Technical Report

Title: *Opportunistic Groundwater Sampling in DGR-1 & DGR-2*

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Authors: Richard Jackson & Dru Heagle

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DGR Site Characterization Document
Intera Engineering Project 06-219

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Document Revision History		
Revision	Effective Date	Description of Changes
0	July 22, 2008	Initial Issue
1	February 9, 2009	Revised HCO_3 calculation for Table 3 and Table 4 and calculations of C^{GW} for isotopes and carbon compounds. Added calculated TDS by summation to TDS by gravimetric methods to Tables 3 and 4. Corrections to selected iodide values in Tables 3 & 4.Revised calculation of C^{GW} for SO_4 in Table 4 with resultant changes in Table 5, Appendix A and related text. Added results of duplicate analyses of OGW-6 and OGW-7 ion chemistry to Tables 3 and 4 and added geochemical modeling calculations for duplicate OGW-6 and OGW-7 in Table 5 and Appendix A. Replaced AQUACHEM with PHREEQC for charge balance equations in order to use the same geochemical modeling software between reports. Removed saturation index calculations.
2	May 19, 2010	Minor editorial changes to address NWMO comments

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1 Introduction

Intera Engineering Ltd. has been contracted by the Nuclear Waste Management Organization (NWMO) to implement the Geoscientific Site Characterization Plan (GSCP) for the Bruce nuclear site located near Tiverton, Ontario. The purpose of this site characterization work is to assess the suitability of the Bruce site to construct a Deep Geologic Repository (DGR) to store low-level and intermediate-level radioactive waste. The GSCP is described by Intera Engineering Ltd. (2006, 2008a).

This report summarizes the results of the opportunistic groundwater sampling program completed at two deep bedrock boreholes (DGR-1 and DGR-2) as part of Phase 1 of the GSCP. Work described in this Techncial Report (TR) was completed in accordance with Intera Test Plan TP-06-11 – DGR-1 and DGR-2 Opportunistic Groundwater Sampling and Analysis (Intera Engineering Ltd., 2007a), Test Plan TP-07-06 – Completion of DGR-1 and DGR-2 with Westbay MP55 Casing (Intera Engineering Ltd., 2007b) and Test Plan TP-07-08 – Phase 1 Lab Testing of Opportunisitic and Westbay Samples of Groundwater (Intera Engineering Ltd., 2008b), all of which were prepared following the general requirements of the DGR Project Quality Plan (Intera Engineering Ltd., 2009a).

The results described in this Technical Report (TR) constitute one component of Intera Engineering Ltd. (2006, 2008a) Geoscientific Site Characterization Plan for the Bruce Deep Geologic Repository program. The GSCP describes recommended methods and approaches to acquire the necessary geoscientific information to support (1) the development of descriptive geosphere models of the Bruce site and (2) the preparation of an environmental impact statement and site preparation and construction license application for submission to the Canadian Nuclear Safety Commission.

Apart from correcting the analytical data for drilling fluid contamination and conducting an ionic charge balance, no computational analysis of these samples is attempted in this TR; preliminary analysis and interpretation of this data will be presented in the Descriptive Geosphere Site Model (DGSM) Report that is in preparation and that will be revised during 2009 to reflect the Phase 2 GSCP results.

2 Background

Drilling of boreholes, DGR-1 and DGR-2, in Phase 1 provided opportunities to sample groundwater in the borehole. These samples are referred to as opportunistic groundwater samples. The term groundwater refers to free flowing groundwater and pore water refers to water from low permeability zones (Gimmi and Waber, 2004). Drilling through permeable bedrock horizons provided sufficient water to obtain opportunistic groundwater samples. Permeable horizons were identified through a loss of drilling fluid from the borehole to the formation or an increase in salinitiy in the water in the drill tubing. Opportunistic groundwater sampling offers the ability to obtain useful information on the groundwaters present in permeable bedrock zones.

When a permeable unit is identified during drilling, a down-hole packer is installed to isolate the test interval in the bottom of the open borehole and is connected to the drill tubing. The tubing and test interval are purged, also termed swabbed, to reduce drilling fluids to <10% of the sample water. This target is appraised in the field by continually measuring the Na-Fluorescein (NaFl) tracer concentration within the swabbed samples. These measurements are made continually in the Field Geochemistry Lab on site. Therefore, opportunistic samples represent a mix of groundwater and drill water that must be accounted for when examining the geochemical results. This report describes the method for determining groundwater concentrations from this mixture.

Additionally, opportunistic samples may be affected by changes in pressure as deep groundwater is brought to the surface, or affected by ingassing of air to the sample. The lower pressure at the surface can cause carbon dioxide to degas from the sample, and ingasssing of air may partially oxidize the sample. The effect of these two processes may be examined by continuously measuring geochemical parameters, including pH, redox potential

(Eh), and dissolved oxygen, during sampling, in order to determine when a sample should be obtained that best represents the formation waters.

Another goal for the opportunistic groundwater sampling program is to allow testing of the conclusion reached by an earlier hydrogeochemical study (Lee et al., 1995) that groundwater in the Devonian rocks beneath the Bruce site is oxygenated. This poses significant monitoring problems because the drilling fluid will itself be oxygenated, consequently dissolved oxygen (DO) will be present in the recovered water. DO from the recovered drilling fluid during purging and diffusion through 50-80 metres of sample tubing can both result in quantities of DO being measured during opportunistic sampling. Therefore, DO measurements alone will likely be inconclusive unless they are in mg/L quantities for samples in which the drilling-fluid tracer is absent.

Consequently, the redox state of the groundwater in the DGR formations must be inferred from several geochemical indicators; such data analysis is beyond the scope of this TR and a discusson of the redox environment within those formations is therefore deferred to the DGSM.

3 Methods

3.1 Sampling

Groundwater sampling was conducted using a submersible Grundfos electric pump placed within the drill tubing (see Figures 1 and 2). Packers were used to isolate the depth interval in the borehole producing groundwater. The pump was connected to the surface with nylon tubing, and pumping began. Small aliquots of pumped groundwater were obtained once every two hours on average, and each aliquot was analyzed for NaFl concentration. These results provided a time series of concentration data that were used to determine when groundwater sampling might take place. Groundwater sampling proceeded once the drilling-fluid tracer concentration was less 10% of its original drilling-fluid tracer (NaFl) concentration measured when swabbing began. Additionally, the NaFl concentrations were used to correct the influence of drilling fluids on the groundwater sample concentrations as discussed below.

Figure 1 Grundfos/Rediflow 2 Submersible Pump and 13 mm Diameter Nylon Tubing Reel

Figure 2 Close-up Photo of the Grundfos/Rediflow 2 Submersible Pump

A total of six opportunistic samples were collected and given identifiers as OGW-1, -2, -3, -4, -6 and -7; the depths and formations involved are given in Table 1. A seventh sample (OGW-5) collected from a tight interval at a depth of 161.0 – 182.94 metres below ground surface (mBGS, i.e., Bass Islands dolostone and Salina G Unit shale) was determined to be Lake Huron – derived drill water – not groundwater – and was not submitted for laboratory analysis. i.e., after one hour of pumping the water had > 6 mg DO/L, an electric conductance of only 116 µS/cm and was coloured as shown in Figure 3.

In accordance with the sample identification procedures of the Project Quality Plan (Intera Engineering Ltd., 2009a), groundwater samples are identified by the borehole name and the depth of the midpoint of the sampling interval in mBGS. The submersible pump was not required to obtain opportunistic groundwater samples 6 and 7 (OGW-6, OGW-7) because artesian conditions produced sufficient flow for sampling**.**

Table 1 Formations and Depths of Opportunistic Groundwater Samples

OGW #	OGW-1	OGW-2	OGW-3	OGW-4	OGW-6	OGW-7
Borehole & Sample No.	DGR1-043.64	DGR1-079.41	DGR1-111.22	DGR1-137.86	DGR2-844.73	DGR2-852.70
Sampling Interval (mBGS)	38.72-47.50	77.77-81.05	107.81-114.63	133.64-142.08	841.96-847.50	843.70-860.70
Bedrock Formation	Amherstburg Dolostone	Bois Blanc Dolostone	Bois Blanc Dolostone	Bass Islands Dolostone	Cambrian Sandstone	Cambrian Sandstone

Samples OGW-6 and OGW-7 were collected from the artesian Cambrian sandstone. OGW-6 was collected in July 2007 following the initial intersection of the upper part of the Cambrian sandstone during drilling and was obtained with a packer isolating the bottom 5.5 m section of the borehole. OGW-7 was collected in November, 2007 following the completion of drilling and after removal of more than 500 m^3 of brine from the Cambrian sandstone. The test interval length for OGW-7 was effectively the full thickness of the Cambrian sandstone although the entire borehole from the top of the Queenston Formation to the Precambrian was exposed during collection of OGW-7. Minor differences in chemistry between OGW-6 and OGW-7 are expected based on the different exposed thicknesses of the Cambrian sandstone, the open borehole during sampling, and the large volume of brine removed between these two groundwater sampling events.

