

# PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING, IGNACE AREA

*WP07 Data Report – Opportunistic Groundwater  
Sampling for IG\_BH03*

**APM-REP-01332-0253**

**February 2021**

**Golder Associates Ltd.**

**nwmo**

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## REPORT

# Phase 2 Initial Borehole Drilling and Testing, Ignace Area

## *WP07 Data Report - Opportunistic Groundwater Sampling for IG\_BH03*

Submitted to:

### **Nuclear Waste Management Organization**

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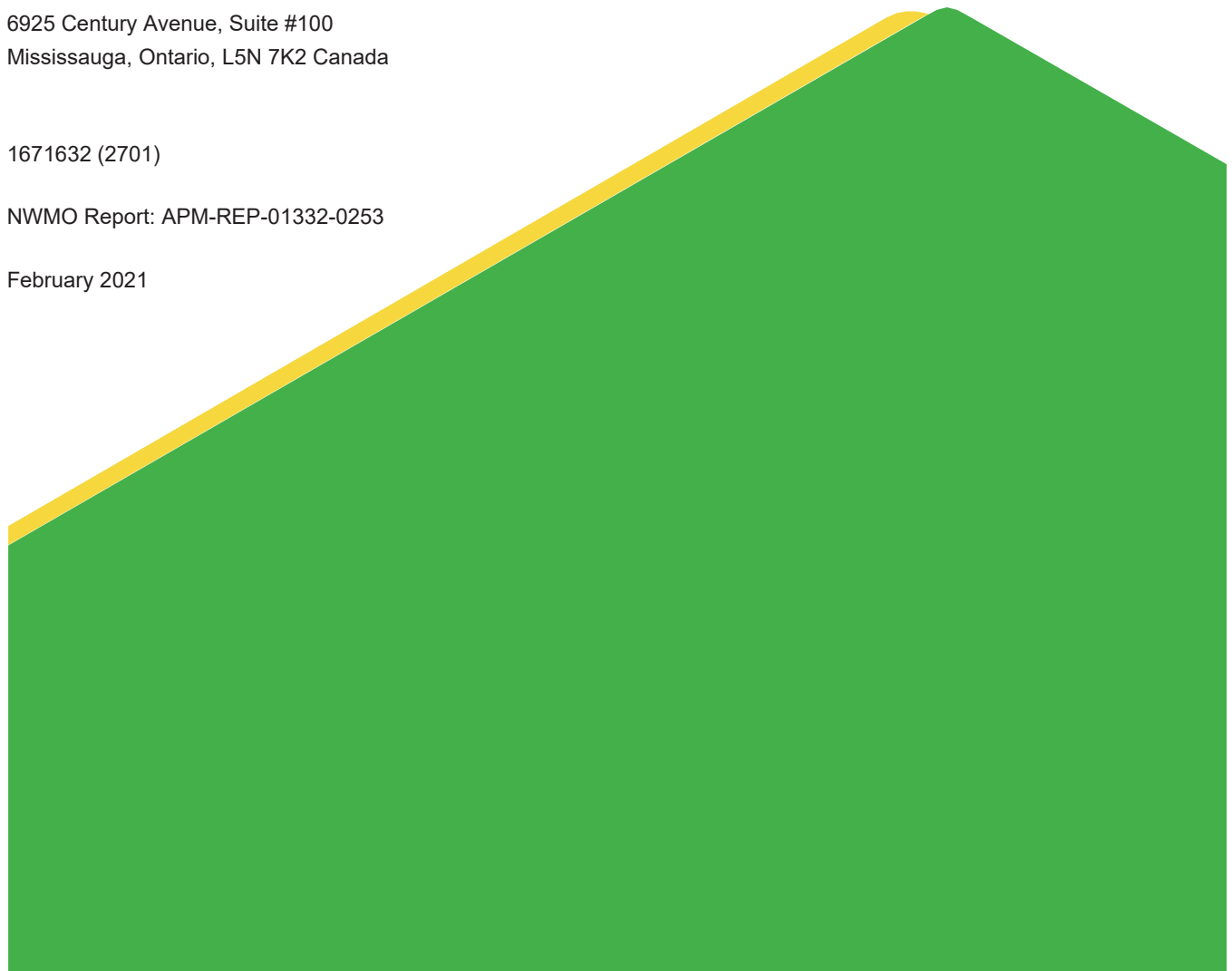
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## WP07 DATA REPORT

### OPPORTUNISTIC GROUNDWATER SAMPLING FOR IG\_BH03

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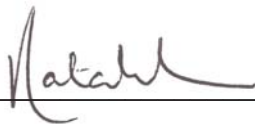
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## 1.0 INTRODUCTION

The Initial Borehole Drilling and Testing project in the Wabigoon and Ignace Area, Ontario is part of Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

This project involves the drilling and testing of three deep boreholes within the northern portion of the Revell batholith. The second drilled borehole, IG\_BH03, is located a direct distance of approximately 23 km southeast of the Wabigoon Lake Ojibway Nation and a direct distance of 42 km northwest of the Town of Ignace. Access to the IG\_BH03 drill site is via Highway 17 and primary logging roads, as shown on Figure 1.

The project was carried out by a team led by Golder Associates Ltd. (Golder) on behalf of the NWMO. This report describes the methodology, activities and results for Work Package 7 (WP07): Opportunistic Groundwater Sampling for IG\_BH03, which includes: identification of permeable intervals during drilling (WP02 and WP03) and / or hydraulic testing (WP06), collection and in-field analysis, and laboratory analysis of samples. This report also describes the analysis of the fresh water and drill water collected as part of Work Package 2 (WP02): Borehole Drilling and Coring for IG\_BH03. IG\_BH03 is an inclined borehole, all depths referred to in this report are in meters below ground surface along the length of the borehole (mbgs along hole), rather than true vertical depth.

## 2.0 BACKGROUND INFORMATION

### 2.1 Geological Setting

The approximately 2.7 billion year old Revell batholith is located in the western part of the Wabigoon Subprovince of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km<sup>2</sup>. Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (Figure 2).

Borehole IG\_BH03 is located within an investigation area of approximately 19 km<sup>2</sup> in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 1).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 2). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone 2009; Stone 2010a; Stone 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz 1996; Stone et al. 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al. 2010).

Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite (Figure 2). Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the

southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of  $2734.2 \pm 0.8$  Ma (Stone et al. 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of  $2732.3 \pm 0.8$  Ma (Stone et al. 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 2). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of  $2694.0 \pm 0.9$  Ma (Stone et al. 2010).

The bedrock surrounding IG\_BH03 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder 2015; Golder and PGW 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG\_BH01, is approximately 15-20 m wide (Figure 2). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of  $1887 \pm 13$  Ma (Stone et al. 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 1). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock.

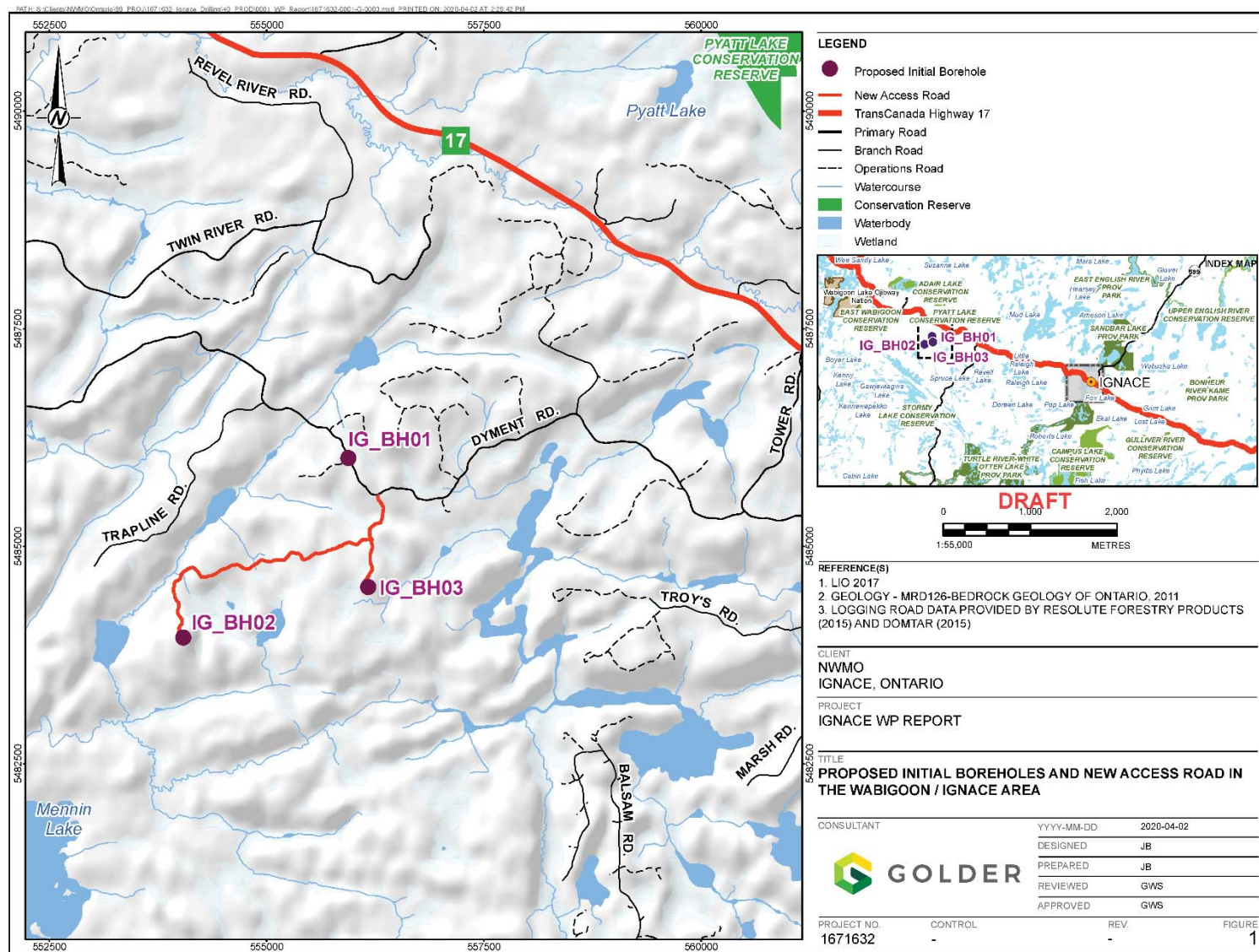


Figure 1: Location of IG\_BH03 in Relation to the Wabigoon / Ignace Area



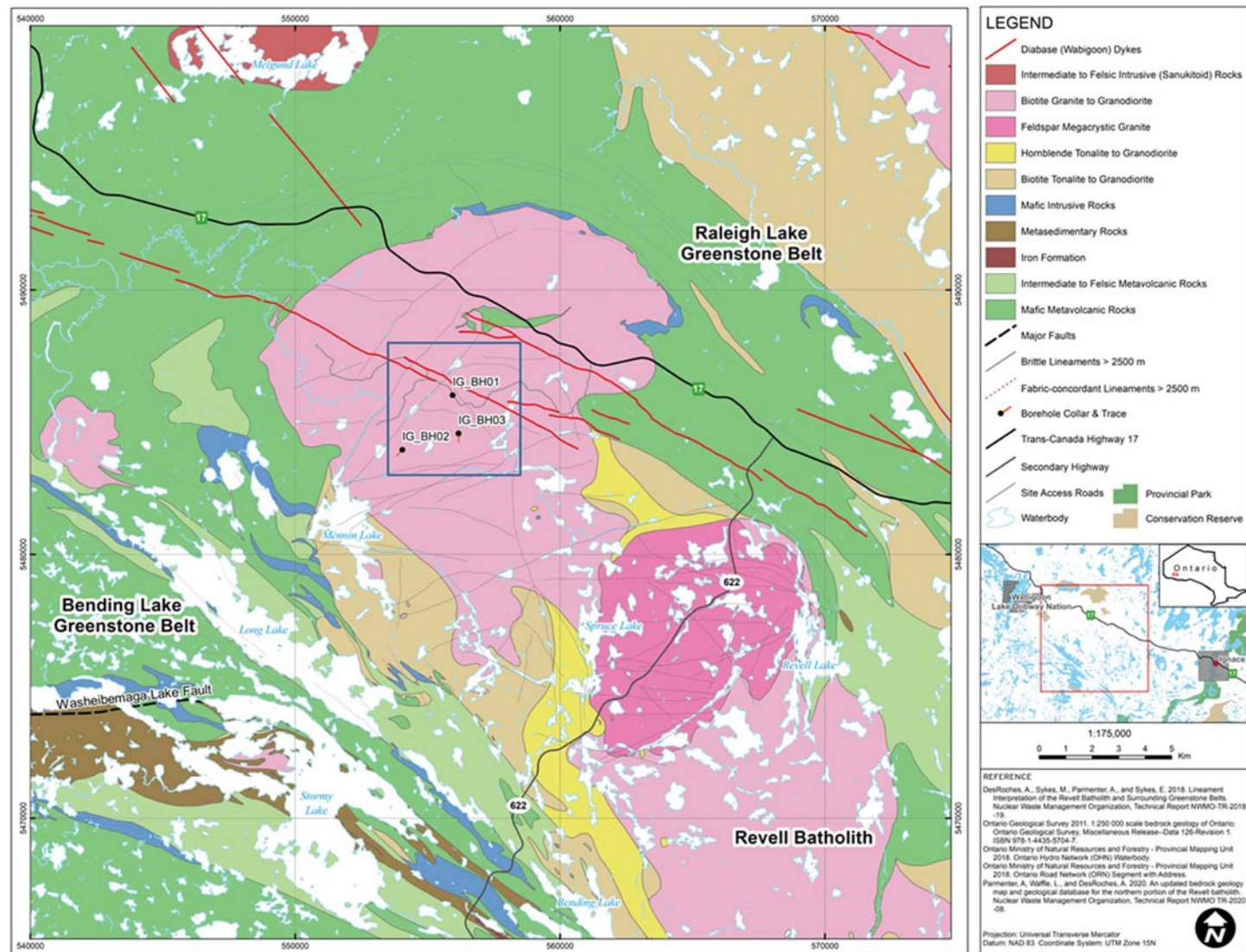


Figure 2: Geological setting and location of boreholes IG\_BH01, IG\_BH02 and IG\_BH03 in the northern portion of the Revell batholith.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 2; DesRoches et al. 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 2). Ductile lineaments, also shown on Figure 2, follow the trend of foliation mapped in the surrounding greenstone belts. Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).

