

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION  
STRUCTURE M-5 (SITE 5)  
REALIGENED BROCK ROAD OVER BROUGHAM CREEK TRIBUTARY 'A'  
Contract No: E2-2012**

**Report to**

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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 a new culvert (Structure M-5) that will carry Brougham Creek Tributary 'A' under the proposed realigned Brock Road, in the City of Pickering, Ontario. The new culvert (and realigned Brock Road) is 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, a stratigraphic profile, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in 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 proposed culvert runs approximately west-east and is located just west of the existing Sideline 16 and approximately 325 m south of the Highway 407-Sideline 16 intersection. The community of Brougham is located approximately 900 m northwest of the proposed culvert site.

At the location of the proposed culvert, Brougham Creek Tributary 'A' flows from west to east. The proposed culvert is located south of the existing creek channel in an agricultural field. Lands surrounding the culvert site consist primarily of agricultural fields and undeveloped areas. A private residence, now abandoned, is located approximately 15 m west of the west end of the proposed culvert.

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 is typically 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' as produced by the Ontario Geological Survey shows that the culvert 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 culvert were carried out between August 14 and 28, 2012. Four boreholes, identified as SM5-01 to SM5-04, were drilled and sampled at this site. The boreholes were advanced to depths of 4.9 m to 15.4 m (Elevation 168.1 to 162.8 m). The Record of Borehole sheets are included in Appendix A.

The boreholes were located along the proposed culvert alignment at approximately 42 m spacing. Boreholes SM5-01, SM5-03 and SM5-04 were located along the south side of the proposed culvert and Borehole SM5-02 is located along the north side of the proposed culvert. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata drawing included in Appendix D.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. Silt fencing was installed between the drill area and the creek for Borehole SM5-04 due to its close proximity to the existing creek channel, to prevent migration of potential sediment laden water into the adjacent creek. As well, Permission to Enter was obtained by MTO for the property accessed during this investigation.

The boreholes were drilled using a B57 track-mounted drill rig and the boreholes were advanced using solid stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (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 during and upon completion of the drilling operations. A standpipe piezometer was installed in Borehole SM5-01 for subsequent monitoring of groundwater levels. The completion details of the piezometers and boreholes are summarized in Table 3.1.

**Table 3.1 – Borehole Completion and Piezometer Installation Details**

<b>Borehole</b>	<b>Piezometer Tip Depth/ Elevation (m)</b>	<b>Completion/Installation Details</b>
SM5-01	15.2 / 163.0	A 19 mm diameter piezometer with 1.5 m slotted screen was installed with filter sand to 11.0 m, bentonite holeplug from 11.0 to 1.4 m, then cuttings to surface.
SM5-02	None installed	Backfilled with bentonite holeplug from 7.8 to 1.0 m, then cuttings to surface.
SM5-03	None installed	Backfilled with bentonite holeplug from 8.1 to 1.9 m, then cuttings to surface.
SM5-04	None installed	Backfilled with cuttings to surface.

#### **4 LABORATORY TESTING**

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

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy along the proposed culvert alignment are presented on the Record of Borehole sheets in Appendix A and the “Borehole Locations and Soil Strata” drawing included in Appendix D. An overall description of the stratigraphy encountered at the proposed culvert 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.

In general, the subsurface stratigraphy encountered at the site consisted of a thin layer of organics or sand fill overlying sandy silt to sand and silt underlain by silty sand till. At the east end of the site, the silty sand till is underlain by clayey sand and silt till towards the bottom of the boreholes. More detailed descriptions of the individual strata are presented below.

##### **5.1 Sand Fill**

A thin layer (200 mm) of sand fill containing trace gravel was encountered at surface in Borehole SM5-01.

##### **5.2 Organics**

A layer of organics containing roots and rootlets was encountered surficially in Boreholes SM5-02 to SM5-04. The thickness of the surficial organics layer ranges from about 175 to 200 mm.

It should be noted that the thickness of the organics layer may vary between and beyond the borehole locations.

##### **5.3 Sandy Silt to Sand and Silt**

A layer of sandy silt to sand and silt was encountered below the sand fill in Borehole SM5-01 and below the surficial organic layer in Boreholes SM5-02 and SM5-03. The sandy silt to sand and silt was brown in colour and contained some clay and trace gravel. Occasional cobbles were noted in this layer in Borehole SM5-01.

The thickness of the sandy silt to sand and silt layer ranged from 0.7 to 1.2 m, with the lower boundary of this layer encountered at depths of 0.9 to 1.4 m (Elev. 177.1 to 172.8 m).

An SPT N-value of 28 blows for 0.3 m penetration, indicating a compact relative density, was recorded in the sandy silt layer. In Borehole SM5-01, an SPT N-value of 50 blows for

0.15 m penetration was recorded, likely upon encountering occasional cobbles. The moisture content of one sample of the sandy silt was 12%.

#### 5.4 Silty Sand Till and Clayey Sand and Silt Till

Silty sand till was encountered below the sandy silt to sand and silt layer in Boreholes SM5-01 to SM5-03 and below the organic layer in Borehole SM5-04. The silty sand till is underlain by clayey sand and silt till at depth in Boreholes SM5-03 and SM5-04. The till was typically brown, becoming grey with depth. The till contains trace to some clay and trace gravel. The presence of occasional cobbles in the till was inferred during drilling.

