Technical Report

Title: ***Drilling and Logging of US-8***

Document ID: **TR-07-19**

Author: **Glen Briscoe**

Revision: **0**

Date: **March 10, 2009**

DGR Site Characterization Document
Intera Engineering Project 06-219

Intera Engineering DGR Site Characterization Document		
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Author(s):	Glen Briscoe	
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0	March 10, 2009	Initial Release

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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 on Lake Huron, 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 drilling and logging of US-8 including a description of drilling methods, drilling fluid management, surface casing installation, chip sample logging, borehole development, drilling waste disposal, borehole orientation testing, and borehole geophysical logging.

Work described in this Technical Report was completed in accordance with Test Plan TP-07-12 – Drilling and Logging of US-8 (Intera Engineering Ltd., 2007a), which was prepared following the general requirements of the DGR Project Quality Plan (Intera Engineering Ltd., 2007b).

2 Background

The DGR facility is proposed to be constructed at depths of 650 to 700 metres below ground surface (mBGS) 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 180 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 180 mBGS are being established to monitor shallow to intermediate bedrock conditions.

Six existing 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 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 (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), pumping/development of open boreholes, and acoustic televiewer, natural gamma and video logging of open boreholes US-3 and US-7. 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. The new monitoring wells (i.e., US-3 and US-7) will provide shallow bedrock monitoring intervals in the vicinity of the proposed DGR. TP-06-03 (Intera Engineering Ltd., 2007c) describes the refurbishment of boreholes US-3 and US-7.

US-8 was constructed as an intermediate depth monitoring well to allow for long-term monitoring of formation pressures and collection of groundwater samples from packer-isolated test intervals above the Salina Formation F-Unit shale.

The Ontario Ministry of Natural Resources (MNR) confirmed that drilling of US-8 to a depth of approximately 180 mBGS at the Bruce site did not require licensing under the MNR. Therefore the Oil, Gas and Salt Resources of Ontario, Provincial Operating Standards did not apply to drilling of US-8. The US-8 drilling program was completed in accordance with the Ontario Ministry of the Environment (MOE), Regulation 903 requirements.

OPG DGR
Site Characterization Plan

Legend

- ◑ Location of US-8
- ◑ Location of DGR-1/2 and US-series Wells
- ▭ Buildings
- — Roads
- ┼ Railway
- ‧‧‧ Transmission Line
- ▨ Pits or Landfills
- — Stream or Drainage

Location of US-8

Figure 1

N

Scale 1:20,000 (approx.)

0 125 250 500 750 1,000 Meters

Date: 25/01/2008	Drawn: NKP
Project: 06-219	Checked: GDB

P:/Projects/2006/06-219/QMS_DGR/TM_Working Files/
TM-07-19/06-219_Location of US-8.mxd

Projection: UTM NAD 83 Zone 17

Data Credits:
NRVIS/OBM, MNR, Ontario Power Generation, Bruce Power

3 Drilling and Borehole Development

The purpose of drilling US-8 was to confirm bedrock stratigraphy and provide access for borehole geophysical testing and future multi-level sampling, monitoring and testing of the upper bedrock to the Salina Formation F-Unit shale. A borehole diameter of 96 mm (3.75 inch) was selected in an effort to ensure successful completion of these tasks. US-8 will provide monitoring intervals from approximately 5 m below top of bedrock (~10 to 15 mBGS) to the Salina F-Unit shale.

Prior to rotary drilling, a vacuum truck was used to “daylight” the borehole from ground surface to native overburden material (approx. 2.3 mBGS) to ensure no underground utilities would be encountered. US-8 was then rotary drilled from 2.3 mBGS to approximately 13.4 mBGS (4.9 metres into bedrock) with a 178 mm diameter tri-cone drill bit to facilitate surface casing installation. Following surface casing installation, the borehole was rotary drilled from 13.4 mBGS to approximately 200.4 mBGS with a 96 mm tri-cone drill bit.

The drilling of US-8 was completed in November 2007 in accordance with Ontario Regulation 903 requirements. A copy of the completed MOE Well Record for US-8 is included in Appendix A. The MOE Well Tag No. for US-8 is A063001.

3.1 Drilling Methods

All drilling activities for US-8 were completed using a truck-mounted Versa-Drill (Model: V2000NG manufactured in 2006) equipped with a hydraulic top-head power swivel. For surface casing drilling the bit rotation speed was approximately 90 to 100 revolutions per minute (RPM) with a torque of approximately ~2.0 kN-m (1500 foot pounds). The stratigraphy encountered during surface casing drilling included approximately 2.3 m of gravel fill underlain by approximately 6.2 m of unconsolidated till over the Lucas Formation dolostone.

For bedrock drilling with the 96 mm diameter tri-cone bit, the bit rotation speed averaged 100 to 120 RPM with a torque of approximately ~1.5 kN-m (1100 foot pounds). The rate of drilling advance ranged from about 3 to 12 m/hr depending on the rock formation and bit condition. The tri-cone drill bits were replaced as they became worn from drilling.

- Bit #1 – drilled from 13.4 to 65.1 mBGS
- Bit #2 – drilled from 65.1 to 109.0 mBGS
- Bit #3 – drilled from 109.0 to 163.7 mBGS
- Bit #4 – drilled from 163.7 to 200.4 mBGS

3.2 Surface Casing Installation

Following completion of the 178 mm diameter borehole to 13.4 mBGS, a 114 mm inside diameter steel surface casing was installed in the following manner:

- The surface casing was extended from the bottom of the borehole (13.4 mBGS) to approximately 0.3 m above ground surface.

- Centralizers were installed on the bottom 1.5 m casing interval to ensure the casing was centred in the borehole. Two 6.1 m casing intervals were welded onto the 1.5 m interval for a total of 13.7 m of steel casing.

- The casing was sealed in place using Type 10 St. Mary's Portland Cement. The cementitious grout was mixed at surface and injected using a tremie pipe down to the bottom of the borehole such that the casing annulus was sealed from the bottom of the borehole to ground surface.

- Three grout samples were collected at the beginning, middle and end of grouting. The samples were inspected for consistency and allowed to cure for 24 hours. All three samples passed final inspection.

- The grout in the borehole was allowed to cure for five days before commencing bedrock drilling below the bottom of casing.

- Following borehole drilling and development, the borehole was completed by extending the surface casing to approximately 1 m above ground surface.

3.3 Drilling Fluid Management

All drilling fluids were prepared using treated Lake Huron water which was obtained from Building B-19 (Spent Solvent Treatment Facility). Water was obtained from a service outlet on the southeast side of the building that is normally used for filling water tankers. Treated Lake Huron water was trucked from Building B-19 by Davidson Drilling and pumped into a 5.5 m^3 capacity drilling fluid tank at the US-8 drill site.

The 178 mm diameter borehole drilled from ground surface to 13.4 mBGS for surface casing installation was drilled using untraced Lake Huron water with no drilling fluid additives. All borehole drilling fluids and cuttings were diverted from the borehole into storage tanks such that the cuttings could be settled out and the drilling fluid re-used for drilling operations. No significant fluid loss or gain was noted during the surface casing drilling.

3.3.1 Drilling Fluid Preparation

Prior to drilling the 96 mm diameter borehole from 13.4 mBGS to depth, drilling fluids were prepared by adding Baroid QUIK-GEL®, a bentonite drilling product, to the traced potable water. The bentonite was added to the water to create a high viscosity drilling mud to aid in drill cuttings removal from the borehole. Sodium Fluorescein (NaFl) was used to trace the drilling fluids for US-8 to the same target concentrations used for drilling DGR-1 and DGR-2. Intera retained responsibility for maintenance of the NaFl target tracer concentration of 1 mg/L and Davidson Drilling was responsible for mixing and maintaining the drilling fluids. Once rotary drilling started, the physical properties of the drilling fluids were monitored for fluid density and viscosity by Davidson Drilling.

3.3.2 Tracer Preparation

NaFl stock solutions were prepared at concentrations of 10 g/L using treated Lake Huron water. NaFl stock solutions were used for dosing the drilling fluid tank to achieve the target drilling fluid concentration of 1 mg/L and for preparing NaFl drilling water standards.

NaFl drilling water standards were prepared at concentrations bracketing the target drilling fluid concentration of 1 mg/L. Standards were prepared from NaFl stock solutions at concentrations of 10, 100, 500, 1000 and 1500 µg/L. The standards were then diluted 1:10 prior to calibration of the fluorometer.

These standards were identified as NaFl-mmmm.m, where NaFl is sodium fluorescein and mmmm.m is the concentration in µg/L. In addition to a name, drilling water standards had the following information on the label:

1. date of preparation;
2. name of the person who prepared it;

3. scientific notebook name and page number showing the record of the standard preparation; and
4. requirement to store standard in a dark place out of direct light.

NaFl standards were stored in the field lab refrigerator, at approximately 4°C.

