June 2015

ENVIRONMENTAL ASSESSMENT OF THE PROPOSED CRRRC

Response to Wallach - Critical Review of Geoscientific Component of TMES EA Final Version, February 2, 2015

Submitted to:
Ontario Ministry of the Environment and Climate Change
Environmental Approvals Branch
135 St. Clair Avenue West, 1st Floor
Toronto, Ontario
M4V 1P5

REPORT

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3 copies – Ministry of Environment and Climate Change – EAB

1 copy – Golder Associates Ltd.

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1.0 INTRODUCTION

This document presents a response to the submission dated February 2, 2015 prepared by Joe Wallach, Ph.D., Structural Geology to Ms. Sue Langlois, President, Capital Region Citizens Coalition for Protection of the Environment (CRCCPE). The document, titled "Critical Review of Geoscientific Component of TMES EA, Final Version", [hereafter referred to as Wallach (2015)] was submitted by the CRCCPE to the Ontario Ministry of Environment and Climate Change (MOECC) as one component of the CRCCPE comments on the December 2014 Final Environmental Assessment (EA) for the Capital Region Resource Recovery Centre (CRRRC) proposed by Taggart Miller Environmental Services (Taggart Miller).

1.1 General Comments

One criticism presented by Wallach (2015) is duplication of information between Volumes I and III of the EA package. As described in Volume I, Section 1.7, the EA submission package consists of the documentation required for both EA Act approval (the current approval being sought by Taggart Miller) and for subsequent approvals under the EPA/OWRA associated with an application to obtain an Environmental Compliance Approval (ECA) for the proposed CRRRC. While Volume I supports the EA Act application, Volume III contains the information for the ECA application. Volume I is a stand-alone document for EA approval. Volume I summarizes key information from Volume III as well as from the Technical Support Documents (TSDs). The requirement for complete documentation for two separate approval processes is the only reason for the inclusion of the same (or very similar) information in both Volumes I and III. Multiple approval submission is also why similar information is presented in both the TSD's and Volume I.

In general, Wallach (2015) is critical of the studies undertaken and information presented in Volumes I and III of the EA package. Wallach (2015) contests the interpretations in the EA, particularly:

- the interpretation of site and regional geological conditions and the lack of identification of faults or probable faults in the bedrock (both in close proximity to the Boundary Road Site and in the general area within which the CRRRC is proposed to be located); and,
- the hazards associated with potential earthquakes, including ground shaking and liquefaction, and their potential effects on the landfill component of the proposed CRRRC.

Wallach (2015) states that relevant information was ignored in the studies related to geology and earthquake effects; sources of information cited in the References section of Volumes I and/or III were not adequately assessed or were casually dismissed; the data used are inadequate to support the suitability of the site for the proposed CRRRC landfill; and the significance of certain information is downplayed and/or described in a way that is deceptive or misleading.

The relevant portions of Volume III were prepared by a team of Canadian licensed professionals, both from Golder Associates and leading independent expert advisors (from Queen's University and the University of Western Ontario), with expertise in structural geology, hydrogeology, seismicity, seismic hazard assessment, and geotechnical earthquake engineering and analysis (refer to Section 1.4 of Volume III). Professionals on this team have decades of relevant experience in these fields, including the assessment of geological conditions of eastern Ontario. In the opinion of both Golder Associates and the other experts, the geo-scientific investigations, studies and interpretations, as well as the assessment of potential effects on the proposed CRRRC, are thorough and scientifically defensible, and are appropriate for the evaluation of the environmental conditions and potential effects of the proposed CRRRC solid non-hazardous waste management facility. The methodology used was from the approved Terms of Reference for this EA, as required under the *EA Act*.

1.2 Missing Information

Wallach (2015) identifies sources of information cited in the References section but not assessed or discussed in the Volume I or III Reports, in particular his own technical paper published in the September 2014 Canadian Journal of Earth Sciences – Wallach, J.L. (2014). *A Low-relief Hill in Eastern Ontario, Canada, Covered by the Easily Erodible Queenston Formation and Derived Sediments – Probably the Result of Quaternary Tectonic Uplift*. The Golder Associates' team was aware of and reviewed this paper during the final stages of preparation of the EA submission. Golder Associates' review identified that: 1) Wallach (2014) contained significant errors in the data used in his analysis, 2) only part of the available data were used in the interpretations, and 3) structural interpretations were based more on speculation than evaluation of proven data.

Professionals from the Golder Associates' team are preparing a comprehensive analysis and alternate interpretations for submittal to the Canadian Journal of Earth Sciences. In the interim, this response includes a discussion of why we included the Wallach (2014) citation in the EA Reference section but decided not to debate or even discuss it in the Volume I or III reports.

Wallach (2014) concludes that he may have identified the first Quaternary-age or younger (last 2.7 million years) fault scarp in eastern North America in the form of the bedrock ridge within which the Russell shale quarry is located, and only a few kilometres east of the proposed CRRRC Boundary Road Site. In the context of the CRRRC project, the presence of a possible Quaternary-age fault (the so-called 'North Russell Fault') along the west side of the Russell Quarry bedrock ridge (Cholowski Hill) was postulated publically, to our knowledge, in the April 7, 2011 edition of the Chesterville Record, where its 'discovery' is attributed to Dr. Wallach. At that time, the site proposed for the CRRRC was the North Russell Road Site. The interpretations and comments provided in Wallach (2015) are the same as have been made by Dr. Wallach since 2011/2012. It is not clear that the large amount of new, high-quality information contained in the EA document package has been considered by Dr. Wallach.

1.3 Form of Response

This response to Wallach (2015) has been divided into three parts. The reference to sections and comments follows the format of Wallach (2015).

Part 1 – Presence of Bedrock Faults in the area of the CRRRC Site, which covers the following comments:

- Section B. – Comments 1, 2 and 3
- Section C. – Letter #1 and report accompanying Letter #1, parts of Letter #2, Letter #3, parts of Letter #4
- Addendum

Part 2 – Seismicity/Tectonics/Liquefaction Potential, which covers the following comments:

- Section B. – Comments 4, 5, 6, 7a and 7d
- Section C. – remainder of Letter #2 and remainder of Letter #4

Part 3 – State of Stress and Potential Earthquake Shaking, which covers the following comments:

- Section B. – Comments 7b, 7c and 7e

We do not present a comment-by-comment response to Wallach (2015). Rather, we have identified what we consider to be the principal points of technical difference between what has been provided in the EA submission volumes and the commentary and information provided by Wallach (2015). Our responses set aside Wallach's commentary on the intentions of the EA submission to mislead and/or deceive the reader. We do not consider these assertions to warrant a response.

2.0 PART 1 – PRESENCE OF BEDROCK FAULTS IN THE AREA OF THE CRRRC SITE

2.1 Review of Data used in Wallach (2014) and Included in Wallach (2015)

2.1.1 Introduction

Wallach (2014) developed a geological model for the stratigraphy and structure of Cholowski Hill and surrounding area to the west, south and east. He relied heavily on subsurface geological data obtained from the MOECC Water Well Information System (MOECC WWIS) and the Ontario Oil, Gas, and Salt Resources Library. As indicated by Wallach (2014), the MOECC WWIS data are not altogether reliable, and considerable scrutiny is required to work successfully with these highly variable data. As such, the review included herein focuses on the quality and appropriateness of data used by Wallach (2014) to develop his geological model for the study area.

Data deficiencies identified through the review of Wallach (2014) are grouped into four categories, as listed below:

- MOECC WWIS Data Included in Wallach (2014)
- MOECC WWIS Data Excluded from Wallach (2014)
- Identification of the Top of Carlsbad Formation
- General Comments

This technical review first explains each of the above data deficiencies with examples from Wallach (2014) and Wallach (2015). A brief description of the geological model when the deficiencies are properly addressed is then provided.

2.1.2 Data Deficiencies

2.1.2.1 MOECC WWIS Data Included in Wallach (2014)

Wallach (2014) interpretation of the structural geology in the area studied relies heavily on data obtained through the MOECC WWIS database. Our first concern with using MOECC WWIS data is the accuracy of the well locations provided in the database. In order to evaluate the well location accuracy, the MOECC WWIS database provides codes for wells based on the reliability of their location coordinates. The MOECC WWIS well location accuracy codes are provided in the table below. The appropriate level of screening of the MOECC data depends partly on the scale and type of project-specific analysis undertaken and the number of available data points. We consider it is prudent (and good practice) to remove all wells with a location accuracy of less than 100 m (i.e., remove all wells with a location accuracy code of 5 or greater).

Location Accuracy Code	Margin of Error
1	<3 m
2	3 m – 10 m
3	10 m – 30 m
4	30 m – 100 m
5	100 m – 300 m
6	300 m – 1 km
7	1 km – 3 km
8	3 km – 10 km
9	Unknown Coordinates

Wallach (2014) includes a table of MOECC WWIS data used in the study (Table 3) with well location coordinates (Northings and Eastings), ground elevation at surface, lithological descriptions, and the elevation of the top of the Carlsbad Formation. Further, Wallach (2014) provides a map showing the interpreted structural geology and top elevation of the Carlsbad Formation within the area studied that was derived using the MOECC WWIS data (Figure 12). In total, 86 MOECC WWIS wells are included in Table 3 of Wallach (2014), and 98 are included on Figure 12. Four wells included in Table 3 are not shown on Figure 12, and 16 wells are included on Figure 12 that are not included in Table 3, (i.e., 102 MOECC WWIS points were used in the Wallach (2014) analysis).

Although the well location accuracy codes were not included in Wallach (2014), we determined the codes by geo-referencing Wallach (2014) Figure 12 (and Table 3) and matching well records in the MOECC WWIS database to those on Figure 12 and in Table 3. In total, 36 of the 102 wells used in the Wallach (2014) analysis (35%) have an accuracy code of 9 (i.e., having "unknown coordinates"), one well has an accuracy code of 5, and one well has no code. All remaining wells have an accuracy code of 4 or lower. Of the 102 wells, therefore, only 64 (63%) have, in our opinion, an acceptable accuracy code. The spatial distribution of the "code 9" wells used in Wallach (2014) is illustrated on the attached Figure 1.

The use of "code 9" records from the MOECC WWIS has major consequences for the subsequent interpretation of the geological stratigraphy and structure. Two example errors are outlined below.

The first example is related to three wells illustrated on Wallach (2014) Figure 12, located in the northwest (upper left) corner of Figure 12, immediately to the west of the Boundary Road Site. Two of these three wells have been assigned a top elevation of the Carlsbad Formation bedrock of 75 mASL (referred to as the "75" wells); one well has been assigned an elevation of 72 mASL (referred to as the "72" well), and are herein referred to as the "northwest corner wells". Wallach (2014) has interpreted a fault roughly along Boundary Road immediately to the east of these "northwest corner wells" because other nearby wells have top surface elevations of the Carlsbad Formation at about 35 m lower than the "northwest corner wells". In Section C Letter # 1 of Wallach (2015), there is specific mention of the discussion between Golder Associates' staff and Dr. Wallach at the June 2013 Groundwater Workshop in regard to the WWIS accuracy codes (of which Dr. Wallach was previously unaware), these same three well records and the presence of the fault inferred by Dr. Wallach from this data. Dr. Wallach describes the method he then used to try to verify the location of water wells in the general location where these three well records plot on a map. However, locating a well in the field that approximates one reported in the WWIS does not inform the subsurface conditions encountered at that location; that has to be obtained from the WWIS data base. The WWIS data base provides the subsurface information in two ways: 1) a summary of the materials encountered and their thickness and 2) access to a copy of the actual driller's log based on the well number. From the MOECC WWIS database, and using the well numbers assigned to these three "northwest corner wells", we have matched three well records to the location coordinates of the two 75 mASL wells, which include Well ID 5603177 for the northernmost "75" well, and Well IDs 5603178 and 1523770 for the southernmost "75" well. For the "72" well, Well ID 1524478 has been matched to this location. The records for these identified wells show that these wells are all located in Marionville, Ontario, approximately 16 km southeast of the locations illustrated on Wallach (2014) Figure 12 (well records and location maps are provided in Appendix A). The geological information provided on these records is representative of the conditions in Marionville, where bedrock is present at shallow depth at ground surface. It is not representative of the subsurface conditions in the area of the Boundary Road Site, which consist of an approximately 30 metre thick deposit of silty clay. The main implication of this error in Wallach (2014) is that without the "northwest corner wells", no information exists to support the interpreted fault in the northwest corner shown on Wallach (2014) Figure 12 that is immediately west of the proposed CRRRC Boundary Road Site.

A second example relates to the plan and cross-sections provided in Wallach (2014) (Figures 14 through 16), some information from which is included on Figures 9 and 11 of Wallach (2015) Section C Letter #1. By matching the MOECC WWIS well location accuracy codes to the data points illustrated on these figures (as described above), we determined that eight of the 29 control point locations (28%) used to generate the sections were derived from MOECC WWIS data with an accuracy code of 9, and one point was derived from data with an accuracy code of 5. To illustrate, as shown on Wallach (2014) cross-section C-D on Figure 15, bedrock elevation offsets are interpreted in the central portion of the figure based on limestone located east of the supposed North Russell fault (NRF). The data point that shows limestone was matched to MOECC WWIS Well ID # 5603497 that has a location accuracy code of 9. A review of the well record indicates that the well is located adjacent to County Road 3, in Russell, Ontario about 5.5 km south of its location shown on Wallach (2014) figures. With this well record removed from the section, no subsurface information exists to support the interpreted faults illustrated on Wallach (2014) Figure 15. The cross-sections on Figure 16 were similarly created using "code 9" data; again, with those wells removed no information exists to suggest the interpreted East Ridge fault on Figure 16. There is no available subsurface information suggesting the presence of the North Russell and East Ridge faults interpreted and named by Dr. Wallach. As described later in this Section and in Section 2.1.5, the results of drilling investigations at the North Russell Road Site (the quarry site) demonstrate that the bedrock ridge is continuously underlain by Queenston shale bedrock and the limestone inferred by Dr. Wallach to exist near surface within the ridge associated with the presence of his inferred North Russell and East Ridge faults is not present.

We anticipate that similar examples to the two explained above can be found with additional review of the MOECC WWIS data. The above examples were randomly chosen from the "code 9" well locations. We consider that these examples demonstrate that the conceptual geological model presented by Wallach (2014) and referred to frequently in Wallach (2015) is based on erroneous data and, therefore, has little to no validity. We also note that the proper use of water well data provides general subsurface information but is, in itself, of limited value for more complex geological interpretation such as that attempted by Dr. Wallach.

2.1.2.2 MOECC Data Excluded from Wallach (2014)

MOECC WWIS data used in Wallach (2014) included 97 wells that contained bedrock units in the lithological descriptions. The five "less-than" points identified on the well logs represent logs that were also used in Wallach (2014) where only unconsolidated overburden deposits were encountered to the full depth of the well; that is, the well did not reach the bedrock surface. At these locations, the bedrock surface has been inferred to be at an elevation below the depth of the well. This data used in Wallach (2014) represents only a small portion of the MOECC WWIS data that are available within the Wallach (2014) study area. Following screening of the WWIS database for location accuracy codes of 5 or greater (i.e., only including wells with a location accuracy of less than 100 m), there are 346 well records with logged bedrock depths, and 26 "less-than" data points within the Wallach (2014) study area (these are illustrated on the attached Figure 2). It appears that only a small fraction of the available MOECC WWIS data with high location accuracy were used in the development of Wallach's geological model. Why Wallach (2014) chose to not use these data points is unknown. The selective use of well data and apparent arbitrary elimination of well data with high location accuracy is considered a major deficiency in the geological model present in Wallach (2014).

In addition to the location accuracy issue associated with the water well data, the descriptions of the material encountered during well drilling (and reported in the WWIS) is provided by the water well driller, an individual with limited technical knowledge of geology. In our experience, the reliable information provided is typically limited to overburden thickness, bedrock surface and well depth, with some definition of soil material such as distinguishing sand and gravel from clayey soil. Our review of the bedrock information provided in the data base for the study area has indicated very inconsistent descriptions of the bedrock varying between limestone and shale, and we have placed little reliability on the data reported at depths below the bedrock surface other than taking into consideration the description of the colour of the bedrock at the bedrock surface.