The till was fully penetrated in Borehole SM5-01 only. The layer was 12.2 m thick in Borehole SM5-01, with the lower boundary of the till encountered at a depth of 13.3 m (Elevation 164.9 m). Boreholes SM5-02 to SM5-04 were terminated within the silty sand/clayey sand and silt till. In these three boreholes, the till was encountered at depths of 0.2 to 1.4 m and the boreholes were terminated at depths of 4.9 to 8.1 m (Elevation 168.1 to 166.1 m).

SPT N-values recorded in the till ranged from 23 blows for 0.3 m penetration to 100 blows for 0.125 m penetration, indicating a compact to very dense relative density. In general, N-values were greater than 50 (very dense). Moisture contents ranged from 6 to 12%.

Grain size analysis testing was performed on seven samples of the silty sand/clayey sand and silt till. The results of these tests are presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curves for these samples are plotted on Figures B1 and B2 in Appendix B. The results of the grain size analysis tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	1 to 7
Sand	42 to 54
Silt	28 to 38
Clay	9 to 21

One sample of the clayey sand and silt till exhibited sufficient plasticity for Atterberg Limits testing, the results of which are summarized below. The results of the Atterberg Limits test are presented on Figure B4 in Appendix B.

	Percentage (%)
Liquid Limit	21
Plastic Limit	13
Plasticity Index	8

It should be noted that glacial tills inherently contain cobbles and boulders.

### 5.5 Lower Sandy Silt

A layer of sandy silt was encountered below the silty sand till in Borehole SM5-01. The sandy silt was grey and contained some clay.

The sandy silt layer was encountered at a depth of 13.3 m (Elevation 164.9 m). Borehole SM5-01 did not fully penetrate this layer and was terminated at a depth of 15.4 m (Elevation 162.8 m).

SPT 'N' values of 50 blows for 0.125 m penetration were recorded in the sandy silt, indicating a very dense relative density. Moisture contents ranged from 12 to 14%.

One sample of the sandy silt underwent laboratory grain size analysis testing, the results of which are summarized below. The grain size distribution curve for this sample is plotted on Figure B3 in Appendix B.

Soil Particles	Percentage (%)
Gravel	0
Sand	22
Silt	60
Clay	18

### 5.6 Groundwater Conditions

Groundwater was not observed in the open boreholes during or upon completion of drilling. One standpipe piezometer was installed at this site, in Borehole SM5-01, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.1 – Measured Groundwater Levels**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
SM5-01	Aug. 15, 2012	14.6	163.6	Piezometer
	Aug. 28, 2012	6.7	171.5	
	Sept. 7, 2012	4.7	173.5	
	Oct. 16, 2012	3.7	174.5	
	Dec. 10, 2012	3.7	174.5	
	Dec. 19, 2012	3.5	174.7	
	Jan. 3, 2013	3.4	174.8	
SM5-02	Aug. 16, 2012	DRY		Open borehole
SM5-03	Aug. 16, 2012	DRY		Open borehole
SM5-04	Aug. 28, 2012	DRY		Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.



## 6 MISCELLANEOUS

The borehole locations were selected by Thurber Engineering Ltd. and staked in the field by Thurber using a 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 B57 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 Mr. Stephane Loranger, C.E.T. of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

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

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

### Thurber Engineering Ltd.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 INTRODUCTION**

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for the design of culvert M-5.

At the location of the proposed culvert, Brougham Creek Tributary 'A' flows from west to east. The proposed culvert is located south of the existing creek channel. The new culvert will carry Brougham Creek Tributary 'A' under the future realigned Brock Road in the City of Pickering, Ontario. The new culvert (and realigned Brock Road) is planned as part of the Highway 407/Brock Road Interchange Connection project.

Details of the proposed culvert are presented in Table 7.1.

**Table 7.1 – Proposed Culvert**

<b>Structure No.</b>	<b>Station (Realigned Brock Rd.)</b>	<b>Description</b>	<b>Culvert Size (m)</b>	<b>Proposed Length (m)</b>	<b>Maximum Fill Height Above Crown (m)</b>
M-5	10+262.342	New culvert under realigned Brock Rd.	3.6 x 1.8	128.51	19

The discussions and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the current investigation. The plans and sections used for preparation of this report were provided by MMM.

**8 FOUNDATION DESIGN**

**8.1 General**

Details regarding the invert levels of the proposed culvert were based on the culvert section drawing. Groundwater level at the proposed culvert location, monitored in the installed piezometer is shown in Table 8.1.

**Table 8.1 – Design Invert Elevations and Groundwater Table**

Structure No.	Design Invert Elevation (m)		Measured Groundwater Elevation (m)
	Inlet	Outlet	
M-5	169.07	166.50	174.8 (Jan. 3, 2013)

The subsurface conditions encountered at the proposed culvert location consist typically of compact to dense sandy silt to sand and silt overlying compact to very dense silty sand to clayey silt and sand till. The proposed culvert will be installed at depths of 5 to 10 m below the existing ground surface. Excavations of the native soils required for culvert installation will be mainly through the silty sand till and partially in the clayey sand and silt till at the easterly portion.