Groundwater was pumped at a steady flow rate of approximately 1 L/min during sampling directly from the borehole into two serially connected flow cells (Solinst Model 475) that contained sensors reading pH, Eh, dissolved oxygen (DO), and temperature (Figure 3). These are considered 'unstable' parameters because of their potential for change through loss of CO_2 or absorption of O_2 or temperature variation. Electrode calibration, measurement and storage procedures are discussed in TP-06-11 (Intera Engineering Ltd., 2007a). Because of the electrode's size, electric conductance was recorded separately from the flow cell.

Electrodes were attached to a digital voltmeter and measurements were recorded in the field lab Scientific Notebook Supplements (Appendix A of TP-06-11, Intera Engineering Ltd., 2007a) generally following the procedures recommended by the USGS (Wilde et al., 2006). The readings typically stabilized after 10-20 minutes to ±0.1 pH units, ±3% for electrical conductivity (if >100 μS/cm) and ±0.3 mg O_2/L. Similarly, a variability of ±20 mV over the course of ten minutes is not considered significant in measurements of Eh, although the variability with the Pt electrode potential for OGW-6, the Cambrian brine, was (instantaneously) ± 60 mV during a second round of testing in November 2007 (OGW-7). Samples were collected and taken to the Geochemical Lab Trailer (50 m distant) where alkalinity titrations, drill-fluid tracer measurements and the colorimetric and electrode tests of sulphide, iodide and iron were conducted. Once the readings stabilized, the flow into the flow cell was stopped and the final pH reading was recorded in order to avoid fluctuations in the pH due to the creation of streaming potentials.

Figure 3 Serially-Connected Flow Cells with Electrodes Connected to Digital Voltmeters

Dissolved oxygen, total and/or ferrous iron, and sulphide were also checked by colourimetric analysis (CHEMetrics, Calverton VA). These tests were conducted visually by immersing an ampoule into a sample and snapping off the tip of the vacuum-sealed ampoule. A fixed volume of sample enters the ampoule and undergoes a colourimetric reaction with the reagent in the ampoule. The colour that develops is compared with a set of standards that are provided with each kit. Iodide concentrations were measured with an Orion iodide selective electrode periodically calibrated to prepared standard solutions. Cadmium acetate was added to precipitate sulphide and thus reduce sulphide interference with the electrode; in addition, Orion ionic strength adjustor was added to compensate for varying total dissolved solids concentrations in the groundwater samples.

A 100 mL aliquot of newly-pumped groundwater was collected for acid and colourimetric titration using a Hach Model 16900 digital titrator. The sample was filtered with a 0.45µm pore-diameter filter disk and titrated to the maximum inflection of pH endpoint (i.e., approximately pH 4.3 to 4.5). A colourimetric indicator provided visual evidence of the approaching inflection end point.

3.2 Preservation

Aliquots of the samples for laboratory analysis were preserved on-site by filtration and acidification, where appropriate, and shipped to Actlabs in Ancaster, Ontario or various university laboratories for isotope and gas analyses, while other aliquots were kept as archived samples at the Core Storage Facility. Methods of preservation are discussed in TP-06-11 (Intera Engineering Ltd., 2007a), while methods of laboratory analysis are presented in TP-07-08 (Intera Engineering Ltd., 2008b).

4 Results

4.1 Time Series Data

The time series data of NaFl for the pumped groundwater before groundwater sampling are shown in Figure 4 (DGR-1) and Figure 5 (DGR-2). The NaFl concentrations in the pumped water decreased with time, indicating the amount of drill fluid in the pumped water was decreasing with time. A conservative assumption is that the NaFl concentration of the first drill water purged from the borehole is representative of 100% drill water, i.e. groundwater is initially not present in the purge water. Decreases in the NaFl concentration by one order of magnitude suggest the purged water was 10% drill water and 90% groundwater. The method used to correct for drill-water contamination of the sampled groundwater is discussed in Section 4.4.

NaFl concentrations in the pumped water decreased over an order of magnitude from the beginning of the pumping until groundwater samples OGW-1 and OGW-2 were obtained. The NaFl concentration in OGW-3 decreased almost one order of magnitude, from 860 µg/L to 96 µg/L. Approximatley 22,300 L of drill water was lost into the interval at OGW-4 during coring, which is likely responsible for the persistent NaFl concentrations between 90 and 100 µg/L.

The NaFl concentration in OGW-6 decreased more than two orders of magnitude indicating <1% of drill fluid remained in the sample. The artesian conditions during the OGW-6 sampling likely contributed to the low drill-water contamination. Artesian flow from the Cambrian exceeded 100 m^3/day for several days in July and August after sampling for OGW-6, therefore, low drill-water contamination was also assumed for OGW-7, which was sampled four months after OGW-6.

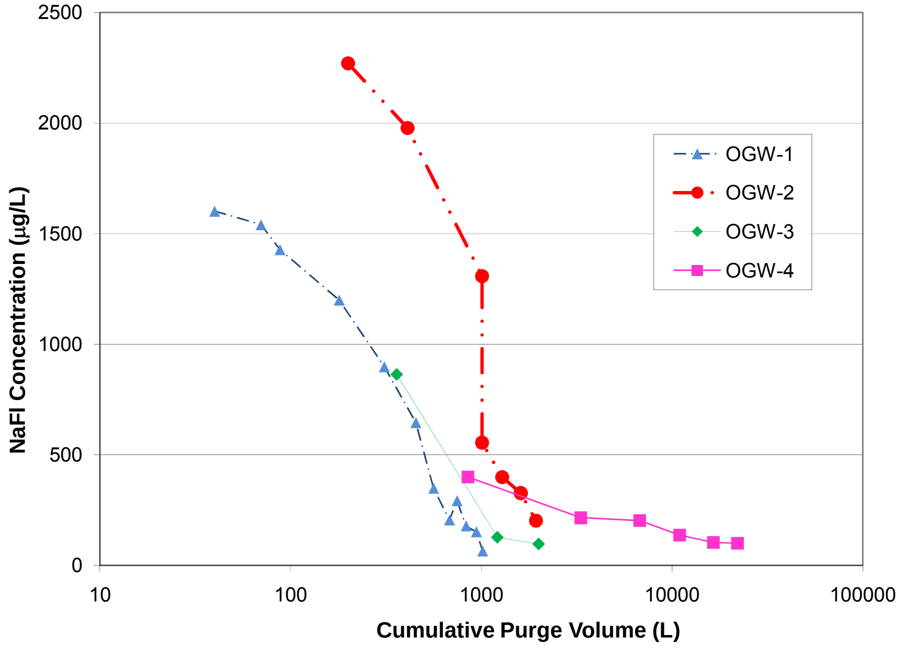

Figure 4 Time Series of NaFl Data for Opportunistic Groundwater Samples Collected from DGR-1

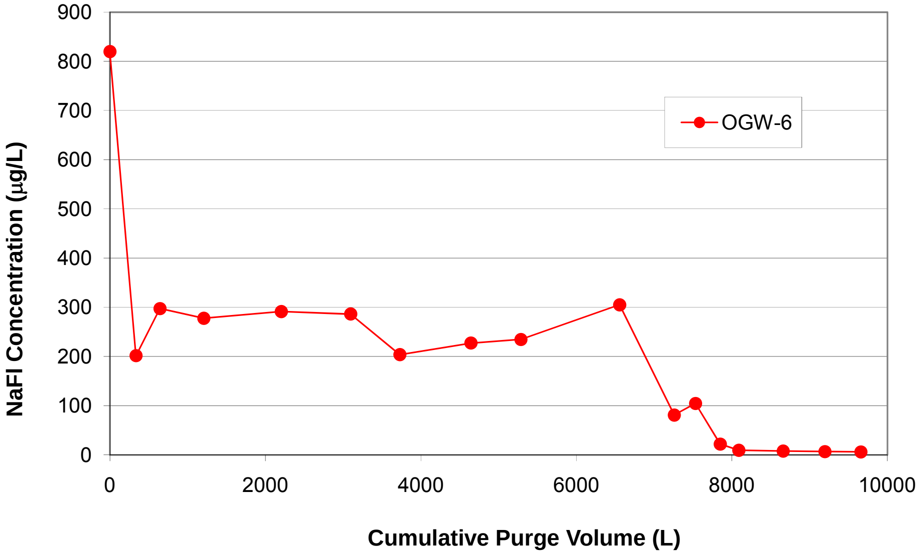

Figure 5 Time Series of NaFl Data for Opportunistic Groundwater Samples Collected from DGR-2

