FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION
STRUCTURE M-10 (SITE 7)
HIGHWAY 407 EBL AND WBL CROSSING
OVER BROUGHAM CREEK TRIBUTARY 'B'
Contract No: E2-2012

Report to

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TABLE OF CONTENTS

THURBER

APPENDICES

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION
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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of new twin bridges that will carry the new eastbound lanes (EBL) and westbound lanes (WBL) of Highway 407 over Brougham Creek, in The City of Pickering, Ontario. The new bridges are planned as part of the Highway 407 east extension and are 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 profiles 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 195 m east of Sideline 16 and 50 m north of the existing Highway 7 at Brougham Creek Tributary 'B'. The community of Brougham is located approximately 1.2 km west of the proposed bridge site.

At the location of the proposed bridge, Brougham Creek Tributary 'B' flows from north to south. To the north of the bridge site, the creek has been dammed off by the land owner. The creek flows in a floodplain that is approximately 9 to 11 m below the existing highway grade. Lands surrounding the bridge site consist primarily of agricultural fields.

The overall slope on the west side of the valley is approximately 6H : 1V. On the east side, the main slope is approximately 7H : 1V though locally steeper at 3H : 1V along the centreline of WBL.

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 October 19 and December 13, 2012 and consisted of drilling and sampling a total of 12 boreholes (identified as SM10-01 to SM10-10, SM10-12 and SM9-06). At the location of the WBL bridge, boreholes were drilled in close proximity to the abutment location on the west side and within 10 to 15 m on the east side. At the location of the EBL bridge, due to the sloping terrain of the creek valley, the presence of surficial peat, organics and soft soils, and the environmental constraints on access preparation, most boreholes were located some 15 to 25 m back from the proposed abutment centrelines. Two shallow boreholes were advanced at the west abutment using portable equipment. The boreholes were advanced to depths ranging from 4.6 to 27.9 m below the existing ground surface (Elevations 135.3 to 159.1m). The Record of Borehole sheets are included in Appendix A.

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 each drilling location that was within the protected zone identified by MNR to prevent sediment laden water from entering Brougham Creek and the adjacent habitat.

Drilling was carried out using a track mounted drill rig, except for Boreholes SM10-04 and SM10-05 located on the slope where a portable tripod rig was used. For the track mounted rig, both solid and hollow stem augers were used to advance the boreholes where feasible. The tri-coning method in conjunction with the use of drilling mud and/or water were required to further advance Boreholes SM10-02, SM10-06, SM10-07, SM10-08, SM10-09, SM10-12 and SM9-06 to the required depth after augering, due to excess water pressure at the base, and the presence of cobbles and/or boulders. For the tripod rig, wash boring with casing was used to advance the boreholes. 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.

Groundwater conditions were observed in the open boreholes throughout and 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 Boreholes SM10-03 and SM10-07. Two standpipes were installed in each of Boreholes SM10-06 and SM10-12. The completion details of the piezometers and boreholes carried out 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
SM10-01	None installed	Backfilled with bentonite holeplug to surface.
SM10-02	None installed	Backfilled with bentonite holeplug to surface.
SM10-03	10.3 / 153.5	Piezometer with 3 m slotted screen installed with sand filter to 7.0 m, bentonite from 7.0 m to surface.
SM10-04	None installed	Caved to 2.4 m, backfilled with cuttings and bentonite holeplug to surface.
SM10-05	None installed	Caved to surface.
SM10-06	14.5 / 155.1 (deeper)	Piezometer with 1.5 m slotted screen installed with sand filter to 12.6 m, bentonite from 12.6 to 7.3.
	6.2 / 163.4 (shallower)	Piezometer with 1.5 m slotted screen installed with sand filter from 7.3 to 4.7 m, bentonite from 4.7 to surface.
SM10-07	12.2 / 151.4	Piezometer with 1.5 m slotted screen installed with sand filter to 10.4 m, bentonite from 10.4 m to surface.
SM10-08	None installed	Grouted to surface.
SM10-09	None installed	Backfilled with bentonite holeplug to surface.
SM10-10	None installed	Borehole caved to 7.9 m; then backfilled with bentonite holeplug to surface.
SM10-12	15.1 / 152.8 (deeper)	Piezometer with 1.5 m slotted screen installed with sand filter to 12.2 m, bentonite from 12.2 to 8.2.
	8.2 / 159.7 (shallower)	Piezometer with 1.5 m slotted screen installed with sand filter from 8.2 to 5.7 m, bentonite from 5.7 to surface.
SM9-06	11.8 / 152.8	Piezometer with 1.5 m slotted screen installed with sand filter to 10.0 m, bentonite from 10.0 m 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 selected cohesive samples were subjected to Atterberg Limits testing. 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. One selected sample was 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 Peat and Topsoil

Peat was encountered in Boreholes SM10-03, SM10-04, SM10-05, SM10-09 and SM9-06. The thickness of the peat ranges from 0.6 to 1.2 m with the lower boundary at Elevations 163.4 to 160.3 m. Where measured, SPT 'N' values were between 0 and 1 blows per 0.3 m penetration indicating a very soft consistency. Measured moisture contents range from 144 to 287%.

Topsoil was encountered at ground surface in Boreholes SM10-06, SM10-10 and SM10-12. The topsoil ranged from 125 to 275 mm in thickness.

The thickness of the peat and topsoil may vary between and beyond the borehole locations.

5.2 Sand and Gravel to Gravelly Sand

A deposit of sand and gravel to gravelly sand was encountered below peat and surficial soils in Boreholes SM10-01, SM10-02, SM10-03, SM10-06, SM10-07 and SM10-09. These soils were brown in colour becoming grey with depth and contained trace to some silt.

This deposit ranges from 6.1 to 10.2 m in thickness in the vicinity of Boreholes SM10-01, SM10-02 and SM10-03 with lower boundary at Elevations 150.8 to 153.0 m (Borehole SM10-01 was terminated in this deposit), tapering to thicknesses between 1.4 and 3.0 m in Boreholes SM10-07 and SM10-09 with lower boundary at Elevations 159.1 and 153.4 m. In Borehole SM10-06, this deposit was 2.2 m thick with a lower boundary at Elevation 165.3 m.

SPT N-values recorded in this layer ranged from 12 blows for 0.3 m penetration to greater than 100 blows for 0.3 m penetration, indicating a compact to typically very dense state. Occasional 'N' values greater than 100 blows for less than 0.3 m penetration and notable resistance to boreholes advance infer the presence of cobbles and boulders. Measured moisture contents ranged from 3 to 15%.

Several samples of the sand and gravel to gravelly sand were 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 curves for these samples are plotted on Figure B1 in Appendix B.

Soil Particles	Percentage (%)
Gravel	21 to 61
Sand	32 to 72
Silt and Clay	5 to 17

5.3 Sand

A deposit of sand was encountered below the peat and surficial soils in all but Borehole SM10-03. Boreholes SM10-04, SM10-05 and SM9-06 were terminated in this deposit. This sand was brown in colour becoming grey with depth and contained trace to some silt and gravel, and trace clay.

Where fully penetrated, the thickness of the sand ranged between 0.9 and 9.1 m, with the lower boundary encountered at Elevations 135.8 to 161.6 m.

SPT N-values recorded in these soils ranged from 0 at shallow depths to greater than 100 blows for 0.3 m penetration indicating a very loose to very dense state. The deposit is typically in a compact to dense state. SPT N-values of over 100 blows for less than 0.3 m penetration infer the presence of cobbles and/or boulders. Measured moisture contents typically ranged from 8 to 20% with an occasional value of 50% recorded below the peat in Borehole SM10-09.

Six samples of the 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 Figure B3 in Appendix B.

Soil Particles	Percentage (%)
Gravel	0 to 19
Sand	68 to 93
Silt	15
Clay	4
Silt and Clay	2 to 13

5.4 Sandy Silt to Sand and Silt

Interlayers of sandy silt, silty sand to sand and silt were encountered at various depths and elevations in Boreholes SM10-01, SM10-02, SM10-04, SM10-05, SM10-06, SM10-07, SM10-08 and SM10-10. Boreholes SM10-02, SM10-06 and SM10-08 terminated within these soils at elevations ranging from 135.3 to 154.3 m. The sands and silts were brown in colour becoming grey with depth.

Where fully penetrated, the thickness of these layers ranged from 1.2 to 3.0 m with the lower boundary at Elevations 153.4 to 162.4 m.

SPT N-values recorded in the silts and sands varied widely from 2 blows for 0.3 m penetration at ground surface to greater than 100 blows for 0.3 m penetration indicating a very loose to very dense state. In general, the upper deposits are in a loose to compact state while the lower deposits are in a dense state. Occasional SPT N-values of greater than 100 blows for less than 0.3 m penetration infer the presence of cobbles and/or boulders. Measured moisture contents ranged from 10 to 38%.

Three samples of the silts and sands 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 B4 in Appendix B.

Soil Particles	Percentage (%)
Gravel	0 to 4
Sand	24 to 37
Silt	50 to 64
Clay	9 to 12

5.5 Silty Clay

A deposit of silty clay was encountered at various elevations in Boreholes SM10-02, SM10-03, SM10-07, SM10-08, SM10-09 and SM10-10. Boreholes SM10-03, SM10-07 and SM10-09 terminated within the silty clay at elevations ranging from 148.3 to 152.8 m. The surficial silty clay was brown in colour becoming grey with depth, and contained rootlets and organics.

The thickness of the surficial layer of silty clay in Boreholes SM10-02, SM10-07, SM10-08 and SM10-10 ranged from Elevations 1.2 to 3.0 m while in Borehole SM10-08, the lower clay deposit was up to 16.5 m thick with a lower boundary at Elevation 137.6 m.

SPT N-values recorded in the silty clay layer near the ground surface ranged from 2 to 24 blows for 0.3 m penetration indicating a soft to very stiff consistency. Within the lower clay layer in Borehole SM10-08, SPT N-values ranged from 37 to greater than 100 blows for 0.3m penetration indicating a hard consistency throughout. Measured moisture contents ranged from 18 to 60%.

Four samples of the silty clay 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 B6 in Appendix B. Atterberg limits were also carried out on the same samples with the results summarized below and also plotted on the plasticity chart on Figure B7 in Appendix B.

Soil Particles	Percentage (%)
Gravel	0
Sand	0
Silt	28 to 60
Clay	40 to 72

Soil Property	Percentage (%)
Liquid Limit	31 to 50
Plasticity Index	13 to 27

The above values indicate that the silty clay has low to intermediate plasticity with a group symbol of CL-CI.

5.6 Silty Sand to Silt and Sand Till

Deposits of silty sand to silt and sand till were encountered in Boreholes SM10-06, SM10-07, SM10-08, SM10-10 and SM10-12 at various elevations. Borehole SM10-10 was terminated at Elevation 152.7 m within this deposit. The cohesionless till was brown to grey in colour, and contained trace to some gravel and trace to some clay. Cobbles and boulders were inferred throughout the deposits.

Where fully penetrated, the glacial till was 0.7 to 5.6 m thick with the lower boundary at Elevations 167.5 to 151.4 m.

SPT N-values recorded in the till at lower elevations ranged from 84 to greater than 100 blows for less than 0.3 m penetration indicating a very dense state. Cobbles and/or boulders were inferred by 'N' >100 blows. At ground surface in Boreholes SM10-06, SM10-08 and SM10-12, the till was in loose to dense state as indicated by 'N' values increasing with depth from 6 to 44 blows. Measured moisture contents ranged from 8 to 15%.

Gradation analyses were conducted on six samples of the cohesionless 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 B5 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	5 to 22
Sand	39 to 62
Silt	23 to 43
Clay	7 to 18
Silt and Clay	27

5.7 Groundwater Levels

Groundwater levels were observed in the open boreholes upon completion of the drilling. Standpipe piezometers were installed in selected boreholes to permit longer term monitoring of groundwater levels. The measured groundwater levels to date are summarized in Table 5.1.

Table 5.1 Measured Groundwater Levels

Borehole	Date	Groundwater Level (m)		Comment
		Depth (m)	Elevation (m)	
SM10-01	Nov. 22, 2012	0.6	163.2	Open borehole
SM10-02	Nov. 22, 2012	0.0	163.0	Open borehole
SM10-03	Dec. 10, 2012 Dec. 12, 2012 Dec. 18, 2012	1.5* 1.0* 0.9*	164.6* 164.1* 164.0*	Piezometer
SM10-04	Nov. 20, 2012	0.1	164.3	Open borehole
SM10-05	Nov. 22, 2012	0.1	163.5	Open borehole
SM10-06	Oct. 24, 2012 Oct. 26, 2012 Nov. 29, 2012 Dec. 4, 2012 Dec. 12, 2012	0.9 0.8 1.0 1.1 1.7	168.7 168.8 168.6 168.5 167.9	Piezometer (deep)
	Oct. 24, 2012 Oct. 26, 2012 Nov. 29, 2012 Dec. 4, 2012 Dec. 12, 2012	0.9 0.8 0.8 0.8 1.5	168.7 168.8 168.8 168.8 168.1	Piezometer (shallow)
SM10-07	Nov. 29, 2012 Dec. 4, 2012 Dec. 12, 2012	2.7 2.6 3.1	160.9 161.0 160.5	Piezometer
SM10-08	Nov. 27, 2012	1.5	161.7	Open borehole
SM10-09	Dec. 7, 2012	1.0	160.0	Open borehole
SM10-10	Dec. 11, 2012	2.4	165.1	Open borehole
SM10-12	Oct. 22, 2012 Oct. 26, 2012 Nov. 29, 2012 Dec. 4, 2012 Dec. 12, 2012	3.0 2.8 2.9 2.8 2.8	164.9 165.1 165.0 165.1 165.1	Piezometer (deep)
	Oct. 22, 2012 Oct. 26, 2012 Nov. 29, 2012 Dec. 4, 2012 Dec. 12, 2012	2.7 2.4 2.5 2.5 2.8	165.2 165.6 165.4 165.4 165.1	Piezometer (shallow)
SM9-06	Dec 13, 2012	0.2*	164.8*	Piezometer
		Destroyed immediately after initial reading		

* Artesian condition – piezometric level above ground surface.

