FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION
STRUCTURE M-1 (SITE 2)
HIGHWAY 407 EBL OVER URFE CREEK
Contract No: E2-2012

Report to

MMM Group Limited

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

January 23, 2013
File: 19-5161-130A

H:\19\5161\130 Hwy 407 - Brock Road Connection\2 Foundations\Reports & Memos\Structure M-1 - Urfe Creek\M-1 Urfe Creek - FINAL FIDR.doc

TABLE OF CONTENTS

APPENDICES

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION
STRUCTURE M-1 (SITE 2)
HIGHWAY 407 EBL OVER URFE CREEK
Contract No: E2-2012

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of a new bridge that will carry the new eastbound lanes of Highway 407 over Urfe Creek, in The City of Pickering, Ontario. The new bridge is planned as part of the Highway 407 east extension and is to be completed as part of the Highway 407/Brock Road Interchange Connection project.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile and sections, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained during the course of the investigation.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited, under the Highway 407 ETR Contract Number E2-2012 (Design).

2 SITE DESCRIPTION

The bridge site is located approximately 450 m west of Brock Road and approximately 10 m south of the existing Highway 407 bridge over Urfe Creek. The community of Brougham is located approximately 700 m northwest of the proposed bridge site.

At the location of the proposed bridge, Urfe Creek flows from north to south. The creek flows in a valley that is approximately 7 to 8 m below the existing highway grade. Lands surrounding the bridge site consist primarily of agricultural fields and undeveloped areas within the Highway 407 right-of-way.

The site is situated in the physiographic region known as the South Slope, which lies between the Oak Ridges Moraine and the Iroquois Plain and typically is characterized by overburden deposits consisting of sand and silt overlying glacial till sheets. Lacustrine clay deposited by Lake Iroquois, is often encountered between or overlying the till sheets. 'Surficial Geology of Southern Ontario' published by The Ontario Geological Survey shows that the bridge site is located in an area covered by sandy silt to silty sand till.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this structure were carried out between September 19 and 21, 2012 and consisted of drilling and sampling a total of four boreholes (identified as SM1-01 to SM1-04). Two boreholes were drilled near each of the proposed east and west approaches. Due to the sloping terrain and restriction on access preparation, these boreholes were located some 10 to 15m back from the proposed abutment centrelines. The boreholes were advanced to depths ranging from 11.3 to 13.9 m below the existing ground surface (Elevations 184.7 to 182.3 m). The Record of Borehole sheets are included in Appendix A.

Previous investigations, one by Peto MacCallum Limited (PML) in 1999 and one by Golder Associates Limited (Golder) in 2010, were carried out in the vicinity of this site. The logs for selected boreholes from these investigations are included in Appendix C.

The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix F.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. Double row silt fencing with straw bales was installed at selected drilling location to prevent sediment laden water from entering Urfe Creek.

Drilling was carried out using a track mounted drill rig and solid stem augers were typically used to advance the boreholes. The tri-coning method was required to further advance Borehole SM1-03 to the required depth after augering, due to the presence of inferred cobbles. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with the Standard Penetration Test (SPT).

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Where practical, groundwater conditions were observed in the open boreholes upon completion of the drilling operations. A standpipe piezometer, consisting of 25 mm diameter PVC pipe with a 1.5 m long slotted screen was installed in each of two selected boreholes near the abutments. The completion details of the piezometers and boreholes conducted in general accordance with O.Reg. 903 are summarized in Table 3-1 below.

Table 3-1. Borehole Completion and Piezometer Installation Details

Borehole	Piezometer Tip Depth/ Elevation (m)	Borehole Backfilling Details
SM1-01	12.2 / 184.0	Piezometer with 1.5 m slotted screen installed with sand filter to 9.8 m, bentonite from 9.8 to 1.8 m, then cuttings to surface.
SM1-02	None installed	Backfilled with bentonite holeplug to 1.2 m, then cuttings to surface.
SM1-03	None installed	Backfilled with bentonite holeplug to 1.5 m, then cuttings to surface.
SM1-04	11.3 / 184.7	Piezometer with 1.5 m slotted screen installed with sand filter to 9.3 m, bentonite from 9.3 to 2.7 m, then cuttings to surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing, where appropriate. The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B. Two selected samples were also subjected to analytical pH and sulphate testing and the results presented in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy near the proposed bridge are presented on the "Borehole Locations and Soil Strata" drawings included in Appendix F. An overall description of the stratigraphy encountered at this site is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

5.1 Topsoil

A thin layer of topsoil was encountered at ground surface in Boreholes SM1-01 and SM1-03. The topsoil was 50 mm thick in Borehole SM1-01 and 75 mm thick in Borehole SM1-03. The thickness of the topsoil layer may vary between and beyond the borehole locations.

5.2 Sand Fill

A layer of sand fill was encountered locally in Borehole SM1-01, below a thin layer of topsoil. The sand fill was grey in colour and contained some silt, some gravel, and occasional asphalt fragments.

The sand fill was 2.7 m thick in Borehole SM1-01 with a lower boundary encountered at a depth of 2.8 m (Elevation 193.4 m).

SPT N-values recorded in the sand fill ranged from 37 to 42 blows for 0.3 m penetration, indicating a dense state. Measured moisture contents ranged from 8 to 13%

One sample of the sand fill underwent laboratory grain size analysis testing. The results of this test are summarized below and are presented on the corresponding Record of Borehole sheet included in Appendix A. The grain size distribution curve for this sample is plotted on Figure B1 in Appendix B.

Soil Particles	Percentage (%)
Gravel	14
Sand	69
Silt and Clay	17

5.3 Clayey Silt Fill

A layer of clayey silt fill was encountered below the topsoil in Borehole SM1-03 and at ground surface in Borehole SM1-04. The clayey silt fill was dark brown to brown in colour and contained varying amounts of sand, trace gravel, and mixed with some organics.

The clayey silt fill was 1.4 m thick in Borehole SM1-03 and 1.3 m thick in Borehole SM1-04, with the lower boundary encountered at depths of 1.5 and 1.3 m, respectively (Elevation 194.7 m).

SPT N-values recorded in the clayey silt fill ranged from 31 to 35 blows for 0.3 m penetration, indicating a hard consistency. Measured moisture contents ranged from 10 to 16%.

5.4 Gravelly Sand

Gravelly sand was encountered locally at the surface in Borehole SM1-02 which was located on the valley slope. The gravelly sand was brown in colour and contained trace to some silt.

This surficial gravelly sand layer was 2.8 m thick with a lower boundary encountered at Elevation 193.1 m.

SPT N-values recorded in this layer ranged from 57 to 77 blows for 0.3 m penetration, indicating a very dense state throughout. Measured moisture contents ranged from 3 to 5%.

One sample of the gravelly sand was selected for laboratory grain size analysis testing. The results of this test are summarized below and are presented on the corresponding Record of Borehole sheet included in Appendix A. The grain size distribution curve for this sample is plotted on Figure B2 in Appendix B.

Soil Particles	Percentage (%)
Gravel	33
Sand	58
Silt and Clay	9

5.5 Silt and Sand Till with Clayey Zones

A layer of silt and sand till was encountered below the clayey silt fill in Borehole SM1-03 and SM1-04. The till was brown in colour and contained some clayey zones and trace gravel. Occasional black sand pockets were observed in the till in Borehole SM1-04.

The thickness of the silt and sand till ranged from 1.8 m in Borehole SM1-03 to 2.1 m in Borehole SM1-04. The lower boundary of this till was encountered at depths of 3.3 and 3.4m (Elevations 192.6 to 192.9 m).

SPT N-values recorded in the silt and sand till ranged from 19 to 86 blows for 0.3 m penetration indicating a compact to very dense state. Measured moisture contents ranged from 14 to 5%, generally decreasing with depth.

One sample of the silt and sand till underwent laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the corresponding Record of Borehole sheet included in Appendix A. The grain size distribution curve for this sample is plotted on Figure B3, Appendix B.

Soil Particles	Percentage (%)
Gravel	2
Sand	33
Silt	38
Clay	27

This sample exhibited sufficient plasticity for Atterberg Limits testing.

THURBER

Index Property	Percentage (%)
Liquid Limit	21
Plastic Limit	12
Plasticity Index	9

The results of the Atterberg Limits testing indicate that the silt and sand till has occasional low plastic zones with a group symbol of CL as plotted of Figure B7 in Appendix B.

5.6 Sand to Silty Sand

Sand to silty sand layers were encountered below the sand fill in Borehole SM1-01, below the gravelly sand in Borehole SM1-02, and below the silt and sand till in Boreholes SM1-03 and SM1-04. The sand to silty sand was brown in colour and contained varying amounts of silt, with trace to some gravel and trace clay. The presence of cobbles was inferred during drilling.

The thickness of the sand to silty sand layers ranged from 3.8 to 6.6 m, with the lower boundary encountered at depths of 7.2 to 9.4 m (Elevations 189.0 to 186.8 m).

SPT N-values recorded in the these layers ranged from 47 blows for 0.3 m penetration to greater than 100 blows for less than 0.3 m penetration, indicating a dense to very dense state. The N-values of over 100 blows may represent the presence of cobbles and/or boulders. Measured moisture contents ranged from 3 to 21%, with lower values measured in samples collected from Boreholes SM1-01 and SM1-02 (3 to 6%), and higher values measured in samples collected from Boreholes SM1-03 and SM1-04 (12 to 21%).

Five samples of the sand and silty sand were selected for laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are plotted on Figures B4 and B5 in Appendix B.

Soil Particles	Sand	Silty Sand
Gravel (%)	0 to 15	6 to 9
Sand (%)	60 to 82	45 to 50
Silt (%)	11 to 23	30 to 36
Clay (%)	3 to 4	5 to 19
Silt and Clay (%)	25	-

5.7 Sandy Silt to Silty Sand Till

A deposit of sandy silt to silty sand till was encountered below the sand to silty sand in all four boreholes. The cohesionless till was brown to predominantly grey with increased depth, and contained trace to some gravel and trace to some clay. In Borehole SM1-03, at a depth of 10.5 m, the till became gravelly with occasional cobbles and boulders.

The sandy silt till was 2.8 m thick in Borehole SM1-01, but was not fully penetrated in any of the other three boreholes. In Borehole SM1-01, the lower boundary of the sandy silt till was encountered at a depth of 12.2 m (Elevation 184.0 m). The till was encountered at a depth of 7.2 to 8.7 m (Elevations 189.0 and 187.2 m) in Boreholes SM1-02 to SM1-04, which were all terminated in this deposit at depths of 11.3 to 13.9 m (Elevations 182.3 and 184.7 m).

SPT N-values recorded in the till were all greater than 50 to 100 blows for less than 0.3 m penetration indicating a very dense state. Measured moisture contents ranged from 6 to 19%.

Gradation analyses were conducted on three samples of the sandy silt to silty sand till. The results are presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are plotted on Figure B6 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0 to 26
Sand	26 to 51
Silt	30 to 69
Clay	6 to 7
Silt and Clay	25

5.8 Groundwater Levels

Groundwater levels were observed in the open boreholes upon completion of the drilling. Two standpipe piezometers were installed at this site, in Boreholes SM1-01 and SM1-04, to monitor groundwater levels. The measured groundwater levels are summarized in Table 5-1.

Table 5-1. Measured Groundwater Levels

Borehole	Date	Groundwater Level (m)		Comment
		Depth (m)	Elevation (m)	
SM1-01	Oct. 16, 2012 Dec. 4, 2012	6.7 6.8	189.5 189.4	Piezometer
SM1-02	Sept. 21, 2012	5.2	190.7	Open borehole
SM1-04	Oct. 16, 2012 Dec. 4, 2012	6.4 6.4	189.6 189.6	Piezometer

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level is expected to be higher during high creek water level, after the spring snowmelt or after periods of heavy precipitation.

6 MISCELLANEOUS

The borehole locations were selected by Thurber Engineering Ltd. and staked in the field using the Trimble Pathfinder ProXRT differential GPS. The co-ordinates and ground surface elevations at the boreholes were surveyed by MMM upon completion of drilling.

Thurber obtained utility clearances for the borehole locations prior to drilling.

DBW Drilling of Ajax, Ontario supplied a track-mounted drill rig and conducted the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu of Thurber. Routine laboratory testing was carried out by Thurber Engineering Ltd. Analytical testing was carried out by AGAT Laboratories in Mississauga.

Overall supervision of the field program was conducted by Ms. Lindsey Blaine, E.I.T. Interpretation of the data and preparation of the report were carried out by Ms. Lindsey Blaine, E.I.T and Mr. Sydney Pang, P.Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects, reviewed the report.

THURBER ENGINEERING LTD.

