~~NK38-38000-10001~~

Trow

GEOTECHNICAL INVESTIGATION PROPOSED HEAVY WATER MANAGEMENT BUILDING DARLINGTON NUCLEAR PLANT DARLINGTON, ONTARIO

NK38-REP-38000-10001-R00

ONTARIOPOWER GENERATION — Darlington Nuclear

ACCEPTED ☒
ACCEPTED AS NOTED ☐
REVISE AND RESUBMIT ☐

John O'Neill — Signature
2 May 2011 — Date

Name: John O'Neill

Department: Design Projects

THIS ACCEPTANCE DOES NOT RELIEVE THE CONTRACTOR FROM RESPONSIBILITY FOR ERRORS OR OMISSIONS OR FROM ANY OBLIGATIONS OR LIABILITY UNDER THIS CONTRACT

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This document has a total of 32 physical pages

Trow Associates Inc.

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Trow

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1. Introduction

This report presents the results of a geotechnical investigation conducted for the proposed Heavy Water Management Building located at the Darlington Nuclear Plant in Darlington, Ontario. The work was authorized by Mr. Eric Jok, P. Eng. of Ontario Power Generation (OPG).

The project involves the design and construction of the proposed Heavy Water Management Building at the existing Darlington Nuclear Plant in Darlington. It is understood that the proposed structure will provide housing for heavy water storage units. The design of the structure has not been finalized.

The purpose of the geotechnical investigation was to determine the subsoil and groundwater conditions at the site by putting down a limited number of sampled boreholes and, based on an assessment of the factual borehole data, provide an engineering report with geotechnical recommendations pertinent to design and construction of the proposed structures.

Our Terms of Reference do not include a Phase I Environmental Site Assessment of the site. However, our Terms of Reference include limited environmental testing on selected soil samples to assess the environmental quality of the soils at the site for general disposal purposes.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed into construction. If changes are made either in the design phase or during construction, this office must be retained to review these modifications. The result of this review may be a modification of our recommendations or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.

2. Site Description

The proposed Heavy Water Management Building is to be located on the west side of the existing D20 Management Building inside the restricted area.

The site currently comprised open land with a gravel covered surface. The ground surface in the area was generally flat.

3. Procedure

The fieldwork for the geotechnical investigation was carried out during the period between September 11 and 15, 2007. At that time, a total of three (3) sampled boreholes were drilled to depths ranging from 12.85 to 19.60 m below existing grade at the approximate locations shown on the attached Borehole Location Plan (Drawing No. 1). The coordinates of each borehole are also shown in the following Table 1.

Table 1
Summary of Borehole Locations

Borehole No.	Easting	Northing	Ground Elevation (m)
1	10052.0	9937.0	99.381
2	10044.0	9926.0	99.701
3	10045.0	9910.0	99.594

The boreholes were advanced using continuous flight solid stem augering equipment owned and operated by a specialist drilling contractor. In each borehole, samples were recovered using conventional split spoon equipment and standard penetration test methods. No relatively undistrubed samples in cohesive soils were successfully recovered using thin-wall shelby tube due to the stiffness of the soil. Pocket penetration testing was conducted on cohesive soils samples to determine the in-situ shear strength.

Water levels were observed in the open boreholes during the course of the fieldwork. At each borehole location, tests for the concentration of flammable gases were carried out using a portable combustible gas tester (MSA Model 60).

At the end of drilling, all the boreholes were backfilled with compacted bentonite pellets.

The fieldwork was supervised by a Trow geotechnical engineer who monitored the drilling operations and logged the borings. All split spoon samples were transported to our laboratory for detailed examination following the clearance from OPG. Laboratory testing included moisture content determination on all recovered soil samples, natural unit weights and grain size analyses on selected soil samples and compressive strength on selected rock samples. In addition, one (1) soil sample was tested for pH and sulphate content. Two (2) soil samples were analyzed for inorganic parameters for soil disposal purposes.

The location and ground surface elevation of the boreholes listed in Table 1 were established in the field and provided by personnel from OPG. It is understood that the ground elevations are referenced to a local datum.

4. Subsurface Conditions

4.1 Soil

The detailed soil and rock profile encountered in each borehole and the results of laboratory moisture content determinations are indicated on the attached borehole logs (Drawing Nos. 2 to 4). It should be noted the soil and rock boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect approximate transition zones and should not be interpreted as exact planes of geological change. The "Notes on Sample Descriptions" preceding the borehole logs form an integral part of and should be read in conjunction with this report.

The stratigraphy of the site, as revealed in the boreholes, comprised surficial granular fill/fill over deposits of clayey silt till, silt and clayey silt underlain by shale bedrock.

A brief description of the soil and rock profiles, in order of depth, follows.

Granular Fill

Surficially, granular fill was encountered in all the boreholes, extending to depths of about 4.2 to 5.8 m below existing grade. The granular fill comprised sand and gravel, trace shale fragments. Based on the standard penetration 'N' values, the granular fill appeared to be in a compact state. Moisture contents of the granular fill ranged from 3 to 8 %. The granular fill was generally wet in the lower zone.

Fill

Locally at Borehole 1, a fill unit was encountered below the surficial granular fill extending to a depth of about 10.5 m below existing grade. The fill comprised black crushed shale and appeared in a compact state. Moisture contents of the shale fill ranged from 7 to 10 %.

Clayey Silt Till

A clayey silt till deposit was encountered below the granular fill and fill units. The till deposit comprised grey clayey silt, trace sand and gravel with scattered wet fine sand and silt seams, cobbles and boulders. The consistency of the clayey silt till was found to be very stiff to hard. Pocket penetrometer testing carried out on the recovered soil samples yielded in-situ shear strengths ranging from about 125 to in excess of 200 kPa. Natural unit weight of the fill ranged from about 21.1 to 23.0 kN/m^3. Moisture contents of the clayey silt till ranged from about 13 to 18 %. The clayey silt till extended to depths of about 7.3 to 11.5 m below existing grade.

A grain size distribution curve for the clayey silt till is included in Appendix A.

Silt

Below the clayey silt till in Borehole 2 and 3, a deposit of silt was encountered and extending to depths of 10.1 to 11.8 m below existing grade. The relative density of the silt deposit was found to be very dense. Unit weight of the soil ranged from 21.4 to 22.9 kN/m^3. Moisture contents of the silt ranged from 12 to 17 %, indicating a wet to saturated condition.

A grain size distribution curve for the silt deposit is included in Appendix A.

Clayey Silt

In Borehole 2, a clayey silt deposit was encountered below the clayey silt till unit and extending to a depth of about 11.8 m below existing grade. The consistency of the clayey silt deposit was found to be very stiff. Pocket penetrometer testing carried out on a soil sample yielded in-situ shear strength of about 150 kPa. Moisture content of the clayey silt unit was about 18 %.

Shale Bedrock

Shale bedrock was encountered below the clayey silt till, silt or clayey silt deposits at depths of about 11.5 to 11.8 m below existing grade. The shale bedrock was penetrated by coring in NQ size using diamond drilling equipment. The core lengths recovered in Boreholes 1 and 3 were about 1.5 m, and about 7.6 m in Borehole 2.

Details of the core logging are recorded on the attached Borehole Logs. Based on the recovery and Rock Quality Designation (RQD), the shale bedrock was weathered to moderately weathered in the upper 1.0 to 2.0 m, becoming sound with depth. It is not unusual to find random clay seams and rubble zones within the shale mass.