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 periods of high creek water level, after the spring snowmelt or after periods of heavy precipitation. It should be noted that artesian groundwater conditions were encountered in Boreholes SM10-03 and SM9-06.

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 Messrs. George Azzopardi and Stephane Loranger of Thurber. Geotechnical 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 Dr. Sydney Pang, P.Eng.

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and also presents geotechnical recommendations for design of the Highway 407 EBL and WBL twin bridge crossing (Structure M-10) over Brougham Creek Tributary "B". The plans and profiles used for preparation of this report were provided by MMM Group Limited.

The proposed overpass structures, as shown on the General Arrangement (GA) drawing dated July 2012, are single span structures with a total supported length of 38.0 m and deck width of about 22 to 23 m. Each bridge will carry three through lanes of traffic along with one speed change lane and two shoulders. However, it is understood from discussions with the designers that the foundations and sub-structure will be constructed to the ultimate width. The structure is to be skewed at approximately 12°15". Integral abutments are proposed with each abutment supported on a single row of H-Piles. The undersides of the abutments are proposed at Elevations 165.61 and 166.20 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 in the order of 9 to 11 m above the floodplain. Observations made during our site visits and borehole drilling program indicate the presence of springs and seepage zones on the existing slopes. Piezometric measurements to date reveal the presence of artesian groundwater conditions below the floodplain. Recommendations on specific drainage requirements for the valley slopes are included herein.

8 STRUCTURE FOUNDATIONS

In general terms, the subsurface at the site consists of surficial peat and organics (especially on the west slope) overlying interlayered deposits of compact to very dense sand and gravel, sand to silty sand and sandy silt with occasional cobbles and/or boulders typically encountered in the sand and gravel deposits and the dense to very dense silty sand till. Near the east abutment of the EBL bridge, the surficial silts, sands and gravel are underlain by a relatively thick deposit of hard silty clay, although its lateral extent has not been well defined in the boreholes. The observed water levels in open boreholes and piezometric levels measured in the boreholes typically lie within 3 m depth immediately below ground surface. Artesian condition of up to an equivalent hydrostatic head of 1 m above ground surface was observed in Borehole SM10-03 located near the approach to the proposed east abutment of the WBL bridge. A small artesian head of 0.2 m above ground surface was also noted in Borehole SM9-06 drilled at the west approach to the EBL bridge.

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 including the presence of up to 1.2 m of peat on the west slope underlain by compact soils, and in view of the shallow groundwater table, artesian conditions, the observed seepage on the west slope face as well as the environmental concerns associated with the creek valley, it is considered that spread footings are not a feasible foundation 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

Due to similar reasons stated above, it is also considered that spread footings bearing on engineered fill consisting of compacted Granular "A" pad are also not a feasible foundation option for the bridge configuration currently considered. However, spread footings on engineered fill pads perched at higher elevations within the approach embankments may be considered if longer bridge decks are to be used. This option is not pursued further at this moment.

8.3 Caissons

Initial consideration was given to the use of caisson foundations to support the abutments. While the founding soils are dense to very dense and potentially could provide high resistance, they are predominantly cohesionless with gravelly layers that are relatively permeable. Caissons would have to be founded below the water table and under artesian conditions at some locations 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. For both abutments of the WBL bridge, steel HP 310x110 piles driven to refusal within the very dense (100-blow) silty sand to sand and silt till, or sand and gravel, may be designed for the geotechnical resistances presented in Table 8.1 below based on the estimated tip elevations shown. At the east abutment of the EBL bridge, a deposit of silty clay exists and will likely be the end-bearing stratum for the piles.

Table 8.1 Estimated Tip Elevations and Axial Resistances for Steel H-piles

Locations	Estimated Pile Tip Elevation (m)	Factored ULS Resistance (kN)	SLS Resistance (kN)
WBL West Abutment (SM10-04, SM10-05 and SM10-06)	At or below 156	1600	1400
WBL East Abutment (SM10-01, SM10-02 and SM10-03)	At or below 156		
EBL West Abutment (SM10-10, SM10-12 and SM9-06)	At or below 156	1600	1400
EBL East Abutment (SM10-08 and SM10-09)	Between 151 and 139*		

Note: * Due to the absence of "100-blow" material until below Elevation 139 m and the presence of the extensive hard silty clay deposit as depicted in Borehole SM10-08, it is anticipated that some piles at this abutment may achieve the required capacity at tip elevations varying between 151 and below 139 m.

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

The tip elevations have been selected based on the level of the 100-blow material as indicated by the available boreholes and typically represent more than 5 m penetration below the base of the CSP. All 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 Artesian Groundwater Flow

Artesian groundwater was encountered on the east and west sides of the creek in Borehole SM10-03 drilled at the valley bottom and in Borehole SM9-06, respectively. The head was at approximately 0.2 to 1 m above ground surface, or at approximate Elevation 165 m.

Any upward artesian water seepage along the shafts of the driven piles will be filtered through the granular berm placed around the piles for facilitating pile driving prior to placement of the approach fills.

8.4.3 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.

Due to the bridge configuration in relation to the topography of the floodplain, an engineered fill berm will need to be constructed at each abutment location to provide a platform for driving the piles. The berm should consist of compacted OPSS Granular B Type II materials compacted in thin (not greater than 150 mm thick) loose lifts to at least 98% of the standard Proctor maximum dry density within ±2% of its optimum moisture content. The maximum particle size of this material should be limited to 75 mm or less in order not to impede penetration of the piles. Prior to placing the granular materials, the subgrade should be prepared as outlined in Section 9 below.

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.

8.4.4 Downdrag

Downdrag on the piles is not considered to be an issue at this site, since the silts, sands and gravel are in a typically dense to very dense state with low clay content, and the silty clay encountered below the sands and silts at the east abutment area of the EBL bridge has a hard consistency. Surficial loose to very loose sands and silts, and firm silty clay, will either be stripped or subject to subgrade preparation procedures prior to constructing the pile driving berm.

8.4.5 Abutment Type

The subsurface conditions at this site are considered suitable for integral or semi-integral 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.

8.4.6 Pile Lateral Resistance

The geotechnical lateral resistance of an H-pile embedded in the silts, sands and gravel may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = n_h\, z / D \quad (\text{kN/m}^3)$$

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

Where
z = depth of embedment of pile in metres
D = pile width in metres
n_h = coefficient of horizontal subgrade reaction
= 10,000 kN/m^3 (in dense to very dense soils)
γ = 20 kN/m^3 (total unit weight)
γ_w = 10 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, $k_s = k_s \times L \times D$ (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, $p_{ult} = p_{ult} \times L \times D$. 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 ULS_f and 50 kN at SLS.

The coefficient of horizontal 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 8.2 with intermediate values obtained by linear interpolation. Alternatively, horizontal loads may be resisted by means of battered piles.

Table 8.2 Reduction Factors for Coefficient of Horizontal 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 the abutment stem must be provided with a minimum of 1.2 m of earth cover as protection against frost action.

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 which includes the Granular B berm for pile driving. The GA drawing also indicates the proposed use of armour stone walls as erosion protection and to retain the forward slopes at the west and east abutment locations. The embankments up to the order of 11 m high should be stable at side slopes of 2H : 1V (or flatter) if constructed using SSM or granular fill, and provided the surficial 1 to 2 m of organics, very loose to loose sands and silts, and firm silty clay are stripped from the embankment footprint. If the peat and soft soils are removed below the embankment, no long term settlement or global stability issues are anticipated for approach embankments built at this site. It is also anticipated that the forward slopes would be stable provided that the armour stone walls are adequately designed and constructed as either gravity walls or tied-back walls.

In light of the artesian seepage conditions observed at the site, the following must be addressed for the design and construction of the approach fills within the limits of the valley:

- Stripping a nominal 1 to 2 m of highly organic soil
- Seepage control during construction
- Permanent drainage of the seepage from below the embankments
- Prevent of loss of fines in the ongoing seepage
- Trafficability of the slope during construction

It is strongly recommended that the contract documents contain a NSSP directing bidders' attention to the soil conditions and requiring them to carry out a site visit during the tender period to make their own assessment of the ground conditions. Even if the inspection has to be carried out in winter, there would probably be several seepage areas that do not freeze which would present a good indication of what should be expected.

9.1 Stripping

All trees and other vegetation must be removed from the footprint of the embankment fill, and the roots and organic soil must be stripped to expose the underlying mineral soil. The contract documents must make it clear that the Contractor will be expected to plan the stripping and other construction activities to take account of the known soil conditions and to minimize the disturbance to the subgrade.

The stripped soil will consist of wet, organic material (muck) probably containing tree roots and it will not be suitable for re-use as fill on the project. It may be considered for slope flattening or landscaping purposes.

9.2 Seepage Control During Construction

Constant seepage will occur from the slope during construction. These wet conditions will mean that the exposed subgrade can be easily disturbed by traffic and possibly some areas will be subject to erosion. This potentially high silt load must be taken into account when specifying the sediment control measures required for the site.

The contract should contain direction to the Contractor and provision for material quantities for the immediate control of localized seepage that is causing erosion on piping into the slope. The Contract Administrator should determine where treatment is needed.

Typically, the materials required will include non-woven geotextile and free draining granular materials.

9.3 Permanent Drainage

Due to the amount of seepage observed in the valley, it is recommended that a permanent drainage blanket be provided under the approach fills constructed in the valley. It is recommended that the drainage blanket consist of a 1.0 m thick layer of OPSS Granular "O" material. This material has a coarser grading than the native soils and will be more free-draining, and will act as a filter against the sandy soils on site. However, it will not filter the finer soils that may migrate with the seepage. For this reason and in order to provide separation between the native soil and the filter blanket, it is recommended that the drainage blanket be underlain by non-woven geotextile filter cloth.

The drainage blanket and filter cloth must extend continuously from toe to toe of the embankment and from Elevation 169.0 down slope to 1.0 m in front of the front face of the armour stone retaining wall. The filter cloth must be wrapped back over the drainage blanket and under the retaining wall to the back face of the wall and extend continuously up the back face to the top of the wall, assuming that the wall is being designed as a gravity structure. If tie-back strips are being incorporated, then the geotextile can only wrap up to the level of the lowest strip. In this case, the granular fill behind the wall must be graded to act as a granular filter and prevent loss of fines through the wall.

Lateral drains, e.g. "Big-O" in geosock, are recommended at the base of the drainage layer behind the abutment and approximately 10 m upslope from the abutment.

The Granular B berms for pile driving should be built on top of the drainage blanket or could be constructed of Granular O at the Contractor's option.

The toe treatment of the embankments below Elevation 169.0 must consist of a rock lined ditch with geotextiles. The rock lining and geotextiles must extend for a minimum of 1.0m up the embankment slope.

The embankment fill above the drainage blanket may consist of granular or SSM as discussed previously.

9.4 Trafficability

The valley lands will be wet and the existing surficial soils are soft to very soft or loose to very loose.

It is recommended that the contract documents contain clear language to alert the bidders to these conditions and the requirement for the successful bidder to carry out the stripping and construction in a manner that does not disturb the subgrade.

10 EROSION CONTROL

Erosion and scour protection must be provided for the bridge foundations. In general, the armour stone walls at the forward slopes will extend above high water level at Elevation 164.3 m. Design of erosion protection measures including the walls must also 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" silty sand to sand and silt till, and the hard silty clay, may be classified as Type 2 soils. After removal of surface vegetation on the valley slopes, excavation of peat, organics 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 may 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.

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 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 parameters 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

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	0.27	0.40	0.31	0.48
Passive	3.7	-	3.3	-
At Rest	0.43	-	0.47	-

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 2. 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 and assuming that the surficial loose sands and silts, and firm silty clay are sub-excavated, 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

Where required, 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	=	0	Not applicable for permeable walls

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, as wells as the extensive silty clay deposit.

- The armour stone wall must be adequately designed and constructed to provide erosion protection as well as retention of the forward slopes.
- The successful performance of the overpass will depend largely depend upon good workmanship and quality control during construction. Pile driving supervision, armour stone and forward slope construction, 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.

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.