L. Blaine
Jan. 23/13

Lindsey Blaine, E.I.T.
Project Manager

Sydney Pang, P.Eng.
Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
S. PANG
Jan 23/13
PROVINCE OF ONTARIO

P. K. Chatterji, P.Eng.
Review Principal

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 23/13
PROVINCE OF ONTARIO

THURBER

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION
STRUCTURE M-1 (SITE 2)
HIGHWAY 407 EBL OVER URFE CREEK
Contract No: E2-2012

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and presents geotechnical recommendations for design of the Highway 407 Eastbound Overpass Bridge (Structure M-1) over Urfe Creek. The plans and profiles used for preparation of this report were provided by MMM Group Limited.

The proposed overpass structure, as shown on the General Arrangement (GA) drawing dated June 2012, is a single span structure with a total supported length of 42.0 m and deck width of about 17.8 m to carry three lanes of traffic with two shoulders. However, it is understood from discussions with the designers that the foundations and sub-structure will be constructed to the ultimate 26.8 m width. The structure is to be skewed at 20°. Integral abutments are proposed with each abutment supported on a single row of H-Piles. The undersides of the abutments are proposed at Elevations 192.16 and 191.28 m for the west and east abutments, respectively. Fill is to be placed on the existing creek slopes behind the abutments to form the west and east approaches which will result in the finished highway grade up to 7 m above the floodplain.

8 STRUCTURE FOUNDATIONS

In general terms, the site was found to be underlain by surficial fill and compact to dense sand with occasional cobbles overlying or interlayered with dense to very dense gravelly sand, sandy silt and silty sand. These soils are underlain by a very dense sandy silt to silty sand till. The piezometric level at the site was measured at 6.8 to 6.4 m below the ground surface (Elevations 189.4 to 189.6m) where measured in the boreholes.

Initial consideration was given to the following foundation types:

- Spread footings:
    - bearing on native soil
    - bearing on a compacted Granular A pad
- Augered caissons (drilled shafts)
- Driven steel H-piles

A comparison of the foundation alternatives, with advantages and disadvantages of each, are included in Appendix D.

8.1 Spread Footings Bearing on Native Soil

Based on the stratigraphy encountered at the borehole locations, design of spread footings could be carried out in accordance with the founding elevations and geotechnical resistances as provided in Table 8-1.

Table 8-1. Founding Elevations and Bearing Resistances for Spread Footings

Locations	Highest Founding Elevation (m)	Factored ULS Resistance (kPa)	SLS Resistance (kPa)
West Abutment (SM1-01 & 02)	192.0	600	400
East Abutment (SM1-03 & 04)	191.5	600	400

The bearing resistances in Table 8-1 are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced as shown in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4. The front toe of the footing must be located at a distance of at least one footing width from the final slope face. Scour protection along the creek banks must extend above the final footing level.

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction. Differential settlement is not expected to exceed 15 mm across the width of the structure.

However, due to access constraints imposed by the valley slopes, the boreholes were drilled at distances of 10 to 15 m from the abutment centrelines. Therefore the stratigraphy and acceptable founding elevations at the abutments are not well defined, but the topographic survey suggests that the existing ground surface varies between Elevations 192 and 194 m, and close to the lower elevation within the southern portion of the west abutment. It would appear, therefore, that spread footings are not a viable option for this site. The proximity to the creek, with an attendant risk of undermining, is also a factor against the use of spread footings.

Accordingly, spread footings are not recommended for use at this site.

8.2 Spread Footings Bearing on Engineered Fill

Alternatively, spread footings could be constructed on engineered fill pads consisting of compacted Granular "A" material perched within the approach embankments.

If an engineered fill pad is used, all organics or other deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material. The engineered fill would bear on native very dense sand and the highest permitted base elevation, at which engineered fill pads may be founded, are giving in Table 8-2.

Table 8-2 Founding Elevations and Bearing Resistances of Engineered Fill Pads

Locations	Highest Founding Elevation (m)	Factored ULS Resistance (kPa)	SLS Resistance (kPa)
West Abutment (SM1-01 & 02)	193.0	700	350
East Abutment (SM1-03 & 04)	193.0		

The geotechnical resistances shown in Table 8-2 are based on a minimum 2.0 m thick layer of engineered granular fill and an assumed minimum footing width of 3 m. Additionally, the resistance values shown are for concentric, vertical loads only. In the case of eccentric or inclined loading, the bearing resistance must be reduced as shown in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4.

The proximity to the creek, with an attendant risk of undermining, is a factor against the use of spread footings on granular pads and they are not recommended for use at this site.

8.3 Caissons

Initial consideration was given to the use of caisson foundations to support the abutments. While the founding soils are very dense and potentially could provide high resistance, they are essentially cohesionless. Caissons would have to be founded below the water table in these cohesionless soils, which presents significant challenges to maintain undisturbed founding conditions, due to the potentially unbalanced head in the groundwater.

Accordingly, caissons are not considered to be a viable option at this site and have not been carried forward.

8.4 Steel H-pile Foundations

The GA drawing shows that the bridge abutments have been designed as integral abutments. The soil stratigraphy encountered at this site is considered to be suitable for the support of foundations on driven steel piles. Steel HP 310x110 piles driven to refusal within the silty sand to sand and silt till may be designed for the geotechnical resistances presented in Table 8-3 based on the tip elevations shown.

Table 8-3 Recommended Tip Elevations and Axial Resistances for Steel H-piles

Locations	Approximate Pile Tip Elevation (m)	Factored ULS Resistance (kN)	SLS Resistance (kN)
West Abutment (SM1-01 & 02)	At or below 187.0	1600	1400
East Abutment (SM1-03 & 04)	At or below 186.0		

The structural resistance of the pile must be checked by the structural designer and pile installation should be in accordance with OPSS 903.

The tip elevations have been selected to provide a minimum of 2.0 m of penetration below the 3 m unsupported length of pile required below the integral abutment. However, the piles must be driven until the specified resistance has been achieved.

8.4.1 Pile Tips

Due to the likely presence of cobbles and/or boulders, the tips of all piles must be reinforced. This can be achieved by fitting the piles with steel H-piles driving shoes in accordance with OPSD 3000.100.

8.4.2 Pile Driving

Piles must be driven in accordance with Standard SS 103-11, i.e. controlled by the Hiley Formula and to the ultimate pile resistance specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The Hiley formula need not be used until the piles are within 2.0 m of the bearing stratum. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile. "R" must have a minimum value of twice the factored design load at ULS. The specified ultimate pile resistance must not exceed 3,200 kN at this site.

If an integral abutment design is adopted, it is necessary to provide a 3 m unsupported length of pile immediately below the abutment stem. To achieve that at this site, it will be necessary to install a 600 mm diameter CSP below the existing ground level. It is suggested that the following (or similar) note be incorporated on the Foundation Drawing.-

Suggested method for installation of the CSP below the abutment stem:

1. Auger a hole to the required depth and of sufficient diameter to accept the CSP. Note that augering into the water table will be required and the Contractor must provide equipment and materials to accommodate this. In particular, it may be necessary to auger an oversize hole and install a temporary steel liner to permit installation of the CSP.
2. Remove any soil that may have entered the CSP. If necessary, maintain a sufficient head of water in the CSP to prevent soil heave due to inflow of groundwater. A maximum depth of 300 mm of loose, disturbed soil inside the CSP may be tolerated.
3. Remove the temporary steel liner, if used, while preventing disturbance of the CSP. The native soil may be allowed to collapse around the CSP.
4. Complete the pile driving.
5. Fill the CSP with sand as specified in the guide for integral abutment design.

As boreholes encountered SPT refusal within the silty sand to sand and silt till and noted the presence of cobbles and/or cobbles, an NSSP should require the QVE to terminate driving before the pile is damaged by overdriving. Suggested texts for NSSP's are included in Appendix E.

8.4.3 Downdrag

Downdrag on the piles is not considered to be an issue at this site, since the till and the sands and silts are in a very dense state with low clay content.

8.4.4 Abutment Type

The subsurface conditions at this site are considered suitable for integral, semi-integral or conventional abutment design. The use of H-piles at the abutments allows for the design of an integral abutment structure as shown on the GA drawing.

For an integral abutment design, the piles must be placed in concentric CSPs as described in the requirements for an MTO integral abutment design.

8.4.5 Pile Lateral Resistance

The geotechnical lateral resistance of an H-pile embedded in the silty sand to sand and silt till may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = n_h z / D \quad (kN/m^3)$$

$$p_{ult} = 3 \gamma z K_p \quad (kPa)$$

Where z = depth of embedment of pile in metres

D = pile width in metres

THURBER

n_h = coefficient of horizontal subgrade reaction
= 10,000 kN/m^3 (in dense to very dense soils)
γ = 21 kN/m^3 (total unit weight)
γ_w = 11 kN/m^3 (submerged unit weight below water table)
K_p = passive earth pressure coefficient
= 3.7 (for dense to very dense soils)

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

The spring constant, k_s, for analysis may be obtained by the expression, $k_s = k_s$ x L x D (kN/m), where L is the length (m) of the pile segment or element used in the analysis and the remaining variables are as defined earlier. The ultimate lateral resistance, p_{ult}, may be obtained from the expression, $p_{ult} = p_{ult}$ x L x D. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements. It is recommended, however, that the total lateral resistance assumed in one pile be limited to no more than 120 kN at ULSf and 50 kN at SLS.

The modulus of subgrade reaction may have to be reduced due to pile interaction, based on the centre-to-centre pile spacing. The reduction factors to be used for a pile group oriented perpendicular and/or parallel to the direction of loading are provided in Table 8-5 with intermediate values obtained by linear interpolation. Alternatively, horizontal loads may be resisted by means of battered piles.

Table 8-4 Reduction Factor for Coefficient of Lateral Subgrade Reaction

Condition	Pile spacing, Centre to centre*	Reduction factor
Pile group oriented **perpendicular** to direction of loading	4D	1.0
	1D	0.5
Pile group oriented ***parallel*** to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

Note: D is the pile width

8.5 Frost cover

The depth of frost penetration at this site is 1.2 m. The base of all pile caps, caissons caps or spread footings, must be provided with a minimum of 1.2 m of earth cover as protection against frost action.

THURBER

8.6 Recommended Foundation

From a geotechnical perspective and based on current information, the recommended abutment foundation consists of steel H-piles driven into the very dense silty sand to sand and silt till for supporting the integral abutments.

9 BRIDGE APPROACHES AND EMBANKMENTS

Placement of new fill will be required on the creek valley slopes to construct the bridge approaches and embankments. Based on Boreholes SM1-1 and SM1-2 drilled at the west approach area, the west approach embankments will be constructed on dense sand fill or very dense native gravelly sand. At the east approach area, Boreholes SM1-3 and SM1-4 indicate that the east approach fills will be placed on hard clayey silt fill overlying compact to dense silt and sand till. The embankments up to 7 m high should be stable at side slopes of 2H : 1V (or flatter) if constructed using SSM or granular fill. Provided proper construction methods are used, no long term settlement or global stability issues are anticipated for approach embankments built at this site.

10 EROSION CONTROL

Erosion and scour protection must be provided for the bridge foundations. In general, the rock protection for the floodplain at this site must extend up the forward slopes to a level above the high water level at Elevation 191.7 m. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field. Vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

11 EXCAVATION AND GROUNDWATER CONTROL

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the existing fill and surficial native soils can be classified as Type 3 soils. The underlying "100-blow" sandy silt, silty sand to sand and silt till may be classified as Type 2 soils. After removal of surface vegetation on the valley slopes, excavation of topsoil, organics, fill and surficial disturbed native soils will likely be required to reach competent native soils prior to placing new fill.

If integral abutments are used as shown on the GA drawing, excavation below the groundwater level will likely not be required, though installation of the CSPs will extend below the groundwater level. The Contractor should be prepared to pump from sumps to remove any perched water, seepage water or surface water collecting in an excavation. If footings are used instead and depending on the founding elevation, excavation below the groundwater level to construct the footings may be required.

The design of a dewatering system, if required, is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. The Contractor should also be prepared to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation. Placement of concrete must be done in the dry. Dewatering must remain operational and effective until the foundation is installed and backfilled.

Furthermore, the excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

12 BACKFILL TO ABUTMENTS

The backfill to the abutment walls must be Granular A or Granular B Type II material meeting the requirements of Special Provisions 110S13 "Amendment to OPSS 1010, April 2004". The backfill must be in accordance with OPSS 902 and placed to the extent shown in OPSD 3101.150.

Compaction equipment to be used adjacent to retaining structures must be restricted in accordance with OPSS 501. The design of the abutment must incorporate a subdrain as shown in OPSD 3101.150.

