FINAL REPORT
REV 2

Hydrogeological Impact Assessment for the Expansion of the Cruickshank Elginburg Quarry

Lot 12 and 13, Concession 5, City of Kingston, County of Frontenac, Ontario

Presented to:

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EXECUTIVE SUMMARY

Morrison Hershfield Limited (MH) was retained by Cruickshank Construction Limited (Cruickshank) to assess the hydrogeological impacts of the westward expansion of the Elginburg Quarry.

The study included background data review, site and area inspections, drilling of eight boreholes using a variety of drilling methods over a three year period, hydraulic testing of open holes, geophysical logging, installation of piezometers in select holes, hydraulic testing of the piezometers, groundwater level monitoring, groundwater sampling/analysis, and a domestic well survey of all wells within 500 m of the existing quarry and proposed expansion. The study also included analysis of the collected field data to prepare a conceptual hydrogeological model of the expansion lands and surrounding area, predictive analysis of drawdown cone propagation, impact assessment, and proposal of monitoring and contingency plans.

The results of the study support the definition of a north- and east-dipping layer-cake hydrostratigraphic model for the bedrock. The most distinctive geological marker within the model is the green beds of the middle member of the Gull River Formation, while the only significant permeability is approximately 7 m below the bottom of these beds. In the southern part of the expansion lands this permeability makes a confined aquifer, locally influenced by the nearby escarpment and also supplying water to residents on Cordukes Road to the west. To protect these wells, a set back of the third lift to the Lot 12/Lot 13 boundary is recommended.

North of the expansion lands, the confined aquifer has not been proven due to its depth, and water supply is sporadic, with some properties relying on cisterns in the absence of a reliable well. The best water supply is obtained from discrete fractures in the shallow bedrock, which are locally recharged by infiltrating precipitation. Due to its proximity to the expansion and not due to the permeability of the rock, a 250 m setback of the third lift is recommended from the closest residence at 2528 Unity Road.

Quarrying and dewatering of the quarry sump will lower the water table at the quarry itself. Using conservative assumptions, the radius of influence for the two-lift and three-lifts parts of the quarry were calculated as 300 m and 180 m, respectively.

Following rehabilitation, lakes are expected to form in the quarries on the north and south side of the pipeline which traverses the property. The north lake is expected to flow into the south lake, and the south lake is expected to equilibrate at approximately the elevation of the current water table at the south side of the property. Approximate post-rehabilitation lake elevations have been estimated at 125 mASL (north lake) and 110 mASL (south lake).

Wells, aquifers, surface water features, and anthropogenic structures were all considered in the impact assessment, and the highest risk receptor is the assumed domestic well closest to the expansion lands at 2528 Unity Road. Assuming the well is present, this is the only well within the estimated radius of influence of the fully extracted quarry, and to minimize the chance of impact to this well, a setback of 250 m is recommended for the third lift of the quarry. Wells at 2034, 2130, 2150, and 2166 Cordukes Road are identified as the next most likely to be affected because they appear to take water from the same confined aquifer as identified at depth within the southern part of the expansion lands. To protect these wells a setback of the third lift to the Lot 12/Lot 13 boundary is recommended.

EXECUTIVE SUMMARY

A minor change in flow along the ditch on the south side of Unity Road where the expansion lands abut is anticipated, and drainage of the south end of the property at 2467 Unity Road must be maintained despite the proposed berming in this area.

To address the possibility of a well impact, monthly groundwater level monitoring is recommended between the potentially affected wells and the quarry at all times during quarry operation; and annual winter seepage face monitoring is recommended as any lift of the quarry advances through the last 250 m of the approach to Unity Road, and through Lot 12 (approximately 400 m).

Since all the evidence suggests that bedrock permeability in the area of the potentially affected wells is generally low, and is derived from relatively discrete bedding plane fractures; grouting of discrete fracture zones, when used in combination with the recommended seepage and groundwater level monitoring, is considered a viable option for reversal of well impacts in the unlikely event they occur.

The following is a summary of recommendations made:

1. Monthly groundwater level monitoring is recommended in DDH 10-01. BH 11-02, BH 11-03, BH 11-04, BH 12-01, BH 12-02, BH 12-03, BH 13-01, the domestic well at 2528 Unity Road, and in the following three additional monitoring wells:
    - Future Monitoring Well 1 (FMW-1) on the Lot 12-Lot 13 boundary, approximately 60 m south of BH 13-01, to be drilled prior to extraction within the western half of Lot 13,
    - FMW-2 on the Lot 11-Lot 12 boundary at the northwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.
    - FMW-3 on the Lot 11-Lot 12 boundary at the southwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.
2. Annual winter photographic seepage face monitoring is recommended on all available extraction faces within 250 m of Unity Road in the western half of Lot 13 and also in Lot 12. This would consist of taking one or more photographs of the rock face from static viewpoints, where possible based on quarry operations. The information will provide a record of seepage into the quarry in the winter when ice will form at key seepage locations.
3. No extraction of the third lift (i.e., below 115 mASL) should occur within 250 m of the property at 2528 Unity Road, and west of the Lot 12/Lot 13 lot line.
4. A grouting pilot study may be considered during extraction of Lift 3 in Lot 13, if suitable conditions exist. The terms of reference for the study are included in Appendix J.
5. In consultation with the property owner, drainage from 2467 Unity Road must be allowed to discharge at the southern end of this property by way of a culvert(s) or break(s) in the berm.
6. The existing PTTW will be sufficient for dewatering of the existing quarry and the expansion area until its expiry in 2022. Upon renewal, it is recommended to combine the monitoring programs proposed in this report for the quarry expansion with the monitoring program for the existing quarry.

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1. INTRODUCTION

Cruickshank Construction Limited (Cruickshank) owns the Elginburg Quarry, Lots 14 and 15, Concession 5, City of Kingston, Ontario. The quarry is licensed under the Aggregate Resources Act (# 2901). Cruickshank intends to expand this quarry westward into Lots 12 and 13, Concession 5 (see Figure 1 in Appendix A). These expansion lands are south of Unity Road and north of Burbrook Road, to the west of the existing quarry.

Morrison Hershfield Limited (MH) was retained by Cruickshank to assess the hydrogeological impacts of the expansion of the Cruickshank Elginburg Quarry in support of the following:

- an application for major site plan amendment under the Aggregate Resources Act (ARA) for the expansion to be made with Ministry of Natural Resources;
- City of Kingston zoning by-law amendment; and,
- an eventual Permit to Take Water (PTTW) application to be made for the expanded quarry with the Ministry of the Environment and Climate Change (MOECC).

1.1 Study Area

The study area is approximately defined by the extents shown on Figure 1 in Appendix A. The study area includes the area to be licensed and the existing and proposed extraction limits, as well as the area surrounding the quarry including the nearest water wells, wetlands, or other features potentially impacted by the project.

1.2 Scope of Work

The scope of work is defined by the Provincial Standards for a Hydrogeological Level 2 Technical Report, Category 2 - Class “A” License for quarrying below the water table. The scope includes field work and hydrogeological analysis deemed necessary to achieve the objective. All work is to be carried out in accordance with applicable industry standard practices.

1.3 Contents of Report

This section of the report provides information on the context for the study, the scope of work and the layout of the report. Section 2 describes the methods used in the study. Section 3 describes the results including background information, the results of field investigations, and any calculations necessary for the impact assessment. Section 4 describes the assessment of the impacts of the project on all identified potential receptors. Section 5 presents a summary of the results and the potential impacts, describes any recommended monitoring, and contingency plans to be implemented in the event of certain occurrences. Section 6 provides a summary of recommendations. Section 7 provides closure notes and signatures of the report authors, and Section 8 presents the limitations and use of this report. References are provided in Section 9. Figures, tables, and supporting documents are provided in the appendices.

2. METHODS

This section describes the methods used in this study. Specifics to the project including dates, specific data sources, and specific details of the chosen methodology are included as part of the results.

2.1 Background Data Review

Background data review was conducted in accordance with industry standard practices using readily available information from federal, provincial, municipal, and other sources of information. The following is a non-exhaustive list of key data sources:

- Cruickshank files and previous reports;
- MOECC Water Well Information System (WWIS, 2012);
- Geology Ontario (maps published by the Ontario Geological Survey);
- Google Earth (for quick reference topographic and land use information); and,
- Land Information Ontario, for detailed topographic and hydrological mapping.

The background review included analysis as necessary to develop an overall understanding of the hydrogeological setting and potential impacts of the expansion. In this case, the analysis included the tabulation and plotting of site-specific borehole information; tabulation and use of WWIS water well information to determine depths and available drawdown in area wells; plan view plotting of surface water features such as streams, rivers, lakes and wetlands to assess groundwater and surface water interaction; and plan view plotting of surficial and bedrock geology to determine the likely occurrence of surficial deposits as well as the occurrence and thickness of sedimentary bedrock.

2.2 Site Inspection

Site inspections were carried out primarily to observe geological and hydrogeological conditions in the existing quarry. During these inspections, the quarry walls were inspected for variations in rock bedding and colour, and for signs of seepage. Photographs were taken of observed features.

2.3 Subsurface Investigation

Hydrogeological analysis and impact assessment requires that the properties of the soil, rock, and groundwater be known in proximity to the area affected by the project. Unless it can be inferred entirely from existing sources, field work such as drilling and soil/rock sampling is required. In this case, subsurface investigations were carried out by two separate consultants over a four year period, for the combined purpose of investigating the rock quality and the hydrogeology. The remainder of this section describes the methods used as they pertain to the subsurface properties.

2.3.1 Diamond Drilling, Core Recovery, Core Logging

Diamond drilling allows for the recovery of a piece of rock core, with diameter determined by the drill bit size. Core is recovered from the core barrel, labeled to indicate depth interval, and inspected and placed in core boxes. Diamond drilling was carried out under MH supervision. Each core was visually inspected for colour, texture and composition of the rocks, fractures in the core, and evidence of fossils or bioturbation. The surface of the core was also scratch-tested for hardness using a pocket blade. The classification shown in Table 2.1 was used to determine the hardness of the rock.

Table 2.1: Rock hardness Classification

Classification	Description
Very Soft	Can be peeled with a knife.
Soft	Can be easily gouged or carved with a knife.
Medium soft	Can be readily scratched with a knife blade; scratch leaves heavy trace of dust and is readily visible after powder blown away.
Hard	Can be scratched with a knife with difficulty; scratch produces little powder and is often faintly visible.
Very Hard	Cannot be scratched with a knife or can barely be scratched with a knife.

Acid testing was carried out on the core samples to distinguish between limestone and dolostone. Acid was prepared by mixing muriatic acid and water in a 1:7 ratio to form a diluted hydrochloric (HCl) acid. The HCl acid was transferred into a squeeze bottle fitted with a cap to enable precise application of small amounts of acid onto the core samples. When applied to limestone, acid reacts and fizzes vigorously as carbon dioxide is produced. When applied to dolostone, acid reacts to a lesser extent and fizzes very slightly. Dolostone surfaces typically need to be scratched prior to adding acid to facilitate a more visible reaction. It is noted that the reaction may also take place on other rock types if calcite is present (e.g. sandstone with calcite cement).

Diamond drilling had also been carried out in December, 2010 at DDH 10-01 by Marathon Drilling Co. Ltd. under the supervision of Golder. The core had been split (apparently using a rotary rock saw) and the remaining half was available for inspection by MH.

2.3.2 Rock Drilling and Rock Chip Logging

The bit of a rock drill is pushed and hammered into the ground, while the crushed rock chips are brought to the surface using compressed air. Common types of rock drills at quarry sites include water well rigs and top-hammer rigs used in quarrying.

The drilling was carried out in intervals and rock chips from each interval were flushed out into piles near the drill. Rock chips samples at each interval were collected using a trowel and placed into zip-lock bags for later analysis. After samples were taken, the piles were cleared out to make room for the next rock chip sample interval so as to avoid mixing sample intervals.

The rock chips were later arranged into compartmentalized boxes for ease of storage and assessment. The rock chips were visually inspected for colour and tested for limestone and/or dolostone using HCl acid (as described in Section 2.2). All observations and field test results were noted down and used to produce borehole logs using Gint software.

2.3.3 Downhole Geophysical Logging

Downhole geophysics was carried out in all boreholes by Notra Inc. of Ottawa using a BMP06 probe which simultaneously measures temperature, apparent conductivity, apparent resistivity, single point resistance, magnetic susceptibility, and natural gamma at a rate of 2 readings per second recorded on a logging computer. The probe was lined up with the top of the casing and a depth of zero was entered in the logging computer. With the computer logging, the probe was lowered at approximately 5 meters per minute, resulting in one data point for all parameters recorded every 4 cm. The probe was stopped briefly at calibrated 10 meter intervals to confirm accuracy of the logged depth. After reaching the end of the hole, the probe was brought back up at a faster rate, while still logging data. The up data is compared to the down data to ensure proper operation of the unit.

Depth data in each borehole were calibrated using the 10 m calibration intervals and each parameter was extracted to an electronic file. The files were then plotted in LogView from which the analysis was conducted. More detailed methodology and analysis are described in the report attached in Appendix E.

2.4 Water Investigation

In hydrogeological studies, especially at a regional scale, it is necessary to understand the interaction of groundwater and surface water.

2.4.1 Groundwater Level Monitoring and Hydraulic Testing

To provide information on the permeability of the subsurface, a rising head (bail) test was performed on all open holes, and on all installed piezometers. Open holes were pumped down using a 51 mm (2”) submersible pump, while piezometers were pumped down using a hand-actuated inertial foot valve on the bottom of tubing installed to the base of the piezometer. Water levels were monitored as the well or piezometer recovered using an electric water level tape. The hydraulic conductivity of the tested media was determined by applying the Hvorslev method to the measured water level recovery data.

To determine information on the variation in hydraulic conductivity with depth within the stratigraphy, packer testing was completed in one open hole. Packer testing is conducted in intervals of an open borehole, which are isolated from the remainder of the borehole using inflatable rubber “packers”. The hydraulic conductivity of the test interval is calculated using the equation (Powers et al., 2007):

$$K = \frac{Q}{2\pi L \Delta H} \ln\left(\frac{L}{r_w}\right) \quad (1)$$

where,

K	=	Hydraulic conductivity of borehole interval [L/T]
L	=	Length of test section [L]
Q	=	Steady injection rate [L^3/T]
ΔH	=	Differential pressure head [L]
r_w	=	Radius of borehole [L].

The differential pressure head is the gauge pressure converted into metres of water, plus the height of the gauge above the water table.

Water level monitoring was also carried out using a electric water level tape on a monthly basis in all installed piezometers.

2.4.2 Piezometer Installation

The design of the piezometers was finalized based on observations of water bearing zones made during drilling. Piezometers were completed using 32 mm inside diameter PVC slotted screen and riser pipe, washed crushed stone for the gravel packs, and bentonite clay seals. The piezometers were installed in conformance with the requirements of Ontario Regulation 903 (Wells) by a licensed well driller.

2.4.3 Groundwater Sampling and Analysis

Groundwater sampling was conducted in open holes and/or piezometers where permeability allowed. The water sampling procedure involved purging three well volumes and then filling the sampling bottles provided by the laboratory with the groundwater. Samples to be analyzed for metals were field filtered using 45 µm filters. The sampling bottles were returned to Caduceon Laboratories Ltd., in Kingston and Ottawa, Ontario, for some or all of the following analyses, depending on setting:

- Inorganics and general chemistry (alkalinity, ammonia, chloride, conductivity, NO_2, NO_3, pH, TSS, sulphate, carbonate, bicarbonate, hardness, phenolics, turbidity);
- Metals (Al, B, Cd, Ca, Co, Cr, Cu, Fe, Pb, Mg, Ni, Ag, Si, K, Na & Zn).

Although there is no requirement to meet these standards, the results were compared to both the Ontario Drinking Water Quality Standards (ODWQS) (MOE, 2003) and the Provincial Water Quality Objectives (PWQO) (MOE, 1994) for reference purposes.

2.4.4 Domestic Well Survey

The intent of the domestic well survey was to verify the presence of wells, to determine their depth and completion details, and to identify water quantity or quality issues in the area, if any.

A desk-top review of property parcels within 500 m from the quarry was undertaken using the City of Kingston K-Maps site. Based on the information collected, letters were sent to a set of addresses notifying the occupants of the dates of the survey.

The survey was conducted by MH staff and Cruickshank staff by enquiry at the addresses identified in the desk-top review. Staff were instructed to include residences or businesses that were present within the search radius but which had not been identified during the desk-top review. The well survey consisted of an interview with the occupant and filling of a well questionnaire form based on the Guidelines for Drinking Well Water Sampling and Testing in Ministry of Transportation Activities, April 2004. Where possible the well was visually inspected. The measurement of water levels and the collection of groundwater samples for analysis were also included in the well survey. Samples were collected from the plumbing system at the residence, upstream of any treatment system where possible, after a five-minute flush of the plumbing system, and for bacteriological samples after the sample location had been disinfected using either the combination of flaming and alcohol swab (outdoor taps) or the alcohol swab alone (kitchen taps). Samples were collected into laboratory prepared bottles, were stored in coolers with ice, and were delivered to the laboratory immediately following the sampling event.

Samples were analyzed for the following parameters:

- Bacteriological (E. coli, Fecal Coliforms, and Total Coliforms)
- Inorganics and general chemistry (alkalinity, ammonia, chloride, conductivity, NO_2, NO_3, pH, TSS, sulphate, carbonate, bicarbonate, hardness, phenolics, turbidity, dissolved organic and inorganic carbon);
- Metals (Al, B, Cd, Ca, Co, Cr, Cu, Fe, Pb, Mg, Ni, Ag, Si, K, Na & Zn).

2.4.5 Surface Water Inspection and Sampling

Surface water and storm water management features were inspected within the existing quarry and in the expansion area. Water samples were collected from strategic locations within and downstream of the existing quarry. Water samples were collected with a clean container which was used for measurement of field parameters (temperature, pH, electrical conductivity, and dissolved oxygen) and to decant the samples into bottles provided by the laboratory. Samples were kept refrigerated, and were shipped to the analytical laboratory under Chain of Custody. Samples were analyzed for the following parameters:

- General chemistry including Alkalinity, Ammonia, Chloride, Conductivity, NO_2, NO_3, TP/TKN, TSS, pH, TDS, Sulphate, Carbonate, Bicarbonate, Phenols (4AAP)
- Metals (Hardness, Al, As, Ba, Be, B, Cd, Ca, Co, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, Ag, Si, Hg, K, Na, Sr, Tl, Ti, V & Zn)
- BOD, COD, DIC, DOC
- Oil and Grease (Total)
- PHC (F1-F4)

Field and laboratory measured parameters were compared to Provincial Water Quality Objectives (PWQO, being referenced as MOE, 1994) to further assess the water quality being discharged from the existing quarry.

2.5 Calculations

2.5.1 Drawdown during Operations Analysis

Drawdown analysis was conducted using two different approaches: a calculation approach based on measured parameters, and an “analogue” approach based on observation of existing conditions.

Calculation Approach

In this approach, drawdown analysis was conducted assuming steady state radial flow towards the extraction area at full development of the quarry, using a two-step process. In the first step, the radius of influence of the dewatering, r_0, was estimated using a variation on the method of Sichart and Kyrieleis (see Powers et al., 2007):

$$r_0 = 3000 s_{qry} \sqrt{K} \qquad (2)$$

where:

r_0	=	radius of influence of the quarry dewatering [L; metres]
s_{qry}	=	drawdown at the quarry face [L; metres]
K	=	Hydraulic conductivity of the bedrock [L; metres per second].

In the second step, the radial distance to the critical drawdown used in the impact assessment (i.e., to determine where to draw contours of drawdown) was calculated from a re-arrangement of the equation describing steady state radial flow in a confined aquifer (see Bear, 1979). That is,

$$r_{crit} = r_0 \left(\frac{r_o}{r_{qry}} \right)^{-\frac{s_{crit}}{s_{qry}}} \quad (3)$$

where:

r_0	=	radius of influence of the quarry dewatering [L; metres]
r_{crit}	=	radius to the critical drawdown s_{crit} [L; metres]
r_{qry}	=	radius of the quarry [L; metres].
s_{qry}	=	drawdown at quarry face [L; metres]
s_{crit}	=	critical drawdown between 0 and s_{qry} for the impact assessment [L; metres]

The main limitation of the calculation method is that it does not account for the propagation of drawdown in discrete fractures which may be intersected by the quarry. In the event that a discrete fracture is intersected by the quarry, water is drained from it such that the groundwater elevation (total head) at the quarry wall is equal to the elevation (elevation head) of the fracture (i.e., the pressure head is zero). The discrete fracture is in fact a tortuous channel within a planar feature, and the reduction in groundwater elevation induced by the drainage propagates backwards through the channel. There will be a transient stage and then an equilibration between the rate of drainage at the quarry wall and the rate of recharge to the facture from the complex interconnectedness with other fractures, both horizontal and vertical, and from recharge infiltrating from the ground surface. As quarries advance so slowly, the groundwater system is in this equilibrium stage at all times except for brief periods after each blasting event. Since modelling of this process at the level of a discrete fracture network requires data that is difficult if not impossible to obtain, alternative methods of assessment are required.

Analogue Approach

To address the need for an assessment of propagation of drawdown in discrete fractures which may be intersected by the quarry, an analogue approach was used. An analogue approach is to infer the behavior of a complex system from another similar (analogous) system, whose behavior is better understood or can be observed. This approach is common in science, generally, and in the earth sciences is especially popular to support predictions over long time scales (e.g., predictions of the performance of a radioactive waste disposal site over millennia). The methodology used in the analogue approach is as follows: find an analogue, study its performance and how this performance can be used as an analogy for the performance of the target system, then use the knowledge gained to make predictions about the future performance of the target system.

2.5.2 Groundwater Inflow Rate

Groundwater inflow to an excavation is dependent on many factors including the hydrogeological setting, the construction method (e.g., use of sheet piles, coffer dams, etc.), and the depth of construction. For various assessments in this report, the following equation was used (Powers et al, 2007) to calculate groundwater inflow:

$$Q_{gw} = 2\pi KB \frac{(h_{outer} - h_{inner})}{\ln(r_{outer}/r_{inner})} \qquad (4)$$

where:

Q_{gw}	=	groundwater inflow rate [L3/T]
K	=	hydraulic conductivity of the aquifer [L/T]
B	=	Thickness of aquifer [L]
$h_{outer} - h_{inner}$	=	Maximum drawdown from expected water table to bottom of excavation [L]
r_{outer}	=	Radius of Influence calculated, for example, with Sichart and Kyrieleis equation (see Section 2.5.1) [L]
r_{inner}	=	Equivalent radius of excavation [L]

This equation was used to assess a variety of inflows to different parts of the quarry and/or at different stages of quarry development.

A groundwater inflow rate for the existing quarry under current conditions was also very approximately calculated based on visual observations of groundwater inflow as ice build-up on the quarry walls between two or more observations times. The volume of ice formed due to groundwater inflow on the quarry walls was estimated from photographs of certain representative sections of the quarry. This was then extrapolated to estimate total volume of ice formed along the quarry walls and ultimately total volume of groundwater inflow in the quarry between the two visits. The groundwater inflow calculated was only for information purposes and not used in any other assessment in this report. The weather record was checked to verify that that no major thaw events occurred between the two visits.

2.5.3 Lake Level Following Rehabilitation Analysis

Following final rehabilitation of the quarry, a lake will be established north and south of the pipeline in the quarries which will no longer be pumped. Lake levels were estimated using best judgment considering the existing water table elevation, rock permeability, estimates of how this rock permeability may change during quarrying, topography, and the influence of evaporation.

2.5.4 Water Balance and Lake Filling Time Calculations

The water balance for the quarry was determined on an annual basis, using meteorological information from Environment Canada, and the estimated groundwater inflow rates. The inflow of water from precipitation was estimated by multiplying an estimated catchment area by the average precipitation rate from the Environment Canada historical weather data for Kingston.

Once the pumps are shut off and the quarry allowed to fill with water, evaporation from the lake surface will occur. The evaporation rate was taken from the Hydrological Atlas of Canada which shows contours of this value over the whole country. The lake filling rate was calculated as the precipitation inflow rate (above) plus the groundwater inflow rate minus evaporation from the lake surface.

The time for complete lake filling was calculated as the volume of the lake divided by the filling rate.

2.6 Storm Water Management Considerations

Management of storm water during operations of the expanded quarry was considered in a qualitative fashion, considering how the quarry is currently operated, and how it may operate in the future.

2.7 Impact Assessment

Groundwater impacts are generally assessed based on calculated or estimated drawdown of the water table/potentiometric surface, and on calculated or estimated changes in volumetric flow (such as loss of baseflow to local streams). The impact assessment is made by considering the impacts of these project-induced calculated or estimated hydrogeological effects on the following potential receptors:

- Wells and Aquifers;
- Surface water;
- Existing subsurface contamination;
- Anthropogenic structures; and,
- Ecology.

3. RESULTS

3.1 Background Data Review

This section describes the results of the background data review. Key documents found during the review were:

- Hydrogeological Investigation of Elginburg Quarry, Part Lots 14 & 15, Conc. V, Township of Kingston, County of Frontenac. Report No. 934000, Gorrell Resource Investigations, 1995.

- Hydrogeological Investigation of the Cruickshank Elginburg Quarry, Lot 14 and 15, Concession V, City of Kingston, County of Frontenac, by Morrison Hershfield, dated September, 2012.

3.1.1 Physiography and Topography

The Elginburg Quarry is located in the Napanee Plain physiographic region (Chapman and Putman, 1984). This region is characterized by the flat topography of the limestone formations. The defining feature of the study area is a north-east to south-west trending escarpment which is approximately coincident with the south end of the existing and proposed expanded Cruickshank Elginburg quarry. The escarpment marks the edge of the limestone plain. At Unity Road the ground surface is essentially flat in the east-west direction, at approximately 140 mASL.

3.1.2 Drainage and Surface Water (Hydrology)

Figure 1 in Appendix A shows the surface water features in and around the existing Elginburg Quarry and the expansion area. The main branch of Collins Creek traverses the south east corner of the Figure 1 map area, flowing northeast to southwest and crossing Bur Brook Road approximately one kilometer west of Silvers Corners. South of the existing quarry and expansion area, Collins Creek turns northwards and flows for approximately 0.5 km on the north side of Bur Brook Road. This section of the Creek is joined by a tributary from the north carrying drainage from the existing quarry and Elginburg village area, and is also the receiver of overland flow from the south part of the expansion area. Drainage from the north part of the expansion area flows overland in the southwesterly direction, discharging to another tributary which joins Collins Creek in a wetland south of Burbrook Road. Collins Creek flows to the south approximately 12 km before draining into Lake Ontario at Collin's Bay.

3.1.3 Geology

Most of the expansion lands are underlain directly by bedrock, with very little overburden soil cover. In some low-lying upland areas (coincident with the drainage features), and at the base of the escarpment, there are massive to well-laminated, fine-textured glaciolacustrine deposits of silt and clay with minor sand and gravel (Ontario Geological Survey, 2010).

Above the escarpment the ground surface is at approximately 126 mASL and the bedrock is mapped as the upper member of the Gull River Formation (Carson, 1981). Below the escarpment the ground surface is at approximately 90 mASL, and the rock is mapped as Precambrian. On the escarpment itself, the rock is mapped as the middle member of the Gull River Formation, which contains buff and green siltstone, and which appears from the mapping to be approximately 20 m thick. The geology from Carson (1981) is approximately shown in plan view and section view on Figures 2 and 3, respectively, in Appendix A.

The MOECC water well database (Water Well Information System or WWIS, accessed June 2012) indicates overburden depths between 0.6 m to 1.8 m throughout the property, and limestone to at least 43 m depth on the northern side of the property and to at least 28 m depth on the western side of the property. The limestone is generally underlain directly by granite, but sometimes by sandstone being the arkosic sandstone, siltstone and shale of the Shadow Lake formation. The geology information from the WWIS is shown schematically on three cross-sections presented in Figures 4, 5, and 6 in Appendix A. The locations of the cross-section lines are shown on Figures 1 and 2 in Appendix A.

An HQ-sized rock core was collected to 36.4 m depth by Golder Associates Ltd. (2011) as part of an aggregate resource assessment for the expansion. The 100 mm diameter diamond-drilled borehole (DDH 10-01) was cased at surface, and left as an open hole. The rock was determined to be Gull River Formation micritic limestone. The borehole log is included in Appendix B.

Three boreholes were advanced in 2011 to 36 m depth by Golder Associates Ltd. (2011). These 152 mm diameter air-rotary (water well rig) boreholes (BH 11-02, BH 11-03, and BH 11-04) were cased at surface and left as an open hole. At the same time, two additional boreholes were advanced on the east side of the existing quarry (BH11-05 and BH11-06). No borehole logs were available for any of these.

3.1.4 Hydrogeology

According to the WWIS, there are approximately 300 water wells in the study area. These vary in depth from approximately 5 m to 123 m, with an average depth of approximately 29 m. The static water levels vary from being at ground surface to approximately 42 m depth, with an average depth of approximately 11 m. Ninety percent of the wells were completed in limestone, seven percent in granite, and two percent in sandstone (Shadow Lake Formation). The final status of approximately 88% of the wells were reported to be for water supply, 5% were reported to have been abandoned for supply reasons, 2% were reported to have been abandoned for quality reasons, and the remaining 5% were reported as observation wells, test holes, or unreported. Furthermore, the water quality of approximately 75% of the wells were reported as fresh water, with an average depth of approximately 28 m. The water quality of approximately 10% of the wells were reported to contain salt (4%), sulphur (9.5%), and/or minerals (0.75%), with average depths of approximately 49 m, 28 m, and 75 m respectively. Based on this, a water quality trend is observed with deeper wells exhibiting higher salt and mineral content. Summary of wells identified in the WWIS is included in Appendix C.

The locations of all houses/businesses observed in satellite imagery or in the area reconnaissance within 500 m of the existing or proposed extraction area are shown on Figure 1 in Appendix A, along with their municipal addresses on Burbrook, Cordukes, or Unity Roads. The closest houses to the expansion area are 2467 Unity Road, where the proposed extraction area is set back further from Unity Road, and 2528 Unity Road, across Unity Road and slightly west of the quarry boundary. An attempt was made to correlate these locations with the WWIS water wells. No WWIS water well could be attributed to the house at 2528 Unity Road. A 32 m deep well in limestone and an abandoned 28 m well in limestone could both be attributed to the house at 2467 Unity Road. No water quality or supply information was available for either well in the database.

One-to-one correlation between specific houses/businesses and specific wells was not possible in a wider area basis, but clusters of houses/businesses could be correlated to clusters of wells in the WWIS.

WWIS water well #2205740 in the northwest corner of the proposed extraction area (see Appendix C and Figure 5 in Appendix A), can be correlated to the houses on Unity Road west of the proposed extraction area. This well was drilled to approximately 44 m depth, through less than a metre of clay overburden and then through limestone. Salty water was found at approximately 23 m depth, and the static level was less than 2 m below ground. Other WWIS wells in this area include #2214366 and #2218761, further to the northwest, completed less than 7 mBGS in limestone. A notable fact from the inspection of the WWIS is that of the six wells in the WWIS at locations within 300 m of the quarry expansion lands frontage on Unity Road, five have status “Abandoned” (for either quality or supply), and one has status “Water Supply” but is known to have been abandoned. This indicates that the limestone in this particularly area (on the north side of the quarry) is of particularly low permeability or is particularly devoid of water bearing fractures.

WWIS water well #2215473 on the east side of Cordukes Road, midway between Unity Road and Bur Brook Road (see Appendix C and Figure 4 in Appendix A), is representative of wells in this area. This well was drilled to approximately 40 m depth through less than a metre of clay soils, underlain by shale and limestone. Fresh water was found at 11 m and 27 m depth, and the static water level was at 9 m depth.

It is noted some of the wells in this area were drilled to over 100 m depth, completed in the underlying granite.

The hydrogeology of the existing quarry site is described in both the Gorrell Resource Investigations (GRI, 1995) and the MH (2012) reports. In 1994, four 6 inch diameter wells were drilled to between 86 to 98 mASL, and water levels were measured and rising head tests were performed in open holes and installed piezometers. The well logs from the GRI Hydrogeological Investigation (1995) are provided in Appendix B. Hydraulic conductivities estimated from recovery data (i.e., rising head test, Hvorslev method of analysis) for the existing quarry open holes and piezometers are summarized in Table 1.

Table 1: Hydraulic Conductivities - Existing Quarry

ID	Hydraulic Conductivity (m/sec)
MW-1 (Open Hole)	2% recovery in one month
MW-2-1	1×10^{-8}
MW-2-2	3% recovery in one hour
MW-2-3	1% recovery in one hour
MW-3-1	1×10^{-5}
MW-3-2	4×10^{-6}
MW-4-1	7×10^{-6}
MW-4-2	1×10^{-5}

These data suggest a very low rock permeability in and around the existing north extraction area, and a higher rock permeability in and around the south extraction area. This conceptual model is supported by the groundwater levels measured between 2007 and 2013 in the existing quarry monitoring wells, and in the residential wells approximately 150 m (2309 Unity Road) and 250 m (2296 Unity Road) east of the existing quarry. The time-series of these data (Figure 7) indicates that only piezometers in MW-3, which is in the centre of the south extraction area, have been affected by rock extraction and dewatering.

All in all, the existing hydrogeological data, including the water well records and the information from the existing on-site monitoring wells suggest that groundwater availability in the rock mass is highly dependent on the presence of fracture flow, and local recharge. The area surrounding the northern extraction area of the existing quarry and expansion area appears to be of particularly low permeability, with very few water bearing fractures.

3.1.5 Existing Permit to Take Water

The existing Elginburg Quarry is dewatered under PTTW 2172-92HR7T, which allows takings as shown in Table 2.

Table 2: Takings Allowable Under the Existing PTTW

Dewatering Situation	Allowable Taking (Million Litres Per Day, MLD)	
	North Quarry	South Quarry
Dewatering in Spring etc.	6.5 MLD, 118 days per year	13.1 MLD, 58 days per year
Maintenance Dewatering	3.9 MLD, 247 days per year	6.2 MLD, 307 days per year

Relevant conditions of the PTTW include establishment of a monitoring program as follows:

1. Monitor the water levels in monitoring wells MW-1, MW-2, MW-3 and MW-4 as well as the residential wells designated as #2309 and #2296 quarterly.

2. The data collected under this monitoring program shall be analyzed and interpreted and summarized in an annual report. The report should provide recommendations on the need for changes to monitoring locations and frequency, pumping patterns and/or the need for mitigation.

The support document for the PTTW application included the following groundwater inflow estimates: 1,362 m^3/day for the north quarry at full extraction, and 2,622 m^3/day for the south quarry at full extraction. These estimates were made using a simple analytical model, and the geometric mean of measured rock permeabilities. It is noted however, that the rock permeabilities available for the north quarry were too low to be used for this purpose, and the rock permeability was assumed to be one order of magnitude lower than the rock permeability for the south quarry.

The total allowable taking of 13 million litres per day allows for two 6 inch pumps to run continuously, which may be required in the spring to remove snow melt. The value also corresponds to the amount of water which will enter the quarry should 2.5 cm of rainfall occur over a 24 hour period.

3.2 Site Inspection

Site inspections were carried out on November 25, 2013, January 10, 2013, and May 29, 2014 (for surface water). The temperature was below freezing on both 2013 days, and frozen discharged groundwater could be observed at various point locations on the quarry walls. An apparently water-bearing fracture was observed at approximately 128 mASL in both the north and south extraction areas. Photographs from the site inspection are included in Appendix D.

3.3 Subsurface Investigation

3.3.1 Diamond Drilling, Core Recovery, Core Logging

Diamond drilling was completed on December 9th and 10th, 2013 by George Downing Estate Drilling Ltd., under the supervision of MH staff. A single core hole named BH 13-01 was drilled to 35.05 m depth in the northwest corner of the property. The coring bit was HQ sized, leaving a 96 mm diameter borehole, and returning a 63 mm diameter core.

A total of twenty-four (24) core runs of between 0.5 m and 1.5 m were collected into 15 core boxes. Micritic limestone of the Gull River Formation was encountered that was generally medium-grained, moderately bedded, and moderately hard. Above 12.5 m depth, the limestone was occasionally interbedded with lime mudstone. Between 12.5 and 19 m depth the lime mudstone beds increased in frequency and thickness (up to 10 cm). Grey-green argillaceous lime mudstone was noted below 25 m depth.

Horizontal clay/shale filled fractures were noted in every core run, while vertical fractures were noted only twice: near the surface, and at approximately 21 m depth. Borehole logs are provided in Appendix B.

3.3.2 Rock Drilling and Rock Chip Logging

Rock drilling was carried out at BH 12-01 to BH 12-03 by Cruickshank Construction Ltd. using a Furukawa HCR1200 track mounted Rock Drill on December 14th, 2012 under the supervision of MH staff.

All three boreholes were terminated at approximately 40.2 m depth. Light to dark grey limestone was encountered in all three boreholes, underlain at various depths by light to greenish grey limestone. Borehole logs are provided in Appendix B.

3.3.3 Downhole Geophysical Logging

Downhole geophysics was carried out by Notra Inc. of Ottawa in DDH 10-01, BH 11-02, BH 11-03, BH 11-04, BH 12-01, BH 12-02, BH 12-03, and BH 13-01. The geophysical logging on all but BH 13-01 and on BH 13-01 was carried out on December 18th, 2012 and December 10, 2013, respectively. Natural gamma rays, temperature and resistivity were measured in the 2012 investigation, while only natural gamma rays were measured in the 2013 investigation.

Correlation of the natural gamma between all eight boreholes was conducted by NOTRA Inc., and the elevation of a marker location was determined in each borehole. The best fit plane through the marker locations, determined using a solver, dips 3.6 m per kilometre to the north, and 2.2 m per kilometre to the east. This provides a useful sense of the strike and dip of the strata, which is shown in cross-section in Figures 3, 4, 5, and 6.

The results of the geophysical testing are provided in Appendix E.

3.4 Water Investigation

3.4.1 Groundwater Level and Hydraulic Testing of Open Holes

Ground water levels were measured and rising head tests were carried out in BH 13-01 and in the existing open holes between December 11 and 18, 2013. The results of the water level monitoring are presented in Table F2 in Appendix F, while the results of the rising head tests are presented in Appendix G and summarized in Table 3 below.

Table 3: Hydraulic Conductivities Measured in Open Holes

BH	Hydraulic Conductivity (m/sec)
DDH 10-01	1×10^{-8}
BH 11-02	3×10^{-8}
BH 11-03	4×10^{-11}
BH 11-04	3×10^{-6}
BH 12-01	1×10^{-7}
BH 12-02	2×10^{-5}
BH 12-03	4×10^{-7}
BH 13-01	6×10^{-8}

These hydraulic conductivity results indicate that the highest hydraulic conductivities were measured in the open holes closest to the escarpment (BH 12-02 and BH 11-04), and that the hydraulic conductivity can be said to decrease with distance northwards away from the escarpment. These results are consistent with the findings in the GRI (1995) report.

Packer testing was carried out in BH 13-01 in 2.74 m (9 ft) intervals with no overlap from 33.64 m depth to 3.46 m depth and again from 4.26 m depth to 1.52 m depth. Gauge pressures of approximately 50 psi were measured in all tests, while injection flow rates in all tests but one were too small to be measurable (i.e., “no-flow”). All tests were performed with approximately five minutes duration.

In the test interval from 30.9 m to 28.16 m, a flow rate of 2.9 litres per minute was measured, which translates to a hydraulic conductivity of 4×10^{-8} m/sec. This is consistent with the hydraulic conductivity measured in the open hole. The results of the packer testing are presented on the borehole log for BH 13-01 in Appendix B.

3.4.2 Piezometer Installation

Based on the result of the open-hole hydraulic testing, it was decided to install three piezometers in each of BH 11-02, BH 12-02, BH 12-03, and BH

13-01. Piezometers were constructed as designed except at BH 12-02, where the uppermost piezometer could not be installed due to a plug of bentonite pellets in the upper part of the hole. Details of the piezometer installations are included in Appendix B and summarized in Table F1 in Appendix F.

3.4.3 Groundwater Level and Hydraulic Testing of Piezometers

Groundwater levels were measured and rising head tests were carried out on all but one of the newly installed piezometers between December 18 and 19, 2013. Piezometer BH 11-02C had become flooded to the top of its casing during installation (a sign of impermeable rock), and had frozen solid before the water level could be measured or the rising head test performed. The results of the water level monitoring are presented in Table F2 in Appendix F, while the results of the rising head tests are presented in Appendix G and summarized in Table 4 below.

Table 4: Hydraulic Conductivities Measured in Piezometers

BH	Hydraulic Conductivity (m/sec)
BH 11-02A	3×10^{-9}
BH 11-02B	1×10^{-7}
BH 11-02C	n/a (dry)
BH 12-02A	8×10^{-7}
BH 12-02B	4×10^{-10}
BH 12-02C	n/a (dry)
BH 12-03A	6×10^{-12}
BH 12-03B	8×10^{-10}
BH 13-01A	2×10^{-7}
BH 13-01B	1×10^{-9}

It is noted that the hydraulic conductivities of the piezometers installed in BH 12-2 and BH 12-3 are lower than those measured in the respective open holes. The difference may be attributed to sealing of permeable zones with bentonite during installation of the piezometers, or to leakage of surface water through the bottom of the ungrouted casing during the open-hole recovery test (unlikely for BH 12-2 since the static level is several metres below the casing), or to some sort of wellbore storage mechanism unaccounted for in the Hvorslev analysis method. No specific water bearing zone was noted in either borehole during drilling, and the hydraulic conductivity measured in the open holes (especially BH 12-2) seems anomalously high relative to all other evidence.

3.4.4 Monthly Groundwater Monitoring / Static Water Levels

In order to determine static water levels in the newly installed piezometers, and to observe seasonal variations in groundwater level, monthly groundwater level monitoring was carried out from late 2013 onwards (with a break during the coldest winter months). The results of the water level monitoring are summarized in Table F2 in Appendix F and shown as a time-series on Figure 8 in Appendix A. Seasonality and other temporal trends are difficult to discern in the data, and the levels tend to fluctuate by less than one metre. Based on inspection, the water levels from December 4, 2015 were chosen for further presentation on borehole logs in Appendix B, and on plan view drawings and cross-sections in Appendix A.

The data indicate high groundwater levels (i.e., close to ground surface) and low vertical hydraulic gradients in the wells furthest north of the escarpment (BH 11-02 and BH 13-01). Along with the hydraulic conductivity results, this data tends to support the supposition that the bedrock rock mass contains no significant hydrostratigraphy, is of low permeability, and is not under-drained by the escarpment.

The data indicate reasonably high groundwater levels (i.e., close to ground surface) in the upper piezometers in the wells closest to the escarpment (BH 12-02 and BH 12-03), and much lower groundwater elevations in the lower piezometers. These strong gradients, and the hydraulic conductivity results imply that there is a permeable zone at depth which is drained by the escarpment.

3.4.5 Groundwater Sampling Results

Based on the results of the hydraulic testing, the following open holes and piezometers were selected for analytical testing of groundwater: BH 11-02B, BH 11-04, BH 12-02A, BH 12-03A, and BH 13-01A. The sampling was carried out on December 19, 2013. Table H1 in Appendix H presents the results from the groundwater chemistry analysis, and highlights exceedances of ODWQS or PWQO criteria limits.

The water quality results indicate quality typical of water from a limestone aquifer, with several general or inorganic parameters (hardness, chloride, sulphate, dissolved organic carbon, turbidity, sodium, and iron) exceeding operational or aesthetic ODWQS, and several parameters (typically metals) exceeding PWQO. Dissolved metals in mineralized groundwater are natural, and the metals concentrations (aluminum, boron, cadmium, cobalt, copper, iron and zinc) above PWQO are expected. In a natural setting, these concentrations would be diluted below PWQO upon mixing of the discharging groundwater with surface water. The groundwater quality results indicate that metals concentrations should be monitored in the quarry discharge.

3.4.6 Domestic Well Survey and Sampling Results

The domestic well survey was carried out in two rounds. Round One was intended to assess only wells within 500 m of the westernmost part of the expansion area, and was carried out from February 12 to March 24, 2015. Round Two was intended to assess all wells within 500 m of the existing quarry and proposed expansion, and was carried out from May 5 to May 7, 2015. The results of both rounds of well survey are reported in this section.

Thirty-seven property parcels with buildings were identified within 500 m of the existing quarry and proposed expansion. The locations are shown on Figure 1 in Appendix A and are listed here:

- 2440, 2506, 2514, 2630, 2643, and 2659 Burbrook Road;
- 1985, 1986 ,1989 ,1995,1998, 2003-2005, 2034, 2039, 2075, 2085, 2130, 2147, 2150, 2166, 2217, 2242, 2243, and 2250 Cordukes Road;
- 2257, 2260, 2265, 2271, 2295, 2296, 2309, 2467, 2528, 2559, 2604, 2610, and 2611 Unity Road

It is noted that 2130 Cordukes Road was surveyed twice on request of the resident. In addition to the above locations, 2196 Unity Road was also surveyed on request of the resident. The results of the survey including the distances of the identified wells from the quarry are included in Appendix I.

All thirty-eight locations were visited over the two rounds of well survey carried out. The following addresses declined to participate in the survey or were unavailable at the time of the survey:

- 2659 Burbrook Road;
- 1995 and 2034 Cordukes Road;
- 2295, 2528 and 2610 Unity Road

Based on the survey of the remaining properties, the following nine properties were reported to not have a well in use on the property:

- 1985 and 2039 Cordukes Road;
- 2257, 2260, 2265, 2271, 2467, 2559, and 2611 Unity Road

Of the remaining twenty-three locations with wells, a total of twenty-nine wells were identified (six locations had two wells on their property). All wells but one were bedrock wells. Four of the twenty-nine wells were reported to be dug wells and the remaining were all drilled. The depth and static water level in each well were either measured with owner's permission or reported by the owner. The well depths for dug wells ranged from approximately 3 m to 6 m below top of casing (mBTOC) with the static water level ranging between approximately less than 1 mBTOC and up to 2 mBTOC. The well depths for drilled wells ranged from approximately 12 mBTOC to 74 mBTOC with the static water levels ranging between approximately 4 mBTOC and 27 mBTOC.

The water quality in all twenty nine wells were reported to have high hardness with 2 wells reported to be salty (with depths of 36.8 mBTOC and 46.5 mBTOC) and 4 wells reported to have sulphur odour from time to time (with depths between 3.4 and 30.5 mBTOC). Two residents, both on Unity Road, reported slow recharge observed in their wells with one of the wells no longer being used. None of the remaining residents had any issue with quantity of water in their wells.

A total of twenty-five groundwater samples were collected and submitted to lab for analysis. This included any duplicate sampling on resident's request. Some wells could not be sampled as they were no longer in use. The results were compared to the Ontario Drinking Water Quality Standards (ODWQS). All wells tested had hardness (as $CaCO_3$) outside the operational guideline range in the ODWQS. Bacteria (E.coli and/or total coliforms) were detected in fourteen wells and the owners were notified immediately by phone. Four wells were observed to have sodium and chloride concentrations exceeding the ODWQS aesthetic objectives, with sulphate concentrations also exceeding the aesthetic objectives in one of the four wells. Sodium, turbidity, and field temperature readings were also observed to exceed the aesthetic objective at three separate wells. No metal exceedances were observed in any well tested. The lab results are included in Appendix H Table H2a for metals and Table H2b for general chemistry.

The results of the domestic well survey suggest that the area bedrock does not produce abundant groundwater. It is inferred that the availability of groundwater is highly dependent on wells intersecting water-bearing fractures. Generally the best water supplies are found when drillers are fortunate enough to intersect a significant water bearing fracture at shallow depth, leading to a fresh, locally recharged water source.

3.4.7 Surface Water Inspection and Sampling Results

The surface water inspection was carried out on May 29, 2014. Drainage of the existing north quarry was observed to be via a pump with its inlet set in a sump established in southeast corner. A sample of the discharge from this sump was collected, with sample ID "E-SW1". The discharge line runs southward through a culvert which traverses beneath the pipeline corridor and discharges into a drainage ditch established by Cruickshank.

Drainage of the existing south quarry has historically been via pumping and/or gravity drainage through a channel cut in the rock in the south east corner. On the day of the inspection there was no flow through this channel, although a sample was collected from the standing water, with sample ID, "E-SW-3". There have been recent changes in the quarry which have changed the use and discharge of surface water in the south part of the quarry.

The first recent change to quarry operations was that the wash plant was moved from the north quarry to the south quarry. Two sedimentation ponds have been established for the wash plant with a pump for removal of excess water during storm events. The discharge from the pump is directed towards an overflow sedimentation pond which flows by gravity into the aforementioned drainage ditch on the east side of the quarry. On the day of the inspection, there was no water being pumped from the wash plant sedimentation ponds and no water flowing out of the overflow sedimentation pond, but a sample of ponded water from the drainage channel was collected, with sample ID "E-SW2".

The second recent change to quarry operations was extraction of rock towards the southwest, creating a new low point below the level of the wash plant in the southwest corner of the quarry. This low point is below the level required for gravity drainage. There was no pump in this area on the day of the site inspection, and there was standing water at the low point of the quarry floor.

The drainage ditch which receives water from both the north and south quarries crosses the south east corner of the south quarry and continues southward over the escarpment. It crosses below the K&P trail (a former rail line) through a culvert (Culvert 1 in Figure 1 in Appendix A), before being joined by the tributary of Collins Creek which drains the Elginburg village area. On the day of the inspection there was no flow in the culvert.

The only defined drainage feature of the expansion area is a very shallow ditch which appears to drain the most northerly part of the expansion area, and to convey water from the municipal ditch on the south side of Unity Road. The drainage ditch appears to flow to the south, but becomes undefined approximately 160 m south of Unity Road. The land in this area is very flat, but the regional topographic gradient is towards the southwest.