2.1.2.3 Delineation of the Top of Carlsbad Formation

Wallach (2014) used data from the Ontario Oil, Gas and Salt Resources Library (OOGSRL) to develop his geological model of his study area. The well cards from the OOGSRL include the elevations of geological formations encountered during drilling, which Wallach (2014) used as the primary data source for interpretation of the elevation of the top surface of the Carlsbad Formation. We assume that by "top surface", Wallach (2014) is referring to the Queenston Formation/Carlsbad Formation contact. Although the data included in the OOGSRL records are in general more reliable and of higher quality than the MOECC WWIS data, a detailed review of these data is necessary before extrapolating them into geological models. As part of the CRRRC studies, we carried out an extensive review of the OOGSRL records including the acquisition of the digital files for the 26 available individual borehole geophysical records. We completed a detailed stratigraphic interpretation of these geophysical records.

We also examined the rock core from the GSC Russell borehole (RU-24, OOGSRL well card T002252) stored at the Tunney's Pasture core library. The well card for RU-24 reports the Queenston/Carlsbad Formation contact at a depth of 39 m. Examination of the actual rock core shows the contact is at 26.8 m, where it has also been labelled in the core box by others. This contact depth also coincides with the borehole geophysical signature and further demonstrates the need to verify contact horizons reported by the OOGSRL well cards. Detailed examination and interpretation of the borehole geophysical records is necessary because the well card information cannot be accepted at face value. Following our core log review, it was clear that of the 26 gas wells in the area only one other gas well encountered the Queenston Formation shale (RU-06, T002451). In contrast, well card records RU-01, RU-02 and RU-04 (T002264, T002386 and T002443) incorrectly reported the presence of the Queenston Formation shale.

The results of our detailed core log review and direct review of well card data identified several instances where Wallach (2014) incorrectly interprets the OOGSRL data. The incorrect interpretation leads to non-representative delineations of the top surface elevation of the Carlsbad formation in Wallach (2014).

The data used by Wallach (2014) are summarized in his Table 2 and Figures 12 and 17. These include a total of 24 OOGSRL wells listed in the Table, and 21 wells shown on his figures. Two wells shown on Figures 12 and 17 are not listed in Table 2 (N002586 and T002630) and four wells that are listed in Table 2 are not shown on Figures 12 and 17 (F019750, T002469, T002468, and T002451). We conclude, therefore, that Wallach (2014) used 26 OOGSRL well records. Our review of the OOGSRL records identified two additional wells (F019777 and N002585) within the Wallach (2014) study area. Wallach (2014) does not explain why these two records were not used.

We found several inconsistencies with the 26 OOGSRL well data points used by Wallach (2014). As previously mentioned, four wells are not shown on any figures. Wells F019750 and T002451 are located outside of the limits of the figures (or might be located beneath the figure legend). For well T002468 and T002469, however, we assume that these wells were omitted from the figures because they are inconsistent with the elevation of the Carlsbad Formation provided in Wallach (2014) Table 2.

In general, there is a good correlation between the data used in Wallach (2014) and that available from the OOGSRL data. At five locations, however, the elevations listed for the top of the Carlsbad Formation in Wallach (2014) differ significantly from the information provided on the corresponding OOGSRL well card. These differences are summarized below:

- For well T002252, the elevation of the Carlsbad Formation used in Wallach (2014) is 49.70 mASL, whereas the elevation provided on the OOGSRL well log is 37.48 mASL (12.22 m lower). It is presumed that the elevation used in the Wallach paper was based on the elevation of 49.5 mASL provided by Williams (1991), though this is not explained. The 49.5 mASL elevation is consistent with the contact depth (88.5 feet) marked in the core box from this borehole.

- For well T002386, the elevation of the Carlsbad Formation used in Wallach (2014) is 71.65 mASL, whereas the elevation provided on the OOGSRL well log is 42.10 mASL (29.55 m lower). However, from our interpretation of the borehole geophysics as discussed in the Volume III Report, there is insufficient Carlsbad shale thickness present in this borehole above the bentonite marker layer at 98 metres to have the Queenston/Carlsbad contact (top of Carlsbad) present in this borehole, i.e., the bedrock starts in the Carlsbad Formation.

- For well T002443, the elevation of the Carlsbad Formation used in Wallach (2014) is 61.28 mASL, whereas the elevation provided on the OOGSRL well log is 37.76 mASL (23.52 m lower). However, from our interpretation of the borehole geophysics as discussed in the Volume III Report, there is insufficient Carlsbad shale thickness present in this borehole above the bentonite marker layer at 86 metres to have the Queenston/Carlsbad contact (top of Carlsbad) present in this borehole, i.e., the bedrock starts in the Carlsbad Formation.

- For well T002468, the elevation of the Carlsbad Formation used in Wallach (2014) is 37.49 mASL, whereas the elevation of the Carlsbad Formation is not provided on the OOGSRL well log. Similarly, elevations provided in Wallach (2014) for the Rockcliffe, Oxford and March Formations are not provided on the well log. The basis for the formation elevations listed in the paper is unknown. Again, from our interpretation of the borehole geophysics as discussed in the Volume III Report, there is insufficient Carlsbad shale thickness present in this borehole above the bentonite marker layer at 88 metres to have the Queenston/Carlsbad contact (top of Carlsbad) present in this borehole, i.e., the bedrock starts in the Carlsbad Formation.
- For well T002469, the elevation of the Carlsbad Formation used in Wallach (2014) is 45.43 mASL, whereas the elevation of the Carlsbad Formation is not provided on the OOGSRL well log (elevations are provided on the well log for the Queenston, Trenton, Black River, Cambrian and Precambrian units). The basis for the elevation indicated in Wallach (2014) is unknown. Again, from our interpretation of the borehole geophysics as discussed in the Volume III Report, there is insufficient Carlsbad shale thickness present in this borehole above the bentonite marker layer at 81 metres to have the Queenston/Carlsbad contact (top of Carlsbad) present in this borehole, i.e., the bedrock starts in the Carlsbad Formation.

Wallach (2014) Table 2 also lists the elevations of the top of other geological formations that underlie the Carlsbad Formation from the OOGSRL well cards. Although there are discrepancies in the elevation of the Carlsbad Formation in a number of the locations as noted above, the elevations of the top of the underlying formations are in general agreement with the values provided on the well cards.

2.1.2.4 General Data Deficiencies

A number of other deficiencies were identified in Wallach (2014) and have been carried through into Wallach (2015). These are summarized below:

- Topographic information used in the study by Wallach (2014) was derived from spot elevations obtained through Google Earth™. Google Earth elevation data represent an average of elevation data for an area centered over the point of interest, and hence are low resolution and do not provide a high degree of accuracy. Though Wallach (2014) acknowledges the inaccuracy associated with using and interpolating the Google Earth™ digital elevation model, the magnitude of this inaccuracy appears underestimated. For example, Wallach (2014) Figure 3 has topographic contours from spot heights interpolated from Google Earth™. In the area immediately to the northwest of the McVagh Quarry, Wallach (2014) shows several circular depressions up to 10 metres deep. Our review of the Land Information Ontario (LIO) 2 m resolution digital elevation model (DEM) for this same area shows that these depressions are located at various points along Shaw's Creek. Shaw's Creek, however, is a continuous channel, not a series of separate depressions. We consider that the spot heights and the 1 m contours interpolated from Google Earth™ by Wallach (2014) are unreliable and unsuited for the level of geomorphic interpretation presented by Wallach (2014).

- Wallach (2014) information in Table 3 used borehole elevation data from the MOECC WWIS database. Similar to the above noted issues associated with UTM coordinate reliability in WWIS data, the well elevation data provided in the WWIS database are often inaccurate and unreliable (note in Table 3 the disproportionate number of data points reported at precise ".00" elevations, which in our opinion misrepresents the real accuracy of the ground surface elevation provided in the WWIS). Appropriate use of the well elevation information requires elevation adjustment of the WWIS elevation based on the application of high-quality DEM data at each well location (as we did for the WWIS data used in the EA assessment presented in Volume III).
- Wallach (2014) Table 4 shows the first two wells with identical coordinates but different lithological descriptions and elevation information for the Carlsbad Formation surface.
- The 8th well listed in Wallach (2014) Table 3 is noted as having a Carlsbad Formation elevation of 55 mASL in the table, but on Wallach (2014) Figure 12 the elevation is shown as 72 mASL.

Following our own review of the data, as a general observation, we do not consider it appropriate to use the lithological descriptions for water wells as a basis for establishing formational contacts encountered along the well bore, given the limited technical capacity of the well drillers in this regard and especially when distinguishing such contacts as that of the Queenston/Carlsbad shale. At best, the descriptions can be used to delineate the bedrock surface and indicate whether or not the well encountered red shale at the bedrock surface. Below the bedrock surface the descriptions were found to be very inconsistent when comparing individual wells in close proximity and not suitable for purposes of geological interpretation (which is the way they were used in preparation of Wallach (2014)).

2.1.3 Geological Interpretation Based on Reliable and Considerable Additional Data

We have completed a detailed review and analysis of the geology that includes the area included by Wallach (2014). Analysis was completed on a regional, local, and site scale. The results are summarized in Volume III of the 2014 Environmental Assessment (EA) of the proposed Capital Region Resource Recovery Centre (CRRRC). Our analysis included, but was not limited to, the following:

- Review of selected geological maps, reports and peer-reviewed publications of the area;
- Delineation of the top-of-bedrock surface using site-specific investigation cored boreholes logged by Golder Associates Ltd., the Ministry of Transportation, and other consultants; WWIS data – screened for inaccuracies as noted above; OOGRSL deep gas exploration well logs; and the deep GSC #2 core hole;
- Interpretation of the bedrock stratigraphy and structure, including delineation of the area underlain by the Queenston Formation Shale as the uppermost bedrock Formation; and,
- Interpretation of the location, extent and vertical separation/displacement of bedrock faults.

Details of the results of the geological studies are included in the aforementioned Volume III document. Key data and interpretations are provided below. Figure numbers in the sections below are those used in the Volume III. The "Site" is the proposed CRRRC site on Boundary Road.

2.1.3.1 Bedrock Surface Topography

Our interpretation of the bedrock surface topography beneath the local study area is shown on Figure 3-5. The interpretation was made from a combined dataset of site-specific investigation boreholes for the CRRRC project and other investigations, MOECC water well information (1,274 data points); and 26 exploration gas wells. The Wallach (2014) study area is inset in Figure 3-5. We found that the bedrock surface has a vertical relief of approximately 90 metres within the local study area. In the southwestern corner of the area where the Oxford Formation dolostone bedrock is at or near surface, bedrock occurs at elevations of approximately 75 mASL to 105 mASL. In the northwestern corner of the local study area where the ground surface is between approximately 65 mASL to 75 mASL, the Carlsbad Formation shale bedrock elevation occurs at approximately 15 mASL to 25 mASL.

Wallach (2014) does not provide bedrock surface contours; rather he presents structure contours for geological formations below the base of the Queenston Formation. Thus, in areas underlain by Queenston Formation as the uppermost bedrock unit (Figure 3-6), it is not possible to compare the top of bedrock map shown on Figure 3-5 to the Wallach (2014) geological interpretation. Where the Queenston Formation is present, however, the top elevation of the Carlsbad Formation (Figure 12) should be below the top-of-bedrock elevation (Figure 3-5). A comparison of the Wallach (2014) Figure 12 and Golder Associates Figure 3-5 indicates major discrepancies. For example, in the area north of the Gloucester Fault Zone and west of Boundary Road (adjacent to the Boundary Road Site), Wallach (2014) interprets the top elevation of the Carlsbad Formation to be significantly higher (60 to 70 mASL) than the top elevation of the bedrock surface in that area (approximately 50 to 55 mASL), and associates this with the presence of a fault. As described in Section 2.1.2.1, this fault was inferred by Dr. Wallach using incorrect water well records from Marionville located some 16 kilometres from the Site.

For the areas north of the Gloucester and Russell-Rigaud fault zones where the Queenston Formation is not present, the top surface of the bedrock (Figure 3-5) should be coincident with the eroded surface of the Carlsbad Formation (Figure 12), not a structural plain. The maps in the Wallach paper and in the EA document are generally in agreement in the areas east of “Cholowski Hill”. Southeast of “Cholowski Hill” and northeast of Russell, Ontario, however, the Wallach (2014) Carlsbad Formation surface elevation is approximately 10 m lower than the bedrock surface elevation presented in the Volume III Report, likely reflecting water well discrepancies as previously discussed.

Section C Letter #2 in Wallach (2015) refers to undulations in the surface of the glacial till and bedrock as shown on a geologic cross-section presented at Open House # 5 in December 2013 and provided as Figure 3-14 in the Volume III Report. Dr. Wallach hypothesizes the reasons for this undulation as either less than rigorous data treatment or the deposition of the till on an uneven bedrock surface. The bedrock surface topography shown on Volume III Figure 3-5 illustrates the irregularities in the shape of the bedrock surface below the Boundary Road Site that are correspondingly reflected in the cross-section. The process by which the glacial till was deposited above the bedrock surface does not result in the till layer being of uniform thickness, as demonstrated by the on-Site drilling program.

2.1.3.2 Local Bedrock Geology

The lateral extent of the uppermost bedrock formations beneath the local study area (Figure 3-6) was interpreted considering the published OGS maps, available site-specific investigation borehole information, and critical review of the OOGSRL and MOECC WWIS (high quality) data. At some locations the OOGSRL data include information considered unrepresentative for the occurrence of Queenston Formation (see Golder, 2014) and, accordingly, only representative data were used in evaluating its extent. The general area underlain by the Queenston Formation, (Figure 3-6), differs from that shown on the published bedrock geology map of the area (OGS Map P.2717 by D.A. Williams, 1985, which is referred to in Section B Comment 1 of Wallach (2015)) and the Sanford GSC map. Our interpretation significantly reduces the extent of the Queenston Formation to the east as supported by the subsurface drilling program at the Russell Quarry site and increases its extent to the west based upon the additional information from boreholes compiled for the EA study including WWIS (high location accuracy) data, OOGSRL data, geotechnical core hole data from previous Golder studies in the area and boreholes drilled as part of the current study. For example, the extension of the Queenston Formation west of Boundary Road as shown on Figure 3-6 is supported by three previously drilled Golder geotechnical boreholes and one OOGSRL gas well (T002451). The extent of the Queenston Formation was also inferred from WWIS data where the well descriptions consistently reported the occurrence of red shale at the bedrock surface as shown colour coded on Figure 3-6. Some outliers of red shale were also reported in the vicinity of the Gloucester Fault where the shale has been preserved as down-dropped fault slivers within the Gloucester Fault zone.

The OGS map interpretation (upon which the Wallach (2014) interpretation is based and which is shown as Figure 1 in Section C Letter #1 of Wallach (2015)) shows the Queenston shale as fault-bounded representing a down-dropped block (graben). Our analysis and interpretation is consistent with the shale occurring as a conformable sequence within a broad synclinal basin (Figure 3-7), where the Queenston shale was deposited on top of the underlying Carlsbad Formation. It is noted that on OGS Map P.2717 the contact between all different bedrock formations was depicted as being along inferred faults, but not because it was known by the author of the map that faults were actually present (especially in the area of the Boundary Road Site where the overburden thickness is greater than 30 metres and factual information available from drilling investigations in this area was very sparse when the map was prepared).

