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Environmental Assessment Services
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RESPONSE TO ADDITIONAL COMMENTS RECEIVED ON GEOLOGY AND SEISMIC ASPECTS CAPITAL REGION RESOURCE RECOVERY CENTRE (CRRRC) ENVIRONMENTAL ASSESSMENT (EA)

Dear Andrew:

This letter presents Golder Associates' (Golder) response to the additional comments received by the Ministry of Environment and Climate Change (MOECC) from Dr. J. Wallach dated January 17, February 2 and February 5, 2016. Dr. Wallach's additional comments are made with reference to the response prepared by Golder Associates Ltd. (Golder) on behalf of Taggart Miller Environmental Services (TMES) dated June 2015 to Mr. Wallach's February 2015 comments on the geo-scientific aspects of the CRRRC Environmental Assessment Study Report (EASR).

Golder's response is a summary overview of the key issues raised in Dr. Wallach's additional comments on the proposed CRRRC project. Detailed responses to technical issues are provided in Appendix A.

Background

Dr. Wallach has made several submissions on the geological and seismic-hazard conditions of the CRRRC project. His interpretations of the bedrock structural geology and potential earthquake hazard rely principally on information obtained from the MOECC Water Well Information System (WWIS). For the reasons set out in the detailed responses to Dr. Wallach's latest submissions attached hereto, it is Golder's opinion that the information submitted to the WWIS by the well drillers is unsuitable for anything other than a general impression of the subsurface conditions and the water supply characteristics of the area in which the well was drilled. Dr. Wallach's geological interpretations are significantly different than the interpretations provided by the Golder team.

Golder's team has been assembled specifically for their expertise in structural geology, earthquake hazard assessment and geotechnical earthquake engineering. Furthermore, the team consists of both Golder staff and leading experts from Queen's University and the University of Western Ontario. These professionals individually have decades of relevant experience in the fields of structural geology, seismicity, seismic hazard assessment and geotechnical earthquake engineering and analysis, including the assessment of geological conditions in eastern Ontario. Golder's analysis incorporates a large amount of high-quality information from existing boreholes and project-specific CRRRC investigations. Golder's data, interpretations and models have been presented in the EASR.

Previous Review

Golder's interpretation of the regional and local geology and seismic conditions/analysis was presented in the June 2014 draft EASR. The MOECC retained the services of NRCan (Dr. Greg Brooks) to review and comment on the geological and seismic aspects of the EA, which were provided by NRCan in July 2014. Overall, Dr. Brooks' review supported the interpretation presented in the draft EASR, although he noted that the final EASR should better reflect the degree of existing uncertainty of existing geological models. Golder, on behalf of TMES, provided a response dated November 14, 2014 and then made appropriate modifications and clarifications in the January 2015 final EASR to address NRCan's comments. The interpretation of geological and seismic conditions in the final EASR did not materially change from the draft EASR.

Proposed CRRRC Site

Two potential sites were initially proposed for the CRRRC project. The North Russell Road site was found to be underlain by thin soil overburden overlying Queenston Formation shale bedrock. The Boundary Road site – about 5 kilometres to the northwest of the North Russell Road site – is underlain by a continuous 30 m thick silty clay deposit resting on glacial till overlying Carlsbad Formation limestone. Through the EA study process, the Boundary Road site was identified and selected as the preferred site for the proposed CRRRC. Accordingly, the North Russell Road site was removed from further consideration. In his February 2015 comments on the EASR, Dr. Wallach posited the existence of bedrock faults directly beneath or immediately adjacent to both sites. Golder's June 2015 response noted that Dr. Wallach's interpreted fault immediately west of the Boundary Road site was based on wells inaccurately located in the WWIS. These wells are actually located some 16 kilometres away from the Boundary Road site. In his January 17, 2016 submission, Dr. Wallach acknowledges this information and concludes that his previously interpreted bedrock fault just west of the Boundary Road site is incorrect. The remainder of Dr. Wallach's additional comments are related to his geological interpretation in the area of the North Russell Road site, which is no longer under consideration for the proposed CRRRC project.

Seismic Hazard at the Boundary Road Site

Unlike buildings that are engineered to provide life safety during future earthquake shaking 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 earthquake hazard for engineering practice 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 2% chance is an acceptable level of risk.