The time series of NaFl data was used in conjunction with time series measurements of purge water pH, dissolved oxygen (DO), redox conditions (Eh) and electrical conductivity (EC) in flow cells, in order to obtain representative groundwater samples. The time series data, shown below for OGW-3 (Figure 6) and OGW-6 (Figure 7), were used to determine when the sample chemistry stabilized and groundwater sampling could begin. Sample degassing was likely responsible for the variable pH evident in both flow cell time series, however the pH eventually became stable and a reading was recorded. The final pH of OGW-6 of 6.6, which is shown as a minima in Figure 5, was confirmed during the second flowing-well field sampling of the Cambrian sandstone (OGW-7).

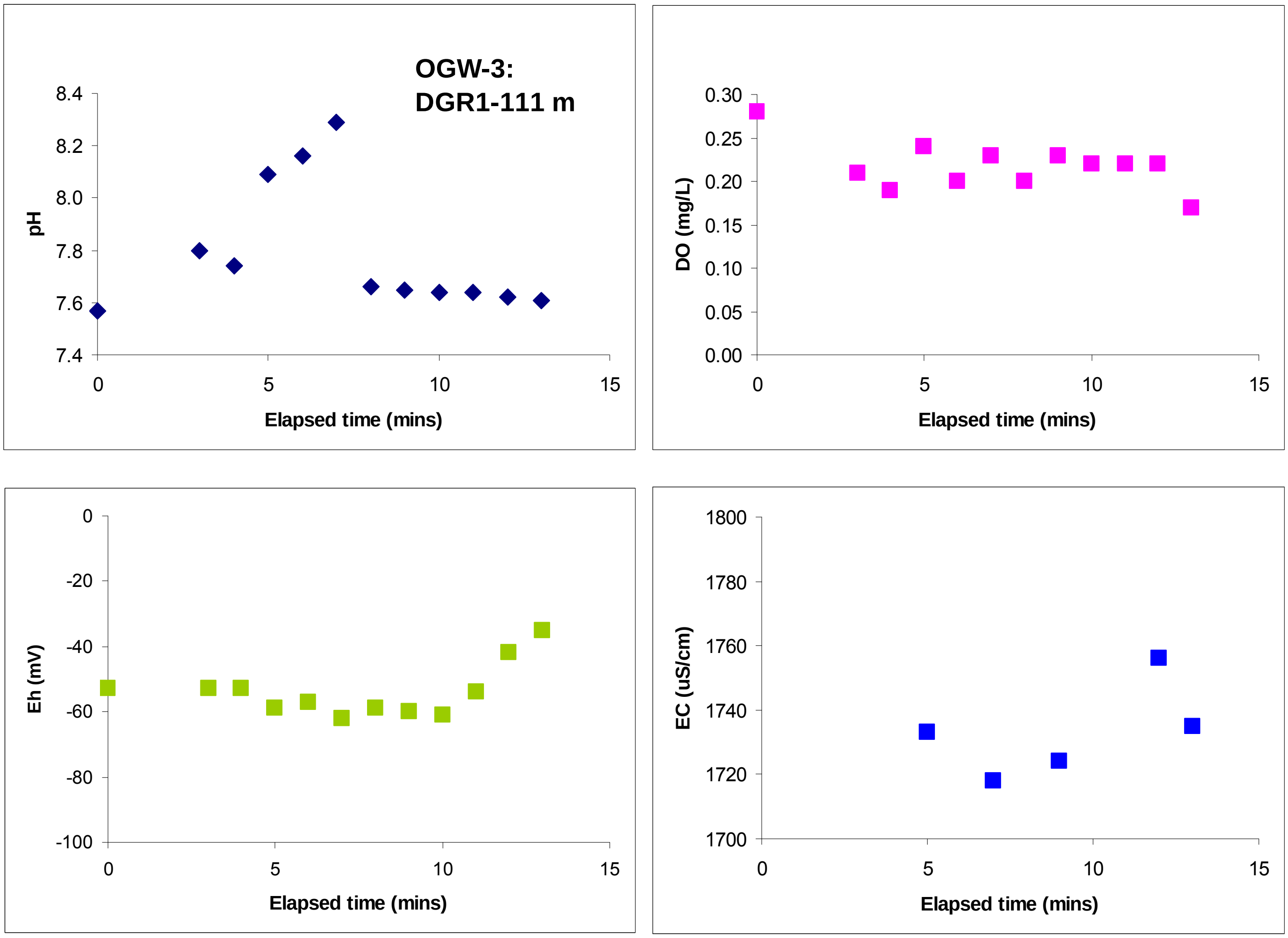

Figure 6 Time Series of Flow-Cell Measurements for OGW-3

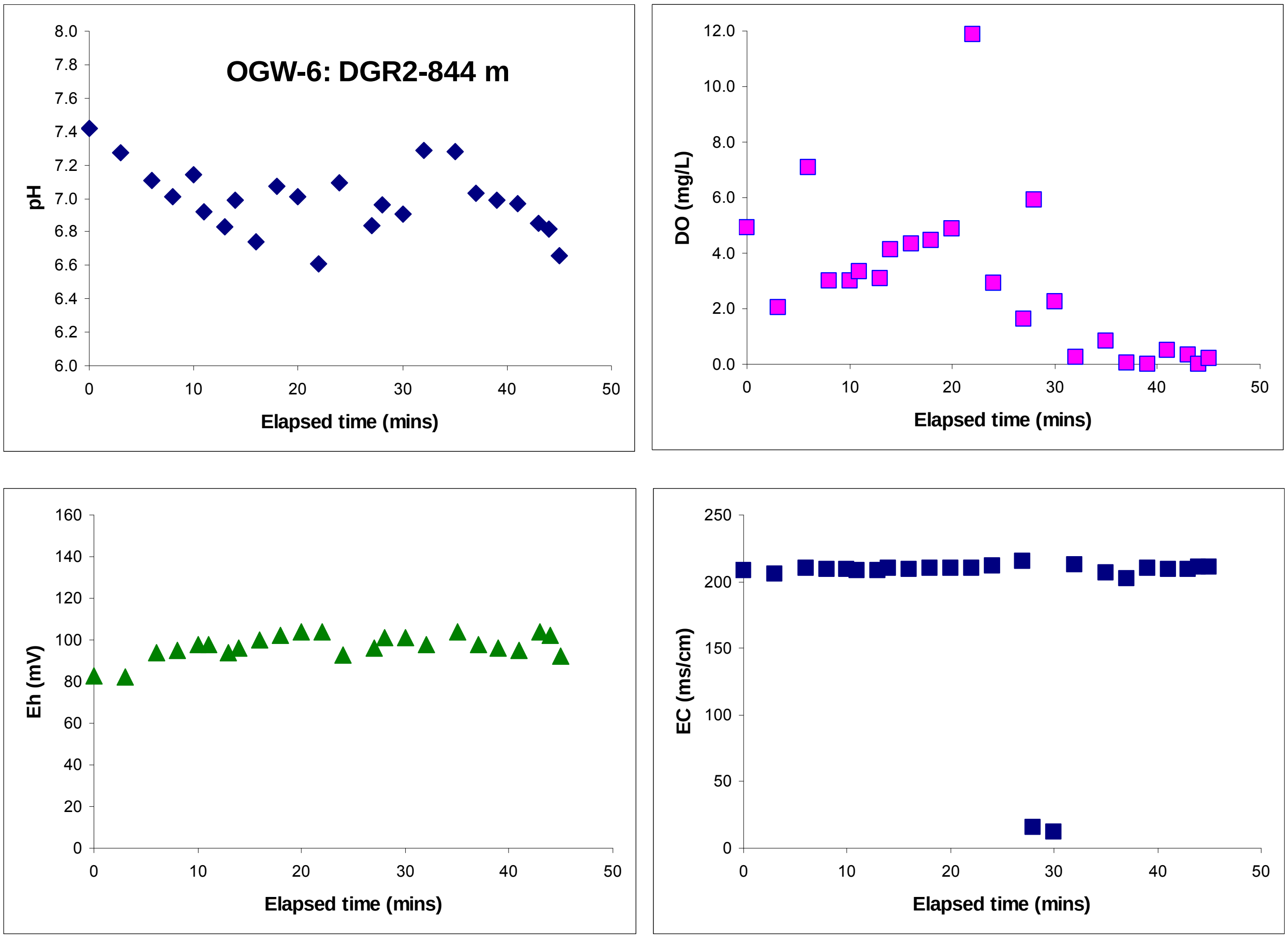

Figure 7 Time Series of Flow-Cell Measurements for OGW-6

4.2 Field Measurements

Once the flow cell measurements of pH, dissolved oxygen (DO), redox conditions (Eh) and electrical conductivity (EC) in the flow cells stablized, the final measurements were recorded (Table 2). OGW-1 was collected over the interval 39.72-47.50 mBGS shortly after the surface casing was cemented in place, consequently the high pH (9.89) reflects the presence of cement residues in the sampled water despite the acceptable drilling-fluid tracer concentration of 4% (see below). Similarly, the pH value for OGW-2 (8.85) shows similar, if less pronounced, cement contamination. Other parameters that are likely to be affected by cement include Ca, Na, Si and K. Following these measurements, the casing water was completely flushed out and fresh drilling fluid made up in order to minimize the carry-over effect of the pH. Subsequent measurements – OGW-3 and OGW-4 – indicated pH values between 7.4 and 8.0, which is in the range of field pHs reported by Lee et al. (1995, Table 4.1A) for groundwaters sampled from the 'US series' Westbay multilevel-monitoring wells at depths between 30 – 100 m BGS.

Measured DO concentrations of the pumped water generally decreased over time to values below 1 mg/L (Figures 6 and 7). Eh values were computed from the measured Pt electrode potential by adding the field measurement using the Ag-AgCl reference electrode and the hydrogen electrode (+210 mV at 10-15°C). The presence of dissolved iron (or sulphide in the case of OGW-1) and the low DO and Eh values in all OGW samples and the presence of pyrite in the two DGR-1 cores indicate that the groundwaters are reducing.

4.3 Laboratory Analyses

The laboratory analyses of the opportunistic groundwater samples are presented in Table 3 along with the lab analysis of the drill water (first drill-water return sample). Methods of laboratory analysis are described in TP-07-08 (Intera Engineering Ltd., 2008b). The Quality Assurance (QA) data for these analyses are discussed in Section 5. Table 3 presents drill water and preliminary groundwater results that have not yet been corrected for drill-water contamination. Two duplicate analyses were submitted for analyses for OGW-6 and OGW-7, and are presented as the values after the commas in Table 3.

Total dissolved solids (TDS) are reported in Table 3 folllowing laboratory determination using gravimetric methods and by summing the total concentrations of solutes reported for all major and minor ions.

Laboratory reported alkalinity values were likely affected by oxidation, as indicated by the low laboratory measured pH for OGW-6 (4.2) compared to the field measured pH (6.6). Drill water was not sampled for OGW-7 because it was sampled four months after drilling had been completed and during this intervening time period all drill water was flushed from the hole several times over.

