CH2M HILL Canada Limited

Supplementary Geotechnical Investigation
Proposed Heavy Water Management Building
OPG Darlington Nuclear Plant
Darlington, Ontario

Project Number
BRM-00287536-C0

Prepared By:

exp Services Inc.
220 Commerce Valley Drive West, Suite 500
Markham, Ontario L3T 0A8
Canada

Date Submitted
April 30, 2012
Revised May 22, 2012

TABLE OF CONTENTS

1. Introduction **1**

2. Site Description **2**

3. Procedure **3**

4. Subsurface Conditions **4**

4.1 Soil and Rock 4

4.2 Groundwater 5

5. Engineering Discussion and Recommendations **6**

5.1 General 6

5.2 Building Construction 6

5.2.1 Foundation Considerations 6

5.2.1.1 Foundation General 8

5.2.2 Groundwater Control 9

5.2.3 Excavation and Shoring 9

5.2.4 Floor Slab Construction and Permanent Drainage 10

5.2.5 Additional Earth Pressure on Subsurface Walls 10

5.2.6 Backfill Considerations 10

5.2.7 Earthquake Considerations 11

6. General Comments **13**

Appendices

Appendix A: Existing Borehole Location Plan and Borehole Logs

Drawings

Borehole Location Plan 1

Borehole Logs 2-4

1. Introduction

This report presents the results of a supplementary 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. Dave Belanger, M. Sc., P. Geo., Vice President of CH2M HILL Canada Limited.

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 with one (1) level of basement.

It should be noted that a previous geotechnical investigation was carried out at the site by Trow Associates Inc. (former identity of **exp Services Inc.**), reference No. BRGE00287536A dated October 12, 2007. All relevant borehole logs are included in Appendix A. The previous report should be read in conjunction with this report.

The purpose of this supplementary geotechnical investigation was to further 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 structure.

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 supplementary geotechnical investigation was carried out on March 7 and 8, 2012. At that time, a total of three (3) sampled boreholes (designated as Boreholes G1, G2 and G3) were drilled to depths ranging from 6.70 to 11.90 m below existing grade at the approximate locations shown on the attached Borehole Location Plan (Drawing No. 1). Borehole G2 was terminated at a depth of about 6.70 m due to possible boulder or obstruction.

The boreholes were advanced using continuous flight hollow 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. It should be noted that the upper 3 m of the boreholes were day-lighted using a vacuum truck and geotechnical soil sampling was not carried out as instructed by OPG personnel.

Water levels were observed in the open boreholes during the course of the fieldwork. At the end of drilling, Borehole G1 was backfilled with compacted bentonite pellets and Boreholes G2 and G3 were converted to monitoring wells to use for ongoing environmental investigations.

The fieldwork was supervised by an **exp Services Inc.** 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 includeds moisture content determination on all recovered soil samples.

The location and ground surface elevation of the boreholes were established in the field and provided by personnel from CH2M HILL Canada Limited. However, the coordinates and ground surface elevations of the boreholes are not available at this time.

4. Subsurface Conditions

4.1 Soil and Rock

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 over deposits of clayey silt till and silt underlain by shale bedrock. The findings for this supplementary investigation are generally similar with findings encountered in the previous geotechnical investigation.

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

Granular Fill/Fill

Surficially, granular fill/fill was encountered in all the boreholes, extending to depths of about 3.0 to beyond 6.6 m below existing grade. The fill comprised sand and gravel, trace shale fragments. Based on the standard penetration 'N' values, the fill appeared to be in a compact state. Moisture contents of the granular fill ranged from 6 to 10 %. The fill was generally wet in the lower zone. Borehole G2 was terminated in the fill unit at a depth of 6.70 m due to possible boulder or obstruction.

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. Moisture contents of the clayey silt till ranged from about 13 to 21 %. The clayey silt till extended to depths of about 7.0 to 7.2 m below existing grade.

Silt

Below the clayey silt till in Borehole G1 and G3, a deposit of silt was encountered and extending to depths of 11.6 to 11.9 m below existing grade. The compactness of the silt deposit was found to be dense to very dense. Moisture contents of the silt ranged from 9 to 15 %, indicating a moist to wet condition.

