feature may be perched based on naturally occurring, low permeability rock that may underlie the pond. However, for the purpose of this assessment, it is assumed that the pond may have a complete hydraulic connection to the underlying groundwater system.



Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers

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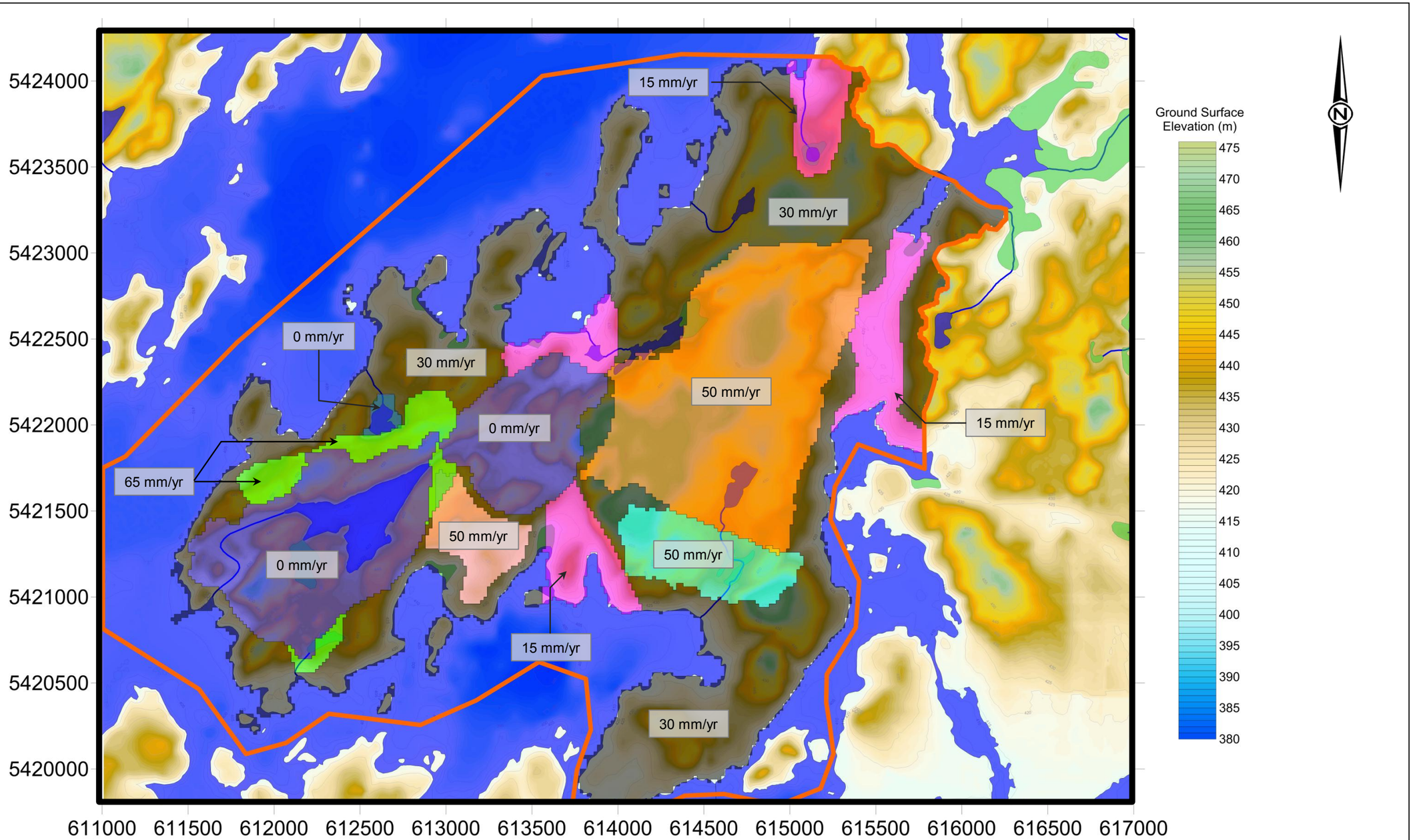
RECHARGE DISTRIBUTION (PRE-PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-3



Note

The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.

Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers

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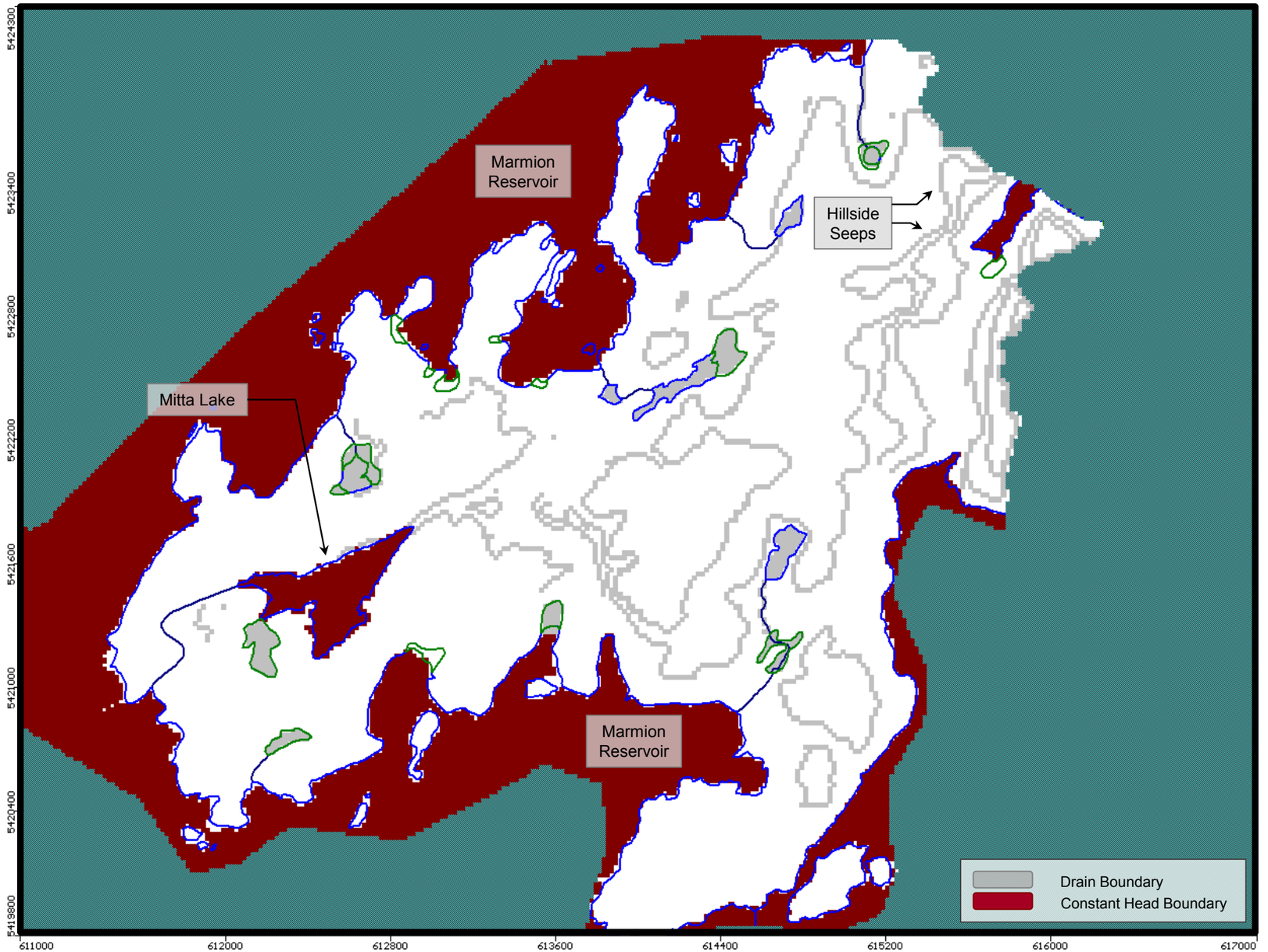
RECHARGE DISTRIBUTION (ULTIMATE PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-4

3.5 Boundary Conditions

The boundary conditions for the pre-pit and ultimate pits conditions are shown on Figure 3-5 and Figure 3-6, respectively. In addition, Figures 3-1 and 3-2 display boundary conditions where they appear in cross-section (refer to the Constant Head Boundary and Drain Boundary outlines as marked in the legend). The following is noted:

- Model cells above topography are inactive until a layer encompasses ground surface for a given grid row and column. Consequently, surficial boundary conditions such as lakes and streams are present in varying layers according to their elevation. However, for illustration purposes, Figure 3-5 and Figure 3-6 show all the boundary condition cells consolidated in a single plan view.
- The majority of the peninsula area is bounded by Marmion Reservoir. This feature is assigned as constant heads cells from lake surface down to approximate bathymetric depth (Golder 2012). The constant head cells are assigned an elevation of 414.3 masl based on an average of daily measured water levels in the lake from the period of 1982 to 2012. Daily water levels are provided in the Hydrology TSD.
- Much of the northeast flank of the model is assigned as a no-flow boundary. This boundary coincides with subwatershed delineations in the area (Figure 2-18 of the Hydrogeology TSD). The application of a no-flow boundary here implies that groundwater flow divides coincide with topographic ones in this area; in the absence of groundwater level data this is considered reasonable.
- Mitta Lake is the largest inland lake within the model domain. This feature is assigned as constant head cells from lake surface down to approximate bathymetric depth. The constant head cells are assigned an elevation of 435 masl based on groundwater levels measured in nearby exploration boreholes and general field observations. Note that Mitta Lake exists in the Pre-Pit Model only; this feature will be dewatered during pit development and will be removed during mine operations.
- There are several small streams, ponds and wetlands within the model domain. These water bodies are assigned as drain cells with heads at topographic elevation (Figure 1-1). The use of the drain boundary condition to characterize these features implies that they are groundwater discharge zones; as such, these streams and wetlands may only remove water from the groundwater system. In addition, the drain assignment allows drawdown to occur at these cells (as opposed to a constant head assignment, which would maintain a fixed head in the cell regardless of drawdown at the surrounding calculated heads).
- In select upland areas, drain cells have been applied around hill slopes to simulate seeps. The drain cell heads are assigned at topographic elevation. The justification for the application of these drains cells is in part due to observations during field reconnaissance as well as inferences during the calibration process that discrete hillside areas with significant mounding are considered potential seep locations.
- The model bottom is set at 0 masl, about 120 m below the bottom of the west pit. The bottom is a no-flow boundary; below this depth groundwater flow is considered negligible.
- For the Ultimate Pit condition, the open pit is assigned with drain cells lining the pit shell throughout its depth and bottom. Each cell is assigned an elevation approximately equal to the pit slope elevation where it abuts.
- The sedimentation pond, which lies north of the west pit, is assigned as a constant head boundary with a head of 433 masl.



Notes

1. Cells above topography are inactive until a layer encompasses ground surface. Consequently, surficial boundary conditions are present in layers according to their elevation. For illustration purposes, all boundary conditions are consolidated in a single plan view.

Legend

Model Extent
Lakes/Ponds
Streams/Rivers
Wetlands

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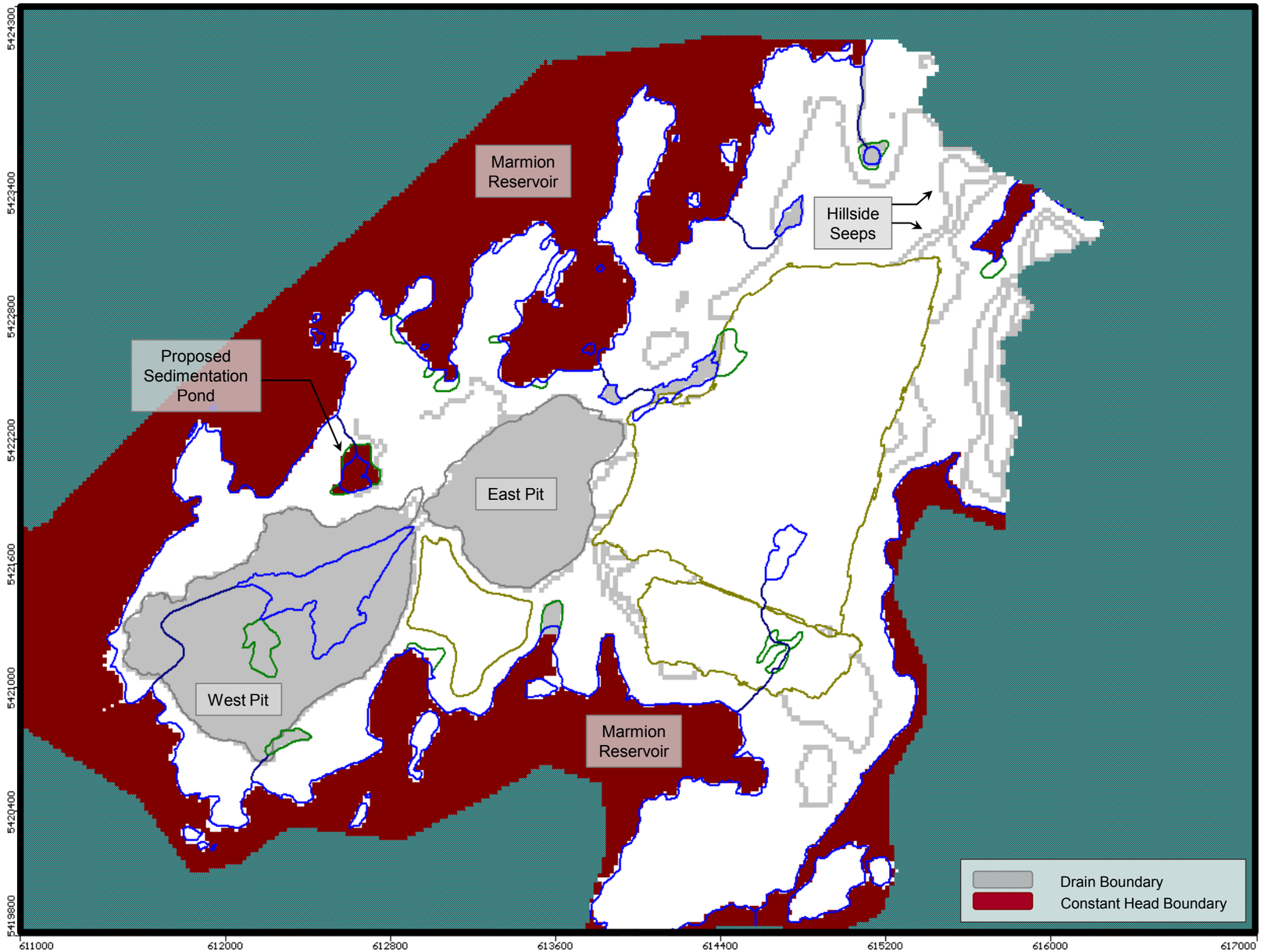
BOUNDARY CONDITIONS (PRE-PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-5



Notes

1. Cells above topography are inactive until a layer encompasses ground surface. Consequently, surficial boundary conditions are present in layers according to their elevation. For illustration purposes, all boundary conditions are consolidated in a single plan view.
2. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.

Legend

Model Extent
Lakes/Ponds
Streams/Rivers
Wetlands
Stockpiles

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BOUNDARY CONDITIONS (ULTIMATE PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 3-6

4.0 MODEL CALIBRATION

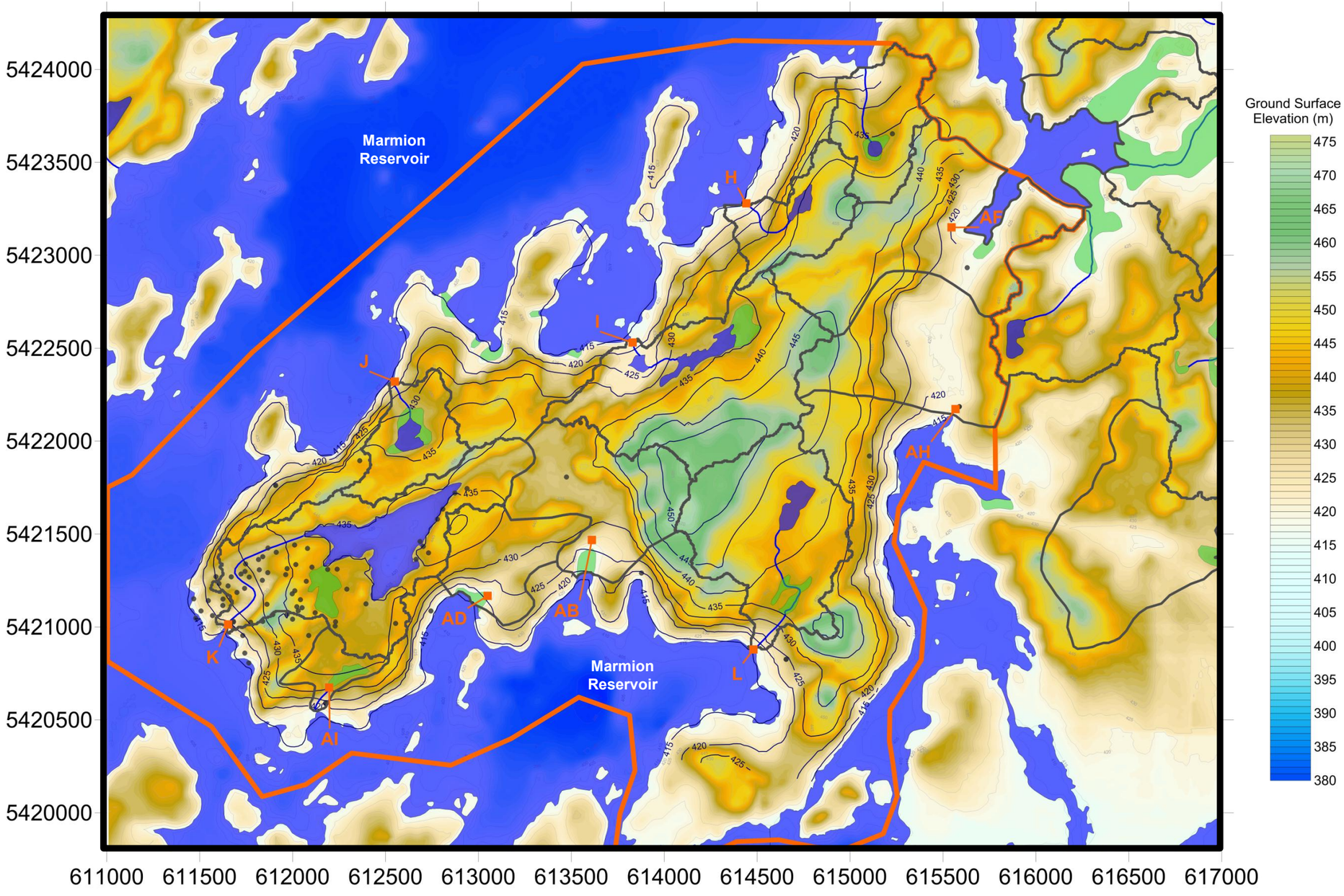
The model is calibrated through a trial-and-error process by varying the recharge and hydraulic conductivity of the hydrostratigraphic units within a reasonable range until simulated groundwater elevations and flow directions compare reasonably well with observed or inferred conditions.