The bedrock is of the Georgian Bay formation (Ordovician period) and underlies this site to a significant depth. The predominate rock type is shale, but this shale is interbedded with limestone and shaley limestone. Typically, Trow has found that the shale component in this formation is of the order of 80 percent in GTA excavations. M.T.C. publication RR229 "Evaluation of Shales for Construction Projects", indicates a nominal 80 to 90 percent shale component in this formation. The limestone and shaley limestone components are generally 50 to 300 mm thick. Laboratory compressive strength testing carried out for four (4) rock core samples indicated compressive strengths ranging from 64.5 to 105.4 MPa. The results are presented in the enclosed borehole logs and Appendix A.

4.2 Groundwater

Groundwater conditions were observed in the open boreholes during the course of the fieldwork. End-of-hole groundwater measurements are included in the attached borehole logs.

Free groundwater was encountered in all the boreholes upon completion of drilling. The water level was observed at depths of about 2.08 to 2.54 m below existing grade.

The observed groundwater appeared to be derived from water perched within the granular fill material and from wet sand and silt seams within the native till. It is likely that this level represents the permanent groundwater level at the site which is inferred to be at a depth of about 2.5 m below existing grade.

A record search of the Lake Ontario level data established that the recorded highest water level at the GTA area since 1906 was at about Elevation 75.90 m. Please note that this elevation is recorded in geodetic, and not the local datum established by OPG.

The groundwater levels reflect conditions at the time of investigation. Groundwater levels are subject to seasonal fluctuations.

4.3 Gas Vapour

Monitoring for explosive gases was carried out at each borehole location using a MSA combustible gas indicator Model 60 calibrated for methane.

Generally, methane gas was not detected in any of the boreholes. However, methane gas may be present in localized pockets.

5. Engineering Discussion and Recommendations

5.1 General

The project involves the design and construction of the proposed Heavy Water Management Building at the existing Darlington Nuclear Plant in Darlington.

It is understood that the proposed structure will provide housing for heavy water storage units. The design of the housing structure has not been finalized. However, it is understood that some storage units may extend onto the underlying bedrock.

5.2 Building Construction

5.2.1 Foundation Considerations

Based on the results of the borehole investigation, it is considered that the site is generally suitable for the construction of the proposed building and storage units. The proposed structures may be supported on either shallow footing foundation, mat foundation, or caisson foundation.

It should be noted that the site is underlain by a deep fill material. The integrity of the fill was evaluated based on the results of the field standard penetration tests. The fill material was generally found to be in a compact to very dense state of compactness. However, the owner should be aware that unless records are kept during placement of the existing fill, this material should be considered as uncontrolled. There is the possibility of the presence of voided material occurring locally which can lead to isolated areas of distress in the footing foundation. If the foregoing is considered to be an unacceptable risk, then it may be necessary to support the proposed structures on mat foundation or caisson foundation.

The preferred means of supporting the structures will be dictated by economics and construction constraints.

Footing Foundation

The proposed structures may be supported on conventional footings founded on the compacted granular fill at or below a depth of about 1.0 m below existing grade. The following bearing capacities may be used in the design.

Factored Capacity at Ultimate Limit State (U.L.S.) =	300 kPa
Bearing Capacity at Serviceability Limit State (S.L.S.) =	200 kPa

It is understood that some storage units may extend onto the underlying bedrock. As such, foundations set on the weathered bedrock may be designed using the following bearing capacities:

Factored Capacity at Ultimate Limit State (U.L.S.) =	2,400 kPa
Bearing Capacity at Serviceability Limit State (S.L.S.) =	1,500 kPa

For S.L.S., the total and differential settlements of well designed and constructed footing are expected to be less than 25 mm and 20 mm, respectively.

Mat Foundation

For design of a mat foundation for the support of the structures, an average modulus of subgrade reaction value of 39,000 kN/m^3 may be used, assuming a Poisson's ratio value of 0.3 and a uniform contact stress of 200 kPa. It is anticipated the mat foundation will be founded at a depth of about 2.0 m below existing grade. The base of the mat foundation should comprise compacted granular fill. Since the fill subgrade material may be wet below a depth of about 2.0 to 2.5 m, the subgrade should be immediately protected with a concrete mud slab upon excavation and inspection and approval by Trow. During winter construction, care should be taken to ensure that the base of the excavation is protected with an insulation blanket at all times to prevent soil from freezing.

Based on the anticipated mat dimensions, the estimated settlement at the centre of the mat is in the range of 20 to 25 mm, and about 10 to 15 mm along the outer edges.

Caisson Foundation

Alternatively, the proposed structures may be supported on augered straight shafted cast-in-place concrete caissons founded into the underlying sound bedrock. The depth to the surface of the bedrock is about 11.5 to 11.8 m below existing grade.

The straight shafted cast-in-place concrete caissons should be extended below the weathered zone to a depth of about 2.0 m into the underlying shale bedrock. An allowable bearing pressure of 4,800 kPa (S.L.S.) may be used in the design for the caissons founded in the sound bedrock at a depth of about 13.5 to 14.0 m below existing grade, subject to inspection during construction. The factored bearing pressure at ultimate limit state (U.L.S.) is 7,600 kPa.

The caissons should be at least 760 mm in diameter and have a minimum length to base diameter ratio of at least 3. Temporary safety liners must be installed to prevent water and wet/loose soil from sloughing into the drilled shaft, and to allow down-hole cleaning and inspection. Hard augering resistance should be expected since crushed shale, cobbles and boulders were encountered in the boreholes. A 150 mm slump for the concrete is recommended for use to prevent the concrete from having a honeycombed structure or 'hang-up' in the liner during withdrawal.

Each caisson base must be properly hand cleaned and then inspected and approved by geotechnical personnel from Trow Associates Inc. prior to placing concrete.

The total and differential settlements of well designed and constructed caisson foundations placed in accordance with the above recommendations are expected to be less than 15 mm and 10 mm, respectively.

For resistance against uplift pressure, an allowable cohesion value of 50 kPa may be used in the calculation for the shaft of the caisson in contact with soil. For the portion of the caisson embedded in the bedrock, a bond resistance of concrete to weathered rock of 0.4 MPa may be used. A minimum of one diameter socket length is required for load transfer to take place.

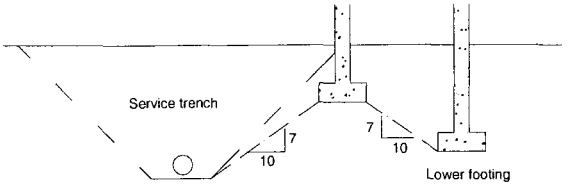
For instantaneous, non-sustained loading condition (i.e., seismic loads), it is estimated that the bearing pressures may be subjected to 30 % additional loading without significant effect to the foundations in limit states design.

Pile Foundation

Pile installation will generate significant noise and vibration. In view of adjacent sensitive structures, the use of driven pile foundation is not recommended for this site.

5.2.1.1 Foundation General

Footings or caissons which are to be placed at different elevations should be located such that the higher footings are set below a line drawn up at 10 horizontal to 7 vertical from the near edge of the lower footing, as indicated on the following sketch:



FOOTINGS NEAR SERVICE TRENCHES OR AT DIFFERENT ELEVATIONS

All footings and grade beams exposed to seasonal freezing conditions should be protected from frost action by at least 1.2 m of soil cover or equivalent insulation, depending on the final design requirements.