The red shale of the Queenston Formation is locally exposed within the Russell Shale Quarry. Earlier site-specific core drilling in the area around the quarry for the EA study found up to 35 metres of Queenston Formation red shale/mudstone overlying the grey shale and limestone of the Carlsbad Formation. The transition from the Queenston Formation to the Carlsbad Formation shale is marked by a laterally-continuous, fine grained, non-porous limestone with minor shale interbeds that caps the Carlsbad Formation (the Russell formation of Williams, 1991). The limestone caprock varies in thickness from approximately 6.4 metres to 8.3 metres at the Russell Shale Quarry site. A five-metre thick section of the limestone caprock containing about 10% interbedded shale and calcareous shale was also encountered in borehole BH12-2-3 at the southwest end of the CRRRC Boundary Road Site and was identified in the GSC Russell borehole core between 26.82 metres and 34.29 metres directly underlying the Queenston shale. We conclude that this limestone caprock is a continuous stratigraphic horizon associated with the Queenston Formation/Carlsbad Formation contact. The caprock rims (encloses) the synclinal basin reflected by the extent of the Queenston shale. This limestone caprock layer will form a buried escarpment feature of similar height to its thickness facing eastward where it projects the bedrock surface directly east of the Russell Quarry as shown on Figure 5. The presence of this limestone rim to the Queenston Formation basin may be a contributing factor to the preservation of the Queenston shale within this area.

At the Russell Shale Quarry site, structure contours of the Carlsbad limestone caprock/Queenston Formation contact define a gentle synclinal fold as shown on Figure 3-8. The axis of the fold plunges gently westward at approximately 1% to 1.5% with inward sloping north and south limbs at approximately 2% to 3%. This open fold is probably a local fold developed within the overall synclinal structure defined by the Queenston shale sub-crop (the interpreted extent of which is shown on Figure 3-6), as well as the overall structure of the Ottawa Embayment. It is noted that all of the detailed borehole and geophysical testing information on which this interpretation is based is presented in TSD#1 of the EA, and was available to Dr. Wallach during his preparation of Wallach (2015). It appears that this information, which is the highest quality information available on the bedrock underlying “Cholowski Hill”, was not considered by Dr. Wallach and so the opinions in Wallach (2015) are based on information that he had compiled and interpreted in 2013 and earlier.

The data used in the EA study defining the contact between the Queenston and Carlsbad Formations in the Russell Quarry area were not publically available when Wallach (2014) was in preparation. With the benefit of this additional information, the postulated Wallach (2014) Carlsbad Formation surface elevation is not considered valid for the Russell Quarry Area. For example, at BH09-7 (see attached Figure 3-8), the Carlsbad Formation surface elevation is below 50 mASL. BH09-7 is located approximately 100 metres west of the interpreted “North Ridge Fault” shown in Wallach (2014) Figure 12 and in Wallach (2015), which presents a Carlsbad Formation elevation of 59 mASL, approximately 10 m above the projected contact elevation indicated on Figure 3-8.

2.1.3.3 Fault Structures

The major fault structure within the Local Study area is the Gloucester and Russell-Rigaud Fault system. As shown on Figure 3-7, the Gloucester Fault comprises a series of fault planes within a zone approximately 0.75 kilometres wide beneath the community of Russell. The Gloucester and Russell-Rigaud Fault system is a well-documented, normal-slip fault.

North of the Russell-Rigaud Fault system, further structural detail is revealed from the formation contact elevations from the OOGSRL wells. From the cluster of OOGSRL wells immediately northwest of Russell, Ontario, an east-west trending fault or series of sub-parallel faults comprise the Gloucester Fault Zone. Farther north, formation contact dips are generally uniform, and additional faults are not apparent. The bedrock stratigraphy and structure shown on the attached Figure 3-7 to extend northward beneath the CRRRC Site are consistent with available borehole data that do not indicate major, or even discernable, fault displacements. The interpreted faults described in Dix and Jolicoeur (2011) were considered and discussed in Section 3.2.1.3 of Volume III; this published work was neither downplayed nor ignored as suggested in Section C Letter #3 in Wallach (2015). As noted in Volume III of the EA document package, it is acknowledged that faults with small vertical displacement on the scale of several metres to several 10’s of metres could occur within this area, consistent with the general structural conditions of the broader Ottawa area. However, because of the spacing of the borehole records and resolution of stratigraphic elevations, relatively small displacements of this scale are not easily discernible.

Section B Comment 3 of Wallach (2015) describes and presents on Figures 3-1, 3-2 and 3-3 specific linear features (lineaments), describes them as indications of potential faults that should be considered and states that these were ignored in the analysis. This is not the case – Section 9.2 of Volume III of the EA package describes that Golder Associates analysed the topography and aerial imagery of the CRRRC Site, and neither of those revealed the existence of tectonic geomorphic features (and also recognized that it is possible that erosion or other processes may have removed diagnostic surface fault features). Regarding the lineament depicted in Figure 3-1 of Wallach (2015) to the north of Highway 417 at Boundary Road, this linear feature is the edge of the approximate location of the ~10,000 years ago former Mer Bleue paleo-channel, which has been largely infilled by subsequent soil deposition and is now the low overburden scarp that forms the south margin of the broad valley within which Bear Brook Creek is located. Regarding the lineament depicted in Figure 3-3 of Wallach (2015) crossing the Boundary Road Site and described as reflecting a suspected fault, the reason for this 'shadow' on the aerial base map is unknown; however, the detailed 0.5 metre contour interval topographic map prepared from low level aerial photography of the Boundary Road site as part of the EA (and shown for example on Figure 4 of Volume IV of the EA submission) does not show any evidence of a lineament crossing the Boundary Road Site.

Our interpretation of open, gentle folding without major faults beyond those already mapped is significantly different to that presented by Wallach (2014) and in Section B Comments 2 and 3 and Section C Letter #1 of Wallach (2015). By contrast, Wallach (2014) infers two north-south striking faults that he has named the North Russell Fault and the East Ridge Fault. Vertical separations along these inferred faults are shown by Wallach (2014) at more than 25 m in some places. Based on the poor quality water well data records used by Wallach (2014) to interpret these faults (as described previously), and the information presented above, we consider that fault displacements of this scale and at this orientation are inconsistent with current knowledge of the geology of the region north of the Gloucester and Russell-Rigaud Fault system. Dr. Wallach's interpretation of the presence of those two specific faults that he named is inconsistent with the subsurface information available from the borehole investigation on the North Russell Road Site as provided in TSD#1 of the EA documents. Rather, these features are consistent with paleo-shorelines within an area where beach ridges have been mapped by the GSC, as discussed below.

2.1.4 Conclusion of Data Review and Interpretation

In Wallach (2014) and Wallach (2015), the subsurface stratigraphy and structural interpretations are based on unreliable and incorrect subsurface data. Specifically, the MOECC WWIS data have major location inaccuracies and limited reliability of geological description; geological contact elevation data from the OOGSL database are sometimes incorrect; and topography interpolated from Google Earth™ is inadequate and inconsistent. Apparently the available high location accuracy MOECC WWIS data were not relied upon by Wallach (2014) for his interpretations. Neither was the high quality information and the interpretations presented in the EA package considered by Dr. Wallach in the preparation of Wallach (2015), which continues to advance an interpretation put forward by Dr. Wallach as early as 2011 in the absence of this information. We conclude that once these systematic errors associated with the data are eliminated, and other available high quality data are included in the interpretation, the stratigraphic and structural interpretations presented in Wallach (2014) and carried into Wallach (2015) (with the exception of the Gloucester and Russell-Rigaud fault system) are unsupported by the available data.

2.1.5 Geologic Structure

As discussed in Sections 2.1.3.2 and 2.1.3.3 of this report, the bedrock elevation offsets on the Wallach (2014) cross-section C-D on Figure 15 (a west-east oriented cross section across Cholowski Hill a little north of the Russell Quarry) were interpreted in the central portion of the figure based on inappropriately used "code 9" water well data. With this well data removed from the section, no data exists to support the interpreted faults (i.e., the North Russell and East Ridge faults interpreted to exist and named by Dr. Wallach) illustrated on Figure 15 of Wallach (2014) and on Figure 7-2 and Figures 9 and 11 of Section C Letter #1 of Wallach (2015).

The attached Figure 5 provides a west-east cross-section through the Russell Quarry site. It is based on subsurface information from the borehole drilling program conducted by Golder Associates at the quarry site and accurate topographic information. Figure 5 has a low (only 5 times) vertical to horizontal scale exaggeration to better illustrate the very subtle surface topography of Cholowski Hill and surrounding area and the dip (slope) of the bedrock formations. Contrary to Figure 15 in Wallach (2014), the section illustrates the continuous presence of the uppermost Queenston Formation shale across the hill and to the west, as well as the termination of the Queenston Formation approximately 1 km to the east of Eadie Road. It also shows the presence of the Carlsbad limestone caprock encountered at the Queenston – Carlsbad contact and the inferred scarp feature that will occur where the limestone intersects the bedrock surface. The investigations and interpretations of subsurface information do not indicate or require the presence of faulting in the bedrock across the hill.

2.1.6 Evidence for Quaternary Tectonic Uplift

In his detailed analysis of the geomorphology, stratigraphy and subsurface structure of Cholowski Hill and its immediate surroundings, Wallach (2014) argues that the existence of Cholowski Hill and features preserved on it are evidence for tectonic movements that have probably affected this part of Ontario during part or all of the Quaternary Period (last 2.6 million years). His principal arguments for a Quaternary timing for tectonic deformation are:

1) Cholowski Hill comprises easily erodible Paleozoic sediments (Queenston shale) that sit topographically higher than the surrounding landscape. That Cholowski Hill exists following a period of regional continental glacial erosion and burial under the Champlain Sea suggests that it has been tectonically uplifted since the last retreat of glacial ice. Wallach (2014) argues that had Cholowski Hill not been tectonically uplifted, then the easily-eroded Queenston shale would not now form a local topographic high;

2) Subdued north-south trending topographic lineaments on the eastern and western sides of Cholowski Hill are fault scarps. Wallach argues that the fault scarps are the surface expression of bedrock faults, and perhaps underlying basement faults. He indicates that these inferred faults have accumulated displacement during multiple phases of activity, including the most recent phase during the Quaternary Period; and,

3) The fault scarps may be coseismic (formed during an earthquake), and similar in origin to the scarps formed in the 1989 Ungava earthquake (M_S 6.3) in northern Quebec.

Cholowski Hill Topographic High

Wallach (2014) concludes that the top of Cholowski Hill has been subjected to glacial erosion because glacial erratics are found on the top of the hill (Wallach 2014; Figure 6). Wallach (2014) also states that the north-south alignment of the erratics, north-south axis of Cholowski Hill, location within a till plain and the general hill morphology all indicate that Cholowski Hill is probably a roche moutonnee (Wallach 2014). As shown on the attached Figure 5, Cholowski Hill bears little resemblance to a roche moutonnee; rather there is very limited topographic relief in either the ground surface or the bedrock surface. Surface slopes are approximately 0.5% to 1.5% or less. As discussed above, the Queenston shale beneath this area is preserved within a gentle, open synclinal fold with a more erosion-resistive limestone rim at the base of the shale. The entire region was in the past ice-covered as indicated by the presence of erratics and glacial till deposits encountered in test pits and geotechnical boreholes. Ice scouring and erosion resulted in a generally flat surface (low slope angles) on the outcropping shale. Erosion also removed significant portions of the red shale as indicated by the colour and composition of the glacial till overlying and extending south of the shale sub-crop area. The low-relief topography of Cholowski Hill is consistent with the bevelled till plains that occur through this part of the Ottawa Valley. There is no evidence that requires Quaternary tectonic uplift to develop Cholowski Hill. Rather it is only noticeable as a "hill" because of the horizontal level of the surrounding Champlain Sea clay deposits. During the retreat of the Champlain Sea, the Cholowski Hill area became emergent as a low island and shoal area. Linear beach deposits associated with this emergence have been well recognized within this area based on published surficial geology mapping as shown by units 5a and 5b on the attached Figure 3-10. These maps show shallow marine and beach deposits scattered across and along Cholowski Hill.

This topographic rise is illustrated by the photographs in Figures 8a, 8b and 10 in Section C Letter #1 of Wallach (2015), also provided in Wallach (2014). We have not ignored the topographic rise as alleged in Wallach (2015); but as discussed above, there is no tectonic geomorphic evidence to support Dr. Wallach's hypothesis for the traces of the North Russell and East Ridge Faults. The fault traces inferred by Dr. Wallach are discussed further below.

In Part B Comment 4 of Wallach (2015) on Figure 3-4, Dr. Wallach states that the "buried bedrock ridge" described in the EA documents is a "euphemism for fault-bounded, tectonically uplifted Cholowski Hill". The faults described in Wallach (2014 and 2015) have not been observed, only interpreted based on indirect data; similarly, "uplift" (which means a change in vertical elevation) has not been documented or otherwise demonstrated. As discussed above and further below, there is no data to support Dr. Wallach's hypothesis for "fault-bounded" or "tectonically uplifted"; the use in the EA documents of "buried bedrock ridge" is factual, appropriately descriptive and accurate based on available high quality data.

Inferred Fault Scarps

The inferred North Russell and East Ridge faults are defined by Wallach (2014) from the north-south trending, subdued topographic scarps with up to about 3 metres in elevation change. Both scarps are downhill-facing. These inferred fault scarps are on the east and west sides of Cholowski Hill. The inferred fault scarps lack any exposures that reveal displaced bedrock, glacial sediments or the fault slip indicators needed to confirm their tectonic origin or sense(s) of displacement. Wallach (2014) uses his bedrock formation structural contouring and magnetic anomaly interpretations to argue for the presence of other faults within the bedrock units beneath and surrounding Cholowski Hill, although only the inferred North Russell and East Ridge Faults have surface expression and are inferred to indicate probable Quaternary activity. While not stated directly, Wallach (2014) implies that the topographic scarps on either side of Cholowski Hill are the traces of Quaternary-active faults because they offset a local Quaternary landform—the so-called roche moutonnee of Cholowski Hill, which as shown on Figure 5 is a misnomer. As demonstrated above, there is no data to support the presence of these faults hypothesized by Dr. Wallach; topography and inferred morphology (or any surface features) are not a basis on which to document faulting.

North Russell Fault

Wallach (2014) argues that the evidence for probable Quaternary tectonic deformation near the Russell Quarry is the presence of a small linear topographical rise (scarp) along Russell Road in the area of the quarry entrance. As shown on the attached Figure 4, this scarp lies within the area of detailed 0.5 metre topographic contours available for this otherwise very low relief area; the detailed topographic mapping was prepared in 2009 as part of the CRRRC project and is provided on Figure 2.1-2 of TSD#1 of the EA documents.

The linear scarp that defines the "North Russell Fault" is clearly visible from Russell Road. The scarp is shown on the attached Figure 4, and it can be traced for about 400 metres where it has an azimuth of about 350° (north- northwest). The scarp is apparent because of a steepening in slope of about 1.5 m to 3.0 m vertically within the otherwise sub-horizontal (near flat) terrain. The surface slope of the scarp is approximately 10% (2.5 metres to 3.0 metres vertical in 25 to 30 metres distance), while the slope of the surrounding terrain to the west is approximately 1%.

The crest elevation of the scarp feature varies between about 85 m to 87 mASL, while the toe of the scarp occurs at an elevation of about 83 mASL. This break in slope can be traced southward approximately 400 m to the west side of Russell Road as is clearly defined by the contours (Figure 4 attached).

East Ridge Fault

A second eastward-facing scarp mapped by Wallach (2014) and named the “East Ridge Fault” is located north of the Russell Quarry excavation. The scarp can be traced to the area directly southwest of the excavation (attached Figure 4). The toe of the scarp north of the quarry has an elevation of approximately 81.5 to 82.5 mASL with a crest elevation of 84 to 85 mASL. South of the quarry, the scarp becomes a very gentle (2%) slope. The topographic contours indicate that this scarp merges with the western scarp about 600 m southwest of the quarry excavation (Figure 4 attached). The terrain between the eastern and western scarps rises to elevations of 86 to 88 mASL.

Origin of the Scarps that form “Cholowski Hill”

Neither of the scarps extends beyond the slopes of Cholowski Hill, as would otherwise be expected if they were the traces of faults that had been formed during single or multiple earthquakes in the Quaternary Period. Because Cholowski Hill was a local topographic high when the Champlain Sea inundated this part of the Ottawa valley, it would have been a small island and shoal complex during some of that time. It is likely, therefore, that a sea level still-stand during the Champlain Sea retreat resulted in localized scarp erosion and sediment transport along the margins of the easily-erodible, fine-grained glacial till and Queenston Formation shale. We see no reason to attribute these gentle scarp features to any other causes than shoreline erosion, contrary to Dr. Wallach’s conclusion (Wallach 2014) that they are fault-related features. We note that the GSC mapped similar shoreline/beach features within the Cholowski Hill area (as illustrated on the attached Figure 3-10).