### 3.0 DESCRIPTION OF ACTIVITIES

#### 3.1 Types of Samples Collected

The following samples were collected for laboratory analysis, in-field geochemistry and microbiology research and development as described in the following section.

- Water supply samples – These were collected under WP02 to characterize the source water prior to introducing it to the drill system. They were denoted IG\_BH03\_WSXXX (“water source”) and included laboratory analyses, in-field parameters and in-field geochemistry analyses.
- Drilling water return, designated IG\_BH03\_DWXXX, included the following types of samples:
  - Archive samples of the drill water return were collected under WP02 every 50 m during drilling;
  - Drill water samples associated with groundwater samples were collected for laboratory analyses, in-field parameters, in-field geochemistry and microbiology analysis; and
  - Samples were specifically collected for microbiology research and development at corresponding core intervals and included laboratory analyses, in-field parameters and microbiology analysis.
- Opportunistic Groundwater (OGW) samples and attempted samples collected during drilling included laboratory analyses, in-field parameters, in-field geochemistry and microbiology analyses, as well as QA/QC samples for laboratory analyses.
- No post drilling sample collection was attempted due to the low available purge rates for all intervals assessed under WP06.

A summary description and details of all analyses for all fluid samples collected for IG\_BH03 can be found in Table A-1 (Appendix A). OGW sample intervals are individually described with results presented and discussed in Section 4.0.

#### 3.2 Technical Objectives

The technical and scientific objectives of WP07 sampling were the following:

- Identification, while drilling and post-drilling during WP06 packer testing, of permeable intervals for collecting OGW samples;
- Collection and preservation of OGW sample volumes for geochemical analysis;

- Measurement of field parameters (tracer concentrations [fluorescein], temperature, pH, oxidation-reduction potential [ORP], electrical conductivity [EC] and turbidity) and in-field analysis (alkalinity, dissolved oxygen [DO], total dissolved sulphide, and ferrous iron);
- Laboratory analysis of collected OGW samples;
- Determining chemical and isotopic character of groundwater with depth; and
- Identify the presence or absence of recent, older post-glacial and glacial recharge, interglacial recharge and very old pre-glacial groundwater with depth.

In the crystalline rock of the Revel Batholith, groundwater was expected to be encountered through fractures in the bedrock. A maximum of 10 sample intervals were planned, following the depth guidelines below:

- 1 sample in the upper 100 m;
- 3 samples in the upper 400 m (including the 1 sample in the upper 100 m); and
- 7 samples in the potential repository zone (400 to 800 m) or below the repository horizon if active or flowing features were encountered.

### 3.3 Methodology

#### 3.3.1 Roles and Responsibilities

Golder drilling supervisors, with assistance from the WP03 core loggers also on site, were responsible for all activities associated with WP07 on site sampling, including:

- Equipment decontamination;
- Lowering the wireline packer assembly to isolate the sample interval;
- Purging the sample interval;
- Collection of the OGW sample;
- Sample in-field geochemistry analyses; and
- Laboratory analysis of collected samples by Bureau Veritas Laboratories (BV) and Isotope Tracer Technologies (IT2).

The Golder WP07 Lead corresponded with the NWMO WP07 Lead and provided direction to the field staff on confirmation to proceed with purging assessments and sample collection.

#### Data Delivery

The data delivery was provided to the NWMO and contains the following components, referred to throughout this report:

- DQC workbooks for each sample (these include all notes associated with in-field and laboratory activities, instrument calibration records and purging data for opportunistic groundwater samples);
- Chain of custody records and sample submission reports from BV and IT2;
- Certificates of analyses for all samples from BV and IT2;

- Calculation file for charge balance and alkalinity speciation of water samples;
- Raw downhole pressure data collected during purging for groundwater samples; and
- Importer template file containing results from analytical laboratory testing.

### 3.3.2 Source Water and Water Tracing

Fresh water was brought from a municipal source in Ignace. Municipal water in Ignace is sourced from Michel Lake and treated to adhere to Ontario drinking water standards; the water undergoes filtering processes and is chlorinated. Once water was collected from Ignace and brought to site, it was stored in designated tanks. As described in the Work Package 2 (WP02) Drilling and Coring Report (Golder, 2020), samples were collected from these fresh water tanks (water source samples) for initial characterization before a fluorescein tracer was added to achieve the targeted concentration of 100 ppb for drilling and flushing activities. After sampling and tracer addition, the fresh water was introduced to the borehole and drill fluid system with approval from the Golder drilling supervisor.

All drill fluid parameters (fluorescein concentration, temperature, pH, EC, ORP, DO, turbidity and density) were measured from the return fluid at the completion of each run so that run to run changes could be observed. This data is presented in the WP02 Data Report and is included in the acQuire data delivery (DE-07). As described in the WP02 Drilling and Coring Report (Golder, 2020), the drill fluid volume change was measured on a run to run basis either through use of totalizing flowmeters, or through manual measurements of the drill fluid system. The drill fluid recycling system used at the start of drilling IG\_BH03 involved a series of settling tanks and a flocculant, but this was switched to a centrifuge system when the borehole was at a depth of 424.64 below ground surface (mbgs) along hole. All drill fluid data and observations are presented in the WP02 Drilling and Coring Report (Golder, 2020).

### 3.3.3 Interval Selection

During drilling, potential opportunistic groundwater sample intervals were identified by a combination of the following:

- Indications from core sample descriptions, such as fractured zones, weathered or stained fractures, large fracture apertures;
- Drilling fluid circulation measurements, such as fluid loss or gain, changes in drilling fluid parameters (see Table 1);
- Drill pump pressure changes that may indicate loss of circulation or the presence of a water producing feature; and
- Drilling performance indicators, such as rod drops, changes in advance rates, or changes in drive head torque.

The observed criteria to initiate WP07 are described in the “Justification to Initiate WP07” tab of the DQC workbooks.

**Table 1: Drill Fluid Field Parameters Measured, and Triggers Observed to Initiate WP07**

Field Parameter	Instrument	Trigger to Initiate WP07
Fluorescein dye (tracer)	Aquafluor Handheld Fluorimeter/Turbidimeter	20% decrease in concentration from previous drill fluid source. Note: Minimum detection limit of the fluorimeter (0.4 ppb)
Turbidity	Horiba U52-2, multi-probe	10% change from previous drill fluid source
Dissolved Oxygen		10% change from previous drill fluid source
Electrical conductivity		10% change from previous drill fluid source
pH		change of at least 0.5 from previous drill fluid source
Temperature		N/A
ORP		N/A
Density	Hydrometer	N/A

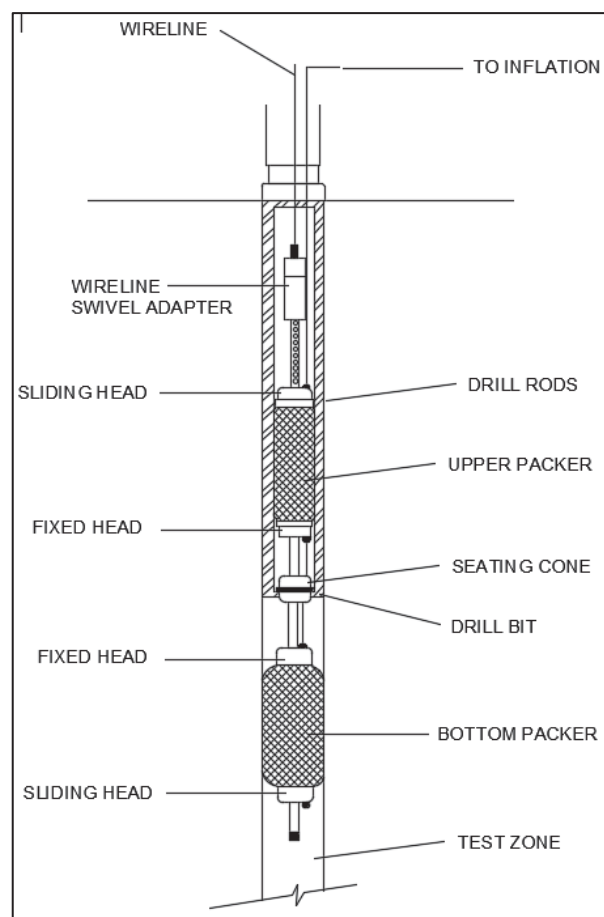
Potential post-drilling sample intervals were identified based on observations from borehole fluid geophysical surveys (WP05), however preliminary hydraulic conductivity estimates while completing WP06 indicated that none of the intervals were capable of sustaining the required purge rate. Therefore, no post-drilling opportunistic groundwater samples were collected.

### 3.3.4 Interval Isolation

For sample intervals identified during drilling, an inflatable wireline packer tool was used to isolate the bottom of the borehole, with the configuration shown in Figure 3. Recorded measurements and calculations for the interval configurations can be found in the “Test Zone Specification” tab of the DQC workbooks for intervals identified during drilling.

For sample intervals identified during drilling, the interval’s ability to sustain the minimum required purge rate of 10 system volumes (borehole volume of isolated interval + volume of water in drill pipe) in 72 hours was assessed by performing a multiple step, constant rate pumping test, as documented in the “Purge Rate Assessment” tab of the DQC workbooks. The available purge rates for potential sample intervals identified during the post-drilling hydraulic testing were estimated based on preliminary field assessments of the intervals’ transmissivity.





**Figure 3: Wireline packer schematic**

### 3.3.5 Purging

Once sample collection from the selected interval was determined to be feasible, purging was carried out to remove the drill fluid from the drill rods, the sample interval and the rock formation to obtain a groundwater sample that was representative of the isolated interval. For all samples, interval purging was achieved using a Grundfos Redi-Flo2 pump, lowered into the drill rods. Purged water was conveyed to surface via 12.7 mm diameter poly tubing connected to the pump. The purge rate was recorded every 30 minutes in the 'Purge Water Volume and Field Parameters' tab of the DQC workbook provided to the NWMO in the data deliverable.

### 3.3.6 Collection of Field Parameters

During purging, the drill fluid field parameters (fluorescein concentration, pH, ORP, DO, EC, turbidity and temperature) were monitored with a Horiba U52-2 multi-parameter water quality meter and recorded every 30 minutes. The Horiba was set up on surface during purging using a flow-through cell and readings were recorded in the 'Purge Water Volume and Field Parameters' tab of the DQC workbook.

Analytical in-field parameter measurements included alkalinity, total dissolved sulfide, DO (colorimetric method) and ferrous iron, with results recorded in the corresponding data tabs of the DQC workbooks, as well as the acQuire DE-07 Groundwater Sample object. The field procedures for these in-field analyses can be found in Appendix C.

### 3.3.7 Sample Collection

OGW sample collection was initiated once the monitored field parameters were within the specified range and confirmation to proceed with sample collection was given by the NWMO, as documented in the “Sample Collection Data” tab of the DQC workbook. The field parameter targets for groundwater sample collection are shown in Table 2.

**Table 2: Field Parameter Targets for Groundwater Sample Collection Determination**

Field Parameter	Instrument	Drilling Fluid Concentration (prior to purging)	Target to Initiate Sample Collection
Fluorescein dye (tracer)	Aquafluor Handheld Fluorimeter/Turbidimeter	≥100 ppb	<1% of drilling fluid concentration. Note: Minimum detection limit of the fluorimeter (0.4 ug/L)
Turbidity	Horiba U52-2, multi-probe	As measured at the start of purging	Stabilized within ± 10% or ± 5 NTU if <50 NTU
DO			Stabilized within ± 10%
Electrical conductivity			Stabilized within ± 10%
Temperature			Stabilized within ± 0.5 degrees C
ORP			Stabilized within ± 10%
pH			Stabilized within ± 0.1 standard pH units
Purge Volume	Electronic flow meter and totalizer	N/A	Ten system volumes or total drilling fluid loss or 72 hours, whichever is greater

OGW sample collection included the following components:

- Collection of groundwater for commercial laboratory analyses and in-field analysis of alkalinity using the Grundfos pump and via the flow-through cell outlet at surface; the samples for commercial analyses were submitted for major elements and metals, anions and nutrients, stable isotopes and radioisotopes (see Table 3 for complete list of parameters; exception is total dissolved sulphide as per below).
- Collection of groundwater for microbiology research and analysis from the Grundfos pump outlet on surface.
- Collection of groundwater using the Westbay Instruments MOSDAX Sampler Probe Model 2532 in-situ sample probe for commercial laboratory analysis of total dissolved sulphide and in-field analysis of total dissolved sulphide, DO and ferrous iron.

**Table 3: Sample bottle requirements for Bureau Veritas Laboratories and Isotope Tracer Technologies**

Parameter Group	Parameter List	Bottle Type Requirement	Sample Volume Requirement	Head Space Requirement	Field Filtering Requirement	Preservative Requirement
Major Elements & Metals (Bureau Veritas)	Na, K, Ca, Mg, Sr, Li, Si, S <sub>Total</sub> , Fe <sub>Total</sub>	HDPE plastic bottles	125 mL	Fill line	Yes, 0.45 µm filter	Trace grade nitric acid
	SiO <sub>2</sub>	HDPE plastic bottles	250 mL	None	Yes, 0.45 µm filter	None
	S <sup>2-</sup> <sub>Total</sub>	HDPE plastic bottles	125 mL	Fill line	Yes, 0.45 µm filter	Zinc acetate & sodium hydroxide solution
Anions & Nutrients (Bureau Veritas)	Br, F, Cl, I, SO <sub>4</sub> , PO <sub>4</sub> , NO <sub>3</sub> , NO <sub>2</sub> , Alkalinity	HDPE plastic bottles	500 mL	None	Yes, 0.45 µm filter	None
	NH <sub>4</sub> +NH <sub>3</sub> , N <sub>Total</sub>	HDPE plastic bottles	250 mL	Fill line	Yes, 0.45 µm filter	Trace grade sulphuric acid
	P <sub>Total</sub>					
Stable Isotopes (IT2)	δ <sup>18</sup> O, δ <sup>2</sup> H	HDPE plastic bottles	30 mL	No headspace	Yes, 0.45 µm filter	None
	<sup>87</sup> Sr/ <sup>86</sup> Sr	HDPE plastic bottle	1000 mL	No headspace	Yes, 0.45 µm filter	None
	δ <sup>13</sup> C DIC	Glass vials, teflon cap	2 x 40 mL glass vials with septa caps	No headspace	Yes, 0.45 µm filter	None
Radioisotopes (IT2)	<sup>14</sup> C-DIC	HDPE plastic bottle	500 mL	No headspace	Yes, 0.45 µm filter	None
	<sup>3</sup> H	HDPE plastic bottle	500 mL	No headspace	Yes, 0.45 µm filter	None

### 3.3.8 QA/QC

For each sample or sample attempt, a Data Quality Confirmation (DQC) workbook was filled out by the field staff on site to record the sample interval details, equipment decontamination, purge rate assessment, Horiba calibration details and sample collection details. The DQC workbooks were completed over the duration of the sampling period, from identification of the potential interval to collection of the actual sample.

