APPENDIX TSD#1-B

Geology, Hydrogeology & Geotechnical Component

February 2013

February 2013

Geology, Hydrogeology & Geotechnical Component
Appendix TSD#1-B

COMPARATIVE EVALUATION OF ALTERNATIVE STUDIES

TAGGART
GROUP OF COMPANIES

miller
THE
MILLER
GROUP

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INTRODUCTION

Two properties that are owned or have been optioned by Taggart Miller have been identified for the proposed Capital Region Resource Recovery Centre (CRRRC) (the Alternative Sites). The Alternative Sites are described below:

- **North Russell Road Site (NRR Site)** – located in the northwest part of the Township of Russell about three kilometres east of the boundary with the City of Ottawa, and about five kilometres south of Provincial Highway 417 between the Boundary Road and Vars exits. The property consists of about 193 hectares (476 acres) of contiguous lands on Part of Lots 18 and 19, Concessions III and IV, Township of Russell.
- **Boundary Road Site (BR Site)** – located in the east part of the City of Ottawa, in the former Township of Cumberland and just southeast of the Highway 417/Boundary Road interchange. The property is on the east side of Boundary Road, east of an existing industrial park, north of Devine Road and west of Frontier Road. The property consists of about 175 hectares (430 acres) of land on Lots 23 to 25, Concession XI, Township of Cumberland.

The CRRRC is proposed to provide facilities and capacity for recovery of resources and diversion of material from disposal generated by the industrial, commercial and institutional (IC&I) and construction and demolition (C&D) sectors primarily in Ottawa and secondarily a portion of eastern Ontario, for management and utilization of surplus and contaminated soils, as well as landfill disposal capacity for material that is not diverted.

1.0 ASSESSMENT CRITERIA, INDICATORS AND DATA SOURCES

The geology, hydrogeology & geotechnical component compared the Alternative Sites using the following criterion:

- Which Site is preferred for protection of groundwater?

The indicators are:

- Geological setting;
- Type and thickness of any natural on-Site attenuation layer;
- Presence and quality of groundwater resources on-Site and in Site-vicinity; and
- Interpreted direction of vertical groundwater flow on-Site and in Site-vicinity, i.e., area of groundwater recharge, transitional flow, or groundwater discharge.

The data sources used are published geological, hydrogeological and geotechnical maps and reports including applicable source water protections plans and related studies/reports; municipal Official Plans, specifically any groundwater protection zones, recharge areas, etc.; Ministry of the Environment (MOE) water well records and determination of water well users in the area (using topographic maps, aerial photos and field reconnaissance); and findings of on-Site testing completed for this project or otherwise available to confirm/compare information.

2.0 PRELIMINARY DESCRIPTION OF EXISTING ENVIRONMENT

The following sections describe the existing environmental conditions for the geology, hydrogeology & geotechnical component at each of the Alternative Sites based on the preliminary investigations and assessments.

2.1 North Russell Road Site

2.1.1 Introduction

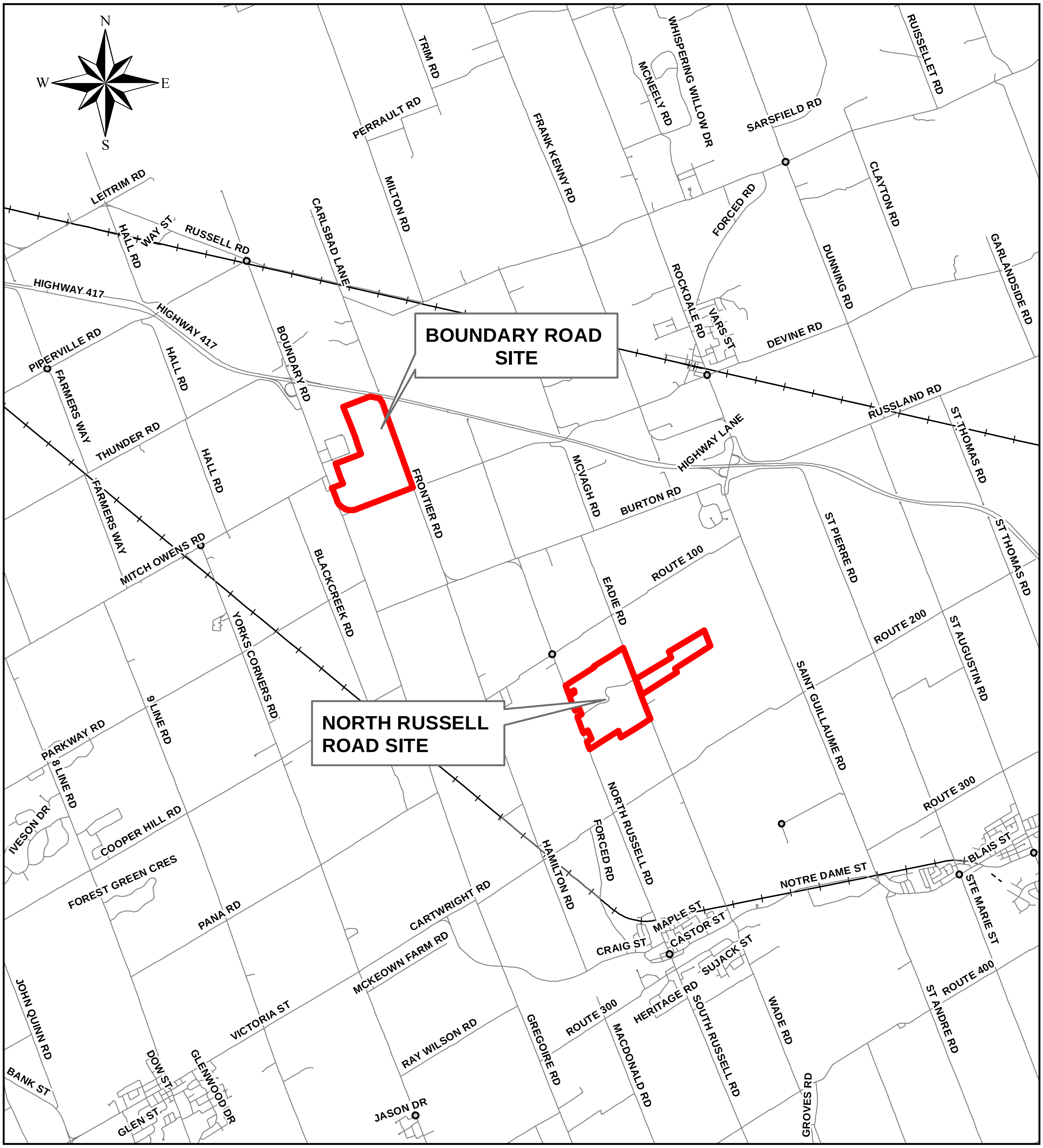
This report summarizes the results of the preliminary subsurface investigation and hydrogeological assessment of the former Hanson Brick Quarry property and adjacent lands located on parts of Lots 18 and 19, Concessions III and IV in the Township of Russell, Ontario. The general location of the NRR Site is shown on Figure 2.1-1. A preliminary subsurface investigation was completed by Golder Associates Ltd. (Golder) to obtain Site-specific geological, hydrogeological and geotechnical information.

2.1.1.1 Site Description

The boundary of the NRR Site is shown on Figure 2.1-2. The NRR Site consists of the former Hanson Brick Quarry property and two pieces of adjoining land. The first piece is a roughly square parcel abutting the northwest side of the former Hanson Brick Quarry property, and the second is a rectangular parcel spanning between Russell Road and Eadie Road to the south of the former Hanson Brick property.

The NRR Site contains a quarry licensed for shale extraction under the *Aggregate Resources Act*, license number 5881, dated May 1999. The approximate extent of the existing quarry extraction area is shown on Figure 2.1-2. The quarry has steep sidewalls and has had material removed down to about elevation 74 metres above sea level (masl), approximately 8 to 12 metres below the surrounding land surface.

The land use surrounding the NRR Site is primarily agricultural and associated rural residential. The NRR Site is generally flat, and slopes from the local high at the western end of the NRR Site towards the lowest portion of the NRR Site found along the eastern edge. Drainage in the vicinity of the NRR Site is mainly by means of a network of agricultural ditches, municipal drains and small creeks. The Fournier Municipal Drain flows easterly away from the NRR Site, and runs through the east portion of the Concession IV part of the property (as shown on Figure 2.1-2). There are also two other Municipal Drains that receive runoff from the Site. The nearest river is the Castor River located about 4.5 kilometres south of the property and running west-east through the Village of Russell.



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

2,500 0 2,500

SCALE 1:100,000 METRES

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

Golder Associates
Ottawa, Ontario

PROJECT No.	12-1125-0045	DATE	FEB. 2013
SCALE	AS SHOWN REV. 0	DESIGN	JPAO
		GIS	BR
		CHECK	PLE
		REVIEW	PAS

TITLE

KEY PLAN

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

FIGURE 2.1-1

Path: \\golder.gds\gal\Ottawa\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-1-KeyPlan.mxd

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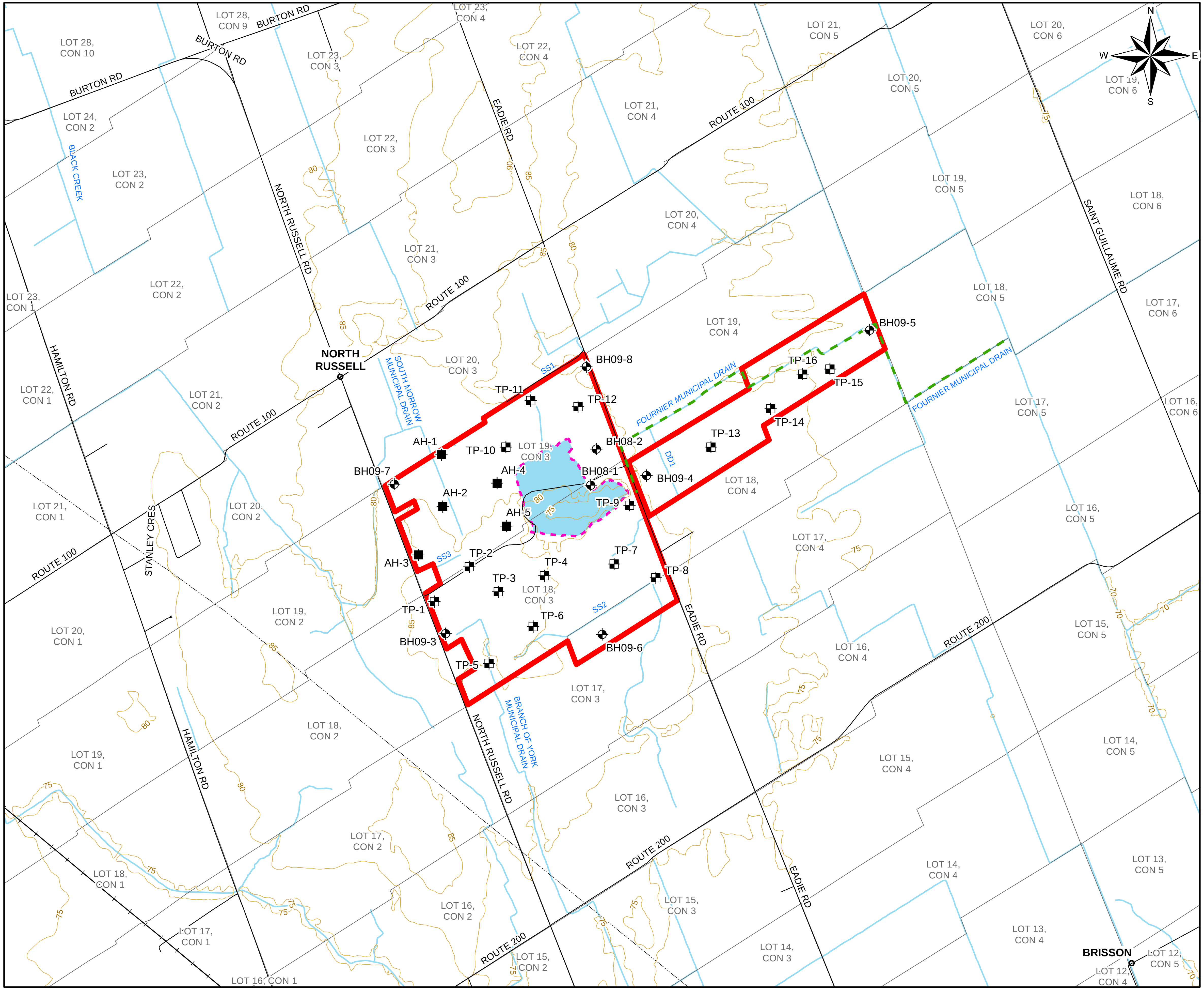

LEGEND

○	POPULATED PLACENAME
■	AUGERHOLE LOCATION
⊕	BOREHOLE/MONITORING WELL LOCATION
▣	TEST PIT LOCATION
—	ROAD
┼	RAIL ROAD
-·-·-	UTILITY LINE
—	CONTOUR LINE, (5m)
- - -	FOURNIER MUNICIPAL DRAIN
—	SURFACE WATER FEATURE
🟦	WATER AREA
☐	LOT/CONCESSION
⬚	APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
🟥	PROPERTY BOUNDARY

390 195 0 390

SCALE 1:20,000 METRES

NOTE

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REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

NRR SITE PLAN

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-2	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

2.1.2 Local Setting

The following sections provide general information from published sources on the local geology and hydrogeology in the vicinity of the NRR Site. This information was gathered as part of a review of background information completed prior to beginning the subsurface investigation at the NRR Site.

2.1.2.1 Surficial Geology

The surficial geology in the vicinity of the NRR Site is shown on Figure 2.1-3.

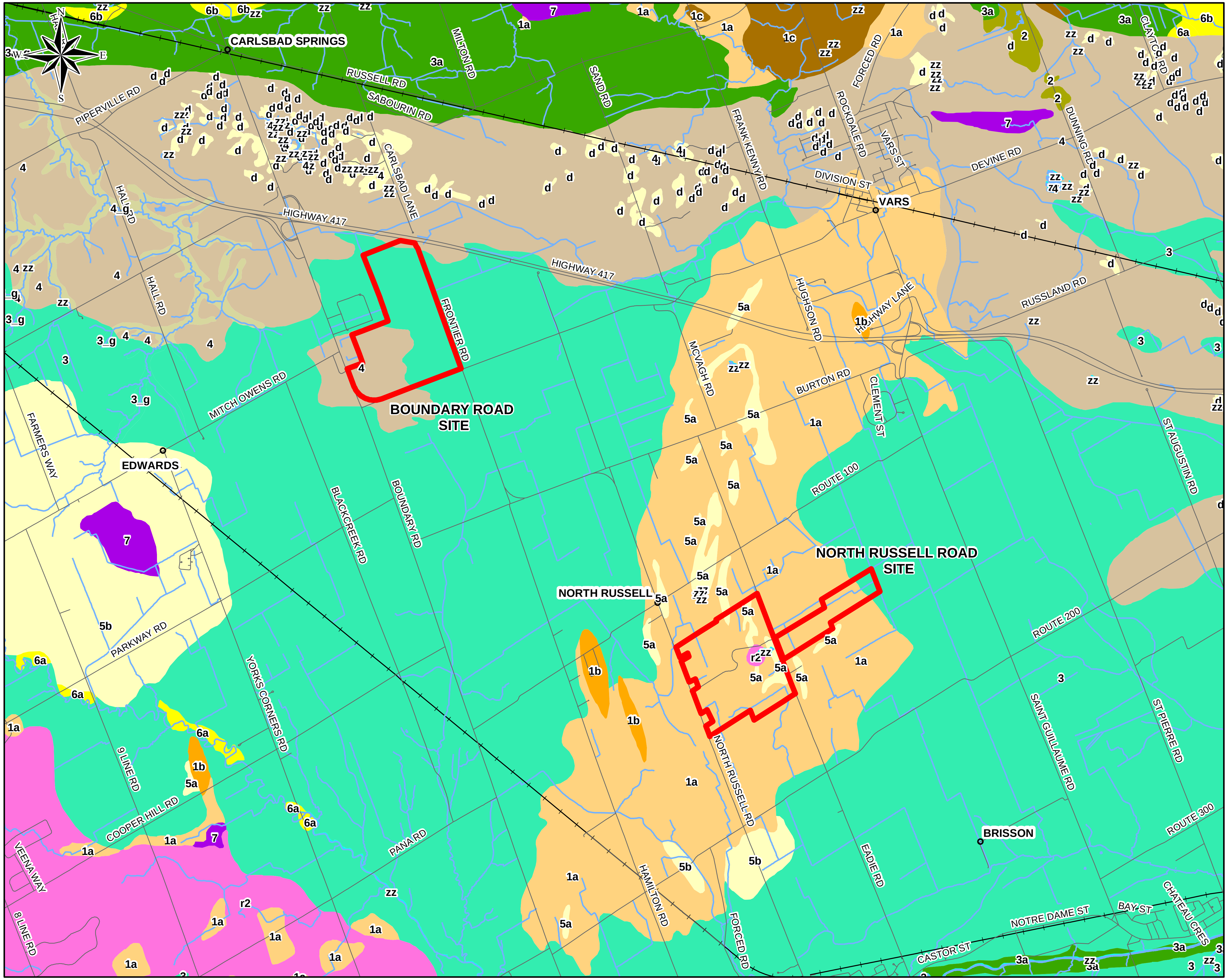
The NRR Site is located within an extensive north-south trending deposit of glacial till (unit 1a on Figure 2.1-3). The glacial till typically consists of sandy silt to silty sand, with gravel, a trace of clay and variable cobble and boulder content. From a review of the published MOE Water Well Information System (WWIS) for wells within the vicinity of the NRR Site, and observations at the NRR Site, the till cover over the bedrock is relatively thin, likely varying from about zero to four metres. The till feature protrudes through, and is surrounded by, an extensive deposit of marine silty clay (unit 3 on Figure 2.1-3). The thickness of the clay generally increases with distance from the till feature, and is indicated from the MOE well records to typically be about 10 to 15 metres thick in the vicinity of the NRR Site, and increasing to about 30 metres with increasing distance from the till feature; the clay is generally underlain by a basal gravelly till deposit followed by bedrock.

2.1.2.2 Bedrock Geology

The bedrock geology in the vicinity of the NRR Site is illustrated on Figure 2.1-4. This figure shows the mapped uppermost bedrock unit beneath the soil cover. The area in the vicinity of the NRR Site is underlain by shale of the Queenston Formation, which is the youngest formation of sedimentary rock in eastern Ontario. Queenston shale is a red, laminated to thickly bedded calcareous siltstone/mudstone and shale. The property is shown to be located near the middle of a band of Queenston shale that is mapped to be approximately 4 kilometres north-south by 15 kilometres west-east. The contacts between bedrock formations are typically caused by a series of near-vertical faults, which caused downthrowing of adjacent blocks of bedrock. To the south, the uppermost bedrock is mapped to be limestone (unit 8 followed by unit 6), while to the north and southwest Carlsbad Formation layered shale and limestone is shown (unit 12). Further southwest is Oxford Formation dolomite (unit 4); this comprises the area of shallow/exposed bedrock shown as unit r2 on Figure 2.1-3.

Information on the thickness of the various bedrock formations in the immediate area of the NRR Site is available from two deep drill cores completed by the Ontario Geological Survey (OGS). As reported in OGS Open File Report 5770 (Williams, 1991), drill hole RU-24, located about two kilometres north of the NRR Site had a total depth of 835 metres and encountered the following: 13 metres of Queenston shale; followed by 187 metres of Carlsbad Formation shale and limestone; followed by the lower formations.

OGS Open File Report 6094 (Armstrong and Sergerie, 2003) was conducted to provide information for Ontario’s brick industry, and reports on drill hole OGS 01-06 completed at the former Hanson Brick Quarry property to a total depth of 61 metres. This hole encountered the following: 1.5 metres of soil followed by 21.5 metres of Queenston shale, and was terminated in the underlying Carlsbad Formation.



LEGEND

- ● POPULATED PLACENAME
- ROAD
- RAILWAY
- SURFACE WATER FEATURE
- 🟥 PROPERTY BOUNDARY

SURFICIAL GEOLOGY

1a	TILL, PLAIN WITH LOCAL RELIEF <5m
1b	TILL, DRUMLINIZED
1c	TILL, HUMMOCKY TO ROLLING WITH LOCAL RELIEF 5 TO 10 m
2	ICE CONTACT STRATIFIED DRIFT: GRAVEL & SAND
3	OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT
3_g	OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT (GULLIES & RAVINES)
3a	OFFSHORE MARINE DEPOSITS: CLAY & SILT UNDERLYING EROSIONAL TERRACES
3a_g	OFFSHORE MARINE DEPOSITS: CLAY & SILT UNDERLYING EROSIONAL TERRACES (GULLIES & RAVINES)
4	DELTAIC AND ESTUARY DEPOSITS: MEDIUM TO FINE GRAINED SAND
4_g	DELTAIC AND ESTUARY DEPOSITS: MEDIUM TO FINE GRAINED SAND (GULLIES & RAVINES)
5a	NEARSHORE SEDIMENTS: GRAVEL, SAND & BOULDERS
5b	NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND
6a	ALLUVIAL DEPOSITS: SILTY SAND, SILT, SAND & CLAY
6a_g	ALLUVIAL DEPOSITS: SILTY SAND, SILT, SAND & CLAY (GULLIES & RAVINES)
6b	ALLUVIAL DEPOSITS: MEDIUM GRAINED STRATIFIED SAND WITH SOME SILT
6b_g	ALLUVIAL DEPOSITS: MEDIUM GRAINED STRATIFIED SAND WITH SOME SILT (GULLIES & RAVINES)
7	ORGANIC DEPOSITS: MUCK & PEAT
d	DUNE
d_g	DUNE (GULLIES & RAVINES)
l	LANDSLIDE AREA
l_g	LANDSLIDE AREA (GULLIES & RAVINES)
r1	BEDROCK: INTRUSIVE & METAMORPHIC
r2	BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE
r2_g	BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE (GULLIES & RAVINES)
zz	WATER

1,000 0 1,000

SCALE 1:50,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

BELANGER, J. R., URBAN GEOLOGY OF THE NATIONAL CAPITAL AREA. GEOLOGICAL SURVEY OF CANADA, OPEN FILE D3256, 2001 © QUEEN'S PRINTER OF ONTARIO.
LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SURFICIAL GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
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GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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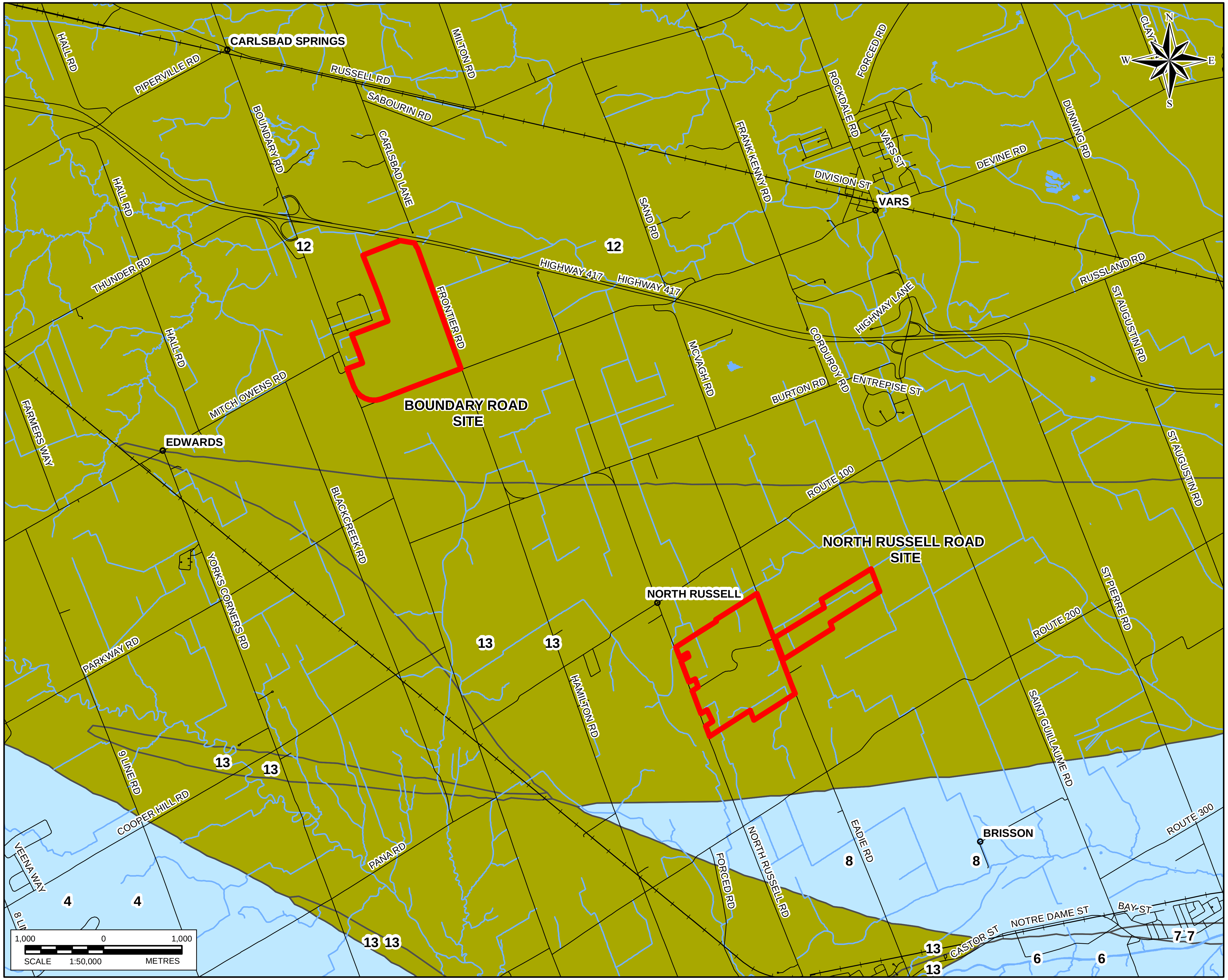

LEGEND

○ POPULATED PLACENAME
— ROAD
—+— RAILWAY
— SURFACE WATER FEATURE
🟥 PROPERTY BOUNDARY

PHANEROZOIC
PALEOZOIC
UPPER ORDOVICIAN

13	QUEENSTON FORMATION: RED TO LIGHT GREENISH GRAY SILTSTONE AND SHALE, WITH INTERBEDS OF SILTY BIOCLASTIC LIMESTONE IN LOWER PART
12	CARLSBAD FORMATION: INTERBEDDED DARK GRAY SHALE, FOSSILIFEROUS CALCAREOUS SILTSTONE, AND SILTY BIOCLASTIC LIMESTONE
11	BILLINGS FORMATION: DARK BROWN TO BLACK SHALE, WITH LAMINATIONS OF CALCAREOUS SILTSTONE
10	EASTVIEW FORMATION: INTERBEDDED SUBLITHOGRAPHIC TO FINE CRYSTALLINE LIMESTONE AND DARK BROWN TO DARK GREY SHALE

MIDDLE TO UPPER ORDOVICIAN

9	LINDSAY FORMATION: SUBLITHOGRAPHIC TO FINE CRYSTALLINE LIMESTONE, NODUALAR IN PART, WITH INTERBEDS OF CALCARENITE AND SHALE
8	VERULAM FORMATION: INTERBEDDED BIOCLASTIC LIMESTONE, SUBLITHOGRAPHIC TO FINE CRYSTALLINE LIMESTONE
7	BOBCAYGEON FORMATION: INTERBEDDED SILTY DOLOMITE, LITHOGRAPHIC TO FINE CRYSTALLINE LIMESTONE, OOLITIC LIMESTONE, SHALE, AND FINE-GRAINED CALCAREOUS QUARTZ SANDSTONE
6	GULL RIVER FORMATION: INTERBEDDED SILTY DOLOMITE, LITHOGRAPHIC TO FINE CRYSTALLINE LIMESTONE, OOLITIC LIMESTONE , SHALE, AND FINE-GRAINED CALCAREOUS QUARTZ SANDSTONE
5	ROCKCLIFFE FORMATION: INTERBEDDED FINE-GRAINED LIGHT GREENISH GREY QUARTZ SANDSTONE, SHALEY LIMESTONE AND SHALE, LOCALLY CONGLOMERATE AT BASE, INTERBEDS OF CALCARENITE (ST. MARTIN MEMBER, 5A) AND SILTY DOLOSTONE IN UPPER PART

LOWER ORDOVICIAN

4	OXFORD FORMATION: SUBLITHOGRAPHIC TO FINE CRYSTALLINE DOLOSTONE
3	MARCH FORMATION: INTERBEDDED QUARTZ SANDSTONE, SANDY DOLOSTONE, AND DOLOSTONE

CAMBRIO ORDOVICIAN

2	NEPEAN FORMATION: FINE TO COARSE GRAINED QUARTZ SANDSTONE, PARTIALLY CALCAREOUS IN UPPER PART
1	COVEY HILL FORMATION: NONCALCAREOUS FELDSPATHIC, FINE TO COARSE GRAINED QUARTZ SANDSTONE AND QUARTZ PEBBLE CONGLOMERATE

UNCONFORMITY

PRECAMBRIAN

PC	UNDIFFERENTIATED METAMORPHIC AND IGNEOUS ROCKS

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

BELANGER, J. R., URBAN GEOLOGY OF THE NATIONAL CAPITAL AREA. GEOLOGICAL SURVEY OF CANADA, OPEN FILE D3256, 2001 © QUEEN'S PRINTER OF ONTARIO.

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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BEDROCK GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-4	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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2.1.2.3 Hydrogeology

Based on a preliminary review of the MOE WWIS, static water levels for private supply wells within 500 metres of the NRR Site were reported to be 1.5 to 7.6 metres below ground surface (mbgs), and the primary aquifer is the Carlsbad Formation (i.e., most wells do not find adequate supplies of water within the Queenston shale). Flow within the bedrock formations occurs through secondary porosity associated with fractures, as both the shale and limestone layers have relatively low intrinsic permeability. Although individual wells installed in the Carlsbad Formation can provide adequate yields for domestic use, yields are often limited due to the proportion of low hydraulic conductivity shale. This unit is considered a poor aquifer due to both uncertainty in yield and poor water quality (Golder, 2003).

Within a five-kilometre radius of the property, water supply wells to the north and south of the NRR Site are reported to encounter water from zones within the shale or limestone bedrock. Elsewhere, where the area is underlain by relatively thick clay deposits, water is typically encountered in drilled wells completed in the basal sand and gravel layer at the soil/bedrock interface, or may be obtained using shallow dug wells completed in a surficial sand layer and upper portion of the clay.

The Prescott Russell Official Plan, dated May 2006, identifies groundwater recharge areas that are interpreted to supply water through communal wells for the Village of Embrun and the Village of Russell as well as the Village of Limoges (see Schedule B of the official plan). Within the limits of the identified groundwater recharge areas, permitted uses are restricted to those which will not result in negative impacts on groundwater. The NRR Site is not located within a groundwater recharge area identified in the official plan. It is noted that both Embrun and Russell have since been connected to the City of Ottawa central water supply system, and the formerly used communal wells are no longer in use.

Additional source water protection work was completed for the Vars and Limoges communal well systems since the Prescott Russell Official Plan was completed in 2006. The results of the additional work are presented in the Assessment Report for the South Nation Source Protection Area dated December 10, 2012. The Vars and Limoges communal wells are the closest communal drinking water supply systems to the NRR Site. Based on the results presented in the Assessment Report, the NRR Site is not located within the wellhead protection area for the Vars or the Limoges communal well system.