13 EARTH PRESSURE

Earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the following expression:

$$p_h = K(\gamma h + q) \quad (kN/m^3)$$

where
- p_h = horizontal pressure on the wall at depth h (kPa)
- K = earth pressure coefficient (see table below)
- γ = unit weight of retained soil (see table below)
- h = depth below top of fill where pressure is computed (m)
- q = value of any surcharge (kPa)

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of the fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

Earth pressure coefficients for backfill to the embankment wall are dependent on the material used as backfill. Typical values are shown in Table 13-1.

The factors in Table 13-1 are "ultimate" values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

Table 13-1. Earth Pressure Coefficients

<table>
<tr><th rowspan="3">Condition</th><th colspan="4">Earth Pressure Coefficient (K)</th></tr>
<tr><th colspan="2">OPSS Granular A or
OPSS Granular B Type II
$\phi = 35°, \gamma = 22.8$ kN/m^3</th><th colspan="2">Existing Sand Fill or
OPSS Granular B Type I
$\phi = 32°, \gamma = 21.2$ kN/m^3</th></tr>
<tr><th>Horizontal Surface Behind Wall</th><th>Sloping Surface Behind Wall (2H:1V)</th><th>Horizontal Surface Behind Wall</th><th>Sloping Surface Behind Wall (2H:1V)</th></tr>
<tr><td>Active</td><td>0.27</td><td>0.40</td><td>0.31</td><td>0.48</td></tr>
<tr><td>Passive</td><td>3.7</td><td>-</td><td>3.3</td><td>-</td></tr>
<tr><td>At Rest</td><td>0.43</td><td>-</td><td>0.47</td><td>-</td></tr>
</table>

14 SEISMIC CONSIDERATIONS

14.1 Seismic Design Parameters

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.05
- Acceleration Related Seismic Zone 1
- Zonal Acceleration Ratio 0.05
- Peak Horizontal Acceleration 0.08

The soil profile type at this site has been classified as Type II. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.2 should be used in seismic design.

14.2 Dynamic Earth Pressures

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 14-1 may be used:

Table 14-1. Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		Existing Sand Fill or OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (K_{AE})*	0.3	0.47	0.34	0.58
Passive (K_{PE})	3.6		3.2	
At Rest (K_{OE})**	0.53		0.58	

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.
** After Woods

14.3 Liquefaction Potential

The potential for liquefaction of the foundation soils was assessed using the Seed and Idriss (1971) method . Using this method, it is estimated that under the existing conditions the foundation soils are not prone to liquefaction.

The approach embankments are above the groundwater level and are not considered to be in danger of undergoing liquefaction. Some toe failure may occur but it is expected to be of limited nature and readily repairable.

15 ROADWAY PROTECTION

Roadway protection may be required to support the existing Highway 407 embankment adjacent to the excavations. The roadway protection must be implemented in accordance with OPSS 539 and designed for Performance Level 2.

Conventional steel soldier piles and timber lagging walls is one option to provide temporary support to the soils during excavation. Timber lagging boards should be installed as soon as the soil face is exposed and properly prepared.

The following parameters apply for design of the temporary shoring system.

γ	=	20 kN/m^3	(bulk soil unit weight)
γ_w	=	10 kN/m^3	(submerged soil unit weight under groundwater table)
K_a	=	0.33	(active pressure coefficient for embankment fill)
	=	0.27	(active pressure coefficient for dense to very dense native soils)
K_p	=	3.0	(Passive pressure coefficient for embankment fill)
	=	3.7	(Passive pressure coefficient for dense to very dense

			native soils)
h_w	=	190 m	(elevation for hydrostatic pressure behind the temporary shoring)

The design of roadway protection should be the responsibility of the Contractor. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system. Temporary groundwater and surface water control measures will be required during construction.

16 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Potential variability of pile lengths due to probable cobbles/boulders and very dense soils. The pile tip must extend at least 2 m below the CSP and hard driving below the CSP is to be expected.
- Excavation below the water level, if required, will involve lowering of the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- Roadway protection must be provided to maintain traffic during construction. Temporary shoring systems should be properly designed by a Professional Engineer experienced in such designs.
- The side embankment slopes should be inspected after construction for surficial disturbance.
- The successful performance of the overpass will largely depend upon good workmanship and quality control during construction. Pile driving supervision, subgrade inspection and field density testing should be carried out by qualified personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications met. Vibrating monitoring during pile driving should be carried out by specialists in this field.

17 CLOSURE

Engineering analysis and preparation of the report was carried out by Dr. Sydney Pang, P.Eng.

The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng. who is a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

Sydney Pang, P.Eng.
Associate, Senior Geotechnical Engineer

Alastair Gorman, P.Eng.
Associate, Senior Foundation Engineer

P. K. Chatterji, P.Eng.
Review Principal

Appendix A
Record of Borehole Sheets
(Current Investigation)

THURBER

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT(1) 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

- SS Split Spoon Sample
- WS Wash Sample
- AS Auger (Grab) Sample
- TW Thin Wall Shelby Tube Sample
- TP Thin Wall Piston Sample
- PH Sampler Advanced by Hydraulic Pressure
- PM Sampler Advanced by Manual Pressure
- WH Sampler Advanced by Self Static Weight
- RC Rock Core
- SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

Bedding	**Bedding Plane Spacing**
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength (MPa)**	**(psi)**	**Field Estimation of Hardness***
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM1-01

METRIC

WP#	E2-2012	LOCATION	N 4 863 718.9 E 336 075.4	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.21 - 2012.09.21	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT	REMARKS (GR SA SI CL)
196.2						
0.0	**TOPSOIL:** (50mm)					
	SAND, some silt, some gravel, occasional asphalt fragments, Dense, Grey, Moist (FILL)	1	SS	37	○	
	Brown	2	SS	36	○	
		3	SS	42	○	14 69 17 (SI+CL)
193.4 / 2.8	**SAND**, trace to some silt, trace to some gravel, Very Dense, Brown, Moist	4	SS	50/ 0.100	○	
		5	SS	100/ 0.100	○	
	Occasional inferred cobbles. Augers grinding from 4.9 to 5.6m					
		6	SS	50/ 0.075	○	15 60 25 (SI+CL)
189.2 / 7.0	Silty **SAND**, trace to some gravel, trace clay, Very Dense, Brown, Moist	7	SS	100/ 0.150	○	9 50 36 5
		8	SS	100/ 0.125	○	
186.8 / 9.4	Sandy **SILT**, trace gravel, trace to some clay, Very Dense, Grey (TILL)					

Elevation scale: 196, 195, 194, 193, 192, 191, 190, 189, 188, 187. Groundwater level symbol at approx. elev. 189.5.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity; 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SM1-01

METRIC

WP# E2-2012	LOCATION N 4 863 718.9 E 336 075.4	ORIGINATED BY	ES
HWY 407	BOREHOLE TYPE Solid Stem Augers	COMPILED BY	AN
DATUM Geodetic	DATE 2012.09.21 - 2012.09.21	CHECKED BY	LRB

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						
	Sandy **SILT**, trace gravel, trace to some clay Very Dense Grey (TILL)				186		
		9	SS	100/ 0.075		o	
					185		
184.0 12.2					184		
183.8 12.4	**SAND**, some silt, some gravel Very Dense Brown Moist to Wet	10	SS	50/ 0.100		o	

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

END OF BOREHOLE AT 12.4m.
Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 16/12	6.7	189.5
Dec. 05/12	6.8	189.4

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM1-02

METRIC

WP#	E2-2012	LOCATION	N 4 863 697.6 E 336 096.5	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.20 - 2012.09.21	CHECKED BY	LRB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
195.9 / 0.0	Gravelly **SAND**, trace to some silt Very Dense Brown Moist
193.1 / 2.8	**SAND**, fine grained, trace gravel Dense to Very Dense Brown Moist Occasional inferred cobbles
189.8 / 6.1	Silty **SAND**, some clay, trace gravel Very Dense Brown Moist
188.7 / 7.2	**SAND**, some silt, trace gravel Very Dense Brown Moist to Wet
187.2 / 8.7	Sandy **SILT**, trace clay, trace gravel Very Dense Brown Moist (TILL)

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	77				
2	SS	63	33	58	9 (SI+CL)	
3	SS	57				
4	SS	47				
5	SS	50/ 0.075				
6	SS	50/ 0.075	6	45	30	19
7	SS	73/ 0.150				
8	SS	100/ 0.125				

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (195, 194, 193, 192, 191, 190, 189, 188, 187, 186); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 1130A.GPJ 1/22/13

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM1-02

METRIC

LOCATION

HWY

BOREHOLE TYPE Solid Stem Augers

DATUM

DATE

ORIGINATED BY ES

COMPILED BY AN

CHECKED BY LRB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION (Continued From Previous Page)	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m3	GR	SA	SI	CL
	Sandy **SILT**, trace clay, trace gravel Very Dense Brown Moist (TILL)	9	SS	100/ 0.125			o		0	26		6
						185						
						184						
183.6		10	SS	100/ 0.125			o					
12.3	END OF BOREHOLE AT 12.3m. WATER LEVEL AT 5.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.2m, THEN CUTTINGS TO SURFACE.											

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM1-03

METRIC

WP#	E2-2012	LOCATION	N 4 863 739.4 E 336 145.0	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers/NW/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.19 - 2012.09.19	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.2							
0.0 / 0.1	**TOPSOIL:** (75mm)				196		
	Clayey **SILT**, with sand, trace gravel, Hard, Brown (FILL)	1	SS	35	195	○	
194.7 / 1.5	**SILT** and **SAND**, trace gravel, with clayey zones, Compact to Dense, Brown, Moist (TILL)	2	SS	45		├○┤	2 33 38 27
		3	SS	26	194	○	
192.9 / 3.3	**SAND**, trace to some silt, trace gravel, trace clay, Very Dense, Brown, Moist	4	SS	86	193	○	
		5	SS	57	192	○	3 82 11 4
		6	SS	95	191, 190	○	
189.0 / 7.2	Silty **SAND**, trace to some gravel, Very Dense, Grey, Moist (TILL)	7	SS	100/ 0.125	189	○	
		8	SS	100/ 0.125	188, 187	○	
	Augers grinding from 10.2 to 10.4m, switch to casing and tricone						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SM1-03

METRIC

WP#	E2-2012	LOCATION	N 4 863 739.4 E 336 145.0	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers/NW/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.19 - 2012.09.19	CHECKED BY	LRB

Column headings: SOIL PROFILE (ELEV / DEPTH; DESCRIPTION; STRAT PLOT); SAMPLES (NUMBER; TYPE; "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT	GR	SA	SI	CL
	Silty **SAND**, trace to some gravel, Very Dense, Grey, Moist (TILL)				186					
185.7 / 10.5	Gravelly zone, occasional cobbles and boulders	9	SS	100/ 0.100		○				
					185					
		10	SS	50/ 0.075	184	○	26	49	25 (SI+CL)	
					183					
		11	SS	50/ 0.075		○				
182.3 / 13.9	END OF BOREHOLE AT 13.9m. BORHEOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.5m, THEN CUTTINGS TO SURFACE.									