It should be noted that the recommended bearing capacities have been calculated by Trow from the borehole information for the design stage only. The investigation and comments are necessarily ongoing as new information on underground conditions becomes available. For example, it should be appreciated that modifications to bearing levels may be required if unforeseen subsoil conditions are revealed after the excavation is exposed to full view or if final design decisions differ from those assumed in this report. For this reason this office should be retained to review final foundation drawings and to examine footing conditions.

5.2.2 Groundwater Control

Provided the excavations do not extent below the observed groundwater level (i.e. 2.5 m below existing grade), no major groundwater dewatering is anticipated. Seepage from perched water in the fill or surface water run-off should be anticipated during construction. It should be possible to control and drain the seepage water using conventional construction dewatering techniques, i.e. pumping from sumps.

For excavations extended to below 2.5 m depth, it is anticipated that significant water seepage will be encountered within the granular and rock fill layers. It is therefore recommended that the groundwater be lowered by a vacuum well point dewatering system prior to excavation. The well points should be installed down to below the granular and/or rock fill layer. Within the native clayey silt till, clayey silt and silt, the permeability of these soils are relatively impervious, and groundwater seepage may be controlled and drained using conventional construction dewatering techniques, i.e. pumping from sumps. For flow rate calculation purposes, the coefficient of hydraulic conductivity for the granular/rock fill, silt and clayey silt till/clayey silt are about $1x10^{-2}$, $1x10^{-5}$ and $1x10^{-6}$ cm/sec, respectively.

Dewatering should be carried out by a special contractor familiar with the site and groundwater conditions using their own equipment and expertise.

5.2.3 Excavation and Shoring

No special problems are envisaged in constructing the shallow foundation for the proposed structure. The bulk excavation is expected to be carried out within the granular fill material. Excavation should be relatively straightforward and must be carried out in accordance with the latest Occupational Health and Safety Act. In this regard, the compacted fill is considered to be a Type 2 soil.

For guidance, side slopes of 1 vertical to 1 horizontal may be used for the shallow temporary excavation anticipated subject to geotechnical inspection. Where loose soil is encountered at shallow depths or within zones of persistent seepage, it may be necessary to locally flatten the side slopes.

Deeper excavations should be adequately sloped. Shoring will be required where there is a space restriction. For calculations of the triangular lateral earth pressure acting on the shoring system, the following values may be used:

Unit weight of soils	$\gamma = 20.5$ kN/m^3
Coefficient of active earth pressure	$K_a = 0.33$
Coefficient of passive earth pressure	$K_p = 3.0$
Surcharge loads (i.e. equipment or fill stockpiles)	$q = 10$ kPa

The shoring system should be designed by a qualified structural engineer and executed by specialist contractors with experience in projects of similar magnitude.

It should be noted that cobbles and boulders occur in glacial deposits and their presence may influence the progress of excavation. Methane gas was not encountered in the boreholes, but could be present in isolated pockets embedded in the bedrock. Consequently, provisions should be made in the contract documents to cover any delays caused by boulder obstructions or occurrence of methane gas pockets.

5.2.4 Floor Slab Construction and Permanent Drainage

Based on the finding in the boreholes, slab-on-grade construction is feasible at the site and may be carried out in accordance with the following recommendations.

Following removal of unsuitable surficial material and rough grading the exposed subgrade should be surface compacted and proofrolled with a heavy vibratory roller under the full-time supervision of Trow Associates Inc. Any soft spots detected should be sub-excavated and the area brought up to design grade using clean approved fill compacted to at least 98 % of its standard Proctor maximum dry density.

All backfilling and compaction operations should be monitored on a full-time basis by geotechnical staff to approve material and to ensure the specified degree of compaction has been achieved.

A 200 mm layer of 19 mm clear stone should be placed between the prepared subgrade and the floor slab to serve as a moisture barrier. Also, within any unheated areas and service entrances to the building, 25 mm of Styrofoam insulation should be provided below the floor slab to protect against frost heave.

For the design of the slab-on-grade construction, an average modulus of subgrade reaction value of 39,000 kN/m^3 may be used, with a maximum allowable bearing pressure of 200 kPa.

The ground floor slab should be set above the exterior finished grade. Around the perimeter of the building the ground surface should be sloped on a positive grade away from the structure to promote surface water run-off and reduce groundwater infiltration adjacent to the foundations.

5.2.5 Additional Earth Pressure on Subsurface Walls

Design ground acceleration for the project site was determined from the Earthquake Hazards Program website by interpolating 2005 National Building Code of Canada Seismic hazards values. The map indicates a peak horizontal ground acceleration (PHGA) value of approximately 0.122 g at the project site. The value is associated with an earthquake having 2 percent probability of exceedance in a 50 – year period (0.000404 per annum probability).

Based on the peak horizontal ground acceleration, the additional inverted earth pressure of 37 pounds per cubic feet (6 kN/m^3) should be included in subsurface wall design.

5.2.6 Backfill Considerations

Backfill used to satisfy underfloor slab requirements, in footings and service trenches, etc., should be compactible fill, i.e. inorganic soil with its moisture content close to its optimum moisture content as determined in the standard Proctor maximum dry density test. The backfill against subsurface walls should be a free draining granular material conforming to OPSS Granular 'B'.

The majority of the excavated material will consist of granular fill. It is considered that the excavated granular fill material would generally be suitable for reuse as backfill.

Any material containing organic or excessively wet or otherwise deleterious material should not be used for backfilling purposes. Any shortfall of suitable on-site excavated material can be made up with imported granular material, OPSS Granular 'B' or equivalent. The backfill should be placed in lifts not more than 300 mm thick in the loose state with each lift being compacted to at least 98 % standard Proctor maximum dry density within the building area before subsequent lifts are placed. The degree of compaction achieved in the field should be checked by in-place density tests.

In general, the overburden soils are not free draining and therefore should not be used where this characteristic is required, or in confined areas. Imported granular material conforming to OPSS Granular 'B' specifications would also be suitable for this purpose.

In areas where substantial cutting and filling is required, the compaction of the fill should be monitored full-time by a representative of this office. This is particularly important under the building where slab-on-grade will be constructed.

5.2.7 Earthquake Considerations

The recommendations for the geotechnical aspects to determine the earthquake loading are presented below.

5.2.7.1 Subsoil Conditions

The subsoil and groundwater information at this site have been examined in relation to Section 4.1.8.4 of the OBC 2006. The subsoil generally consisted of, in succession, fill, native clayey silt till and silt. The shallow foundations, such as footing or raft, will be founded in the compacted granular fill. The reported N-values for the soil below the founding level ranged from 16 to 90.

There have been no shear wave velocity measurements carried out at this site and therefore, undrained shear strength and N-values will have to be used to determine the site classification.

5.2.7.2 Corrected N-Values N_{60}

The Average Standard Penetration Resistance shown in Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2006 refers to N_{60} which is defined as "Average Standard Penetration Resistance for the top 30m, corrected to a rod energy efficiency of 60% of the theoretical maximum". It should be noted that the drillers in the GTA area do not have their rod energy efficiencies measured and therefore, computed N_{60} values are not available for this site.

For the CME automatic hammer used by the driller for the boreholes at this site, the energy transfer compiled by Utah State and reported by GRL in Cleveland, Ohio, indicated that the range would be 67-83% and 59-91% for one and two standard deviations respectively. In our opinion, the reported N-value would therefore be approximately equivalent to the normalized N_{60} values as noted in the OBC 2006 for the purpose of establishing the site classification.