## 8.2 Foundation Design

Foundation design issues for culverts include mainly subgrade preparation, bearing resistance, settlement of foundation soils under the weight of the new roadway embankment fill, and stability of the new embankment adjacent to the culvert.

Initial considerations were given to the following foundation types:

- Closed box culvert
- Open frame culvert with spread footings on native soils

Based on the site conditions, it is recommended that closed box culvert be employed at this structure location. However, recognizing that an open bottom culvert design may be preferred from other perspectives, considerations may be given to the use of spread footings founded on native soils.

Use of a precast concrete culvert may be preferred over a cast-in-place culvert since installation is likely to be faster with lower potential for disturbance of the founding soils during construction.

## 8.3 Closed Box Culvert

Following excavation to the design founding level of the culvert, any remaining fill, topsoil, peat, streambed deposits or soft/loose soils within the culvert footprint should be removed to the underlying undisturbed native till. The exposed surface must be inspected to confirm that the subgrade is uniformly competent. Any soft areas must be subexcavated and replaced with well compacted granular fill. Any fill placed below the culvert to re-establish the founding level must consist of well-compacted Granular A or Granular B Type II material. This work should be carried out in accordance with OPSS 902. Anticipated soil conditions at or below the culvert invert elevations are summarized in Table 8.2. This table indicates that the culvert subgrade will consist of very dense to hard glacial till.

In order to provide a uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS Granular A requirements should be provided under the base of box culvert, as per OPSD 803.010. The bedding material should be placed and compacted in

accordance with OPSS 501 as soon as practical following inspection and approval of the final subgrade as protection from disturbance during construction.

**Table 8.2 – Anticipated Depths of Excavation for Box Culvert**

Structure No.	Location	Borehole	Culvert Invert Elevation (m)	Approx. Depth below G. S. (m)	Underlying Soil Type
M-5	Inlet	SM5-01	169.07	9.7	Very dense sandy silt till
	Middle	SM5-02	168.60	8.5	
		SM5-03	167.60	7.7	Hard clayey sand & silt till
	Outlet	SM5-04	166.50	4.3	

A box culvert founded on the native, undisturbed, very dense or hard sand & silt till at the anticipated levels should be designed using geotechnical resistances at factored ULS of 650 kPa and at SLS of 450 kPa for vertical concentric loads.

Settlement of the culvert will be governed by the compression of the foundation soils beneath the culvert under the weight of the road embankment. Comments regarding culvert settlement are presented in a subsequent section of this report.

#### 8.4 Open Frame Culvert with Spread Footings on Native Soils

Spread footings for open frame culvert should be founded on the native, undisturbed very dense or hard sand & silt till to achieve sufficient bearing resistance. Following excavation to the design founding level, any remaining fill, topsoil, peat, streambed deposits or soft soils on and below the bearing surface should be removed and replaced with well-compacted Granular A material in accordance with OPSS 902.

The anticipated soil conditions at or below the footing base elevations are summarized in Table 8.3 below. This table indicates that the open footings will be founded on very dense sandy silt till or hard clayey sand and silt till.

**Table 8.3 – Anticipated Footing Depths and Elevations at Footing Base**

Structure No.	Location	Borehole	Culvert Invert Elevation (m)	Footing Depth below G. S. (m)	Footing Base Elevation (m)	Underlying Soil Type
M-5	Inlet	SM5-01	169.07	10.6	167.2	Very dense sandy silt till
	Middle	SM5-02	168.60	9.4	166.6	
		SM5-03	167.60	8.6	165.6	Hard clayey sand & silt till
	Outlet	SM5-04	166.50	5.2	164.6	

The following geotechnical resistances are recommended for design of spread footings founded on the native, undisturbed, very dense or hard sand & silt till for different footing widths subjected to vertical concentric loading:

	Sand & Silt Till		
Footing Width (m)	<u>0.9</u>	<u>1.2</u>	<u>1.5</u>
Factored Geotechnical Resistance at ULS (kPa)	600	650	675
Geotechnical Resistance at SLS (kPa)	400	425	450

These resistance values are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

All founding surfaces comprising native soils should be protected from disturbance during construction by placement of a mud slab on the prepared bearing surface as soon as practical following inspection and approval.

A frost penetration depth of 1.2 m should be used during foundation and backfill design to provide protection against frost action on the culvert footings. All footing bases should have a minimum earth cover of 1.2 m.

Frost tapers must be included in accordance with the requirements of OPSD803.030 or OPSD803.031 as appropriate.

The lateral resistance developed along the base of cast-in-place footings founded on the native, undisturbed sand and silt till may be computed using an ultimate friction coefficient of 0.4. This is an “ultimate” value and requires a degree of sliding movement (typically less than 5 mm) to occur to fully mobilize the resistance.

## 8.5 Settlement

Settlement of the culvert will be controlled primarily by settlement of the foundation soils under the weight of the new roadway embankment fill. The magnitude of settlement will depend upon the height of new embankment to be constructed and the type and thickness of foundation soils and subgrade.

