Technical Report

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Author:	Michael Melaney
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DGR Site Characterization Document Intera Engineering Project 06-219



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0	August 25, 2008	Initial Release							
1	February 5, 2009	Updated Section 5 to indicate the probable presence of the Lucas Formation overlying the Amherstburg Formation in both boreholes.							



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1 Introduction

Intera Engineering Ltd. has been contracted by Ontario Power Generation (OPG) to implement the Geoscientific Site Characterization Plan (GSCP) for the Bruce 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 in the Geoscientific Site Characterization Plan, OPG's Deep Geologic Repository for Low and Intermediate Level Waste Report (Intera Engineering Ltd., 2006).

This report summarizes the borehole geophysical logging of boreholes US-3 and US-7 completed as part of the refurbishment of these boreholes for future groundwater monitoring purposes.

Work described in this Technical Report was completed in accordance with Test Plan TP-06-03 (Intera Engineering Ltd., 2007a) that describes the refurbishment of boreholes US-3 and US-7 and relevant parts of TP-07-05 (Intera Engineering Ltd., 2007b), that describes log-specific procedures for borehole geophysical logging of boreholes DGR-1 and DGR-2. This Test Plan was prepared following the general requirements of the Intera DGR Project Quality Plan (Intera Engineering Ltd., 2007c).

2 Background

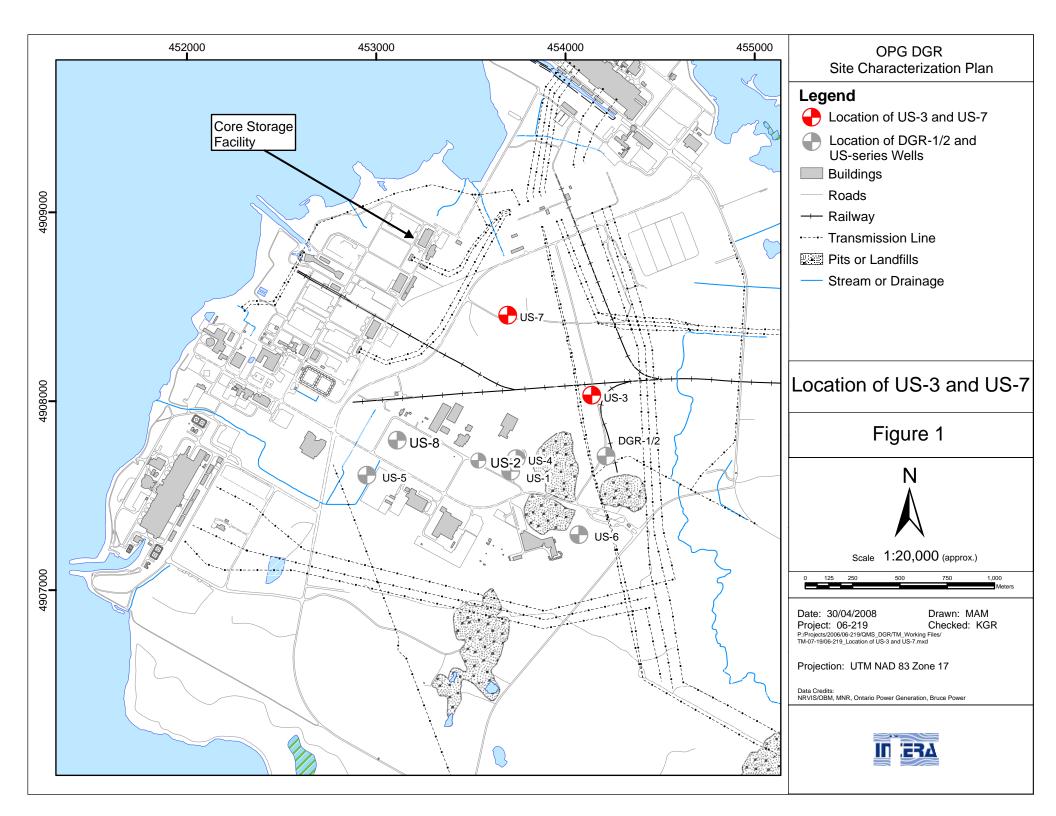
The DGR facility is proposed to be constructed within the argillaceous limestone of the Cobourg Formation. As part of the GSCP, a network of deep bedrock boreholes (DGR Series) is being established, which primarily tests and monitors isolated borehole intervals from the Salina Formation F-Unit shale at approximately 200 mBGS down to the Precambrian bedrock at approximately 860 mBGS. In addition to this new network of deep boreholes, a network of shallow bedrock boreholes (US series) with depths of approximately 100 to 200 mBGS are being established to monitor shallow to intermediate hydrogeologic conditions. These shallow US-series boreholes also help to verify the contact elevations in the upper bedrock formations including the Lucas, Amherstburg, Bois Blanc, Bass Island and Salina G Unit Formations.

Six existing shallow bedrock boreholes and monitoring wells are located on the Bruce site in the vicinity of the proposed DGR (i.e., US-1, US-3, US-4, US-5, US-6 and US-7) completed into the upper 100 m of the bedrock. Figure 1 shows the location of these boreholes and monitoring wells on the Bruce site. Four of the six boreholes (US-1, US-5, US-6 and US-7) were instrumented with Westbay MP38 multi-level groundwater monitoring was systems when they were drilled in the late 1980's. Detailed sampling and groundwater monitoring was performed in these monitoring wells until about 1994 (Lee et al., 1995) and later in selected intervals of these wells.

Refurbishment and instrumentation of two existing boreholes located on OPG-retained lands (i.e., US-3 and US-7) was recently completed as part of Phase 1 of the GSCP. Refurbishment included removal of existing monitoring casings (US-7), the geophysical logging of natural gamma, acoustic televiewer, and video, and the pumping/development of open boreholes. Refurbishment was required to prepare for installation of new Westbay MP38 multi-level groundwater monitoring systems to establish future shallow bedrock monitoring wells for the Bruce DGR project. TR-07-20 (Intera Engineering Ltd., 2009a) describes the refurbishment and installation of the new Westbay MP38 multi-level groundwater monitoring systems of boreholes US-3 and US-7.

The new monitoring wells (i.e., US-3 and US-7) will provide shallow bedrock monitoring intervals in the vicinity of the proposed DGR. The approximate location of US-3 and US-7 using NAD83 UTM Zone 17N coordinates are 454137.540 Easting and 4908030.430 Northing for US-3 and 453687.040 Easting and 4908459.601 Northing for US-7. The ground surface elevations of US-3 and US-7 are 184.56 m above sea level (mASL) and 182.98 mASL, respectively.





3 Methods

3.1 Borehole Geophysical Logging of US-3 and US-7

A limited suite of borehole geophysical logs was conducted prior to installation of Westbay MP38 multilevel monitoring systems in boreholes US-3 and US-7. The refurbishment procedures as outlined in TP-06-03 for both US-3 and US-7 boreholes were modified by Intera Engineering Ltd. to conduct the borehole geophysical logging prior to borehole purging and sampling. This deviation was approved as it was deemed beneficial to complete the geophysics in boreholes that are in a relatively stable hydraulic state. The geophysical logging for natural gamma, acoustic televiewer (ATV) and borehole video logs was conducted by Lotowater Technical Services (Lotowater), based in Paris, Ontario, Canada, under contract to Intera Engineering Ltd.

Each of the borehole natural gamma and ATV logs were referenced to ground surface, accounting for the 0.25 m and 0.24 m stick-up of the steel well casing in US-3 and US-7, respectively. The natural gamma and ATV logs collected in US-7 and US-3 were conducted on November 20, 2007 and November 21, 2007, respectively. The natural gamma log was collected using a Mount Sopris Instruments Co. Inc. 2 PGA Gamma logger. The ATV logs were collected using Mount Sopris Instruments Co. ABI-40 slimhole acoustic televiewer. The video logs for both US-3 and US-7 were collected on November 21, 2007 using a Laval R2000 DUAL CAM camera.