The calibration dataset is comprised of the following (Figure 4-1):

- Average static water levels measured at 18 monitoring wells.
- Singular measured water levels at 68 exploration boreholes (assumed to be static). For angled exploration holes, the measuring point, or "screen" elevation, of the hole is assumed to be coincident with borehole's 3D intersection with the Shear Zone. As such the location of the calibration point shown in Figure 4-1 may be offset from its collar position.
- Spot flow measurements at 10 surface water stations. The name of each surface water station corresponds to the subwatershed where it is located (Figure 4-1). Each station was measured four or less times during 2011 to 2012. The majority of the measurements were taken during or shortly after spring melt, when surficial runoff is high. Thus the measured flow may include high volumes of surface water input relative to groundwater baseflow. Conversely, there have been occasions where some of these features are dry. In any event, the small amount of data at these sites has precluded meaningful baseflow separation to ascertain average groundwater discharge. As such, these flow rates are not strict calibration targets per se; rather they are used as a check to ensure that the modelled groundwater baseflow at these locations is generally less than the measured flow.

The Pre-Pit (calibrated model) simulated water table is presented on Figure 4-1. The model output indicates a quasi-radial flow pattern from upland areas out to Marmion Reservoir with local convergence on Mitta Lake. The simulated gradient is relatively gradual in the upland areas and increases towards the shoreline in a manner similar to topography. In general, the simulated flow patterns compare reasonably well with the inferred groundwater flow directions presented in Figures 2-5 and 2-6 of the Hydrogeology TSD.

Figure 4-2 shows a head calibration plot for the model, or simulated versus measured water levels. Table 2 provides the head calibration data utilized in the model, the simulated head at each well, and the residual. In general, the simulated groundwater levels compare well with the measured groundwater levels. Following the calibration process, the residual mean is minus 0.1 m, the absolute residual mean is 1.9 m, and the normalized root mean square (NRMS) error is 9.7%. These results suggest that the model satisfactorily represents observed water levels.



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. The contour lines shown reflect the simulated water table elevations under Pre-Pit (current) conditions (5m contour interval).

Legend

- Model Extent
- Active Model Domain
- Simulated Water Table Elevation (m)
- Lakes
- Wetlands
- SW Flow Stations
- Streams/Rivers
- Surface Water Subwatersheds
- GW Head Calibration Point

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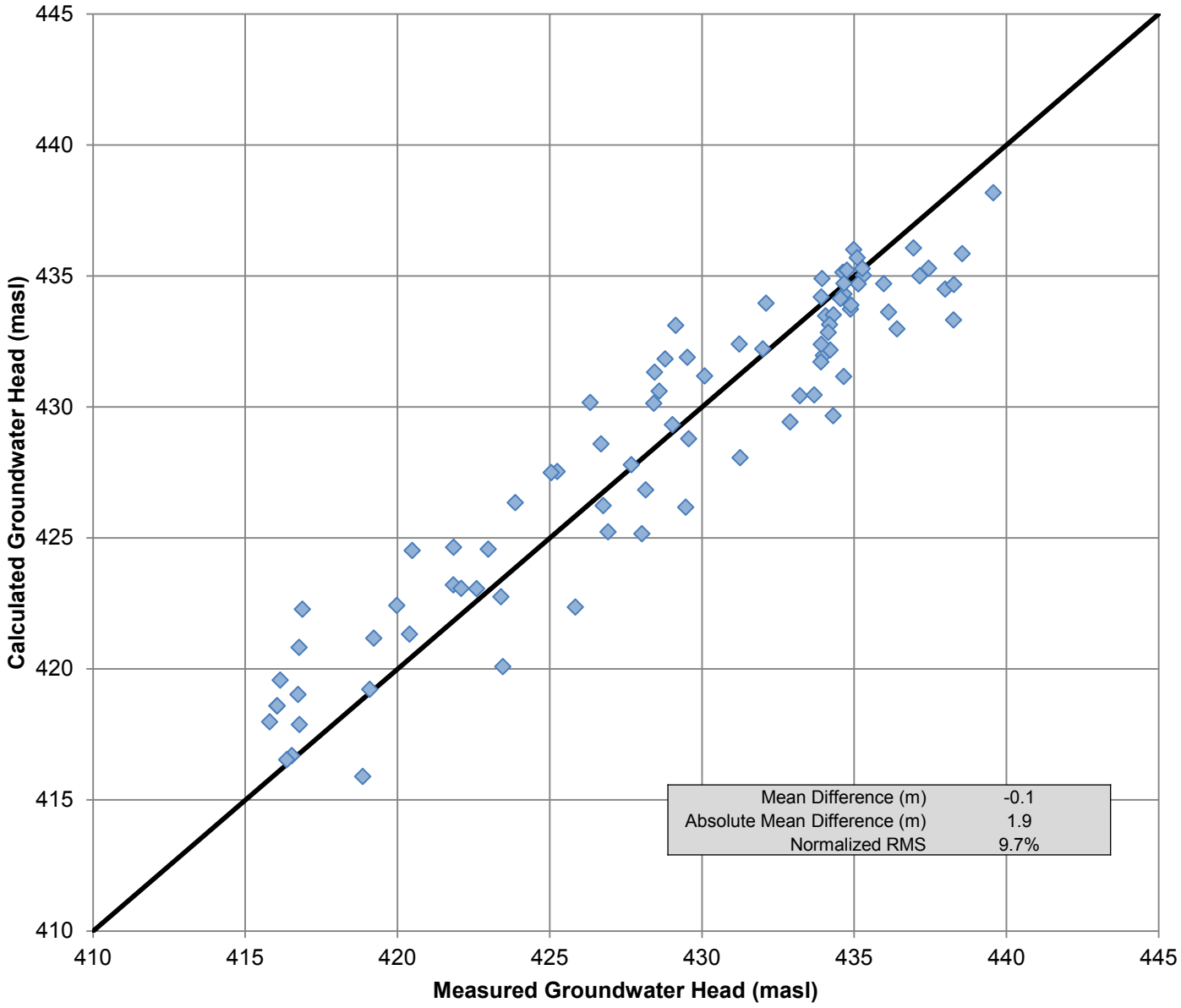
SIMULATED WATER TABLE (PRE-PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 4-1



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HEAD CALIBRATION PLOT

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 4-2

Table 2: Head Calibration Data and Results

Borehole	Collar Easting	Collar Northing	M.P. Easting	M.P. Northing	M.P. Elevation (masl)	Obs. Head (masl)	Calc. Head (masl)	Residual (m)
BR-0046	611,696	5,420,961	611,679	5,420,994	395.4	419.1	419.2	0.1
BR-0058	612,075	5,421,101	612,043	5,421,147	365.7	438.0	434.5	-3.5
BR-0061	611,862	5,420,985	611,840	5,421,030	349.8	425.3	427.5	2.3
BR-0073	611,672	5,421,085	611,626	5,421,150	345.3	421.8	423.2	1.4
BR-0081	612,031	5,420,899	611,971	5,421,068	174.5	434.3	429.7	-4.7
BR-0090	612,320	5,421,165	612,292	5,421,203	335.5	434.7	434.3	-0.4
BR-0092	612,266	5,421,275	612,240	5,421,311	366.7	434.0	434.9	0.9
BR-0097	612,195	5,421,298	612,188	5,421,309	377.4	434.6	435.1	0.5
BR-0101	612,112	5,421,310	612,105	5,421,322	411.7	435.0	436.0	1.0
BR-0115	612,715	5,421,403	612,686	5,421,459	273.9	434.1	433.5	-0.6
BR-0169	613,559	5,422,084	613,550	5,422,099	425.8	438.3	433.3	-5.0
BR-0216	612,085	5,421,005	612,023	5,421,109	195.1	434.7	431.2	-3.5
BR-0220	612,040	5,420,973	612,000	5,421,041	314.9	434.0	432.0	-2.0
BR-0226	612,062	5,421,037	612,031	5,421,087	343.7	434.3	433.5	-0.8
BR-0231	612,033	5,421,161	612,012	5,421,194	393.8	435.3	435.0	-0.3
BR-0325	612,895	5,421,681	612,873	5,421,721	415.1	437.2	435.0	-2.2
BR-0384	611,751	5,421,332	611,747	5,421,339	420.3	428.4	430.1	1.7
BR-0390	612,797	5,421,554	612,780	5,421,580	365.0	435.1	434.7	-0.5
BR-0399	611,519	5,421,073	611,507	5,421,086	326.4	416.8	417.9	1.1
BR-0401	611,479	5,421,140	611,469	5,421,151	414.3	418.9	415.9	-3.0
BR-0408	611,536	5,421,043	611,479	5,421,047	336.3	416.5	416.7	0.1
BR-0413	611,584	5,421,039	611,569	5,421,061	300.2	416.2	419.6	3.4
BR-0433	611,849	5,420,891	611,774	5,421,025	183.3	421.9	424.6	2.8
BR-1003	612,167	5,421,015	612,122	5,421,076	318.7	434.9	433.7	-1.2
BR-1012	612,925	5,421,547	612,888	5,421,620	304.3	434.9	433.9	-1.0
BR-1028	612,751	5,421,358	612,732	5,421,398	225.4	434.2	432.2	-2.1
BR-1042	611,875	5,421,103	611,862	5,421,122	394.7	433.2	430.4	-2.8
BR-1048	612,066	5,421,080	612,051	5,421,103	356.8	434.6	434.1	-0.4
BR-1051	612,591	5,420,965	612,554	5,421,019	102.7	426.7	428.6	1.9
BR-1056	612,009	5,421,163	611,998	5,421,178	395.4	434.7	434.7	0.0
BR-1060	611,967	5,420,960	611,893	5,421,066	164.7	431.3	428.1	-3.2
BR-1061	612,078	5,421,239	612,073	5,421,245	391.7	435.1	435.7	0.6
BR-1069	611,963	5,421,281	611,963	5,421,281	433.2	433.9	434.2	0.3
BR-1093	612,082	5,421,418	612,080	5,421,422	439.4	437.0	436.1	-0.9
BR-1095	612,031	5,421,411	612,011	5,421,441	393.7	437.5	435.3	-2.2
BR-1102	611,873	5,421,414	611,867	5,421,425	418.2	429.1	433.1	4.0
BR-1128A	611,752	5,421,285	611,744	5,421,299	392.6	432.9	429.4	-3.5
BR-1129	611,743	5,421,261	611,722	5,421,285	387.4	429.6	428.8	-0.8
BR-1135	611,769	5,420,895	611,732	5,420,954	154.8	422.6	423.1	0.5
BR-1146	611,752	5,421,192	611,742	5,421,207	317.4	425.1	427.5	2.4
BR-1154	612,132	5,420,876	612,087	5,420,953	194.2	433.7	430.4	-3.2

Table 2: Head Calibration Data and Results (Continued)

Borehole	Collar Easting	Collar Northing	M.P. Easting	M.P. Northing	M.P. Elevation (masl)	Obs. Head (masl)	Calc. Head (masl)	Residual (m)
BR-1159	612,433	5,421,064	612,395	5,421,124	226.3	432.0	432.2	0.2
BR-1163	611,839	5,421,275	611,821	5,421,307	376.5	428.6	430.6	2.0
BR-1168A	612,285	5,420,929	612,229	5,421,005	205.7	433.9	431.7	-2.2
BR-1174	611,590	5,421,268	611,587	5,421,270	425.8	426.9	425.2	-1.7
BR-1176	611,864	5,421,204	611,838	5,421,251	322.2	426.3	430.2	3.8
BR-1177	611,824	5,420,729	611,743	5,420,859	117.1	420.0	422.4	2.4
BR-1187	611,608	5,421,228	611,604	5,421,234	406.1	428.0	425.2	-2.9
BR-1188	611,639	5,421,091	611,625	5,421,115	285.4	416.9	422.3	5.4
BR-1190	611,882	5,421,269	611,867	5,421,292	344.5	430.1	431.2	1.1
BR-1193	612,257	5,420,970	612,231	5,421,027	295.2	434.2	433.1	-1.1
BR-1197A	611,821	5,421,356	611,817	5,421,363	404.7	428.5	431.3	2.9
BR-1198	611,564	5,421,114	611,547	5,421,141	374.9	423.5	420.1	-3.4
BR-1207	611,849	5,421,363	611,840	5,421,378	403.4	428.8	431.8	3.0
BR-1214	611,931	5,421,375	611,912	5,421,402	406.1	436.1	433.6	-2.5
BR-1216	611,683	5,421,251	611,670	5,421,269	415.9	427.7	427.8	0.1
BR-1227	611,731	5,421,133	611,701	5,421,186	336.3	426.8	426.2	-0.5
BR-1228	611,782	5,421,246	611,767	5,421,268	375.7	429.0	429.3	0.3
BR-1229	611,971	5,421,312	611,971	5,421,314	435.7	438.3	434.7	-3.6
BR-1237	612,017	5,421,336	612,017	5,421,336	436.5	438.6	435.8	-2.7
BR-1248	611,675	5,421,175	611,652	5,421,221	385.6	429.5	426.2	-3.3
BR-1251A	611,866	5,420,634	611,764	5,420,806	106.4	425.8	422.3	-3.5
BR-6004	612,747	5,421,364	612,704	5,421,433	235.3	434.2	432.8	-1.3
BR-6021	612,830	5,421,598	612,809	5,421,634	374.9	436.0	434.7	-1.3
BR-6051	612,613	5,421,703	612,604	5,421,717	355.8	434.8	435.2	0.4
BR-6057	612,702	5,421,297	612,664	5,421,364	236.9	433.9	432.4	-1.5
BR-6103A	612,869	5,421,494	612,843	5,421,533	243.5	436.4	433.0	-3.4
BR-6144	612,950	5,421,723	612,938	5,421,745	384.7	432.1	434.0	1.8
BRH-0001A	611,909	5,421,762	611,909	5,421,762	411.3	423.9	426.3	2.5
BRH-0001B	611,909	5,421,761	611,909	5,421,761	423.7	428.2	426.8	-1.3
BRH-0002A	612,178	5,420,590	612,178	5,420,590	405.0	423.4	422.7	-0.7
BRH-0002B	612,177	5,420,589	612,177	5,420,589	418.4	422.1	423.1	1.0
BRH-0003	612,744	5,421,086	612,744	5,421,086	415.6	416.4	416.5	0.2
BRH-0004	613,474	5,421,807	613,474	5,421,807	426.1	429.5	431.9	2.4
BRH-0005B	612,361	5,421,894	612,361	5,421,894	435.6	439.6	438.2	-1.4
BRH-0006	613,857	5,422,544	613,857	5,422,544	413.9	416.7	419.0	2.3
BRH-0007A	614,656	5,420,825	614,656	5,420,825	409.4	420.5	424.5	4.0
BRH-0007B	614,656	5,420,826	614,656	5,420,826	420.9	423.0	424.6	1.6
BRH-0008A	611,683	5,421,030	611,683	5,421,030	400.9	420.4	421.3	0.9
BRH-0008B	611,682	5,421,026	611,682	5,421,026	415.6	419.2	421.2	1.9
BRH-0009	613,878	5,421,290	613,878	5,421,290	409.3	415.8	418.0	2.2
BRH-0010	615,228	5,423,654	615,228	5,423,654	434.6	435.3	435.3	0.0

Table 2: Head Calibration Data and Results (Continued)

Borehole	Collar Easting	Collar Northing	M.P. Easting	M.P. Northing	M.P. Elevation (masl)	Obs. Head (masl)	Calc. Head (masl)	Residual (m)
BRH-0011	615,105	5,421,919	615,105	5,421,919	429.3	431.2	432.4	1.2
BRH-0012A	615,589	5,422,185	615,589	5,422,185	414.3	416.1	418.6	2.5
BRH-0012B	615,589	5,422,185	615,589	5,422,185	415.2	416.1	418.6	2.5
BRH-0013	615,631	5,422,933	615,631	5,422,933	413.0	416.8	420.8	4.0

Notes: M.P. stands for Measuring Point or the "screen" location in MODFLOW. For angled exploration holes (BR-series) the M.P. is offset from the collar easting/northing and generally corresponds to the point at which the borehole intersects the Shear Zone. Eastings and northings are in UTM15 NAD83.

Table 3 lists the spot flow measurement data and simulated baseflow results. Note that simulated baseflow results include both direct groundwater discharge to surface features as well as groundwater discharge to seeps within the catchment which will eventually report to surface features.

Table 3: Flow Calibration Data and Results

Flow Station	Easting	Northing	Measured Flow Range (m^3/d)	Simulated Baseflow (m^3/d)
AB	613,611	5,421,468	173	32
AD	613,050	5,421,167	112	7
AF	615,546	5,423,150	259	17
AH	615,568	5,422,172	0	38
AI	612,197	5,420,673	173	1
G	615,097	5,423,978	Not measured	8
H	614,442	5,423,279	0 to 259.2	0
I	613,830	5,422,530	86 to 147	41
J	612,550	5,422,320	86 to 259	13
K	611,653	5,421,013	0 to 259	42
L	614,480	5,420,879	259 to 432	21

Notes: Eastings and northings are in UTM15 NAD83.

Modelled flows are generally less than measured, with the exception of Station AH. While comparison to this dataset does not provide a rigorous calibration protocol, it does at least suggest that the simulated baseflows are likely not an overestimation.

4.1 Pre-Pit Groundwater Flow Budget

Table 4 tabulates the global groundwater flow budget for the calibrated model.

Table 4: Pre-Pit Calibrated Model Groundwater Flow Budget

Source/Sink	Inflow (m^3/d)	Outflow (m^3/d)
Recharge	847	0
Marmion Reservoir	0	610
Mitta Lake	10	27
Seeps	0	152
Wetlands/Streams	0	68
Total	**857**	**857**

The majority of input to the model is via recharge, with a small amount of leakage from Mitta Lake. Marmion Reservoir serves as the primary discharge location for groundwater; however, some discharge occurs along hillside seeps and into streams and wetlands. It should be noted that discharge from surface water seeps would likely report to the associated stream/wetland discharge complexes; however, these flows are separated for groundwater flow budgeting purposes.