The western scarp and an associated clearly defined longshore spit feature at the southern end of the western scarp (North Russell Fault of Wallach (2014)) are consistent with a westward-facing paleo-shoreline formed by a relative sea level at about an 83 mASL elevation. Farther south, there is a distinct north-south orientated narrow feature approximately 120 metres in length and 10 to 15 metres wide occurring at elevations between 81.0 and 82.5 mASL. This topographic feature has a distinct form suggesting its origin as an offshore bar, which would have developed in close association with the sea scarp farther east. Similarly, the eastern scarp is consistent with an eastward-facing paleo-shoreline formed at the same 83 mASL elevation along what was formerly a low island relief between the eastern and western scarps. The geomorphology of these features is consistent with a southward-flowing longshore drift current within a recessional phase of the Champlain Sea, where Cholowski Hill locally became a north-south orientated small island that protruded above the paleo sea level. Considering that the till moraine soil beneath the area is dominantly silt and clay with few gravel clasts, current and wave erosion may have left the former shoreline scarps with minimal beach sands and gravels. These features are illustrated on the attached Figure 4.

Paleo-shorelines and beach deposits associated with topographic erosion features have been well documented within the Russell Quarry area as indicated on the Geological Survey of Canada map by Belanger (2001), and as shown on the attached Figure 3-10 from the Volume III Report. These features were interpreted before maps of the detailed topographic relief of the Russell Quarry site area became available.

Co-seismic Origins

Having interpreted the two Cholowski Hill lineaments as probable Quaternary active faults, Wallach (2014) speculates further that these faults could be the sources of past large and potential future earthquakes. Correctly, he notes that only one co-seismic surface fault rupture is known from historic earthquakes in eastern Canada, although there is ample evidence from eastern North America that large (M > 7) earthquakes have occurred throughout the Holocene Epoch (last 11,700 years). Indeed, Holocene-age earthquakes that have generated surface fault scarps are known from the tectonically stable regions of most major continents other than Antarctica. Based on available evidence, we do not consider that these less than 1 kilometre long, poorly–preserved topographic lineaments are tectonic faults. Rather, as discussed above, we believe the scarps are likely shoreline features associated with the retreat of the Champlain Sea

3.0 PART 2 – SEISMICITY/TECTONICS/LIQUEFACTION POTENTIAL

In Section B comments 4 through 7a and 7b, Wallach (2015) sets out his hypotheses related to:

- The locations and magnitudes of historic earthquakes;
- Earthquake shaking at the CRRRC site associated with the past earthquakes and potential future earthquakes;
- Selection of earthquake acceleration time histories for seismic stability analyses; and,
- Evidence for the presence of surface fault rupture and liquefaction hazards at the proposed CRRRC site.

Historical Earthquakes

Wallach (2015) argues that the historical earthquake record surrounding the site has been "downplayed" and, in particular, that the July 12, 1861 earthquake has been ignored. In developing a project catalog to evaluate the historical earthquake record in the region surrounding the CRRRC site, we relied primarily on the composite Canadian seismicity catalog for eastern Canada (CCSC east) developed by Fereidoni et al. (2012). We consider this catalog to be the most reliable and consistent to evaluate the historical earthquake record because it was developed:

- from a careful evaluation and synthesis of existing historical and instrumental catalogs for Canada and the northern USA;
- with a common moment magnitude (**M**) scale for all earthquake events, and,
- to form the underlying earthquake catalogue for the 2015 revision of the Canadian National Seismic Hazard Model.

The July 12, 1861 earthquake is included in the CCSC east catalog. The epicentre reported for this earthquake is about 7 km northeast of the CRRRC site as shown in Volume III Figure 4-1. The magnitude assigned to this earthquake, however, is **M** 4.7, not the local magnitude (M_L) assigned by Lamontagne (2010). Because the magnitude listed in the CCSC catalog is less than **M** 5, it was not included in Volume III Table 4.1. Furthermore, it is common earthquake engineering practise to focus only on those earthquakes of **M** ≥ 5 because smaller earthquakes result in little or no damage to modern engineered structures. This lower magnitude value is reasonable because the 1861 earthquake reportedly had a "low impact" (ceiling damage and fallen objects) on early to mid-19th century structures (Lamontagne 2010). By modern standards, mid-19th century structures would not be considered to be well engineered. On this basis (low magnitude and low impact), the 1861 earthquake was not ignored; rather it did not warrant further detailed discussion in our analysis.

There are significant uncertainties associated with the estimation of earthquake epicentre locations and magnitudes for pre-instrumental earthquakes. Location estimates for pre-instrumental earthquake epicentres are based on damage reports, and only from the locations where there were sufficient structures to have damage that was both noticed and recorded. While an epicentre location must be assigned for an earthquake catalog, the location errors can range from 10s to 100s of kilometres. Similarly, magnitude estimates are based on felt reports that are used to assign local and moment magnitudes calibrated by relevant instrumental records.

There is no scientific disagreement with Wallach (2015) that the Ottawa-Bonnechere Graben and Western Quebec Seismic Zone are areas of elevated historical earthquake activity compared to many regions of eastern North America. The issue to be considered is whether or not the record of the last 200 years or so is representative of the expected magnitude and location of future earthquakes, and whether shaking from these earthquakes has been appropriately included in the engineering design of the proposed CRRRC. This question is discussed further below.

Design Future Earthquake Shaking

A key issue of concern for Wallach (2015) is whether the shaking associated with historical earthquakes and the anticipated future earthquake shaking has been appropriately considered in the design of the landfill and its containment measures. Unlike buildings that are engineered to provide life safety during future earthquakes by compliance with the 2010 National Building Code of Canada (NBCC), landfills in Ontario are not subject to a prescriptive code or specific guideline. The 2010 NBCC, however, provides guidance as to the level of generally accepted hazard in engineering practice for seismic safety of communities in Ontario and throughout Canada. The 2010 NBCC earthquake design level is for a level of ground shaking that has a 2% probability of being exceeded (98% chance of **not** being exceeded) in the next 50 years, which is the same as the earthquake shaking with a return period of 2,475 years. This earthquake design criterion accepts that there is a probability that the design level can be exceeded in the next 50 years (a 2% chance), but that this is an acceptable level of risk.

In the United States, where there is a Federal (and often State) regulation to govern the design of new landfills, the Code of Federal Regulations (CFR) developed by the US Environmental Protection Agency (EPA) provides minimum national criteria for the design and operation of municipal landfills (40 CFR Chapter 1 Part 258). For seismic design, these criteria require that where the 2,475-year return period earthquake ground motion exceeds 0.10 g, then for new landfill units and lateral expansions of existing landfills, the owner or operator must demonstrate that all containment structures are designed to resist the maximum horizontal acceleration in lithified earth material for the site. Additionally, new landfills and lateral expansions of existing landfills shall not be located within 60 metres of a fault that has had displacement in Holocene time unless the owner or operator demonstrates that an alternative setback distance of less than 60 metres will prevent damage to the structural integrity of the landfill and will be protective of human health and the environment.

In the absence of a specific code or guideline for landfill design in Ontario, we developed a seismic design approach for the CRRRC landfill component that is consistent with the acceptable level of seismic design in Canada for buildings (2010 NBCC) and for landfills in the USA. The USA and Canadian codes and regulations have been developed to recognize that it is impractical to design a building or landfill to resist the worst- or near worst-case earthquake shaking event. Rather, a level of earthquake ground shaking that has a return period of about 2,500 years is an acceptable compromise between designing for an extreme earthquake event, no matter how rare, and designing for a level of life safety and environmental protection acceptable to society.

Because the expected 2,475-year peak horizontal ground accelerations (PGA) at the proposed CRRRC site are greater than 0.10 g (0.24 g and 0.32 g for rock and soil conditions, respectively--Volume III, Appendix Q), the CRRRC design team ensured that the landfill structures and control systems were designed to resist these earthquake accelerations. The site-specific, dynamic seismic stability analyses of the landfill slopes are described in Volume III, Appendix Q and the assessment of the expected performance of the leachate containment and leachate collection system is described in Section 11.3.3 of Volume I and Section 11.4 of Volume III. These analyses demonstrated that the landfill is stable and that the leachate containment and leachate collection system will perform as designed under site-specific earthquake loads that have an expected return period of 2,475-years.

Selection of Earthquake Acceleration Time Histories

The philosophy for the design of Canadian buildings and USA landfills for a 2,475-year return period earthquake ground motion was also the basis used to select earthquake acceleration time histories for the dynamic analysis of landfill stability at the proposed CRRRC. As explained in detail in Volume III, Appendix Q, a systematic approach was taken to select appropriate synthetic acceleration time histories to evaluate landfill stability under the earthquake shaking conditions associated with a 2,475-year return period.

In dynamic analyses that use probabilistically-developed ground motions, it is common to identify the earthquake magnitude-distance pairs that contribute the greatest to the seismic hazard at the site and time period of interest. The best magnitude-distance pair is identified through a process known as “de-aggregation of the site seismic hazard”. The de-aggregation plots for the proposed CRRRC site were obtained from the 2010 NBCC national seismic hazard model for the 2,475-year return at spectral periods of 0.2 second and 1.0 second. The 0.2 second de-aggregation plot indicated that the greatest earthquake hazard source for the CRRRC site is from a mean **M** 6.4 earthquake with an epicentre located about 38 kilometres from the site. For the 1.0 second period, the greatest earthquake hazard comes from a mean magnitude **M** 6.9 with an epicentre located 63 kilometres from the site.

We conservatively selected an **M** 7 earthquake occurring anywhere between 50 and 99 km from the site to represent a wide range of possible earthquake scenarios that could cause the expected strong ground shaking at the CRRRC site. This technical approach is the standard of practice in earthquake engineering when there is a need to select representative earthquake ground motions for earthquake stability analysis. While it is technically possible to have selected an **M** 7 earthquake occurring on the Gloucester and Russell-Rigaud fault for dynamic analysis, the resulting ground motions would have much longer return periods (and lower probability of occurrence) than the 2,475-year design-level earthquake.

The de-aggregation plots also indicate that some degree of site hazard at both 0.2 and 1 second periods is contributed by **M** 5 to **M** 6 earthquakes located at less than about 30 kilometres from the proposed CRRRC site, although they are not the dominant contributors. While these earthquakes are closer, their magnitudes and duration of shaking are less than the **M** 7 earthquakes at 50+ kilometres distance. Empirical evidence also indicates that earthquakes less than about **M** 6 do not result in appreciable damage to well-engineered massive earth structures such as dams, embankments and landfills.

Surface Fault Rupture and Liquefaction

Wallach (2015) suggests that statements in the EA submission package imply that unless a fault breaks through the ground surface, the potential effects from an earthquake would not be as damaging. His allegation is not correct.

As indicated in the USA landfill EPA design criteria, it is necessary to establish that the footprint of the landfill is not located within 60 metres of a known Holocene (last 11,700 years) active fault. While not required by any Canadian regulation or code, Volume III Section 9 of the EA package was developed to evaluate the potential for a Holocene-active surface fault rupture within the proposed CRRRC landfill footprint and up to about 100 metres from the proposed footprint. The evaluation of the presence of surface rupture and its potential effects is site-specific. For the fault rupture hazard evaluation, the existence of Holocene-active faults more than about 100 metres away is not a critical fault rupture hazard to the site. These more distant faults, when they exist, are accounted for in the earthquake shaking model.

The conclusion of the fault rupture analysis in the EA that the potential for future surface fault rupture is negligible is based on the following:

- Early Holocene Champlain Sea horizontal deposits that cover the site and occur within about 100 metres of the site show no tectonic geomorphic evidence that they have been disrupted by surface fault ruptures; and,
- The presumed early Holocene-age thin silty layer at a depth of about 4 to 6 metres below ground surface at the CRRRC site shows no evidence of major vertical offset.

We consider that these data indicate that the site has not been subjected to any surface fault rupture in the last 11,700 years, and that the probability that new fault rupture will occur at the site within the contaminating lifespan of the landfill component of the CRRRC is extremely low.

Lastly, Wallach (2015, p.16) states that “the clay foundation is liquefiable”. Marine clays are not generally liquefiable because they are cohesive and too fine grained to develop sufficient pore pressures during strong shaking. Wallach presents no evidence to the contrary.

4.0 PART 3 – STATE OF STRESS AND POTENTIAL EARTHQUAKE SHAKING

Wallach (2015) sets out a range of observations using the regional tectonic setting, orientation and displacements along faults and fractures within some surface outcrops, the presence and absence of calcite veins and known borehole displacements to argue that these are all indications of the relatively high, near-surface stresses in the region surrounding the site. These observations are not in dispute. In Part B Comment 7c of Wallach (2015) it is stated "There are active tectonic stresses in the area, which means that there are active faults, which account for the earthquakes". The area of the proposed CRRRC project is not different than other places; there is active stress everywhere on the Earth; however, the stress state in the Earth's crust does not automatically lead to active faults. Otherwise there would be active faults everywhere.

There is also clear evidence from similar observations to confirm that the region is subjected to relatively high differential stresses that cause small to moderate earthquakes (strains). Recent modelling by Baird et al. (2010) provides an example of how pre-existing faults—in this case associated with an ancient meteor impact structure superimposed on rift faults—can localize these stresses and reactivate favourably-oriented existing fault structures. Similarly, Ma and Audet (2014) argue that the largest earthquake in almost 80 years to occur within the Ottawa-Bonnechere Graben (**M** 4.7) can reactivate high-angle, unfavorably oriented existing basement and bedrock faults. There is no evidence, however, that any of these faults have ruptured to the ground surface.

Our analysis differs, however, in that we do not consider that these high differential stresses and ongoing small to moderate earthquakes indicate that a large (**M** 7) earthquake generated by the reactivation of bedrock faults is imminent. While it is impossible to rule out that near surface faults in the region including the site will not be reactivated and generate surface rupture and large earthquakes, we have found no evidence from the tectonic geomorphology that this has happened in the recent past (i.e., Holocene). Without this evidence, it is unreasonable to design landfill facilities with a relatively short contaminating lifespan for such an unknown and speculative future event. Instead, we have relied upon the historical record of about the last 200 years that forms the basis of a probabilistic seismic hazard model developed by the GSC for the 2010 NBCC. This model has been used to estimate and design for earthquake ground motions that are unlikely to be exceeded in the next 2,500 years or so. This approach is in general accordance with the approach used to design Canadian buildings to protect lives and for environmental safety of landfills in the USA.

5.0 CONCLUSIONS

As explained in detail in this response, we conclude that Wallach (2014) has developed subsurface stratigraphic and structural geological interpretations in the area of the proposed CRRRC Boundary Road site and on the topographic feature to the east that he named Cholowski Hill based on unreliable and incorrect subsurface data. In addition, we consider that Wallach (2014) has provided insufficient evidence to establish the existence and Quaternary activity of the low scarps he named the North Russell and East Ridge Faults. In our view, it is unsupported speculation that these topographic features represent uplifted land surface due to faults and more particularly, Quaternary-active faults.

We have used a detailed review of reliable and high quality data and examined relevant information to prepare an interpretation of the geological conditions within a 15 by 20 kilometre study area. The interpretation is presented in the EA package for the CRRRC. The high quality information and the interpretations presented in the EA package do not appear to have been fully considered in Wallach (2015), which continues the interpretations put forward by Dr. Wallach as early as 2011 in the absence of this information. We conclude that once Dr. Wallach's systematic errors associated with the data are eliminated, and other available high quality data are included, the interpretation presented in the EA submission package is appropriate. To the contrary, the stratigraphic and structural interpretations presented in Wallach (2014) and carried into Wallach (2015) (with the exception of the well-known and documented Gloucester and Russell-Rigaud fault system) are unsupported by the available data.