Borehole geophysical logging and calibration procedures were followed as described for natural gamma, ATV, and video logging in TP-07-05 (Intera Engineering Ltd., 2007c). All recorded depths for natural gamma and ATV logs are accurate within 1% of the measured depth.

On completion of the video logs borehole features such as smooth competent zones, fractures, highly broken rock, breakout zones and voids were noted. Video log review notes are included as Tables A.1 and A.2 in Appendix A for US-3 and US-7, respectively. The results from the video log were used to determine the elevations of fractures in the bedrock, which was important for designing the configuration of the Westbay MP38 multi-level groundwater monitoring systems. The video logs were provided to OPG under cover letter dated January 14, 2008.

The natural gamma and acoustic caliper logs and the formation stratigraphy logs of boreholes US-3 and US-7 are given in Appendix B. The formation contacts of these logs were referenced from previously created borehole logs based on detailed logging of recovered core (Lukajic, 1988). These historical boreholes logs, which are provided in Appendix C, provide detailed information on the stratigraphy, lithology and rock quality encountered by boreholes US-3 and US-7.

3.2 Natural Gamma Log

The natural gamma log measures the natural radioactivity of the bedrock. An increase in radioactivity is indicated by elevated gamma radiation counts. The gamma radiation is measured in counts per second (cps) and allows for the useful identification of lithology and stratigraphic correlation. This is primarily a measurement of potassium, but also uranium and thorium content, which are preferentially concentrated in clays particles. Therefore the log indicates the variation in clay content within the bedrock. This log cannot distinguish between lithologies of similar gamma emission and cannot be used to define geologic boundaries alone. However this log is an excellent tool to locate boundaries between lithologies of substantially different levels of clay content, such as shales versus dolostones.

3.3 ATV Image Log

The acoustic televiewer (ATV) log provides images of the borehole wall that are not available by any other geophysical logging techniques or other borehole investigation methods. The tool generates an image of the



borehole wall by transmitting ultrasonic pulses from a rotating sensor and recording the amplitude and travel time of the signals reflected at the interface between the borehole liquid and borehole wall. The amplitude of these reflections is representative of the rock conditions surrounding the borehole. The reflected amplitude is displayed as a colour spectrum image. The image is a planar representation of a cylindrical object which plots from true north (0 azimuth degrees) back to true north, drawing from left to the right side of the image. This unravelled image plots angled fractures and bedding planes as sinusoidal waves. The amplitude and position of these waves allows for the magnitude and direction of the dipping features to be measured.

3.4 ATV Caliper Log

The acoustic travel time of a pulse generated by the tool and reflected by the borehole wall is used to measure the borehole diameter. The acoustic travel time represents the borehole shape and diameter and is used to provide exceptionally accurate borehole diameter measurements, which makes the tool ideal for casing inspection and structural geology. After calibrating the fluid velocity with a known diameter, (usually inside the casing), the average travel time of the reflected signal around the circumference of the borehole is used to calculate a caliper log. This caliper log indicates the average diameter and locates areas of possible fractures or borehole breakouts.

3.5 Borehole Orientation

The raw data file collected from the ATV logging tool was processed to create the tilt and azimuth direction of both US-3 and US-7. The tilt of the borehole represents the degrees off vertical measured from inclinometers embedded within the ATV logging tool. Similarly the azimuth direction of this tilt was measured from embedded magnetometers.

3.6 Borehole Video Log

The video log collected using the R2000 DUAL CAM borehole camera provides a colour image in a standard axial downhole view and side-view with continuous 360° rotation. The depth difference between the side view camera and the downhole view camera is 76 mm, with the downhole camera being deeper. The depth encrypted on the video log was referenced to ground surface with a starting depth of 0.84 mBGS in both US-3 and US-7 where the depth is measured at the side view camera.

A source of error pertaining to the video log depth encryption is cable stretch. Unlike the other borehole geophysical logs the collective error associated with the depth encryption on the video log cannot be corrected after recording is complete. In order to adjust for this potential error associated with cable stretch, major features identified in the borehole video logs were correlated to these same features identified in the ATV image and ATV caliper logs. Borehole video log features listed in Table A.1 and A.2 for boreholes US-3 and US-7 are depth corrected to ATV logs.

4 Results

4.1 Natural Gamma Logs

The natural gamma logs for boreholes US-3 and US-7, as provided on the borehole logs in Appendix B, are relatively flat, typically less than 50 cps reflecting the relatively uniform bedrock lithology in boreholes US-3 and US-7 as dolostone. The natural gamma logs show several thin (< 1 m) zones of elevated gamma response greater than 100 cps in both boreholes that are likely indicative of clay-rich horizons in the dolostone bedrock of the Amhertsburg and Bois Blanc Formations. These gamma highs in combination with a lack of fracturing are target horizons for setting of MP38 casing packers for effectively isolating groundwater monitoring intervals.



4.2 ATV Logs

The ATV logs are illustrated on the borehole logs of US-3 and US-7 in Appendix B. The borehole logs show the ATV image of the borehole wall, the calculated average borehole diameter in inches, and the orientation of the borehole azimuth and tilt.

The ATV images of the borehole wall are of very good quality, showing the occurrence of both horizontal and inclined fractures, bedding planes and seams, discontinuities, borehole breakouts and other sedimentological features including zones of enhanced porosity and presence of chert nodules. The high quality of the ATV is most likely due to the completion of boreholes US-3 and US-7 using conventional diamond coring methods.

The ATV calculated average borehole diameters for US-3 and US-7 are relatively uniform at 3.0 and 3.8 inches as expected based on the drilling of these boreholes using N and H size coring equipment. The acoustic caliper logs show good correlation with the results of the ATV images of the borehole walls, with increases in borehole diameter corresponding to occurrence of large open discontinuities and seams.

Zones of borehole enlargement or fracture occurrence were noted at depths of 21.5, 23.0, 25.8, 51.9, 54.1, 58.6 and 72.6 mBGS in borehole US-3. Zones of borehole enlargement or fracture occurrence were noted at depths of 21.6, 23.6, 25.0, 28.1, 31.9, 38.4, 49.1, 57.5, 59.6, 63.5, 64.5, 67.5 and 80.2 mBGS in borehole US-7.

4.3 Borehole Video Logs

Tabular summaries of borehole video logs for US-3 and US-7 presented in Appendix A, show a good correlation with borehole features mapped from ATV image logging. Although the depth accuracy of the borehole video logs is much poorer than that of the ATV, the colour and resolution of the borehole video images are superior and allow identification of sedimentological features such as mudstone clasts, shaley layers, chert clasts, porous zones and occasionally fracture infilling minerals (e.g., calcite crystals) that are often not discernable with ATV logs. When used in conjunction with depth-accurate ATV logs, the video logs provide excellent images for identifying fractures, breakouts, voids, sedimentological features and smooth competent zones for setting of MP38 packers.

4.4 Borehole Orientation

Based on ATV logs US-3 has a measured tilt of less than 1.3 degrees from vertical in a varied north to northeast direction from approximately 22 mBGS to 50 mBGS and in a northern direction from approximately 50 m BGS and below. US-7 has a measured tilt of less than 1 degree from vertical in a general eastern direction across the entire drilled length. The measured tilt of both holes verifies that the holes are vertical.

5 Data Quality and Use

Data on bedrock formation nomenclature and occurrence in this Technical Report are based on historical borehole logs by Lukajic (1988). Logging and expert geological review of the stratigraphy in borehole DGR-1 at the Bruce site (Intera Engineering Ltd., 2009b) showed the presence of the Lucas Formation overlying the Amherstburg formation. Although the borehole logs by Lukajic (1988) did not identify the Lucas Formation, it most likely overlies the Amherstburg Formation in both US-3 and US-7.

The data presented in this Technical Report were used in the design of Westbay MP38 multi-level monitoring casings for boreholes US-3 and US-7.

The data presented in this Technical Report are also suitable for improving the shallow bedrock geological framework for development of Phase 1 descriptive geosphere site models of the Bruce DGR site.



6 References

Intera Engineering Ltd., 2009a. Technical Report: Westbay MP38 Casing Completions in US-3, US-7 & US-8, TR-07-20, Revision 0, in preparation, Ottawa.