2.1.3 Study Methodology

To allow for a preliminary assessment of the suitability of the NRR Site for use as a waste management facility, a work plan was develop to gather Site-specific geological, hydrogeological and geotechnical data to supplement the available published information. The methodology applied during the subsurface investigation and hydrogeological assessment is briefly described below.

2.1.3.1 Test Pit and Augerhole Program

The purpose of the test pit excavation and augerhole drilling program was to define the overburden types, and the thickness and distribution of the overburden on the property. Excavation of the test pits and drilling of the augerholes was monitored by a member of Golder’s field staff, who was responsible for classifying the materials exposed on the sides of the test pit and in the samples collected from the augerholes (split spoon sampling) through a visual and tactile examination. Samples of the various materials encountered were collected, labelled and returned to Golder’s Ottawa office for subsequent examination. The groundwater seepage conditions were also observed in the open test pits, and the location where water was encountered in the augerholes was noted.

2.1.3.2 Borehole Drilling

The borehole drilling program at the NRR Site was divided into two programs, which included the borehole coring program and the air rotary drilling program.

2.1.3.2.1 Borehole Coring Program

The borehole coring program at the NRR Site included the drilling of four boreholes. The cored boreholes were identified as BH09-3, BH09-4, BH09-5 and BH09-6 (see locations on Figure 2.1-2). At each hole, HW sized casing was installed into the top of the bedrock, and an appropriate stick-up was left as a protective casing. The boreholes were drilled by Marathon Drilling Co. Ltd. (Marathon Drilling) using rotary drilling methods, and involved the collection of rock core from each borehole (HQ or NQ size core). The rock core obtained from each borehole was logged on-Site by Golder staff, and returned to Golder's Ottawa office for detailed core logging by an experienced geologist.

2.1.3.2.2 Air Rotary Drilling Program

The air rotary drilling program at the NRR Site included the drilling of four boreholes. The boreholes were identified as BH08-1, BH08-2, BH09-7 and BH09-8 (see locations on Figure 2.1-2). All four boreholes were drilled as 0.15-metre diameter open holes using an air rotary drill rig supplied and operated by Bourgeois Well Drilling Ltd. Steel water well casing was installed at all locations, and the annular space between the casing and the formation was sealed using a bentonite grout slurry. Samples of the bedrock (chip samples) produced during the drilling process were collected at regular intervals (i.e., approximately every three metres) for the entire length of the borehole. The samples were examined and described on-Site by Golder staff and returned to Golder's Ottawa office for additional examination by an experienced geologist.

2.1.3.3 Packer Testing

Pressure packer testing was conducted in the four cored holes (BH09-3, BH09-4, BH09-5 and BH09-6) to assess the hydraulic conductivity of the bedrock along the length of the boreholes. The packer testing was carried out using the drill rig and equipment supplied by Marathon Drilling. The packer testing initially involved a single packer array at the base of the borehole, followed by upstaging to ground surface using a double packer array with a test interval of 2.44 metres.

2.1.3.4 Borehole Geophysical Logging Program

For the purpose of further defining the distribution of the bedrock units at the NRR Site (including potential stratigraphic and/or structural controls) and interpreting the bedrock geology across the NRR Site, boreholes BH09-3 through BH09-8 were geophysically logged.

Locations BH09-3, BH09-5 and BH09-6 were logged for stratigraphy only (see below), while BH09-4, BH09-7 and BH09-8 also included logging for structure (optical/acoustic televiewer and caliper) and "hydrogeophysical" logs (fluid temperature, fluid resistivity and heat pulse flow meter). The term "hydrogeophysical" describes the logs that can be used to infer flowing fractures in the borehole wall and the vertical migration of fluid within the borehole.

A list of the geophysical logs collected includes:

- Stratigraphy:
  - Natural Gamma - passive nuclear log
  - Electromagnetic Induction - apparent conductivity
- Structure:
  - Optical/Acoustic Televiewer - borehole wall imaging
  - Caliper - borehole diameter
- Hydrogeophysics:
  - Fluid Temperature - borehole fluid temperature
  - Fluid Resistivity - borehole fluid resistivity
  - Heat Pulse Flow Meter - vertical borehole fluid movement

At locations BH09-4, BH09-7 and BH09-8, the log acquisition procedure consisted of the following:

- The optical televiewer log was collected first to take advantage of undisturbed (clear) water in the boreholes.
- The natural gamma, apparent conductivity, caliper, acoustic televiewer logs were then collected in no particular order.
- The fluid temperature and fluid resistivity logs were collected under static (non-pumping) and dynamic (pumping) borehole conditions. For the dynamic testing, the pump was run at a rate that would cause drawdown in the boreholes. A 51-milimetre diameter submersible Grundfoss pump was used for the pumping from the borehole for the dynamic testing.

2.1.3.5 Monitoring Well Installation and Elevation Surveying Program

Multi-level groundwater monitoring wells were constructed in BH09-3, BH09-4 and BH09-6 through BH09-8. A single monitoring well was installed in BH09-5, and locations BH08-1 and BH08-2 were left as open holes. The monitoring wells were installed at specific depths to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the various bedrock formations encountered at the NRR Site. The conversion of the boreholes into multi-level monitoring wells was completed by Golder Associates Innovative Applications (GAIA). GAIA is a licensed well contractor. The preferred locations for the screened intervals of the monitoring wells were determined based on observations during the drilling program, geophysical data and geological core log data and packer testing data (in the case of the cored boreholes), or visual examination of the rock chips (in the case of the air rotary boreholes).

All monitoring wells were constructed of 0.032-metre diameter, threaded, PVC slot #10 screen and solid risers. Clear stone was placed in the borehole around the screened portions of the monitors and bentonite was used to provide seals between the screened intervals and to seal the borehole up to ground surface. Each monitoring well is protected at surface by a steel casing with a lockable cap. An elevation survey of the ground surface and top of casing for the monitoring wells was completed by Golder.

The deepest monitoring well installation at each borehole is designated as monitoring well “A”, with each successively shallower monitoring well at each borehole designated as “B” and “C”, where appropriate. The monitoring wells were developed following their installation prior to undertaking hydraulic conductivity testing, groundwater level measurements and groundwater sampling.

2.1.3.6 Hydraulic Conductivity Testing

Well response tests were carried out in the monitoring intervals using the rising-head method. The well response testing was undertaken to provide information on the *in-situ* horizontal hydraulic conductivity of the bedrock adjacent to the monitoring well intervals. The rising-head tests consisted of pumping each monitor for approximately 15 to 30 seconds using inertial samplers and polyethylene tubing, followed by monitoring of the groundwater level recovery within the monitor. Before the start of the hydraulic testing, static water levels were measured at all locations. Each hydraulic test was deemed complete when the monitoring well recovered to approximately 95% of the original static water level, or after two hours of monitoring for locations having slow recovery.

The intervals for response testing were defined as the gravel pack interval (i.e., the zone filled with gravel surrounding the screens) between the bentonite seals. The water level recovery data were analyzed using the Hvorslev method (Hvorslev, 1951) to provide an estimate of the horizontal hydraulic conductivity.

2.1.3.7 Groundwater Level Monitoring Program

A groundwater level monitoring program was conducted to provide information on hydraulic gradients, the range in water levels observed at the NRR Site over time and the groundwater flow direction(s). The depth to groundwater was measured relative to the surveyed top of PVC pipes for the monitoring wells in BH09-3 through BH09-8, and from the top of the steel casing for open holes BH08-1 and BH08-2. The water elevations in the monitoring wells were calculated by subtracting the measured depth to water from the top of pipe reference elevations.

Pressure transducers and data loggers were installed at four selected monitoring intervals to provide an ongoing record of groundwater levels. The data loggers were set to record the groundwater levels at the four locations every six hours (i.e., four readings per day).

2.1.3.8 Groundwater Quality Sampling Program

The water quality sampling program at the NRR Site was divided into two programs, which included the on-Site monitoring well sampling program and the residential water supply well sampling program.

2.1.3.8.1 On-Site Monitoring Well Sampling Program

The on-Site monitoring well water quality sampling program involved collecting groundwater samples from the depth-specific monitoring wells installed in BH09-3 through BH09-8. The primary objective of the water quality monitoring program is to define existing background groundwater quality at the NRR Site over a sufficient period of time to establish the potential seasonal and/or spatial/depth variability in groundwater quality. The groundwater samples were analyzed for the parameters specified in *Ontario Regulation 232/98* (except for total suspended solids), which relates to the construction and expansion of landfill sites. Three rounds of groundwater sampling were conducted as part of this study. All samples were entered on Chain of Custody forms and delivered to Exova Laboratories of Ottawa, Ontario for the required analysis.

2.1.3.8.2 Residential Well Sampling Program

The residential water supply well sampling program involved collecting groundwater samples from supply wells in the vicinity of the NRR Site to characterize background groundwater quality for typical organic and inorganic landfill leachate parameters. The parameters analyzed for the residential wells were the same as the on-Site monitoring wells. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply (i.e., well type, depth, location, satisfaction with water quality and quantity, etc.). If the water supply is treated (i.e., water softener), the water sample was collected from an untreated location, or the treatment system was bypassed. All samples were entered on Chain of Custody forms and delivered to Maxxam Analytics Inc. (Maxxam) of Ottawa, Ontario for the required analysis.

2.1.4 Results and Discussion

2.1.4.1 Test Pit and Augerhole Program

A total of five augerholes and 16 test pits were completed across the NRR Site between November 18 and 23, 2009, to define the overburden types, and the thickness and distribution of the overburden. The approximate locations of the augerholes and test pits are shown on Figure 2.1-2. A description of the various material and groundwater conditions encountered in the test pits and augerholes are provided in the augerhole and test pit records in Attachment TSD#1-B-1.

All test pits and augerholes were excavated/advanced to bedrock refusal with the exception of test pits TP-15 and TP-16 on the easternmost extent of the property where the bedrock is at a depth greater than six metres. For the augerholes and test pits reaching refusal, bedrock was found between 0.25 mbgs (AH09-3) and 4.5 mbgs (TP09-14). Overall, the bedrock is less than 2.7 mbgs, with the exception of the eastern half of the Concession IV portion of the property east of Eadie Road (i.e., at TP09-14, TP09-15 and TP09-16).

The central portion of the NRR Site has various thicknesses of completely weathered shale overlying the shale bedrock. In the northwestern and southwestern portions of the NRR Site, the bedrock is typically overlain by glacial till. At some locations, the glacial till is overlain by a thin layer of silty clay or silty sand. On the eastern half of the Concession IV portion of the property, the bedrock surface is deeper with significant thicknesses of overlying silty clay and glacial till (i.e., greater than six metres).

Laboratory testing for water content and Atterberg Limits was completed using a variety of weathered shale samples collected from TP09-2, TP09-3 and TP09-6, and silty clay samples collected from TP09-14 and TP09-15. The results of the laboratory testing are provided on the test pit logs in Attachment TSD#1-B-1. Grain size analyses were also carried out on selected samples collected from TP09-3 (completely weathered shale at 0.5 mbgs), TP09-14 (silty clay at 0.45 to 0.70 mbgs) and TP09-15 (silty clay at 1.20 mbgs). The grain size curves are provided following the test pit logs in Attachment TSD#1-B-1.

2.1.4.2 Borehole Drilling Program

The subsurface conditions encountered in the boreholes at the NRR Site are shown on the Record of Drillhole Sheets in Attachment TSD#1-B-2-1.

2.1.4.2.1 Overburden

The following presents a summarized overview of the overburden encountered within the boreholes.

Topsoil

Approximately 240, 250 and 200 millimetres of topsoil was encountered at ground surface at BH09-3, BH09-5 and BH09-6, respectively.

Sandy Silt

The topsoil at BH09-6 is underlain by about 0.7 metres of sandy silt.

Sensitive Silty Clay

The topsoil at BH09-5 is underlain by a deposit of silty clay. The silty clay was fully penetrated to a depth of about 7.9 metres below the existing ground surface.

The upper 3.1 metres of the silty clay have been weathered to a grey brown crust. The silty clay below the depth of weathering is grey in colour and unweathered. This unweathered portion of the deposit is about 4.6 metres thick.

Glacial Till

The topsoil at BH09-3 and the silty clay at BH09-5 are underlain by a deposit of glacial till. The glacial till is a heterogeneous mixture of gravel, cobbles and boulders in a matrix of sandy silt and clayey silt with a trace of clay. This deposit was fully penetrated to depths of about 5.0 and 16.5 metres below the existing ground surface at BH09-3 and BH09-5, respectively.

A thin layer of sand and gravel underlies the glacial till at BH09-5.

2.1.4.2.2 Borehole Coring Program

The coring program at the NRR Site included the drilling of four boreholes. The cored boreholes were identified as BH09-3, BH09-4, BH09-5 and BH09-6 (see locations on Figure 2.1-2). The following table provides the drilling details for cored holes.

Table 2.1-1: NRR Site Cored Hole Drilling Details – BH09-3 through BH09-6

Location	Date Drilled	Ground Surface Elevation (masl)	Depth to Bedrock (m)	Total Depth (m)
BH09-3	Nov. 17-18, 2009	86.30	5.0	30.56
BH09-4	Nov. 3-9, 2009	79.05	0.61	30.84
BH09-5	Nov. 11-16, 2009	73.93	16.92	25.60
BH09-6	Nov. 24-26, 2009	84.94	0.91	30.51

The intent of the borehole coring program was to penetrate the entire thickness of the Queenston Formation and to finish the cored holes in the upper part of the underlying Carlsbad Formation. An assessment of the lithology and stratigraphy was completed using the bedrock core recovered from BH09-3 through BH09-6. The assessment involved a systematic description of the core including: weathered state; structure; colour; grain size; bedding; texture; material type; and, the location of open bedding planes/voids. The geologic descriptions and sequence of bedrock formations encountered in BH09-3 through BH09-6 are included in the drillhole logs provided in Attachment TSD#1-B-2-1.

The following provides a summary of the material encountered at each borehole location:

- BH09-3: 5 metres of glacial till underlain by 5.5 metres of Queenston Formation followed by the Carlsbad Formation to the end of the borehole (30.5 mbgs);
- BH09-4: 0.6 metres of completely weathered mudstone underlain by 20.7 metres of Queenston Formation followed by the Carlsbad Formation to the end of the borehole (30.8 mbgs);
- BH09-5: 7.9 metres of silty clay underlain by 8.5 metres of glacial till followed by the Carlsbad Formation to the end of the borehole (25.6 mbgs); and
- BH09-6: 3.6 metres of overburden (sandy silt followed by moderately to completely weathered mudstone) underlain by 4.1 metres of Queenston Formation followed by the Carlsbad Formation to the end of the borehole (30.5 mbgs).

Based on the results of the borehole coring program, the bedrock at the NRR Site is typically close to ground surface with the exception of the eastern extent of the property where close to 17 metres of overburden was present. The thickness of the Queenston Formation in the cored boreholes is variable across the NRR Site and ranges between 0 metres at BH09-5 and 20.7 metres at BH09-4. The Carlsbad Formation was encountered in all cored boreholes.

2.1.4.2.3 Air Rotary Drilling Program

The air rotary drilling program at the NRR Site included the drilling of four boreholes. The boreholes were identified as BH08-1, BH08-2, BH09-7 and BH09-8 (see locations on Figure 2.1-2). The following table provides the drilling details for air rotary boreholes.

Table 2.1-2: NRR Site Air Rotary Drilling Details - BH08-1, BH08-2, BH09-7 and BH09-8

Location	Date Drilled	Ground Surface Elevation (masl)	Depth to Bedrock (m)	Total Depth (m)
BH08-1	April 24, 2008	82.57	1.0	9.1
BH08-2	April 24, 2008	80.77	1.5	9.1
BH09-7	Nov. 20, 2009	83.52	4.88	33.55
BH09-8	Nov. 30, 2009	79.38	2.13	30.50

BH08-1 and BH08-2 were drilled to monitor changes in water levels in the shallow bedrock during the dewatering of the on-Site quarry in the spring and summer of 2008. The deeper boreholes (BH09-7 and BH09-8) were completed to a depth of approximately 30 metres for the purpose of defining Site stratigraphy (using geophysical methods) at key locations. The geology at all four locations was assessed based on chip samples collected during drilling (the overburden was not sampled as part of the air rotary drilling program). A summary of the geology encountered at BH08-1, BH08-2, BH09-7 and BH09-8 is provided on the borehole logs in Attachment TSD#1-B-2-1. The MOE water well records for the four boreholes are also provided in Attachment TSD#1-B-2-1.

The following provides a summary of the material encountered at each borehole location:

- BH08-1 – 1 metre of overburden followed by the Queenston Formation to the end of the borehole (9.1 mbgs);
- BH08-2 – 1.5 metres of overburden followed by the Queenston Formation to the end of the borehole (9.1 mbgs);
- BH09-7 – 4.9 metres of overburden followed by the Queenston Formation to the end of the borehole (33.6 mbgs); and
- BH09-8 – 2.1 metres of overburden underlain by 23.6 metres of Queenston Formation followed by Carlsbad Formation to the end of the borehole (30.5 mbgs).

The results of the air rotary drilling program indicates there is a significant thickness of the Queenston Formation along the northern extent of the NRR Site. The thickest sequence of Queenston Formation observed at the NRR Site was encountered at BH09-7, where the formation was greater than 28 metres in thickness.

2.1.4.3 Packer Testing

A total of 30 packer tests were carried out to assess the horizontal hydraulic conductivity of the bedrock beneath the NRR Site. The packer tests were conducted in the open cored boreholes (BH09-3 through BH09-6) prior to the installation of the monitoring wells. The test intervals for the packer testing ranged between 2.44 and 3.05 metres, and focused on the bedrock between the bottom of the hole and the water table or the casing, whichever was lower. The hydraulic conductivity estimates obtained during the packer testing are provided on the drillhole logs for BH09-3 through BH09-6 provided in Attachment TSD#1-B-2-1. The results of the packer testing for all intervals tested are provided in Table TSD#1-B-3-1 in Attachment TSD#1-B-3. The following table summarizes the packer testing result for all zones where a measurement of hydraulic conductivity could be obtained (i.e., all intervals having “no take” are not presented in the table below).

Table 2.1-3: NRR Site Packer Testing Results

Location	Interval Tested (mbgs)	Hydraulic Conductivity (m/sec)	Formation Tested
BH09-3	7.32 to 9.75	1.7×10^{-7}	Queenston Formation
BH09-4	2.74 to 5.18	3.0×10^{-6}	Queenston Formation
BH09-4	4.88 to 7.32	3.0×10^{-7}	Queenston Formation
BH09-4	24.69 to 27.74	2.3×10^{-8}	Carlsbad Formation
BH09-6	18.29 to 21.34	1.3×10^{-8}	Carlsbad Formation

Based on the results of the packer testing, 25 of the 30 intervals tested had “no take” indicating the hydraulic conductivity for the interval being tested was less than 1×10^{-8} metres per second (m/sec). Overall, the hydraulic conductivity of the bedrock beneath the NRR Site is low with the exception of some areas of slightly enhanced permeability in the Queenston Formation within the upper 10 metres at BH09-3 and BH09-4.

2.1.4.4 Borehole Geophysical Logging Program

This section provides an interpretation and summary of the borehole geophysical logging carried out at boreholes BH09-3, BH09-4, BH09-5, BH09-6, BH09-7 and BH09-8. Locations BH09-3, BH09-5 and BH09-6 were logged for stratigraphy only, while BH09-4, BH09-7 and BH09-8 also include logging for structure (optical/acoustic televiewer and caliper) and “hydrogeophysical” logs (fluid temperature, fluid resistivity and heat pulse flow metre). The geophysical logging of the boreholes was completed between November 30 and December 4, 2009.

The natural gamma and apparent conductivity logs are presented on Figure TSD#1-B-4-1-1 through Figure TSD#1-B-4-1-5 in Attachment TSD#1-B-4-1 and are interpreted to show the stratigraphic correlation between the boreholes. The geophysical logs (full suite) for BH09-4, BH09-7 and BH09-8 are presented in Attachment TSD#1-B-4-2, TSD#1-B-4-3 and TSD#1-B-4-4, respectively. The data presented includes measured and derived log data. The measured logs are for natural gamma, apparent conductivity, optical televiewer, acoustic televiewer (amplitude and travel time), caliper (3-arm) and fluid temperature, fluid resistivity and heat pulse flow meter under static and dynamic borehole fluid conditions. The derived logs include the average caliper from the acoustic televiewer travel time and the structure and tadpole logs interpreted from the optical and acoustic televiewer logs. The logs have been annotated to show permeable zones in the borehole walls interpreted from the hydrogeophysical logs.

2.1.4.4.1 Stratigraphic Interpretation

The natural gamma and apparent conductivity logs are presented on Figure TSD#1-B-4-1-1 in Attachment TSD#1-B-4-1 and interpreted sections are shown on Figure TSD#1-B-4-1-2 through Figure TSD#1-B-4-1-5. These logs are shown together with schematic geological logs based on the borehole logs in Attachment TSD#1-B-2-1.

The log data were compared to the lithologic logs and geologic contacts were plotted based on both sets of data. The natural gamma signatures were found to be consistent with the lithologic description but were used to refine the logged depths. The schematic geology logs show overburden (from drill records) and the stratigraphy in the underlying bedrock, which consists of sedimentary bedrock of the Queenston and Carlsbad Formations. A “marker bed” was identified within the Queenston Formation allowing for a correlation of the stratigraphy between boreholes. The contoured surface of the top of the “marker bed” interpolated from boreholes BH09-3 through BH09-8 is shown in the inset on Figure TSD#1-B-4-1-1.

The stratigraphy is interpreted to dip at two to three degrees from BH09-3, BH09-6 and BH09-5 towards BH09-7 and BH09-8. This is supported by the predominant dip direction for bedding/banding/foliation and geological planes encountered in boreholes BH09-4, BH09-7 and BH09-8 (i.e., at low angle and slightly west of north).

2.1.4.4.2 Structure Analysis

Geophysical logs for boreholes BH09-4, BH09-7 and BH09-8 were analyzed for structure intersecting the borehole walls including:

- Major open fractures;
- Minor open fractures;
- Partially open fractures;
- Healed fractures;
- Bedding, banding and foliation; and
- Geological contacts (where apparent).

The structure data (structure sinusoids and tadpoles) are shown on the logs together with summary plots in Attachments TSD#1-B-4-2, TSD#1-B-4-3 and TSD#1-B-4-4 for borehole BH09-4, BH09-7 and BH09-8, respectively. Depicted on the structure summary logs is a Schmidt Plot for the plane feature strike and a rose plot of the dip azimuth.

2.1.4.4.3 Hydrogeophysical Logs

The fluid temperature/resistivity and heat pulse flow meter logs were collected under non-pumping and pumping conditions. Both sets of data are shown on the logs in Attachments TSD#1-B-4-2, TSD#1-B-4-3 and TSD#1-B-4-4. The data are also shown in tables contained within the appendices.

The general result for boreholes BH09-4, BH09-7 and BH09-8 is that the majority of flow encountered is shallow, from within the shallow fractured bedrock zones, and that permeability is lower with depth.

2.1.4.5 Monitoring Well Installation and Elevation Surveying Program

Groundwater monitoring wells were constructed to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the various bedrock formations encountered at the NRR Site. Multi-level groundwater monitoring wells were constructed in BH09-3, BH09-4 and BH09-6 through BH09-8. A single monitoring well was installed in BH09-5, and locations BH08-1 and BH08-2 were left as open holes. The selected locations for the screened intervals were determined based on observations during the drilling and geophysical logging programs. To isolate the potential water bearing zones within the bedrock, the monitoring intervals were completed such that permeable zones identified during the packer testing in the cored holes (i.e., where there was water take) and the flow zones identified by the hydrogeophysical logs completed at BH09-7 and BH09-8 were included within the selected screened intervals.

The following table summarizes the monitoring well completion details for the monitoring wells constructed in boreholes BH09-3 through BH09-8. The monitoring well installations are shown on the borehole/drillhole logs in Attachment TSD#1-B-2-1.

Table 2.1-4: NRR Site Monitoring Well Completion Details

Location	Ground Surface Elevation (masl)	TOP Elevation (masl)	Screened Interval* (mbgs)	
			Top	Bottom
BH08-1	82.57	83.17	open hole to 9.1 mbgs	
BH08-2	80.77	81.44	open hole to 9.1 mbgs	
BH09-3A	86.30	87.13	15.80	21.95
BH09-3B	86.30	87.13	6.10	13.41
BH09-4A	79.05	79.94	16.46	21.95
BH09-4B	79.05	79.96	1.83	7.62
BH09-5	73.93	74.69	18.90	25.60
BH09-6A	84.94	85.06	16.46	22.56
BH09-6B	84.94	85.09	4.88	10.36
BH09-7A	83.52	84.29	26.16	33.55
BH09-7B	83.52	84.31	18.29	24.23
BH09-7C	83.52	84.31	6.71	11.89
BH09-8A	79.38	80.27	24.38	30.50
BH09-8B	79.38	80.31	14.02	21.34
BH09-8C	79.38	80.33	3.96	8.23

Notes: TOP – top of pipe
* The screened interval refers to the entire gravel pack area – not just the length of the slotted screen

2.1.4.6 Hydraulic Conductivity Testing

Well response tests were carried out in the 13 monitoring intervals installed within the on-Site boreholes using the rising-head method. The results of the *in-situ* hydraulic conductivity testing are summarized in the following Table 2.1-5. The depth of the screened interval and comments relating to the interval tested are provided. The packer testing result for the corresponding interval is also provided for the cored boreholes (BH09-3 through BH09-6).

Table 2.1-5: NRR Site Hydraulic Conductivity Results

Location	Screened Interval* (mbgs)	Hydraulic Conductivity (m/sec)		Formation Monitored	Comments
		Rising-Head Test	Corresponding Packer Test**		
BH09-3A	15.80 to 21.95	8.6×10^{-7}	$<1 \times 10^{-8}$	Carlsbad	hydraulic conductivity from packer testing is an estimate based on no observed take
BH09-3B	6.10 to 13.41	1.0×10^{-6}	1.7×10^{-7}	Queenston/ Carlsbad Contact	- -
BH09-4A	16.46 to 21.95	5.7×10^{-8}	$<1 \times 10^{-8}$	Queenston/ Carlsbad Contact	hydraulic conductivity from packer testing is an estimate based on no observed take
BH09-4B	1.83 to 7.62	2.4×10^{-6}	3.0×10^{-6}	Queenston	- -
BH09-5	18.9 to 25.60	1.3×10^{-6}	$<1 \times 10^{-8}$	Carlsbad	hydraulic conductivity from packer testing is an estimate based on no observed take
BH09-6A	16.46 to 22.56	9.7×10^{-7}	1.3×10^{-8}	Carlsbad	- -
BH09-6B	4.88 to 10.36	6.0×10^{-8}	$<1 \times 10^{-8}$	Queenston/ Carlsbad Contact	hydraulic conductivity from packer testing is an estimate based on no observed take
BH09-7A	26.16 to 33.53	7.8×10^{-7}	- -	Queenston	- -
BH09-7B	18.29 to 24.23	2.5×10^{-6}	- -	Queenston	- -
BH09-7C	6.71 to 11.89	5.3×10^{-7}	- -	Queenston	- -
BH09-8A	24.38 to 30.48	2.0×10^{-8}	- -	Queenston/ Carlsbad Contact	- -
BH09-8B	14.02 to 21.34	3.6×10^{-9}	- -	Queenston	- -
BH09-8C	3.96 to 8.23	$>1.0 \times 10^{-2}$	- -	Queenston	hydraulic conductivity from rising-head test is an estimate because recovery was too fast to complete the test

Notes:

No hydraulic testing was completed in open holes BH08-1 and BH08-2.

* The screened interval refers to the entire gravel pack area – not just the length of the slotted screen.

** The approximate corresponding packer testing interval may not be identical to the interval tested during the rising-head test.

For the above table, if there was more than one packer testing interval included with the rising-head test interval, the higher of the two packer testing results was reported. It was assumed the more conductive feature would dominate the hydraulic conductivity within the screened interval. Overall, the packer testing and rising-head test results are similar, with the exception of BH09-5 where the results differ by approximately two orders of magnitude.

Based on the results of the *in-situ* hydraulic conductivity testing completed at the NRR Site (packer testing and rising-head tests), the following ranges in hydraulic conductivities were observed in the bedrock formations at the NRR Site:

- Queenston Formation: 3.6 x 10^{-9} m/sec to >1.0 x 10^{-2} m/sec;
- Carlsbad Formation: <1 x 10^{-8} m/sec to 1.3 x 10^{-6} m/sec; and
- Queenston Formation/Carlsbad Formation Contact: <1 x 10^{-8} m/sec to 1.7 x 10^{-7} m/sec.

Overall, the majority of the Queenston Formation and the Carlsbad Formation is tight; however, at some locations there is enhanced permeability in the upper portion of the Queenston Formation (observed at BH09-3 and BH09-4). There does not appear to be a zone of enhanced permeability at the contact between the Queenston Formation and the Carlsbad Formation.

2.1.4.7 Water Level Monitoring Program

A groundwater level monitoring program was conducted to provide information on hydraulic gradients, the range in groundwater levels observed at the NRR Site over time and the groundwater flow direction(s). Groundwater levels were measured 36 times in the on-Site monitoring wells between January 8, 2010 and December 6, 2012. In addition to the groundwater level measurements, the elevation of the water level in the quarry was measured 16 times between May 20, 2011 and October 29, 2012. The groundwater and quarry level elevation data collected to date are provided in Table TSD#1-B-5-1 in Attachment TSD#1-B-5.

2.1.4.7.1 Groundwater Elevations

Graphs showing the trends in groundwater levels over time for the monitoring locations are shown on Figure TSD#1-B-5-1 through Figure TSD#1-B-5-7 in Attachment TSD#1-B-5. The following provides general observations about the groundwater elevations measured at the NRR Site:

- All groundwater monitoring locations at the NRR Site display seasonal variations. In general, water levels are highest during the spring freshet, which is followed by a decline in water levels during the late spring and summer. Groundwater levels typically rise during the fall, and decline again during the winter;
- At locations BH09-4, BH09-6 and BH09-8, the shallow installations typically display slightly greater seasonal variations than observed in the deeper installation(s);
- Locations BH09-3 (A and B), BH09-6 (A and B) and BH09-7 (A, B and C) typically have the highest groundwater elevations at the NRR Site and have ranged between 79.5 and 83.7 masl between January 8, 2010 and December 6, 2012. These monitoring well locations are found on the western and southern boundaries of the NRR Site;

- On June 29, 2010, location BH08-1 was developed and sampled (see Figure TSD#1-B-5-1). Due to the low hydraulic conductivity bedrock in the vicinity of this monitoring well, it required over two months for the groundwater level to return to static; and
- The erratic groundwater levels observed for locations BH09-8A and BH09-8B between January 8, 2010 and October 23, 2011 on Figure TSD#1-B-5-7 are a result of well development on January 8, 2010, and sampling events completed on February 12, 2010, June 29, 2010 and September 7, 2010. Following the October 3, 2011 sampling event, groundwater levels gradually returned to static levels over the next six to eight months. The slow recovery in water levels at these locations is a result of the low hydraulic conductivity bedrock in the vicinity of the monitoring intervals.