The proposed culvert will be founded at depths up to 10 m below the existing ground surface. Based on the borehole data, the typical founding soils will be very dense or hard sand and silt till with trace clay to clayey. Assuming that the very dense sand and silt till extends to a significant depth below the proposed culvert, the anticipated settlements along the proposed culvert under the new embankment of realigned Brock Road and Ramp S-E are shown in Table 8.4 below.

A camber and, if necessary, articulated joints should be applied along box culvert to accommodate the settlement profile indicated in the table.

**Table 8.4 – Estimated Culvert Settlement**

Structure No.	Approximate Embankment Height (m)	Estimated Settlement (mm)				
		West Toe	West Shoulder	Centreline	East Shoulder	East Toe
M-5	11 to 13*	5	14	17	15	5

\* Approximate fill height above the existing ground surface

Standard embankment slope inclination of 2H:1V in granular or earth fill is expected to be stable on the foundation soils consisting of dense to very dense sandy silt and sand and silt till. For embankment fill greater than 8 m in height, a 2 m wide, mid height berm should be provided.

## 8.6 Subgrade Preparation

A number of boreholes encountered surficial organic matters. The presence of alluvial and organic deposits should be expected in the vicinities of the watercourse. The actual depths of organics are noted in Section 5 of this report.

Base elevations for subexcavation have been selected with the intent of placing the foundations on suitable, undisturbed native soil. However, soil stratigraphy is inherently variable and the Contractor's QVE must verify that the base of the completed excavation is free of topsoil, peat, fill, loose, soft or disturbed soil or other deleterious materials.

Backfill to subexcavation for reinstating the founding elevation should consist of Granular A or Granular B Type II material placed and compacted in accordance with OPSS 902.

## 9 BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert must consist of free-draining granular material conforming to OPSS Granular A or Granular B Type II specifications. The granular material should be placed at least to the extents shown in OPSD 803.010.

Backfill must be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation must be within 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501.

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

$$p = K (\gamma h + q)$$

Where:  $p$  = horizontal pressure on the wall at depth  $h$  (kPa)

$K$  = earth pressure coefficient (see table below)

$\gamma$  = 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)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for closed box culvert walls. Active pressures should be used for any wing walls or unrestrained walls.

**Table 9.1 – Earth Pressure Coefficients (K)**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active $K_a$ (Unrestrained Wall)	0.27	0.40*	0.31	0.48*
At rest $K_0$ (Restrained Wall)	0.43	-	0.47	-
Passive $K_p$ (Movement Towards Soil Mass)	3.7	-	3.3	-

\* For wing walls, if employed.

The parameters presented in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design should be assessed from Figure C6.16 of the Commentary to the CHBDC.

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 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.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill and avoid the potential build-up of hydrostatic pressures behind the walls. Alternatively, the culvert walls must be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

## 10 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

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

The Soil Profile Type at this site has been classified as Type II. Thus, according to Table 4.4 of the CHBDC, a Site Coefficient “S” of 1.2 should be used in seismic design.

The seismic earth pressure coefficients for active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) conditions to be used in design at this site are shown in Table 10.1. In accordance with Clause 4.6.4 of the CHBDC, structures should be designed using earth pressure coefficients that incorporate the effects of earthquake loading.

**Table 10.1 – Earth Pressure Coefficients ( $K_E$ ) for Seismic Design**

Condition	Earth Pressure Coefficient ( $K_E$ ) for Earthquake Loading			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \delta = 17^\circ$		OPSS Granular B Type I $\phi = 32^\circ, \delta = 16^\circ$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active*, $K_{AE}$ (Unrestrained Wall)	0.30	0.47	0.34	0.58
At rest**, $K_{0E}$ (Restrained Wall)	0.53	-	0.58	-
Passive*, $K_{PE}$ (Movement Towards Soil Mass)	3.6	-	3.2	-

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

\*\* After Woods

In Table 10.1, the angle of friction between the wall and the backfill,  $\delta$ , is taken as 50% of the angle of internal friction of the backfill,  $\phi$ .

The potential for liquefaction of the foundation soils has been assessed using the Seed and Idriss (1971) method<sup>1</sup>. Using this method, it was determined that the foundation soils are not in danger of liquefaction under earthquake loading.

## 11 SCOUR PROTECTION AND EROSION CONTROL

Culvert foundation must be provided with scour protection. Erosion protection must be provided at the culvert inlet and outlet areas as applicable. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. Treatment at outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in accordance with OPSS 804.

<sup>1</sup> Seed, H.B. and Idriss, I.M. 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential" *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 101, No. SM9, pp. 1249 – 1273.



It is recommended that a clay seal or a concrete cut-off wall be used at the inlet to minimize the potential for flow of water through the granular backfill around the culvert and accompanying risk of erosion. The clay seal should extend at least 0.3 m above the high water level, have a minimum thickness of 0.5 m, and extend laterally the width of the granular backfill material. The material requirements should be in accordance with OPSS 1205. A prefabricated geosynthetic clay liner, such as Bentofix NSL, may be used as an alternative to clay.

## **12 EXCAVATION AND GROUNDWATER CONTROL**

In general, surface vegetation, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the culvert area prior to culvert installation.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purpose of assessing excavation slope requirements in compliance with the OHSA, the dense to very dense sandy silt and very dense or hard sand & silt till are classified as Type 2 soil.