Intera Engineering Ltd., 2009b. Technical Report: Bedrock Formations in DGR-1 and DGR-2, TR-07-05, Revision 2, February 2, Ottawa.

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Lee, D., T. Kotzer and K. King, 1995. Preliminary Assessment of Low- and Intermediate-Level Waste Disposal in the Michigan Basin: Isotopic and Geochemical Measurements, Atomic Energy of Canada Ltd., Chalk River Laboratories, Report COG-95-248-I, June.

Lukajic, B.J., 1988. Preliminary Results of the 1986-87 Geological Investigations, BNPD Proposed Underground Irradiated Fuel Storage Facility, Ontario Hydro Report GHED-DR-8801, July, Toronto.



APPENDIX A

Video Log Review Notes - US-3 & US-7 Table A.1 - US-3 Video Log Review Notes Table A.2 - US-7 Video Log Review Notes

Table A.1 - US-3 Video Log Review Notes

Zo	ne	Borehole Wall Description
Top Bottom		
(mBGS)	(mBGS)	
	21.0	Bottom of surface casing
21.0	21.4	Cement
	21.5	Breakouts
	22.0	Vertical fracture
22.0	22.6	Smooth, unfractured
	22.6	Single horizontal fracture breakout
22.6	22.9	Smooth, unfractured
23.1	23.3	Two breakouts
23.2	24.0	Smooth, unfractured
	24.0	Single horizontal fracture breakout
24.0	24.7	Smooth, unfractured
	24.7	Horizontal fracture
24.7	25.0	Smooth, unfractured
	25.0	Two fractures
25.0	25.6	Smooth, unfractured
25.7	25.8	Breakout
25.8	26.9	Smooth, unfractured
	26.9	Fracture breakout
26.9	29.1	Smooth, unfractured
	29.1	Fracture breakout
29.1	31.7	Smooth, unfractured
	31.7	Horizontal fracture
31.7	34.2	Smooth, unfractured
34.2	34.3	Vertical fracture and voids
34.3	35.1	Smooth, unfractured
	35.1	Breakout
35.1	35.6	Smooth, unfractured
	35.6	Breakout
35.6	38.4	Smooth, unfractured
	38.4	Breakout
38.4	39.0	Smooth, unfractured
39.0	39.9	Voids
	39.9	Fracture
39.9	41.2	Smooth, unfractured
	41.2	Horizontal fracture
41.2	41.5	Smooth, unfractured
	41.5	Two fractures
41.5	41.8	Smooth, unfractured
	41.8	Two fractures or breakouts
41.8	45.8	Smooth, unfractured
45.0	45.8	Breakout
45.8	48.0	Smooth, unfractured
40.0	48.0	Breakout or void
48.0	49.2	Smooth, unfractured
49.2	49.4	Vertical fracture
40.5	49.5	Sub-vertical fracture
49.5	50.1	Smooth, unfractured
	50.1	Horizontal fracture and breakout



Zo	ne	Borehole Wall Description
Top Bottom		
(mBGS)	(mBGS)	
50.1	50.4	Smooth, unfractured
	50.4	Sub-vertical fracture breakout
50.4	50.6	Smooth, unfractured
	50.6	Horizontal fracture, breakout
50.6	50.9	Smooth, unfractured
	50.9	Horizontal fracture
50.9	51.8	Smooth, unfractured
	51.8	Fractures (three) with breakout
51.8	52.2	Breakout with sub-vertical and vertical fractures
52.2	53.1	Smooth, unfractured
	53.1	Breakout
53.1	53.5	Smooth, unfractured
	53.5	Breakout
53.5	54.0	Smooth, unfractured
	54.0	Breakout
54.0	54.3	Smooth, unfractured
	54.3	Breakout
54.3	54.9	Smooth, unfractured
	54.9	Breakout
54.9	57.0	Smooth, unfractured
57.0	57.3	Sub - vertical fracture
57.3	58.5	Smooth, unfractured
58.5	58.8	Sub - vertical fracture and breakout
58.8	59.5	Smooth, unfractured
59.5	59.6	Sub - vertical fracture
59.6	62.0	Smooth, unfractured
	62.0	Horizontal fracture and breakout
62.0	64.6	Smooth, unfractured
64.6	65.3	Sub-vertical fracture and voids
65.3	65.9	Smooth, unfractured
65.9	66.5	Vertical fracture
66.5	67.1	Smooth, unfractured
	67.1	Horizontal fracture
67.1	67.4	Smooth, unfractured
67.4	67.5	Vertical fracture
67.5	70.1	Smooth, unfractured
70.1	70.3	Sub - vertical fracture
70.3	70.4	Sub - vertical fracture breakout
70.4	72.5	Smooth, unfractured
	72.5	Horizontal fracture and breakout
72.5	72.9	Smooth, unfractured
72.9	73.2	Poor visibility, murky
	73.2	End depth of video log

Table A.1 - US-3 Video Log Review Notes (cont'd)

Notes:

mBGS = metres below ground surface



Table A.2 - US-7 Video Log Review Notes

70	ne	Borehole Wall Description
Top Bottom		
(mBGS)	(mBGS)	
. ,	19.8	Bottom of surface casing
19.9	20.1	Sub - vertical fracture with voids
20.1	20.3	Smooth, unfractured
20.1	20.3	Horizontal fracture with breakout
20.3	20.7	Smooth, unfractured
20.0	20.7	Breakout
20.7	20.7	Smooth, unfractured
20.7	21.1	Breakout
21.2	21.7	Dark staining
21.2	21.7	Localized voids
21.5	21.3	Vertical fracture
	21.7	
21.3 21.7		Breakout with horizontal fractures
	22.4	Localized voids
22.4	22.6	Vertical fracture
22.0	22.6	Two horizontal fractures with breakout
22.6	23.3	Smooth, localized voids
	23.3	Horizontal fracture with breakout
	23.6	Horizontal fracture with breakout
23.6	24.1	Smooth, unfractured
	24.1	Horizontal fracture with breakout
	24.4	Breakout
24.5	24.4	Horizontal fractures
	24.7	Breakout
	25.0	Horizontal fracture breakout
25.0	25.3	Increased void density
25.3	25.9	Smooth, unfractured
	25.9	Sub - vertical fracture
25.9	26.2	Localized voids
26.2	26.5	Sub - vertical to vertical fracture
26.5	27.4	Smooth, unfractured, dark staining
	27.4	Horizontal fracture with breakout
27.7	28.0	Four sub - vertical fractures
28.0	28.5	Vertical fracture breakout
28.5	29.0	Sub - vertical fracture breakout
29.0	29.5	Smooth, unfractured, dark staining
	29.5	Horizontal fracture breakout
29.5	29.7	Sub - vertical fracture
29.7	30.2	Smooth, unfractured
30.2	30.4	Sub - vertical fracture
30.7	30.5	Sub - vertical fracture
30.5	31.6	Unfractured, localized voids
31.8	32.1	Sub - vertical fractures
32.1	32.4	Smooth, unfractured
32.4	32.6	Multiple sub - vertical fractures
32.8	33.1	Sub - vertical fractures
33.1	34.7	Smooth, unfractured, dark staining
34.7	37.9	Unfractured, localized breakouts and voids
	37.9	Breakout
37.9	38.5	Unfractured, localized voids
	38.5	Horizontal fracture breakout
38.5	41.2	Unfractured, localized voids
41.2	41.5	Sub - vertical fracture
41.5	42.0	Smooth, unfractured
42.0	42.3	Unfractured, localized voids and breakouts
42.3	43.4	Smooth, unfractured
	43.4	Breakout
μ		



Table A.2 - US-7 Video Log Review Notes (cont'd)