The surface water quality results from the three collected samples are included in Table H3a (metals) and H3b (PHC and general chemistry) in Appendix H. The results indicate much lower concentration of general and inorganic parameters than in the groundwater. Only aluminum (E-SW1 and E-SW3), boron (E-SW1) and zinc (E-SW1) were present in concentrations marginally above the PWQO.

3.5 Calculations

3.5.1 Results of the Conceptual Modelling

The bedrock potentially affected by the quarry operation, through extraction or through dewatering, is the upper and middle units of the Gull River Formation. The results of the study support the definition of a north- and east-dipping layer-cake hydrostratigraphic model for the bedrock.

Based on the evidence, an aquitard exists from ground surface to approximately 7 m below the bottom of the grey-green argillaceous lime mudstone in the middle member of the Gull River Formation, as shown in the cross sections of Figures 3, 4 and 5 in Appendix A. The bulk hydraulic conductivity of this aquitard is presented as $6x10^{-9}$ m/s, which is the geometric mean of those measured in open holes DDH 10-01, BH 11-03, and BH 12-01, and in piezometers BH 11-02A and B, BH 12-02B, BH12-03B, and BH13-01A and B).

The December, 2015 groundwater elevations in the aquitard are shown in cross section on Figures 4, 5, and 6 and the water table is shown in plan view on Figure 9 in Appendix A. Strong vertical hydraulic gradients of 0.69 and 1.3 are observed within the aquitard between the deep (A) and intermediate (B) piezometers at BH 12-02 and BH12-03, respectively. Strong horizontal hydraulic gradients of 0.1 and 0.2 are observed within the aquitard between the shallow interval and the quarry floor at MW-2 and DDH 10-01, respectively.

Groundwater flow within the aquitard is most likely to be downwards towards any underlying aquifer (i.e., over a distance of less than 100 m) rather than horizontally towards the escarpment or quarry. Very localized quarry-related influence has been inferred for the drawing of the water table in Figure 9, and quarry-related drawdown has been noted at MW-3 which is less than 30 m from the extraction area. Other than that, the minimal quarry-related influences observed in the groundwater level monitoring data for the existing quarry (see Figures 7 and 8 in Appendix A) supports this supposition.

Below the aquitard, a confined aquifer is identified in the southern part of the expansion lands which appears to extend westward to an area of reliable water supply on Cordukes Road (2130, 2150, and 2166 Cordukes Road). The depth of the confined aquifer within the geological sequence (see cross sections) is based mainly on the observation of higher permeability *and* lower groundwater elevations in the deep (A) interval at BH 12-02 and in the open hole at BH 11-04, and lower groundwater elevation (in the absence of higher permeability) in the deep (A) interval at BH 12-03. The fact that open holes BH 12-01, DDH 10-01 and piezometer BH 12-03A penetrate this hydrostratigraphic zone, but show no to only a slightly enhanced permeability indicates the fracture-dependency of this aquifer and/or the lack of escarpment-related weathering.

The December, 2015 groundwater elevations in the confined aquifer are shown in plan view on Figure 10 in Appendix A. A horizontal hydraulic gradient of 0.04 is observed between the on-site monitoring wells and the residences on the east side of Cordukes Road. Groundwater flow within the confined aquifer is towards to escarpment.

The confined aquifer has not been proven anywhere but in the area of potentiometric lines shown in Figure 10 of Appendix A. North of the expansion lands, the confined aquifer has not been proven due to its depth, although some supply of salty water is known to exist at depth in this area.

3.5.2 Estimated Drawdown During Quarry Operation

Based on the conceptual model, it is recommended that the part of the quarry expansion in Lot 12 be contained vertically within the confines of the aquitard, and that it not extent into the confined aquifer. To that end, the floor of the quarry is assumed to be no lower than 115 mASL in Lot 12 in all calculations.

A measure of the radius of influence of the quarry when fully contained within the aquitard was determined as 7 m using the method of Sichart and Kyrieleis (Equation 2 in Section 2.5), based on a maximum drawdown, s_{qry}, of 30 m at the quarry wall and using the geometric mean of the aquitard ($6x10^{-9}$ m/s) as K. This is an underestimation due to the influence of discrete water bearing fractures being intersected by the quarry, and because of other factors not considered in the method such as the large size of the excavation

Another method to estimate the radius of influence is to assume that future horizontal hydraulic gradients will be similar to those observed in proximity to the existing quarry. In this case each metre of drawdown at the quarry wall can be roughly translated to a 10 m radius of influence. At the Lot 11/12 boundary where 18 m of drawdown is anticipated within the aquitard, a 180 m radius of influence can be inferred.

Based on the above, a radius of influence of 300 m was assumed for the three lift part of the quarry (floor of 103 mASL), and a radius of influence of 180 m was assumed for the two lift part of the quarry (floor of 115 mASL). Using Equation 3 in Section 2.5.1 to calculate the distance to intermediate drawdown contours, the results of this assessment are presented on Figure 9.

Inspection of the cross sections in Figures 4 and 5 in Appendix A indicates that the three lift part of the quarry floor (103 mASL) would extend below the bottom of the aquitard, as estimated, south and west of BH12-01. At BH12-02, where the potentiometric surface is approximately 110 mASL, a dewatered quarry with floor elevation of 103 mASL would translate to a drawdown of approximately 7 m in the aquifer. This amount of drawdown is not considered to have a radius of influence greater than that conservatively estimated for the quarry fully contained in the aquitard for the following reasons:

1. The westerly edge of the three lift part of the quarry is almost 400 m east of the westerly edge of the two lift part of the quarry (that is it is almost 400 m further from the receptors);

2. The aquifer does not appear to have a high bulk hydraulic conductivity (e.g., BH12-03A has very low permeability, and the only high permeabilities, being BH12-02A, and BH11-04 appear escarpment-related);

3. The “bottom of aquitard”, as shown in the cross sections, and being 7 m below the bottom of the grey-green argillaceous limestone, is an upper bound (e.g., the high permeability in BH12-02A was measured below 101 m ASL).

3.5.3 Estimated Inflow During Quarry Operation

The rate of groundwater inflow to the existing south quarry was very approximately estimated to be less than 1 m^3 per day based on visual observations of ice build-up between November 25, 2013 and January 10, 2014, as described in Section 2.5.2. The analytical method described in Section 2.5.2 could not be used to calculate a comparable inflow rate because the inflowing groundwater was judged to be locally and very recently recharged groundwater from the unsaturated zone, whereas the model is applicable to steady state flow below the water table. For comparison however, a groundwater inflow rate for the existing north quarry was calculated using the analytical method described in Section 2.5.2 as 0.6 m^3 per day (this value was calculated using the aquitard geometric mean hydraulic conductivity of $6x10^{-9}$ m/s).

A groundwater inflow rate for the fully expanded quarry at full extraction was calculated using the analytical method described in Section 2.5.2, using the parameters shown in Table 5. To provide an estimate for the entire quarry the hydraulic conductivity was calculated as the geometric mean of the hydraulic conductivities identified in each open hole and all piezometers (presented in Table 1, Table 3 and Table 4). The highest observed head and a 250 m predicted radius of influence were used to obtain a groundwater inflow rate of 260 m^3/day. Approximately half of this flow would enter the north quarry and half the south, but an amount must be included to account for seasonal inflow from the unsaturated zone (as has been seen in the quarry, and which is shown in photographs in Appendix D).

Table 5: Groundwater Inflow Calculation

Parameter	Value	
K	$6x10^{-8}$	m/sec
Aquifer Thickness	100	m
T	$6x10^{-6}$	m^2/sec
h_{inner}	103	m
h_{outer}	133	m
r_{inner}	600	m
r_{outer}	850	m
Inflow Rate	260	m^3/day

It is noted that the calculated groundwater inflow rate is lower than the rates previously calculated for the PTTW application (see Section 3.1.5), which is a result of the lower bedrock permeabilities included in the updated geometric mean hydraulic conductivity value. This serves to highlight the uncertainty surrounding the actual inflow rates. All other evidence suggests that the rock in the area is of very low hydraulic conductivity and the groundwater inflow rates to the quarry will be low relative to other quarries of similar size. For lake filling calculations, 260 m^3/day flowing into each of the north and south quarry is assumed.

3.5.4 Estimated Lake Levels Following Rehabilitation

The level in the lake north of the pipeline was estimated to be 125 mASL. This is the approximate elevation of the culvert which presently traverses beneath the pipeline on the east side of the quarry, and is approximately 5 m below the low point of the quarry rim. Even if the culvert becomes blocked, it is difficult to imagine the lake level rising above this level due to the presence of fractures and weathered rock in the upper part of the rock pillar holding up the pipeline which will separate the north and south quarries. Water from the north lake will flow through the culvert and/or the shallow weathered rock and into the south lake.

The level in the lake south of the pipeline was estimated to be 110 mASL. This is approximately equal to the present day water table elevation at the south end of the quarry. According to this estimate, the water in the south lake will flow as groundwater through the pillar of bedrock which will remain between the quarry and the escarpment, and will discharge to the tributary of Collins Creek at the toe of the slope.

3.5.5 Water Balance and Lake Filling Time

Lake filling times for both the north and south quarry were calculated using the method described in Section 2.5.4 and the parameters and outputs shown in Table 6.The filling time and groundwater proportion for the north quarry was estimated at 28 years and 41%, respectively and the filling time and groundwater proportion for the south quarry was estimated at 13 years and 31%, respectively. In these calculations, the lake evaporation rate was assumed to be lower than typical values seen in the Atlas of Canada as the lake will be shaded much more than a typical lake.

Table 6: Lake Filling Calculations

Parameter or Output	North Quarry		South Quarry	
Precipitation Rate	960	mm/year	960	mm/year
Catchment Area	52	hectares	82	hectares
Precipitation Input	499,200	m^3/year	787,200	m^3/year
Evaporation Rate	650	mm/year	650	mm/year
Evaporation Area	41	hectares	74	hectares
Evaporation Output	266,500	m^3/year	481,000	m^3/year
Groundwater Inflow Rate	260	m^3/day	260	m^3/day
Filling Rate	327,665	m^3/year	401,165	m^3/year
Lake Depth	22	m	7	m
Lake Volume	9,020,000	m^3	5,180,000	m^3
Filling Time	28	years	13	years
Proportion of H_20 as GW	29	%	24	%

As a sensitivity analysis due to the uncertainty associated with inflow rates, a value of 2,000 m^3/day was substituted for the 260 m^3/day specified in Table 6. This reduced the north and south lake filling times to 9 years and 5 years, respectively, and increased the groundwater proportions to 76% and 70%, respectively.

3.6 Stormwater Management Considerations

Based on discussions with Cruickshank, the following stormwater management options are proposed:

1) A berm will be constructed in the 30 m offset south of Unity Road where the northerly part of the expansion area abuts Unity Road. This berm will prevent the southwards flow of water from the municipally-owned ditch (there is presently a very shallow southwards-running ditch on the expansion lands, see Section 3.4.7), and will force the water to flow either west or east. Ideally, the berm and ditching would be adjusted to encourage the water to flow westwards, which will allow it to discharge to a southwards-running ditch on the south side of Unity Road approximately 260 m west of the western property line of the expansion area. This ditch connects to the tributary of Collins Creek, effectively routing the drainage the same point that it currently arrives at, via a different route.

2) The berm around the south end of 2467 Unity Road will prevent southerly drainage of water from this property. Gravity drainage of this water can only occur into the quarry expansion lands, through a culvert or break in the berm designed for such a purpose.

3) Stormwater from the northern quarry will continue to be directed to a sump in the southeast corner of the existing quarry, where it will drain via gravity or by pumping through the culvert below the pipeline and into the drainage ditch. Depending on the levels of the quarry floor, an intermediate pumping step may be required. Expansion of the quarry footprint is not anticipated to change the quality of the water being discharged to the ditch. The taking from the northern quarry allowable under the existing PTTW will likely be sufficient until expiry of the PTTW in 2022.

4) Stormwater from the southern quarry will continue to be discharged via gravity drainage or pumping. The taking from the southern quarry allowable under the existing PTTW will likely be sufficient until expiry of the PTTW in 2022.

5) Cruickshank has submitted an application for Environmental Compliance Approval (ECA) for a large self-draining sump in the southwest corner of the existing quarry. The design includes an excavation in the rock down to approximately 110 mASL with sufficient volume to capture storm flows of a specified size/return period. The sump will be self-draining over extended periods as the water table in this area will be approximately coincident with the elevation of the sump floor. The sump will provide a location for sedimentation, and the discharge from the sump will travel briefly southward through the rock before discharging to the surface water feature at the toe of the escarpment. The monitoring system proposed for the sump includes collection and analysis of surface water samples during periods of direct discharge, and collection and analysis of groundwater samples from down-gradient of the sump.

4. IMPACT ASSESSMENT

4.1 Impact on Wells and Aquifers

Impacts on wells are assessed on an individual basis or group basis in Table 7. Refer to Figure 1 in Appendix A for locations. Note that there is no well at 2467 Unity Road, and the house at 2559 Unity Road is abandoned. A cistern visible in the front yard indicates that there is no well at this property.

Table 7: Impacts on Local Wells

Well	Distance from Proposed Limits of Extraction	Depth	Impact
2528 Unity Road	More than 70 m	Unknown	This is the closest well to the quarry. Little is known about the well as the owner chose not to participate in the well survey. There is no evidence of a well in the front yard, however, which suggests that the well is at least 70 m and, unless it is inside the basement, likely more than 100 m from the proposed northerly edge of extraction. The water supply from the well, if it is fresh, is likely derived from a local source of recharge and is taken from a shallow fracture in the rock. If the water supply is salty, then it likely is derived from a deeper water bearing zone. The low permeability of the rock in this area suggests that, in the absence of a water-bearing fracture, drawdown from the quarry will not propagate to the well. If a very shallow water bearing fracture connects the well and the quarry, then a well impact is theoretically possible. The recommended seepage monitoring during quarrying in the final 250 m towards Unity Road in the western half of Lot 13 is designed to provide empirical data concerning any change in groundwater elevation over time. To address the possibility of quarry-related drawdown affecting this well, no extraction of the third lift (i.e., below 115 mASL) should occur within 250 m of this well. The grouting-based contingency plan is designed to mitigate the unlikely event of a well impact.
2604 Unity Road	440 m	5.5 m	This is a shallow dug well for outdoor use only. Given the rock permeability and the distance from the extraction area, the risk of impact is negligible.

Well	Distance from Proposed Limits of Extraction	Depth	Impact
2610 and 2611 Unity Road	430 m	Unknown	One of these two properties is on a cistern, while nothing is known of the depth of the well at the other. Given the rock permeability and the distance from the extraction area, the risk of impact is negligible.
2075, 2085, 2147, 2243, 2242, and 2250 Cordukes Road	465-500 m	21-44 m	These wells all show similar characteristics, with no major issues to the homeowner. Given the rock permeability and the distance from the extraction area, the risk of impact is negligible.
2130, 2150, and 2166 Cordukes Road	300-400 m	27 m	These wells all show similar characteristics, with no major issues to the homeowner. These are the closest wells to the westernmost limit of the quarry, and appear to take water from the same confined aquifer identified below the southern part of the expansion lands. To address the possibility of quarry-related drawdown affecting these wells, no extraction of the third lift (i.e., below 115 mASL) should occur west of the Lot 12/Lot 13 lot line. Given that they are presently more than 1 km from the closest area of existing extraction, there will likely be several decades of water level monitoring data available to discern any problematic water level lowering prior to the quarry expansion's approach to these wells. The recommended seepage monitoring during quarrying in Lot 12 (it alone is approximately 400 m in width) is designed to provide empirical data concerning any change in groundwater elevation over time.
2034 Cordukes Road	~150 - 350 m	Unknown	Little is known about the well as the owner chose not to participate in the well survey. Impacts to this well are assessed as being similar to those at 2130, 2150, and 2166 Cordukes Road.
1986 and 1998 Cordukes Road	360 m	19-37 m	These wells all show similar characteristics, with no major issues to the homeowner. These wells are intrinsically less susceptible to impacts than wells further to the north due to the lower ground surface. Given this fact, the rock permeability and the distance from the extraction area, the risk of impact is negligible.
1985, 1989, 1995, 2003-2005, 2039 Cordukes Road	450-500 m		Some of these properties had dry wells or no well, while the rest had typical bedrock wells, with no issues reported. Given the rock permeability and the distance from the extraction area, the risk of impact is negligible.

Well	Distance from Proposed Limits of Extraction	Depth	Impact
2440, 2506, 2514, 2630, 2643, 2659 Burbrook Road	300-500 m		By virtue of the ground surface elevation being below or just above the proposed quarry floor, and by virtue of their distance from the proposed quarry, the risk of impact is negligible.

In summary, due to the separation distances and the low permeability of the rock, the risk to well impacts is considered negligible in all wells except at 2528 Unity Road and at 2034, 2130, 2150, and 2166 Cordukes Road. To address the possibility of quarry-related drawdown affecting these wells, modifications to the quarry design are recommended, as is a monthly groundwater level monitoring program designed to discern problematic groundwater level lowering prior to well impacts.

Industrial use of the expansion lands presents a risk of accidental release of fuel, and/or other potential contaminants. There will be no run-off from the quarry, and all waters will be collected in the quarry sump where they may be treated in the event of a contaminant spill within the quarry. Water quality monitoring of groundwater down-gradient of a self-draining sump will be carried out as a condition of an applied-for ECA. It is concluded that the risk of contamination of aquifers and local water wells due to spilled fuel is negligible.

4.2 Impact on Surface Water

4.2.1 Flow Routing

A berm will be constructed in the 30 m offset south of Unity Road where the northerly part of the expansion area abuts Unity Road. This berm will prevent the southwards flow of water from the municipally-owned ditch (there is presently a very shallow southwards-running ditch on the expansion lands, see Section 3.4.6), and will force the water to flow either west or east. Ideally, the ditching would be adjusted to encourage the water to flow westwards, which will allow it to discharge to a southwards-running ditch on the south side of Unity Road approximately 260 m west of the western property line of the expansion area. This ditch connects to the tributary of Collins Creek, effectively taking the drainage the same point that it currently arrives at, via a different route.

In consultation with the property owner, drainage from 2467 Unity Road must be allowed to discharge at the southern end of this property by way of a culvert(s) or break(s) in the berm.

4.2.2 Flow Volumes

The very low permeability of the bedrock ensures that the upland portions (i.e., above the escarpment) of the two north-to-south flowing tributaries of Collin's Creek flows are not significantly fed by groundwater, and thus will not experience reductions in baseflow due to operation of the quarry sump. Groundwater discharge at the base of the escarpment may be reduced by the quarrying and pumping of the quarry sump, although the pumped water will be discharged back into the same ultimate receiver. Conversely, if a self-draining sump is incorporated into the design of the quarry, this will enhance groundwater discharge to the receiver at the base of the escarpment. No impacts in terms of the quantity of water present in surface water features are anticipated.

4.2.3 Water Quality

The quarry is currently dewatered using sumps and sedimentation ponds, and the water quality was acceptable on the day of the inspection. The expansion of the quarry is not anticipated to change the quality of the water being discharged, and no impacts to the surface water quality are anticipated. Cruickshank is considering options for a self-draining sump at the southwest corner of the existing quarry that will allow for pump-free discharge of storm water from the south quarry through a natural bedrock filter.

Industrial use of the expansion lands presents a risk of accidental release of fuel, and/or other potential contaminants. Spilled contaminants may migrate to the quarry sump, where there is potential for them to be discharged to surface water. This risk is low, and is mitigated by implementing prevention measures discussed in Section 5.

An Environmental Compliance Approval (ECA) for the treatment and disposal of industrial process wastewater from the quarry has been applied for by Cruickshank. Conditions of the ECA will almost certainly include a requirement for ongoing monitoring of contaminant levels in the discharge.

4.3 Impact on Existing Contamination

There are no existing groundwater contamination issues within the radius of influence of dewatering. No impacts to existing contamination are identified.

4.4 Impact on Anthropogenic Structures

Dewatering of the bedrock is not anticipated to result in significant consolidation of soils or bedrock. No impact to structures is anticipated.

4.5 Impact on Ecology

According to the natural environment technical report for the quarry expansion (Ecological Services, 2012), ecological receptors include a Sugar Maple dominated woodland and a potential reptile hibernacula (fractured exposed bedrock on a south facing slope, with field habitat further south), both on the escarpment.

It was confirmed by Rob Snetsinger of Ecological Services (personal communication, February 24, 2014) that neither of these receptors will be impacted by any potential changes in volume of groundwater discharge resulting from the operational plan. Therefore, no impacts to ecological receptors are anticipated.

5. ENVIRONMENTAL PROTECTION / MITIGATION

5.1 Recommended Monitoring Plan

The monitoring plan, with monitoring locations, depths, and frequencies, are shown on Figure 11 in Appendix A.

Monthly groundwater level monitoring is recommended in DDH 10-01. BH 11-02, BH 11-03, BH 11-04, BH 12-01, BH 12-02, BH 12-03, BH 13-01, the domestic well at 2528 Unity Road, and in the following three additional monitoring wells:

- Future Monitoring Well 1 (FMW-1) on the Lot 12-Lot 13 boundary, approximately 60 m south of BH 13-01, to be drilled prior to extraction within the western half of Lot 13,
- FMW-2 on the Lot 11-Lot 12 boundary at the northwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.
- FMW-3 on the Lot 11-Lot 12 boundary at the southwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.

Annual winter photographic seepage face monitoring is recommended on all available extraction faces within 250 m of Unity Road in the western half of Lot 13 and also in Lot 12. This would consist of taking one or more photographs of the rock face from static viewpoints, where possible based on quarry operations. The information will provide a record of seepage into the quarry in the winter when ice will form at key seepage locations.

This monitoring will provide data to verify the predicted groundwater drawdown; will provide useful data to address water well interference complaints, if any; and will allow for mitigation of impacts to receptors in case groundwater drawdown is greater than estimated. The groundwater level and seepage face monitoring will provide critical data to ensure the success of the grouting-based contingency plan, if enacted.

5.2 Recommended Contingency Plan

The impact assessment found that it is highly unlikely that the key receptors will be negatively impacted by the quarry dewatering. Notwithstanding this finding, groundwater level monitoring is recommended in strategically-located monitoring wells to observe any changes in groundwater level as quarrying progresses. This section provides a contingency plan to respond to specific events.

5.2.1 A Water Well Interference Complaint

If a water well interference complaint is received by Cruickshank, either directly or through other channels (i.e., the Ministry of Natural Resources or MOECC), and the complaint concerns a water well within 500 m of the licensed area, Cruickshank will:

1. Immediately provide an interim potable water supply (within 12 hours);
2. Notify the MOECC of the complaint (if they are not already aware);
3. Retain a qualified professional to conduct a site investigation, determine the cause of the interference, and provide recommendations to remedy the problem; and,
4. If it is found that the water well interference resulted from Cruickshank dewatering and quarry operations, the water supply will be restored to its original condition or replaced with an equivalent water supply. In the context of the monthly groundwater level monitoring program and annual seepage face monitoring, the unlikely event of a quarry-related water well interference will almost certainly be associated with a sudden event such as inadvertent extraction-related drainage of a discrete fracture zone tapped by a water well. That is the well interference will be correlated to a discrete inflow at the quarry wall.

Several options are available for restoration of an affected water supply. These may include adjustment to the well such as lowering the pump inlet; deepening an existing well; or drilling a replacement well. In the event that these methods are unsuccessful, a method will be chosen to seal up the inflow into the quarry which has caused the well interference. The most likely viable option to accomplish this will be to grout the discrete fracture zone using standard techniques used for this purpose in mines and open pits around the world. More information on the suitability of rock grouting as a contingency measure and the terms of reference for a pilot study are included in Appendix J. Another method for sealing the identified inflow may include backfilling the quarry wall with a suitable quantity of low-permeability soil. The final decision on method will be determined as in Point 3 of the list above, in consultation with MOECC, and all affected parties.

5.2.2 Monitoring Data Which Suggests a Potential Impact to a Receptor

If groundwater level monitoring data suggests greater-than-expected groundwater drawdown which is quarry-related; and if, based on the judgment of a qualified professional, there is a potential for this lowering to impact a receptor, Cruickshank will:

1. Modify quarry operations;
2. Consult with the potentially affected party;
3. Make provisions to mitigate the potential impact.

6. SUMMARY OF RECOMMENDATIONS

The following is a summary of recommendations made:

1. Monthly groundwater level monitoring is recommended in DDH 10-01. BH 11-02, BH 11-03, BH 11-04, BH 12-01, BH 12-02, BH 12-03, BH 13-01, the domestic well at 2528 Unity Road, and in the following three additional monitoring wells:
   - Future Monitoring Well 1 (FMW-1) on the Lot 12-Lot 13 boundary, approximately 60 m south of BH 13-01, to be drilled prior to extraction within the western half of Lot 13,
   - FMW-2 on the Lot 11-Lot 12 boundary at the northwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.
   - FMW-3 on the Lot 11-Lot 12 boundary at the southwest corner of the part of the expansion lands in Lot 12, to be drilled prior to extraction within Lot 12.
2. Annual winter photographic seepage face monitoring is recommended on all available extraction faces within 250 m of Unity Road in the western half of Lot 13 and also in Lot 12. This would consist of taking one or more photographs of the rock face from static viewpoints, where possible based on quarry operations. The information will provide a record of seepage into the quarry in the winter when ice will form at key seepage locations.
3. No extraction of the third lift (i.e., below 115 mASL) should occur within 250 m of the property at 2528 Unity Road, and west of the Lot 12/Lot 13 lot line.
4. A grouting pilot study may be considered during extraction of Lift 3 in Lot 13, if suitable conditions exist. The terms of reference for the study are included in Appendix J.
5. In consultation with the property owner, drainage from 2467 Unity Road must be allowed to discharge at the southern end of this property by way of a culvert(s) or break(s) in the berm.
6. The existing PTTW will be sufficient for dewatering of the existing quarry and the expansion area until its expiry in 2022. Upon renewal, it is recommended to combine the monitoring programs proposed in this report for the quarry expansion with the monitoring program for the existing quarry.

7. CLOSURE

We trust the information presented in this report meets your requirements. If you have any further questions or need addition details, please do not hesitate to contact our office.

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8. LIMITATIONS AND USE

This report has been prepared for the exclusive use of Cruickshank Construction Limited, by Morrison Hershfield Limited (Morrison Hershfield). Morrison Hershfield hereby disclaims any liability or responsibility to any person or party, other than Cruickshank Construction Limited, for any loss, damage, expense, fines, or penalties which may arise from the use of any information or recommendations contained in this report by a third party.

The report, which specifically includes all tables, figures and appendices is based on data and information collected during investigations conducted by Morrison Hershfield and is based solely on the conditions of the site at the time of the investigation, supplemented by historical information and data obtained by Morrison Hershfield as described in this report.

Morrison Hershfield has exercised professional judgment in collecting and analyzing the information and formulating recommendations based on the results of the study. The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to this study. No other warranty or representation, either expressed or implied, as to the accuracy of the information or recommendations included or intended in this report.

9. REFERENCES

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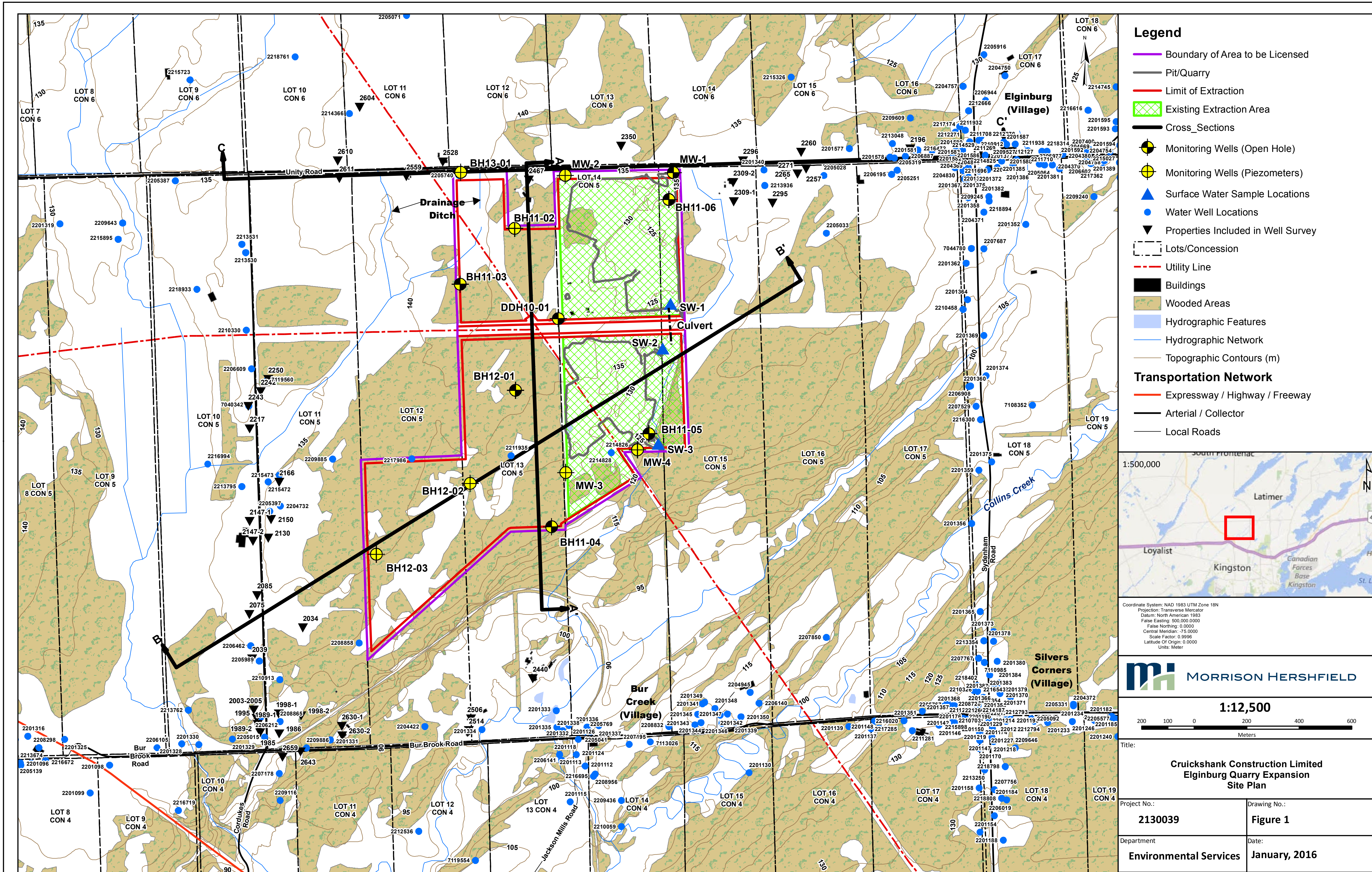
APPENDIX A: Figures


Legend
Boundary of Area to be Licensed
Pit/Quarry
Limit of Extraction
Existing Extraction Area
Cross_Sections
Monitoring Wells (Open Hole)
Monitoring Wells (Piezometers)
Surface Water Sample Locations
Water Well Locations
Properties Included in Well Survey
Lots/Concession
Utility Line
Buildings
Wooded Areas
Hydrographic Features
Hydrographic Network
Topographic Contours (m)
Transportation Network
Expressway / Highway / Freeway
Arterial / Collector
Local Roads
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Latimer
Loyalist
Kingston
Canadian Forces Base Kingston
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Title:
Cruickshank Construction Limited
Elginburg Quarry Expansion
Site Plan
Project No.:
2130039
Drawing No.:
Figure 1
Department
Environmental Services
Date:
January, 2016
Elginburg (Village)
Bur Creek (Village)
Silvers Corners (Village)
Unity Road
Bur Brook Road
Sydenham Road
Jackson Mills Road
Cordukes Road
Collins Creek
Drainage Ditch
Culvert
BH13-01
MW-2
MW-1
BH11-02
BH11-06
BH11-03
DDH10-01
SW-1
SW-2
BH12-01
BH11-05
SW-3
MW-4
MW-3
BH12-02
BH11-04
BH12-03
A
A'
B
B'
C
C'
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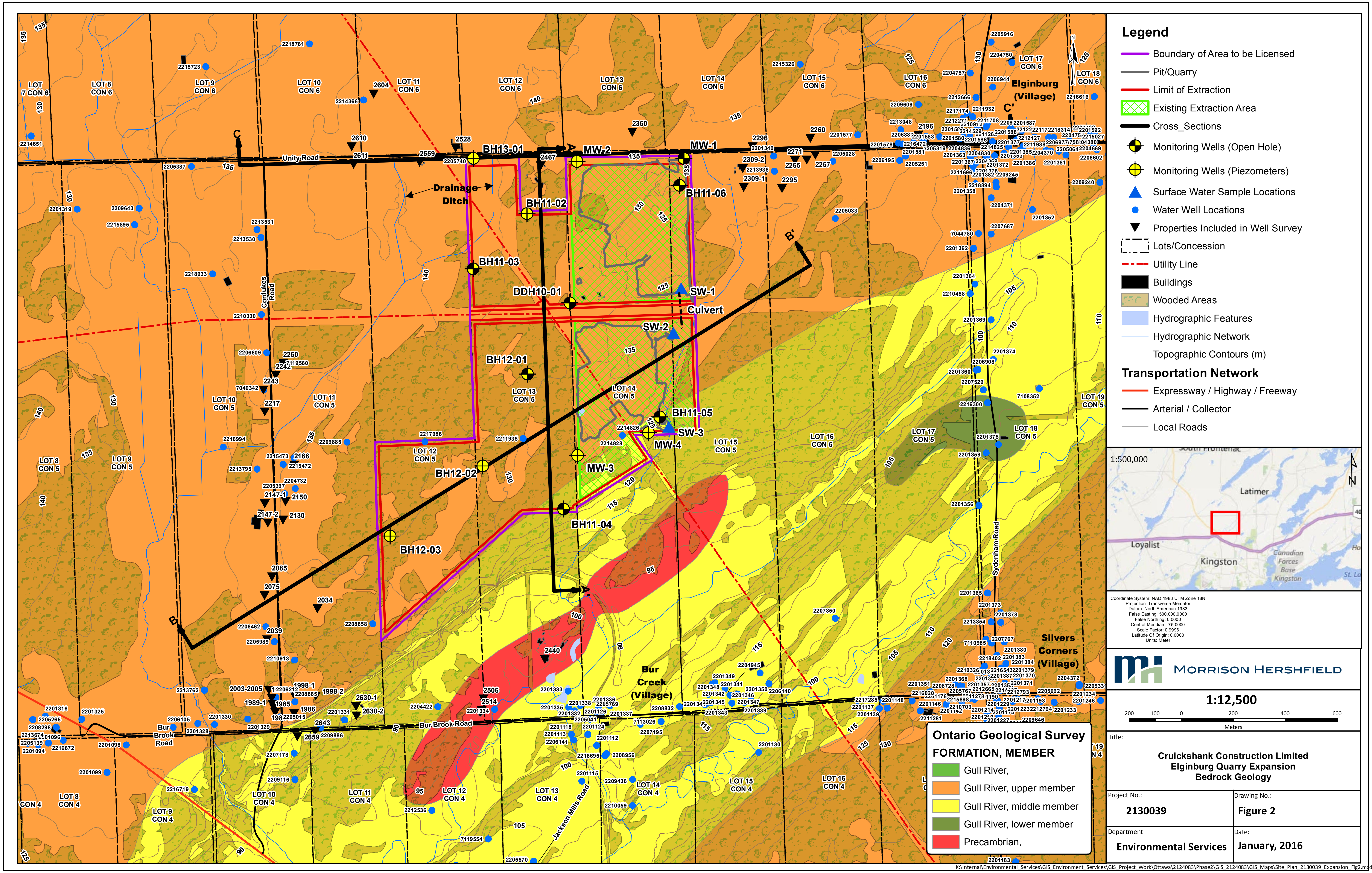
Legend
Boundary of Area to be Licensed
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Utility Line
Buildings
Wooded Areas
Hydrographic Features
Hydrographic Network
Topographic Contours (m)
Transportation Network
Expressway / Highway / Freeway
Arterial / Collector
Local Roads
Ontario Geological Survey
FORMATION, MEMBER
Gull River,
Gull River, upper member
Gull River, middle member
Gull River, lower member
Precambrian,
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Loyalist
Kingston
Canadian Forces Base Kingston
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Title:
Cruickshank Construction Limited
Elginburg Quarry Expansion
Bedrock Geology
Project No.:
2130039
Drawing No.:
Figure 2
Department
Environmental Services
Date:
January, 2016
Elginburg (Village)
Bur Creek (Village)
Silvers Corners (Village)
Unity Road
Burbrook Road
Sydenham Road
Jackson Mills Road
Cordukes Road
Drainage Ditch
Culvert
BH13-01
MW-2
MW-1
BH11-02
BH11-06
BH11-03
DDH10-01
SW-1
SW-2
BH12-01
BH11-05
SW-3
MW-4
MW-3
BH12-02
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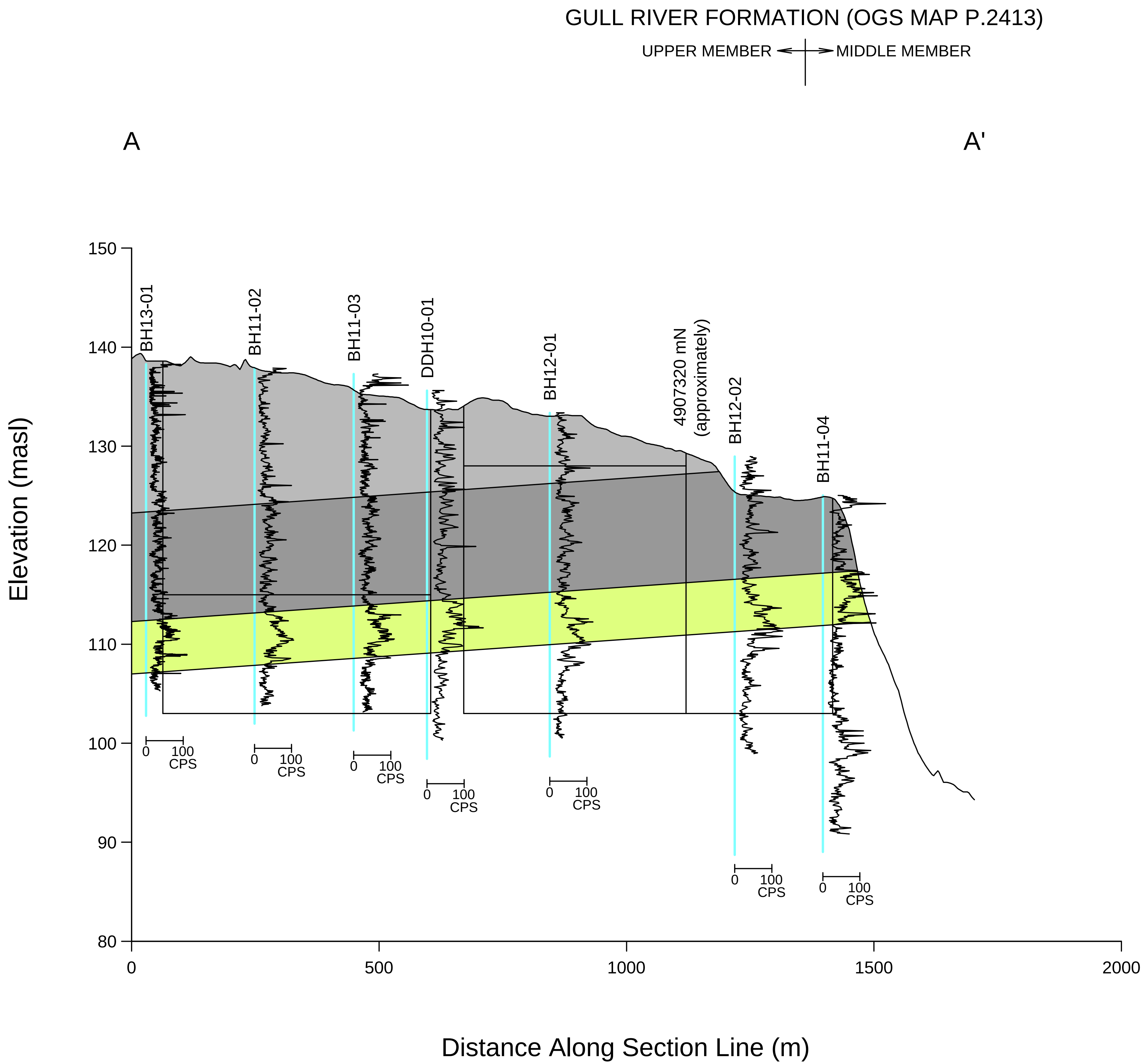
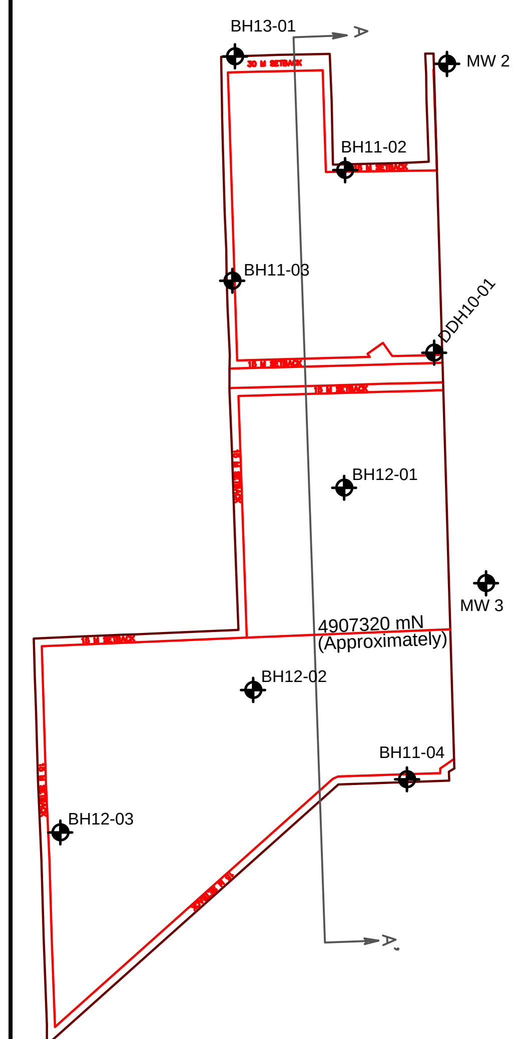


Legend

- Light Grey Limestone
- Limestone with Dark Grey Beds
- Limestone with Green Beds
- Limestone



MORRISON HERSHFIELD

Scale: See Axes

Title: Stratigraphic Model based on Geophysical Logging

Project No.: 2130039	Drawing No.: Figure 3
Department: Environmental Services	Date: January 16

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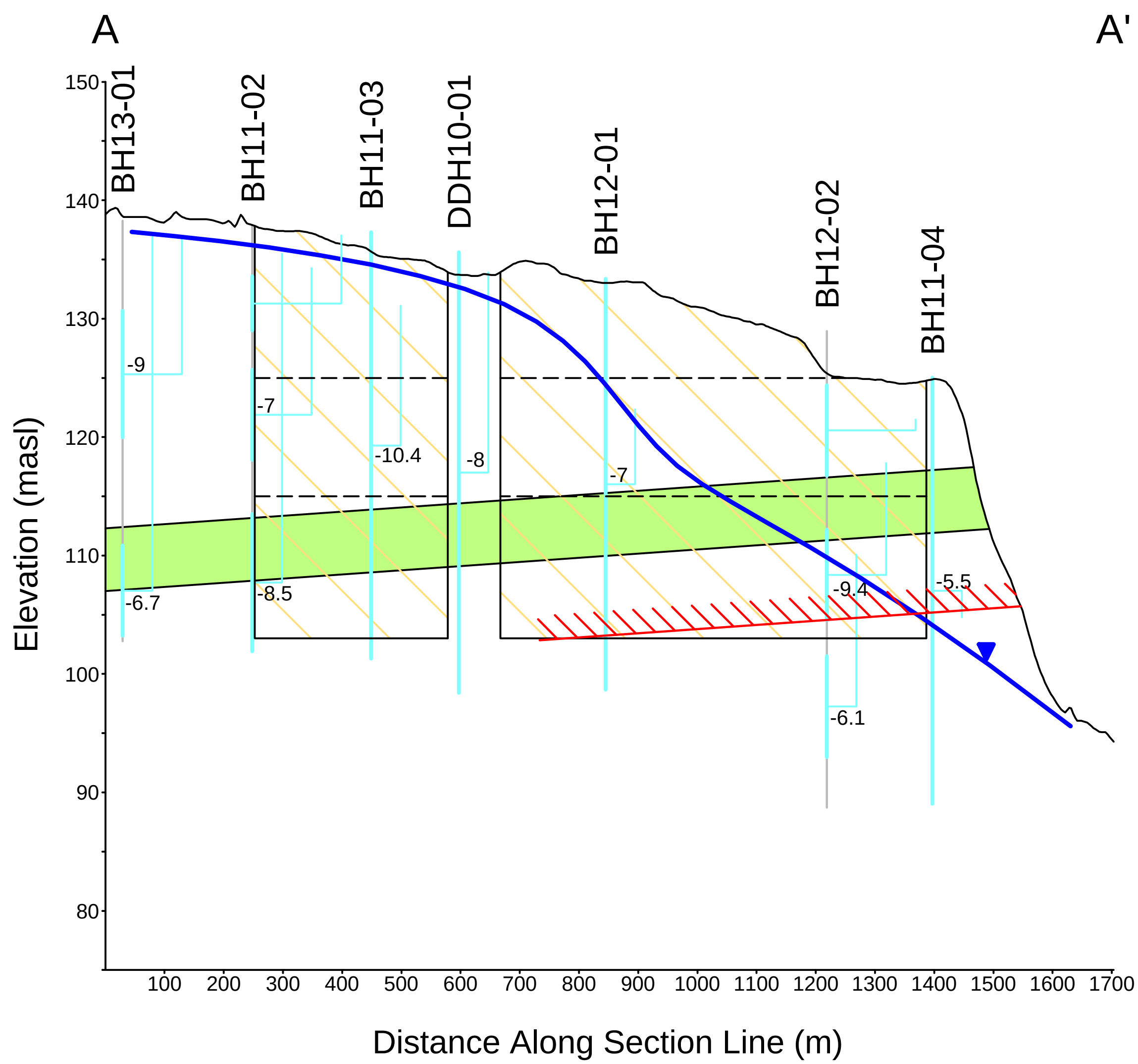


Legend

- Limestone
- Water Table or Deeper Potentiometric Surface
- Monitoring Well Interval
- Head Elevations, with log of measured Hydraulic Conductivities
- Bottom of Aquitard
- To be Licensed Extraction Area
- Limestone with Green Beds (Shows stratigraphic model only)

MORRISON HERSHFIELD

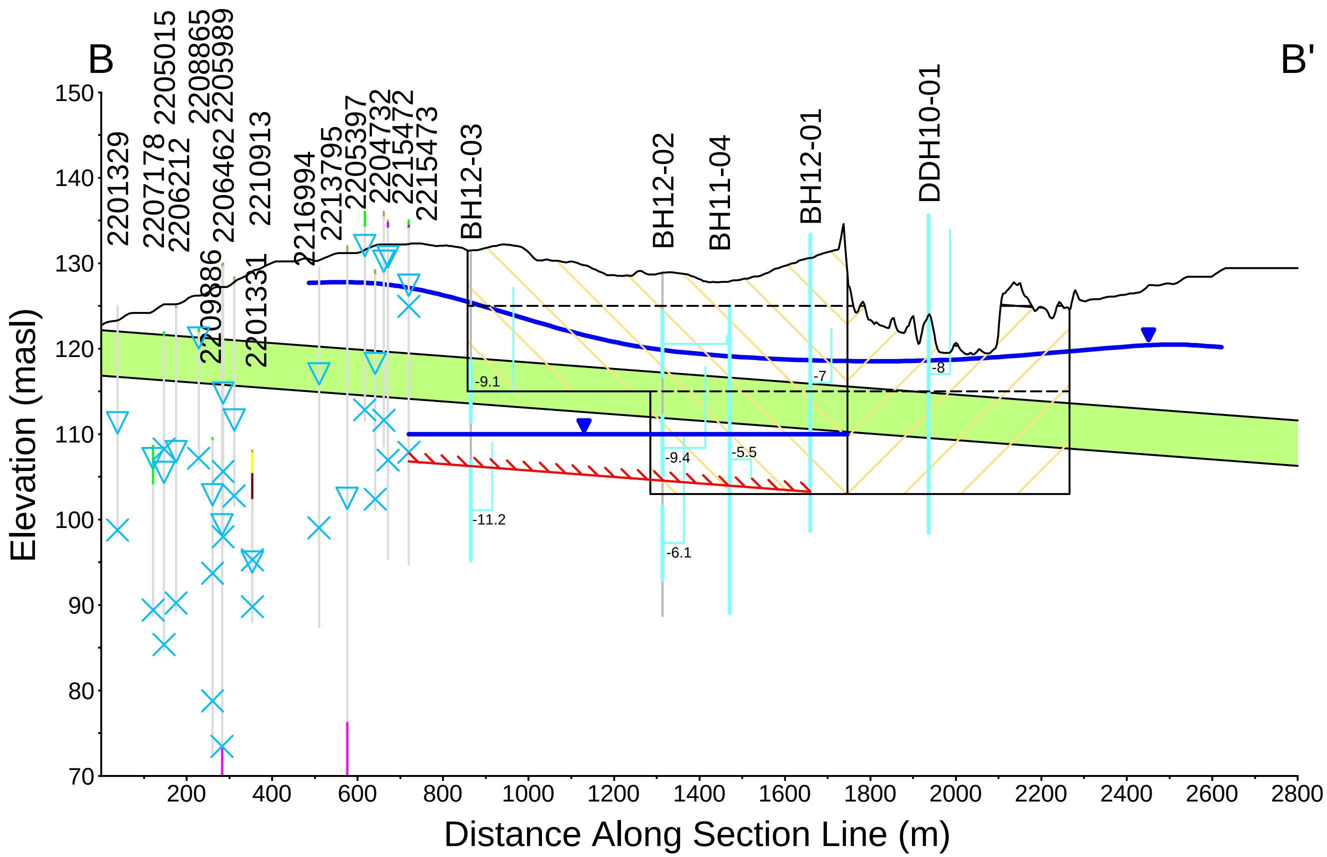
Scale:

See Axes

Title:

Cruickshank Construction Limited
Elginburg Quarry Expansion -
Hydrogeological Cross Section AA'

Project No.: 2130039	Drawing No.: Figure 4
Department: Environmental Services	Date: January 16



Legend

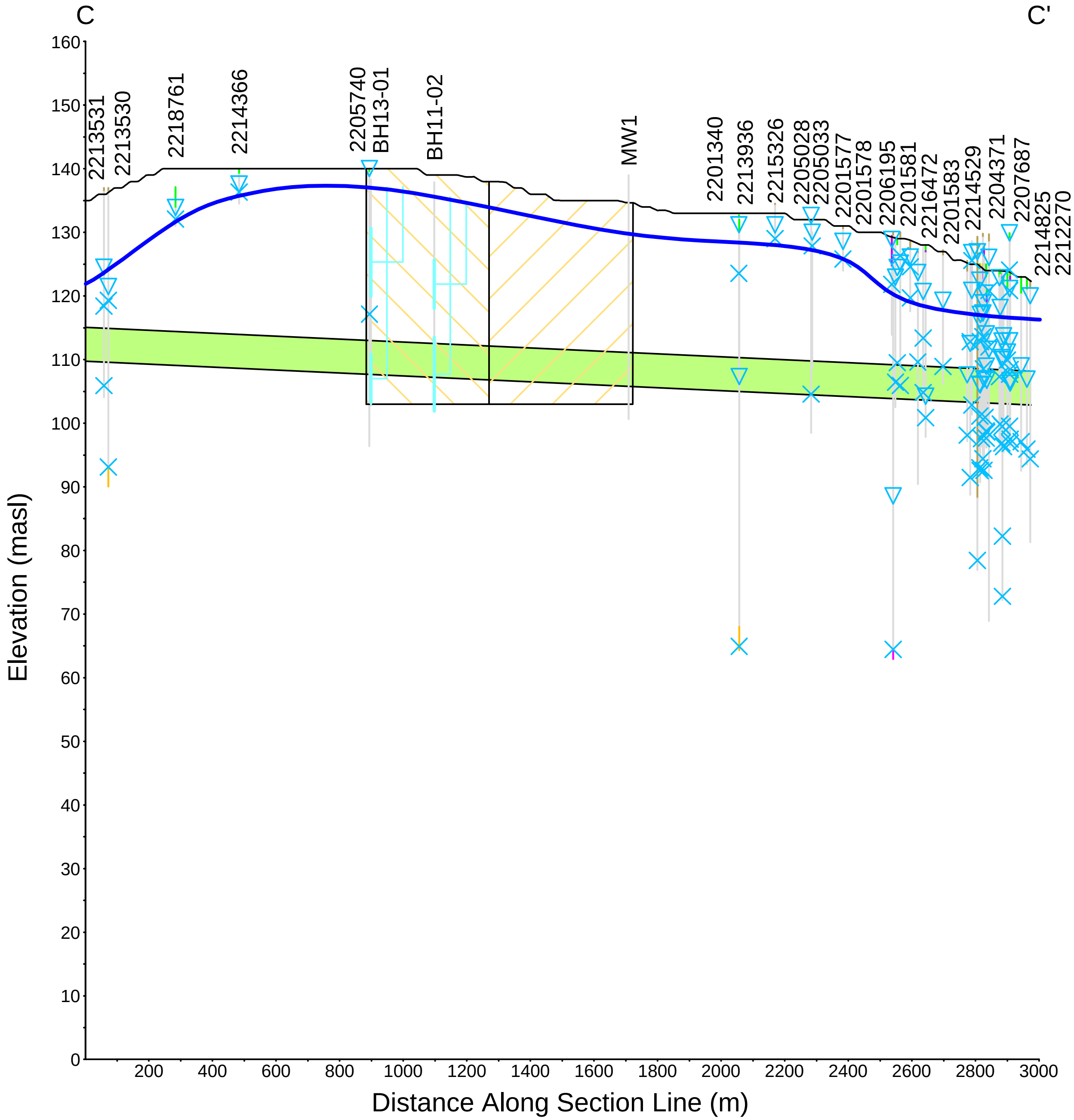
- Silt and/or Clay
- Sand and/or Gravel
- Overburden
- Shale
- Limestone
- Sandstone
- Granite
- Water Table or Deeper Potentiometric Surface
- Groundwater Elevation
- Elevation of Water Found
- Monitoring Well Interval
- Head Elevations, with log of measured Hydraulic Conductivities
- Bottom of Aquitard
- Licensed Extraction Area
- To be Licensed Extraction Area
- Limestone with Green Beds (Shows stratigraphic model only)

MORRISON HERSHFIELD

Scale: See Axes

Title: Cruickshank Construction Limited
Elginburg Quarry Expansion -
Hydrogeological Cross Section BB'

Project No.: 2130039	Drawing No.: Figure 5
Department: Environmental Services	Date: January 16

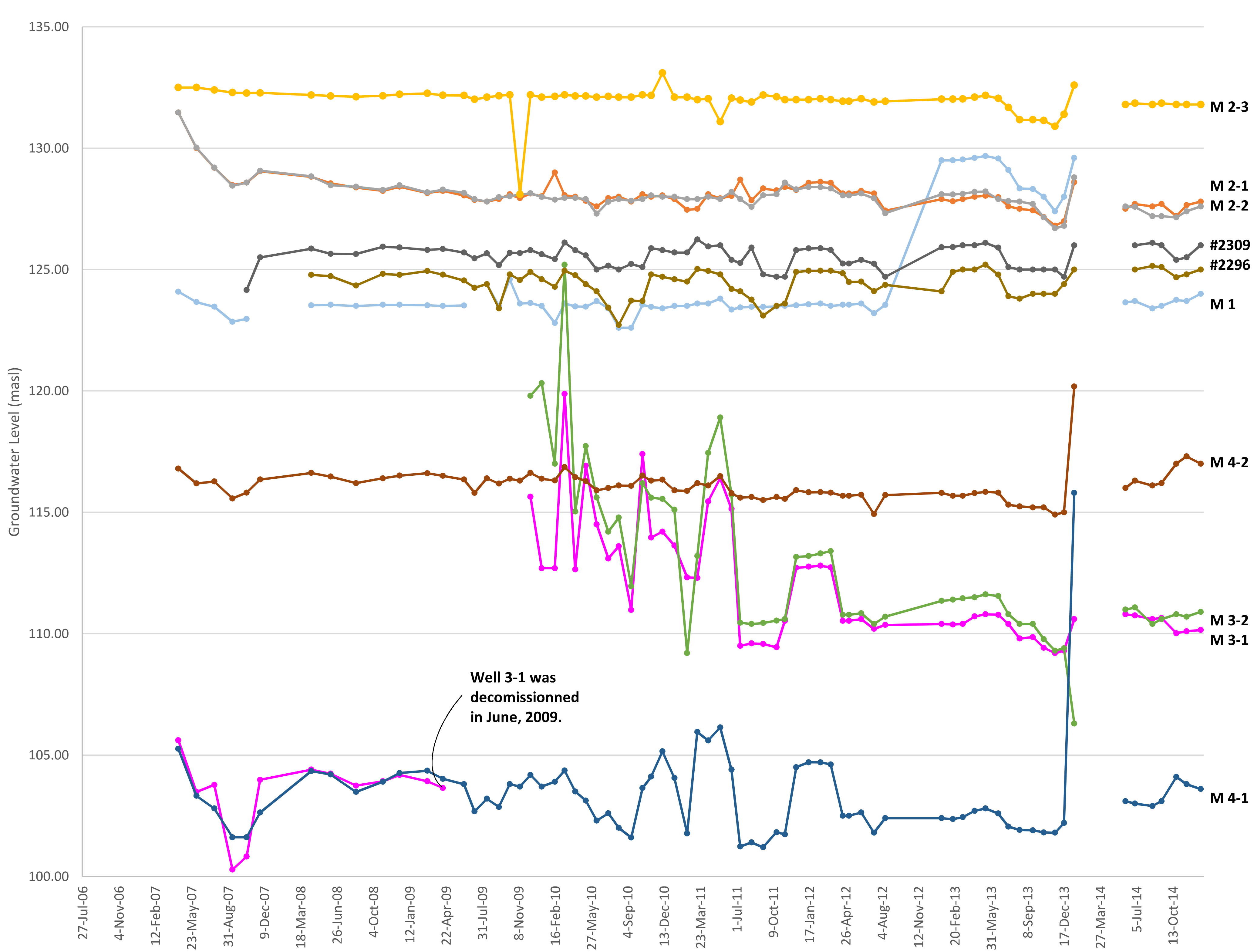


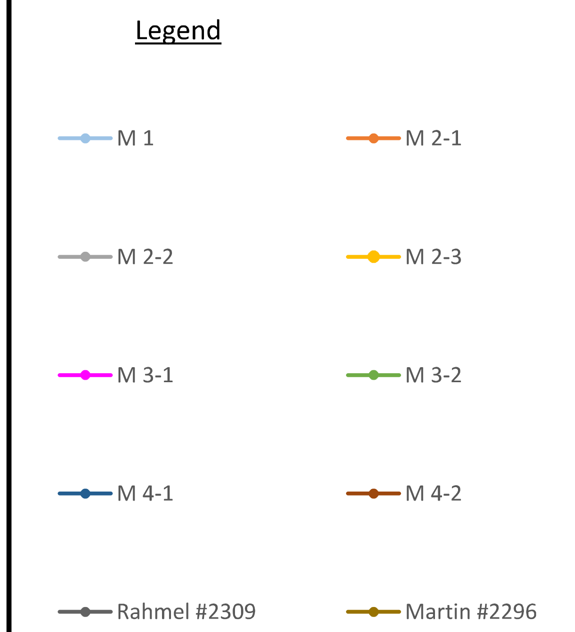
Legend

- Silt and/or Clay
- Sand and/or Gravel
- Overburden
- Shale
- Limestone
- Sandstone
- Granite
- Water Table
- Groundwater Elevation
- Elevation of Water Found
- Monitoring Well Interval
- Head Elevations
- Licensed Extraction Area
- To be Licensed Extraction Area
- Limestone with Green Beds (Shows stratigraphic model only)

MORRISON HERSHFIELD

Scale: See Axes	
Title: Cruickshank Construction Limited Elginburg Quarry Expansion - Hydrogeological Cross Section CC'	
Project No.: 2130039	Drawing No.: Figure 6
Department: Environmental Services	Date: January 16





MORRISON HERSHFIELD

Scale:

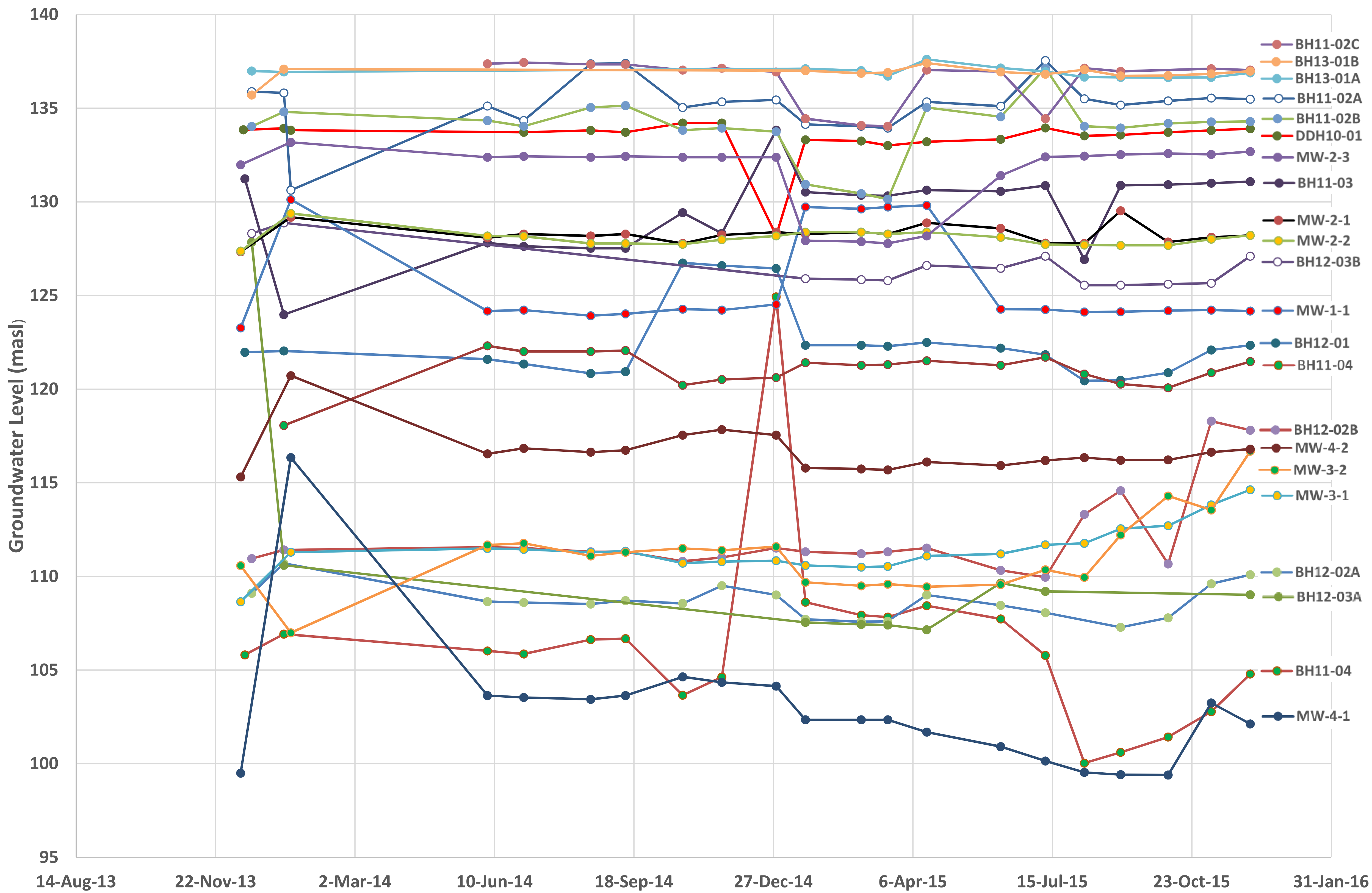
See Axes

Title:

Cruickshank Construction Limited
Elginburg Quarry Expansion -
Groundwater Level Monitoring Data

Project No.:	Drawing No.:
2130039	Figure 7

Department:	Date:
Environmental Services	January 2016



Legend

DDH10-01	BH12-01
BH11-03	BH11-04
BH11-02A	BH11-02B
BH11-02C	BH12-02A
BH12-02B	BH12-02C
BH12-03A	BH12-03B
BH13-01A	BH13-01B
MW-1-1	MW-2-1
MW-2-2	MW-2-3
MW-3-1	MW-3-2
MW-4-1	MW-4-2

Project Name:

Hydrogeological Impact Assessment for the Expansion of the Cruickshank Elginburg Quarry

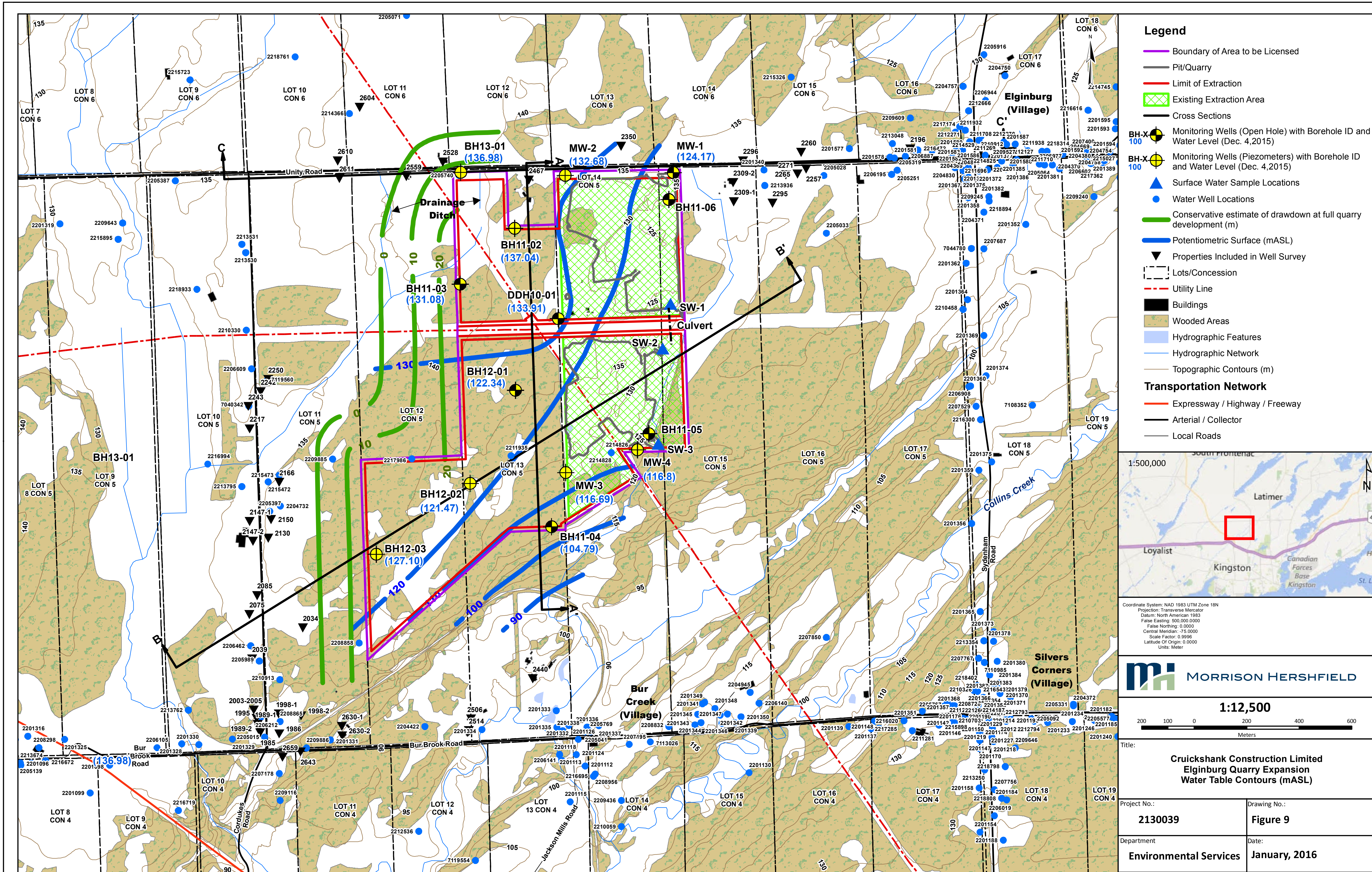
Scale:

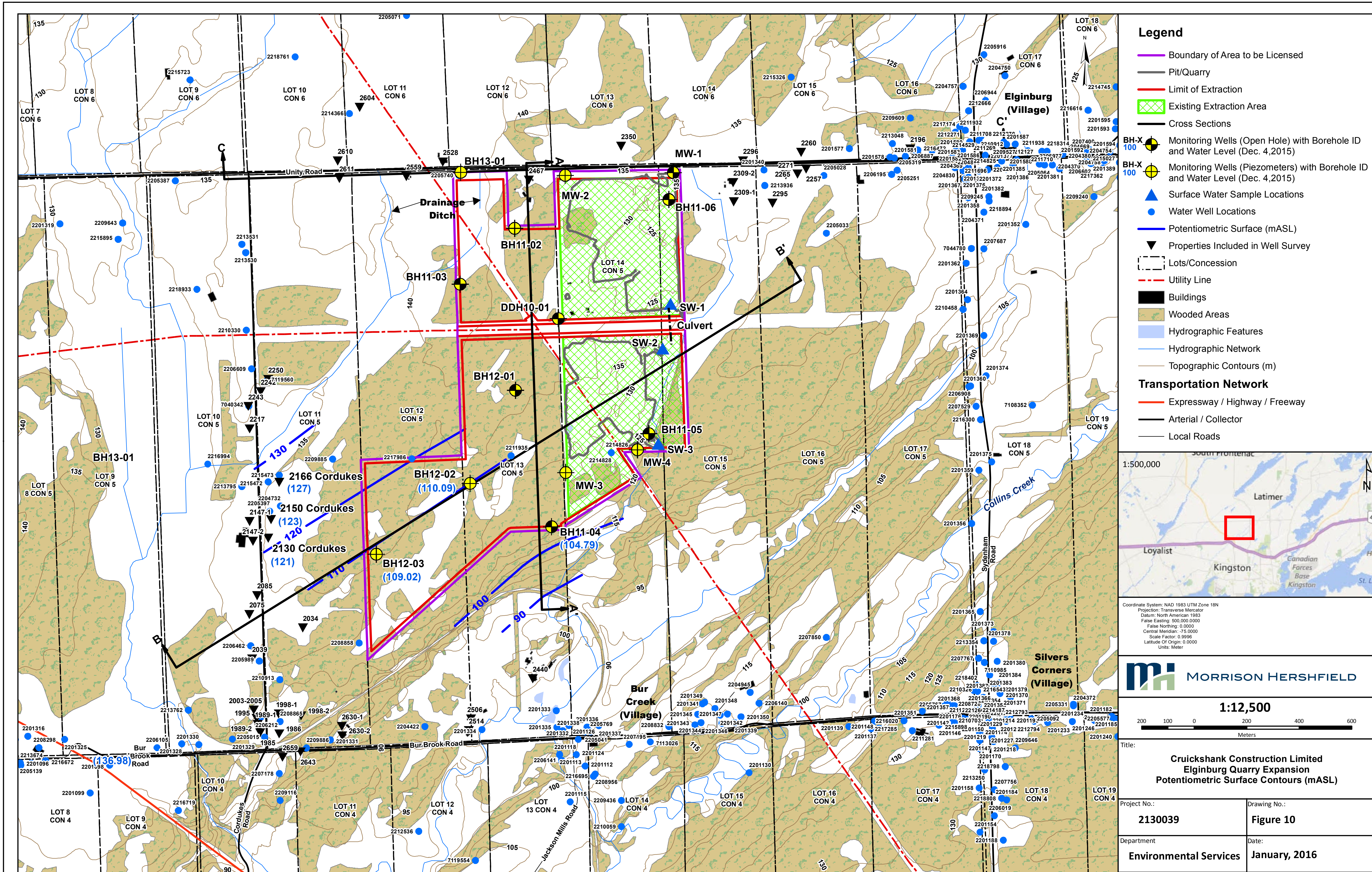
See Axis

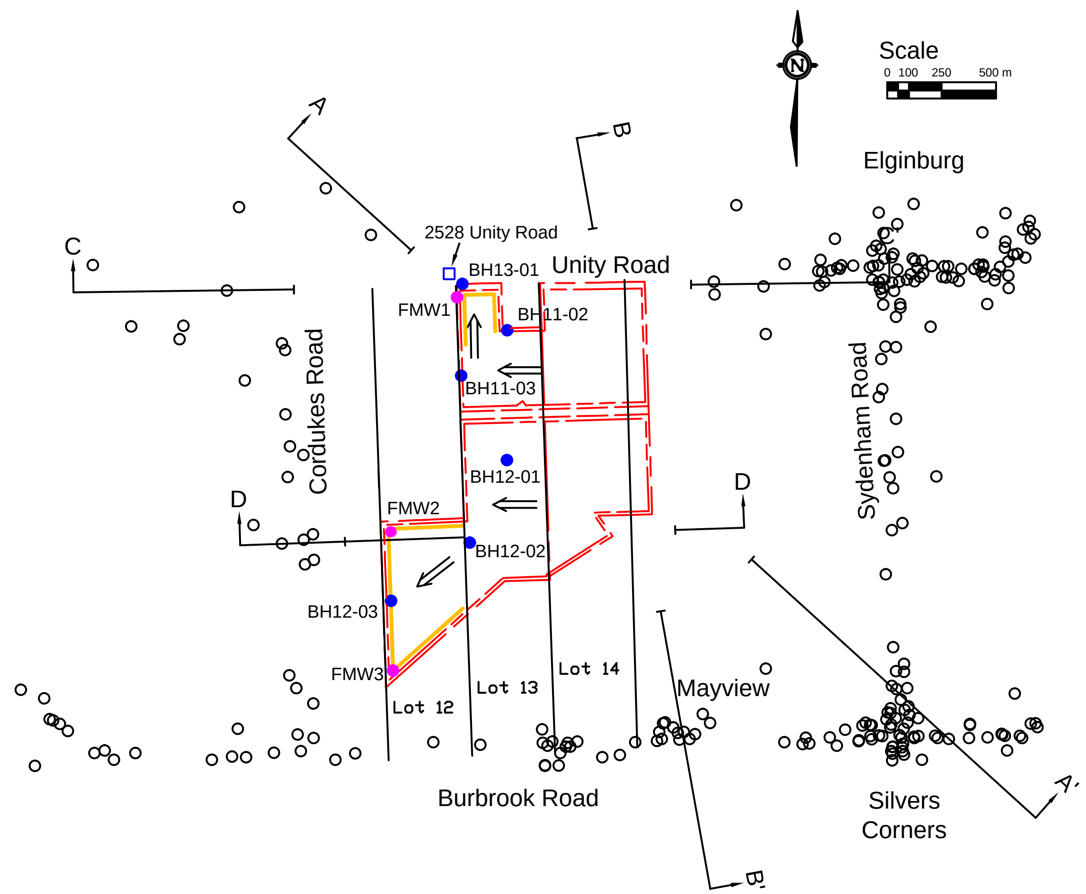
MORRISON HERSHFIELD

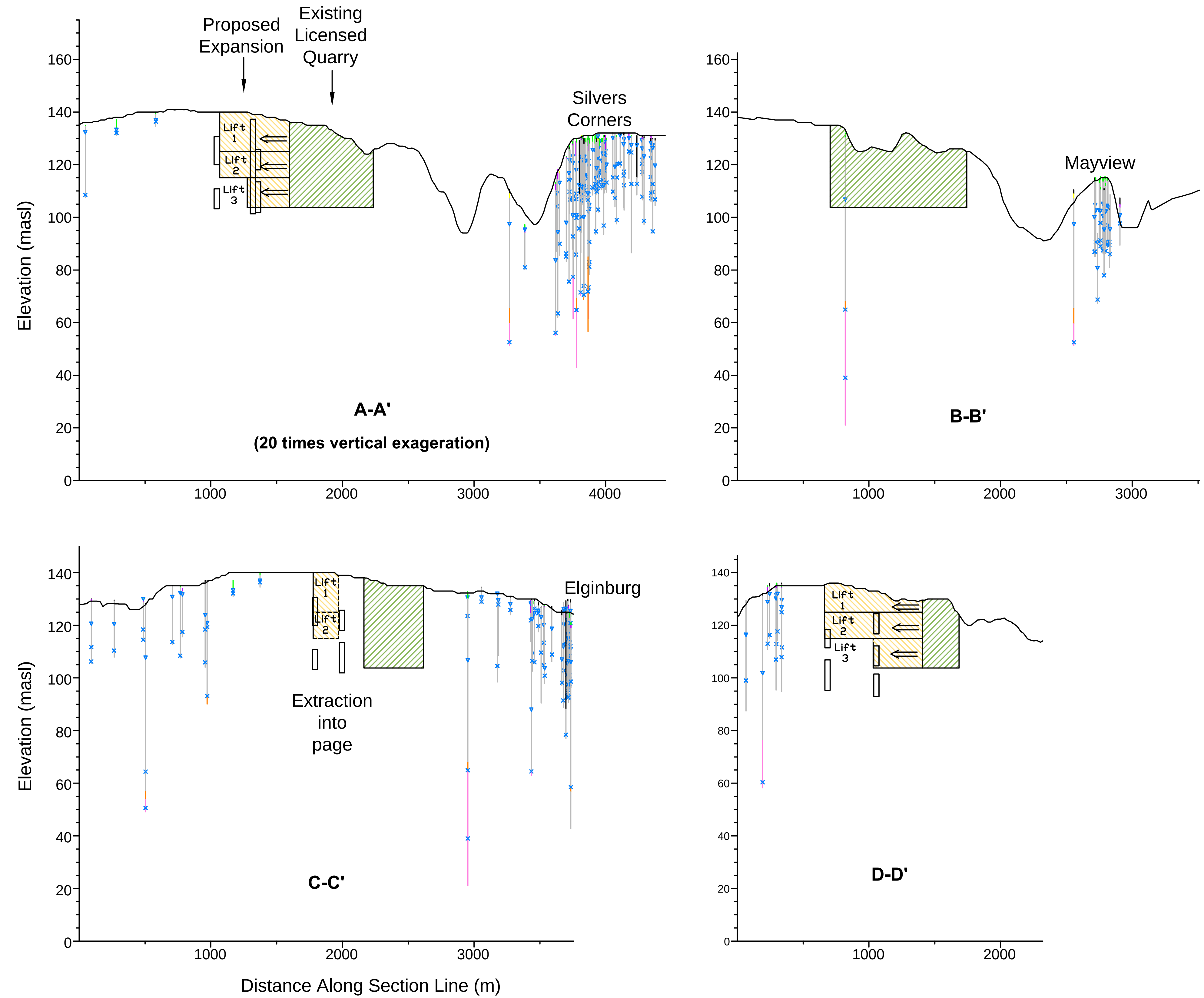
Drawing Title:
Cruickshank Construction Limited
Elginburg Quarry Expansion - Groundwater Level Monitoring Data

Project No:	Drawing No:
2130039	Figure 8
Department: Environmental Services	Date: January 2016


Legend
Boundary of Area to be Licensed
Pit/Quarry
Limit of Extraction
Existing Extraction Area
Cross Sections
Monitoring Wells (Open Hole) with Borehole ID and Water Level (Dec. 4,2015)
Monitoring Wells (Piezometers) with Borehole ID and Water Level (Dec. 4,2015)
Surface Water Sample Locations
Water Well Locations
Conservative estimate of drawdown at full quarry development (m)
Potentiometric Surface (mASL)
Properties Included in Well Survey
Lots/Concession
Utility Line
Buildings
Wooded Areas
Hydrographic Features
Hydrographic Network
Topographic Contours (m)
Transportation Network
Expressway / Highway / Freeway
Arterial / Collector
Local Roads
1:500,000
Latimer
Loyalist
Kingston
Canadian Forces Base Kingston
Elginburg (Village)
Bur Creek (Village)
Silvers Corners (Village)
Unity Road
Bur Brook Road
Sydenham Road
Jackson Mills Road
Cordukes Road
Collins Creek
Drainage Ditch
Culvert
MW-1 (124.17)
MW-2 (132.68)
MW-3 (116.69)
MW-4 (116.8)
BH13-01 (136.98)
BH11-02 (137.04)
BH11-03 (131.08)
DDH10-01 (133.91)
BH12-01 (122.34)
BH12-02 (121.47)
BH12-03 (127.10)
BH11-04 (104.79)
BH11-05
BH11-06
SW-1
SW-2
SW-3
MORRISON HERSHFIELD
1:12,500
Meters
Title:
Cruickshank Construction Limited
Elginburg Quarry Expansion
Water Table Contours (mASL)
Project No.: 2130039
Drawing No.: Figure 9
Department: Environmental Services
Date: January, 2016


Legend
Boundary of Area to be Licensed
Pit/Quarry
Limit of Extraction
Existing Extraction Area
Cross Sections
Monitoring Wells (Open Hole) with Borehole ID and Water Level (Dec. 4,2015)
Monitoring Wells (Piezometers) with Borehole ID and Water Level (Dec. 4,2015)
Surface Water Sample Locations
Water Well Locations
Potentiometric Surface (mASL)
Properties Included in Well Survey
Lots/Concession
Utility Line
Buildings
Wooded Areas
Hydrographic Features
Hydrographic Network
Topographic Contours (m)
Transportation Network
Expressway / Highway / Freeway
Arterial / Collector
Local Roads
1:500,000
Latimer
Loyalist
Kingston
Coordinate System: NAD 1983 UTM Zone 18N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -75.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
MORRISON HERSHFIELD
1:12,500
Meters
Elginburg (Village)
Bur Creek (Village)
Silvers Corners (Village)
Unity Road
Bur Brook Road
Sydenham Road
Jackson Mills Road
Cordukes Road
Collins Creek
Drainage Ditch
Culvert
BH13-01
MW-1
MW-2
MW-3
MW-4
BH11-02
BH11-03
BH11-04
(104.79)
BH11-05
BH11-06
DDH10-01
BH12-01
BH12-02
(110.09)
BH12-03
(109.02)
SW-1
SW-2
SW-3
2166 Cordukes
(127)
2150 Cordukes
(123)
2130 Cordukes
(121)
(136.98)
LOT 14 CON 5
Title:
Cruickshank Construction Limited
Elginburg Quarry Expansion
Potentiometric Surface Contours (mASL)
Project No.: 2130039
Drawing No.: Figure 10
Department: Environmental Services
Date: January, 2016
K:\Internal\Environmental_Services\GIS_Environment_Services\GIS_Project_Work\Ottawa\2124083\Phase2\GIS_2124083\GIS_Maps\Site_Plan_2130039_Expansion_Fig10.mxd





Legend

- Silt and/or Clay
- Sand and/or Gravel
- Overburden
- Shale
- Limestone
- Sandstone
- Granite
- Water Table
- Groundwater Elevation
- Elevation of Water Found
- Existing Licensed Quarry
- Proposed Expansion - with lift number
- Lot Lines
- Extraction Face for Photographic Seepage Monitoring
- Well from MOE WWIS
- Monitoring Well
- Neighboring Well
- Future Monitoring Well
- Monitoring Well Interval in Section
- Direction of Extraction

Monitoring		
Type	**Location**	**Frequency**
Groundwater Level	2528 Unity Road, BH13-01, BH12-01, BH12-02, BH12-03, BH11-02 and BH11-03; and FMW1, FMW2 and FMW3 once installed	Monthly
Photographic Seepage Monitoring	All Extraction Faces on Lot 12 Expansion and Extraction Faces within 250 m of Unity Road, Western Half of Lot 13	Annually in Winter

MORRISON HERSHFIELD

Elginburg Quarry Quarterly Groundwater Monitoring Program for Proposed Expansion

Project No: 2130039

Drawing No: Fig 11

Department: Environmental Services

Date: January 2016

APPENDIX B: Well Logs and Well Completions

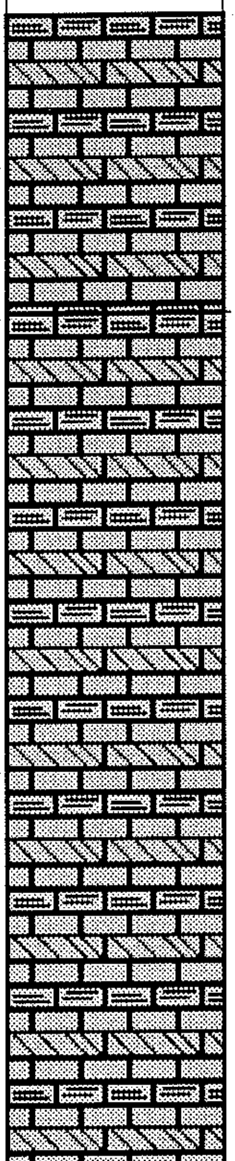
PROJECT: 934000

DRILL TYPE: Rotary with water

HOLE NUMBER: 1

DATE: June 2, 1994

LOCATION: northeast corner of site, just east of old access road

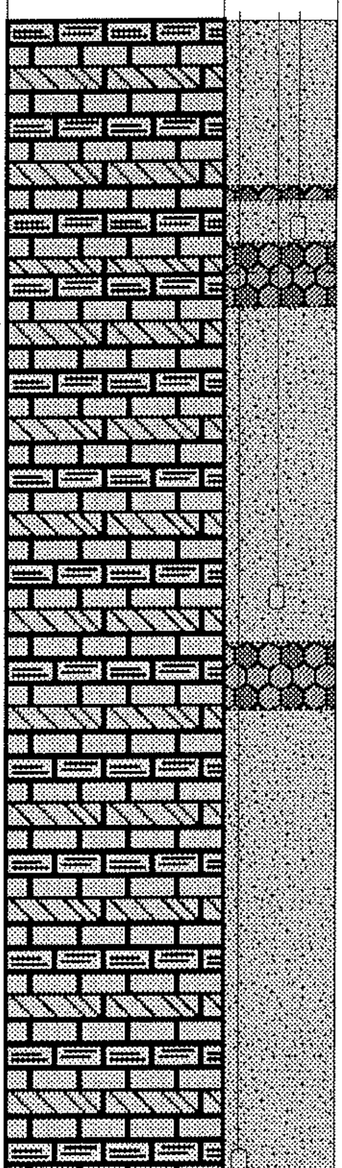
DEPTH (m)	STRATIGRAPHIC SECTION	PIEZ.	ELEVATION (m asl)	Major Bedding Plane	Estimated Cumulative Yield (L/min)	MATERIAL DESCRIPTION
0			131.2			0 to 9.75 UPPER GULL RIVER FORMATION
				2.44, 3.66		-dark grey, fine crystalline limestones, thinly bedded (5 to 10 cm) with shale between limestones -noticable drops at 2.44, 3.66, 8.53, and 9.75
5					0	-no water present
				8.53		
10			121.45	9.75		9.75 TO 38.10 m - LOWER GULL RIVER FORMATION
					0	-interbedded limestone, silty dolostone, quartz sandstone and shale -first thick green dolostone bed which was noticed was at 20.73 m -small drops at 27.13 to 28.04, 29.87, 30.18 and 35.97
15						-calcite-rich areas which may be the characteristic vugs of the Formation were encountered at 27.13 to 28.04 m
					0	
20						-below 35.97 the amount of green dolostone appears to increase
					0	
25						
				27.13		-there is virtually no water in well, after 5 days the static water level was greater than 36 m below the surface
				28.04		-what water there is in the well appears to be mineralized
30				29.87 30.18	0	
35						after 1 month there was less than 0.7 m of water in the drill hole
				36.97		
			92.89		0	
40						

PROJECT: 934000 DRILL TYPE: Rotary with water

HOLE NUMBER: 2

DATE: June 2, 1994

LOCATION: northwest corner of property, where new office is to be constructed



DEPTH (m)	ELEVATION (m asl)	Major Bedding Plane	Estimated Cumulative Yield (L/min)
0	136.8		
		3.66	
5		4.57	
		5.49, 5.79	0
	129.31		
	128.27	8.53 to 9.75	
10		11.58	0
15			
	117.24	19.51	0
20		20.73 to 21.34	
25		25.60 to 26.21	0
30			0
		32.0	
35			
	98.55		0
40			

MATERIAL DESCRIPTION

0 to 8.53 UPPER GULL RIVER FORMATION

-dark grey to black, fine crystalline limestones,
-thinly bedded (5 to 10 cm) with shale between limestones
- noticable drops at 3.66, 4.57, 5.49, 5.79 and 8.53
- very black cuttings; shale
-no water present

8.53 TO 38.10 m - LOWER GULL RIVER FORMATION

-interbedded limestone, silty dolostone, quartz sandstone and shale
-first thick green dolostone bed which was noticed was at 25.6 to 26.21 m
-small drops at 8.53 to 9.75, 11.58, 19.51, 20.73 to 21.34, 25.60 to 26.21 and 32.0
-calcite-rich areas which may be the characteristic vugs of the Formation were encountered at 18.29 and 23.32 m
-below 14.63 m the colour of the limestone changed to light grey to fine grained; changed to dark grey to black at 23.32
-below 32 m started to encounter very fine grained grey/brown thinly bedded limestones

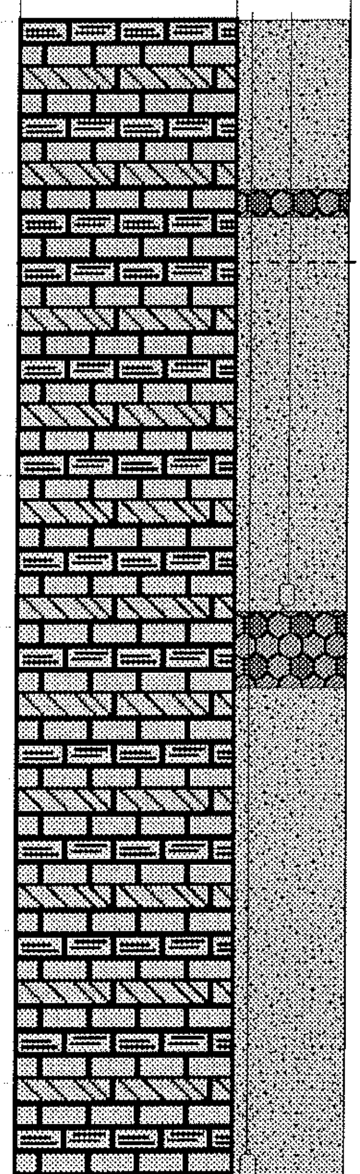
-there is virtually no water in well, the static in the well after 5 days was 8.80 m and appears to be entering at the base of the casing

PROJECT: 934000 DRILL TYPE: Rotary with water

HOLE NUMBER: 3

DATE: June 2, 1994

LOCATION: southwest corner of property, in area of small test quarry



DEPTH (m)	STRATIGRAPHIC SECTION	PIEZ.	ELEVATION (m asl)	Major Bedding Plane	Estimated Cumulative Yield (L/min)	MATERIAL DESCRIPTION
0, 5			128.4	0.91 2.44 3.66 4.88, 5.19	0	0 to 7.92 UPPER GULL RIVER FORMATION -dark grey to black, fine crystalline limestones, -thinly bedded (5 to 10 cm) with shale between limestones - noticable drops at 0.91, 2.44, 3.66, 4.88 and 5.19 m - very black cuttings; shale -no water present
10, 15, 20, 25, 30, 35			120.48 109.50	8.53 10.36 to 14.63 21.95 23.77 26.21 28.04	18.18 18.18 20.45** 29.54**	7.92 TO 38.10 m - LOWER GULL RIVER FORMATION -interbedded limestone, silty dolostone, quartz sandstone and shale -first thick green dolostone bed which was noticed was at 11.28 to 12.19 m -small drops at 8.53, 10.36 to 14.63, 21.95, 23.77, 26.21 and 28.04 m -calcite-rich areas which may be the characteristic vugs of the Formation were encountered at 10.36 to 12.19 and 21.95 -below 15.24 m the colour of the limestone changed to light grey to fine grained; -below 23.77 m started to encounter very fine grained grey/brown thinly bedded limestones -occurance of greenish dolostone increases below 26.21 m -the well has a yield estimated to be on the order of 40.9 L/min -all of this water is from the 10.36 to 14.63 m zone and cascading was noted until the static water level rose above this level
40			90.17		40.90**	

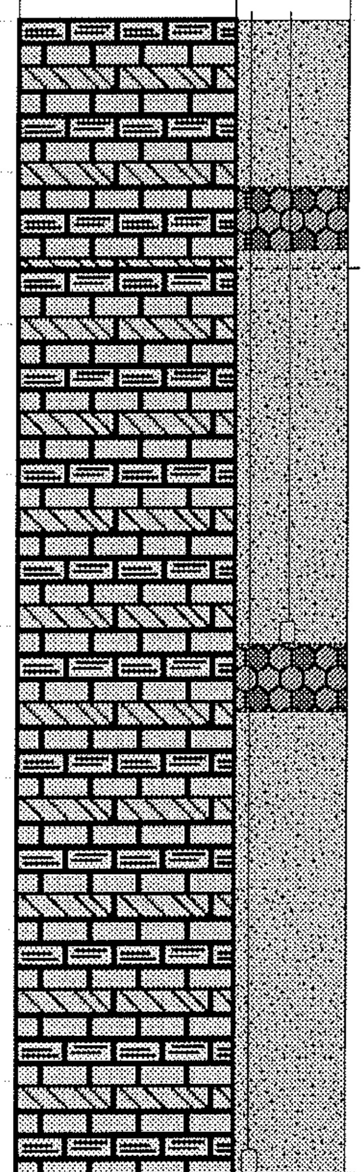
** the increase was due to the development of the 11.28 to 14.63 zone and does not reflect the interception of additional water bearing zones

PROJECT: 934000 DRILL TYPE: Rotary with water

HOLE NUMBER: 4

DATE: June 3, 1994

LOCATION: southeast corner of property, east of hydro-line and just south of existing quarry; between quarry and berm

DEPTH (m)	STRATIGRAPHIC SECTION	PIEZ.	ELEVATION (m asl)	Major Bedding Plane	Estimated Cumulative Yield (L/min)	MATERIAL DESCRIPTION
0			124.8			0 to 8.23 UPPER GULL RIVER FORMATION
				1.23, 1.83		-dark grey to black, fine crystalline limestones,
				2.44		-thinly bedded (5 to 10 cm) with shale between limestones
5						- noticable drops at 1.22, 1.83, 2.44 and 8.23 m
					0	- very black cuttings; shale
						-no water present
			116.57	8.23		8.23 TO 38.10 m - LOWER GULL RIVER FORMATION
10						-interbedded limestone, silty dolostone, quartz sandstone and shale
					0	-first thick green dolostone bed which was noticed was at 17.98 m
15						-small drops at 8.23, 17.98, 28.04, 35.97 and 37.19 to 37.49 m
				17.23		-calcite-rich areas which may be the characteristic vugs of the Formation were encountered at 35.97 m
					9.09	
20						-below 35.97 m started to encounter very fine grained grey/brown thinly bedded limestones
					9.09	-occurance of greenish dolostone increases below 26.21 m
25						- there is less than 9 L/min (2 IGPM) cumulative from the well, all this water was being derived from the 17.98 m level
				28.04		
30					9.09	
35				35.97		
				37.19 to 37.49		
			86.45		9.09	
40						

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open Sampler for a distance of 300 mm (12 in.)
DD- Diamond Drilling

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

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

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

III. SOIL DESCRIPTION

(a) **Cohesionless Soils**

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

(b) **Cohesive Soils**

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

IV. SOIL TESTS

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

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

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (cont'd.)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

PROJECT: 10-1127-0091

GEOPHYSICAL LOG OF: DDH10-01

LOCATION: See Site Plan

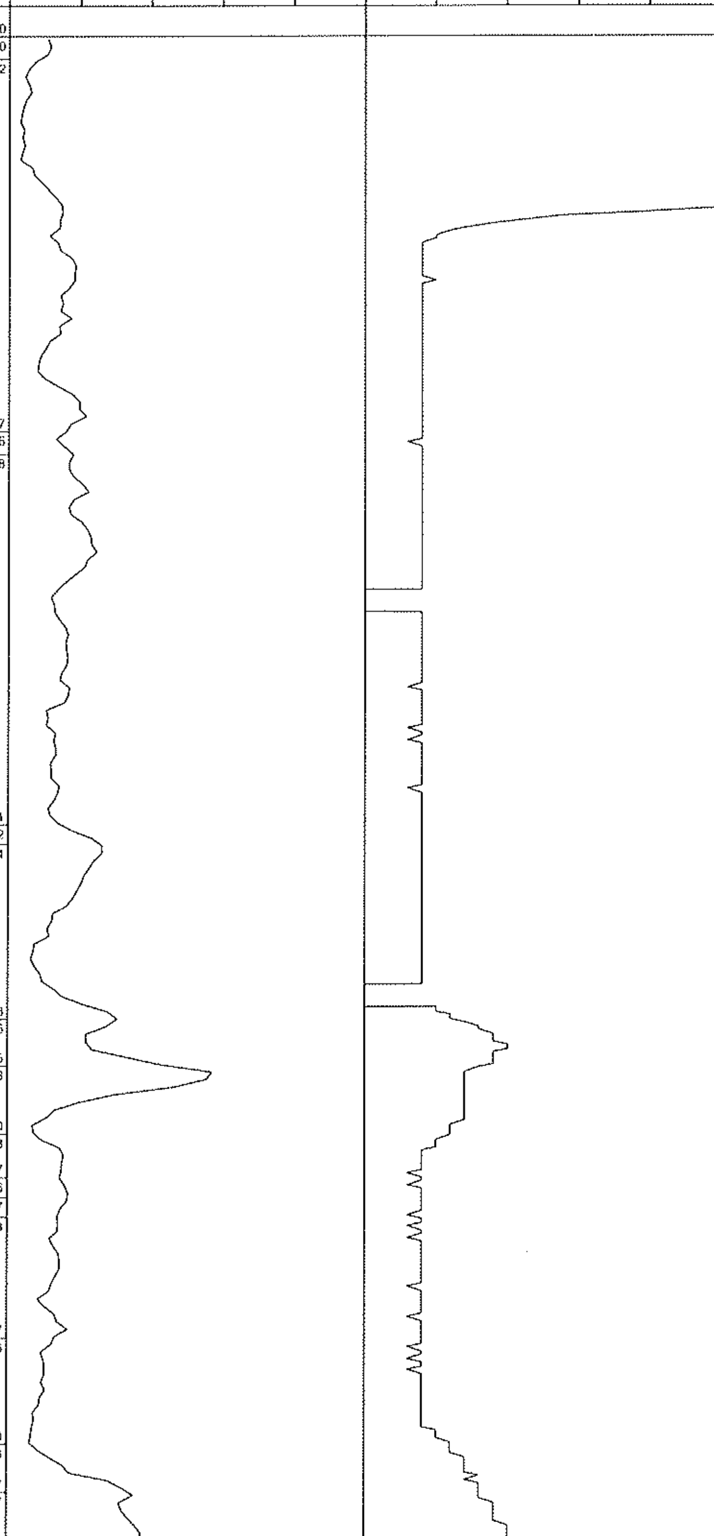
DRILLING DATE: Dec. 13, 2010

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling Co. Ltd.