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Review Principal

Appendix A

Record of Borehole Sheets

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**		**Field Estimation of Hardness***
	(MPa)	**(psi)**	
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 SM10-01

METRIC

WP# E2-2012	LOCATION N 4 864 873.4 E 337 433.8	ORIGINATED BY GA
HWY 407	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2012.11.22 - 2012.11.22	CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
163.8 / 0.0	Silty **SAND**, some clay, occasional rootlets and organics; Very Loose; Brown; Wet	1	SS	2	∇			
		2	SS	2				
162.4 / 1.4	**SAND**, some gravel, some silt; Compact; Grey; Wet	3	SS	17				
		4	SS	12				
160.8 / 3.0	**SAND** and **GRAVEL**, some silt; Dense; Grey; Wet	5	SS	35				38 45 17 (SI+CL)
		6	SS	35				
	occasional cobbles and boulders; Very Dense	7	SS	50/ 0.150				35 54 11 (SI+CL)
	Augers grinding							
		8	SS	50/ 0.150				
		9	SS	89				

Elevation scale: 163, 162, 161, 160, 159, 158, 157, 156, 155, 154

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O 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

Continued Next Page

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

ONTMT4S 1130A.GPJ 12/18/12

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-01

METRIC

WP# E2-2012	LOCATION N 4 864 673.4 E 337 433.8		ORIGINATED BY GA
HWY 407	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2012.11.22 - 2012.11.22		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: O 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										
	SAND and **GRAVEL**, some silt, occasional cobbles and boulders Very Dense Grey Wet		10	SS	94		153		o		
152.7 11.1	END OF BOREHOLE AT 11.1m. WATER LEVEL AT 0.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

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+ ³, × ³: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-02

METRIC

WP#	E2-2012	LOCATION	N 4 864 861.5 E 337 447.0	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.22 - 2012.11.23	CHECKED BY	LRB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
163.0					163					
0.0	Silty **CLAY**, some organics, trace sand, Very Soft, Brown, Wet	1	SS	2						
		2	SS	2	162					
161.8 / 1.2	**SAND**, trace to some gravel, trace to some silt, trace roots, Compact, Brown to Grey, Wet	3	SS	17	161					
		4	SS	14			0	90	10 (SI+CL)	
		5	SS	15	160					
					159					
	becoming Dense	6	SS	30	158					
156.9 / 6.1	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles and boulders, Very Dense, Grey, Moist	7	SS	113	157					
	Wet				156					
		8	SS	128	155		46	44	10 (SI+CL)	
		9	SS	82	154					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; 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; 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 12/21/12

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-02

METRIC

WP#	E2-2012	LOCATION	N 4 864 861.5 E 337 447.0	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.22 - 2012.11.23	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	GR	SA	SI	CL
	SAND and **GRAVEL** Very Dense Grey Wet				153				
		10	SS	113	152				
150.8 12.2	Sandy **SILT**, some clay Very Dense Grey Wet	11	SS	115	151	0	25	64	11
	Slight artesian water flow observed between 12.2m and 13.7m, water flow stopped with augers pulled up				150				
149.1 13.9	END OF BOREHOLE AT 13.9m. BOREHOLE OPEN TO 6.1m AND WATER LEVEL AT GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.	12	SS	103					

ONTMT4S 1130A.GPJ 12/21/12

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-03

METRIC

WP#	E2-2012	LOCATION	N 4 864 861.9 E 337 444.6
HWY	407	BOREHOLE TYPE	Hollow Stem Augers
DATUM	Geodetic	DATE	2012.12.10 - 2012.12.10

ORIGINATED BY GA
COMPILED BY AN
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)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
163.1								
0.0	**PEAT**, clayey, trace sand, occasional rootlets Very Soft Dark Brown Wet	1	SS	0				
162.5 0.6	**SAND** and **GRAVEL**, trace silt Compact Dark Grey Wet	2	SS	13				
		3	SS	21	61	34	5 (SI+CL)	
	Grey	4	SS	17				
		5	SS	16				
	Augers filled with water							
	becoming Very Dense	6	SS	67	60	32	8 (SI+CL)	
157.0 6.1	Gravelly **SAND**, trace silt Very Dense Grey Wet	7	SS	104				
		8	SS	132	21	72	7 (SI+CL)	
	Slight artesian water flow observed (0.6m head above ground surface); water flow stopped as drilling progressed.	9	SS	106/ 0.150				

Elevation scale: 163, 162, 161, 160, 159, 158, 157, 156, 155, 154

Continued Next Page

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-03

METRIC

WP#	E2-2012	LOCATION	N 4 864 861.9 E 337 444.6	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.10 - 2012.12.10	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT (WATER CONTENT %)	UNIT WEIGHT kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						153				
152.3 / 10.8	Silty **CLAY**		10	SS	107				○		
152.1 / 11.0	END OF BOREHOLE AT 11.0m. WATER LEVEL AT 0.3m. WHEN AUGERS PULLED OUT.										

Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Dec. 10/12	1.5*	164.6
Dec. 12/12	1.0*	164.1
Dec. 18/12	0.9*	164.0

NOTE:
* ABOVE GROUND SURFACE (ARTESIAN CONDITION)

Legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-04

METRIC

WP#	E2-2012	LOCATION	N 4 864 828.4 E 337 413.5	ORIGINATED BY	RK
HWY	407	BOREHOLE TYPE	Portable B-Casing (Tri-pod)	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.20 - 2012.11.20	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
164.4 / 0.0	**PEAT**, with roots and rootlets Black Saturated				∇ (water level 0.1 m)		
163.3 / 1.1	**SAND** and **SILT**, trace clay, trace gravel Loose to Compact Grey Wet	1	SS	14		o	
		2	SS	5		o	
		3	SS	7		o	4 37 50 9
		4	SS	19		o	
160.3 / 4.1	**SAND**, some silt, trace to some gravel Very Dense Grey Wet	5	SS	63		o	
	No sample recovery, possible cobble	6	SS	100/ 0.275			
157.7 / 6.7	END OF BOREHOLE AT 6.7m. WATER LEVEL AT 0.1m DURING DRILLING. BOREHOLE CAVED TO 2.4m UPON COMPLETION. BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG.						

Elevation scale: 164, 163, 162, 161, 160, 159, 158

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O 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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-05

METRIC

WP#	E2-2012	LOCATION	N 4 864 822.9 E 337 431.3	ORIGINATED BY	RK
HWY	407	BOREHOLE TYPE	Portable B-Casing (Tri-pod)	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.22 - 2012.11.22	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
163.6 / 0.0	**PEAT**, roots and rootlets Black Saturated					▽ (0.1 m)	163						
162.6 / 1.1	Sandy **SILT**, trace clay, trace gravel Loose to Compact Grey Wet		1	SS	8			~38					
			2	SS	15		162	~38					
161.3 / 2.3	**SAND**, some silt, trace to some gravel, trace clay Compact to Very Dense Grey Wet		3	SS	26		161	~15					
			4	SS	71		160	~19		6	75	15	4
159.1 / 4.6	Casing blocked by gravel; unable to take sample at 4.6m												

END OF BOREHOLE AT 4.6m. WATER LEVEL AT 0.1m DURING DRILLING. BOREHOLE CAVED UPON COMPLETION.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O 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, × ³: Numbers refer to Sensitivity

15-◯-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-06

METRIC

WP#	E2-2012	LOCATION	N 4 864 803.7 E 337 401.3	ORIGINATED BY	SLL
HWY	407	BOREHOLE TYPE	Solid Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.10.22 - 2012.10.22	CHECKED BY	LRB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
169.6	
0.0	**TOPSOIL**, with roots and rootlets: (150mm)
0.2	Clayey **SILT**, some sand, trace gravel, trace roots and rootlets Firm Brown Moist (TILL) Hard
167.5 / 2.1	**SAND** and **GRAVEL**, some silt Dense Brown/Grey Wet
165.3 / 4.3	**SAND**, coarse grained, some silt, trace gravel Compact to Very Dense Brown/Grey Wet
161.6 / 8.0	Silty **SAND**, some gravel Very Dense Brown Moist to Wet (TILL) Occasional cobbles Grey

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	7	
2	SS	31	
3	SS	36	36 56 8 (SI+CL)
4	SS	34	
5	SS	20	
6	SS	40	
7	SS	100	
8	SS	84	

GROUND WATER CONDITIONS

ELEVATION SCALE: 169, 168, 167, 166, 165, 164, 163, 162, 161, 160

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 SM10-06

METRIC

WP#	E2-2012	LOCATION	N 4 864 803.7 E 337 401.3	ORIGINATED BY	SLL
HWY	407	BOREHOLE TYPE	Solid Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.10.22 - 2012.10.22	CHECKED BY	LRB

SOIL PROFILE | SAMPLES | 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	GR	SA	SI	CL
	Silty **SAND**, some gravel Very Dense Brown Moist to Wet (TILL)				159				
	Occasional inferred cobbles	9	SS	87		22	51	27 (SI+CL)	
					158				
	Some clay to clayey	10	SS	100/ 0.225	157				
156.3 / 13.3	Sandy **SILT**, trace to some clay, trace gravel Very Dense Grey Moist				156				
		11	SS	100/ 0.225		1	24	63	12
					155				
	No sample recovery due to cobbles or boulders	12	SS	100/ 0.050					
154.3 / 15.3	END OF BOREHOLE AT 15.3m.								

Monitoring well installation consists of two 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

DEEP WELL
WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 24/12	0.9	168.7
Oct. 26/12	0.8	168.8
Nov. 29/12	1.0	168.6
Dec. 04/12	1.1	168.5
Dec. 12/12	1.7	167.9

SHALLOW WELL
WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 24/12	0.9	168.7
Oct. 26/12	0.8	168.8
Nov. 29/12	0.8	168.8
Dec. 04/12	0.8	168.8
Dec. 12/12	1.5	168.1

ONTMT4S 1130A.GPJ 12/21/12

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-07

METRIC

WP#	E2-2012	LOCATION	N 4 864 857.4 E 337 491.0	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.26 - 2012.11.26	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
163.6 / 0.0	Silty **CLAY**, some sand, with organics and rootlets, Firm, Brown, Moist	1	SS	5						
		2	SS	8	163					
162.2 / 1.4	**SAND**, some silt, trace gravel, Dense, Brown, Wet	3	SS	34	162					
161.3 / 2.3	Silty **SAND**, some gravel, trace clay, Dense, Brown, Wet (TILL)	4	SS	38	161		11	49	30	10
160.5 / 3.0	**SAND** and **GRAVEL**, trace silt, Dense, Brown, Wet	5	SS	46	160					
159.1 / 4.4	Sandy **SILT**, Dense, Grey, Wet	6	SS	57	159, 158					
157.5 / 6.1	**SAND**, trace to some gravel, trace silt, Dense to Very Dense, Brown/Grey, Wet	7	SS	32	157		15	78	7 (SI+CL)	
156.9 / 6.7	Loose	8	SS	6	156, 155					
154.9 / 8.7		9	SS	102	154					

Column headings: SOIL PROFILE; SAMPLES; 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

15 (20, 5, 10) (%) STRAIN AT FAILURE

ONTMT4S 1130A.GPJ 12/21/12

RECORD OF BOREHOLE No SM10-07

METRIC

WP#	E2-2012	LOCATION	N 4 864 857.4 E 337 491.0
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone
DATUM	Geodetic	DATE	2012.11.26 - 2012.11.26

ORIGINATED BY GA
COMPILED BY AN
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	GR	SA	SI	CL
152.9 / 10.7	Silty **SAND**, trace gravel, Very Dense, Grey, Wet (TILL)	10	SS	152				
151.4 / 12.2	Silty **CLAY**, Hard, Grey	11	SS	104	0	0	60	40
151.1 / 12.5								

Elevation scale: 153, 152

END OF BOREHOLE AT 12.5m.
WATER LEVEL AT 3.0m UPON COMPLETION.

Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Nov. 29/12	2.7	160.9
Dec. 04/12	2.6	161.0
Dec. 12/12	3.1	160.5

ONTMT4S 1130A.GPJ 12/21/12

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-08

METRIC

WP#	E2-2012	LOCATION	N 4 864 853.1 E 337 476.5
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone
DATUM	Geodetic	DATE	2012.11.27 - 2012.11.27

ORIGINATED BY: GA
COMPILED BY: AN
CHECKED BY: LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
163.2 / 0.0	**SAND**, some silt, trace to some gravel, trace clay, occasional rootlets Loose Brown Moist (TILL)		1	SS	6		12 62 19 7
			2	SS	7		
162.0 / 1.2	Silty **CLAY**, with sand, trace gravel Very Stiff Brown		3	SS	16	∇	
160.8 / 2.4	**SAND**, trace to some silt Compact to Very Dense Grey Wet		4	SS	20		
			5	SS	18		0 90 10 (SI+CL)
			6	SS	50		
	Filled augers with water						
157.1 / 6.1	Silty **SAND**, trace gravel, some clay, occasional cobbles Very Dense Grey Wet (TILL)		7	SS	68		9 57 23 11
	Started tri-coning						
155.6 / 7.6	**SAND**, some gravel to gravelly, trace silt Very Dense Grey Wet		8	SS	110		
154.1 / 9.1	Silty **CLAY** Hard Grey Wet		9	SS	42		

ELEVATION SCALE: 163, 162, 161, 160, 159, 158, 157, 156, 155, 154

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 SM10-08

METRIC

WP#	E2-2012	LOCATION	N 4 864 853.1 E 337 476.5	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.11.27 - 2012.11.27	CHECKED BY	LRB

SOIL PROFILE | SAMPLES | 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 (%)

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	Silty **CLAY** Hard Grey Wet				153				
		10	SS	37	152				
		11	SS	42	151				
					150				
		12	SS	43	149	0	0	28	72
		12	SS	42	148				
					147				
		13	SS	44	146				
		14	SS	51	145				
					144				

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No SM10-08

METRIC

WP#	E2-2012	LOCATION	N 4 864 853.1 E 337 476.5
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone
DATUM	Geodetic	DATE	2012.11.27 - 2012.11.27

ORIGINATED BY GA
COMPILED BY AN
CHECKED BY LRB

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, Hard, Grey, Wet	15	SS	60	143	○	
		16	SS	48	142	○ (WP–WL plotted)	0 0 36 64
		17	SS	52	140	○	
		18	SS	103	139 / 138	○	
137.6 / 25.6	**SAND**, fine grained, Very Dense, Grey, Wet	19	SS	100/ 0.150	137	○	
135.8 / 27.4	Sandy **SILT**, Very Dense, Grey, Wet	20	SS	100	136	○	
135.3 / 27.9	END OF BOREHOLE AT 27.9m. WATER LEVEL AT 1.5m UPON COMPLETION. BOREHOLE GROUTED UPON COMPLETION.						