In the EA document, it was not considered appropriate or necessary to include an interpretation to explain the origin and presence of the so-named Cholowski Hill. However, this topic is central to the interpretation presented in Wallach (2014), and also in Wallach (2015) that is highly critical of the interpretations presented in the EA document. As such, in this response we have provided an alternative, and in our view more appropriate interpretation based on reliable subsurface records and geomorphic analysis that suggests these two north-south trending low scarps and Cholowski Hill have an erosional origin. The simpler, non-tectonic origin suggests that these features were developed during a recessional sea level still-stand of the Champlain Sea in latest Pleistocene-early Holocene time. The marine origin is consistent with observations of marine erosional and construction landforms in the Russell area, and with a bedrock structural geology model supported by observations of major east-west striking normal faults and gentle, open folding away from faults.

The seismic analysis for the CRRRC landfill footprint considered the historic record of earthquakes in southeastern Canada, potential effects of surface fault rupture, strong earthquake shaking and potential liquefaction of the clay deposit that underlies the CRRRC site. Interpretation of subsurface soil layers, particularly a single, less than 1 m thick silty layer encountered beneath the proposed landfill footprint found no evidence that the clay deposit has been offset by Holocene-active faults or subjected to liquefaction. The potential effects of future strong earthquake shaking on the proposed CRRRC landfill component was considered for a 2,475-year return period – the return period used in the assessment of earthquake life safety for buildings in Canada and environmental protection for landfills in the US. We considered a conservatively selected range of possible earthquake shaking scenarios to assess landfill slope stability and a design approach that represents the standard of practice in earthquake engineering design throughout North America.

Contrary to the statement in Section 4 of Wallach (2015), the Golder Associates' team and its independent experts have no doubt about the suitability of the Boundary Road Site for the proposed CRRRC from a geologic and seismic perspective.

GOLDER ASSOCIATES LTD.

Paul Smolkin, P.Eng.
Principal

PAS/RB/AH/LG/md

Prepared by:

P. Smolkin, P.Eng., Principal, Golder Associates Ltd.- Canada

R. Blair, M.Sc., P.Geo., Senior Geologist, Golder Associates Ltd.- Canada

A. Hull, Ph.D., C.E.G., Seismic Hazard Practice Leader, Golder Associates Inc. (United States)

Reviewed by:

Professor L. Godin, Ph.D., Professor of Structural Geology and Tectonics (Independent Advisor)

6.0 REFERENCES

Baird, A.; McKinnon, S., Godin, L., 2010. Relationship between structures, stress and seismicity in the Charlevoix seismic zone revealed by 3-D geomechanical models: Implications for the seismotectonics of continental interiors. Journal of Geophysical research 115, B11402, doi: 10.1029/2010JB007521,2010.

Belanger, J.R., Urban Geology of the National Capital Area. Geological Survey of Canada, Open File D3256.

Dix, G.R., and Jolicoeur, C., 2011. Tectonostratigraphic Framework of Upper Ordovician Source Rocks, Ottawa Embayment (Eastern Ontario). Bulletin of Canadian Petroleum Geology, Vol. 59, NO. 1, March 2011, P. 7-26.

Ma, S., Audet, P. 2014: The 5.2 magnitude earthquake near Ladysmith, Quebec 17 May 2013: implications for the seismotectonics of the Ottawa-Bonnechere Graben. Canadian Journal of Earth Sciences 51, p. 439-451.

Ministry of the Environment (MOECC). (2013). Water Well Information System (WWIS). http://www.ene.gov.on.ca/environment/en/mapping/wells/index.htm (Accessed June 10, 2013).

Ministry of Natural Resources and Forestry, Oil, Gas and Salt Resource Library.

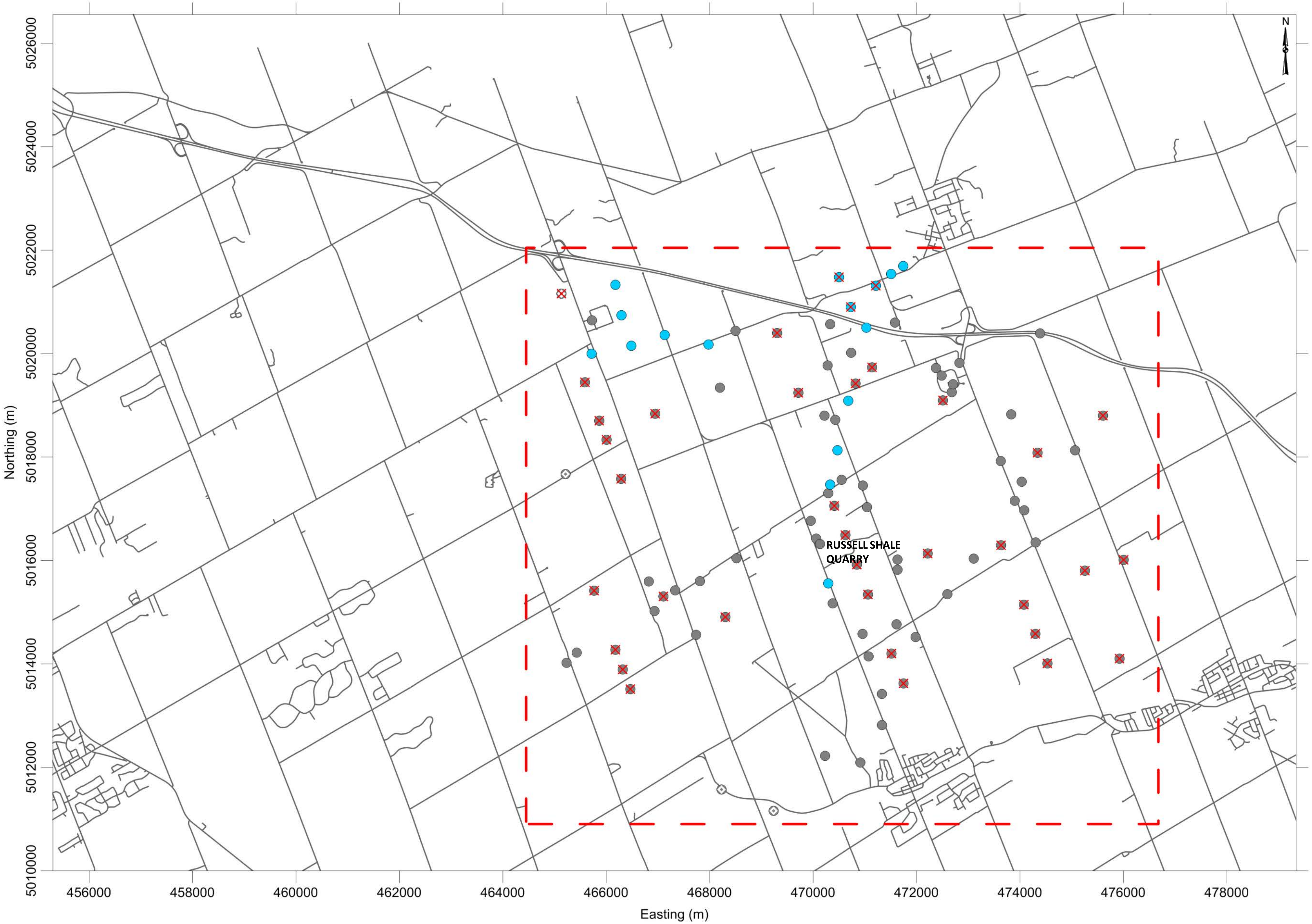
Ontario Geological Survey, 1985. Paleozoic Geology Russell-Thurso Area, Map P.2717, scale 1:50,000.

Sanford, B. V. and Arnott, R. W. C., 2010. Stratigraphic and structural framework of the Potsdam Group in eastern Ontario, western Quebec, and northern New York State, Geological Survey of Canada Bulletin 597.

Taggart Miller Environmental Services. 2014. Environmental Assessment of the Proposed Capital Region Resource Recovery Centre. December 2014.

Wallach, J.L. (2014). A Low-relief Hill in Eastern Ontario, Canada, Covered by the Easily Erodible Queenston Formation and Derived Sediments - Probably the Result of Quaternary Tectonic Uplift. Canadian Journal of Earth Sciences. 51. p. 862–876.

Williams, D.A., 1991. Paleozoic Geology of the Ottawa-St. Lawrence Lowland, Southern Ontario; Ontario Geological Survey, Open File Report 5770, 292p.



LEGEND

LOCATION OF MOECC WWIS DATA POINTS USED IN WALLACH (2014)

- ALL DATA
- DATA ONLY INCLUDED IN FIGURES
- DATA ONLY INCLUDED IN TABLE 3
- DATA WITH LOCATION CODE ACCURACY = "9"
- BOUNDARY OF WALLACH (2014) STUDY AREA
- ROADS

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

CLIENT

TAGGART MILLER ENVIRONMENTAL SERVICES

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

CONSULTANT

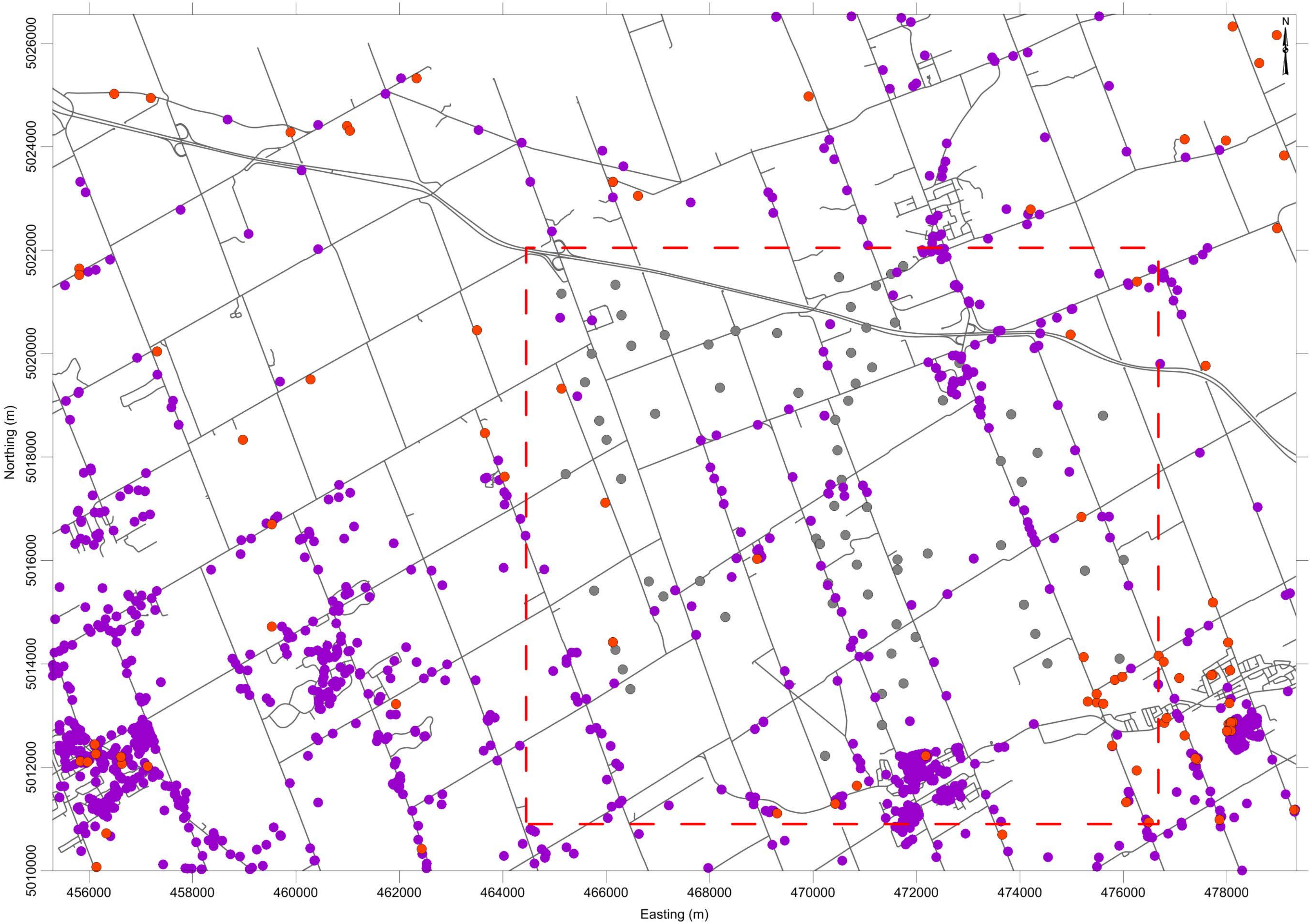
Golder Associates

YYYY-MM-DD	2015-03-16
PREPARED	NFB
DESIGN	NFB
REVIEW	PS
APPROVED	PS

TITLE

LOCATION OF MOECC WWIS DATA USED IN WALLACH (2014)

PROJECT No.	Phase	Rev.	FIGURE
12-1125-0045	13000	0	1



LEGEND

- DATA USED IN WALLACH (2014)
- MOECC WWIS DATA WITH BEDROCK, LOCATION ACCURACY CODE <5
- MOECC WWIS "LESS-THAN" DATA (HOLE DID NOT REACH BEDROCK)
- BOUNDARY OF WALLACH (2014) STUDY AREA
- ROADS

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

CLIENT
TAGGART MILLER ENVIRONMENTAL SERVICES

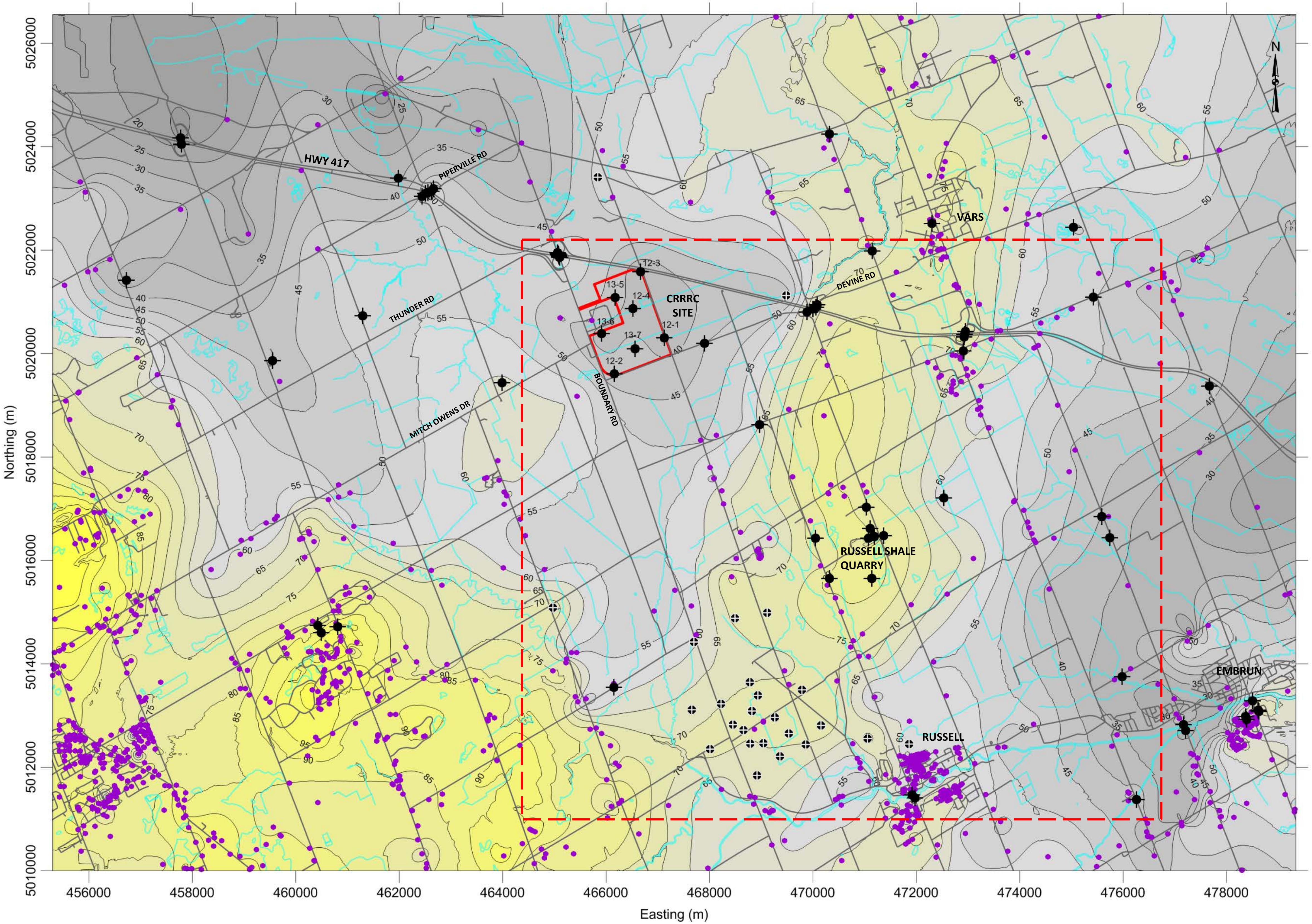
PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-16
PREPARED	NFB
DESIGN	NFB
REVIEW	PS
APPROVED	PS