Shale Bedrock

Boreholes G1 and G3 refused on probable bedrock at depths of about 11.6 to 11.9 m below existing grade. Coring of rock was not carried out to confirm bedrock during this investigation. However, the bedrock was penetrated by coring in NQ size using diamond drilling equipment from the previous investigation and as encountered at depths of about 11.6 to 11.9 m below existing grade.

Based on the recovery and Rock Quality Designation (RQD) from the previous investigation, 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. 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 2.13 to 2.74 m below existing grade.

The observed groundwater appeared to be derived from water perched within the 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.

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, with one level of basement. The design of the housing structure has not been finalized. However, based on preliminary design plan supplied to exp, it was noted that the proposed one (1) level of basement will extend to about Elevation 87 m, and the foundations will 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 structures with one (1) level of basement. The proposed structures may be supported on either a combination of footing and caisson foundation or a caisson foundation.

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

Footing Foundation

With the exception of Boreholes 1 and G1, the proposed structures may be supported on conventional footings founded on the native very stiff clayey silt till or dense silt at or below a depth of about 6.0 m below existing grade. The following bearing capacities may be used in the design.

Factored Capacity at Ultimate Limit State (U.L.S.) = 450 kPa

Bearing Capacity at Serviceability Limit State (S.L.S.) = 300 kPa

Alternatively, the footing foundations may extend onto the underlying bedrock. 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

The bearing capacity at S.L.S. (Serviceability Limit States) does not govern for 'unyielding soil'.

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.

In the vicinity of Boreholes 1 and G1 where deep fill is encountered (i.e. > 6 to 10 m), portion of the proposed structures may be supported on a caisson foundation, as discussed in the following subsection.

Caisson Foundation

Alternatively, the proposed entired 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 11.6 to 11.9 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. A factored bearing pressure of 4,800 kPa (U.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 bearing capacity at S.L.S. (Serviceability Limit States) does not govern for 'unyielding soil'.

It should be noted the above recommended high bearing value of 4800 kPa is applicable to properly constructed caisson. Each caisson base must be properly hand cleaned and then inspected and evaluated by geotechnical personnel from exp to ensure the required bearing capacity is accurate prior to placing concrete.

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.

Although this approach has been used successfully on other projects in the area, it is possible proper sealing may not be achieved. Also, it has been our experience that other factors including the presence of methane gas in the caisson hole may preclude downhole inspection. Further, some contractors will not perform downhole cleaning and allow downhole evaluation of the bedrock due to their own Health and Safety policies. In this event, the alternative approach is to use friction caissons socketed sufficiently deep into sound bedrock to provide the resistance for the caissons under full design load. The recommended adhesion value for concrete to sound shale bedrock is 70 psi. The upper weathered zone is assumed to be about 1.0 to 2.0 m. The advantage of using friction caissons is that the friction in the sound shale may also be used to resist tension loads.

Depending on the amount of water present in the caisson hole, the tremie method may be required for placement of caisson concrete. In general, routine concrete placement can be carried out into a maximum of 50 mm of free standing water provided cement is added to the water in the caisson hole to create a grout slurry, after which concrete can be placed. Any quantity of water greater than this will require the tremie method.

A concrete to sound shale bond of 70 psi at ULS may be used for the design for either compression or tension loading. For concrete to native soil contact, an adhesion value of 50 kPa may be used for the design to resist tension loading if end bearing caissons are used. The size of the caisson can vary to support individual columns. Where limestone layers are encountered, coring will be required to advance the caisson hole.

It should be noted cobbles and boulders occur in glacial deposits and their presence may influence the progress of caisson installations. Consequently, provisions should be made in the contract documents to cover any delays caused by boulder obstructions.

The caisson installation operation must be monitored on a full time basis by geotechnical personnel from exp to confirm bedrock elevation, bearing conditions, founding elevations and alignment.

For caissons founded on shale bedrock, the total and differential settlements are expected to be less than 12 mm and 6 mm, respectively.