ONTMT4S 1130A.GPJ 1/22/13

+ ³, × ³: Numbers refer to Sensitivity

20, 15 ⊕ 5, 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM1-04

METRIC

WP#	E2-2012	LOCATION	N 4 863 723.2 E 336 153.0	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.19 - 2012.09.19	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.0 / 0.0	Clayey **SILT**, some sand, mixed with organics; Hard; Brown/Dark Brown; Moist; (FILL)	1	SS	31	
194.7 / 1.3	**SILT** and **SAND**, trace gravel, with clayey zones; Compact to Dense; Brown; Moist; (TILL); Occasional black sand pocket	2	SS	19	
		3	SS	37	
		4	SS	53	
192.6 / 3.4	**SAND**, fine grained, some silt to silty, trace clay; Very Dense; Brown; Moist; Wet	5	SS	72	0 74 23 3
	Occasional silt and gravel seam	6	SS	61	
188.8 / 7.2	Silty **SAND**, some gravel, trace clay; Very Dense; Grey; Moist; (TILL)	7	SS	50/ 0.050	
		8	SS	50/ 0.100	12 51 30 7

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (196, 195, 194, 193, 192, 191, 190, 189, 188, 187); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM1-04

METRIC

WP#	E2-2012	LOCATION	N 4 863 723.2 E 336 153.0	ORIGINATED BY	ES
HWY	407	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.09.19 - 2012.09.19	CHECKED BY	LRB

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) 20 40 60 80 100	WATER CONTENT (%) (PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **SAND**, some gravel, trace clay Very Dense Grey Moist (TILL)						186				
			9	SS	50/ 0.050				○		
							185				
184.7 11.3	END OF BOREHOLE AT 11.3m UPON AUGER REFUSAL ON PROBABLE BOULDER. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 16/12	6.4	189.6
Dec. 05/12	6.4	189.6

ONTMT4S 1130A.GPJ 1/22/13

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

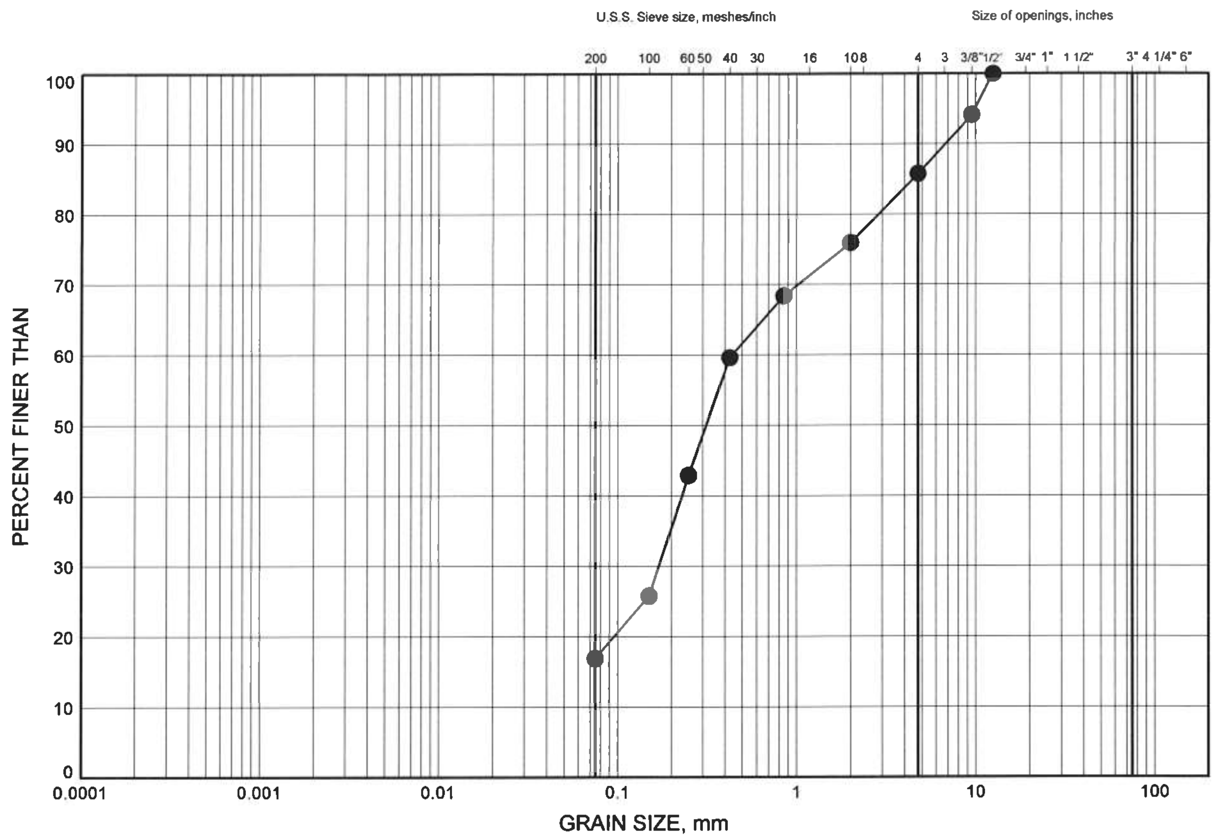
Appendix B
Laboratory Test Results
(Current Investigation)

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-01	2.59	193.61

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

Chkd. SKP

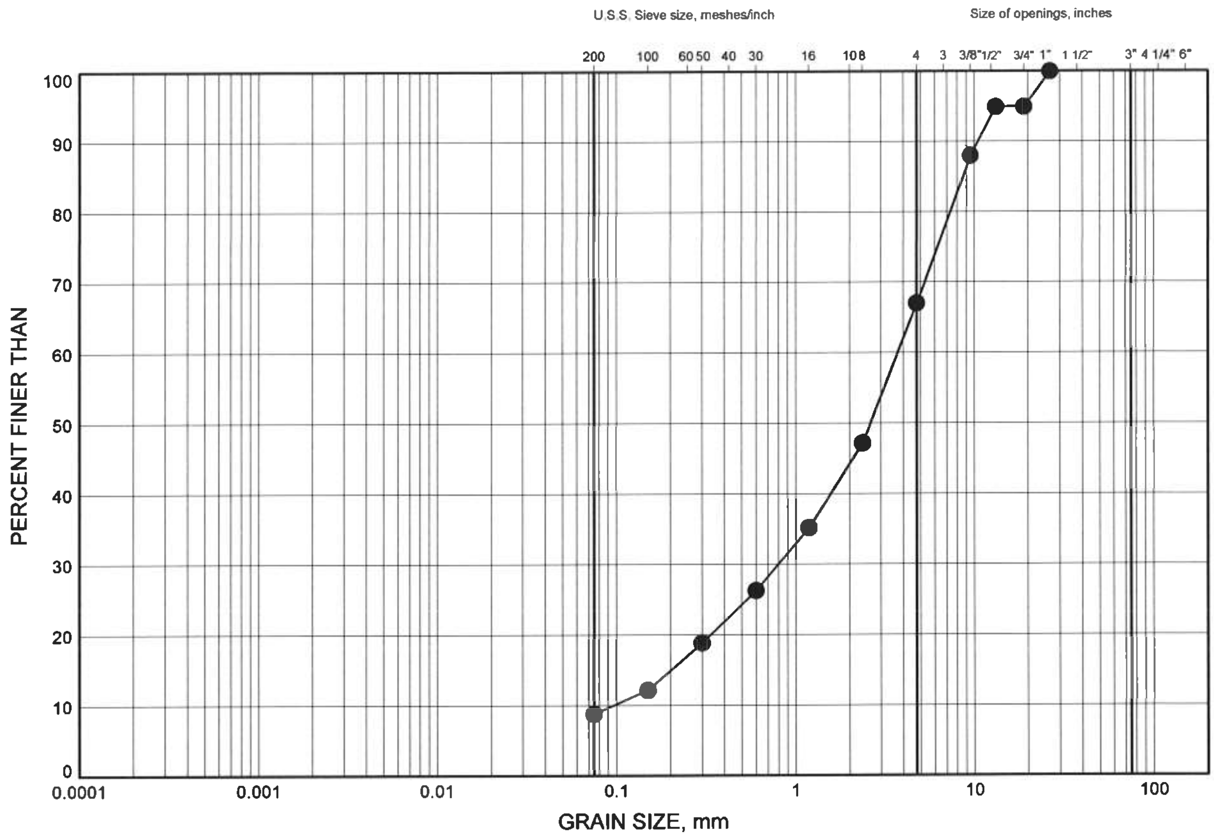
GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 1/22/13

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

GRAVELLY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-02	1.83	194.07

GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 1/22/13

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

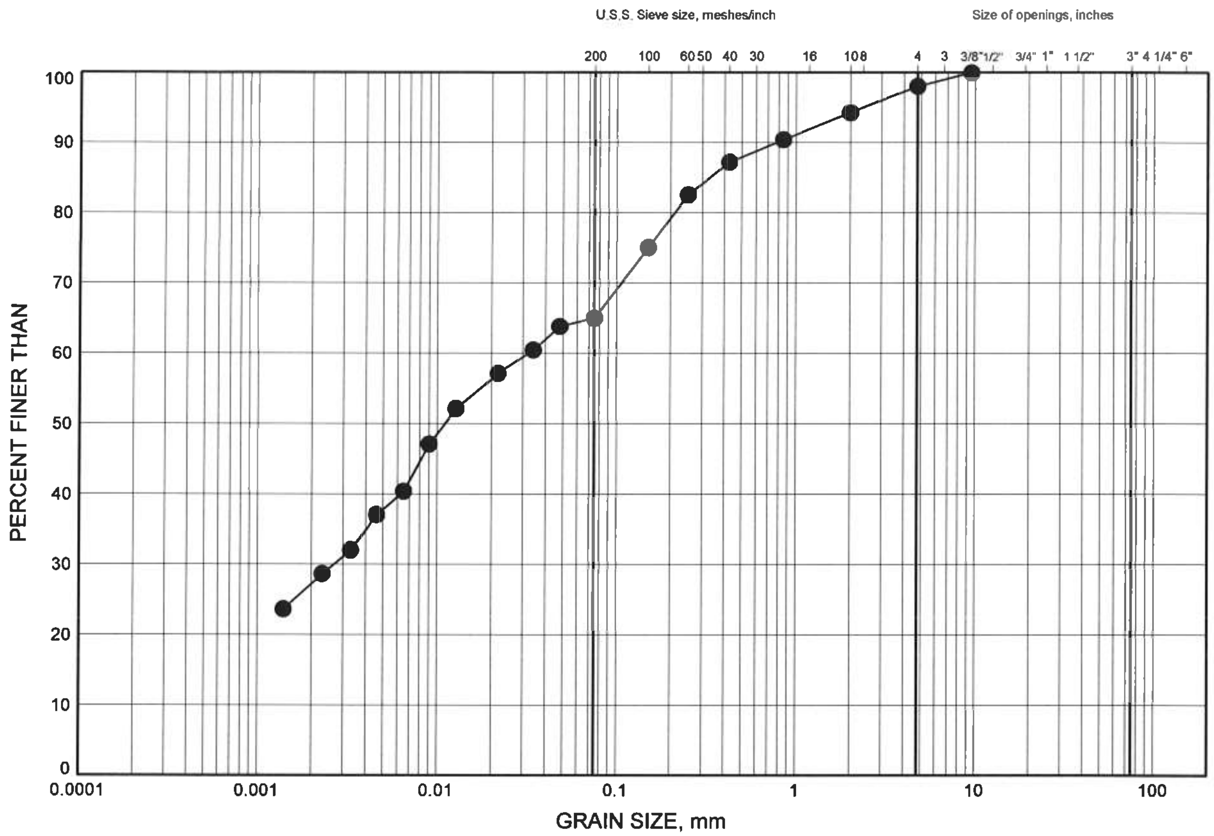
Chkd. SKP

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILT & SAND TILL with Clayey Zones



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-03	1.83	194.37

GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 1/22/13

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

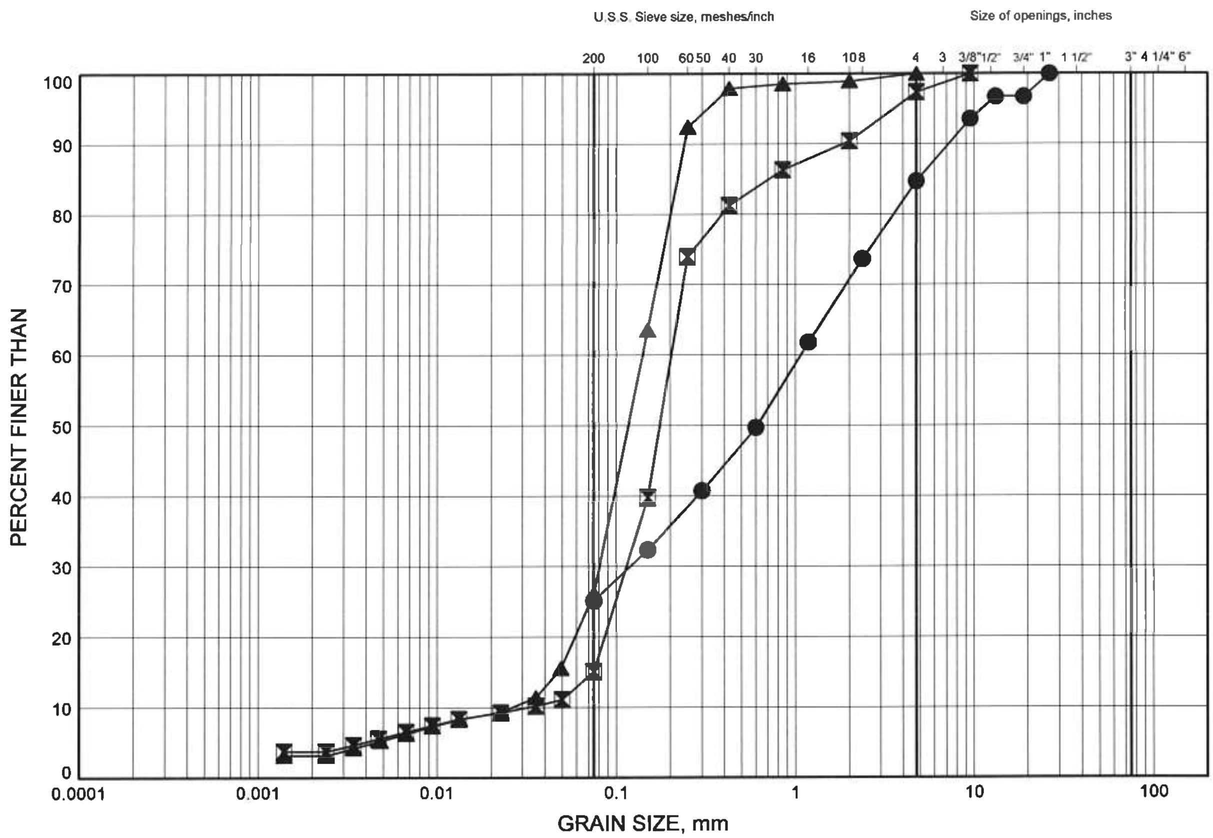
Chkd. SKP

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-01	6.21	189.99
⧖	SM1-03	4.88	191.32
▲	SM1-04	4.80	191.20