#### Instrument Calibration Checks

Instrument calibration checks were typically carried out for the Horiba probe and Aquafluor at the start of every day-shift during regular coring activities (WP02), and all records can be found in the WP02 data delivery.

Full manual calibration checks and calibrations of each sensor of the Horiba probe were carried out according to the manufacturer's instructions prior to in-field geochemistry analyses for water source and drill water samples, and groundwater sample purging events. The appropriate reference solutions were used for each sensor's calibration, as listed in the "pH, Eh, Cond, Turb, DO" tab of the DQC workbook.

#### Drill Fluid Sampling

Drill fluid samples associated with the OGW samples were collected when potential sample intervals were identified, to provide baseline chemistry parameters. For Interval 1 (GW004), this sample was collected from the drill tank once confirmation to purge the interval was received.

#### Equipment Decontamination

All equipment lowered downhole was decontaminated prior to use. Field staff used new, powder-free latex or nitrile gloves while cleaning and handling decontaminated equipment. Alconox® powdered detergent was used with distilled water to remove any dirt, grease or residue from the equipment, followed by a thorough rinse with laboratory grade deionized water. The equipment was then laid on a clean surface and allowed to dry free from dust and contaminants before going downhole. If the equipment was cleaned pre-emptively, it was stored in new plastic bags until required for use. The packer assembly, water level tape indicator, RST transducer, Grundfos submersible pump with electrical cable and Waterra tubing, flow-through cell, and the in-situ sample probe were decontaminated as required and recorded in the "Equipment Decontamination" tab of the DQC workbook for each interval.

#### Field Blanks

Field blanks for laboratory analyses at BV and IT2 were collected with laboratory grade deionized water following the same sampling procedures used for the groundwater sample. One field blank was collected for Interval 1 (151.63 to 154.61 mbgs along hole), associated with GW004.

#### Duplicates

A duplicate sample was collected for Interval 1 (GW004). The duplicate sample was collected immediately subsequent to the actual groundwater sample using the same sampling procedures.

#### Sample Handling and Laboratory Documentation

Both BV and IT2 adhere to the requirements of ISO 17025:2005. Chain of custody (COC) forms were filled out by site staff to ship all samples to the required laboratories. If multiple samples were sent in a single shipment, they were included on a single COC and all results that followed contained all samples that were shipped together in a single report. The DE-09 Chain of Custody object in acQuire was used to document COCs and reconcile samples sent to the laboratories with results received from the laboratories.

Sample bottle labels were filled out before the sample was collected in the bottles. Information included on sample bottle labels included the sample name, date and time collected, preservative and analysis required. Once the collected samples were transferred to the sample bottles as listed in Table 3, the bottles were temporarily stored in a refrigerator on site. As part of the WP03 daily quality confirmation checks, the temperature of the refrigerators was checked to ensure they remained at 4°C. Sample bottles were packed in coolers with ice packs and the appropriate COC for shipment to the laboratories.

Upon receipt by BV and IT2, Golder was notified via email and a sample submission report was provided. Both labs included a copy of the COCs, verifying the received condition of the sample and confirming the analyses to be performed. The documented received sample condition from the laboratories included the temperature received and any broken bottles. For samples collected using the Westbay sampler probe where limited volume was available and sample bottles were not able to be filled completely, Golder documented this on the COC and the laboratory confirmed in the sample submission document. Laboratory QA/QC is described in Section 4.5.

### 3.3.9 Methods of Chemical and Isotopic Analysis

For the commercial and in-field analyses, information on the chemical and isotopic analyses, including the method and method detection limit (MDL) for each parameter is attached in Appendix A (Table A-2).

### 3.3.10 Method to Calculate Drill Water Ratio in Ground Water samples

During drilling, pressurized drill water will enter aquifers or fractures from which groundwater samples are to be collected. The extent of drill water remaining in the water-bearing features can be reduced through purging prior to collection of a ground water sample. Fluorescein tracer was added to drill water to permit evaluation of the extent of drill water present in ground water samples. This evaluation requires measurement of the fluorescein concentration in both the drill water and groundwater sample. It is assumed that the initial fluorescein concentration in groundwater is zero. Equation 1 permits determination of the proportion of drill water by evaluating the difference in fluorescein concentrations. Equation 2 determines the proportion of groundwater in a sample, given a known proportion of drill water from equation 1. Finally, equation 3 permits correction of measured groundwater concentrations based upon the proportion of drill water and groundwater in a sample, and the measured concentration of a given parameter in drill water and groundwater. Equation 3 applies to any single parameter where the parameter was measured above detection limits in both drill water and groundwater. Equation 3 must be repeated for each parameter to be corrected in a given sample, whereas equations 1 and 2 will have a single result for each drill water and groundwater sample pair.

$$Proportion_{DW} = \frac{Fluorescein_{GW}}{Fluorescein_{DW}} \quad (1)$$

$$Proportion_{GW} = 1 - Proportion_{DW} \quad (2)$$

$$GW\ Conc_{actual} = \frac{GW\ Conc_{measured} - (DW\ Conc \times Proportion_{DW})}{Proportion_{GW}} \quad (3)$$

Where:

DW = Drill Water

GW = Groundwater

## 4.0 RESULTS

Sample intervals were identified during drilling from drill fluid volume losses or apparent gains and / or drill fluid parameter changes, as outlined in Table 1. During the drilling of IG\_BH03, only 1 interval was encountered where there was sufficient inflow into the borehole for the purge volume requirements to be met and a groundwater sample to be collected; this sample interval was from 146.88 to 154.61 mbgs (along hole). As described herein, the general low permeability of the bedrock did not allow sufficient purging to collect other OGW samples during drilling.

Golder drilling supervisors (WP02) were responsible for the field identification of potential sample intervals and corresponded with the Golder work package Lead for WP07 when these were identified. As discussed in the WP02 Drilling and Coring Data Report (Golder, 2020), parameter triggers for DO, EC and pH were encountered with some frequency, but were typically attributed to the addition of fresh, traced water and subsequent equalizing in the drill system. The drill fluid became increasingly saturated with the drill cuttings as drilling progressed, which caused a gradual change of the drill fluid parameters with each run. Turbidity was not an indicator of permeable intervals since the measurements were above the Horiba multi-probe's measurement range for the majority of the program (turbidity was greater than 1000 NTU).

Fluorescein concentration was found to generally decrease in the system as drilling progressed and cuttings were removed from the drill fluid either through the settling tanks or with the centrifuge. Therefore, the drill water required the addition of fluorescein by directly mixing the fluorescein into the drill tank to bring the concentration back to the targeted range. The system was also required to be topped up with fresh, traced water as the volume of the hole increased and drill fluid was lost to the rock formation and removed with the disposal of cuttings. These two actions required time for the system to equalize and mix, which caused fluorescein concentration decreases below the trigger threshold to be observed frequently. Further trends related to the drill fluid parameters are discussed in the WP02 report (Golder, 2020).

Drill fluid volume loss, in combination with observations of the drill core were therefore found to be the most reliable indications of water bearing fractures in the crystalline rock.

A total of twenty (20) water samples were submitted for analysis in WP07. Of these, ten (10) were water supply samples, supplied from the Town of Ignace municipal water supply. Four (4) samples of drill water return were collected, plus three (3) drill water additive samples. One OGW sample was collected, with two associated QA/QC samples (a blank and a duplicate).

Complete analytical results of water source, drill water, and drill water additive, are presented in Table A-3. Opportunistic groundwater samples and QA/QC samples (blank) are presented in Table A-4. Calculated values for ferric iron (via subtraction of field measured ferrous iron concentrations from laboratory reported dissolved iron concentrations) are not presented due to dissolved iron concentrations below detection limit in the majority of samples, and where both dissolved iron and ferrous was detected, the calculation yielded negative values for ferric iron. Calculated negative ferric iron concentrations may be due to heterogeneity in iron content of the water submitted for laboratory analysis versus that used for the field measurements or analytical uncertainty at concentrations close to the detection limit. Fluorescein concentrations were measured in field but not in the laboratory because no commercial laboratory was identified that was able to complete this analysis. Sulphide concentrations were reported below detection limit in all field and laboratory measurements; accordingly, calculated values for hydrogen sulphide and bisulphide are not presented.

The Hach instrument was not zeroed after reading the reagent blank value for the following in-field ferrous iron samples:

- IG\_BH03\_WS002
- IG\_BH03\_WS003
- IG\_BH03\_WS005
- IG\_BH03\_WS006
- IG\_BH03\_WS007
- IG\_BH03\_DW007

Per the manufacturer's instructions, the blank value is to be subtracted from the sample reading when this occurs. The corrected field measurement values are stated in Tables A-3, and B-1 (and in the acQuire DE-07).

## 4.1 Interval Selection and Purging

### Sample Interval 1 (GW004)

During core run CR63, from 151.63 to 154.61 mbgs (along hole), a volume loss of 192 L was encountered, along with stained joints and an amphibolite dyke in the drill core indicating a possible location for collecting an OGW sample. This was communicated to the Golder work package Lead and the decision was made to isolate the interval and assess the achievable purge rate.

The drill string was pulled up, with the bit positioned at 145.60 mbgs (along hole), to position the packer tool above the suspected water bearing fractures and isolate the interval from 146.88 to 154.61 mbgs (along hole).

Once the packer was in place and inflated, and the groundwater stabilized to the assumed static level, the purge rate was assessed in a 3-step constant rate pumping test. A Grundfos Redi-Flo2 submersible pump was lowered into the borehole, with the groundwater flow conveyed to surface through 12.7 mm diameter poly tubing. The tubing was directed out of the hole and to a flow-through cell and totalizer set up in the drilling support shack. A calibration check of the totalizer was performed prior to its use and documented in the 'Flowmeter Calibration Check' tab of the DQC. The purged groundwater was redirected to the sump at the borehole collar via 12.7 mm diameter poly tubing, where it was pumped to the waste-water poly tanks.

With a system volume of approximately 704 litres, the minimum purge rate required to achieve 10 system volumes in 72 hours was 1.6 litres per minute (L/min). The interval was able to sustain this rate, and an average rate of approximately 2.5 litres per minute was sustained through the purge event.

Water quality parameters were continuously monitored with the Horiba probe installed in the flow-through cell and were read every 30 minutes during purging. Four (4) archive samples were collected during purging (IG\_BH03\_GW001, IG\_BH03\_GW002, IG\_BH03\_GW003 and IG\_BH03\_GW008). Purging was carried out for 21.5 hours before sampling was initiated, with a total purge volume of 3422 litres or 4.9 system volumes removed, and EC, ORP, DO and turbidity stabilized within 10% variability between readings, temperature within 0.5 degrees C, and 0.1 pH. Fluorescein concentration was approximately 5% of the source drill fluid and slowly dropping when the rest of the field parameters were within their targets. Sample collection was initiated at 5% fluorescein concentration with the decision confirmed by the NWMO, given the extended time it would take to get to the 1% target listed in Table 2.

After groundwater sample collection (IG\_BH03\_GW004, IG\_BH03\_GW005 and IG\_BH03\_GW006), a drill fluid sample was taken from the drill tank, IG\_BH03\_DW007, and was sampled for laboratory analyses and in-field analyses. Archive samples of the purge water were collected at two, three, four and five system volumes, with the



5<sup>th</sup> volume collected just after the groundwater sample collection. The groundwater sample was collected with a duplicate, IG\_BH03\_GW005, and a field blank, IG\_BH03\_GW006. Tables A-1 and A-2 in Appendix A contain the descriptions and in-field parameters and analyses collected for Interval 1, with the results presented and discussed in this section.

Following collection of the OGW samples from the outlet of the flow-through cell, the Westbay in-situ sampler probe was deployed twice in order to collect sufficient sample volume to perform the sulphide, DO, alkalinity and ferrous iron in-field analyses in addition to filling of the sulphide bottle submitted to BV. The sample chamber was nitrogen purged to prevent sample exposure to the atmosphere.

## 4.2 Water Supply Samples

Water supply samples were of relatively consistent composition over the duration of WP07, which was expected given that the samples were taken from municipal water supply for drinking water. Ignace's municipal water is sourced from Michel Lake, with water supply for IG\_BH03 collected from the municipal source from 7 July 2019 to 17 September 2019. The results are summarized as follows:

- Field pH ranged from 6.43 to 7.37;
- Total alkalinity ranged from 14 to 28 mg/L CaCO<sub>3</sub> (16 to 22 mg/L HCO<sub>3</sub>) in field measured values for all samples, and ranged from 13 to 15 mg/L CaCO<sub>3</sub> (16 to 18 mg/L HCO<sub>3</sub>) in laboratory measured values for samples IG\_BH03\_WS006, IG\_BH03\_WS007, IG\_BH03\_WS008, IG\_BH03\_WS009, and IG\_BH03\_WS010;
- Sulphate ranged from 1.2 to 2.4 mg/L;
- Total dissolved sulphide was below the method detection limit (<0.02 mg/L) in all samples;
- Dissolved oxygen concentration measured by Hach meter ranged from 8.3 to 10.6 mg/L, and ranged from 6.76 to 13.43 mg/L in samples measured by the Horiba probe;
- Oxygen-18 ( $\delta^{18}\text{O}$ ) ranged from -8.78 to -7.29 ‰ VSMOW;
- Deuterium ( $\delta^2\text{H}$ ) ranged from -73.9 to -67.1 ‰ VSMOW;
- $\delta^{13}\text{C}$ -DIC ranged from -17.8 to -2.1 ‰ PDB;
- $^{14}\text{C}$ -DIC ranged from 180 to 1245 years BP;
- $^3\text{H}$  ranged from 7.6 to 13.3 TU; and
- $^{87}\text{Sr}/^{86}\text{Sr}$  ratio ranged from 0.710 to 0.730.

Relative results of key major ions are presented in a piper plot in Figure 4. Water supply samples are clustered and demonstrate that the major ion composition is generally consistent. The major ion chemistry of the water supply samples is represented by similar proportions of calcium and sodium, with lesser concentrations of magnesium, and a higher proportion of bicarbonate relative to other anions.

Oxygen-18 and deuterium results are presented in Figure 5 and are compared to the Global Meteoric Water Line (GMWL) and Local Meteoric Water Line (LMWL). The LMWL presented is for Atikokan, Ontario (Fritz et al., 1987). This LMWL is considered a reasonable representation (based on distance) of the LMWL for Ignace, Ontario, for which a closer published LMWL has not been identified. All water supply samples plot below and to the right of the LMWL and GMWL.