TITLE
LOCATION OF AVAILABLE MOECC WWIS DATA WITH HIGH LOCATION ACCURACY

PROJECT No.	Phase	Rev.	FIGURE
12-1125-0045	13000	0	2



LEGEND

- CORED BOREHOLE LOCATION
- WATER WELL LOCATION
- OIL AND GAS EXPLORATION WELL LOCATION
- WATERBODIES
- ROADS
- PROPERTY BOUNDARY
- BOUNDARY OF WALLACH STUDY AREA

BEDROCK SURFACE COLOUR SCALE
(mASL)

105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5

1000 0 1000
METRES
SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
ELEVATION CONTOUR INTERVAL = 5m
CONTOUR DATUM IS mASL

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010)

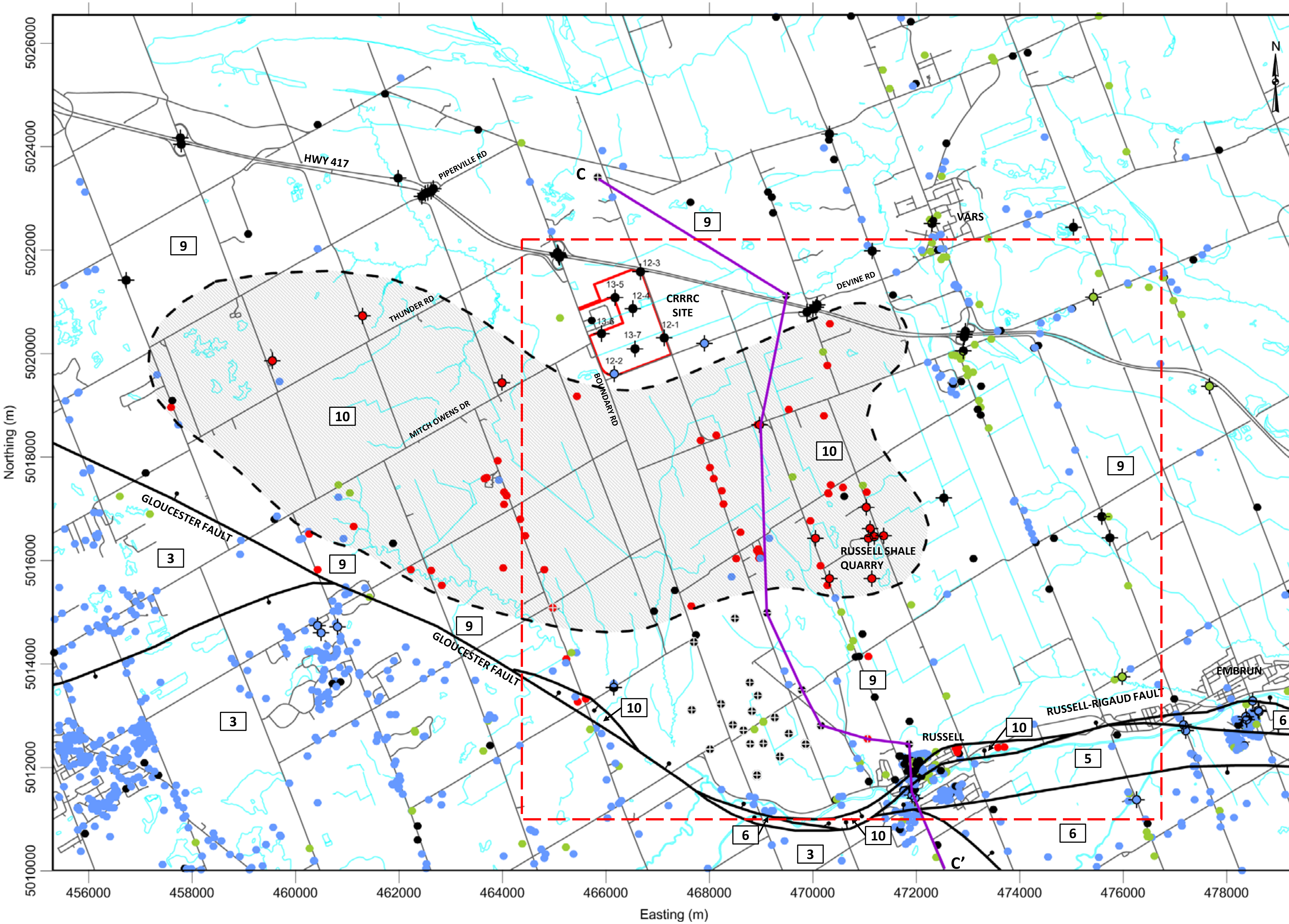
PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
LOCAL BEDROCK SURFACE ELEVATION MAP

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 3-5	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Golder Associates
Ottawa, Ontario

N:\Active\2012\1125 - Environmental and Civil Engineering\12-1125-0045 CRRRC EA Eastern ON\Phase 4000_EA_Documentation\Vol 3 - G H&G\Geology Figures\ppt



LEGEND

UPPERMOST BEDROCK FORMATION DESCRIPTION:

- RED BEDROCK (ALL FORMATIONS)
- GREY OR BLACK SHALE
- LIMESTONE (ALL COLOURS)
- OTHER DESCRIPTIONS

- WATERBODIES
- ROADS
- INTERPRETED FAULT – DOWNTHROWN SIDE INDICATED BY STICK AND BALL
- STRATIGRAPHIC CONTACT
- INTERPRETED EXTENT OF QUEENSTON FORMATION
- PROPERTY BOUNDARY
- CORED BOREHOLE LOCATION
- WATER WELL LOCATION
- OIL AND GAS EXPLORATION WELL LOCATION
- CROSS-SECTION C-C' (FIGURE 3-7)
- BOUNDARY OF WALLACH STUDY AREA

STRATIGRAPHY

- 10 QUEENSTON FORMATION – RED SHALE AND MUDSTONE
- 9 CARLSBAD/BILLINGS FORMATION – DARK GREY SHALE, MINOR LIMESTONE
- 6 BOBCAYGEON FORMATION – BROWNISH GREY CRYSTALLINE LIMESTONE
- 5 GULL RIVER FORMATION – LIGHT GREY VERY FINE GRAINED LIMESTONE
- 3 OXFORD/MARCH FORMATION – GREY DOLOSTONE

1000 0 1000

METRES

SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010)

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

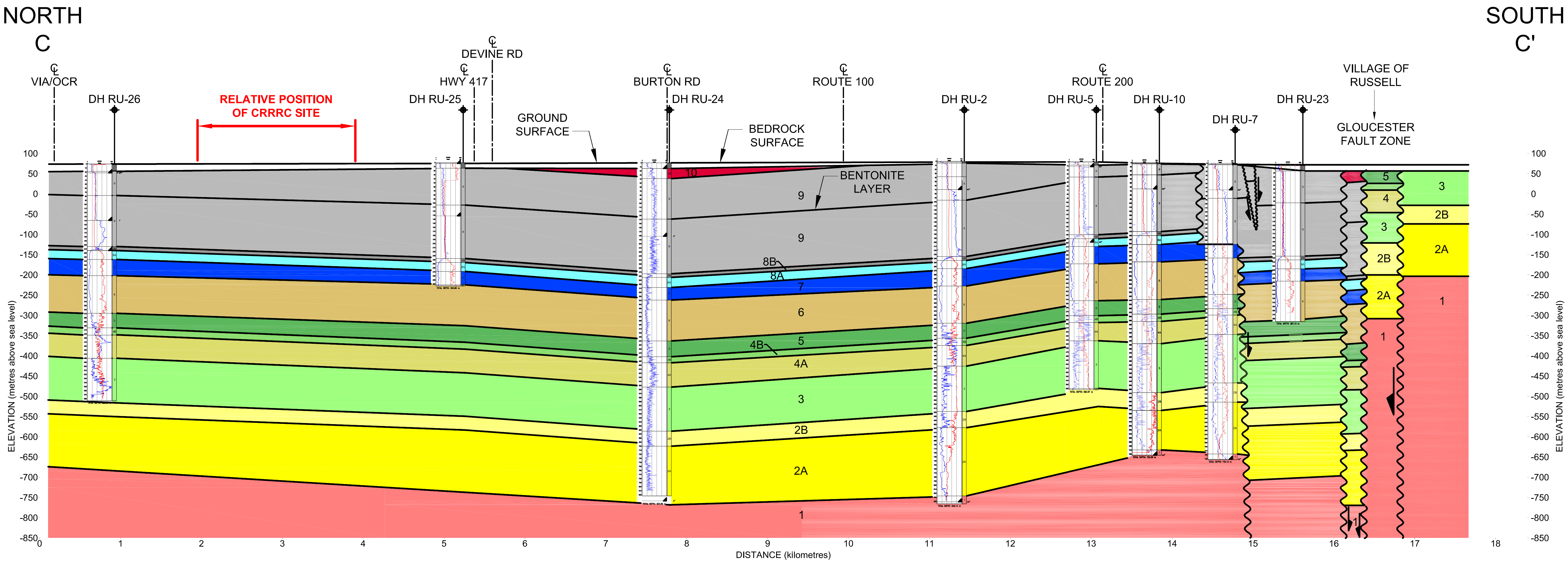
TITLE

INTERPRETED LOCAL BEDROCK GEOLOGY MAP

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013		
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

FIGURE 3-6



BOREHOLE GEOPHYSICAL RECORDS

NATURAL GAMMA LOG

NEUTRON LOG

DEPTH OF DRILL CASING

HORIZONTAL

1600 0 1600 3200

SCALE 1:50000 METRES

VERTICAL

320 0 320 640

SCALE 1:10000 METRES

NOTE:
VERTICAL SCALE EXAGGERATED 5 TIMES THE HORIZONTAL SCALE FOR PRESENTATION PURPOSES

BEDROCK GEOLOGY

10 QUEENSTON FORMATION

Dark reddish brown calcareous mudstone with interbeds of greenish grey siltstone and mudstone.

9 CARLSBAD/BILLINGS FORMATIONS

Dark grey shale interbedded with micritic limestone interbeds (Carlsbad Fm) grading down to dark grey to dark brownish black bituminous shale with minor laminations to very thin interbeds of calcareous siltstone and dolomitic limestone (Billings Fm).

8B UPPER LINDSAY FORMATION (EASTVIEW MEMBER)

Interbedded dark brownish black bituminous shale and dark brownish grey nodular micritic limestone.

8A LOWER LINDSAY FORMATION

Medium to dark brownish grey thickly bedded micritic to calcarenitic nodular limestone.

7 VERULAM FORMATION

Medium brownish grey thinly to medium bedded shaley calcarenitic limestone with interbeds of nodular limestone, minor thin lithoclastic calcarenite limestone beds and numerous dark grey to black very thin to thinly interbeds shale.

6 BOBCAYGEON FORMATION

Light to medium brownish grey, medium to thickly bedded calcarenitic limestone and interbedded units of argillaceous nodular limestone and shaley limestone.

5 GULL RIVER FORMATION

Medium grey, micritic to lithographic limestone, argillaceous to calcareous dolostone and medium to very thickly bedded dolostone, minor interbedded black shale, shaley dolostone, dolomitic siltstone and partly bioturbated quartz sandstone.

4B UPPER ROCKCLIFFE FORMATION

Interbedded sequence composed of medium to thick beds of dolostone and calcareous dolostone, dark grey to black shale, medium grey, argillaceous limestone, minor light grey, calcareous cemented quartz sandstone.

4A LOWER ROCKCLIFFE FORMATION

Light whitish grey, laminar textured to rippled and cross bedded, thin to thick bedded silica cemented quartz sandstone, minor interbeds of shale.

3 OXFORD/MARCH FORMATIONS

Fine grained, micritic dolostone, calcareous dolostone, argillaceous nodular dolostone, subordinate beds lithoclastic dolostone, dark grey to black shale laminations in upper half (Oxford Fm), grading down to sandy dolostone to dolomitic sandstone and carbonate cemented quartz sandstone.

2 NEPEAN FORMATION

Light grey, laminar to cross bedded, silica cemented quartz sandstone. Includes widely spaced interbeds of grey shale and shaley siltstone with individual beds of quartz pebbles and cobbles set in a coarse grained quartz sandstone matrix. 2A Golder pick for top contact of Nepean Fm marking transition into silica sandstone sequence, 2B MNR Well Card pick for top of Nepean Fm (possible dolomitic sandstone of March Fm). Includes un-subdivided Covey Hill Fm sandstone and conglomerate at base if present.

1 PRECAMBRIAN BASEMENT

Quartz feldspar biotite gneiss or dolomitic marble typically weathered near the unconformable surface with either the overlying Covey Hill Formation quartz pebble cobble conglomerate or the Nepean Formation sandstone.

LEGEND

✦ BOREHOLE LOCATION

NOTES

1. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
2. FOR LOCATION OF SECTION C-C' SEE FIGURE 3-6
3. FOR DETAILS OF BOREHOLE GEOPHYSICAL RECORDS SEE FIGURES A1 to A3 IN APPENDIX A

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

LOCAL STRUCTURAL GEOLOGIC CROSS-SECTION C-C'

Golder Associates
Ottawa, Ontario, Canada

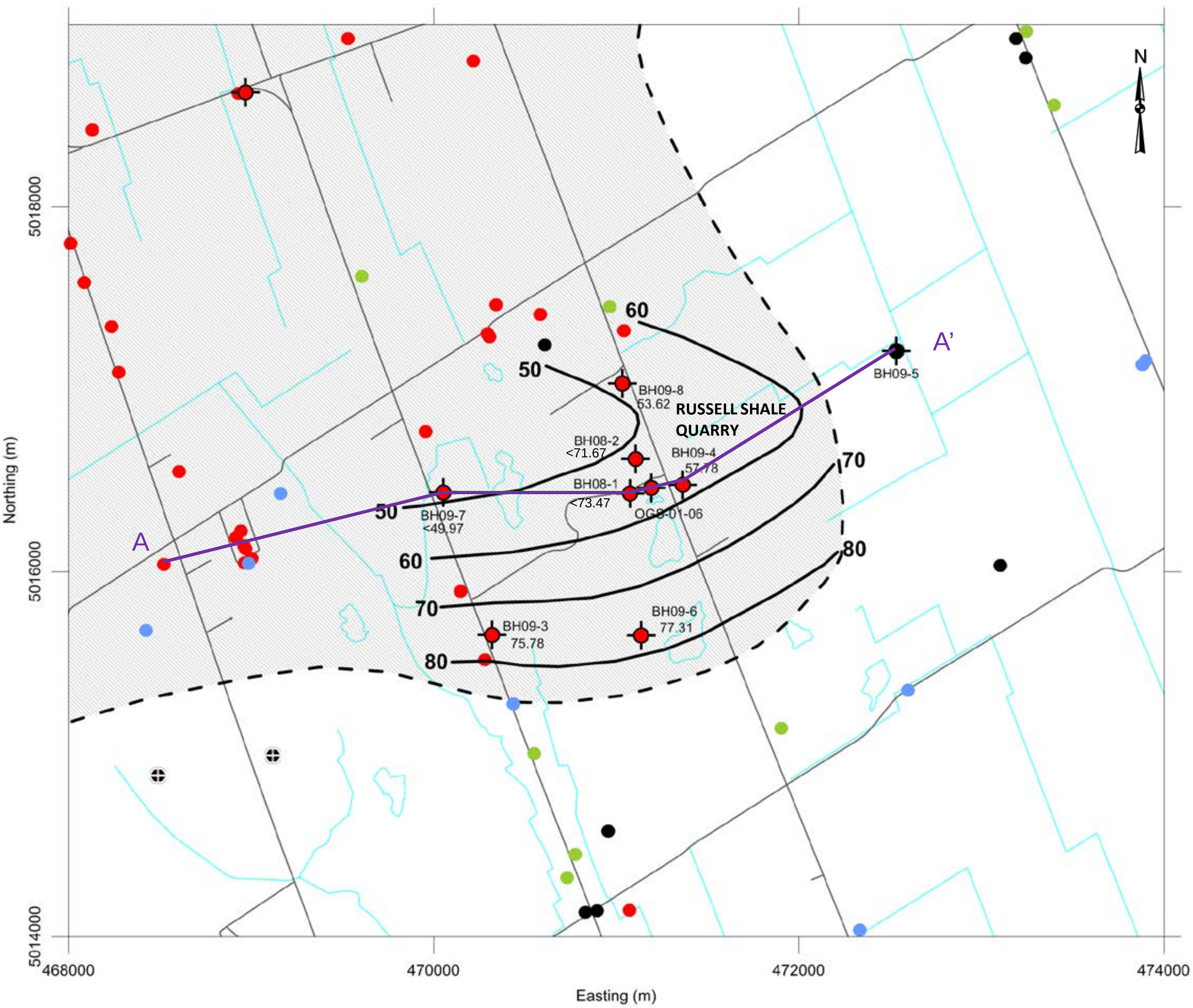
PROJECT No.		12-1125-0045
DESIGN	JPAO	Sept. 2013
CAD	JM/JFC	Feb. 2014
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-3-7.dwg

SCALE AS SHOWN REV.