Temporary shoring may be required to retain the native soils during culvert installation. Based on the available subsurface information, a shoring system consisting of steel H-piles with timber lagging may be considered. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent surcharge loads and any sloping retained surfaces. Roadway protection, if required, should be supplied in accordance with OPSS 539 and designed for Performance Level 2.

Based on the measured water levels shown in Table 8.1, the groundwater level is up to 5.7 m above the culvert invert level at the inlet. Excavation to reach culvert subgrade will be carried out below the groundwater level. The native sand and silt till at this site is relatively impermeable as evidenced by the dry open boreholes during drilling. However, localized water bearing granular layers are to be anticipated during the excavation. An effective dewatering plan must be in place prior to the start of excavation for box culvert or footing excavation for open frame culvert so that the subgrade is dry, and to prevent sloughing of the sides and disturbance to the base of excavation due to groundwater inflow. Excavation for the culvert must start at the outlet end to provide positive drainage for any seepage water. The dewatering plan should be able to lower the groundwater level to be below the base of excavation and must maintain a stable, unwatered excavation throughout the subgrade preparation or footing construction. Dewatering must remain operational and effective until the culvert is constructed and backfilled. This excavation and backfilling operation should be done expeditiously to avoid any problem with seepage.

An NSSP should be included in the Contract Documents specifying that an appropriate dewatering operation shall be provided to maintain a stable and reasonably dry excavation.

Decisions regarding dewatering, shoring methods and sequencing should be made by the Contractor and submitted to the Contract Administrator for information purposes.

### 13 CONSTRUCTION CONCERNS

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

- Excavation for installation of the culvert may encounter soft, loose, organic, wet or otherwise deleterious materials requiring flattening of excavation side slopes or installation of temporary shoring. Temporary shoring system should be properly designed by a Professional Engineer experienced in such design.
- Care must be exercised during excavation to avoid disturbing the founding subgrade. The exposed subgrade should be protected from physical disturbance, and the granular bedding and/or a mud slab must be placed on the approved subgrade as soon as practical following excavation. An effective dewatering plan is essential to maintaining a reasonably dry excavation.
- The subgrade exposed at the design level should be examined and any deleterious materials removed and replaced with compacted granular bedding materials. The culvert subgrade must be uniformly competent and should be inspected and approved by the Contractor's QVE.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

## 14 CLOSURE

Engineering analysis and preparation of the foundation design report was carried out by Mr. Keli Shi, P.Eng. and Mr. Alastair Gorman, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Keli Shi, P.Eng., M.Eng.  
Geotechnical Engineer



Alastair Gorman, P.Eng., M.Sc.  
Senior Geotechnical Engineer



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

**Appendix A**  
**Record of Borehole Sheets**

## METRIC

[illegible]

+<sup>3</sup> ×<sup>3</sup> Numbers refer to Sensitivity

## METRIC

[illegible][illegible]

+ 3, X 3: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No SM5-02

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 136.0 E 337 232.3 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.08.16 - 2012.08.16 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
175.9 0.0	ORGANICS with roots and rootlets: (175mm)  SAND and SILT, some clay, trace gravel Compact Brown Moist  Silty SAND, some clay, trace gravel, occasional cobbles  Compact to Very Dense Brown Moist (TILL)  <														

ONTMT4S 1130A.GPJ 1/24/13

# RECORD OF BOREHOLE No SM5-03

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 135.0 E 337 276.3 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.08.16 - 2012.08.16 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED	+ FIELD VANE		w <sub>p</sub>	w	w <sub>L</sub>		
								● QUICK TRIAXIAL	× LAB VANE						
174.2						20	40	60	80	100	20	40	60		
0.0	ORGANICS with roots and rootlets: (200mm)														
0.2	Sandy SILT, some clay, trace gravel Compact Brown Moist		1	SS	28										
172.8															
1.4	Silty SAND, trace clay, trace gravel, occasional cobbles Very Dense Brown Moist (TILL)		2	SS	100/ 0.150										
			3	SS	90										
			4	SS	100/ 0.125										
	Grey		5	SS	100/ 0.200										
168.1															
6.1	Clayey SAND and SILT, trace gravel, occasional cobbles Hard Grey Moist (TILL)		6	SS	100/ 0.125										
166.1			7	SS	100/ 0.275										
8.1	END OF BOREHOLE AT 8.1m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.9m, THEN CUTTINGS TO SURFACE.														

ONTMT4S 1130A.GPJ 1/24/13



# RECORD OF BOREHOLE No SM5-04

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 143.7 E 337 319.3 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.08.28 - 2012.08.28 CHECKED BY LRB