Supply water samples are collected from the municipal water supply, which is sourced from a local lake, therefore it is known that the samples are primarily composed of modern precipitation. Tritium results are consistent with this origin, as tritium contents greater than 5 TU in natural waters are a consequence of anthropogenic nuclear activities.

### 4.3 Drill Water Samples

Drill water samples demonstrate a greater extent of variability in composition and high turbidity as compared to water supply samples. The results are summarized as follows:

- Field pH ranged from 8.37 to 10.32;
- Total alkalinity was 98 mg/L  $\text{CaCO}_3$  (121 mg/L  $\text{HCO}_3$ ) in field measured values (IG\_BH03\_DW007), and ranged from 74 to 260 mg/L  $\text{CaCO}_3$  (90 to 317 mg/L  $\text{HCO}_3$ ) in laboratory measured values;
- Sulphate ranged from 3.2 to 6.4 mg/L;
- Total dissolved sulphide was below method detection limit (<0.02 mg/L) in all samples;
- DO concentration measured by Hach meter was 12.8 mg/L (IG\_BH03\_DW007), and ranged from below detection to 7.6 mg/L in samples measured by the Horiba probe;
- Oxygen-18 ( $\delta^{18}\text{O}$ ) ranged from -9.69 to -8.19 ‰ VSMOW;
- Deuterium ( $\delta^2\text{H}$ ) ranged from -72.6 to -68.9 ‰ VSMOW;
- $\delta^{13}\text{C}$ -DIC ranged from -22.9 to -10.1 ‰ PDB;
- $^{14}\text{C}$ -DIC ranged from 2539 to 5167 years BP;
- $^3\text{H}$  ranged from 7.9 to 10.6 TU; and
- $^{87}\text{Sr}/^{86}\text{Sr}$  ratio ranged from 0.755 to 0.801.

Relative results of key major ions are presented in a piper plot in Figure 4. Drill water samples are clustered and demonstrate that they are of generally consistent composition. The major ion compositions of the samples are more dominated by sodium, potassium, and bicarbonate. Total cation concentrations in drill water are more than four-times greater than supply water samples.

Oxygen-18 and deuterium results are presented in Figure 5, and all drill water samples plot below and to the right of the LMWL.

Drill water samples are derived from supply water, which is collected from the municipal water supply. This water is sourced from Lake Michel, therefore it is known that the samples are primarily comprised of modern precipitation. Tritium results are consistent with this origin, as tritium contents greater than 5 TU in natural waters are a consequence of anthropogenic nuclear activities.

Three samples of drill water additive (IG\_BH03\_DW001, IG\_BH03\_DW002, IG\_BH03\_DW005) were collected and analyzed according to a revised analytical parameter set defined by NWMO. Isotopic parameters were not analyzed and therefore the sample does not appear on this figure. The key results are summarized as follows:

- Field pH ranged from 8.38 to 10.71;
- Turbidity ranged from below detection limit to 1000 NTU;

- Total alkalinity was not recorded for field measured values and ranged from 49 to 110 mg/L  $\text{CaCO}_3$  (60 to 134 mg/L  $\text{HCO}_3$ ) in laboratory measured values (IG\_BH03\_DW002 and IG\_BH03\_DW005);
- DO concentration was not measured by Hach meter and ranged from 4.06 to 13.04 mg/L in samples measured by the Horiba probe;
- Fluoride concentration ranged from <0.10 to 0.32 mg/L;
- Sulphate concentration ranged from 3.6 to 11 mg/L; and
- Sodium concentration ranged from 7.8 to 70 mg/L.

Relative results of key major ions are presented in a piper plot in Figure 4. The two drill water additive samples do not cluster and demonstrate that they are of differing composition. The major cation composition in both samples is dominated by sodium (and calcium for IG\_BH03\_DW002). The major anion composition in both samples are dominated by bicarbonate.

#### 4.4 Groundwater Samples

##### Sample Interval 1 (146.88 – 154.61 mbgs)

Sample IG\_BH03\_GW004 was collected at a relatively shallow depth within the borehole (146.88 – 154.61 mbgs). Key analytical results are summarized as follows:

- Field pH of 8.82;
- Total alkalinity of 171 mg/L  $\text{CaCO}_3$  (208 mg/L  $\text{HCO}_3$ );
- Sulphate concentration of <1.0 mg/L;
- Total dissolved sulphide was below method detection limit (<0.02 mg/L) in all samples;
- Oxygen-18 ( $\delta^{18}\text{O}$ ) of -14.8 ‰ VSMOW;
- Deuterium ( $\delta^2\text{H}$ ) of -107.3 ‰ VSMOW;
- $\delta^{13}\text{C}$ -DIC of -12.7 ‰ PDB;
- $^{14}\text{C}$ -DIC of 13336 years BP;
- $^3\text{H}$  of 1.3 TU; and
- $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of 0.721.

Results for key major ions are presented in a piper plot in Figure 4. Based on the major ion chemistry, the dominant major ions in IG\_BH03\_GW004 are bicarbonate and sodium. Concentrations of chloride and sulphate were low as compared to other sample types.

Oxygen-18 and deuterium results are presented in Figure 5, and the sample plots in isolation from all other WP07 samples, in the lower left area of the plot on both the LMWL and GMWL.

Analytical results of tritium indicate a lower proportion of modern precipitation as compared to the water supply and drill water values. Sample IG\_BH03\_GW004 was reported to contain a detectable concentration of tritium which was below the threshold of 5 TU that is indicative of a predominantly modern original due to the influence of anthropogenic nuclear activities.

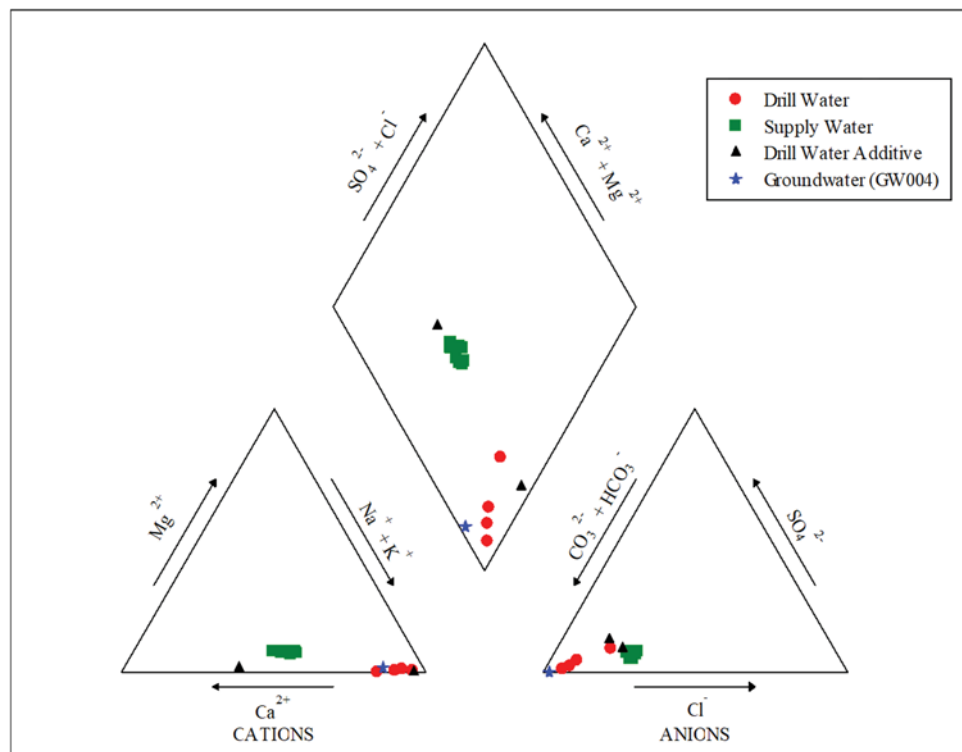


Figure 4: Piper plot of available WP07 water samples results

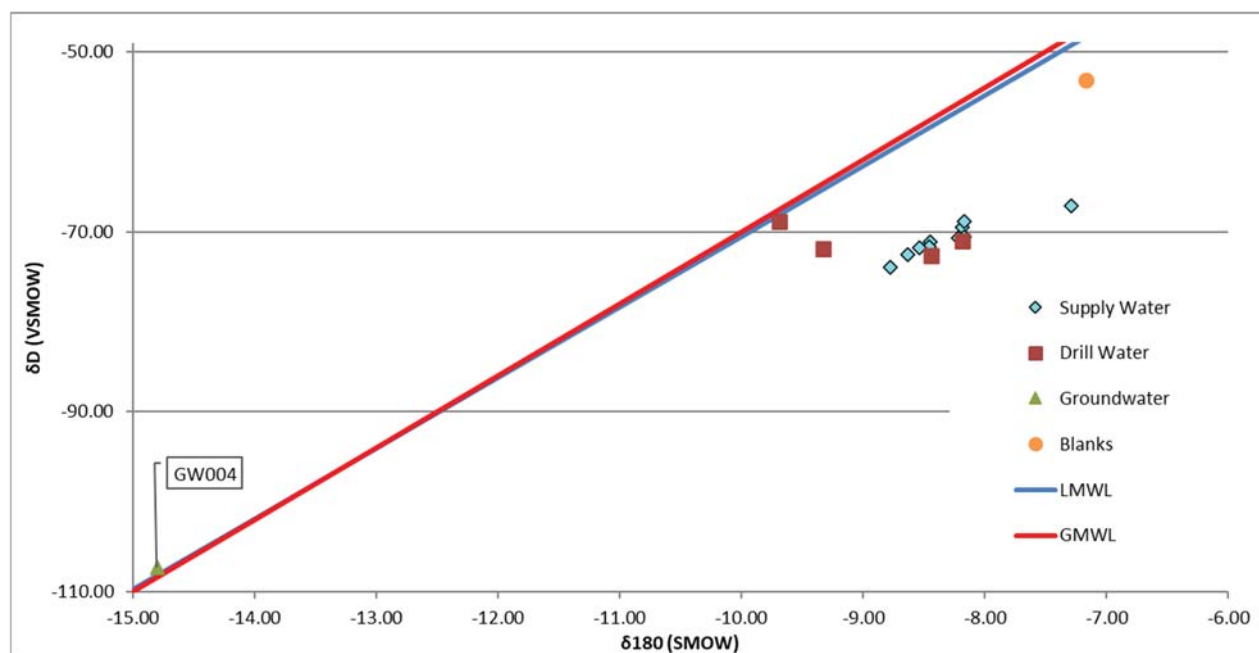


Figure 5: Oxygen ( $\delta^{18}\text{O}$ ) - Deuterium ( $\delta^2\text{H}$ ) plot of WP07 water samples

## 4.5 QA/QC Samples

To evaluate the consistency of analytical results for IG\_BH03\_GW004 and duplicate sample IG\_BH03\_GW005, relative percent difference (RPD) was calculated for all laboratory parameters. However, reported concentrations less than five times the detection limit were excluded to prevent misrepresentation of variability at values reported close to the detection limit. A single set of field measurements was completed for field parameters. The RPD values for all parameters except silicon were below 10% and less than the screening criteria of 20%, which is a typical limit for identifying variation in sample results outside normal ranges. The RPD for silicon was 26%.

One field blank was submitted for analysis and all parameters except total Kjeldahl nitrogen were reported below the method detection limits. The total Kjeldahl nitrogen concentration for this sample was 0.13 mg/L and the reportable detection limit was 0.10 mg/L; at less than twice the detection limit, this is considered an acceptable result.

Laboratory completed duplicate analyses (laboratory QA/QC on single samples submitted in addition to blind duplicate results submitted by field staff) for select parameters were completed for twelve (12) samples. RPD was calculated for all duplicate results, with all RPD values less than 20%.

The QA/QC program for WP07 water samples did not identify any data quality concerns.

## 4.6 Comparison of Water Supply, Drill Water, and Groundwater Results

Water supply samples (Section 4.2) generally contain lower concentrations of most constituents as compared to drill water and groundwater samples. This is consistent with the nature of the water as a treated potable supply. Comparing drill water results to IG\_BH03\_GW004, the drill water samples contain higher concentrations of most parameters, while bromide, nitrite, nitrate, and sulphide are below the method detection limits in all drill water samples as well as IG\_BH03\_GW004. Drill water samples were turbid, and samples IG\_BH03\_DW007, IG\_BH03\_DW012, IG\_BH03\_DW018, IG\_BH03\_DW024 all reported turbidity equal to or greater than 1000 NTU. No clear pattern was evident between sample types for sulphate, while pH and total alkalinity were greater in drill water and groundwater samples as compared to water supply samples.

Drill water samples have a cation composition (Figure 4) which is sodium and potassium dominant as compared to water supply samples. The drill water and water supply samples all have a bicarbonate dominant anion composition. Groundwater sample IG\_BH03\_GW004 generally has similar relative cation and anion characteristics to drill water samples, with a stronger bicarbonate signature.

Drill water and water supply samples are weakly clustered within the upper right quadrant of Figure 5, indicating the oxygen-18 – deuterium composition of drill water is reflective of the original water supply from which it was derived. IG\_BH03\_GW004 plots well to the lower left of all other samples, with more strongly negative values for both  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ .

The field blank sample plots in the far upper right of the figure and has a distinct composition as compared to all other samples, which is appropriate given that the de-ionized water was supplied by the laboratory, and therefore bears no relation to local waters.

## 4.7 Drill Water Contamination of Groundwater Samples

As described in Section 3.3.10, calculations can be completed to determine the proportion of drill water that comprises a groundwater sample, and subsequently this result can be used to determine corrected parameter concentrations for groundwater samples.

Prior to the start of purging for sample IG\_BH03\_GW004 (146.88 – 154.61 mbgs, along borehole), the borehole was circulated with clean drill water with a measured fluorescein concentration of 88.4 ppb. Sample IG\_BH03\_DW007 is the drill water sample associated with groundwater sample IG\_BH03\_GW004. Sample IG\_BH03\_GW004 contained 5.5 ppb fluorescein. The percentage of drill fluid in sample IG\_BH03\_GW004 can be calculated as 6.2% based on a fluorescein concentration in the drill fluid ranging of 88.4 ppb. The corrected analyte values applying 6.2% drill water composition are presented in Appendix B.