In the United States, where there is a Federal (and often State) regulation pertaining to 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 are not to be located within 60 metres of a fault that has had displacement in Holocene time (last 11,700 years) 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. As noted above, the Boundary Road site is located approximately 5 kilometres away from the North Russell Road site area where Mr. Wallach continues to speculates that fault displacement may be present and possibly ongoing.

In the absence of a specific code or guideline for landfill design in Ontario, Golder 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, standards 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 an appropriate level of life safety and environmental protection.

While not required by any Ontario regulations or guidelines, the EASR assessments included evaluation of 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 to mimic the USA requirements. 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.

Landfill Seismic Stability

The geological assessment described in the EASR concluded that there is no evidence of surface fault rupture from any past earthquakes at the proposed Boundary Road site or its immediate vicinity. The assessment further concluded that there is negligible hazard at the Boundary Road site of future fault movement that might cause large scale differential displacements at the surface or shallow subsurface. Analyses also demonstrated that there is little potential for differential settlement associated with strong earthquake shaking (liquefaction) at the Boundary Road site.

The proposed leachate containment and collection system has been designed to withstand relatively large differential movements and continue to perform its intended function during and following large, local earthquakes. For example, the containment and collection system has been designed to function when experiencing the predicted displacements associated with long term consolidation of the clay deposit beneath the landfill, i.e., total settlements of 6 to 8 metres under the central portion of the landfill. The containment and collection system has also been designed to accommodate lateral displacements of up to 350 mm under seismic loading conditions. The leachate containment and collection system was designed to account for these longer term settlements so that it would continue to perform as expected during and after the settlement. In addition, as discussed in the EASR, the groundwater analyses show that even if there was an early failure of the leachate collection system, the thickness and low hydraulic conductivity of the natural silty clay deposit would provide the required off-Site groundwater protection. Further, it is noted that the “contaminating lifespan” of the landfill (the period during which it is predicted to result in landfill leachate above MOECC Reasonable Use criteria) is only in the order of several decades, which is a very short period in geological terms. For these reasons, the effects of surface or subsurface displacements from local fault movement, in the very unlikely event that it occurs at all let alone during the short contaminating lifespan of the landfill are and would be inconsequential for engineering design or performance of the CRRRC landfill.

In summary, the geotechnical and geological assessments considered the geological conditions, static stability, seismic (dynamic) stability and longer term settlement expectations. A site specific geometry with restricted height and flattened side slopes is proposed to minimize any static slope movements. The stability of the landfill under earthquake shaking conditions considered the potential movement of the waste, movement of the underlying clay soils and the potential lateral displacement of the landfill. Predicted seismic displacements were found to be less than 340 millimetres during the design earthquake.

Concluding Statements

In Golder's detailed geological and seismic analyses presented in the draft and final EASR, the subsequent June 2015 response to Dr. Wallach's comments on the EASR and in this document, we have concluded that Dr. Wallach's geological interpretations are based on unreliable and/or incorrect subsurface data. Further, Dr. Wallach's interpretation that the low topographic rise on which the North Russell Road site is located is the result of uplift due to Quaternary-active faults is highly speculative. In any event, Dr. Wallach's structural interpretation of the North Russell Road site is largely irrelevant to the performance of and environmental impacts from the proposed CRRRC on the Boundary Road site that is located 5 kilometres away.

If there are any questions, please do not hesitate to contact us.

GOLDER ASSOCIATES LTD.

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Attachments: Response Appendix