Records of the above tracer preparation were retained in scientific notebooks (ID: SN-07-12-Drilling & Logging of US-8).

3.3.3 Sample Collection

Samples of the prepared drilling fluid were collected for NaFl analyses two times per day during active bedrock drilling. Drilling fluid tracer samples collected from the drill-water tank (DWT) were identified by DWT-XXXX-YY where XXXX is the borehole identifier and YY is the index number of the sample. All drilling fluid samples required the time and date of sampling to be recorded on the sample label, as well as the name of the person who collected the sample.

Eight representative samples of Lake Huron water used as drilling fluid were also collected and submitted for tritium analysis. The Lake Huron water samples were collected from the water truck discharge line prior to mixing with drilling fluid additives. Two representative samples of Lake Huron water (DWT-US8-02 and DWT-US8-11) were also submitted for analyses of major and trace metals, major anions and environmental isotopes (^{18}O and ^{2}H) during the drilling program.

Samples collected for NaFl analyses were collected as well-mixed grab samples in 250 millilitre (mL) high density polyethylene (HDPE) containers that were protected from heat and light and stored in refrigerators. The samples were allowed to settle for a reasonable period of time (i.e. up to 3 or 4 hours) to remove suspended fine particulate. Approximately 20 mL of sample was filtered with a 0.45µm filter using a syringe. A 2 mL sample of the filtered drilling fluid was collected with a 1-5 mL pipettor (Measurement and Test Equipment [MTE] ID: PIP-01) and was mixed with 18 mL of deionized water, which was collected with a 2-10 mL pipettor (MTE ID: PIP-02), to generate a 20 mL water sample for analysis of NaFl content.

Samples of drilling water were collected for specific analytical tests in high density polyethylene (HDPE) bottles. Samples were kept in the refrigerators in the Core Storage Facility, at approximately 4°C until analysis or shipment to laboratories. Archived water samples were also stored in the Core Storage Facility refrigerators. Table 1 summarizes the sample container and preservation requirements for the analysis of selected drilling fluid parameters.

Table 1 Summary of Sample Requirements for Drilling Fluids

Analytes	***Bottle Type***	***Volume (mL)***	***Preservation***	***Headspace***
NaFl	HDPE	250	None required	No
Major and Trace Metals	HDPE	60	Filter to 0.45 μm Acidify to pH <2 with Nitric Acid (~5 drops of 50% HNO_3); 4°C	No
Major Anions	HDPE	60	4°C	
^{18}O and ^{2}H in water	HDPE	30	None required	No
Tritium	HDPE	250	None required	No
Archive	HDPE	1000	4°C	No

3.3.4 Sample Analyses

NaFl concentrations were measured in the field laboratory using a Turner Designs Trilogy Model 7200-000 fluorometer (MTE ID: FL-01). The fluorometer was calibrated once per batch of NaFl tracer stock solution mixed using prepared NaFl standards. The NaFl standards were prepared using treated Lake Huron water. The calibration was checked using manufacturer-prepared solid state standards each time the fluorometer was used to measure drilling fluid tracer concentrations. Both standards and collected samples were diluted 1:10 to optimize tracer measurement within the fluorometer linearity range.

NaFl tracer concentrations were measured with a linearity of $0.99R^2$ and a lower detection limit that was not more the 1% of drilling fluid tracer concentrations. Both of these tolerance levels were met by the Turner fluorometer assuming a drilling fluid source concentration of 1 mg/L and 10:1 dilution on prepared drilling fluid samples and standards (note maximum linear range for NaFl detection with the Trilogy Model 7200-000 fluorometer is about 150 µg/L).

Records of the above NaFl analyses and fluorometer calibrations were retained in scientific notebook (ID: SN-07-12-Drilling & Logging of US-8). Results of the NaFl analyses are presented in Table B.1 in Appendix B.

Tritium analyses were completed by the Environmental Isotope Laboratory, University of Waterloo in Waterloo, Ontario. Major and Trace Metals and Major Anions analyses were completed by Activation Laboratories Ltd. in Ancaster, Ontario. ^{18}O and ^{2}H analyses were completed by the University of Ottawa in Ottawa, Ontario. Results of the laboratory analyses are presented in Table B.2 in Appendix B. Plots of NaFl and tritium versus depth are presented in Figure C.1 in Appendix C.

3.4 Zones of Drilling Fluid Loss

Zones of drilling fluid loss were observed and noted during the drilling of US-8. Zones of increased drilling fluid loss were documented in the scientific notebook (ID: SN-07-12-Drilling & Logging of US-8) for future reference and consideration when designing the Westbay MP38 multi-level groundwater monitoring system. Zones of drilling fluid loss were noted in the following formations at the following approximate depths below ground surface:

- Lucas Formation - 28 mBGS;
- Bois Blanc Formation - 97 to 109 mBGS;
- Bois Blanc Formation - 125 to 136 mBGS; and
- Bass Islands Formation - 155 to 160 mBGS.

Slow steady fluid loss was reported for the majority of the rotary drilling of US-8. Drilling fluid losses in US-8 ranged from about 0.5 to 1.0 m^3/hr.

3.5 Borehole Development

Following completion of drilling, the borehole was developed to remove drilling fluid from the borehole and the formation. The borehole was developed by pumping approximately two borehole volumes of traced Lake Huron water into the bottom of the borehole to displace the drilling fluid. The drilling fluid was collected at surface and disposed off site. Once the drilling fluid was displaced, the borehole was further developed by air lifting the traced Lake Huron water and formation water from the borehole with the drill rig. The traced Lake Huron water and formation water was also captured at surface for off site disposal. In total over 30 borehole volumes were purged from the well during development.

Drilling fluid tracer (NaFl) concentrations and turbidity were monitored during development to determine when sufficient development had been completed. The duration of borehole development was determined based on the removal of cuttings (judged by the visible clarity of development water), concentration of tracer in the pumped fluids and cumulative volume of water pumped from the borehole. Results of the NaFl analyses are presented in Table B.3 in Appendix B.

At the end of borehole development a Grundfos pump was used to collect one final sample (OHGW-US8-01) for lab analyses of major and trace metals, major anions, tritium and environmental isotopes (^{18}O and ^{2}H). Results of the laboratory analyses for OHGW-US8-01 are included in Table B.2 in Appendix B.

3.6 Drilling Waste Disposal

Drilling fluid and cuttings generated during the field program were captured and contained in tanks on site. Borehole cuttings and drilling fluids produced during US-8 drilling operations were considered to be inert fill and were transported offsite using a vacuum truck and disposed of as inert fill. Water produced during borehole development was also disposed off site.

4 Logging

Logging of US-8 included chip sample logging, borehole orientation testing, and borehole geophysical logging.

4.1 Chip Sample Logging

Drill cutting samples were collected every 3 metres during bedrock drilling and placed in clear re-sealable sample bags for further inspection and logging. Each sample bag was clearly labelled with permanent marker stating the borehole name (US-8), date, time, depth of sample and sample collector.

All samples were logged for general bedrock stratigraphy and organized in a box for storage and future reference. Bedrock stratigraphy followed the nomenclature of Armstrong and Carter (2006). Chip sample logging was recorded in scientific notebook (ID: SN-07-12-Drilling & Logging of US-8). A summary of the chip samples collected and sample descriptions are presented in the borehole log in Appendix D.

4.2 Borehole Orientation Testing

A borehole orientation test was to be completed during the geophysical logging of the hole with an acoustic televiewer. Due to the borehole conditions encountered during logging, the acoustic televiewer tool could not be run to the bottom of the hole and therefore borehole orientation testing was not completed on US-8. Borehole US-8 is assumed to be essentially vertical.

4.3 Borehole Geophysics

After drilling and borehole development were completed, a limited suite of borehole geophysical logs were to be conducted prior to installation of a Westbay MP38 multilevel monitoring system. The suite of borehole geophysical logs that were to be completed in US-8 included acoustic televiewer (ATV), natural gamma and borehole video.

The geophysical logging of US-8 was completed by Lotowater Technical Services Inc. of Paris, Ontario. A borehole video log was completed by Lotowater on November 28 and 29 2007 using a Laval R2000 DUAL CAM camera. The video log was referenced to ground surface, accounting for the 0.99 metre stick up well casing. The video log was reviewed by Intera personnel to document borehole conditions prior to designing the Westbay MP38 multi-level groundwater monitoring system. Borehole features such as smooth competent zones, fractures, highly broken rock, breakout zones and voids were noted. Video log review notes are included as Table D.1 in Appendix D. The video log is available on DVD upon request.

A natural gamma log was also completed on November 29, 2007 using a Mount Sopris Instruments Co. Inc. 2 PGA Gamma logger. The natural gamma log data are presented on the borehole log found in Appendix D. Borehole geophysical logging followed the general procedures as described for video and natural gamma logging in TP-07-05 (Intera Engineering Ltd., 2007d).