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**APPENDIX A**

Table A-1: Sample Summary Description for IG\_BH03  
Fluid Samples

Table A-2: Laboratory Analytical Methodology

Table A-3: Water Source and Drill Water Sample Results

Table A-4: QA/QC Water Quality Results

Table A-1: Sample Summary Description for IG\_BH03 Fluid Samples

Sample ID	Date Collected	Time Collected	Depth		Bottle Sets for Laboratory Analysis												In-Field Geochemistry				Microbiology			Purpose of Sample	
					Major Elements & Metals <sup>2</sup>			Anions & Nutrients <sup>2</sup>			Stable Isotopes <sup>3</sup>			Radioisotopes <sup>3</sup>											
			From (mbs)	To (mbs)	Na, K, Ca, Mg, Sr, U, Si, $\Sigma_{Total}$ Fe <sub>Total</sub>	SiO <sub>2</sub>	S <sup>2-</sup> <sub>Total</sub>	Br, F, Cl, I, SO <sub>4</sub> , PO <sub>4</sub> , NO <sub>3</sub> , NO <sub>2</sub>	Alkalinity	NH <sub>4</sub> +NH <sub>3</sub> , N <sub>Total</sub> P <sub>Total</sub>	$\delta^{18}O$ , $\delta^2H$	$\delta^{34}S$ /Sr	$\delta^{13}C$ DIC	$^{14}C$ DIC	$^3H$	Sulphide	Dissolved Oxygen	Ferrous Iron	Alkalinity	In-Field Measurements <sup>1</sup>	PLFA	DNA	Cell Count		
IG_BH03_DW001	9-Jul-19	16:00	0.00	4.51	✓ <sup>4</sup>			✓												✓				Drill fluid additive sample, AMC Pure-Vis	
IG_BH03_DW002	18-Jul-19	17:30	25.61	25.62	✓ <sup>4</sup>			✓	✓											✓				Drill fluid additive sample, AMC Floc Block	
IG_BH03_DW003	20-Jul-19	3:20	49.59	52.62																✓				Archive @ 50m	
IG_BH03_DW004	22-Jul-19	5:00	97.62	100.58																✓				Archive @ 100m	
IG_BH03_DW005	01-Aug-19	11:55	124.57	124.58	✓	✓		✓	✓											✓				Drill fluid additive sample, AMC Pure-Vis	
IG_BH03_DW006	01-Aug-19	6:00	150.58	151.63																✓				Archive @ 150m	
IG_BH03_DW007 <sup>5</sup>	06-Aug-19	20:04	146.88	154.61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Drill fluid for OGW GW004, microbiology sample interval	
IG_BH03_DW008	05-Aug-19	6:30	146.88	154.61																	✓	✓	✓	Microbiology QA/QC, duplicate of DW007	
IG_BH03_DW009	05-Aug-19	6:20	146.88	154.61																	✓	✓	✓	Microbiology QA/QC, blank of DW007	
IG_BH03_DW010	06-Aug-19	1:54	166.60	169.63																	✓			Archive, drill fluid additive (Pure-Vis)	
IG_BH03_DW011	09-Aug-19	8:45	199.61	202.09																	✓			Archive @ 200m	
IG_BH03_DW012 <sup>7</sup>	12-Aug-19	21:00	229.64	232.59	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Microbiology sample interval	
IG_BH03_DW013	10-Aug-19	15:30	229.64	232.59																		✓	✓	✓	Microbiology QA/QC, duplicate of DW012
IG_BH03_DW014	10-Aug-19	15:30	229.64	232.59																		✓	✓	✓	Microbiology QA/QC, blank of DW012
IG_BH03_DW015	11-Aug-19	7:00	247.63	250.64																	✓				Archive @ 250m
IG_BH03_DW016	13-Aug-19	8:30	298.61	301.61																	✓				Archive @ 300m
IG_BH03_DW017	14-Aug-19	23:20	349.65	352.62																	✓				Archive @ 350m
IG_BH03_DW018 <sup>8</sup>	15-Aug-19	16:00	370.56	373.48	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Microbiology sample interval
IG_BH03_DW019	15-Aug-19	12:00	370.56	373.48																		✓	✓	✓	Microbiology QA/QC, duplicate of DW018
IG_BH03_DW020	15-Aug-19	12:00	370.56	373.48																		✓	✓	✓	Microbiology QA/QC, blank of DW018
IG_BH03_DW021	16-Aug-19	16:15	397.63	400.65																	✓				Archive @ 400m
IG_BH03_DW022	20-Aug-19	2:30	448.63	451.61																	✓				Archive @ 450m
IG_BH03_DW023	22-Aug-19	2:00	499.63	502.63																	✓				Archive @ 500m
IG_BH03_DW024 <sup>6</sup>	23-Aug-19	22:00	517.60	520.59	✓ <sup>4</sup>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Microbiology sample interval
IG_BH03_DW025	23-Aug-19	18:30	517.60	520.59																		✓	✓	✓	Microbiology QA/QC, duplicate of DW024
IG_BH03_DW026	23-Aug-19	18:30	517.60	520.59																		✓	✓	✓	Microbiology QA/QC, blank of DW024
IG_BH03_DW027	25-Aug-19	5:00	547.64	550.65																	✓				Archive @ 550m
IG_BH03_DW028	27-Aug-19	10:30	598.62	601.62																	✓				Archive @ 600m
IG_BH03_DW029	29-Aug-19	4:54	649.64	652.64																	✓				Archive @ 650m
IG_BH03_DW030	30-Aug-19	21:53	697.63	700.63																	✓				Archive @ 700m
IG_BH03_DW031	01-Sep-19	19:47	751.60	754.63																	✓				Archive @ 750m
IG_BH03_DW032	05-Sep-19	12:23	799.63	802.57																	✓				Archive @ 800m
IG_BH03_DW033	09-Sep-19	2:00	850.63	853.65																	✓				Archive @ 850m
IG_BH03_DW034	11-Sep-19	22:50	898.64	901.66																	✓				Archive @ 900m
IG_BH03_DW035	14-Sep-19	2:45	949.62	952.64																	✓				Archive @ 950m
IG_BH03_DW036	16-Sep-19	10:11	997.63	1000.53																	✓				Archive @ 1000m
IG_BH03_GW001	03-Aug-19	7:37	146.88	154.61																	✓				Purge Archive for GW004
IG_BH03_GW002	03-Aug-19	14:20	146.88	154.61																	✓				Purge Archive for GW004
IG_BH03_GW003	03-Aug-19	20:50	146.88	154.61																	✓				Purge Archive for GW004
IG_BH03_GW004	04-Aug-19	2:30	146.88	154.61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Opportunistic GW sample
IG_BH03_GW005	04-Aug-19	3:00	146.88	154.61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Duplicate of OGW GW004
IG_BH03_GW006	07-Aug-19	2:25	146.88	154.61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Blank with OGW GW004
IG_BH03_GW007	-	-	-	-																	✓				Null sample ID
IG_BH03_GW008	04-Aug-19	4:15	146.88	154.61																	✓				Purge Archive for GW004
IG_BH03_WS001	07-Jul-19	15:55	0.00	0.01	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS002	09-Jul-19	20:50	1.40	1.41	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS003	13-Jul-19	14:10	5.80	5.81	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS004	19-Jul-19	18:00	31.64	31.65	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS005	26-Jul-19	14:30	100.58	100.59	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS006	12-Aug-19	17:15	154.61	154.62	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS007	12-Aug-19	17:45	190.61	190.62	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS008	16-Aug-19	13:00	391.63	391.64	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS009	29-Aug-19	13:00	655.63	655.64	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling
IG_BH03_WS010	17-Sep-19	10:41	1000.53	1000.54	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample used during WP05, WP06, and WP09

Notes

IG\_BH03\_GWxxx indicates a groundwater sample

IG\_BH03\_DSxxx indicates a drill water sample

IG\_BH03\_WSxxx indicates a water source (fresh water supply) sample

<sup>1</sup>In-field measurements include the fluorescein concentration measured with an Aqualuor Fluorometer, and the following parameters measured with a Horiba U52-2 Multiprobe: temperature, pH, electrical conductivity, ORP, turbidity and dissolved oxygen. Density measurements were also collected for archive drill water samples using a hydrometer and included as part of WP02 Data Delivery. In-field measurements for archive drill water samples are reported under WP02 Data Delivery.

<sup>2</sup>Laboratory analyses completed at Bureau Veritas Laboratories (BV)

<sup>3</sup>Laboratory analyses completed at Isotope Tracer Technologies (ITT)

<sup>4</sup>S<sub>Total</sub> not analysed

<sup>5</sup>Fe<sub>Total</sub> not analysed

<sup>6</sup>IG\_BH03\_DW007 sampled for microbiology on 05-Aug-19 at 06:30; IG\_BH03\_DW012 sampled for microbiology on 10-Aug-19 at 17:15; IG\_BH03\_DW018 sampled for microbiology on 15-Aug-19 at 15:00; IG\_BH03\_DW024 sampled for microbiology on 23-Aug-19 at 18:30

Prepared By: BT  
Checked By: NS  
Reviewed By: ML





Parameter	Units	Method	Method Detection Limit (conventional parameters) Standard Deviation (isotopes)
<b>ANIONS &amp; NUTRIENTS</b>			
Bromide	mg/L	Ion Chromatography (CAM SOP-00435)	1.0
Chloride	mg/L	Ion Chromatography (CAM SOP-00435)	1.0
Iodide	mg/L	Ion Chromatography (CAL SOP-00057)	0.1
Fluoride	mg/L	Potentiometry - ISE (CAM SOP-00449)	0.1
Nitrite	as N mg/L	Colourimetry (CAM SOP-00440)	0.01
Nitrate	as N mg/L	Colourimetry (CAM SOP-00440)	0.1
Total Ammonia	as N mg/L	Colourimetry (CAM SOP-00441)	0.05
Total Kjeldahl Nitrogen	as N mg/L	SKAL (CAM SOP-00938)	0.1
Orthophosphate	mg/L	KONE (CAM SOP-00461)	0.01
Total Phosphorus	mg/L	Colourimetry (CAM SOP-00407)	0.02
Sulphate	mg/L	Automated Colourimetry	1.0
Sulphide	mg/L	ISE (CAM SOP-00455)	0.02
<b>TOTAL AND DISSOLVED METALS</b>			
Calcium	mg/L	ICP/MS (CAM SOP-00447)	0.2
Iron	mg/L	ICP/MS (CAM SOP-00447)	0.1
Lithium	mg/L	ICP/MS (CAM SOP-00447)	0.005
Magnesium	mg/L	ICP/MS (CAM SOP-00447)	0.05
Potassium	mg/L	ICP/MS (CAM SOP-00447)	0.2
Silicon	mg/L	ICP/MS (CAM SOP-00447)	0.05
Sodium	mg/L	ICP/MS (CAM SOP-00447)	0.1
Strontium	mg/L	ICP/MS (CAM SOP-00447)	0.001
Silica	mg/L	KONE (AB SOP-00011)	0.05
Sulphur	mg/L	ICP/MS (CAM SOP-00447)	0.05
<b>STABLE ISOTOPES</b>			
$\delta^{18}\text{O}$	VSMOW	Cavity Ring Down Spectroscopy	$\pm 0.1\text{‰}$
$\delta^2\text{H}$	VSMOW	Cavity Ring Down Spectroscopy	$\pm 1\text{‰}$
$^{87}\text{Sr}/^{86}\text{Sr}$	ratio	Thermal Ionization Mass Spectrometry	$\pm 0.0001$
$\delta^{13}\text{C}$ DIC	PDB	Finnigan MAT, DeltaPlus XL IRMS	$\pm 0.2\text{‰}$
<b>RADIOISOTOPES</b>			
$^{14}\text{C}$ -DIC	years BP	Accelerator Mass Spectrometry	25-111
$^3\text{H}$	TU	Liquid Scintillation Counting	$\pm 1$

**Notes:**

- 1) Detection limits are not applicable to isotopes as measurement is relative to a standard rather than absolute.
- 2) When a sample required dilution, the detection limit is adjusted accordingly. Adjusted detection limits are specified in the Laboratory Certificates of Analyses (COAs) for BV included in the data deliverable.

Prepared By: NS

Checked By: BT

Reviewed By: ML

Table A-3: Water Source and Drill Water Sample Results

1671632 (2701)