70	ne	Borehole Wall Description
Top Bottom		
(mBGS)	(mBGS)	
43.5	43.7	Unfractured, localized voids
43.7	44.5	Smooth, unfractured
	44.5	Sub - vertical fracture
44.5	49.1	Unfractured, localized voids and breakouts
49.1	48.8	Breakout void with crystal development
48.8	51.2	Poor visibility, very murky
51.2	51.7	Smooth, unfractured
	51.7	Breakout
51.7	53.2	Smooth, unfractured
	53.2	Horizontal breakout
	53.4	Two breakouts
53.4	54.3	Smooth, unfractured
	54.3	Horizontal breakout
54.3	55.2	Smooth, unfractured
	55.2	Breakout
55.2	56.2	Smooth, unfractured
	56.2	Horizontal breakout
56.2	56.9	Smooth, unfractured
56.9	57.1	Sub - vertical fracture
	57.1	Horizontal breakout
	57.5	Horizontal breakout
	57.8	Voids and breakouts
57.8	59.5	Smooth, unfractured
	59.5	Horizontal fracture breakout
59.5	59.8	Smooth, unfractured
	59.8	Sub - vertical fracture
	60.0	Localized voids
60.0	62.6	Smooth, unfractured
	62.6	Breakout
62.6	63.4	Smooth, unfractured
	63.4	Horizontal breakout
63.4	64.0	Smooth, unfractured
	64.0	Horizontal breakout
64.0	65.2	Smooth, unfractured
	65.2	Sub - vertical fracture, breakout
65.2	66.4	Smooth, unfractured
	66.4	Breakout
66.6	66.8	Sub - vertical fracture with breakout
	67.4	Horizontal breakout
67.4	68.8	Smooth, unfractured
	69.3	Vertical fracture
69.3	71.6	Smooth, unfractured
	71.6	Horizontal fracture breakout
	72.6	Sub - vertical fracture
	73.0	Sub - vertical fracture
	73.1	Fracture
73.1	74.5	Smooth, unfractured
	74.5	Sub - vertical fracture with breakout
74.5	76.7	Smooth, unfractured
	76.7	Fracture
76.7	80.0	Smooth, unfractured
	80.0	Horizontal breakout
80.0	88.5	Smooth, unfractured, few localized voids
	88.5	End of video log
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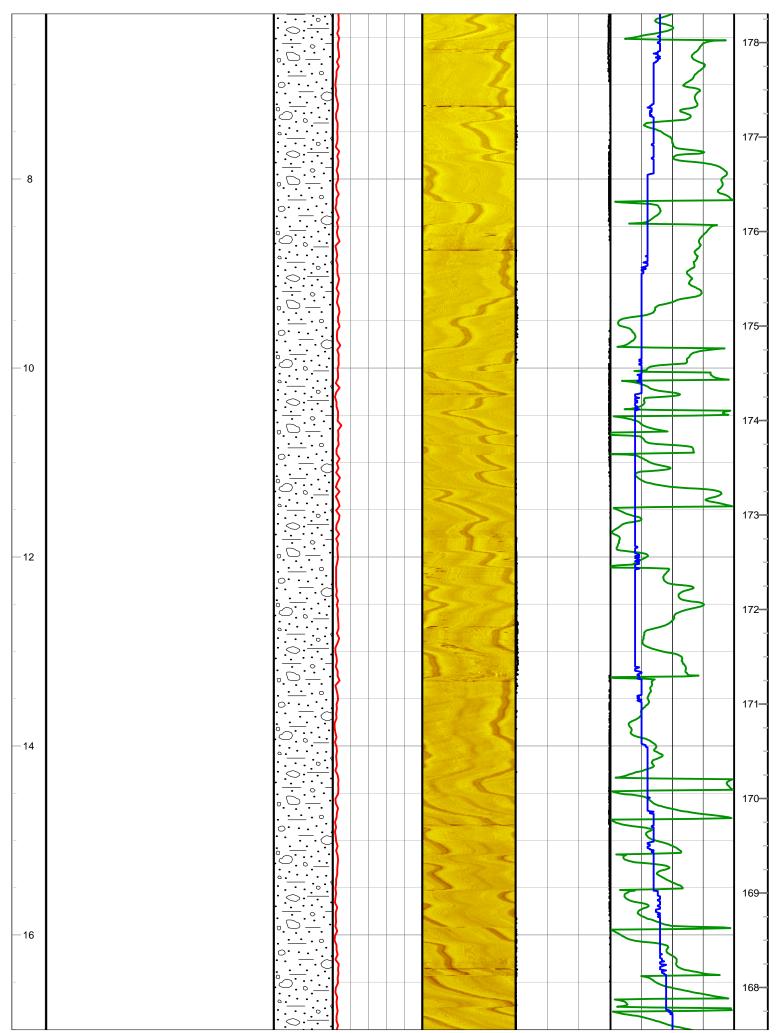
mBGS = metres below ground surface