Legend: 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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-09

METRIC

WP#	E2-2012	LOCATION	N 4 864 840.5 E 337 491.0	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.07 - 2012.12.07	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
161.0 / 0.0	**PEAT**, clayey, with sand, trace rootlets, Very Soft, Dark Brown, Wet	1	SS	0		144				
160.3 / 0.7	**SAND**, trace to some silt, trace gravel, trace organics, Very Loose to Compact, Grey, Wet	2	SS	0	∇ (approx. El. 160.1)					
		3	SS	0						
		4	SS	4						
		5	SS	12			0	93	7 (SI+CL)	
156.4 / 4.6	**SAND** and **GRAVEL**, some silt, Compact to Dense, Grey, Wet	6	SS	12						
		7	SS	39			40	43	17 (SI+CL)	
153.4 / 7.6	**SAND**, Very Dense, Grey, Wet	8	SS	58						
151.8 / 9.1	Silty **CLAY**, Hard, Grey, Wet	9	SS	120						

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O 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 (%). Elevation scale 161 to 152.

Continued Next Page

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-09

METRIC

WP#	E2-2012	LOCATION	N 4 864 840.5 E 337 491.0	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.07 - 2012.12.07	CHECKED BY	LRB

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page					151	
	Silty **CLAY** Hard Grey Wet	10	SS	115		150	0 0 41 59
						149	
148.3		11	SS	108			
12.6	END OF BOREHOLE AT 12.6m. WATER LEVEL AT 1.0m UPON COMPLETION. BOREHOLE BACFKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.						

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O 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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-10

METRIC

WP#	E2-2012	LOCATION	N 4 864 797.8 E 337 431.9	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.11 - 2012.12.11	CHECKED BY	LRB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
168.1						
0.0	**TOPSOIL:** (125mm)					168
0.1	Silty **CLAY**, occasional rootlets Firm to Very Stiff Brown	1	SS	7		
	trace to some sand, trace gravel	2	SS	8		167
		3	SS	11		166
		4	SS	24	∇	
165.0 3.1	**SAND**, trace gravel, trace silt Compact to Very Dense Brown Wet	5	SS	19		165
						164
		6	SS	20		163
	Grey	7	SS	70		162
	Filled augers with water					161
		8	SS	63		160
		9	SS	111		159

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-10

METRIC

WP# E2-2012 | LOCATION N 4 864 797.8 E 337 431.9 | ORIGINATED BY GA

HWY 407 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2012.12.11 - 2012.12.11 | CHECKED BY LRB

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace gravel, trace silt Compact to Very Dense Grey Wet					158			
		10	SS	106			○		
						157			
155.9 12.2	**SILT**, trace sand Very Dense Grey Wet	11	SS	103/ 0.150		156	○		
						155			
		12	SS	112/ 0.150			○		
						154			
153.4 14.7	**SAND**, trace silt, trace gravel Very Dense Grey Wet (TILL)					153			
152.7 15.4		13	SS	104/ 0.150			○		
	END OF BOREHOLE AT 15.4m. WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE CAVED TO 7.9m, BACKFILLED WITH BENTONITE HOLEPLUG 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

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

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SM10-12

METRIC

WP#	E2-2012	LOCATION	N 4 864 783.7 E 337 442.2	ORIGINATED BY	SLL
HWY	407	BOREHOLE TYPE	Solid Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.10.19 - 2012.10.19	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
167.9					
0.0 / 167.6	**TOPSOIL**, with roots and rootlets: (275mm)				
0.3	**SILT** and **SAND**, some clay, trace gravel, Loose to Dense, Brown, Moist (TILL)	1	SS	8	
		2	SS	10	6 40 36 18
		3	SS	44	
164.9 / 3.0	**SAND**, some gravel to gravelly, trace silt, Compact to Dense, Brown, Wet	4	SS	22	
	Grey	5	SS	24	19 68 13 (SI+CL)
		6	SS	31	
		7	SS	38	
159.1 / 8.8	**SILT** and **SAND**, some clay, trace gravel, Very Dense, Grey, Moist to Wet (TILL)	8	SS	50/ 0.150	5 39 43 13

Ground water level symbol shown at approx. elev. 165.2.

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (167 to 158); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O 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

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

ONTMT4S 1130A.GPJ 12/21/12

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM10-12

METRIC

WP#	E2-2012	LOCATION	N 4 864 783.7 E 337 442.2
HWY	407	BOREHOLE TYPE	Solid Stem Augers/Tricone
DATUM	Geodetic	DATE	2012.10.19 - 2012.10.19
ORIGINATED BY	SLL	COMPILED BY	AN
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
	SILT and **SAND**, some clay, trace gravel Very Dense Grey Moist to Wet (TILL)	9	SS	100/ 0.150	157
					156
		10	SS	100/ 0.175	155
		11	SS	100/ 0.125	154
153.5 / 14.4	**SAND**, some silt Very Dense Grey Wet				153
152.5 / 15.4	END OF BOREHOLE AT 15.4m.	12	SS	100/ 0.150	

END OF BOREHOLE AT 15.4m.
Monitoring well installation consists of two 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

DEEP WELL
WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 22/12	3.0	164.9
Oct. 26/12	2.8	165.1
Nov. 29/12	2.9	165.0
Dec. 04/12	2.8	165.1
Dec. 12/12	2.8	165.1

SHALLOW WELL
WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct. 22/12	2.7	165.2
Oct. 26/12	2.4	165.6
Nov. 29/12	2.5	165.4
Dec. 04/12	2.5	165.4
Dec. 12/12	2.8	165.1

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No SM9-06

METRIC

WP#	E2-2012	LOCATION	N 4 864 788.3 E 337 467.2	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.13 - 2012.12.13	CHECKED BY	LRB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
164.6		
0.0	**PEAT**, clayey, rootlets Very Soft Dark Brown Wet	(peat)
163.4 1.2	**SAND**, trace to some gravel, trace silt Compact to Loose Brown Wet	(sand)
	Grey	
	Filled augers with water becoming Very Dense	

SAMPLES

NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	0	160	
2	SS	2	267	
3	SS	13		
4	SS	12		11 84 5 (SI+CL)
5	SS	5		
6	SS	10		
7	SS	106		
8	SS	110		
9	SS	114/ 0.150		

GROUND WATER CONDITIONS

ELEVATION SCALE: 164, 163, 162, 161, 160, 159, 158, 157, 156, 155

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 SM9-06

METRIC

WP#	E2-2012	LOCATION	N 4 864 788.3 E 337 467.2	ORIGINATED BY	GA
HWY	407	BOREHOLE TYPE	Hollow Stem Augers/Tricone	COMPILED BY	AN
DATUM	Geodetic	DATE	2012.12.13 - 2012.12.13	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace gravel Very Dense Grey Wet								
						154			
			10	SS	102/ 0.150		○		11 87 2 (SI+CL)
						153			
152.3 / 12.3			11	SS	121/ 0.150		○		

END OF BOREHOLE AT 12.3m.
WATER LEVEL AT 0.6m UPON COMPLETION.
Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Dec. 19/12	0.2*	164.8

* Above ground surface (Artesian Condition)

NOTE:
Piezometer broken at 2.3m below ground surface.

Chart headings: 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; GROUND WATER CONDITIONS; REMARKS & GRAIN SIZE DISTRIBUTION (%).

$+^3, \times^3$: Numbers refer to Sensitivity   15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Appendix B

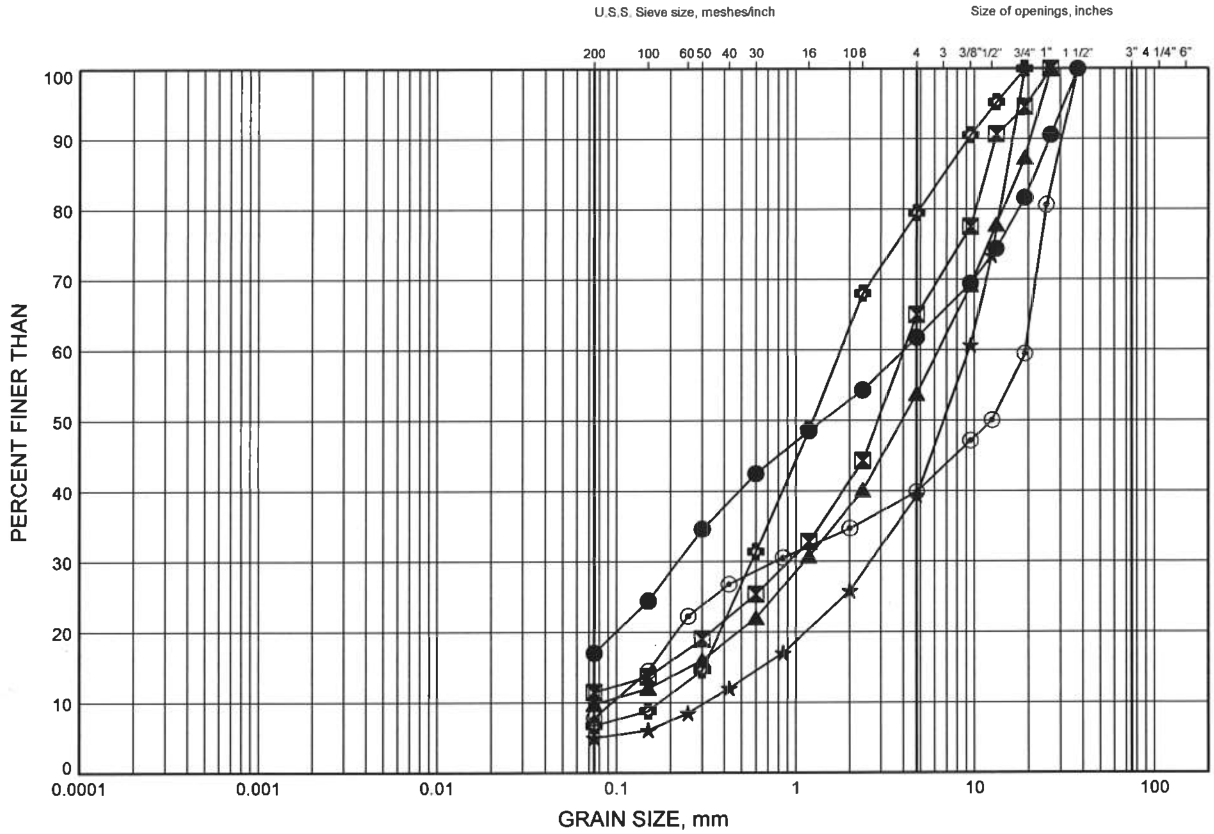
Geotechnical Laboratory Test Results

Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND and GRAVEL to Gravelly SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-01	3.35	160.46
⊠	SM10-01	6.40	157.41
▲	SM10-02	7.92	155.09
★	SM10-03	1.83	161.97
⊙	SM10-03	4.88	158.92
✿	SM10-03	7.92	155.87

Date December 2012

WP# E2-2012

THURBER

Prep'd MFA

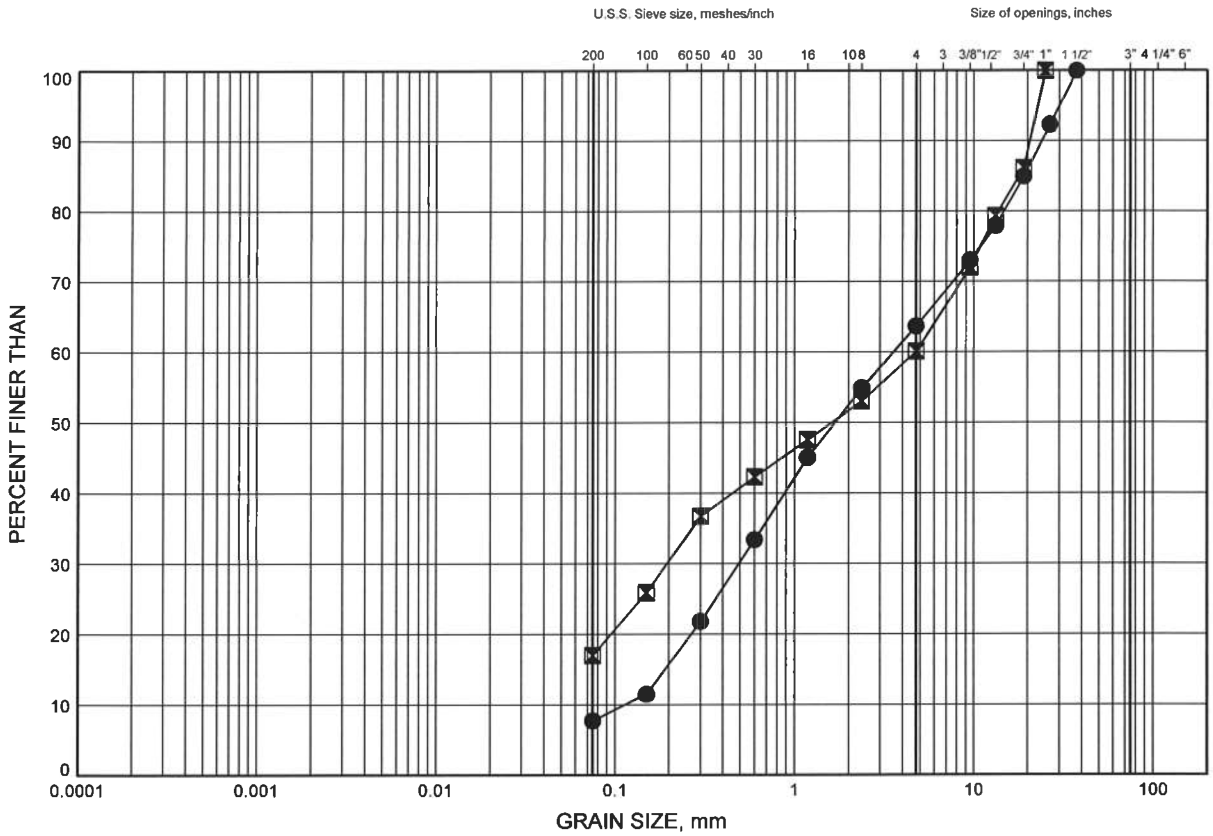
Chkd. SKP

Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND and GRAVEL to Gravelly SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-06	2.59	167.01
⊠	SM10-09	6.40	154.59