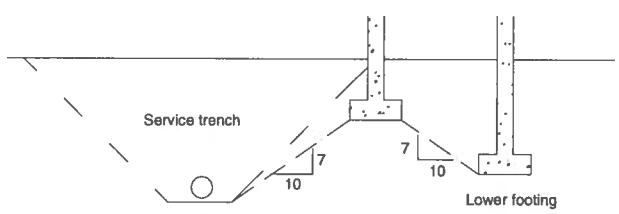
For instantaneous, non-sustained loading condition (i.e., seismic loads), it is estimated that the bearing pressures may be subjected to 30 % additional loading without significant effect to the foundations in limit states design.

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

Seepage from perched water in the fill or surface water run-off should be anticipated during construction. For shallow excavation, it should be possible to control and drain the seepage water using conventional construction dewatering techniques, i.e. pumping from sumps. However, for excavations extended to below the measured groundwater level (i.e. 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 sump wells or 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 and native clayey silt till and silt. 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, clayey silt till and silt are considered to be Type 2 soils.

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 **exp Services 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, fill, clayey silt till and silt. It is considered that the excavated granular fill and clayey silt till materials would generally be suitable for reuse as backfill. However, portion of the materials are wet and will require drying for proper compaction.

Any material containing organic, large rock 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.

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. Shale bedrock was encountered at depths of about 11.5 to 11.9 m below existing grade. The foundations, such as footing or caisson, will be founded in the native soils or shale bedrock. 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 11.9 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".

6. General Comments

Exp should be retained for a general review of the final design and specifications to verify the recommendations in this report address all the relevant geotechnical parameters regarding the design and construction of the proposed development. If not accorded the privilege of making this review, exp will assume no responsibility for interpretation of the recommendations in the report.

The preliminary 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, exp Services Inc. should be contacted to assess the situation and additional testing and reporting may be required. Exp has qualified personnel to provide assistance in regards to future geotechnical and environmental issues related to this property.

We trust this report is satisfactory for your purposes. Should you have any questions or comments, please do not hesitate to contact this office.

Yours truly,

Exp Services Inc.