APPENDIX B

Borehole Geophysical Logs - US-3 & US-7

RECORD OF BOREHOLE US-3

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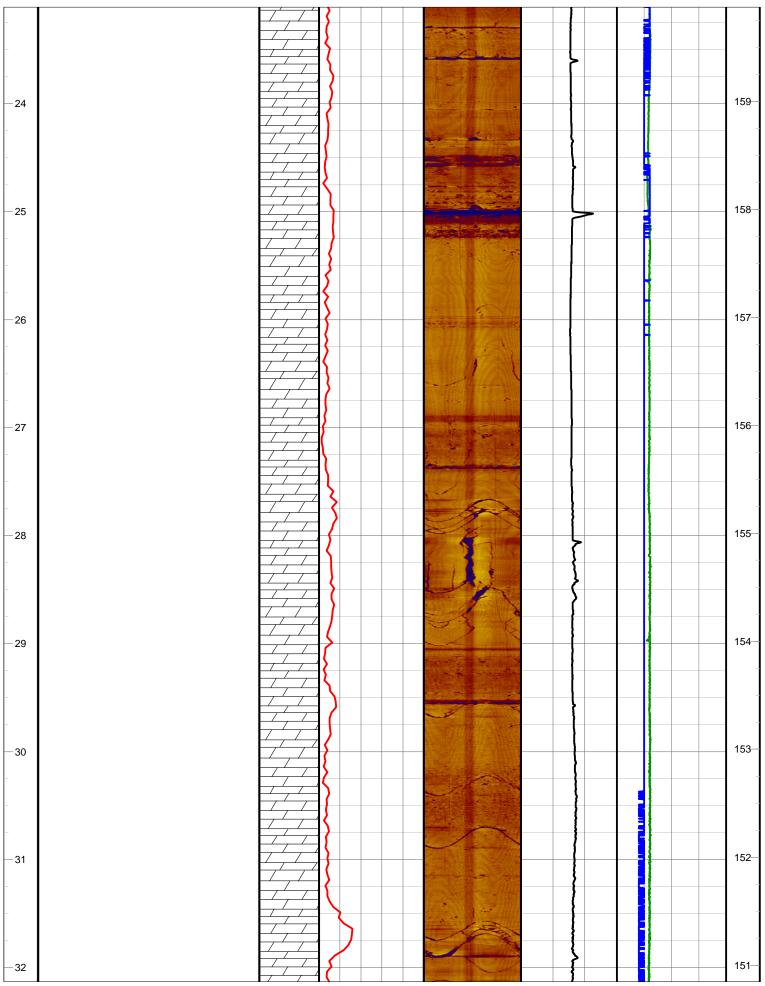
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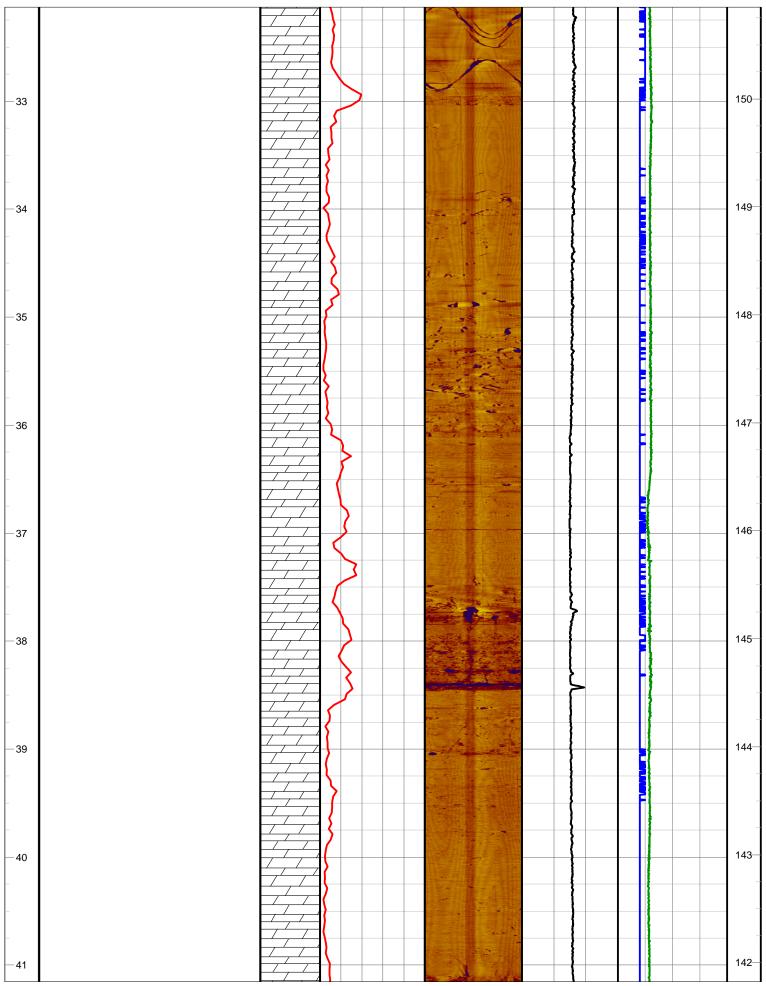
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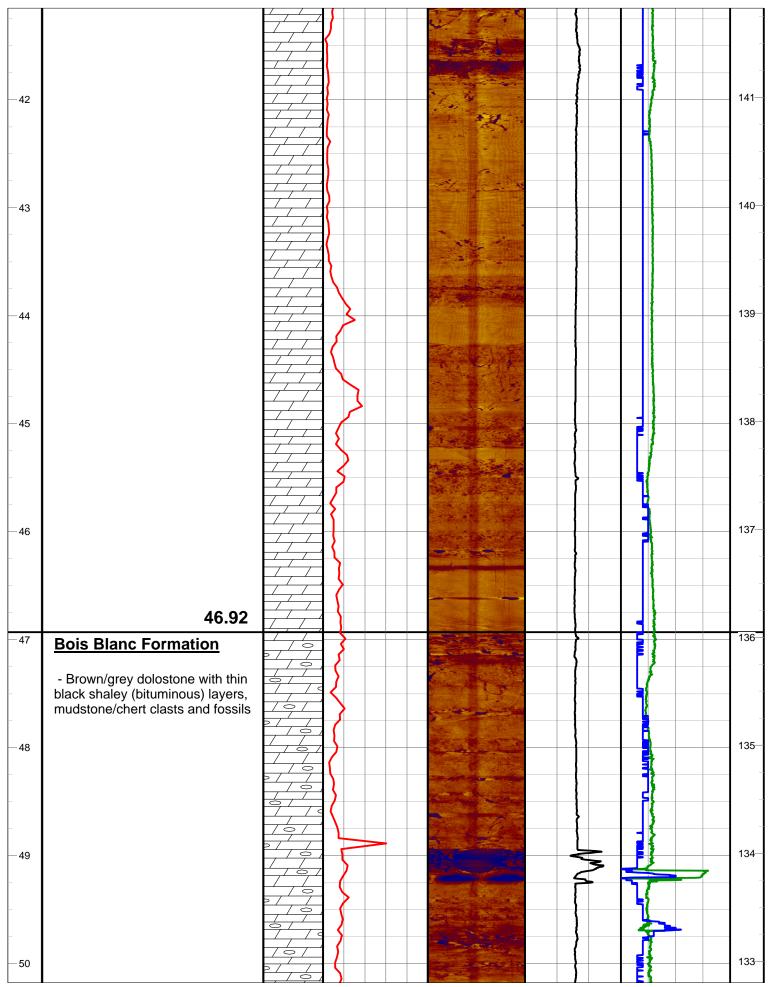
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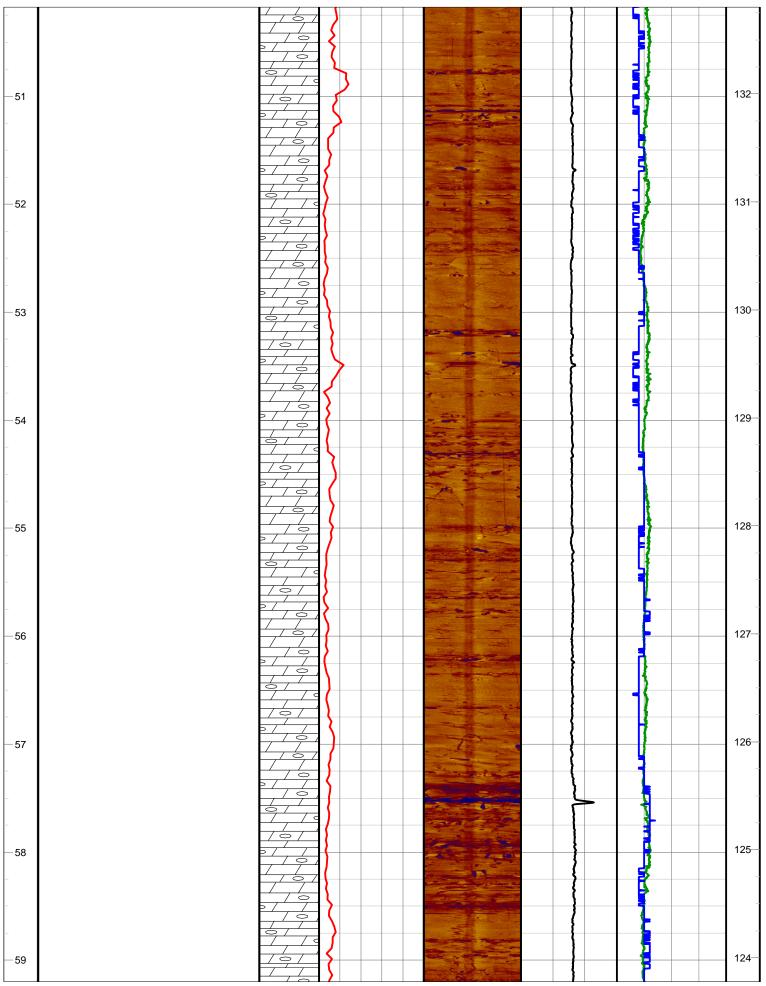
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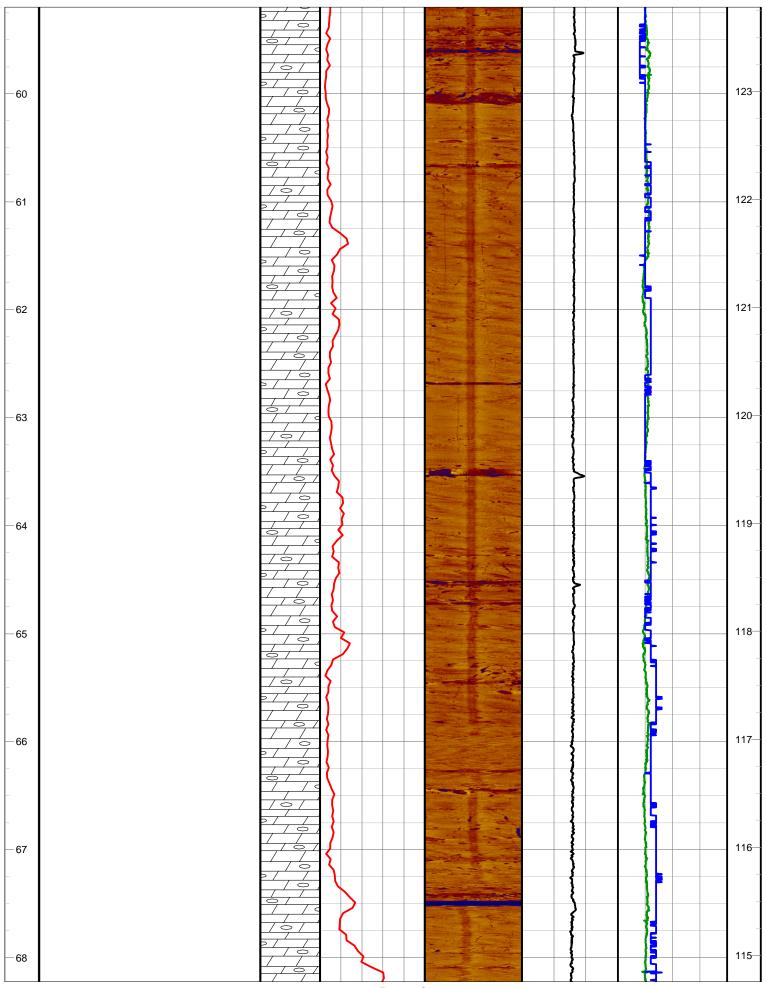
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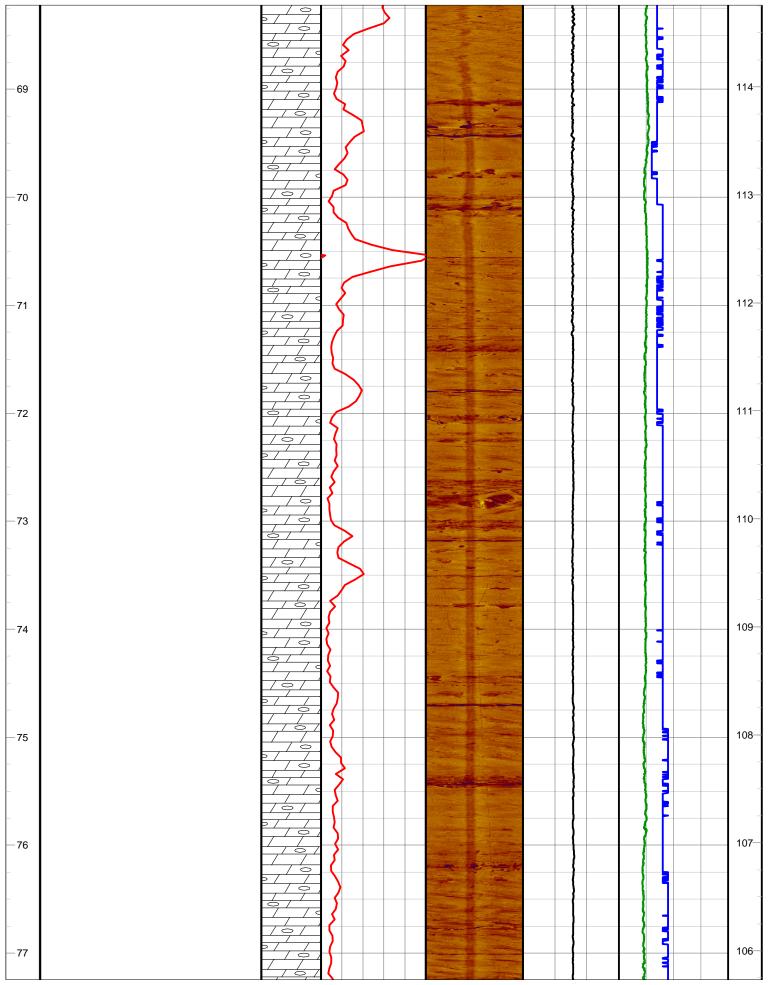