2.1.4.7.2 Quarry Water Elevations

The elevation of the water level in the quarry was measured 16 times between May 20, 2011 and October 29, 2012. Figure TSD#1-B-5-8 in Attachment TSD#1-B-5 displays the trend in quarry water levels over time. The water level in the quarry was measured using staff gauge SG-1 between May 20, 2011 and May 30, 2012. The top of SG-1 was surveyed, and the elevation of the quarry water was measured relative to the known top of gauge elevation. Based on the measurements at SG-1, the water level in the quarry gradually declined approximately 0.12 metres during the summer of 2011. This was followed by an increase of approximately 0.15 metres during the fall rains in 2011.

There were no staff gauge measurements in January and February 2012 because the water in the quarry was frozen. Following the spring melt in March 2012, the quarry water level increased by approximately 0.5 metres. Based on the measurements at SG-2, the water level in the quarry continued to increase through the spring of 2012 to a maximum elevation of 78.07 in May 2012. At that time, staff gauge SG-1 was almost under water, so a new staff gauge (SG-2) was installed and surveyed. The water level in the quarry gradually declined between May 2012 and September 2012. A slight increase in the water level in the quarry was observed in October 2012. The increase in water levels observed in October 2012 is interpreted to be associated with the fall rains.

2.1.4.7.3 Vertical Gradients

The following table provides a summary of the direction of vertical gradients observed at the NRR Site.

Table 2.1-6: NRR Site Direction of Vertical Gradient

Locations	Interpreted Direction of Vertical Gradient/Comments
BH09-3A and BH09-3B	no significant vertical gradient observed
BH09-4A and BH09-4B	downward vertical gradient
BH09-6A and BH09-6B	typically downward vertical gradient; however, the gradient tends to switch to upward during periods of low groundwater levels at BH09-6B (i.e., during summer)
BH09-7A, BH09-7B and BH09-7C	no significant vertical gradient observed between BH09-7A and BH09-7B; an upward gradient is typically observed between BH09-7B and BH09-7C; however, the gradient has been downward between these monitors since September 2012
BH09-8A, BH09-8B and BH09-8C	During the period of stabilized groundwater levels at BH09-8A and BH09-8B (i.e., between July 2011 and December 2012), the vertical gradient between the intermediate/deep groundwater (BH09-8B and BH09-8A) and the shallow groundwater (BH09-8C) was typically downward. However, the gradient switched to upward during the summer of 2012 (i.e., during a period of low water levels at BH09-8C)

Based on the groundwater elevation data collected to date, vertical gradients at the NRR Site are typically downward, or absent, for most of the year; however, the gradient may switch to upward at some locations during the summer (i.e., BH09-6 and BH09-8). BH09-7 is the only monitoring location at the NRR Site that consistently has an upward gradient.

2.1.4.7.4 Continuous Groundwater Level Monitoring

Pressure transducers and data loggers were installed on May 20, 2010 at BH09-4 (A and B) and BH09-7 (A and C) to provide an ongoing record of groundwater levels. The results of the continuous groundwater level monitoring are presented on Figure TSD#1-B-5-9 and Figure TSD#1-B-5-10 in Attachment TSD#1-B-5. A selection of manual readings is plotted on the continuous groundwater level plots to confirm that the data loggers are collecting reliable data. The manual readings agree with the continuous data logger data. The data loggers measured a groundwater level every six hours (i.e., four readings per day), and provide a detailed record of seasonal variations in groundwater levels at the NRR Site.

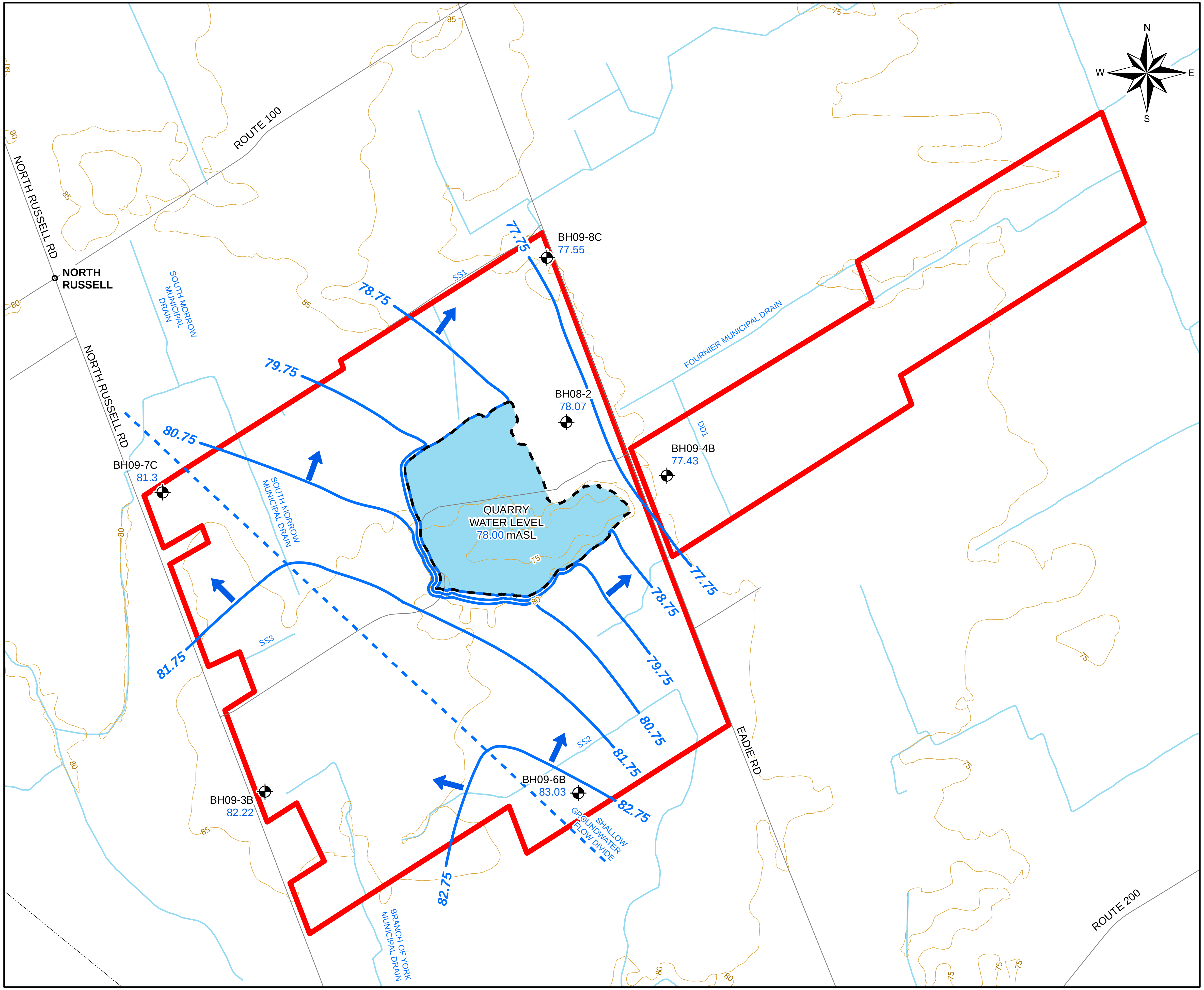
2.1.4.7.5 Groundwater Flow Direction

An estimate of the groundwater flow direction for the shallow and intermediate bedrock at the NRR Site was obtained using appropriately positioned (vertically) on-Site monitoring intervals. The following locations were used to provide an estimate of the shallow groundwater flow direction: BH08-2; BH09-3B; BH09-4B; BH09-6B; BH09-7C; and, BH09-8C. The groundwater levels collected from these locations on June 28, 2012, and October 29, 2012, were used to produce the groundwater contours shown on Figure 2.1-5 and Figure 2.1-6, respectively. As shown on Figure 2.1-5 and Figure 2.1-6 the groundwater contours are used to interpret the shallow groundwater flow direction in the bedrock at the NRR Site.

Based on the groundwater levels collected on June 28, 2012, the shallow groundwater flow direction for the majority of the NRR Site is interpreted to be towards the northeast; however, a shallow groundwater flow divide is interpreted to be present in the southwestern portion of the NRR Site. Shallow groundwater to the west of this divide is interpreted to be flowing towards the northwest. Based on the groundwater contour spacing shown on Figure 2.1-5, the hydraulic gradient (i.e., potential for groundwater flow) is greater on the east side of the divide than on the west side. As such, groundwater on the east side of the divide is interpreted to have a higher average linear groundwater velocity.

Based on the groundwater levels collected on October 29, 2012, the shallow groundwater flow direction for the entire NRR Site is interpreted to be towards the northeast. The shallow groundwater flow divide in the southwestern portion of the NRR Site observed based on the groundwater levels collected on June 28, 2012, is not apparent. The presence/absence of the shallow groundwater flow divide is primarily controlled by the groundwater levels at BH09-6B and BH09-3B. The shallow groundwater flow divide is interpreted to be a seasonal feature that is present during periods of high water levels at the Site and when groundwater levels are higher at BH09-6B than at BH09-3B.

As shown on Figure 2.1-5 and Figure 2.1-6, the shallow groundwater flow contours are influenced by the presence of the quarry at the NRR Site. The elevation of the water in the quarry on June 28, 2012, and October 29, 2012, was 78.00 and 77.90 masl, respectively. Based on the contours plotted on Figure 2.1-5 and Figure 2.1-6, the water level in the quarry is depressed relative to the surrounding shallow groundwater levels.



LEGEND

- ○ POPULATED PLACENAME
- ⊕ BOREHOLE/MONITORING WELL LOCATION
- — ROAD
- -··- UTILITY LINE
- — CONTOUR LINE, (5m)
- — SURFACE WATER FEATURE
- 🟦 WATER AREA
- ⬚ APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
- 🟥 PROPERTY BOUNDARY
- ➡ INTERPRETED GROUNDWATER FLOW DIRECTION
- - - SHALLOW GROUNDWATER FLOW DIVIDE
- — INTERPRETED GROUNDWATER CONTOUR
- 77.43 GROUNDWATER ELEVATION (JUNE 28, 2012)

200 100 0 200

SCALE 1:10,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

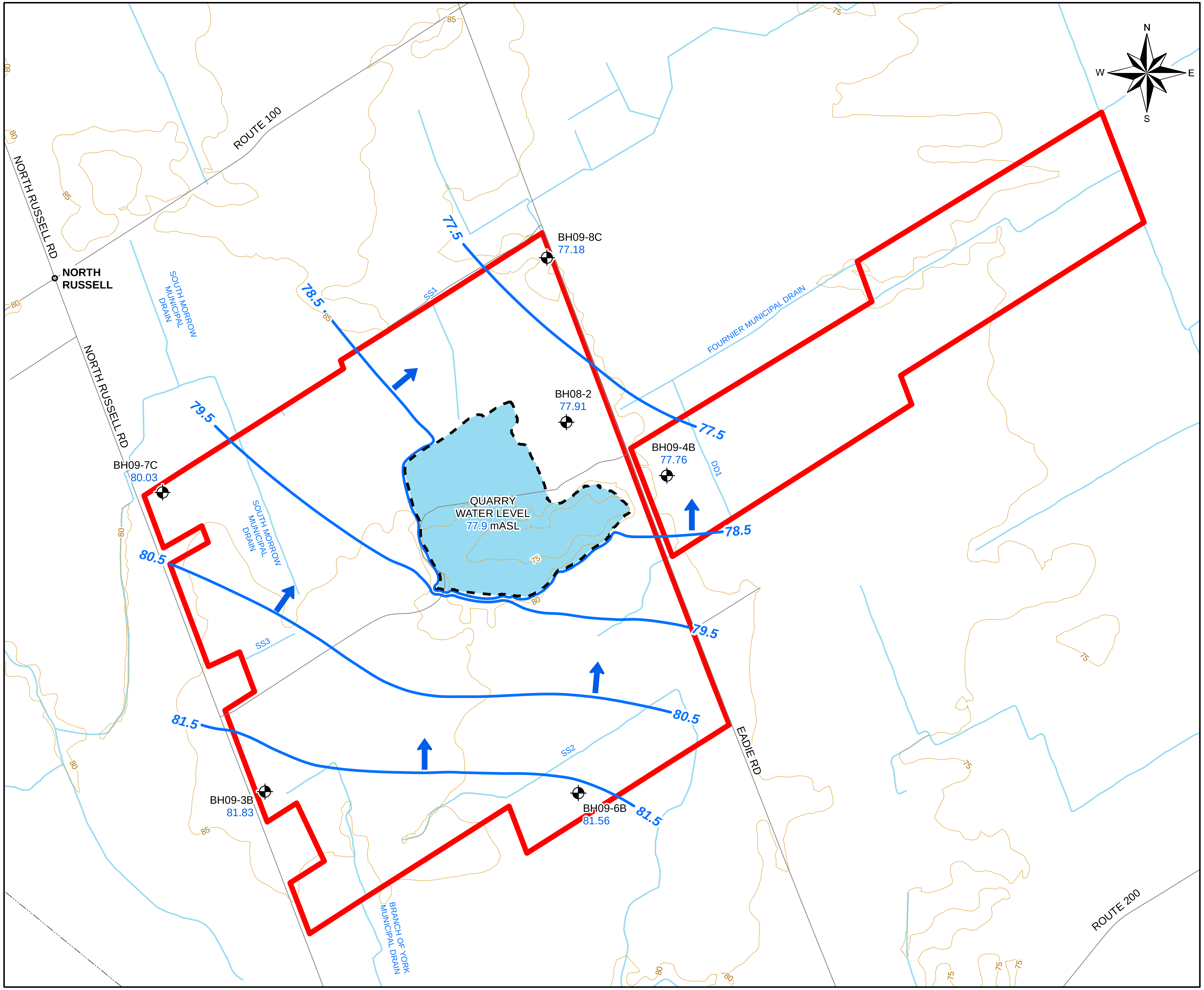
TITLE

NRR SITE
SHALLOW BEDROCK GROUNDWATER FLOW
(JUNE 28, 2012)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-5	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-5-ShallowBedGWFlow.mxd



LEGEND

- ○ POPULATED PLACENAME
- ⊕ BOREHOLE/MONITORING WELL LOCATION
- — ROAD
- -·- UTILITY LINE
- — CONTOUR LINE, (5m)
- — SURFACE WATER FEATURE
- ▨ WATER AREA
- ⬚ APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
- 🟥 PROPERTY BOUNDARY
- ➡ INTERPRETED GROUNDWATER FLOW DIRECTION
- — INTERPRETED GROUNDWATER CONTOUR
- 77.76 GROUNDWATER ELEVATION (OCTOBER 29, 2012)

200 100 0 200

SCALE 1:10,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
NRR SITE
SHALLOW BEDROCK GROUNDWATER FLOW
(OCTOBER 29, 2012)

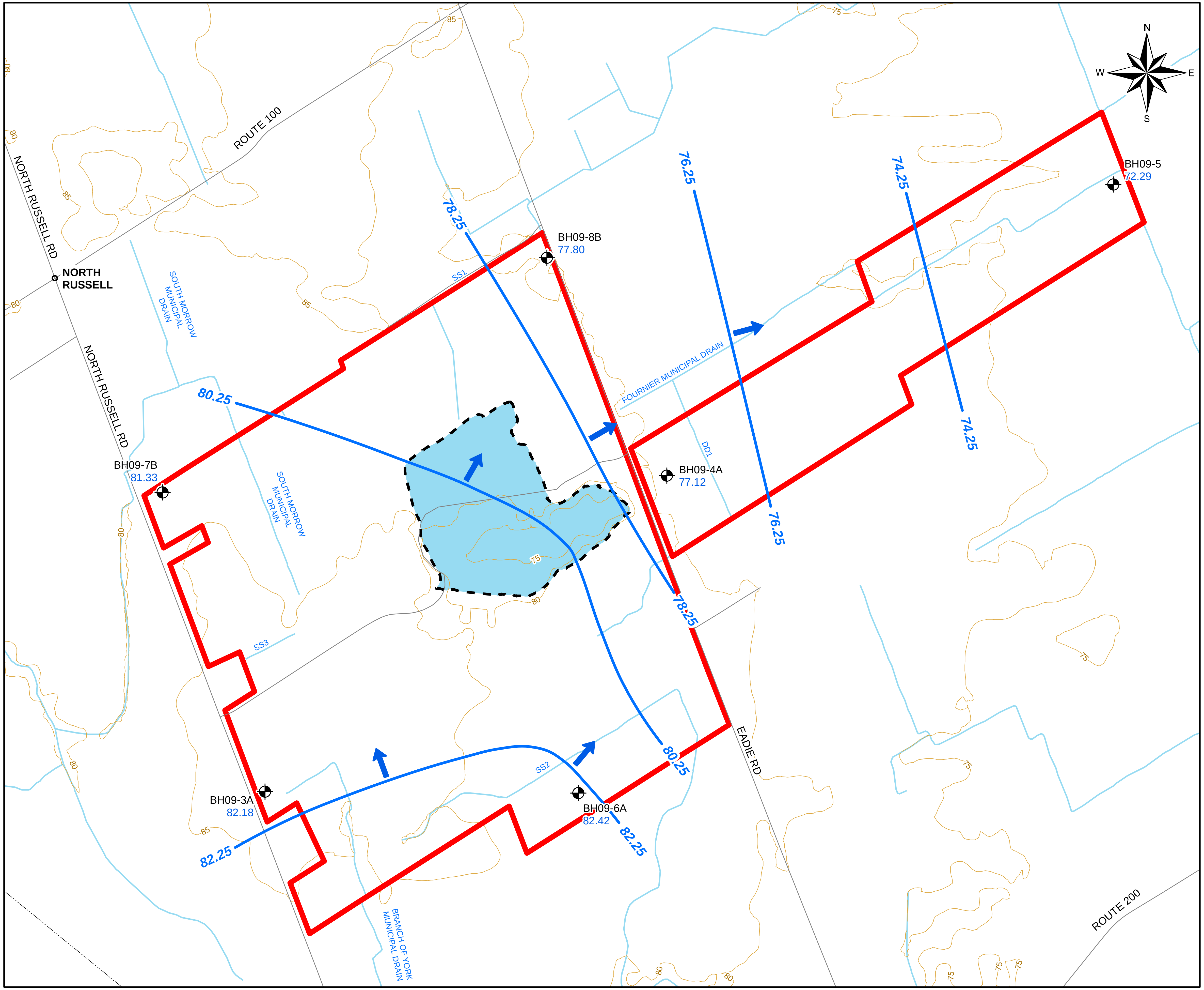
Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-6	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-6-ShallowBedGWFlow.mxd

An estimate of the groundwater flow direction for the intermediate bedrock zone at the NRR Site (i.e., between approximately 16 and 25 mbgs) was obtained using appropriately positioned (vertically) on-Site monitoring intervals. The following locations were used to provide an estimate of the intermediate groundwater flow direction: BH09-3A; BH09-4A; BH09-5; BH09-6A; BH09-7B and BH09-8B. The groundwater levels collected from these locations on June 28, 2012, and October 29, 2012, were used to produce the groundwater contours shown on Figure 2.1-7 and Figure 2.1-8, respectively. As shown on Figure 2.1-7 and Figure 2.1-8, the groundwater contours are used to interpret the groundwater flow direction in the intermediate bedrock at the NRR Site.

Based on the groundwater levels collected on June 28, 2012 and October 29, 2012, the intermediate groundwater flow direction for the NRR Site is interpreted to be towards the northeast on the portion of the Site west of Eadie Road, and towards the east on the portion of the Site east of Eadie Road. The top of the monitoring well intervals used to estimate the intermediate groundwater flow direction are completed at least 3.5 metres below the deepest portion of the former quarry at the Site, and it is interpreted that the groundwater flow direction in the intermediate bedrock at the Site is not influenced by the presence of the quarry.



LEGEND

- ○ POPULATED PLACENAME
- ⊕ BOREHOLE/MONITORING WELL LOCATION
- ROAD
- UTILITY LINE
- CONTOUR LINE, (5m)
- SURFACE WATER FEATURE
- WATER AREA
- APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
- PROPERTY BOUNDARY
- INTERPRETED GROUNDWATER FLOW DIRECTION
- INTERPRETED GROUNDWATER CONTOUR
- 77.76 GROUNDWATER ELEVATION (JUNE 28, 2012)

200 100 0 200

SCALE 1:10,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

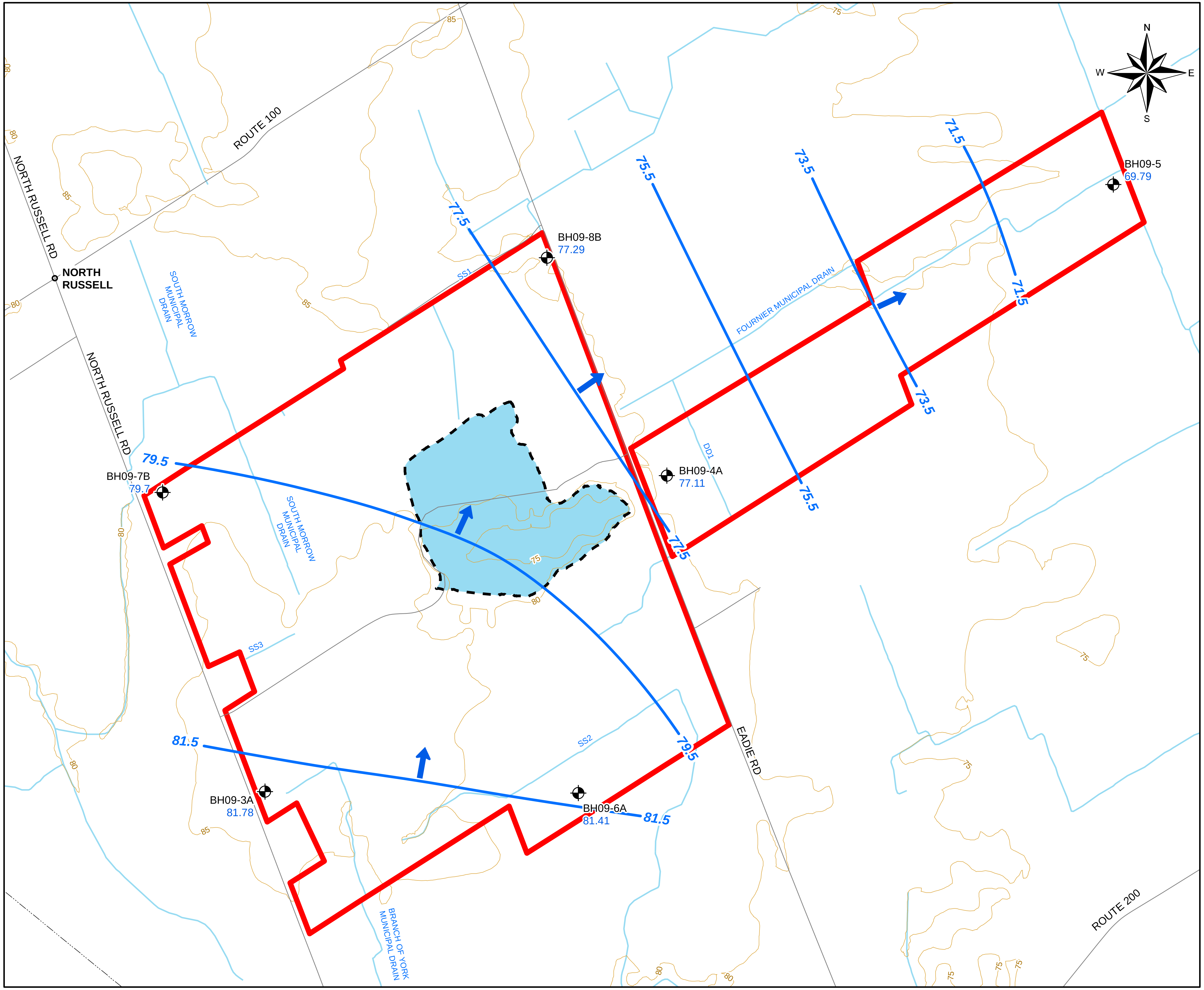
PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
NRR SITE
INTERMEDIATE BEDROCK GROUNDWATER FLOW
(JUNE 28, 2012)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-7	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-7-InterBedGWFlow.mxd



LEGEND

- ○ POPULATED PLACENAME
- ⌖ BOREHOLE/MONITORING WELL LOCATION
- ROAD
- UTILITY LINE
- CONTOUR LINE, (5m)
- SURFACE WATER FEATURE
- ▇ WATER AREA
- ▭ APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
- ▭ PROPERTY BOUNDARY
- ➡ INTERPRETED GROUNDWATER FLOW DIRECTION
- INTERPRETED GROUNDWATER CONTOUR
- 77.76 GROUNDWATER ELEVATION (OCTOBER 29, 2012)

200 100 0 200

SCALE 1:10,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

NRR SITE
INTERMEDIATE BEDROCK GROUNDWATER FLOW
(OCTOBER 29, 2012)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-8	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-8-InterBedGWFlow.mxd

2.1.4.8 Groundwater Quality Sampling Program

2.1.4.8.1 On-Site Monitoring Well Sampling Program

The on-Site groundwater quality sampling program involved collecting samples from the monitoring wells installed in BH09-3 through BH09-8 (i.e., the open hole locations BH08-1 and BH08-2 were not included in the groundwater monitoring program). A total of three rounds of groundwater quality sampling were completed at the NRR Site. The groundwater sampling dates are summarized below:

- Session 1 – between February 11 and 12, 2010 (all sample locations except BH09-4B which was frozen and subsequently sampled on March 11, 2010);
- Session 2 – between June 23 and 29, 2010; and
- Session 3 – between September 3 and 7, 2010.

The groundwater samples were analyzed for the parameters specified in *Ontario Regulation 232/98* (except for total suspended solids), which lists generic parameters that should be monitored at landfill sites. Total suspended solids were not measured in the samples collected from the monitoring wells because the analysis would be measuring material in the well that has accumulated over time, and was then re-suspended during the sampling process.

The groundwater quality results for the on-Site monitoring wells are provided in Table TSD#1-B-6-1-1 in Attachment TSD#1-B-6-1. For reference, the Ontario Drinking Water Quality Standards (ODWQS) health based standards and aesthetic objectives are provided on Table TSD#1-B-6-1. Based on the results of the groundwater quality sampling, locations BH09-5, BH09-8A and BH09-8B displayed groundwater quality that was different than what was observed elsewhere on the NRR Site. The following table provides a list of the parameters at BH09-5, BH09-8A and BH09-8B that were elevated relative to most sampling locations at the NRR Site.

Table 2.1-7: NRR Site Elevated Parameters - BH09-5, BH09-8A and BH09-8B

Location	Elevated Parameters
BH09-5	calcium, sodium, COD, ammonia, TKN, TDS, total phosphorus, conductivity, barium and chloride
BH09-8A	calcium, sodium, TDS, conductivity, chloride and sulphate
BH09-8B	calcium, sodium, TDS, conductivity, nitrite, nitrate, chloride and sulphate

Notes: COD – chemical oxygen demand; TKN – total kjeldahl nitrogen; and TDS – total dissolved solids

In addition to the above, elevated sulphate and TDS concentrations were measured at BH09-4A. The elevated concentrations measured at BH09-4A, BH09-5, BH09-8A and BH09-8B are interpreted to be naturally occurring.

Overall, the shallow bedrock groundwater is indicated to be relatively fresh; with depth, in both the Queenston and Carlsbad Formations, the groundwater quality deteriorates with elevated concentrations of chloride, sodium, TDS, iron, manganese and occasionally sulphate, arsenic and barium compared to the ODWQS.

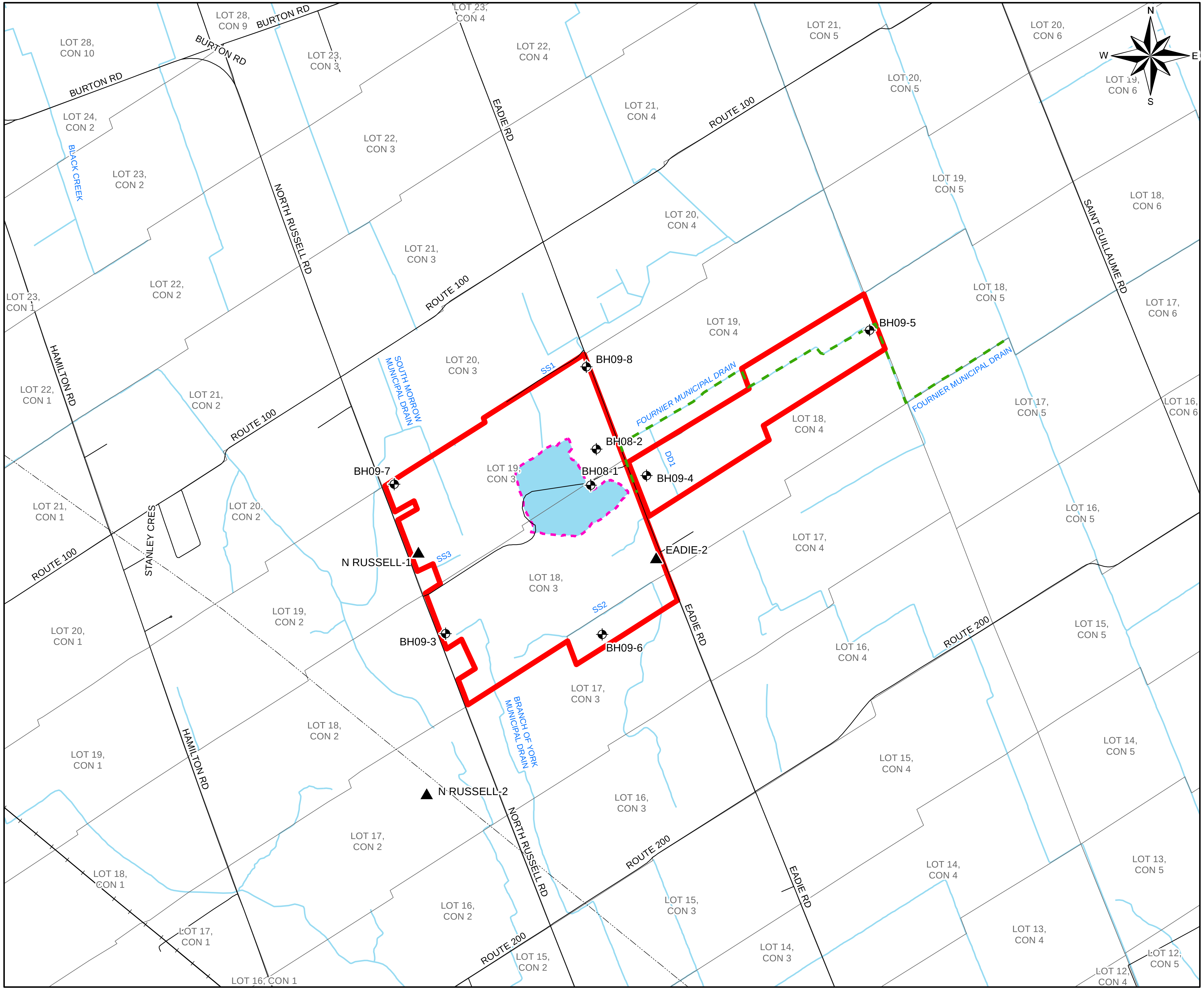
2.1.4.8.2 Residential Well Sampling Program

The residential water supply well sampling program involved collecting groundwater samples from supply wells in the immediate vicinity of the NRR Site to characterize background groundwater quality for typical organic and inorganic landfill leachate parameters. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply. Copies of the completed surveys are provided in Attachment TSD#1-B-7-1.