For the purpose of determining the averaged N-values, only the overburden values were used. Where the split spoon met refusal in the overburden soil, the N-value has been taken as 100.

5.2.7.3 Depth of Boreholes

Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2006 indicated that to determine the site classification, the average properties in the top 30 m are to be used. The boreholes advanced at the site were to a maximum depth of about 19.60 m depth as per the terms of references. Bedrock was encountered within the depths investigated (i.e. about 11.5 to 11.8 m below existing grade). The site classification recommendation is based on the available information as well as our interpretation of conditions below the boreholes.

5.2.7.4 Site Classification

Based on the above assumptions and interpretations and the known soil conditions, and in accordance with Table 4.1.8.4.A, Site Classification for Seismic Site Response, OBC 2006, the Site Class for this site is "D". However, where the entire structure (i.e., building and floor loads) is supported on the sound bedrock, the Site Class 'B' may be used in seismic design.

5.2.8 Subsurface Concrete

One (1) soil sample from Borehole 2 was submitted for analysis of pH, sulphate and chloride content. The test results indicated a pH value of 8.3 and sulphate content of 27.3 ppm as SO_4, indicating a "negligible" degree of sulphate attack on subsurface concrete structures. The chloride content was 11.0 ppm, indicating a "negligible" degree of chloride attack on subsurface steel reinforcing. For information regarding selection of cement type for subsurface concrete structures, reference is made to C.S.A. Standard CAN3-A23. The results are enclosed in Appendix B for reference.

5.3 Limited Environmental Testing

Two (2) soil samples were tested for general inorganic parameters in the MOE "Guideline For Use At Contaminated Sites In Ontario" revised February 1997. Sample location and analytical data and the results of the chemical testing (Certificates of Analysis) are compiled in Appendix B.

The two (2) soil samples analyzed for general inorganic parameters met fine to medium grained commercial/industrial land use criteria in Table B of the MOE Guideline for sites in a non-potable groundwater condition. Therefore, any excess soils requiring disposal during construction may be taken to any land based site (except for sensitive sites) accepting fill, subject to the individual site owner's approval.

6. General Comments

Trow Associates Inc. should be retained for a general review of the final design and specifications to verify this report has been properly interpreted and implemented. If not accorded the privilege of making this review, Trow Associates Inc. will assume no responsibility for interpretation of the recommendations in the report.

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, during the future development of the property, conditions not observed during this investigation may become apparent; should this occur, Trow Associates Inc. should be contacted to assess the situation, and additional testing and reporting may be required. Trow has qualified personnel to provide assistance in regard to future geotechnical issues related to this property.

Yours truly,

Trow Associates Inc.

So-Lim Yip, P. Eng.
Project Manager

Peter Chan, P.Eng.
Manager, Markham Office

Distribution:	OPG	(5)
	Trow Markham	(1)
	Trow Brampton	(1)

Appendix A

Laboratory Soil/Rock Testing
Grain Size Analysis
Compressive Testing

Trow

UNIFIED SOIL CLASSIFICATION SYSTEM

GRAIN SIZE DISTRIBUTION

PROJECT NO: BRGE 00287536A

PROJECT: Heavy Water Management Building
LOCATION: Darlington Nuclear Plant
BOREHOLE #:2
SAMPLE #: 7
DEPTH: 20-21.5ft
ELEVATION:

Classification of Sample:

Clayey Silt, trace sand, some gravel

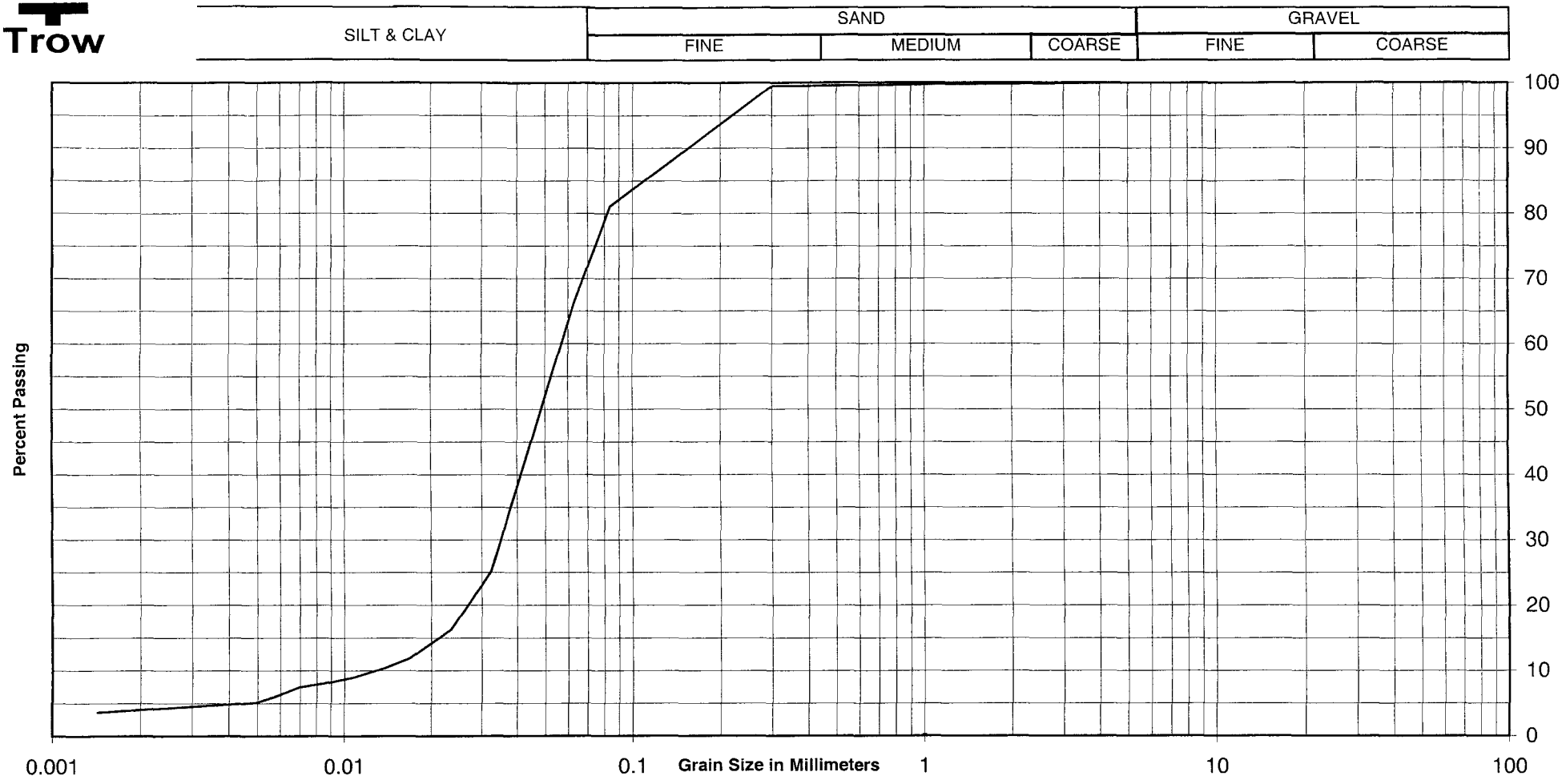
ENCLOSURE No.:

Trow

UNIFIED SOIL CLASSIFICATION SYSTEM

GRAIN SIZE DISTRIBUTION

PROJECT NO: BRGE 00287536A



PROJECT: Heavy Water Management Building
LOCATION: Darlington Nuclear Plant
BOREHOLE #: 3
SAMPLE #: 9
DEPTH: 25 - 26.5 ft
ELEVATION:

Classification of Sample:

Silt, trace clay and sand

ENCLOSURE No.:

Trow

Compressive Strength of Rock Cores

Project No.: BRGE00287536a

Project Name: OPG - Darlington

Date: September 24, 2007

Core No.	BH 1 Sample 1	BH 2 Sample 1	BH 2 Sample 2	BH 3 Sample 1
Location	39'4"	45'1"	54'9"	41'2"
Date Cored				
Date Tested	Sep. 21, 2007	Sept. 21, 2007	Sept. 21, 2007	Sept. 21, 2007
Height - (mm)	47.8	43.0	85.0	44.0
Average Diameter - (mm)	47.5	47.5	47.5	47.5
Area (mm^2)	1772	1772	1772	1772
L/D Ratio (2.5 - 3.0)	1.01*	0.91*	1.79*	0.93*
Failure Load (kN)	131.11	201.14	152.47	186.83
Compressive Strength - (MPa)	64.5	98.8	84.7	105.4
Remarks				

* The length too short, the L/D should have between 2.5-3.0. We getting higher results on the shorter samples.

Laboratory Representative Signature

Sept. 25/07
Date

Appendix B

pH and Sulphate Chemical Analysis

ENTECH
A Division of Agri-Service Laboratory Inc.

6820 Kitimat Rd., Unit #4
Mississauga, Ontario, Canada
L5N 5M3

TEL: (905) 821-1112
FAX: (905) 821-2095

LABORATORY USE ONLY
Work Order#:
Comments:

CHAIN OF CUSTODY RECORD[QC-2(2)]

Client: Trow Markham
Address: 70 Gibson Gibson Drive, Unit 12, Markham, Ontario L3R 4C2
Contact: So-Lim Yip
Tel: 905-470-0073 Fax: 905-470-9848
Invoice to (if other than the client)

Client P.O.#:
Client Project #: BRGE00287536A
Entech Quote#:
Sampled by: Raymond Lam
Guidelines needed:

Total # of Samples:
Anticipated health or chemical hazard:

Analysis Required

Entech's Bottles YES NO

Sample #	Client Sample I.D.	Date Sampled	Sample Matrix *	Sampling Information (W) Filtered Yes/No ***	Preserved Yes/No	Specify details if SDWA i.e Reg.170 /03 applies+	Decom. Guidelines (General+Inorganics)	Reg. 558 + PCBs	BTEX/PHC(F1-F4)	pH + SO_4 + Chloride	Corrosivity						Sample Temp °C	Number of Containers	LAB USE ONLY Lab Number
1	BH 2 SS 7	12Sept07	SOIL	N	N					X								1	
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			

Turn Around Time
STD: 5-7 Working Days
RUSH: Specify ☐
☐ Contact Lab
Rush Charges Apply for <5 days Turnaround Time.

Relinquished to Entech (sign): Raymond Lam — Date: Sept 21 Time: AM Method of Shipment: Pick-up
Received by Entech (sign): Date: Time: Condition:
Samples Logged By: Date: Time:

NOTE: Samples will only be retained for 30 days after reporting of results unless specifically requested by client. (Storage charges may then be applicable.)
*** 1) Soil/Sediment/Groundwater/Surface Water/Effluent/Drinking Water etc. - Pls. Specify.**
**** 2) Please call the laboratory BEFORE submitting any samples which fall under Safe Drinking Water Act-2002/Reg. 169/03**
***** 3) Please specify if water samples are to be filtered by lab before analysis.**
+4) Unless specified otherwise, all water samples will not be considered as Drinking Water.as defined in R170/03.

See Overleaf

Rev. 4.0 (21 Apr. 2004)

ENTECH
A Division of Agri-Service Laboratory Inc.

6820 Kitimat Rd., Unit #4
Mississauga, Ontario, Canada
L5N 5M3

TEL: (905) 821-1112
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LABORATORY USE ONLY
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Comments:

CHAIN OF CUSTODY RECORD[QC-2(2)]

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Invoice to (if other than the client)

Client P.O.#:
Client Project #: BRGE00287536A
Entech Quote#:
Sampled by: Raymond Lam
Guidelines needed:

Total # of Samples:
Anticipated health or chemical hazard:

Analysis Required

Sample #	Client Sample I.D.	Date Sampled	Sample Matrix *	Sampling Information (W) Filtered Yes/No ***	Preserved Yes/No	Specify details if SDWA i.e Reg.170 /03 applies+	Decom. Guidelines (General+Inorganics)	Reg. 558 + PCBs	BTEX/PHC(F1-F4)	pH + Sulphate	Corrosivity						Entech's Bottles YES NO: Sample Temp °C	Number of Containers	LAB USE ONLY Lab Number
1	BH 2 SS 8	Sept 12	Soil	N	N		X											1	
2	BH 3 SS 4	Sept 13	Soil	N	N		X											1	
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			

Turn Around Time
STD: 5-7 Working Days
RUSH: Specify ☐ _____
☐ Contact Lab
Rush Charges Apply for <5 days Turnaround Time.

Relinquished to Entech (sign): Date: Sept 25 Time: PM Method of Shipment: Pick-up
Received by Entech (sign): Date: Time: Condition:
Samples Logged By: Date: Time:

NOTE: Samples will only be retained for 30 days after reporting of results unless specifically requested by client. (Storage charges may then be applicable.)
* 1) Soil/Sediment/Groundwater/Surface Water/Effluent/Drinking Water etc. - Pls. Specify.
** 2) Please call the laboratory BEFORE submitting any samples which fall under Safe Drinking Water Act-2002/Reg. 169/03
*** 3) Please specify if water samples are to be filtered by lab before analysis.
+4) Unless specified otherwise, all water samples will not be considered as Drinking Water.as defined in R170/03.

See Overleaf

Rev. 4.0 (21 Apr. 2004)

Client: Trow - Markham
Attention: So-Lim Yip
Project: BRGE00287536A
P.O.:
Sample Type: Soil
Date Received: Sept. 21, 2007
Date Analysed: Sept. 26, 2007
Date Reported: Sept. 28, 2007

ENTECH
A Division of Agri-Service Lab Inc.
6820 Kitimat Rd., Unit #4
Mississauga, ONT L5N 5M3
TEL: (905) 821-1112

TOTAL P.03

Certificate of Analysis

Data Pertain To Specific Sample(s) Tested

PARAMETER	MDL	CONTROL SAMPLE			SAMPLE DATA						
		Expected	Found	Recovery %	Blank	80591 BH2 SS7	80591 BH2 SS7 Duplicate				
Sulphate (µg/g)	0.25	16.7	16.9	101	<0.25	27.3	27.4				
pH (units)	-	7.41	7.37	99	-	8.3	8.3				
Chloride (µg/g)	0.25	11.0	11.3	102	<0.25	11.0	11.1				

Sample Disposal: 30 Days from the Reporting Date.
Analyst: MA, OZ

Method :
Anions - Extraction / Ion Chromatography (EPA 300.0)
pH: Electrometric/pH-Meter (EPA 150.1)