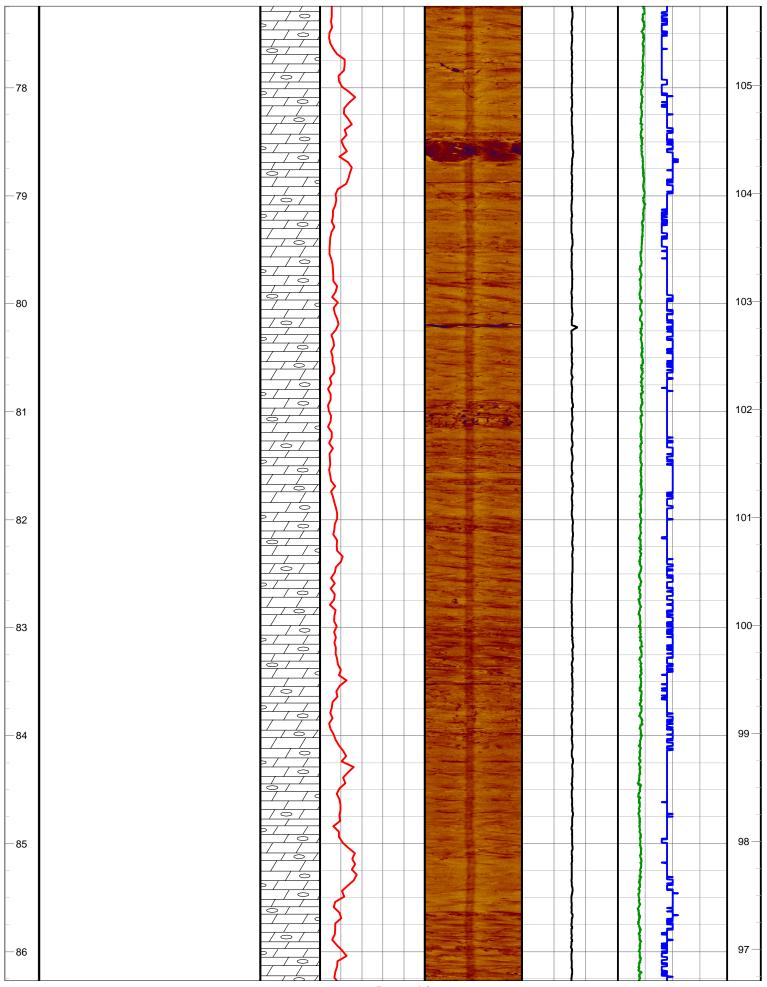












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APPENDIX C

Stratigraphic and Casing Installation Logs - Boreholes US-3 & US-7

*	boi	T	1	lata 'N' value	100	borehole log			ter inf. 'k'	field test special	\$	labo	oratory tes shear			
scale - 1	elev depth 606.29	sample no.	sample type	per ft RQD %	A water level	description	remarks	observation well data	soil/ rock cm/s water press. test	tests & result	natural density s lb/ft ³	istur	strenç psi		specia test	
	603.67					OVERBURDEN (TIII)	(W.L. on compl)									
	566.29 40.00					CONTINUED ON SHEET 2 OF 7	7									

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#	elev	no.	Í	lata 'N' value per ft	ter level cavino	borehole log		ter inf. 'k' soil/ rock	sp	l tests Jecial ests	natural			ory tesi shear trength	\$	ipecia tests
	depth 566.29 40.00	sampie	sample type	ROD %	water and c	description remarks	observation well data	water press test	•		density Ib/ft ³	moisture content %	type	psi results	+	Γ
42 44 46 50 52 44						OVERBURDEN (Till)										
2	546.29 40.00			33		AMHERSTBURG FORMATION Triconed DOLOSTONE grey, fine grained, hard, lightly fractured, massive bedded, some bituminous partings along bedding planes at 90° to core axis 62.8—64.0 ft: irregular vertical joints possible soft seam washed out \pm 68.5 ft: joint (20°)										
	<u>26.29</u> 50.00			65 10 98 84		76.6-76.8 ft: vuggy CONTINUED ON SHEET 3 OF 7				ունուցիումիումիումիումիումիունունը։						