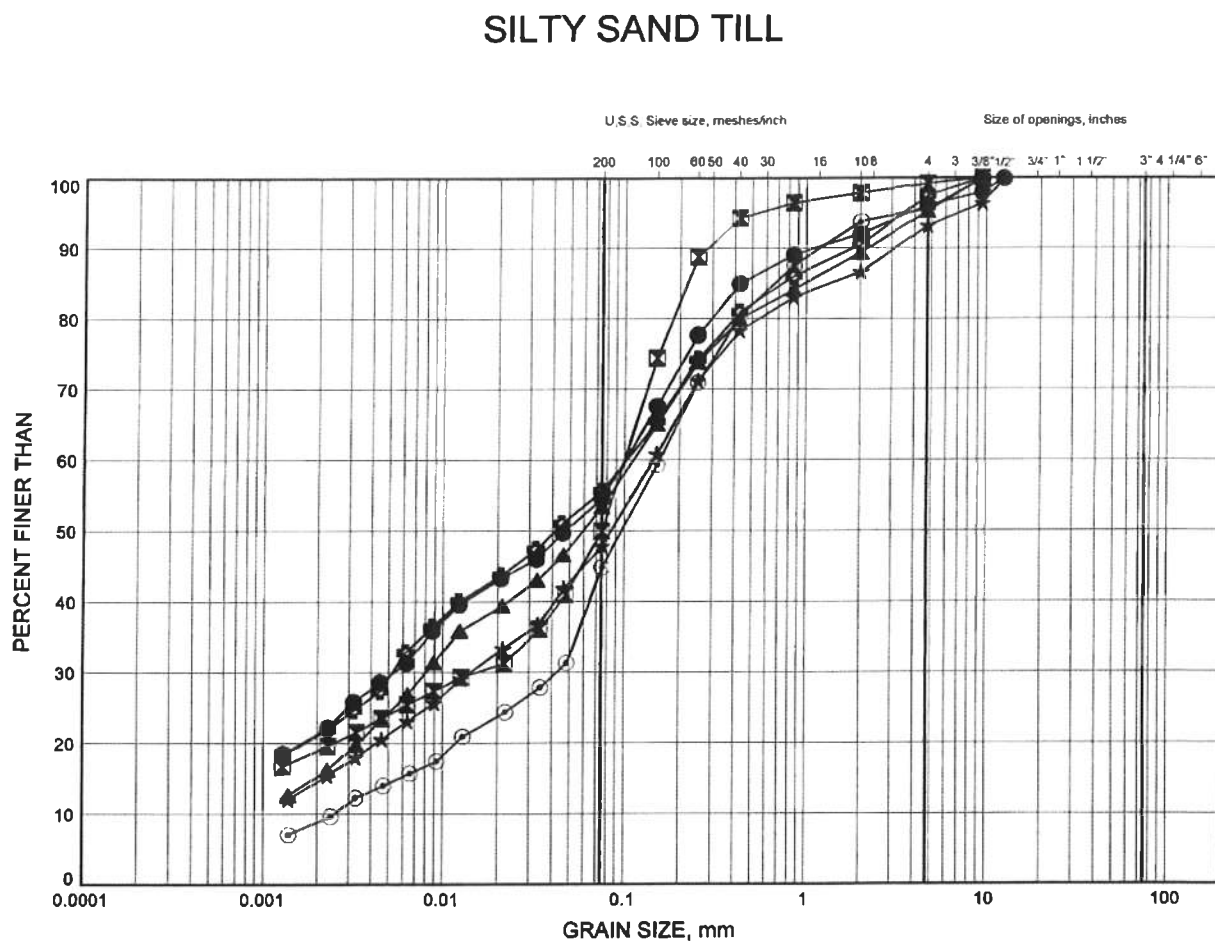
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
172.1												
0.0	ORGANICS with roots and rootlets: (200mm)						172					
0.2	Silly SAND, trace gravel, trace to some clay Very Dense Brown Moist (TILL)		1	SS	85		171					
			2	SS	50/ 0.150		170					
	Occasional cobbles		3	SS	100/ 0.275		169					
			4	SS	100/ 0.275		168					
168.1												
4.0	Clayey SAND and SILT, trace gravel, occasional cobbles Hard Grey Moist (TILL)		5	SS	100/ 0.125							
167.2												
4.9	END OF BOREHOLE AT 4.9m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.											

**Appendix B**  
**Laboratory Test Results**

# Hwy 407 Brock Road Connection - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM5-01	1.83	176.37
⊠	SM5-01	9.33	168.87
▲	SM5-02	1.07	174.83
★	SM5-02	3.21	172.69
⊙	SM5-03	2.59	171.61
⊕	SM5-03	6.31	167.89