Through the calibration process it is found that recharge rates, the hydraulic conductivities of the geologic units, and the simulated flow patterns are in good agreement with available field data. The calibrated model parameters are therefore considered to represent reasonable estimates for use in estimating Ultimate Pit inflows.

5.0 BASE CASE ULTIMATE PIT MODELLING RESULTS

The proposed pit extents and stockpile footprints at end of mine life are added to the calibrated model, thus producing the base case "Ultimate Pit" scenario. The Ultimate Pit model is used to evaluate the following:

- Pit Inflows.
- Drawdown.
- Stockpile and Sedimentation Pond Seepage Volumes and Pathways.
- Revised Groundwater Flow Budget and Baseflow Changes.

5.1 Pit Inflows

The simulated steady state inflow to the Ultimate Pit totals 740 m^3/d. The west pit inflows contribute 505 m^3/d while the east pit inflows contribute 235 m^3/d. Table 5 provides a breakdown of the inflow contribution based on general hydrostratigraphic groupings.

Table 5: Pit Inflows

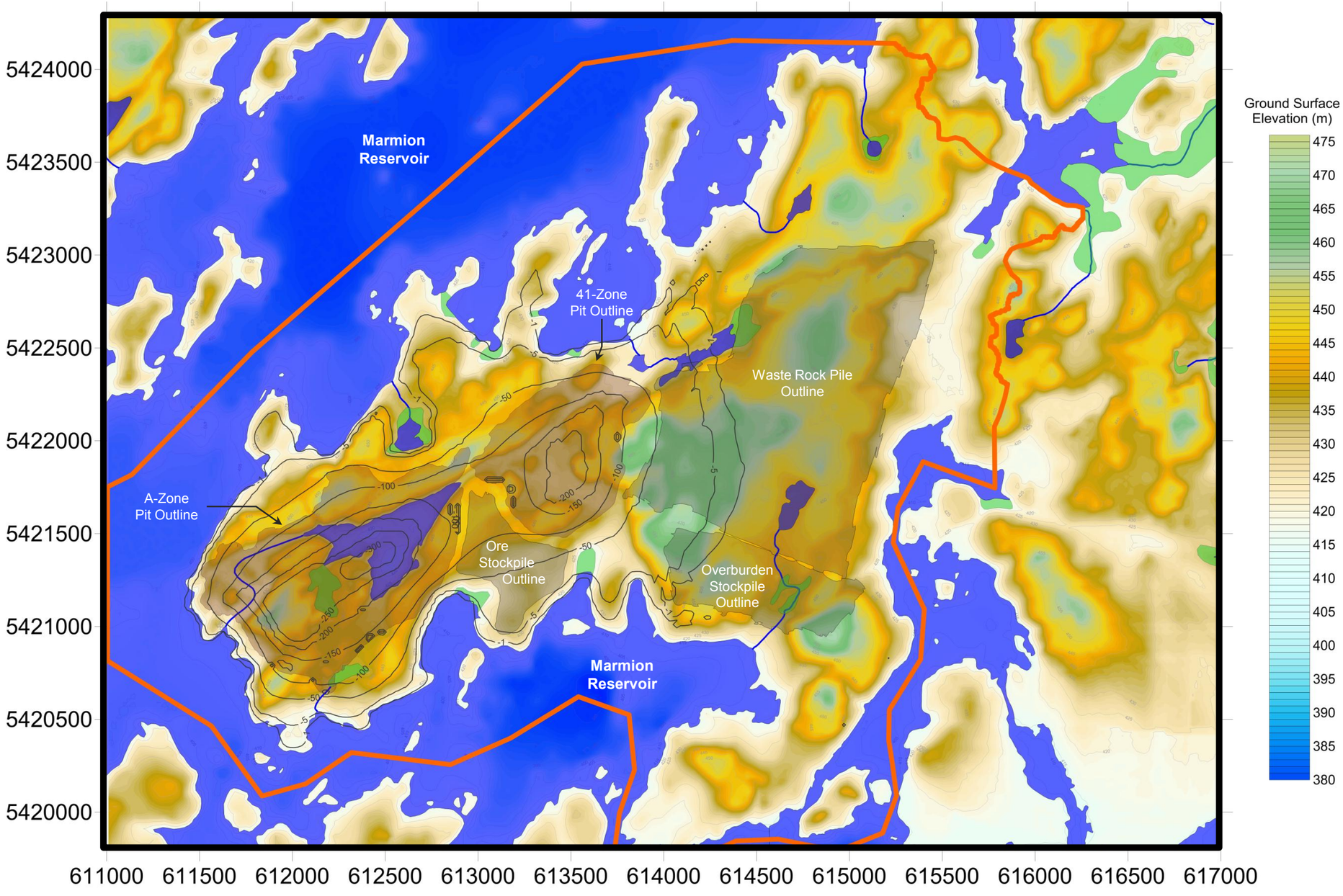
Unit	Steady State Pit Inflow (m^3/d)	% Of Inflow
0 to 30 mbgs	0	0
Shear Zones (30+ mbgs)	268	36%
Ore Zone (30+ mbgs)	370	50%
Host Rock Zone (30+ mbgs)	102	14%
Total	**740**	**100%**

Notes:
mbgs = Metres below ground surface.

The shallow fractured rock system surrounding the pit is dewatered by the end of the life of mine; as such all of the inflow to the pit occurs at depths greater than 30 mbgs. About 50% of the pit inflows emanate from the Ore Zone whereas only 14% originates from the Host Rock Zone; this is reflective of the pit walls being primarily exposed to the ore and the Ore Zone's higher hydraulic conductivity at depth (relative to adjacent rock). The remaining 36% of inflow occurs from the Shear Zones. Despite their narrow intersection with the pit, these features provide a substantial amount of flow due to their relatively high transmissivity over the entire pit depth and their direct (assumed) connection with Marmion Reservoir.

5.2 Drawdown

The Ultimate Pit water table drawdown at steady state is shown on Figure 5-1; the Ultimate Pit water table is shown on Figure 5-2. Maximum drawdown of 315 m and 220 m occur in the west and east pits respectively, in accordance with their pit bottom depths. The western, southern and northern extents of the drawdown cone terminate at Marmion Reservoir. To the east, the 1 m drawdown contour extends a maximum of about 700 m from the edge of the east pit and about halfway beneath the waste rock stockpile.



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (variable contour interval -1. -5, -50, -100, -150, -200, -250, and -300m)

Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Simulated Groundwater Drawdown (m)

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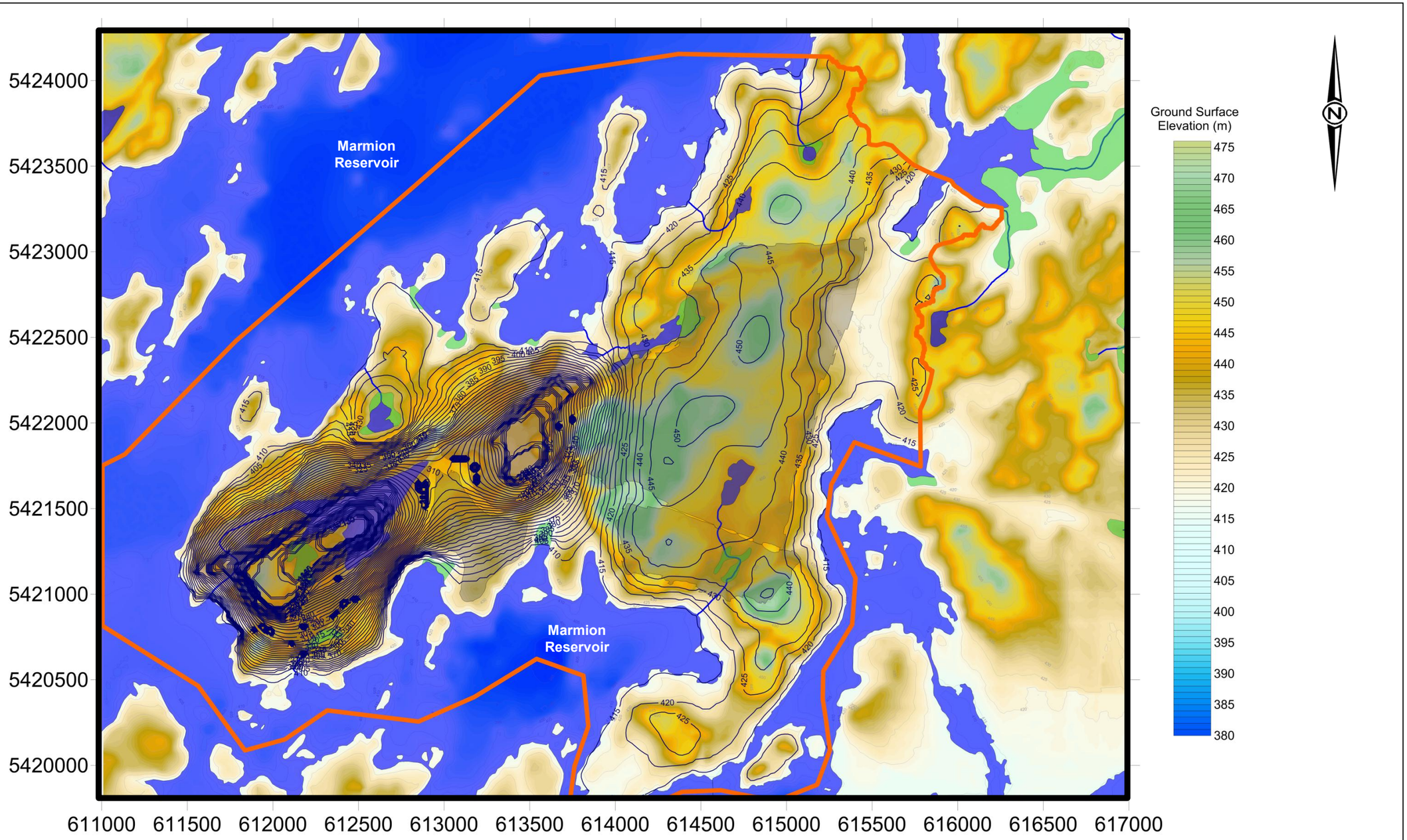
SIMULATED DRAWDOWN (ULTIMATE PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 5-1



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. The contour lines shown reflect the simulated water table elevations under Ultimate Pit conditions (5m contour interval).

Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Simulated Water Table Elevation (m)

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SIMULATED WATER TABLE (ULTIMATE PIT)

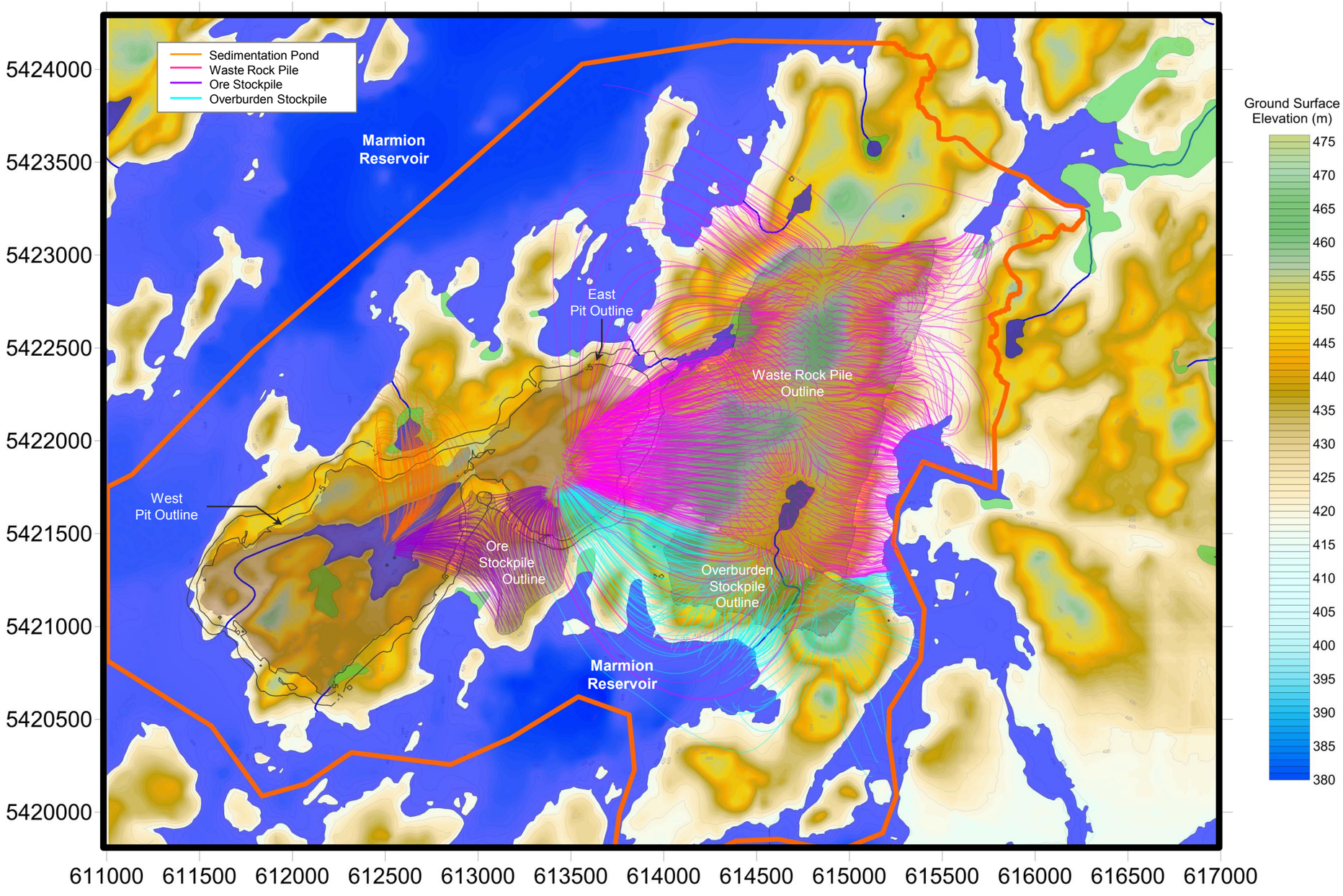
OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 5-2

5.3 Stockpile and Sedimentation Pond Seepage

Stockpile and sedimentation pond seepage pathways are derived via forward particle tracking in each upper cell underlying the piles (Figure 5-3). Seepage rates and discharge to receptors are further quantified via zone budget analysis (Table 6).

Table 6: Stockpile Seepage

Stockpile	Total Seepage (m^3/d)	Receptor	Receiving Discharge (m^3/d)
Waste rock	241	East pit	133
		Marmion Reservoir	108
Low-grade ore	32	West and east pits	32
Overburden	52	East pit	16
		Marmion Reservoir	36
Sedimentation pond	37	Primarily west pit	36
		Marmion Reservoir	1



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. Particle pathlines are shown for steady-state conditions, and their three-dimensional direction is projected to surface on a two dimensional plane.

Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers

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STOCKPILE SEEPAGE PATHWAYS (ULTIMATE PIT)

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 5-3

5.4 Ultimate Pit Groundwater Flow Budget

The groundwater flow budget with the Ultimate Pit in place is listed in Table 7.

Table 7: Ultimate Pit Model Flow Budget

Source/Sink	Inflow (m^3/d)	Outflow (m^3/d)
Recharge (waste rock stockpile)	241	0
Recharge (low-grade ore stockpile)	32	0
Recharge (overburden stockpile)	52	0
Recharge (Other)	477	0
Marmion Reservoir	396	376
Mitta Lake	-	-
Seeps	0	82
Wetlands/Streams	0	37
Pit	0	740
Sedimentation pond	37	0
Total	**1,235**	**1,235**

Notes: Mitta Lake will be removed to develop the mine and is not represented in the Ultimate Pit Model.

The total recharge to the groundwater model has decreased to from 847 m^3/d to 802 m^3/d as infiltration over the pit and sedimentation pond footprints is eliminated.

The gradient induced by the Ultimate Pit results in Marmion Reservoir providing 396 m^3/d into the system, most of which reports directly to the pit. Elsewhere, Marmion Reservoir still receives 376 m^3/d of discharge from the regional system.

Slightly more than half of the 740 m^3/d of pit inflow is sourced from Marmion Reservoir; however, about 344 m^3/d is taken from the surrounding regional system (including, in part, seepage from the sedimentation pond and stockpiles). As a result, some baseflow loss occurs at hillside seeps (a total decrease from 152 m^3/d to 82 m^3/d) and wetlands and streams (a total decrease from 68 m^3/d to 37 m^3/d). However, additional seepage emanating from the stockpiles ultimately results in greater discharge to some nearby surface water features. Table 8 details changes to groundwater baseflow on a subwatershed level.

Table 8: Simulated Subwatershed Groundwater Discharge To Seeps, Wetlands and Streams

Subwatershed	Pre-Pit Discharge (m^3/d)	Ultimate Pit In-Place Discharge (m^3/d)	% Change
AB	32	0	-100%
AD	7	0	-100%
AF	17	25	+47%
AH	38	55	+45%
AI	1	0	-100%
G	8	8	0%

Subwatershed	Pre-Pit Discharge (m^3/d)	Ultimate Pit In-Place Discharge (m^3/d)	% Change
H	0	0	0%
I	41	25	-39%
J	13	1	-92%
K	42	0	-100%
L	21	0	-100%

Notes: Subwatershed K is fully excavated by the Ultimate Pit. The majority of Subwatershed L is enveloped by the waste rock stockpile, including the surface water features.