The ATV log was not completed for US-8 due to adverse borehole conditions encountered during logging. During initial logging, the ATV tool was temporarily lodged in the borehole at depths of approximately 50 and 68 m bgs. The video log showed zones of borehole enlargement, and loose rock at those depths and deeper. Consequently, the ATV log was not completed for fear that the ATV tool would become lodged in the borehole.

5 Data Quality and Use

Data on bedrock formation nomenclature and occurrence in this Technical Report are based on rock chip sample logging and expert geological review of conditions observed in borehole DGR-1 at the Bruce site. Many contacts between individual bedrock formations in DGR-1 and US-8 are gradational rather than sharp and the selected contacts reflect the interpretation of Intera geologists based on the US-8 borehole chip and geophysical logs and the results of detailed core and geophysical logging from DGR-1.

The data presented in this Technical Report are suitable for providing the framework for development of Phase 1 geological, hydrogeological and geomechanical descriptive site models of the Bruce DGR site. The data will also be used to design the Westbay MP38 multilevel monitoring system for US-8.

6 References

Armstrong, D. K. and T. R. Carter, 2006. An Updated Guide to the Subsurface Paleozoic Stratigraphy of Southern Ontario, Ontario Geological Survey, Open File Report 6191, 214 p.

Intera Engineering Ltd., 2007a. Test Plan for Drilling and Logging of US-8, TP-07-12, Revision 0, November 9, Ottawa.

Intera Engineering Ltd., 2007b. Project Quality Plan, DGR Site Characterization, Revision 3, January 17, Ottawa.

Intera Engineering Ltd., 2007c. Test Plan for Refurbishment of Boreholes US-3 and US-7, TP-06-03, Revision 2, November 8, Ottawa.

Intera Engineering Ltd., 2007d. Test Plan for DGR-1and DGR-2 Borehole Geophysical Logging, TP-07-05, Revision 1, April 27, Ottawa.

Intera Engineering Ltd., 2006. Geoscientific Site Characterization Plan, OPG's Deep Geologic Repository for Low and Intermediate Level Waste, Report INTERA 05-220-1, OPG 00216-REP-03902-00002-R00, April, Ottawa.

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. AECL Chalk River Laboratories, Chalk River, Ontario, Report No. COG-95-248-I.

APPENDIX A

MOE Well Record

Ontario Ministry of the Environment

Well Tag No. *(Place Sticker and/or Print Below)*
A 063001
A063001

Well Record

Regulation 903 Ontario Water Resources Act

Page ______ of ______

Well Owner's Information

First Name OPG	Last Name	E-mail Address	☐ Well Constructed by Well Owner

Mailing Address (Street Number/Name, RR) c/o Intera Engineering, 1 Raymond St. Suite 200	Municipality Ottawa	Province ON	Postal Code K1R1A2	Telephone No. *(inc. area code)* 6132382525

Part A Construction and/or Major Alteration of a Well

Address of Well Location (Street Number/Name, RR) Bruce Nuclear Site	Township Bruce	Lot 25	Concession LR

County/District/Municipality BRUCE	City/Town/Village TIVERTON	Province **Ontario**	Postal Code

UTM Coordinates NAD 83	Zone 17	Easting 453168	Northing 4907744	GPS Unit Make Garmin eTREX	Model Venture	Mode of Operation: ☒ Undifferentiated ☐ Averaged ☐ Differentiated, specify ________

Overburden and Bedrock Materials *(see instructions on the back of this form)*

General Colour	Most Common Material	Other Materials	General Description	Depth (~~Metres~~) Ft. From	To
Brown	Fill	Clay, stones		0	8'
Grey	Clay	Stones	Hard	8'	28'
Brown	Limestone			28'	44'
Brown	Limestone with	grey layers		44'	640'
Grey/Blue	Shale			640'	656'

Annular Space/Abandonment Sealing Record

Depth Set at (~~Metres~~) From	To Ft.	Type of Sealant Used *(Material and Type)*	Volume Placed *(Cubic Metres)*
0	44'	Cement	

Results of Well Yield Testing

Check box if after test of well yield, water was:
☒ Clear and sand free
☐ Cannot develop to sand-free state

If pumping discontinued, give reason:

Pumping test method

Pump intake set at *(Metres)*

Pumping rate *(Litres/min)*

Duration of pumping
____ hrs + ____ min

Final water level end of pumping *(Metres)*

Recommended pump type
☐ Shallow ☐ Deep

Recommended pump depth
________ Metres

Recommended pump rate *(Litres/min)*

If flowing give rate *(Litres/min)*

Draw Down Time *(Min)*	Water Level *(Metres)*	Recovery Time *(Min)*	Water Level *(Metres)*
Static Level		Static Level	
1		1	
2		2	
3		3	
4		4	
5		5	
10		10	
15		15	
20		20	
25		25	
30		30	
40		40	
50		50	
60		60	

Method of Construction

☐ Cable Tool
☒ Rotary (Conventional)
☐ Rotary (Reverse)
☐ Rotary (Air)
☐ Air percussion
☐ Other, *specify* ________
☐ Diamond
☐ Jetting
☐ Driving
☐ Digging
☐ Boring

Water Use

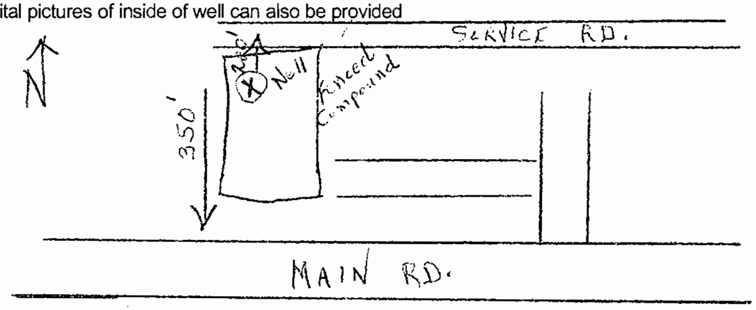
☐ Public
☐ Domestic
☐ Livestock
☐ Irrigation
☐ Industrial
☐ Other, *specify* ________
☐ Commercial
☐ Municipal
☐ Test Hole
☐ Cooling & Air Conditioning
☒ Not used
☐ Dewatering
☐ Monitoring

Status of Well

☐ Water Supply
☐ Replacement Well
☐ Test Hole
☐ Recharge Well
☐ Dewatering Well
☐ Abandoned, Insufficient Supply
☐ Abandoned, Poor Water Quality
☐ Abandoned, other, *specify* ________
☒ Observation and/or Monitoring Hole
☐ Alteration (Construction)
☐ Other, *specify* ________

Location of Well

Please provide a map below showing:
- all property boundaries, and measurements sufficient to locate the well in relation to fixed points,
- an arrow indicating the North direction
- detailed drawings can be provided as attachments no larger than legal size (8.5" by 14")
- vidigital pictures of inside of well can also be provided



Water Details

Water found at Depth		Kind of Water
82	~~Metres~~ Ft. ☐ Gas	☒ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
410	~~Metres~~ Ft. ☐ Gas	☒ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
	Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals

Casing Used	Screen Used
☐ Galvanized	☐ Galvanized
☒ Steel	☐ Steel
☐ Fibreglass	☐ Fibreglass
☐ Plastic	☐ Plastic
☐ Concrete	☐ Concrete

No Casing and Screen Used
☒ Open Hole

Disinfected?
☐ Yes ☐ No

Casing and Well Details

Diameter of the Hole *(Centimetres)*: 4-inch
Depth of the Hole (~~Metres~~) Ft.: 656
Wall Thickness (~~Metres~~): .188"
Inside Diameter of the Casing (~~Metres~~): 3 3/4"
Depth of the Casing (~~Metres~~) Ft.: 44

Date Well Completed *(yyyy/mm/dd)* 2007/11/24	Was the well owner's information package delivered? ☐ Yes ☐ No	Date the Well Record and Package Delivered to Well Owner *(yyyy/mm/dd)*

Well Contractor and Well Technician Information

Business Name of Well Contractor DAVIDSON WELL DRILLING LIMITED	Well Contractor's Licence No. 1737

Business Address (Street No./Name, number, RR) 147 North St. W.	Municipality WINGHAM

Province ON	Postal Code N0G2W0	Business E-mail Address info@davidsondrilling.com

Bus.Telephone No. *(inc. area code)* 5193571960	Name of Well Technician (Last Name, First Name) FENTON DOUG

Well Technician's Licence No. 2103	Signature of Technician J. C. Riordan	Date Submitted *(yyyy/mm/dd)* 2007/12/06

Ministry Use Only

Audit No. **Z 75443**	Well Contractor No.
Date Received *(yyyy/mm/dd)*	Date of Inspection *(yyyy/mm/dd)*
Remarks	