Sample Type	Water Source											Drill Water				Drill Water Additive			
Sample Date (mm/dd/yyyy)	07-07-2019	07-09-2019	07-13-2019	07-19-2019	07-26-2019	08-12-2019	08-12-2019	08-16-2019	08-29-2019	09-17-2019		08-06-2019	08-12-2019	08-15-2019	08-23-2019	07-09-2019	07-18-2019	08-01-2019	
Sample ID	IG_BH03_WS001	IG_BH03_WS002	IG_BH03_WS003	IG_BH03_WS004	IG_BH03_WS005	IG_BH03_WS006	IG_BH03_WS007	IG_BH03_WS008	IG_BH03_WS009	IG_BH03_WS010		IG_BH03_DW007	IG_BH03_DW012	IG_BH03_DW018	IG_BH03_DW024	IG_BH03_DW001	IG_BH03_DW002	IG_BH03_DW005	
Associated OGW Sample												IG_BH03_DW004							
GENERAL PARAMETERS																			
pH (field)	-	6.71	6.43	7.12	6.86	6.95	6.69	6.53	7.37	7.17	6.55	8.67	10.32	8.86	8.37	8.38	10.5	10.71	
Temperature (field)	°C	23.42	18.73	21.11	21.8	19.36	19.85	19.32	16.56	15.69	20.29	25.34	21.31	18.56	18.7	22.48	23.23	15.26	
ORP (field)	mV	378	629	146	715	700	361	622	696	625	607	38	-101	-626	179	108	95	126	
EC (field)	mS/cm	0.047	0.051	0.051	0.048	0.043	0.054	0.051	0.039	0.040	0.043	0.208	0.229	0.286	0.616	0.114	0.139	0.372	
Turbidity (field)	NTU	BDL	2.5	BDL	BDL	0.2	BDL	BDL	BDL	BDL	0.2	>1000	>1000	>1000	>1000	BDL	148	>1000	
Fluorescein (field)	ppb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	88.4	86.26	- <sup>1</sup>	108.6	-	-	85.63	
Dissolved Oxygen (field-Horiba)	mg/L	9.10	9.56	10.18	8.81	8.86	9.87	7.63	6.76	13.43	9.00	0.84	4.9	BDL	7.6	6.91	4.06	13.04	
<sup>1</sup> Dissolved Oxygen (field-Hach)	mg/L	10.6	8.4	9.43	8.9	8.3	8.4	8.5	9.3	8.8	8.3	12.8	-	-	-	-	-	-	
Total Alkalinity (lab)	mg/L CaCO <sub>3</sub>	18	18	18	16	15	28	18	20	20	13	99	74	120	260	-	49	110	
<sup>2</sup> Total Alkalinity (field)	mg/L CaCO <sub>3</sub>	18	18	18	16	15	28	18	20	20	14	98	-	-	-	-	-	-	
Total Alkalinity	mg/L HCO <sub>3</sub> <sup>-</sup>	21	21	22	19	19	18	16	16	16	16	121	90	146	317	- <sup>3</sup>	60	134	
Hydroxide Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	11	17	
Hydroxide Alkalinity (speciated)	mg/L OH <sup>-</sup>	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	6	
Carbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	0	0	0	1	0	0	0	0	0	0	4	45	8	6	- <sup>3</sup>	29	77	
Carbonate Alkalinity (speciated)	mg/L CO <sub>3</sub> <sup>2-</sup>	0	0	0	1	0	0	0	0	0	0	3	27	5	4	- <sup>3</sup>	17	46	
Bicarbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	17	18	18	14	15	15	13	13	13	13	94	22	112	254	- <sup>3</sup>	9	15	
Bicarbonate Alkalinity (speciated)	mg/L HCO <sub>3</sub> <sup>-</sup>	21	21	22	18	19	18	16	16	16	16	115	26	136	310	- <sup>3</sup>	11	18	
Charge Balance	-	-7.3%	-0.4%	-2.0%	-0.4%	0.0%	1.8%	3.7%	1.6%	8.6%	6.3%	2.9%	7.4%	8.2%	19.4%	- <sup>3</sup>	2.2%	9.1%	
ANIONS & NUTRIENTS																			
Bromide	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Chloride	mg/L	7.6	7.5	7.6	7.6	6.9	7.5	6	6.6	6.1	5.9	12	13	12	20	7.7	8.8	14	
Iodide	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Fluoride	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.38	0.21	0.55	1.3	<0.10	<0.10	0.32	
Nitrite	as N mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.050	<0.050	0.025	0.073	0.010	
Nitrate	as N mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.50	<0.10	<0.10	<0.10	<0.10	
Nitrite + Nitrate	as N mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.50	<0.10	<0.10	<0.10	<0.10	
Ammonium	mg/L	0.16	<0.05	<0.05	0.10	<0.0061	<0.0061	0.23	<0.0061	<0.0061	<0.0061	0.45	<0.055	0.13	0.17	-	-	-	
Total Ammonia	as N mg/L	0.12	<0.050	<0.050	0.090	<0.050	<0.050	0.18	<0.050	<0.050	<0.050	0.44	0.2	0.12	0.14	-	-	-	
Total Kjeldahl Nitrogen	as N mg/L	-	-	-	0.18	0.2	0.29	0.23	0.18	0.18	0.31	5.6	6.3	11	21	-	-	-	
Orthophosphate	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.017	0.066	0.042	0.044	0.22	<0.010	0.26	
Total Phosphorus	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.044	0.16	0.19	0.28	-	-	-	
Sulphate	mg/L	2.4	2.3	2.3	1.4	2.2	1.9	1.5	1.9	1.3	1.2	5.8	6.4	3.6	3.2	4.6	3.6	11	
Sulphide (lab)	mg/L	<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	-	-	-	
<sup>5</sup> Sulphide (field)	mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-	-	-	-	-	-	
Hydrogen Sulphide (field)	mg/L	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	
Bisulphide (field)	mg/L	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	
Reactive Silica (SiO <sub>2</sub> )	mg/L	2.4	2.4	2.2	2.5	2.7	2.8	3.3	3	3.4	3.6	14	16	11	12	-	-	18	
METALS																			
Dissolved Calcium	mg/L	5.1	5.2	5.5	4.5	4.5	5.2	4.4	4.3	4.5	4.5	6.2	9	5.7	8.8	0.96	18	3.1	
Dissolved Iron	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<0.1	3.6	-	<0.1	<0.1	0.19	
<sup>5</sup> Ferrous Iron (field-Hach)	mg/L	0.11	<sup>6</sup> 0.01	<sup>6</sup> BDL	0.03	<sup>6</sup> BDL	<sup>6</sup> 0.02	<sup>6</sup> BDL	<sup>6</sup> BDL	<sup>6</sup> BDL	<sup>6</sup> BDL	<sup>6</sup> 0.21	-	-	-	-	-	-	
Dissolved Lithium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.063	0.046	0.12	0.32	<0.005	0.0077	0.033	
Dissolved Magnesium	mg/L	0.89	0.85	0.98	0.88	0.81	0.85	0.81	0.82	0.87	0.8	0.37	0.12	0.83	1	0.081	0.48	0.062	
Dissolved Potassium	mg/L	0.61	0.48	0.51	0.51	0.46	0.5	0.43	0.44	0.48	0.39	12	11	15	32	0.38	3.5	8.1	
Dissolved Silicon	mg/L	1.2	1.2	1	1.3	1.3	1.4	1.3	1.4	1.8	1.7	7.8	8.6	28	6.8	1.3	5.4	10	
Dissolved Sodium	mg/L	4.4	6.2	5.3	5.7	5.7	5.4	4.7	4.9	5.6	5	45	36	60	170	21	7.8	70	
Dissolved Strontium	mg/L	0.015	0.014	0.013	0.012	0.012	0.014	0.012	0.013	0.012	0.011	0.015	0.024	0.027	0.031	0.0016	0.068	0.0058	
Total Sulphur	mg/L	0.65	0.62	0.59	0.63	0.76	0.61	0.47	0.64	0.65	0.6	2.2	2.5	1.5	2.2	-	-	4.5	
STABLE ISOTOPES																			
<sup>18</sup> O	VSMOW	-8.45	-8.46	-8.78	-8.63	-8.54	-8.19	-8.22	-7.29	-8.17	-8.17	-8.44	-8.19	-9.69	-9.33	-	-	-	
<sup>2</sup> H	VSMOW	-71.1	-71.7	-73.9	-72.5	-71.8	-69.5	-70.7	-67.1	-70.6	-68.9	-72.6	-71.0	-68.9	-71.9	-	-	-	
<sup>87</sup> Sr/ <sup>86</sup> Sr	ratio	0.72775	0.71884	0.72884	0.72981	0.73028	0.71041	0.73040	0.73047	- <sup>5</sup>	0.73002	0.76818	0.75462	0.79941	0.80148	-	-	-	
<sup>13</sup> C DIC	PDB	-2.1	-3.2	-9.1	-17.8	-8.0	-7.4	-9.2	-9.2	-6.8	-15.7	-22.9	-10.1	-18.6	-20.4	-	-	-	
RADIOISOTOPES																			
<sup>14</sup> C-DIC	years BP	180	389	- <sup>8</sup>	514	- <sup>8</sup>	1245	- <sup>8</sup>	- <sup>8</sup>	- <sup>8</sup>	- <sup>8</sup>	2808	5167	3240	2539	-	-	-	
<sup>3</sup> H	TU	7.6	10.4	9.4	8.7	7.6	11.5	9.5	9.8	10.8	13.3	10.5	8.9	10.6	7.9	-	-	-	

**Notes:**<sup>1</sup>Hach model DR2800 Spectrophotometer used for field readings.<sup>2</sup>Alkalinity kit model 10-400 mg/L Model AL-DT used for field titration.<sup>3</sup>Calculation not possible due to at least one input either below detection limit or not reported.<sup>4</sup>Reading masked by high turbidity.<sup>5</sup>Sample signal died before measurement, entire sample used<sup>6</sup>Produced gas from preparation work not sufficient for analysis<sup>7</sup>Total Alkalinity as HCO<sub>3</sub><sup>-</sup> calculated based on laboratory reported alkalinity result. Where only a field reported alkalinity result was available, the field value was used.<sup>8</sup>The test plan and manufacturer's procedure specified a reagent blank was to be prepared and used to zero the spectrophotometer prior to sample readings. These samples were associated with a blank reading recorded as a calibration check only and the instrument not zeroed. Following the Hach recommendation for non-zero blank readings where the instrument is not zeroed, the blank value has been subtracted from the sample reading. This corrected value is the reported value.

For Charge Balance, Total Alkalinity and speciated value calculations, see Calculations spreadsheet as part of the Data Deliverable

"NA": Parameter not applicable to this sample type.

"-": Analyses not performed. No value reported.

<sup>9</sup>"BDL": Result below method detection limit.

Prepared By: SR  
 Checked By: BT  
 Reviewed By: ML

Sample Type		Opportunistic Groundwater Samples	Blank	Duplicate	
Sample Date (mm/dd/yyyy)		08-04-2019	08-07-2019	08-04-2019	Relative Percent Difference (%)
Sample ID		IG_BH03_GW004	IG_BH03_GW006	IG_BH03_GW005	
Associated OGW Sample			IG_BH03_GW004	IG_BH03_GW004	
GENERAL PARAMETERS					
pH (field)	-	8.82	7	8.82	0.0
Temperature (field)	°C	13.44	15	13.44	0.0
ORP (field)	mV	-457	-	-457	0.0
EC (field)	mS/cm	0.309	-	0.309	0.0
Turbidity (field)	NTU	24.8	-	24.8	0.0
Fluorescein (field)	ppb	5.5	-	5.5	0.0
Dissolved Oxygen (field-Horiba)	mg/L	BDL	-	BDL	<sup>-3</sup>
<sup>1</sup> Dissolved Oxygen (field-Hach)	mg/L	0.157	-	-	<sup>-3</sup>
Total Alkalinity (lab)	mg/L CaCO <sub>3</sub>	-	-	-	<sup>-3</sup>
<sup>2</sup> Total Alkalinity (field)	mg/L CaCO <sub>3</sub>	171	-	-	<sup>-3</sup>
<sup>6</sup> Total Alkalinity	mg/L HCO <sub>3</sub> <sup>-</sup>	208	-	-	<sup>-3</sup>
Hydroxide Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	0	-	-	<sup>-3</sup>
Hydroxide Alkalinity (speciated)	mg/L OH <sup>-</sup>	0	-	-	<sup>-3</sup>
Carbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	11	-	-	<sup>-3</sup>
Carbonate Alkalinity (speciated)	mg/L CO <sub>3</sub> <sup>2-</sup>	6	-	-	<sup>-3</sup>
Bicarbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	160	-	-	<sup>-3</sup>
Bicarbonate Alkalinity (speciated)	mg/L HCO <sub>3</sub> <sup>-</sup>	195	-	-	<sup>-3</sup>
Charge Balance	-	7.8%	-	-	<sup>-3</sup>
ANIONS & NUTRIENTS					
Bromide	mg/L	<1.0	<1.0	<1.0	<sup>-3</sup>
Chloride	mg/L	3.2	<1.0	3.4	-6.1
Iodide	mg/L	<0.10	<0.10	<0.10	<sup>-3</sup>
Fluoride	mg/L	3.4	<0.10	3.3	3.0
Nitrite	as N mg/L	<0.010	<0.010	<0.010	<sup>-3</sup>
Nitrate	as N mg/L	<0.10	<0.10	<0.10	<sup>-3</sup>
Nitrite + Nitrate	as N mg/L	<0.10	<0.10	<0.10	<sup>-3</sup>
Ammonium	mg/L	0.065	<0.00061	0.11	<sup>-4</sup>
Total Ammonia	as N mg/L	0.059	<0.050	0.098	<sup>-4</sup>
Total Kjeldahl Nitrogen	as N mg/L	0.76	0.13	0.69	9.7
Orthophosphate	mg/L	0.012	<0.010	0.012	0.0
Total Phosphorus	mg/L	0.032	<0.020	0.038	<sup>-4</sup>
Sulphate	mg/L	<1.0	<1.0	<1.0	<sup>-3</sup>
Sulphide (lab)	mg/L	<0.020	<0.020	<0.020	<sup>-3</sup>
<sup>1</sup> Sulphide (field)	mg/L	BDL	-	-	<sup>-3</sup>
Hydrogen Sulphide (field)	mg/L	<sup>-3</sup>	-	-	<sup>-3</sup>
Bisulphide (field)	mg/L	<sup>-3</sup>	-	-	<sup>-3</sup>
Reactive Silica (SiO2)	mg/L	12	<0.050	12	0.0
Metals					
Dissolved Calcium	mg/L	13	<0.2	13	0.0
Dissolved Iron	mg/L	0.49	<0.1	1.3	<sup>-4</sup>
<sup>1</sup> Ferrous Iron (field-Hach)	mg/L	0.34	-	-	<sup>-3</sup>
Dissolved Lithium	mg/L	0.057	<0.005	0.058	-1.7
Dissolved Magnesium	mg/L	1.5	<0.05	1.5	0.0
Dissolved Potassium	mg/L	3.2	<0.2	3.3	-3.1
Dissolved Silicon	mg/L	7.7	<0.05	10	-26.0
Dissolved Sodium	mg/L	80	<0.1	79	1.3
Dissolved Strontium	mg/L	0.16	<0.001	0.16	0.0
Total Sulphur	mg/L	0.16	<0.05	0.16	0.0
STABLE ISOTOPES					
δ <sup>18</sup> O	VSMOW	-14.80	-7.17	-14.88	-0.5
δ <sup>2</sup> H	VSMOW	-107.3	-53.2	-108.4	-1.0
<sup>87</sup> Sr/ <sup>86</sup> Sr	ratio	0.72106	0.71086	0.72129	0.0
δ <sup>13</sup> C DIC	PDB	-12.7	-17.1	-13.0	-2.3
RADIOISOTOPES					
<sup>14</sup> C-DIC	years BP	13336	<sup>-5</sup>	13232	0.8
<sup>3</sup> H	TU	1.3	47.9	<0.8	<sup>-3</sup>

**Notes:**<sup>1</sup>Hach model DR2800 Spectrophotometer used for field readings<sup>2</sup>Alkalinity kit model 10-400 mg/L Model AL-DT used for field titration<sup>3</sup>Calculation not possible due to at least one input either below detection limit or not reported.<sup>4</sup>RPD calculation not valid at concentrations within five times the detection limit.<sup>5</sup>Inadequate signal strength to acquire measurement.<sup>6</sup>Total Alkalinity as HCO<sub>3</sub><sup>-</sup> calculated based on laboratory reported alkalinity result. Where only a field reported alkalinity result was available, the field value was used.

For Charge Balance, Total Alkalinity and speciated value calculations, see Calculations spreadsheet as part of the Data Deliverable

Relative Percent Difference calculated per method described in APHA (American Public Health Association). 2017. Standard Methods for the Examination of Water and Wastewater, 23rd Edition. Washington, DC, USA.

"NA": Parameter not applicable to this sample type.

"-": Analyses not performed. No value reported.

"BDL": Result below method detection limit.