A total of four residential water supply wells were sampled between January 17 and 18, 2013. Residential water supply wells are situated along North Russell Road within the western limit (N Russell-1) and just southwest (N Russell-2) of the NRR Site, and along Eadie Road at the northern (Eadie-1) and southeastern extent (Eadie-2) of the NRR Site. The locations of N Russell-1, N Russell-2 and Eadie-2 are shown in Figure 2.1-9. Residential water supply wells N Russell-1 and Eadie-1 are drilled and completed in the bedrock (shale) and N Russell-2 and Eadie-2 are dug wells are completed in the overburden.

The groundwater quality results for the residential water supply wells are provided in Table TSD#1-B-7-1-1 in Attachment TSD#1-B-7-1. The results of residential water supply sampling program indicate that all parameters analyzed were below the respective ODWQS for which health based standards and aesthetic objectives have been established, with the exception of a few parameters at residential water supply wells Eadie-1, Eadie-2 and N Russell-2. Parameters exceeding the ODWQS include TDS and sodium at water supply wells Eadie-1 and Eadie-2 and nitrate at N Russell-2 only. Elevated concentrations of nitrate were also observed at N Russell-1.

The results of the residential water supply wells sampling program indicate that groundwater quality at the private well locations is consistent with the groundwater quality observed at all on-Site monitoring wells at the NRR Site, with the exception of monitoring wells BH09-5, BH09-8A and BH09-8B that generally had elevated parameters compared to other monitoring wells.



LEGEND

⊕	BOREHOLE/MONITORING WELL LOCATION
▲	RESIDENTIAL WATER SUPPLY WELL LOCATION
—	ROAD
┼	RAIL ROAD
-·-·-	UTILITY LINE
- - -	FOURNIER MUNICIPAL DRAIN
—	SURFACE WATER FEATURE
🟦	WATER AREA
☐	LOT/CONCESSION
▭	APPROXIMATE EXTENT OF EXISTING QUARRY EXCAVATION
🟥	PROPERTY BOUNDARY

390 195 0 390

SCALE 1:20,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
NRR SITE
RESIDENTIAL WATER SUPPLY
WELL LOCATIONS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.1-9	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.1-9-ResidentialWaterSupplyWellLocations.mxd

2.1.5 Summary of Conditions at North Russell Road Site

Table 2.1-8: Summary of NRR Site Considerations

Environmental Component	Summary of Site Considerations
Geology, Hydrogeology & Geotechnical	Geological Setting: ■ NRR Site is on a local bedrock high with the bedrock surface declining in elevation, and the overburden thickness overlying the bedrock increasing in all directions away from the Site. ■ The overburden at the NRR Site is typically less than two metres thick. The central portion of the NRR Site has various thicknesses of completely weathered shale overlying the shale bedrock. In the northwestern and southwestern portions of the NRR Site, the bedrock is typically overlain by glacial till. At some locations, the glacial till is overlain by a thin layer of silty clay or silty sand. On the eastern half of the Concession IV portion of the property, the bedrock surface is deeper resulting in significant thicknesses of overlying silty clay and glacial till. ■ The majority of the NRR Site is underlain by the Queenston Formation shale bedrock followed by the Carlsbad Formation limestone and shale. The Queenston Formation varies in thickness from zero at the eastern extent of the property to 28 metres in the northwestern portion of the NRR Site. ■ Overall, the majority of the Queenston Formation and the Carlsbad Formation at the NRR Site have a low hydraulic conductivity (i.e., less than 2.5 x 10^{-8}m/sec); however, at some locations there is enhanced permeability in the upper portion of the Queenston Formation (observed at BH09-8). The hydraulic conductivity of the upper bedrock generally ranges from 10^{-8} m/sec to 10^{-2} m /sec; below the upper bedrock zone, the hydraulic conductivity is typically 10^{-8} m/sec or less. There does not appear to be a zone of enhanced permeability at the contact between the Queenston Formation and the Carlsbad Formation. ■ In the unlikely event of an unmitigated leachate release from the proposed landfill to the shallow on-Site groundwater system, leachate-impacted groundwater would enter the bedrock and migrate downward and then in an easterly direction.
	Type and thickness of any natural on-Site attenuation layer: ■ The on-Site natural attenuation layer for vertical groundwater flow would rely on hydraulic properties of the shale bedrock. ■ The thickness of the shale bedrock is highly variable across the Site. ■ The shale is indicated to have an overall low hydraulic conductivity; however the hydraulic conductivity of the upper bedrock is variable, with the presence of zones of enhanced permeability due to fracturing and weathering.

Environmental Component	Summary of Site Considerations
	Presence and quality of groundwater resources on-Site and in Site-vicinity: ■ The on-Site shallow bedrock groundwater is indicated to be relatively fresh; with depth, in both the Queenston and Carlsbad Formations, the groundwater quality deteriorates with elevated concentrations of chloride, sodium, TDS, iron, manganese and occasionally sulphate, arsenic and barium compared to the ODWQS. ■ The results of a limited residential water supply sampling program indicate that all parameters analyzed were below the respective ODWQS for which health based standards and aesthetic objectives have been established, with the exception of a few parameters at residential water supply wells Eadie-1, Eadie-2 and N Russel-2. Parameters exceeding the ODWQS include TDS and sodium at water supply wells Eadie-1 and Eadie-2 and nitrate at N Russel-2 only. Elevated concentrations of nitrate were also observed at N Russel-1. ■ The results of the limited residential water supply wells sampling program indicate that groundwater quality at the private well locations is consistent with the groundwater quality observed at all on-Site monitoring wells at the NRR Site, with the exception of monitoring wells BH09-5, BH09-8A and BH09-8B that generally had elevated parameters compared to other monitoring wells. ■ In the unlikely event of an unmitigated release of leachate from the proposed landfill to the shallow groundwater system, leachate-impacted groundwater would enter the bedrock and migrate downward and eastward.
	Interpreted direction of vertical groundwater flow on-Site and in Site-vicinity (i.e., area of groundwater recharge, transitional flow, or groundwater discharge): ■ Based on the groundwater elevation data collected to date, vertical gradients at the NRR Site are typically downward, or absent, for most of the year. ■ The NRR Site is interpreted to be located within a large regional groundwater recharge area for the bedrock flow system. As such, in the event of a leachate release, leachate-impacted groundwater would move downward in the bedrock flow system. ■ Predictive modelling would be required to assess the potential for development of the CRRRC on the NRR Site to affect the availability of groundwater for off-Site users. However, in view of the relatively small portion of the overall recharge ridge area occupied by the CRRRC project, and the relatively low overall water demand from the bedrock in the area, it is not expected that it would have a noticeable effect on off-Site availability.

2.2 Boundary Road Site

2.2.1 Introduction

This report summarizes the results of the preliminary subsurface investigation and hydrogeological assessment of the BR Site located on the east side of Boundary Road on Lots 23 to 25, Concession XI, Township of Cumberland, Ontario. The general location of the BR Site is shown on Figure 2.1-1. A preliminary subsurface investigation was completed by Golder to obtain Site-specific geological, hydrogeological and geotechnical information.

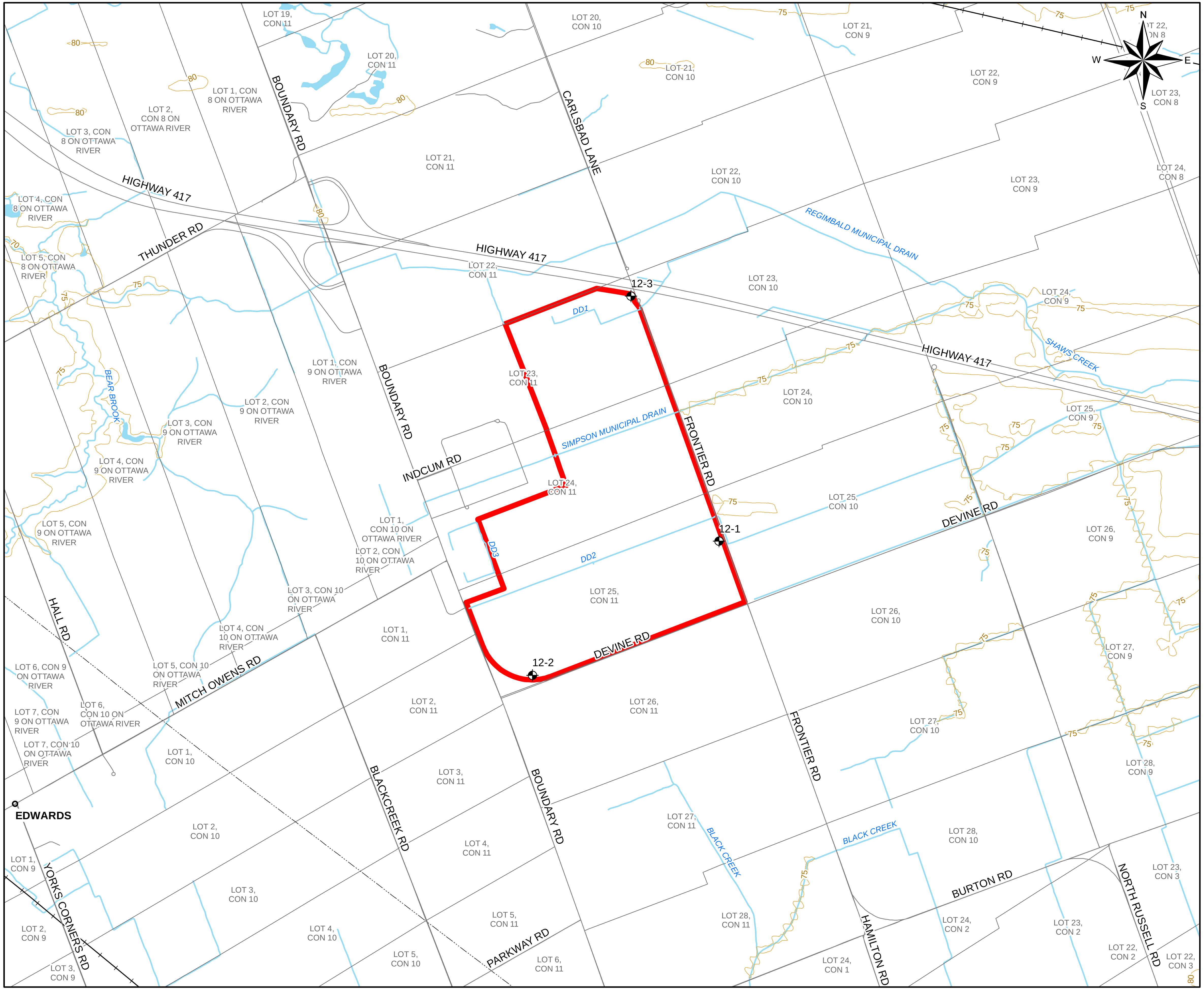
2.2.1.1 Site Description

The boundary of the BR Site at the time of this evaluation is shown on Figure 2.2-1. The BR Site is located in the east part of the City of Ottawa, in the former Township of Cumberland and just southeast of the Highway 417/Boundary Road interchange. The property is on the east side of Boundary Road, east of an existing industrial park, north of Devine Road and west of Frontier Road and totals about 175 hectares (430 acres) of land. Part of the northern portion of the BR Site is used for agricultural purposes, and the remainder of the BR Site is heavily vegetated.

The land use surrounding the BR Site is primarily a mix of commercial/light industrial and agricultural. The agricultural land use is found immediately east of the BR Site, as well as to the southeast, south and southwest; however, areas of undeveloped (heavily vegetated) land generally exist between the BR Site and the agricultural lands in these directions. The industrial land use is found to the west of the northern portion of the BR Site. Residential development in the vicinity of the BR Site is limited to some homes near the northern end of Frontier Road (on the BR Site and to be removed once facility construction commences), and some homes mixed in with the commercial/industrial uses along Boundary Road.

2.2.2 Local Setting

The following sections provide general information on the local geology, hydrogeology and geotechnical conditions in the vicinity of the BR Site taken from published sources and findings and interpretations of previous subsurface investigations. This information was gathered as part of a review of background information completed prior to beginning the subsurface investigation at the BR Site.



LEGEND

⊕	BOREHOLE/MONITORING WELL LOCATION
—	ROAD
┼	RAIL ROAD
—	CONTOUR LINE, (5m)
-··-	UTILITY LINE
—	SURFACE WATER FEATURE
▇	WATER AREA
☐	LOT/CONCESSION
🟥	PROPERTY BOUNDARY

490 245 0 490

SCALE 1:20,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BR SITE PLAN

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045		
DESIGN	JPAO	JAN. 2013
GIS	BR	JAN. 2013
CHECK	PLE	AUG. 2014
REVIEW	PAS	AUG. 2014

SCALE AS SHOWN

REV. 0

FIGURE 2.2-1

2.2.2.1 Surficial Geology

The surficial geology in the vicinity of the BR Site is shown on Figure 2.1-3. The BR Site and surrounding areas are underlain by an extensive and thick deposit of silty clay soil of marine origin (unit 3 on Figure 2.1-3). Based on published mapping, the marine clay in the western portion of the BR Site is overlain by deltaic and estuary deposits consisting of medium to fine grained sand. As shown on Figure 2.1-3, an extensive deposit of medium to fine grained sand overlying the marine clay is shown to the north of the BR Site. Based on previous investigations completed in the vicinity of the BR Site, the surficial sand material is discontinuous and is underlain by weathered silty clay (Golder, 1974a; WESA, 1986). The surficial sand and weathered clay typically do not extend beyond two to three metres depth. Below the weathered clay is the remainder of the silty clay deposit with an estimated thickness of 30 to 35 metres in the vicinity of the BR Site. The clay deposit is in turn underlain by approximately 1.5 to 5 metres of basal gravelly glacial till, followed by bedrock (Golder, 1974a; WESA, 1986).

From previous geotechnical investigations in the vicinity of the BR Site, it is reported that below the upper weathered zone, the clay deposit has a relatively soft consistency to a depth of about 10 metres, below which its shear strength gradually increases with depth and becomes stiff. The silty clay is a high plasticity soil with high natural water content, which is typical of the marine clay deposit in the Ottawa area (Golder, 1974a; Golder, 1974b, MTO, 1968; MTO 1969).

2.2.2.2 Bedrock Geology

The bedrock geology in the vicinity of the BR Site is illustrated on Figure 2.1-4. This figure shows the mapped uppermost bedrock unit beneath the soil cover. The area in the vicinity of the BR Site is underlain by interbedded shale, siltstone and limestone of the Carlsbad Formation. The shales are dark grey in colour and calcareous to non-calcareous. The siltstones and limestones are very thinly to medium bedded, medium grey to greenish grey in colour, and weathering a buff to reddish brown colour (Williams, 1991). Based on previous investigations in the Ottawa area, the total thickness of the Carlsbad Formation in the vicinity of the BR Site is reported to range between approximately 115 to 150 metres (Williams, 1991).

To the south of the BR Site, the uppermost bedrock unit is mapped as the shale of the Queenston Formation, which is indicated to exist in a west-east oriented band. The Queenston Formation to the south of the BR Site is underlain by the Carlsbad Formation. The Queenston Formation is the youngest formation of sedimentary rock in eastern Ontario and is described as a red, laminated to thickly bedded calcareous siltstone/mudstone and shale (Williams, 1991). The contacts between bedrock formations are typically caused by a series of near-vertical faults, which caused downthrowing of adjacent blocks of bedrock.

2.2.2.3 Hydrogeology

Water supply to residences, farms and commercial/industrial properties in the area of the BR Site utilizes individual wells. Drilled wells in this area typically obtain their water supply from the basal till/bedrock contact zone or from within the upper part of the bedrock. The yield of water from this zone is usually adequate for domestic use, with well yields reported to typically range from 15 to 25 litres/minute, and up to 45 to 65 litres/minute in certain wells. In the immediate vicinity of the BR Site, there are few wells registered in the MOE WWIS; these wells are completed in the basal till/bedrock contact zone and are indicated to yield enough water for domestic use. However, the groundwater quality in the immediate vicinity of the BR Site is reported as salty, sulphurous or mineralized; the presence of methane gas in the groundwater is also reported (WESA, 1986). For this reason, it is understood that most residents in the vicinity of the BR Site use shallow dug wells to provide a water supply from the upper sand layer and weathered clay zone. The groundwater quality problems in the basal till/bedrock contact zone are known to exist as far as three or four kilometres to the north of the BR Site to the area of Carlsbad Springs and also to the west. The City of Ottawa extended the municipal water supply to a portion of the Carlsbad Springs area to address these water supply issues. Further to the southwest and southeast, drilled wells are also completed in the basal till and the groundwater quality is reported as fresh (Charron, 1978; WESA, 1986; WESA and Earthfx, 2006).

In the absence of effective drainage in this flat lying terrain, the groundwater level in this fine grained soil is at or near ground surface throughout much of the year. In view of its low permeability characteristic, there is limited horizontal or vertical groundwater flow in the silty clay deposit; groundwater movement in the silty clay deposit would be very locally influenced adjacent to ditches or other watercourses. The silty clay deposit is an aquitard and does not allow recharge of the basal till and bedrock. Groundwater flow occurs in the basal till and bedrock; the direction of regional groundwater flow in these zones is indicated to be towards the northeast (Charron, 1978; WESA and Earthfx, 2006; WESA, 2010).

Based on a review of the City of Ottawa Official Plan, and the Source Water Protection work completed for the Rideau Valley Source Protection Area and the South Nation Source Protection Area, the BR Site is not located within a groundwater protection zone, or within a significant groundwater recharge area.

2.2.3 Study Methodology

To allow for a preliminary assessment of the suitability of the BR Site for use as a waste management facility, a work plan was develop to gather Site-specific geological, hydrogeological and geotechnical data to supplement the available published information. The methodology applied during the subsurface investigation and hydrogeological assessment is briefly described below.

2.2.3.1 Borehole Drilling

The field program for the BR Site includes the drilling of multiple test holes at three locations across the BR Site (numbered BH12-1, BH12-2 and BH12-3, inclusive). The approximate positions of the three investigation locations are shown on the attached, Site Plan, Figure 2.2-1. These locations correspond to locations E, A and Y as shown on Figure C-2.2-1 of the approved TOR. The test holes were advanced using a track-mounted drill rig supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario.

At each location, the following drilling program was typically carried out:

- Cone Penetration Testing (CPT) – CPTs were advanced at each location and are identified as CPT12-1-1, CPT12-2-1 and CPT12-3-1. The CPT consists of a probe with a cone shaped tip that is equipped with electronic sensing elements to continuously measure tip resistance, local side friction on a sleeve behind the tip, and porewater pressure. The cone is pushed at a constant rate into the ground using a drill rig. A continuous stratigraphic profile together with engineering properties, such as strength, stress history and density, can be interpreted from the results of the CPT. The CPTs were advanced to a depth of about 25 metres.
- Nilcon Vane Testing – Nilcon *in-situ* vane test boreholes were also advanced at each location and are identified as BH12-1-2, BH12-2-2 and BH12-3-2. In each boring, soil sampling and standard penetration tests were first carried out in the surficial native sand deposits and upper silty clay to depths of between about 1.8 and 2.1 metres, to reach the native unweathered silty clay. Below that depth, the boreholes were advanced using an electric Nilcon *in-situ* vane testing apparatus, with measurements taken at 1.0-metre

depth intervals. This vane testing was carried out under conditions of a constant rate of strain/rotation. The undrained shear strength of remoulded silty clay was also measured (to thereby measure the sensitivity) for about one out of every three to five test intervals. The boreholes were advanced within the silty clay deposit to depths between about 26.8 and 31.1 metres below the existing ground surface.

- Monitoring Well Installations – Monitoring wells were installed in four boreholes at each location and those boreholes are identified as BH12-1-3 to BH12-1-6, inclusive; BH12-2-3 to BH12-2-6, inclusive; and BH12-3-3 to BH12-3-6, inclusive, as well as BH12-1-3.1. These boreholes included installations within the bedrock, glacial till, silty clay and surficial sandy deposits, for measurement of the groundwater level, hydraulic conductivity testing and/or future 'down hole' geophysical testing. Standard penetration tests and 'split-barrel' soil sampling were carried in the lower portion of the silty clay at BH12-1-3 and within the glacial till at BH12-1-3, BH12-2-3 and BH12-3-3. In addition, 73-millimetre diameter thin-walled Shelby tube samples of the silty clay were obtained using a fixed piston sampler in BH12-1-3, BH12-2-3, BH12-3-3 and BH12-3-5. The boreholes were advanced up to maximum depths between about 36.7 and 40.6 metres where the bedrock surface was encountered.

- Once the bedrock was encountered at BH12-1-3, BH12-2-3, BH12-3-3 and BH12-1-3.1, the boreholes were extended between about 5 and 6 metres into the bedrock using rotary diamond drilling equipment while retrieving HQ size bedrock core.

The drilling was coordinated and observed by a Golder technician who located the test holes, monitored the drilling operations, logged the test holes, monitored the *in-situ* testing, and took custody of the soil samples retrieved.

Upon completion of the drilling operations, samples of the soils and rock core encountered in the boreholes were transported to our laboratory for examination by the project engineer and a geologist, and for laboratory testing.

2.2.3.2 Monitoring Well Installation and Elevation Surveying Program

Combined bedrock monitoring well and vertical seismic profiling (VSP) casing installations were constructed (as a single pipe) in BH12-2-3 and BH12-3-3. However, the VSP casing and bedrock monitoring well at location 12-1 were installed in two separate boreholes (i.e., BH12-1-3 and BH12-1-3.1, respectively) due to construction difficulties encountered with having a dual-purpose installation in a single borehole. The installations in BH12-2-3 and BH12-3-3 were constructed of 0.063-metre diameter, threaded, PVC slot #10 screen and solid risers. The VSP installation at BH12-1-3 was constructed of 0.076-metre diameter PVC solid risers. The bedrock monitoring well at BH12-1-3.1 was constructed of 0.050-metre diameter, threaded, PVC slot #10 screen and solid risers. Silica sand backfill was placed in the boreholes around the screened portion within the bedrock and then a combination of peltonite and bentonite-cement grout was used to seal the boreholes up to the ground surface.

Within the overburden soils, multi-level groundwater monitoring wells within the glacial till and silty clay were installed in BH12-1-4, BH12-1-5, BH12-2-5, BH12-3-4 and BH12-3-5. Single monitoring wells were installed within the sandy surficial deposits at BH12-1-6, BH12-2-6 and BH12-3-6 as well as within the deep silty clay at BH12-2-4. The monitoring wells were installed at specific depths to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the various soils and bedrock encountered at the BR Site. The preferred locations for the screened intervals of the monitoring wells were determined based on observations during the drilling program and on the results of the CPT and Nilcon vane testing. These monitoring wells were constructed of either 0.025-metre, 0.032-metre or 0.050-metre diameter, threaded, PVC slot #10 screen and solid risers.

Silica sand backfill was placed in the boreholes around the screened portions of the monitors. A combination of bentonite, peltonite and/or bentonite-cement grout was used to provide seals between the screened intervals and to seal the borehole up to ground surface.

Each monitoring well is protected at surface by a steel casing with a lockable cap. A survey of the ground surface and top of casing elevation for the monitoring wells was completed by Golder.

Where dual/multi-level wells were installed in single boreholes, the deepest monitoring well installation at each borehole is designated as monitoring well “A”, with each successively shallower monitoring well at each borehole designated as “B”, “C”, etc., where appropriate.

The monitoring wells were developed following their installation and prior to undertaking hydraulic conductivity testing, groundwater level measurements and groundwater sampling.

2.2.3.3 Hydraulic Conductivity Testing

Well response tests were carried out in the monitoring intervals. The well response testing was undertaken to provide information on the *in-situ* horizontal hydraulic conductivity of the overburden and bedrock adjacent to the monitoring well intervals. The falling-head/rising-head tests consisted of inserting or removing a slug of known volume into each of the monitoring wells, followed by monitoring the groundwater level dissipation/recovery within the monitor. Before the start of the hydraulic testing, static water levels were measured at all locations. Each hydraulic test was deemed complete when the monitoring well recovered to approximately 95% of the original static water level, or after two hours of monitoring for locations having slow recovery.

The intervals for response testing were defined as the sand pack interval (i.e., the zone filled with sand surrounding the screens) between the bentonite seals. The water level recovery data were analyzed using the Hvorslev method (Hvorslev, 1951) to provide an estimate of the horizontal hydraulic conductivity.

2.2.3.4 Groundwater Level Monitoring Program

A groundwater level monitoring program was conducted to provide information on hydraulic gradients and the groundwater flow direction(s) at the BR Site. The depth to groundwater was measured relative to the surveyed top of PVC pipes for the monitoring wells. The water elevations in the monitoring wells were calculated by subtracting the measured depth to water from the top of pipe reference elevations.

2.2.3.5 Groundwater Quality Sampling Program

The water quality sampling program at the BR Site was divided into two programs, which included the on-Site monitoring well sampling program and the residential water supply well sampling program.

2.2.3.5.1 On-Site Monitoring Well Sampling Program

The on-Site monitoring well water quality sampling program involved collecting groundwater samples from the depth-specific monitoring wells installed in BH12-1, BH12-2 and BH12-3. The primary objective of the water quality monitoring program is to define existing background groundwater quality at the BR Site. The groundwater samples were analyzed for the parameters specified in *Ontario Regulation 232/98* (except for total suspended solids), which relates to the construction and expansion of landfill sites. All samples were entered on Chain of Custody forms and delivered to Maxxam for the required analysis.

2.2.3.5.2 Residential Well Sampling Program

The limited residential water supply well sampling program involved collecting groundwater samples from supply wells in the immediate vicinity of the BR Site to characterize background groundwater quality for typical organic and inorganic landfill leachate parameters. The parameters analyzed for the residential wells were the same as the on-Site monitoring wells. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply (i.e., well type, depth, location, satisfaction with water quality and quantity, etc.). If the water supply is treated (i.e., water softener), the water sample was collected from an untreated location, or the treatment system was bypassed. All samples were entered on Chain of Custody forms and delivered to Maxxam for the required analysis.

2.2.4 Results and Discussion

In the following discussion, the borehole locations are generally referred to only by the designation of each group of boreholes (i.e., 12-1, 12-2 and 12-3) without reference to the individual test holes at each location.

2.2.4.1 Borehole Drilling Program

The CPT profiles for normalized cone resistance, sleeve friction, and porewater pressure during pushing together with an interpreted profile of the stratigraphy are presented in Attachment TSD#1-B-2-2. The subsurface conditions encountered in the boreholes along with the results of the Nilcon vane testing are shown on the Record of Borehole and Drillhole Sheets in Attachment TSD#1-B-2-2. The results of the water content and Atterberg limit testing are indicated on the Record of Borehole sheets. The results of grain size distribution testing of the surficial sandy deposits and glacial till are also provided in Attachment TSD#1-B-2-2.

The following presents a summarized overview of the subsurface conditions encountered within the test holes.

2.2.4.1.1 Topsoil

About 200 to 250 millimetres of topsoil was encountered at ground surface at all of the test hole locations.

2.2.4.1.2 Sandy Deposit

The topsoil is underlain by about 0.3 to 1.3 metres of silty sand, sand, and/or sandy silt. Standard penetration tests carried out within the sandy soils gave ‘N’ values of between 2 and 10 blows per 0.3 metres of penetration indicating a very loose to compact state of packing.

The measured natural water contents of two samples of the sandy deposit were about 19% and 23%. The results of grain size distribution testing of two samples of this deposit are shown on the figure in Attachment TSD#1-B-2-2.

2.2.4.1.3 Clay to Silty Clay

The surficial sandy deposits are underlain by a thick deposit of clay to silty clay. The clay to silty clay was fully penetrated to depths between about 34.1 and 35.8 metres below the existing ground surface at BH12-1, BH12-2 and BH12-3. The thickness of this deposit ranges from about 32 to 35 metres.

The upper 0.7 metres of the silty clay at BH12-1 have been weathered to a red brown crust. One standard penetration test carried out in the weathered material gave an ‘N’ value of four blows per 0.3 metres of penetration indicating a stiff consistency (based on local experience with the correlation to undrained shear strength). No similar weathering was encountered at BH12-2 and BH12-3.

The clay to silty clay below the sandy deposit or weathering (where present) is unweathered. The results of *in-situ* Nilcon vane testing in this unweathered material gave undrained shear strengths ranging from about 14 to greater than 100 kilopascals, generally increasing with depth. These results indicate a generally soft consistency to about 9 to 10 metres depth, followed by a firm consistency to about 15 to 18 metres depth, and stiff to very stiff below that.

The results of Atterberg limit testing carried out on four samples of the unweathered clay to silty clay gave plasticity index values ranging between about 44% and 80%, and liquid limits values between about 75% and 114%. These results indicate a relatively high plasticity soil. The measured water contents of the samples were between about 71% and 87%.

The results of the CPT testing indicate the variable occurrence of sand and silt seams within the upper portion of the clay to silty clay. These seams were encountered at depths between about 1.8 and 6.6 metres and are interpreted to vary in thickness from about 0.1 to 0.3 metres. Information to be obtained from the remainder of the drilling and testing program will be used to assess the presence, characteristics and continuity of these seams.

2.2.4.1.4 Glacial Till

The silty clay is underlain by a deposit of glacial till. Based on the retrieved samples and observations of the sampler/drilling resistance, the glacial till is considered to generally consist of a heterogeneous mixture of gravel, cobbles and boulders in a matrix of sand and silt with a trace to some clay. This deposit was fully penetrated to depths between about 36.7 and 40.6 metres below the existing ground surface. The thickness ranges from about 2 to 6 metres.

Standard penetration tests carried out within the glacial till gave ‘N’ values of between 16 and 97 blows per 0.3 metres of penetration indicating a compact to very dense state of packing. Sampler ‘refusal’ was also encountered for one sample attempt, likely reflecting the cobble/boulder content.

The measured natural water contents of two samples of the glacial till were about 9% and 10%. The results of grain size distribution testing of two samples of this deposit are shown on the figure in Attachment TSD#1-B-2-2. It should be noted, however, that the samples were retrieved using a 35-millimetre inside diameter sampler and therefore the results don’t reflect the boulder, cobble or full gravel content.

2.2.4.1.5 Bedrock

Coring of the bedrock was carried out in four of the boreholes (i.e., BH12-1-3, 12-1-3.1, 12-2-3 and 12-3-3). The following table provides details of the cored boreholes.

Table 2.2-1: BR Site Cored Hole Drilling Details – BH12-1-3, BH12-1-3.1, BH12-2-3 and BH12-3-3

Location	Date Drilled	Ground Surface Elevation (masl)	Depth to Bedrock (m)	Bedrock Surface Elevation (masl)	Total Depth Cored (m)
BH12-1-3	November 15 to 19, 2012	76.01	40.61	35.40	5.86
BH12-1-3.1	November 23, 2012	76.10	39.78	36.32	5.59
BH12-2-3	January 11 and 14, 2013	76.94	36.74	40.20	5.21
BH12-3-3	December 3 to 5, 2012	76.22	39.84	36.38	5.58

The bedrock encountered in the boreholes typically consists of fresh, laminated to thinly bedded, grey to black, fine to coarse grained, moderately porous interbedded limestone and shale bedrock of the Carlsbad Formation.

The Rock Quality Designation (RQD) values measured on recovered bedrock core samples typically range from about 59% to 100%, indicating a fair to excellent quality rock. However, two lower RQD values of 12% and 29% were measured within the upper portion of the bedrock at BH12-3-3 and BH12-2-3, respectively, indicating poorer quality bedrock.