LICENSED PROFESSIONAL ENGINEER
S-L. YIP
PROVINCE OF ONTARIO

So-Lim Yip, P. Eng.
Senior Engineer

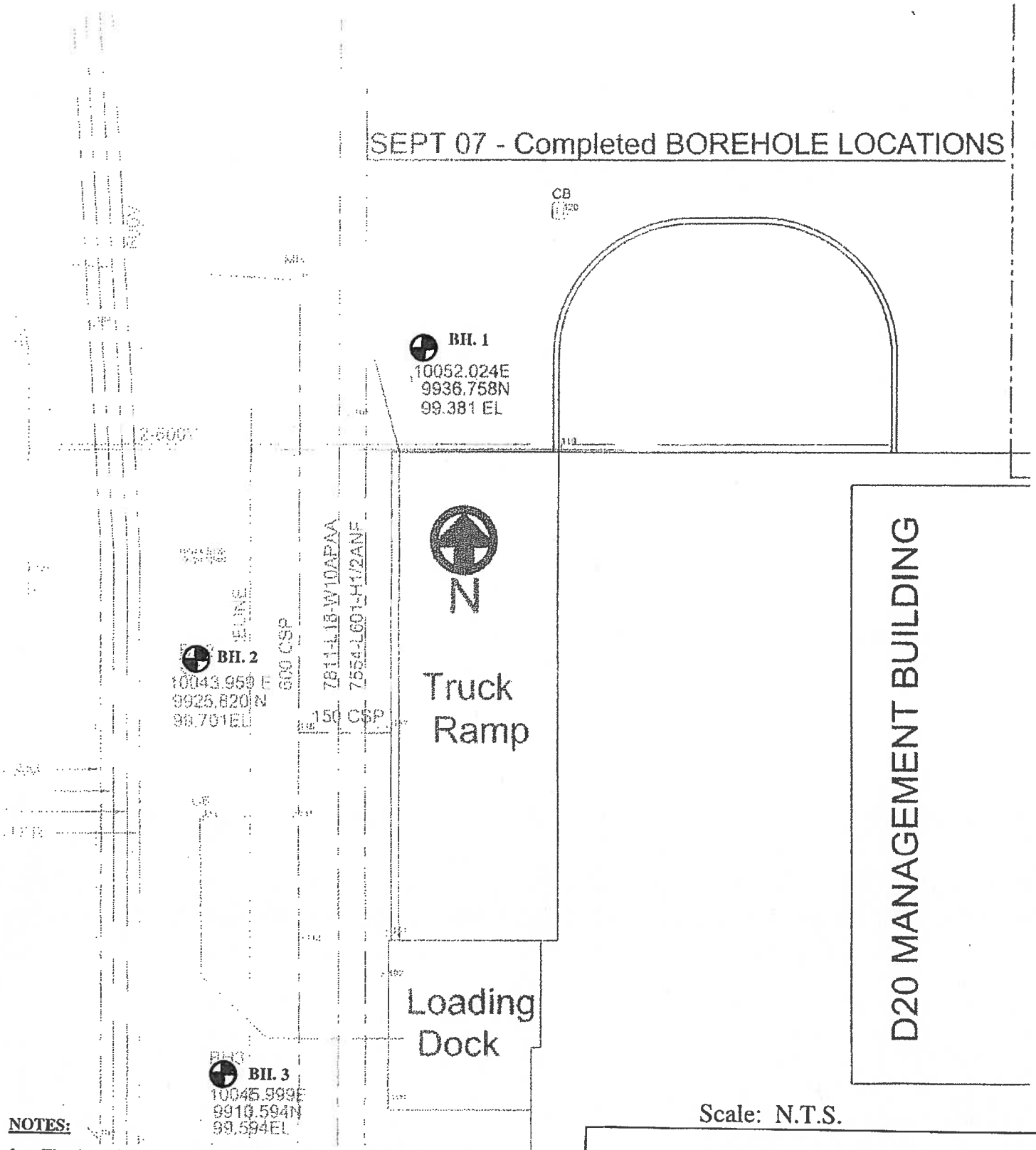
Peter Chan, P. Eng.
Manager, Geotechnical Division

REGISTERED PROFESSIONAL ENGINEER
P T-L. CHAN
PROVINCE OF ONTARIO

Distribution:		
	Client	(3)
	exp Markham	(1)
	exp Brampton	(1)

Appendix A

Existing Borehole Location Plan and 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

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

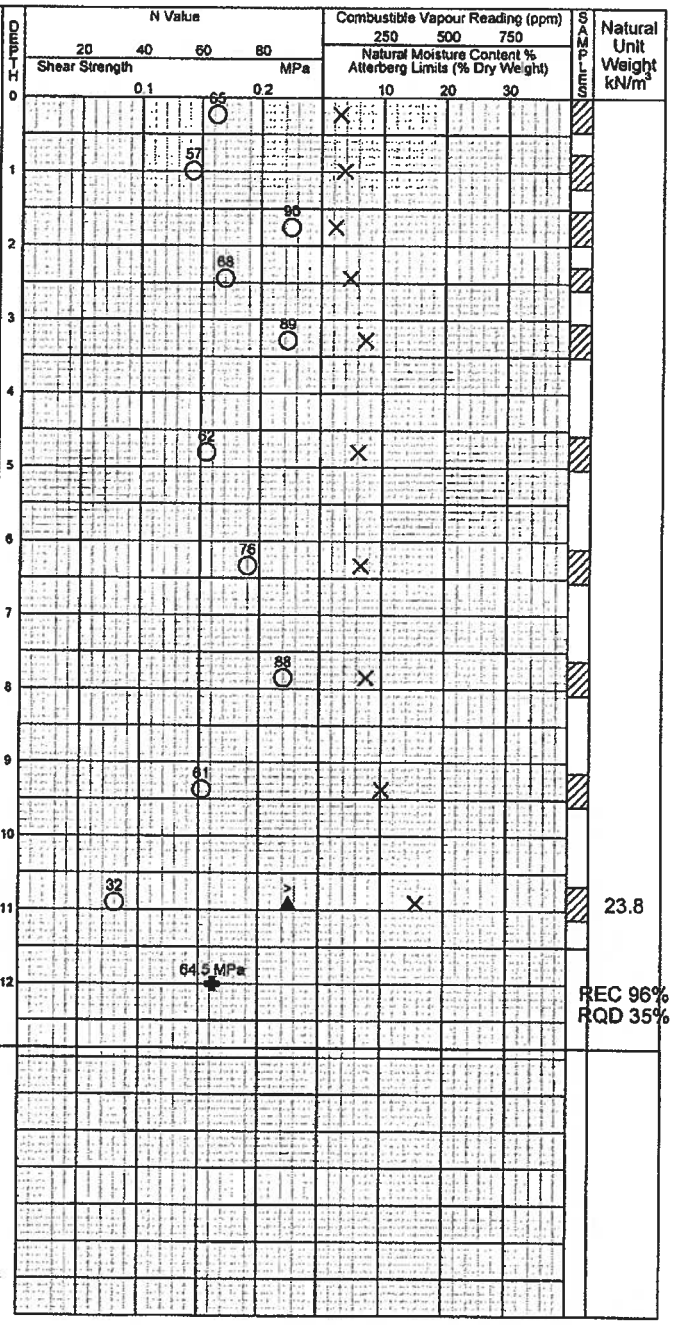
Drill Type: Hollow Stem Augers (CME 75)