Comment	Summary of Comment	Response
1	Golder Associates excluded information from the Wallach (2014) paper in the EASR	This was previously addressed in the June 2015 response to Dr. Wallach's review of the geo-scientific component of the Final EA. In summary, the Golder team reviewed the Wallach (2014) paper during the preparation of the final EASR. The review identified that Wallach (2014) contained significant errors in the data used; used only part of the available data in its interpretations; and that structural geology interpretations were based more on speculation than evaluation of reliable data. This paper did not affect our analysis or conclusions and in our opinion did not merit specific comments in the EASR.
2	Golder excluded faults inferred by Williams and Dix/Jolicoeur	Golder did not exclude faults inferred by Williams (mapped at all bedrock Formation contacts), nor did Golder say Williams did anything incorrectly when he made interpretations in preparing the published OGS bedrock geology map in 1985. Golder simply noted that Williams did not have the benefit of all the subsurface information that has been obtained since that time. As compiled, interpreted and reported in the final EA, the result is an updated interpretation of the extent of the Queenston Formation and how the Queenston shale conformably overlies the Carlsbad Formation. The EASR work considered and discussed the Dix/Jolicoeur paper, which using 3 widely-spaced boreholes inferred the presence of a post-depositional fault feature with about 10 metres of vertical offset. When considered by Golder with all the available data in a larger regional context, Golder concluded that such a fault was not required to interpret the bedrock structure. The EASR acknowledged, however, that faults on the scale of several metres to several tens of metres are relatively common throughout the region.
3	Golder missed the faulting documented in the log of test well T002580	The log of T002580 available to Golder from the Ontario Oil Gas and Salt Resources Library (OOGSRL) does not report information on fracturing that could be indicative of faulting. Regardless, this well is located near the Gloucester Fault, in an area where it would not be unexpected to see evidence of faulting. This is further illustrated on the regional cross-section (discussed in Section 3.2.1 in EASR Volume III, Figure 3-7 included as a part of Attachment 1 for reference), where the geological units are offset from one another by faulting in the Gloucester Fault zone.
4	Golder demonstrated that the data Wallach used to delineate the NW trending fault near the TMES site is inaccurate, and this fault is no longer interpreted to be there	The acknowledgement by Dr. Wallach, based on information provided by Golder in the June 2015 response, that his previously interpreted bedrock fault just to the west of the Boundary Road site is incorrect, is noted. This is a good example of the problems with relying on information from driller's logs from the MOECC WWIS, as Dr. Wallach has done, to try to interpret geology and bedrock structure.

Comment	Summary of Comment	Response
5	Revised interpretation of the WWIS data supports the presence of the North Russell fault in the north end of Cholowski Hill, per the information below:	Responses provided below.
a)	In the area around Route 100 and North Russell Road, one WWIS data point (with an interpreted Carlsbad Formation surface elevation of 44 mASL) may be anomalous or indicative of additional faulting, since two additional WWIS records in this area (with interpreted Carlsbad surface elevations of 78 mASL and 79 mASL) should represent the Carlsbad surface	All three of these water wells appear to be located correctly based on the information on the individual well records. The well with a contact elevation of 44 mASL (#5601756) appears to fit Golder's interpreted contact surface with the Queenston formation, though the well with an interpreted contact elevation of 78 mASL (either #5604201 or #5604202) does not. Regardless, Golder does not agree that WWIS records provide the necessary information to determine the contact elevation (see response to comment # 9 below for further detail). This is especially true for the interpreted Carlsbad surface elevation of 79 mASL (well #5600955), where the well record provides minimal geological descriptions (i.e., no bedrock colour is given to suggest whether the bedrock is 'red' [shale] or 'grey' [limestone]).
b)	The well record with a Carlsbad contact elevation of 75 mASL on McVagh Rd (well #1536361) does not support the interpreted fault, but well #1512811 (contact elevation 60 mASL to the SE), well #15116396 (contact elevation 55 mASL to the north) and the bedrock exposure to the west (contact elevation 75 mASL) support the interpreted presence of the fault	Upon further review of the record for well #15116396, Golder notes that the coordinates of this well provided in the WWIS database (and used by Dr. Wallach) are not correct, despite the reported accuracy code of '4'. Based on the lot and concession information and the driller's location map, this well is located approximately 1,300 m south of the location used by Dr. Wallach (near the intersection of Burton Road and McVagh Road; see Figure 1, attached). It should be noted that Golder also considered this well in its incorrect location to help delineate the lateral extent of the Queenston Formation in its northeast corner, though this error is not pertinent to Golder's overall conclusions regarding the geological setting. The remaining wells appear to be correctly located. As noted by Dr. Wallach, Golder agrees that well #1536361 does not support the presence of his interpreted fault. As discussed in the June 2015 response, it is Golder's opinion the WWIS information does not provide the level of detail necessary for determining the contact elevation of bedrock formations or interpretation of structural geology. The WWIS has been, and continues to be relied on heavily by Dr. Wallach, to the apparent exclusion in whole or in part of the high quality subsurface information available and presented in the EASR package.