Prepared By: SR  
 Checked By: BT  
 Reviewed By: ML

**APPENDIX B**

**Table B-1: Drill Water  
Contamination Correction Values**

Sample Type		Opportunistic Groundwater Sample	Drill Water Sample	Corrected Result
Sample Date (mm/dd/yyyy)		08-04-2019	08-06-2019	08-04-2019
Sample ID		IG_BH03_GW004	IG_BH03_DW007	IG_BH03_GW004
<b>GENERAL PARAMETERS</b>				
pH (field)	-	8.82	8.67	8.83
Temperature (field)	°C	13.44	25.34	-
ORP (field)	mV	-457	38	-
EC (field)	mS/cm	0.309	0.208	-
Turbidity (field)	NTU	24.8	>1000	-
Fluorescein (field)	ppb	5.5	88.4	-
Dissolved Oxygen (field-Horiba)	mg/L	BDL	0.84	-
<sup>1</sup> Dissolved Oxygen (field-Hach)	mg/L	0.157	12.8	-
Total Alkalinity (lab)	mg/L CaCO <sub>3</sub>	-	99	- <sup>3</sup>
<sup>2</sup> Total Alkalinity (field)	mg/L CaCO <sub>3</sub>	171	98	176
<sup>4</sup> Total Alkalinity	mg/L HCO <sub>3</sub> <sup>-</sup>	208	121	214
Hydroxide Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	0	0	0
Hydroxide Alkalinity (speciated)	mg/L OH <sup>-</sup>	0	0	0
Carbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	11	4	11
Carbonate Alkalinity (speciated)	mg/L CO <sub>3</sub> <sup>2-</sup>	6	3	7
Bicarbonate Alkalinity (speciated)	mg/L CaCO <sub>3</sub>	160	94	164
Bicarbonate Alkalinity (speciated)	mg/L HCO <sub>3</sub> <sup>-</sup>	195	115	200
Charge Balance	-	7.8%	2.9%	-
<b>ANIONS &amp; NUTRIENTS</b>				
Bromide	mg/L	<1.0	<1.0	- <sup>3</sup>
Chloride	mg/L	3.2	12	2.6
Iodide	mg/L	<0.10	<0.10	- <sup>3</sup>
Fluoride	mg/L	3.4	0.38	3.6
Nitrite	as N mg/L	<0.010	<0.010	- <sup>3</sup>
Nitrate	as N mg/L	<0.10	<0.10	- <sup>3</sup>
Nitrite + Nitrate	as N mg/L	<0.10	<0.10	- <sup>3</sup>
Ammonium	mg/L	0.065	0.45	0.039
Total Ammonia	as N mg/L	0.059	0.44	0.034
Total Kjeldahl Nitrogen	as N mg/L	0.76	5.6	0.44
Orthophosphate	mg/L	0.012	0.017	0.012
Total Phosphorus	mg/L	0.032	0.044	0.031
Sulphate	mg/L	<1.0	5.8	- <sup>3</sup>
Sulphide (lab)	mg/L	<0.020	<0.020	- <sup>3</sup>
<sup>1</sup> Sulphide (field)	mg/L	BDL	BDL	- <sup>3</sup>
Hydrogen Sulphide (field)	mg/L	- <sup>3</sup>	- <sup>3</sup>	- <sup>3</sup>
Bisulphide (field)	mg/L	- <sup>3</sup>	- <sup>3</sup>	- <sup>3</sup>
Reactive Silica (SiO <sub>2</sub> )	mg/L	12	14	12
<b>METALS</b>				
Dissolved Calcium	mg/L	13	6.2	13
Dissolved Iron	mg/L	0.49	0.12	0.51
<sup>1</sup> Ferrous Iron (field-Hach)	mg/L	0.34	<sup>5</sup> 0.21	0.35
Dissolved Lithium	mg/L	0.057	0.063	0.057
Dissolved Magnesium	mg/L	1.5	0.37	1.6
Dissolved Potassium	mg/L	3.2	12	2.6
Dissolved Silicon	mg/L	7.7	7.8	7.7
Dissolved Sodium	mg/L	80	45	82
Dissolved Strontium	mg/L	0.16	0.015	0.17
Total Sulphur	mg/L	0.16	2.2	0.02
<b>STABLE ISOTOPES</b>				
δ <sup>18</sup> O	VSMOW	-14.80	-8.44	-15.22
δ <sup>2</sup> H	VSMOW	-107.3	-72.6	-109.6
<sup>87</sup> Sr/ <sup>86</sup> Sr	ratio	0.72106	0.76818	0.7179
δ <sup>13</sup> C DIC	PDB	-12.7	-22.9	-12.0
<b>RADIOISOTOPES</b>				
<sup>14</sup> C-DIC	% modern	19.0%	70.5%	15.6%
<sup>3</sup> H	TU	1.3	10.5	0.7

**Notes:**<sup>1</sup>Hach model DR2800 Spectrophotometer used for field readings<sup>2</sup>Alkalinity kit model 10-400 mg/L Model AL-DT used for field titration<sup>3</sup>Calculation not possible due to at least one input either below detection limit or not reported.<sup>4</sup>Total Alkalinity as HCO<sub>3</sub><sup>-</sup> calculated based on laboratory reported alkalinity result. Where only a field reported alkalinity result was available, the field value was used.<sup>5</sup>The test plan and manufacturer's procedure specified a reagent blank was to be prepared and used to zero the spectrophotometer prior to sample readings. These samples were associated with a blank reading recorded as a calibration check only and the instrument not zeroed. Following the Hach recommendation for non-zero blank readings where the instrument is not zeroed, the blank value has been subtracted from the sample reading. This corrected value is the reported value.

For Charge Balance, Total Alkalinity and speciated value calculations, see Calculations spreadsheet as part of the Data Deliverable

"-": Analyses not performed. No value reported.

"BDL": Result below method detection limit.

Prepared By: BT

Checked By: ML

Reviewed By: KD

**APPENDIX C**

**Analytical In-field Analysis  
Procedures**

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## 1.0 ANALYTICAL IN-FIELD PARAMETER MEASUREMENTS

The samples analyses for alkalinity, total sulfide, dissolved oxygen and ferrous iron can be impacted by contact with the atmosphere. In order to collect, prepare and analyze samples while preventing contact to the atmosphere, the samples were collected using an in-situ fluid sampler probe to collect groundwater from directly above the packers. The in-situ fluid sampler probe that was used is the Westbay Instruments MOSDAX Sampler Probe Model 2532.

The fluid sampler was lowered on the wireline winch with the 1L sample chamber closed. Once the fluid sampler was positioned approximately 1 meter above the inflated packers, the chamber was opened using the MSI control system, allowing fluid to enter the chamber. The chamber was then closed and retrieved to surface.

Once the filled chamber was at the surface, the fluid sampler valve cap was removed, exposing the inlet port. A rubber sleeve was slid over the inlet port. Pressurized nitrogen was directed through the port to flush any trapped atmospheric air above the water sample and to extrude the OGW water into the sampling tube.

If additional sample volume was required for analyses, the chamber was decontaminated following Section 3.1 and lowered downhole to collect additional volume. This process can be repeated as often as required.

### Alkalinity

Alkalinity of the OGW sample was measured in the field using a titration method that determines the phenolphthalein and total alkalinities. The titration method consists of incremental addition of sulphuric acid ( $\text{H}_2\text{SO}_4$ ), while using phenolphthalein and bromcresol green-methyl red indicators to visually identify key endpoints in the titration. Once the phenolphthalein and total alkalinities were determined, the proportion of the phenolphthalein alkalinity relative to the total alkalinity was used to estimate the hydroxide, carbonate and bicarbonate alkalinities.

The OGW sample for alkalinity analysis was first collected by passing the sample through a 0.45  $\mu\text{m}$  groundwater filter and into a clean flask (rinsed with nanopure deionized water). Next, a Hach kit and digital titrator was used to complete alkalinity measurements.

### Sulphide

Total sulphide ( $\text{S}^{2-}_{\text{Total}}$ ) was measured in the field immediately after sample collection using the Methylene Blue Method. Hach sulphide reagents and spectrophotometer was used to carry out the analysis in the field. First, two standard Hach reagents, referred to as Sulphide 1 Reagent and Sulphide 2 Reagent, were readied by loading two separate 1 mL syringes (fitted with a hypodermic needle) with each reagent with no headspace. A blank was prepared with 25 mL deionized water in a Hach spectrophotometer sample cell; the blank was used to zero the Hach spectrophotometer before reading the OGW sample. The Hach spectrophotometer was turned on and readied, as it needs time to warm-up prior to use. These steps were completed first in order to minimize the time between the OGW sample collection and the analysis.

Next, a glass syringe was connected to the sample tubing and an OGW sample was extruded into the glass syringe with compressed nitrogen. A glass syringe is needed (rather than plastic) to mitigate the ingress or egress of gases through the syringe wall. About 10 mL of sample was extruded into the glass syringe and then the syringe was disconnected to bleed out any air and some of the sample; this was to ensure there is no headspace. The syringe was then reconnected to the sample tubing and the full OGW sample volume (25 mL) was collected with no air bubbles. A steady flow from the sample tube was maintained at a slow rate upon reconnection of the

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syringe to assist with mitigating the entry of air bubbles. Once the 25 mL sample was attained, the syringe was disconnected and the tip capped with a rubber septum. If there are air bubbles present after attaching the rubber septum, the OGW sample was discarded and the sample collection steps repeated until an OGW sample was attained with no air bubbles. The syringe with 1 mL of Sulphide 1 Reagent was then immediately inserted through the rubber septum into the glass syringe and the first reagent was then injected into the OGW sample. The syringe with 1 mL of Sulphide 2 Reagent was then immediately inserted through the rubber septum into the glass syringe and the second reagent was then injected into the OGW sample. The reagents also need to be added to the blank in the same sequence immediately after adding to the OGW sample: 1 mL of Sulphide 1 Reagent, then 1 mL of Sulphide 2 Reagent. The timer on the Hach spectrophotometer was then started for a 5 minimum reaction time. Once the 5 minute reaction time was complete, the blank was inserted into the Hach spectrophotometer to zero the instrument. The sample in the glass syringe was then injected into a sample cell and inserted into the Hach spectrophotometer for an immediate sample reading; the reading value was recorded directly into the AcQuire groundwater sampling data entry object. If there is dissolved sulphide in the OGW sample, the sample will turn a blue colour during the reaction time; therefore, the colour of the OGW sample was recorded in field notes as a qualitative indicator of presence/absence of sulphide. Given the importance of the potential presence of dissolved sulphide on the long-term chemical stability of some of the barrier components associated with the deep geological repository, this procedure was repeated twice to attain a duplicate in-field measurement of total sulphide ( $S^{2-}_{Total}$ ).

Prior to collecting the OGW sample, a series of five sulphide standards was prepared using a sulphide stock standard solution (Radiello™ Methylene Blue Calibration Standard). Using the stock standard solution, five standards were prepared at different concentrations that are expected to encompass the range of sulphide concentrations in the OGW sample (0.01 mg/L to 1 mg/L). The known concentrations of the standards can be compared to the values measured using the Hach spectrophotometer to determine a sample-specific correction factor. Preparation and analysis of standards were completed prior to the start of, and during, field work as a QA check on the operation of the Hach spectrophotometer and recorded in the Data Quality Confirmation Workbook.

The concentrations of hydrogen sulphide ( $H_2S$ ) and unionized hydrogen sulphide (or bisulphide ion,  $HS^-$ ) were calculated using the total sulphide ( $S^{2-}_{total}$ ) concentration and pH. Concentration of  $S^{2-}$  ions will not be measured or calculated, given that the concentrations of  $S^{2-}$  ions under natural conditions are negligible.

## Dissolved Oxygen

Dissolved oxygen (DO) was measured in the field immediately after sample collection using the Indigo Carmine Method. Hach AccuVac Ampuls and spectrophotometer were used to carry out the analysis in the field. The Hach AccuVac Ampuls are glass cells pre-loaded with reagent and under a vacuum so that the sample is sucked into the ampul without exposure to atmospheric conditions. The DO results were compared to the DO measured using the multiprobe; all values were recorded in the Data Quality Confirmation Workbook.

## Ferrous Iron

Ferrous iron ( $Fe^{2+}$ ) was measured in the field after sample collection using the 1-10 Phenanthroline Method. Hach AccuVac Ampuls and spectrophotometer was used to carry out the analysis in the field. As with the Hach DO AccuVac Ampuls, the Hach Ferrous Iron AccuVac Ampuls are glass cells that are pre-loaded with reagent and under a vacuum so that the sample is sucked into the ampul without exposure to atmospheric conditions. This method is only applicable for concentrations up to 3 mg/L; in the case when samples contain concentrations of ferrous iron greater than 3 mg/L, the sample would need to be diluted with nanopure water (attained from a



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laboratory) to bring the concentration within the detection range of the method. The concentration would then be corrected by the dilution factor.

Ferrous iron oxidizes very rapidly at neutral pH conditions, but oxidizes at a much slower rate under acidic conditions. As such, an alternative to completing the analysis immediately in the field during the collection of the OGW samples is to preserve a filtered OGW sample with trace grade nitric acid (HNO<sub>3</sub>). The Hach method can then be completed later in the day or within a 24 hour period. This would provide some additional time to complete the analysis, which is particularly useful if the concentrations in the OGW sample are greater than 3 mg/L and sample dilution is necessary to complete the analysis.

Similar to the hydrogen sulphide analysis, a series of five ferrous iron standards were prepared using ferrous ammonium sulfate, hexahydrate (Fe(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub>·6H<sub>2</sub>O). These standards were prepared at different concentrations, which are expected to encompass the range of ferrous iron concentrations in the OGW sample; in this case, it is expected that the concentrations will be relatively low (<1 mg/L). The standards will be analysed using the 1-10 Phenanthroline Method and the known concentrations of the standards were compared to the values measured using the Hach spectrophotometer to determine a sample-specific correction factor. Preparation and analysis of standards were completed prior to the start of, and during, field work as a QA check on the operation of the Hach spectrophotometer and recorded in the Data Quality Confirmation Workbook.

## 2.0 SAMPLE COLLECTION FOR MICROBIOLOGY RESEARCH AND DEVELOPMENT

The University of Waterloo will order and ship required sampling equipment to the Ignace office for Golder to use during sampling. This section provides the field instructions for collection of samples for microbiology research and development. For each opportunistic sampling event, take water samples for deoxyribonucleic acid (DNA), phospholipid fatty acid (PLFA) and cell count analysis, as described in this section.