Dissolved iron in the filtered samples (Table 4) suggests ferrous iron was present, since ferric iron has a low solubility at near neutral pH ($K = 10^{-38.3}$, pg. 253 Appelo and Postma, 1996), the dissolved iron is likely ferrous iron. This assumption is also corroborated by the low dissolved oxygen values (Table 2). Oxidation of dissolved ferrous iron releases acid, even in anaerobic conditions, by the following equation

$$Fe^{2+} + 3H_2O = Fe(OH)_3 + 3H^+ + e^-$$

Iron oxidation may occur between the time the groundwater samples were obtained and the laboratory measured the alkalinity. Therefore, alkalinity results from titrations performed in the field almost immediately after sample collection are considered more reliable that the laboratory determined alkalinities.

Stable environmental isotope contents of ^{18}O and ^{2}H reported in Table 3 for OGW-6 and OGW-7 brine groundwater samples are corrected for salinity effects following the method of Horita et al. (1993).

Table 2 Field Parameters for Opportunistic Groundwater Samples

	OGW-1		OGW-2		OGW-3		OGW-4		OGW-6		OGW-7	
Depth Interval (mBGS)	39.72 - 47.50		77.77 - 81.05		107.81 - 114.63		133.64 - 142.08		841.96 - 847.50		843.70 - 860.70	
	First Purge Drill Water	Ground-water	First Purge Drill Water	Ground-water	First Purge Drill Water	Ground-water	First Purge Drill Water	Ground-water	First Purge Drill Water	Ground-water	First Purge Drill Water	Ground-water
pH	12.72	9.8	--	8.8	9.12	7.6	8	7.9	6.85	6.6	--	6.5
Eh (mV)	36	334	--	-17	-3	-48	102	105	35	165	--	166
DO (mg/L)	6.89	0.37	--	0.45	5.34	0.22	4.2	0.34	0.9	1.24	--	1.24
Electrical Conductance (mS/cm)	1.86	0.58	0.58	0.99	0.46	1.76	0.92	0.88	207.4	200.4	--	130
Temperature °C	11	11.8	--	2.2	12	4.4	13.1	5.3	19.8	17.9	--	17.9
NaFl Drill water tracer (ug/L)	1601.7	64.5	2270.4	179.6	863.8	53.6	~1000	182.9	820	6.2	--	2.0
% Drill Water Contamination		4%		8%		6%		18%		<1%		<1%
Bicarbonate (mg/L)	--	0	--	40	--	74	--	84	--	23	--	23
Carbonate (mg/L)	--	9.6	--	0	--	0	--	0	--	0	--	0
Hydroxide (mg/L as $CaCO_3$)	--	28	--	0	--	0	--	0	--	0	--	0
Ferrous or Total Iron (mg/L)	--	0	--	0.6	--	1	--	1	--	>10	--	>10
Sulphide (mg/L)	--	0.1	--	0	--	0	--	0	--	0	--	0

Table 3 Uncorrected Laboratory Drill Water and Groundwater Concentration Results

Depth (mBGS)	**OGW-1** 39.72 - 47.50		**OGW-2** 77.77 - 81.05		**OGW-3** 107.81 - 114.63		**OGW-4** 133.64 - 142.08		**OGW-6** 841.96 - 847.50		**OGW-7** 843.70 - 860.70	
General Parameters	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})
pH (Lab)	11.7	9.1	10.9	7.9	7.8	7.9	7.8	7.9	6.7	4.2, 4.15	--	4.9, 3.92
Alkalinity (mg/L as $CaCO_3$)	439	45	201	56	415	126	246	171	61	<2, <2	--	<2, <2
TDS - Grav (mg/L)	1720	556	555	1380	697	1680	1420	1580	449000	228000, 243000	--	--, 159000
TDS – Sum (mg/L)	831	562	515	1753	928	2156	1866	2075	388000	227000, 238000	--	--, 247800
Fluid Density @ 25°C (g/L)	998.8	996.9	1010	1001	1011	1008	977.2	995.6	1243.8	1160.8, 1160	--	1166, 1190
Major Cations (mg/L)												
Na	30.1	21.9	212	37.4	165	52.5	103	74.6	62900	38000, 38500	--	>35000, 35700
Ca	326	72.3	69.3	294	66	396	318	340	59400	38500, 39900	--	>20000, 42000
Mg	<0.1	53.1	0.113	130	15	98.6	81.6	84.8	1920	5600, 6620	--	5940, 6410
K	52.9	4.98	13	5.69	34.3	6.69	11.2	8.01	2750	632, 873	--	690, 785
Sr	2.58	5.6	0.72	14.7	0.305	9.57	8.49	8.67	1010	861, 720	--	>200, 964
Fe	0.17	0.04	0.17	0.14	4.1	0.66	1.2	1.15	<10	43.3, 8.36	--	49.8, 17.6
Mn	0.0003	0.0003	0.0019	0.0133	0.037	0.0468	0.078	0.0525	7.09	14.2, 12.4	--	17.8, 16.1
Major Anions (mg/L)												
Cl	144	8.84	43.7	18.5	80.5	24	54	34	259000	141000, 150000	--	118000, 160000
Br	1.1	<0.1	0.23	<0.4	<0.3	<3	<3	<3	530	1670, 1400	--	1420, 1500
F	<0.1	1.3	<0.02	1.4	0.7	<1	<1	<1	<20	<10, <3	--	<10, 0.32
I	0.002	0.005	0.012	0.004	<0.01	0.01	<0.01	0.007	19	177, <300	--	8.99, 2.6
Si	0.6	6.8	17.6	3.1	21	3.6	6	4.6	<200	<200, 0.88	--	<200, 0.51
SO_4	9.9	378	35.1	1180	34.9	1410	982	1310	189	450, <500	--	550, 370
NO_3	0.5	<0.04	2.53	<0.1	<0.1	<1	<1	<1	<10	<10, <50	--	<10, <5
CO_3	263	9.6	121	<1	<1	<1	<1	<1	<1	<1, <2	--	--
HCO_3	<1	0	<1	68	506	154	300	209	74	<2, <2	--	6, <2