Date December 2012

WP# E2-2012

THURBER

Prep'd MFA

Chkd. SKP

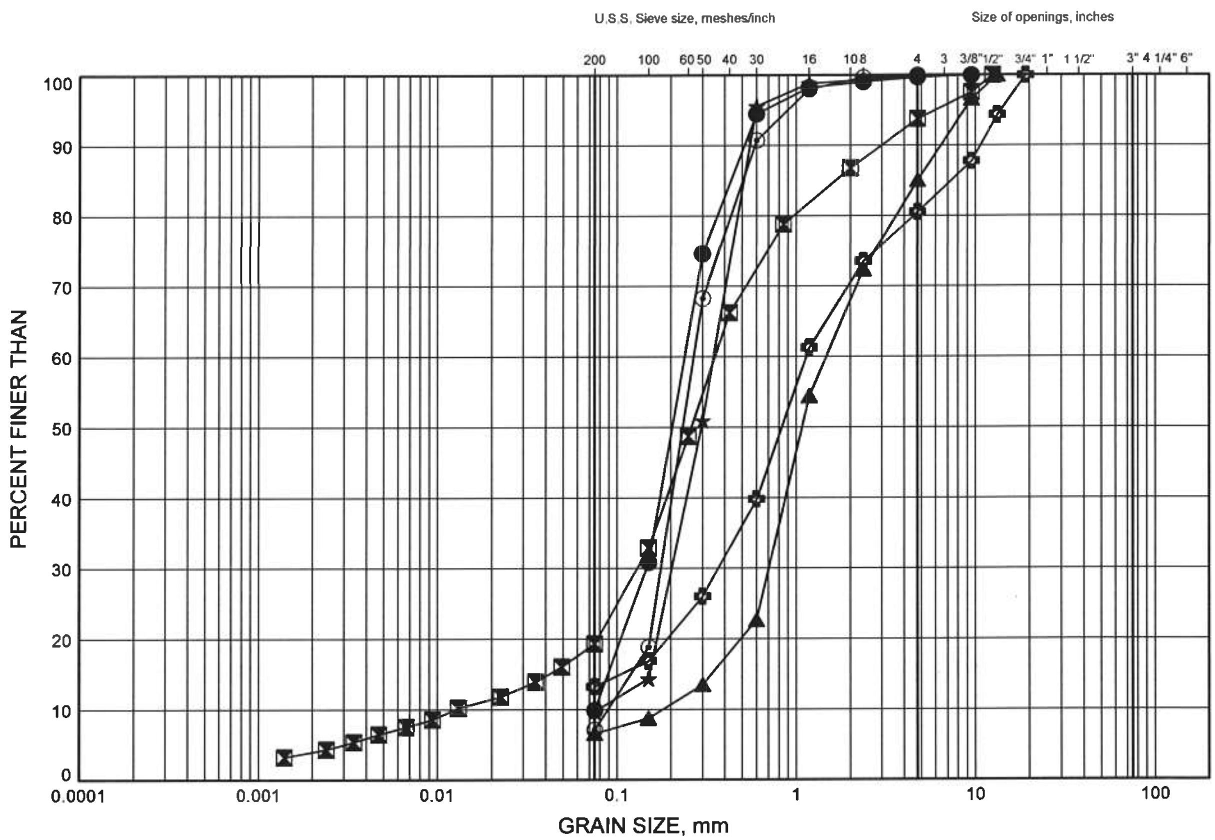
GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 12/19/12

Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-02	2.59	160.42
⊠	SM10-05	3.35	160.27
▲	SM10-07	6.40	157.16
★	SM10-08	3.35	159.85
⊙	SM10-09	3.35	157.64
✪	SM10-12	4.88	163.02

Date December 2012

WP# E2-2012

THURBER

Prep'd MFA

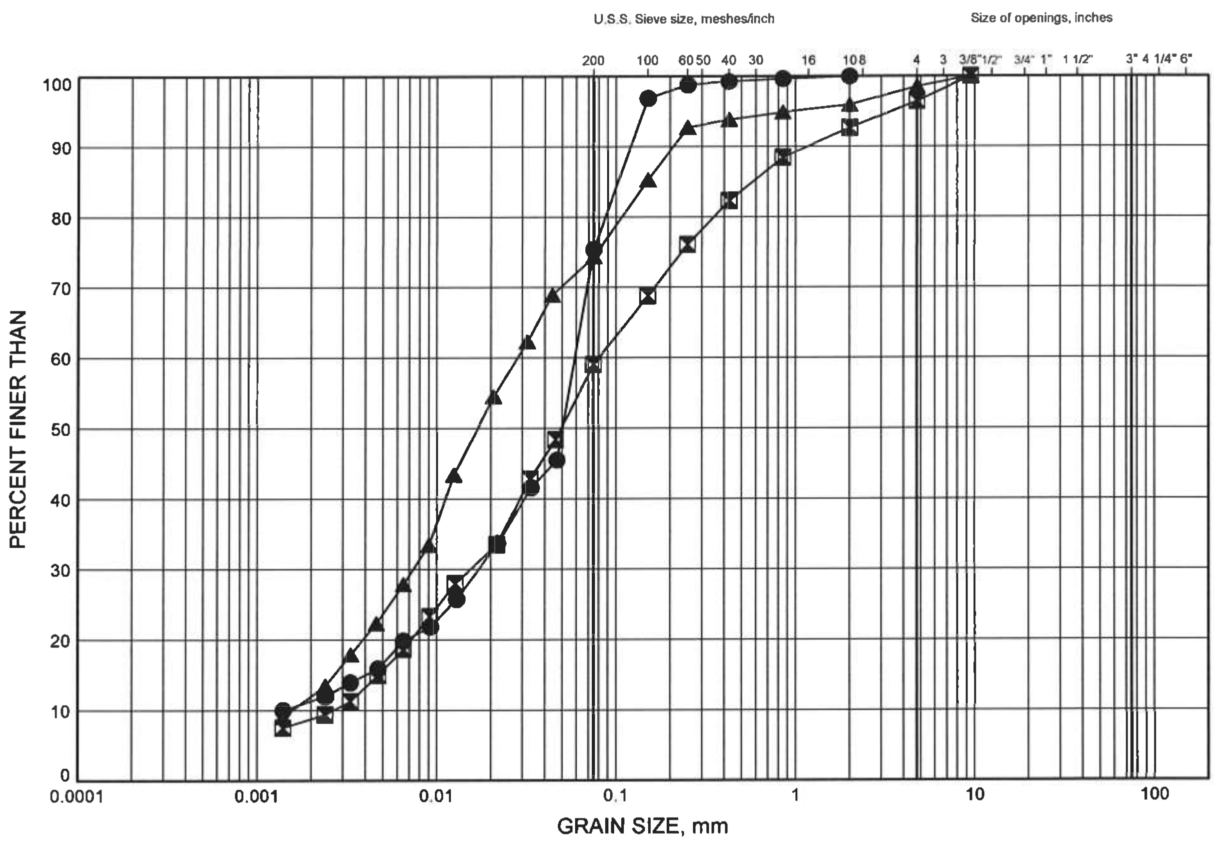
Chkd. SKP

Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4

Sandy SILT to SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-02	12.50	150.51
⊠	SM10-04	2.59	161.79
▲	SM10-06	13.83	155.77

Date December 2012

WP# E2-2012

THURBER

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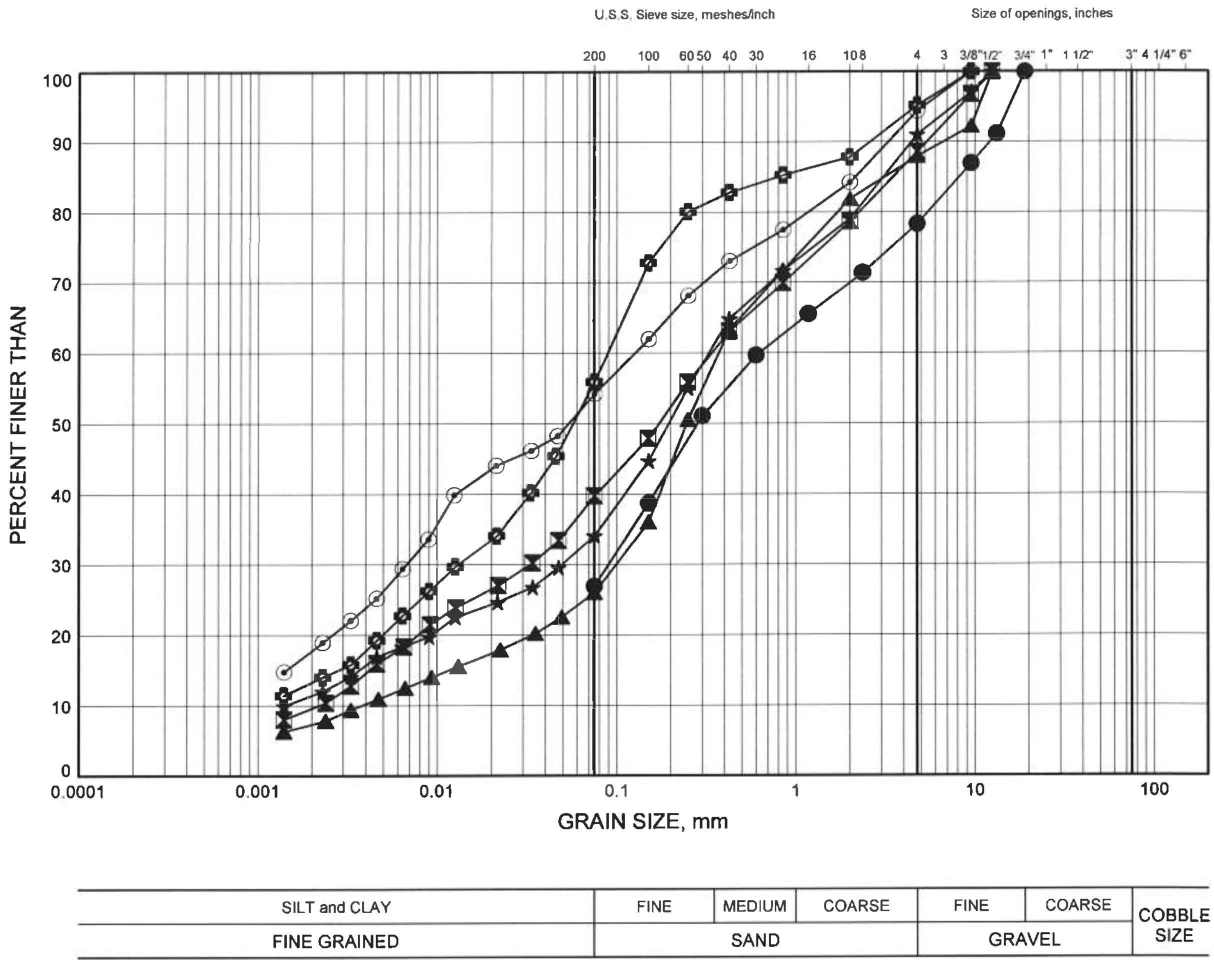
Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

Silty SAND to SILT and SAND TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-06	10.90	158.70
⧗	SM10-07	2.51	161.04
▲	SM10-08	0.30	162.90
★	SM10-08	6.40	156.80
⊙	SM10-12	1.83	166.07
✿	SM10-12	9.30	158.60

Date	December 2012	Prep'd	MFA
WP#	E2-2012	Chkd.	SKP

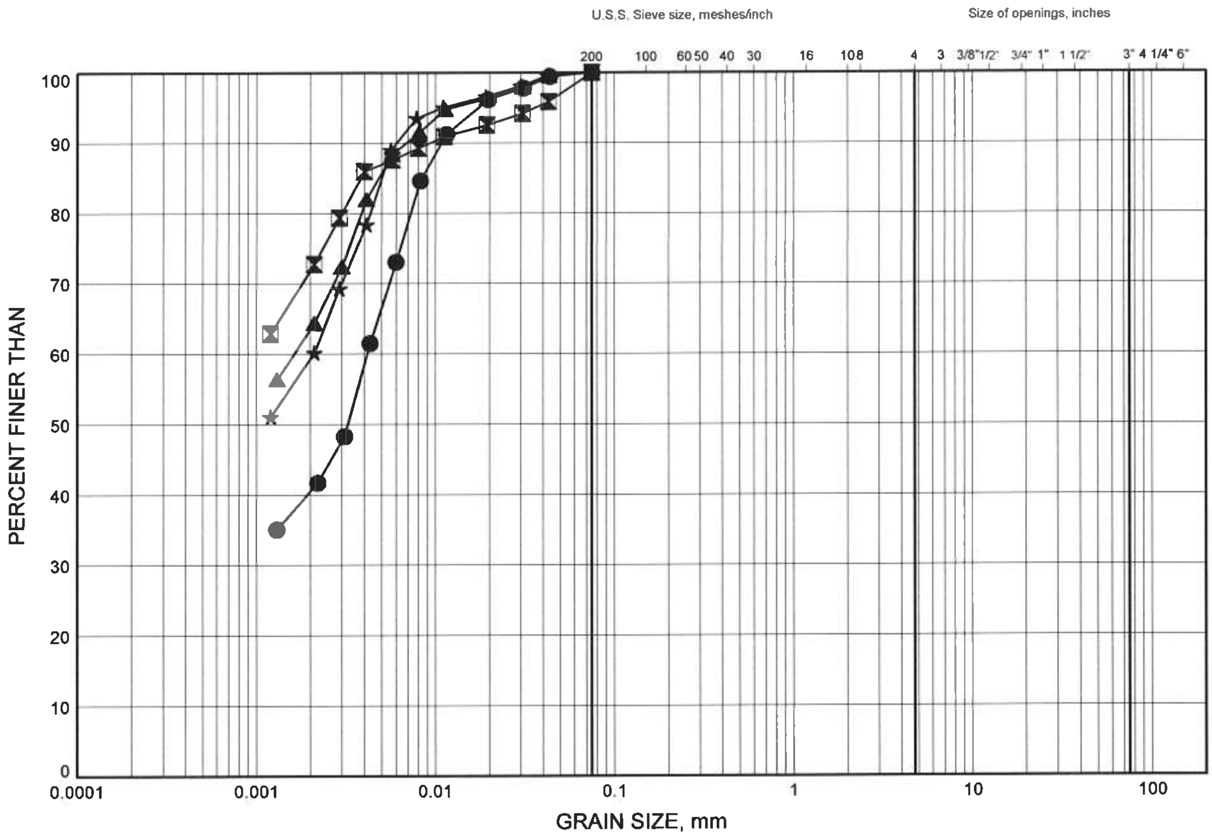
THURBER

Hwy 407 Brock Road Connection - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B6