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
			99.38
		GRANULAR FILL - sand and gravel, scattered shale fragments; brown, moist to very moist	
			96.79
			93.6
		FILL - crushed shale; black, very moist to wet	
			88.9
		CLAYEY SILT TILL - trace gravel; grey, about plastic limit, hard	
			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)	
			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

LAGWGL02 GE00287536A.GPJ NEW.GDT 10/1/07

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

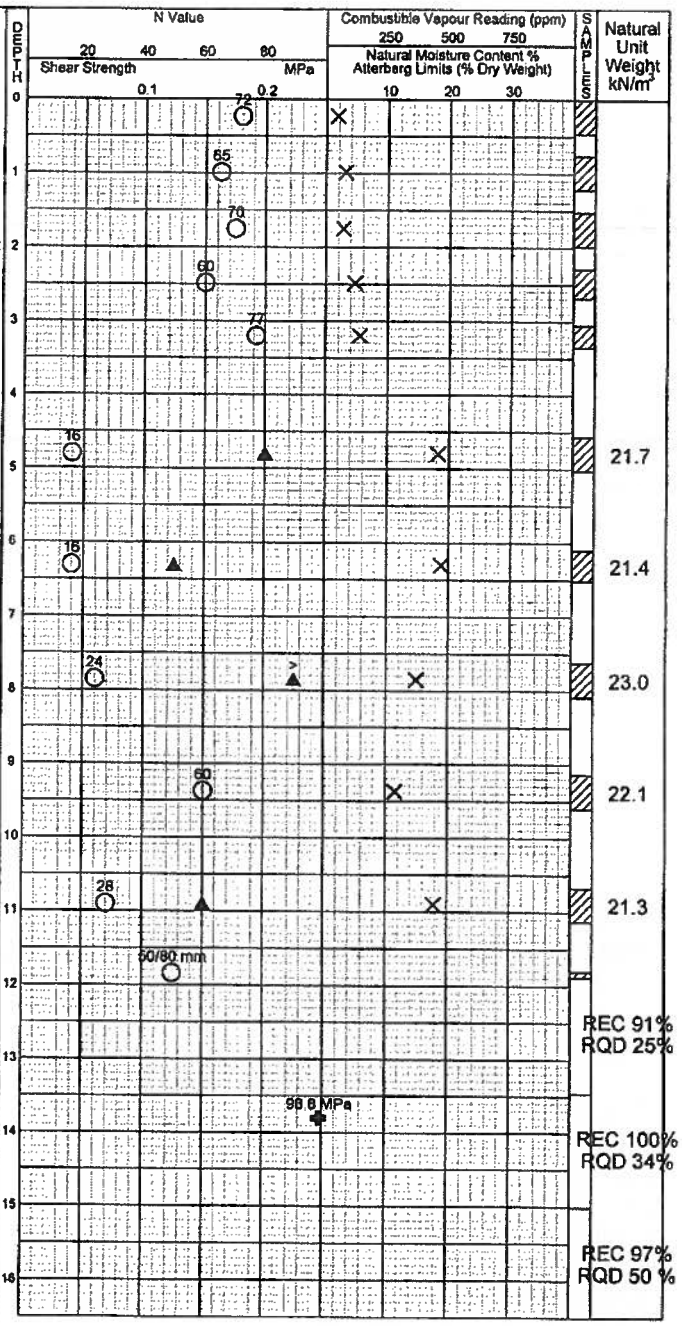
Drill Type: Hollow Stem Augers (CME 75)