Table 3 Uncorrected Laboratory Drill Water and Groundwater Concentration Results (Cont'd)

Depth (mBGS)	**OGW-1** 39.72 - 47.50		**OGW-2** 77.77 - 81.05		**OGW-3** 107.81 - 114.63		**OGW-4** 133.64 - 142.08		**OGW-6** 841.96 - 847.50		**OGW-7** 843.70 - 860.70	
Isotopes, DIC & DOC	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})
Tritium (TU)	224.4	8.6	220.3	58.4	126.1	15.2	37.4	27.2	547.8	4.3	--	2.5
Rn-222 (Bq/L)	-	-	-	16	-	<10	-	-	-	20	--	12
δD (‰)	-53.2	-87.3	-56.3	-90.6	-56.2	-90.7	-80.4	-82.3	-36.2	-43.3	--	-35.8
δ^{18}O (‰)	-6.63	-12.69	-7.01	-12.33	-6.92	-13.49	-10.89	-12.22	-5.2	-4.97	--	-4.71
DIC (mg/L)	-	4.35	-	13.46	-	33.25	-	38.91	-	6.19	--	5.4
δ^{13}C(DIC)	-	-7	-	-4	-	-3.8	-	-4.7	-	-7.2	--	-8.35
DOC (mg/L)	-	6.77	-	73.34	-	74.28	-	149.8	-	0.2	--	0.1
δ^{13}C(DOC)	-	-27.4	-	-31.2	-	-16.1	-	-19.7	-	NEC	--	NEC
Trace Elements (µg/L)												
Ag	< 0.2	< 0.2	< 0.2	< 0.2	< 2	< 0.2	< 2	< 0.2	< 200	< 200, NA	--	<200, <1
Al	117	5	157	4	350	4	80	40	<2000	<2000, 1950	--	<2000, 170
As	0.36	0.46	51.7	6.1	2.1	0.62	1.7	2.18	<30	117, 509	--	<30, 830
Au	< 0.002	0.002	0.008	< 0.002	< 0.02	< 0.002	< 0.02	< 0.002	< 2	< 2, NA	--	3.06, NA
Ba	1160	61.1	76.4	101	2610	161	756	280	1090	1020, 893	--	967, 1040
Be	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<1	<0.1	<100	<100, <0.5	--	<100, <2
Bi	<0.3	<0.3	<0.3	<0.3	<3	<0.3	<3	<0.3	<300	<300, 0.4	--	<300, 3
Cd	0.16	0.05	0.1	0.08	0.6	0.05	0.2	0.13	<10	<10, 1.8	--	<10, 1.3
Ce	< 0.001	< 0.001	0.003	0.024	1.2	0.03	0.26	0.179	< 1	< 1, NA	--	1.86, 10
Co	0.155	<0.005	0.19	0.455	0.82	0.679	0.72	0.603	<5	<5, 21.6	--	<5, 26.2
Cr	25.8	2	19.3	<0.5	11	<0.5	<5	1.3	<500	<500, 10	--	<500, <50
Cs	2.8	0.15	0.32	0.037	0.05	0.022	0.02	0.017	71	20.9, NA	--	19.7, 10
Cu	7.3	<0.2	4.2	0.3	15	0.5	5	1.5	346	<200, 50	--	<200, 140
Dy	< 0.001	< 0.001	< 0.001	< 0.001	0.14	0.003	0.03	0.019	< 1	< 1, NA	--	<1, NA
Er	< 0.001	< 0.001	< 0.001	< 0.001	0.07	0.002	0.02	0.011	< 1	< 1, NA	--	<1, NA
Eu	0.026	0.009	0.014	0.016	0.06	< 0.001	0.02	< 0.001	< 1	< 1, NA	--	<1, NA
Ga	0.71	0.03	0.31	0.03	0.2	<0.01	<0.1	0.03	<10	<10, NA	--	<10, NA

Table 3 Uncorrected Laboratory Drill Water and Groundwater Concentration Results (Cont'd)

	OGW-1		**OGW-2**		**OGW-3**		**OGW-4**		**OGW-6**		**OGW-7**	
Depth (mBGS)	39.72 - 47.50		77.77 - 81.05		107.81 - 114.63		133.64 - 142.08		841.96 - 847.50		843.70 - 860.70	
Trace Elements (µg/L)	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})
Gd	0.007	<0.001	<0.001	0.002	0.18	0.005	0.04	0.022	<1	<1, NA	--	2.7, <5
Ge	0.01	0.03	0.03	1.04	0.2	0.2	0.1	0.11	< 10	< 10, NA	--	<10, NA
Hf	< 0.001	0.006	< 0.001	< 0.001	0.05	0.003	0.02	0.012	< 1	< 1, NA	--	<1, NA
Hg	<0.2	<0.2	0.8	<0.2	<2	<0.2	<2	<0.2	<200	<200, NA	--	<200, NA
Ho	< 0.001	< 0.001	< 0.001	< 0.001	0.02	0.001	< 0.01	0.004	< 1	< 1, NA	--	<1, NA
In	< 0.001	< 0.001	0.002	< 0.001	< 0.01	< 0.001	< 0.01	< 0.001	< 1	< 1, NA	--	<1, NA
La	< 0.001	0.001	0.005	0.029	1.18	0.03	0.23	0.125	< 1	< 1, NA	--	1.68, NA
Li	135	25	53	33	50	26	40	28	44700	10000, 6220	--	9540, 3000
Lu	< 0.001	< 0.001	< 0.001	< 0.001	0.01	< 0.001	< 0.01	0.002	< 1	< 1, NA	--	<1, NA
Mo	36.7	13.1	16.1	16.6	6	5.7	21	20.7	<100	<100, 6.2	--	<100, 12
Nb	< 0.005	< 0.005	0.01	< 0.005	0.18	0.009	0.07	0.049	< 5	< 5, NA	--	<5, NA
Nd	< 0.001	< 0.001	0.003	< 0.001	0.86	0.02	0.14	0.098	< 1	< 1, NA	--	1.63, NA
Ni	0.3	2.2	0.6	15.6	17	14	22	18.8	771	<300, 317	--	<300, 370
Os	< 0.002	< 0.002	< 0.002	< 0.002	< 0.02	< 0.002	< 0.02	< 0.002	< 2	< 2, NA	--	<2, NA
Pb	0.17	0.02	0.71	0.02	5.7	0.2	1.5	0.69	20.2	17.1, 1.6	--	17.1, 4
Pd	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.01	< 0.1	< 0.01	16.2	11.1, NA	--	<10, NA
Pr	< 0.001	< 0.001	< 0.001	< 0.001	0.23	0.005	0.04	0.025	< 1	< 1, NA	--	<1, NA
Pt	< 0.3	< 0.3	< 0.3	< 0.3	< 3	< 0.3	< 3	< 0.3	< 300	< 300, NA	--	<300, NA
Rb	138	8.1	30.5	7.18	9.39	3.87	5.79	4.13	3430	1500, NA	--	1410, 1640
Re	0.259	0.077	0.169	0.441	0.14	0.031	0.17	0.119	< 1	< 1, NA	--	<1, NA
Ru	< 0.01	< 0.01	0.02	< 0.01	< 0.1	< 0.01	< 0.1	< 0.01	< 10	< 10, NA	--	<10, NA
Sb	0.35	1.01	2.65	50.4	2	3.55	7.4	5.99	<10	<10, 9.2	--	<10, 9
Sc	< 1	4	8	2	< 10	1	< 10	2	< 1000	< 2000, NA	--	<1000,
Se	1.6	1.5	5.9	290	4	22.2	5	3.1	<200	293, 60	--	<200, 200
Sm	0.001	< 0.001	0.005	0.002	0.18	0.004	0.05	0.021	1.41	< 1, NA	--	<1, NA
Sn	< 0.1	< 0.1	< 0.1	< 0.1	< 1	< 0.1	< 1	< 0.1	< 100	< 100, 4.9	--	<100, 8
Ta	< 0.001	< 0.001	< 0.001	< 0.001	0.02	< 0.001	< 0.01	< 0.001	< 1	< 1, NA	--	<1, NA
Tb	< 0.001	< 0.001	< 0.001	< 0.001	0.03	0.002	< 0.01	0.004	< 1	< 1, NA	--	<1, NA
Te	< 0.1	< 0.1	< 0.1	< 0.1	< 1	< 0.1	< 1	< 0.1	< 100	< 100, NA	--	<100, NA