6.0 UNCERTAINTY ANALYSIS

An uncertainty analysis is conducted on the base case Ultimate Pit model to establish a range of potential pit inflows and drawdown. The uncertainty analysis is not a recalibration nor is there an attempt to quantify the degree of uncertainty associated with each simulation; rather key parameters are adjusted with the intent of producing a range of possible, but less likely, results. Eight additional modelling scenarios are considered:

- **Uncertainty 1:** Increase the shear's hydraulic conductivity from 1×10^{-7} m/s to 1×10^{-6} m/s. This simulation reflects the possibility that the bulk hydraulic conductivity of the shear material is higher than that inferred from field data.
- **Uncertainty 2:** Increase the shear's hydraulic conductivity from 1×10^{-7} m/s to 1×10^{-5} m/s. This run is intended to approximate the situation where the shear structure infill is compromised by the hydraulic gradients that will get progressively higher as the pit is deepened.
- **Uncertainty 3:** Deepen the upper 10 m fractured zone to 30 m deep, in effect increasing the hydraulic conductivity to 1×10^{-6} m/s to a depth of 30 m. This simulation considers the possibility that the upper fractured zone is deeper than conceptualized.
- **Uncertainty 4:** Reduce the Ore Zone hydraulic conductivity distribution to that of the Host Rock Zone. There is some possibility that these distinct units may be hydraulically similar.
- **Uncertainty 5:** Increase recharge by 25% to account for uncertainty in the infiltration estimate.
- **Uncertainty 6:** Decrease recharge by 25% to account for uncertainty in the infiltration estimate.
- **Uncertainty 7:** Set all layer types to "Type 0 Confined". The base case layer types are defined in MODFLOW by the "Type 3 Confined / Unconfined" setting. Under this setting a given cell may range from fully saturated to entirely dewatered (i.e., dry) and as such the transmissivity may vary. This setting best approximates the hydrogeological condition for the site. However, under some circumstances, particularly where a higher permeability unit is underlain by a lower permeability one, there may be the potential for shallower units to continue to transmit water into the pit despite the water table falling beneath the unit itself (i.e., a perched condition). The Type 0 Confined designation approximates this condition by retaining transmissivity in the layer. However, it is should be noted that the cell transmissivity is the entire cell thickness multiplied by the hydraulic conductivity. As it is unlikely that a perched unit would remain entirely saturated this simulation may tend to over predict inflows and drawdown.
- **Uncertainty 8:** Approximate shallow pit excavation and determine transient, early-time pit inflows. Water released from storage, heretofore negligible in the Ultimate Pit steady state models, will contribute a large volume of water in early mining. The purpose of this run is to approximate the magnitude of inflows that might be expected as excavation progresses below the water table and into the upper fractured rock. For this run, a uniform 30 m deep, "instantaneous" excavation is assumed to occur across the mine footprint. The model is run transiently from time 0 to 90 days. Specific yields of 0.3 and 0.03 are considered for the upper fractured zone (0 m to 10 m) and competent rock, respectively, based on literature values for porosity in granite (Davis 1969). A specific storage of 1×10^{-6} was assumed for all units.

The pit inflows for each steady-state simulation are shown in Table 9. The steady-state Ultimate Pit inflows range from 632 m^3/d to 1,814 m^3/d.

Table 9: Uncertainty Analysis Steady-State Pit Inflows

Uncertainty Scenario	Pit Inflows (m^3/d)	% Change From Base Case
1	958	+29%
2	1,814	+145%
3	901	+21%
4	632	-15%
5	773	4%
6	717	-3%
7	1,055	+42%

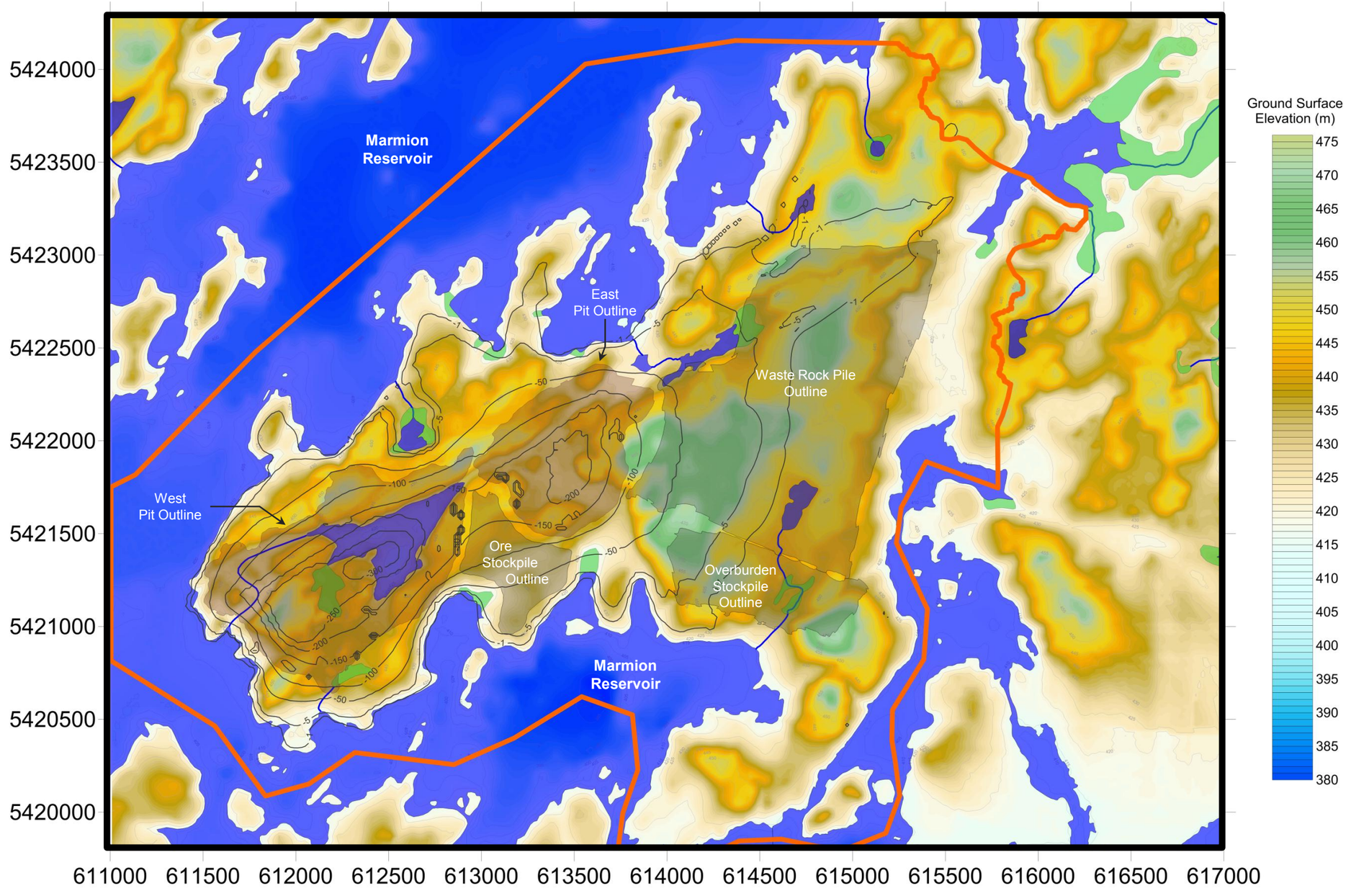
Increasing the Shear Zone hydraulic conductivity by one to two orders of magnitude results in increase in pit inflows from 29% to 145%. The model results are sensitive to an increase in hydraulic conductivity of the shears because the increase is transmitted the entire depth of the pit and the shears themselves run the length of the model domain. The eastern extent of drawdown extends about 2 km to 3 km northeast of the east pit perimeter, or over 1 km to 2 km more than in the base case, with the greatest drawdown in this area being centred along the inferred Shear Zone extension (Figure 6-1, and, in particular, Figure 6-2 compared to Figure 5-1).

Pit inflows are increased 21% as a result of extending the fractured zone depth another 20 m; the degree of this change is somewhat muted because a significant amount of the shallow rock is dewatered by end of life of mine. However, far-field from the pit, where this unit is largely saturated, drawdown extends further east than in the base case (Figure 6-3 compared to Figure 5-1). Some of this drawdown, particularly towards the eastern edge of the model domain, may not be due to pit dewatering as much as the water table lowering due to greater ease of vertical seepage in the shallow units.

Setting the Ore Zone hydraulic conductivity to that of the Host Rock Zone results in a 21% decrease in pit inflows. This is expected as the Host Rock Zone is, at some elevations, a half order magnitude lower permeability than the neighbouring base case Ore Zone permeability. The drawdown in this scenario is similar to the base case (Figure 6-4 compared to Figure 5-1).

The model results are not particularly responsive to the +/-25% change in recharge rates, this stems from the recharge input being low in the base case to begin with. As illustrated in Figure 6-5 and Figure 6-6, the drawdown resulting from these changes are close to the base case (Figure 6-5 and Figure 6-6 compared to Figure 5-1). In the case of Figure 6-6 some of this drawdown, particularly towards the eastern edge of the model domain, may not be due to pit dewatering as much as the water table lowering due to less recharge.

Setting all model layers to Confined Type 0 “restores” the transmissivity of units partially or fully dewatered under the base case model. The result is a 42% increase in pit inflows and an expanded drawdown cone (Figure 6-7 compared to Figure 5-1). However, as mentioned previously, the results of this simulation are considered conservative.



Notes

1. The current modelling work considers the pit shell provided by Osisko dated July 26, 2012.
2. The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (variable contour interval -1. -5, -50, -100, -150, -200, -250, and -300m)

Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers
Simulated Groundwater Drawdown (m)

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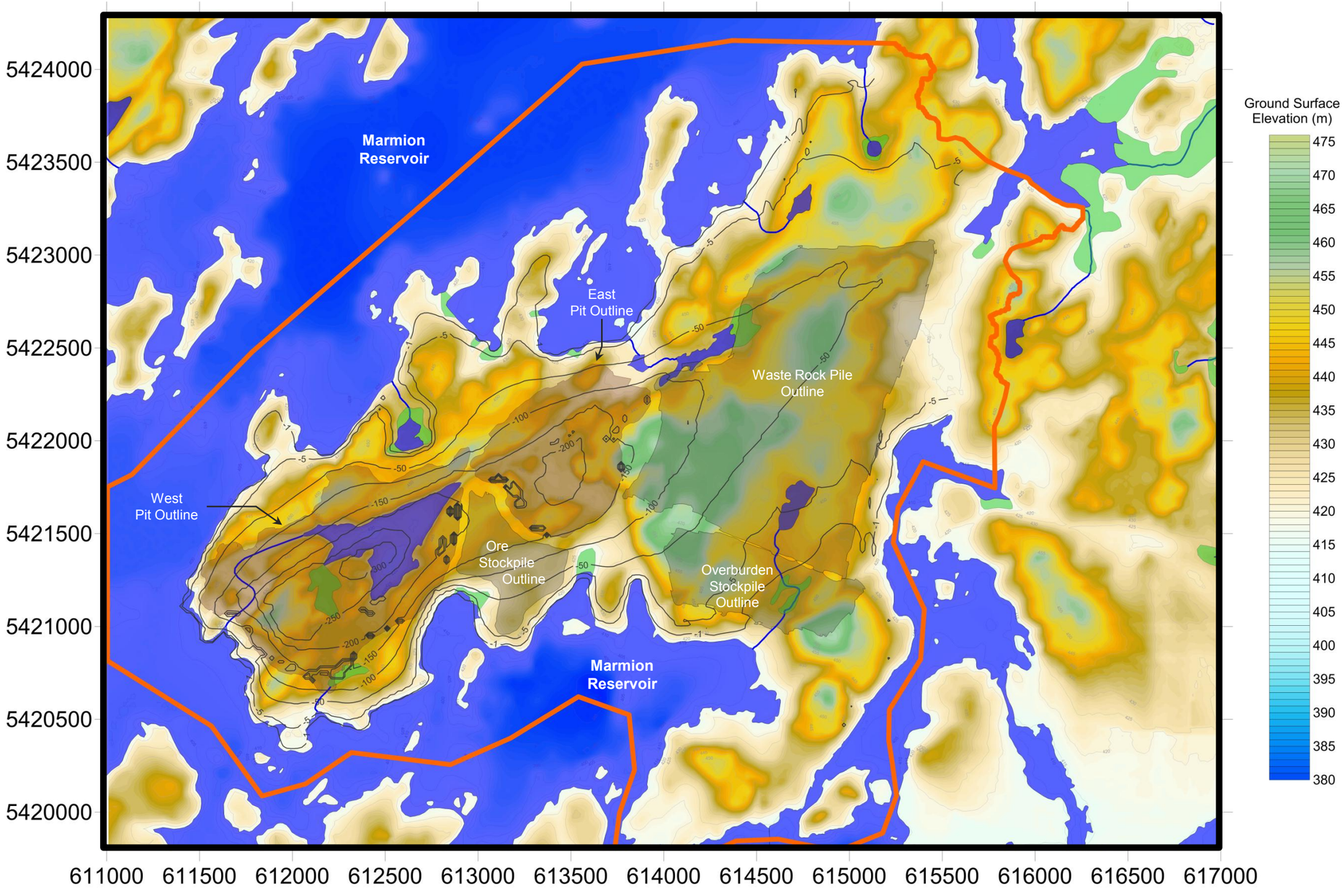
UNCERTAINTY SCENARIO 1 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-1



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2. The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (variable contour interval -1. -5, -50, -100, -150, -200, -250, and -300m)

Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Simulated Groundwater Drawdown (m)

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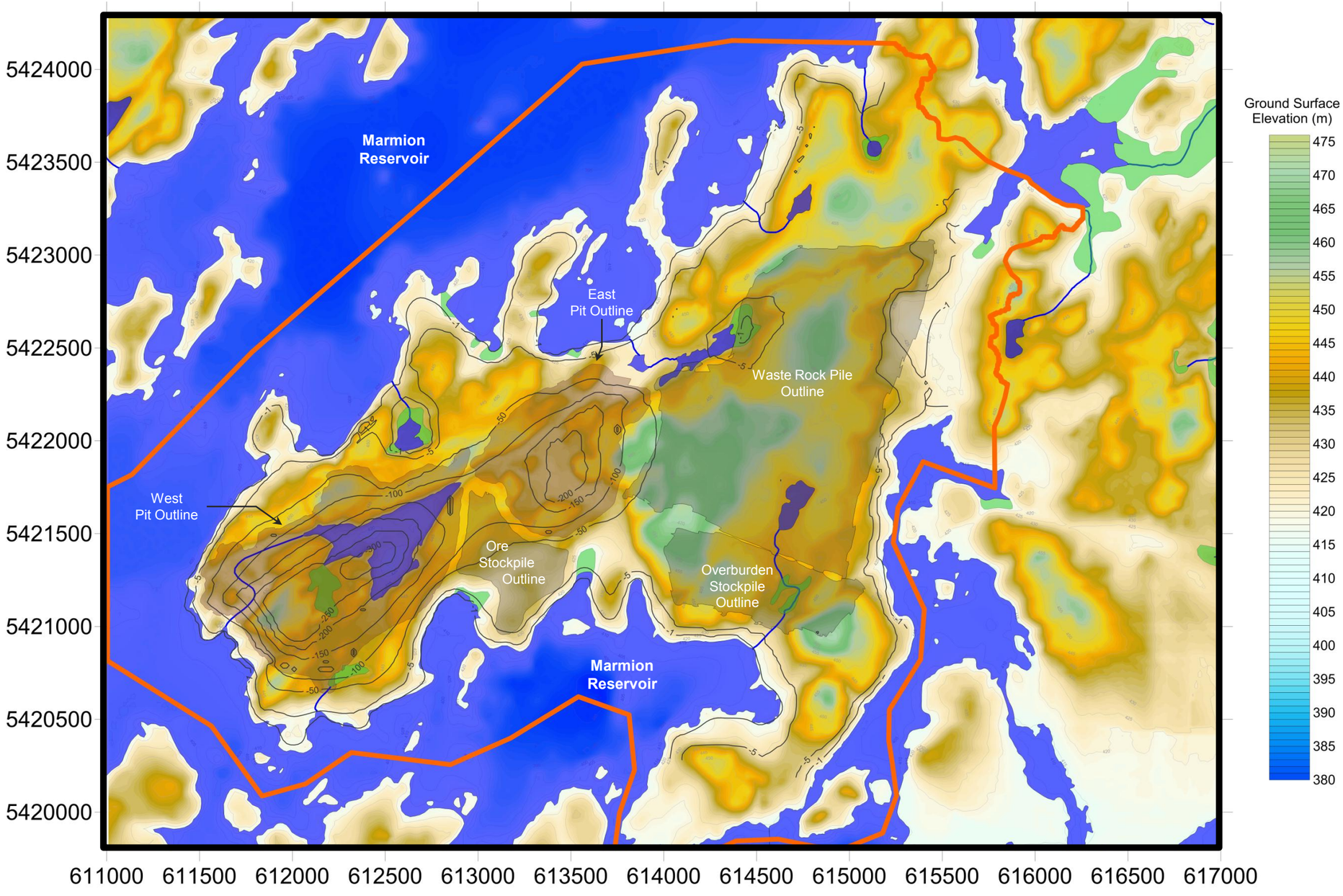
UNCERTAINTY SCENARIO 2 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-2



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2. The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (variable contour interval -1. -5, -50, -100, -150, -200, -250, and -300m)

Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers
Simulated Groundwater Drawdown (m)

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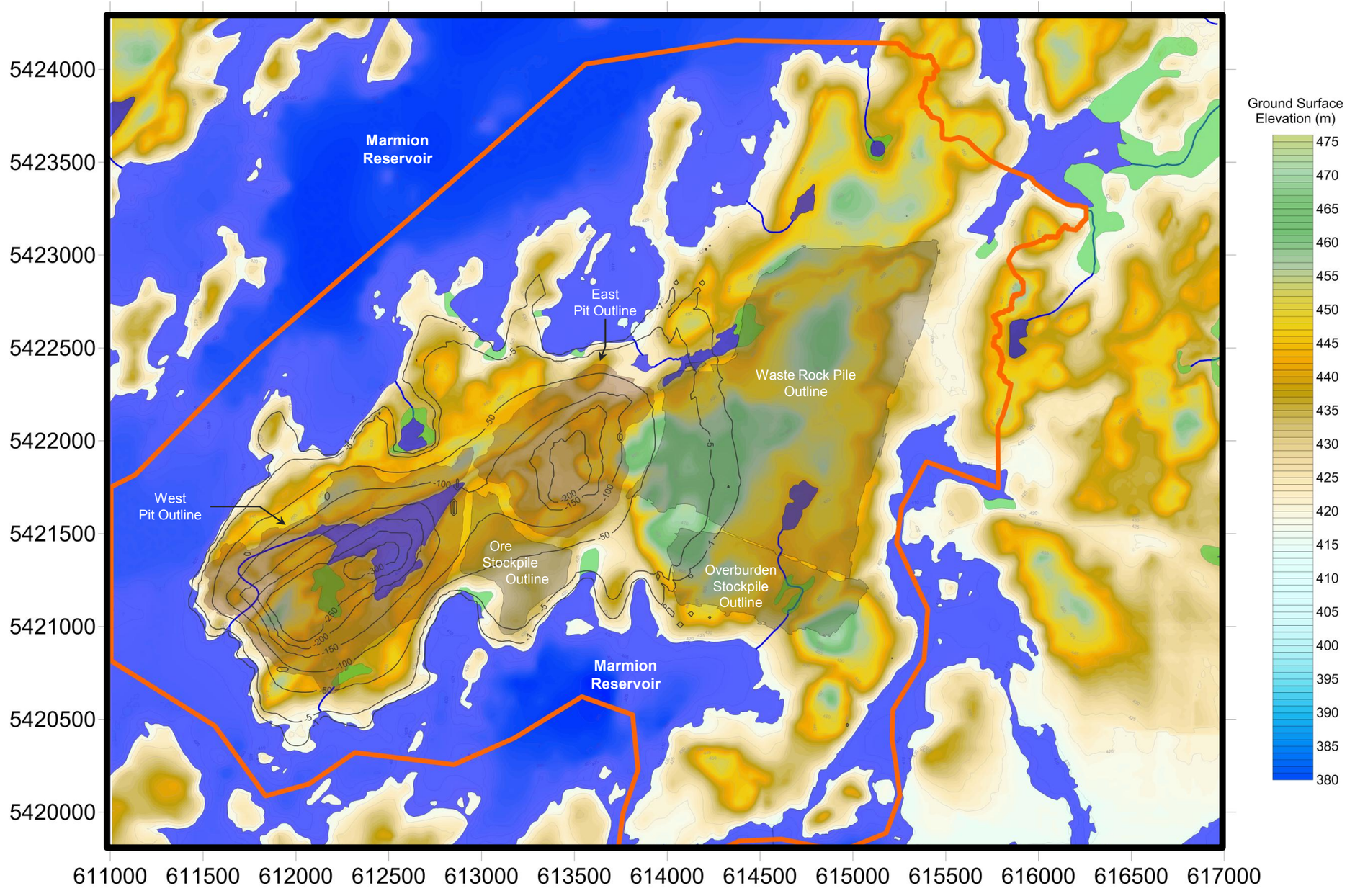
UNCERTAINTY SCENARIO 3 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-3