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
CLAYEY SILT TILL - trace gravel, scattered fine sand partings; grey, about plastic limit, very stiff	95.6
SILT - occasional wet silty fine sand seams; grey, moist, very dense	91.1
CLAYEY SILT - with saturated silt seams; grey, about plastic limit, very stiff	89.6
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)	87.9



LAGWGL02 GE00287536A.GPJ NEW.GDT 10/1/07

Continued Next Page

Trow

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

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 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
			83.20					
				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

LAGWGL02 GE00287536A.GPJ NEW.GDT 10/1/07

Trow

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

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 ✚ 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	99.59	0	58	×		
				1	65	×		
				2	61	×		
▼			97.05		68	×		
				3	50	×		
			94.9	4				
		CLAYEY SILT TILL - trace gravel, with fine sand and silt seams; grey, about plastic limit, very stiff		5	20 ▲	×		22.4
				6	17 ▲	×		21.1
			92.3	7				
		SILT - occasional clayey silt seams and layers; grey, moist to saturated, very dense		8	60	×		22.4
				9	93	×		21.4
				10				
				11	57	×		22.9
			87.8	12				
		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)			105+ MPa ✚			REC 100% RQD 36%
			86.1	13				

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

LAGWGL02 GE00287536A.GPJ NEW.GDT 10/1/07

Trow

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

Drawings

Borehole Location Plan
Borehole Logs

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.

0 2 5 10 15 20 30 meters

LEGEND:

BOREHOLE LOCATION

exp Services Inc.
t: +1 905.958.3217 | f: +1 905.695.0169
220 COMMERCE VALLEY DRIVE WEST, UNIT 500
MARKHAM, ON L3T 0A8
Canada
www.exp.com

exp. The new identity of Stear

PROJECT TITLE AND LOCATION:	DRAWING TITLE:	PROJECT #: BRM-00287536-C0	DWN.: LC
PROPOSED HEAVY WATER MANAGEMENT BUILDING OPG DARLINGTON NUCLEAR PLANT DARLINGTON, ONTARIO	GEOTECHNICAL INVESTIGATION BOREHOLE LOCATION PLAN	SCALE: SEE ABOVE	CHKD.: SLY
		DATE: APRIL 2012	DWG. 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 G1

Project No. BRM-00287536-C0 Drawing No. 2

Project: Geotechnical Investigation - Proposed Heavy Water Management Building Sheet No. 1 of 1

Location: OPG Darlington, Darlington, Ontario

Date Drilled: March 7, 2012

Drill Type: Hollow Stem Augers (CME 75)