Table 3 Uncorrected Laboratory Drill Water and Groundwater Concetation Results (Cont'd)

	OGW-1		**OGW-2**		**OGW-3**		**OGW-4**		**OGW-6**		**OGW-7**	
Depth (mBGS)	39.72 - 47.50		77.77 - 81.05		107.81 - 114.63		133.64 - 142.08		841.96 - 847.50		843.70 - 860.70	
Trace Elements (µg/L)	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})	1st Purge Drill Water	Ground-water (C^{mix})
Th	<0.001	0.007	<0.001	0.007	0.15	0.019	0.08	0.053	<1	<1, 0.69	--	<1, NA
Ti	0.4	1.8	2.9	1.1	27	1.5	8	4.2	<100	<100, 13	--	1300, 20
Tl	0.016	0.029	0.044	0.045	0.03	0.014	0.02	0.013	1.99	<1, NA	--	<1, 0.7
Tm	< 0.001	< 0.001	< 0.001	< 0.001	0.01	< 0.001	< 0.01	0.002	< 1	< 1, NA	--	<1, NA
U	<0.001	1.09	0.003	111	8.11	4.01	5.34	4.29	<1	<1, <0.03	--	<1, 0.5
V	0.6	8.6	3.8	5.6	10	1.8	<1	0.9	<100	<100, <0.1	--	<100, <3
W	11.6	12.3	720	130	150	30	108	60	<20	<20, NA	--	<20, NA
Y	0.009	0.031	0.01	0.071	1.09	0.061	0.26	0.172	4.24	7.57, NA	--	4.99, NA
Yb	< 0.001	< 0.001	0.001	< 0.001	0.07	0.003	0.02	0.012	< 1	< 1, NA	--	<1, NA
Zn	75.2	19.7	13.2	151	292	128	231	122	<500	<500, 50	--	1450, 1700
Zr	<0.01	0.33	0.02	0.14	2	0.18	1	0.5	<10	<10, NA	--	<10, NA

4.4 Correction for Drill-Water Contamination

The laboratory-reported value of the concentration of component 'i' is actually a weighted sum (C^{mix}) of the concentrations of i in the drill water (C^{DW}) and the true concentration of i in the groundwater (C^{GW}):

$$C_i^{DW} \bullet V^{DW} + C_i^{GW} \bullet V^{GW} = C_i^{mix}\left(V^{DW} + V^{GW}\right) \qquad (1)$$

Therefore, using the ratio of NaFl drill-water tracer in the 'groundwater', i.e., C^{mix}, to that in the first purge of the drill water (C^{DW}) to estimate the fraction of drill-water contamination in the lab analysis, the data of Table 3 are corrected in Table 4 for drill-water contamination by the dilution formula given as Equation 1 to give C^{GW}.

In addition to Equation 1, in which only C^{DW} and C^{mix} are known, the following identity is also known:

$$\frac{V^{DW}}{V^{mix}} + \frac{V^{GW}}{V^{mix}} = 1 \qquad (2)$$

where V^{mix} is the volume of the groundwater sample. Finally, we assume the following identity for CF, the correction factor (i.e., for removing the influence of drilling fluid):

$$CF = \frac{V^{DW}}{V^{mix}} = \frac{V^{DW}}{V^{GW} + V^{DW}} \qquad (3)$$

This yields three equations in three unknowns, i.e., C^{GW}, V^{DW} and V^{GW}. The correction factors are applied to Table 4 using Equation 1 resulting in corrected groundwater concentration (C^{GW}) according to:

$$C^{GW} = \left(C^{mix} - (CF)\left(C^{DW}\right)\right) \div (1 - CF) \qquad (4)$$

Thus, the Na^+ concentration for OGW-1, which is reported in Table 4, is given by:

$$21.6 = \left(21.9 - (0.04)(30.1)\right) \div (1 - 0.04) \qquad (5)$$

The correction factors for OGW-1 through OGW-4 are the percentages of drilling water (C^{DW}) estimated from the Na Fluorescein (NaFl) tracer present in the groundwater sample when it was collected (C^{mix}). They are:

OGW-1: 4%; OGW-2: 8%; OGW-3: 6%; OGW-4: 18%;

OGW-6, which had an estimated drill-fluid contamination of 0.8%, was not adjusted on account that it was recovered under artesian head two days after the drill water return tritium sample was collected and is a brine, such that any correction would be meaningless in a quantitative sense for such concentrations. The same condition applies to OGW-7, which was collected much later than OGW-6 and after several hundred m^3 of brine discharged from the Cambrian interval of DGR-2 during drilling and prior to sealing the Cambrian with a downhole packer. For some analytes that were not measured in drill water but were measured in the mixed sample, it was not possible to calculate groundwater concentrations and NC (not calculated) is shown in Table 4.

The correction factors calculated from the equivalent tritium concentrations are identical for OGW-1 and OGW-6, but higher for the other samples. The tritium concentration in the drill water varied from an average of 191 TU in DGR-1 samples to an average of 371 TU in DGR-2 samples (Intera Engineering Ltd, 2009b). Tritium in precipitation at the Bruce site is elevated and averaged 1700 TU during 2005-2006 (Bruce Power, 2008).

Table 4 Lab Analyses of Groundwater (C^{mix}) and Values Corrected for Drill Water Contamination (C^{GW})

	OGW-1		**OGW-2**		**OGW-3**		**OGW-4**		**OGW-6**	**OGW-7**
Depth (mBGS)	39.72 - 47.50		77.77 - 81.05		107.81 - 114.63		133.64 - 142.08		841.96 - 847.50	843.70 - 860.70
General Parameters	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{GW}	C^{GW}
Alkalinity (mg/L as $CaCO_3$)	45	28.6	56	43.4	126	107.6	171	154.5	<2	<2, <2
TDS - Grav (mg/L)	556	507.5	1380	1451.7	1680	1742.7	1580	1615.1	228000, 243000	--, 159000
TDS - Sum (mg/L)	562	558	1753	1864	2156	2234	2075	2120	227000, 238000	--, 247800
Fluid Density (g/L)	996.9	996.8	1001	1000.2	1008	1007.8	995.6	999.6	1160.8, 1160	1166, 1190
Major Cations (mg/L)										
Na	21.9	21.6	37.4	22.2	52.5	45.3	74.6	68.4	38000, 38500	>35000, 35700
Ca	72.3	61.7	294	313.5	396	417.1	340	344.8	38500, 39900	>20000, 42000
Mg	53.1	53.1	130	141.3	98.6	103.9	84.8	85.5	5600, 6620	5940, 6410
K	4.98	3	5.69	5.1	6.69	4.9	8.01	7.3	632, 873	690, 785
Sr	5.6	5.7	14.7	15.9	9.57	10.2	8.67	8.7	861, 720	>200, 964
Fe	0.04	0	0.14	0.1	0.66	0.4	1.15	1.1	43.3, 8.36	49.8, 17.6
Mn	0.0003	0	0.0133	0	0.0468	0	0.0525	0	14.2, 12.4	17.8, 16.1
Major Anions (mg/L)										
Cl	8.84	3.2	18.5	16.3	24	20.4	34	29.6	141000, 150000	118000, 160000
Br	<0.1	<0.1	<0.4	<0.4	<3	<3	<3	<3	1670, 1400	1420, 1500
F	1.3	1.3	1.4	1.4	<1	<1	<1	<1	<10, <3	<10, 0.32
I	0.005	0.005	0.004	0.003	0.01	0.01	0.007	0.007	177, <300	8.99, 2.6
Si	6.8	7.1	3.1	1.8	3.6	2.5	4.6	4.3	<200, 0.88	<200, 0.51
SO_4	378	393	1180	1279.6	1410	1497.8	1310	1382	450, <500	550, 370
NO_3	<0.04	<0.04	<0.1	<0.1	<1	<1	<1	<1	<10, <50	<10, <5
CO_3	9.6	8.2	<1	<1	<1	<1	<1	<1	<1, <2	--
HCO_3	0	0	68	53	154	131	209	188	<2, <2	6, <2