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Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Simulated Groundwater Drawdown (m)

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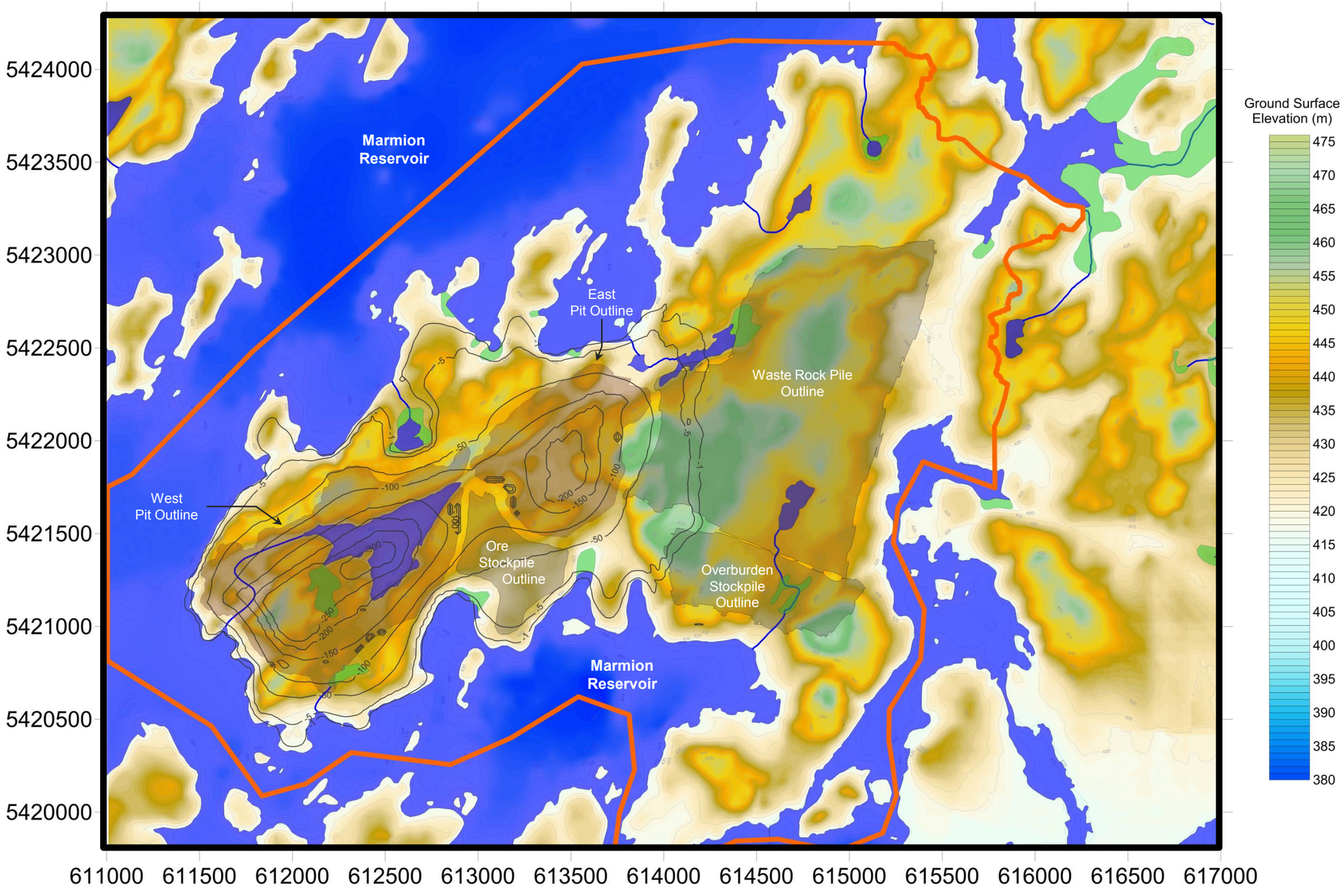
UNCERTAINTY SCENARIO 4 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-4



Notes

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2. The contour lines shown reflect the change in simulated groundwater elevations from the calibrated Pre-Mining Model (variable contour interval -1. -5, -50, -100, -150, -200, -250, and -300m)

Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers
Simulated Groundwater Drawdown (m)

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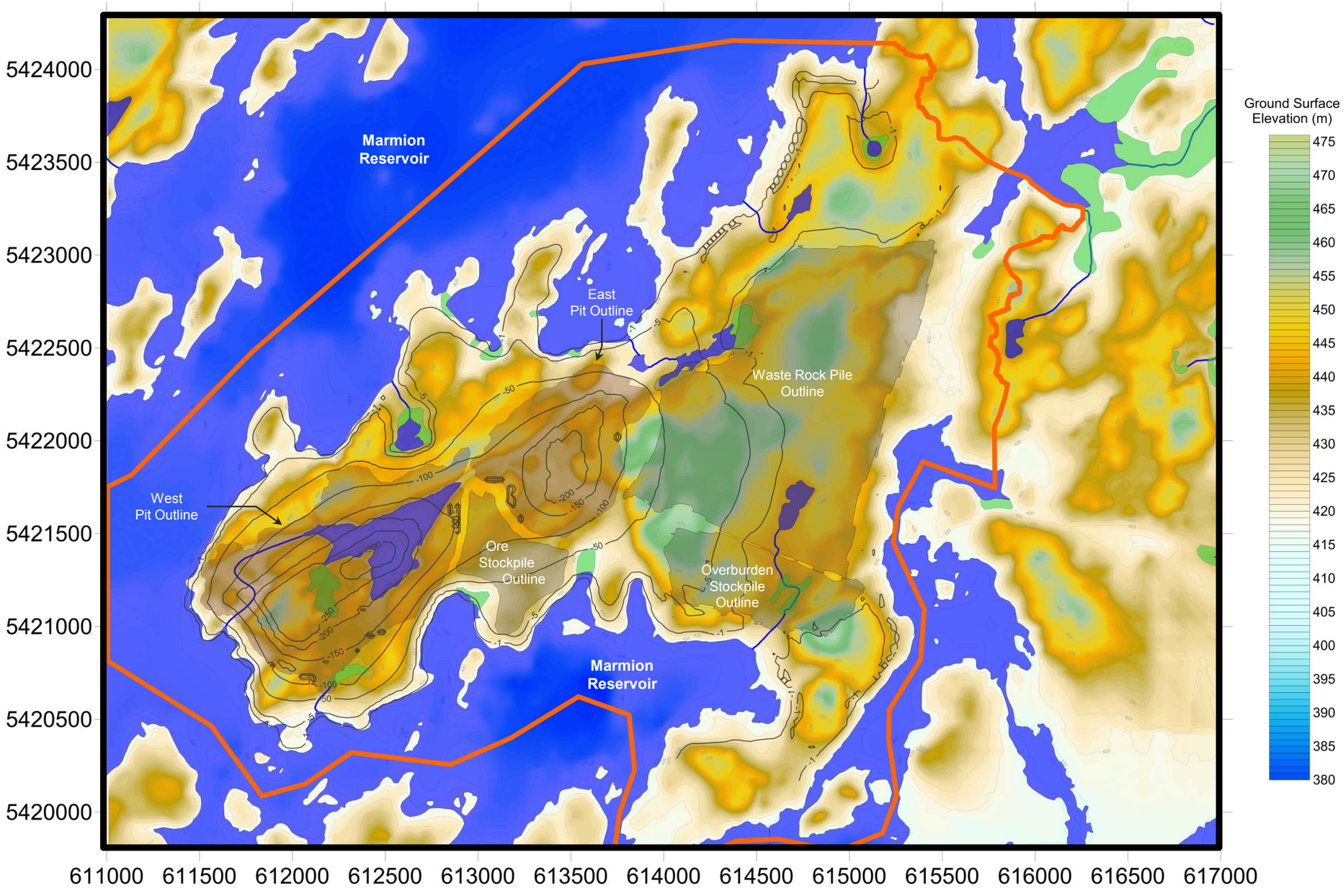
UNCERTAINTY SCENARIO 5 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-5



Notes

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Legend

- Model Extent
- Active Model Domain
- Lakes
- Wetlands
- Streams/Rivers
- Simulated Groundwater Drawdown (m)

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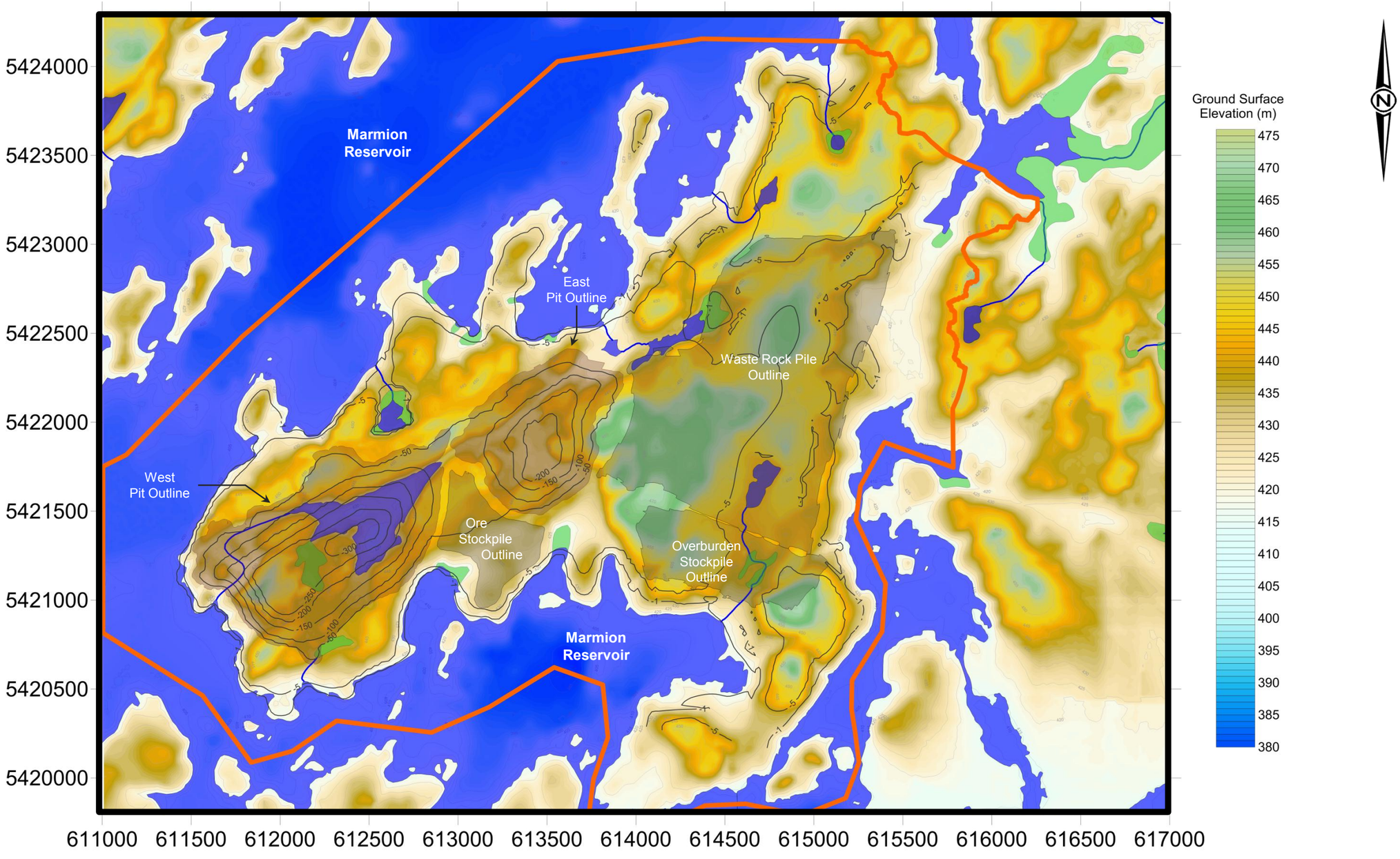
UNCERTAINTY SCENARIO 6 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-6



Notes

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Legend

Model Extent
Active Model Domain
Lakes
Wetlands
Streams/Rivers
Simulated Groundwater Drawdown (m)

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UNCERTAINTY SCENARIO 7 DRAWDOWN

OCTOBER 2012	PROJECT: 11-1118-0079	FIGURE 6-7

The transient, early-mining inflows for Uncertainty Simulation 8 are listed in Table 10. The pit inflows range from 7,760 m^3/d at time "zero" to 422 m^3/d at 90 days and 212 m^3/d at steady-state. Note that steady-state would not likely be reached during early mining as the pit is progressed almost continually; however, the steady-state inflow is reported for comparison.

Table 10: Uncertainty Analysis Transient Early Mine Pit Inflows

Uncertainty Scenario	Pit Inflows (m^3/d)
Day 0 to Day 5	7,760
Day 5 to Day 10	1,260
Day 10 to Day 20	861
Day 20 to Day 30	700
Day 30 to Day 60	503
Day 60 to Day 90	422
Steady State	212

The high inflows at early time are largely due to release of water from storage from the pit perimeter. As this initial release is depleted, the mine inflows rapidly decrease with time and approach a steady state condition. The brief simulation period produces a relatively small drawdown cone at 90 days (Figure 6-8). It is important to note that this simulation is an approximation of an early mine scenario. Aside from a 30 m instantaneous excavation being impossible, it is likely that significant depressurization would occur prior to or during excavation to offset sudden inflows on the order of those reported herein. In addition, the model results could be further refined through additional field or laboratory testing to determine an in-situ storage value for the shallow rock material.

7.0 LIMITATIONS

7.1 General Reporting Limitations

The factual information, descriptions, interpretations, comments, conclusions and recommendations contained herein are specific to the project described in this report and do not apply to any other project or site. Under no circumstances may this information be used for any other purposes than those specified in the scope of work unless explicitly stipulated in the text of this report or formally authorized by Golder. This document must be read in its entirety, and, ideally, in conjunction with the Hydrogeology TSD; some sections could be misinterpreted when taken individually or out-of-context. As well, the final version of this document and its content supersedes any other text, opinion or preliminary version produced by Golder.

Plans, specifications, calculations, notes, electronic files and similar material used to construct the groundwater model and to conduct simulations are instruments of service, not products. Golder shall not be held responsible for damages resulting from unpredictable or unknown underground conditions, from erroneous information provided by and/or obtained from sources other than Golder, and from ulterior changes in the site conditions unless Golder has been notified by OHRG of any occurrence, activity, information or discovery, past or future, susceptible of modifying the underground conditions described herein, and have had the opportunity of revising its interpretations, comments and recommendations. Furthermore, Golder shall not be held responsible for damages resulting from any future modification to the applicable regulations, standards and criteria, for any use of this report and its content by a third party, and/or for its use for other purposes than those intended. Golder shall not be held responsible for any decrease, real or perceived, of a property's value or any failure to complete a transaction, as a consequence of this report.

7.2 Groundwater Modelling General Limitations

Hydrogeological investigations and groundwater modelling are dynamic and inexact sciences. They are dynamic in the sense that the state of any hydrogeological system is changing with time, and in the sense that the science is continually developing new techniques to evaluate these systems. They are inexact in the sense that subsurface conditions are not known between the specific investigation locations, and there is invariably a lack of complete information both spatially and temporally about the geological and hydrogeological conditions. A groundwater model uses the laws of science and mathematics to draw together the available data into a mathematical or computer-based representation of the essential features of an existing hydrogeological system. While the model itself obviously lacks the detailed reality of the existing hydrogeological system, the behaviour of a valid groundwater model reasonably approximates that of the real system. The validity and accuracy of the model depends on the amount of data available relative to the degree of complexity of the geologic formations, the site geochemistry, the fate and transport of the dissolved compounds, and on the quality and degree of accuracy of the data entered. Therefore, every groundwater model is a simplification of a reality and the model described in this report is not an exception.

The professional groundwater modelling services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practising under similar conditions, subject to the quantity and quality of available data, the time limits and financial and physical constraints applicable to the services. Unless otherwise

specified, the results of previous or simultaneous work provided by sources other than Golder and quoted and/or used herein are considered as having been obtained according to recognised and accepted professional rules and practices, and therefore deemed valid. This model provides a predictive scientific tool to evaluate the impacts on a real groundwater system of specified hydrological stresses and/or to compare various scenarios in a decision-making process. However, and despite the professional care taken during the construction of the model and in conducting the simulations, its accuracy is bound to the normal uncertainty associated to groundwater modelling and no warranty, express or implied, is made.

8.0 REFERENCES

Davis, S.N. (1969). *Porosity and permeability of natural materials*. Flow Through Porous Media, R.J.M de Wiest, Editor, Academic Press, NY.