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

Chkd. SKP

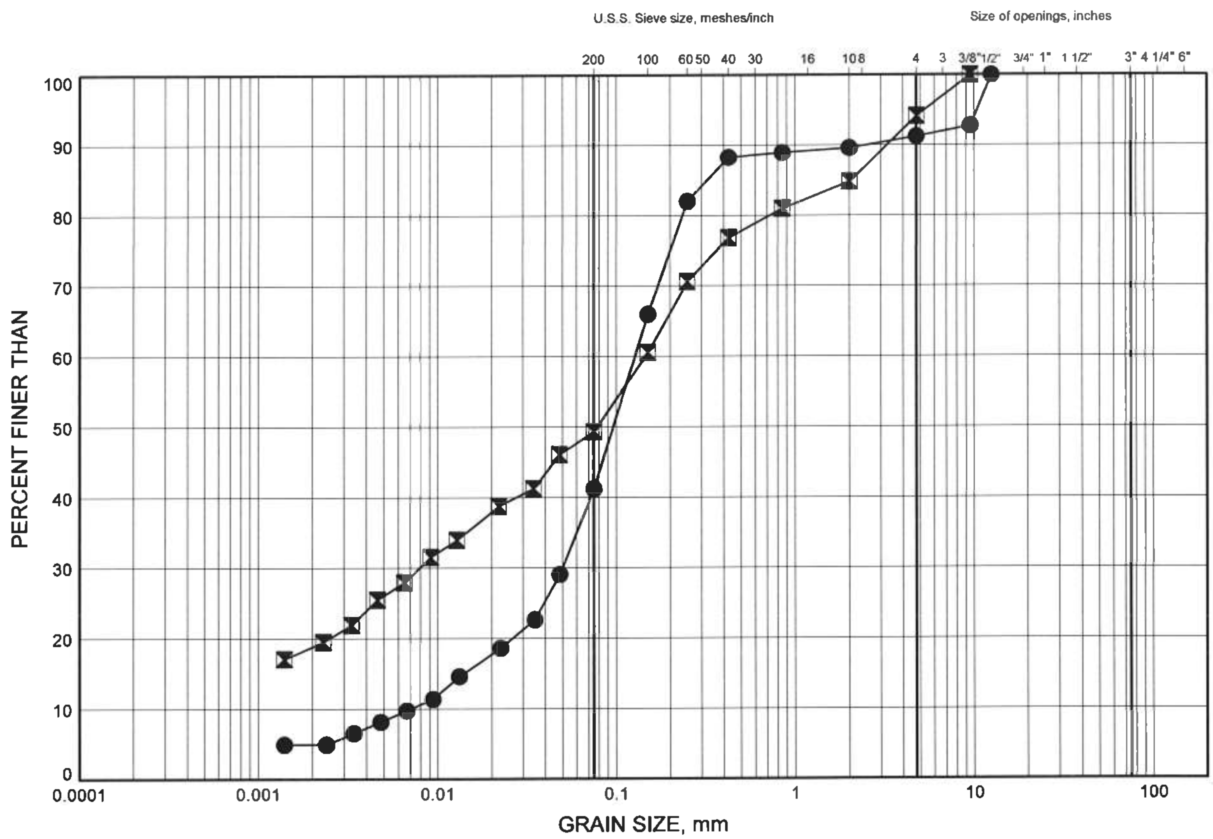
GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 1/22/13

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-01	7.68	188.52
⊠	SM1-02	6.21	189.69

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

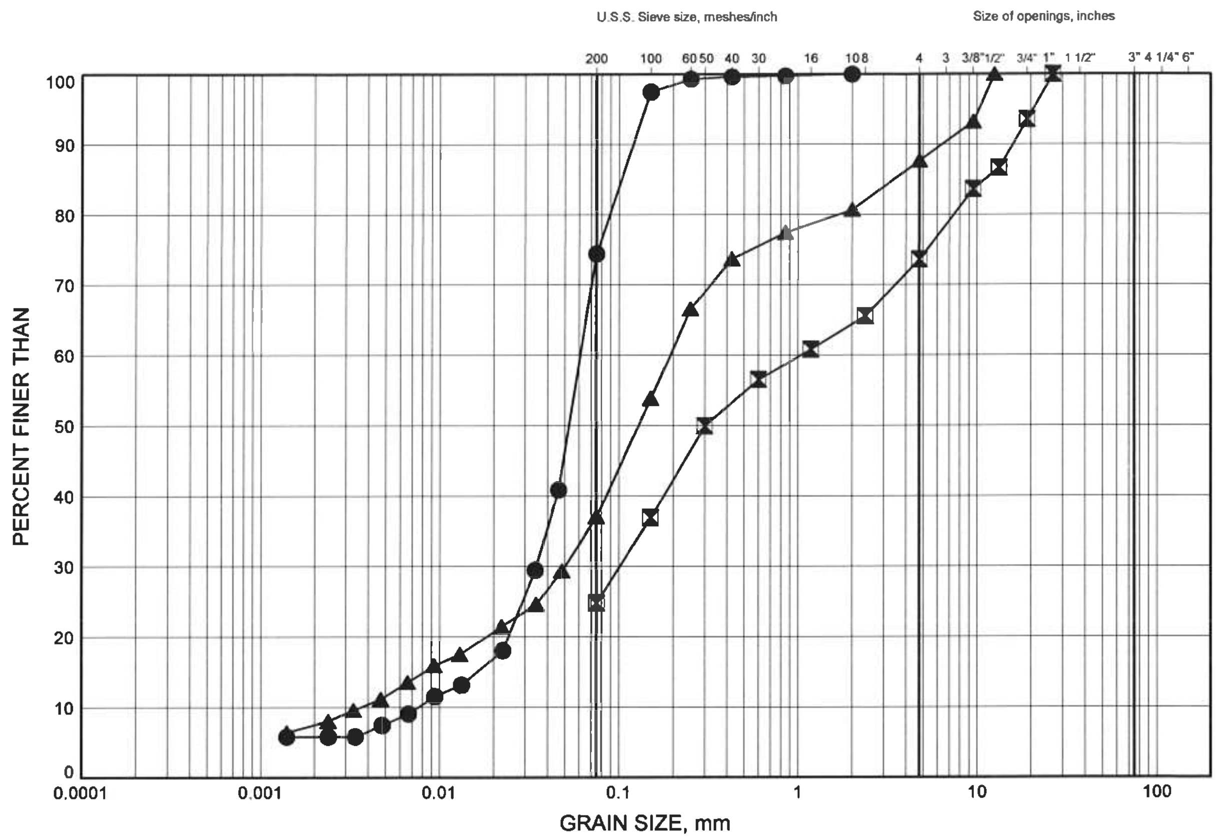
Chkd. SKP

HWY 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B6

SANDY SILT to SILTY SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-02	10.73	185.17
⧗	SM1-03	12.31	183.89
▲	SM1-04	9.28	186.72

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

Chkd. SKP

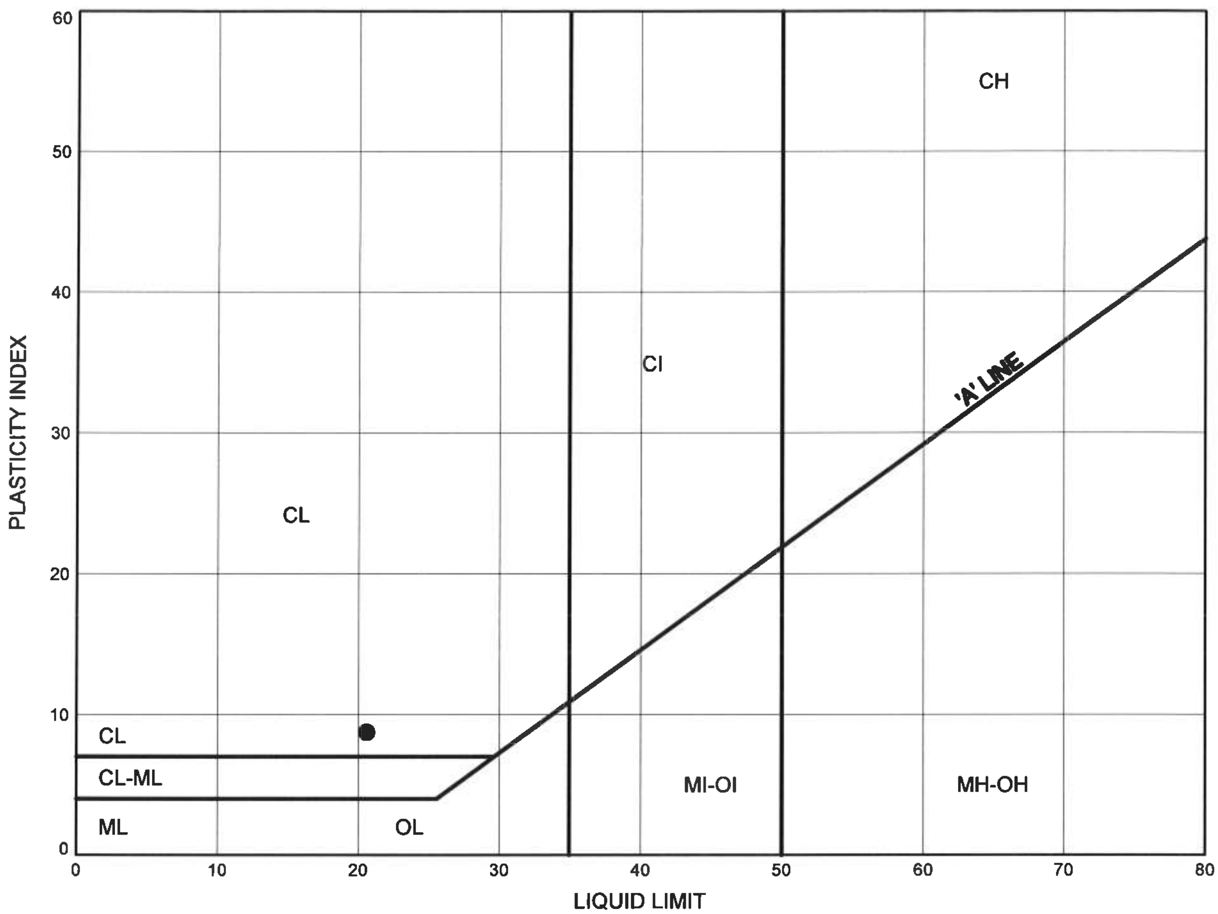
GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 1/22/13

HWY 407 Brock Road Connection - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILT & SAND TILL with Clayey Zones



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM1-03	1.83	194.37

THURBALT 1130A.GPJ 1/22/13

Date January 2013

WP# E2-2012

THURBER

Prep'd AN

Chkd. SKP

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 13T677837
PROJECT NO: 19-5161-130A

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Lindsey Blaine

O. Reg. 153(511) - ORPs (Soil) pH

DATE RECEIVED: 2013-01-08

DATE REPORTED: 2013-01-11

Parameter	Unit	G / S	RDL	SM1-02 SS#4	SM1-04 SS#6	SM2-02 SS#4	SM2-08 SS#3	SM2-11 SS#2	SM2-17 SS#4	SM4-02 SS#1	SM4-04 SS#2
SAMPLE TYPE:				Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
DATE SAMPLED:				1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013
				4058631	4058632	4058634	4058636	4058638	4058640	4058642	4058644
pH, 2:1 CaCl2 Extraction	pH Units		NA	7.90	7.91	7.98	7.92	7.44	7.89	7.83	7.90

Parameter	Unit	G / S	RDL	SM4-07 SS#4	SM8-03 SS#5	SM8-04 SS#6	SM9-02 SS#2	SM9-06A SS#3	SM9-08 SS#4	SM10-09 SS#2
SAMPLE TYPE:				Soil	Soil	Soil	Soil	Soil	Soil	Soil
DATE SAMPLED:				1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013
				4058646	4058648	4058650	4058652	4058654	4058656	4058658
pH, 2:1 CaCl2 Extraction	pH Units		NA	8.02	8.06	7.94	7.92	7.91	7.86	7.39

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard
4058631-4058658 pH was determined on the 0.01M CaCl2 extract obtained from 2:1 leaching procedure (2 parts extraction fluid :1 part wet soil).