2.2.4.2 Monitoring Well Installation and Elevation Surveying Program

Groundwater monitoring wells were constructed to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the soil and bedrock encountered at the BR Site. Combined bedrock monitoring wells and VSP casing installations were installed in BH12-2-3 and BH12-3-3. However, the VSP casing and bedrock monitoring well at location BH12-1 were installed in separate boreholes (i.e., BH12-1-3 and BH12-1-3.1, respectively). Multi-level groundwater monitoring wells within the glacial till and silty clay were installed in BH12-1-4, BH12-1-5, BH12-2-5, BH12-3-4 and BH12-3-5. Single monitoring wells were installed within the surficial sandy deposits at BH12-1-6, BH12-2-6 and BH12-3-6 as well as within the deep silty clay at BH12-2-4. The preferred locations for the screened intervals of the monitoring wells were determined based on observations during the drilling program and on the results of the CPT and Nilcon vane testing. The screened locations within the shallow monitoring wells in the silty clay deposit were selected based on the presence of sand and silt layers inferred from the results of the CPT.

The following table summarizes the monitoring well completion details for the monitoring wells constructed in boreholes. The monitoring well installations are shown on the borehole/drillhole logs in Attachment TSD#1-B-2-2.

Table 2.2-2: BR Site Monitoring Well Completion Details

Location	Ground Surface Elevation (masl)	TOP Elevation (masl)	Screened Interval* (mbgs)	
			Top	Bottom
BH12-1-3.1	76.10	76.84	40.1	45.4
BH12-1-4A	76.08	77.03	36.0	39.5
BH12-1-4B	76.08	77.01	27.0	31.0
BH12-1-5A	76.06	76.87	12.8	15.3
BH12-1-5B	76.06	76.84	4.0	6.0
BH12-1-6	76.06	76.82	0.3	1.5
BH12-2-3	76.94	77.77	37.0	42.0
BH12-2-4	77.09	77.95	30.0	32.2
BH12-2-5A	76.99	77.82	18.6	20.7
BH12-2-5B	76.99	77.77	3.8	7.6
BH12-2-6	77.13	78.07	0.4	2.3
BH12-3-3	76.22	77.00	40.1	45.4
BH12-3-4A	76.23	77.20	35.1	38.7
BH12-3-4B	76.23	77.20	28.0	30.5
BH12-3-5A	76.23	77.18	13.8	15.8
BH12-3-5B	76.23	77.21	4.0	6.1
BH12-3-6	76.27	77.09	0.3	1.5

Notes: TOP – top of pipe.
* The screened interval refers to the entire sand pack area – not just the length of the slotted screen.

2.2.4.3 Hydraulic Conductivity Testing

Well response tests were carried out in the 12 monitoring intervals installed within the on-Site boreholes using the rising-head and/or falling-head methods. The results of the *in-situ* hydraulic conductivity testing are summarized in the following table. The depth of the screened interval and comments relating to the interval tested are provided.

Table 2.2-3: BR Site Hydraulic Conductivity Results

Location	Screened Interval* (mbgs)	Hydraulic Conductivity (m/sec)	Formation Monitored	Comments
BH12-1-3.1	40.1 to 45.4	3×10^{-7}	Carlsbad Bedrock	--
BH12-1-4A	36.0 to 39.5	4×10^{-6}	Glacial Till	--
BH12-1-5B	4.0 to 6.0	1×10^{-7}	Shallow Clay	Sand/silt seam between 5.1 and 5.2 mbgs
BH12-1-6	0.3 to 1.5	1×10^{-7}	Shallow sand, silt and clay (Sandy Deposit)	--
BH12-2-3	37.0 to 42.0	2×10^{-5}	Carlsbad Bedrock	--
BH12-2-5B	3.8 to 7.6	5×10^{-7}	Shallow Clay	Sand/silt seam between 6.3 and 6.6 mbgs
BH12-2-6	0.4 to 2.3	3×10^{-5}	Shallow sand, silt and clay (Sandy Deposit)	--
BH12-3-3	40.1 to 45.4	4×10^{-6}	Carlsbad Bedrock	--
BH12-3-4A	35.1 to 38.7	1×10^{-6}	Glacial Till	--
BH12-3-5B	4.0 to 6.1	3×10^{-7}	Shallow Clay	Sand/silt seam between 4.6 and 4.9 mbgs
BH12-3-6	0.3 to 1.5	6×10^{-6}	Shallow sand, silt and clay (Sandy Deposit)	--

Note: * The screened interval refers to the entire sand pack area – not just the length of the slotted screen.

Based on the results of the *in-situ* hydraulic conductivity testing completed at the Site (falling and rising-head tests), the following ranges in hydraulic conductivities were observed in the various overburden and bedrock formations at the Site:

- Shallow sand, silt and clay (Sandy Deposit): 1×10^{-7} m/sec to 3×10^{-5} m/sec;
- Shallow clay with sand/silt seam: 1×10^{-7} m/sec to 5×10^{-7} m/sec;
- Glacial Till: 1×10^{-6} m/sec to 4×10^{-6} m/sec; and
- Carlsbad Formation: 3×10^{-7} m/sec to 2×10^{-5} m/sec.

2.2.4.4 Groundwater Level Monitoring Program

A groundwater level monitoring program was conducted to provide information on hydraulic gradients, the range in water levels observed at the BR Site and the groundwater flow direction(s).

2.2.4.4.1 Groundwater Elevations

Groundwater levels were collected at the on-Site monitoring wells following well development from January 14 (BH12-1 and BH12-3 only) to January 22, 2013 and are presented in Table 2.2-4 below. Monitoring well installations were completed in borehole location BH12-2 following the completion of the drill program on January 14, 2013; therefore groundwater elevation data are limited to only one monitoring event at this location at this time.

Table 2.2-4: BR Site Groundwater Elevations

Location	Ground Surface Elevation (masl)	TOP Elevation (masl)	January 14, 2013	January 22, 2013
			Groundwater Depth (masl)	Groundwater Depth (masl)
BH12-1-3.1	76.10	76.84	74.52	75.56
BH12-1-4A	76.08	77.03	74.41	74.42
BH12-1-4B	76.08	77.01	74.46	74.47
BH12-1-5A	76.06	76.87	Frozen	Frozen
BH12-1-5B	76.06	76.84	75.64	75.68
BH12-1-6	76.06	76.82	75.85	Frozen
BH12-2-3	76.94	77.77	—	75.11
BH12-2-4	77.09	77.95	—	(76.56)/65.06*
BH12-2-5A	76.99	77.82	—	Frozen
BH12-2-5B	76.99	77.77	—	(76.05)/76.07*
BH12-2-6	77.13	78.07	—	76.64
BH12-3-3	76.22	77.00	74.47	74.53
BH12-3-4A	76.23	77.20	74.41	74.59
BH12-3-4B	76.23	77.20	75.70	75.66
BH12-3-5A	76.23	77.18	Frozen	Frozen
BH12-3-5B	76.23	77.21	75.75	75.78
BH12-3-6	76.27	77.09	76.22	Frozen

Notes: — Monitoring well location not yet established
( ) Groundwater elevation prior to well development on January 21, 2013
* Non-stabilized groundwater elevation following well development

The water levels at BH12-2-4 and BH12-2-5B are interpreted to be influenced by on-Site data collection activities. The water level recovery in these wells is slow. The decrease in the groundwater elevation at these locations shown in Table 2.2-4 is interpreted to be a result of monitoring well development and groundwater sampling completed on January 21, 2013. The groundwater levels in BH12-2-4 and BH12-2-5B are expected to gradually increase over time until the stabilized static water levels are reached. If the BR Site is identified as the preferred Site for the Undertaking, a groundwater monitoring program for on-Site monitoring wells at the BR Site will be established in order to further characterize the long-term hydrogeological conditions present at the BR Site.

2.2.4.4.2 Vertical Gradients

Table 2.2-5 provides a summary of the direction of vertical gradients observed at the Site.

Table 2.2-5: BR Site Direction of Vertical Gradient

Locations	Interpreted Direction of Vertical Gradient/Comments
BH12-1-3.1, BH12-1-4A, BH12-1-4B, BH12-1-5B and BH12-1-6	Typical downward vertical gradient in overburden between BH12-1-6 through to BH12-1-4A; and, slight upward gradient observed between BH12-1-3.1 (bedrock) and BH12-1-4A
BH12-2-4, BH12-2-5B and BH12-2-6	Typical downward vertical gradient in overburden between BH12-2-6 and BH12-2-5B; and slight upward gradient observed between BH12-2-4 and BH12-02-5B, likely the result of non-stabilized groundwater levels in the deep and shallow clay
BH12-3-3, BH12-3-4A, BH12-3-4B, BH12-3-5A, BH12-2-5B and BH12-3-6	Typical downward vertical gradient in overburden between BH12-3-6 through to BH12-3-4A; and negligible upwards vertical gradient between BH12-3-3 (bedrock) and BH12-3-4A

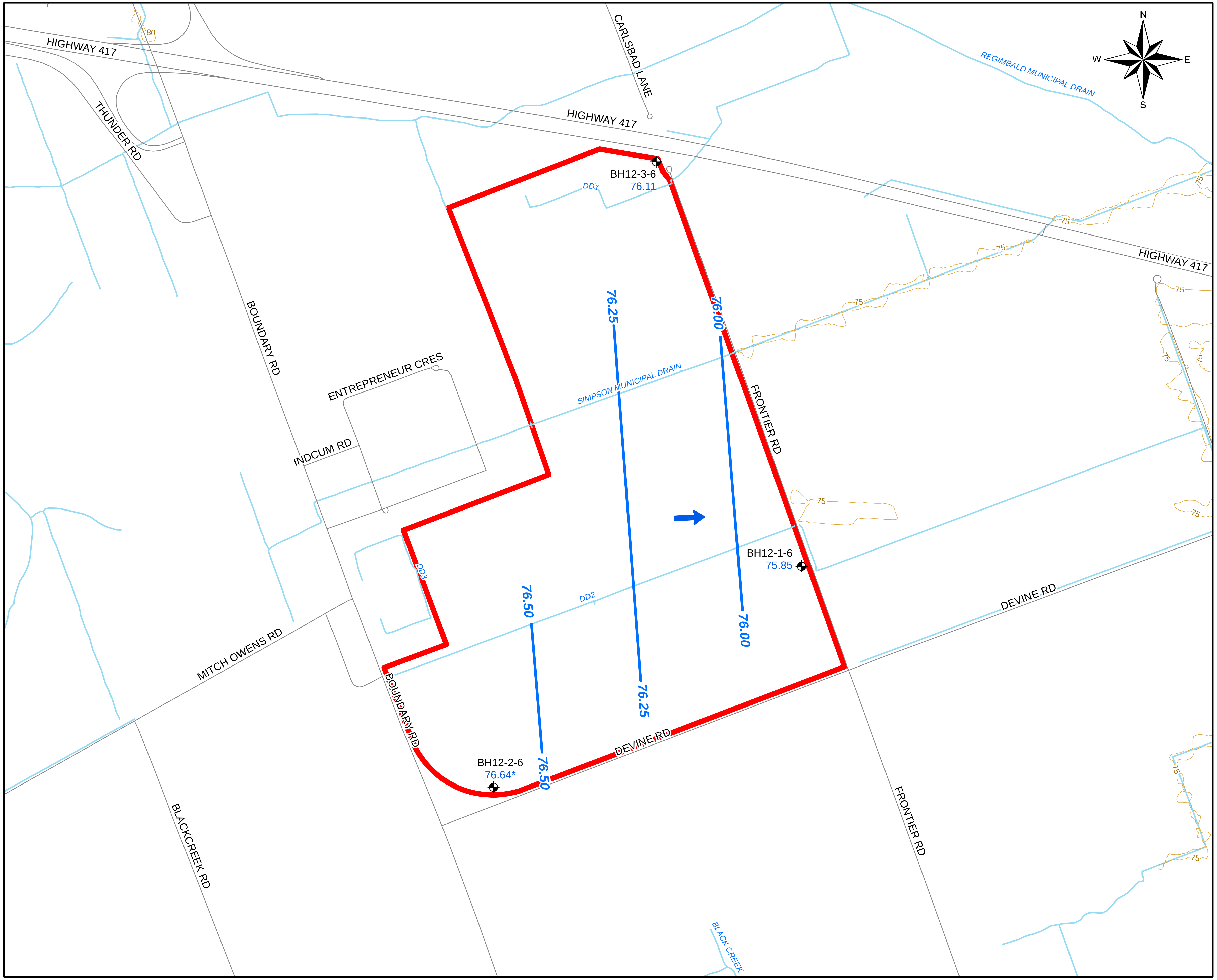
Based on the groundwater elevation data collected to date, vertical gradients at the Site are typically weakly downward, or absent, with the exception of a slight upward vertical gradient between BH12-1-3.1 and BH12-1-4A and possibly BH12-2-4 and BH12-2-5B based on the available groundwater data (likely non-stabilized). Vertical gradients could not be adequately assessed between the deep clay (BH12-1-4B, BH12-2-4 and BH12-3-4B) and middle clay (BH12-1-5A, BH12-2-5A and BH12-3-5A) due to the groundwater in the monitoring wells screened within the middle clay deposit being consistently frozen, however downward gradients are assumed based on these observations. If the BR Site is identified as the preferred Site for the Undertaking, as additional groundwater level data are collected in 2013, the variation in magnitude and direction of the vertical gradients associated with seasonal variations in groundwater levels will be assessed.

2.2.4.4.3 Groundwater Flow Direction

An estimate of the groundwater flow direction for the shallow overburden (sand, silt and clay), shallow clay (with sand/silt seam), and shallow bedrock at the BR Site was obtained using appropriately positioned (vertically) on-Site monitoring intervals.

The following locations were used to provide an estimate of the shallow groundwater flow direction in the shallow overburden: BH12-1-6; BH12-2-6 and BH12-3-6. The groundwater levels collected from these locations on January 14 (BH12-1-6 and BH12-3-6) and January 22 (BH12-2-6 only), 2013 were used to produce the groundwater contours shown on Figure 2.2-2. Monitoring well BH12-2-6 was not installed during the January 14, 2013 monitoring session, while groundwater in monitoring wells BH12-1-6 and BH12-3-6 was frozen during the January 22, 2013 monitoring event; therefore the available data was combined to estimate groundwater flow direction. Based on the available groundwater levels collected in January 2013 at BH12-1-6, BH12-2-6 and BH12-3-6, the groundwater flow in the shallow overburden for the BR Site is interpreted to be towards the east.

Groundwater flow direction in the shallow clay was estimated using monitoring well locations BH12-1-5B, BH12-2-5B and BH12-3-5B. The groundwater levels collected from these locations on January 22, 2013 were used to produce the groundwater contours and interpret the groundwater flow direction in the shallow clay as shown on Figure 2.2-3. The groundwater flow direction in the shallow clay is interpreted to be towards the east at the BR Site.



LEGEND

⊕	BOREHOLE/MONITORING WELL LOCATION
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
■	WATER AREA
🟥	PROPERTY BOUNDARY
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
—	INTERPRETED GROUNDWATER CONTOUR
76.61	GROUNDWATER ELEVATION (JANUARY 14, 2013)
76.64*	GROUNDWATER ELEVATION (JANUARY 22, 2013)

200 100 0 200

SCALE 1:12,000 METRES

NOTE

1. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B.
2. MONITORING WELLS BH 12-1-6 AND BH 12-3-6 FROZEN ON JANUARY 22, 2013.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

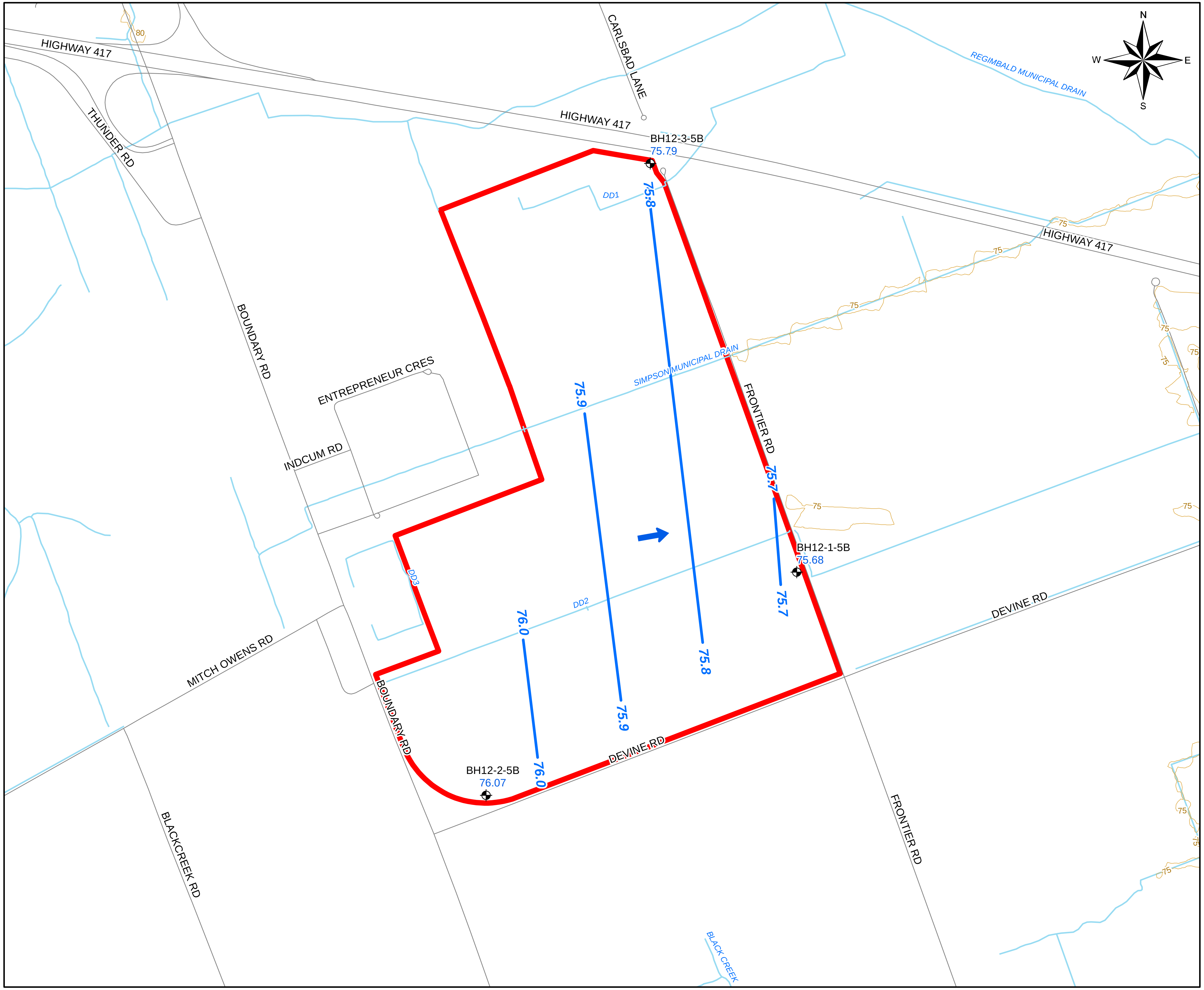
TITLE

BR SITE
SHALLOW OVERBURDEN GROUNDWATER FLOW
(JANUARY 14 AND 22, 2013)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.2-2	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase4000\TSD1\1211250045-4000-2-2-2-WaterTableGWFlow.mxd



LEGEND

⌖	BOREHOLE/MONITORING WELL LOCATION
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
■	WATER AREA
▭	PROPERTY BOUNDARY
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
—	INTERPRETED GROUNDWATER CONTOUR
75.79	GROUNDWATER ELEVATION (JANUARY 22, 2013)

190 95 0 190

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BR SITE
SHALLOW CLAY GROUNDWATER FLOW
(JANUARY 22, 2013)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.2-3	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase4000\TSD1\1211250045-4000-2.2-3-ShallowClayGWFlow.mxd

Monitoring wells were installed within the glacial till at borehole locations BH12-1 and BH12-3 only; therefore it was not possible to estimate the groundwater flow direction within this unit. However, given the general understanding of the surficial geology at the Site, the glacial till layer trends towards the east and it's likely that the groundwater flow direction is consistent with the slope of the glacial fill surface and towards the east.

The following locations were used to provide an estimate of the shallow bedrock groundwater flow direction (i.e., between approximately 37 and 45.4 mbgs): BH12-1-3.1; BH12-2-3 and BH12-3-3. The groundwater levels collected from these locations on January 22, 2013 were used to produce the groundwater contours shown on Figure 2.2-4, which indicates that groundwater flow in the shallow bedrock is interpreted to be towards the east at the BR Site.

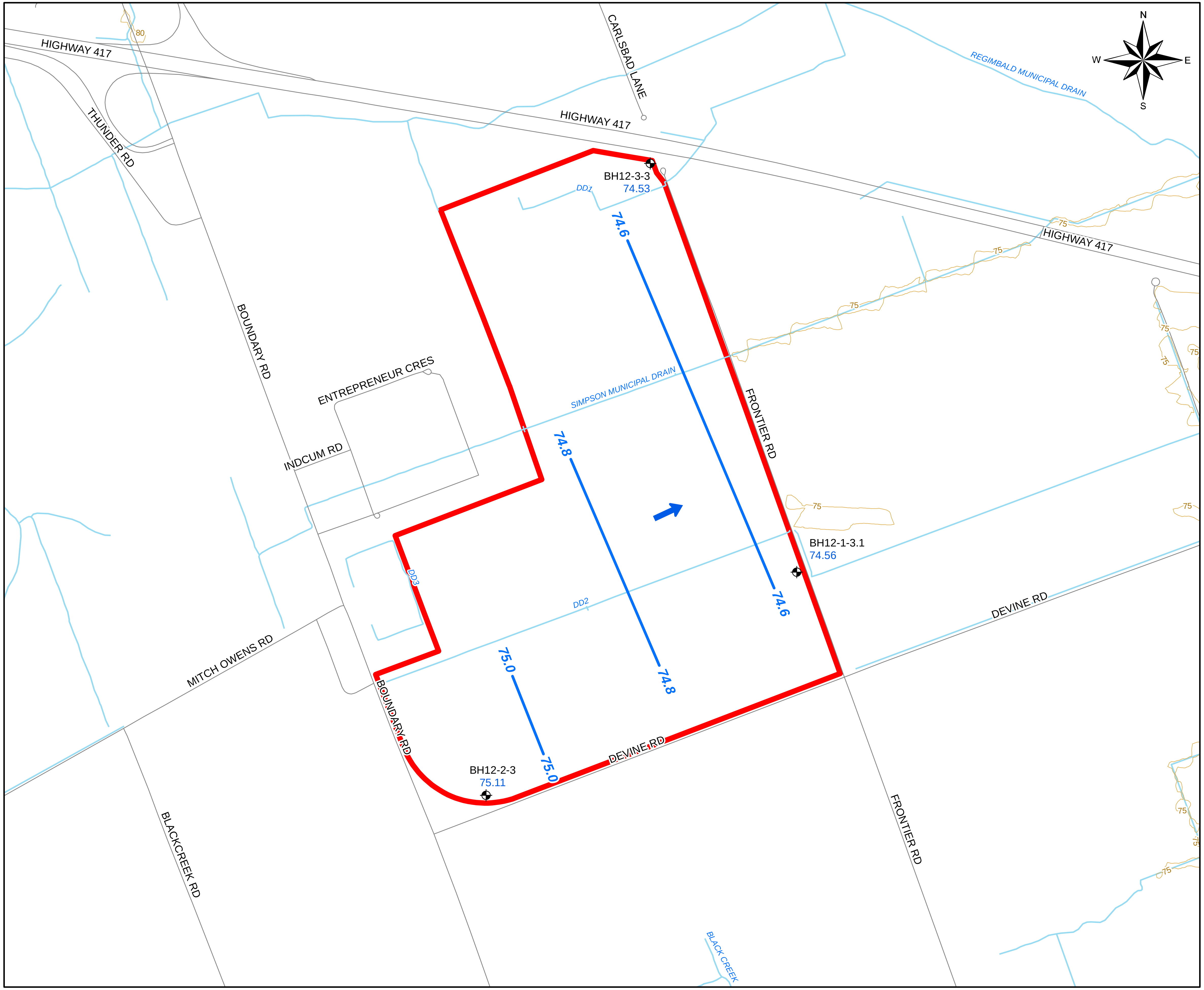
Based on the groundwater levels collected on January 14 and 22, 2013, groundwater flow direction for the BR Site is interpreted to be towards the east within all layers, consistent with the dip direction of the respective units. Based on the groundwater contour spacing shown on Figures 2.2-2, 2.2-3 and 2.2-4, the horizontal hydraulic gradient (i.e., potential for horizontal groundwater flow) appears to be consistent across the Site due to the relatively level topography in each stratigraphic unit.

2.2.4.5 Groundwater Quality Sampling Program

2.2.4.5.1 Monitoring Well Sampling Program

The groundwater quality sampling program involved collecting samples from selected on-Site monitoring wells installed in BH12-1 through BH12-3 (standpipe locations BH12-1-4B, 12-1-5A, BH12-2-4B, BH12-2-5A, BH12-3-4B and BH12-3-5A were not included in the groundwater monitoring program). To date, one round of groundwater quality sampling has been completed. Groundwater samples were collected from the selected monitoring locations on January 11 (BH12-1 and BH12-3) and January 21 (BH12-2), 2013. The groundwater samples were analyzed for the parameters specified in *Ontario Regulation 232/98* (except for total suspended solids), which lists generic parameters that should be monitored at landfill sites. Total suspended solids were not measured in the samples collected from the monitoring wells because the analysis would be measuring material in the well that has accumulated, and was then re-suspended during the sampling process. All groundwater samples collected were odourless, very light brown to dark brown in colour and had little to high sediment loading (BH12-1-5B, BH12-2-5B, BH12-2-6 and BH12-3-5B only).

The groundwater quality results for the on-Site monitoring wells are provided in Table TSD#1-B-6-2-1 in Attachment TSD#1-B-6-2. Based on the results of the first round of groundwater quality sampling, groundwater quality was variable across the BR Site. Table 2.2-6 provides a list of the parameters at monitoring wells that were elevated relative to most sampling locations at the BR Site.



LEGEND

⌖	BOREHOLE/MONITORING WELL LOCATION
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
▨	WATER AREA
▭	PROPERTY BOUNDARY
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
—	INTERPRETED GROUNDWATER CONTOUR
74.53	GROUNDWATER ELEVATION (JANUARY 22, 2013)

190 95 0 190

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
BR SITE
SHALLOW BEDROCK GROUNDWATER FLOW
(JANUARY 22, 2013)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	JAN. 2013	FIGURE 2.2-4	
GIS	BR	JAN. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase4000\TSD1\12112250045-4000-2-2-4-ShallowBedGWFlow.mxd

Table 2.2-6: BR Site Elevated Parameters at On-Site Monitoring Wells

Location	Elevated Parameters
BH12-1-3.1	ammonia, BOD, chloride, conductivity, TDS, barium, boron, magnesium, potassium, sodium, methane
BH12-1-4A	ammonia, BOD, chloride, conductivity, TDS, barium, boron, magnesium, potassium, sodium
BH12-1-5B	COD, chloride, total phosphorus, magnesium, sodium
BH12-1-6	sulfate, calcium
BH12-2-3	chloride, conductivity, sulfate, boron, potassium, sodium
BH12-2-5B	COD, DOC, total phosphorus
BH12-2-6	total phosphorus
BH12-3-3	ammonia, chloride, conductivity, TDS, barium, boron, magnesium, potassium, sodium, benzene, toluene, methane
BH12-3-4A	ammonia, chloride, conductivity, TDS, barium, boron, magnesium, potassium, sodium
BH12-3-5B	BOD, COD, DOC, total phosphorus, sulfate, calcium, manganese, benzene, toluene, vinyl chloride
BH12-3-6	calcium

Notes: BOD – biological oxygen demand; COD – chemical oxygen demand; and TDS – total dissolved solids

Elevated concentrations of total phosphorus observed at all shallow clay monitoring wells (BH12-1-5B, BH12-2-5B and BH12-3-5B) and the shallow overburden monitoring well BH12-2-6 are likely due to the samples having high sediment loadings. A minimum of 5 purge volumes were removed as part of the monitoring well development program prior to groundwater sampling.

The elevated concentrations measured at monitoring wells presented in Table 2.2-6 are interpreted to be naturally occurring, with the exception of benzene and toluene at monitoring well BH12-3-3 (0.0072 and 0.0027 mg/L, respectively) and BH12-3-5B (0.0043 and 0.0011 mg/L, respectively) and vinyl chloride at monitoring well BH12-3-5B (0.0013 mg/L) only. Groundwater samples collected at BH12-3-3 and BH12-3-5B were re-analyzed for volatile organic compounds (VOCs) and the results indicate that concentrations of benzene and toluene in BH12-3-3 and benzene, toluene and vinyl chloride at BH12-3-5B remain elevated, but within the applicable ODWQS. Elevated concentrations of these parameters were not anticipated given there is no known source of contaminants near the monitoring well, especially in regards to the monitoring well screened within the shallow bedrock (BH12-3-3) which is overlain by approximately 5.8 metres of moderately permeable glacial till and 32.5 metres of low permeability clay. Additional groundwater quality sampling at BH12-3-5B and BH12-3-3 scheduled as part of the on-going characterizing of background conditions at the BR Site (if the BR Site is identified as the preferred Site) will confirm the presence of VOC contaminants at these locations.

Groundwater quality results obtained at the BR Site consistently exceeded ODWQS for the following parameters: TDS (all locations), chloride and sodium (all locations, with the exception of BH12-2-6) and DOC (all locations, with the exception of BH12-1-6 and BH12-3-6). Based on the available information, groundwater quality at the BR Site varies from fresh to brackish and deteriorates with depth, where elevated concentrations of barium, chloride, sodium and TDS and occasionally manganese are observed in the shallow bedrock and glacial till, compared to the applicable ODWQS. Groundwater quality samples collected in the shallow bedrock were also analyzed for dissolved methane, which exceeded the ODWQS at monitoring wells BH12-1-3.1 and BH12-3.3.