Date November 2012

W.P.# E2-0212



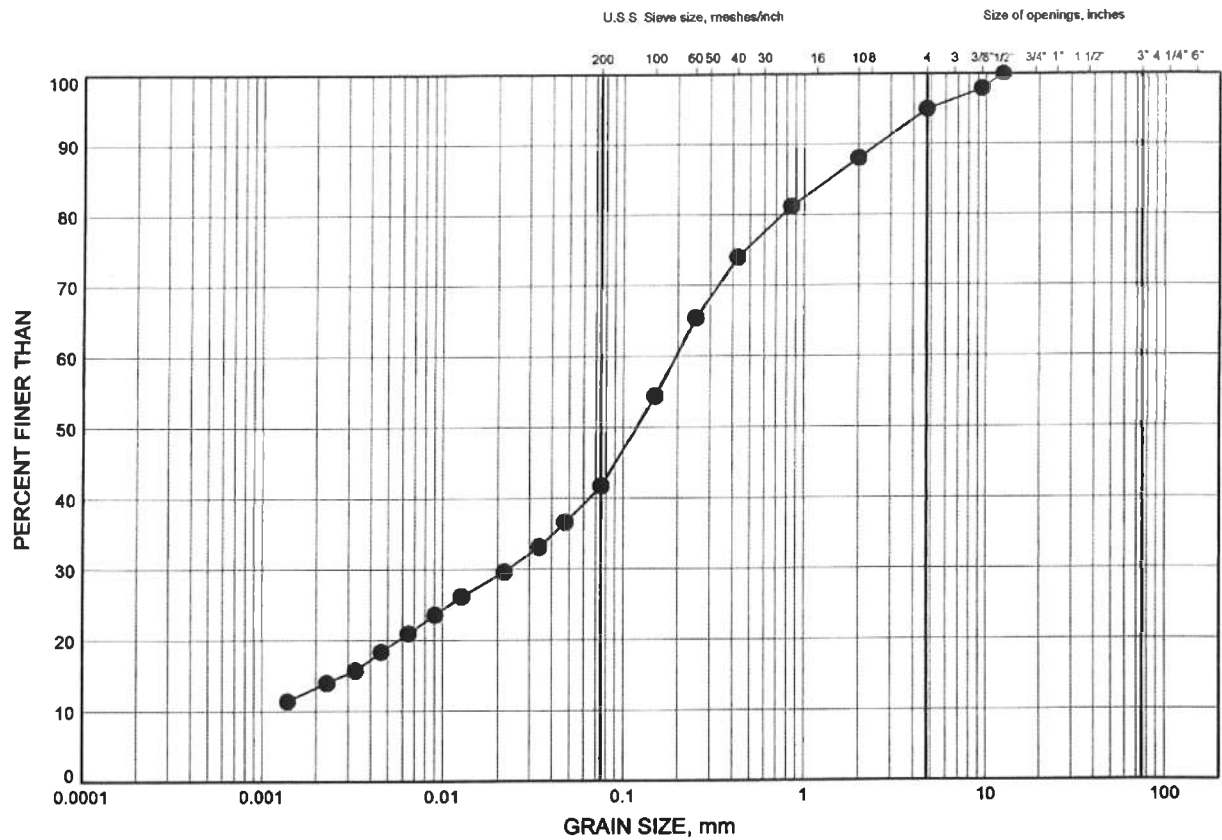
Prep'd AN

Chkd. LRB

Hwy 407 Brock Road Connection - Foundations  
**GRAIN SIZE DISTRIBUTION**

**FIGURE B2**

**SILTY SAND TILL**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM5-04	2.50	169.60

Date November 2012  
W.P.# E2-0212

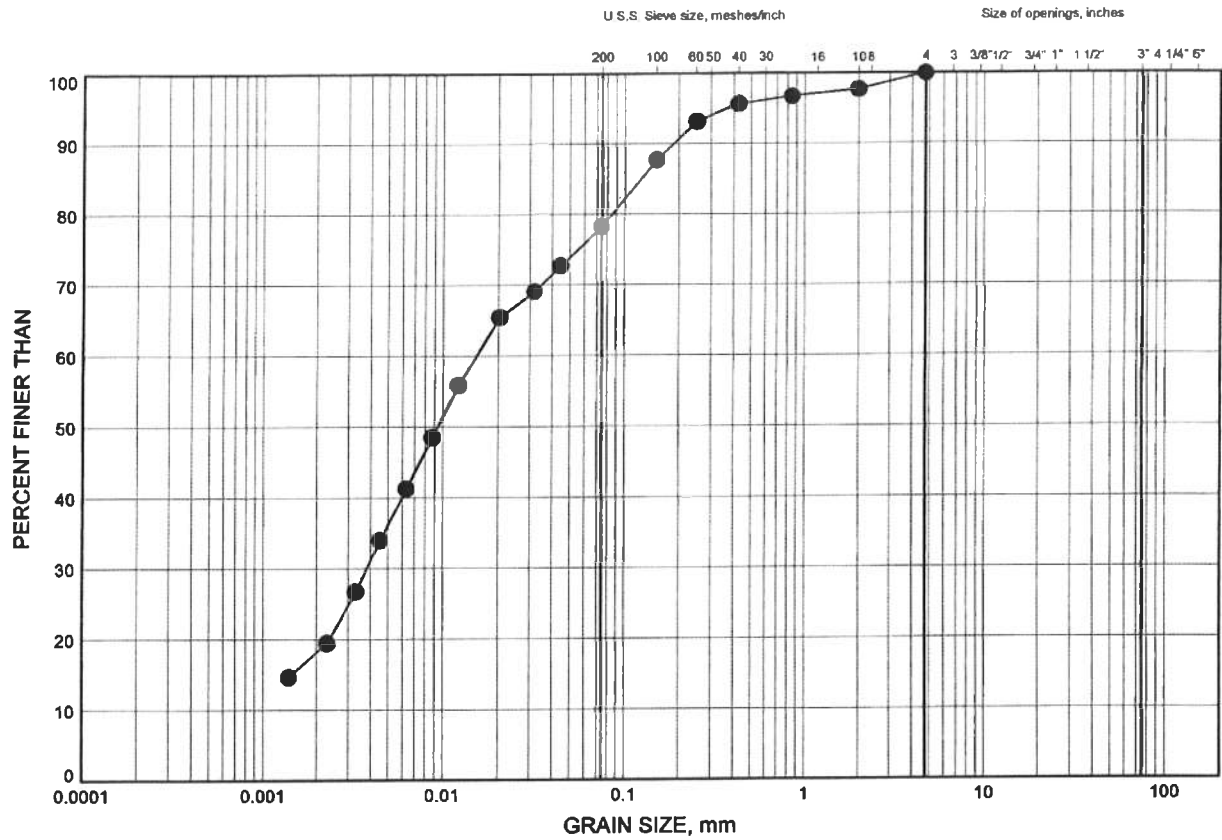


Prep'd AN  
Chkd. LRB

Hwy 407 Brock Road Connection - Foundations  
**GRAIN SIZE DISTRIBUTION**

**FIGURE B3**

**SANDY SILT**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM5-01	13.78	164.42

GRAIN SIZE DISTRIBUTION - THURBER 1130A.GPJ 11/29/12