Table 4 Lab Analyses of Groudnwater (C^{mix}) and Values Corrected for Drill Water Contamination (C^{GW}) (Cont'd)

	OGW-1		**OGW-2**		**OGW-3**		**OGW-4**		**OGW-6**	**OGW-7**
Depth (m BGS)	39.72 - 47.50		77.77 - 81.05		107.81 - 114.63		133.64 - 142.08		841.96 - 847.50	843.70 - 860.70
Isotopes & C Compounds	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{GW}	C^{GW}
Tritium (TU)	8.6	0	58.4	58	15.2	8.1	27.2	25	4.3	2.5
δD (‰)	-87.3	-88.7	-90.6	-93.9	-90.7	-92.9	-82.3	-82.7	-43.3	-35.8
δ^{18}O (‰)	-12.69	-12.94	-12.33	-12.79	-13.49	-13.91	-12.22	-12.51	-4.97	-4.71
DIC (mg/L)	4.35	NC	13.46	NC	33.25	NC	38.91	NC	6.19	5.4
δ^{13}C(DIC)	-6.97	NC	-4	NC	-3.8	NC	-4.7	NC	-7.2	-8.35
DOC (mg/L)	6.77	NC	73.34	NC	74.28	NC	149.8	NC	0.2	0.1
δ^{13}C(DOC)	-27.41	NC	-31.2	NC	-16.1	NC	-19.7	NC	Insufficient C	Insufficient C
Trace Elements (µg/L)										
Ag	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 200, NA	<200, <1
Al	5	0.33	4	0	4	0	40	31.2	<2000, 1950	<2000, 170
As	0.46	0.46	6.1	2.135	0.62	0.526	2.18	2.29	117, 509	<30, 830
Au	0.002	0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 2, NA	3.06, NA
Ba	61.1	15.31	101	103.1	161	4.681	280	175.5	1020, 893	967, 1040
Be	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<100, <0.5	<100, <2
Bi	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<300, 0.4	<300, 3
Cd	0.05	0.05	0.08	0.078	0.05	0.015	0.13	0.115	<10, 1.8	<10, 1.3
Ce	< 0.001	< 0.001	0.024	0.026	0.03	0	0.179	0.161	< 1, NA	1.86, 10
Co	<0.005	<0.005	0.455	0.478	0.679	0.67	0.603	0.577	<5, 21.6	<5, 26.2
Cr	2	1.01	<0.5	<0.5	<0.5	<0.5	1.3	0.017	<500, 10	<500, <50
Cs	0.15	0.04	0.037	0.012	0.022	0.02	0.017	0.016	20.9, NA	19.7, 10
Cu	<0.2	<0.2	0.3	0	0.5	0	1.5	0.732	<200, 50	<200, 140
Dy	< 0.001	<0.2	< 0.001	< 0.001	0.003	0	0.019	<1	< 1, NA	<1, NA
Er	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0	0.011	<1	< 1, NA	<1, NA
Eu	0.009	0.01	0.016	0.016	< 0.001	< 0.001	< 0.001	< 0.001	< 1, NA	<1, NA
Ga	0.03	0	0.03	0.006	<0.01	<0.01	0.03	0.03	<10, NA	<10, NA
Gd	<0.001	<0.001	0.002	0.002	0.005	0	0.022	0.018	<1, NA	2.7, <5
Ge	0.03	0.03	1.04	1.128	0.2	0.2	0.11	0.112	< 10, NA	<10, NA

Table 4 Lab Analyses of Groundwater (C^{mix}) and Values Corrected for Drill Water Contamination (C^{GW}) (Cont'd)

Depth (m BGS)	OGW-1 39.72 - 47.50		OGW-2 77.77 - 81.05		OGW-3 107.81 - 114.63		OGW-4 133.64 - 142.08		OGW-6 841.96 - 847.50	OGW-7 843.70 - 860.70
Trace Elements (μg/L)	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{GW}	C^{GW}
Hf	0.006	0.006	< 0.001	< 0.001	0.003	0	0.012	0.01	< 1, NA	<1, NA
Hg	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<200, NA	<200, NA
Ho	< 0.001	< 0.001	< 0.001	< 0.001	0.001	0	0.004	0.004	< 1, NA	<1, NA
In	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 1, NA	<1, NA
La	0.001	0.001	0.029	0.031	0.03	< 0.001	0.125	< 0.001	< 1, NA	1.68, NA
Li	25	20.42	33	31.26	26	24.47	28	25.37	10000, 6220	9540, 3000
Lu	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0	< 1, NA	<1, NA
Mo	13.1	12.12	16.6	16.643	5.7	5.681	20.7	20.634	<100, 6.2	<100, 12
Nb	< 0.005	< 0.005	< 0.005	< 0.005	0.009	0	0.049	0.044	< 5, NA	<5, NA
Nd	< 0.001	< 0.001	< 0.001	< 0.001	0.02	0	0.098	0.089	< 1, NA	1.63, NA
Ni	2.2	2.28	15.6	16.9	14	13.81	18.8	18.1	<300, 317	<300, 370
Os	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 2, NA	<2, NA
Pb	0.02	0.01	0.02	0	0.2	0	0.69	0.512	17.1, 1.6	17.1, 4
Pd	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	11.1, NA	<10, NA
Pr	< 0.001	< 0.001	< 0.001	< 0.001	0.005	0	0.025	0.022	< 1, NA	<1, NA
Pt	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 300, NA	<300, -
Rb	8.1	2.69	7.18	5.152	3.87	3.518	4.13	3.766	1500, NA	1410, 1640
Re	0.077	0.069	0.441	0.465	0.031	0.024	0.119	0.108	< 1, NA	<1, NA
Ru	< 0.01	<0.01	< 0.01	<0.01	< 0.01	<0.01	< 0.01	<0.01	< 10, NA	<10, NA
Sb	1.01	1.04	50.4	54.55	3.55	3.65	5.99	5.68	<10, 9.2	<10, 9
Sc	4	4	2	1.48	1	1	2	2	< 2000, NA	<1000,
Se	1.5	1.5	290	314.704	22.2	23.362	3.1	2.683	293, 60	<200, 200
Sm	< 0.001	< 0.001	0.002	0.002	0.004	0	0.021	0.015	< 1, NA	<1, NA
Sn	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 100, 4.9	<100, 8
Ta	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 1, NA	<1, NA
Tb	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0	0.004	0.004	< 1, NA	<1, NA
Te	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 100, NA	<100, NA
Th	0.007	0.01	0.007	0.007	0.019	0.011	0.053	0.047	<1, 0.69	<1, NA
Ti	1.8	1.86	1.1	0.943	1.5	0.0	4.2	3.366	<100, 13	1300, 20

Table 4 Lab Analyses of Groundwater (C^{mix}) and Values Corrected for Drill Water Contamination (C^{GW}) (Cont'd)

Depth (m BGS)	OGW-1 39.72 - 47.50		OGW-2 77.77 - 81.05		OGW-3 107.81 - 114.63		OGW-4 133.64 - 142.08		OGW-6 841.96 - 847.50	OGW-7 843.70 - 860.70
Trace Elements (µg/L)	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{mix}	C^{GW}	C^{GW}	C^{GW}
Tl	0.029	0.03	0.045	0.045	0.014	0.013	0.013	0.011	<1, NA	<1, 0.7
Tm	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0.002	< 1, NA	<1, NA
U	1.09	1.09	111	120.65	4.01	3.75	4.29	4.06	<1, <0.03	<1, 0.5
V	8.6	8.93	5.6	5.76	1.8	1.28	0.9	0.9	<100, <0.1	<100, <3
W	12.3	12.33	130	78.7	30	22.34	60	49.46	<20, NA	<20, NA
Y	0.031	0.03	0.071	0.076	0.061	0	0.172	0.153	7.57, NA	4.99, NA
Yb	< 0.001	< 0.001	< 0.001	< 0.001	0.003	0	0.012	0.01	< 1, NA	<1, NA
Zn	19.7	17.39	151	162.98	128	117.53	122	98.07	<500, 50	1450, 1700
Zr	0.33	0.33	0.14	0.15	0.18	0.064	0.5	0.39	<10, NA	<10, NA

Because of the observed variability of tritium in drill water and because of the much more frequent measurement of NaFl, the correction factors derived from the NaFl data are used to create Table 4 from Table 3.