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-07	12.34	151.21
⧗	SM10-08	14.02	149.18
▲	SM10-08	21.56	141.64
★	SM10-09	10.97	150.02

Date December 2012

WP# E2-2012

THURBER

Prep'd MFA

Chkd. SKP

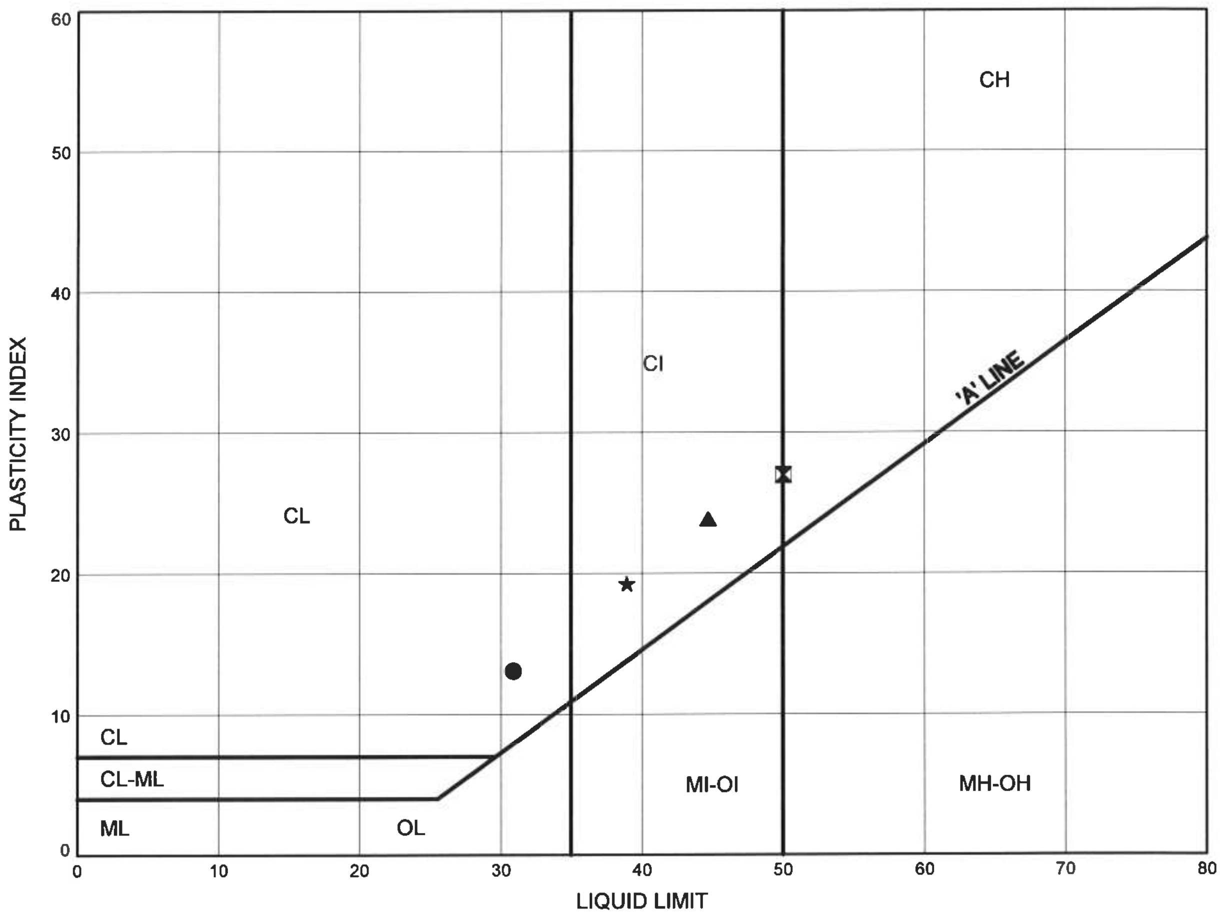
GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 12/21/12

Hwy 407 Brock Road Connection - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM10-07	12.34	151.21
⧗	SM10-08	14.02	149.18
▲	SM10-08	21.56	141.64
★	SM10-09	10.97	150.02

THURBALT 1130A.GPJ 12/21/12

Date December 2012

WP# E2-2012

THURBER

Prep'd MFA

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**

			SAMPLE DESCRIPTION:	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
Parameter	Unit	G / S	RDL	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

			SAMPLE DESCRIPTION:	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
Parameter	Unit	G / S	RDL	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 Polakowska

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**

			SAMPLE DESCRIPTION:	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
Parameter	Unit	G / S	RDL	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

			SAMPLE DESCRIPTION:	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
Parameter	Unit	G / S	RDL	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

Foundation Comparison

THURBER

COMPARISON OF FOUNDATION ALTERNATIVES FOR BRIDGE ABUTMENTS

Spread Footings on Native Soil	Spread Footings on Engineered Fill	Caissons	Driven H-Piles
Advantages: i. Generally less costly construction than deep foundation elements.	***Advantages:*** i. Generally less costly construction than deep foundation elements. ii. Footings on fill pads may be perched at higher elevations within the approach fills	***Advantages:*** i. Potentially higher geotechnical resistances than spread footings. ii. Construction of caissons could continue in freezing weather.	***Advantages:*** i. Higher geotechnical resistances can be achieved when piles are driven to practical refusal in the very dense glacial till ii. Installation of piles could continue in freezing weather iii. Foundation construction will require less volume of excavation than footings. iv. Required for integral abutment
Disadvantages: i. Dewatering and/or other forms of groundwater control (e.g. cofferdams) will be required to facilitate excavation to base of foundation for footing construction. ii. Concerns given the environmental sensitivity of the creek valley. iii. Risk of footing being undermined should the armour stone wall fail to provide scour protection along the creek banks.	***Disadvantages:*** i. Dewatering may be required, depending on depth of excavation. ii. Risk of footing being undermined should the armour stone wall fail to provide scour protection along the creek banks. iii. If footings are to be perched within the approach fills at higher elevations, a longer bridge span and therefore higher cost would result.	***Disadvantages:*** i. Higher costs 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. Concerns related to the above installation techniques given the environmental sensitivity of the creek valley. iv. Potential difficulty in maintaining undisturbed founding conditions due to unbalanced head in groundwater.	***Disadvantages:*** i. Higher unit costs than footings. ii. Pile lengths required to achieve design resistance may vary. iii. Compacted granular pad is required at each abutment location to facilitate pile driving.
NOT RECOMMENDED	**NOT RECOMMENDED**	**NOT RECOMMENDED**	**FEASIBLE**

Appendix D

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

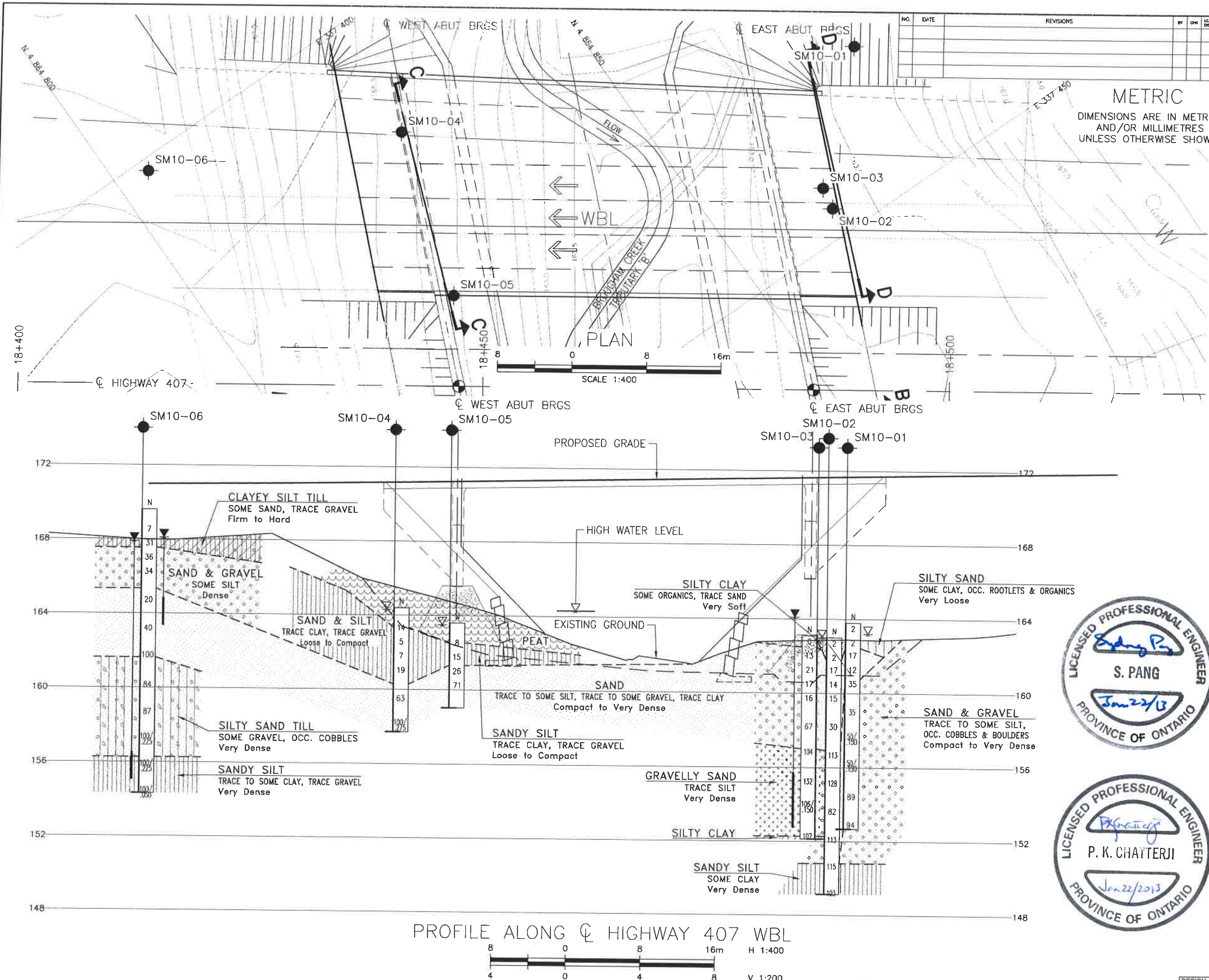
2. Suggested text for a NSSP on Pile Installation

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 E

Borehole Locations and Soil Strata Drawings



PROFILE ALONG ℄ HIGHWAY 407 WBL

H 1:400

V 1:200

CONTRACT No. E2-2012

HWY 407/BROCK ROAD INTERCHANGE

STRUCTURE M-10 (SITE 7)
PROPOSED HWY 407 WBL OVER
BROUGHAM CREEK TRIB. 'B'
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

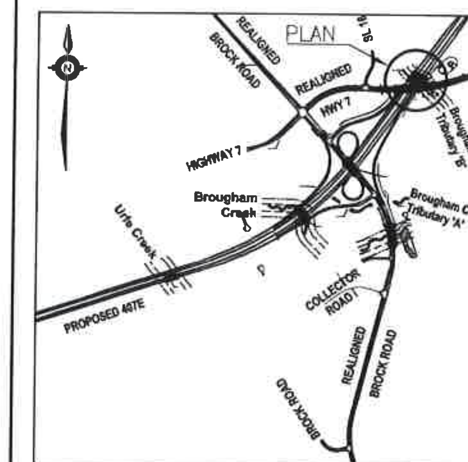
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

407 ETR Express Toll Route

MMM GROUP

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

⯁	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
SM10-01	163.8	4 864 873.4	337 433.8
SM10-02	163.0	4 864 861.5	337 447.0
SM10-03	163.1	4 864 861.9	337 444.6
SM10-04	164.4	4 864 828.4	337 413.5
SM10-05	163.6	4 864 822.9	337 431.3
SM10-06	169.6	4 864 803.7	337 401.3
SM10-07	163.6	4 864 857.4	337 491.0
SM10-08	163.2	4 864 853.1	337 476.5
SM10-09	161.0	4 864 840.5	337 491.0
SM10-10	168.1	4 864 797.8	337 431.9
SM10-12	167.9	4 864 783.7	337 442.2
SM9-06	164.6	4 864 788.3	337 467.2

LICENSED PROFESSIONAL ENGINEER S. PANG Jan 22/13 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER P. K. CHATTERJI Jan 22/2013 PROVINCE OF ONTARIO

-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.