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scale	depth 526.29	sample	sample	RQD %	A wate		CONTINUED FROM SHEET 2 OF 7	observation well data	water press test	¢	results	density lb/ft ³	 type	results	type	resu
22	80.00			84			AMHERSTBURG FORMATION DOLOSTONE: (For Description See Sheet 2 of 7)		0.4 120							
6				83			84.8—84.9 ft: vuggy									
0					·····		87.7 ft: joint (35°)									
2				100					0.22							
				87												
				100	100%							-				
	<u>501.66</u> 104.63			100			AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: prownish grey, fine grained, hard, ightly fractured, finely laminated, nottled, fossillferous, massive bedded, 3 few bituminous partings occur along		0.23							
				100		Ľ	pedding planes at 90° to core axis	-		*************	uninersised in the					
	<u>491,65</u> 114,64			100		L C	MHERSTBURG FORMATION IMESTONE: Ifey to brown, fine grained, hard, ghtly fractured, massive bedded, edding at 90° to core axis				<u>lensbens</u> tusileentus					
	187,82 118,47 186,29 120,00			100		נ (MHERSTBURG FORMATION IMESTONE: For Description See Sheet 4 of 7) CONTINUED ON SHEET 4 OF 7				սեւտերություն, ու նրանությեն ու նրանությունը ու նրանությունը։					

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4	<u>460.99</u> 145.30	······································		100		AMHERSTBURG FORM CORAL LIMESTONE: grey, coarse grain lightly fractured, h massive bedded, s	ed, hard, Ighly fossiliferous,												
Q 2				100			iding at 90° to core	GXİ\$		0.05					0.000000000000000000000000000000000000		4 1 1 1 1 1 1 1 1 1 1		
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0,	156.26 446.29 160.00			100		158.7 ff: vuggy, ca AMHERSTBURG FORM DOLOMITIC LIMESTO (For Description of CONTINUED ON SHEE	ATION NE See Sheet 5 of 7)					**************************	sstaastijnaatida peiden ei seaden ei saaden ei eestijneeda seaden ei deerden ei deerden ei deerden eeden eeden				4 		

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areas	depth 446,29	sample	samp	RQD %	and and	CONTINUED FROM SHEET 4 OF 7	observation well data	water press. test	type	results	density Ib/ft ³	moisture content %	type	results	type	resul
2 4	160.00			100		AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: brownish grey, fine grained. lightly fractured, massive bedded, bedding at 90° to core axis		0.05								
	441,21 165.08			97		BOIS BLANC FORMATION LIMESTONE: grey, fine grained, hard, large chert nodules throughout, lightly fractured, massive bedded,										
77 77				\$ 7		bedding at 90° to core axis		0								
				100				170								
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						193.7 ft: joint (30°) calcite crystals 195.0 ft: thin bituminous partings		0.08		síne de secte en elses						
	06.20			97 100		196.1 ff: joint (40°) calcite crystals 196.5 ft: joint (40°) bituminous coated		0,75		ւհահանակո						
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¥ - 0	elev	le no.	e type	'N' value per ft	ter level	description remarks	ration data	'k' soil/ rock cm/s		pecial tests	natural density	at Ke	\$	shear trength psi	E	pecial tests
scale	depth 406.29	sample	sample	RQD %	Wat Wat		observation well data	water press. test	type	results	ıb∕ft ³	moisture content %	type	results	type	resul
- 202 - 204	200.00			100	·······	BOIS BLANC FORMATION LIMESTONE: grey, fine grained, hard, large chert nodules throughout, lightly fractured, massive bedded. Bedding at 90° to core axis		0.75								
206 208				100												
210 212 212				100												
216 210 222				100		214.0—215.3 ft: vuggy, pyrife and calcite crystals										
20				- .	100%	218.8 ft: joint (10°) very rough, bituminous coated										
22				100				0.72 205								
226 228 300 332 334 336 40			W199889999999999999999999994	100		225.0 ft: joint (30°) very rough, bituminous coated			*****							
30 32		************************	<u> </u>	97									·			
<u>34</u> 36																
38				100					***************		-					
40	366.29 240.00					CONTINUED ON SHEET 7 OF 7		1	a a se a				*****			

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	bo			lata 'N' value	-	borahola	i log	wa	ter inf. /'k'	1	ld tests		labo	T	ory test shear	S	
scale - ft	elev depth	sample no.	sample type	per ft	iter level d caving	description	remarks	observation well data	soll/ rock cm/s		ipecial tests	natural density	1 8		trength psi	A	pecia lests
	366.29	Sar	\$am	RQD %	wat and	CONTINUED FROM SHEET 6 OF	f 7	obse	water press. test	type	results	lb/ft ³	Conte	type	results	type	resu
42	240.00			100	100%	BOIS BLANC FORMATION LIMESTONE: (For Description See Sheet	6 of 7)		0.72 205								
44	362.49 243.80		-			END OF BOREHOLE	C.R. 96%	-									
46							G.R. 70 R										
48																	
<u>60</u>						NOTES 1. Geological contacts are a	100 main ain					-					
						2. Sorehole left open on con 3. For Log of Joints and Disc see following pages	npletion					-					
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lo	oject cation atum		+83N	UNDER 1, 28+58		DPG) h dip 90° d	ole type ole size rilled rawn		ROTARY DIA HQ 11-18 JULY I 28 JULY 88	18	observ compil checke approv	led J. Gra	55
	boi	reho	ie d	ata 'N'	T	borehole log	wa	iter inf.	field tests		labo	oratory tests	T
H • 6	elav	le no.	e type	value per ft	water level and caving	description remarks	observation weil data		special tests	natura	ent %to	shear strength psi	specia tests
scale - ft	depth 603.80	sample no	sample type	RQD %	≪ wat	DATUM = DRILL PLATFORM SURFACE	obser weil	water press, test	-	density Ib/ft ³	moisture content %	results	resu
2	600.75 3.05					Ground Surface				ահուլու			
4 6 8 10 12 14 16 22 24 26 28 30 32						West Bay PVC Casing (Datum El 602.15)			1 1				
ž	566.55 37.25 563.80 40.00			15		PW casing AMHERSTBURG FORMATION DOLOSTONE: ground core (For Description See Sheet 2) CONTINUED ON SHEET 2 OF 8 See Sheet 2 -		- 14					
						Ontario Hydro				and the second	le no.		lg.

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	atum bo	CG reho		ata		bearing borshole log	dra		iter inf.	0.000	ULY 88 (Id tests	3P			B. Luk		
ų.	elev	ou e	type	'N' value per ft	water level and caving	le contra de la cont			'k'	s	ipecial tests	natural]	Τ	shear trength psi		pecia tests
scale - ft	depth 563.80	sample no	sample type	RQD %	Mate and c	description rel CONTINUED FROM SHEET 1 OF 8	marks	observation well data	water press. test	type	results	density Ib/it ³	moisture content %	type	results	type	rest
- 42 44 46	40.00			15		AMHERSTBURG FORMATION DOLOSTONE: grey to buff, fine grained, thin to medium bedded, lightly to highly fractured 41.4-50.0 ft. brecclated rock West Bay Ca 44.2-45.1 ft. vuggy limestone bed	- ising		0.43 5.2								
48 50 52				0		ground ground 50.0-57.25 ft. highly fractured	core 于										
54 56 58			-			ground 58.25-59.6 ft. highly fractured	cole <u>–</u>		No Test (See Not	9 2)							
60 62 64				25	100%	60.6-60.9 ft. sandstone bed (very porous) ground 60.9-61.2 ft. open vuggy zone 63.0-64.0 ft. vuggy limestone bed	core									1147 65 M	
<u>66</u> 68				63		(lost water at 63.5 ft) 64.5-65.8 ft. highly fractured HW c: (See f 67.35-85.1 ft. finely laminated dolostone with bituminous stringers	asing Note 2)	-									
70 72 76 78				57		pa pumping port a ground of	acker		1.7 5.0				- 1999 - 1997			1997	
78	523.80 80.00					ground a	core						n yeri 				