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APPENDIX 3.I

Groundwater Quality

February 2013
Project No. 10-1118-0020
Hammond Reef Gold Project

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0001B					BRH-0002A					BRH-0002B				
						Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12
Physical Tests																				
Conductivity (EC)	uS/cm	3.0	—	—	—	262	313	360	353	337	346	354	366	481	521	268	249	343	300	262
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	129	155	175	198	143	164	166	141	207	187	108	131	90	138	110
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.97	7.29	7.54	7.78	7.68	7.58	7.77	7.86	7.85	7.64	7.04	6.67	6.96	7.19	6.61
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	2480	109	137	364	366	4860	795	5600	3770	901	10100	1150	2510	2220	1060
Total Dissolved Solids	mg/L	10	—	—	500[q]	190	188	183	232	212	304	242	218	349	314	217	192	166	204	206
Anions and Nutrients																				
Acidity (as CaCO3)	mg/L	2.0	—	—	—	4.8	6.8	3.2	7.2	8.4	8.0	3.0	2.4	3.6	3.8	17.8	09.4	8.4	9.8	30.2
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	127	156	184	174	160	173	180	178	151	157	126	118	149	128	110
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.040	<0.020	<0.020	0.044	0.053	0.321	0.211	0.17	0.237	0.270	0.388	0.052	0.157	0.137	0.082
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	154	190	223	212	160	210	218	216	184	157	153	144	182	157	110
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	1.22	0.99	1.17	1.43	1.39	2.30	2.43	2.65	33.8	36.8	2.98	3.17	3.17	7.99	6.80
Fluoride	mg/L	0.030	—	—	1.5	0.061	<0.030	<0.030	0.050	0.057	0.100	0.057	0.085	0.095	0.121	<0.030	<0.030	<0.030	<0.030	<0.030
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	0.155	0.030	0.308	0.429	0.359	<0.030	0.206	0.03	<0.030	0.082	<0.030	<0.030	<0.030	0.063	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	0.025	0.069	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.027	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	0.0125
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	1.60	0.06	0.19	0.509	0.196	1.61	0.01	0.204	0.137	0.140	3.41	0.58	1.56	1.40	0.32
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	12.7	05.6	03.4	6.18	7.20	7.65	5.43	5.23	35.3	41.9	8.61	3.17	14.5	9.63	6.48
Cyanides																				
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																				
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	47.1	05.2	05.0	3.8	3.7	7.1	5.7	7.3	4.6	4.2	9.9	10.2	11.8	6.8	11.5
Total Organic Carbon	mg/L	1.0	—	—	—	53.9	05.1	04.7	4.3	3.7	8.4	5.8	6.9	4.7	5.0	14.2	10.4	13.4	10.2	11.2
Dissolved Metals																				
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.275	0.018	0.005	0.0344	0.0265	<0.010	<0.10	0.0055	<0.0050	0.0118	0.058	0.048	0.0414	0.0387	0.121
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	0.0011	<0.0010	0.0020	0.0018	<0.0010	<0.0010	0.0015	<0.0010	<0.0010	<0.0010	<0.0031	***<0.0052***	0.0037	0.0024	0.0039
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	<0.010	0.017	0.012	0.020	0.016	0.030	0.022	0.024	0.031	0.027	<0.0170	<0.0320	0.042	0.024	0.024
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.50	<0.050	0.109	0.168	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.00017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	***0.000056***	***0.000095***	<0.000090	<0.000090	***0.000094***	***0.000043***	***0.00004***	<0.000090	<0.000090	<0.000090	***0.000019***	***0.000023***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	47.8	57.9	63.7	73.5	53.4	58.6	66.7	50.3	75.7	68	40.8	49.3	52.4	52.0	41
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	<0.00050	0.00098	0.0007	0.00136	<0.00050	0.00165	0.00055	0.00091	<0.00050	<0.00050	0.00085	0.00050	0.00081	<0.00050	0.00078
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[l]	0.001-0.005[f][m]	1[q]	***0.0056***	***0.0033***	0.0026	<0.0010	0.0018	<0.0010	0.001	***0.0045***	<0.0010	<0.0010	0.0011	<0.0010	0.0015	<0.0010	0.0016
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	0.056	<0.050	<0.020	***1.59***	0.06	0.244	0.187	<0.020	***1.31***	***0.866***	***1.65***	***2.17***	***1.88***	***1.13***	***1.93***
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<1.0	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	2.41	2.58	3.96	3.46	2.24	4.28	<5.0	3.84	4.37	4.14	1.59	1.91	2.55	1.94	1.86
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.373	1.390	0.896	0.895	0.386	0.439	0.347	0.229	0.469	0.386	0.665	0.867	1.06	1.25	1.43
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	***0.000077***	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0056	0.0025	0.0151	0.0076	0.0032	0.0116	0.0215	0.0231	0.0141	0.0122	0.0047	0.0090	0.0073	0.0053	0.0033
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	0.0048	0.0064	0.0059	0.0022	0.0083	0.0083	0.0088	<0.0020	<0.0020	0.0023	0.0052	0.0027	<0.0020	<0.0020
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	4.2	<1.0	3.6	2.16	1.11	1.5	1.4	2.4	1.55	1.65	<1.0	<1.0	<1.0	0.63	0.56
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	4.4					6.7					5.9				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	4.60	2.00	5.83	6.35	3.93	12.2	06.8	23.9	21.8	31.2	15.3	08.1	36	9.03	6.91
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.179	0.217	0.256	0.294	0.227	0.297	0.236	0.28	0.298	0.200	0.0958	0.0841	0.14	0.161	0.093
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	0.163	<0.010	0.028	0.011	<0.010	0.011	0.017	0.033	0.166	0.057	0.015	0.015	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0015	0.0027	0.0031	0.0014	0.0024
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0031	0.0161	<0.0030	0.0111	0.0094	0.0094	0.0073	0.0291	<0.0030	<0.0030	0.0089	0.0031	<0.0030	0.0038	0.0107
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	0.0016	<0.0010	0.0013	0.0011	0.0015	0.0022	0.0015	0.0016	0.0021
Aggregate Organics																				
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	***0.0165***	***0.0051***	<0.0010	<0.0010	<0.0010	0.0022	0.0028	<0.0010	<0.0010	<0.0010	***0.0049***	0.0015	<0.0010	<0.0010	<0.0010

Notes:

See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0003					BRH-0004					BRH-0005B					
						Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11		Aug-11	Oct-11	Apr-12	Aug-12
Physical Tests																Duplicate					
Conductivity (EC)	uS/cm	3.0	—	—	—	181	248	287	272	378	436	513	482	475	445	195	197	239	220	250	219
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	92.3	133	133	136	171	229	212	218	236	207	123	81.3	111	93.5	176	98
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	6.87	7.34	7.16	7.48	7.35	7.32	7.18	7.54	7.54	7.32	6.71	6.70	6.79	6.88	7.11	6.87
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	1330	922	264	185	106	246	629	378	553	185	74.0	61.5	181	35.8	71.5	49.7
Total Dissolved Solids	mg/L	10	—	—	500[q]	110	150	100	137	232	320	372	268	254	274	180	120	152	103	141	142
Anions and Nutrients																					
Acidity (as CaCO3)	mg/L	2.0	—	—	—	6.2	3.6	4.8	7.4	17.4	12.2	11.4	2.8	14.2	05.4	16.0	20.0	04.0	5.6	12.8	11.2
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	80.7	114.0	126	124	183	211	207	229	222	206	90.6	92.2	107.0	99	115	097
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.020	<0.020	<0.020	<0.020	0.052	<0.020	0.106	0.134	0.392	0.357	<0.020	<0.020	<0.020	<0.020	<0.020	<0.02
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	98.0	138.0	154	152	183	256	252	279	271	206	110	112	131	121	140	097
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	3.20	3.80	4.01	2.22	4.80	3.67	6.49	4.97	7.97	5.41	1.02	0.95	1.25	0.76	0.62	1.25
Fluoride	mg/L	0.030	—	—	1.5	<0.030	<0.030	<0.030	<0.030	0.056	<0.15	<0.0450	<0.030	0.038	0.052	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	0.088	0.175	0.86	0.339	0.040	<0.030	0.153	<0.030	0.064	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.238
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.10	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.105	0.178	0.101	0.0583	0.0303	0.109	0.098	0.0553	0.131	0.082	0.0439	0.0833	0.0739	0.0196	0.0435	0.0130
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	5.19	6.01	4.22	5.05	3.88	11.5	47.8	11.6	10.7	11.2	6.94	6.78	11.50	6.2	6.60	5.58
Cyanides																					
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																					
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	4.3	3.7	5.2	4.8	6.4	25.6	22.4	12.5	16.0	12.1	5.2	5.5	5.0	4.8	4.1	6.2
Total Organic Carbon	mg/L	1.0	—	—	—	5.9	4.3	5.8	4.9	6.3	24.7	22.3	15.5	19.1	12.0	5.5	5.7	5.1	4.7	4.6	6.3
Dissolved Metals																					
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.035	0.041	0.0122	0.0146	0.0223	0.012	<0.10	0.0065	0.0173	0.0226	0.035	0.084	0.181	0.086	0.0221	0.117
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.0060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0014	<0.010	0.002	0.0020	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	<0.010	<0.010	<0.010	<0.010	0.011	0.053	<0.10	0.051	0.083	0.083	<0.010	<0.010	<0.010	<0.010	0.015	<0.010
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.50	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	***0.000109***	<0.000090	***0.000031***	***0.000209***	<0.000090	<0.00090	<0.000090	<0.000017	***0.00002***	***0.000155***	***0.000119***	***0.000159***	***0.000146***	***0.000110***	***0.000232***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	35.6	51.8	51.6	52.4	58	83.8	76.2	77.3	83.4	74.0	46.0	30.8	42.3	35.7	67.2	37.6
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00235	<0.0050	0.00085	0.00053	<0.00050	0.00237	0.00129	0.00219	0.00166	0.00179	0.00121
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[l]	0.001-0.005[f][m]	1[q]	***0.0023***	***0.0035***	***0.0044***	0.0017	***0.0038***	0.0024	<0.010	0.0023	<0.0010	<0.0010	***0.0084***	***0.0094***	***0.0081***	***0.0086***	0.0025	***0.01***
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	<0.050	<0.050	<0.020	<0.020	<0.020	***2.80***	<0.50	***0.685***	***7.15***	***0.575***	<0.050	<0.050	0.122	<0.020	0.214	<0.020
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	0.0021	0.0015	0.0014	<0.0010	0.0025
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<1.0	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	0.82	0.93	1.06	1.23	6.4	4.84	5.20	6.09	6.60	5.26	2.02	1.03	1.36	1.08	1.98	0.959
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.0259	0.0081	0.006	0.0025	0.458	1.16	1.06	1.18	1.28	1.03	0.835	1.08	1.350	1.59	1.25	1.32
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000010	<0.000010	0.000011	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	0.000023	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	<0.0010	<0.0010	0.0014	<0.0010	0.0137	0.0063	0.0220	0.0081	0.0033	0.0028	0.0052	0.0021	0.0049	0.0023	0.0056	0.0022
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0043	<0.020	0.0025	0.0021	<0.0020	0.0065	0.0026	0.0091	0.005	0.0067	0.0032
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	<1.0	<1.0	<1.0	<0.50	0.83	1.4	<10	2.5	1.79	1.85	1.4	<1.0	<1.0	<1.0	0.86	0.59
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	4.8					5.8					4.4	5.1				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	***0.00015***	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	1.01	1.69	3.06	2.05	12.50	13.6	37.4	40.2	25.3	24.5	2.42	1.75	2.15	2.37	2.25	2.19
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.0556	0.0855	0.0888	0.0934	0.1780	0.234	0.309	0.319	0.373	0.395	0.152	0.111	0.148	0.132	0.237	0.134
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.0030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	<0.010	<0.010	<0.010	<0.010	<0.010	0.018	<0.10	<0.010	<0.010	<0.010	0.155	0.034	0.016	<0.010	0.021	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	0.0061	<0.0050	<0.050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0062	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0118	0.0196	0.0058	0.0058	0.0134	0.0194	<0.030	<0.0030	<0.0030	0.0036	0.0241	0.0102	0.0258	0.0221	0.0164	0.0157
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	0.0012	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																					
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	***0.0276***	***0.0430***	***0.0074***	0.0038	0.0015	***0.0060***	<0.0010	0.0015	<0.0010	<0.0010	<0.0010

Notes:

See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0006					BRH-0007A					BRH-0007B			BRH-0008A					
						Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Oct-11	Apr-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	
Physical Tests																			Duplicate					
Conductivity (EC)	uS/cm	3.0	—	—	—	293	343	371	346	370	277	274	274	280	260	207	289	183	277	273	312	319	383	531
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	134	165	162	168	144	152	155	139	151	132	119	141	110	138	137	164	153	195	192
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.12	7.31	7.31	7.59	7.7	7.63	7.68	7.84	7.91	7.92	7.20	7.79	7.3	7.43	7.40	7.39	7.46	7.67	7.79
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	193	115	74.5	89.4	58.6	1090	434	703	159	112	1800	4590	2980	126	154	135	2.8	106	81.4
Total Dissolved Solids	mg/L	10	—	—	500[q]	176	196	186	201	228	216	154	130	169	158	222	152	139	176	170	201	159	218	312
Anions and Nutrients																								
Acidity (as CaCO3)	mg/L	2.0	—	—	—	14.0	04.2	4	7.0	6.6	5.4	2.6	2	3.8	4.6	9.2	2.4	4.4	6.8	7.2	5.0	4.2	5.6	3.8
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	143	162	141	158	169	140	137	133	137	130	84.0	131	72.8	133	133	152.0	147	166	194
Ammonia-N, Total	mg/L	0.020	—	—	—	0.183	0.134	0.056	0.070	0.085	<0.040	<0.020	<0.020	<0.020	<0.02	<0.040	<0.020	<0.020	0.074	0.068	0.085	0.079	0.059	0.083
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	174	197	171	192	169	170	166	162	167	130	102	158	88.8	162	161	184	179	202	194
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	1.39	2.10	1.9	1.95	3.56	0.60	0.51	0.5	0.32	0.36	1.47	1.27	0.76	0.92	0.83	0.79	0.86	12.6	18.9
Fluoride	mg/L	0.030	—	—	1.5	<0.030	<0.0480	0.033	0.048	0.049	<0.030	<0.030	<0.030	<0.030	0.031	<0.030	<0.030	<0.030	<0.030	<330	<0.030	<0.030	<0.030	0.05
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	<0.030	<0.030	<0.030	<0.030	<0.030	0.182	0.238	0.204	0.168	0.226	<0.030	0.285	0.078	<0.030	<0.030	<0.030	0.119	<0.030	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.044	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	0.0051	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.0050	<0.0050	<0.60	<0.060	<0.60	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.157	0.072	0.0731	0.0546	0.0557	1.26	0.20	0.348	0.177	0.057	0.504	0.45	0.946	0.133	0.141	0.037	0.0229	0.0298	0.0490
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	11.1	14.5	40.3	12.7	14.1	7.00	5.19	3.73	6.56	5.13	18.8	9.3	12.3	11.6	10.3	11.6	10.1	10.4	46.8
Cyanides																								
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																								
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	4.2	3.4	4.2	3.1	3.5	2.0	2.2	2.8	2.3	1.5	7.8	4.3	5.1	6.7	7.3	5.9	6.6	9.0	9.1
Total Organic Carbon	mg/L	1.0	—	—	—	5.3	3.6	4	3.4	3.8	2.8	2.4	3.2	2.3	1.3	7.3	4.8	5.1	7.7	8.4	5.9	7.5	9.0	10.2
Dissolved Metals																								
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.011	<0.010	<0.0050	0.0065	0.0194	<0.010	0.014	<0.0050	<0.0050	0.0116	0.011	<0.0050	0.0141	0.016	0.016	0.029	0.0126	0.0118	0.0148
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.002
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	0.267	0.296	0.251	0.244	0.202	0.011	0.015	0.012	0.016	0.018	0.017	0.016	<0.010	0.058	0.059	0.081	0.077	0.102	0.107
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	***0.000025***	***0.000031***	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017	<0.000090	<0.000090	***0.000069***	<0.000090	<0.000090	<0.000090	<0.000090	***0.000047***	***0.000057***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	44.9	54.8	54	55.5	48.3	46.2	47.3	41.5	45.2	40.6	42.2	50.6	39.2	49.7	49.1	59.5	55.4	69.1	67.7
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	0.00155	0.00057	0.00076	0.00066	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00061	0.00079	<0.00050	0.00106	0.00100	0.00077	0.00113	0.00102	<0.00050
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[i]	0.001-0.005[f][m]	1[q]	0.0026	0.0023	***0.0038***	<0.0010	0.0012	0.0021	0.0017	***0.0039***	0.0013	0.0013	***0.0047***	***0.0046***	***0.0051***	0.0010	0.0011	0.0012	***0.0052***	0.0011	<0.0010
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	0.252	0.186	0.021	***0.338***	***0.455***	<0.050	<0.050	<0.020	<0.020	<0.020	<0.050	<0.020	<0.020	<0.050	<0.050	<0.050	0.041	***0.320***	0.057
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<0.050	<0.050	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	5.22	6.77	6.72	7.05	5.78	8.79	9.02	8.49	9.31	7.52	3.41	3.49	2.85	3.43	3.48	3.64	3.69	5.40	5.55
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	7.26	4.20	3.86	4.38	2.7	0.0144	0.0086	0.0259	0.0012	0.0010	0.0716	0.142	0.0696	1.28	1.30	1.2500	1.21	1.31	1
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000010	0.000017	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0042	0.0052	0.0055	0.0033	0.0060	0.0028	0.0021	0.002	0.0024	0.0023	0.0065	0.0166	0.0070	0.0057	0.0058	0.0060	0.0087	0.0109	0.0121
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	0.0037	0.0022	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0085	0.0124	0.0069	0.0047	0.0050	<0.0020	0.0085	0.0021	<0.0020
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	3.2	2.8	2.8	2.68	2.74	<1.0	<1.0	<1.0	<0.50	<0.50	1.3	<1.0	<0.50	<1.0	<1.0	<1.0	<1.0	0.86	1.22
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	***0.0011***
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	4.8					4.8					4.3			5.4	5.1				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	5.40	7.44	9.09	8.07	8.02	1.82	1.59	1.67	1.92	1.65	23.7	11.4	9.57	4.62	4.81	02.6	3.67	6.72	26.00
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.131	0.161	0.176	0.176	0.167	0.117	0.126	0.122	0.137	0.119	0.171	0.222	0.162	0.161	0.164	0.167	0.17	0.228	0.260
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	<0.010	<0.010	<0.010	<0.010	<0.010	0.024	0.013	0.01	<0.010	<0.010	0.502	0.4	0.149	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0063
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	0.0014	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.001	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0117	0.0041	0.0033	<0.0030	0.0058	0.0045	0.0059	<0.0030	0.0035	0.0039	0.0095	0.0123	0.0102	0.0095	0.0089	<0.0030	0.0082	0.0067	0.0073
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	0.0014	0.0015	0.001	0.0010	<0.0010
Aggregate Organics																								
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	<0.0010	<0.0010	0.0012	<0.0010	<0.0010	<0.0010	***0.0041***	<0.0010	<0.0010	0.0011	0.0016	<0.0010	<0.0010	0.0020	0.0026	0.0029	<0.0010	0.0027	0.0021