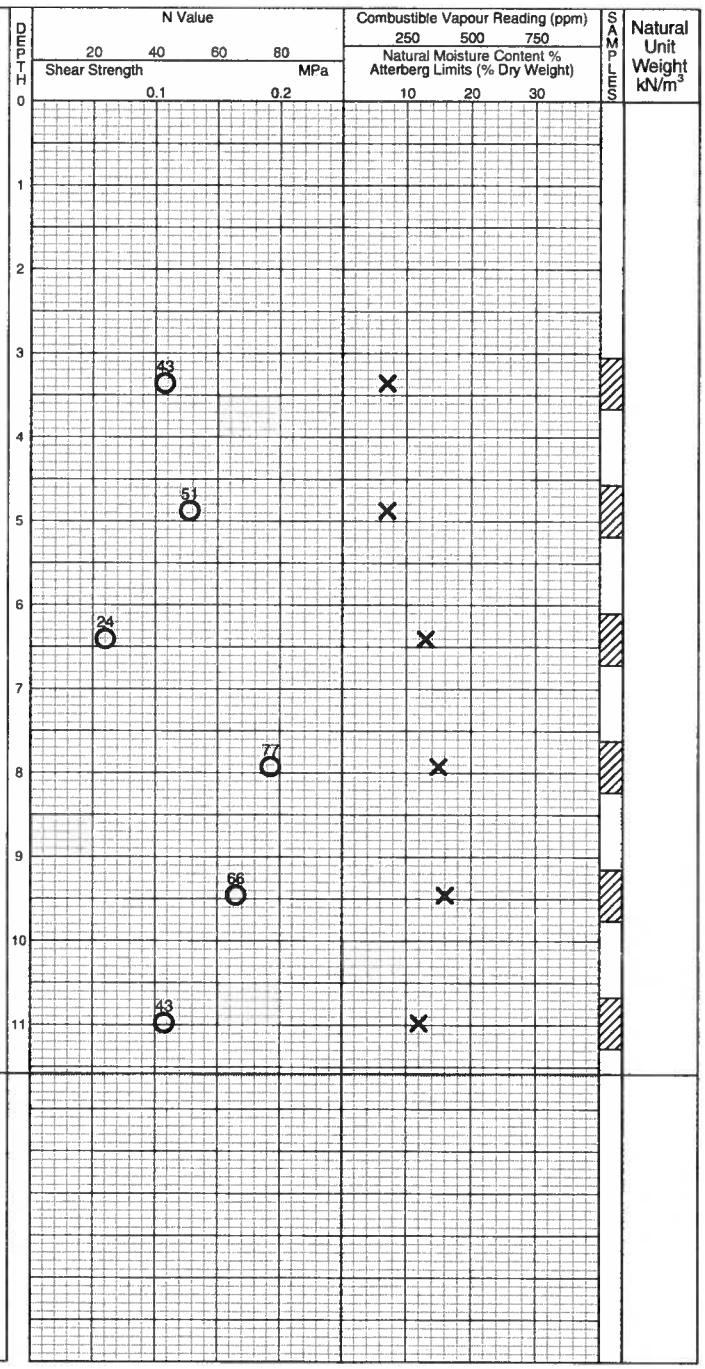
Datum: Existing Grade

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
		NO SAMPLING DONE	
		FILL - sand and gravel, trace silt, scattered rock fragments; brown, wet	
		CLAYEY SILT TILL - trace gravel; grey, moist, very stiff	
		SILT - trace gravel, silty fine sand seams; grey, moist, very dense	
		END OF BOREHOLE	

NOTES:
1. Borehole terminated upon auger refusal due to bedrock



Time	Water Level (m)	Depth to Cave (m)
On completion	2.74	11.58

LAGWGL02 BRM00287536C0.GPJ NEW.GDT 4/26/12

Log of Borehole G2

Project No. BRM-00287536-C0 Drawing No. 3

Project: Geotechnical Investigation - Proposed Heavy Water Management Building Sheet No. 1 of 1

Location: OPG Darlington, Darlington, Ontario

Date Drilled: March 7, 2012

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	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
		NO SAMPLING DONE		0				
				1				
				2				
		FILL - sand and gravel, trace silt, scattered rock fragments; dark brown/black, wet		3	49			
				4	35			
		- asphalt pieces		5	84			
					50/130mm			
				6	45			
		END OF BOREHOLE						

NOTES:
1. Borehole terminated upon auger refusal due to possible boulder or obstruction.

LAGWGL02 BRM00287536C0.GPJ NEW.GDT 5/22/12

exp.