It is recognized that the microbiology samples are lower priority than the geochemical analyses described in previous sections. The overall goal is to prepare for future site characterization activities by assessing detection limits and contamination sources. The water volumes requested are best case scenario. If less water is available, please note the volume of the sample. Duplicate samples for DNA, PLFA, and cell count will be taken if water is available. Always sample one replicate for DNA, PLFA, and cell count first, before collecting the duplicate samples. This way we ensure at least one replicate for each analysis.

Important: Please verify that the item number of the Sterivex filter is SVGV010RS and discard any other Sterivex filter types as they were shipped for previous sampling but are not suitable anymore. The procedures and equipment for DNA and PLFA sampling are identical.

Note: Take a field blank for DNA and PLFA (one each) for each groundwater sample. There is no need to take a field blank for DNA and PLFA when taking the drill water return associated with the groundwater sample. Do take a field blank for DNA and PLFA (one each) when sampling the drill water return associated with core sampling.

### Opportunistic water samples for DNA analysis

- For DNA samples, filter opportunistic water via syringe filtration as described below. Although a specific syringe filter is noted, any syringe filter rated for DNA extraction with at least a 0.45 micron pore size and ideally a 0.22 pore size to capture smaller organisms can be used.

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- For DNA analysis water volumes should be the minimum required to clog the filter such that no further water can pass to a maximum of 1200 mL.
  - DNA filtering is carried out by filling a syringe (Fisher, BD 60 mL Luer Lok syringe, catalogue number B309653) with ground water (by removing the plunger) and after replacing the plunger passing the water through Sterivex filters (Fisher Scientific, Millipore SVGV010RS, Sterivex-GV 0.22 µm, PVDF).
  - Water must be passed through the filter until the filter is clogged. When the filter clogs, record the volume of water passed through the filter. If clogging does not occur, stop filtering at 1200 ml. The easiest way to refill the syringe is to unscrew the Sterivex filter, withdraw the plunger from the syringe (being sure to keep it clean and handle only with clean sterile surgical gloves; you can store the plunger in the clean wrapper from the syringe), then reattach the filter, pour more groundwater sample into the syringe. Fill the syringe all the way until the water bulges before placing the plunger back in. This way, no air will be introduced into the syringe (once wetted, the membrane is not air permeable and any air would reduce the filtration area in the filter unit). Then push the sample through and repeat. If the syringe is filled all the way, it holds 72 ml liquid (16.5 syringe volumes = 1,200 ml). Once the filter plugs, follow-up with a final slug of air to force the water on the upstream side of the filter through and out (e.g. this dewatering step ensures freezing occurs without a lot of water to prevent expansion and casing cracking).
  - Once the DNA filter is clogged and dewatering is complete, place the DNA filter in a 50 cc plastic centrifuge tube (Fisher, Tube screw cap grad 50 mL, catalogue number C352070), place the tube in a Ziploc bag and store in freezer. Once frozen, try not to thaw and refreeze. Sample should remain frozen and be shipped on dry ice.
  - Along with each sample, collect a field blank by setting up the filter and syringe in preparation to sample and then placing the filter in the 50 cc tube and treating as a sample.

### Opportunistic water samples for PLFA analysis

- For PLFA samples, filter opportunistic water via syringe filtration as described below. In the case of PLFA sampling, only solvent extractable filter material can be used, therefore make sure to use SVGV010RS, Sterivex-GV 0.22 µm, PVDF.
- For PLFA analysis water volumes should be the minimum required to clog the filter such that no further water can pass through, to a maximum of 1200 mL.
- PLFA filtering is carried out by filling a syringe (Fisher, BD 60 mL Luer Lok syringe, catalogue number B309653) with groundwater (by removing the plunger) and after replacing the plunger passing the water through Sterivex filters (Fisher Scientific, Millipore SVGV010RS, Sterivex-GV 0.22 µm, PVDF).
- Water must be passed through the filter until the filter is clogged. When the filter clogs, record the volume of water passed through the filter. If clogging does not occur, stop filtering at 1200 ml. The easiest way to refill the syringe is to unscrew the Sterivex filter, withdraw the plunger from the syringe (being sure to keep it clean and handle only with clean sterile surgical gloves; you can store the plunger in the clean wrapper from the syringe), then reattach the filter, pour more groundwater sample into the syringe. Fill the syringe all the way until the water bulges before placing the plunger back in. This way, no air will be introduced into the syringe (once wetted, the membrane is not air permeable and any air would reduce the filtration area in the filter unit). Then push the sample through and repeat. If the syringe is filled all the way, it holds 72 ml liquid (16.5 syringe volumes = 1,200 ml). Once the filter plugs, follow-up with a final slug of air to force the water on the upstream

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side of the filter through and out (e.g. this dewatering step ensures freezing occurs without a lot of water to prevent expansion and casing cracking).

- Once the PLFA filter is clogged and dewatering is complete, place the PLFA filter in a 50 cc plastic centrifuge tube (Fisher, Tube screw cap grad 50 mL, catalogue number C352070), place the tube in a Ziploc bag and store in freezer. Once frozen, try not to thaw and refreeze. Sample should remain frozen and be shipped on dry ice.
- Along with each sample collect a field blank by preparing the syringe and filter as for collection of sample, then without filtering water, collect the filter and treat as a sample.

### Cell count sample

- The cell count samples are collected by adding opportunistic water to the 50 cc tubes preloaded with 2% glutaraldehyde. Store **refrigerated but do not freeze** the samples before they are picked up by NWMO.
- Collect a field blank by opening a 50 cc tube, reclosing and treating as a sample.

## 2.1 Drill water samples for assessing contamination

A grab sample of the drill water return (DWR) immediately **following both opportunistic groundwater and core sampling**. The grab sample can be obtained by collecting a bucket sample of the drill water return.

Please coordinate with the core sampler to make sure that drill water samples are taken at the same time.

Core samples will be taken at the following approximate intervals (summarized in WP3):

- Approximately 100m depth
- Following the first opportunistic water sampling below 200m
- Approximately 534m depth

When core or opportunistic groundwater samples are collected, the drill water return can be sampled by the following method:

- Wear disposable surgical gloves when sampling drill water return.
- Collect drill water return in a bucket.
- pH, Eh (redox), electrical conductivity, temperature, and alkalinity should be measured, as per above.
- Samples of drill water should be taken for commercial laboratory analysis, as per above.
- Sampling for DNA analysis, PLFA analysis and total cell counts as described below.

The on-site geochemical measurements will be logged in the Data Quality Confirmation workbook and will be identified by DWR-XXXX-YYY, where XXXX is the borehole identifier and YYY is the consecutive index number of the sample unique to the borehole. The core run number, date and depth associated with the sample should also be noted in the Data Quality Confirmation workbook. The sample identifier will be used to label the filters and water samples described below.

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## Drill fluid samples for DNA analysis

- For DNA samples, filter drill water return via syringe filtration as described below. Although a specific syringe filter is noted, any syringe filter rated for DNA extraction with at least a 0.45 micron pore size and even better a 0.22 pore size to capture smaller organisms can be used.
- For DNA analysis water volumes should be the minimum required to clog the filter such that no further water can pass to a maximum of 1200 mL.
- DNA filtering is carried out by filling a syringe (Fisher, BD 60 mL Luer Lok syringe, catalogue number B309653) with drill water return (by removing the plunger) and after replacing the plunger passing the water through Sterivex filters (Fisher Scientific, Millipore SVGV010RS, Sterivex-GV 0.22 µm, PVDF).
- Water must be passed through the filter until the filter is clogged. When the filter clogs, record the volume of water passed through the filter. If clogging does not occur, stop filtering at 1200 ml. The easiest way to refill the syringe is to unscrew the Sterivex filter, withdraw the plunger from the syringe (being sure to keep it clean and handle only with clean sterile surgical gloves; you can store the plunger in the clean wrapper from the syringe), then reattach the filter, pour more sample into the syringe. Fill the syringe all the way until the water bulges before placing the plunger back in. This way, no air will be introduced into the syringe (once wetted, the membrane is not air permeable and any air would reduce the filtration area in the filter unit). Then push the sample through and repeat. If the syringe is filled all the way, it holds 72 ml liquid (16.5 syringe volumes = 1,200 ml). Once the filter plugs, follow-up with a final slug of air to force the water on the upstream side of the filter through and out (e.g. this dewatering step ensures freezing occurs without a lot of water to prevent expansion and casing cracking).
- Once the DNA filter is clogged and dewatering is complete, place the DNA filter in a 50 cc plastic centrifuge tube (Fisher, Tube screw cap grad 50 mL, catalogue number C352070), place the tube in a Ziploc bag and store in freezer. Once frozen, try not to thaw and refreeze. Sample should remain frozen and be shipped on dry ice.

## Drill fluid samples for PLFA analysis

- For PLFA samples, filter drill return water via syringe filtration as described below. In the case of PLFA sampling, only solvent extractable filter material can be used, therefore make sure to use SVGV010RS, Sterivex-GV 0.22 µm, PVDF
- For PLFA analysis water volumes should be the minimum required to clog the filter such that no further water can pass through, to a maximum of 1200 mL.
- PLFA filtering is carried out by filling a syringe (Fisher, BD 60 mL Luer Lok syringe, catalogue number B309653) with drill water (by removing the plunger) and after replacing the plunger passing the water through Sterivex filters (Fisher Scientific, Millipore SVGV010RS, Sterivex-GV 0.22 µm, PVDF).
- Water must be passed through the filter until the filter is clogged. When the filter clogs, record the volume of water passed through the filter. If clogging does not occur, stop filtering at 1200 ml. The easiest way to refill the syringe is to unscrew the Sterivex filter, withdraw the plunger from the syringe (being sure to keep it clean and handle only with clean sterile surgical gloves; you can store the plunger in the clean wrapper from the syringe), then reattach the filter, pour more sample into the syringe. Fill the syringe all the way until the water bulges before placing the plunger back in. This way, no air will be introduced into the syringe (once wetted,

the membrane is not air permeable and any air would reduce the filtration area in the filter unit). Then push the sample through and repeat. If the syringe is filled all the way, it holds 72 ml liquid (16.5 syringe volumes = 1,200 ml). Once the filter plugs, follow-up with a final slug of air to force the water on the upstream side of the filter through and out (e.g. this dewatering step ensures freezing occurs without a lot of water to prevent expansion and casing cracking).

- Once the PLFA filter is clogged and dewatering is complete, place the PLFA filter in a 50 cc plastic centrifuge tube (Fisher, Tube screw cap grad 50 mL, catalogue number C352070), place the tube in a Ziploc bag and store in freezer. Once frozen, try not to thaw and refreeze. Sample should remain frozen and be shipped on dry ice.
- Along with each sample collect a field blank by preparing the syringe and filter as for collection of sample, then without filtering water, collect the filter and treat as a sample.
- Once filtering is complete, remove filter and put the filter into its own Ziploc bag store in a freezer. Once frozen, try not to thaw and refreeze. Sample should remain frozen and be shipped on dry ice. Dewatering is not necessary in this case.

### Cell count sample

- The cell count samples are collected by adding drill water return to the 50 cc tubes preloaded with 2% glutaraldehyde. Store **refrigerated but do not freeze** the samples before they are picked up by NWMO.

## 2.2 Additional Sources of Contamination Sampling

- After the final core sampling (~534m), to complete the assessment of possible sources of contamination, collect one 50 cc tube of each of the drilling mud components (e.g. bentonite, detergents, oils, polymers). **Store refrigerated but do not freeze.**
- These are one-time samples. The samples will not be labelled according to the by DWR-XXXX-YYY convention. These sample labels will clearly identify the type of material and the date of collection.

## 2.3 Summary of sampling equipment for microbiology samples

Sampling equipment will be gathered and shipped by University of Waterloo. The following table summarizes the equipment.

**Table 1: Microbiology sampling equipment**

Quantity	Part number	Item description	Purpose
4 boxes	19-188-587 fishersci.com	Kimberly-Clark™ KC500 Purple Nitrile Sterile Exam Gloves (2x medium and 2x large)	Sampling
2 each	----	Red and black Sharpie markers	Labelling
60	82028-488 vwr.com	2000 mL Nalgene bottle, polypropylene	Container to hold water before filtering/ sampling
80	B309653 Fishersci.com	60 mL Luer Lok syringe	Microbiology (DNA and PLFA)

Quantity	Part number	Item description	Purpose
150	SVG010RS Fishersci.com	Millipore SVG010RS, Sterivex-GV 0.22 µm, PVDF	Microbiology (DNA and PLFA)
150	C352070 Fishersci.com	Centrifuge tube screw cap graduated 50 mL	Microbiology
60	O2957-1 fishersci.com	25% glutaraldehyde solution, certified	Microbiology (cell counts)
2 boxes		Ziploc heavy duty freezer bags (2x 28 Gallon size)	Microbiology (core samples)
1 box		Ziploc bags small (x40)	To hold collected DNA / PLFA filters for storage

## 2.4 Microbiology sample preservation summary and shipping

Microbiology samples are stored frozen or refrigerated, as outlined in Table 2. At the end of sampling, all samples will be transported on ice packs in coolers to the Ignace office and placed into refrigerator/freezer. The NWMO will coordinate shipping all samples to McMaster/Waterloo University. Frozen samples should be shipped on dry ice. Refrigerated samples can be shipped with ice packs.

**Table 2: Samples for microbiology research and development for opportunistic water and core sampling events**

Sample Type	Analysis type	Sample storage	Sample type	Total number of samples
Opportunistic groundwater	DNA	Frozen	Filter	10 total (20 total with replicates) = one from each OGW sample interval
Opportunistic groundwater	PLFA	Frozen	Filter	10 total (20 total with replicates) = one from each OGW sample interval
Opportunistic groundwater	Cell count	Refrigerate	Water in tube with glutaraldehyde	10 total (20 total with replicates) = one from each OGW sample interval
Field blank	DNA	Frozen	Filter	13 total = one from each OGW sample interval + and one from each core sample interval
Field blank	PLFA	Frozen	Filter	13 total = one from each OGW sample interval (10) + and one from each core sample interval (3)

Sample Type	Analysis type	Sample storage	Sample type	Total number of samples
Field blank	Cell count	Refrigerate	Water in tube with glutaraldehyde	13 total = one from each OGW sample interval (10) + and one from each core sample interval (3)
Drill water	DNA	Frozen	Filter	13 total (26 total with replicates) = one from each OGW sample interval (10) + and one from each core sample interval (3)
Drill water	PLFA	Frozen	Filter	13 total (26 total with replicates) = one from each OGW sample interval (10) + and one from each core sample interval (3)
Drill water	Cell count	Refrigerate	Water in tube with glutaraldehyde	13 total (26 total with replicates) = one from each OGW sample interval (10) + and one from each core sample interval (3)
Core	DNA, PLFA	Frozen	Core	3 total (6 total with replicates)



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