DATUM:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80; CONDUCTIVITY (mS/m) 5 10 15 20	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		135.30		
0		**OVERBURDEN, 0.0 m to 0.15 m**		0.00		
		BEDROCK SURFACE, 0.15 m, GULL RIVER FORMATION, 0.15 m to 36.37 m		0.2		
1						
2		**UNIT 7, 0.15 m to 7.28 m ,** Weathered broken rock, 0.15 m to 3.00 m, partly broken to 0.91 m. Fresh, medium brownish grey, fine grained partly crystalline with disseminated medium grained calcite crystals, thinly bedded **MICRITIC LIMESTONE** with secondary interlaminations of medium grained calcarenite, occasional argillaceous partings, minor bioturbation associated with horizontal burrow casts 2 to 10 mm dia. Becomes medium bedded with traces of brachiopod fossils, extensive bioturbation associated with horizontal burrow casts 1 to 10 mm dia infilled with fine to medium grained calcarenite, below 3.66 m. Micritic lithoclastic bed with fossils occurs between 2.62 and 2.77 m. Medium brownish grey, oolitic, partly crystalline micrite bed occurs from 5.23 to 5.36 m. Laminated, dark grey, argillaceous micritic limestone and fine grained calcarenite occur from 6.52 to 6.63 m. Light brownish grey fine to medium grained argillaceous calcarenite from 6.63 to 6.83 m.		132.7 / 2.6 ; 2.8		
3						
4						
5				130.1 / 5.2 ; 5.4		
6						
				128.8 / 6.5		
				128.5 / 6.8		
7				128.0 / 7.3		
		UNIT 6, 7.28 m to 9.65 m, Fresh, medium brownish grey, fine grained partly crystalline, thinly to medium bedded, nodular textured **MICRITIC LIMESTONE.** Nodular beds occur between 7.28 and 7.57 m, 7.70 and 7.83 m, 8.63 and 9.33 m. Fine to medium grained, porous oolitic, calcarenite occur between 7.57 and 7.70 m, 7.83 and 8.63 m, with medium crystalline calcarenite with argillaceous partings between 9.33 and 9.65 m.		127.7 / 7.6 ; 7.7 ; 7.8		
8				126.7 / 8.6		
9				126.0 / 9.3		
		UNIT 5, 9.65 m to 11.66 m, Fresh, medium dark grey,		125.7 / 9.7		
10						



CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RDB
CHECKED: RDB

GEOPHYSICAL LOG OF: DDH10-01

PROJECT: 10-1127-0091

LOCATION: See Site Plan

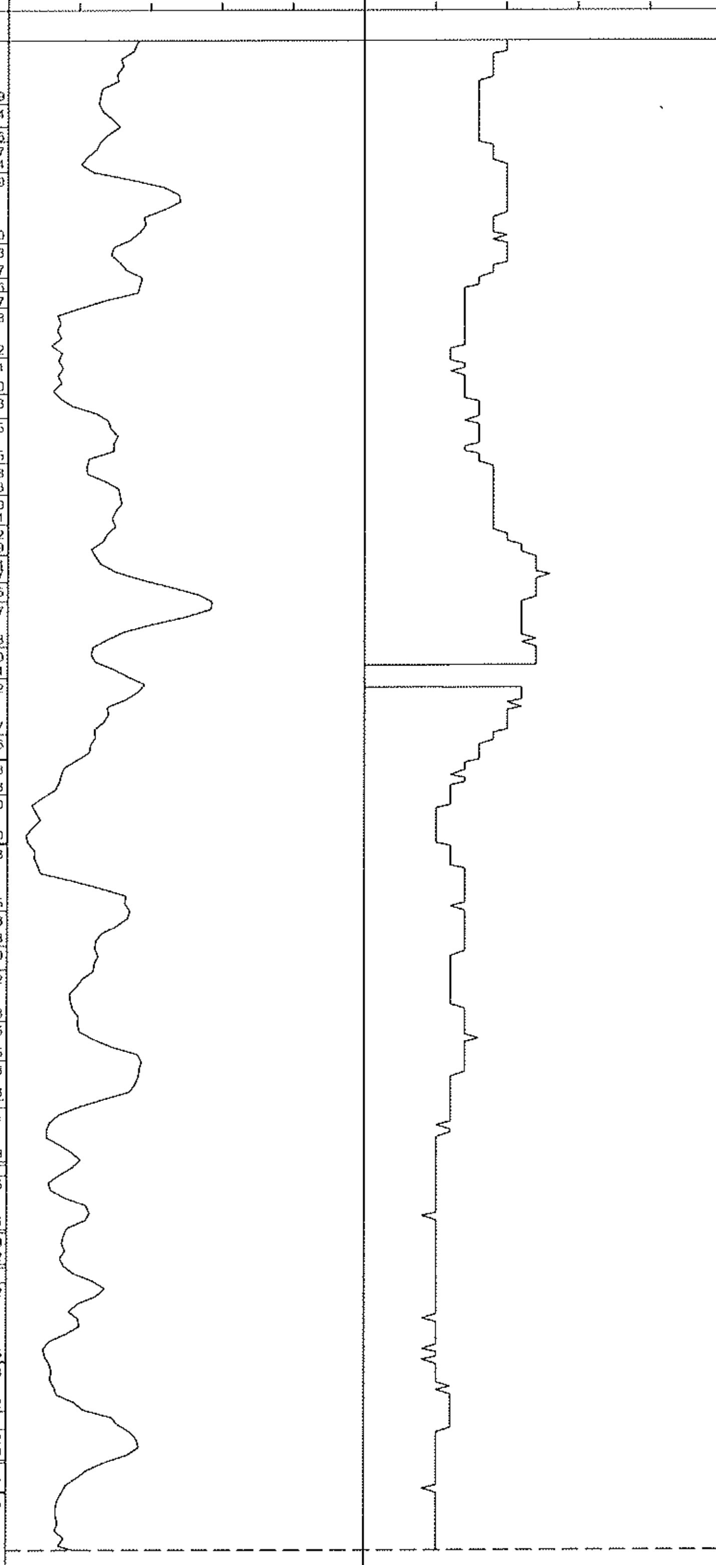
DRILLING DATE: Dec. 13, 2010

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling Co. Ltd.

DATUM:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80	CONDUCTIVITY (mS/m) 5 10 15 20	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---					
10 – 11.66		interlaminated to very thinly interbedded very fine to medium grained micritic and calcarenitic **LIMESTONE** with argillaceous partings and minor bioturbation, Partly crystalline oolitic micrite beds occur between 10.42 and10.57 m, 10.67 and 10.87 m, Poorly developed lithoclastic argillaceous micritic limestone bed occurs between 11.34 and 11.57 m,		124.9 / 10.4; 10.6; 10.7 / 124.4; 10.9; 124.0 / 11.3; 123.7 / 11.6			
11.66 – 16.50		**UNIT 4, 11.66 m to 16.50 m,** Fresh, light to medium brownish grey, interbedded sequence of fine to medium grained, medium bedded lithoclastic **CALCARENITIC LIMESTONE** and medium bedded argillaceous, laminar to nodular textured **MICRITIC LIMESTONE**, transitional contact with overlying unit marked by change from argillaceous micrite to laminated micrite and calcarenite. Lithoclastic calcarenite beds comprised of 1 to 10 mm dia, subrounded micrite clasts in calcarenite matrix occur between 11.77 and 12.10 m (first well developed lithoclastic bed), 12.34 and 12.50 m (argillaceous calcarenite), 13.01 and 13.21 m, 13.41 and 13.59 m (fossiliferous), 13.59 and 13.72 m (bioturbated), 14.02 and 14.23 m (argillaceous calcarenite), 14.60 and 14.76 m, 16.00 and 16.16 m. Argillaceous calcarenite beds occur between 12.10 and 12.34 m (porous, oolitic), 12.50 and 12.80 m (partly oolitic). Argillaceous, laminar to nodular textured micrite beds occur between 11.66 and 11.77 m, 13.21 and 13.41 m (lithoclastic), 13.72 and 14.02 m (dark grey), 14.23 and 14.60 m (nodular, bioturbated), 14.77 and 15.00 m, 15.00 and 15.32 m (first lithographic bed with fine stylolites and burrow casts), 15.33 and 15.77 m (nodular, bioturbated), 15.77 and 16.00 m (medium to dark grey with Lithoclasts), 16.16 and 16.50 (bioturbated). Black argillaceous to shaley bedding partings occur between 14.76 and 14.77 m, 15.32 and 15.33 m.		11.7; 11.8; 123.2; 12.1; 123.0; 12.3; 12.5; 122.5; 12.8; 122.3; 13.0; 122.1; 13.2; 121.9; 13.4; 121.7; 13.6; 13.7; 121.3; 14.0; 121.1; 14.2; 120.7; 14.6; 14.8; 120.3; 15.0; 120.0; 15.3; 119.5; 15.8; 119.3; 16.0; 16.2; 118.8			
16.50 – 20.60		**Unit 3, 16.50 m to 20.60 m,** Fresh, medium brownish grey, very fine to fine grained with disseminated calcite crystals, medium to thickly bedded, massive textured **LITHOGRAPHIC LIMESTONE** with black argillaceous to shaley bedding partings and interbedded layers of lithoclastic calcarenite and argillaceous micritic limestone. Individual lithographic beds occur between 16.50 and 16.76 m, 17.07 and 17.43 m, 18.23 and 19.08 m, 19.42 and 20.60 m. Lithoclastic calcarenite beds with shaley partings occur between 17.52 and 18.23 m. Lithoclastic micrite beds occur between 17.45 and 17.52 m, 19.08 and 19.20 m, 19.20 and 19.40 (argillaceous). Dark grey laminar textured, argillaceous to shaley micrite bed occurs between 16.76 and 17.02 m. Black, very thin shaley bedding partings occur between 17.02 and .07 m, 17.43 and .45 m, 17.88 and .90 m, 18.11 and .13 m, 18.75 and .76 m, 19.40 and .42, 19.61 and .62 m, 20.04 and .06 m, 20.21 and .23 m, 20.37 and 39 m.		16.5; 118.5; 16.8; 118.3; 17.1; 117.9; 17.5; 117.4; 17.9; 117.2; 18.1; 18.2; 116.6; 18.8; 116.2; 19.1; 19.2; 115.9; 19.4; 115.7; 19.6			
20		*CONTINUED NEXT PAGE*					



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RDB

CHECKED: RDB

PROJECT: 10-1127-0091

LOCATION: See Site Plan

GEOPHYSICAL LOG OF: DDH10-01

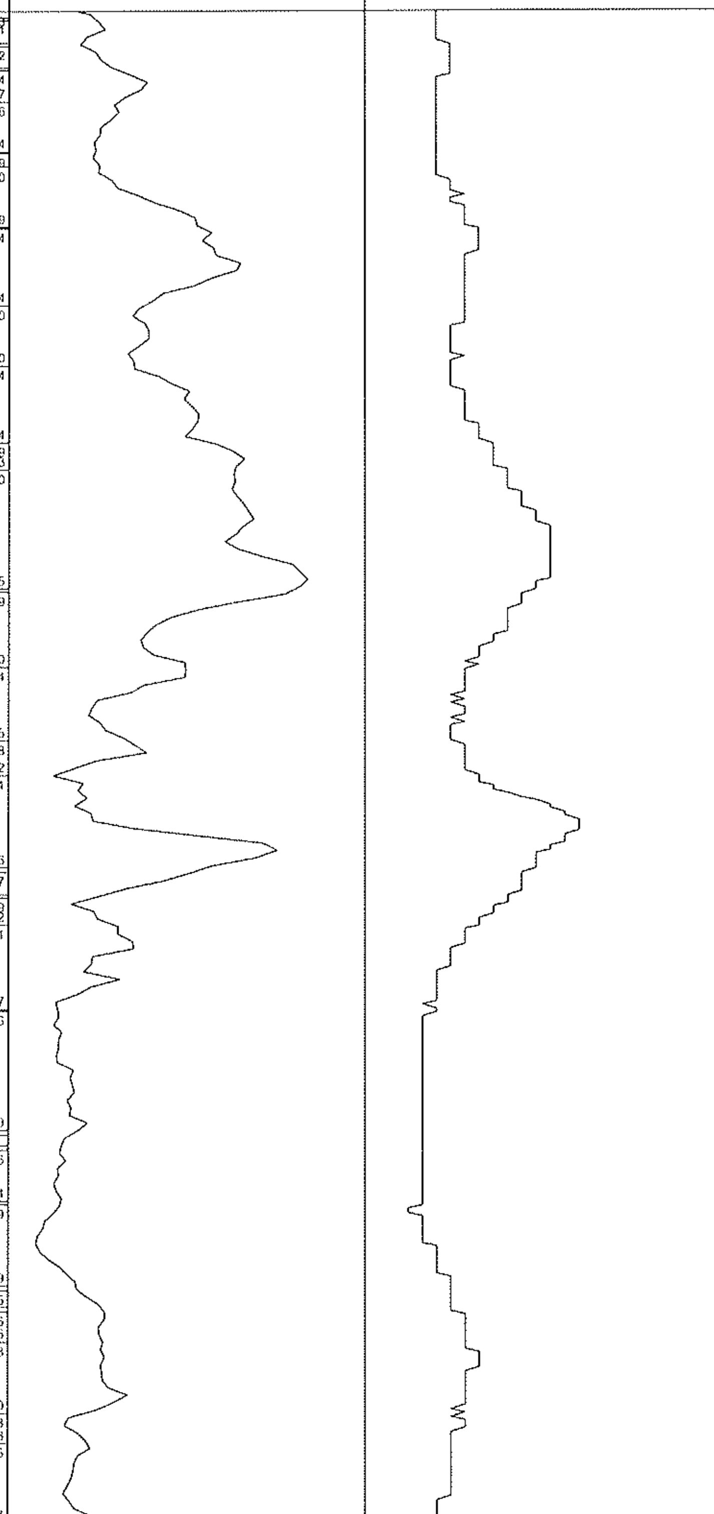
DRILLING DATE: Dec. 13, 2010

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling Co. Ltd.

DATUM:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80	CONDUCTIVITY (mS/m) 5 10 15 20	PIEZOMETER OR STANDPIPE INSTALLATION
20		--- CONTINUED FROM PREVIOUS PAGE ---		115.2 / 20.1; 20.2; 20.4 / 114.7			
21		**Unit 2, 20.60 m to 25.88 m,** Fresh, light to medium grey, fine grained, medium to thickly bedded, massive textured to bioturbated **MICRITIC LIMESTONE** with interbeds of micrite and calcarenite, lithoclastic micrite and calcarenite and shaley partings. Distinct medium grey, fine crystalline, massive textured, thick dolostone bed occurs between 23.04 and 23.83 m with a 1 cm grey shale bottom overlying dolomitic limestone between 23.84 and 24.35 m. Lithoclastic calcarenite with fining upward clasts occurs between 20.60 and 20.93 m, 21.95 and 22.35 m (tabular clasts, partly oolitic). Lithoclastic micrite bed occurs between 20.93 and 21.03 m, 24.84 and 25.07 m. Light grey, fine to medium grained, massive textured calcarenite between 22.35 and 22.86 m. Black, shaley argillaceous partings occur between 20.93 and 20.94 m, 21.43 and 21.44 m. Medium grey, fissile, clayey, calcareous shale beds occur between 23.84 and 23.85 m, 25.68 and 25.71 m, 25.86 and 25.88 m.		20.6; 114.4; 20.9; 21.0; 113.9; 21.4; 113.4; 22.0; 113.0; 22.4; 112.4; 22.9 / 112.3; 23.0; 111.5; 23.9; 111.0; 24.4; 110.5; 24.8; 110.2; 25.1; 109.6; 25.7			
26		**UNIT 1, 25.88 m to 36.37 m,** Fresh, light to medium grey, fine grained partly crystalline, medium to thickly bedded, non fossiliferous, massive textured, **MICRITIC LIMESTONE** with well developed fine stylolites and occasional interbeds of darker grey micritic dolomitic limestone and numerous 1 to 5 mm thick argillaceous bedding partings. Top of unit marked by light grey, partly crystalline, lithoclastic micritic limestone between 25.88 and 26.06 m. Dolomitic limestone beds occur between 28.59 and 28.82 m, 29.29 and 29.49 m (argillaceous, fossiliferous), 33.83 and 34.23 m, 35.63 and 36.37 m. Dark grey, laminar textured argillaceous micrite beds occur between 33.51 and 33.59 m, 34.93 and 35.20 m. Light grey lithographic micrite bed occurs between 32.03 and 32.31 m. Argillaceous bedding partings 1 to 5 mm thick occur at 26.62 m, 27.42 m, 27.52 m, 27.69 m, 28.45 m, 28.59 m, 30.01 m, 30.18 m, 30.51 m, 31.68 m, 32.31 m, 32.84 m, 33.12 m, 34.23 m. Limestone breccia infilled with vuggy coarse grained calcite occurs between 35.57 and 35.63 m.		25.9 / 109.2; 26.1; 108.7; 26.6; 107.9; 27.6; 107.4; 27.9; 106.9; 28.5; 28.6 / 106.5; 28.8; 106.0; 29.3 / 105.8; 29.5; 105.3			
22, 23, 24, 25, 27, 28, 29, 30							



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DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RDB

CHECKED: RDB

PROJECT: 10-1127-0091

GEOPHYSICAL LOG OF: DDH10-01

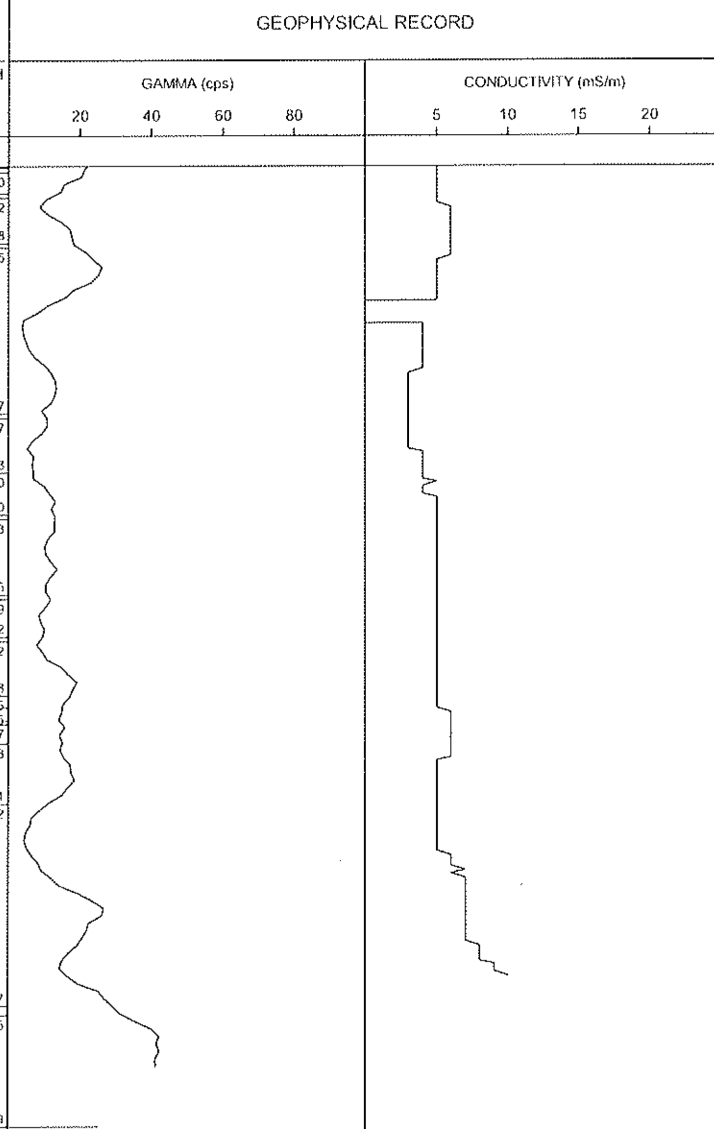
SHEET 4 OF 4

LOCATION: See Site Plan

DRILLING DATE: Dec. 13, 2010
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling Co. Ltd.

DATUM:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	GEOPHYSICAL RECORD	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---				
30				30.0		
				30.2		
				104.8 / 30.5		
31						
				103.7 / 31.7		
32				103.3 / 32.0		
				103.0 / 32.3		
				102.5 / 32.9		
33				102.2 / 33.2		
				101.8 / 33.5		
				33.6		
				33.7		
34				33.8		
				101.1 / 34.2		
35						
				99.7 / 35.6		
36				98.9		
		36.37 m, End Of Borehole.		36.4		
37						
38						
39						
40						



DEPTH SCALE
1 : 50

Golder Associates

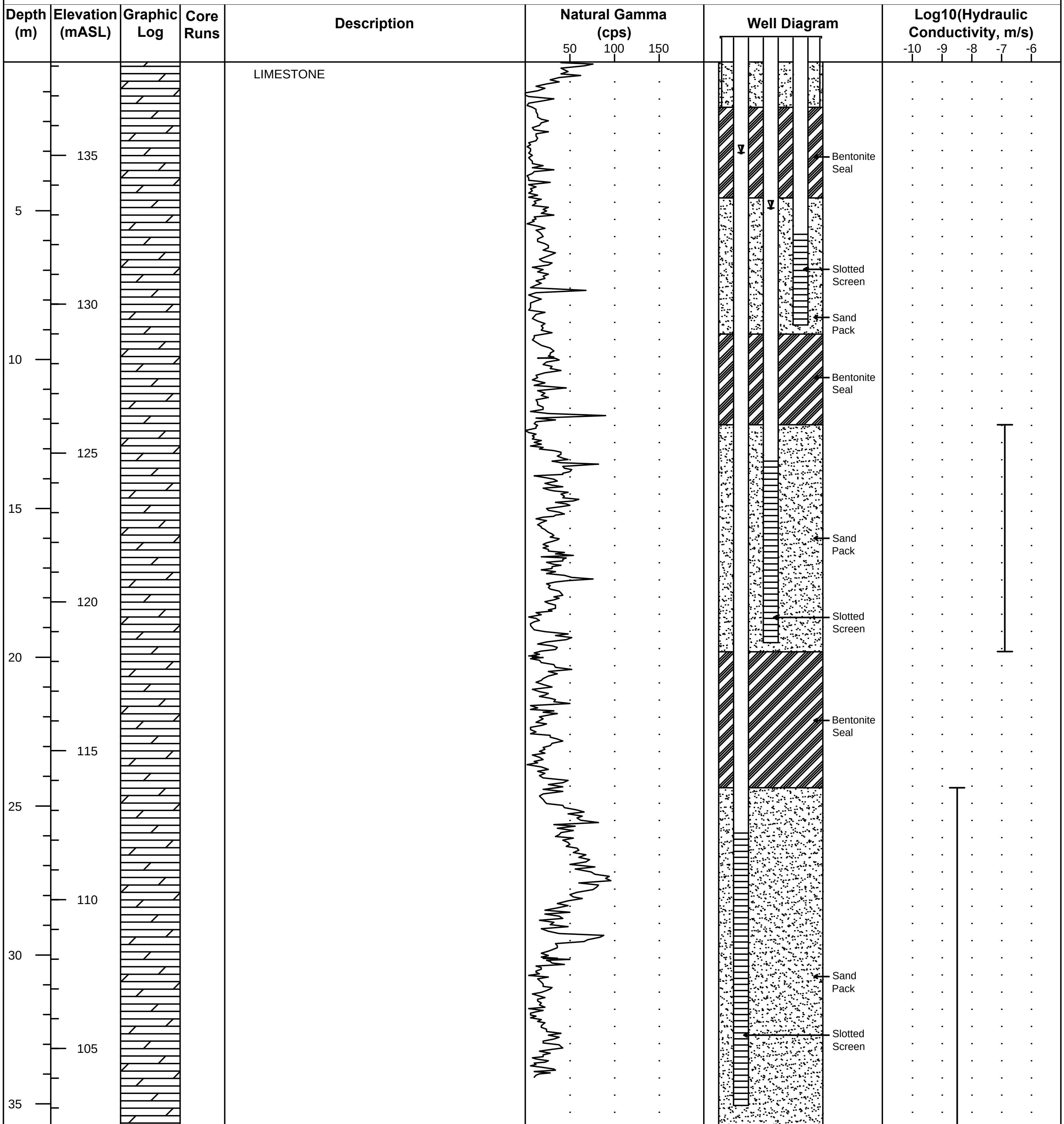
LOGGED: RDB
CHECKED: RDB

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH11-02

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375321 mE, 4908199 mN (UTM Zone 18 NAD 83)
Date Completed 12/12/2013
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 138.14 mASL
Casing Top Elevation 138.94 mASL
Static Water Level See Well Diagram



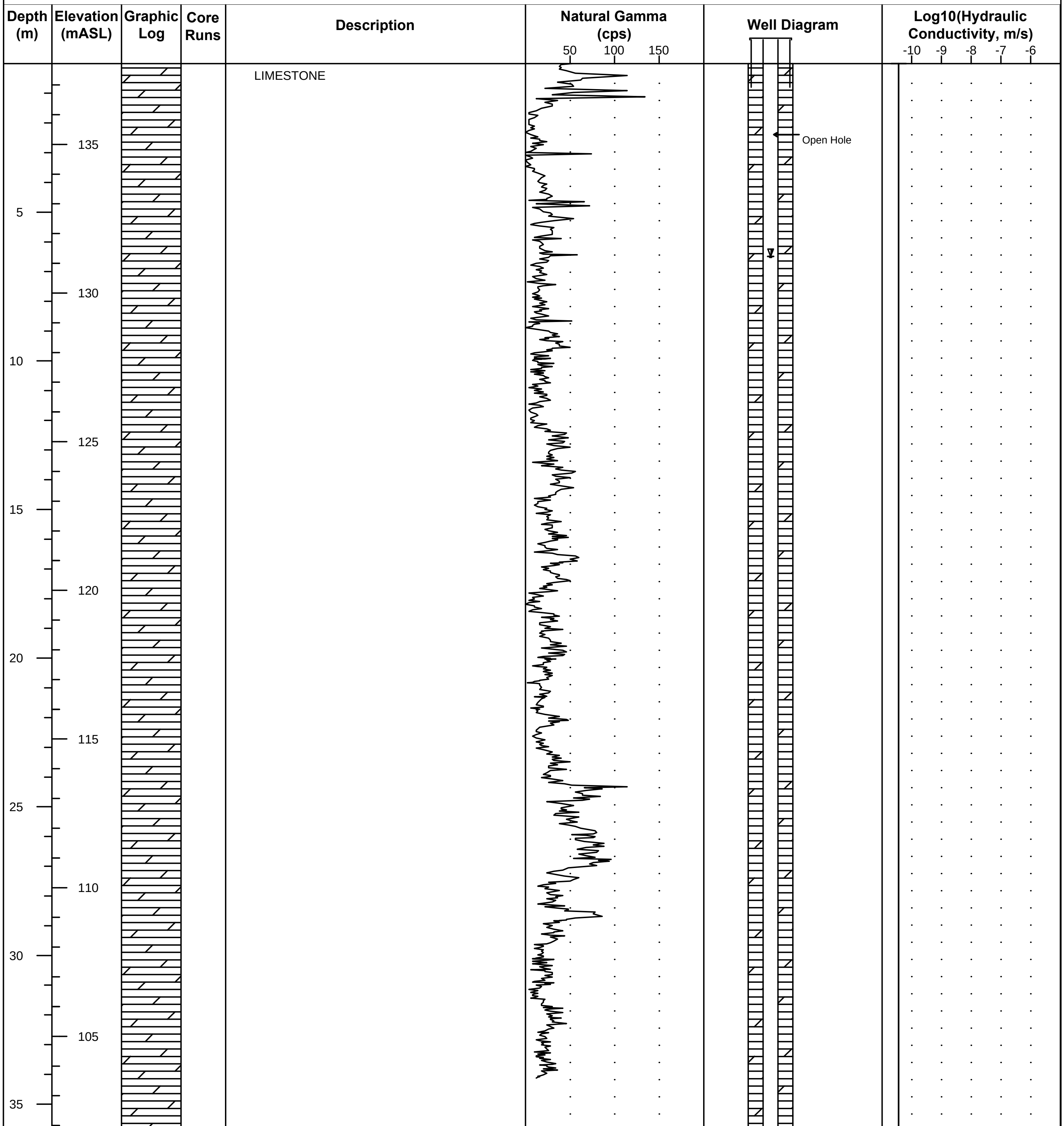
End of Borehole at 102.18 mASL

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH11-03

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375109 mE, 4907991 mN (UTM Zone 18 NAD 83)
Date Completed 2011
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 137.72 mASL
Casing Top Elevation 138.52 mASL
Static Water Level See Well Diagram



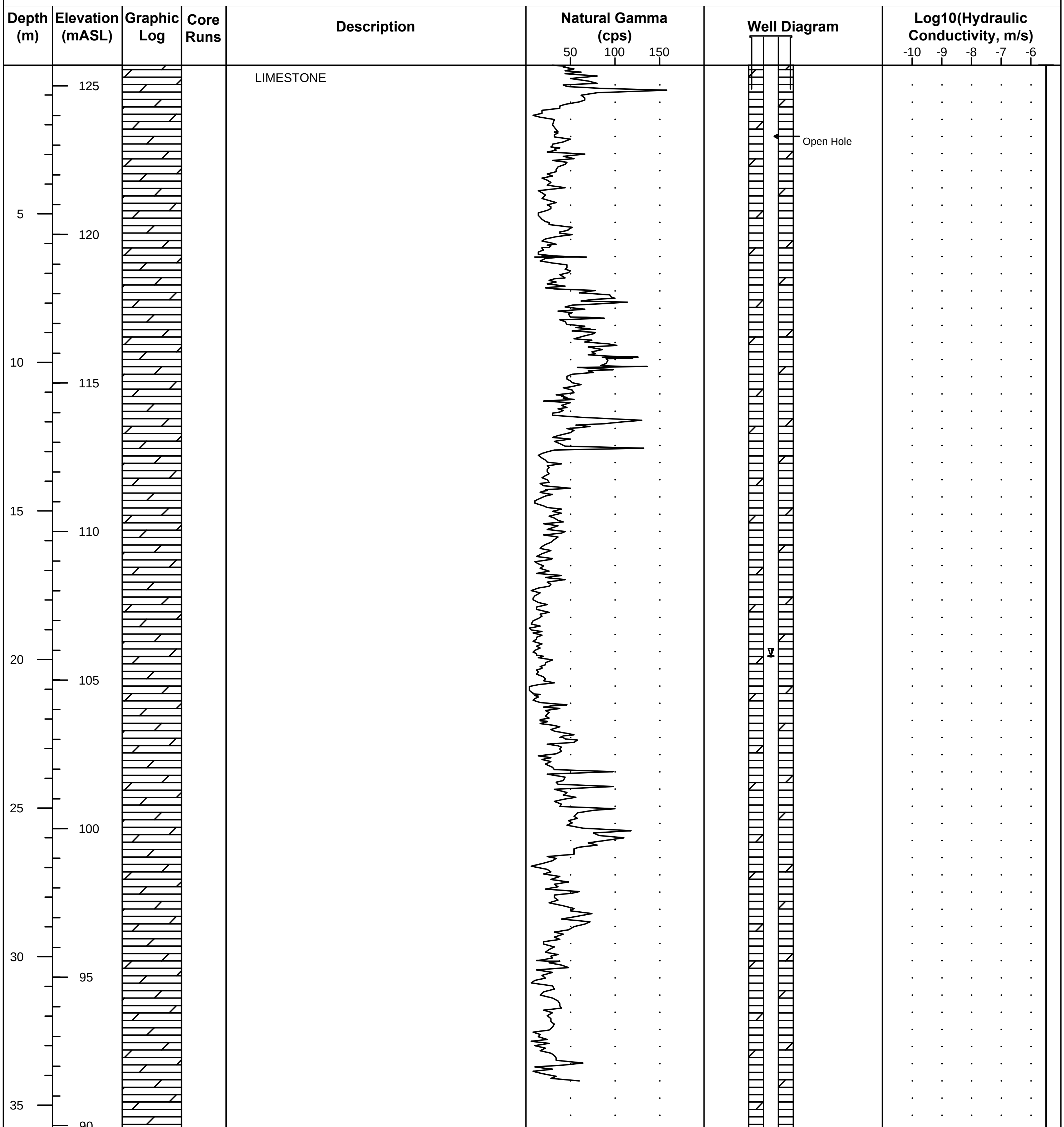
End of Borehole at 101.72 mASL

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH11-04

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375437 mE, 4907054 mN (UTM Zone 18 NAD 83)
Date Completed 2011
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 125.69 mASL
Casing Top Elevation 126.63 mASL
Static Water Level See Well Diagram



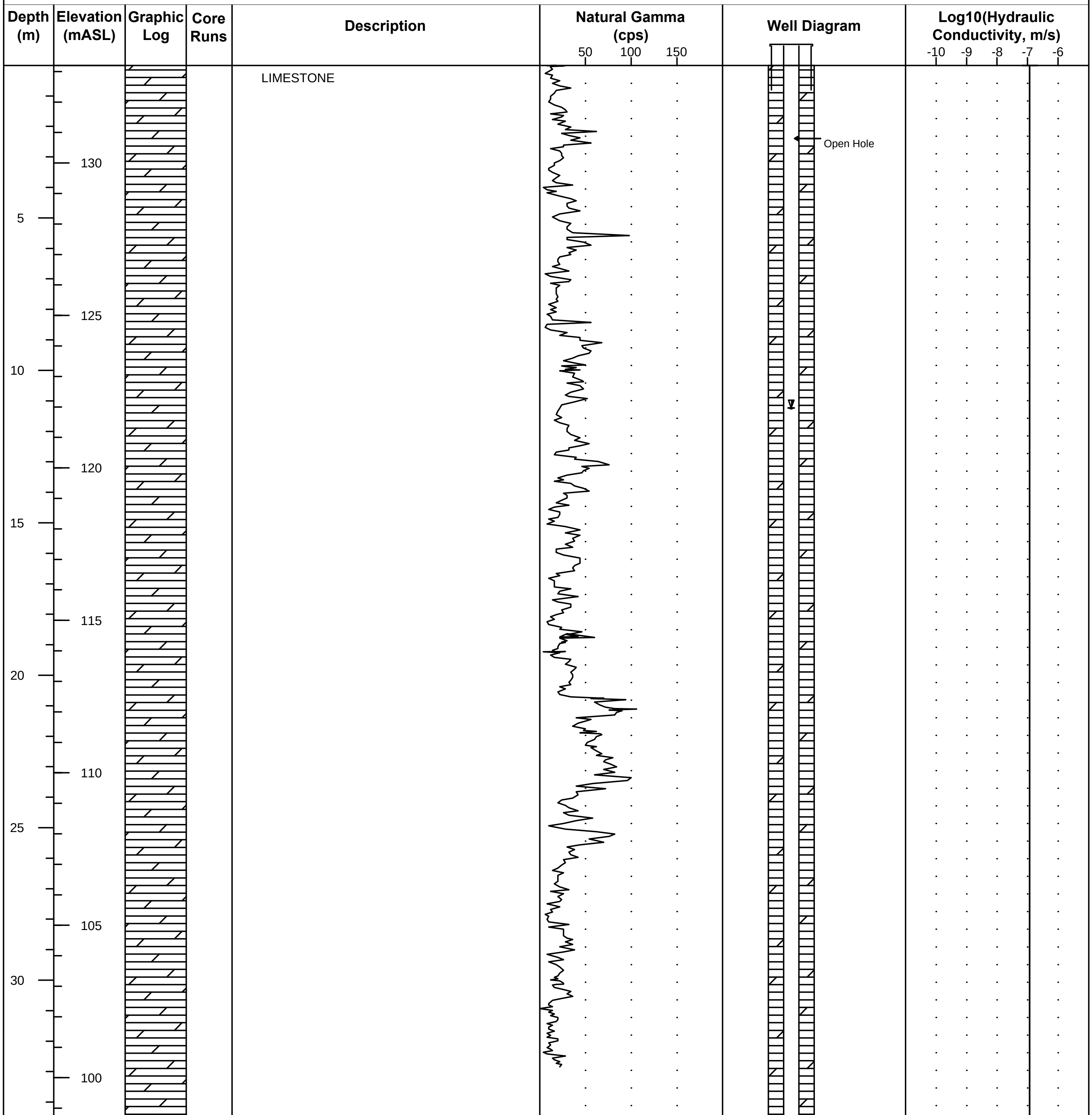
End of Borehole at 89.69 mASL

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH12-01

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375319 mE, 4907602 mN (UTM Zone 18 NAD 83)
Date Completed 12/14/2012
Hole Size 4 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 133.20 mASL
Casing Top Elevation 133.84 mASL
Static Water Level See Well Diagram



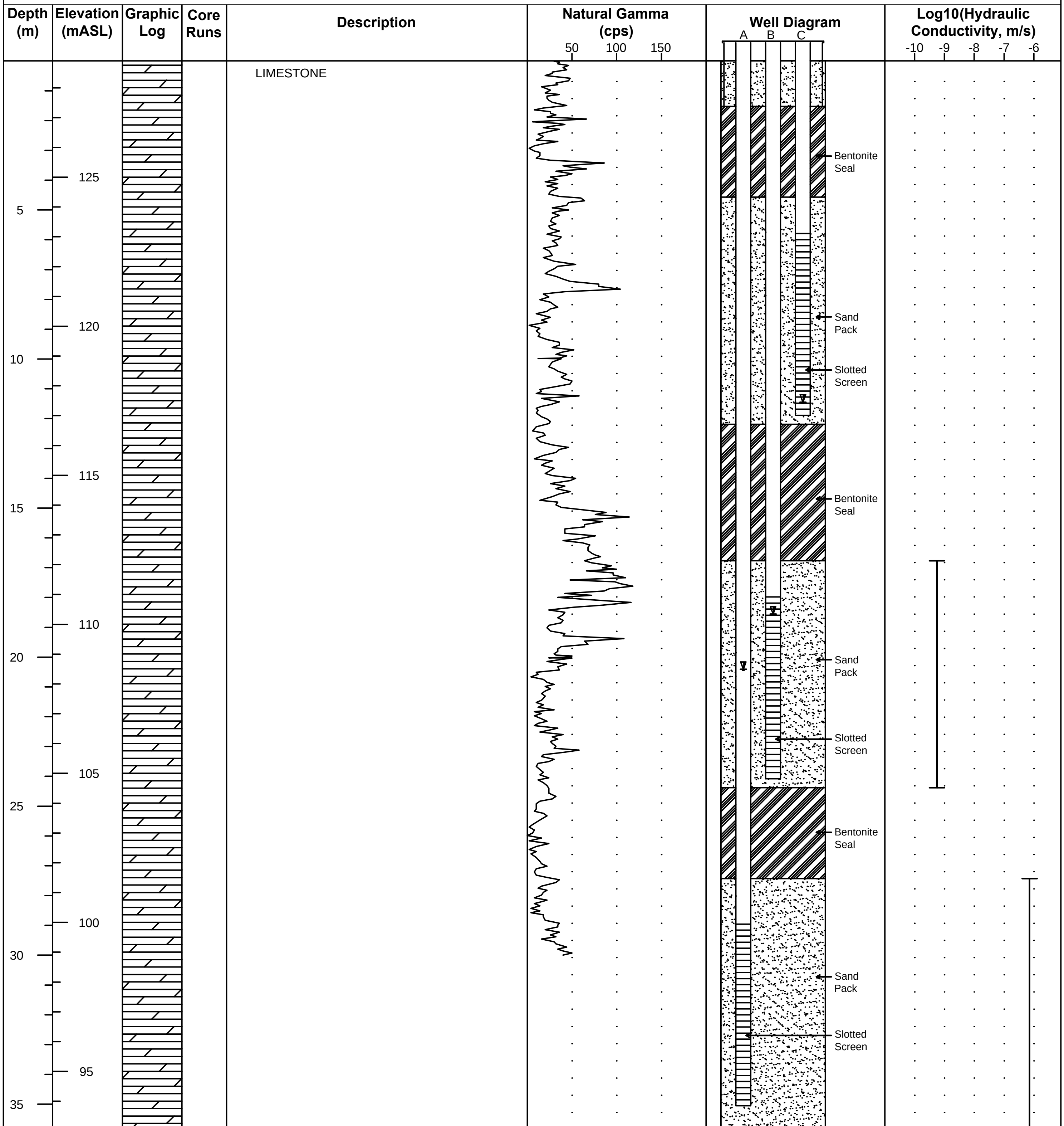
End of Borehole at 98.50 mASL

BORING NUMBER BH12-02

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375148 mE, 4907222 mN (UTM Zone 18 NAD 83)
Date Completed 12/12/2013
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 128.90 mASL
Casing Top Elevation 129.51 mASL
Static Water Level See Well Diagram



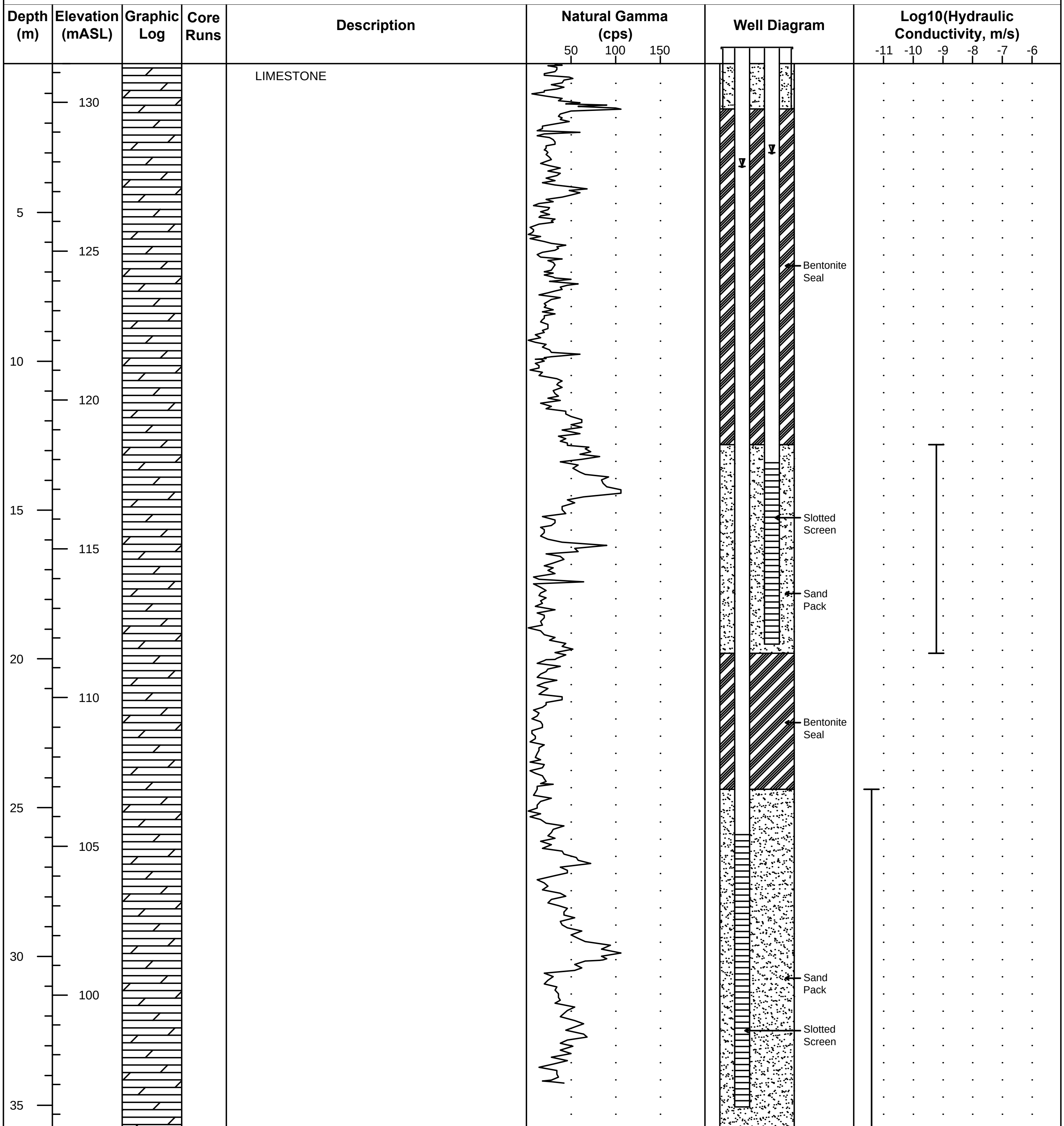
End of Borehole at 92.94 mASL

Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH12-03

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 374786 mE, 4906954 mN (UTM Zone 18 NAD 83)
Date Completed 12/12/2013
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 131.30 mASL
Casing Top Elevation 131.80 mASL
Static Water Level See Well Diagram



End of Borehole at 95.34 mASL

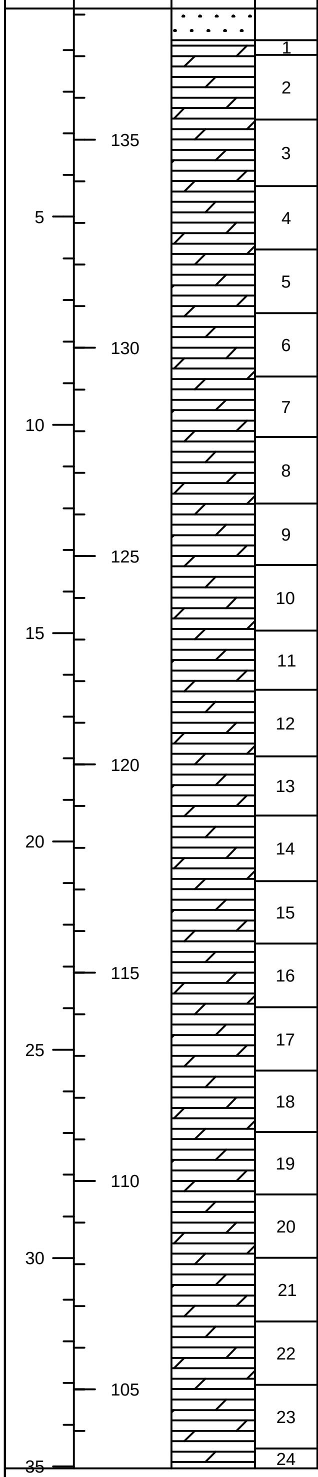
Morrison Hershfield
2440 Don Reid Drive
Ottawa, ON K1H 1E1

BORING NUMBER BH13-01

Client Cruickshank Construction Limited
Project Number 2130039.00
Well Location 375115 mE, 4908411 mN (UTM Zone 18 NAD 83)
Date Completed 12/12/2013
Hole Size 6 inch

Project Name Elginburg Quarry Expansion ARA Application
Project Location Elginburg Quarry
Ground Surface Elevation 138.15 mASL
Casing Top Elevation 138.61 mASL
Static Water Level See Well Diagram

Depth (m) | Elevation (mASL) | Graphic Log | Core Runs



Description

TOPSOIL

LIMESTONE. Light to dark blue grey. Solid, medium soft to hard, micritic to medium grained. Blocky to fractured with smooth to rough fractures. Occasionally interbedded with lime mudstone.

LIMESTONE. Light to dark blue grey. Solid, medium soft to hard, micritic to medium grained. Blocky to fractured with smooth to rough fractures. Extensive lime mudstone bedding (up to 10 cm in thickness).

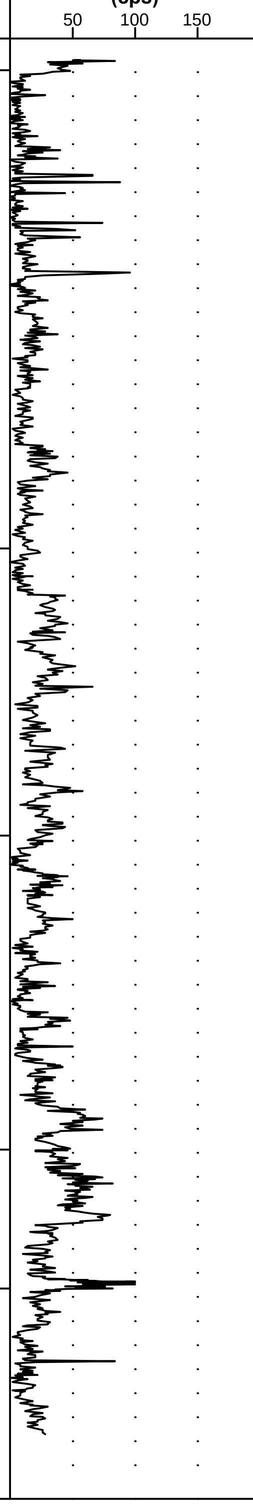
LIMESTONE. Light to dark blue grey. Solid, medium soft to hard, micritic to medium grained. Blocky to fractured with smooth to rough fractures. Occasional lime mudstone interbedding (up to 3 cm in thickness).

Dark grey silty clay layer present between 24.69 m and 24.89 m.