Time	Water Level (m)	Depth to Cave (m)
On completion	2.59	6.71

Log of Borehole G3

Project No. BRM-00287536-C0 Drawing No. 4

Project: Geotechnical Investigation - Proposed Heavy Water Management Building Sheet No. 1 of 1

Location: OPG Darlington, Darlington, Ontario

Date Drilled: March 8, 2012

Drill Type: Hollow Stem Augers (CME 75)

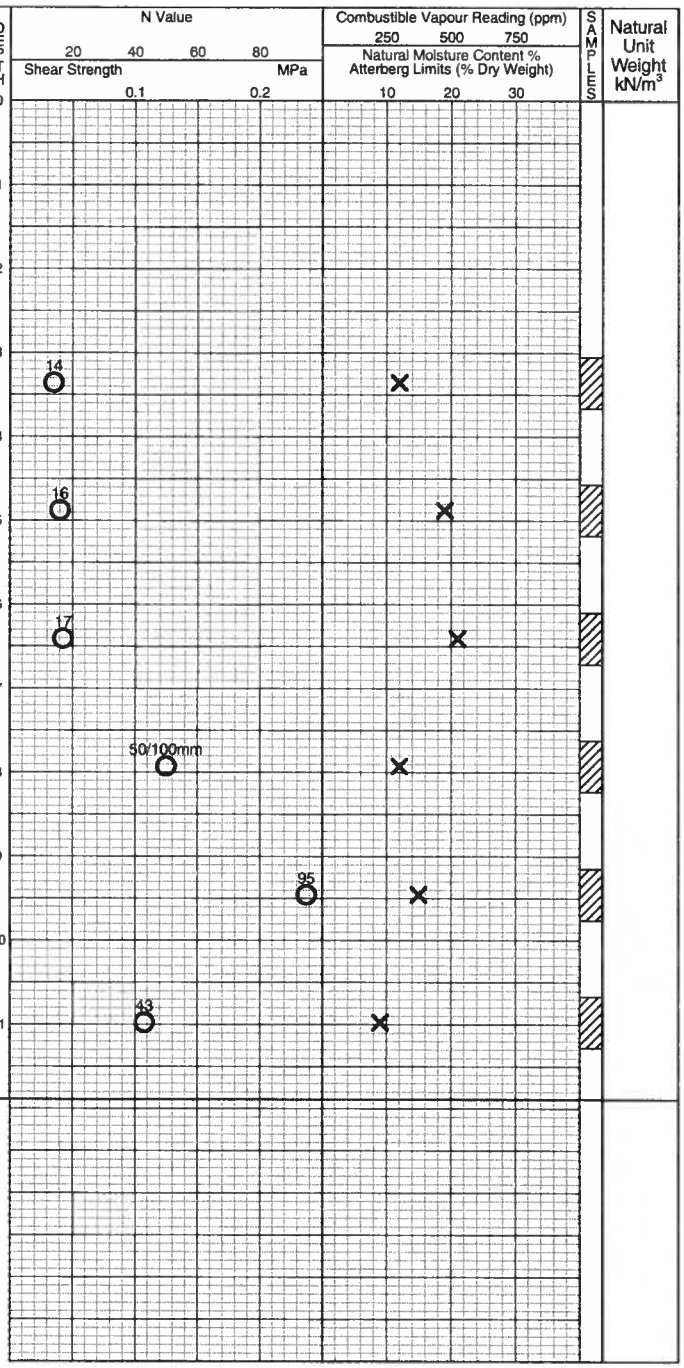
Datum: Existing Grade

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	DEPTH
		NO SAMPLING DONE		0–3
		CLAYEY SILT TILL - trace gravel; grey, moist, very stiff		3–7
		SILT - trace gravel, silty fine sand seams; grey, moist, very dense		7–11
		- shale fragments		11
		END OF BOREHOLE		

NOTES:
1. Borehole terminated upon auger refusal due to bedrock



Time	Water Level (m)	Depth to Cave (m)
On completion	2.13	11.89

LAGWGL02 BRM00287536C0.GPJ NEW.GDT 4/26/12