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		rehc c	T	'N' value	level aving	borehole log		iter inf. 'k' soil/ rock	field tests	natural	ΤΤ	shear shear strength	specia
scale - II	elev depth	sample no	sample type	per ft RQD %	water ler and cavi	description remarks	observation well data	water press.	tests	density ib/ft ³	107	psí <u>e</u> results	tests
82	523.80 80.00				W.R	AMHERSTBURG FORMATION LIMESTONE: grey to buff, fine grained, thin to medium bedded, lightly to highly fractured		1.7 5.0		unformente			
84 86				57	100%	85.1- 85.9 ft. vuggy limestone bed (lost water) pressure port #7	-0						
88 90						packer		5.7		***			
92 94						pumping port #6	- 3						
96 98				61	50%			<u>1.0</u> 5.0					
00	<u>503.40</u> 100.40					99.8-100.1 ft. highly fractured (lost water at 100.05 ft) AMHERSTBURG FORMATION LIMESTONE: grey brown, fine grained, fossiliterous,							
04 06	<u>499.40</u> 104.40					AMHERSTBURG FORMATION							
						grey, lithographic, massive bedded, lightly fractured		<u>NII</u> 5.0					
10													
08 10 12 14 16				65	0%	packer							
	486.30 117.50 483.80					AMHERSTBURG FORMATION LIMESTONE: (For Description See Sheet 4)							
2	120.00				****	CONTINUED ON SHEET 4 OF 8		***********					

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=	elev	e no.	type	'N' value per ft	water level			ation		'k' bil/ rock m/s	special tests	natu	iral g	1 %	shear strength psi	speci test
ğ	depth 483.80	sample no	sample type	RQD %	Mater and c			marks voite		ater ress. est	g result	- den: s lb/f	sity <u>7</u> t ³	content %	results	res
-	120.00 481.60 122.20			65		AMHERSTBURG FORMATION UMESTONE: grey, fine grained, fossiliferous, with some bituminous, coated bedding planes, lightly fractured			-	5.0						
126 128 130							pumping port West Bay Ca		0 5	90		3/13/15/15/15/15/15/15/15/15/15/15/15/15/15/				
132 134 36						AMHERSTBURG FORMATION CORAL LIMESTONE: grey to brown, fine to coarse gr highly fosiliferous, massive bedo lightly fractured										
38 40 42 44				89	0%		pressure port	#50		×=====================================						
46	<u>457.50</u> 146.30		······			AMHERSTBURG FORMATION DOLOSTONE: brown, fine grained, massive bedded, lightly fractured			<u> </u>			fr 1				
56	46.80 57.00			76		BOIS BLANC FORMATION (For Description See Sheet 5)	pa	acker								
	43.80 50.00					CONTINUED ON SHEET 5 OF 8										

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lo	roject cation atum	34 CC	+83 iD	N, 28+5i	1.1.1.1	UND NUCLEAR 1 DPG)	dip bearing	90°	See See	vn	;	HQ 11-18 28 JI	ARY DIAI	8		led ed ved	R. Hai J. Gra JG,EC B. Lui	iss kajic	
scale - ft	elev depth	rehc ou eidues	sample type	lata 'N' value per ft RQD	water level and caving	description	borehole i	og rømar	ks	observation well data	er inf. 'k' soil/ rock cm/s water	s	id tests pecial tests	natural density ib/ft ³	8%	s	ory tests shear trength psi	s	pecia tests
- 162 - 164 -	443.80 160.00		G	% 76	W.R.	CONTINUED FROM	A SHEET 4 OF	8 West Bay Casing		** -+	press. test	type	results			type	results	(ypa	resi
166 - 168 - 170 - 172								ground corr pumping port #4	· -Ŧ		<u>0.3</u> 5.0								
174 176 78 80 82				88	0%	BOIS BLANC FORM LIMESTONE: brown to grey, fine fossiliferous, chert n massive bedded, lig thin shaly partings o	grained, odules throughd htly fractured,			φ		о то							
84 86 88 90 92 94								packer			NII 4.5								
98	<u>403.80</u> 200.00					CONTINUED ON SH	EET 6 OF 8	ground core		میں میں ایک	Name and Association and Associatio and Association and Association and Association and Associ				VANAA				
	3			 		Ontario H & Construction I	ydro	geotei			data			hol	e no. US-7			lg.	

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- 1	bor	ehd	le d		T	borshole log		wa	ter inf.	tie	ld tests		lab	orate	ory tests	ļ	
	iløv	sampie no.	sample type	'N' value per ft	er level I caving	description re	marks	observation well data	'k' soll/ rock cm/s		pecial tests	naturai density	57	s	shear trength psi		pecial tests
4(epth 03.80 00.00	Sam	samp	ROD %	Wate W.R.	CONTINUED FROM SHEET 5 OF 8		obse	water press. test	type	results	Ιb/π ³	DE 20	type	results	type	resu
02																	
04 06				64	0%	pumping port	#3	8									
08									0.45 4.5								
10 12													-				
14						pressure port	#3	ō									
16				93		BOIS BLANC FORMATION LIMESTONE: brown to grey, fine grained,			· · · · · · · · · · · · · · · · · · ·								
8						tossiliferous, chert nodules throughout, massive bedded, lightly fractured, thin shaly partings occur throughout	T		<u>NII</u> 4.5								
22						p	ecker _					-					
14					25%					*********	~	· •					
8			1						20 4.5			-					
<u>io</u>												***					
2				91		pumping port	#2	8			<u>, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13</u>	-					
32 34 36									NI 4.5								
											13.13.15.15.1.1.2	-	4 P 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2				
240	<u>3.80</u>).00			•		CONTINUED ON SHEET 7 OF 8		. .			ւուրություն		**************************************		1999		
			1994 (1995)		and a												
						Ontario Hydro						hol	e no. US-7			lg.	
	k.					n & Construction Branch geo ring & Architecture Dept	otechn	ical	data	she	et	she	US-7 net	6	0F 8	ig.	

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scale - ft	elev depth 363.80	Γ	Π	'N' value per ft	water level and caving	boreholé l			ter inf. 'k' soil/ rock cm/s	51	d tests pecial tests	natural		shear strength psi		spe te:	
		sample no.	sample type	ROD %	× water and c	description CONTINUED FROM SHEET 6 OI	remarks F 8	observation well data	water press. test	type	results	density Ib/It ³	moisture content %	type	results	type	re
242	240.00						West Bay Casing										
244				91			pressure port #2										
246			-	11 min 4147 min waar wa			_		NII 4.5								
250							packer										
252 - 254							لـ pressure port #1	-0		render de la render de							
256																	
~ 258 ~				89		BOIS BLANC FORMATION CHERTY LIMESTONE: brown to grey, fine grained,	pumping port #1	-8	<u>Nil</u> 4.5			-					
260					25%	fossiliferous, chert nodules through massive bedded, lightly fractured, thin shaly partings occur throughout						-					
262 - 264												-			-		
266 - 268			f				End Cap		18			-			49 (M) ()		
- 270							(El 267.52)		1.8 4.5								
<u>272</u>												-					
- 270 272 274 274 276 276				95							<u>authanlun</u>		******				
1									<u>Ni</u> 4.5		hreefnanskaaaskaandaanskaandaanskaandaandaandaanskaandaanskaandaanskaandaanskaandaanskaandaanskaandaanskaandaa						
280	323.80 280.00					CONTINUED ON SHEET 8 OF 8		·			<u>iharilant</u> a						
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datum CGD borehole data					bearing dra borehole log	water					approv labo	oved B. Luk			
# elev	a no.	type	'N' value per ft	water level and caving		ation lata	'k' soil/ rock cm/s	special tests		natural	2%	shear strength psi			ipecia tests
depth	sample no	sample type	ROD	water and c	description remarks	observation well data	water press.	type	results	density Ib/ft ³	moisture content %	type	results	type	resi
323.80 280.00				W.R.	CONTINUED FROM SHEET 7 OF 8 BOIS BLANC FORMATION		test			E					
282					CHERTY LIMESTONE: brown to grey, fine grained, fossiliferous, chert nodules throughout,		N								
284			95		massive bedded, lightly fractured, thin shaly partings occur throughout										
286															
288				-											
288				25%			<u>Nii</u> 4.5								
290 292															
292	*******		97												
294															
296										hunda					
<u>305.70</u>															
297.10					END OF BOREHOLE C.R. 98 %					Ē					
<u>306.70</u> 298 297.10					 NOTES: 1. All geological contacts are approximate 2. Due to sections of fractured rock HW casing drilled to 67.85 ft and grouted 3. For details of structural features see Log of Discontinuities 4. West Bay Multi-Level Casing installed Nov, 1988 5. Water pressure test performed using constant head method 										

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