Comment	Summary of Comment	Response
6	Golder's two boreholes (BH09-7 and BH09-3) support Dr. Wallach's North Russell Fault interpretation	In making this interpretation, Dr. Wallach is simply looking at two boreholes located on the western part of the North Russell Road site that happen to be located on either side of his interpreted North Russell Fault location, and require the supposition that the fault is actually present (which Golder does not agree with). In developing their interpretation, Golder used all the boreholes on the North Russell Road site to interpret the geology and the synclinal folds and basin in which the Queenston Formation shale was deposited. The continuity and characteristics of the Queenston shale in the area of the quarry and surrounding lands is demonstrated by: (i) the position and continuous 2 to 3 degree dip to west of north of the marker bed in the lower Queenston as illustrated on Figure TSD#1-B-4-1-1 in TSD#1 of the EASR package [included as a part of Attachment 1 for reference] and discussed in section 2.1.4.4.1 of TSD#1-B; and, (ii) the continuous presence of red Queenston shale as the uppermost bedrock unit in all boreholes and test pits covering the topographically higher area in the vicinity of the quarry.
7	The general pattern of the Carlsbad Formation surface to the east and west of the hill support the presence of the faults interpreted by Dr. Wallach, including Golder boreholes	As explained and illustrated in the EASR, faults are not required to explain the pattern of the Carlsbad bedrock surface. The interpreted bedrock surface displays the general topographic relief and slope that would be expected for sedimentary rock in Eastern Ontario. This is further reflected in Golder's interpreted bedrock surface (discussed in Section 3.2.1.1 in Volume III of the EASR and shown on Figure 3-5, included as a part of Attachment 1 for reference) for areas outside of the Queenston formation and north of the Gloucester Fault zone).
8	Cholowski Hill is a roche moutonnee (Golder ignored the effects of glacial erosion). To demonstrate this Golder's cross section should have been north-south.	Cholowski Hill is not a roche moutonnee; it is a very subtle topographic feature within otherwise flat terrain. It is agreed that the area has experienced glacial erosion from the north to south migration of glaciers during the last ice age, which has sculpted the surface. However, this feature has remained much the same since it became emergent from the Champlain Sea, as evidenced by the thin ancient near shore and beach deposits and shoreline erosional features that occur over the surface of the hill as mapped by the Geological Survey of Canada (GSC) as shown on Figure 3-10 of the EASR Volume III submission (included as a part of Attachment 1). Further, the detailed 0.5 m contour interval topographic mapping in the area of the Russell Quarry site has enabled the characterization of the low topographic rise adjacent to the North Russell Road site on North Russell Road as a Champlain Sea recessional shoreline feature (Figure 4 of the June 2015 response to Dr. Wallach's technical review of geoscientific component of the EA, included as a part of Attachment 1). This shoreline

Comment	Summary of Comment	Response
		feature includes a very distinct longshore spit (Figure 4) that identifies the former north to south direction of the ancient longshore current that sculpted the western facing 4 m to 6 m topographic rise that has in our view been erroneously interpreted by Dr. Wallach as the "North Russell Fault". The purpose of the east-west cross-section (Figure 5 of the June 2015 response, included as a part of Attachment 1) was not to comment on Dr. Wallach's interpreted "roche moutonee", but rather to illustrate the continuity of the Queenston shale across the topographic rise and to use the high quality subsurface information available from investigations of the North Russell Road site to show the absence of the two faults inferred by Dr. Wallach that are based on inappropriate use of water well information from the WWIS.
9	- Golder ignored WWIS data when drawing structural contours of the Queenston/Carlsbad contact. - Golder's interpretation of the syncline only considered the eastern portion of the feature. - Golder only considered the "fold" in one stratigraphic unit (i.e., the Queenston) (page 6, #2)	The Golder interpretation of the geotechnical borehole log information enabled the development of an elevation contour plan of the contact between the Queenston Formation and the underlying Carlsbad Formation within the Russell Quarry site (Figure 3-8 of EASR Volume III and reproduced in the June 2015 response document, included in Attachment 1). This contact is marked by the transition from the shale/mudstone with limestone interbeds forming the basal beds of the Queenston Formation overlying the limestone caprock of the Carlsbad Formation, and is based upon detailed core logging (BH09-3, 09-4 and 09-6) and interpretation of borehole natural gamma logs to define the contacts in BH09-7 and 09-8 that were drilled by a water well rig (without coring) and subsequently geophysically logged to provide formation control. Also, in BH 09-7, 09-8, 08-1 and 08-2 the geology was assessed by Golder staff based on chip samples collected during drilling. The elevation contours developed from this controlled, high quality data set defined a shallow dipping, gently westward plunging synclinal fold structure. The interpretation shown does not extend beyond the limits of the geotechnical borehole information. The eastern extent of the 70 mASL and 80 mASL contours of Figure 3-8 terminate against the projected bedrock surface contact line between the formations, beyond which the contoured surface no longer exists since the overlying Queenston Formation has been removed by erosion. The contours of this stratigraphic horizon were used to define the synclinal fold shape, noting that the fold itself is not restricted to just this contact horizon and will also be penetrative to depth within the underlying Carlsbad Formation strata and extend east of the Queenston/Carlsbad contact line. This shallow dipping fold is likely a local sympathetic fold (or drag fold warp) developed within the overall synformal basin that contains the Queenston Formation shale as discussed in the EASR Volume III. This gentle deformation of the strata is sub-parallel to the