Notes:
See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0009							BRH-0012A						BRH-0012B				
						Jun-11	Aug-11		Oct-11	Apr-12	Aug-12		Jun-11	Aug-11		Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11	Apr-12	Aug-12
Physical Tests							Duplicate				Duplicate			Duplicate									
Conductivity (EC)	uS/cm	3.0	—	—	—	273	317	301	312	172	277	274	280	310	319	321	343	327	199	253	270	337	288
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	120	157	159	152	91.4	130	132	144	189	185	162	169	164	96.8	136	133	151	128
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.49	7.32	7.27	7.44	7.49	7.44	7.42	7.71	7.93	7.74	7.97	7.83	7.85	7.15	7.12	7.22	7.27	7.25
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	20400	5290	5440	3170	2380	850	772	3540	8890	9030	2140	1850	1090	628	14000	1050	6960	3170
Total Dissolved Solids	mg/L	10	—	—	500[q]	266	208	276	130	122	188	180	284	274	246	176	226	226	210	284	266	310	222
Anions and Nutrients																							
Acidity (as CaCO3)	mg/L	2.0	—	—	—	6.2	5.8	7.0	2.4	4.8	9.0	9.2	4.0	2.8	05.4	2	3.8	5.8	8.4	6.8	2.6	5.8	6.0
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	128	145	149	151	76.3	130.0	127.0	135	156	150	157	140	153	81.9	098	112	70.8	92.0
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.040	<0.040	<0.040	<0.020	<0.020	<0.02	<0.02	<0.040	<0.040	<0.040	0.208	0.033	<0.02	<0.040	<0.040	0.21	0.143	0.044
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	155	176	181	184	93.1	130.0	127.0	163	188	182	189	170	153	100	120	136	86.4	92.0
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	1.00	0.79	0.81	0.69	0.53	0.78	0.79	3.52	2.14	2.26	2.86	11.4	05.9	9.30	9.21	11.4	52.1	27.2
Fluoride	mg/L	0.030	—	—	1.5	<0.030	<0.0490	0.032	0.034	<0.030	0.035	0.035	0.050	0.052	0.052	<0.030	0.034	0.047	<0.030	<0.030	<0.030	<0.030	<0.030
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	<0.030	1.34	0.063	0.184	0.034	0.085	0.063	0.167	0.214	0.389	0.2	0.316	0.303	0.354	0.490	0.265	0.698	0.462
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	8.32	4.460	3.5000	2.44	1.64	0.60	0.60	1.53	4.94	4.73	1.43	1.56	0.57	0.263	4.02	2.1	6.81	1.19
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	14.3	16.0	8.47	7.43	5.65	7.91	7.81	7.40	05.7	15.00	4.3	4.64	5.50	3.65	13.60	2.89	3.43	4.10
Cyanides																							
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																							
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	3.4	2.6	3.3	4.3	4.8	2.9	2.5	2.4	2.0	1.9	1.7	2.0	1.6	3.9	2.9	2.7	4.3	2.2
Total Organic Carbon	mg/L	1.0	—	—	—	4.4	3.1	3.7	4.6	5.4	2.8	2.6	4.5	3.5	4.3	2.7	4.0	2.5	5.4	7.8	5	7.7	6.9
Dissolved Metals																							
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	<0.010	<0.010	<0.010	<0.0050	0.0145	0.0149	0.0137	<0.010	<0.010	0.013	<0.0050	<0.0050	0.0153	0.011	0.022	<0.0050	0.0084	0.0326
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.154
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	<0.000090	***0.000021***	***0.000054***	***0.000018***	<0.000090	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017	<0.000090	<0.000090	<0.000090	<0.000017	***0.000036***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	35.8	47.7	48.1	45.9	28.0	40.7	41.5	39.3	50.7	49.8	44.2	46.3	45.8	28.0	39.4	38.2	43.7	38.3
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[f]	0.001-0.005[f][m]	1[q]	0.0020	<0.0010	<0.0010	0.0026	0.0013	0.0014	<0.0010	<0.0010	<0.0010	<0.0010	0.0022	<0.0010	0.0014	0.0017	0.0015	***0.0059***	0.0014	<0.0010
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	<0.050	<0.050	<0.050	<0.020	<0.020	<0.020	<0.020	<0.050	<0.050	<0.050	<0.020	<0.020	<0.020	<0.050	<0.050	<0.020	<0.020	<0.020
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	7.41	9.14	9.43	9.09	5.24	6.88	7.03	11.0	15.10	14.70	12.6	13.1	12.0	6.54	09.1	9.15	10.1	07.9
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.0936	0.24	0.263	0.274	0.137	0.204	0.206	0.194	0.1370	0.136	0.0992	0.0220	0.0155	0.0790	0.014	0.0042	0.0029	0.0033
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0044	0.0051	0.0053	0.0052	0.0049	0.0046	0.0046	0.0016	0.0015	0.0015	0.0012	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0082
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	<0.0020	<0.0020	<0.0020	0.0033	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	<1.0	<1.0	<1.0	<1.0	<0.50	<0.50	<0.50	1.4	1.6	1.6	1.6	1.29	1.37	<1.0	<1.0	<1.0	0.85	1.16
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	4.7							4.5						4.6				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	6.45	4.20	4.42	3.77	2.35	2.87	2.95	4.05	2.06	2.05	2.47	1.94	1.81	1.69	1.95	1.98	2.69	6.67
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.112	0.212	0.208	0.202	0.145	0.215	0.217	0.114	0.159	0.1500	0.148	0.156	0.150	0.0705	0.101	0.102	0.119	0.105
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	0.018	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.071	0.099	0.097	0.073	0.077	0.064	0.011	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	<0.0030	<0.0030	<0.0030	<0.0030	0.0190	0.0078	<0.0030	<0.0030	0.0033	<0.0030	<0.0030	<0.0030	0.0038	<0.0030	<0.0030	0.0075	<0.0030	***0.0359***
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																							
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	<0.0010	<0.0010	0.0024	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	0.0017	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010

Notes:
See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-00013					BRH-00014A									BRH-0014B				
						Jun-11	Aug-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11		Oct-11		Apr-12		Aug-12		Jun-11	Aug-11	Oct-11	Apr-12	Aug-12
													Duplicate		Duplicate		Duplicate		Duplicate					
Physical Tests																								
Conductivity (EC)	uS/cm	3.0	—	—	—	213	200	204	191	192	248	256	255	260	261	253	253	246	246	248	255	261	253	245
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	97.5	110	107	101	90.2	111	123	123	115	112	117	118	111	111	113	123	116	118	117
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	6.97	6.89	6.86	7.13	7.21	7.75	7.81	7.88	7.84	8.01	7.99	8.08	7.9	7.96	7.72	7.89	7.76	8.06	8
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	1210	540	442	524	562	1550	454	533	99.5	163	349	267	83	143	815	5430	1492	3330	7100
Total Dissolved Solids	mg/L	10	—	—	500[q]	194	116	138	82	130	196	172	176	134	124	141	143	174	147	268	286	156	170	160
Anions and Nutrients																								
Acidity (as CaCO3)	mg/L	2.0	—	—	—	11.6	13.2	5.6	8.0	14.6	4.8	04.0	3.6	4.4	3	3.2	3.0	2.8	2.8	5.6	2.8	5	2.4	2.0
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	98.9	93.5	93.2	85.8	89.8	125	128.0	128.0	127	128	120	123	125	125	125	128	129	125	124
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.040	<0.020	<0.020	<0.020	0.041	<0.020	<0.020	<0.020	<0.020	<0.020	0.021	0.020	<0.02	<0.02	0.045	0.06	0.355	0.046	0.067
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	120	114	114	105	89.8	151	155	155.0	154	155	146	150	125	125	152	155	156	152	124
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5	<5.0	<5.0	<5.0	<5.0	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	0.81	0.53	0.45	0.29	0.76	0.78	0.46	0.59	0.53	0.54	0.32	0.31	0.30	0.30	0.62	0.59	0.52	0.32	0.39
Fluoride	mg/L	0.030	—	—	1.5	<0.030	<0.030	<0.030	<0.030	0.176	0.195	0.202	0.208	0.178	0.188	0.204	0.208	0.217	0.237	0.187	0.242	0.15	0.202	0.185
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	0.154	0.126	0.082	0.083	0.038	<0.030	0.198	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.395	0.203	0.0814	0.0955	0.0525	0.615	0.084	0.0674	0.0502	0.0945	0.102	0.104	0.066	0.059	2.25	3.750	3.09	2.21	1.43
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	8.91	6.79	5.59	6.91	6.98	5.58	4.79	3.83	3.15	3.47	3.48	3.49	3.50	3.50	4.18	4.37	4.04	3.47	3.65
Cyanides																								
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																								
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	3.3	3.8	3.6	3.4	2.8	1.8	1.3	1.1	1.2	2	1.6	1.4	2.6	3.9	2.0	1.5	1.6	1.3	1.4
Total Organic Carbon	mg/L	1.0	—	—	—	4.2	3.8	4.9	3.5	4.4	1.8	1.4	1.4	1.3	2	1.8	1.3	2.5	3.9	2.2	1.5	1.8	1.6	1.4
Dissolved Metals																								
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.013	0.017	0.0071	0.0106	0.0216	0.011	<0.010	0.01	<0.0050	<0.0050	<0.0050	<0.0050	0.0133	0.0146	<0.010	<0.010	<0.0050	<0.0050	0.0126
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	0.0013	0.0014	0.0016	0.0016	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0010	0.0013	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	0.012	0.012	0.012	0.015	0.015	0.016	0.016	<0.010	0.011	0.01	0.011	0.012
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	<0.000017	***0.000025***	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017	<0.000017	<0.000017	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	31.3	35.0	33.5	31.7	28.4	35.4	39.4	39.0	36.6	35.5	37.0	37.1	36	35.8	35.7	38.9	36.5	37.2	37.5
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[f]	0.001-0.005[f][m]	1[q]	0.0012	0.0015	***0.0028***	<0.0010	0.0017	<0.0010	<0.0010	<0.0010	0.0012	0.0024	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	***0.0023***	<0.0010	<0.0010
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	<0.050	<0.050	<0.020	0.036	0.022	0.101	0.183	0.16	<0.020	<0.020	0.089	0.085	0.042	0.043	<0.050	<0.050	<0.020	0.043	<0.020
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	4.70	5.37	5.55	5.33	4.68	5.57	6.07	6.13	5.85	5.72	6.07	6.20	5.24	5.26	5.73	6.32	6.07	6.19	5.64
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.0854	0.1210	0.152	0.0897	0.058	0.189	0.1780	0.1820	0.189	0.187	0.186	0.184	0.173	0.173	0.187	0.190	0.196	0.194	0.184
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	***0.000081***	***0.000042***	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0022	0.0022	0.0022	0.0019	0.0019	0.0017	0.0018	0.0017	0.0017	0.0018	0.0021	0.0018	0.0018	0.0018
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	<1.0	<1.0	<1.0	<0.50	<0.50	2.1	2.3	2.3	2.3	2.2	2.22	2.23	2.11	2.11	2.0	2.2	2.2	2.20	2.17
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	3.8					6.2									6.0				
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	2.85	1.86	1.9	1.64	1.44	9.20	9.48	9.45	8.79	8.58	7.46	7.64	6.86	6.89	6.79	7.83	7.91	7.34	7.00
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.0849	0.0784	0.0843	0.0780	0.0673	0.106	0.1150	0.1170	0.117	0.115	0.115	0.116	0.112	0.111	0.0958	0.101	0.103	0.106	0.103
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0056	0.0062	0.0063	0.0056	0.0057	0.0062	0.0060	0.0058	0.0057	0.0057	0.0066	0.0057	0.0063	0.0061
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0055	0.0049	<0.0030	<0.0030	0.0038	0.0044	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																								
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	0.0016	<0.0010	<0.0010	<0.0010	0.0014	<0.0010	0.0029	***0.0068***	<0.0010	<0.0010	<0.0010	<0.0010	0.0017	<0.0010	<0.0010	***0.0063***	<0.0010	<0.0010	<0.0010

Notes:
See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0017A				BRH-0017B				BRH-0020A						
						Jun-11	Oct-11	Apr-12	Aug-12	Jun-11	Oct-11	Apr-12	Aug-12	Jun-11	Aug-11	Oct-11		Apr-12	Aug-12	
Physical Tests																	Duplicate			Duplicate
Conductivity (EC)	uS/cm	3.0	—	—	—	235	255	218	219	179	333	214	243	130	134	138	133	131	123	125
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	97.8	104	100	92.2	82.2	124	96.2	96.4	57.8	66.6	62.4	57.9	60.1	54.9	56.3
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.73	7.77	7.82	7.94	7.00	7.06	7.17	7.42	6.90	7.12	6.94	7.11	7.03	6.99	7.06
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	821	2120	106	280	10800	9010	4120	6180	92.4	62.4	31.6	35.8	40	170	6.9
Total Dissolved Solids	mg/L	10	—	—	500[q]	140	132	138	152	134	206	204	192	104	122	100	66	116	140	110
Anions and Nutrients																				
Acidity (as CaCO3)	mg/L	2.0	—	—	—	3.8	4.6	6.8	4	4.2	5.2	7.2	12.2	7.0	4.0	6.8	2.8	9.0	6.2	4.6
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	109	115	99.0	102	79.4	161	96.5	122.0	59.0	060	62.3	60.3	59.1	56.8	57.1
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.020	0.045	<0.020	0.029	<0.040	0.13	0.025	0.037	<0.020	<0.020	<0.020	<0.020	0.021	0.046	<0.02
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	132	139	121	102	97.0	196	118	122	72.0	073	76	73	72.1	56.8	57.1
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	1.34	1.2	0.35	0.47	1.66	2.33	1.29	0.60	0.69	0.83	0.6	0.52	0.44	0.49	0.38
Fluoride	mg/L	0.030	—	—	1.5	0.202	0.13	0.164	0.159	0.096	0.07	0.098	0.110	<0.030	0.047	<0.030	0.049	0.048	0.051	0.047
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	<0.030	<0.030	<0.030	0.185	<0.030	<0.030	<0.030	0.055	0.077	0.098	<0.030	<0.030	<0.030	<0.030	0.049
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.734	0.433	0.0515	0.242	2.53	2.98	1.69	1.5100	0.0394	0.022	0.0391	0.0325	0.0569	0.0437	0.0130
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	10.7	8.96	7.30	8.31	10.0	5.55	8.34	3.97	4.29	04.0	3.53	3.47	3.64	3.75	4.74
Cyanides																				
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																				
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	4.5	5.5	1.4	1.9	4.7	6.3	3.6	3.8	4.6	4.2	4.6	3.7	4.1	6.2	2.3
Total Organic Carbon	mg/L	1.0	—	—	—	5.3	6.6	1.6	2.2	6.1	8.8	4.6	4.0	4.8	4.5	4.7	4.2	4.8	8.9	2.3
Dissolved Metals																				
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	<0.010	<0.0050	<0.0050	0.0056	<0.010	0.0061	0.0094	0.0175	0.014	0.018	0.01	0.0089	0.0140	0.0231	0.0122
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	0.0040	0.0042	**0.0052**	0.0046	<0.0010	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	0.013	0.018	0.020	0.022	<0.010	0.012	<0.010	<0.010	<0.010	0.012	0.011	0.011	0.012	0.011	<0.010
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.00017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000017	<0.000017	<0.000090	<0.000090	***0.000045***	***0.000056***	<0.000090	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017	***0.000023***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	30.7	32.5	32.5	29.6	23.1	36.7	28.9	28	19.7	22.8	21.2	19.7	20.5	18.9	19.7
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	0.00121	0.00107	<0.00050	<0.00050	0.00191	0.00198	0.00156	0.00085	0.00079	0.00075	0.00073	0.00071	0.00087	0.00091	0.00155
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[l]	0.001-0.005[f][m]	1[q]	***0.0025***	0.0014	<0.0010	<0.0010	***0.0023***	***0.0069***	0.0011	0.0019	<0.0010	0.0016	0.0019	0.0016	0.0012	<0.0010	***0.0198***
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	0.206	***1.3***	***0.440***	***0.522***	0.110	***0.712***	***0.618***	0.109	***1.91***	***1.930***	***1.8***	***1.68***	***1.74***	***1.83***	***0.31***
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.050	<0.050	<0.050	<0.10	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	5.15	5.61	4.67	4.43	5.97	7.89	5.84	6.42	2.09	2.39	2.27	2.11	2.13	1.89	1.75
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.179	0.289	0.178	0.162	0.321	0.968	0.783	0.568	0.574	0.618	0.61	0.576	0.601	0.571	0.009
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0055	0.0191	0.0029	0.0029	0.0061	0.008	0.0049	0.0053	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	0.0023	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	***0.0102***
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	3.5	3.7	3.26	3.08	2.2	3.2	2.23	2.21	1.1	1.2	1.2	1.1	1.13	1.02	1.19
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	5.4				8.1				7.7						
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	***0.00016***
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	12.9	16	6.77	6.01	4.88	23.6	18.1	15.40	1.64	01.9	1.94	2.01	1.64	1.60	1.52
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.103	0.115	0.106	0.0901	0.0664	0.111	0.0820	0.069	0.0442	0.055	0.0515	0.0503	0.0527	0.0457	0.0422
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	0.403	0.153	0.023	0.019	0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.237
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0064	<0.0030	<0.0030	<0.0030	0.0073	0.012	0.0071	0.0069	<0.0030	0.0040	<0.0030	<0.0030	<0.0030	<0.0030	0.0145
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																				
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	***0.0042***	0.0017	<0.0010	0.0018	***0.0070***	0.0016	<0.0010	***0.0142***	0.0026	***0.0055***	<0.0010	<0.0010	<0.0010	0.0021	0.0016