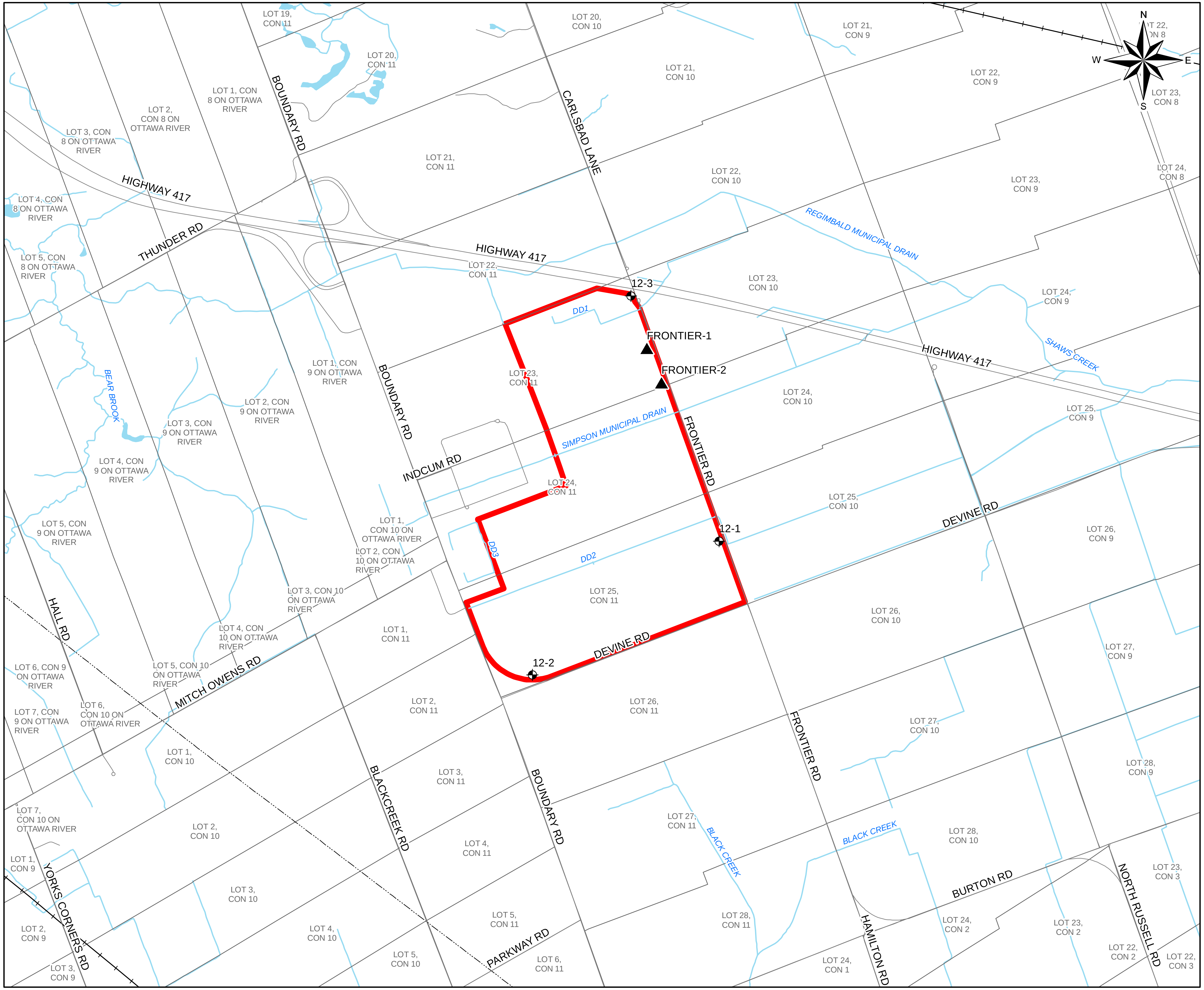
2.2.4.5.2 Residential Water Supply Well Sampling Program

The limited residential water supply well sampling program involved collecting groundwater samples from accessible supply wells in the immediate vicinity of the BR Site to characterize background groundwater quality for typical organic and inorganic landfill leachate parameters. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply. Copies of the completed surveys are provided in Attachment TSD#1-B-7-2.

Two residential water supply wells and one commercial water supply well were sampled between January 17 and January 18, 2013. Residential water supply wells are situated along Frontier Road (two: Frontier-1 and Frontier-2) within the northeast limits of the BR Site, and one commercial supply well (Boundary-1) is situated west of the BR Site. The residential water supply wells are shown on Figure 2.2-5. The water supply well survey completed at location Boundary-1 identified the supply well operates at a commercial property and is primarily used for washing equipment. All water supply wells sampled during this program are completed to an approximate depth of 3.7 to 6.1 metres (unknown well depth at Frontier-2) in the overburden and consist of dug wells.

The groundwater quality results for the residential and commercial water supply wells are provided in Table TSD#1-B-7-2-1 in Attachment TSD#1-B-7-2. The results of the water supply sampling program indicate that all parameters analyzed were below the respective ODWQS with the exception of a few parameters at all water supply wells. Parameters exceeding the ODWQS include DOC and manganese at all three water supply locations, along with TDS and iron at the commercial water supply well only (Boundary-1).

The results of the residential water supply wells sampling program indicate that groundwater quality at the private well locations differs significantly from the groundwater quality observed at on-Site monitoring wells at the BR Site. Groundwater quality at on-Site monitoring wells appears to be of poor quality compared to the residential and commercial water supply dug wells sampled, as evidenced by elevated concentrations of parameters at a majority of the groundwater monitoring locations.



LEGEND

⌖ BOREHOLE/MONITORING WELL LOCATION

WATER SUPPLY WELL LOCATION

▲ RESIDENTIAL WATER SUPPLY WELL

— ROAD

┼ RAIL ROAD

-··- UTILITY LINE

— SURFACE WATER FEATURE

🟦 WATER AREA

🟥 PROPERTY BOUNDARY

☐ LOT/CONCESSION

500 250 0 500

SCALE 1:20,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING APPENDIX TSD1-B

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BR SITE
RESIDENTIAL WATER SUPPLY WELL LOCATIONS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045		
DESIGN	JPAO	JAN. 2013
GIS	BR	JAN. 2013
CHECK	PLE	AUG. 2014
REVIEW	PAS	AUG. 2014

SCALE AS SHOWN REV. 0

FIGURE 2.2-5

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase0500\Task0120_GHandG\1211250045-2.2-5-ResidentialWaterSupplyWellLocations.mxd

2.2.5 Summary of Conditions at Boundary Road Site

Table 2.2-7: Summary of BR Site Considerations

Environmental Component	Summary of Site Considerations
Geology, Hydrogeology & Geotechnical	Geological Setting: ▪ Variable thickness of surficial silty sand up to 1.5 m thick overlying about 30 m of clay to silty clay. ▪ The results of the CPT testing indicate the variable presence of sand and silt seams within the upper portion of the clay to silty clay, encountered at depths between about 1.8 and 6.6 metres and interpreted to vary in thickness from about 0.1 to 0.3 metres. ▪ Surficial geological mapping indicates that the surficial sand layer pinches out (or is of minimal thickness) to the east of the BR Site and on the northern part of the BR Site. ▪ Based on the available groundwater levels, the groundwater flow in the shallow overburden, shallow clay, glacial till and shallow bedrock is interpreted to be towards the east at the BR Site (i.e., away from off-Site groundwater users). ▪ The horizontal/hydraulic gradient is quite small, mirroring the flat terrain in the area of the BR Site. ▪ In the unlikely event of an unmitigated leachate release to the shallow on-Site groundwater system, leachate-impacted groundwater would migrate easterly primarily through the surficial silty sand layer unless intercepted.
	Type and thickness of any natural on-Site attenuation layer: ▪ An on-Site natural attenuation (containment) layer for flow in the vertical direction is present (about 30 m of clay to silty clay). ▪ Upper surficial silty sand layer has a moderate horizontal hydraulic conductivity of between 10^{-7} m/sec to 10^{-5} m/sec.
	Presence and quality of groundwater resources on-Site and in Site-vicinity: ▪ Off-Site groundwater users typically obtain water from dug wells completed in the upper 3 to 7 m of overburden. ▪ Based on the available information from the monitoring wells, groundwater quality at the BR Site varies from fresh to brackish and deteriorates with depth, where elevated concentrations of barium, chloride, sodium and TDS and occasionally manganese are observed in the shallow bedrock and glacial till, compared to the applicable ODWQS. Groundwater quality samples collected in the shallow bedrock were also analyzed for dissolved methane, which exceeded the ODWQS at monitoring wells BH12-1-3.1 and BH12-3.3. ▪ The results of the limited well water supply sampling program indicate that all water quality parameters analyzed were below the respective ODWQS with the exception of a few parameters at all water supply wells. Parameters exceeding the ODWQS include DOC and manganese at all three water supply locations, along with TDS and iron only at the one commercial water supply well on Boundary Road. ▪ In the unlikely event of an unmitigated potential release of leachate to the shallow groundwater system, leachate would enter the surficial sand layer and migrate in the direction of groundwater flow (i.e., to the east, away from groundwater users). ▪ In the surficial sand layer, the moderate horizontal hydraulic conductivity and low hydraulic gradient result in a relatively slow groundwater flow velocity through this unit. ▪ The presence of the thick clay to silty clay unit restricts the downward migration of leachate-impacted groundwater regardless of vertical gradients.

Environmental Component	Summary of Site Considerations
	Interpreted direction of vertical groundwater flow on-Site and in Site-vicinity (i.e., area of groundwater recharge, transitional flow, or groundwater discharge): ▪ Based on the groundwater elevation data collected to date, vertical gradients at the Site are indicated to be typically weakly downward, or absent. ▪ The BR Site is not part of a regional groundwater recharge system to the basal glacial till and bedrock. ▪ The shallow overburden used locally for dug wells is recharged locally by precipitation; therefore development of the BR Site will not affect off-Site groundwater availability.

3.0 SITE COMPARISON – GEOLOGY, HYDROGEOLOGY & GEOTECHNICAL

3.1 Comparison of Sites

For the purpose of selecting the preferred Site based on the geology, hydrogeology and geotechnical disciplines, the assessment criteria is “Which Site is preferred for protection of groundwater?” The associated indicators considered are geological setting; type and thickness of natural on-Site attenuation layer; presence and quality of groundwater resources on-Site and in Site-vicinity; and, interpreted direction of vertical groundwater flow on-Site and in Site-vicinity (i.e., area of groundwater recharge, transitional flow, or groundwater discharge). The technical factors considered in applying these indicators are associated with the geological and hydrogeological setting; the geotechnical characteristics are related to design of the facilities on the preferred Site.

The BR Site is not part of a regional groundwater recharge system to the basal glacial till and bedrock. The shallow overburden used locally off-Site for dug wells is recharged locally by precipitation; therefore development of the BR Site is not expected to affect off-Site groundwater availability. The NRR Site is interpreted to be located within a large regional groundwater recharge area; however, in view of the relatively small portion of the recharge ridge area occupied by the Undertaking and the relatively low overall water demand, it is not expected there would be noticeable effects on off-Site groundwater availability.

The BR Site and its associated thick natural low permeability silty clay attenuation layer offers more favourable natural containment properties (i.e., natural backup to an engineered system, etc.) compared to the NRR Site in the unlikely event of an unmitigated release of leachate from the engineered containment components of the waste management facility.

Based on the assessment criteria for the geology, hydrogeology and geotechnical disciplines and the associated indicators, the preferred site from the perspective of the protection of groundwater is clearly the BR Site.

3.2 Results of Site Comparison

The preferred site based on the geology, hydrogeology and geotechnical disciplines is the BR Site.

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ATTACHMENT TSD#1-B-1

Records of Test Pits and Augerholes and Grain Size Distribution (NRR Site)

February 2013

Record of Augerholes and Test Pits

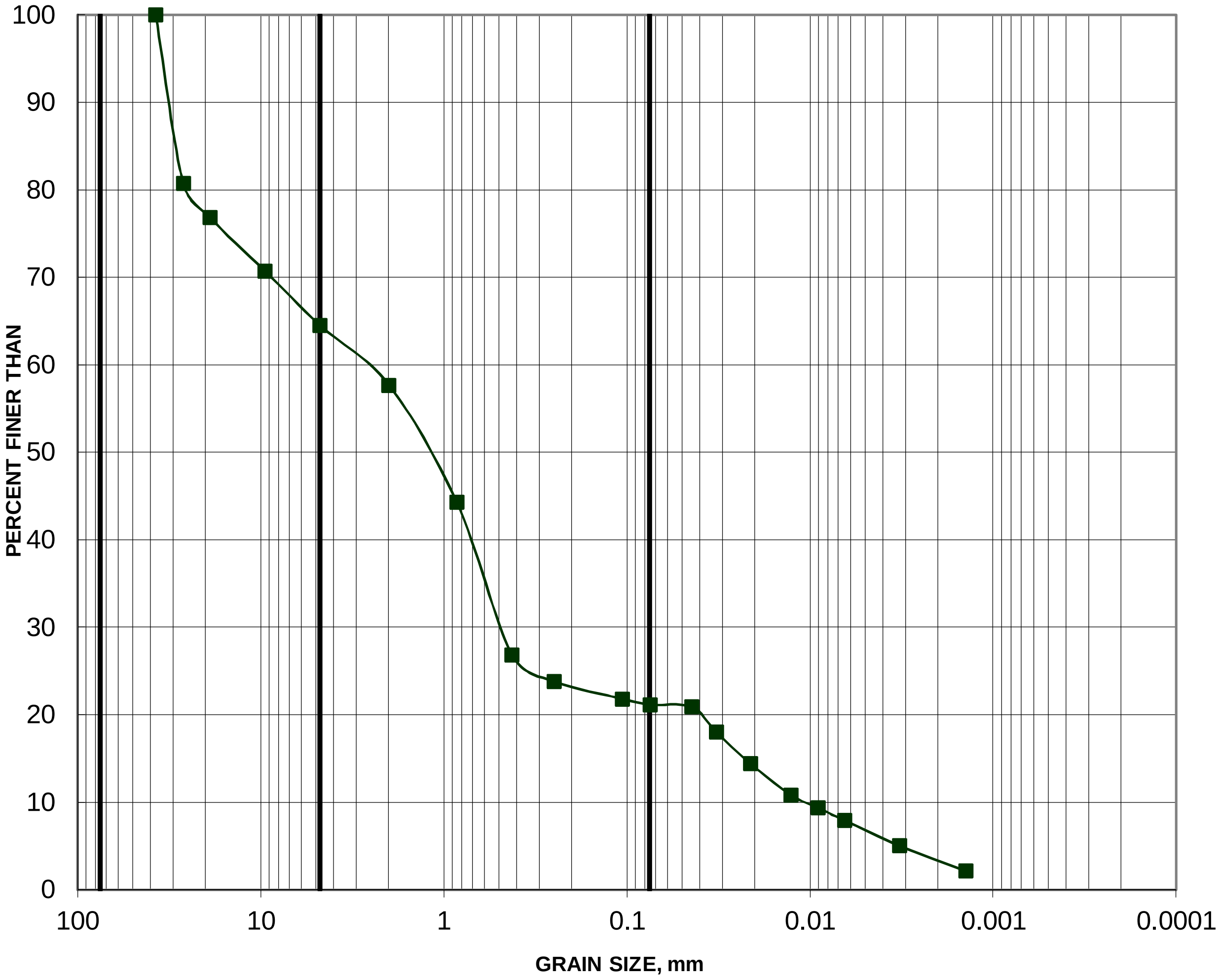
AUGERHOLE (AH)/ TEST PIT (TP) NUMBER (ground surface elevation, masl)	DEPTH (mbgs)	DESCRIPTION
AH09-1 (82.16)	0.00 – 0.22	Dark brown TOPSOIL
	0.22 – 0.78	Grey brown SILTY CLAY with clayey silt and fine sand seams
	0.78 – 2.7	Red brown silty sand and gravel to sandy silt and gravel (GLACIAL TILL)
	2.70 to 3.00	Weathered red brown shale BEDROCK, effective auger refusal
		Water encountered at 1.00 mbgs
AH09-2 (83.40)	0.00 – 0.20	Dark brown and red brown TOPSOIL
	0.20 – 1.50	Red brown SILTY SAND and SANDY SILT with gravel, some cobbles (GLACIAL TILL)
	1.50 – 1.70	Weathered red brown shale BEDROCK, effective auger refusal
		Water encountered at 0.50 mbgs
AH09-3 (80.76)	0.00 – 0.25	Dark brown TOPSOIL
	0.25 – 2.20	Weathered red brown shale BEDROCK, effective auger refusal
		Augerhole dry to 2.20 mbgs
AH09-4 (84.51)	0.00 – 0.20	Dark brown to red brown TOPSOIL
	0.20 – 0.80	Red brown SANDY SILT with gravel (completely weathered shale)
	0.80 – 1.40	Moderately weathered red brown and greenish grey shale (BEDROCK)
	1.40 to 1.50	Slightly weathered red brown shale BEDROCK
		Augerhole dry to 1.5 mbgs
AH09-5 (85.31)	0.00 – 0.20	Dark brown TOPSOIL
	0.20 – 0.96	Red brown SANDY SILT with shaley gravel (completely weathered shale)
	0.96 – 1.40	Moderately to slightly weathered red brown shale (BEDROCK)
	1.40	Fresh shale BEDROCK
		Augerhole dry to 1.4 mbgs
TP09-1 (87.36)	0.00 – 0.15	Dark brown TOPSOIL
	0.15 – 2.50	Red brown silty sand and gravel, some cobbles (GLACIAL TILL)
	2.50	Red and greenish grey shale BEDROCK
		Test pit dry at 2.50 mbgs
TP09-2 (85.33)	0.00 – 0.30	Dark brown TOPSOIL
	0.30 – 1.50	Red brown, occasional green-grey pocket, SILTY CLAY with shaley gravel (completely weathered shale)
	1.50	Slightly weathered shale BEDROCK
		Water seepage at 1.5 mbgs
		19% water content in sample collected from 1.0 mbgs

AUGERHOLE (AH)/ TEST PIT (TP) NUMBER (ground surface elevation, masl)	DEPTH (mbgs)	DESCRIPTION
TP09-3	0.00 – 0.22	Dark brown TOPSOIL
(87.05)	0.22 – 1.50	Red brown, occasional green-grey pocket, SILTY CLAY with shaley gravel (completely weathered shale)
	1.50 – 2.30	Weathered shale (BEDROCK)
	2.30	Fresh red brown shale BEDROCK
		Water seepage at 2.00 mbgs
		14.6% water content in sample collected from 0.5 mbgs
		Atterberg Limits: $W_L = 22.2$ W_P = N/P
TP09-4	0.00 – 0.20	Dark brown TOPSOIL
(84.69)	0.20 – 0.60	Red brown, occasional green-grey pocket, SILTY CLAY with shaley gravel (completely weathered shale)
	0.60 – 1.20	Weathered red brown and greenish grey shale (BEDROCK)
	1.20	Becoming fresh shale BEDROCK
		Test pit dry at 1.20 mbgs
TP09-5	0.00 – 0.20	Dark brown TOPSOIL
(85.06)	0.20 – 2.10	Red brown SANDY SILT and CLAYEY SILT with shaley gravel
	2.10 – 2.60	Grey brown and red brown silty sand and gravel and cobbles (GLACIAL TILL)
	2.60 – 2.80	Fresh shale BEDROCK (some green seams)
		Water seepage at 1.90 mbgs
TP09-6	0.00 – 0.22	Dark brown TOPSOIL
(85.28)	0.22 – 1.20	Red brown CLAYEY SILT with shaley gravel
	1.20 – 2.20	Highly weathered shale
	2.20 – 3.00	Moderately to slightly weathered red brown and green grey shale (BEDROCK)
	3.00	Fresh shale BEDROCK
		Water seepage at 1.30 mbgs
		9.1% water content in sample collected from 0.70-0.80 mbgs
TP09-7	0.00 – 0.25	Dark brown TOPSOIL and root material
(81.99)	0.25 – 1.10	Red brown SILTY CLAY with shaley gravel (completely weathered shale)
	1.10 – 2.00	Weathered red brown and green grey shale (BEDROCK)
	2.00	Fresh shale BEDROCK
		Water seepage at 1.60 mbgs
TP09-8	0.00 – 0.25	Dark brown TOPSOIL
(82.27)	0.25 – 1.30	Red brown, SILTY CLAY, some shaley gravel (completely weathered shale)
	1.30 – 2.00	Highly to moderately weathered red brown shale (BEDROCK)
		Fresh shale BEDROCK
	2.00	Water seepage at 0.95 mbgs

AUGERHOLE (AH)/ TEST PIT (TP) NUMBER (ground surface elevation, masl)	DEPTH (mbgs)	DESCRIPTION
TP09-9	0.00 – 0.95	Red brown sandy silt and clayey silt with shaley gravel (FILL)
(81.93)		Dark brown TOPSOIL
	0.95 – 1.10	Greenish grey CLAYEY SILT
	1.10 – 1.40	Red brown CLAYEY SILT with shaley gravel
	1.40 – 2.10	moderate to slightly weathered shale BEDROCK
	2.10 – 3.00	Test pit dry at 3.00 mbgs
	3.00	
TP09-10	0.00 – 0.22	Dark brown TOPSOIL
(83.81)	0.22 – 1.00	Red brown SANDY SILT and SILTY CLAY with shaley gravel (completely weathered shale)
	1.00 – 2.20	Moderately weathered shale (BEDROCK)
	2.20	Slightly weathered shale BEDROCK
		Test pit dry at 2.20 mbgs
TP09-11	0.00 – 0.20	Dark brown TOPSOIL
(80.28)	0.20 – 0.75	Red brown SILT with shaley gravel (completely weathered shale)
	0.75 – 1.20	Moderately weathered shale (BEDROCK)
	1.20 – 1.60	Slightly weathered to fresh with depth red brown shale BEDROCK
		Test pit dry at 1.60 mbgs
TP09-12	0.00 – 0.14	Dark brown TOPSOIL and sod
(80.15)	0.14 – 0.80	Red brown SILTY CLAY with shaley gravel (completely weathered shale)
	0.80 – 1.20	Red brown slightly weathered shale (BEDROCK)
	1.20	Fresh shale BEDROCK
		Test pit dry at 1.20 mbgs
TP09-13	0.00 – 0.28	Dark brown TOPSOIL
(77.27)	0.28 – 1.30	Red brown SILTY CLAY with shaley gravel (completely weathered shale)
	1.30 – 2.30	Moderately to slightly weathered with depth, red brown and greenish grey shale (BEDROCK)
	2.30	Fresh shale BEDROCK
		Water seepage at 1.00 mbgs and Water inflow at 2.20 mbgs
TP09-14	0.00 – 0.25	Dark brown TOPSOIL with organics (wet)
(75.49)	0.25 – 0.35	Yellow brown SILTY FINE SAND
	0.35 – 0.90	Grey brown and red brown silty clay (WEATHERED CRUST)
	0.90 – 4.50	Red brown and red grey sandy silt and gravel, some cobbles/boulders (GLACIAL TILL)
	4.50	Fresh green grey siltstone/limestone BEDROCK
		Water seepage at 0.70 mbgs
		Water inflow at 1.00 mbgs
		25.7% water content in sample collected from 0.45-0.70 mbgs
		Atterberg Limits: $W_L = 46.9$ $W_P = 22.6$ LI = 0.1 PI = 24.3

AUGERHOLE (AH)/ TEST PIT (TP) NUMBER (ground surface elevation, masl)	**DEPTH (mbgs)**	**DESCRIPTION**
TP09-15	0.00 – 0.28	Dark brown TOPSOIL (wet)
(74.16)	0.28 – 3.00	Grey brown and red brown silty clay (WEATHERED CRUST)
	3.00 – 6.20	Grey SILTY CLAY
	6.20	Grey sandy silt with gravel (GLACIAL TILL)
		Some water seepage at 1.5 mbgs
		36.4% water content in sample collected from 0.6 mbgs
		36.3% water content in sample collected from 1.20 mbgs
		Atterberg Limits: W_L = 52.5 W_P = 25.7 LI = 0.4 PI = 26.8
		39.1% water content in sample collected from 1.70 mbgs
		69.0% water content in sample collected from 2.20 mbgs
		65.8% water content in sample collected from 2.70 mbgs
		71.3% water content in sample collected from 3.20 mbgs
		87.8% water content in sample collected from 4.50 mbgs
TP09-16	0.00 – 0.18	Dark brown TOPSOIL
(74.88)	0.18 – 0.60	Yellow brown silty fine sand
	0.60 – 2.30	Grey brown and red brown silty clay (WEATHERED CRUST)
	2.30 – 3.30	Grey SILTY CLAY
	3.30 – 6.00	Grey and red brown sandy silt and gravel, some cobbles (GLACIAL TILL)
		Some water at 1.5 mbgs and Water inflow at 3.5 mbgs

GRAIN SIZE DISTRIBUTION



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

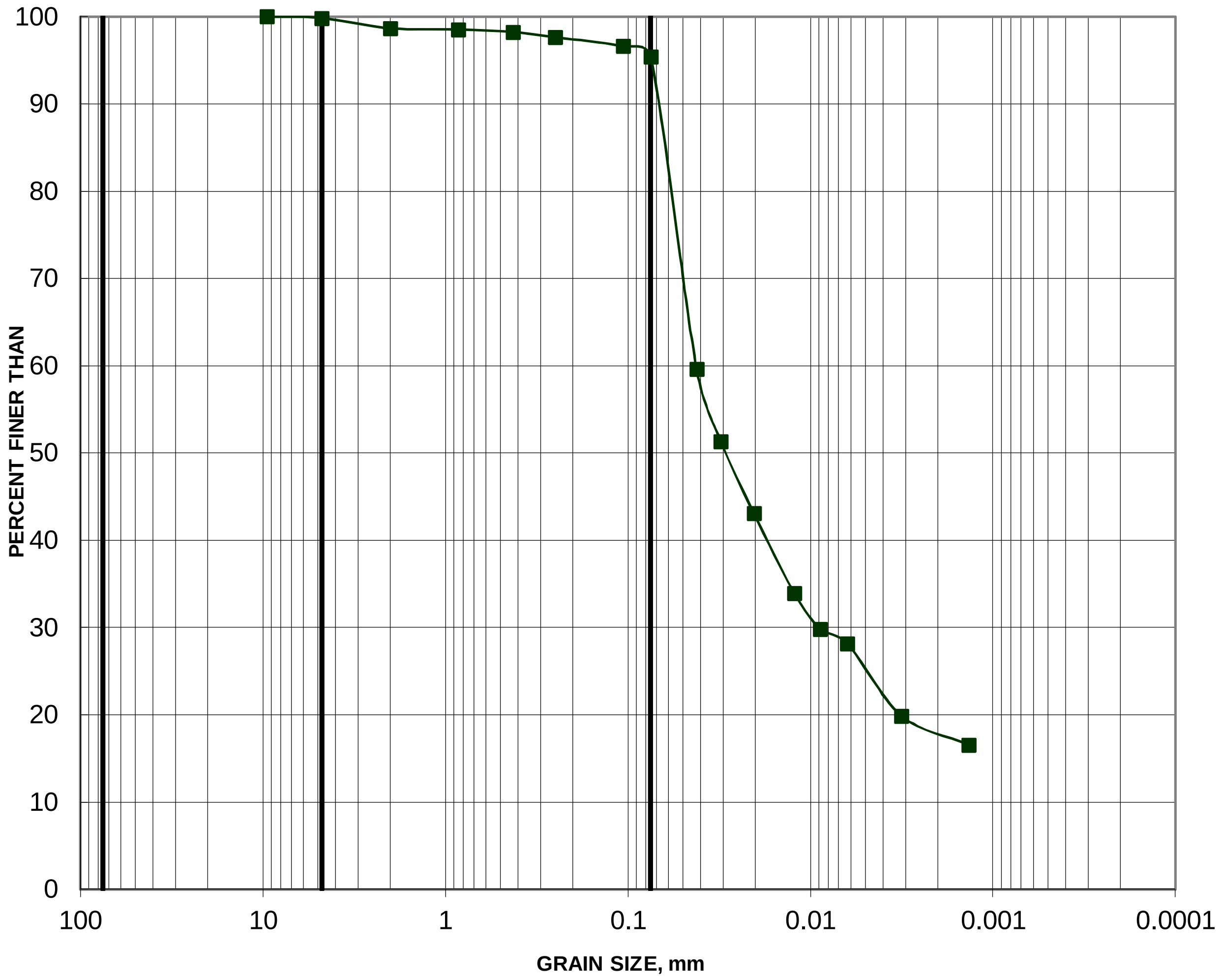
Test Pit	Sample	Depth (m)
■ 09-3	1	0.50

Created by: CW
Checked by: CNM

Project: 12-1125-0045

Golder Associates

GRAIN SIZE DISTRIBUTION



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Test Pit	Sample	Depth (m)
■ 09-14	1	0.45-0.70

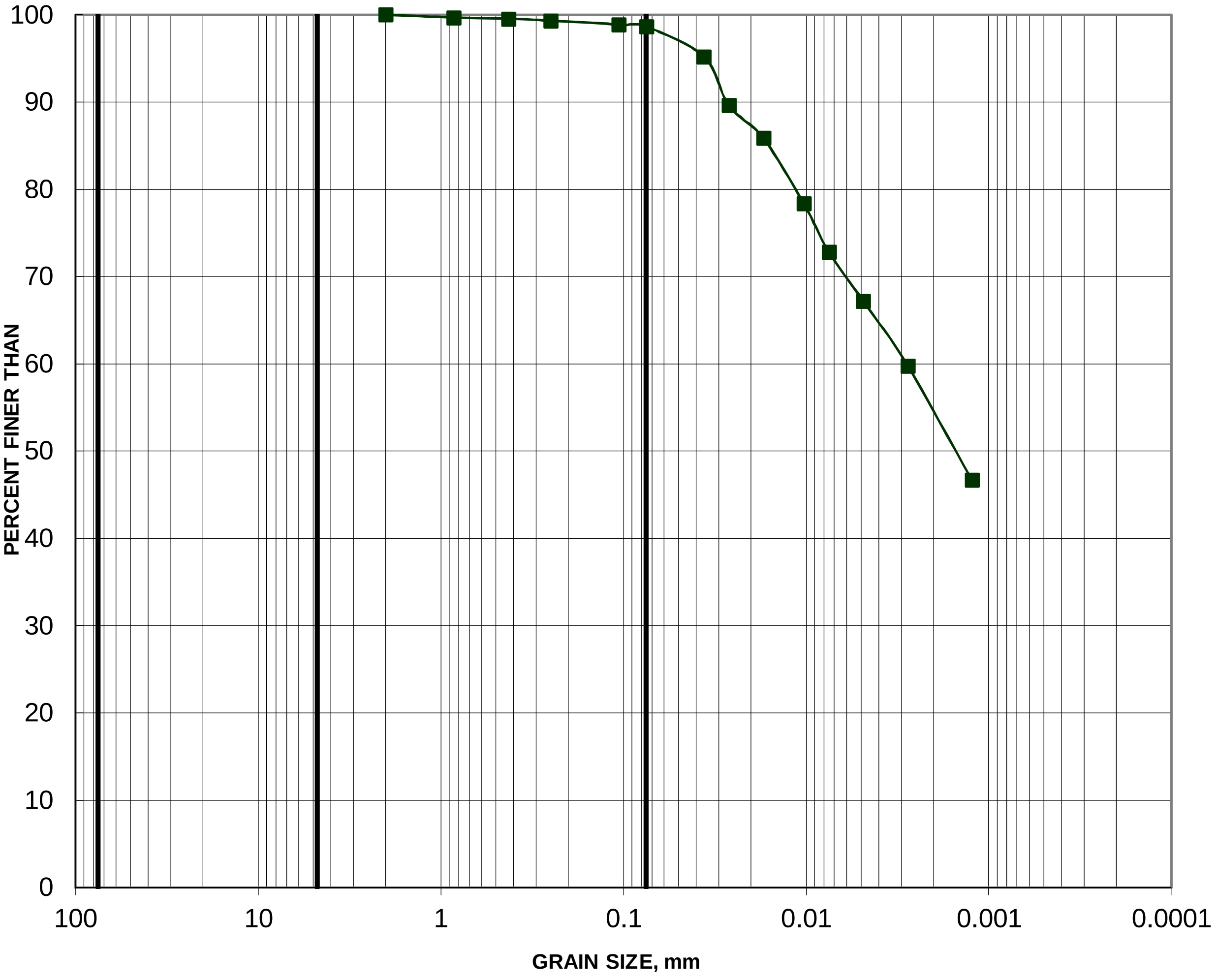
Project: 12-1125-0045

Golder Associates

Created by: CW

Checked by: CNM

GRAIN SIZE DISTRIBUTION



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Test Pit	Sample	Depth (m)
■ 09-15	2	1.20

Project: 12-1125-0045

Golder Associates

Created by: CW

Checked by: CNM

ATTACHMENT TSD#1-B-2

Borehole/Drillhole Logs and MOE Water Well Records

TSD#1-B-2-1 – NRR Site

TSD#1-B-2-2 – BR Site

ATTACHMENT TSD#1-B-2-1

Borehole/Drillhole Logs and MOE Water Well Records (NRR Site)

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample
DT	Dual Tube sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open Sampler for a distance of 300 mm (12 in.)