Comment	Summary of Comment	Response
		northwest trending Gloucester Fault, being situated on the down-dropped side of the fault that has likely resulted in the elongated northwest trending shape of the gentle synformal basin that has preserved the Queenston Formation within this area as indicated on Figure 3-2 of EASR Volume III. This figure is included as a part of Attachment 1 (regional geology, copied from Sanford and Arnot, 2010). The Golder interpretation has strictly relied upon the geotechnical information rather than the water well record information, because the information provided under description of overburden and bedrock materials in the WWIS records is typically very general in nature and not collected by individuals with geological expertise. Well driller notes tend to provide a very general indication of the types of materials believed to have been encountered during the well drilling; however, they do not provide adequate reliable information for the development of complex structural geological interpretations (as Dr. Wallach has done). The reliability codes provided with the MOE well records pertain to location only and not the quality of the information contained within the record. Further, there is limited elevation control or accuracy in the WWIS since the ground surface elevation (from which all other elevations, such as bedrock surface or bedrock formation contact) of the reported wells is not surveyed. An example of the differences between detailed geotechnical and geophysical logging and a water well log prepared and submitted by the well driller is provided by consideration of Golder boreholes BH09-7 and BH09-8 located on the Russell Quarry site (Attachment 2). These holes were drilled by a water well driller under Golder supervision and they were subsequently geophysically logged. BH09-7, located on the west side of the site, was drilled to a depth of 33.5 m and the natural gamma log provided a strong Queenston shale signature, including a negative marker signature at 32.0 - 32.2 m (thin limestone bed) that sits approximately 4 m above the Carlsbad contact, based upon correlation with the gamma logs from the cored boreholes. This placed the projected Queenston/Carlsbad contact at a depth of approximately 36 m (elevation 47.5 mASL). In contrast, the well driller reported on their log a contact between red shale and grey limestone at 29.8 m depth, some 6 m above the projected formation contact based on Golder's geological interpretation. It should be noted that BH09-7 corresponds to the data point provided by Dr. Wallach on Figure 1 and Figure 2 of his January 15, 2016 submission, with an elevation of the Carlsbad surface shown as 59.00 mASL (corresponding to a depth of 24.8 m based on the surveyed ground surface

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		elevation of 83.5 mASL), and a reliability code of 3 (well ID #7137158). The elevation of 59.00 mASL noted by Dr. Wallach is not correct, as the transition from red to grey rock (i.e. the Queenston/Carlsbad contact based on Dr. Wallach's methods) noted on the water well record occurs at a depth of 29.8 m, which is 5 m lower than the depth used by Dr. Wallach – see Attachment 2). BH09-8, drilled on the east side of the site, penetrated deeper into the sequence and interpretation of the natural gamma log identified the Queenston Formation/Carlsbad Formation contact at a depth of approximately 28 m based on correlations from the negative gamma markers at 22.2 - 22.3 m and 24.5 - 24.85 m, the latter being a bioclastic limestone bed identified from core logging. Again, the well driller's reported contact between red shale and grey limestone was higher at 22.8 m (elevation 51 mASL). Another example of concerns and potential issues from relying on water well driller's logs for geological interpretation is provided from the area of Stanley Crescent, a small subdivision approximately 2 km directly west of the Russell Quarry site. There are 7 wells reported along Stanley Crescent, which are assigned a high level of confidence regarding location (RC3). This is a relatively dense cluster of high confidence well location data within a small area about 180 m x 40 m as indicated on the attached Google image (Attachment 3). The available subsurface materials information quoted from the 7 well records including the contractor identification number (3 different contractors for the 7 wells) and the dates drilled between 1987 and 1998 are provided in the table in Attachment 3. The information is summarized in Attachment 3, on a north-south cross-section taken through the center of each reported well location. The ground surface in this area is essentially flat and the measurements shown are in feet as reported on the records. The colour and description for the subsurface material reported for each well are provided beside them, respectively, as quoted directly from the well record. Examination of the information in Attachment 3 clearly indicates that the subsurface material information reported within this very localized cluster of wells is largely random and incoherent from a professional geological perspective. Only the position of the bedrock surface has some consistency but still varies in depth by 22 ft. in a localized area where it would be anticipated to be relatively flat given the regional bedrock surface trend. The bedrock to the depths these wells reached would also be expected to be relatively uniform reddish brown Queenston shale given the location directly westward from the quarry area toward the shale basin center. It is possible that the Queenston red