NO.	DATE	REVISIONS	BY	CHK	LEAD DISC	PROJ MAN

DESIGN SKP	CHK AEG	CODE	LOAD	DATE JAN. 2013
DRAWN MFA	CHK SKP	SITE 7	STRUCT M-10	DWG 1

DRAWING NAME: H:\Drafting\19\5161\130\ted1130A-M10-BoreholePlan&Profile.dwg
CREATED: December 17, 2012 MODIFIED: January 23, 2013

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

CONTRACT No. E2-2012

HWY 407/BROCK ROAD INTERCHANGE

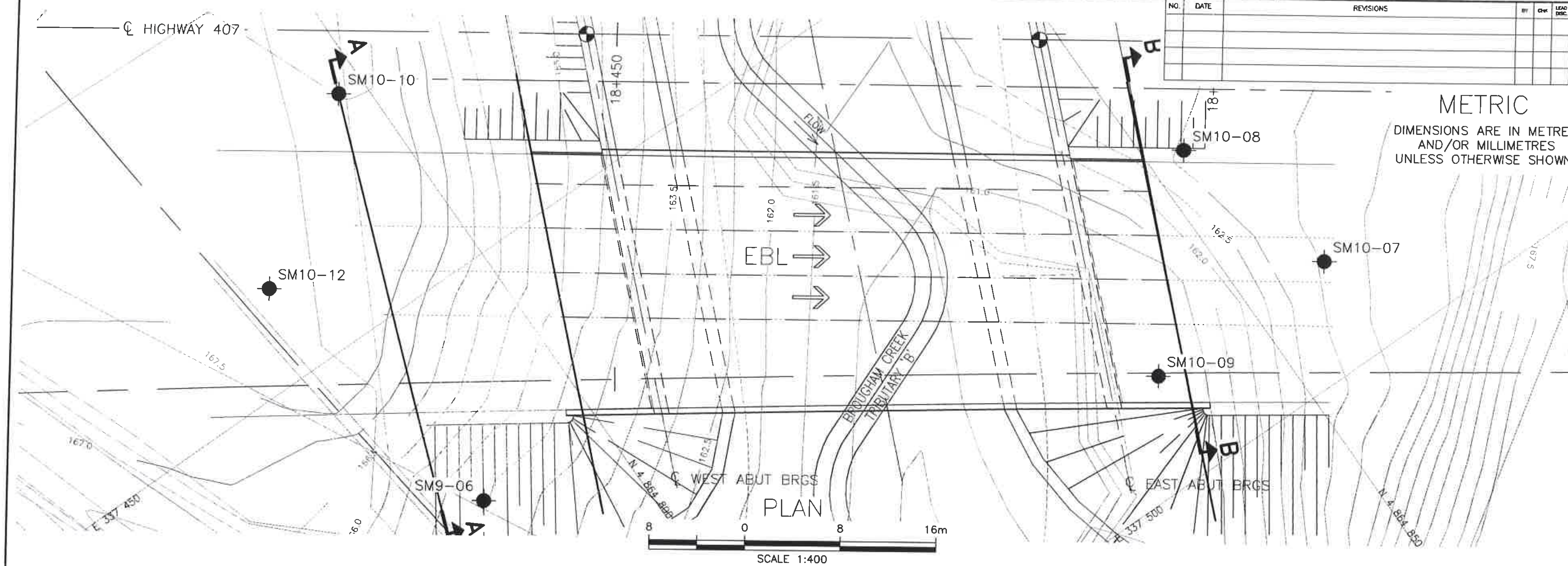
STRUCTURE M-10 (SITE 7)
PROPOSED HWY 407 EBL OVER BROUGHAM CREEK TRIB. 'B'
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

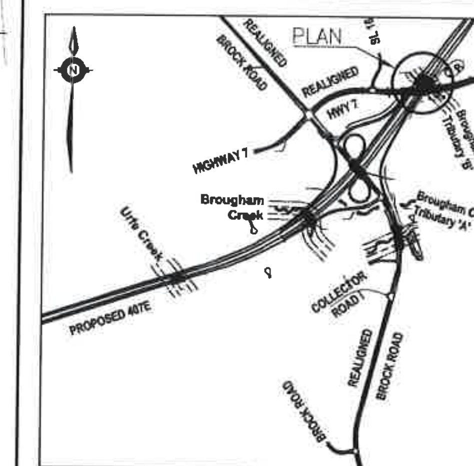
407 ETR Express Toll Route

MMM GROUP

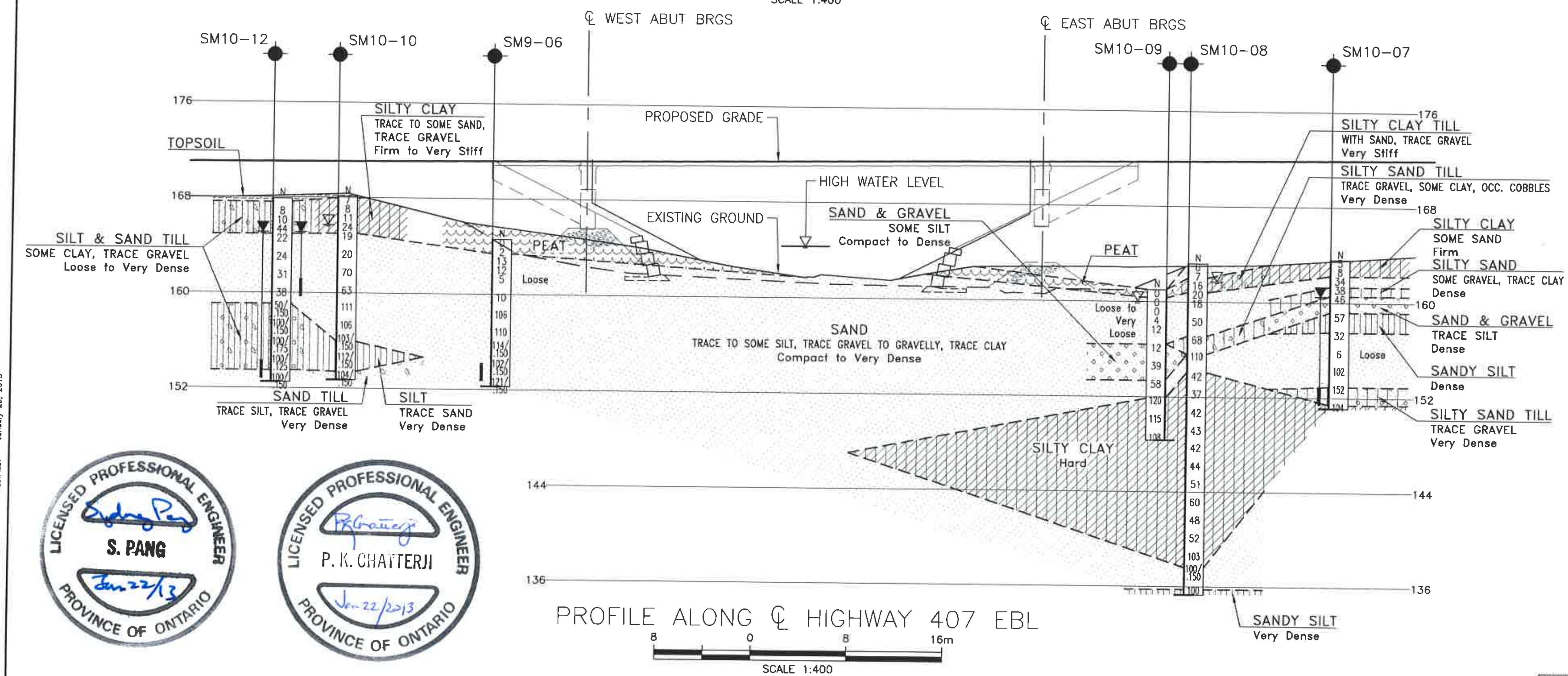
THURBER ENGINEERING LTD.



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



KEYPLAN



LEGEND

Symbol	Description
⯁	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
SM10-01	163.8	4 864 873.4	337 433.8
SM10-02	163.0	4 864 861.5	337 447.0
SM10-03	163.1	4 864 861.9	337 444.6
SM10-04	164.4	4 864 828.4	337 413.5
SM10-05	163.6	4 864 822.9	337 431.3
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SM10-10	168.1	4 864 797.8	337 431.9
SM10-12	167.9	4 864 783.7	337 442.2
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DESIGN SKP	CHK AEG	CODE	LOAD	DATE JAN. 2013
DRAWN MFA	CHK SKP	SITE 7	STRUCT M-10	DWG 2

DRAWING NAME: H:\Drafting\19\5161\130\ed1130A-M10-BoreholePlan&Profile.dwg
CREATED: December 17, 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-10 (SITE 7)
PROPOSED HWY 407 EBL OVER BROUGHAM CREEK TRIB. 'B'
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