FIGURE 3-7

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-3-7.dwg



LEGEND

UPPERMOST BEDROCK FORMATION DESCRIPTION:

- RED BEDROCK (ALL FORMATIONS)
- GREY OR BLACK SHALE
- LIMESTONE (ALL COLOURS)
- OTHER DESCRIPTIONS
- WATERBODIES
- ROADS
- BH09-3 75.78 — BOREHOLE LOCATION AND ELEVATION OF QUEENSTON-CARLSBAD CONTACT (mASL) AT RUSSELL QUARRY
- SECTION A-A' (SEE FIGURE 5)

- STRATIGRAPHIC CONTACT
- INTERPRETED EXTENT OF QUEENSTON FORMATION
- PROPERTY BOUNDARY
- CORED BOREHOLE LOCATION
- WATER WELL LOCATION
- OIL AND GAS EXPLORATION WELL LOCATION
- INTERPRETED CONTOUR OF QUEENSTON-CARLSBAD CONTACT (mASL)

500 0 500

METRES

SCALE 1:17,000 (APPROX.)

NOTES

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING REPORT
THE LOCATION OF OGS-01-06 IS SUSPECT AND THERE IS NO ELEVATION DATA AVAILABLE FOR THIS BOREHOLE

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

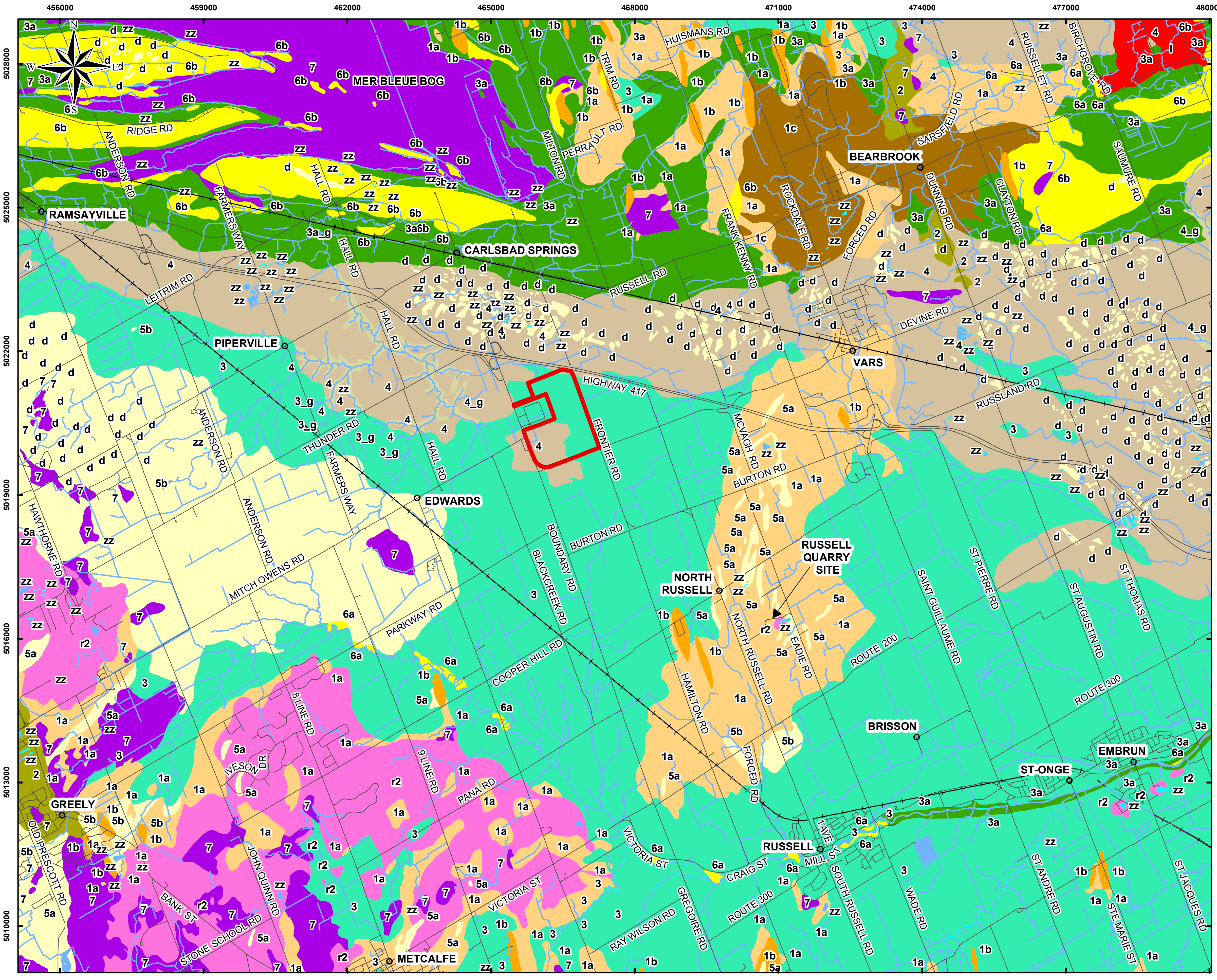
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

ELEVATION OF QUEENSTON FORMATION BASAL CONTACT AT RUSSELL QUARRY

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	NB	16 JAN. 2014	SCALE AS SHOWN	REV.0
GIS	--	--	FIGURE 3-8	
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		



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)

2,000 1,000 0 2,000

SCALE 1:80,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

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

CAPITAL REGION RESOURCE RECOVERY CENTRE

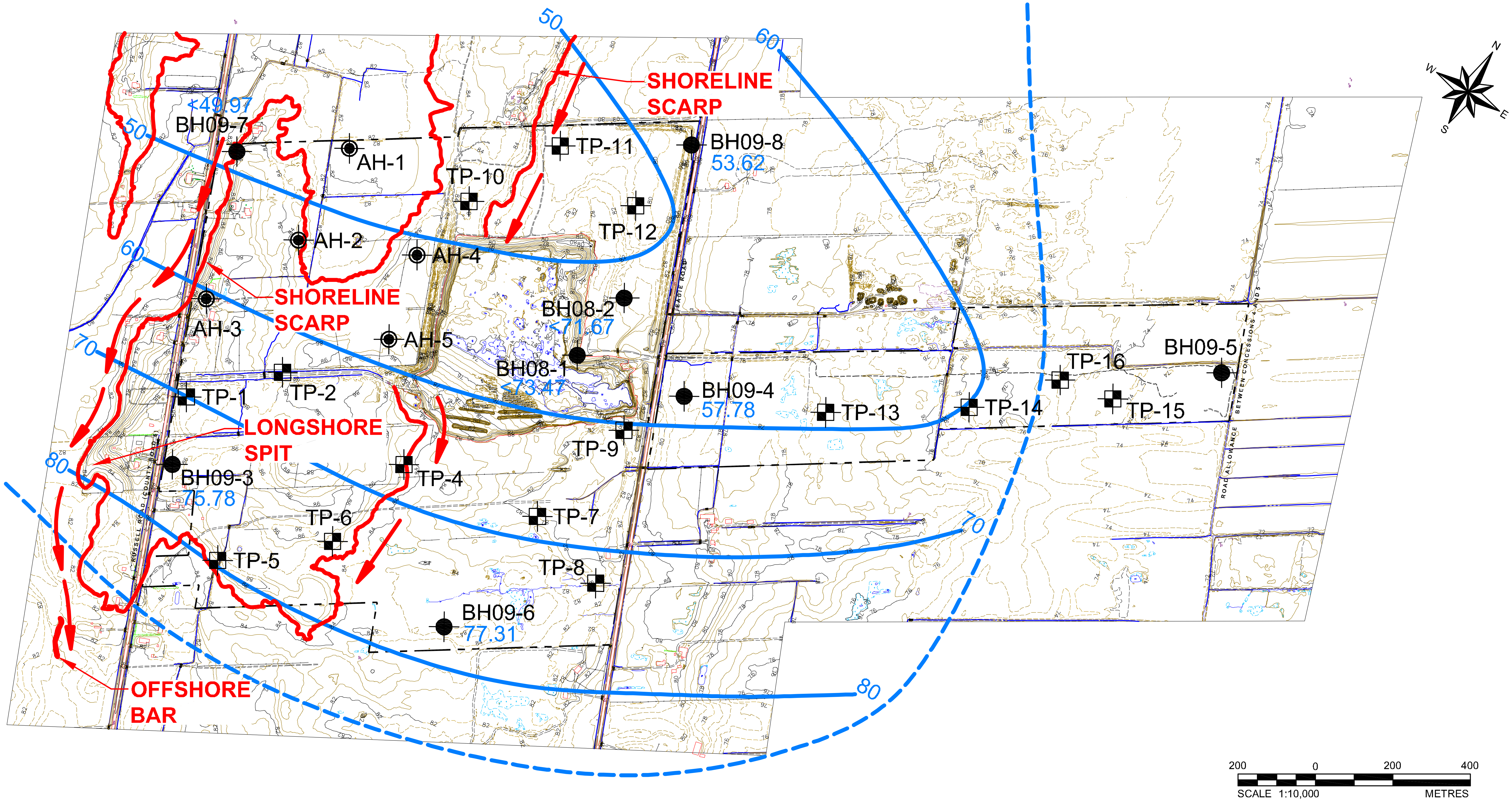
TITLE

LOCAL SURFICIAL GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	DEC. 2013		
GIS	BR/PM	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

FIGURE 3-10



LEGEND

— - — -	LIMITS OF PROPERTY OWNED OR OPTIONED BY 2122063 ONTARIO INC.
	SURFACE WATER FEATURE
	LONGSHORE CURRENT DIRECTION
	CORED BOREHOLE LOCATION
57.78	QUEENSTON-CARLSBAD CONTACT ELEVATION(mASL)
	INTERPRETED QUEENSTON - CARLSBAD CONTACT ELEVATION CONTOUR (mASL)
	INTERPRETED EXTENT OF QUEENSTON FORMATION

REFERENCES

1. THE PROPERTY LINES PROVIDED BY STANTEC GEOMATICS LTD. FOR PART OF LOTS 17, 18, & 19, CONCESSION 3 FROM JOB No. 16169900-100, DATED JANUARY 31, 2008.
2. BASE DRAWING PROVIDED IN A DIGITAL FORMAT BY: BASE MAPPING CO. LTD., CONTRACT No. 2250-08, PHOTO DATE: NOVEMBER 2 2009.
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: MTM ZONE 9

NOTE

1. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

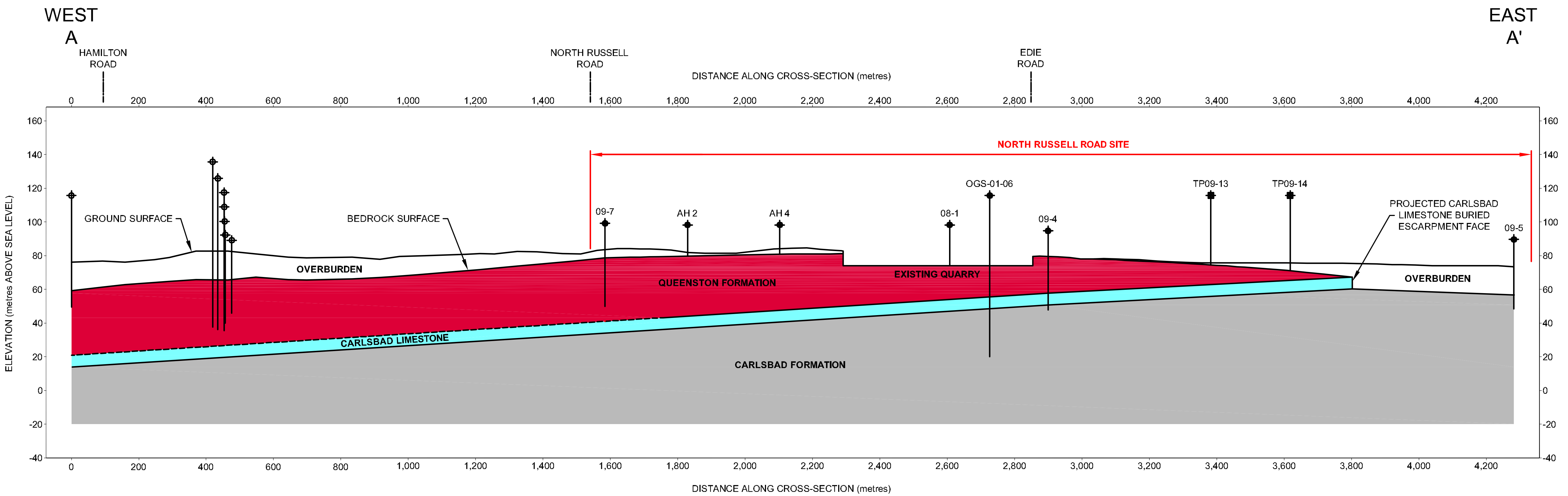
TITLE

INTERPRETED CHAMPLAIN SEA RECESSIONAL SHORELINES RUSSELL QUARRY AREA

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045	FILE No.1211250045-13000-04.dwg	
DESIGN	RB/NFB	Mar. 2015	SCALE AS SHOWN	REV. 0
CAD	MLF/JM	Mar. 2015	FIGURE No.	
CHECK	PAS	Mar. 2015	4	
REVIEW	PAS	Mar. 2015		

PLOT DATE: March 20, 2015
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase13000\1211250045-13000-04.dwg



HORIZONTAL

250 0 250

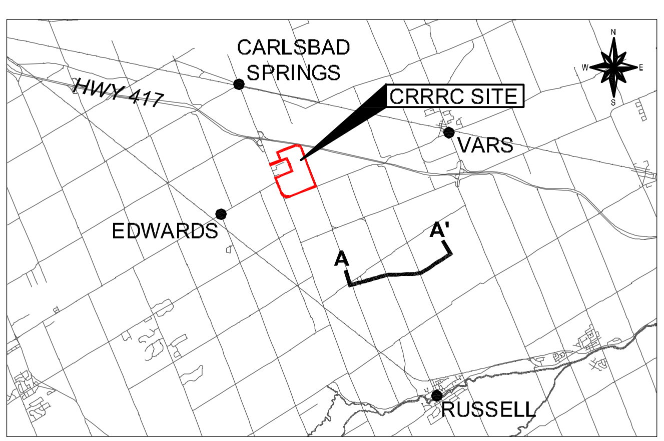
SCALE 1:12,500 METRES

VERTICAL

50 0 50

SCALE 1:2500 METRES

NOTE:
VERTICAL SCALE EXAGGERATED 5 TIMES THE HORIZONTAL SCALE FOR PRESENTATION PURPOSES



KEY MAP
1:300,000

LEGEND

- BOREHOLE LOCATION
- TEST PIT LOCATION
- MINISTRY OF THE ENVIRONMENT AND CLIMATE CHANGE WATER WELL RECORD LOCATION

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

LOCAL GEOLOGIC CROSS-SECTION A-A'

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.	12-1125-0045	FILE No.	1211250045-13000-05.dwg
DESIGN	NFB	Mar. 2015	SCALE AS SHOWN REV.
CAD	JM	Mar. 2015	
CHECK	RB	Mar. 2015	FIGURE 5
REVIEW	PAS	Mar. 2015	

PLOT DATE: March 20, 2015
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase13000\1211250045-13000-05.dwg

APPENDIX A

MOECC Water Well Records

Ministry of the Environment
Ontario

The Ontario Water Resources Act
WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11 | 1524478 | MUNICIP 15009 | CON. CON 11

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON., BLOCK, TRACT, SURVEY, ETC.	LOT 25-27
[redacted]	woods	11	pt 3-4

Marionville Ont.