Certified By: Elizabeth Rolakowska

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 13T677837
PROJECT NO: 19-5161-130A

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: THURBER ENGINEERING LTD **ATTENTION TO: Lindsey Blaine**

Sulphate (Soil)

DATE RECEIVED: 2013-01-08 **DATE REPORTED: 2013-01-11**

Parameter	Unit	G / S	RDL	SM1-02 SS#4	SM1-04 SS#6	SM2-02 SS#4	SM2-08 SS#3	SM2-11 SS#2	SM2-17 SS#4	SM4-02 SS#1	SM4-04 SS#2
SAMPLE TYPE:				Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
DATE SAMPLED:				1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013
				4058631	4058632	4058634	4058636	4058638	4058640	4058642	4058644
Sulphate (2:1)	µg/g		2.0	3.0	9.7	157	3.9	181	35.8	11.6	6.0

Parameter	Unit	G / S	RDL	SM4-07 SS#4	SM8-03 SS#5	SM8-04 SS#6	SM9-02 SS#2	SM9-06A SS#3	SM9-08 SS#4	SM10-09 SS#2
SAMPLE TYPE:				Soil	Soil	Soil	Soil	Soil	Soil	Soil
DATE SAMPLED:				1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013	1/7/2013
				4058646	4058648	4058650	4058652	4058654	4058656	4058658
Sulphate (2:1)	µg/g		2.0	8.9	9.4	23.3	5.8	15.3	10.3	544

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard
4058631-4058658 The soluble Sulphate was determined on the DI water extract obtained from the 2:1 leaching procedure (2 part DI water: 1 part dry soil).

Certified By: Elizabeth Rolakowska

Appendix C
Selected Borehole Logs
(Previous Investigations by others)

PetoMacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 105

N 4 863 491
E 336 089

PROJECT HIGHWAY 407 EAST, W.P. 282-86-01
SITE Urfe Creek Structure
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE November 23, 1998
OUR PROJECT 98TF083A
ENGINEER M. R. Anderson
TECHNICIAN F. Portella

GROUND ELEVATION 196.69

DEPTH in METRES	DESCRIPTION	ELEVATION	SAMPLE NUMBER	TYPE	BLOWS/0.3m N-VALUES	WATER CONTENT (%)	GROUNDWATER OBSERVATIONS AND REMARKS
0.38	TOPSOIL : Dark brown sandy silt						Bentonite Seal
	SILTY SAND: Compact to dense, brown, some gravel, damp	196					
1.5		195	1	SS	27		Native Backfill
3.0		194, 193	2	SS	31		19mm PVC pipe No further penetration at 4.25m. Moved 1.2m west and re-augered.
3.95	with cobbles/boulders, trace of gravel	192	3	SS	35		Grain Size Distribution (%): GR 6, SA 49, SI 33, CL 12
6.0		191, 190	4	SS	50/50mm*		*Sampler bouncing on probable cobble.
7.65	becoming wet	189, 188					Bentonite Seal Filter Sand
9.0			5	SS	134		
9.50	BOREHOLE TERMINATED AT 9.50m	187					Upon completion of augering, free water at 7.80m.

Chart headings: SHEAR STRENGTH C_u (kPa) ▲ 50 100 150 200; DYNAMIC CONE PENETRATION x; STANDARD PENETRATION TEST ● BLOWS/0.3M 20 40 60 80; LIQUID LIMIT W_L; PLASTIC LIMIT W_P; WATER CONTENT W; WATER CONTENT % 10 20 30

Depth scale: 0, 1.5, 3.0, 4.5, 6.0, 7.5, 9.0, 10.5, 12.0, 13.5, 15.0, 16.5

DATE	DEPTH TO WATER (m)
Nov. 30	7.70

NOTES:

CHECKED BY: [signature]

PetoMacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 107

N 4 863 494
E 336 112

PROJECT HIGHWAY 407 EAST, W.P. 282-86-01
SITE Urfe Creek Structure
BORING METHOD Continuous Flight Solid Stem Augers

OUR PROJECT 98TF083A
BORING DATE November 25, 1998
ENGINEER M. R. Anderson
TECHNICIAN F. Portella

SHEAR STRENGTH C_u (kPa) ▲ 50 100 150 200
DYNAMIC CONE PENETRATION x
STANDARD PENETRATION TEST •
BLOWS/0.3M 20 40 60 80

LIQUID LIMIT —— W_L
PLASTIC LIMIT —— W_P
WATER CONTENT —— W
WATER CONTENT % 10 20 30

GROUND ELEVATION 189.36

DEPTH in METRES	DESCRIPTION	ELEVATION	NUMBER	TYPE	BLOWS/0.3m N - VALUES	GROUNDWATER OBSERVATIONS AND REMARKS (Grain Size Distribution (%) GR SA SI CL)
0.20 / 0.45	PEAT: Brown fibrous peat, becoming dark grey	189	1	AS		Organic content = 4.6%; 69%. Free water observed at 0.35m
2.50	SILTY SAND: Very dense, grey, some gravel, occasional cobbles/boulders, saturated	188, 187	2	SS	85	No further penetration at 1.20m. Probable boulders. Moved 1.0m west and re-augered.
4.05	GRAVELLY SAND: Very dense, grey, medium to coarse-grained, trace of silt	186	3	SS	82	
6.40	SAND: Very dense, grey, trace to some gravel	185, 184	4	SS	105	
		183	5	SS	95	
	BOREHOLE TERMINATED AT 6.40m					Upon completion of augering, free water at 0.00m, cave at 3.00m.

Depth scale: 0, 1.5, 3.0, 4.5, 6.0, 7.5, 9, 10.5, 12.0, 13.5, 15.0, 16.5

NOTES:

CHECKED BY: [signature]

PetoMacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 108

N 4 863 502
E 336 109

PROJECT HIGHWAY 407 EAST, W.P. 282-86-01
SITE Urfe Creek Structure
BORING METHOD Continuous Flight Solid Stem Augers

OUR PROJECT 98TF083A
BORING DATE November 25, 1998 ENGINEER M. R. Anderson
TECHNICIAN F. Portella

GROUND ELEVATION 189.69

DEPTH in METRES	DESCRIPTION (SOIL PROFILE)	ELEVATION
0.30	PEAT : Brown fibrous peat	
	SILTY SAND : Very dense, grey sand, some gravel, occasional cobbles/boulders, wet	189 – 185
4.80	SAND : Very dense, grey medium sand, trace of gravel and silt	184 – 183
6.55	BOREHOLE TERMINATED AT 6.55m	183

SAMPLE NUMBER	TYPE	BLOWS/0.3m N - VALUES	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	101	26	38	26	10
2	SS	110				
3	SS	72				

Chart headings: SHEAR STRENGTH C_u (kPa) ▲ 50 100 150 200; DYNAMIC CONE PENETRATION x; STANDARD PENETRATION TEST •; BLOWS/0.3M 20 40 60 80; LIQUID LIMIT W_L; PLASTIC LIMIT W_p; WATER CONTENT W; WATER CONTENT % 10 20 30

Depth scale: 0, 1.5, 3.0, 4.5, 6.0, 7.5, 9.0, 10.5, 12.0, 13.5, 15.0, 16.5

GROUNDWATER OBSERVATIONS AND REMARKS

Upon completion of augering, free water at 0.45m, cave at 2.45m.

NOTES:

CHECKED BY: [signature]

PetoMacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 112

N 4 863 507
E 336 130

PROJECT HIGHWAY 407 EAST, W.P. 282-86-01
SITE Urfe Creek Structure
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE November 26, 1998
OUR PROJECT 98TF083A
ENGINEER M. R. Anderson
TECHNICIAN F. Portello

GROUND ELEVATION 195.62

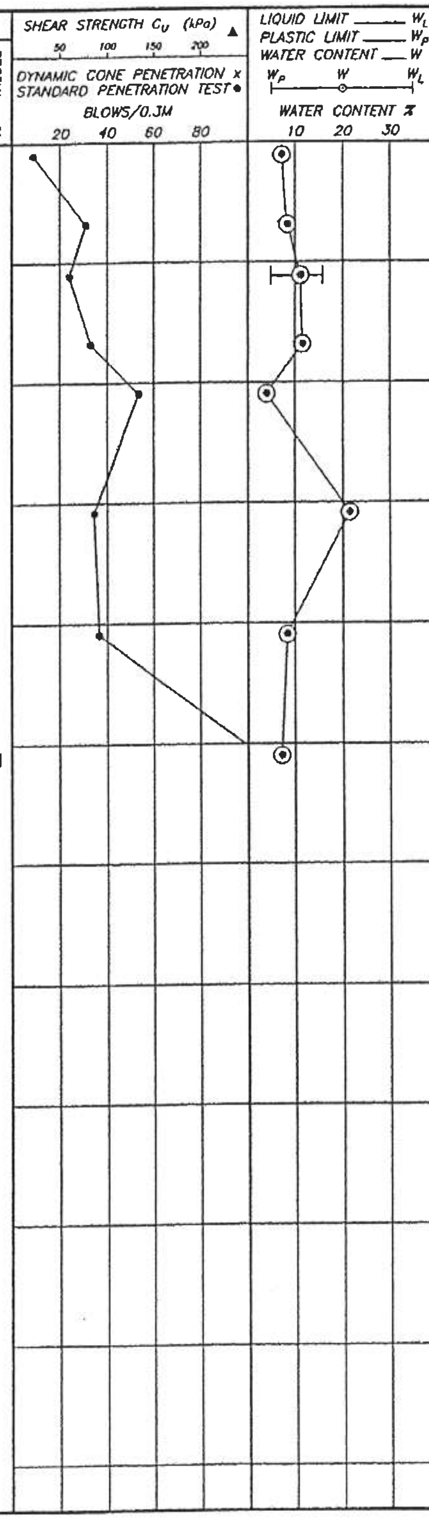
SOIL PROFILE

DEPTH in METRES	DESCRIPTION
0.25	TOPSOIL: Dark brown sandy silt
0.70	SANDY SILT: Loose, brown, moist
2.90	SILTY SAND: Compact to dense, brown, trace of clay and gravel, moist, occasional cobble/boulders
4.05	SAND : Very dense, brown, fine sand, with silt, damp
5.55	becoming dense, wet
7.10	SILTY SAND: Dense, grey, some gravel, wet
7.90	becoming very dense
	BOREHOLE TERMINATED AT 7.90m

Elevation marks: 195, 194, 193, 192, 191, 190, 189, 188, 187

SAMPLES

NUMBER	TYPE	N - VALUES (BLOWS/0.3m)
1	SS	9
2	SS	31
3	SS	23
4	SS	32
5	SS	74
6	SS	36
7	SS	38
8	SS	101



GROUNDWATER OBSERVATIONS AND REMARKS

Grain Size Distribution (%) GR SA SI CL

- Bentonite Seal
- 6 40 39 15
- Native Backfill
- 3 74 21 2
- 19mm PVC pipe
- Bentonite Seal
- Free water observed at 5.20m.
- Filter Sand

Upon completion of augering, free water at 5.50m. cave at 7.30m.