4.5 Data Analysis

The corrected values shown in Table 4 were tested for ionic charge balance that provides a rough check on the quality of the laboratory analysis using the software PHREEQC assuming that all important ionic species were in fact measured and converted to milliequivalents per litre (meq/L). N.B. The charge balance for the first set of analytical results for OGW-7 were not calculated because of an incomplete analysis by the laboratory, i.e., greater than values reported for Sr, Na and Ca. The results are reported in Table 5 in which the charge balance is given by:

$$\frac{\sum(cations - anions)}{\sum(cations + anions)} * 100 \qquad (6)$$

Table 5 Electroneutrality Calculations

Component	OGW-1	OGW-2	OGW-3	OGW-4	OGW-6	OGW-7
Sum of Anions (meq/L)	8.85	28.0	34.0	32.8	5182, 5593	6034
Sum of Cations (meq/L)	8.60	28.8	31.8	27.7	5264, 5580	5607
Charge Balance (%)	-1.5	+1.3	-3.4	-8.5	+0.8, -0.1	-3.7

Only OGW-4 had a charge balance ≥ 5%, which is considered to be a matter of QA concern. OGW-4 is from the zone of lost drilling-fluid circulation near the Devonian-Silurian boundary and was estimated to contain about 18% drill-water contamination and shows a deficit of cations that may be caused by overestimation of anions or underestimation of cations. The remaining charge balance results were <5%, which is considered adequate for interpretation.

A summary of the charge balance calculations carried out using PHREEQC is shown in Appendix A. More detailed analysis, including calculation of mineral saturation indices using the Pitzer database, will be presented in PR-08-01, the Descriptive Geosphere Site Model Report.

5 Data Quality and Use

Caution is needed in the use of these data. Cement contamination as a result of the installation of the upper permanent casing in DGR-1 caused high pH values in the opportunistic samples OGW-1 and OGW-2, preventing further interpretation of the data.

Tritium is one of the more notable variables affected by drill water contamination. The drill water tank reached approximatey 550 TU during drilling of DGR1 and DGR 2. Even a small amount of drill water in the water sample may lead to the small amounts of tritium detected. This background is due to the average annual concentration of tritium in precipitation at the Bruce site of greater than 2,000 TU (Bruce Power, 2008).

Field measurements of redox state are well-known to be only semi-quantitative and cannot be relied upon to yield reliable mineral equilibria predictions. Thus the observation of pyrite in many cores is a more reliable indicator of anoxic conditions than are the relatively high and positive potentials measured with the Pt electrode that reflect mixed potentials (Stumm & Morgan, 1981, pp. 490-493).

A number of other processes occurring during drilling and sampling – dissolution/precipitation of reactive solids such as pyrite and calcite, ion exchange with drilling-produced fines in the borehole and, in particular, degassing with pressure drop – are likely to have played unquantifiable roles in affecting the measured parameters (Pearson, 1994). These will be considered – to the extent possible – in the forthcoming report, the Descriptive Geosphere Site Model. The effect of degassing on pH is clearly evident in the time series plots of OGW-3 and OGW-6 shown in Figures 6 and 7.

Table 6 Analytical Laboratory Quality Assurance

	Certified Standard	**OGW-1&-2**	**OGW-3 & -4**	**OGW-6**	**OGW-7**
		Measured	**Measured**	**Measured**	**Measured**
Major Cations (ug/L)	Tested against NIST 1640 ICPMS Certified Standard Solution				
Na	**29400**	29300	29100	31300	30900
Ca	**7050**	7000	7000	7600	7200
Mg	**5820**	5810	5100	6260	6090
K	**994**	990	994	1010	980
Sr	**124**	123	130	126	136
Fe	**34.3**	30	30	30	30
Mn	**122**	122	120	124	115
Major Anions (mg/L)	Tested against IC Reference Standard Solution				
Cl	**15.00**	15.10	15.20	14.80	15.3
Br	**10.00**	10.10	10.10	9.97	10.2
F	**2.00**	1.97	1.96	1.90	2.05
SO_4	**15.00**	15.3	15.1	15.00	15.2
NO_3	**3.00**	3.04	3.05	2.99	3.05

The criteria of Pearson (1994, p.52) suggests the opportunistic groundwater samples with drilling fluid contamination of 3% to 10% are "only marginally suitable for quantitative geochemical interpretation". Therefore OGW-1 through OGW-3 would be marginally suitable, except for the fact that OGW-1 and OGW-2 showed clear cement contamination from the installation of the first casing and are not suitable for hydrogeochemical interpretation. OGW-3 (DGR1-111) meets the charge balance constraints of ≤ 3% and has 3-10% drilling fluid contamination and may be used cautiously in interpretation. Those samples in excess of 10% drilling fluid contamination are clearly "grossly contaminated"; in this case OGW-4 meets this description and is thus also not suitable for hydrogeochemical interpretation. Therefore, only OGW-6 and OGW-7 can be considered suitable for hydrogeochemical interpretation without qualification; OGW-6 and OGW-7 were collected as flowing samples from the Cambrian Formation aquifer and also meets the charge balance constraints of ≤ 5% of electroneutrality.

Table 6 presents results of QA checks during testing of OGW samples by the analytical laboratory showing the measured values for major ions against those for ICP/MS and ion chromatograph certified standards. The measured values are shown for three batches of OGW samples received by the laboratory. Some minor departures from the standard values are noted particularly for OGW-6, the Cambrian brine.

6 Conclusions

A total of six opportunistic groundwater samples were obtained from Phase I drilling of DGR-1 and DGR-2. Four samples were pumped from shallow depths – i.e., < 150 mBGS – in the lower Devonian and upper Silurian and two samples were collected under artesian head from the Cambrian Formation. Chemical analysis indicates that drill-water contamination of the samples was less than 10% in all but one case, which case was associated with loss-of-circulation of several thousand gallons of the drill water. Charge balances were ≤5% in all but one sample.

Based upon the Pearson (1994) criteria and the absence of cement-influenced pH, samples OGW-3 (DGR-1-111), OGW-6 (DGR-2-844) and OGW-7 (DGR-2-852.70) can be described as being suitable for hydrogeochemical interpretation, although OGW-3 contained a substantial concentration (6%) of drilling fluid and must be interpreted with caution.

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APPENDIX A

Summary of Charge Balance Calculations Performed Using PHREEQC

Ion	**OGW-1** 39.72 - 47.50	**OGW-2** 77.77 - 81.05	**OGW-3** 107.81 - 114.63	**OGW-4** 133.64 - 142.08	**OGW-6** 841.96 - 847.50	**OGW-7** 843.70 - 860.70
Na	0.94	0.97	1.97	2.98	2138, 2199	2064
Ca	1.54	7.84	10.43	8.62	1242, 1307	1393
Mg	2.19	5.82	4.28	3.53	298.0, 357.7	350.6
K	0.08	0.13	0.13	0.19	20.9, 26.7	26.69
Sr	0.07	0.18	0.12	0.10	12.7, 10.8	14.63
Cl	0.09	0.46	0.58	0.84	5143, 5556	5999
Br	0.00	0.00	0.00	0.00	27.03, 23.01	24.96
SO_4	4.09	13.35	15.63	14.42	6.06, 6.84	5.12
Alkalinity (as $CaCO_3$)	0.57	0.87	2.15	3.09	0.05, 0.05	0.05
Charge Balance (% error)	-1.5	+1.3	-3.4	-8.5	0.8, -0.1	-3.7

Note: all concentrations are as milli-molality ($mmol/kg_{water}$), and charge balance is presented as %.