0506E (11/2006)

Well Owner's Copy

© Queen's Printer for Ontario, 2006

APPENDIX B

Summary Tables of Drilling Fluid Field Measurements and Laboratory Analyses for US-8

Table B.1 – Summary of Sodium Fluoresein Measurements for US-8 Drilling

Table B. 2 – Summary of Laboratory Analysis for US-8 Fluid Samples

Table B.3 – Summary of Sodium Fluorescein Measurements for US-8 Development

Table B.1 - Summary of Sodium Fluorescein Measurements for US-8 Drilling

Sample ID	Date Collected	Time Collected	Depth (mBGS)	Fluorometer Reading (µg/L)	NaFl Concentration (µg/L)
DWT-US-8-01	14-Nov-07	14:25	17.34	114.59	1145.9
DWT-US-8-02	15-Nov-07	8:10	35.64	--	--
DWT-US-8-03	15-Nov-07	9:00	38.69	129.44	1294.4
DWT-US-8-04	15-Nov-07	15:50	60.04	107.53	1075.3
DWT-US-8-05	16-Nov-07	9:20	65.09	--	--
DWT-US-8-06	16-Nov-07	9:35	65.09	103.70	1037.0
DWT-US-8-07	16-Nov-07	14:25	78.34	110.63	1106.3
DWT-US-8-08	17-Nov-07	10:15	90.54	78.03	780.3
DWT-US-8-09	17-Nov-07	10:55	90.54	--	--
DWT-US-8-10	17-Nov-07	14:15	102.74	83.69	836.9
DWT-US-8-11	20-Nov-07	14:11	108.84	--	--
DWT-US-8-12	20-Nov-07	14:30	111.89	152.06	836.3*
DWT-US-8-13	20-Nov-07	16:13	117.99	106.40	1064.0
DWT-US-8-14	21-Nov-07	8:37	130.19	--	--
DWT-US-8-15	21-Nov-07	8:35	130.19	121.95	1219.5
DWT-US-8-16	21-Nov-07	12:14	148.49	99.60	996.0
DWT-US-8-17	21-Nov-07	15:17	160.69	117.06	1170.6
DWT-US-8-18	22-Nov-07	10:59	163.74	--	--
DWT-US-8-19	22-Nov-07	11:10	163.74	132.67	1326.7
DWT-US-8-20	22-Nov-07	15:15	178.99	122.42	1224.2
DWT-US-8-21	23-Nov-07	8:55	188.14	--	--
DWT-US-8-22	23-Nov-07	8:48	188.14	127.01	1270.1
DWT-US-8-23	23-Nov-07	12:16	200.39	130.66	1306.6

Notes:

NaFl concentration = 10 times fluorometer reading due to dilution factor

* = exception, dilution factor of 5.5

mBGS = metres below ground surface.

µg/L = micrograms per litre

-- = Parameter not analyzed.

Table B.2 - Summary of Laboratory Analyses for US-8 Fluid Samples

Parameter	**MDL**	**Units**	**DWT-US-8-02**	**DWT-US-8-11**	**OHGW-US8-01**
Depth (mBGS)>			35.64	108.84	Open Hole
Date Sampled>			15-Nov-07	20-Nov-07	25-Nov-07
General Parameters					
pH	0.1	pH units	--	--	--
Total Dissolved Solids	NV	mg/L	152	176	511
Alkalinity	2	mg/L $CaCO_3$	--	--	--
Fluid Density	NV	g/L	1005.1	1005.96	1003.75
Cations					
Calcium	0.7	mg/L	>20	>20	>20
Iron	0.01	mg/L	<0.01	<0.01	<0.01
Magnesium	0.001	mg/L	7.36	7.18	>20
Manganese	0.0001	mg/L	0.0009	0.0004	0.0164
Potassium	0.03	mg/L	0.78	10.3	2.19
Silicon	0.2	mg/L	1.00	0.90	8.5
Sodium	0.005	mg/L	6.75	6.66	>35
Strontium	0.00004	mg/L	0.153	0.121	>0.2
Anions					
Bromide	0.03	mg/L	<0.03	0.11	<0.06
Chloride	0.03	mg/L	10.4	20.2	17.9
Fluoride	0.01	mg/L	0.06	0.06	1.88
Iodide	0.001	mg/L	--	--	--
Bicarbonate	1	mg/L	--	--	--
Carbonate	1	mg/L	--	--	--
Nitrate	0.01	mg/L	0.29	0.31	<0.02
Nitrite	0.01	mg/L	<0.01	<0.01	0.05
Phosphate	0.02	mg/L	<0.02	<0.02	<0.04
Sulphate	0.03	mg/L	16.2	16.0	97.9
Isotopes					
Tritium, ^{3}H	0.1	TU	102.2	158.5	431.4
Deuterium, ^{2}H		δD (‰)	-55.09	-54.42	-74.50
Oxygen-18, ^{18}O		δ18O (‰)	-6.84	-6.89	-10.68
Selected Trace Elements					
Aluminum	2	µg/L	5.0	5.0	2
Antimony	0.01	µg/L	0.16	0.1	2.5
Arsenic	0.03	µg/L	0.52	0.52	4.27
Barium	0.1	µg/L	214	241	>400
Beryllium	0.1	µg/L	<0.1	<0.1	<0.1
Bismuth	0.3	µg/L	<0.3	<0.3	<0.3
Cadmium	0.01	µg/L	0.06	0.03	0.06
Cesium	0.001	µg/L	<0.001	0.003	0.026
Chromium	0.5	µg/L	<0.5	<0.5	<0.5
Cobalt	0.005	µg/L	0.027	0.019	0.69
Copper	0.2	µg/L	10.1	3.9	0.4
Gadolinium	0.001	µg/L	0.002	0.002	0.002

Table B.2 - Summary of Laboratory Analyses for US-8 Fluid Samples

Parameter	**MDL**	**Units**	**DWT-US-8-02**	**DWT-US-8-11**	**OHGW-US8-01**
Depth (mBGS)>			35.64	108.84	Open Hole
Date Sampled>			15-Nov-07	20-Nov-07	25-Nov-07
Gallium	0.01	µg/L	<0.01	<0.01	0.02
Lead	0.01	µg/L	0.52	0.02	0.01
Lithium	1	µg/L	1.0	<1	12
Mercury	0.2	µg/L	<0.2	<0.2	<0.2
Molybdenum	0.1	µg/L	0.5	0.5	11.1
Nickel	0.3	µg/L	33.5	1.4	16.9
Rubidium	0.005	µg/L	0.386	1.69	2.64
Selenium	0.2	µg/L	<0.2	<0.2	19.4
Thallium	0.001	ug/L	0.001	0.003	0.033
Titanium	0.1	µg/L	3.1	3.4	3.8
Tungsten	0.02	µg/L	<0.02	<0.02	0.1
Uranium	0.001	µg/L	0.287	0.293	15.3
Vanadium	0.1	µg/L	<0.1	<0.1	2.5
Zinc	0.5	µg/L	77.3	73.2	7.6

Notes:

mBGS = metres below ground surface.

MDL = Method Detection Limit.

-- = Parameter not analyzed.

<0.01 = Not detected above MDL.

Table B.3 - Summary of Sodium Fluorescein Measurements for US-8 Development

Sample ID	Date Collected	Time Collected	Depth (mBGS)	Fluorometer Reading (ug/L)	NaFl (ug/L)
DWT-US-8-24	24-Nov-07	9:35	200.39	--	--
DWT-US-8-25	24-Nov-07	9:40	BH Development	169.29	1692.9
DWT-US-8-26	24-Nov-07	10:40	BH Development	21.19	211.9
DWT-US-8-27	24-Nov-07	11:40	BH Development	7.92	79.2
DWT-US-8-28	24-Nov-07	12:55	BH Development	5.35	53.5
DWT-US-8-29	24-Nov-07	13:45	BH Development	3.29	32.9
DWT-US-8-30	24-Nov-07	14:59	BH Development	7.94	79.4
DWT-US-8-31	24-Nov-07	15:30	BH Development	10.67	106.7
DWT-US-8-32	24-Nov-07	16:00	BH Development	5.12	51.2
DWT-US-8-33	25-Nov-07	9:18	grundfos purge	17.54	175.4
DWT-US-8-34	25-Nov-07	10:35	grundfos purge	18.24	182.4
OHGW-US8-01	25-Nov-07	11:40	open hole	11.32	113.2

Notes:

mBGS = metres below ground surface.