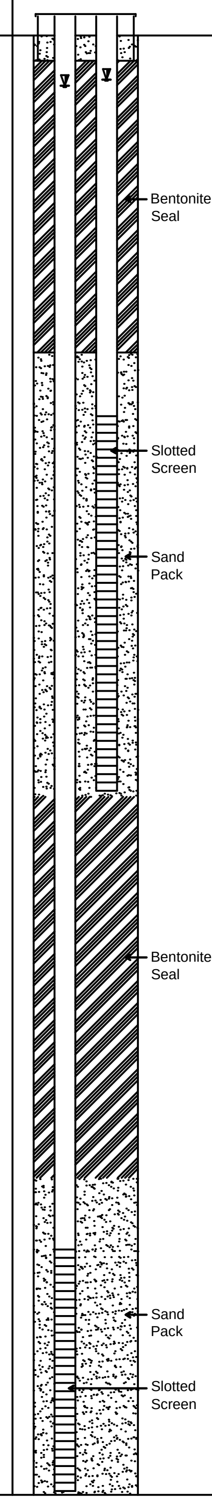
LIMESTONE. Light to dark blue grey. Solid, medium soft to hard, micritic to medium grained. Blocky to fractured with smooth to rough fractures. Contains grey-green argillaceous lime mudstone interbedding.

LIMESTONE. Light to dark blue grey. Solid, medium soft to hard, micritic to medium grained. Blocky to fractured with smooth to rough fractures.

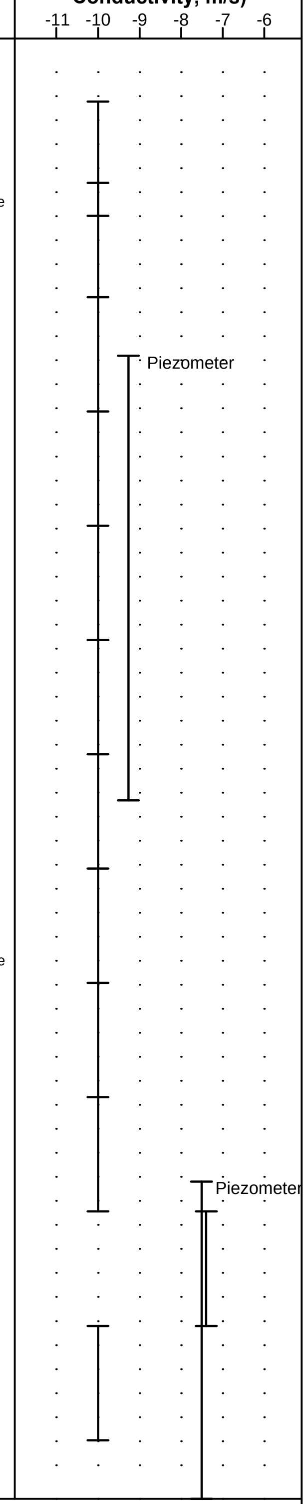
Natural Gamma (cps)



Well Diagram



Log10(Hydraulic Conductivity, m/s)



End of Borehole at 103.10 mASL

Hydraulic Conductivity are from Packer Test unless noted otherwise.
Packer Test: No flow assumed equal to 1 x 10^{-10} m/s

APPENDIX C: Water Well Information System (Well Records)

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2201087	373135	4906139	128.66	20.73	2	5 15	128.66 127.44 107.94	1	108.55	111.9
2201088	373224	4906048	125.66	20.73	2	5 15	125.66 124.45 104.94	1	107.38	123.84
2201090	373290	4906137	126	43.28	3	2 5 15	126.00 125.70 125.09 82.72	3	119.90 103.14 83.94	119.6
2201094	373401	4906161	126	14.02	3	2 5 15	126.00 125.70 123.56 111.98	2	114.42 113.20	115.03
2201096	373441	4906155	126.87	19.81	2	17 15	126.87 122.29 107.05	1	113.76	122.29
2201098	373779	4906155	125.03	18.29	2	2 15	125.03 124.42 106.74	1	109.79	122.9
2201099	373705	4906049	126.98	35.36	1	15	126.98 91.62	3	116.31 102.59 94.97	116.31
2201103	374778	4905199	90	29.87	2	17 15	90.00 83.29 60.13	1	66.84	77.81
2201105	374974	4905641	95.48	12.8	2	5 15	95.48 93.65 82.68	1	85.73	90
2201106	375035	4905253	93.04	27.13	2	5 15	93.04 89.99 65.92	1	70.18	85.73
2201108	375172	4905371	90.41	12.5	1	15	90.41 77.91	1	78.22	87.06
2201112	375591	4906152	101.6	22.86	2	5 15	101.60 100.99 78.74	1	83.32	86.36
2201113	375494	4906196	90.37	24.69	2	17 15	90.37 87.33 65.68	1	65.99	83.97
2201115	375534	4906015	96.36	23.47	2	5 15	96.36 94.53 72.89	1	74.72	82.95
2201118	375494	4906194	90.39	19.81	3	2 17 15	90.39 89.78 83.38 70.58	1	72.1	78.2
2201124	375557	4906195	95.93	15.24	3	2 15 15	95.93 95.01 89.53 80.69	1	82.52	85.87
2201126	375565	4906253	93.43	14.63	1	15	93.43 78.80	1	83.98	83.98
2201130	376215	4906126	97.32	18.29	1	15	97.32 79.03	1	82.08	86.65
2201137	376680	4906294	115.77	28.65	1	15	115.77 87.12	1	104.19	108.46
2201139	376595	4906302	107.4	17.98	3	2 17 15	107.40 104.96 103.74 89.41	1	97.64	100.08
2201142	376998	4906316	130	23.47	2	5 15	130.00 128.48 106.53	1	116.28	120.86
2201146	376938	4906307	130	43.59	1	15	130.00 86.41	1	111.71	111.71
2201147	377094	4906249	130	14.02	2	5 15	130.00 126.95 115.98	1	117.81	128.17
2201148	376710	4906296	117.35	31.7	2	9 15	117.35 116.75 85.66	1	89.92	112.48
2201150	377088	4906262	130	16.76	2	5 15	130.00 126.34 113.24	1	116.89	116.89
2201154	377095	4905900	130	13.41	1	15	130.00 116.59	1	117.81	127.56
2201158	377092	4906068	130	12.8	2	2 15	130.00 129.70 117.20	1	118.42	126.65
2201170	377092	4906218	130	19.81	2	5 15	130.00 128.78 110.19	1	118.42	119.03

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2201174	377093	4906280	130	21.95	2	5 15	130.00 128.17 108.05	1	111.1	114.76
2201176	376939	4906311	130	59.74	3	5 15 21	130.00 128.17 71.48 70.26	1	71.48	99.52
2201182	377598	4906338	131	15.24	2	5 15	131.00 130.39 115.76	1	117.28	121.25
2201183	377205	4905705	130	19.51	2	9 15	130.00 128.78 110.49	1	112.32	120.25
2201184	377196	4906023	130	23.47	2	17 15	130.00 126.95 106.53	1	108.66	122.38
2201185	377596	4906341	131	15.24	1	15	131.00 115.76	1	120.33	128.56
2201188	377184	4905869	130	26.82	2	17 15	130.00 127.87 103.18	1	107.14	122.99
2201190	377031	4906334	130	25.91	2	5 15	130.00 126.95 104.09	1	114.76	114.76
2201193	377212	4906331	131	20.42	2	17 15	131.00 125.82 110.58	1	124.6	124.6
2201214	377142	4906295	130	19.51	2	5 15	130.00 128.48 110.49	1	111.71	120.86
2201217	377135	4906323	130.21	21.03	2	5 15	130.21 129.30 109.18	1	113.45	125.64
2201218	377147	4906245	130.02	20.42	2	5 15	130.02 129.10 109.60	1	113.25	119.35
2201219	377140	4906262	130	20.73	2	5 15	130.00 128.78 109.27	1	117.81	118.11
2201223	377194	4906322	131	20.12	2	1 15	131.00 130.39 110.88	1	123.68	127.95
2201226	377183	4905220	130	15.24	3	2 15 15	130.00 129.39 123.90 114.76	2	126.95 119.33	129.09
2201227	377137	4906279	130	17.37	2	5 15	130.00 128.48 112.63	1	114.15	123.6
2201229	377095	4906282	130	28.04	2	2 15	130.00 129.70 101.96	1	102.87	116.28
2201232	377171	4905353	130	9.75	2	2 15	130.00 129.70 120.25	1	124.21	128.48
2201233	377352	4906318	132	13.11	3	2 17 15	132.00 131.09 129.87 118.89	1	120.42	130.48
2201234	377446	4906321	132	17.37	2	17 15	132.00 129.26 114.63	1	124.99	129.56
2201235	377185	4905242	130	20.73	1	15	130.00 109.27	1	110.49	120.86
2201237	377179	4905498	130	20.42	2	24 15	130.00 116.28 109.58	1	112.32	124.51
2201238	377165	4905217	130	22.86	2	17 15	130.00 124.21 107.14	1	108.36	117.5
2201240	377620	4906264	131	24.99	3	2 17 15	131.00 130.70 129.78 106.01	1	107.23	121.86
2201241	377777	4906328	129.41	22.56	3	2 17 15	129.41 128.80 126.97 106.86	1	108.69	125.15
2201244	377598	4906338	131	24.38	3	2 17 15	131.00 130.39 129.48 106.62	1	107.84	125.51
2201246	377531	4906325	131	22.56	2	24 15	131.00 115.15 108.44	1	112.71	126.73
2201316	373468	4906265	128	22.25	2	2 15	128.00 127.70 105.75	1	108.19	118.86
2201317	373214	4906409	130.8	20.42	2	2 15	130.80 129.89 110.38	1	112.51	126.53
2201318	373261	4906386	130	67.06	3	5 15 15	130.00 129.09 127.26 62.94	1	62.94	76.66

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2201319	373590	4908218	129.55	21.64	2	2 15	129.55 129.25 107.91	1	110.35	119.8
2201321	372988	4906537	135	22.25	2	17 15	135.00 133.17 112.75	1	116.71	120.67
2201324	373081	4906544	135.16	15.85	3	2 17 15	135.16 134.85 132.11 119.31	1	130.89	133.63
2201325	373608	4906253	128	18.59	2	17 15	128.00 127.39 109.41	1	120.38	125.56
2201326	372923	4906581	136	15.24	2	5 15	136.00 135.70 120.76	1	126.55	135.09
2201328	374054	4906237	116.14	25.91	3	5 17 15	116.14 115.83 113.70 90.23	1	91.75	112.48
2201329	374247	4906254	125	26.82	1	15	125.00 98.18	1	98.79	110.06
2201330	374119	4906233	123.14	30.48	3	2 17 15	123.14 122.83 121.61 92.66	1	113.99	113.99
2201331	374620	4906251	108.1	20.12	4	2 12 14 15	108.10 107.79 105.35 102.31 87.98	2	95.30 89.81	93.77
2201332	375528	4906306	89.17	15.85	2	5 18	89.17 75.75 73.32	1	73.93	89.17
2201333	375481	4906362	89	13.72	2	2 21	89.00 87.17 75.28	1	76.81	83.51
2201334	375197	4906291	89.05	16.15	2	5 21	89.05 88.13 72.89	1	74.42	85.39
2201335	375483	4906299	89	28.65	2	5 21	89.00 66.75 60.35	1	61.87	88.7
2201336	375598	4906300	91.89	22.25	2	5 21	91.89 73.60 69.64	2	72.08 70.55	86.4
2201337	375643	4906305	93.76	26.52	1	15	93.76 67.24	1	68.76	80.04
2201338	375505	4906286	89.08	26.21	3	2 15 21	89.08 88.16 64.70 62.87	1	70.79	79.94
2201339	376160	4906317	113.75	23.47	1	15	113.75 90.28	1	96.99	103.09
2201340	376272	4908423	132.69	21.95	2	5 15	132.69 132.39 110.75	1	123.55	129.95
2201341	376046	4906394	114.43	29.26	2	5 15	114.43 114.13 85.17	1	87	104.07
2201342	376105	4906346	114.86	28.35	2	5 15	114.86 113.64 86.52	1	87.43	104.5
2201343	376009	4906309	115	25.6	2	5 15	115.00 113.78 89.40	1	90.62	101.59
2201344	376032	4906317	115.6	26.21	2	5 15	115.60 114.38 89.38	1	90.6	101.58
2201345	376020	4906349	115.49	27.43	2	5 15	115.49 113.96 88.05	1	88.97	101.77
2201346	376112	4906315	115	26.52	2	5 15	115.00 113.78 88.48	1	89.7	103.72
2201347	376133	4906350	115	28.96	2	5 15	115.00 113.48 86.04	1	87.57	99.76
2201348	376085	4906371	114.18	24.38	2	5 15	114.18 112.96 89.79	1	90.71	101.99
2201349	376038	4906389	114.99	25.3	2	5 15	114.99 113.46 89.69	1	90.6	101.88
2201350	376185	4906339	112.83	26.52	2	5 15	112.83 111.61 86.31	1	87.23	101.55
2201351	376875	4906360	125.64	19.81	1	15	125.64 105.83	1	106.75	113.45
2201352	377269	4908216	116.93	27.74	2	5 15	116.93 115.11 89.20	1	98.65	106.27

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BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2201353	377124	4908424	123.9	25.6	2	5 15	123.90 123.59 98.29	2	120.85 99.51	111.71
2201354	377066	4906407	130	20.73	2	5 15	130.00 128.78 109.27	1	110.19	122.38
2201355	377088	4906384	130	22.86	2	5 15	130.00 129.09 107.14	1	108.66	120.86
2201356	377063	4907076	97.17	17.07	3	5 17 15	97.17 95.95 94.12 80.10	1	81.01	94.73
2201357	376998	4906381	129.37	21.03	2	9 15	129.37 128.46 108.34	1	110.17	119.92
2201358	377050	4908317	125	25.6	2	2 15	125.00 124.09 99.40	1	100.92	119.21
2201359	377091	4907279	109.52	19.51	3	5 17 15	109.52 108.30 106.48 90.02	1	92.76	104.95
2201360	377053	4907598	105.34	22.25	2	5 15	105.34 104.73 83.09	1	83.4	96.81
2201362	377042	4908067	120	29.26	2	2 15	120.00 119.39 90.74	1	92.57	104.76
2201363	377032	4908420	125	24.38	2	5 15	125.00 123.78 100.62	1	112.81	115.86
2201364	377047	4907929	115.1	21.34	2	17 15	115.10 112.05 93.76	1	96.2	112.35
2201365	377096	4906740	118.1	56.08	3	17 15 15	118.10 114.44 65.07 62.02	1	63.54	93.72
2201366	377071	4906440	130.99	26.21	2	5 15	130.99 129.77 104.78	1	110.57	121.85
2201367	377043	4908370	125	17.37	3	2 17 15	125.00 124.39 122.56 107.63	1	108.54	117.68
2201368	376955	4906379	128.77	43.59	2	17 15	128.77 123.28 85.18	2	108.95 85.79	100.11
2201369	377110	4907792	105.3	22.86	2	5 15	105.30 105.00 82.44	1	87.01	99.21
2201370	377171	4906428	131	22.56	2	5 15	131.00 128.56 108.44	1	111.19	124.9
2201371	377163	4906393	131	21.34	2	5 15	131.00 127.95 109.66	1	112.71	124.9
2201372	377092	4908419	124.08	26.52	2	5 15	124.08 122.86 97.56	1	107.32	121.64
2201373	377147	4906664	127.12	25.6	2	5 15	127.12 124.98 101.51	1	109.74	121.02
2201374	377118	4907639	108.27	28.96	2	5 15	108.27 107.36 79.31	1	88.46	105.22
2201375	377139	4907311	109.3	31.39	3	5 17 15	109.30 108.39 107.17 77.91	1	98.63	105.03
2201376	377051	4908395	125	27.13	2	5 15	125.00 122.87 97.87	1	98.79	112.81
2201377	377220	4908445	121.08	27.43	2	2 15	121.08 119.25 93.65	1	108.28	112.24
2201378	377147	4906627	128.57	28.96	3	2 17 15	128.57 127.96 126.44 99.61	1	107.23	122.47
2201379	377211	4906413	131.54	15.24	2	9 15	131.54 129.10 116.30	1	122.4	130.02
2201380	377161	4906551	130.82	27.13	1	15	130.82 103.69	1	106.43	122.28
2201381	377398	4908427	123.85	28.04	2	5 15	123.85 118.06 95.81	1	96.73	104.35
2201382	377101	4908381	124	27.74	3	5 17 15	124.00 123.39 122.48 96.26	1	96.87	108.76
2201383	377132	4906499	130.79	22.86	2	5 15	130.79 129.57 107.93	1	108.84	121.03

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BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2201384	377167	4906468	131	20.73	2	5 15	131.00 129.78 110.27	1	111.49	118.81
2201385	377160	4908433	123	30.48	2	5 15	123.00 120.26 92.52	1	97.09	107.76
2201386	377195	4908425	122.07	25.6	2	5 15	122.07 119.02 96.47	1	97.69	106.83
2201387	377149	4906451	131	69.49	3	17 15 21	131.00 124.90 73.39 61.51	1	73.39	101.43
2201388	377626	4908452	123.68	18.59	3	2 17 15	123.68 122.77 121.55 105.09	1	115.15	122.46
2201389	377568	4908458	125	22.86	2	17 15	125.00 120.12 102.14	1	103.36	118.9
2201390	377752	4906390	130	21.64	2	2 15	130.00 129.39 108.36	1	109.58	126.65
2201392	377730	4906388	130	23.77	2	17 15	130.00 128.78 106.23	1	115.37	124.51
2201577	376597	4908504	131	7.01	3	2 15 15	131.00 130.39 124.90 123.99	1	125.82	127.34
2201578	376752	4908472	129.45	15.54	2	17 15	129.45 124.57 113.90	1	121.83	127.62
2201580	377028	4908498	124.91	25.91	2	2 15	124.91 124.30 99.00	1	101.13	121.25
2201581	376769	4908469	129.01	0.91	1	5	129.01 128.10	1	109.51	123.22
2201582	377003	4908496	125.42	24.08	2	17 15	125.42 122.98 101.34	1	102.87	119.63
2201583	376912	4908497	127.21	21.03	2	2 15	127.21 126.30 106.18	1	108.92	118.07
2201586	377115	4908479	123.94	27.43	2	5 15	123.94 121.19 96.51	1	109.92	109.92
2201587	377196	4908520	122.03	30.48	2	5 15	122.03 119.90 91.55	1	94.6	109.84
2201588	377208	4908485	121.55	18.59	2	17 15	121.55 117.90 102.96	1	104.49	113.63
2201589	377182	4910014	125	17.37	2	5 15	125.00 120.43 107.63	1	108.54	120.12
2201590	377323	4910082	125	13.11	2	12 15	125.00 124.39 111.89	2	115.25 113.42	123.17
2201591	377256	4909612	125	21.03	3	2 17 15	125.00 124.39 121.65 103.97	1	113.42	118.29
2201592	377511	4908493	125	14.02	2	5 15	125.00 124.09 110.98	1	112.81	120.43
2201593	377610	4908580	125.92	28.65	1	15	125.92 97.27	1	103.06	118.3
2201594	377589	4908492	125	28.96	1	15	125.00 96.04	1	103.66	112.81
2201595	377613	4908607	126	31.09	2	2 15	126.00 125.39 94.91	1	96.43	107.71
2201596	377694	4908664	127	32	2	5 15	127.00 124.56 95.00	1	95.61	120.9
2201597	377719	4908676	127	41.15	2	5 15	127.00 125.17 85.85	1	85.85	117.86
2203997	377705	4908534	122.89	20.42	3	2 15 15	122.89 122.28 120.76 102.47	1	104.91	114.36
2204369	377050	4908432	124.8	28.65	2	5 15	124.80 122.67 96.15	1	97.67	107.73
2204370	377370	4908442	122.4	18.29	4	2 5 9 15	122.40 121.49 118.44 118.13 104.11	1	118.44	121.49
2204371	377110	4908262	123.14	27.74	2	5 15	123.14 121.92 95.40	1	96.32	112.47

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2204372	377450	4906382	132	29.26	2	2 15	132.00 131.39 102.74	2	117.37 112.19	128.95
2204380	377410	4908482	124.47	21.03	2	5 15	124.47 122.03 103.44	1	104.35	110.45
2204422	374980	4906302	89.23	10.67	3	5 17 15	89.23 87.40 86.18 78.56	1	82.53	87.71
2204668	372990	4908302	131.89	14.02	3	2 17 15	131.89 130.98 126.41 117.87	1	125.8	128.24
2204669	377470	4908482	125	41.15	2	5 15	125.00 122.56 83.85	1	84.16	97.57
2204732	374430	4907142	136	27.43	3	2 15 15	136.00 135.39 133.56 108.57	1	111.62	128.99
2204750	377190	4908782	129.16	14.02	6	2 5 9 15 15 15	129.16 127.64 125.50 121.84 116.05 115.44 115.14	1	115.44	122.15
2204754	377490	4908502	125	22.86	2	9 15	125.00 122.26 102.14	2	114.03 103.97	117.68
2204757	377030	4908742	129.78	35.66	6	2 15 15 15 15 15	129.78 129.17 113.62 112.71 95.03 94.42 94.12	2	113.62 94.42	116.06
2204758	377470	4908482	125	17.07	2	5 15	125.00 123.78 107.93	1	117.99	121.34
2204761	377670	4908552	124.14	31.7	2	5 15	124.14 123.22 92.44	3	102.49 96.09 92.74	102.19
2204830	377000	4908432	125	36.27	1	15	125.00 88.73	2	112.81 91.47	111.28
2204836	377030	4908422	125	32.61	2	5 15	125.00 124.09 92.39	1	93	104.88
2204942	377760	4906372	130	25.6	3	2 15 15	130.00 129.09 126.34 104.40	1	106.84	119.03
2204945	376220	4906432	114.96	29.87	2	2 15	114.96 114.05 85.09	1	86.92	99.42
2204963	373230	4906402	130.52	14.94	2	2 15	130.52 130.22 115.59	1	128.69	128.08
2205015	374370	4906262	121.95	37.19	2	5 15	121.95 121.34 84.77	2	108.24 85.38	104.27
2205028	376500	4908402	132	33.53	1	15	132.00 98.47	1	104.57	131.39
2205033	376510	4908182	130	21.34	1	15	130.00 108.66	1	127.87	128.78
2205041	375590	4906282	92.29	15.24	2	5 15	92.29 91.07 77.05	1	77.96	86.8
2205064	377340	4908442	121.7	9.14	3	5 11 15	121.70 118.35 118.04 112.56	1	118.04	119.26
2205071	374910	4909012	142	26.82	2	15 15	142.00 137.43 115.18	1	116.09	135.6
2205092	377290	4906332	132	23.16	2	2 15	132.00 131.70 108.84	2	115.24 109.75	129.56
2205139	373480	4906162	127	19.2	2	15 15	127.00 125.78 107.80	2	117.86 108.71	124.56
2205251	376780	4908422	130	24.38	2	2 15	130.00 129.09 105.62	2	126.34 105.92	123.9
2205265	373420	4906252	127.57	21.34	3	2 15 15	127.57 127.27 125.44 106.24	1	114.77	122.39
2205319	376850	4908482	128	24.38	2	15 15	128.00 124.95 103.62	2	113.37 104.84	119.47
2205331	377450	4906387	132	28.35	2	2 15	132.00 131.09 103.65	1	115.85	127.12

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2205332	375290	4905617	90.21	14.02	2	5 15	90.21 88.99 76.19	1	77.11	80.77
2205387	374030	4908382	135	22.25	2	2 15	135.00 134.70 112.75	1	113.66	130.12
2205394	377680	4906332	130	21.95	3	2 15 15	130.00 128.78 125.12 108.05	1	109.27	127.56
2205397	374390	4907122	136	24.38	2	5 15	136.00 134.17 111.62	1	112.84	130.82
2205435	377730	4908622	125.91	28.35	3	2 5 15	125.91 125.60 124.69 97.56	1	98.48	106.71
2205568	375310	4905652	91.81	21.64	2	5 15	91.81 90.89 70.17	1	71.08	81.14
2205569	375324	4905680	92.46	28.65	2	5 15	92.46 91.55 63.81	1	64.72	81.79
2205570	375348	4905707	94.25	27.13	2	5 15	94.25 93.33 67.12	1	67.73	83.58
2205577	377610	4906332	130.67	33.53	2	2 15	130.67 130.06 97.14	1	98.66	122.44
2205740	375110	4908402	140	43.59	2	5 15	140.00 139.39 96.41	1	117.14	138.78
2205767	376970	4906392	128.85	22.86	2	2 15	128.85 127.93 105.99	1	106.9	117.26
2205769	375610	4906282	93.08	17.68	2	2 15	93.08 91.56 75.40	1	76.32	86.38
2205916	377110	4908862	129.89	12.8	2	5 15	129.89 128.98 117.09	1	124.1	128.67
2205989	374350	4906552	129.84	123.44	5	2 15 15 21 21	129.84 129.53 78.02 73.45 16.15 6.39	2	73.45 16.45	98.14
2205992	377690	4906322	130	35.97	2	2 15	130.00 129.70 94.03	2	112.63 94.64	125.73
2206019	377150	4905962	130	13.11	1	15	130.00 116.89	1	122.08	128.48
2206063	375210	4905442	91	18.59	1	15	91.00 72.41	1	74.24	81.86
2206105	373960	4906222	120.72	16.15	1	15	120.72 104.57	1	109.45	120.42
2206140	376254	4906391	111.3	21.34	2	5 15	111.30 110.39 89.97	2	97.89 91.19	101.85
2206141	375502	4906173	92.21	19.81	3	5 17 15	92.21 91.30 87.95 72.40	1	76.06	84.29
2206180	377360	4905422	130	21.64	2	17 15	130.00 128.78 108.36	1	126.95	126.95
2206195	376758	4908406	130	67.06	4	2 15 15 21	130.00 129.39 70.56 64.47 62.94	1	64.47	87.33
2206212	374356	4906338	124.98	35.66	2	2 15	124.98 124.68 89.32	1	90.24	106.7
2206462	374317	4906610	130	32.92	2	2 15	130.00 129.70 97.08	2	105.62 98.00	113.54
2206602	377517	4908447	125	29.87	2	1 15	125.00 123.78 95.13	1	97.87	112.81
2206609	374320	4907665	135.81	20.73	2	1 15	135.81 134.59 115.09	1	116.31	131.24
2206887	376810	4908475	128.54	10.97	2	1 15	128.54 127.32 117.57	2	124.58 119.70	124.88
2206908	377059	4907600	105.45	15.24	2	2 15	105.45 103.31 90.21	2	96.61 93.86	97.52
2206944	377116	4908688	128.76	22.25	2	2 15	128.76 128.15 106.51	1	107.73	119.92

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2206977	377321	4908445	120.94	32.31	2	2 15	120.94 120.64 88.63	1	88.94	104.48
2207178	374426	4906123	108.62	19.81	2	5 15	108.62 104.05 88.81	1	89.42	105.88
2207195	375758	4906234	103.16	22.25	2	2 15	103.16 102.55 80.91	1	89.44	90.05
2207400	377510	4908502	125	37.49	2	2 15	125.00 124.39 87.51	1	89.03	106.71
2207529	377080	4907522	110.02	31.7	2	5 15	110.02 109.41 78.32	2	96.00 80.15	103.62
2207545	374830	4905422	90.8	35.66	3	2 15 21	90.80 90.19 59.71 55.14	1	55.75	74.03
2207687	377110	4908122	120.21	21.95	2	2 15	120.21 118.68 98.26	1	99.48	111.67
2207721	377210	4909222	125	27.13	2	5 15	125.00 123.48 97.87	2	108.24 103.05	118.6
2207756	377150	4906062	130	13.41	2	12 15	130.00 128.48 116.59	1	117.5	128.78
2207767	377090	4906562	129.78	68.28	5	2 15 15 15 21	129.78 129.48 126.12 80.40 77.66 61.51	1	77.36	120.03
2207804	375130	4905322	88.74	44.2	3	5 15 15	88.74 86.91 49.42 44.54	1	46.68	79.59
2207850	376510	4906642	110.46	59.13	5	1 28 15 18 21	110.46 108.94 107.11 65.35 59.56 51.33	1	52.55	96.75
2208206	374790	4905322	90	32.31	3	2 15 18	90.00 89.09 61.04 57.69	1	59.52	79.33
2208298	373510	4906222	127.54	77.72	4	15 15 21 21	127.54 75.73 72.37 60.49 49.82	1	69.94	113.52
2208513	374890	4905322	93.37	46.33	5	2 15 15 15 21	93.37 93.07 92.15 62.28 58.02 47.04	1	55.88	77.83
2208635	374990	4905142	94.83	37.8	3	5 15 15	94.83 92.70 58.87 57.04	1	58.26	87.52
2208636	374930	4905282	95	60.05	4	5 15 15 21	95.00 92.56 56.90 55.38 34.95	1	35.26	86.47
2208728	376990	4906382	129.27	34.75	2	23 15	129.27 108.54 94.52	1	95.74	111.59
2208832	375910	4906302	110.88	33.22	2	1 15	110.88 110.27 77.66	1	77.96	94.73
2208858	374729	4906621	129.21	28.04	2	2 15	129.21 128.60 101.17	1	102.39	117.02
2208865	374429	4906321	122.42	15.85	2	5 15	122.42 121.81 106.57	1	107.18	119.98
2208895	377229	4905621	130	29.57	1	15	130.00 100.43	1	101.96	120.86
2208956	375629	4906121	105	21.95	3	2 15 21	105.00 104.39 88.24 83.05	1	88.54	88.54
2209099	377329	4905521	130	27.43	1	23	130.00 102.57	1	104.4	120.25
2209116	374429	4906021	98.53	37.19	2	2 15	98.53 97.61 61.34	1	62.56	81.46
2209240	377529	4908321	121.65	32.31	3	2 26 15	121.65 121.04 119.82 89.34	1	95.74	103.06
2209245	377129	4908321	123.7	27.13	2	2 15	123.70 123.39 96.57	2	108.46 97.49	105.41

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2209314	373255	4909472	135	14.33	3	5 15 15	135.00 134.09 132.56 120.67	2	124.33 121.59	129.82
2209436	375729	4906021	109.75	27.43	2	17 15	109.75 108.53 82.32	2	88.11 83.54	97.56
2209527	377229	4908521	121	26.52	2	2 15	121.00 119.48 94.48	1	95.09	106.06
2209609	376829	4908621	127	36.58	2	2 15	127.00 126.70 90.42	1	109.63	122.43
2209643	373829	4908221	128.39	79.25	4	2 15 18 21	128.39 127.48 56.76 53.71 49.14	2	64.38 50.67	107.05
2209646	377229	4906221	131	33.53	6	5 15 15 15 46 15	131.00 130.39 110.27 109.05 99.00 98.69 97.47	2	115.15 99.00	119.42
2209880	377329	4909621	125	18.59	3	2 15 15	125.00 124.09 121.34 106.41	1	110.06	117.68
2209885	374629	4907321	135	41.45	5	2 15 15 15 15	135.00 134.70 126.16 97.20 95.07 93.55	1	95.68	119.15
2209886	374529	4906221	109.56	37.19	5	5 15 15 15 15	109.56 109.25 87.61 84.26 79.69 72.37	2	93.71 78.77	101.63
2210059	375729	4905921	106.58	20.42	2	2 15	106.58 105.67 86.16	1	89.82	89.82
2210264	374977	4905105	95.36	20.12	2	5 15	95.36 89.88 75.25	1	78.6	89.27
2210265	373147	4906194	128.42	29.26	2	2 15	128.42 128.11 99.16	1	121.41	122.32
2210326	377085	4906437	130.96	62.18	8	2 15 15 15 15 15 15 18	130.96 130.66 129.74 104.75 97.43 79.14 74.57 70.30 68.78	2	111.15 73.96	111.15
2210330	374300	4907812	136	22.86	2	5 15	136.00 134.48 113.14	2	118.02 115.27	129.9
2210332	373007	4907272	138.97	16.76	3	2 15 15	138.97 138.36 123.73 122.20	2	128.30 123.12	136.22
2210458	377030	4907892	114.87	35.05	5	5 15 15 15 15	114.87 114.56 111.21 93.53 91.09 79.81	2	93.23 81.64	106.03
2210703	376992	4906331	130	60.35	2	2 15	130.00 127.87 69.65	1	70.56	99.52
2210766	377219	4909420	125	15.54	3	2 15 15	125.00 124.39 120.73 109.46	2	115.25 110.98	119.82
2210912	377098	4908551	124	51.82	5	15 15 15 15 15	124.00 82.55 81.94 75.54 74.01 72.18	2	82.24 72.79	109.06
2210913	374428	4906481	128.39	26.82	6	2 15 15 15 15 15	128.39 127.47 116.19 114.37 108.57 106.44 101.56	1	102.78	110.4
2211269	377091	4908536	124.26	28.35	5	11 5 15 15 15	124.26 123.96 123.35 100.49 99.88 95.92	1	99.88	116.95

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2211278	377084	4906371	130	47.85	5	5 15 15 15 15	130.00 129.09 105.62 103.48 85.50 82.15	1	83.06	104.09
2211279	373298	4906354	129.12	26.21	2	2 15	129.12 128.51 102.90	1	121.8	121.8
2211281	376837	4906286	128.69	40.84	5	5 17 15 15 15	128.69 127.78 127.17 101.26 99.13 87.85	1	92.73	100.04
2211429	372867	4909452	136	34.14	1	15	136.00 101.86	1	103.39	115.27
2211432	377317	4905277	130	54.86	3	23 15 21	130.00 103.18 79.10 75.14	1	76.96	105.62
2211696	377037	4908389	125	28.65	2	11 15	125.00 124.70 96.35	1	97.57	114.33
2211708	377056	4908530	125	82.3	7	5 15 15 15 15 18 15	125.00 123.17 90.86 89.03 68.92 58.55 56.72 42.70	1	58.55	110.37
2211710	377331	4908494	121.33	28.04	5	5 28 15 15 15	121.33 118.28 117.67 100.91 95.73 93.29	1	95.73	99.38
2211932	377039	4908574	127.66	35.66	3	2 17 15	127.66 127.36 126.14 92.00	1	92.61	105.72
2211935	375308	4907334	131.49	14.94	3	2 15 15	131.49 130.28 126.62 116.56	1	126.62	128.45
2211938	377277	4908496	120.66	27.43	4	5 15 15 15	120.66 117.01 104.20 102.38 93.23	2	110.00 94.15	103.59
2212127	377235	4908462	121	30.78	3	5 15 15	121.00 120.70 93.87 90.22	1	91.74	103.32
2212270	377186	4908530	122.44	41.15	2	2 15	122.44 121.22 81.29	1	94.4	118.79
2212271	377018	4908588	129.34	52.43	2	24 15	129.34 88.19 76.91	1	78.44	125.68
2212536	374957	4905903	95.84	27.43	6	2 5 18 21 21 21	95.84 95.54 95.23 87.31 71.76 71.15 68.41	2	71.76 70.85	91.27
2212665	377145	4906364	130.93	37.49	6	5 5 15 15 15 15	130.93 130.01 129.71 105.93 103.19 94.66 93.44	2	111.42 94.66	114.16
2212666	377052	4908648	129.69	20.12	4	2 15 15 15	129.69 128.47 127.25 121.77 109.57	2	120.85 112.01	124.81
2212793	377192	4906328	131	37.49	4	5 15 15 15	131.00 130.39 116.67 116.06 93.51	1	96.86	111.49
2212794	377302	4906322	132	28.04	1	15	132.00 103.96	1	107.31	118.59
2213048	376762	4908524	129.32	26.82	1	15	129.32 102.50	1	106.46	121.7
2213126	377704	4905266	130	28.04	1	15	130.00 101.96	1	103.18	114.76
2213250	377113	4906137	130	33.83	2	23 15	130.00 101.65 96.17	1	98	109.58
2213354	377110	4906629	126.48	51.51	4	2 15 15 15	126.48 125.87 120.99 76.80 74.97	2	114.29 75.58	116.11

Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2213530	374298	4908108	137	46.94	7	2 15 15 15 15 18 18	137.00 136.39 134.56 98.90 94.33 92.80 90.06 90.06	2	119.32 93.11	120.24
2213531	374283	4908139	137	32.92	3	2 15 15	137.00 136.39 135.48 104.08	2	118.41 105.91	123.28
2213578	377317	4905277	130	67.06	3	2 15 21	130.00 129.09 65.38 62.94	4	112.32 108.66 105.62 64.77	117.5
2213632	373189	4906505	135.14	30.48	1	15	135.14 104.66	1	105.87	130.56
2213674	373440	4906163	127	22.56	5	2 17 15 15 15	127.00 126.39 125.78 114.81 113.89 104.44	1	113.89	113.59
2213760	374600	4909546	139.63	31.39	2	5 15	139.63 138.41 108.24	1	109.15	135.97
2213762	374080	4906365	125.94	35.36	5	2 15 15 15 15	125.94 125.63 121.98 105.82 95.15 90.58	2	94.24 91.80	106.74
2213795	374283	4907217	132	73.76	10	2 15 15 15 15 15 15 21 21 21	132.00 131.09 130.17 121.94 87.20 85.98 81.10 76.22 63.73 60.07 58.24	1	60.37	101.22
2213833	377627	4908517	124.83	39.93	1	15	124.83 84.90	2	94.96 85.20	111.11
2213835	377748	4908641	126.34	36.58	2	15 15	126.34 92.51 89.77	1	92.51	106.23
2213837	377317	4905277	130	19.51	2	5 21	130.00 123.29 110.49	2	121.16 113.54	126.95
2213936	376275	4908364	132	110.95	5	5 15 15 18 21	132.00 130.17 74.09 67.99 64.33 21.05	2	64.94 39.04	106.09
2214187	377126	4906335	130.15	21.34	2	2 15	130.15 128.32 108.81	3	112.77 110.94 109.72	117.95
2214332	375790	4905220	108.99	49.38	3	2 21 21	108.99 107.16 72.11 59.61	2	79.12 62.05	94.97
2214366	374693	4908638	140	5.49	2	5 15	140.00 139.09 134.51	1	136.34	136.34
2214529	376989	4908488	125.56	28.35	2	2 15	125.56 123.73 97.21	1	98.12	106.35
2214651	373413	4908500	130	24.38	5	2 17 15 15 15	130.00 129.70 129.09 112.93 111.10 105.62	2	111.71 106.23	119.94
2214745	377614	4908739	126	35.36	6	2 15 15 15 15 15	126.00 124.48 115.33 114.11 96.74 95.22 90.64	1	95.22	105.58
2214825	377178	4908457	122.76	29.26	3	5 15 15	122.76 120.93 96.55 93.50	1	95.94	105.69
2214826	375690	4907346	128.97	38.1	4	17 15 15 15	128.97 128.36 116.78 116.17 90.87	1	116.78	117.7

Prepared by: AC
Reviewed by: AW
Date: 9/23/2015
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Table C1 - MOECC Water Well Record Querry Results

BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2214828	375690	4907346	128.97	38.1	2	17 15	128.97 128.36 90.87	1	110.99	116.17
2215027	377503	4908467	125	36.88	1	15	125.00 88.12	2	104.27 89.64	104.27
2215326	376375	4908776	134.5	6.1	2	2 15	134.50 134.20 128.41	1	129.02	129.93
2215472	374384	4907235	135	39.62	7	2 17 15 15 15 15 15	135.00 134.70 134.09 123.11 122.20 107.26 106.96 95.38	1	106.96	129.51
2215473	374426	4907260	135	40.23	5	5 17 15 15 15	135.00 134.39 134.09 125.25 124.03 94.77	2	124.94 107.87	126.16
2215723	374086	4908766	135	27.43	5	5 15 15 15 15	135.00 134.39 119.15 117.93 108.79 107.57	1	108.48	131.65
2215868	376776	4909600	123.75	42.67	1	15	123.75 81.08	3	115.52 107.29 99.97	122.83
2215895	373812	4908158	130	15.85	8	5 17 15 15 15 15 15 15	130.00 129.70 128.78 125.12 124.82 118.42 118.11 114.76 114.15	2	118.42 114.46	129.39
2215898	377047	4906330	130	51.82	6	5 15 15 15 15 15	130.00 127.87 114.76 113.54 91.90 90.38 78.18	2	90.68 81.23	102.57
2216020	376805	4906324	123.15	39.93	6	5 17 15 15 15 15	123.15 122.85 122.24 92.37 87.80 83.53 83.23	2	86.27 85.05	97.25
2216169	377629	4908394	121.25	22.56	6	2 15 15 15 15 15	121.25 120.95 110.89 109.97 101.14 100.83 98.70	2	107.23 100.83	107.84
2216300	377097	4907472	111	23.16	7	5 17 15 15 15 15 15	111.00 109.17 108.56 97.59 96.98 89.66 88.75 87.84	3	103.68 102.16 96.98	103.99
2216472	376858	4908499	128	30.18	6	5 17 15 15 15 15	128.00 127.09 126.78 114.28 101.18 100.87 97.82	1	100.87	103.01
2216478	377725	4908703	127	35.36	1	15	127.00 91.64	2	94.69 92.25	108.71
2216505	377657	4906527	131	44.5	6	5 15 15 15 15 15	131.00 130.70 115.15 112.71 110.27 109.05 86.50	2	124.60 112.71	126.73
2216506	377650	4908548	124.64	35.97	3	5 17 15	124.64 124.03 123.42 88.67	2	97.81 90.50	100.86
2216543	377108	4906413	130.98	74.37	11	5 15 15 15 15 15 18 18 18 18 18	130.98 129.15 126.41 125.19 85.87 85.56 84.95 71.54 67.27 62.09 61.18 56.61	2	106.59 71.85	108.42

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BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2216560	375216	4909560	140	6.1	3	2 5 15	140.00 139.70 138.17 133.90	2	138.17 134.82	135.12
2216616	377507	4908651	125.33	32.92	7	5 17 15 15 15 15 15	125.33 122.29 121.98 117.10 112.84 106.44 99.12 92.41	1	96.68	104
2216672	373536	4906172	127.11	31.09	6	5 15 15 15 15 15	127.11 126.20 115.23 114.92 114.01 113.40 96.02	1	105.78	108.22
2216695	375623	4906113	105	32.31	3	2 17 15	105.00 104.39 103.48 72.69	2	80.92 75.13	88.24
2216719	374042	4905983	124.42	28.04	6	15 15 15 15 15 15	124.42 123.51 114.97 111.62 98.82 98.51 96.38	1	98.51	108.27
2216821	372843	4905108	88	20.42	8	5 15 15 15 15 15 15 15	88.00 86.17 85.87 77.94 77.03 71.54 69.71 69.10 67.58	2	77.33 69.71	84.34
2216863	377561	4909621	125	37.49	3	2 17 15	125.00 124.39 123.78 87.51	2	105.80 89.64	110.98
2216930	373572	4905130	126	24.69	1	15	126.00 101.31	1	104.05	106.19
2216931	374321	4905160	109.37	26.52	4	5 17 15 15	109.37 108.76 104.80 85.60 82.85	2	90.47 85.60	90.47
2216961	374321	4905160	109.37	18.59	7	5 17 15 15 15 15 15	109.37 108.76 106.93 99.92 98.70 93.21 92.30 90.78	2	99.62 92.61	101.75
2216994	374153	4907302	129.51	42.06	1	15	129.51 87.45	1	99.03	115.8
2217174	377001	4908567	128.62	7.01	1	15	128.62 121.61	1	125.57	125.57
2217187	372828	4906013	130	35.05	2	15 15	130.00 127.56 94.95	2	119.33 109.27	129.39
2217285	376694	4906323	113.15	57.91	9	5 17 15 15 15 15 15 15 21	113.15 112.54 110.10 99.43 94.56 84.50 79.62 60.72 56.15 55.24	1	56.15	82.97
2217362	377563	4908430	124.98	25.91	3	28 17 15	124.98 123.76 122.85 99.08	2	115.84 99.99	117.06
2217381	373033	4906456	134	6.71	2	2 15	134.00 133.70 127.29	1	130.34	131.87
2217986	374930	4907322	135.22	29.87	2	17 15	135.22 134.00 105.35	2	124.24 117.84	125.46
2218258	377329	4909173	125	22.4	6	5 28 17 15 15 15	125.00 124.10 122.90 122.30 107.10 104.90 102.60	2	114.40 106.80	121.35
2218313	375177	4905408	90.6	29.1	6	5 17 15 15 15 15	90.60 90.30 89.70 83.00 76.30 75.10 61.50	2	79.90 75.60	85.4
2218314	377350	4908494	122.08	27.1	7	5 28 17 15 15 15 15	122.08 120.28 119.08 118.18 114.78 112.68 102.28 94.98	1	98.08	104.18
2218317	376999	4905262	130.89	20.1	2	15 15	130.89 113.49 110.79	1	113.49	118.09

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BH ID	Easting	Northing	Ground Surface (masl)	Total Depth (m)	# of Form-ation	Form-ation Mat1 Codes*	Formation Contact Elevations (masl)	# Water Found	Water Found Elevations (masl)	Heads (masl)
2218402	377085	4906458	131	36.6	3	28 17 15	131.00 130.40 129.20 94.40	1	100.2	110.9
2218761	374486	4908854	137.09	6.09	2	5 15	137.09 133.79 131.00	1	132.09	132.65
2218798	377191	4906150	130	74.4	8	5 15 15 15 15 15 18 18	130.00 129.70 78.80 72.10 71.80 67.50 66.90 65.70 55.60	2	118.40 71.80	123.9
2218808	377178	4906029	130	74.4	5	5 17 15 18 18	130.00 127.90 127.00 116.30 60.50 55.60	2	122.40 58.00	128.4
2218894	377130	4908304	123.65	27.4	4	5 17 15 15	123.65 123.05 122.45 96.85 96.25	1	96.85	105.05
2218933	374112	4907968	133.93	18.3	3	17 15 15	133.93 132.73 119.33 115.63	1	117.53	131.13
2219208	372987	4908510	139.15	23.2	4	5 15 15 15	139.15 138.85 129.45 128.45 115.95	1	129.15	132.75
7040342	374310	4907523	135	24.1	7	5 17 15 15 15 15 15	135.00 134.50 132.00 124.30 122.80 119.80 116.70 110.90	1	113	128.2
7044780	377062	4908124	121	24.7	3	5 17 15	121.00 120.00 118.90 96.30	1	98.6	105.5
7105739	377339	4909136	125	24.4	3	5 17 15	125.00 124.70 123.80 100.60	2	108.60 103.10	120.6
7105742	377320	4909174	125	35.7	5	5 17 15 15 15	125.00 124.70 122.00 117.40 112.20 89.30	1	101	121.6
7108352	377295	4907527	110.02	24.4	3	5 17 15	110.02 109.12 107.92 85.62	2	98.02 89.02	102.22
7110985	377112	4906547	130	87.17	5	5 15 15 18 21	130.00 128.17 74.53 69.04 64.77 42.83	2	99.82 64.77	100.13
7113026	375839	4906244	108.58	23.47	1	15	108.58 85.11	1	86.03	94.8
7119554	375173	4905792	90.44	28.65	3	5 17 15	90.44 90.13 89.52 61.79	2	72.15 63.01	72.88
7119560	374382	4907625	135.96	21.64	7	15 15 15 15 15 15 15	135.96 133.82 124.37 123.76 119.80 119.19 117.67 114.32	1	117.67	131.32
7119565	375049	4905691	92	29.57	3	5 17 15	92.00 91.69 89.86 62.43	1	89.16	77.15

Note:

*Legend of Mat1 Codes can be seen in Table C2 in Appendix C

All data obtained from Ministry of Environment of Ontario Water Well Information System Database updated November 2012

Table C2 - Legend of Mat1 Codes

Code	Description		Code	Description
00	Unknown Type		39	Feldspar
01	Fill		40	Flint
02	Topsoil		41	Gneiss
03	Muck		42	Greywacke
04	Peat		43	Gypsum
05	Clay		44	Iron Formation
06	Silt		45	Marble
07	Quicksand		46	Quartz
08	Fine Sand		47	Schist
09	Medium Sand		48	Soapstone
10	Coarse Sand		60	Cemented
11	Gravel		61	Clayey
12	Stones		62	Clean
13	Boulders		63	Coarse-Grained
14	Hardpan		64	Crystalline
15	Limestone		65	Dark-Coulourd
16	Dolomite		66	Dense
17	Shale		67	Disrty
18	Sandstone		68	Dry
19	Slate		69	Fine-Grained
20	Quartzite		70	Fosiliferous
21	Granite		71	Fractured
22	Greenstone		72	Gravelly
23	Previously Dug		73	Hard
24	Previously Drilled		74	Layered
25	Overburden		75	Light-Coloured
26	Rock		76	Limy
27	**		77	Loose
28	Sand		78	Medium-Grained
29	Fine Gravel		79	Packed
30	Medium Gravel		80	Posour
31	Coarse Gravel		81	Sandy
32	Pea Gravel		82	Shaly
33	Marl		83	Sharp
34	Till		84	Silty
35	Wood Fragments		85	Soft
36	Basalt		86	Sticky
37	Chert		87	Stoney
38	Conglomerate		88	Thick
			89	Thin
			90	Very
			91	Water-Bearing
			92	Weathered

APPENDIX D: Photographs from Site Inspection

Photo 1: Ice on west wall of south existing quarry, approx. elevation 128 masl, taken Nov. 25, 2013

Photo 2: Same location, on January 10, 2014

Photo 3: North quarry, looking north.
Note the same ice production at approximately 128 masl.

Photo 4: South quarry, looking south.
Note the ice at various locations, at approximately 120 masl.

Photo 5: South wall of south quarry. Note the ice at approximately 120 masl.

Photo 6: Close up of rust staining and ice at point groundwater discharge location.