Notes:
See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BRH-0020B							BRH-0024							BH12-4
						Jun-11		Aug-11	Oct-11	Apr-12		Aug-12	Jun-11	Aug-11	Oct-11		Apr-12	Aug-12		Aug-12
Physical Tests							Duplicate				Duplicate					Duplicate			Duplicate	
Conductivity (EC)	uS/cm	3.0	—	—	—	126	126	133	130	128	128	125	70.7	90.6	91.2	90.6	63	85.4	85	243
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	59.3	56.8	60.7	60.6	57.8	60.7	59.1	28.4	40.6	38.4	37.7	25.1	35.2	34.7	143
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	6.81	6.82	6.99	6.82	6.94	6.96	7.21	6.91	6.87	6.96	6.95	7.01	6.81	6.86	7.3
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	4.5	5.0	67.6	515	14.4	18.6	5.1	3150	1360	963	441	272	285	239	1720
Total Dissolved Solids	mg/L	10	—	—	500[q]	84	66	095	88	99	99	108	27	084	38	42	55	63	56	246
Anions and Nutrients																				
Acidity (as CaCO3)	mg/L	2.0	—	—	—	10.0	7.0	5.6	5	9.0	9.4	6.2	3.8	6.8	4.6	4.4	2.2	6.4	2.8	7.2
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	—	—	57.3	57.5	58.0	58.5	56.3	56.2	57.3	30.9	38.0	39.7	39.5	24.5	36.1	35.5	119
Ammonia-N, Total	mg/L	0.020	—	—	—	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.02	0.289	0.062	0.152	0.175	<0.020	<0.02	<0.02	0.225
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	70.0	70.0	71.0	71	68.7	68.6	57.3	38.0	46.0	48	48	29.9	36.1	35.5	119
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5.0	<5.0	<5.0	<5.0	<5.0	<5	<5	<5
Chloride (Cl)	mg/L	0.10	—	—	250[q]	0.39	0.48	0.25	0.34	0.14	0.13	0.15	0.33	0.19	0.23	0.24	0.10	0.10	0.11	0.53
Fluoride	mg/L	0.030	—	—	1.5	<0.030	0.041	0.062	0.05	0.048	0.044	0.050	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.122
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	0.044	0.055	0.374	0.041	0.037	0.034	0.044	<0.030	<0.030	0.043	0.045	<0.030	<0.030	0.032	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.0050	<0.60	<0.60	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.0372	0.0535	0.12	0.0785	0.0128	0.0101	0.0129	2.68	2.2400	1.07	1.09	0.255	0.118	0.114	0.78
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	4.95	4.93	04.9	3.98	4.18	4.16	4.36	4.21	3.69	2.75	2.72	3.51	3.67	3.70	1.09
Cyanides																				
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.005	<0.0050
Organic / Inorganic Carbon																				
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	2.5	2.5	1.9	2.6	2.8	2.4	1.5	1.7	1.8	1.9	2	1.8	1.2	1.4	9.1
Total Organic Carbon	mg/L	1.0	—	—	—	3.0	3.0	2.3	2.6	2.7	2.3	1.8	3.1	2.0	2.7	2.7	1.8	1.3	1.5	20.7
Dissolved Metals																				
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	<0.010	<0.010	<0.010	<0.0050	<0.0050	0.0145	0.013	<0.0100	0.012	<0.0050	<0.0050	0.0103	0.0164	0.0174	0.0169
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.039
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	<0.000090	<0.000017	<0.000017	***0.000025***	<0.000090	<0.000090	<0.000090	<0.000090	***0.000019***	<0.000017	<0.000017	***0.00002***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	20.5	19.6	21.0	20.8	20.0	20.8	20.6	9.81	14.2	13.5	13.3	8.80	12.3	12.2	47.9
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	0.00095	0.00087	0.00064	0.00069	0.00072	0.00090	0.00158	<0.00050	0.00062	<0.00050	<0.00050	<0.00050	0.00059	0.00057	0.00112
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[f]	0.001-0.005[f][m]	1[q]	***0.0024***	***0.0023***	0.0020	***0.0027***	0.0011	0.0011	***0.0196***	0.0019	***0.0069***	***0.0046***	***0.0038***	0.0015	***0.0033***	***0.0034***	<0.0010
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	***1.40***	***1.25***	***1.180***	***0.809***	***0.653***	***1.73***	***0.372***	<0.050	<0.050	<0.020	<0.020	0.051	0.105	0.089	***0.55***
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	1.97	1.89	2.02	2.12	1.92	2.12	1.85	0.94	1.24	1.13	1.11	0.748	1.1	1.06	5.69
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.0473	0.0431	0.020	0.0165	0.0106	0.605	0.0098	0.0975	0.107	0.307	0.313	0.183	0.107	0.104	0.387
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010	<0.000010	<0.000020	<0.000020	<0.000010	<0.000010	0.000023	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0017	0.0017	0.0014	0.0014	<0.0010	<0.0010	<0.0010	0.0023	0.0017	0.0011	0.0012	<0.0010	<0.0010	<0.0010	0.0053
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	0.0044	0.0045	0.0058	0.0054	0.0048	<0.0020	0.0102	0.0066	0.0065	0.0029	0.0029	<0.0020	0.0031	0.0031	***0.0029***
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	1.3	1.2	1.3	1.3	1.22	1.15	1.27	<1.0	<1.0	<1.0	<1.0	<0.50	<0.50	<0.50	3.27
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0010
Silicon (Si)-Dissolved	mg/L	1.0	—	—	—	6.1	6.3						4.5							
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	***0.00014***	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	1.61	1.48	1.61	1.93	1.58	1.64	1.60	0.93	1.13	1.43	1.42	0.90	1.10	1.10	3.94
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.0415	0.0428	0.0447	0.0429	0.0435	0.0538	0.0436	0.0173	0.0227	0.0241	0.0239	0.0167	0.0217	0.0218	0.095
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	0.064	0.060	0.166	0.115	0.122	<0.010	0.240	0.015	0.049	0.015	0.015	<0.010	0.036	0.032	0.076
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0075	0.0075	0.0044	0.0044	0.0075	<0.0030	0.0152	0.0066	0.0115	0.0042	0.0042	<0.0030	0.0051	0.0063	0.0106
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																				
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	0.0024	<0.0010	0.0025	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	0.0016	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	***0.0167***

Notes:
See next page for Notes.

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 1656263

TABLE 1
Shallow Groundwater Quality Notes

Notes:	
Values in ***bold italics*** exceed the CCME guidelines.	
Values <u>underlined</u> exceed the PWQO guidelines.	
Values in shaded grey exceed the ODWQS guidelines.	
— = No guideline available for analyte.	
(a) Total concentrations are assumed, unless stated otherwise.	
(b) Canadian Council of Ministers of the Environment, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Update 7.1 (December 2007).	
(c) Provincial Water Quality Objectives, Ministry of Environment and Energy (February 1999).	
(d) Ontario Drinking Water Standards, Objectives and Guidelines, Ministry of the Environment (June 2003)	
(e) Under clear flow: + 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). average + 5 mg/L from background levels for longer term exposures (24 h<discharge<30 d). Under high flow: + 25 mg/L from background levels at any time when background levels between 25 and 250 mg/L. + 10% of background levels when background is >250 mg/L.	
(f) Interim Guideline	
(g) Aluminium guideline	= 15 µg/L at 4.5<pH<5.5 =+10% at 5.5<pH<6.5 =75 µg/L at 6.5<pH<9
(h) Beryllium guideline	= 11 µg/L at hardness<75 mg$CaCO_3$/L = 1100 µg/L at hardness>75 mg$CaCO_3$/L
(i) Respectively for long term and short term exposure	
(j) Guideline based on Cd=10^{0.86[log(hardness)]-3.2}	
(k) Cadmium guideline	= 0.1 µg/L at hardness<100 mg$CaCO_3$/L = 0.5 µg/L at hardness>100 mg$CaCO_3$/L
(l) Copper guideline	= 2 µg/L at a water hardness of 0–120 mg/L (soft to medium) as $CaCO_3$ = 3 µg/L at a water harness of 120–180 mg/L (hard) as $CaCO_3$ = 4 µg/L at a water harness >180 mg/L (very hard) as $CaCO_3$
(m) Copper guideline	= 1 µg/L at hardness<20 mg $CaCO_3$/L = 5 µg/L at hardness>20 mg $CaCO_3$/L
(n) Lead guideline	= 1 µg/L at a water harness of 0–60 mg/L (soft) as $CaCO_3$ = 2 µg/L at a water harness of 60–120 mg/L (medium) as $CaCO_3$ = 4 µg/L at a water harness of 120–180 mg/L (hard) as $CaCO_3$ = 7 µg/L at a water harness >180 mg/L (very hard) as $CaCO_3$
(o) Lead guideline	= 1 µg/L at hardness<30 mg $CaCO_3$/L = 3 µg/L at 30<hardness<80 mg $CaCO_3$/L = 5 µg/L at hardness>80 mg $CaCO_3$/L
(p) Nickel guideline	= 25 µg/L at a water harness of 0–60 mg/L (soft) as $CaCO_3$ = 65 µg/L at a water harness of 60–120 mg/L (medium) as $CaCO_3$ = 110 µg/L at a water harness of 120–180 mg/L (hard) as $CaCO_3$ = 150 µg/L at a water harness >180 mg/L (very hard) as $CaCO_3$
(q) Aesthetic Objective	
(r) Interim Maximum Acceptable Concentration	

Submitted as part of the Version 3 HRGP Amended EIS/EA Documentation
January 2018 - 16562

TABLE 2
Pumped Groundwater Quality
June 2011 to April 2012

Parameter[a]	Unit	MDL	CCME[b]	PWQO[c]	ODWQS[d]	BR-0220					BR-0231				BR-0220		
						Sep-10 (10:50)	Sep-10 (13:30)	Sep-10 (16:15)	Sep-10 (21:40)		Sep-11 (18:05)	Sep-12 (11:30)	Sep-12 (14:30)	Sep-12 (17:00)	Mar-11 (12:00)	Mar-12 (14:30)	Mar-14 (14:00)
Physical Tests										Duplicate							
Conductivity (EC)	uS/cm	3.0	—	—	—	405	408	405	404	404	323	340	340	341	424	440	426
Hardness (as CaCO3)	mg/L	2.4	—	—	80-100	188	193	192	188	191	163	157	157	157	212	217	207
pH	pH	0.10	6.5-9	6.5 - 8.5	6.5-8.5	7.56	7.58	7.6	7.58	7.61	7.55	7.74	7.75	7.77	7.57	7.58	7.6
Total Suspended Solids	mg/L	2.0	+5-25[e]	—	—	185	14	6.9	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	6.5	6.6	2.2
Total Dissolved Solids	mg/L	10	—	—	500[q]	274	254	246	251	250	206	213	201	199	222	226	227
Anions and Nutrients																	
Acidity (as CaCO3)	mg/L	2.0	—	—	—	6.4	5.4	5.6	5.4	5.6	3.8	3.6	4.6	4.2	7.4	7.4	6.8
Alkalinity, Total (as CaCO3)	mg/L	5.0	—	-25%	30-500	218	218	216	216	216	167	178	178	177	223	221	215
Ammonia-N, Total	mg/L	0.020	—	—	—	0.071	0.091	0.084	0.09	0.089	<0.020	0.055	0.065	0.057	0.224	0.124	0.142
Bicarbonate (HCO3)	mg/L	5.0	—	—	—	265	265	263	262	262	203	215	216	215	272	269	263
Carbonate (CO3)	mg/L	5.0	—	—	—	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	mg/L	0.10	—	—	250[q]	2.3	2.32	2.33	2.34	2.38	1.15	1.12	1.1	1.21	2.56	2.49	2.36
Fluoride	mg/L	0.030	—	—	1.5	0.076	<0.030	0.103	0.066	0.1	0.076	0.068	0.067	0.147	<0.030	<0.030	0.06
Nitrate-N (NO3-N)	mg/L	0.030	—	—	10	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nitrite-N (NO2-N)	mg/L	0.020	—	—	1	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Orthophosphate (PO4-P)	mg/L	0.60	—	—	—	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60	<0.0050	<0.0050	<0.0050
Phosphorus (P)-Total	mg/L	0.0050	—	—	—	0.314	0.0133	0.0123	<0.0050	0.0058	<0.0050	0.0058	<0.0050	<0.0050	0.0111	0.0094	0.0079
Sulphate (SO4)	mg/L	0.30	—	—	500[q]	1.18	1.17	1.28	1.27	1.33	4.03	4.28	4.41	4.4	1.67	2.38	3.13
Cyanides																	
Cyanide, Free	mg/L	0.0050	0.005	0.005	0.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Organic / Inorganic Carbon																	
Dissolved Organic Carbon	mg/L	1.0	—	—	5[q]	5.8	6.2	6.2	6.4	6	5.4	4.5	4.3	4.8	5.8	6.3	5.9
Total Organic Carbon	mg/L	1.0	—	—	—	6.4	6.2	6.5	6.7	6.1	5.5	4.9	5.2	4.8	6	6.2	6.7
Dissolved Metals																	
Aluminum (Al)-Dissolved	mg/L	0.010	0.005-0.1	0.015-0.075[f][g]	0.1	0.047	<0.010	<0.010	<0.010	0.01	0.015	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050
Antimony (Sb)-Dissolved	mg/L	0.00060	—	0.02[f]	0.006[r]	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Arsenic (As)-Dissolved	mg/L	0.0010	0.005	0.005	0.025[r]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Barium (Ba)-Dissolved	mg/L	0.010	—	—	1	0.261	0.259	0.257	0.249	0.252	0.317	0.181	0.177	0.176	0.267	0.258	0.237
Beryllium (Be)-Dissolved	mg/L	0.0010	—	0.011-1.1[h]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Dissolved	mg/L	0.050	1.5-29[i]	0.2[f]	5[r]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.057	0.055	0.052
Cadmium (Cd)-Dissolved	mg/L	0.000090	0.000017[f][j]	0.0001-0.0005[f][k]	0.005	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000090	<0.000017	***0.00002***	***0.000021***
Calcium (Ca)-Dissolved	mg/L	0.50	—	—	—	49.8	50.6	50	49	49.7	45.9	40.6	40.5	40.7	53.3	54.4	52.7
Chromium (Cr)-Dissolved	mg/L	0.0010	0.099	0.099	0.05	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Dissolved	mg/L	0.00050	—	0.0009	—	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Copper (Cu)-Dissolved	mg/L	0.0010	0.002-0.004[l]	0.001-0.005[f][m]	1[q]	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron (Fe)-Dissolved	mg/L	0.050	0.3	0.3	0.3[q]	***1.35***	***1.1***	***1.06***	***1.03***	***1.06***	0.283	***0.326***	***0.326***	***0.331***	<0.020	<0.020	<0.020
Lead (Pb)-Dissolved	mg/L	0.0010	0.001-0.007[n]	0.001-0.005[f][o]	0.01	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li)-Dissolved	mg/L	0.10	—	—	—	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.050	<0.050	<0.050
Magnesium (Mg)-Dissolved	mg/L	0.50	—	—	—	15.5	16.1	16.2	15.8	16.2	11.8	13.5	13.6	13.6	19.1	19.7	18.2
Manganese (Mn)-Dissolved	mg/L	0.0010	—	—	0.05[q]	0.506	0.323	0.3	0.279	0.288	0.708	0.376	0.382	0.381	0.222	0.25	0.257
Mercury (Hg)-Dissolved	mg/L	0.000020	0.000026	0.0002	0.001	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	mg/L	0.0010	0.073[f]	0.04[f]	—	0.0321	0.0296	0.0274	0.0246	0.025	0.0063	0.0117	0.0117	0.0118	0.0134	0.012	0.0122
Nickel (Ni)-Dissolved	mg/L	0.0020	0.025-0.15[p]	0.025	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Potassium (K)-Dissolved	mg/L	1.0	—	—	—	3	3	2.9	2.9	2.9	2.4	2.7	2.7	2.7	2.73	2.76	2.58
Selenium (Se)-Dissolved	mg/L	0.0020	0.001	0.1	0.01	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010
Silver (Ag)-Dissolved	mg/L	0.00010	0.0001	0.0001	—	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)-Dissolved	mg/L	0.50	—	—	200[q]	15.8	15.2	14.9	14.8	15	5.63	11.5	11.8	12	16.2	16.4	15.2
Strontium (Sr)-Dissolved	mg/L	0.0010	—	—	—	0.802	0.877	0.873	0.871	0.881	0.31	0.506	0.51	0.513	0.98	1.03	0.963
Tellurium (Te)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Thallium (Tl)-Dissolved	mg/L	0.00030	0.0008	0.0003[f]	—	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Tin (Sn)-Dissolved	mg/L	0.0010	—	—	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Dissolved	mg/L	0.0020	—	—	—	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Tungsten (W)-Dissolved	mg/L	0.010	—	0.03[f]	—	0.094	0.067	0.056	0.049	0.048	0.028	0.031	0.03	0.03	0.019	0.017	0.015
Uranium (U)-Dissolved	mg/L	0.0050	—	0.005[f]	0.02	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Vanadium (V)-Dissolved	mg/L	0.0010	—	0.006[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	mg/L	0.0030	0.03	0.02[f]	5[q]	0.0061	0.0052	0.0041	<0.0030	0.0033	0.0066	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Zirconium (Zr)-Dissolved	mg/L	0.0010	—	0.004[f]	—	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Aggregate Organics																	
Phenols (4AAP)	mg/L	0.0010	0.004	0.005	—	***0.0057***	***0.0195***	***0.0242***	***0.012***	***0.02***	***0.0284***	***0.0427***	***0.0177***	***0.0273***	<0.0010	<0.0010	<0.0010

Notes:
See next page for Notes.

TABLE 2
Pumped Groundwater Quality Notes

Notes:	
Values in ***bold italics*** exceed the CCME guidelines.	
Values underlined exceed the PWQO guidelines.	
Values in shaded grey exceed the ODWQS guidelines.	
— = No guideline available for analyte.	
(a) Total concentrations are assumed, unless stated otherwise.	
(b) Canadian Council of Ministers of the Environment, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Update 7.1 (December 2007).	
(c) Provincial Water Quality Objectives, Ministry of Environment and Energy (February 1999).	
(d) Ontario Drinking Water Standards, Objectives and Guidelines, Ministry of the Environment (June 2003)	
(e) Under clear flow: + 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). average + 5 mg/L from background levels for longer term exposures (24 h<discharge<30 d). Under high flow: + 25 mg/L from background levels at any time when background levels between 25 and 250 mg/L. + 10% of background levels when background is >250 mg/L.	
(f) Interim Guideline	
(g) Aluminium guideline	= 15 µg/L at 4.5<pH<5.5 =+10% at 5.5<pH<6.5 =75 µg/L at 6.5<pH<9
(h) Beryllium guideline	= 11 µg/L at hardness<75 mg$CaCO_3$/L = 1100 µg/L at hardness>75 mg$CaCO_3$/L
(i) Respectively for long term and short term exposure	
(j) Guideline based on Cd=10^{0.86[log(hardness)]-3.2}	
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(q) Aesthetic Objective	
(r) Interim Maximum Acceptable Concentration	