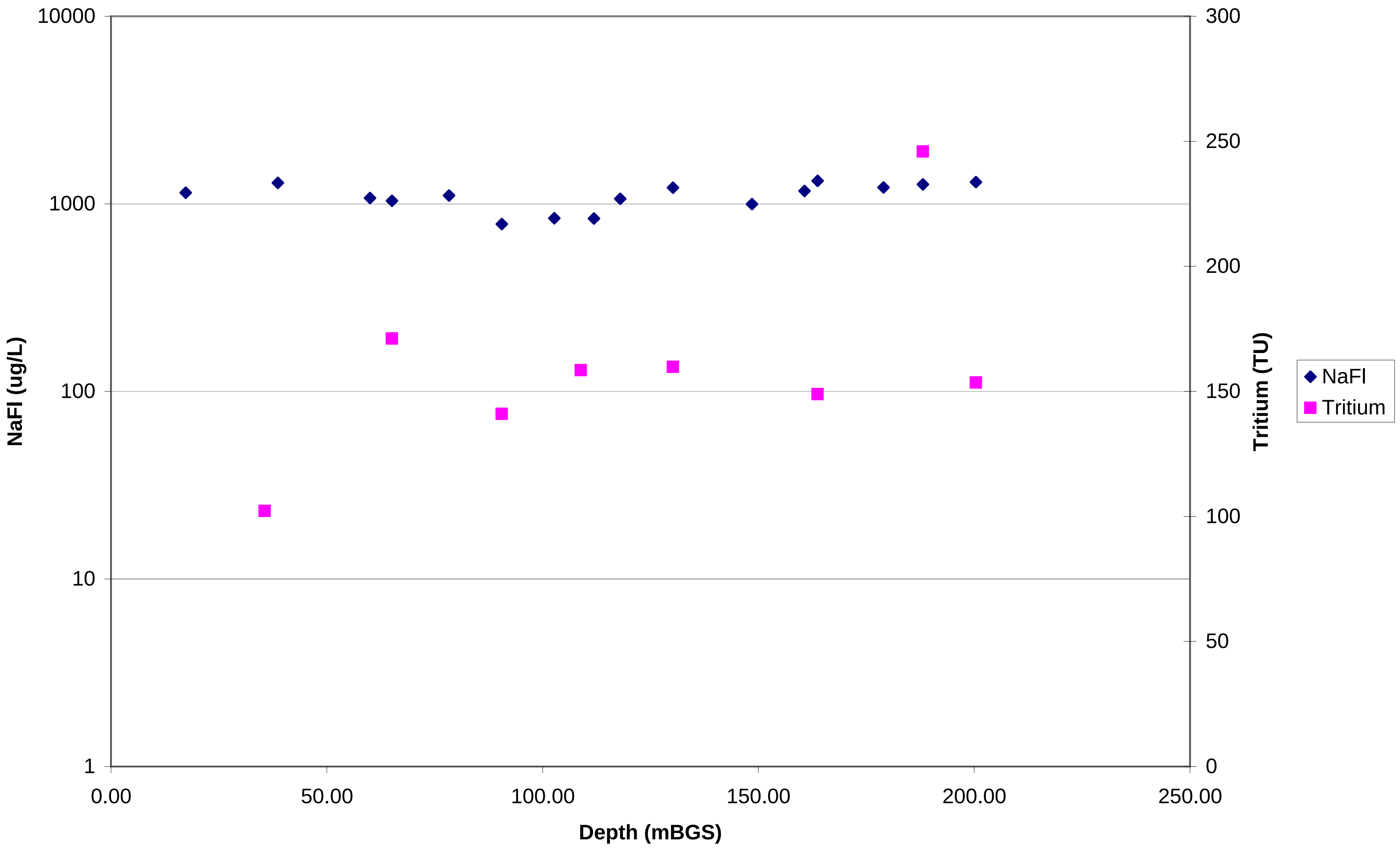
µg/L = micrograms per litre

-- = Parameter not analyzed.

APPENDIX C

Plots of Selected Drilling Fluid Analyses for US-8

Figure C.1 - NaFl and Tritium in US-8 Drilling Fluid



APPENDIX D

Record of Borehole for US-8

Table D.1 – US-8 Video Log Review Notes

RECORD OF BOREHOLE US-8

Borehole Number :	US-8	MOE Well Licence No.:	A063001
Project Number:	06.219.25.35	Date Completed:	23-NOV-2007
Client:	Ontario Power Generation	Supervisor:	Sean Sterling
Site Location:	Tiverton, Ontario, Canada	Reference Surface Elevation:	187.2 mASL
Coordinates:	NAD83 UTM Zone 17N, Northing = 907793.4m, Easting =453110.7m	Drill Rig:	Versa Rotary Drill, Davidson

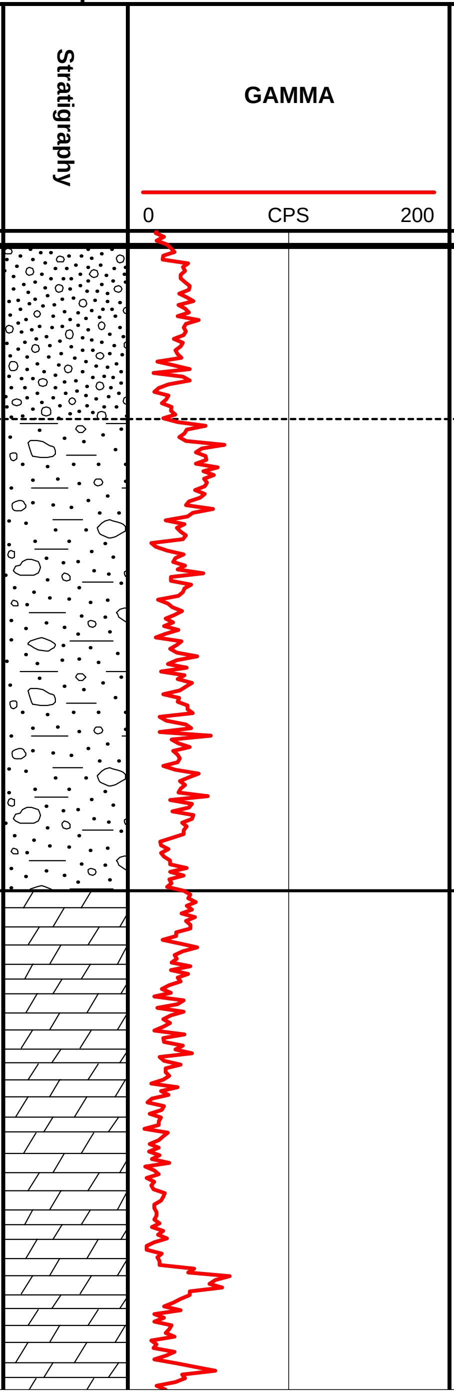
Stratigraphic Legend

▨ Fill	▨ Dolostone	▨ Cherty Dolostone
▨ Till	▨ Argillaceous Dolostone	▨ Dolomitic Shale

Contact Legend

- ━━ Borehole Boundary
- ── Formation Contact
- ------ Stratigraphic Contact

Depth (mBGS)	Stratigraphic Description Veritical Exageration 1m: 100m	Rotary Drilling Chip Sample ID#	Elev. (mASL)
0 2	**Fill** - Gravel fill material **2.29**		186
4 6 8	**Till** - Grey clay **8.53**		184 182 180
10 12 14	**Lucas Formation** **Dolostone** - Grey/brown dolostone **Dolostone** - Grey/brown limestone/dolostone, slight petroliferous odour, finer chips	US-8-009.60 US-8-012.04	178 176 174



16

18

20

22

24

26

28

30

32

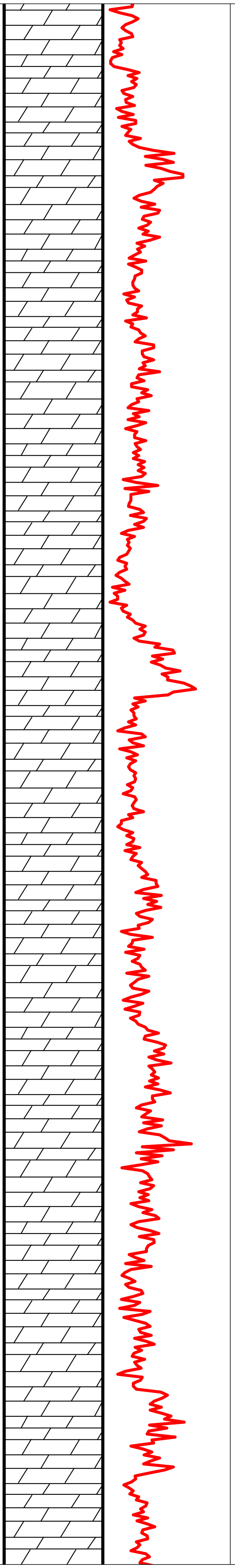
34

36

38

40

Dolostone - Grey/brown dolostone, 3-5 mm size chips	US-8-016.41
Dolostone - Grey/brown dolostone, 3-5 mm size chips	US-8-017.34
Dolostone - Grey/brown dolostone, 3-5 mm size chips	US-8-020.39
Dolostone - Brown/grey fine-grained dolostone, 3-5 mm size chips	US-8-023.44
Dolostone - Brown/grey fine-grained dolostone, 3-5 mm size chips	US-8-026.49
Dolostone - Brown/grey fine-grained dolostone, slightly larger than 3-5 mm size chips	US-8-029.54
Dolostone - Brown/grey dolostone, 3-5 mm size chips	US-8-032.59
Dolostone - Brown/grey dolostone, 3-5 mm size chips	US-8-035.64
Dolostone - Brown fine-grained dolostone	US-8-038.69