Asit Raksit, Ph. D., C. Chem
Manager

ENTECH
A Division of Agri-Service Lab Inc.
6820 Kitimat Rd., Unit #4
Mississauga, ON L5N 5M3

TEL: (905) 821-1112
FAX: (905) 821-2095

TOTAL P.01

Client: Trow - Markham
Attention: So-Lim Yip
Project: BRGE00287536A
P.O. :
Sample Type: Soil
Date Received: Sept. 25, 2007
Date Analysed: Sept. 24-28, 2007
Date Reported: Oct. 01, 2007

CERTIFICATE OF ANALYSIS - SOIL STANDARDS FOR USE UNDER PART XV.I OF THE ENVIRONMENTAL PROTECTION ACT (GENL. & INORGANIC)

Data Pertain To Specific Sample(s) Tested

PARAMETER	Standards (µg/g)			Method Detection Limit (µg/g)	CONTROL SAMPLE			SAMPLE DATA (µg/g)			
					Expected Concentration (µg/g)	Concentration Found (µg/g)	Recovery %	Blank	80640 BH2 SS8	80641 BH3 SS4	
	Tables 2 Agricultural & Other Prop. Use.	Tables 2 & 3 Res./Ind. Comm	Tables 4 & 5 Res./Ind. Comm								
Dry Matter (%)	-	-	-	-	-	-	-	-	99.7	96.4	
pH (units)	5 to 9	5 to 9	5 to 11	-	7.41	7.37	-	-	8.9	8.7	
E C (mS/cm)	0.7	0.7/1.4	N.A./N.A.	-	0.15	0.15	-	-	0.09	0.12	
SAR	5	5/12	N.A./N.A.	-	-	-	-	-	0.56	0.61	
Arsenic	20	20/40	40/N.V.	1	75.0	74.8	100	<1	<1	<1	
Cadmium	3	12/12	41/41	1	34.0	34.7	102	<1	<1	<1	
Chromium (VI) *	8	8/8	600/1100	1	23.0	20.0	87	<1	<1	<1	
Chromium (total)	750	750/750	2500/5000	1	64.0	59.3	93	<1	12.0	6.5	
Cobalt	40	40/80	2500/3400	1	28.0	29.8	106	<1	4.6	3.0	
Copper	150	225/225	2500/2500	1	690	798	116	<1	8.4	4.9	
Lead	200	200/1000	1000/N.V.	2	233	219	94	<2	2.6	<2	
Mercury	10	10/10	57/57	0.05	0.19	0.18	95	<0.05	<0.05	<0.05	
Molybdenum	5	40/40	550/550	2	48.7	52.1	107	<2	<2	<2	
Nickel	150	150/150	710/710	2	231	203	88	<2	6.4	2.9	
Boron(HWE) *	1.5	1.5/2.0	2.0/N.V.	0.02	1.00	1.02	102	<0.02	0.08	0.10	
Cyanide Free	100	100/100	100/390	0.1	0.10	0.10	100	<0.1	<0.1	<0.1	
Selenium	2	10/10	2500/2500	1	0.80	0.75	94	<1	<1	<1	
Silver	20	20/40	240/240	0.3	1.90	1.86	98	<0.3	<0.3	<0.3	
Zinc	600	600/600	2500/5000	1	177	195	110	<1	29	21	
Antimony *	13	13/40	44/44	1	0.0100	0.0098	98	<1	<1	<1	
Barium	750	750/1500	2500/4100	1	102	102	100	<1	57.6	35.3	
Beryllium	1.2	1.2/1.2	1.2/3.1	0.5	0.50	0.49	98	<0.5	<0.5	<0.5	
Vanadium	200	200/200	910/910	1	19.0	21.7	114	<1	20.3	15.4	
Thallium	4.1	4.1/32	32/150	1	133	110	82	<1	<1	<1	

a) Table 2: Full Depth Generic Site Condition Standards in a potable groundwater condition
b) Table 3: Full Depth Generic Site Condition Standards in a non-potable groundwater condition
c) Table 4: Stratified Site Condition Standards in a potable groundwater condition (subsurface soil)
d) Table 5: Stratified Site Condition Standards in a non-potable groundwater condition (subsurface soil)

All guideline criteria are for coarse textured soil
HWE - Hot water extractable
Sample data and MDL units are in µg/g unless otherwise specified

Sample Disposal: 30 Days from the Reporting Date.

Analyst(s): PZ, QS, OZ, MA

** Control Sample Unit is µg/mL for the specified parameter instead of µg/g unless otherwise specified.*

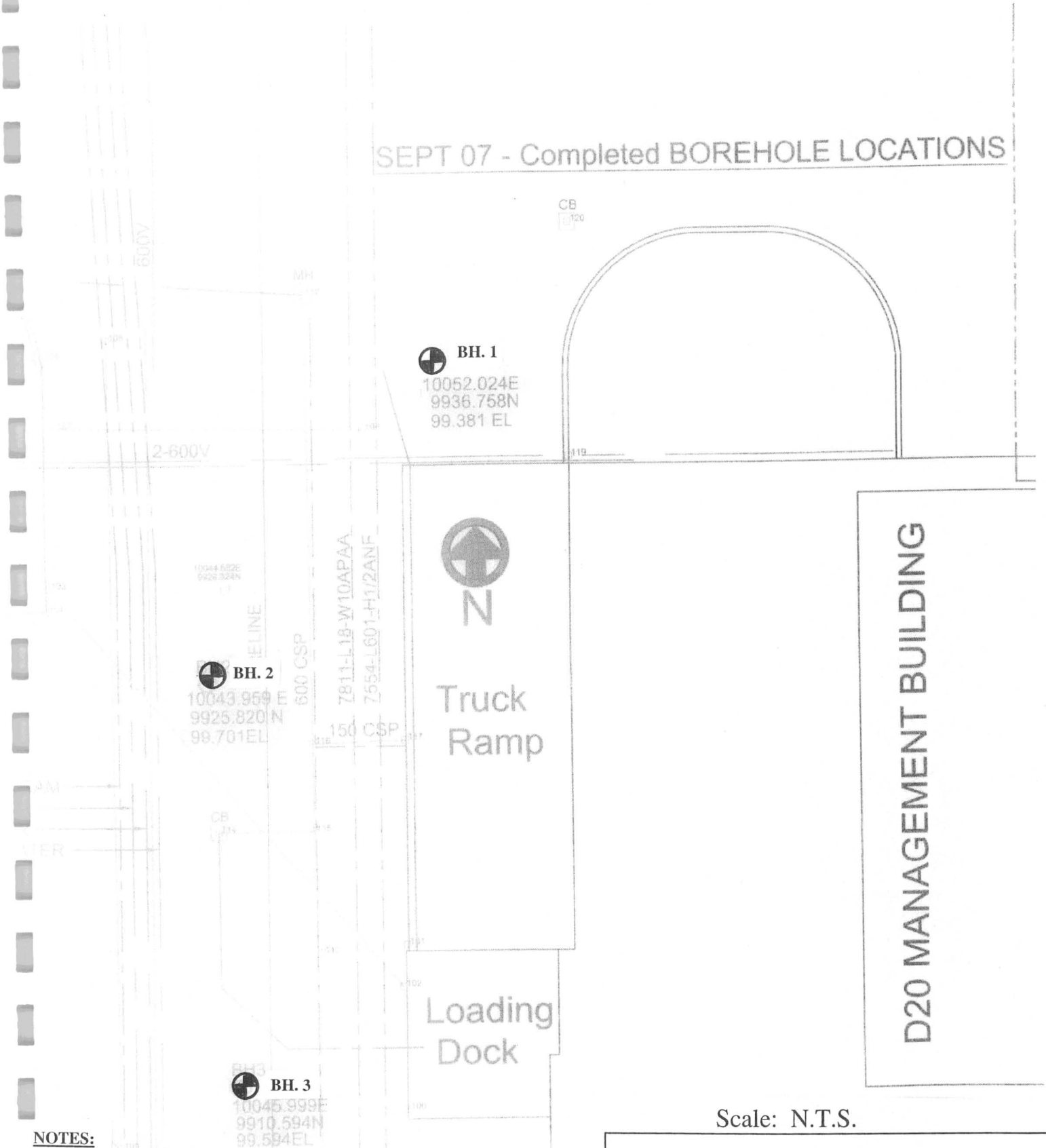
Method:

pH: Extraction/Electrometric (EPA 9045)
EC: Extraction/Electrometric (EPA 120.1)
As, Se, Sb: Digestion/HGFAAS (EPA 3050A/7062/7742)
Hg: Digestion/CV-AAS (EPA 7471A/245.5)
SAR: Extraction/ICP-AES (EPA 200.7)
Metals: Digestion/ICP-AES (EPA 3050A/200.7)
Cyanide Free: Extraction/Auto-Color (EPA 335.4)
B (HWE): Extraction/ICP-AES
Cr(VI): Alkaline Digestion/Colorimetry (EPA 3060A/7196)

Asit Raksit, Ph. D., C. Chem
Manager

Drawings

Borehole Location Plan
Borehole Logs



Scale: N.T.S.

NOTES:

1. The boundaries and soil types have been established only at Borehole locations. Between Boreholes they are assumed and may be subject to considerable error.
2. Soil samples will be retained in storage for 3 months and then destroyed unless client advises that an extended time period is required.
3. Borehole locations are approximate.
4. Borehole elevations should not be used to design building(s) or floor slab(s) or parking lot(s) grades.

GEOTECHNICAL INVESTIGATION
HEAVY WATER MANAGEMENT BUILDING
DARLINGTON NUCLEAR POWER PLANT
DARLINGTON, ONTARIO

BOREHOLE LOCATION PLAN

BRGE00287536A	Date : September 2004	Drawing No. 1

Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by Trow also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002 0.006 0.02 0.06 0.2 0.6 2.0 6.0 20 60 200

EQUIVALENT GRAIN DIAMETER IN MILLIMETERS

CLAY (PLASTIC) TO	FINE	MEDIUM	CRS.	FINE	COARSE
SILT (NONPLASTIC	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Log of Borehole 1

Project No. BRGE00287536A

Drawing No. 2

Project: Geotechnical Investigation - Proposed Addition

Sheet No. 1 of 1

Location: Heavy Water Management Building, Darlington Nuclear Power Plant

Date Drilled: September 15, 2007

Drill Type: Hollow Stem Augers (CME 75)

Datum: existing grade

Auger Sample ⊠
SPT (N) Value ○ ▨
Dynamic Cone Test —
Shelby Tube ■
Field Vane Test ✚ S

Combustible Vapour Reading □
Natural Moisture ×
Plastic and Liquid Limit ⊢—⊖
Undrained Triaxial at % Strain at Failure ⊕
Penetrometer ▲

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH	N Value (20 40 60 80) / Shear Strength (0.1 0.2 MPa)	Combustible Vapour Reading (ppm) (250 500 750) / Natural Moisture Content % / Atterberg Limits (% Dry Weight) (10 20 30)	SAMPLES	Natural Unit Weight kN/m³
		GRANULAR FILL - sand and gravel, scattered shale fragments; brown, moist to very moist	99.38	0	65	×		
				1	57	×		
				2	90	×		
▼			96.79		68	×		
				3	89	×		
				4				
				5	62	×		
			93.6					
		FILL - crushed shale; black, very moist to wet		6	76	×		
				7				
				8	88	×		
				9	61	×		
			88.9	10				
		CLAYEY SILT TILL - trace gravel; grey, about plastic limit, hard		11	32 ▲ >	×		23.8
			87.9					
		SHALE BEDROCK - black shale, low to medium strength, highly weathered, scattered 5 to 10 mm thick limestone seams, poor to fair quality (Georgian Bay Formation)		12	64.5 MPa ✚			REC 96% RQD 35%
			86.5					

END OF BOREHOLE

NOTES:
1. REC: Recovery
   RQD: Rock Quality Designation
2. Water Return for all coring was 100%
3. Gas reading in open borehole: 0% using MSA Model 60
4. NQ Rock Core Barrel was used

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Trow

Time	Water Level (m)	Depth to Cave (m)
Prior to rock coring	2.59	

Log of Borehole 2

Project No. BRGE00287536A

Drawing No. 3

Project: Geotechnical Investigation - Proposed Addition

Sheet No. 1 of 2

Location: Heavy Water Management Building, Darlington Nuclear Power Plant

Date Drilled: September 13, 2007

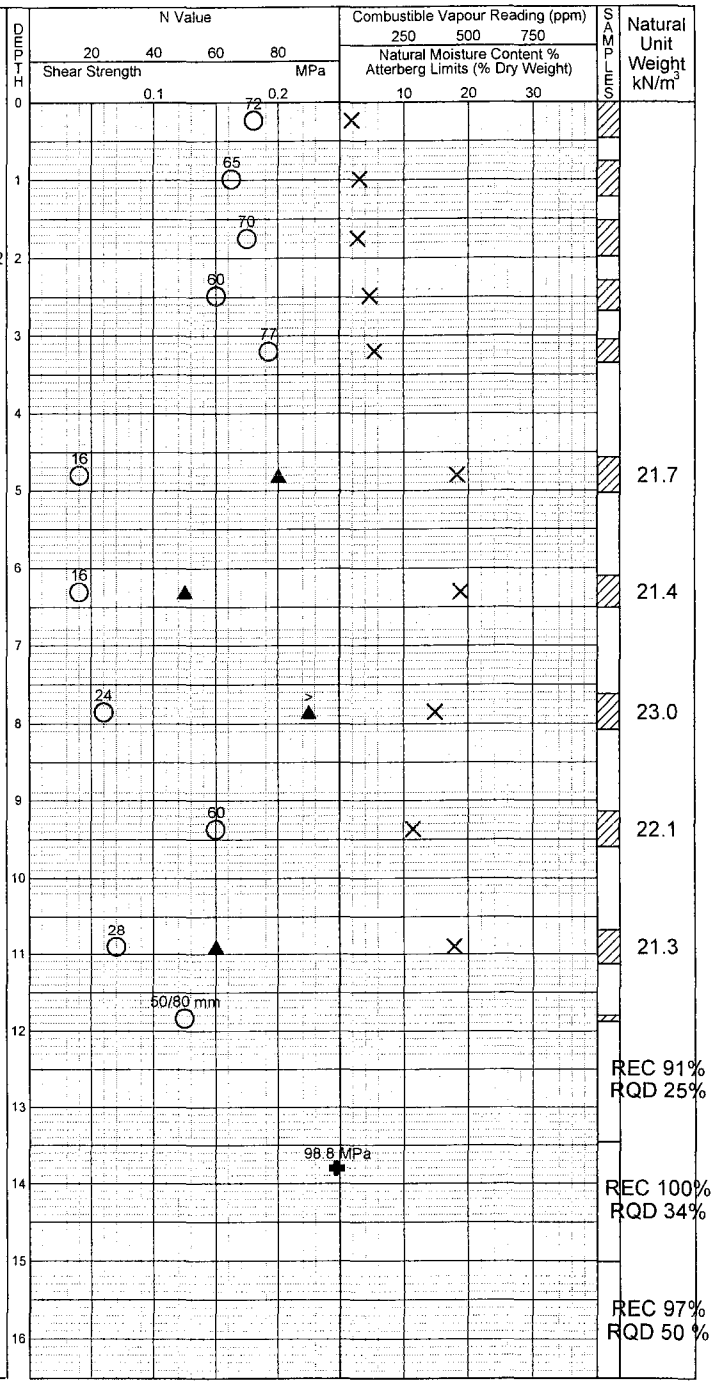
Drill Type: Hollow Stem Augers (CME 75)