DATE COMPLETED 48-53: DAY 14 MO March YR 90

RC | ELEVATION | RC | BASIN CODE

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Brown	clay	stone		0	5
Brown	hard pan	clay stone		5	9
grey	limestone		hard	9	60

31

32

41 WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
58	1 ☑ FRESH 2 ☐ SALTY 3 ☐ SULPHUR 4 ☐ MINERALS 6 ☐ GAS
	1 ☐ FRESH 2 ☐ SALTY 3 ☐ SULPHUR 4 ☐ MINERALS 6 ☐ GAS
	1 ☐ FRESH 2 ☐ SALTY 3 ☐ SULPHUR 4 ☐ MINERALS 6 ☐ GAS
	1 ☐ FRESH 2 ☐ SALTY 3 ☐ SULPHUR 4 ☐ MINERALS 6 ☐ GAS
	1 ☐ FRESH 2 ☐ SALTY 3 ☐ SULPHUR 4 ☐ MINERALS 6 ☐ GAS

51 CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6 1/4	1 ☑ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE 5 ☐ PLASTIC	188	0	20
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE 5 ☐ PLASTIC			
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE 5 ☐ PLASTIC			

SCREEN

SIZE(S) OF OPENING (SLOT NO.) | DIAMETER INCHES | LENGTH FEET
MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
0	20	grout

71 PUMPING TEST

PUMPING TEST METHOD: 1 ☐ PUMP 2 ☐ BAILER
PUMPING RATE: 30 GPM
DURATION OF PUMPING: HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
25 FEET	40 FEET	30 FEET	35 FEET	40 FEET	40 FEET

WATER LEVELS DURING: 1 ☐ PUMPING 2 ☐ RECOVERY

IF FLOWING, GIVE RATE: GPM
PUMP INTAKE SET AT: 60 FEET
WATER AT END OF TEST: 1 ☐ CLEAR 2 ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☑ DEEP
RECOMMENDED PUMP SETTING: 50 FEET
RECOMMENDED PUMPING RATE: 15 GPM

FINAL STATUS OF WELL

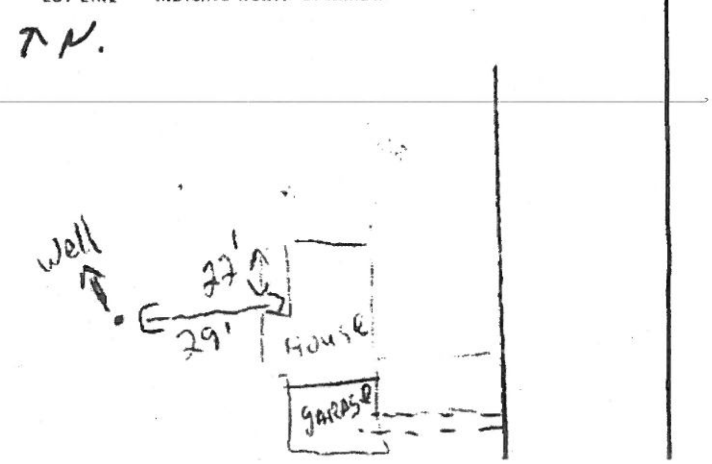
1 ☑ WATER SUPPLY
2 ☐ OBSERVATION WELL
3 ☐ TEST HOLE
4 ☐ RECHARGE WELL
5 ☐ ABANDONED, INSUFFICIENT SUPPLY
6 ☐ ABANDONED, POOR QUALITY
7 ☐ UNFINISHED
☐ DEWATERING

WATER USE

1 ☑ DOMESTIC
2 ☐ STOCK
3 ☐ IRRIGATION
4 ☐ INDUSTRIAL
☐ OTHER
5 ☐ COMMERCIAL
6 ☐ MUNICIPAL
7 ☐ PUBLIC SUPPLY
8 ☐ COOLING OR AIR CONDITIONING
9 ☐ NOT USED

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW



BH ID
103 75744

Ministry of the Environment
Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11 | 5603177 | MUNICIP. 15009 | CON. CON

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON, BLOCK, TRACT, SURVEY, ETC.	LOT
[redacted]	Russell	Plan M-34	4

[redacted] Marionville Ont.

DATE COMPLETED: DAY 28 MO 6 YR 84

[redacted] NORTHING | RC | ELEVATION | RC | BASIN CODE | II | III | IV

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
Brown	Hardpan	Boulders	Hard	0	2
Grey	limestone		Hard	2	35

31

32

41 WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
32	1 ☑ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

51 CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6 1/4"	1 ☑ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.188	0	20
6"	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☑ OPEN HOLE		20	35
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.) | DIAMETER INCHES | LENGTH FEET
MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
0	20'	Cement grout

71 PUMPING TEST

PUMPING TEST METHOD: 1 ☐ PUMP 2 ☑ BAILER	PUMPING RATE: 10 GPM	DURATION OF PUMPING: 1 HOURS 0 MINS		
STATIC LEVEL: 6 FEET	WATER LEVEL END OF PUMPING: FEET	WATER LEVELS DURING: 1 ☑ PUMPING 2 ☐ RECOVERY		
	15 MINUTES: 15 FEET	30 MINUTES: 15 FEET	45 MINUTES: 15 FEET	60 MINUTES: 15 FEET
IF FLOWING, GIVE RATE: GPM	PUMP INTAKE SET AT: 35 FEET	WATER AT END OF TEST: 1 ☑ CLEAR 2 ☐ CLOUDY		
RECOMMENDED PUMP TYPE: ☑ SHALLOW ☐ DEEP	RECOMMENDED PUMP SETTING: 20 FEET	RECOMMENDED PUMPING RATE: 10 GPM		

FINAL STATUS OF WELL

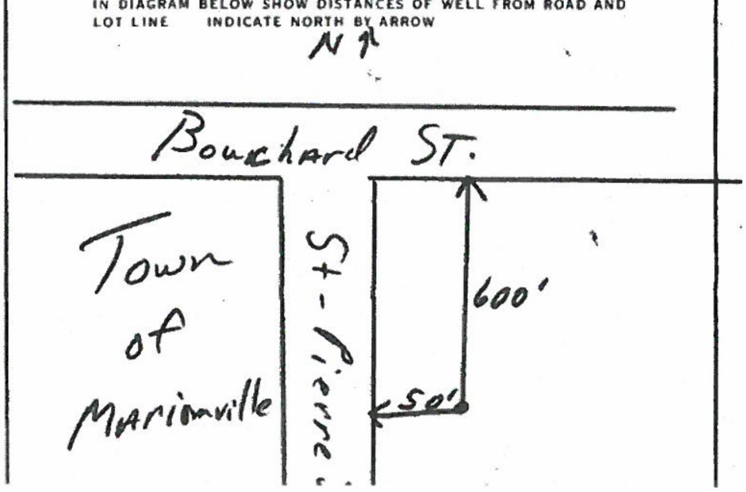
1 ☑ WATER SUPPLY
2 ☐ OBSERVATION WELL
3 ☐ TEST HOLE
4 ☐ RECHARGE WELL
5 ☐ ABANDONED, INSUFFICIENT SUPPLY
6 ☐ ABANDONED, POOR QUALITY
7 ☐ UNFINISHED

WATER USE

1 ☑ DOMESTIC
2 ☐ STOCK
3 ☐ IRRIGATION
4 ☐ INDUSTRIAL
☐ OTHER
5 ☐ COMMERCIAL
6 ☐ MUNICIPAL
7 ☐ PUBLIC SUPPLY
8 ☐ COOLING OR AIR CONDITIONING
9 ☐ NOT USED

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW



BH ID 10375745

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11 | 5603178 | MUNICIP. 15009 | CON. CON 11

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON, BLOCK, TRACT, SURVEY, ETC.	LOT
[redacted]		Plan	7

[redacted] Marionville Ont.

DATE COMPLETED: DAY 29 MO 6 YR 84

NORTHING | RC | ELEVATION | RC | BASIN CODE | II | III | IV

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Brown	Hardpan	Boulders	Hard	0	6
Gray	limestone		Hard	6	35

31

32

41 WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
32	1 ☑ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

51 CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6¼"	1 ☑ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.188	0	20
6"	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☑ OPEN HOLE		20	35
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.) | DIAMETER INCHES | LENGTH FEET

MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
0	20'	Cement grout

71 PUMPING TEST

PUMPING TEST METHOD: 1 ☐ PUMP 2 ☑ BAILER

PUMPING RATE: 10 GPM

DURATION OF PUMPING: 1 HOURS 0 MINS.

STATIC LEVEL	WATER LEVEL END OF PUMPING	15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
5 FEET	15 FEET	15 FEET	15 FEET	15 FEET	15 FEET

WATER LEVELS DURING: 1 ☑ PUMPING 2 ☐ RECOVERY

IF FLOWING GIVE RATE: GPM

PUMP INTAKE SET AT: 35 FEET

WATER AT END OF TEST: 1 ☑ CLEAR 2 ☐ CLOUDY

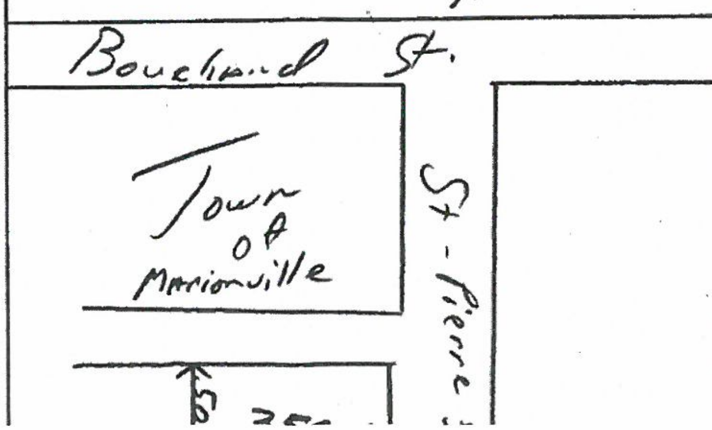
RECOMMENDED PUMP TYPE: ☑ SHALLOW ☐ DEEP

RECOMMENDED PUMP SETTING: 20 FEET

RECOMMENDED PUMPING RATE: 10 GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



FINAL STATUS OF WELL

1 ☑ WATER SUPPLY
2 ☐ OBSERVATION WELL
3 ☐ TEST HOLE
4 ☐ RECHARGE WELL
5 ☐ ABANDONED, INSUFFICIENT SUPPLY
6 ☐ ABANDONED, POOR QUALITY
7 ☐ UNFINISHED

WATER USE

1 ☑ DOMESTIC
2 ☐ STOCK
3 ☐ IRRIGATION
4 ☐ INDUSTRIAL
☐ OTHER
5 ☐ COMMERCIAL
6 ☐ MUNICIPAL
7 ☐ PUBLIC SUPPLY
8 ☐ COOLING OR AIR CONDITIONING
9 ☐ NOT USED

BHID
10045544

Ministry of the Environment
Ontario

The Ontario Water Resources Act

WATER WELL RECORD

OTTAWA-CARLETON

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11 | 1523770 | 15009 | CON

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON, BLOCK, TRACT, SURVEY, ETC.	LOT
[redacted]	[redacted]sell	Plan M 38	7

[redacted] Marionville

DATE COMPLETED: DAY 1 MO 8 YR 84

ELEVATION | RC | BASIN CODE

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
Brown	Hardpan	Boulders	Packed	0	6
Grey	limestone	Rock	Hard	6	45

RETURNED FOR CORRECTION
NO CARD PUNCHED
☐ Missing Data ☐ Incomplete Info.
☐ Illegible Info. ☐ Code Not Punched
☐ Obsolete Form ☐ Other
☐ Invalid Data
DISCREPANCY CIRCLED. Do Not Remove Tag when Re-submitting to Key Punch Dept.

31
32

41 WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
42	1 ☒ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

51 CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6 1/4"	1 ☒ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.188	0	20
6"	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☒ OPEN HOLE		20	45
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.) | DIAMETER INCHES | LENGTH FEET
MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
0	28'	Cement grout

71 PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
1 ☐ PUMP 2 ☒ BAILER	20 GPM	1 HOURS 0 MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
8 FEET	20 FEET	20	20 FEET	20 FEET	20 FEET

WATER LEVELS DURING: 1 ☒ PUMPING 2 ☐ RECOVERY

IF FLOWING, GIVE RATE: GPM

PUMP INTAKE SET AT: 45 FEET

WATER AT END OF TEST: 1 ☒ CLEAR 2 ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☒ DEEP

RECOMMENDED PUMP SETTING: 40 FEET

RECOMMENDED PUMPING RATE: 10 GPM

FINAL STATUS OF WELL

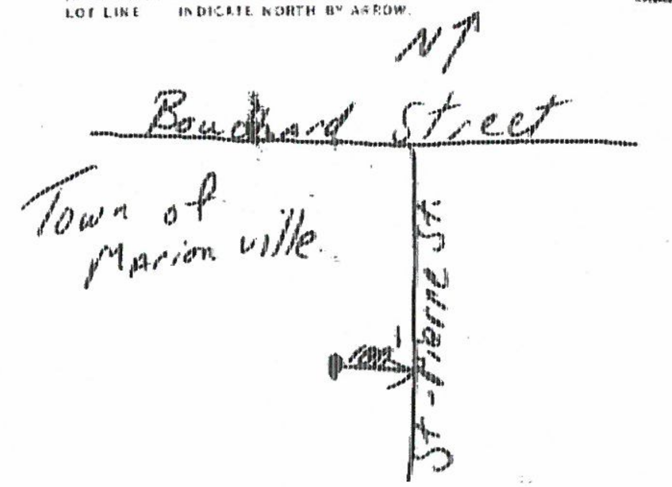
1 ☒ WATER SUPPLY
2 ☐ OBSERVATION WELL
3 ☐ TEST HOLE
4 ☐ RECHARGE WELL
5 ☐ ABANDONED, INSUFFICIENT SUPPLY
6 ☐ ABANDONED, POOR QUALITY
7 ☐ UNFINISHED

WATER USE

1 ☒ DOMESTIC
2 ☐ STOCK
3 ☐ IRRIGATION
4 ☐ INDUSTRIAL
☐ OTHER
5 ☐ COMMERCIAL
6 ☐ MUNICIPAL
7 ☐ PUBLIC SUPPLY
8 ☐ COOLING OR AIR CONDITIONING
9 ☐ NOT USED

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1931 Robertson Road
Ottawa, Ontario, K2H 5B7
Canada
T: +1 (613) 592 9600

Golder Associates