DATE	DEPTH TO WATER (m)
Nov. 30	6.05

NOTES:

CHECKED BY: [signature]

Golder Associates

RECORD OF BOREHOLE No WMA-1

 METRIC

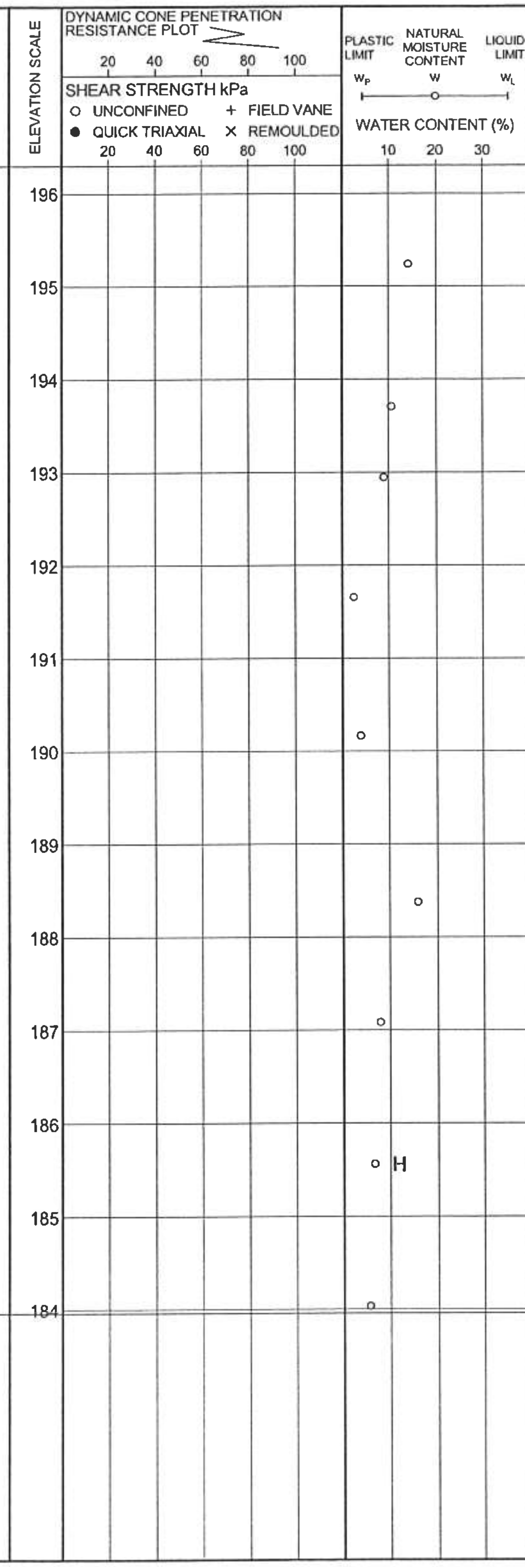
PROJECT 07-1111-0053

W.O. 07-20015 LOCATION N 4863719.6 ;E 336079.0 ORIGINATED BY GD/JZ

DIST Central HWY 407 BOREHOLE TYPE 210 mm O.D. Hollow Stem Augers COMPILED BY DD

DATUM Geodetic DATE January 31 and February 4, 2008 CHECKED BY TZ/HJ

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.3	GROUND SURFACE					
196.0 / 0.0	Sandy silt, trace clay, containing organics (FILL) Loose Dark brown Moist	1	SS	9		
0.3	Sand and gravel (FILL) Loose Brown Moist	2	SS	4		
194.8 / 1.5	Silty sand, trace to some clay, trace gravel (FILL) Compact to loose Brown Moist	3	SS	20		3 68 22 7
		4	SS	8		
193.3 / 3.1	SAND, trace to some silt, occasional cobbles Dense Brown Moist	5	SS	34		
191.7 / 4.6	SAND and GRAVEL, some silt, trace clay, occasional cobbles Very dense Brown Moist Boulder at 5.5 m depth	6	SS	61/0.15		
		7	SS	61/0.07	∇ (190)	44 37 16 3
188.7 / 7.6	SAND, trace to some silt Very dense Brown Moist	8	SS	87		
187.5 / 8.8	SAND and SILT, trace to some clay and gravel (TILL) Very dense Brown to grey Moist	9	SS	75/0.15		10 45 39 6
		10	SS	50/0.13		8 43 43 6
184.1 / 12.3	SAND and GRAVEL Very dense Brown Moist to wet	11	SS	50/0.25		
	END OF BOREHOLE					



NOTES:

1. Water level measured in open borehole upon completion of drilling at a depth of 6.4 m below ground surface (Elevation 189.9 m).

$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No WMA-2

 METRIC

PROJECT 07-1111-0053
W.O. 07-20015 LOCATION N 4863738.8 ;E 336142.1 ORIGINATED BY JZ/HM
DIST Central HWY 407 BOREHOLE TYPE 210 mm O.D. Hollow Stem Augers COMPILED BY DD
DATUM Geodetic DATE February 8 and 11, 2008 CHECKED BY TZ/HJ

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.0	GROUND SURFACE					
0.0	Sandy silt, trace clay and gravel, containing organics (FILL) Loose to compact Brown Moist	1	SS	5	o	
		2	SS	12	o	
194.5 / 1.5	SAND and SILT, trace to some clay, trace gravel (TILL) Compact Brown Moist to wet	3	SS	20		
		4	SS	17	o with range	6 42 40 12
		5	SS	34	o	
192.5 / 3.5	SAND, some silt, trace clay Dense Brown Moist	6	SS	42	o	0 80 17 3
	Wet below 6.1 m depth	7	SS	47		
189.3 / 6.7	SAND and SILT, some gravel, trace clay, containing cobbles and boulders (TILL) Very dense Grey Wet to moist	8	SS	50/0.13	o	
		9	SS	50/0.13	o H	22 39 32 7
185.3	Sand seams at a depth of 10.7 m	10	SS	50/0.07		
10.7	END OF BOREHOLE					

NOTES:

1. Water level measured in piezometer at a depth of 5.4 m below ground surface (Elevation 190.6 m) on April 4, 2008.

Elevation scale: 195, 194, 193, 192, 191, 190, 189, 188, 187, 186

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

+ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Appendix D
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR BRIDGE ABUTMENTS

Spread Footings on Native Soil	Spread Footings on Engineered Fill	Caissons	Driven H-Piles
Advantages:	***Advantages:***	***Advantages:***	***Advantages:***
i. Generally less costly construction than deep foundation elements.	i. Generally less costly construction than deep foundation elements. ii. Lesser depth of excavation is required compared to footings on native soils.	i. Potentially higher geotechnical resistances than spread footings. ii. Construction of caissons could continue in freezing weather.	i. Higher geotechnical resistances can be achieved when piles are driven into the dense glacial till ii. Installation of piles could continue in freezing weather iii. Foundation construction may require less volume of excavation than footings. iv. Required for integral abutment
Disadvantages:	***Disadvantages:***	***Disadvantages:***	***Disadvantages:***
i. Excavation to base of foundation is required for footing construction. ii. Dewatering will be required. iii. Risk of footing being undermined should scour protection along the creek banks fail to protect the forward slope.	i. Dewatering may be required, depending on depth of excavation. ii. Risk of footing being undermined should scour protection along the creek banks fail to protect the forward slope. iii. If footing is to be perched within the approach fill at higher elevations, a longer bridge span and therefore higher cost would result.	i. Higher cost than spread footings ii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils under the water table. iii. Potential difficulty in maintaining undisturbed founding conditions due to unbalanced head in groundwater.	i. Higher unit costs than footings. ii. Pile lengths required to achieve design resistance may vary. iii. Pile tip must extend to the minimum design depth below the CSP.
NOT RECOMMENDED	**NOT RECOMMENDED**	**NOT RECOMMENDED**	**FEASIBLE**

Appendix E

List of SPs and OPSS, and Suggested Text for NSSP

1. List of Special Provisions and OPSS Documents Referenced in this Report

- Special Provision 110S13
- OPSS 501
- OPSS 539
- OPSS 902
- OPSS 903
- OPSS 1010
- OPSD 3000.100
- OPSD 3101.150

2. Suggested text for a NSSP on Pile Installation

The presence of cobbles and boulders in the dense glacial till may potentially have an impact on the installation of piles at the site. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:

- The cobbles and boulders may impede the driving of the piles resulting in more arduous driving in the very dense soils
- Some piles may meet refusal on boulders that are large enough not to be dislodged or broken by the pile driving
- As a result of the presence of boulders, piles may meet refusal at varying depths
- The pile tip must extend to a minimum 2 m below the CSP
- Pile driving must be controlled according to the criteria specified for the site.

Appendix F

Borehole Locations and Soil Strata Drawings

THURBER

NO.	DATE	REVISIONS	BY	CHK	LEAD DISC	PROJ MAN

CONTRACT No. E2-2012
HWY 407/BROCK ROAD INTERCHANGE

STRUCTURE M-1 (SITE 2)
HIGHWAY 407 EBL
OVER URFE CREEK
BOREHOLE LOCATIONS AND SOIL STRATA

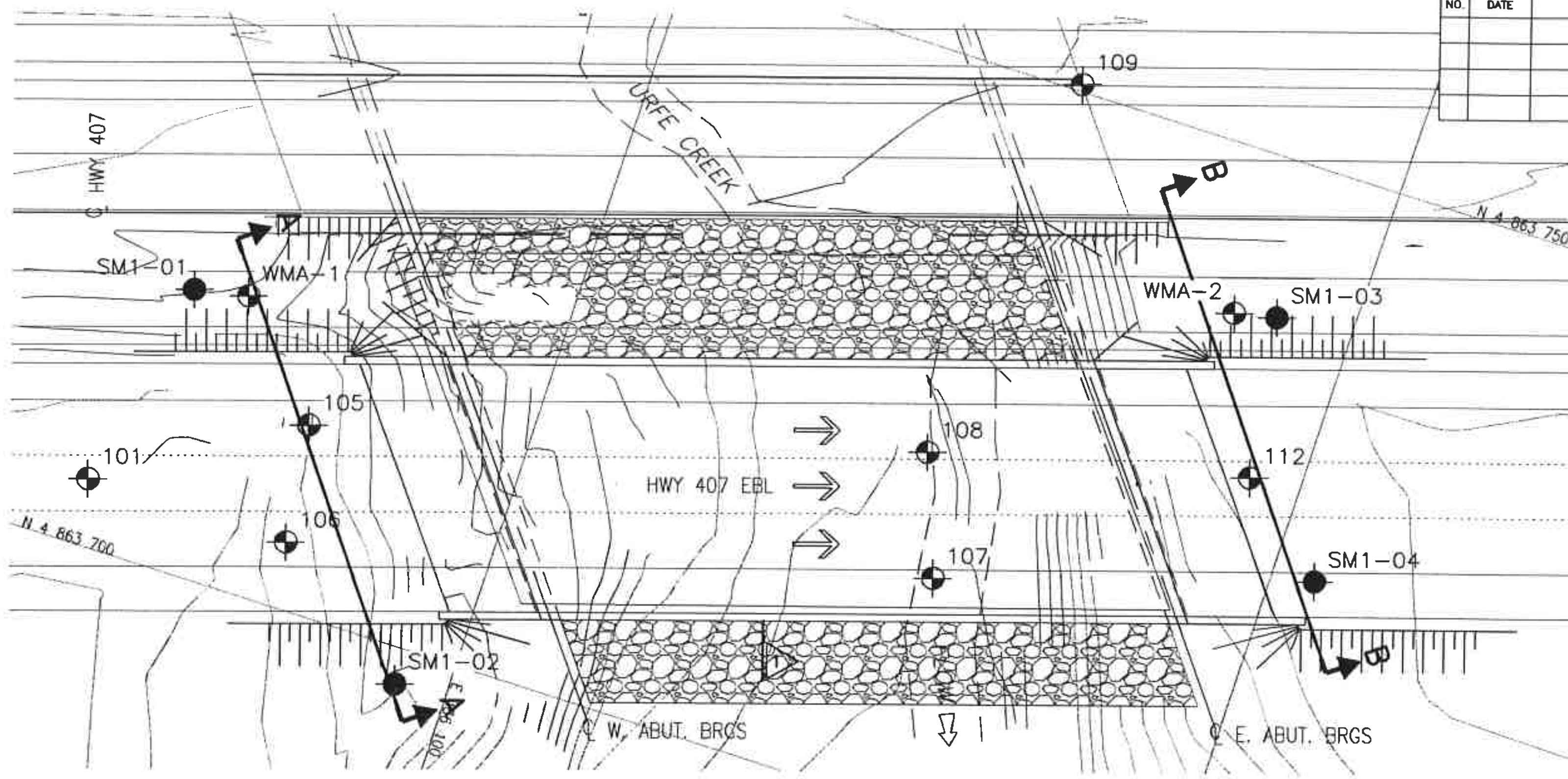
SHEET

407 ETR Express Toll Route

MMM GROUP

THURBER ENGINEERING LTD.