Photo 7: Pumping from the sump of north excavation

Photo 8: North pump junction. Black pipe goes to culvert and to south quarry (SW1)


Photo 9: Wash plant sediment ponds in south quarry


Photo 10: Wash plant pond with pump for flood events


Photo 11: Overflow sediment pond (SW2)


Photo 12: Southwest corner of south quarry, with ponded water

Photo 13: Drainage ditch exiting quarry at the south end (SW3)

Photo 14: Rectangular culvert under K&P trail (taken from upstream end)

APPENDIX E: Downhole Geophysics Report

NOTRA

SUMMARY OF THE PHYSICAL PROPERTY BOREHOLE GEOPHYSICAL SURVEYS CONDUCTED AT ELGINBURG, ONTARIO

Submitted To:

Morrison Hershfield

Date
29 January 2013

Prepared By:

NOTRA Inc.
Dennis Gamble, P.Geo.

EXECUTIVE SUMMARY

A potential quarry expansion has been identified along the west and south west side of the current operations near Elginburg, ON, north of Kingston, Ontario.

In order to determine if suitable rock materials are sufficient and shallow enough to make a quarry operation feasible, a series of three (3) additional bore holes were commissioned throughout the property (in addition to 3 previously drilled). One hole, DDH10-01 (2010) was cored using a diamond drill borehole rig, allowing for a core log to be determined as well as additional chemical analysis. The geologic sections determined from DDH10-01 served as a reference log of the local geology and other boreholes.

An additional three (3) holes were drilled using reverse circulation techniques in 2012, holes BH1201, BH1202 and BH1203, which result in only rock dust being retrieved from the holes. Three other holes drilled in 2011 were also surveyed (BH1102, BH1103 and BH1104). In order to determine the lithology in these holes, borehole physical property surveys were conducted and the results compared to the reference log of DDH10-01.

Morrison Hershfield contracted NOTRA Inc. to conduct the seven (7) borehole physical property surveys. The Instruments for Geophysics (IFG) BMP06 multi-parameter probe was used along with the IFG 100 meter winch with optical depth encoder. The BMP06 simultaneously measures six (6) parameters at a rate of two (2) readings per second. The site was large; with limited access to the holes that were distributed over an area of approximately 1.2 km x 500m. A Side by Side ATV was used to transport the equipment from hole to hole.

Following analysis of the data it was determined that the natural gamma displayed a very close resemblance between all seven (7) boreholes. Using the DDH10-01 results, marker locations for the other 6 holes were projected using the natural gamma and resistivity data.

At the time of this report the results of the core and chemical analysis were not provided, however, the geophysical markers can be used to interpolate the relative depths any zones of interest from DDH10-01 to the other holes.

The overall trend indicates that the sedimentary rock sequences dip linearly to the south relative to the ground surface (elevation data has not be collected or provided). Over approximately 1100 meters from north to south, the top of DDH10-01 is found to have an additional 13 meters of sedimentary rock above it, implying a dip of approximately 0.6 Degrees.

TABLE OF CONTENTS

1.0 Introduction

On 18 December 2012, NOTRA conducted a physical property borehole survey of seven (7) Boreholes that were approximately 35m in depth. Borehole DDH10-01 was a cored hole from which geophysical markers were identified. The other six (6) holes were drilled using reverse circulation and no core logs were produced.

The purpose of the borehole survey was to provide a manner to compare the geology sequences and depths between the cored hole and the six non-cored holes. An IFG BMP06 multi-parameter borehole tool was used to log data at approximately 5 cm intervals in all seven (7) holes.

The water table was found to be relatively deep, between 8 to 20 meters for the five (5) holes. The Apparent Resistivity and Single Point Resistance can only work within the water column and were deleted in the dry section of each hole. The Magnetic Susceptibility and Apparent Conductivity reacted only to the casing and were not used otherwise. The temperature data is presented, but only provides information of possible porous fractures.

The natural gamma data works within casing, dry sections of holes and within the water column with no variation. It was this parameter that was reproducible from hole to hole and can be used to imply the depths of any sequence relative to the sequences present in DDH10-01.

2.0 Methodology and Approach

BMP06

The BMP06 measures simultaneously the temperature (T), apparent conductivity (AC), apparent resistivity (AR), single point resistance (SPR), magnetic susceptibility (MS) and natural gamma (NG) at a rate of 2 reading per second. The depth is also measured using an optical depth encoder that is part of the pulley mechanism affixed to the casing.

During the survey a 5 mA current is transmitted into the electrode from the control unit (remotely placed 25 meters from the borehole). This is used for the apparent resistivity measurements.

Upon placing the borehole probe in the hole, the depth of Zero is entered in the logging computer after the top of the probe has been lined up with the top of the casing. All depth references are to the top of the casing.

With the computer logging, the probe is lowered at approximately 5 meters per minute, resulting in one data point for all parameters being recorded every 4 cm. The probe is stopped briefly at 10 meter intervals (to confirm the accuracy of the optical depth encoder). Following completion of the hole, data is then collected while bringing the probe up, although at a faster rate. This up data is compared to the down run data to ensure proper operation of the unit. In the event there is a depth dispute when the probe reaches the top of the casing, the hole is resurveyed.

From each file the depth values are also confirmed (using the 10 m calibration points) and each parameter is extracted to an asc file. These files were then plotted in LogView from which analysis can be conducted.

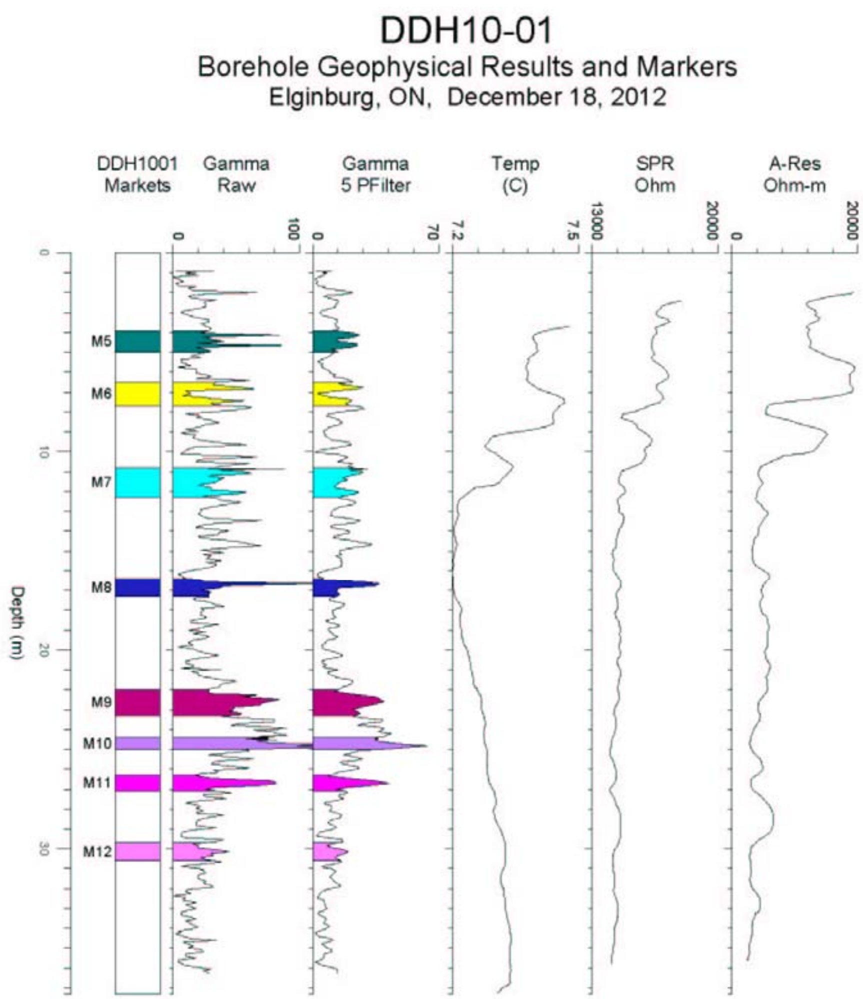
Annex A has a complete description of the BMP06 probe and winch used during this survey.

Annex B has a description of the portable, manual 100m winch.

3.0 Results

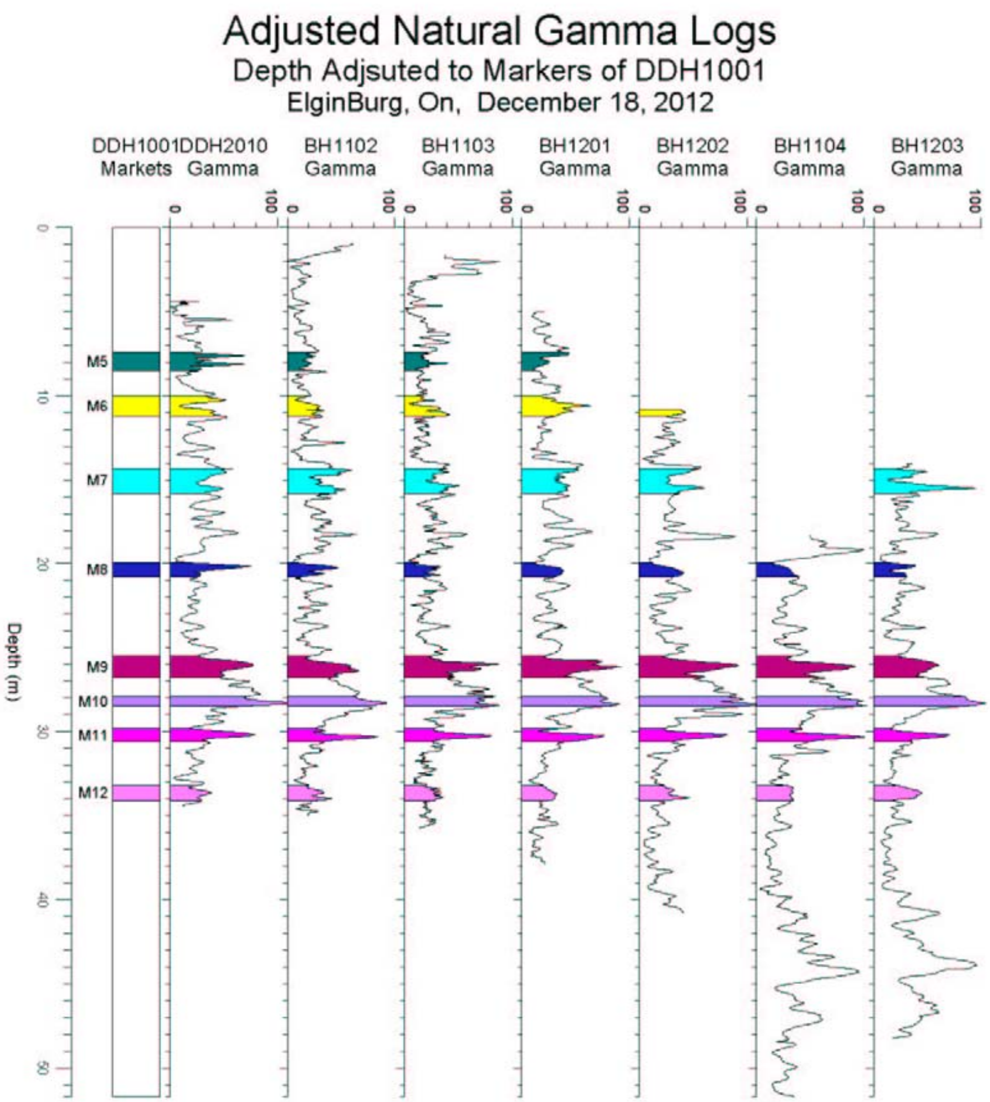
DDH10-01 was surveyed and divided into the eight markers (8) units based on the natural gamma profiles starting at marker 5 (marker 1 to 4 to be attributed to markers higher in the sedimentary sequence than present at the ground level of DDH10-01).

Figure 1 – DDH10-01 with Markers



After determining location of these markers depths for the remaining 6 holes, the relative depth was adjusted until they matched that of the natural gamma markers (M5 toM12), the Natural Gamma data was plotted for all the holes and adjusted to line up (on BH1102 – the highest). - The complete logs for BH1102-BH1104, to BH1201-BH1203 are contained in Annex B.

Figure 2 - Natural Gamma Data – Levelled to Markers



The natural gamma data maps profiles for each hole are very similar when adjusted by a vertical shift and aligned to specific features in the profiles.

The following table summarizes the depth of each hole surveyed, the water table depth and the relative shift to the natural gamma profiles to align the markers to BH1102.

Table 1 - Borehole Summary

	Depth in meters		
Borehole	Water	Hole Length	Shift to Align Markers
DDH1001	3.7	37.2	4.4
BH1102	4.9	35.9	0.9
BH1103	8.8	36.0	1.6
BH1104	19.8	36.0	18.3
BH1201	11.4	34.7	5.0
BH1202	17.6	39.1	10.8
BH1203	2.0	36.1	14.0

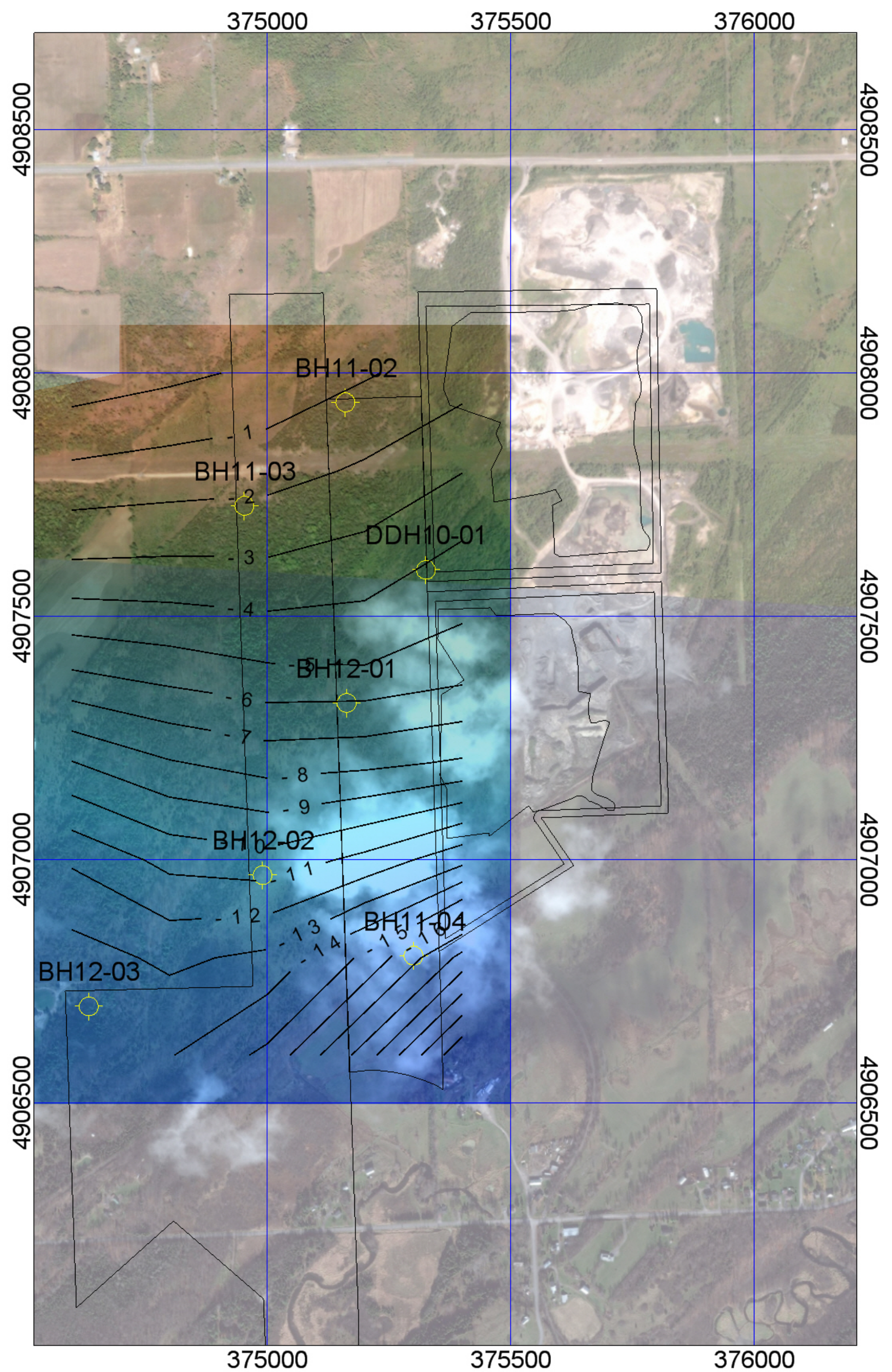
By plotting the location of each hole and the shift required to align the Natural Gamma data, the relative dip and strike of the sedimentary rocks can be plotted relative to the top of the borehole casing (the reference for each profile). Table 2 below has the locations (provided by Morrison Hershfield) and the shift.

Table 2 - Borehole Locations and Shift to Align Markers

Name	X	Y	Shift to Align Gamma
DDH10-01	375326.5	4907596.0	4.4
BH11-02	375161.1	4907940.2	0.9
BH11-03	374953.6	4907727.6	1.6
BH11-04	375301.2	4906803.1	18.3
BH12-01	375163.5	4907322.5	5.0
BH12-02	374990.9	4906968.5	10.8
BH12-03	374634.1	4906698.8	14.0

Figure 3 is a contour map of the borehole locations and the shift applied to match the markers identified in the natural gamma data.

<u>Figure 3 – Contour Map of Shift applied to Alien Natural Gamma Data</u>



4.0 Conclusions

At the Elginburg Site, natural gamma (NG) data can be used to determine the locations of lithology between all seven (7) Boreholes.

Markers relating to Natural Gamma data can be identified and located on all of the holes surveyed. Markers M5 to M12 were located on the reference hole, DDH10-01 and located on the additional six (6) boreholes

By shifting the elevation of each hole, the Natural Gamma and markers were aligned. A plot of this shift value for each hole using the provided borehole location indicates a dip of less than 1 degree to the south relative to ground surface (top of casings for each hole).

This implies a significant additional amount of rock of over 10 meters is above the beginning sedimentary rock units present at the top of DDH10-01 at a distance of 1 km to the south, increasing to 18m at a distance of 1200m.

The locations of fractures can be obtained from the temperature and temperature gradient data; however, at this time this information is not required.

5.0 Statement of Limitations

This Geophysical Survey Report has been prepared exclusively for Morrison Hershfield. The purpose of this report is to provide them with an assessment of the lithology of six (6) Boreholes relative to one (1) Diamond Drill Hole. This report is neither an endorsement nor a condemnation of the subject property.

The borehole geophysical techniques employed typically produce methods to map and differentiate structure in bead rock. However, each technique has limitations, especially in areas in which there is little magnetic changes, conductivity changes or in dry portions of wells.

The results and conclusions documented in this report have been prepared for a specific application to this project and have been developed in a manner with that level of skill normally exercised by qualified professionals currently practicing in this area of geophysical surveying. No other warranty, expressed or implied, is made.

Reports or memoranda resulting from this assignment are not to be used in whole or in part outside Morrison Hershfield without prior written permission.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. NOTRA Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

If new information is developed in future work (which may include the survey in of borehole locations and elevations or changes to the diamond drill logs), NOTRA should be contacted to re-evaluate the conclusions of this report and to provide amendments as required.

Dennis Gamble

Dennis Gamble, P.Geo, P.Geoph.
Senior Geophysicist, NOTRA Inc.
January 29, 2013

ANNEX A
EQUIPMENT DESCRIPTION

- BMP06 Multi-Component Probe
- 100m Winch

Instruments for Geophysics (IFG) - BMP06 Multi-Component Probe

General Description

The BMP-06 is a multi-component probe designed by the IFG Corporation in Brampton, Ontario. It simultaneously measures temperature (T), Relative Conductivity (RC), Magnetic Susceptibility (MS), Natural Gamma (NG), Single Point Resistance (SPR) and Apparent Resistivity (AR).

The probe is a total length of 196 cm (from cable head to tip). The parameters measured are located along the full probe length.

Parameter Description

Temperature

A temperature sensor is located 182 cm below the cable head. The temperature sensor is resilient to drift and measurements are repeatable to within 0.01 of a degree Celsius. For additional calculations such as gradient or differential temperature, the temperature data is interpolated to a fixed depth interval.

As the probe goes down the hole it disturbs the static water column. For this reason the initial down run is used for presentation and interpretation. It is also preferable to conduct the survey when the water within the hole has been allowed to settle following drilling, purging or other actions.

Temperature is effective at detecting water-flowing fractures. When water from the surrounding rock enters of leaves the borehole, it may be evident as a rapid change in temperature that may be enhanced with temperature gradient calculations. To enhance water leaving the column, the borehole column can be heated and the temperature resurveyed.

Relative Conductivity

The RC sensor is located 120 cm below the cable head. The sensor, coincident loop coil, is tuned for relatively conductive environments (sulfide differentiation) and is susceptible to drift due to temperature changes, especially in low conductivity environments (0.1 to 20 mS/m).

The RC may be used to measure large conductivity contrasts in the borehole.

Magnetic Susceptibility

The MS sensor is located 150 cm below the cable head. The coincident loop coil is tuned to measure the in phase response that may be related to magnetic materials in the borehole. This relationship may breakdown in highly conductive environments (sulfides) and the MS response is susceptible to drift due to temperature changes.

Rock units that have contrasting iron content may be mapped with the MS.

Natural Gamma

The natural gamma sensor is located 92 cm below the cable head. The natural gamma measures gamma rays in the spectrum between 0.1 and 3 MeV in counts per second.

In most rock units it is the variations in potassium content that results in variations in the gamma values (ranging from 30 to 500 cps). This technique is the most successful at differentiating changes in lithology, especially in a multi-hole project in which subtle variations may be related from hole to hole.

The introduction of concentrations of uranium (and to some degree thorium) may result in a significant increase in count rate of well over 1000 cps. As the energies of the gamma rays are not measured, it is not possible to attribute a high gamma count rate to a specific element.

The natural gamma sensor is not sensitive to temperature changes and can be used in the presence of borehole casing.

Single Point and Apparent Resistivity

The single point resistance (SPR) is the electrical resistance measured between the cable head and the casing or grounded electrode at surface. The SPR may be used to differentiate rock units that have large resistivity variations.

For the Ares, a constant 5 mA current is applied between the grounded electrode (or casing) and the cable head and the voltage measured between two additional electrodes below the cable head. The scale factor used to calculate the apparent resistivity (AR) is;

AR = pi (V/i)/ 0.406 where V is the measured voltage and i is the constant current

Although the AR closely matches the SPR, it is a more precise measurement of the rock resistivity. For both AR and SPR, the probe must be submerged in water.

Instruments for Geophysics (IFG) - 100 m Winch - General Description

The borehole winch used is the IFG 100 meter manual winch with external controller. The system is ideal for shallow environmental surveys due to its relative portability.

The basic system includes a winch with a geared hand crank and 100 m of 4-conductor cable. A pulley placed on the borehole casing or affixed to the winch has a laser counter built in to measure cable motion (depth).

A controller box is used to power the various probes that may be attached to the winch, to digitize the analog signal from the probes and to digitize the counter signal. A stream of digital data is transmitted from the controller to a laptop computer at a rate of 1 complete data set/second. The controller requires 200 Watts of power and can be powered by portable 12 volt battery with and a small inverter (12v DC to 110 v AC).

The IFG DAS software is used to control data acquisition and monitor data quality.

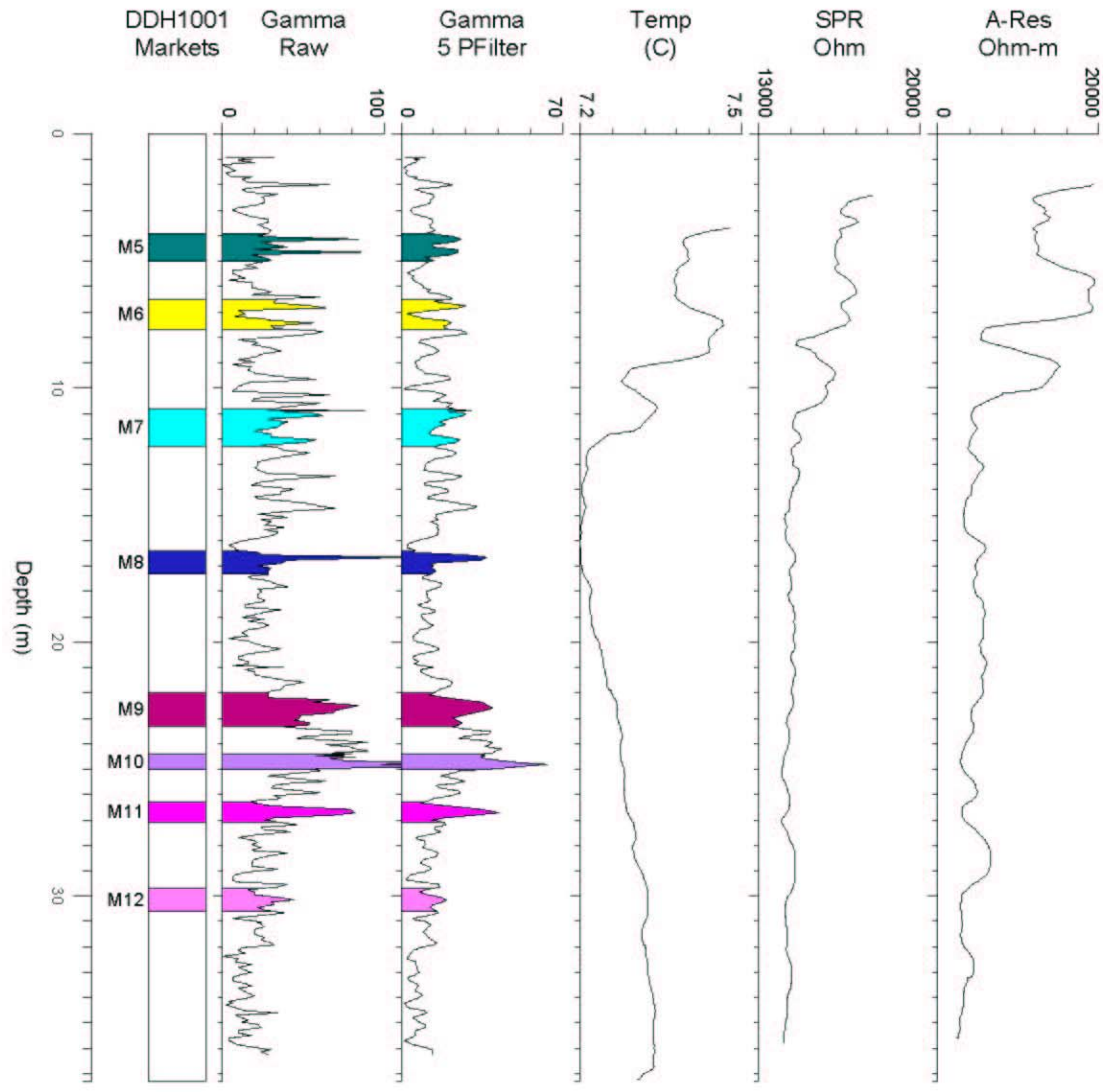
Field Procedures

During each survey the zero depth is established as the location of the cable head (to the probe) relative to the top of the casing. As the probe is lowered at a rate of 4cm/sec data is stored to a *down run file*. As there is the possibility of pulley slippage or dirt and ice interference, the borehole cable has markings at 10 meter intervals. At each 10 meter marking the digitized depth is noted. Any deviation between measured depth and actual depth is corrected during post processing.

When the end of hole is encountered the down run file is closed and an up run file is opened. The up run is collected as a check against probe operation. Provided there is no deviation between runs for a particular parameter, only one run is presented in profiles.

ANNEX B
COMPLETED LOGS

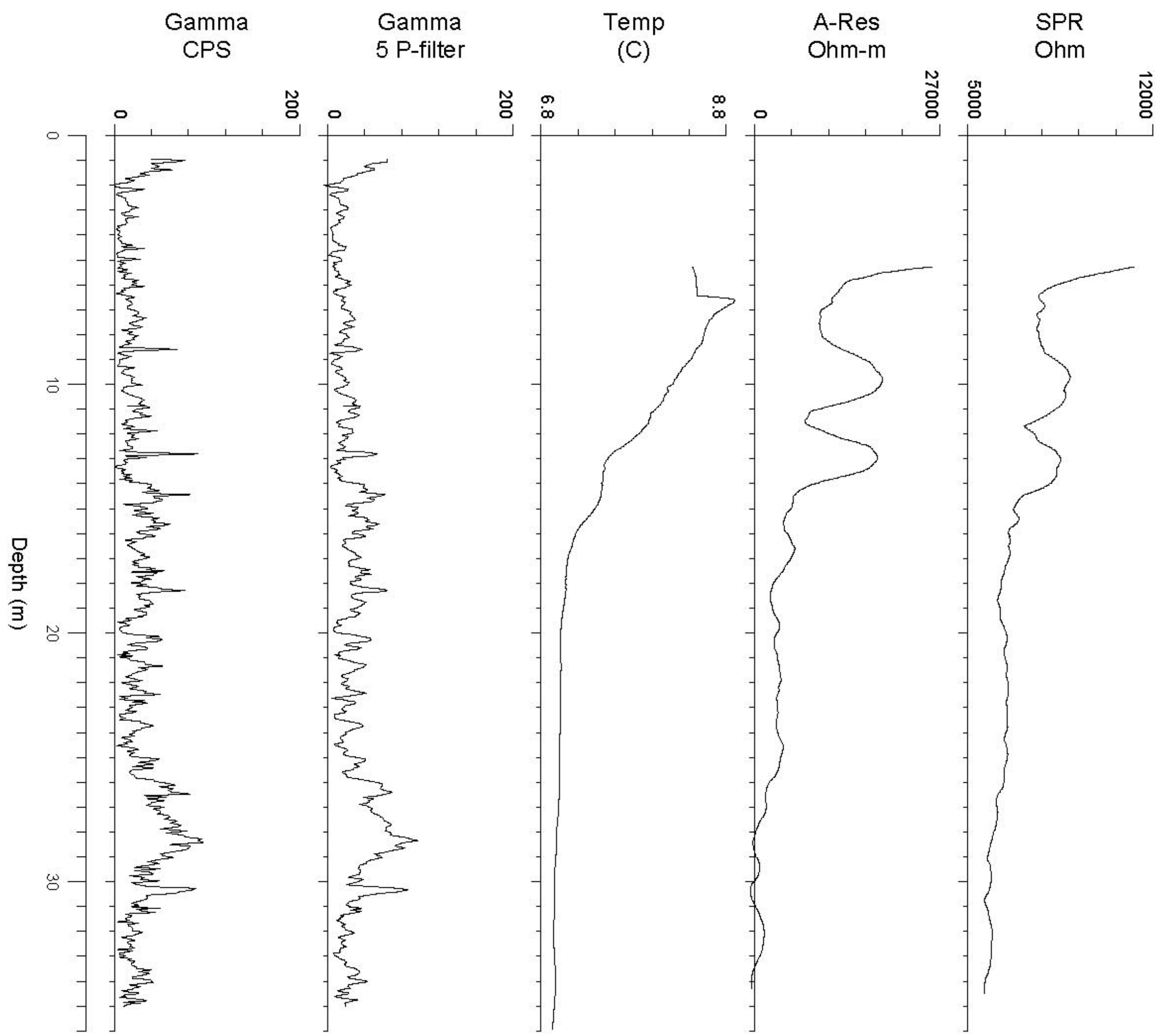
DDH10-01
Borehole Geophysical Results and Markers
Elginburg, ON, December 18, 2012



BH1102

Borehole Geophysical Results

Elginburg, ON, December 18, 2012

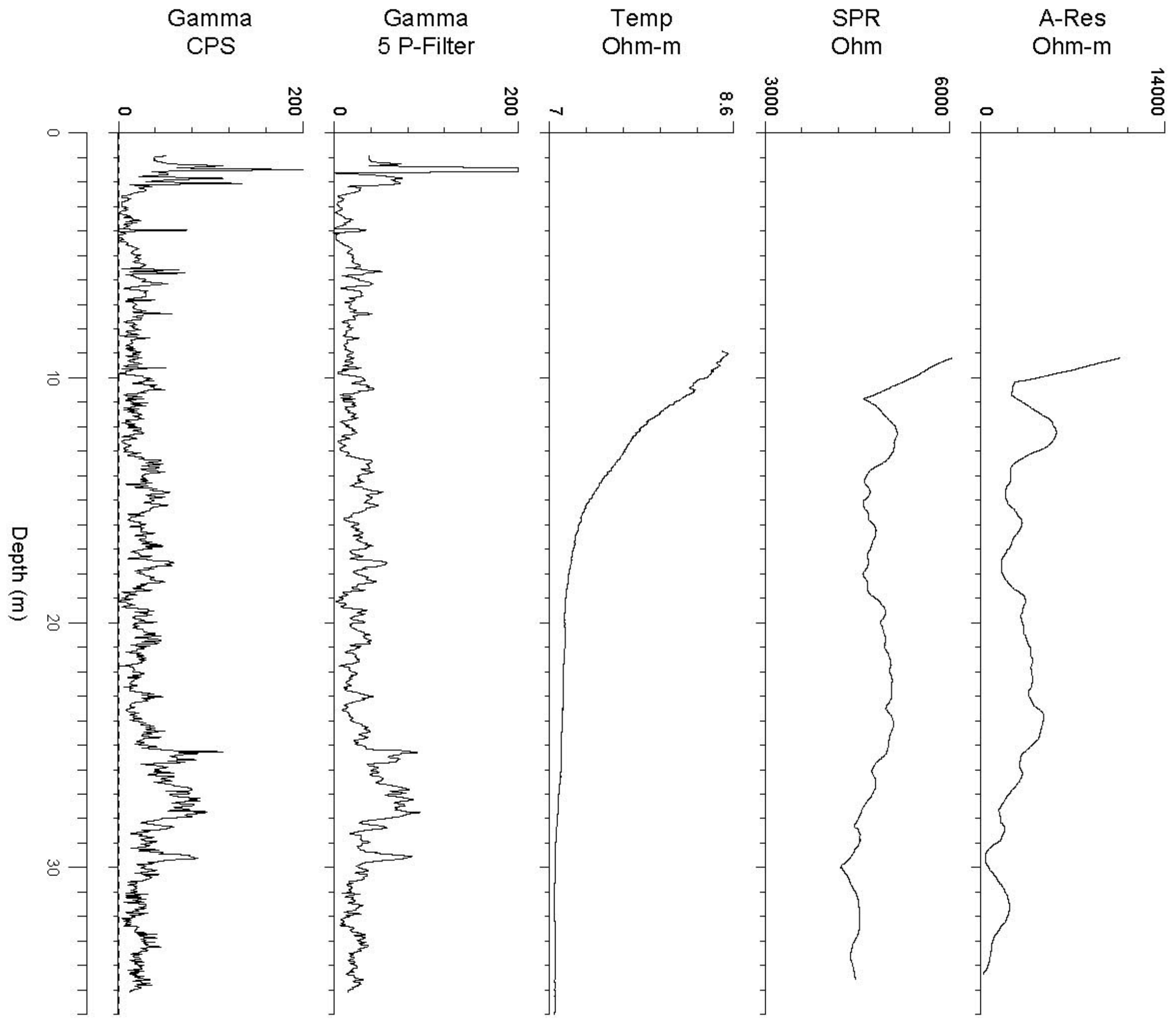


NOTRA

BH1103

Borehole Geophysical Results

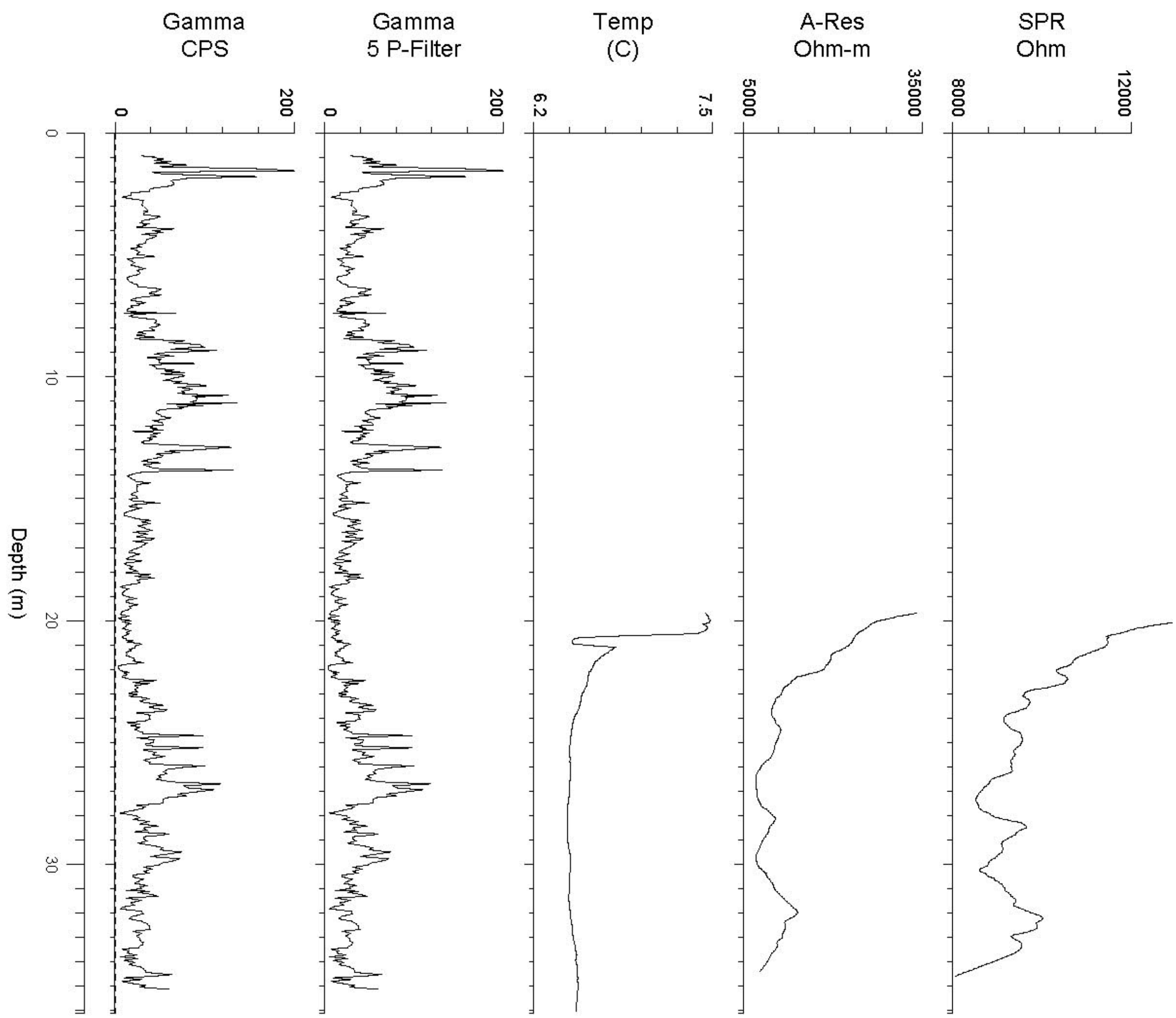
Elginburg, ON, December 18, 2012



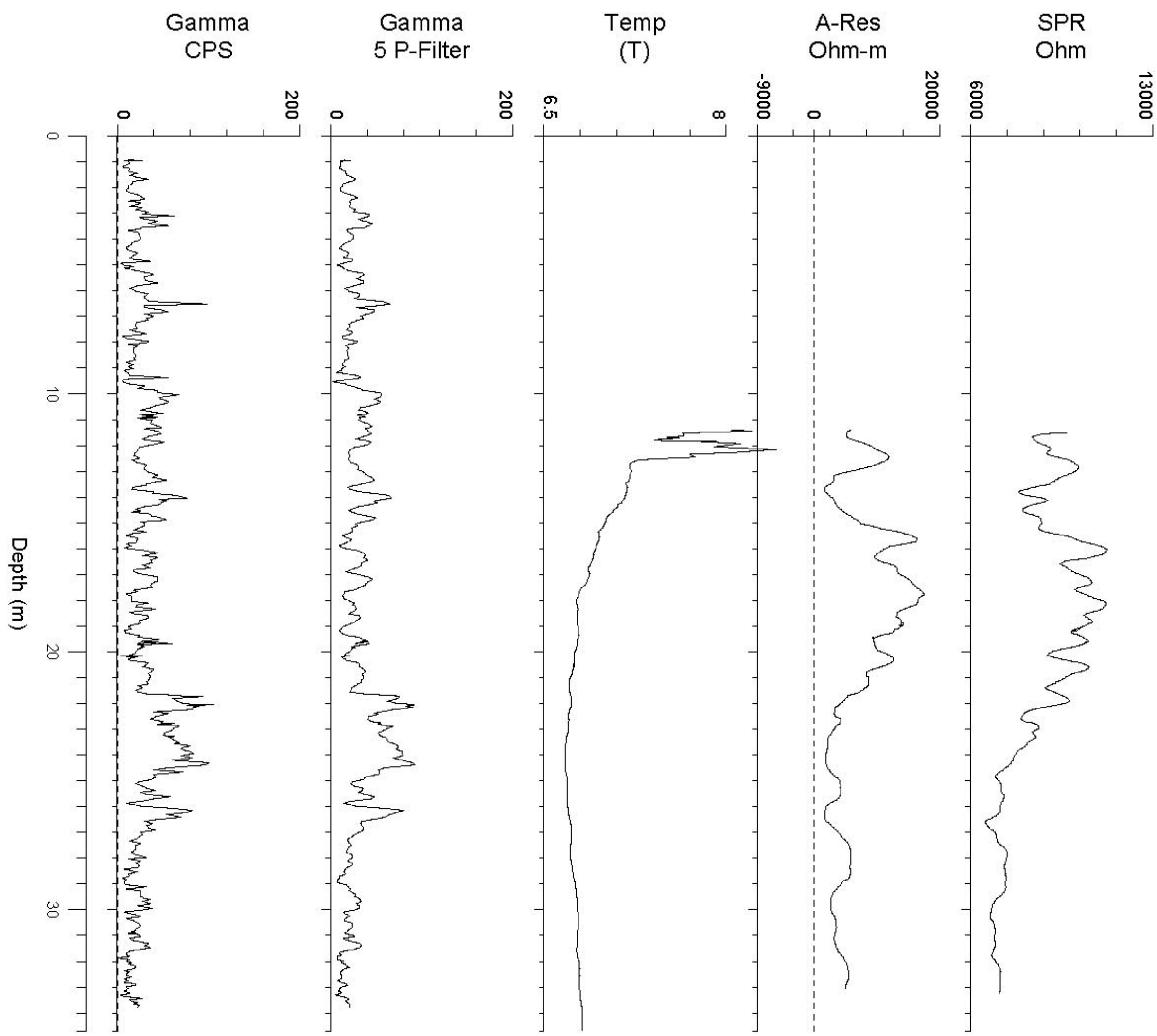
BH1104

Borehole Physical Property Log

Elginburg, ON, December 18, 2012



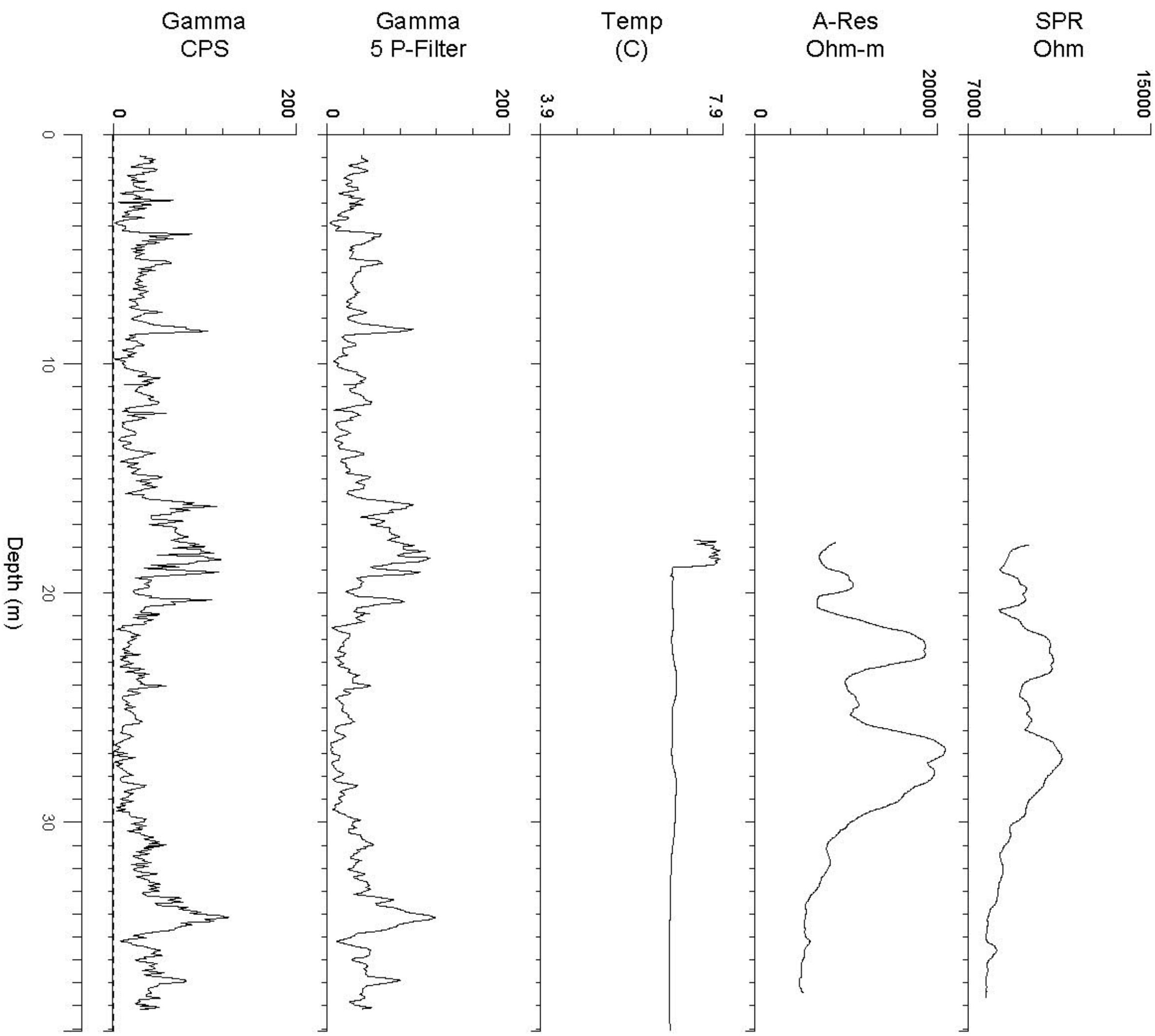
BH1201
Borehole Geophysical Results
Elginburg, ON, December 18, 2012