DD- Diamond Drilling

Dynamic Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive Uncased a 50 mm (2 in.) diameter, 60^0 cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Peizo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60^0 conical tip and a projected end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded Electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	**N** Blows/300 mm Or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	**C_u or S_u**	
	Kpa	Psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	Over 200	Over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limited
w_l	liquid limit
C	consolidaiton (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	modified Proctor compaction test
SPC	standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane test (LV-laboratory vane test)
γ	unit weight

Note:

1. Tests which are anisotropically consolidated prior shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	= 3.1416
ln x, natural logarithm of x	
$\log_{10}$ x or log x, logarithm of x to base 10	
g	Acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma'$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma''$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1\sigma_2\sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma'=\gamma-\gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R= p_s/p_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is p. Unit weight symbol is γ where γ=pg(i.e. mass density x acceleration due to gravity)

(a) Index Properties (cont'd.)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity Index=(w_l-w_p)
w_s	shrinkage limit
I_L	liquidity index=(w-w_p)/I_p
I_c	consistency index=(w_l-w)/I_p
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index-(e_{max}-e)/(e_{max}-e_{min}) (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	Overconsolidation ratio=σ'_p/σ'_{vo}

(d) Shear Strength

$\tau_p\tau_r$	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction=tan δ
c'	effective cohesion
c_u,s_u	undrained shear strength (ϕ=0 analysis)
p	mean total stress ($\sigma_1+\sigma_3$)/2
p'	mean effective stress ($\sigma'_1+\sigma'_3$)/2
q	($\sigma_1-\sigma_3$)/2 or ($\sigma'_1-\sigma_3$)/2
q_u	compressive strength ($\sigma_1-\sigma_3$)
S_t	sensitivity

Notes: 1. τ=c'σ' tan |'
2. Shear strength=(Compressive strength)/2

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 08-1

SHEET 1 OF 1

LOCATION: N 5018490.0 ;E 393506.0

BORING DATE: Apr. 24, 2008

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ├─○W─┤ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		82.57							
0	Rotary Drill Steel Casing	Overburden	▩	0.00							
1		Queenston Formation 1.0 m to 9.1 m	▤	81.57 1.00							
5	Rotary Drill Open Hole										∇
9		End of Borehole		73.47 9.10							W.L. in open hole at Elev. 77.37 m on May 20, 2010

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: P.A.H.

CHECKED:

MIS-BHS 001 0911251008-3000-3090.GPJ GAL-MIS.GDT 5/28/10 JM

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 08-2

SHEET 1 OF 1

LOCATION: N 5018679 0 ;E 393531 0

BORING DATE: Apr. 24, 2008

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0 3m				
		GROUND SURFACE		80.77							
0	Rotary Drill Steel Casing	Overburden	▩	0 00							
1				79.27							
	Rotary Drill Open Hole	Queenston Formation 1 5 m to 9 1 m	▤	1 50							
2											
3											∇
4											
5											
6											
7											
8											
9				71.67							
		End of Borehole		9 10							W L in open hole at Elev 78 05 m on May 20, 2010
10											
11											
12											
13											
14											
15											

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-3

SHEET 1 OF 3

LOCATION: N 5017702.0 ;E 392764.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 17-18, 2009

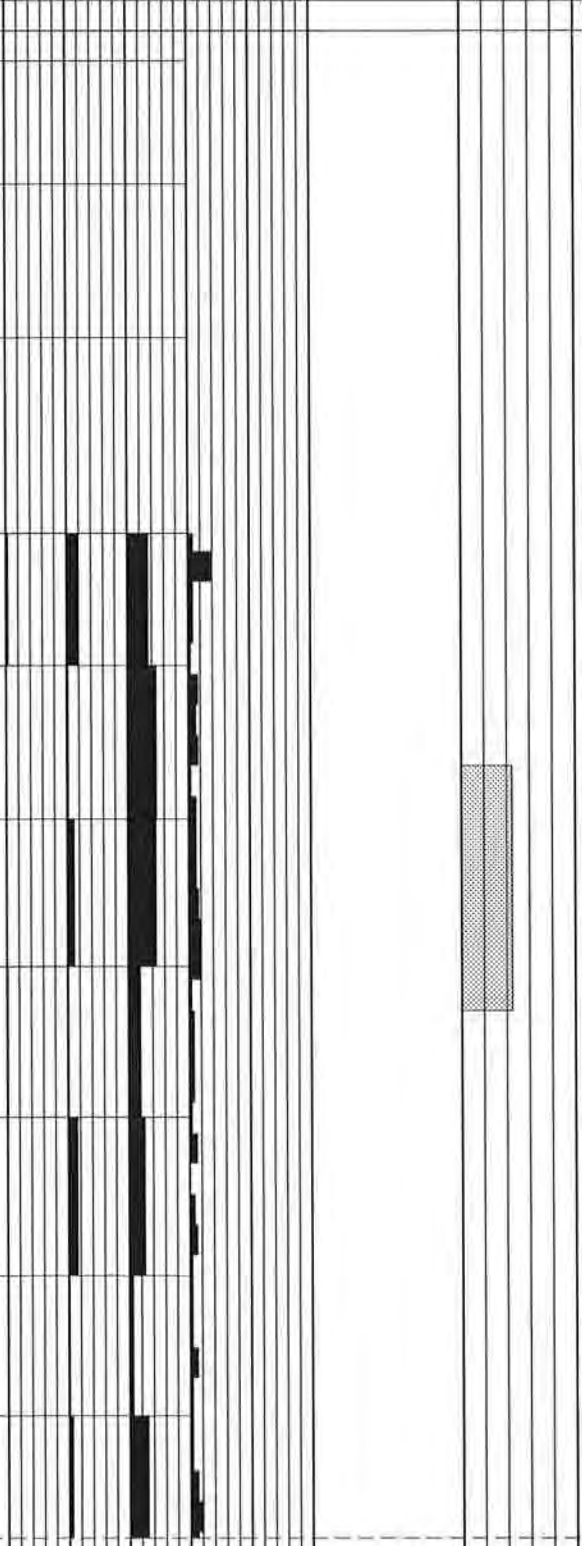
DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE
CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH. BREAK
SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING
VN-VEIN	S-SLICKENSIDED	PL-PLANAR	C-CURVED	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE	86.30		
0		TOPSOIL	0.00		
	Rotary Drill HW Casing	Red brown SANDY SILT/CLAYEY SILT, with gravel and cobbles (GLACIAL TILL)	0.24	1 2 3	Bentonite Seal
5		Queenston Formation 5.00 m to 10.52 m Fresh, medium to dark reddish brown, fine grained thin to medium bedded calcareous MUDSTONE interbedded with medium grey, thin to medium bedded LIMESTONE beds. Mudstone slakes on exposure to wetting and drying. Marker Bed occurs between 7.17 m and 7.55 m comprised of reddish grey bioclastic calcarenitic limestone with numerous mollusk and brachiopod fossils and lithoclastic fragments. Mudstone becomes dark grey and shaley from 9.33 m to 10.55 m.	81.30 5.00	C1 C2 C3 C4	Silica Sand 32mm Diam. PVC #10 Slot Screen 'B'
	Rotary Drill HQ Core	Carlsbad Formation 10.52 m to 30.56 m Fresh, medium to dark grey, fine to medium grained, thin to medium bedded LIMESTONE with bioclastic sections, burrow casts, thin lithoclastic limestone beds, occasional stylolites and dark grey to black shale partings	75.78 10.52	C5 C6 C7	Silica Sand Bentonite Seal
15					



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DEPTH SCALE
1 : 75

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-3

SHEET 2 OF 3

LOCATION: N 5017702.0 ;E 392764.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 17-18, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE
CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH. BREAK
SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING
VN-VEIN	S-SLICKENSIDED	PL-PLANAR	C-CURVED	

Columns: DEPTH SCALE METRES; DRILLING RECORD; DESCRIPTION; SYMBOLIC LOG; ELEV. DEPTH (m); RUN No; PENETRATION RATE (m/min); COLOUR % RETURN; FLUSH; RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.3 (5 10 15 20); DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); DIAMETRAL POINT LOAD INDEX (MPa) (2 4 6); NOTES WATER LEVELS INSTRUMENTATION

--- CONTINUED FROM PREVIOUS PAGE ---

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Drilling record: Rotary Drill, HQ Core

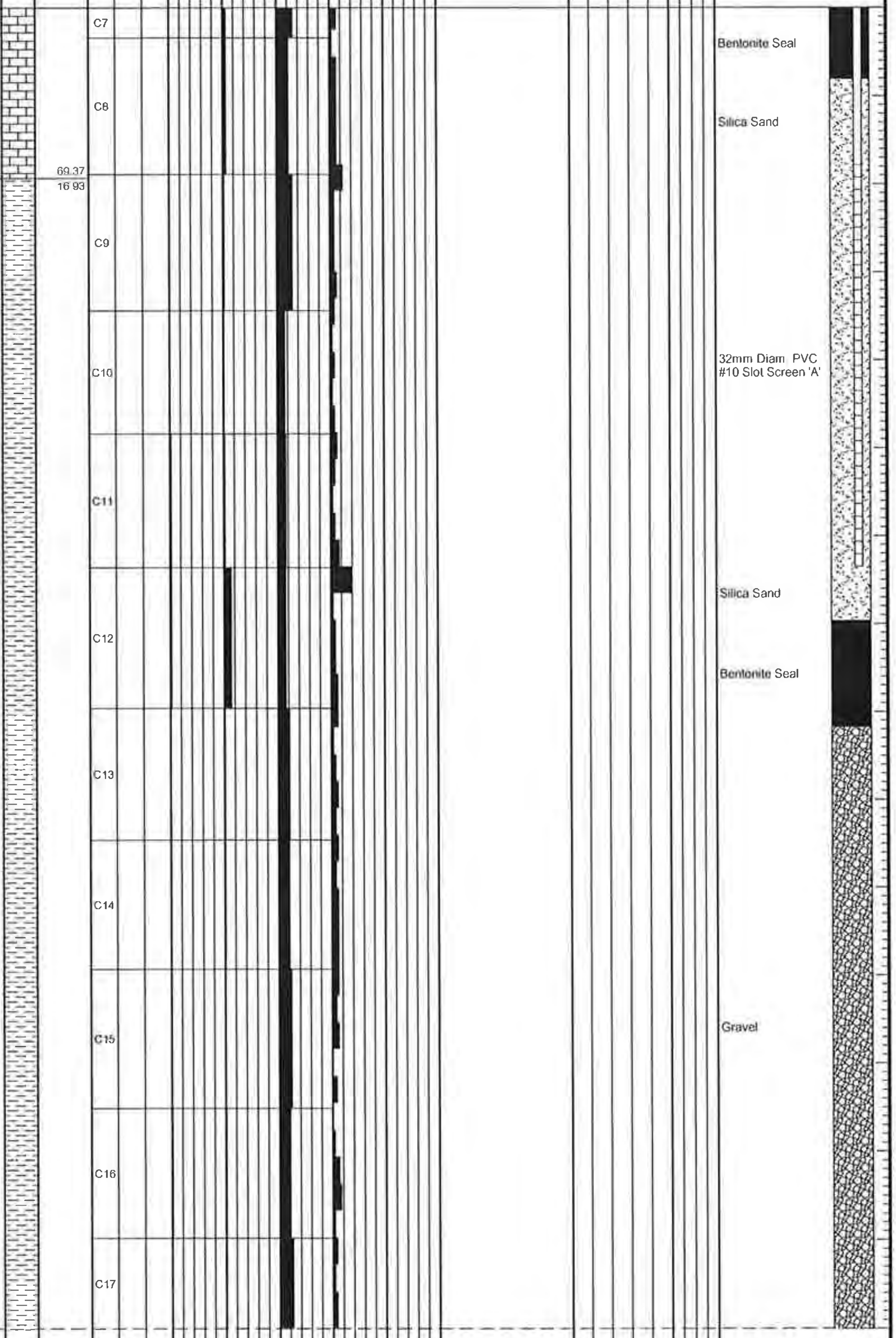
Carlsbad Formation
10.52 m to 30.56 m

Fresh, medium to dark grey, fine to medium grained, thin to medium bedded LIMESTONE with bioclastic sections, burrow casts, thin lithoclastic limestone beds, occasional stylolites and dark grey to black shale partings

69.37
16.93

Carlsbad Formation
10.52 m to 30.56 m

Fresh, dark grey, slake susceptible, fissile SHALE interbedded with subordinate amounts of medium grey, medium grained, laminated to thin bedded calcarenitic LIMESTONE with occasional fossils and weakly developed stylolites



Run No: C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17

Notes: Bentonite Seal; Silica Sand; 32mm Diam. PVC #10 Slot Screen 'A'; Silica Sand; Bentonite Seal; Gravel

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED: JM

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-3

SHEET 3 OF 3

LOCATION: N 5017702.0 ;E 392764.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov 17-18, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT INDEX PER 0.3 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	DIAMETRAL POINT LOAD INDEX (MPa) 2 4 6	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---														
30	HQ Core			55.74	C17											Gravel ▨
		End of Drillhole		30.56												
31																W.L. in screen 'A' at Elev. 81.63 m on May 20, 2010
32																W.L. in screen 'B' at Elev. 81.66 m on May 20, 2010
33																
34																
35																
36																
37																
38																
39																
40																
41																
42																
43																
44																
45																

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-4

SHEET 1 OF 3

LOCATION: N 5018544 0 ;E 393796 0

INCLINATION: -90° AZIMUTH: ---

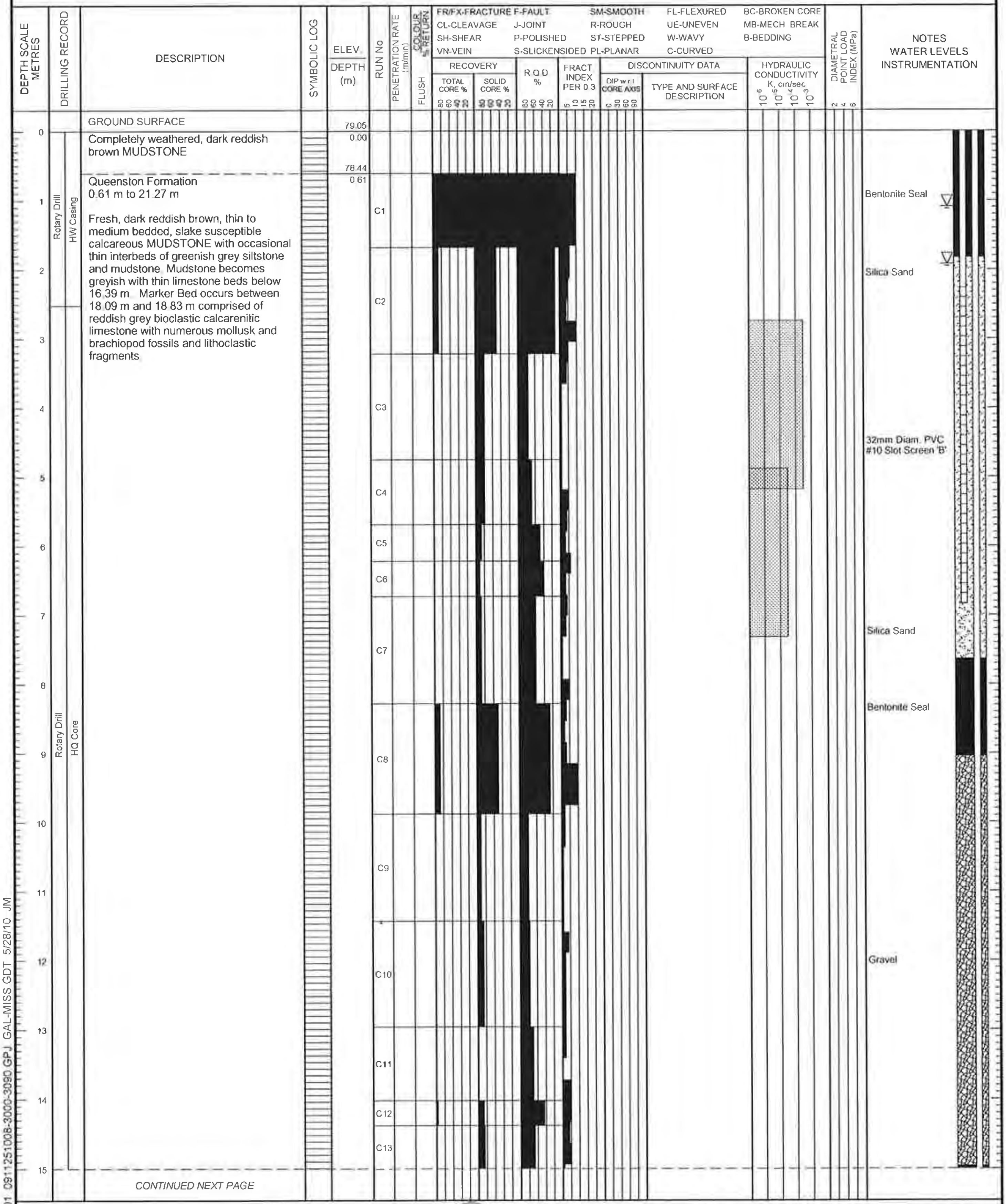
DRILLING DATE: Nov 3-9, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE
CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH BREAK
SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING
VN-VEIN	S-SLICKENSIDED	PL-PLANAR	C-CURVED	



GROUND SURFACE

Completely weathered, dark reddish brown MUDSTONE

Queenston Formation
0.61 m to 21.27 m

Fresh, dark reddish brown, thin to medium bedded, slake susceptible calcareous MUDSTONE with occasional thin interbeds of greenish grey siltstone and mudstone. Mudstone becomes greyish with thin limestone beds below 16.39 m. Marker Bed occurs between 18.09 m and 18.83 m comprised of reddish grey bioclastic calcarenitic limestone with numerous mollusk and brachiopod fossils and lithoclastic fragments

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-4

SHEET 2 OF 3

LOCATION: N 5018544 0 ;E 393796 0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov 3-9, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No | PENETRATION RATE (m/min) | COLOUR % RETURN | FLUSH | RECOVERY: TOTAL CORE % 80 60 40 20, SOLID CORE % 80 60 40 20 | R Q.D % 80 60 40 20 | FRACT INDEX PER 0 3 5 10 15 20 | DISCONTINUITY DATA: DIP w r t CORE AXIS 0 30 60 90, TYPE AND SURFACE DESCRIPTION | HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3} | DIAMETRAL POINT LOAD INDEX (MPa) 2 4 6 | NOTES WATER LEVELS INSTRUMENTATION

--- CONTINUED FROM PREVIOUS PAGE ---

Rotary Drill

HQ Core

Queenston Formation
0 61 m to 21 27 m

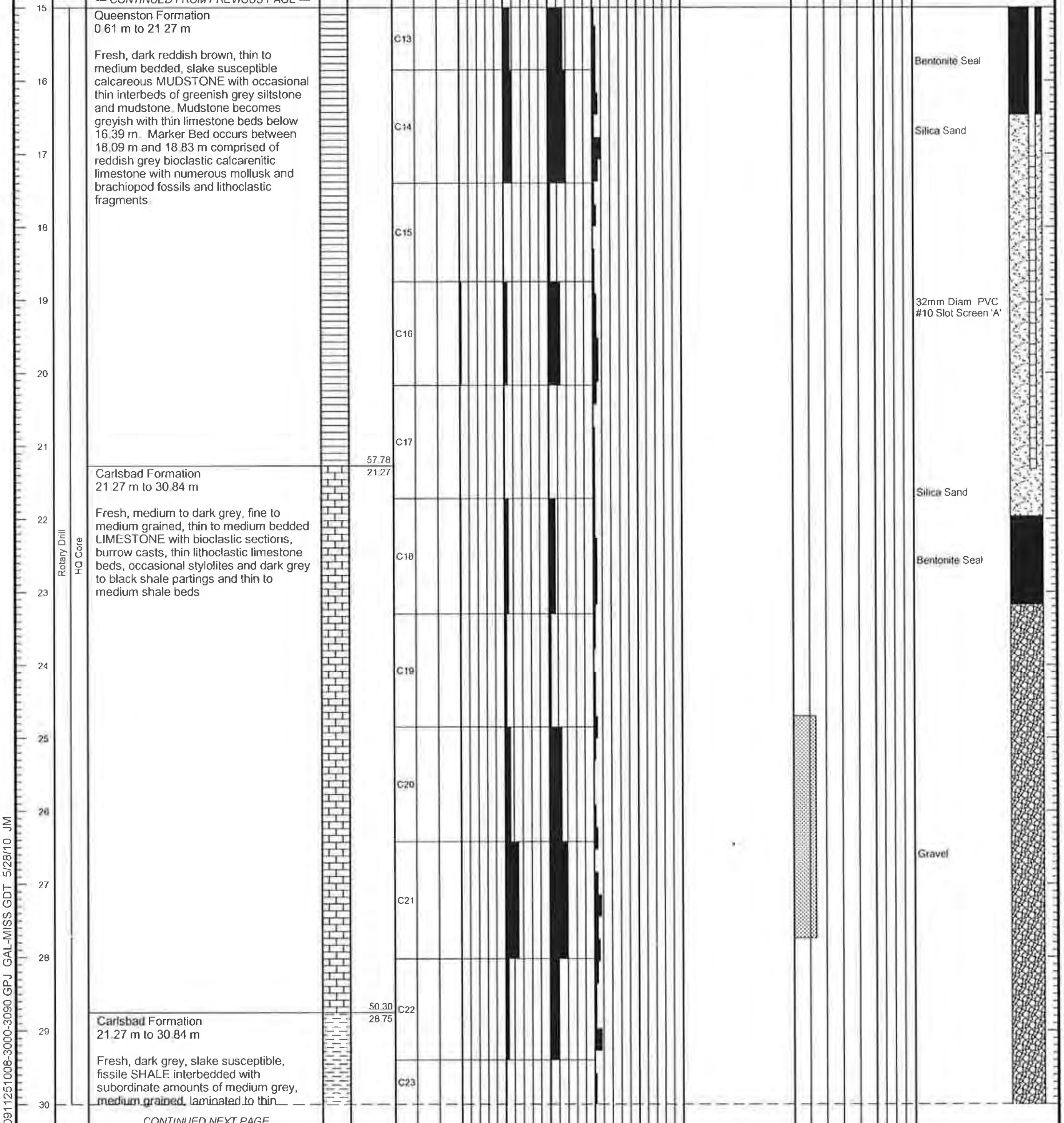
Fresh, dark reddish brown, thin to medium bedded, slake susceptible calcareous MUDSTONE with occasional thin interbeds of greenish grey siltstone and mudstone. Mudstone becomes greyish with thin limestone beds below 16 39 m. Marker Bed occurs between 18 09 m and 18 83 m comprised of reddish grey bioclastic calcarenitic limestone with numerous mollusk and brachiopod fossils and lithoclastic fragments.

Carlsbad Formation
21 27 m to 30 84 m

Fresh, medium to dark grey, fine to medium grained, thin to medium bedded LIMESTONE with bioclastic sections, burrow casts, thin lithoclastic limestone beds, occasional stylolites and dark grey to black shale partings and thin to medium shale beds

Carlsbad Formation
21 27 m to 30 84 m

Fresh, dark grey, slake susceptible, fissile SHALE interbedded with subordinate amounts of medium grey, medium grained, laminated to thin



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DEPTH SCALE
1 : 75

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-4

SHEET 3 OF 3

LOCATION: N 5018544 0 ;E 393796 0

INCLINATION: -90° AZIMUTH: --

DRILLING DATE: Nov 3-9, 2009
DRILL RIG: CME 850
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No	PENETRATION RATE (m/min)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT INDEX PER 0.3 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	DIAMETRAL POINT LOAD INDEX (MPa) 2 4 6	NOTES WATER LEVELS INSTRUMENTATION
		— CONTINUED FROM PREVIOUS PAGE —														
30	Rotary Drill HQ Core	bedded micritic to partly crystalline calcarenitic LIMESTONE with occasional fossils and weakly developed stylolites.		48.21	C23											Gravel
31		End of Drillhole		30.84												W.L in screen 'A' at Elev 77.13 m on May 20, 2010
32																W.L in screen 'B' at Elev 77.96 m on May 20, 2010
33																
34																
35																
36																
37																
38																
39																
40																
41																
42																
43																
44																
45																

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-5

SHEET 1 OF 2

LOCATION: N 5019324 0 ;E 394945 0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 11-16, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D % 80 60 40 20	FRACT INDEX PER 0.3 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	DIAMETRAL POINT LOAD INDEX (MPa) 2 4 6	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE		73.93												
0	Rotary Drill NQ Core / HW Casing	TOPSOIL		0.00												
		Grey brown SILTY CLAY (Weathered Crust)		0.25												Bentonite Seal
1																
					1											
2																
3					2											
		Grey SILTY CLAY		70.58 3.35												
4					3											
5																
6																
7					4											
8		GLACIAL TILL		66.00 7.93												Silica Sand
					5											
9																
10					6											
11																
12																
13					7											
14					8											
15					9											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: P.A.H.

CHECKED:

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-5

SHEET 2 OF 2

LOCATION: N 5019324.0 ;E 394945.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov 11-16, 2009

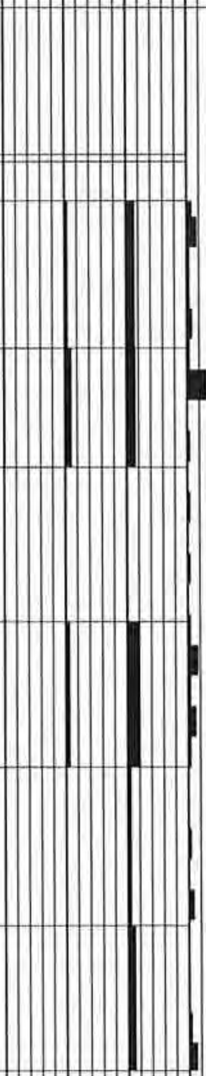
DRILL RIG: CME 850

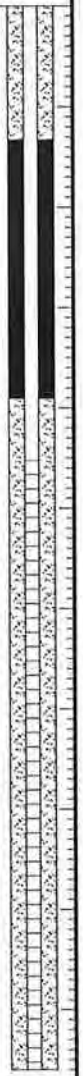
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
15		--- CONTINUED FROM PREVIOUS PAGE ---			
	Rotary Drill NQ Core / HW Casing	GLACIAL TILL		9	Silica Sand
16			57.47 16.46		
		SAND and GRAVEL, with cobbles	57.01 16.92	10	
17		Carlsbad Formation 16.92 m to 25.6 m Fresh, dark grey, slake susceptible, fissile SHALE interbedded with subordinate amounts of medium grey, medium grained, laminated to thin bedded micritic to partly crystalline calcarenitic LIMESTONE with occasional fossils and weakly developed stylolites		C1	Bentonite Seal
18	Rotary Drill NQ Core			C2	Silica Sand
20				C3	
22				C4	32mm Diam. PVC #10 Slot Screen
23				C5	
24				C6	
25			48.33 25.60		
		End of Drillhole			W.L. in screen at Elev. 72.71 m on May 20, 2010





DEPTH SCALE

1 : 75

LOGGED: P.A.H.