172

170

168

166

164

162

160

158

156

154

152

150

148

146

Dolostone
- Brown/grey fine-grained dolostone

US-8-041.74

42

44

Dolostone
- Brown/grey fine-grained dolostone

US-8-044.79

46

Dolostone
- Brown/grey fine-grained dolostone

US-8-047.84

48

50

Dolostone
- Brown/grey fine-grained dolostone

US-8-050.89

52

Dolostone
- Brown/grey fine-grained dolostone

US-8-053.94

54

54.50

Amherstburg Formation

56

Dolostone
- Brown/grey fine-grained dolostone

US-8-056.99

58

Dolostone
- Brown and dark grey fine-grained dolostone

60

US-8-060.04

62

Dolostone
- Brown/dark brown fine-grained dolostone with some dark grey fine-grained dolostone

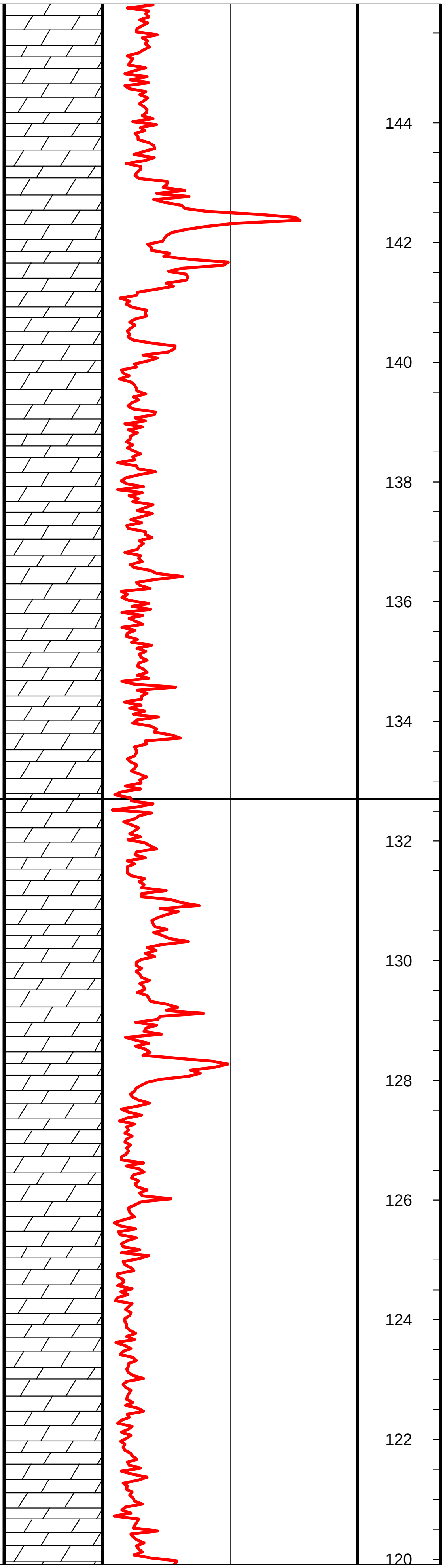
US-8-063.09

64

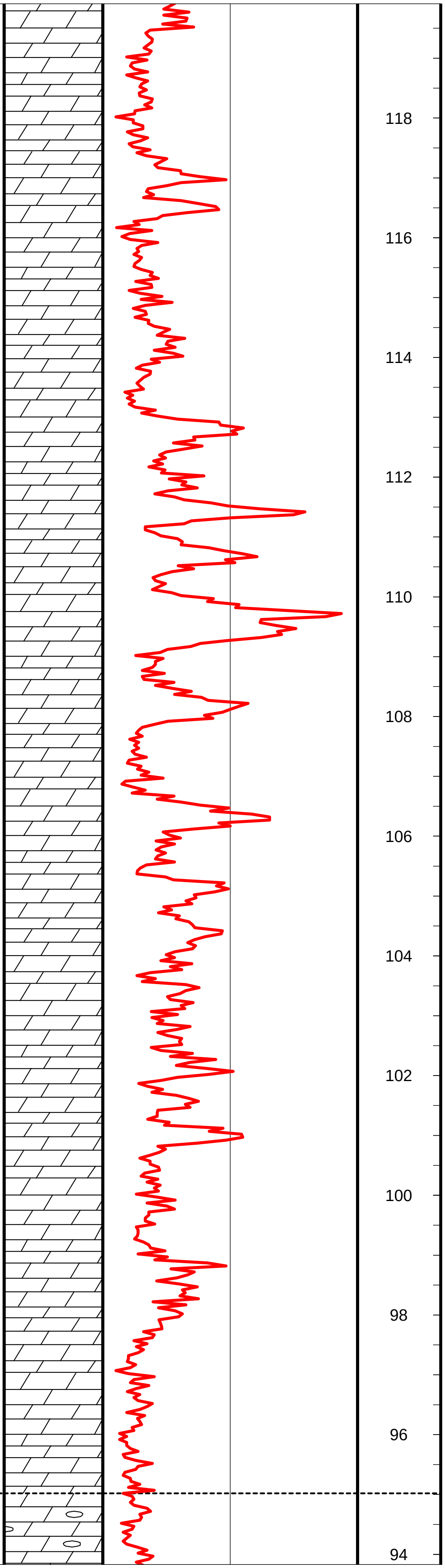
Dolostone
- Brown/grey fine-grained dolostone

66

US-8-066.14



68		
	Dolostone - Brown/grey fine-grained dolostone	US-8-069.19
70		
72	**Dolostone** - Brown/grey fine to medium fine-grained dolostone	US-8-072.24
74		
	Dolostone - Brown/grey fine to medium fine-grained dolostone	US-8-075.29
76		
78	**Dolostone** - Grey fine-grained dolostone	US-8-078.34
80		
	Dolostone - Grey fine-grained dolostone	US-8-081.39
82		
84	**Dolostone** - Grey fine-grained dolostone	US-8-084.44
86		
	Dolostone - Brown/dark grey fine-grained to medium fine-grained dolostone	US-8-087.49
88		
90	**Dolostone** - Brown/dark grey fine-grained to medium fine-grained dolostone	US-8-090.54
92		
	Cherty Dolostone - Dark brown/grey fine-grained dolostone	US-8-093.59



93.90

94

Bois Blanc Formation

96

Cherty Dolostone
- Dark grey/brown fine-grained dolostone

US-8-096.64

98

Cherty Dolostone
- Grey/brown fine-grained dolostone

US-8-099.69

100

102

Cherty Dolostone
- Dark grey/dark brown more crystalline than fine-grained dolostone

US-8-102.74

104

Cherty Dolostone
- Grey fine-grained dolostone

US-8-105.79

106

108

Cherty Dolostone
- Grey fine-grained dolostone

US-8-108.84

110

Cherty Dolostone
- Grey/brown medium-grained dolostone

112

US-8-111.89

114

Cherty Dolostone
- Grey/brown medium-grained dolostone

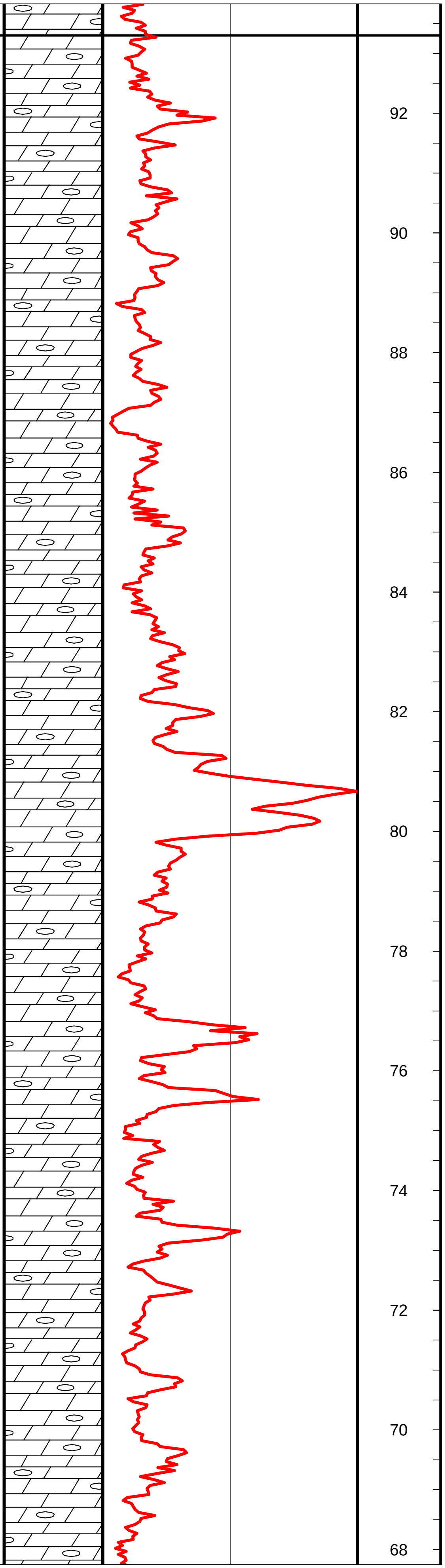
US-8-114.94

116

Cherty Dolostone
- Light grey medium-grained dolostone

118

US-8-117.99



120

Cherty Dolostone
- Light grey medium-grained with some small-grained dolostone

US-8-121.04

122

124

Cherty Dolostone
- Light grey medium-grained dolostone

US-8-124.09

126

Cherty Dolostone
- White/grey medium/fine-grained (high shale content)