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		shale/Carlsbad dark grey shale contact could have been encountered within these depths (up to 155 ft. below ground surface). However, considering the apparent general randomness of the material reported in each well as indicated in the cross-section, it is not possible to identify a specific stratigraphic horizon with any degree of confidence for stratigraphic or structural interpretation purposes. One could assume that the information presented was factual and representative of complex geological conditions, but that is improbable. The cross-section in Attachment 3 illustrates the general inappropriateness of relying on this source of data, i.e., the MOE WWIS, for stratigraphic and structural interpretation. This is especially the case in areas where the available well locations are dispersed over much broader areas In summary, Golder places very little credibility on water well record data for purposes of complex structural geological interpretation due to the very limited and inconsistent nature of the information provided, above and beyond the difficulties associated with obtaining accurate well locations and ground surface elevations. The well records were never intended for this purpose. They were intended to provide a general indication of types of materials encountered based on descriptions by persons of limited technical training in describing geological materials, as well as an indication of the depth where an adequate supply of water for domestic purposes might be found and a description of its general quality (fresh, salty, etc.). Information from water well records that is of more value include the overburden thickness and bedrock surface intersection (considering this is usually associated with the installation of well casings and provided the well location accuracy is acceptable), depth to finding water, potential well yield and static water levels, items generally involving direct measurements that bear directly upon the successful completion of a well. In the case of the CRRRC study, the colour reported for bedrock materials encountered was taken into consideration by Golder in interpreting the potential lateral extent of the Queenston Formation as indicated on Figure 3-6 of EASR Volume III and included in the June 2015 response to comments. However, this was treated as more of a two-dimensional statistical interpretation considering the variability in the reported information as shown on Figure 3-6 (included as a part of Attachment 1 for reference).

Comment	Summary of Comment	Response
10	Golder's cross section C-C' should be oriented north-south along the spine of Choloski Hill (page 6, #3)	Golder's section line C-C' (Figure 3-7 in Volume III of the EASR) is deliberately through the OOGSRL borehole locations, which are all located west of the Hill, so that the overall continuity and thickness of the bedrock formations in these deep holes could be assessed. The section uses all the available deep bedrock stratigraphic information and a project-specific detailed interpretation of the geophysical logs, as well as Golder's knowledge of the total thickness of the various Formations in eastern Ontario. This deep borehole information is not available along Cholowski Hill. In Golder's opinion, there is insufficient reliable subsurface information from which to prepare a credible north-south cross-section along the spine of Cholowski Hill. There is only unreliable water well information to relatively limited depth, except for Golder and other high quality information (to relatively limited depth) on the North Russell Road site in the south portion of the Hill. Section line C-C' is located west of the Hill and passes through the boreholes to limit the distortion associated with projection of a borehole onto a section line, such as would be the case with a straight line section.
11	Golder's assertion that Wallach depicts the limestone (Carlsbad frm) contact near the surface in Cholowski Hill is false and it was 'not even remotely intimated' in Wallach (2014)	Golder's comment refers to figures in Wallach (2014) that illustrate limestone to be near ground surface in the Cholowski Hill area. For example, Figure 15 cross-section C-D of Wallach 2014 (provided in Attachment 4) depicts the Queenston Formation to be absent, and Carlsbad limestone is shown at elevation 79 mASL (near ground surface) with the North Russell and East Ridge Faults interpreted and shown to be present on either side of this elevated Carlsbad surface. This was concluded by Dr. Wallach based on poorly located WWIS data points rather than, rather than considering the available high quality data presented in the EASR.
12	A much broader syncline than that depicted on Golder's Figure 3-8 is illustrated on Golder's cross-section C-C', but the two do not match. (page 6, #4)	As discussed above, the fold structure identified beneath the Russell Quarry site is considered to be a sympathetic fold within the broader synformal structure shown on Section C-C'. This small scale folding is only recognizable due to the density of boreholes beneath the Russell Quarry site. However, it is considered quite likely that this type of small scale warping, including companion antiformal warps, occurs throughout the broader synclinal structure. As for the position of the axis in the broader syncline shown on Figure 3-7, it focuses on borehole RU-24 by means of the construction of the section drawn from borehole contact to borehole contact. The axis could be between boreholes RU-25 and RU-2 to the south, but that would involve speculation beyond the limit of available borehole data.