Datum: existing grade

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

Soil Description	ELEV. m
GRANULAR FILL - sand and gravel, scattered shale fragments; brown, moist	99.70
	97.62
	95.6
CLAYEY SILT TILL - trace gravel, scattered fine sand partings; grey, about plastic limit, very stiff	
	91.1
SILT - occasional wet silty fine sand seams; grey, moist, very dense	
	89.6
CLAYEY SILT - with saturated silt seams; grey, about plastic limit, very stiff	
	87.9
SHALE BEDROCK - black shale, low to medium strength, highly weathered in upper 2 m, moderatedly to slightly weathered below, scattered 5 to 10 mm thick limestone seams, poor to fair quality to about 16.5 m, good quality below (Georgian Bay Formation)	



Continued Next Page

Time	Water Level (m)	Depth to Cave (m)
Prior to rock coring	Dry	
September 14, 2007	2.08	

Trow

Log of Borehole 2

Project No. BRGE00287536A

Drawing No. 3

Project: Geotechnical Investigation - Proposed Addition

Sheet No. 2 of 2

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH	N Value 20 40 60 80 / Shear Strength MPa 0.1 0.2	Combustible Vapour Reading (ppm) 250 500 750 / Natural Moisture Content % Atterberg Limits (% Dry Weight) 10 20 30	SAMPLES	Natural Unit Weight kN/m³
			83.20		0.7 MPa			
				17				REC 100 % RQD 78%
				18				
				19				REC 100 % RQD 66%
			80.1					
		END OF BOREHOLE						

NOTES:
1. REC: Recovery
   RQD: Rock Quality Designation
2. Water Return for all coring was 100%
3. Gas reading in open borehole: 0% using MSA Model 60
4. NQ Rock Core Barrel was used

Time	Water Level (m)	Depth to Cave (m)
Prior to rock coring	Dry	
September 14, 2007	2.08	

Trow

Log of Borehole 3

Project No. BRGE00287536A

Drawing No. 4

Project: Geotechnical Investigation - Proposed Addition

Sheet No. 1 of 1

Location: Heavy Water Management Building, Darlington Nuclear Power Plant

Date Drilled: September 14, 2007

Drill Type: Hollow Stem Augers (CME 75)

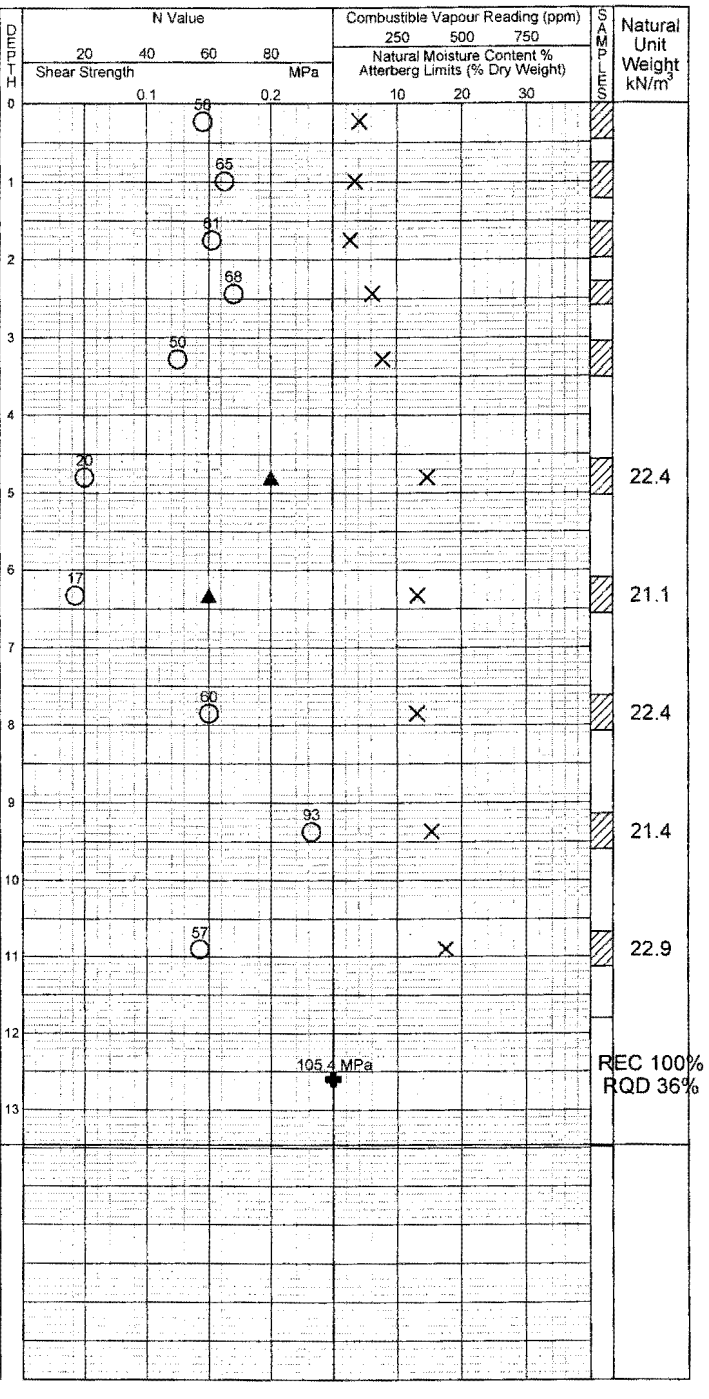
Datum: existing grade

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

GWL	SYMBOL	Soil Description	ELEV. m
		GRANULAR FILL - sand and gravel, scattered shale fragments; brown, moist to very moist	99.59
			97.05
			94.9
		CLAYEY SILT TILL - trace gravel, with fine sand and silt seams; grey, about plastic limit, very stiff	
			92.3
		SILT - occasional clayey silt seams and layers; grey, moist to saturated, very dense	
			87.8
		SHALE BEDROCK - black shale, low to medium strength, highly weathered, scattered 5 to 10 mm thick limestone seams, poor to fair quality (Georgian Bay Formation)	86.1
		END OF BOREHOLE	

NOTES:
1. REC: Recovery
   RQD: Rock Quality Designation
2. Water Return for all coring was 100%
3. Gas reading in open borehole: 0% using MSA Model 60
4. NQ Rock Core Barrel was used



Time	Water Level (m)	Depth to Cave (m)
Prior to rock coring	2.54	

Trow

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