127.20

US-8-127.14

128

130

Dolostone
- Light grey/grey medium-grained

US-8-130.19

132

Dolostone
- Light grey, medium-grained dolostone with soft shale (white)

US-8-133.24

134

Dolostone
- Light grey/white fine-grained dolostone

136

US-8-136.29

138

US-8-139.34

Dolostone
- Dark grey medium-grained dolostone

140

Dolostone
- Light grey, fine-grained dolostone

142

US-8-142.39

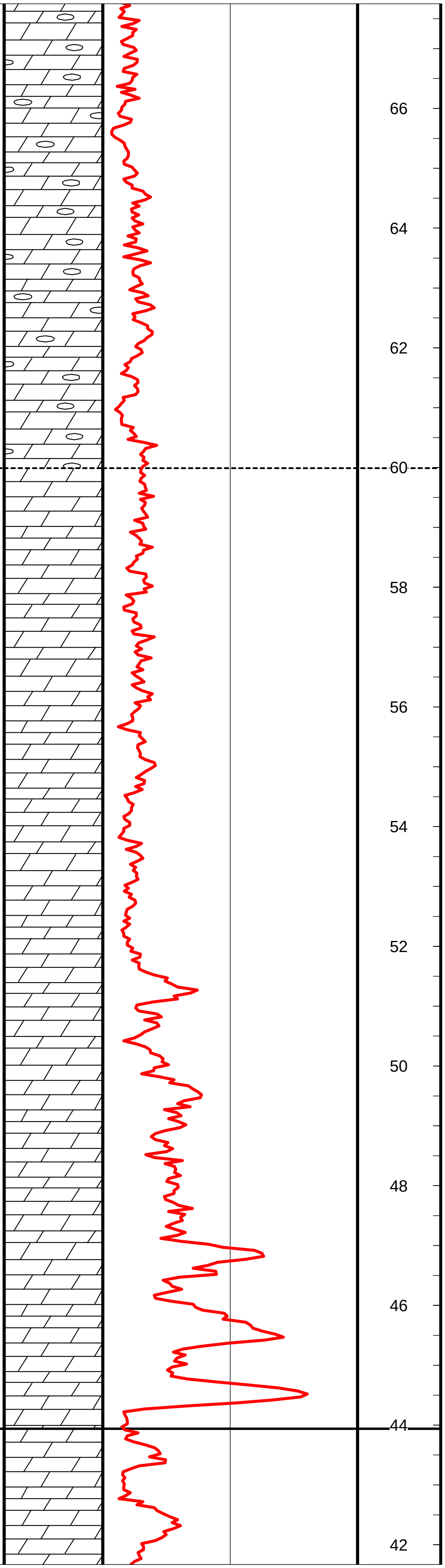
143.26

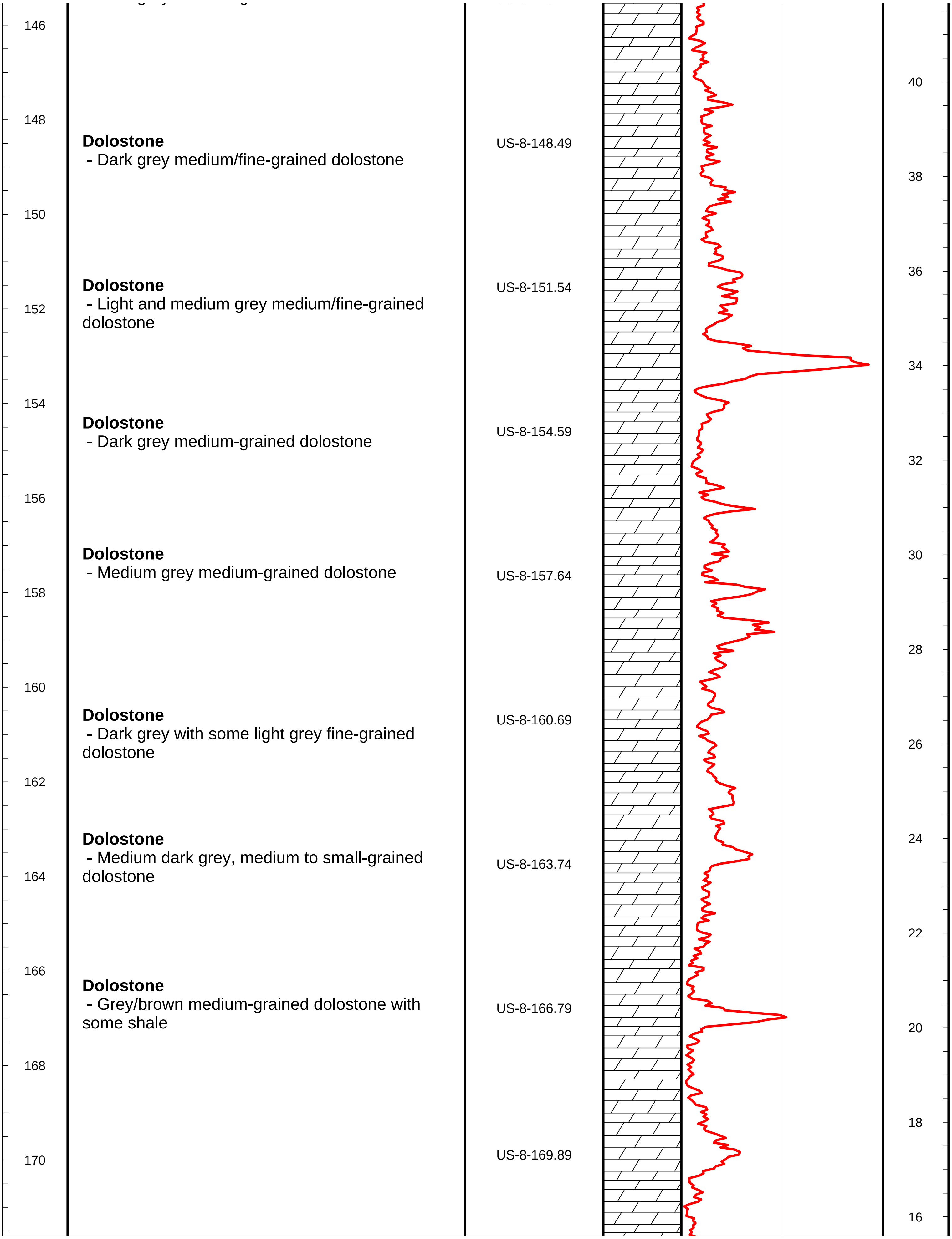
Bass Islands Formation

144

Dolostone
- Dark grey medium-grained dolostone

US-8-145.44





Dolostone
- Dark grey medium/fine-grained dolostone

US-8-148.49

Dolostone
- Light and medium grey medium/fine-grained dolostone

US-8-151.54

Dolostone
- Dark grey medium-grained dolostone

US-8-154.59

Dolostone
- Medium grey medium-grained dolostone

US-8-157.64

Dolostone
- Dark grey with some light grey fine-grained dolostone

US-8-160.69

Dolostone
- Medium dark grey, medium to small-grained dolostone

US-8-163.74

Dolostone
- Grey/brown medium-grained dolostone with some shale

US-8-166.79

US-8-169.89

Dolostone
- Light brown medium-grained dolostone

Dolostone
- Grey/brown medium-grained dolostone

Dolostone
- Dark grey with black flecks medium-grained dolostone

179.80

Argillaceous Dolostone
- Grey/brown medium-grained dolostone with some soft blue shale

Argillaceous Dolostone
- Brown/grey medium-grained dolostone with some blue shale