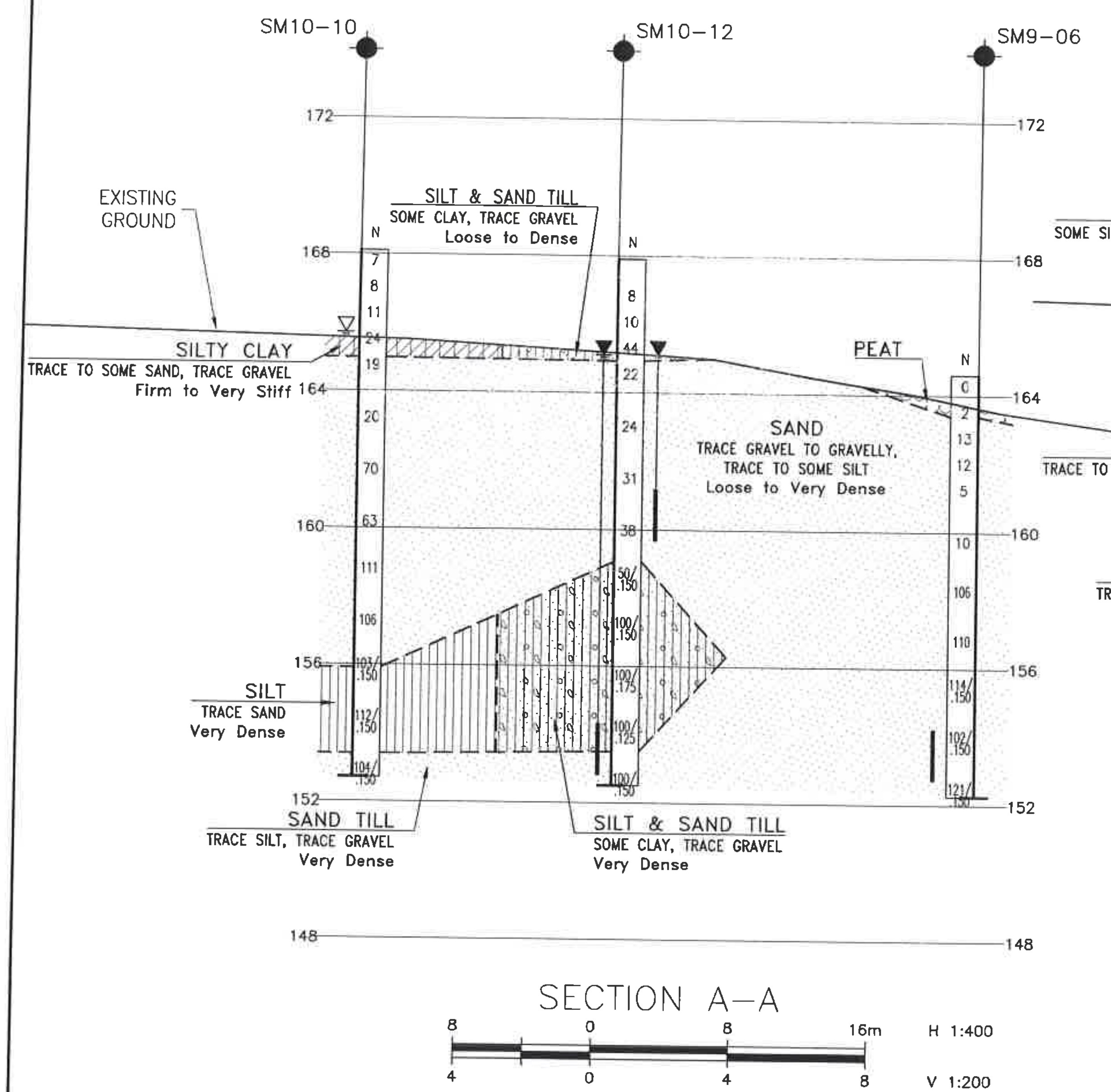
407 ETR Express Toll Route

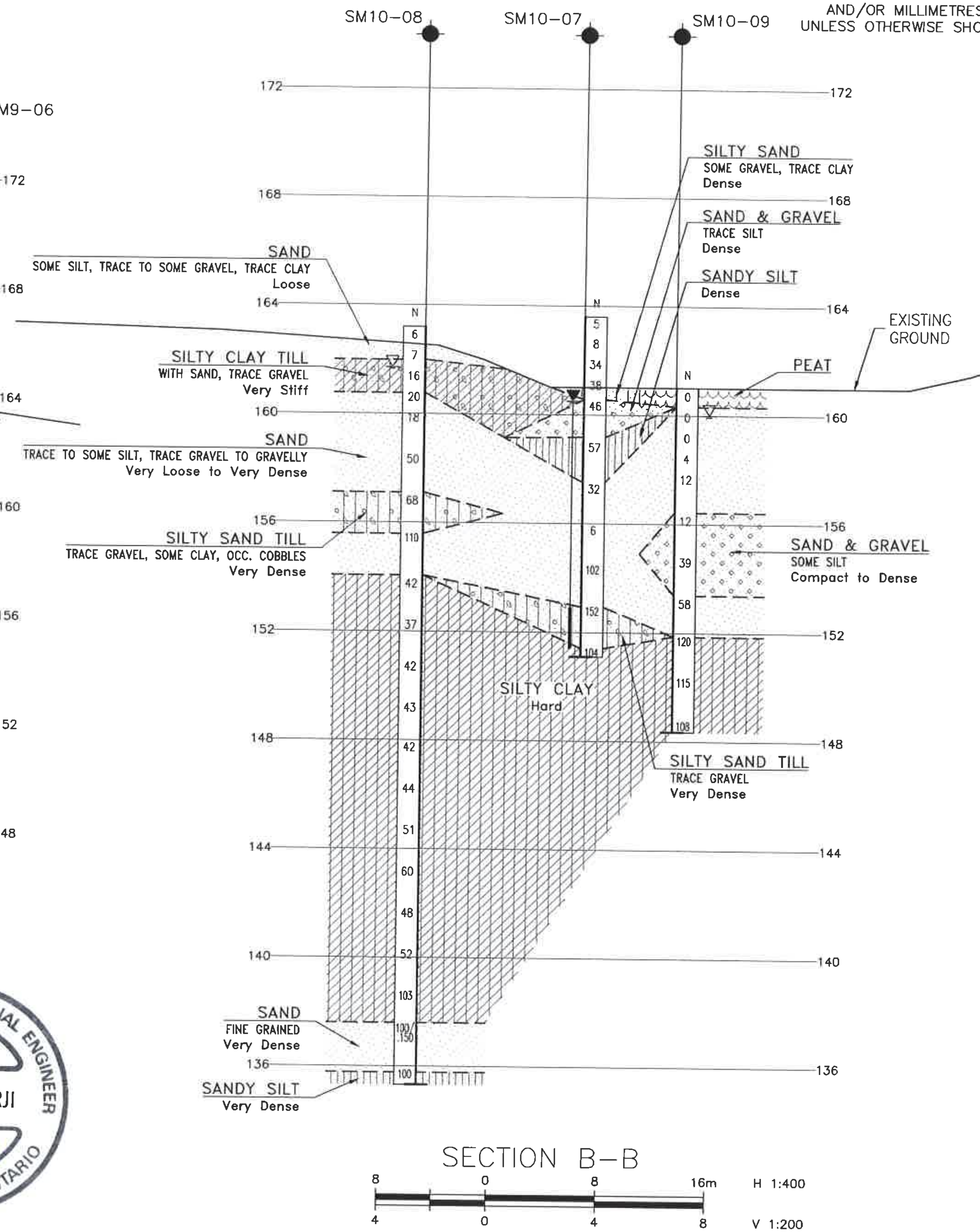
MMM GROUP

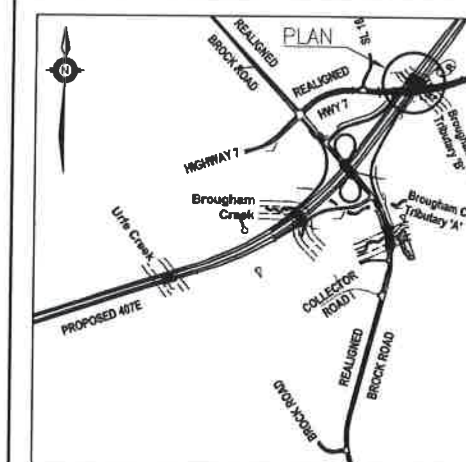
THURBER ENGINEERING LTD.

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN







KEYPLAN

LEGEND

Symbol	Description
⌖	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
SM10-01	163.8	4 864 873.4	337 433.8
SM10-02	163.0	4 864 861.5	337 447.0
SM10-03	163.1	4 864 861.9	337 444.6
SM10-04	164.4	4 864 828.4	337 413.5
SM10-05	163.6	4 864 822.9	337 431.3
SM10-06	169.6	4 864 803.7	337 401.3
SM10-07	163.6	4 864 857.4	337 491.0
SM10-08	163.2	4 864 853.1	337 476.5
SM10-09	161.0	4 864 840.5	337 491.0
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CREATED: December 17, 2012 MODIFIED: January 23, 2013

DESIGN SKP	CHK AEG	CODE	LOAD	DATE JAN. 2013
DRAWN MFA	CHK SKP	SITE 7	STRUCT M-10	DWG 3

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

CONTRACT No. E2–2012

HWY 407/BROCK ROAD INTERCHANGE

STRUCTURE M–10 (SITE 7)
PROPOSED HWY 407 WBL OVER BROUGHAM CREEK TRIB. 'B'
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

407 ETR Express Toll Route

MMM GROUP

THURBER ENGINEERING LTD.

METRIC

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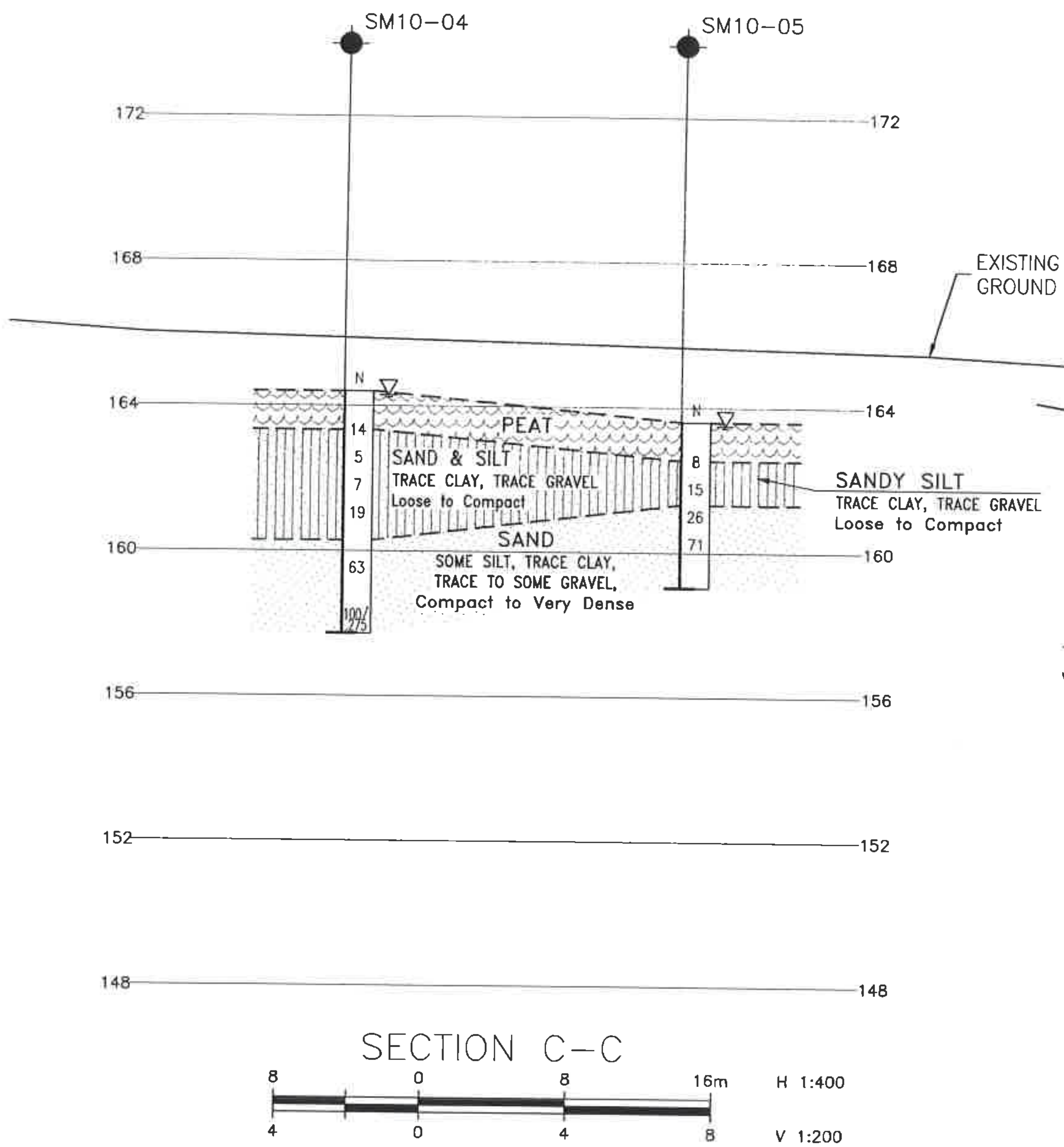
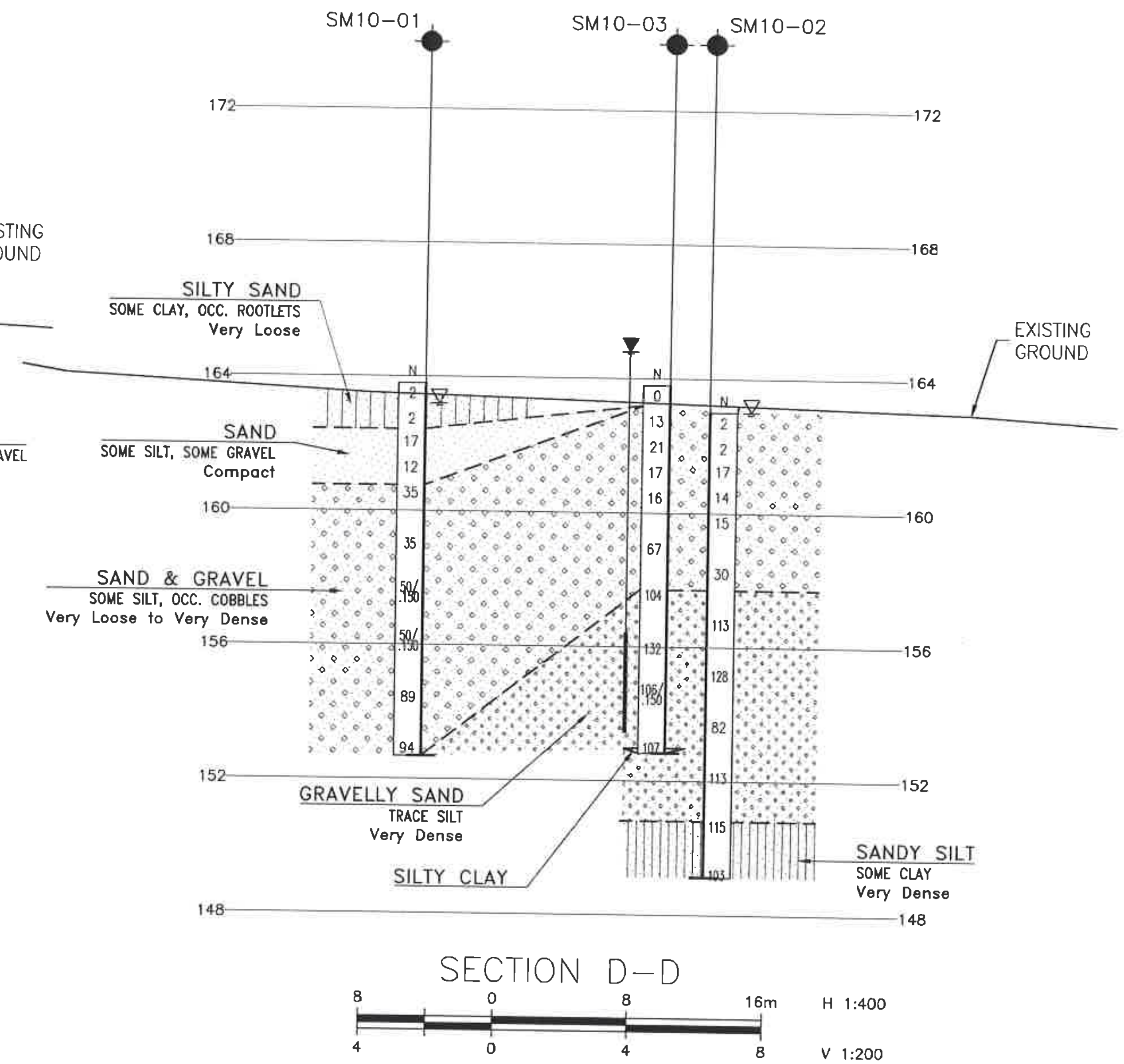
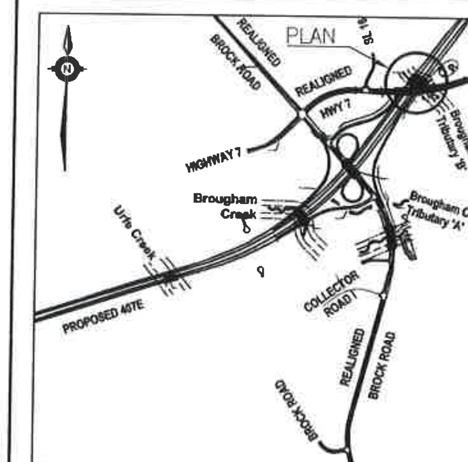


SECTION C–C



SECTION D–D



KEYPLAN

LEGEND

⯁	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
SM10–01	163.8	4 864 873.4	337 433.8
SM10–02	163.0	4 864 861.5	337 447.0
SM10–03	163.1	4 864 861.9	337 444.6
SM10–04	164.4	4 864 828.4	337 413.5
SM10–05	163.6	4 864 822.9	337 431.3
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LICENSED PROFESSIONAL ENGINEER
S. PANG
Jan 22/13
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 22/2013
PROVINCE OF ONTARIO

DESIGN SKP	CHK AEG	CODE	LOAD	DATE JAN. 2013
DRAWN MFA	CHK SKP	SITE 7	STRUCT M–10	DWG 4

DRAWING NAME: H:\Drafting\19\5161\130\ted1130A–M10–BoreholePlan&Profile.dwg
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