BH1202

Borehole Geophysical Results

Elginburg, ON, December 18, 2012

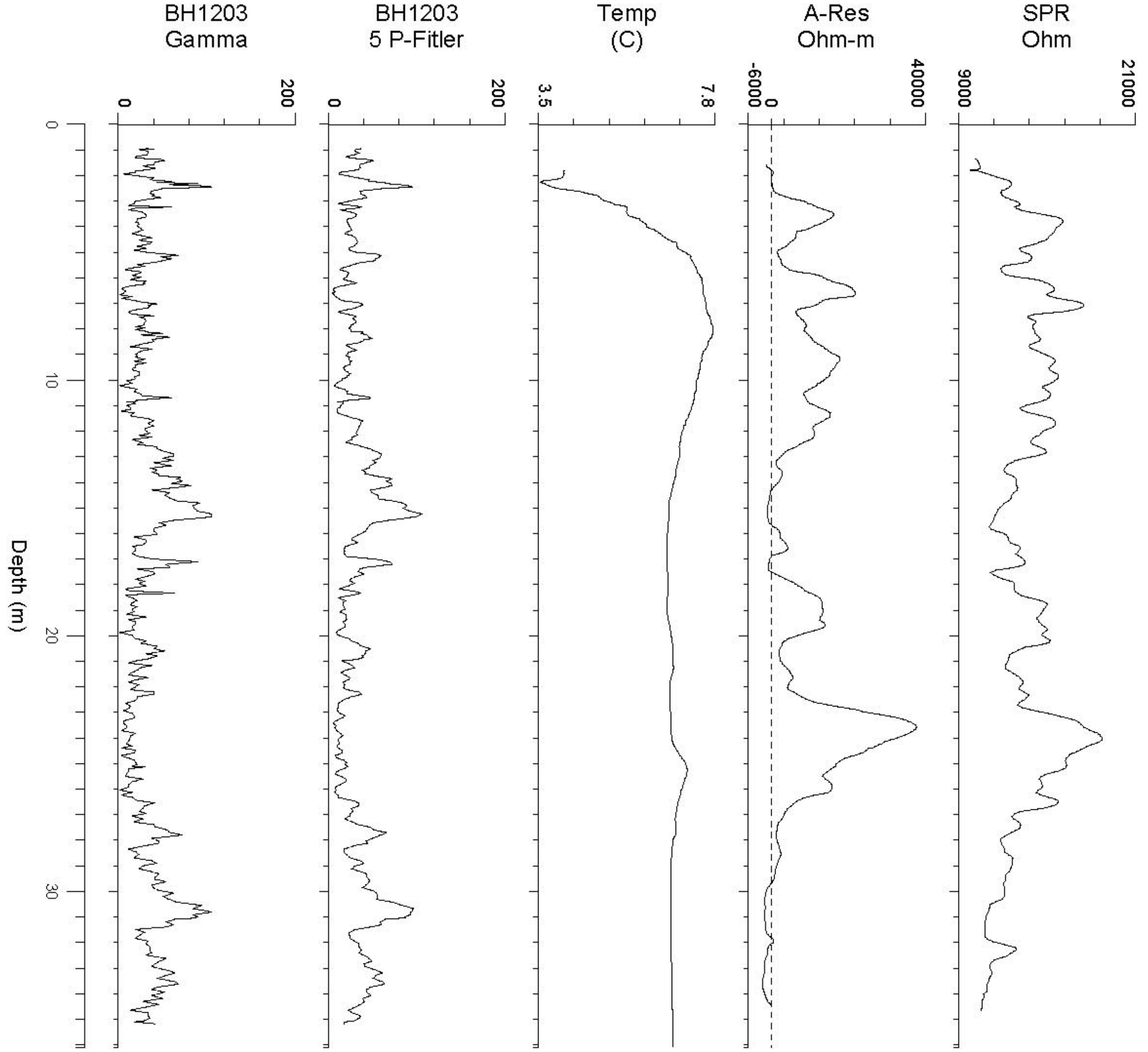


NOTRA

BH1203

Borehole Geophysical Results

Elginburg, ON, December 18, 2012



ANNEX C
PICTURES

System Logging –DDH10-01

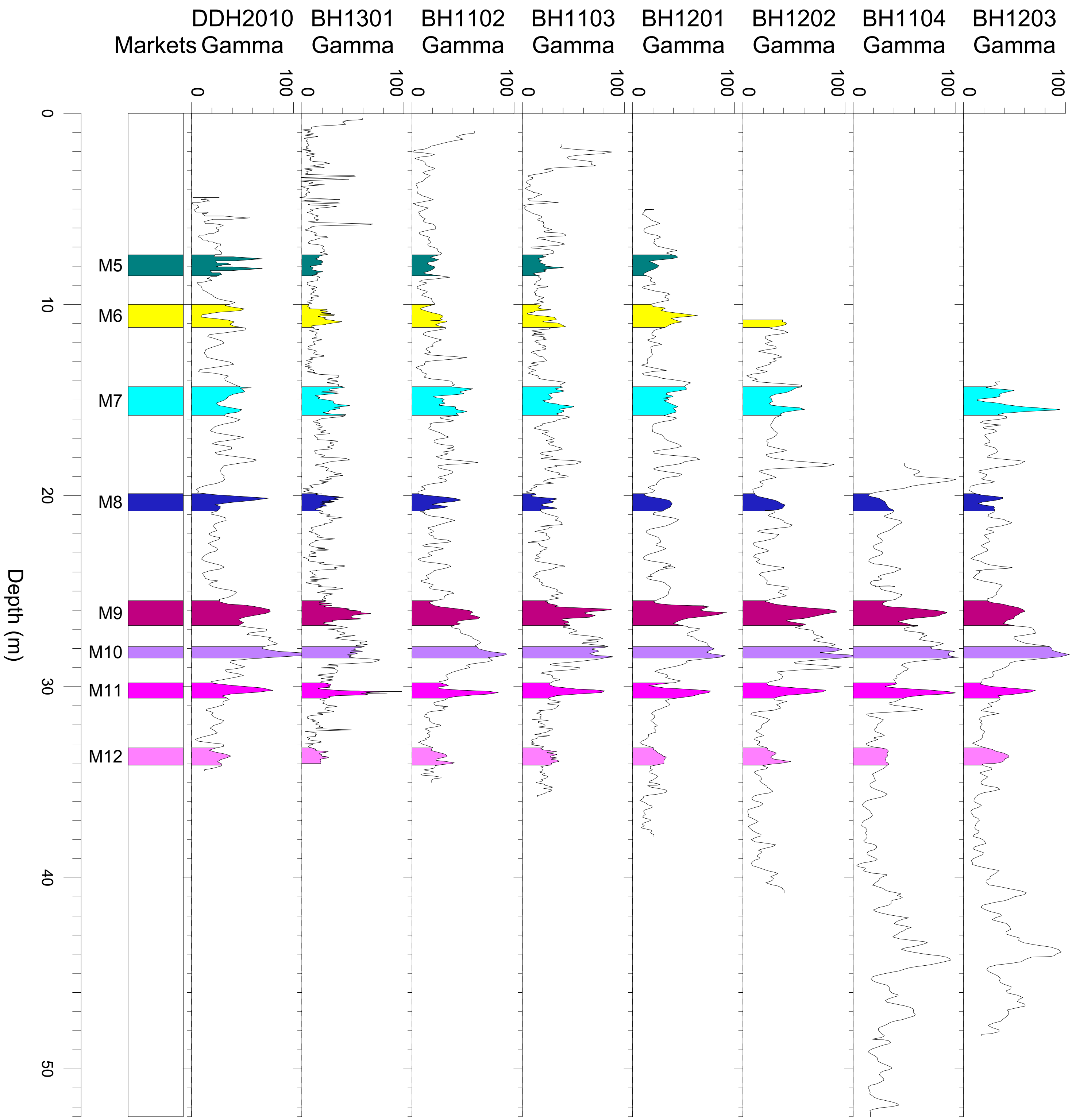
Setting Up System – BH1203

The IFG BMP06 Probe – BH1102

Adjusted Natural Gamma Logs

Depth Adjsuted to Markers of DDH1001

ElginBurg, On, December 10, 2013



APPENDIX F: Groundwater Level Monitoring Data

Table F1 - Well Installation Information

BH	Easting	Northing	Ground Surface (mASL)	Casing Height (m)	Casing Top Elev. (mASL)	Hole Depth (mBGS)	Base of Hole Elev. (mASL)	Top of Screened Interval (mBGS)	Bottom of Screened Interval (mBGS)	Top of Screened Interval Elev. (mASL)	Bottom of Screened Interval Elev. (mASL)
DDH10-01	375488	4907856	135.37	0.84	136.21	37.20	98.17	-	-	135.37	98.17
BH11-02	375321	4908199	138.14	0.80	138.94	35.90	102.24	-	-	138.14	102.24
BH11-03	375109	4907991	137.72	0.80	138.52	36.00	101.72	-	-	137.72	101.72
BH11-04	375437	4907054	125.69	0.94	126.63	36.00	89.69	-	-	125.69	89.69
BH12-01	375319	4907602	133.20	0.64	133.84	34.70	98.50	-	-	133.20	98.50
BH12-02	375148	4907222	128.90	0.61	129.51	40.23	88.67	-	-	128.90	88.67
BH12-03	374786	4906954	131.30	0.50	131.80	36.10	95.20	-	-	131.30	95.20
BH13-01	375115	4908411	138.15	0.46	138.61	35.51	102.64	-	-	138.15	102.64
BH11-02A	375321	4908199	138.14	0.80	138.94	35.96	102.18	24.38	35.96	113.76	102.18
BH11-02B	375321	4908199	138.14	0.80	138.94	35.96	102.18	12.19	19.81	125.95	118.33
BH11-02C	375321	4908199	138.14	0.80	138.94	35.96	102.18	4.57	9.14	133.57	129.00
BH12-02A	375148	4907222	128.90	0.61	129.51	35.96	92.94	27.43	35.96	101.47	92.94
BH12-02B	375148	4907222	128.90	0.61	129.51	35.96	92.94	16.76	24.38	112.14	104.52
BH12-02C	375148	4907222	128.90	0.61	129.51	35.96	92.94	4.57	12.19	124.33	116.71
BH12-03A	374786	4906954	131.30	0.50	131.80	35.96	95.34	24.38	35.96	106.92	95.34
BH12-03B	374786	4906954	131.30	0.50	131.80	19.51	111.79	12.80	19.81	118.50	111.49
BH13-01A	375115	4908411	138.15	0.46	138.61	35.05	103.10	27.43	35.05	110.72	103.10
BH13-01B	375115	4908411	138.15	0.46	138.61	18.29	119.86	7.62	18.29	130.53	119.86
MW-1-1	375926	4908412	131.20	0.52	131.72	38.31	92.89	-	-	-	-
MW-2-1	-	-	136.80	0.58	137.38	38.25	98.55	22.50	38.25	114.30	98.55
MW-2-2	-	-	136.80	0.58	137.38	19.56	117.24	9.40	20.30	127.40	116.50
MW-2-3	-	-	136.80	0.58	137.38	7.49	129.31	5.90	7.30	130.90	129.50
MW-3-1	-	-	128.40	0.69	129.09	38.23	90.17	22.10	38.23	106.30	90.17
MW-3-2	-	-	128.40	0.69	129.09	18.90	109.50	6.50	19.60	121.90	108.80
MW-4-1	-	-	124.80	0.54	125.34	38.35	86.45	23.20	38.35	101.60	86.45
MW-4-2	-	-	124.80	0.54	125.34	20.67	104.13	7.70	20.80	117.10	104.00

mASL - metres Above Sea Level

mBGS - metres Below Ground Surface

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016
WWIS and Water Level Measurements.xlsx

Table F2 - Measured Groundwater Levels

BH	CT Elev.	GWL*	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE
	(mASL)	Prior to Dec/13		11/12/2013		12/12/2013		13/12/2013		18/12/2013		10/1/2014		15/01/2014		5/06/2014		1/07/2014		18/08/2014		12/09/2014		23/10/2014	
DDH10-01	136.21	-	-	-	-	2.36	133.85	-	-	-	-	2.28	133.93	2.39	133.82	-	-	2.50	133.71	2.40	133.81	2.50	133.71	2.00	134.21
BH11-02	138.94	-	-	4.42	134.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH11-03	138.52	-	-	-	-	-	-	7.29	131.23	-	-	14.54	123.98	-	-	10.71	127.81	10.90	127.62	11.00	127.52	11.00	127.52	9.10	129.42
BH11-04	126.63	-	-	-	-	-	-	20.82	105.81	-	-	19.71	106.92	-	-	20.61	106.02	20.77	105.86	20.00	106.63	19.95	106.68	22.97	103.66
BH11-05	-						-							1.90	-	1.90	-	2.00	-	2.10	-	2.10	-	2.10	-
BH11-06	-						-							16.50	-	9.00	-	9.10	-	9.00	-	8.90	-	7.00	-
BH12-01	133.84	-	-	-	-	-	-	11.87	121.97	-	-	11.80	122.04	-	-	12.25	121.59	12.50	121.34	13.00	120.84	12.90	120.94	7.10	126.74
BH12-02	129.51	-	-	-	-	19.70	109.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH12-03	131.80	-	-	-	-	1.60	130.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH13-01	138.61	-	-	0.90	137.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH11-02A	138.94	-	-	-	-	-	-	-	-	3.05	135.89	3.13	135.81	8.32	130.62	3.82	135.12	4.60	134.34	1.57	137.37	1.55	137.39	3.90	135.04
BH11-02B	138.94	-	-	-	-	-	-	-	-	4.91	134.03	4.14	134.80	--	-	4.60	134.34	4.90	134.04	3.90	135.04	3.80	135.14	5.12	133.82
BH11-02C	138.94	-	-	-	-	-	-	-	-	-	-	-	-	--	-	1.57	137.37	1.50	137.44	1.60	137.34	1.60	137.34	1.90	137.04
BH12-02A	129.51	-	-	-	-	-	-	-	-	20.41	109.10	18.81	110.70	-	-	20.85	108.66	20.90	108.61	20.98	108.53	20.80	108.71	20.95	108.56
BH12-02B	129.51	-	-	-	-	-	-	-	-	18.56	110.95	18.10	111.41	-	-	17.94	111.57	18.00	111.51	18.20	111.31	18.20	111.31	18.70	110.81
BH12-02C	129.51	-	-	-	-	-	-	-	-	-	-	11.45	118.06	-	-	7.20	122.31	7.50	122.01	7.50	122.01	7.45	122.06	9.30	120.21
BH12-03A	131.80	-	-	-	-	-	-	-	-	3.95	127.85	21.20	110.60	-	-	-	-	-	-	-	-	-	-	-	-
BH12-03B	131.80	-	-	-	-	-	-	-	-	3.49	128.31	2.92	128.88	-	-	-	-	-	-	-	-	-	-	-	-
BH13-01A	138.61	-	-	-	-	-	-	-	-	1.62	136.99	1.67	136.94	-	-	-	-	-	-	-	-	-	-	-	-
BH13-01B	138.61	-	-	-	-	-	-	-	-	2.91	135.70	1.52	137.09	-	-	-	-	-	-	-	-	-	-	-	-
MW-1-1	131.72	7.93	123.27	-	-	-	-	-	-	-	-	-	-	1.60	130.12	7.55	124.17	7.50	124.22	7.80	123.92	7.70	124.02	7.45	124.27
MW-2-1	137.38	9.47	127.33	-	-	-	-	-	-	-	-	-	-	8.20	129.18	9.30	128.08	9.10	128.28	9.20	128.18	9.10	128.28	9.60	127.78
MW-2-2	137.38	9.43	127.37	-	-	-	-	-	-	-	-	-	-	8.00	129.38	9.20	128.18	9.22	128.16	9.60	127.78	9.60	127.78	9.65	127.73
MW-2-3	137.38	4.82	131.98	-	-	-	-	-	-	-	-	-	-	4.20	133.18	5.00	132.38	4.95	132.43	5.00	132.38	4.95	132.43	5.00	132.38
MW-3-1	129.09	19.75	108.65	-	-	-	-	-	-	-	-	-	-	17.80	111.29	17.60	111.49	17.65	111.44	17.80	111.29	17.75	111.34	18.38	110.71
MW-3-2	129.09	17.82	110.58	-	-	-	-	-	-	-	-	-	-	22.10	106.99	17.41	111.68	17.32	111.77	18.00	111.09	17.80	111.29	17.60	111.49
MW-4-1	125.34	25.30	99.50	-	-	-	-	-	-	-	-	-	-	9.00	116.34	21.70	103.64	21.80	103.54	21.90	103.44	21.70	103.64	20.70	104.64
MW-4-2	125.34	9.49	115.31	-	-	-	-	-	-	-	-	-	-	4.62	120.72	8.80	116.54	8.50	116.84	8.70	116.64	8.60	116.74	7.80	117.54

CT Elev - Casing Top Elevation
GWL - Groundwater Level in metres Below Top of Casing
GWE - Groundwater Elevation in metres Above Sea Level
* GWL in metres Below Ground Surface
NOTE - Data from 2015 provided by Cruickshank and reported by Morrison Hershfield

Table F2 - Measured Groundwater Levels

BH	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE	GWL	GWE
	20/11/2014		29/12/2014		19/01/2015		28/02/2015		19/03/2015		16/04/2015		8/06/2015		10/07/2015		7/08/2015		2/09/2015		6/10/2015		6/11/2015		4/12/2015	
DDH10-01	2.00	134.21	8.00	128.21	2.90	133.31	2.96	133.25	3.20	133.01	3.00	133.21	2.87	133.34	2.26	133.95	2.69	133.52	2.64	133.57	2.50	133.71	2.40	133.81	2.30	133.91
BH11-02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH11-03	10.20	128.32	4.70	133.82	8.00	130.52	8.17	130.35	8.20	130.32	7.90	130.62	7.96	130.56	7.65	130.87	11.60	126.92	7.64	130.88	7.60	130.92	7.52	131.00	7.44	131.08
BH11-04	22.00	104.63	1.70	124.93	18.00	108.63	18.70	107.93	18.80	107.83	18.20	108.43	18.90	107.73	20.85	105.78	26.60	100.03	26.02	100.61	25.20	101.43	23.85	102.78	21.84	104.79
BH11-05	2.00	-	2.00	-	13.00	-	12.75	-	12.90	-	12.25	-	12.18	-	11.85	-	12.95	-	9.20	-	20.92	-	15.80	-	17.30	-
BH11-06	7.50	-	7.60	-	2.00	-	1.91	-	2.10	-	1.80	-	1.35	-	1.64	-	1.40	-	1.04	-	1.33	-	1.19	-	1.20	-
BH12-01	7.25	126.59	7.40	126.44	11.50	122.34	11.50	122.34	11.55	122.29	11.35	122.49	11.65	122.19	12.00	121.84	13.40	120.44	13.37	120.47	12.96	120.88	11.75	122.09	11.50	122.34
BH12-02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH12-03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH13-01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH11-02A	3.60	135.34	3.50	135.44	4.80	134.14	4.90	134.04	5.00	133.94	3.60	135.34	3.83	135.11	1.40	137.54	3.44	135.50	3.77	135.17	3.55	135.39	3.40	135.54	3.46	135.48
BH11-02B	5.00	133.94	5.20	133.74	8.00	130.94	8.50	130.44	8.80	130.14	3.90	135.04	4.40	134.54	1.80	137.14	4.90	134.04	4.99	133.95	4.75	134.19	4.67	134.27	4.65	134.29
BH11-02C	1.80	137.14	2.00	136.94	4.50	134.44	4.86	134.08	4.90	134.04	1.90	137.04	1.98	136.96	4.50	134.44	1.80	137.14	1.97	136.97	-	-	1.83	137.11	1.90	137.04
BH12-02A	20.00	109.51	20.50	109.01	21.80	107.71	21.93	107.58	21.90	107.61	20.50	109.01	21.06	108.45	21.45	108.06	-	-	22.23	107.28	21.72	107.79	19.90	109.61	19.42	110.09
BH12-02B	18.50	111.01	18.00	111.51	18.20	111.31	18.30	111.21	18.20	111.31	18.00	111.51	19.19	110.32	19.55	109.96	16.20	113.31	14.93	114.58	18.84	110.67	11.22	118.29	11.70	117.81
BH12-02C	9.00	120.51	8.90	120.61	8.10	121.41	8.24	121.27	8.20	121.31	8.00	121.51	8.24	121.27	7.80	121.71	8.70	120.81	9.24	120.27	9.44	120.07	8.63	120.88	8.04	121.47
BH12-03A	-	-	-	-	24.25	107.55	24.37	107.43	24.40	107.40	24.65	107.15	22.15	109.65	22.60	109.20	-	-	-	-	-	-	-	-	22.78	109.02
BH12-03B	-	-	-	-	5.90	125.90	5.95	125.85	6.00	125.80	5.20	126.60	5.35	126.45	4.70	127.10	6.25	125.55	6.25	125.55	6.20	125.60	6.15	125.65	4.70	127.10
BH13-01A	-	-	-	-	1.50	137.11	1.60	137.01	1.90	136.71	1.00	137.61	1.46	137.15	1.65	136.96	1.95	136.66	1.97	136.64	1.98	136.63	1.97	136.64	1.72	136.89
BH13-01B	-	-	-	-	1.60	137.01	1.74	136.87	1.70	136.91	1.20	137.41	1.67	136.94	1.80	136.81	1.55	137.06	1.89	136.72	1.87	136.74	1.78	136.83	1.63	136.98
MW-1-1	7.50	124.22	7.20	124.52	2.00	129.72	2.10	129.62	2.00	129.72	1.90	129.82	7.45	124.27	7.47	124.25	7.60	124.12	7.59	124.13	7.53	124.19	7.50	124.22	7.55	124.17
MW-2-1	9.15	128.23	9.00	128.38	9.10	128.28	9.00	128.38	9.10	128.28	8.50	128.88	8.80	128.58	9.58	127.80	9.60	127.78	7.86	129.52	9.52	127.86	9.27	128.11	9.17	128.21
MW-2-2	9.40	127.98	9.20	128.18	9.00	128.38	9.00	128.38	9.10	128.28	9.00	128.38	9.27	128.11	9.66	127.72	9.69	127.69	9.71	127.67	9.71	127.67	9.37	128.01	9.17	128.21
MW-2-3	5.00	132.38	5.00	132.38	9.45	127.93	9.50	127.88	9.60	127.78	9.20	128.18	5.98	131.40	4.98	132.40	4.94	132.44	4.86	132.52	4.80	132.58	4.85	132.53	4.70	132.68
MW-3-1	18.30	110.79	18.25	110.84	18.50	110.59	18.60	110.49	18.55	110.54	18.00	111.09	17.89	111.20	17.40	111.69	17.32	111.77	16.54	112.55	16.38	112.71	15.27	113.82	14.46	114.63
MW-3-2	17.70	111.39	17.50	111.59	19.40	109.69	19.60	109.49	19.50	109.59	19.65	109.44	19.52	109.57	18.74	110.35	19.14	109.95	16.88	112.21	14.80	114.29	15.54	113.55	12.40	116.69
MW-4-1	21.00	104.34	21.20	104.14	23.00	102.34	23.00	102.34	23.00	102.34	23.65	101.69	24.43	100.91	25.20	100.14	25.80	99.54	25.92	99.42	25.94	99.40	22.10	103.24	23.22	102.12
MW-4-2	7.50	117.84	7.80	117.54	9.55	115.79	9.60	115.74	9.65	115.69	9.23	116.11	9.42	115.92	9.15	116.19	9.00	116.34	9.14	116.20	9.12	116.22	8.70	116.64	8.54	116.80

CT Elev - Casing Top Elevation

GWL - Groundwater Level in metres Below Top of Casing

GWE - Groundwater Elevation in metres Above Sea Level

* GWL in metres Below Ground Surface

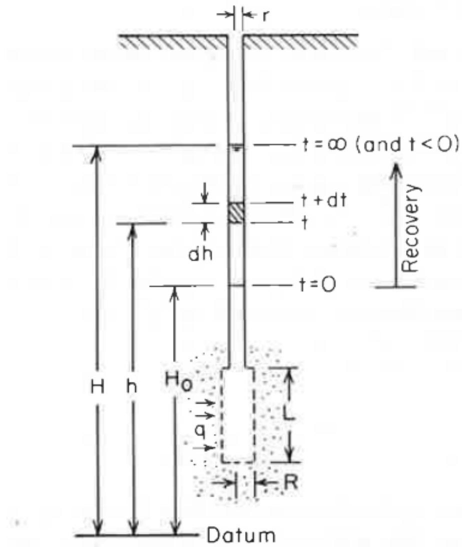
NOTE - Data from 2015 provided by Cruickshank and reported by Morrison Hershfield

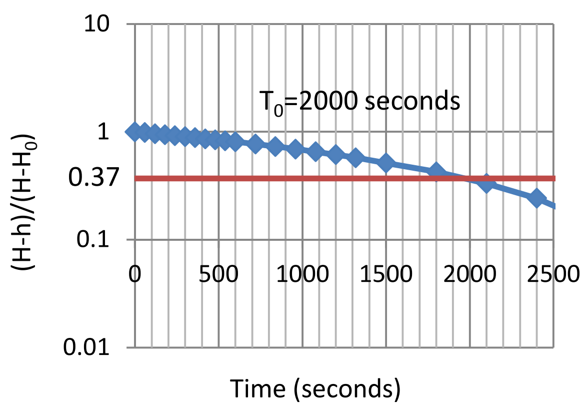
APPENDIX G: Hvorslev Analysis

Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry DDH10-01-01		
Top of Individual Well Casing Elevation	109.03	masl
H	106.67	masl
H_0	101.38	masl
R (screen radius)	0.05	m
r (riser radius)	0.05	m
L (screen length)	35.68	m
T_0	20000	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	101.38	1
60	101.48	0.981096408
120	101.59	0.960302457
180	101.69	0.941398866
240	101.8	0.920604915
300	101.92	0.897920605
360	102.01	0.880907372
420	102.12	0.860113422
480	102.22	0.84120983
540	102.31	0.824196597
600	102.4	0.807183365
720	102.61	0.767485822
840	102.81	0.729678639
960	103.02	0.689981096
1080	103.22	0.652173913
1200	103.43	0.612476371
1320	103.63	0.574669187
1500	103.96	0.512287335
1800	104.42	0.425330813
2100	104.92	0.330812854
2400	105.39	0.241965974
2700	105.87	0.151228733
3000	106.25	0.079395085
3300	106.46	0.039697543
3600	106.56	0.020793951





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

$K=$ 1.2E-08 m/seconds

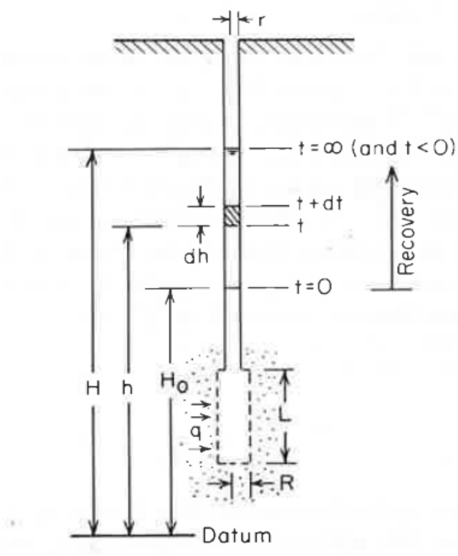
Prepared by: AC
Reviewed by: AW

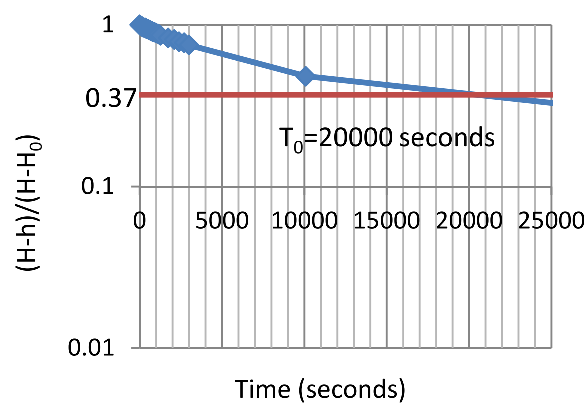
MORRISON HERSHFIELD

Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH11-02	
Top of Individual Well Casing Elevation	109.03 masl
H	104.61 masl
H_0	102.61 masl
R (screen radius)	0.08 m
r (riser radius)	0.08 m
L (screen length)	32.28 m
T_0	20000 seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	102.61	1
60	102.64	0.985
120	102.65	0.98
180	102.67	0.97
240	102.68	0.965
360	102.7	0.955
420	102.72	0.945
540	102.74	0.935
660	102.77	0.92
780	102.79	0.91
900	102.81	0.9
1020	102.83	0.89
1140	102.86	0.875
1260	102.89	0.86
1740	102.95	0.83
2100	102.99	0.81
2400	103.04	0.785
2700	103.06	0.775
3000	103.11	0.75
10080	103.65	0.48
64500	104.37	0.12
96480	104.45	0.08





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 2.7E-08 m/seconds

Prepared by: AC
Reviewed by: AW

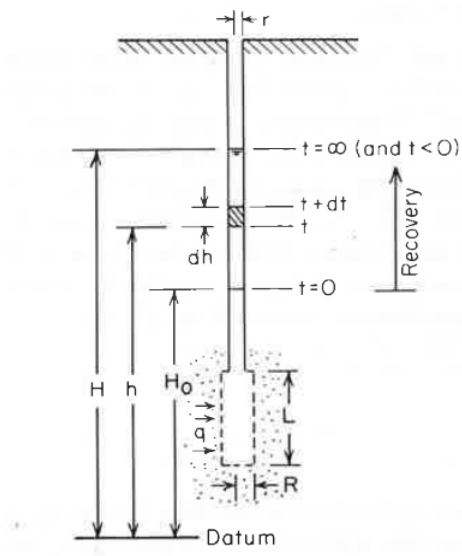
Morrison Hershfield

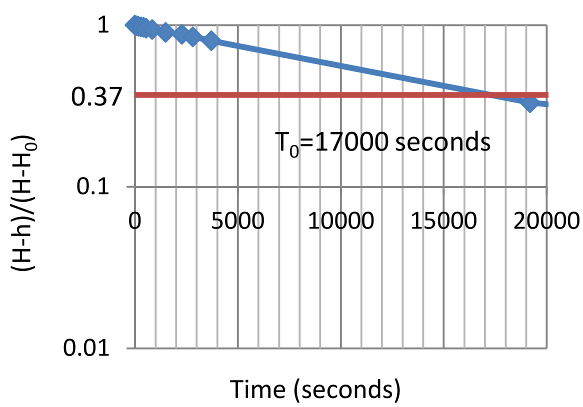
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH11-02A

Top of Individual Well Casing Elevation	109.03	masl
H	106.05	masl
H_0	87.23	masl
R (screen radius)	0.08	m
r (riser radius)	0.02	m
L (screen length)	11.58	m
T_0	17000	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	87.23	1
60	87.38	0.992029756
180	87.55	0.982996812
300	87.73	0.973432519
420	87.86	0.966524973
540	88.03	0.95749203
840	88.39	0.938363443
1500	89.14	0.898512221
2280	89.53	0.877789586
2820	90.12	0.846439957
3720	91.01	0.799149841
19200	99.83	0.330499469
81960	104.97	0.05738576





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

$K=$ 3.2E-09 m/seconds

Prepared by: AC
Reviewed by: AW

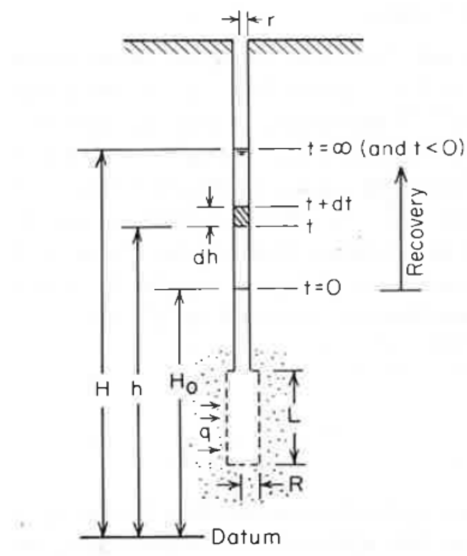
MORRISON HERSHFIELD

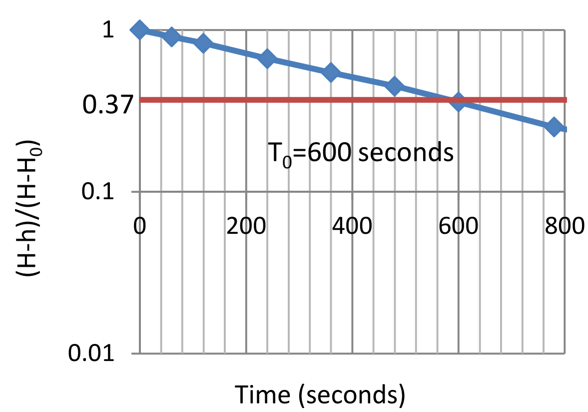
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH11-02B

Top of Individual Well Casing Elevation	109.03	masl
H	104.16	masl
H_0	95.39	masl
R (screen radius)	0.08	m
r (riser radius)	0.02	m
L (screen length)	7.62	m
T_0	600	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	95.39	1
60	96.21	0.90649943
120	96.91	0.82668187
240	98.33	0.664766249
360	99.38	0.545039909
480	100.22	0.449258837
600	101.02	0.358038769
780	101.96	0.250855188
1020	102.59	0.179019384
1140	102.98	0.134549601
1320	103.21	0.108323831
1560	103.44	0.082098062
2520	103.85	0.035347777
18060	104.37	-0.023945268
80760	104.39	-0.02622577





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

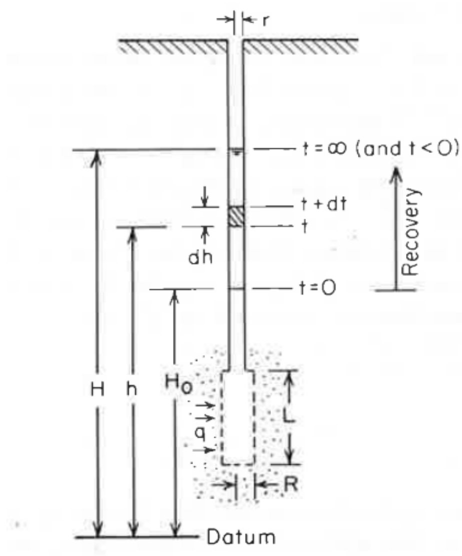
$K=$ 1.3E-07 m/seconds

Prepared by: AC
Reviewed by: AW

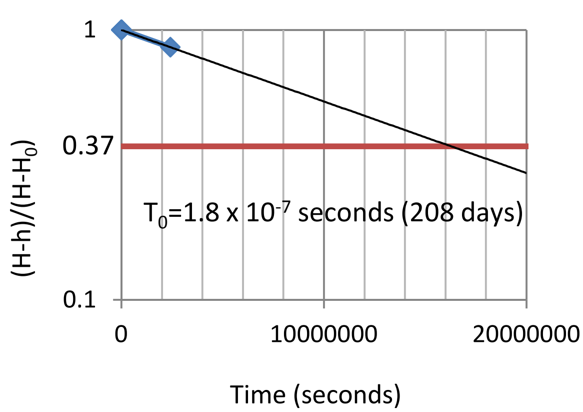
Morrison Hershfield

Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH11-03		
Top of Individual Well Casing Elevation	109.03	masl
H	101.74	masl
H_0	93.33	masl
R (screen radius)	0.08	m
r (riser radius)	0.08	m
L (screen length)	29.51	m
T_0	16000000	seconds



time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	93.33	1
60	93.34	0.998810939
120	93.34	0.998810939
180	93.34	0.998810939
240	93.34	0.998810939
540	93.34	0.998810939
840	93.34	0.998810939
1740	93.34	0.998810939
2940	93.34	0.998810939
7140	93.34	0.998810939
2419200	94.49	0.862068966



Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 4E-11 m/seconds

Prepared by: AC
Reviewed by: AW

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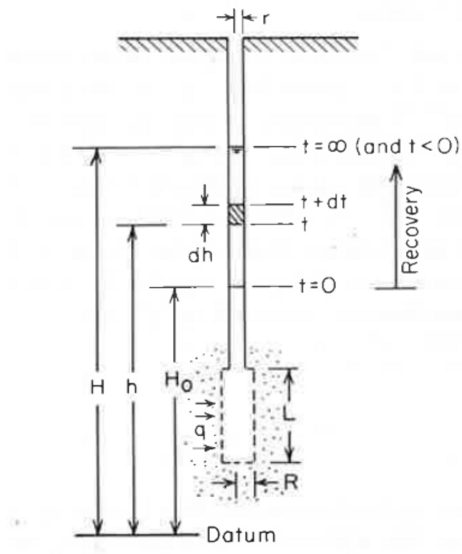
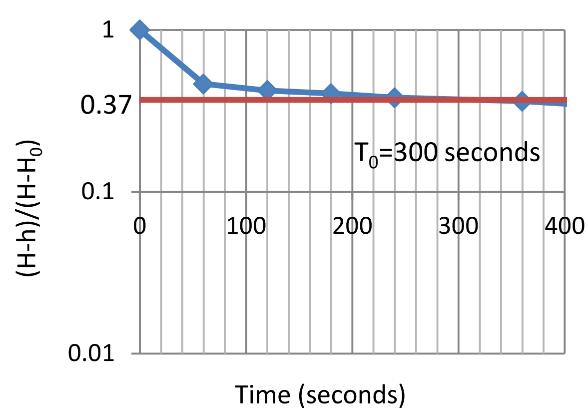
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH11-04

Top of Individual Well Casing Elevation	109.03	masl
H	88.21	masl
H_0	86.03	masl
R (screen radius)	0.08	m
r (riser radius)	0.08	m
L (screen length)	16.12	m
T_0	300	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	86.03	1
60	87.2	0.463302752
120	87.29	0.422018349
180	87.33	0.403669725
240	87.38	0.380733945
360	87.42	0.362385321
420	87.46	0.344036697
480	87.49	0.330275229
540	87.51	0.321100917
600	87.54	0.30733945
660	87.56	0.298165138
780	87.61	0.275229358
960	87.68	0.243119266
1140	87.75	0.211009174
1560	87.86	0.160550459
1860	87.93	0.128440367
2160	87.97	0.110091743
2760	88.06	0.068807339
3840	88.13	0.036697248





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 3.2E-06 m/seconds

Prepared by: AC
Reviewed by: AW

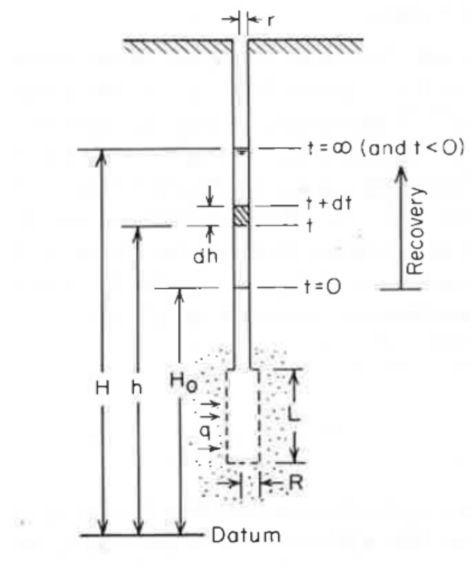
Morrison Hershfield

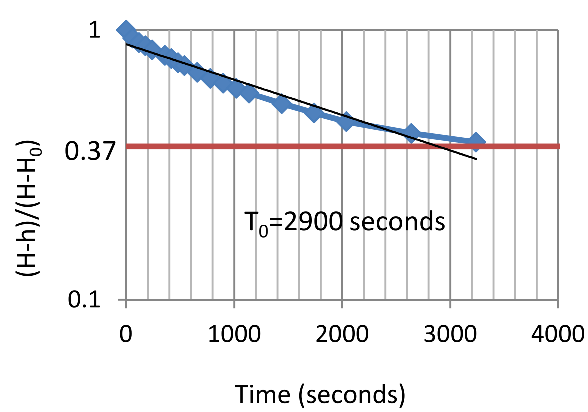
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-01

Top of Individual Well Casing Elevation	109.03	masl
H	97.16	masl
H_0	93.49	masl
R (screen radius)	0.05	m
r (riser radius)	0.05	m
L (screen length)	23.47	m
T_0	2900	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	93.49	1
60	93.73	0.934604905
120	93.86	0.899182561
180	93.95	0.874659401
240	94.06	0.844686649
360	94.2	0.80653951
420	94.28	0.784741144
480	94.38	0.757493188
540	94.45	0.738419619
660	94.6	0.697547684
780	94.73	0.662125341
900	94.83	0.634877384
1020	94.93	0.607629428
1140	95.02	0.583106267
1440	95.2	0.534059946
1740	95.35	0.493188011
2040	95.48	0.457765668
2640	95.64	0.414168937
3240	95.75	0.384196185
7800	96.06	0.29972752
16140	96.25	0.247956403
285840	96.44	0.196185286
446160	96.43	0.198910082





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 1.2E-07 m/seconds

Prepared by: AC
Reviewed by: AW

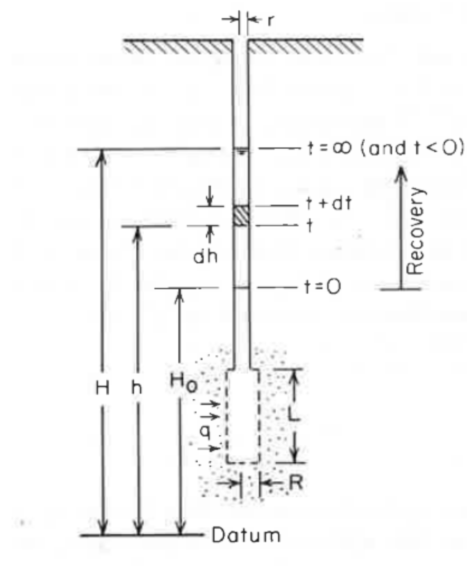
Morrison Hershfield

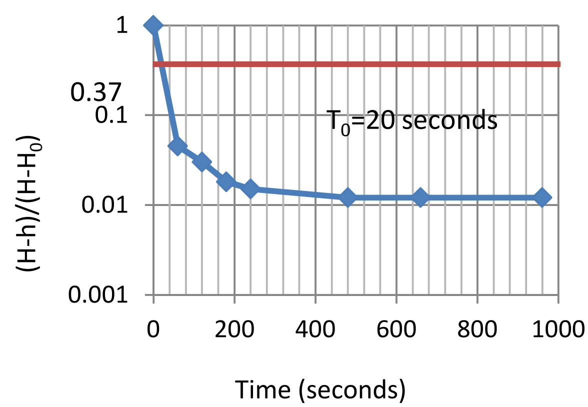
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-02

Top of Individual Well Casing Elevation	109.03	masl
H	89.33	masl
H_0	86.03	masl
R (screen radius)	0.05	m
r (riser radius)	0.05	m
L (screen length)	21.14	m
T_0	20	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	86.03	1
60	89.18	0.045454545
120	89.23	0.03030303
180	89.27	0.018181818
240	89.28	0.015151515
480	89.29	0.012121212
660	89.29	0.012121212
960	89.29	0.012121212





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 1.8E-05 m/seconds

Prepared by: AC
Reviewed by: AW

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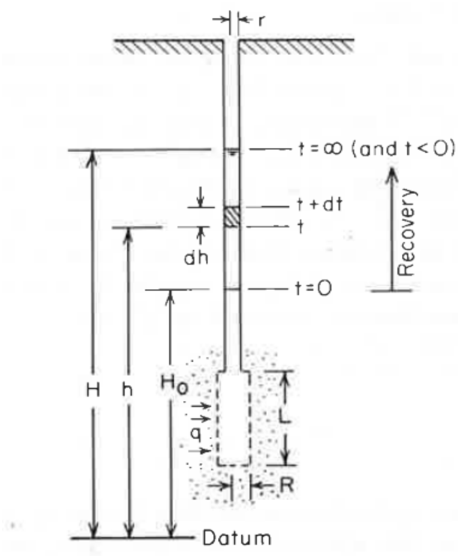
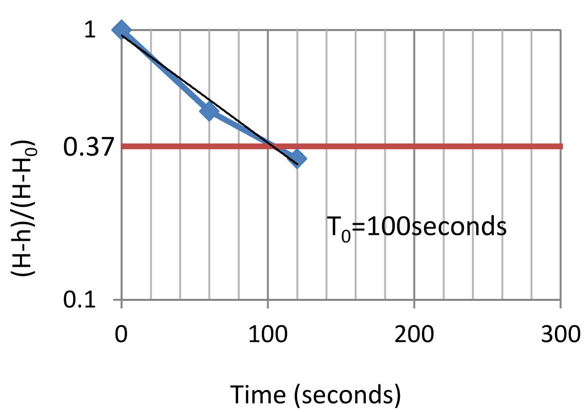
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-02A

Top of Individual Well Casing Elevation	109.03	masl
H	88.73	masl
H_0	88.67	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	8.53	m
T_0	100	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	88.67	1
60	88.7	0.5
120	88.71	0.333333333
180	88.71	0.333333333
300	88.71	0.333333333





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 7.7E-07 m/seconds

Prepared by: AC
Reviewed by: AW

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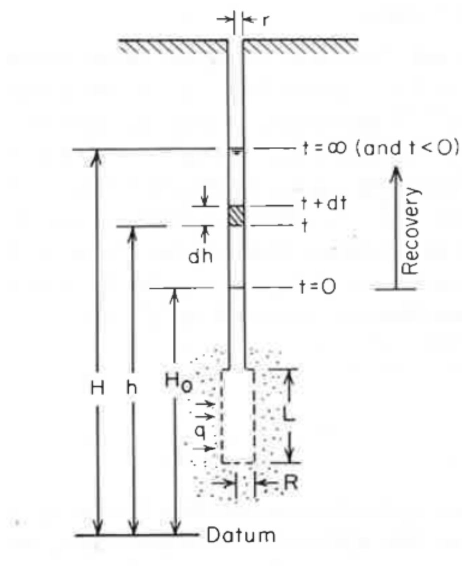
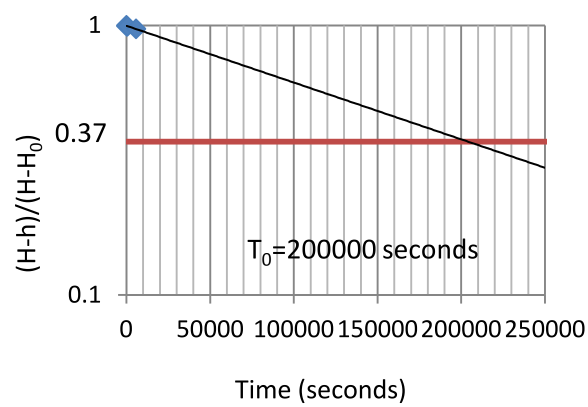
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-02B

Top of Individual Well Casing Elevation	109.03	masl
H	90.53	masl
H_0	88.26	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	7.62	m
T_0	200000	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	88.26	1
60	88.27	0.995594714
120	88.27	0.995594714
180	88.27	0.995594714
240	88.27	0.995594714
420	88.28	0.991189427
720	88.28	0.991189427
5760	88.33	0.969162996





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

$K=$ 4.2E-10 m/seconds

Prepared by: AC
Reviewed by: AW

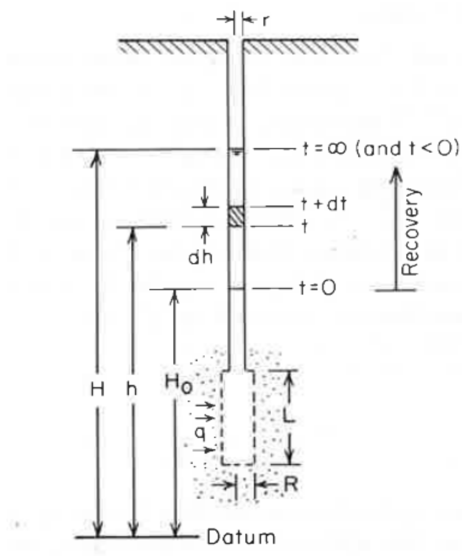
MORRISON HERSHFIELD

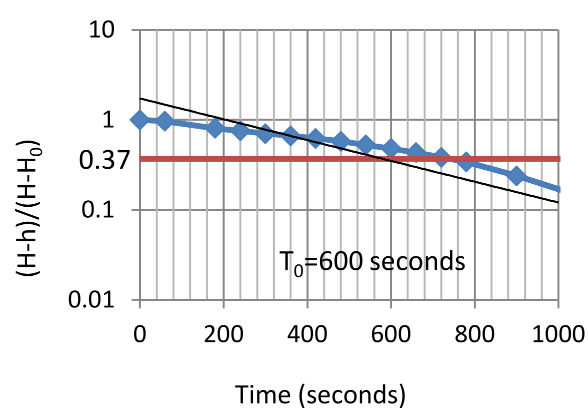
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-03

Top of Individual Well Casing Elevation	109.03	masl
H	107.43	masl
H_0	103.03	masl
R (screen radius)	0.05	m
r (riser radius)	0.05	m
L (screen length)	35.00	m
T_0	600	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	103.03	1
60	103.18	0.965909091
180	103.88	0.806818182
240	104.11	0.754545455
300	104.33	0.704545455
360	104.5	0.665909091
420	104.69	0.622727273
480	104.88	0.579545455
540	105.11	0.527272727
600	105.31	0.481818182
660	105.53	0.431818182
720	105.74	0.384090909
780	105.93	0.340909091
900	106.38	0.238636364
1020	106.73	0.159090909
1140	107.06	0.084090909
1260	107.23	0.045454545
1380	107.29	0.031818182
1500	107.32	0.025
1620	107.35	0.018181818
1740	107.37	0.013636364





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

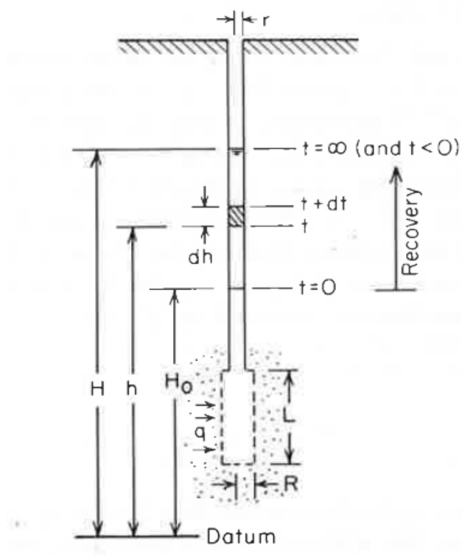
$K=$ 4.0E-07 m/seconds

Prepared by: AC
Reviewed by: AW

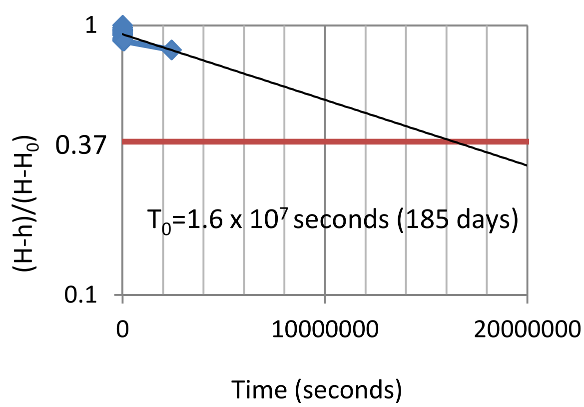
MORRISON HERSHFIELD

Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-03A		
Top of Individual Well Casing Elevation	109.03	masl
H	105.11	masl
H_0	83.8	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	11.58	m
T_0	16000000	seconds



time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	83.8	1
240	84.18	0.982167996
300	84.48	0.968090099
360	84.58	0.963397466
420	84.69	0.95823557
480	84.79	0.953542938
600	85	0.943688409
720	85.23	0.932895354
840	85.42	0.923979352
1020	85.55	0.91787893
1620	86.03	0.895354294
2280	86.26	0.884561239
2820	86.32	0.881745659
4080	86.4	0.877991553
5040	86.43	0.876583763
74040	86.47	0.87470671
2419200	87.83	0.810886908



Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 5.9E-12 m/seconds

Prepared by: AC
Reviewed by: AW

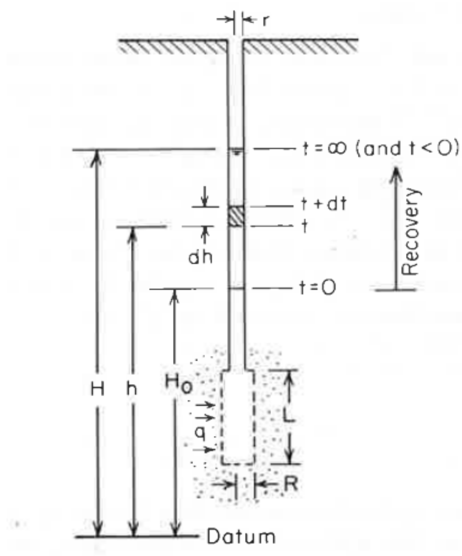
MORRISON HERSHFIELD

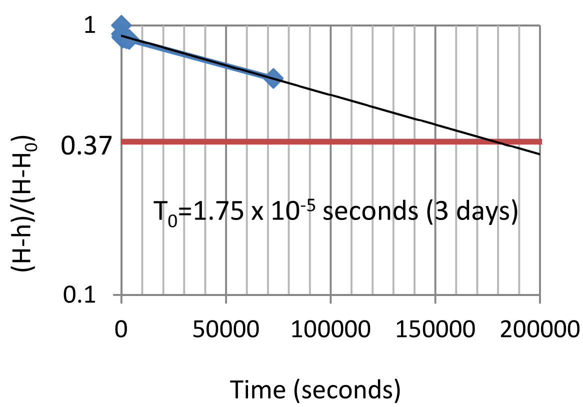
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH12-03B

Top of Individual Well Casing Elevation	109.03	masl
H	105.56	masl
H_0	100.63	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	7.01	m
T_0	175000	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	100.63	1
60	100.98	0.929006085
240	101.09	0.906693712
420	101.11	0.902636917
540	101.13	0.898580122
720	101.13	0.898580122
900	101.13	0.898580122
1320	101.13	0.898580122
2520	101.16	0.892494929
3660	101.19	0.886409736
72660	102.43	0.634888438





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 8.1E-10 m/seconds

Prepared by: AC
Reviewed by: AW

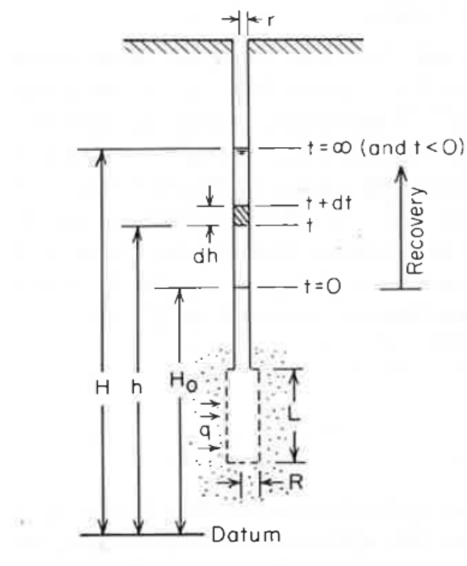
Morrison Hershfield

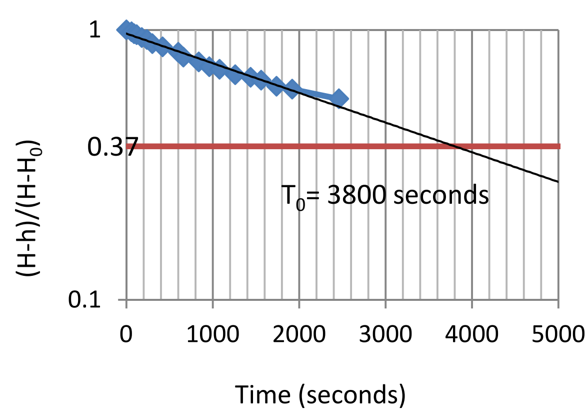
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH13-01

Top of Individual Well Casing Elevation	109.03	masl
H	108.13	masl
H_0	107.5	masl
R (screen radius)	0.05	m
r (riser radius)	0.05	m
L (screen length)	35.07	m
T_0	3800	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	107.5	1
60	107.51	0.984126984
90	107.52	0.968253968
120	107.525	0.96031746
180	107.54	0.936507937
240	107.55	0.920634921
300	107.57	0.888888889
420	107.585	0.865079365
600	107.61	0.825396825
660	107.63	0.793650794
840	107.65	0.761904762
960	107.67	0.73015873
1080	107.68	0.714285714
1260	107.7	0.682539683
1440	107.71	0.666666667
1560	107.72	0.650793651
1740	107.74	0.619047619
1920	107.75	0.603174603
2460	107.78	0.555555556





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

$K=$ 6.1E-08 m/seconds

Prepared by: AC
Reviewed by: AW

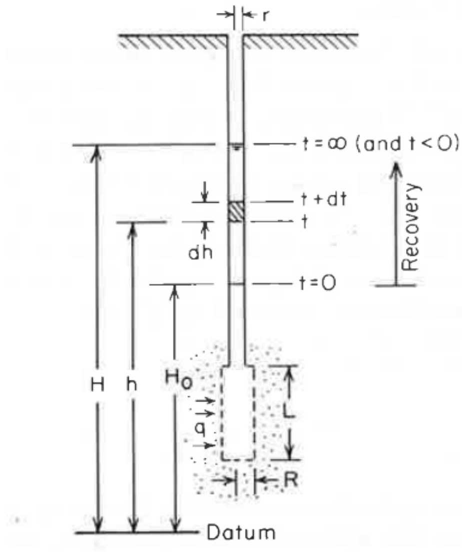
Morrison Hershfield

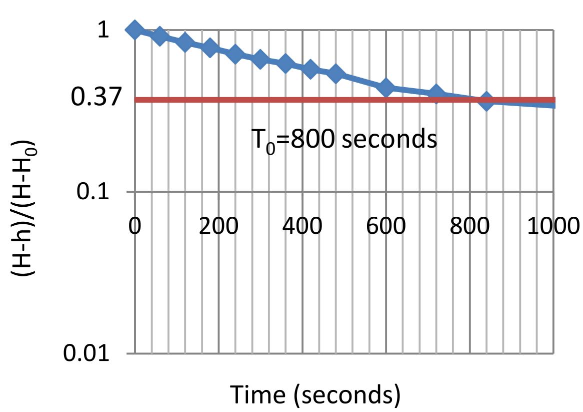
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH13-01A
Top of Individual
Well Casing

Elevation	109.03	masl
H	107.48	masl
H_0	99.25	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	7.62	m
T_0	800	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	99.25	1
60	99.98	0.911300122
120	100.6	0.835965978
180	101.11	0.77399757
240	101.65	0.708383961
300	102.07	0.657351154
360	102.39	0.618469016
420	102.79	0.569866343
480	103.07	0.535844471
600	103.87	0.438639125
720	104.17	0.40218712
840	104.5	0.362089915
1080	104.77	0.329283111
1680	105.24	0.27217497
2280	105.72	0.213851762
2880	105.95	0.185905225
3480	106.16	0.160388821
5520	106.38	0.133657351
11580	106.54	0.114216282
27240	106.83	0.078979344
88440	106.92	0.068043742





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

$K=$ 1.6E-07 m/seconds

Prepared by: AC
Reviewed by: AW

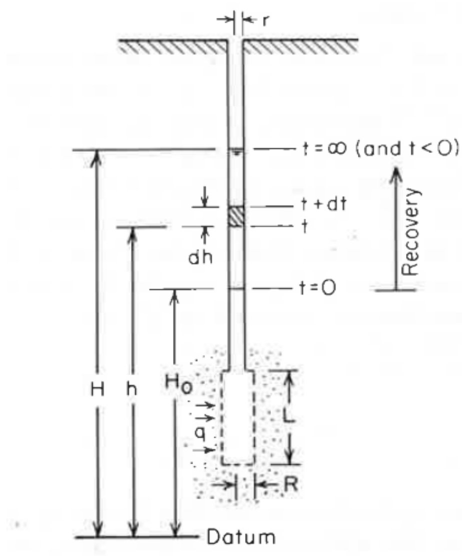
Morrison Hershfield

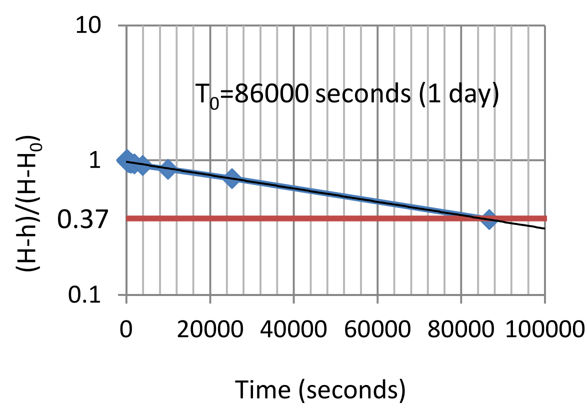
Hvorslev Analysis of Slug or Bail Test

Elginburgh Quarry BH13-01B

Top of Individual Well Casing Elevation	109.03	masl
H	106.23	masl
H_0	96.53	masl
R (screen radius)	0.05	m
r (riser radius)	0.02	m
L (screen length)	10.67	m
T_0	84000	seconds

time (seconds)	h(t)	$(H-h)/(H-H_0)$
0	96.53	1
120	96.68	0.984536082
240	96.45	1.008247423
360	96.82	0.970103093
480	96.88	0.963917526
720	96.93	0.958762887
900	96.97	0.954639175
1200	97.02	0.949484536
1920	97.12	0.939175258
3900	97.37	0.913402062
9960	97.92	0.856701031
25260	99.13	0.731958763
86760	102.71	0.362886598





Hvorslev Formula (see Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln L/R}{2LT_0}$$

K= 1.2E-09 m/seconds

Prepared by: AC
Reviewed by: AW

Morrison Hershfield

APPENDIX H: Analytical Results

Table H1 - Monitoring Well Metals and General Chemistry

Parameter	Units	M.D.L.	PWQO[2]	ODWQS[1]	BH11-02B	BH11-04	BH12-02A	BH12-03A	BH13-01A
Electrical Conductivity (EC)	umho/cm	1	NV	NV	2250	560	3570	804	22800
pH*		NA	6.5-8.5	6.5-8.5	7.47	7.79	7.41	**8.87**	7.56
Total Hardness (as CaCO3)*	mg/L	1	NV	80-100	**272**	**378**	**2210**	19	**3200**
Total Suspended Solids	mg/L	2	NV	NV	2500	198	330	13800	1370
Alkalinity (as CaCO3)**	mg/L	3	NV	30-500	296	232	202	330	99
Chloride**	mg/L	0.50	NV	250	**391**	9.3	**396**	3.6	**5030**
Nitrate as N	mg/L	0.1	NV	10	0.1	0.2	0.2	0.4	0.3
Nitrite as N	mg/L	0.1	NV	1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulphate	mg/L	1	NV	500	269	49	**1250**	79	156
Ammonia (N) - Total	mg/L	0.005	NV	NV	1.01	0.033	0.598	0.789	5.31
Ammonia (unionized)	mg/L	NA	0.02	NV	0.0034	0.0002	0.0018	0.0620	0.0221
Dissolved Organic Carbon**	mg/L	0.2	NV	5	**8.9**	4.5	3.1	**228**	**92.9**
Dissolved Inorganic Carbon	mg/L	0.2	NV	NV	56.3	43	34.3	91	13.3
Phenolics	mg/L	0.001	0.001	NV	0.003	<0.001	0.002	<0.001	<0.001
Carbonate (as CaCO3)	mg/L	3	NV	NV	<3	<3	<3	37	<3
Bicarbonate (as CaCO3)	mg/L	3	NV	NV	296	232	202	294	99
Turbidity**	NTU	0.2	NV	5	**970**	**127**	**438**	**7830**	**1270**
Calcium	mg/L	0.02	NV	NV	60	126	718	6.66	603
Magnesium	mg/L	0.01	NV	NV	29.8	15.4	100	0.68	411
Sodium**	mg/L	0.2	NV	200	**350**	8.1	**496**	197	**3450**
Potassium	mg/L	0.1	NV	NV	8	1.6	16.9	0.6	47.2
Aluminum***	mg/L	0.01	0.075	0.1/0.2	0.13	0.28	0.19	0.54	0.16
Boron	mg/L	0.005	0.2	5	1.87	0.082	0.602	0.096	1.26
Cadmium	mg/L	0.00002	0.0002	0.005	5E-05	3E-05	0.0003	8E-05	0.0002
Chromium	mg/L	0.002	0.0089	0.05	<0.002	0.004	<0.002	<0.002	<0.002
Cobalt	mg/L	0.0001	0.0009	NV	0.0081	0.0274	0.0121	0.0157	0.0067
Copper**	mg/L	0.0001	0.005	1	0.0022	0.0032	0.004	0.003	0.0264
Iron**	mg/L	0.005	0.3	0.3	0.214	**1.25**	0.107	**0.402**	0.067
Lead	mg/L	0.00002	0.025	0.01	9E-05	0.0039	3E-05	0.0025	0.0013
Nickel	mg/L	0.01	0.025	NV	<0.01	<0.01	0.02	<0.01	<0.01
Silicon	mg/L	0.01	NV	NV	4.55	2.85	3.22	3.72	1.91
Silver	mg/L	0.00002	0.0001	NV	<0.0000	<0.0000	<0.0000	<0.0000	5E-05
Zinc**	mg/L	0.005	0.03	5	0.006	0.023	0.009	0.008	0.088
Temperature (field)	°C	NA	NV	NV	6	8.6	8.1	5.9	5.6
pH (field)		NA	NV	NV	7.26	8	7.72	10.03	8.1
EC (field)	umho/cm	10	6.5-8.5	6.5-8.5	3095	672	3363	1046	3999

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

(2) Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy, July 1994.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

*** Standard based on Guidelines for Canadian Drinking Water Quality, March 2006. This is an **operational guidance** value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. The value of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Ottawa

Values shaded exceed PWQO Standards	**Values in bold exceed ODWQS Standards**

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016

Table H2a - Domestic Well Metals

		Location:		[redacted]				
		Sample ID:		NW2	NW4	NW4	NW2	NW1
		Date Collected:		12-Feb-15	12-Feb-15	23-Mar-15	24-Mar-15	5-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS(1)**					
Aluminium (dissolved)*	mg/L	0.01	0.1	0.02	0.03	0.01	0.02	0.04
Boron	mg/L	0.005	5	0.296	0.247	0.554	0.462	2.01
Cadmium	mg/L	0.00002	0.005	<0.00002	<0.00002	<0.00002	<0.00002	0.00003
Calcium	mg/L	0.02	-	61.2	82.3	55.9	75.2	132
Chromium	mg/L	0.002	0.05	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/L	0.005	-	0.007	<0.005	<0.005	<0.005	<0.005
Copper**	mg/L	0.002	1	0.047	0.005	<0.002	<0.002	0.022
Iron**	mg/L	0.005	0.3	<0.005	0.016	0.078	<0.005	<0.005
Lead	mg/L	0.00002	0.01	0.00137	0.0005	<0.00002	0.00107	0.00022
Magnessium	mg/L	0.01	-	18.7	27.7	31.2	22.2	56.5
Nickel	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	mg/L	0.1	-	4.6	9.1	5.2	7.3	14.7
Silicon	mg/L	0.01	-	2.62	3.47	5.7	3.22	4.24
Silver	mg/L	0.00002	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium**	mg/L	0.2	200	47.4	62.4	77.4	37.7	**251**
Zinc**	mg/L	0.005	5	0.05	0.006	<0.005	0.0024	0.018

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2a - Domestic Well Metals

Parameter	Units	M.D.L.	ODWQS[1]					
		Location:		[redacted]				
		Sample ID:		NW2	NW3	NW4	NW5	NW6
		Date Collected:		5-May-15	5-May-15	5-May-15	5-May-15	5-May-15
Aluminium (dissolved)*	mg/L	0.01	0.1	<0.01	0.02	0.04	0.03	0.04
Boron	mg/L	0.005	5	0.399	0.485	0.144	0.535	1.36
Cadmium	mg/L	0.00002	0.005	0.00002	<0.000002	<0.00002	<0.00002	0.00004
Calcium	mg/L	0.02	-	0.8	66.1	103	110	158
Chromium	mg/L	0.002	0.05	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/L	0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Copper**	mg/L	0.002	1	0.011	<0.002	0.011	<0.002	0.011
Iron**	mg/L	0.005	0.3	<0.005	0.028	<0.005	<0.005	<0.005
Lead	mg/L	0.00002	0.01	0.00018	0.00005	0.00068	0.00017	0.00107
Magnessium	mg/L	0.01	-	0.25	22.1	18.5	29.7	65.4
Nickel	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	mg/L	0.1	-	0.4	5	3.3	6.3	18.5
Silicon	mg/L	0.01	-	3.07	5.32	2.56	3.23	3.17
Silver	mg/L	0.00002	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium**	mg/L	0.2	200	**220**	14.9	28.6	57.1	**420**
Zinc**	mg/L	0.005	5	0.007	0.012	0.029	<0.005	0.044

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2a - Domestic Well Metals

		Location:		[redacted]				
		Sample ID:		NW7	NW8	NW9	NW10	NW11
		Date Collected:		5-May-15	5-May-15	5-May-15	5-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS(1)**					
Aluminium (dissolved)*	mg/L	0.01	0.1	0.03	0.04	0.02	0.02	0.02
Boron	mg/L	0.005	5	0.14	0.018	0.661	0.079	0.011
Cadmium	mg/L	0.00002	0.005	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Calcium	mg/L	0.02	-	122	68.2	77.7	103	77.8
Chromium	mg/L	0.002	0.05	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/L	0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Copper**	mg/L	0.002	1	0.006	0.097	<0.002	0.013	0.287
Iron**	mg/L	0.005	0.3	<0.005	0.014	<0.005	<0.005	<0.005
Lead	mg/L	0.00002	0.01	0.00037	0.00068	0.00006	0.00015	0.00013
Magnessium	mg/L	0.01	-	19.9	13.9	37.9	12.2	5.35
Nickel	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	mg/L	0.1	-	3.2	1.3	5.9	1.3	0.6
Silicon	mg/L	0.01	-	2.62	2.95	5.7	2.09	2.73
Silver	mg/L	0.00002	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium**	mg/L	0.2	200	40.8	6.3	112	28	9.6
Zinc**	mg/L	0.005	5	0.008	0.009	0.01	0.008	<0.005

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2a - Domestic Well Metals

			Location:	[redacted]				
			Sample ID:	NW12	NW13	NW14	NW15	NW16
			Date Collected:	6-May-15	6-May-15	6-May-15	6-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS**(1)					
Aluminium (dissolved)*	mg/L	0.01	0.1	0.03	0.06	0.02	0.03	0.03
Boron	mg/L	0.005	5	0.029	3.98	0.025	0.045	0.052
Cadmium	mg/L	0.00002	0.005	<0.00002	0.00004	0.00002	<0.00002	<0.00002
Calcium	mg/L	0.02	-	127	311	90.4	128	130
Chromium	mg/L	0.002	0.05	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/L	0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Copper**	mg/L	0.002	1	<0.002	0.005	0.14	0.01	0.005
Iron**	mg/L	0.005	0.3	0.034	<0.005	<0.005	<0.005	<0.005
Lead	mg/L	0.00002	0.01	0.00006	0.00066	0.00039	0.00032	0.00021
Magnessium	mg/L	0.01	-	11	147	14.3	11.5	12.8
Nickel	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	mg/L	0.1	-	9	35.5	3.4	20.6	30.8
Silicon	mg/L	0.01	-	2.73	4.28	3.98	3.33	3.62
Silver	mg/L	0.00002	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium**	mg/L	0.2	200	52.6	**953**	20.8	29.8	27.8
Zinc**	mg/L	0.005	5	0.316	0.051	0.051	0.018	<0.005

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016
Analytical Summary_Elginburg Quarry.xlsx

Table H2a - Domestic Well Metals

			Location:	[redacted]				
			Sample ID:	NW17	NW18	NW19	NW20	NW21
			Date Collected:	6-May-15	6-May-15	6-May-15	6-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS[(1)]**					
Aluminium (dissolved)*	mg/L	0.01	0.1	0.02	0.03	0.02	<0.01	0.03
Boron	mg/L	0.005	5	0.261	0.193	0.016	0.227	0.047
Cadmium	mg/L	0.00002	0.005	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Calcium	mg/L	0.02	-	91.7	114	0.08	0.04	152
Chromium	mg/L	0.002	0.05	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/L	0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Copper**	mg/L	0.002	1	0.039	0.033	0.02	0.012	<0.002
Iron**	mg/L	0.005	0.3	<0.005	<0.005	0.018	<0.005	0.044
Lead	mg/L	0.00002	0.01	0.00015	0.0004	0.00067	0.0001	0.00029
Magnessium	mg/L	0.01	-	16.4	19.3	<0.01	0.02	15.1
Nickel	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	mg/L	0.1	-	3.1	3.2	0.3	0.3	1.3
Silicon	mg/L	0.01	-	4.41	2.87	3.32	6.03	3.4
Silver	mg/L	0.00002	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium**	mg/L	0.2	200	20.1	104	72.5	147	**215**
Zinc**	mg/L	0.005	5	0.006	0.025	0.005	<0.005	0.005

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2b: Domestic Well Bacteria and General Chemistry

		Location:		[redacted]				
		Sample ID:		NW2	NW4	NW4	NW2	NW1
		Sample Date:		12-Feb-15	12-Feb-15	23-Mar-15	24-Mar-15	5-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS[(1)]**					
E. coli	ct/100mL	1	0	0	0	0	0	0
Faecal Coliforms	ct/100mL	1	-	0	0	0	0	0
Total Coliforms	ct/100mL	1	0	**2**	0	**1**	**13**	0
Alkalinity as CaCO3*	mg/L	3	30-500	218	307	204	258	270
Chloride**	mg/L	1	250	88.2	127	149	49.8	**385**
CO3 as CaCO3	mg/L	3	-	<3	<3	<3	<3	<3
Conductivity	uS/cm	-	-	734	994	966	722	2210
Dissolved Inorganic Carbon	mg/L	0.2	-	54.5	76.8	49	64.5	67.5
Dissolved Organic Carbon**	mg/L	0.2	5	3.2	4	2	3.6	2.2
Hardness as CaCO3*	mg/L	1	80-100	**230**	**320**	**268**	**279**	**563**
HCO3 as CaCO3	mg/L	3	-	218	307	204	258	270
Ammonia & Ammonium as N	mg/L	0.05	-	<0.05	0.1	0.49	<0.05	<0.05
Nitrite as N	mg/L	0.1	1	<0.10	<0.10	<0.10	<0.1	<0.1
Nitrate as N	mg/L	0.1	10	1	<0.10	<0.10	0.3	0.8
pH*		-	6.5-8.5	7.73	7.75	7.97	7.79	7.76
Phenols	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate**	mg/L	1	500	51	72	97	55	294
Total P	mg/L	0.01	-	0.04	0.03	<0.01	0.02	<0.01
Total Suspended Solids	mg/L	3	-	<3	<3	<3	<3	<3
Turbidity**	NTU	0.2	5	0.3	0.5	0.7	0.4	<0.2
Field pH*			6.5-8.5	7.84	7.86	7.88	8.15	7.16
Field Temperature**	°C		15	9.6	9.6	6.7	6.7	10.1
Field Conductivity	µs		-	805	1065	998	669	2260

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2b: Domestic Well Bacteria and General Chemistry

Parameter	Units	M.D.L.	ODWQS[1]					
		Location:		[redacted]				
		Sample ID:		NW2	NW3	NW4	NW5	NW6
		Sample Date:		5-May-15	5-May-15	5-May-15	5-May-15	5-May-15
E. coli	ct/100mL	1	0	0	0	0	0	0
Faecal Coliforms	ct/100mL	1	-	0	0	0	0	0
Total Coliforms	ct/100mL	1	0	**3**	0	0	**3**	0
Alkalinity as CaCO3*	mg/L	3	30-500	299	225	264	278	315
Chloride**	mg/L	1	250	62.3	10.5	59.4	82.5	**812**
CO3 as CaCO3	mg/L	3	-	<3	<3	<3	<3	<3
Conductivity	uS/cm	-	-	911	551	812	1010	3220
Dissolved Inorganic Carbon	mg/L	0.2	-	71.8	56.3	66	69.5	78.8
Dissolved Organic Carbon**	mg/L	0.2	5	3.4	3.6	3.3	2.8	2.6
Hardness as CaCO3*	mg/L	1	80-100	**3**	**256**	**333**	**398**	**663**
HCO3 as CaCO3	mg/L	3	-	299	225	264	278	315
Ammonia & Ammonium as N	mg/L	0.05	-	<0.05	0.19	<0.05	0.1	0.66
Nitrite as N	mg/L	0.1	1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate as N	mg/L	0.1	10	0.9	<0.1	<0.1	0.4	0.9
pH*		-	6.5-8.5	8.14	7.94	7.78	7.79	7.71
Phenols	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate**	mg/L	1	500	72	53	66	128	172
Total P	mg/L	0.01	-	<0.01	0.01	0.01	<0.01	0.01
Total Suspended Solids	mg/L	3	-	<3	<3	14	<3	<3
Turbidity**	NTU	0.2	5	<0.2	0.3	**10.7**	<0.2	0.3
Field pH*			6.5-8.5	7.79	7.57	7.24	7.37	7.05
Field Temperature**	°C		15	14.8	13.5	12.8	11.7	12
Field Conductivity	µs		-	940	556	830	1538	3244

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2b: Domestic Well Bacteria and General Chemistry

			Location:	[redacted]				
			Sample ID:	NW7	NW8	NW9	NW10	NW11
			Sample Date:	5-May-15	5-May-15	5-May-15	5-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS**(1)					
E. coli	ct/100mL	1	0	0	**1**	0	0	0
Faecal Coliforms	ct/100mL	1	-	0	0	0	0	0
Total Coliforms	ct/100mL	1	0	0	**4**	0	**5**	**110**
Alkalinity as CaCO3*	mg/L	3	30-500	282	196	201	216	201
Chloride**	mg/L	1	250	73.7	6.9	196	63.3	6.8
CO3 as CaCO3	mg/L	3	-	<3	<3	<3	<3	<3
Conductivity	uS/cm	-	-	896	417	1200	695	421
Dissolved Inorganic Carbon	mg/L	0.2	-	70.5	51	48.2	54	50.3
Dissolved Organic Carbon**	mg/L	0.2	5	2.7	**16.3**	1.1	2	4.5
Hardness as CaCO3*	mg/L	1	80-100	**387**	**228**	**350**	**308**	**216**
HCO3 as CaCO3	mg/L	3	-	282	196	201	216	201
Ammonia & Ammonium as N	mg/L	0.05	-	<0.05	<0.05	0.46	<0.05	<0.05
Nitrite as N	mg/L	0.1	1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate as N	mg/L	0.1	10	1.1	0.6	0.2	0.4	0.2
pH*		-	6.5-8.5	7.8	7.42	7.97	7.88	7.77
Phenols	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate**	mg/L	1	500	84	10	111	48	8
Total P	mg/L	0.01	-	0.01	0.01	<0.01	<0.01	0.02
Total Suspended Solids	mg/L	3	-	<3	<3	<3	<3	<3
Turbidity**	NTU	0.2	5	<0.2	0.5	0.3	<0.2	0.4
Field pH*			6.5-8.5	7.15	6.52	7.26	7.18	7.29
Field Temperature**	°C		15	10.9	11.9	12.9	11.8	10.1
Field Conductivity	µs		-	919	430	1207	706	429

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2b: Domestic Well Bacteria and General Chemistry

			Location:	[redacted]				
			Sample ID:	NW12	NW13	NW14	NW15	NW16
			Sample Date:	6-May-15	6-May-15	6-May-15	6-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS**(1)					
E. coli	ct/100mL	1	0	0	0	0	0	**1**
Faecal Coliforms	ct/100mL	1	-	0	0	0	1	0
Total Coliforms	ct/100mL	1	0	**25**	0	0	**3**	**3**
Alkalinity as CaCO3*	mg/L	3	30-500	335	210	218	289	320
Chloride**	mg/L	1	250	82.1	**1970**	44.8	58.9	48.6
CO3 as CaCO3	mg/L	3	-	<3	<3	<3	<3	<3
Conductivity	uS/cm	-	-	906	6680	604	826	849
Dissolved Inorganic Carbon	mg/L	0.2	-	83.8	52.5	56.7	72.3	80
Dissolved Organic Carbon**	mg/L	0.2	5	4.4	1.1	2.3	4.7	**5.6**
Hardness as CaCO3*	mg/L	1	80-100	**363**	**1380**	**285**	**367**	**377**
HCO3 as CaCO3	mg/L	3	-	335	210	218	289	320
Ammonia & Ammonium as N	mg/L	0.05	-	<0.05	1.62	<0.05	<0.05	<0.05
Nitrite as N	mg/L	0.1	1	<0.1	<0.1	<0.1	<0.1	0.3
Nitrate as N	mg/L	0.1	10	0.1	0.2	2	3.7	1.7
pH*		-	6.5-8.5	7.61	7.74	7.48	7.58	7.61
Phenols	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate**	mg/L	1	500	14	**507**	13	34	39
Total P	mg/L	0.01	-	<0.01	<0.01	0.02	0.1	0.03
Total Suspended Solids	mg/L	3	-	<3	3	<3	<3	<3
Turbidity**	NTU	0.2	5	1.1	<0.2	0.5	<0.2	<0.2
Field pH*			6.5-8.5	7	7.17	7.1	7	7.1
Field Temperature**	°C		15	8.3	10	11.3	12.9	13.6
Field Conductivity	µs		-	915	>3999	616	857	857

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H2b: Domestic Well Bacteria and General Chemistry

		Location:		[redacted]				
		Sample ID:		NW17	NW18	NW19	NW20	NW21
		Sample Date:		6-May-15	6-May-15	6-May-15	6-May-15	6-May-15
Parameter	**Units**	**M.D.L.**	**ODWQS(1)**					
E. coli	ct/100mL	1	0	0	0	0	0	0
Faecal Coliforms	ct/100mL	1	-	0	0	1	0	1
Total Coliforms	ct/100mL	1	0	0	**2**	**70**	0	**>200**
Alkalinity as CaCO3*	mg/L	3	30-500	230	307	123	210	349
Chloride**	mg/L	1	250	25.5	140	2.4	30.7	**338**
CO3 as CaCO3	mg/L	3	-	<3	<3	<3	<3	<3
Conductivity	uS/cm	-	-	630	1130	287	599	1760
Dissolved Inorganic Carbon	mg/L	0.2	-	57.5	76.8	33.2	52.5	90.7
Dissolved Organic Carbon**	mg/L	0.2	5	2.9	3	**15.1**	1.9	3.4
Hardness as CaCO3*	mg/L	1	80-100	**297**	**365**	<1	<1	**443**
HCO3 as CaCO3	mg/L	3	-	230	307	123	210	349
Ammonia & Ammonium as N	mg/L	0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite as N	mg/L	0.1	1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate as N	mg/L	0.1	10	3.3	3.4	0.2	0.4	0.1
pH*		-	6.5-8.5	7.81	7.66	7.24	7.9	7.45
Phenols	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate**	mg/L	1	500	44	46	16	41	32
Total P	mg/L	0.01	-	<0.01	0.01	<0.01	<0.01	<0.01
Total Suspended Solids	mg/L	3	-	<3	3	<3	<3	<3
Turbidity**	NTU	0.2	5	0.2	0.2	0.3	<0.2	0.5
Field pH*			6.5-8.5	7.1	7.1	6.95	7.41	6.71
Field Temperature**	°C		15	**19**	10.5	11.1	12	7.69
Field Conductivity	µs		-	641	1130	287	619	1789

Notes:

(1) Ontario Drinking Water Quality Standards, O.Reg 169/03, Safe Drinking Water Act, 2002.

* Standards based on ODWQS **Operational Guideline**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

** Standards based on ODWQS **Aesthetic Objective**, Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2006.

MDL - Method Detection Limit

Analyses completed by Caduceon Environmental Laboratories of Kingston.

Values in bold exceed ODWQS Standards

Table H3a - Surface Water Metals

Parameter	Units	M.D.L.	PWQO Criteria [1]	E-SW1	E-SW2	E-SW3
			Sample ID:	E-SW1	E-SW2	E-SW3
			Date Collected:	29-May-14	29-May-14	29-May-14
Magnesium	mg/L	0.01	NV	29.1	12.5	15.1
Sodium	mg/L	0.2	NV	41.3	21.6	25
Potassium	mg/L	0.1	NV	8.2	3.7	6.4
Aluminum (total)	mg/L	0.01	0.075	0.08	0.06	0.09
Arsenic	mg/L	0.0001	0.1	0.0004	0.0003	0.0003
Barium	mg/L	0.001	NV	0.042	0.038	0.04
Beryllium	mg/L	0.002	1.1	< 0.002	< 0.002	< 0.002
Boron	mg/L	0.005	0.2	0.258	0.119	0.174
Cadmium	mg/L	0.00002	0.0002	< 0.00002	< 0.00002	< 0.00002
Chromium	mg/L	0.002	0.0089	< 0.002	0.003	< 0.002
Cobalt	mg/L	0.0001	0.0009	0.0008	0.0002	0.0003
Copper	mg/L	0.0001	0.005	0.0014	0.0011	0.0009
Iron (Total)	mg/L	0.005	0.3	0.136	0.106	0.131
Lead	mg/L	0.00002	0.025	0.00005	0.00005	0.00016
Manganese (Total)	mg/L	0.001	NV	0.051	0.051	0.024
Mercury	mg/L	0.00002	0.0002	< 0.00002	< 0.00002	< 0.00002
Molybdenum	mg/L	0.0001	0.04	0.0072	0.0023	0.0035
Nickel	mg/L	0.0005	0.025	0.0067	0.0043	0.0059
Silicon	mg/L	0.01	NV	1.53	1.67	0.55
Silver	mg/L	0.00002	0.0001	< 0.00002	< 0.00002	< 0.00002
Strontium	mg/L	0.001	NV	2.48	0.999	1.47
Thallium	mg/L	0.00005	0.0003	0.00008	< 0.00005	< 0.00005
Titanium	mg/L	0.005	NV	< 0.005	0.005	0.006
Vanadium	mg/L	0.005	0.006	< 0.005	< 0.005	< 0.005
Zinc	mg/L	0.005	0.03	0.032	0.009	0.009

Notes: (1) Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy July, 1994

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016

Table H3b - Surface Water PHC and General Chemistry

Parameter	Units	M.D.L.	PWQO Criteria [1]	E-SW1	E-SW2	E-SW3
			Date Collected:	29-May-14	29-May-14	29-May-14
Hardness (as CaCO3)	mg/L	1	NV	405	276	280
Alkalinity(CaCO3) to pH4.5	mg/L	5	NV	138	182	146
Bicarbonate(as CaCO3)	mg/L	5	NV	138	182	146
Carbonate (as CaCO3)	mg/L	5	NV	< 5	< 5	< 5
pH @25°C	pH Units		6.5-8.5	8.21	8.26	8.27
Conductivity @25°C	µmho/cm	1	NV	886	577	627
Field Dissolved Oxygen			NV	7.16	8.47	9.57
Field Temperature	°C		NV	19.7	17.1	17.2
Field pH	pH Units		NV	7.01	7.02	7.42
Field Conductivity	µmho/cm		NV	715	591	623
Total Suspended Solids	mg/L	3		< 3	7	12
Chloride	mg/L	0.5	NV	52.1	23.5	25.9
Nitrite (N)	mg/L	0.1	1	< 0.1	< 0.1	< 0.1
Nitrate (N)	mg/L	0.1	10	0.3	0.2	0.2
Sulphate	mg/L	1	NV	254	90	148
Calcium	mg/L	0.02	NV	114	89.9	87
Ammonia (N)-Total	mg/L	0.01	NV	< 0.01	0.03	0.01
Ammonia (unionized) [2]	mg/L		0.02	< 0.00004	0.00010	0.00008
Total Kjeldahl Nitrogen	mg/L	0.05	NV	0.25	0.47	0.41
Phosphorus-Total	mg/L	0.01	0.03	< 0.01	< 0.01	0.02
Phenolics	mg/L	0.001	NV	< 0.001	< 0.001	< 0.001
BOD	mg/L	3	NV	< 3	< 3	< 3
COD	mg/L	5	NV	35	38	36
Dissolved Organic Carbon	mg/L	0.2	NV	4.1	4.2	3.6
Dissolved Inorganic Carbon	mg/L	0.2	NV	33.1	43.7	35
PHC F1 (C6-C10)	µg/L	20	NV	< 20	< 20	< 20
PHC F2 (>C10-C16)	µg/L	50	NV	< 50	< 50	< 60
PHC F3 (>C16-C34)	µg/L	400	NV	< 400	< 400	< 500
PHC F4 (>C34-C50)	µg/L	400	NV	< 400	< 400	< 500
Oil & Grease-Total	mg/L	1	NV	< 1.0	< 1.0	< 1.0

Notes:

(1) Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy July, 1994

(2) Calculated based on field measurements of pH and temperature

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016

APPENDIX I: Domestic Well Survey Summary

Table I - Domestic Well Survey Summary

Address	Well on Property (Yes/No)	Distance from Quarry (m)	Participation in Survey (Yes/No)	Well Depth	Well Type	Acquifer Type	Well Record (Yes/No)	Comments/Issues Noted	Static WL (mbtoc)
2440 Burbrook Road	Yes	450	Yes	Unkown	Drilled	Bedrock	No	Hard water, no quantity issue	Not Measured
2506 Burbrook Road	Yes	450	Yes	~21.3 m	Drilled	Bedrock	No	Sediment in water, buried well	Not Measured
2514 Burbrook Road	Yes	450	Yes	~12.2 m	Drilled	Bedrock	No	Hard water, no quantity issue	Not Measured
2630 Burbrook Road #1	Yes	325	Yes	Unkown	Drilled	Bedrock	No	Spring fed well, no issues	Not Measured
2630 Burbrook Road #2	Yes	325	Yes	Unkown	Drilled	Bedrock	No	Spring fed well, had bacteria previously detected	Not Measured
2643 Burbrook Road	Yes	450	Yes	~30.5 m	Drilled	Bedrock	No	Slight sulfur smell recently	Not Measured
2659 Burbrook Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Interested, unavailable at time of survey	N/A
1985 Cordukes Road	No	N/A	No	N/A	N/A	N/A	N/A	Well dry, on a cistern	N/A
1986 Cordukes Road	Yes	450	Yes	32.92 m (from well record)	Drilled	Bedrock	Yes	Hard water, no quantity issue	18.59 (from well record)
1989 Cordukes Road #1	Yes	500	Yes	73.8 m (from well record)	Drilled	Bedrock	Yes	Hard water, no quantity issue	Not Measured
1989 Cordukes Road #2	Yes	500	Yes	26.5 mbtoc	Drilled	Bedrock	No	Not in use	19.29
1995 Cordukes Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Declined to participate	N/A
1998 Cordukes Road #1	Yes	390	Yes	36.81 mbtoc	Drilled	Bedrock	Yes	Salty due to treatment, no quantity issue	22.77
1998 Cordukes Road #2	Yes	340	Yes	19.4 mbtoc	Drilled	Bedrock	Yes	None	17.52
2003-2005 Cordukes Road	Yes	480	Yes	46.5 mbtoc	Drilled	Bedrock	No	Salty, some odour after rain, no quantity issue	24.67
2034 Cordukes Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Declined to participate	N/A
2039 Cordukes Road	No	N/A	No	N/A	N/A	N/A	N/A	No wells	N/A
2075 Cordukes Road	Yes	460	Yes	Unkown	Drilled	Bedrock	No	Had lower basement flooded 3 years ago	Not Measured
2085 Cordukes Road	Yes	450	Yes	44 mbtoc	Drilled	Bedrock	No	None	26.39
2130 Cordukes Road	Yes	340	Yes	~25.9 m	Drilled	Bedrock	No	None	14.45
2147 Cordukes Road #1	Yes	475	Yes	13.24 mbtoc	Drilled	Bedrock	No	None	8.39
2147 Cordukes Road #2	Yes	475	Yes	14.49 mbtoc	Drilled	Bedrock	No	None	9.62
2150 Cordukes Road	Yes	300	Yes	27.4 m	Drilled	Bedrock	No	None	11.62
2166 Cordukes Road	Yes	300	Yes	26.8 m	Drilled	Bedrock	No	None	8.38
2217 Cordukes Road	Yes	450	Yes	24.3 mbtoc	Drilled	Bedrock	No	Hard water and sulfur odour, no quantity issues	6.1

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016

Table I - Domestic Well Survey Summary

Address	Well on Property (Yes/No)	Distance from Quarry (m)	Participation in Survey (Yes/No)	Well Depth	Well Type	Acquifer Type	Well Record (Yes/No)	Comments/Issues Noted	Static WL (mbtoc)
2242 Cordukes Road	Yes	450	Yes	~25.9 m	Drilled	Bedrock	No	Buried well, no issues	Not Measured
2243 Cordukes Road	Yes	480	Yes	27.67 mbtoc	Drilled	Bedrock	No	None	9.37
2250 Cordukes Road	Yes	440	Yes	21.6 m (from well record)	Drilled	Bedrock	Yes	None	4.63 (from well record)
2196 Unity Road	Yes	880	Yes	3.4 mbtoc	Dug	Bedrock	No	Hard water and sulfur odour, no quantity issues	0.81
2257 Unity Road	No	N/A	No	N/A	N/A	N/A	N/A	Well dry, on a cistern	N/A
2260 Unity Road	No	N/A	Yes	N/A	N/A	N/A	N/A	No well, on a cistern	N/A
2265 Unity Road	No	N/A	Yes	N/A	N/A	N/A	N/A	No well, on a cistern	N/A
2271 Unity Road	No	N/A	Yes	N/A	N/A	N/A	N/A	No well, on a cistern	N/A
2295 Unity Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Unavailable at time of survey	N/A
2296 Unity Road	Yes	245	Yes	~6.1 m	Dug	Bedrock	No	Hard water, sulfur smell sometimes, slow recharge	1.55
2309 Unity Road #1	Yes	200	Yes	~3.7 m	Dug	Overburden	No	None	0.84
2309 Unity Road #2	Yes	200	Yes	~18.3 m	Drilled	Unknown	No	Not in use, slow recharge	Not Measured
2350 Unity Road	N/A	N/A	No	N/A	N/A	N/A	N/A	No house/vacant	N/A
2467 Unity Road	No	N/A	Yes	N/A	N/A	N/A	N/A	No well, on a holding tank	N/A
2528 Unity Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Declined to participate	N/A
2559 Unity Road	No	N/A	No	N/A	N/A	N/A	N/A	Vacant house, Cistern observed on property	N/A
2604 Unity Road	Yes	400	Yes	Unkown	Dug	Bedrock	No	Only outdoor use	Not Measured
2610 Unity Road	N/A	N/A	No	N/A	N/A	N/A	N/A	Unavailable at time of survey	N/A
2611 Unity Road	No	N/A	Yes	N/A	N/A	N/A	N/A	Well not in use, on a cistern	N/A

Prepared by: AC
Reviewed by: AW
Date: 1/8/2016

APPENDIX J: Terms of Reference for Grouting Study

MEMORANDUM

MORRISON HERSHFIELD

TO:	Ken Bangma	ACTION BY:	
FROM:	Anthony West	FOR INFO OF:	
PLEASE RESPOND BY:		PROJECT No.:	2130039
RE:	Terms of Reference for a Grouting Study for Elginburg Quarry Expansion	DATE:	November 5, 2015

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Background

Cruickshank intends to expand their Elginburg Quarry westward, and a hydrogeological study was conducted to assess the potential impacts. The results of the study found that the Gull River Formation in the area of the expansion is of very low bulk permeability – producing very low yield monitoring wells on-site, and a higher than typical proportion of abandoned (for quality or quantity reasons) domestic wells in the area. The study found that one well was within a conservatively-estimated radius of influence of the fully extracted quarry expansion (250 m), and that four other wells were outside this area but warranted special consideration. All such wells were north and west of the existing quarry and situated such that the quarry would slowly (over decades) expand towards them.

To address residents' concerns relating to their wells, a robust monitoring program was proposed such that lowering of the water table can be observed within the intervening (buffer) lands between the quarry face and the closest residences. To address the unlikely event that a well is impacted, rock grouting is proposed as a contingency measure to reverse the effects of an inadvertent draining of a critical water bearing zone.

Groundwater in the Gull River Formation in the vicinity of the Elginburg Quarry is thought to flow in channels embedded within planar fracture features (Tsang, C. and Neretnieks, I., 1998). When intercepted by a quarry wall, such channels present themselves as point sources of water, distributed along the horizontal planar feature. An example of such channels is shown in Photo 1 taken at the Elginburg Quarry, which shows frozen inflowing groundwater (see Photo 1). Note that this photo shows rock which is in fact above the water table, and the inflowing groundwater represents recent precipitation which has found the "path of least resistance" to the quarry (flowing laterally to the quarry rather than downward to the water table). Channelized discharge can also be seen in Photo 2 showing a rock cut in the Gull River Formation along Highway 401 at Montreal Street, 7 km south west of the quarry. In this photo, the channels can be seen as the regular pattern of ice approximately 1-2 m above the road surface. It is noted that this rock cut is shallow compared to the quarry, and likely much more permeable. Little appreciable permeability has been found on the north and west side of the quarry expansion area, and the frequency of discharge points is expected to be lower than in the photo.

In this hydrogeological environment, wells in the area of the Elginburg Quarry take their water from discrete water bearing zones that are channels embedded within planar features. Given the otherwise very low permeability of the rock, the most likely scenario for a well impact is that such a channel is drained into the quarry when it is intercepted by the advancing rock face.

Photo 1: Existing Elginburg South Quarry
– Channelized flow in a Planar Feature, noting that this very fresh, very shallow groundwater

Photo 2: Highway 401 and Highway 11 Intersection – Channelized flow in a planar feature. Note the regularly-spaced ice mounds, about car height.

In this scenario, the impact to the well is considered reversible through grouting, or otherwise sealing up the affected channel. There are several key factors which support grouting or sealing up of water bearing channels as a contingency measure in the event of a well impact:

1. It is proposed within the context of what will be a robust water level and quarry seepage monitoring record;

2. The separation distances between the quarry and the nearest wells are substantial;

3. The quarry will advance slowly towards the wells, allowing trends in water level in the intervening rock (buffer zone) to be monitored;

4. Several lines of evidence support the conceptual model that the water flow is concentrated in discrete features in the rock;

5. A pilot study may be carried out before extraction of the rock that could result in well impacts.

Timing of the Grouting Study

The grouting study would be best completed during extraction of Lift 3 in Lot 13. The study would be triggered by positive identification of a discrete seepage zone on the western Lift 3 quarry wall thought to be associated with a downwards trend in groundwater level in one or more of the piezometers installed in BH12-01 or BH12-02 (see Figure 9).

The intent of conducting the study at this later stage is to ensure that the knowledge gained from the study is not lost in intervening years, to ensure that a critical seepage face is available for study, and to take advantage of the two multi-level monitoring wells in Lot 13 that are internal to the extraction area.

Goal of the Grouting Study

To demonstrate that grouting can be used to halt inflow from a specific seepage location in the wall of the third lift, and that the cessation of inflow can be correlated to an associated increase in hydraulic head in the rock distal to the seepage face.

The following methodology assumes that a suitable seepage feature is encountered during excavation of the quarry.

Study Methodology

1. Review the monitoring information to understand how groundwater between the receptors and the quarry is being affected by the advancing rock face;

2. Review any applicable hydrogeology studies;

3. Review grouting methods used in existing quarries and underground mines;

4. Identify a seepage zone or zones in the critical seepage face, which is thought to be associated with a downward trend in groundwater elevation in a nearby monitoring well(s). According to the conceptual understanding of the hydrogeology of the area, this should be a discrete point or area in an otherwise fairly dry rock face;

5. Carry out any pre-grouting tests, such as injecting water with or without tracer into the nearby monitoring well(s) and observing its discharge at the seepage zone,

6. Undertake a grouting program, either from above or from within the quarry, with the goal of reducing or completely sealing off the target seepage zone or zones.

7. Monitor the seepage and water level in the monitoring well(s) over a 1 year period, to determine if the grouting program has eliminated the seepage and caused a reversal of any pre-existing downwards trend in groundwater level.

8. Undertake additional grouting and monitoring as necessary;

9. Carry out any post-grouting tests;

10. Write a report summarizing the background, methods, findings, and recommendations.

References

Tsang, C. and Neretnieks, I., 1998. Flow Channeling in Heterogeneous Fractured Rocks, Reviews of Geophysics, Volume 36, pp 275-298.

Approximate Cost of the Grouting Study

The approximate cost of the grouting study is estimated at $123,000, broken down in Table 1 as shown below. In developing this price, the following assumptions were made:

1. The target fracture zone is discrete an no more than 5 m wide and 2 m high;
2. Drilling of grout holes will be from the quarry floor above, through the 12 m thick third lift;
3. A line of 10 grout holes will be drilled on 3 m centres, and the volume of rock receiving grout will be approximately 30 m long by 6 m wide, by 2 m deep;
4. The porosity of the rock receiving grout is no more than 5% (likely a gross overestimation)
5. Each 50 lb bag of grout will yield approximately 13 L of grout at flowable consistency

Table 1 Break Down of Estimated Cost for Grouting Study

Item	Descriptions	Unit of Measure	Unit Price	Estimated Quantity	Estimated Cost
1	Annual research stipend for a graduate student	yr	$20,000	2	$40,000
2	Dye, equipment, misc expenses	Lump sum	$5,000	1	$5,000
3	15 m deep, 6" diameter borehole drilled with water well rig	ea	$1,500	10	$15,000
4	Grouting pump and personnel	hr	$300	70	$21,000
5	Cementious grout, including shipping	bag	$16	1000	$16,000
6	Mobilization (driller, grouter)	Lump sum	$1,000	4	$4,000
7	Consultant oversight	hr	$200	50	$10,000
8	Cruickshank Project Manager	hr	$120	100	$12,000
Total					**$123,000**