187.30

Salina Formation - G Unit

Argillaceous Dolostone
- Brown/grey medium-grained dolostone with some blue shale

191.30

Dolostone
- Brown dolostone with blue grey shale and

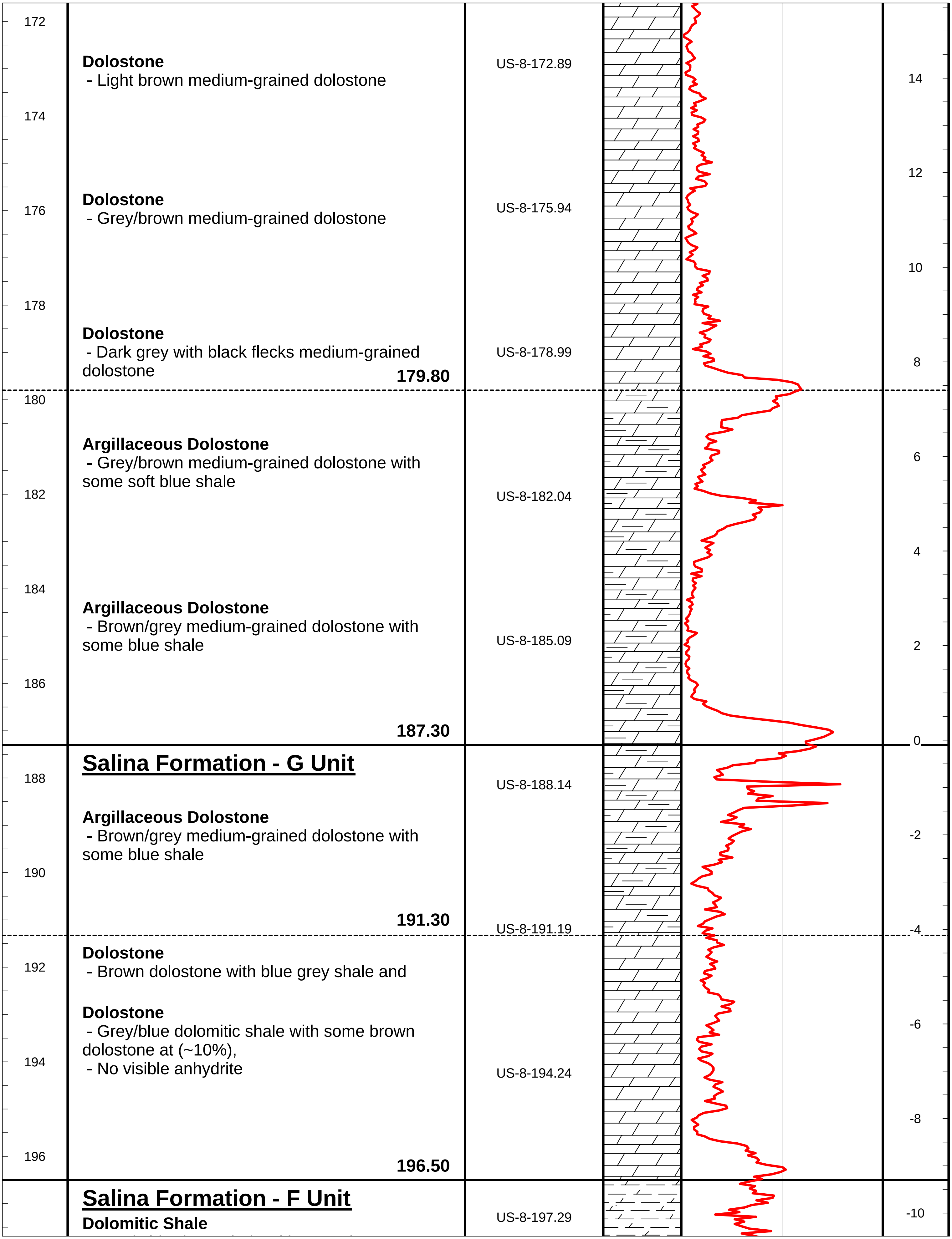
Dolostone
- Grey/blue dolomitic shale with some brown dolostone at (~10%),
- No visible anhydrite

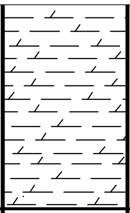
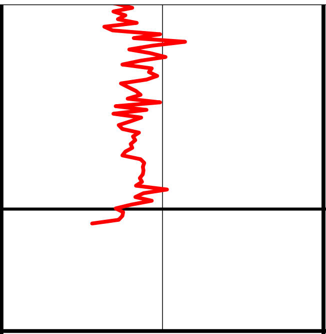
196.50

Salina Formation - F Unit

Dolomitic Shale

US-8-172.89
US-8-175.94
US-8-178.99
US-8-182.04
US-8-185.09
US-8-188.14
US-8-191.19
US-8-194.24
US-8-197.29



Depth (mBGS)	Stratigraphic Description Veritical Exageration 1m: 100m	Rotary Drilling Chip Sample ID#	Stratigraphy	GAMMA 0 CPS 200	Elev. (mASL)
198 200	- Mostly blue/grey shale with <15% brown **Dolomitic Shale** - Blue shale >85% with some minor brown dolostone **200.39**	US-8-200.39			-12
	Total Depth= 200.39 mBGS				-14

Prepared by: MAM
Checked by: SNS (27-May-08)

Doc. 06-219_US8_R0

INTERA

Table D.1 - US-8 Video Log Review Notes

Zone		Borehole Wall Description
Top (mbgs)	Bottom (mbgs)	
	13.4	Bottom of surface casing
13.4	13.7	Breakout zone
14.6	14.9	Enlarged borehole
16.2	18.3	Highly broken
	20.1	Large breakout
	20.7	Breakout
21.3	21.6	Breakout
21.9	24.4	Good -smooth, unfractured
	24.7	Breakout
25.0	27.4	Very broken
	28.3	Extremely broken
	28.7	Good
29.3	30.8	Very broken
31.4	32.9	Good
33.8	34.4	Broken
34.4	35.4	Good
	35.4	Broken
35.4	37.5	Good
	40.2	Thin breakout
	42.7	Breakout
	44.5	Breakout
	45.4	Breakout
46.3	48.8	Good
	49.1	Extreme breakout
50.3	54.9	Good
56.4	64.0	Good
64.6	65.2	Broken
	68.6	Broken
68.6	71.6	Good
71.6	72.2	Broken
72.5	73.5	Broken
73.5	76.2	Good
76.5	76.8	Minor breakouts
	77.7	Minor breakouts
	78.3	Vertical fracture
78.9	81.4	Good
82.3	83.8	Horizontal fractures
85.0	86.9	Broken
88.1	91.4	Minor horizontal fractures
91.4	94.8	Good
	95.7	Broken localized
	96.9	Broken localized
	98.1	Broken localized
	98.5	Broken localized
98.5	101.5	Good
	103.6	Vertical fracture
104.2	111.9	Good

Notes:

mbgs = metres below ground surface

Table D.1 - US-8 Video Log Review Notes (cont'd)

Zone		Borehole Wall Description
Top (mbgs)	Bottom (mbgs)	
112.2	112.8	Minor fractures
	113.7	Major breakout
114.3	117.3	Good
	118.6	Local breakout
	119.5	Local breakout
	131.1	Extreme breakout
131.4	131.7	Minor breakout
132.0	132.3	Major breakout
132.9	133.2	Breakout
135.6	137.2	Good
	137.5	Minor breakout
	139.0	Minor breakout
	140.2	Minor breakout
141.7	143.3	Good
143.3	146.3	Minor fractures
146.3	150.3	Good
	150.6	Fractures & moderate breakout
150.9	153.6	Minor breakout
153.6	155.4	Good
155.4	156.1	Minor breakout
156.4	161.5	Good
161.8	162.2	Minor voids
162.2	163.7	Minor voids
163.7	166.7	Good
	167.0	Large voids, major horizontal fracture
	167.6	Horizontal fractures
167.9	169.5	Good
169.8	170.7	Extreme breakout
	171.3	Inclined fracture, anhydrite inclusions
171.6	176.8	Good
178.3	179.5	Horizontal fractures
179.8	180.4	Minor voids
	182.3	Minor voids
	182.9	Minor breakouts
183.2	185.9	Good
186.5	186.8	Minor voids
187.1	187.8	Enlarged borehole, top of anhydrite layering
	188.1	Anyhydrite layers - poor visibility, murky
	188.4	Good - poor visibility, very murky
	189.9	Start of layering
	190.2	Horizontal and vertical fractures
	191.4	Horizontal fractures
	193.5	Good
	194.5	Anhydrite infilled fracture
	195.1	Fracture
	195.7	Horizontal fracture
	196.9	Good
	197.2	Anhydrite seams
	198.7	Anhydrite layers

Notes:

mbgs = metres below ground surface