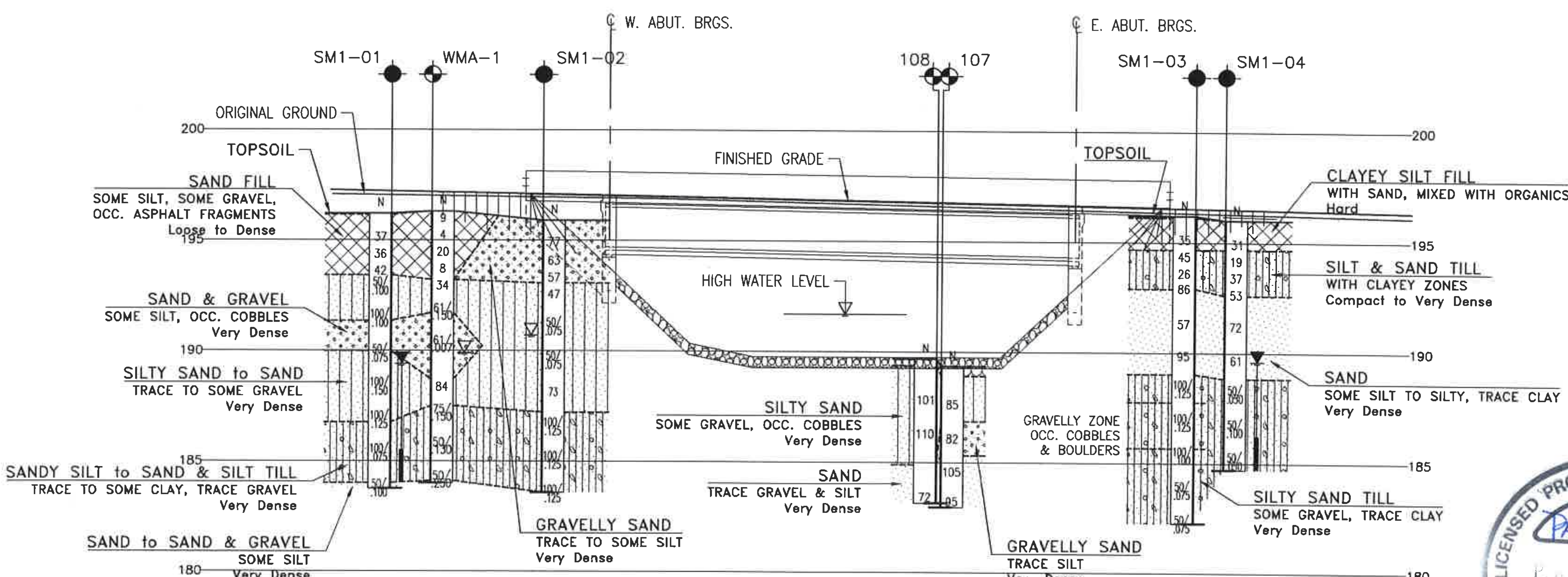
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN

10 0 10 20m
SCALE 1:500

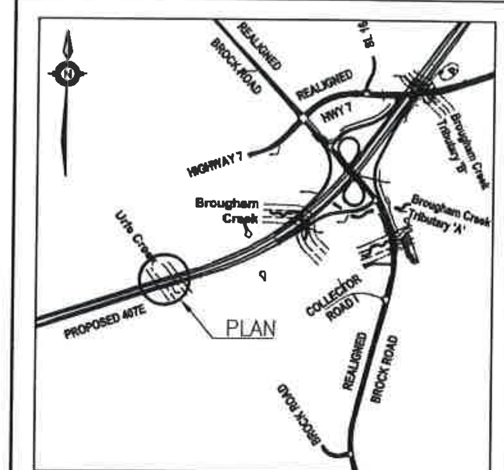
LICENSED PROFESSIONAL ENGINEER
S. PANG
Jan 23/13
PROVINCE OF ONTARIO



PROFILE ALONG HWY 407 EBL ℄

10 0 10 20m H 1:500
5 0 5 10 V 1:250

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 23/13
PROVINCE OF ONTARIO



KEYPLAN

LEGEND

Symbol	Description
⊕ (solid)	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SM1-01	196.2	4 863 718.9	336 075.4
SM1-02	195.9	4 863 697.6	336 096.5
SM1-03	196.2	4 863 739.4	336 145.0
SM1-04	196.0	4 863 723.2	336 153.0
WMA-1	196.3	4 863 719.6	336 079.0
WMA-2	196.0	4 863 738.8	336 142.1
105	196.7	4 863 712.5	336 085.6
107	189.4	4 863 715.5	336 128.6
108	189.7	4 863 723.5	336 125.6
112	195.6	4 863 728.5	336 146.6

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

DESIGN LRB	CHK SKP	CODE	LOAD	DATE JAN. 2013
DRAWN AN	CHK LRB	SITE 2	STRUCT M-1	DWG 1

DRAWING NAME: H:\Drafting\19\5161\130\ted11304-M1-BoreholePlan&Profile.dwg
CREATED: November 20, 2012 MODIFIED: January 23, 2013

NO.	DATE	REVISIONS	BY	CHK	LEAD DISC.	PROJ. MAN.

CONTRACT No. E2-2012
HWY 407/BROCK ROAD INTERCHANGE

STRUCTURE M-1 (SITE 2)
HIGHWAY 407 EBL
OVER URFE CREEK
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

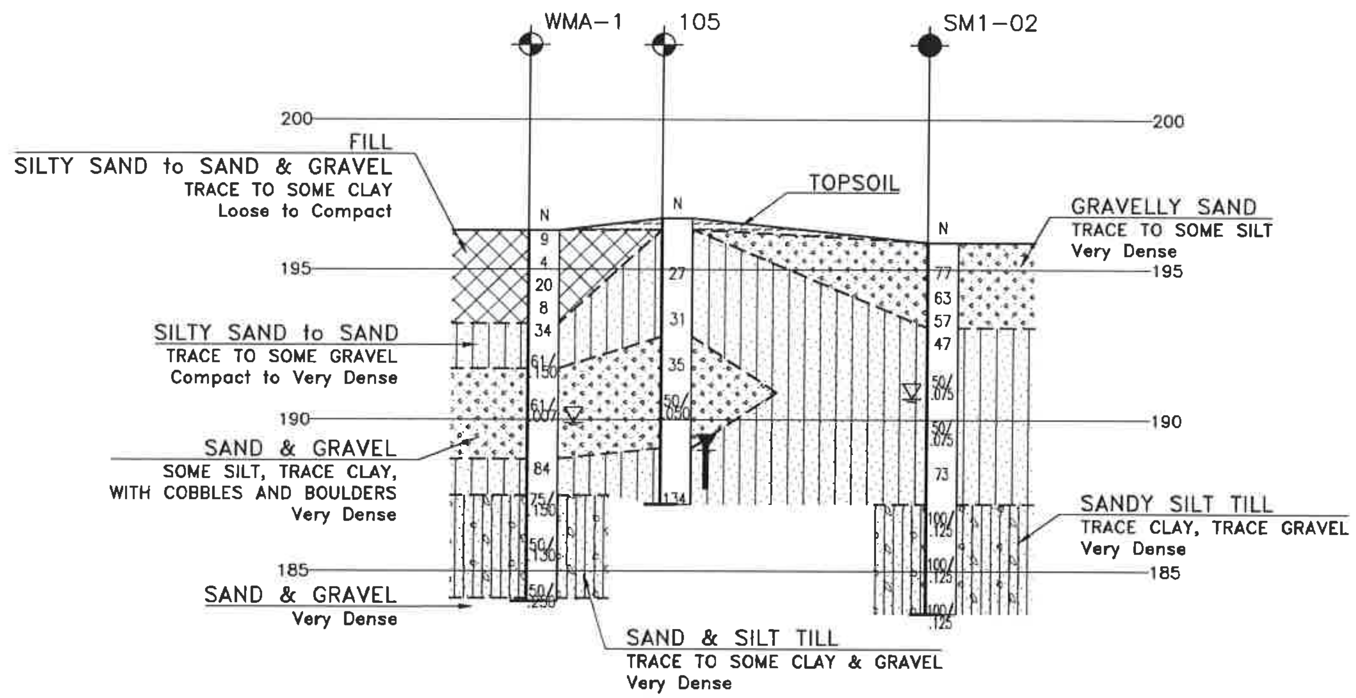
407 ETR Express Toll Route

MMM GROUP

THURBER ENGINEERING LTD.

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

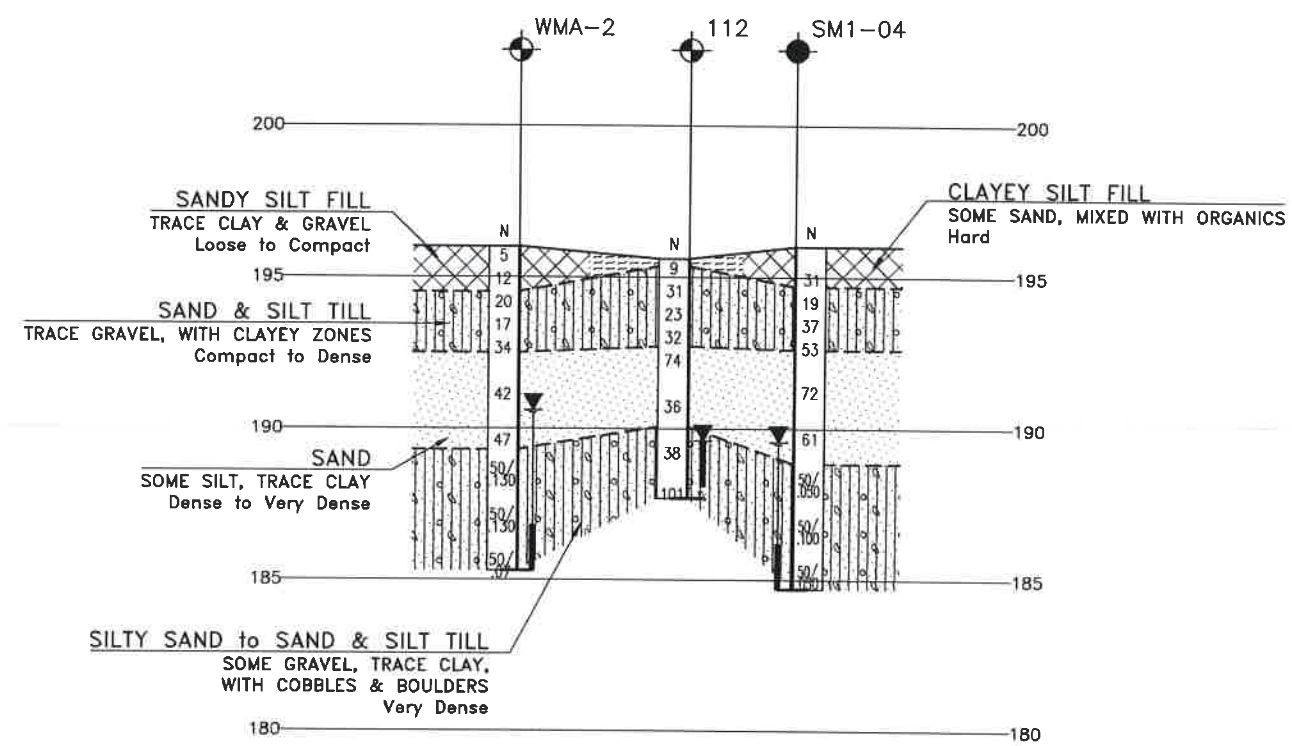


PROFILE ALONG A-A

10 0 10 20m H 1:500
5 0 5 10 V 1:250

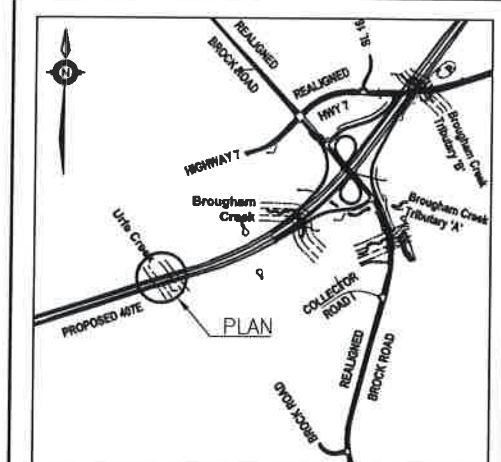
LICENSED PROFESSIONAL ENGINEER
S. PANG
Jan. 23/13
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. CHATTERJI
Jan 23/13
PROVINCE OF ONTARIO



PROFILE ALONG B-B

10 0 10 20m H 1:500
5 0 5 10 V 1:250



KEYPLAN

LEGEND

(symbol)	Borehole
(symbol)	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
(symbol)	Water Level
(symbol)	Head Artesian Water
(symbol)	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SM1-01	196.2	4 863 718.9	336 075.4
SM1-02	195.9	4 863 697.6	336 096.5
SM1-03	196.2	4 863 739.4	336 145.0
SM1-04	196.0	4 863 723.2	336 153.0
WMA-1	196.3	4 863 719.6	336 079.0
WMA-2	196.0	4 863 738.8	336 142.1
105	196.7	4 863 712.5	336 085.6
107	189.4	4 863 715.5	336 128.6
108	189.7	4 863 723.5	336 125.6
112	195.6	4 863 728.5	336 146.6

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

DESIGN LRB	CHK SKP	CODE	LOAD	DATE JAN. 2013
DRAWN AN	CHK LRB	SITE 2	STRUCT M-1	DWG 2

DRAWING NAME: H:\Drafting\19\5161\130\ted1130A-M1-BoreholePlan&Profile.dwg
CREATED: November 20, 2012 MODIFIED: January 23, 2013