CHECKED: JMD

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-6

SHEET 1 OF 3

LOCATION: N 5017714.0 ;E 393580.0
INCLINATION: -90° AZIMUTH: ---

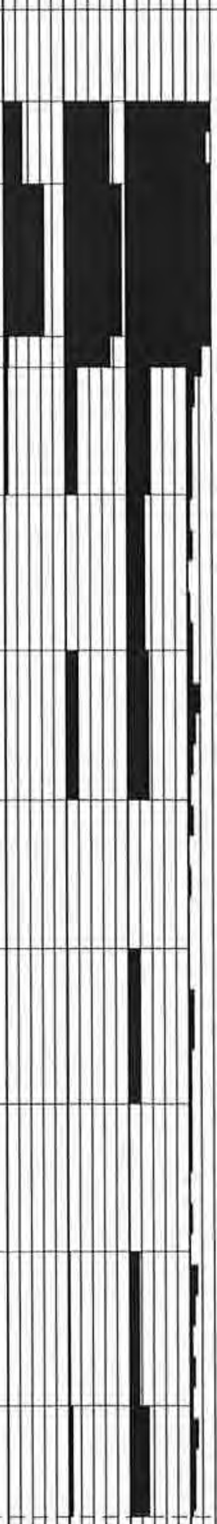
DRILLING DATE: Nov. 24-26, 2009
DRILL RIG: CME 850
DRILLING CONTRACTOR: Marathon Drilling

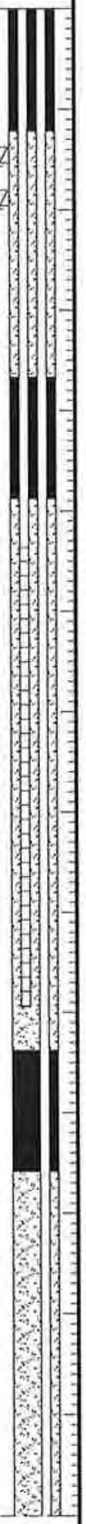
DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH. BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE	84.94		
0		TOPSOIL	0.00		
		Red brown SANDY SILT, with shaley gravel	0.20		Bentonite Seal
1	Rotary Drill HW Casing	Moderately to completely weathered, dark reddish brown MUDSTONE	84.03 0.91	C1 C2 C3	Silica Sand
3.56		Queenston Formation 3.56 m to 7.63 m Fresh, dark reddish brown, thin to medium bedded, slake susceptible calcareous MUDSTONE with occasional thin interbeds of greenish grey siltstone and mudstone. Mudstone becomes greyish with thin limestone beds below 6.71 m. Marker Bed occurs between 5.70 m and 6.02 m comprised of reddish grey bioclastic calcarenitic limestone with numerous mollusk and brachiopod fossils and lithoclastic fragments.	81.38 3.56	C4 C5 C6	Bentonite Seal Silica Sand
7.63	Rotary Drill HQ Core	Carlsbad Formation 7.63 m to 30.51 m Fresh, medium to dark grey to black, fine to medium grained, thin to medium bedded LIMESTONE with bioclastic sections, burrow casts, thin lithoclastic limestone beds, occasional stylolites and dark grey to black shale partings and thin to medium shale beds	77.31 7.63	C7 C8 C9 C10 C11	32mm Diam. PVC #10 Slot Screen 'B' Silica Sand Bentonite Seal Silica Sand
15					

RECOVERY: TOTAL CORE % / SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.3 (5 10 15 20); DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); DIAMETRAL POINT LOAD INDEX (MPa) (2 4 6); PENETRATION RATE (m/min); COLOUR % RETURN; FLUSH; SYMBOLIC LOG





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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED: JJD

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-6

SHEET 2 OF 3

LOCATION: N 5017714.0 ;E 393580.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 24-26, 2009

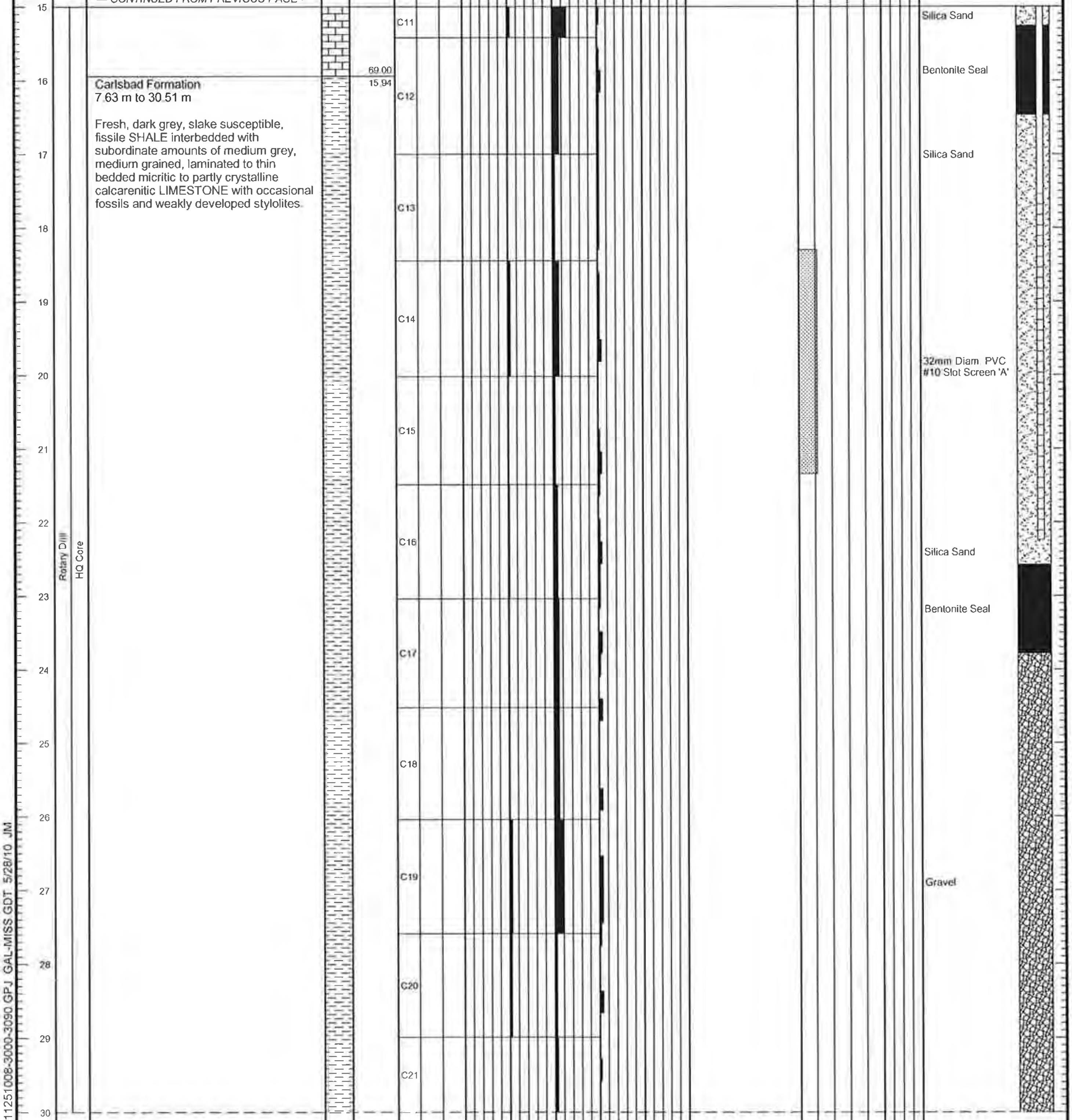
DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No	PENETRATION RATE (m/min)	COLOUR % RETURN / FLUSH	RECOVERY: TOTAL CORE % / SOLID CORE %	R Q D %	FRACT INDEX PER 0.3	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS / TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
		— CONTINUED FROM PREVIOUS PAGE —												
15–30	Rotary Drill HQ Core	**Carlsbad Formation** 7.63 m to 30.51 m Fresh, dark grey, slake susceptible, fissile SHALE interbedded with subordinate amounts of medium grey, medium grained, laminated to thin bedded micritic to partly crystalline calcarenitic LIMESTONE with occasional fossils and weakly developed stylolites.		69.00 15.94	C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21									Silica Sand Bentonite Seal Silica Sand 32mm Diam. PVC #10 Slot Screen 'A' Silica Sand Bentonite Seal Gravel
		CONTINUED NEXT PAGE												



DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED: JB

PROJECT: 09-1125-1008

RECORD OF DRILLHOLE: 09-6

SHEET 3 OF 3

LOCATION: N 5017714.0 ;E 393580.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 24-26, 2009

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH. BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No	PENETRATION RATE (m/min)	COLOUR % RETURN	FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT INDEX PER 0.3 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{6} 10^{5} 10^{4} 10^{3}	DIAMETRAL POINT LOAD INDEX (MPa) 2 4 6	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---															
30			▤	54.43 30.51	C21												Gravel ▩
		End of Drillhole															
31																	W.L. in screen 'A' at Elev. 82.98 m on May 20, 2010
32																	W.L. in screen 'B' at Elev. 83.41 m on May 20, 2010
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	
41																	
42																	
43																	
44																	
45																	

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 09-7

SHEET 1 OF 3

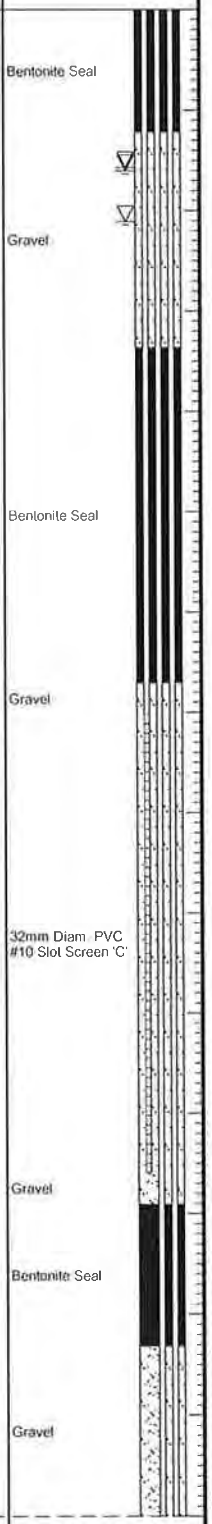
LOCATION: N 5018476.0 ;E 392482.0

BORING DATE: Nov. 20, 2010

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		63 52							
0	Rotary Drill / Steel Casing (0 to 6)	Overburden		0.00							
4.88		Queenston Formation 4.88 m to 33.55 m		78.64 4.88							
6 – 15	Rotary Drill / Open Hole										

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15



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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

MIS-BHS 001 09111251008-3000-3090.GPJ GAL-MIS.GDT 5/28/10 JM

PROJECT: 09-1125-1008

LOCATION: N 5018476.0 ;E 392482.0

RECORD OF BOREHOLE: 09-7

BORING DATE: Nov. 20, 2010

SHEET 2 OF 3

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
15	Rotary Drill Open Hole	Queenston Formation 4.88 m to 33.55 m									
16											Gravel
17											
18											Bentonite Seal
19											Gravel
20											
21											32mm Diam. PVC #10 Slot Screen 'B'
22											
23											
24											Gravel
25											Bentonite Seal
26											Gravel
27											
28											32mm Diam. PVC #10 Slot Screen 'A'
29											
30		CONTINUED NEXT PAGE									

DEPTH SCALE
1 : 75

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

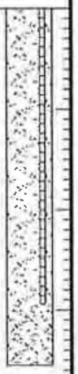
RECORD OF BOREHOLE: 09-7

SHEET 3 OF 3

LOCATION: N 5018476 0 ;E 392482.0

BORING DATE: Nov. 20, 2010

DATUM: Geodetic



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		— CONTINUED FROM PREVIOUS PAGE —									
30	Rotary Drill Open Hole	Queenston Formation 4.88 m to 33.55 m	▤								
31											32mm Diam. PVC #10 Slot Screen 'A'
32											
33											Gravel
		End of Drillhole		49.97 33.55							
34											W.L. in screen 'A' at Elev. 81.92 m on May 20, 2010
35											W.L. in screen 'B' at Elev. 81.95 m on May 20, 2010
36											W.L. in screen 'C' at Elev. 81.41 m on May 20, 2010
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 09-8

SHEET 1 OF 3

LOCATION: N 5019106.0 ;E 393472.0

BORING DATE: Nov. 30, 2010

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{6} 10^{5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		79.38							
0	Rotary Drill Steel Casing	Overburden	▨	0.00							Bentonite Seal
1											∇
2		Queenston Formation 2.13 m to 25.76 m	▤	77.25 2.13							Gravel
3	Rotary Drill Open Hole										Bentonite Seal
4											Gravel
5											
6											32mm Diam. PVC #10 Slot Screen 'C'
7											
8											Gravel Bentonite Seal
9											
10											
11											Gravel
12											
13											Bentonite Seal
14											Gravel
15											32mm Diam. PVC ∇ #10 Slot Screen 'B'

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED:

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 09-8

SHEET 2 OF 3

LOCATION: N 5019106.0 ;E 393472.0

BORING DATE: Nov. 30, 2010

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ / WATER CONTENT PERCENT Wp ├──○W──┤ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		— CONTINUED FROM PREVIOUS PAGE —									
15	Rotary Drill Open Hole	Queenston Formation 2.13 m to 25.76 m									
16											
17											
18											32mm Diam. PVC #10 Slot Screen 'B'
19											
20											
21											Gravel
22											
23											Bentonite Seal
24											
25											Gravel
26		Carlsbad Formation 25.76 m to 30.50 m		53.62 25.76							
27											
28											32mm Diam. PVC #10 Slot Screen 'A'
29											
30											
		CONTINUED NEXT PAGE									

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: P.A.H.
CHECKED: JCh

PROJECT: 09-1125-1008

RECORD OF BOREHOLE: 09-8

SHEET 3 OF 3

LOCATION: N 5019106.0 ;E 393472.0

BORING DATE: Nov. 30, 2010

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30		Carlsbad Formation 25.76 m to 30.50 m	▨	48.88 30.50							Gravel ▨
		End of Drillhole									
31											W.L. in screen 'A' at Elev. 64.56 m on May 20, 2010
32											W.L. in screen 'B' at Elev. 64.53 m on May 20, 2010
33											W.L. in screen 'C' at Elev. 78.11 m on May 20, 2010
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: P.A.H.

CHECKED:

Ontario Ministry of the Environment

Well Tag No. (Place Sticker and/or Print Below)
A 057512
A057512

Well Record

Regulation 903 Ontario Water Resources Act

Page ____ of ____

MW-1

BH08-1

#1

Well Owner's Information

First Name: 2122063
Last Name: Ontario Inc.
E-mail Address:
☐ Well Constructed by Well Owner
Mailing Address (Street Number/Name, RR): 708-225 Metcalfe St
~~Municipality~~: Ottawa
Province: Ontario
Postal Code: K2A1A9
Telephone No. (inc. area code): 6132929600

Part A Construction and/or Major Alteration of a Well

Address of Well Location (Street Number/Name, RR): 19 Eadie RD
Township: Russell
Lot: 19
Concession: 3
County/District/Municipality: Russell
City/Town/Village: Russell
Province: **Ontario**
Postal Code: K0A3B0
UTM Coordinates: NAD 83 Zone 18 Easting 472107 Northing 5016434
GPS Unit Make:
Model:
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) From	Depth (Metres) To
Red	Clay		Soft	0	1
Red	Shale		Layered	1	9.1

Annular Space/Abandonment Sealing Record

Depth Set at (Metres) From	Depth Set at (Metres) To	Type of Sealant Used (Material and Type)	Volume Placed (Cubic Metres)
0	1.5	ciment grout	1 Bag

Method of Construction

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

Water Use

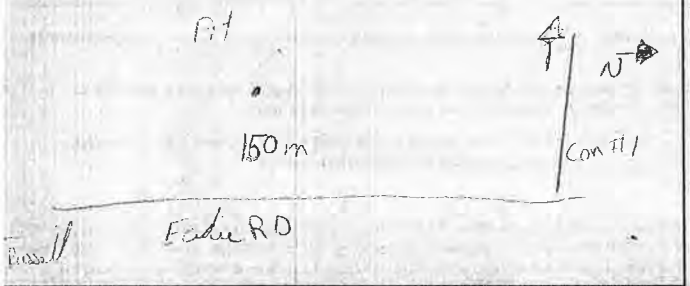
☐ Public
☐ Domestic
☐ Livestock
☐ Irrigation
☐ Industrial
☐ Other, specify
☐ Commercial
☐ Municipal
☑ Test Hole
☐ Cooling & Air Conditioning
☐ Not used
☐ Dewatering
☐ Monitoring

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



Date Well Completed (yyyy/mm/dd): 2008/04/24
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: Bourgeois Well Drilling
Well Contractor's Licence No.: 1414
Business Address (Street No./Name, number, RR): 1182 400 East
Municipality: Nation
Province: Ontario
Postal Code: K0A3C0
Business E-mail Address: N/A
Bus. Telephone No. (inc. area code): 6139875291
Name of Well Technician (Last Name, First Name): Alain Bourgeois
Well Technician's Licence No.: 2710
Signature of Technician: Alain Bourgeois
Date Submitted (yyyy/mm/dd): 2008/04/24

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)

NA

Draw Down Time (Min)	Draw Down Water Level (Metres)	Recovery Time (Min)	Recovery 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	

Water Details

NA

Water found at Depth	Kind of Water
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals

Casing Used

☐ Galvanized
☑ Steel
☐ Fibreglass
☐ Plastic
☐ Concrete

Screen Used

☐ Galvanized
☐ Steel
☐ Fibreglass
☐ Plastic
☐ Concrete

No Casing and Screen Used

☑ Open Hole
Disinfected? ☐ Yes ☑ No

Casing and Well Details

Diameter of the Hole (Centimetres): 15.55
Depth of the Hole (Metres): 9.1
Wall Thickness (Metres): 0.48
Inside Diameter of the Casing (Metres): 15.55
Depth of the Casing (Metres): 1.5

Ministry Use Only

Audit No. **Z 79805**
Well Contractor No.
Date Received (yyyy/mm/dd)
Date of Inspection (yyyy/mm/dd)
Remarks

0506E (11/2006)

Well Owner's Copy

BH08-2

MW-2

Ontario Ministry of the Environment

#2

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

A 057520

A 057520

Well Record

Regulation 903 Ontario Water Resources Act

Page ____ of ____

Well Owner's Information

First Name	Last Name	E-mail Address	☐ Well Constructed by Well Owner
2122063	Ontario Inc.	NA	

Mailing Address (Street Number/Name, RR)	Municipality	Province	Postal Code	Telephone No. *(inc. area code)*
		Ontario		

Part A Construction and/or Major Alteration of a Well

Address of Well Location (Street Number/Name, RR)	Township	Lot	Concession
LOT 19 Eadie RD	Russell	19	3

County/District/Municipality	City/Town/Village	Province	Postal Code
Russell	Russell	Ontario	

UTM Coordinates	Zone	Easting	Northing	GPS Unit Make	Model	Mode of Operation
NAD 83	18	472110	3501661172	Magellan	UTM	☐ 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)* From	To
Red			Soft	0	1.5
Red	Shale		layered	1.5	9.1

Annular Space/Abandonment Sealing Record

Depth Set at *(Metres)* From	To	Type of Sealant Used *(Material and Type)*	Volume Placed *(Cubic Metres)*
0	2.1	Ciment grout	3 Bag

Method of Construction

☐ Cable Tool
☐ Rotary (Conventional)
☐ Rotary (Reverse)
☑ Rotary (Air)
☐ Air percussion
☐ Other, specify ____
☐ Diamond
☐ Jetting
☐ Driving
☐ Digging
☐ Boring

Water Use

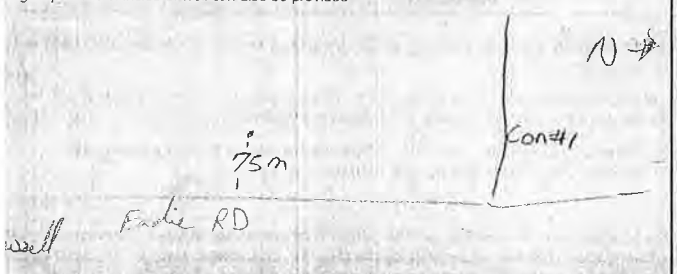
☐ Public
☐ Domestic
☐ Livestock
☐ Irrigation
☐ Industrial
☐ Other, specify ____
☐ Commercial
☐ Municipal
☐ Test Hole
☐ Cooling & Air Conditioning
☐ Not used
☐ Dewatering
☐ Monitoring

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")
digital pictures of inside of well can also be provided



Date Well Completed *(yyyy/mm/dd)*	Was the well owner's information package delivered?	Date the Well Record and Package Delivered to Well Owner *(yyyy/mm/dd)*
2008/04/24	☐ Yes ☑ No	

Well Contractor and Well Technician Information

Business Name of Well Contractor	Well Contractor's Licence No.
Bourgeois Well Drilling	1414

Business Address (Street No./Name, number, RR)	Municipality
82 900 East	Nation

Province	Postal Code	Business E-mail Address
Ont.	K0A2C0	NA

Bus. Telephone No. *(inc. area code)*	Name of Well Technician (Last Name, First Name)
6139872291	Alain Bourgeois

Well Technician's Licence No.	Signature of Technician	Date Submitted *(yyyy/mm/dd)*
2710	Alain Bourgeois	2008/04/24

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)*

NA

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	

NA

Water Details

Water found at Depth	Kind of Water
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals
____ Metres ☐ Gas	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals

NA

Casing Used

☐ Galvanized
☑ Steel
☐ Fibreglass
☐ Plastic
☐ Concrete

Screen Used

☐ Galvanized
☐ Steel
☐ Fibreglass
☐ Plastic
☐ Concrete

No Casing and Screen Used

☑ Open Hole

Disinfected?
☐ Yes ☑ No

Casing and Well Details

Diameter of the Hole *(Centimetres)*: 15.55

Depth of the Hole *(Metres)*: 9.1

Wall Thickness *(Metres)*: 0.48

Inside Diameter of the Casing *(Metres)*: 15.55

Depth of the Casing *(Metres)*: 2.1

Ministry Use Only

Audit No.	Well Contractor No.
Z79806	
Date Received *(yyyy/mm/dd)*	Date of Inspection *(yyyy/mm/dd)*

Remarks

0506E (11/2006)

#1 / BH09-7

Ontario Ministry of the Environment

Measurements recorded in: ☑ Metric ☐ Imperial

Well Tag No. *(Place Sticker and/or Print Below)*
A088095

Well Record

Regulation 903 Ontario Water Resources Act

Page ______ of ______

Well Owner's Information

First Name 2122063	Last Name / Organization Ontario Inc.	E-mail Address	☐ Well Constructed by Well Owner
Mailing Address (Street Number/Name) 708-225 Metcalfe St.	Municipality Ottawa	Province Ontario	Postal Code K2P 1P9
Telephone No. *(inc. area code)*			

Well Location

Address of Well Location (Street Number/Name) Russell RD	Township Russell	Lot 19	Concession 3
County/District/Municipality Prescott Russell	City/Town/Village Russell	Province **Ontario**	Postal Code
UTM Coordinates NAD 83 Zone 18 Easting 470058 Northing 5016121	Municipal Plan and Sublot Number	Other	

Overburden and Bedrock Materials/Abandonment Sealing Record *(see instructions on the back of this form)*

General Colour	Most Common Material	Other Materials	General Description	Depth (m/ft) From	To
Red	clay	silt	Hard	0	4.8
Red	shale		layered	48	28.8
grey	limestone		layered	29.8	[illegible]
					33.5

Annular Space

Depth Set at (m/ft) From	To	Type of Sealant Used (Material and Type)	Volume Placed (m³/ft³)
0	6	Cement grout	1 Bag

Results of Well Yield Testing

After test of well yield, water was:
☐ Clear and sand free
☐ Other, specify

If pumping discontinued, give reason:

Pump intake set at *(m/ft)*

Pumping rate *(l/min / GPM)*

Duration of pumping ____ hrs + ____ min

Final water level end of pumping *(m/ft)*

If flowing give rate *(l/min / GPM)*

Recommended pump depth *(m/ft)* N/A

Recommended pump rate *(l/min / GPM)*

Well production *(l/min / GPM)*

Disinfected? ☐ Yes ☑ No

Draw Down Time (min)	Water Level (m/ft)	Recovery Time (min)	Water Level (m/ft)
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)
☐ Boring
☐ Air percussion
☑ Other, specify Rotary Air
☐ Diamond
☐ Jetting
☐ Driving
☐ Digging

Well Use

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

Construction Record - Casing

Inside Diameter (cm/in)	Open Hole OR Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)	Wall Thickness (cm/in)	Depth (m/ft) From	To
15.55	Steel	.48	+.6	6
15.55	Open Hole		6	[illegible]
				33.5

Status of Well

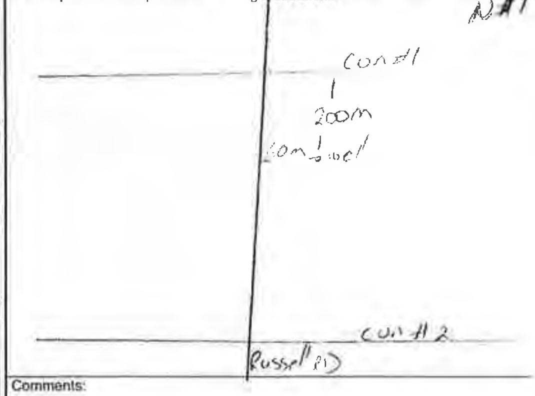
☐ Water Supply
☐ Replacement Well
☑ Test Hole
☐ Recharge Well
☐ Dewatering Well
☐ Observation and/or Monitoring Hole
☐ Alteration (Construction)
☐ Abandoned, Insufficient Supply
☐ Abandoned, Poor Water Quality
☐ Abandoned, other, specify
☐ Other, specify

Construction Record - Screen

Outside Diameter (cm/in)	Material (Plastic, Galvanized, Steel)	Slot No.	Depth (m/ft) From	To

Map of Well Location

Please provide a map below following instructions on the back



Comments:

Water Details

Water found at Depth 23 (m/ft) ☐ Gas | Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas | Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas | Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify

Hole Diameter

Depth (m/ft) From	To	Diameter (cm/in)
0	6	21.23
6	[illegible]	15.55
	33.5	

Well Contractor and Well Technician Information

Business Name of Well Contractor Bourgeois Well Drilling	Well Contractor's Licence No. 7617
Business Address (Street Number/Name) 151 Martin D'Aoust	Municipality Nation
Province Ontario	Postal Code K0A 3K0
Business E-mail Address NA	
Bus. Telephone No. *(inc. area code)* 6139875791	Name of Well Technician (Last Name, First Name) Michael Grier
Well Technician's Licence No. 3191	Signature of Technician and/or Contractor
Date Submitted 20091130	

Well owner's information package delivered ☐ Yes ☑ No

Date Package Delivered Y Y Y Y M M D D

Date Work Completed 20091130

Ministry Use Only
Audit No. Z108068
Received

0506E (12/2007)

Well Owner's Copy

BH09-8

Ontario Ministry of the Environment

Well Record

Regulation 903 Ontario Water Resources Act

Well Tag No. (Place Sticker and/or Print Below) **A 088103**

Measurements recorded in: ☑ Metric ☐ Imperial

Page ____ of ____

Well Owner's Information

First Name: 2122063
Last Name / Organization: Ontario inc
E-mail Address:
☐ Well Constructed by Well Owner
Mailing Address (Street Number/Name): 208-225 Metcalfe St.
Municipality: Ottawa
Province: Ontario
Postal Code: K2P1P9
Telephone No. (inc. area code):

Well Location

Address of Well Location (Street Number/Name): Eadie RD
Township: Russell
Lot: 19
Concession: 3
County/District/Municipality: Prescott Russell
City/Town/Village: Russell
Province: **Ontario**
Postal Code:
UTM Coordinates NAD 8 3 Zone 18 Easting 472042 Northing 5017030
Municipal Plan and Sublot Number:
Other:

Overburden and Bedrock Materials/Abandonment Sealing Record *(see instructions on the back of this form)*

General Colour	Most Common Material	Other Materials	General Description	Depth (m/ft) From	Depth (m/ft) To
Red	clay	shale	Hard	0	2.1
Red	shale		layered	2.1	22.8
Grey	limestone		layered	22.8	30.48

Annular Space

Depth Set at (m/ft) From	To	Type of Sealant Used (Material and Type)	Volume Placed (m³/ft³)
0	3	~~[illegible]~~ Bentonyte	2 Bag

Method of Construction

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

Well Use

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

Construction Record - Casing

Inside Diameter (cm/in)	Open Hole OR Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)	Wall Thickness (cm/in)	Depth (m/ft) From	Depth (m/ft) To
15.55	Steel	.48	+.6	3
15.55	Open Hole		3	30.48

Construction Record - Screen

Outside Diameter (cm/in)	Material (Plastic, Galvanized, Steel)	Slot No.	Depth (m/ft) From	Depth (m/ft) To

Status of Well

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

Results of Well Yield Testing

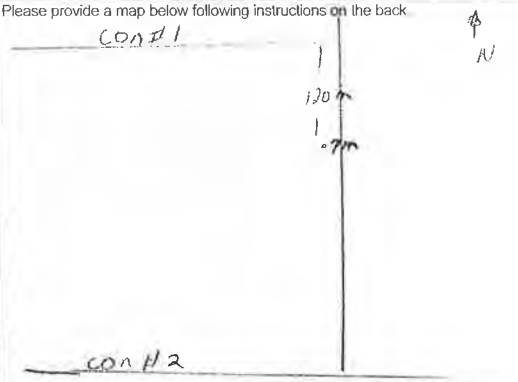
After test of well yield, water was:
☐ Clear and sand free
☐ Other, specify
If pumping discontinued, give reason:
Pump intake set at (m/ft)
Pumping rate (l/min / GPM)
Duration of pumping ____ hrs + ____ min
Final water level end of pumping (m/ft)
If flowing give rate (l/min / GPM)
Recommended pump depth (m/ft)
Recommended pump rate (l/min / GPM)
Well production (l/min / GPM)
Disinfected? ☐ Yes ☐ No

N/A

Draw Down Time (min)	Draw Down Water Level (m/ft)	Recovery Time (min)	Recovery Water Level (m/ft)
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	

Map of Well Location

Please provide a map below following instructions on the back



Comments:

Water Details

Water found at Depth 8 (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify

Hole Diameter

Depth (m/ft) From	Depth (m/ft) To	Diameter (cm/in)
0	3	21.23
3	30.48	15.55

Well Contractor and Well Technician Information

Business Name of Well Contractor: Bourgeois Well Drilling
Well Contractor's Licence No.: 3 4 1 1 7
Business Address (Street Number/Name): 151 Montée D'Aoust
Municipality: Nation
Province: Ontario
Postal Code: K0A 3C0
Business E-mail Address: NA
Bus. Telephone No. (inc. area code): 6139875291
Name of Well Technician (Last Name, First Name): Michael Genier
Well Technician's Licence No.: 3 4 9 4
Signature of Technician and/or Contractor
Date Submitted: 2 [illegible]

Well owner's information package delivered ☐ Yes ☑ No
Date Package Delivered Y Y Y Y M M D D
Date Work Completed [illegible]

Ministry Use Only
Audit No. Z108066
Received

0506E (12/2007)

Well Owner's Copy

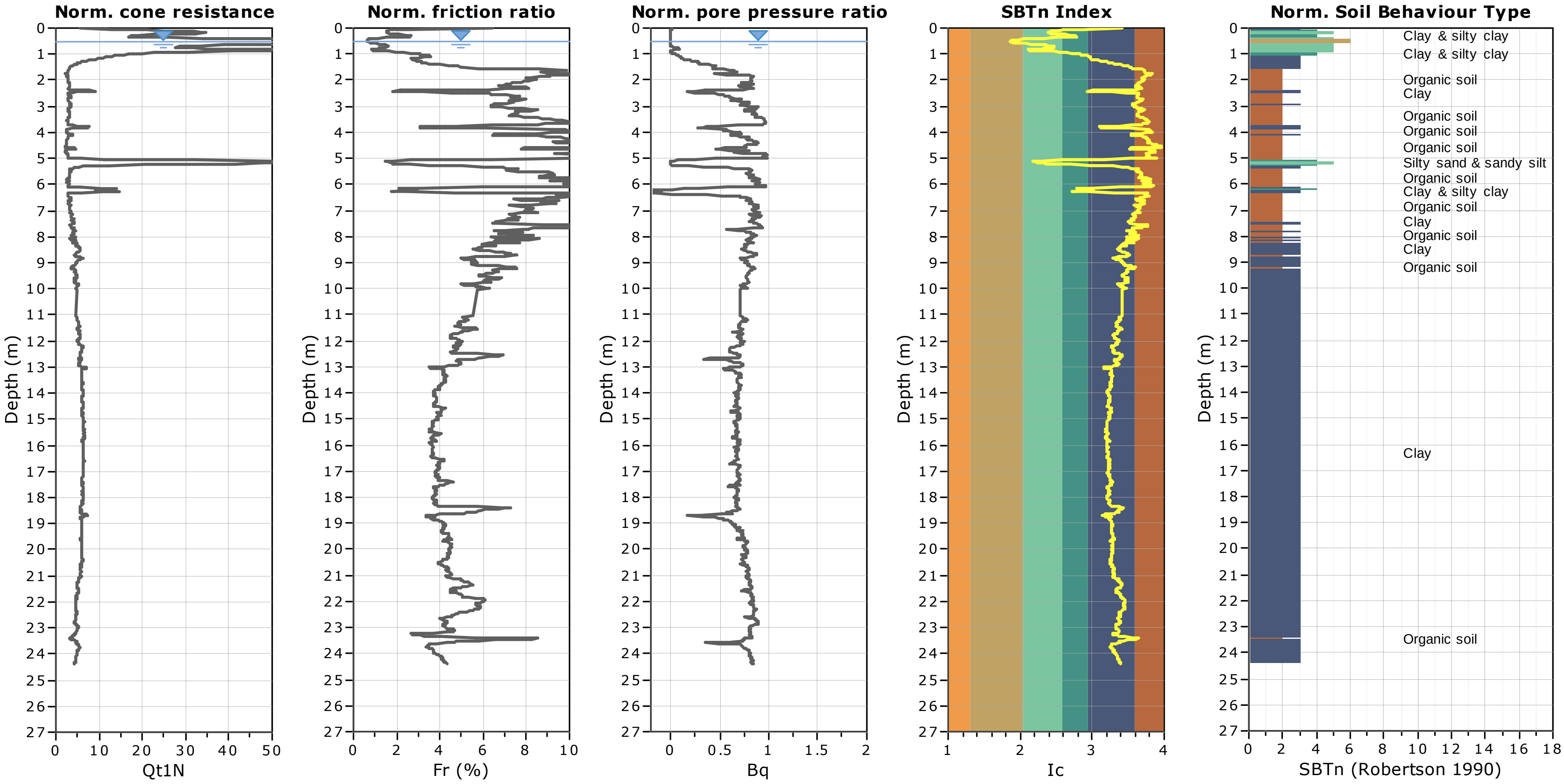
ATTACHMENT TSD#1-B-2-2

CPT Logs, Borehole Logs and Grain Size Distribution (BR Site)

Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-1-1 Rev 1
Total depth: 24.38 m, Date: 11/14/2012
Surface Elevation: 75.99 m
Coords: X:467130.45, Y:5020302.87
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

Project: 12-1125-0045 - CRRRC EA Eastern Ontario
Location: Boundary Road Site



SBTn legend

🟥 1. Sensitive fine grained
🟫 2. Organic material
🟦 3. Clay to silty clay
🟩 4. Clayey silt to silty clay
🟩 5. Silty sand to sandy silt
🟫 6. Clean sand to silty sand
🟧 7. Gravely sand to sand
⬛ 8. Very stiff sand to clayey sand
⬜ 9. Very stiff fine grained