Comment	Summary of Comment	Response
13	Golder used too few data points to define the dip of the Queenston/Carlsbad contact – how do we know the surface isn't horizontal (page 7, #6)	Section A-A' on Figure 5 was drawn with a 5 times vertical exaggeration in an east- west direction transversely across Cholowski Hill primarily to illustrate the topographic expression of the feature. The ground surface topography is nearly flat including the slight topographic rise at North Russell Road even when shown at the 5 times vertical exaggeration of the section line. The section shows the westward dip of the bedrock surface, including interpretation of the bedrock surface elevation from well records located in the off-site areas taken from Figure 3-5 of the EASR Volume III. The projected very gentle westward slope of the underlying bedrock strata of approximately 1% reflects the westward slope of the axial trend of the fold defined beneath the Russell Quarry site as shown in Figure 3-8. This slope also approximately coincides with the westward slope of the bedrock surface. Borehole intersections were used to define the Queenston/Carlsbad contact and thickness of the Carlsbad limestone caprock (boreholes OGS-01-06 and BH09-4) at the locations shown, and then the contact horizons were simply projected based on the axial slope.
14	Golder needs to better explain the longshore spit feature, and the "red upland" present along Cooper Hill Road (page 7, #7)	As has been discussed in the previous Golder submissions, the Russell Quarry site and Cholowski Hill were submerged beneath the Champlain Sea. As the sea retreated the emergent topographic rise formed a local island feature that was subjected to shoreline erosion. The GSC has recognized shoreline features on the surface of the site (Figure 3-10 of EASR Volume III) and the recently available 0.5 m topographic mapping of the quarry site has enabled the more precise recognition of shoreline features as shown on Figure 4 of Golder's June 2015 response submission. With regard to that figure, the westward facing paleo-shoreline along North Russell Road (shown on west side of figure) has developed through erosion of reddish brown coloured glacial till up to approximately 5 m thick based upon the boreholes and test pits excavated in the immediate area. Borehole BH09-7 was drilled on the crest of the northern end of the shoreline scarp where 4.8 m of overburden was encountered. Looking southward along the feature, AH-3 encountered only 0.25 m of soil above the weathered shale while test pit TP-1 encountered 2.5 m of glacial till, borehole BH09-3 encountered 5 m of glacial till above shale and test pit TP-5 encountered 2.6 m of till over weathered shale. In fact, most of the Russell Quarry site has 1-2 m of glacial till overlying the weathered shale bedrock, while in some areas the weathered shale bedrock is exposed at surface, demonstrating the glaciated nature of the feature. Close examination (enlarging) of the longshore spit feature identified along the southwest side of Figure 4 indicates a near classic geomorphic shape as defined by the 0.5 m

Comment	Summary of Comment	Response
		topographic contours, with the beak curving southward indicating the direction of the former longshore current and sediment drift as Cholowski Hill became emergent as the Champlain Sea retreated. The Queenston Formation is of very limited extent within the Ottawa Valley area. It is limited to the Russell area and largely buried beneath marine clay deposits and glacial till. However, the Queenston Formation outcrops over quite broad areas along the Niagara Escarpment in southern Ontario, where the same slake-susceptible mudstone forms significant areas of very prominent topography in front of and independent of the underlying dolostone caprock.