Date November 2012  
W.P.# E2-0212



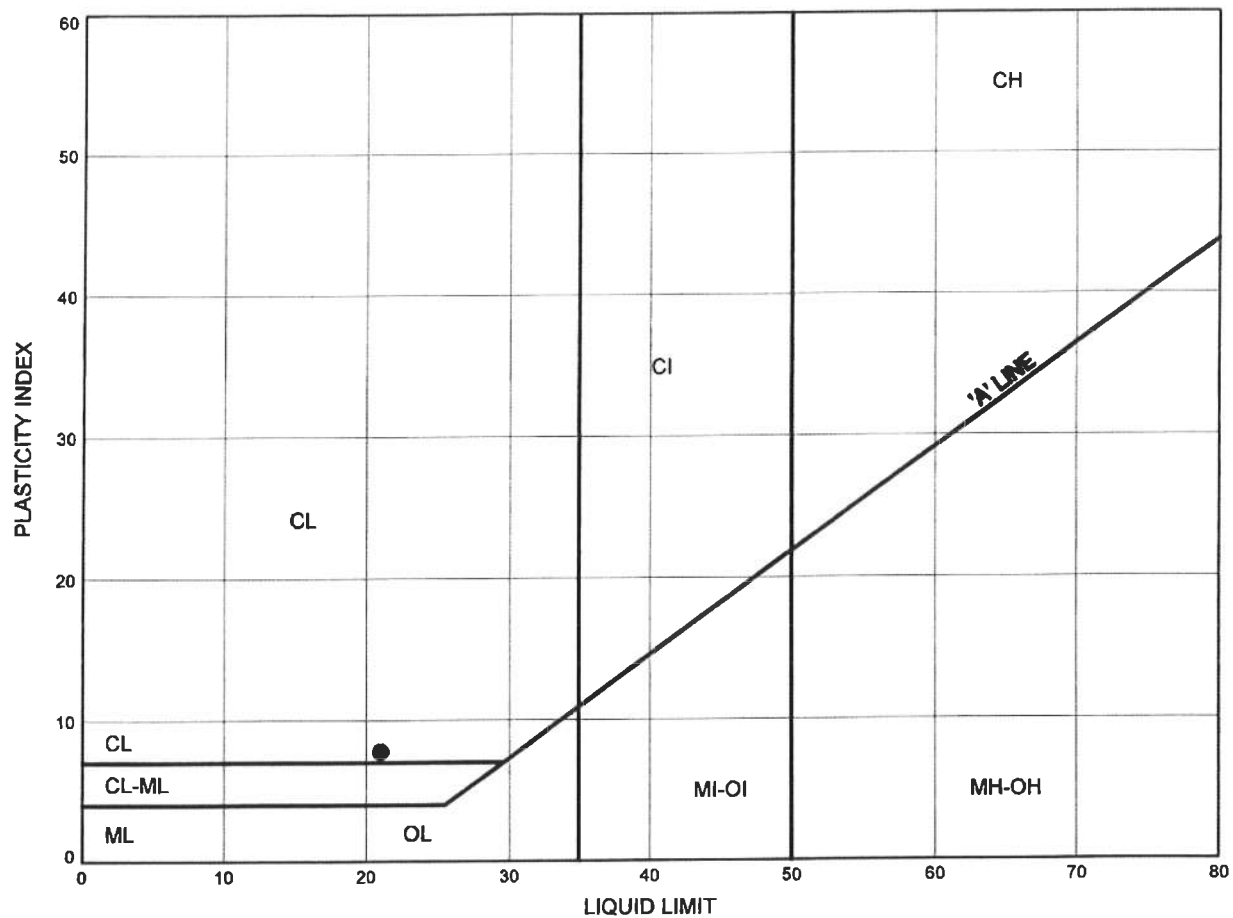
Prep'd AN  
Chkd. LRB

# Hwy 407 Brock Road Connection - Foundations

## ATTERBERG LIMITS TEST RESULTS

FIGURE B4

### SILTY SAND TILL



#### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM5-02	1.07	174.83

Date November 2012  
W.P.# E2-0212



Prep'd AN  
Chkd. LRB

**Appendix C**  
**Selected Site Photographs**

Structure M-5: Realigned Brock Road over Brougham Creek Tributary 'A'  
Highway 407/Brock Road Interchange Connection

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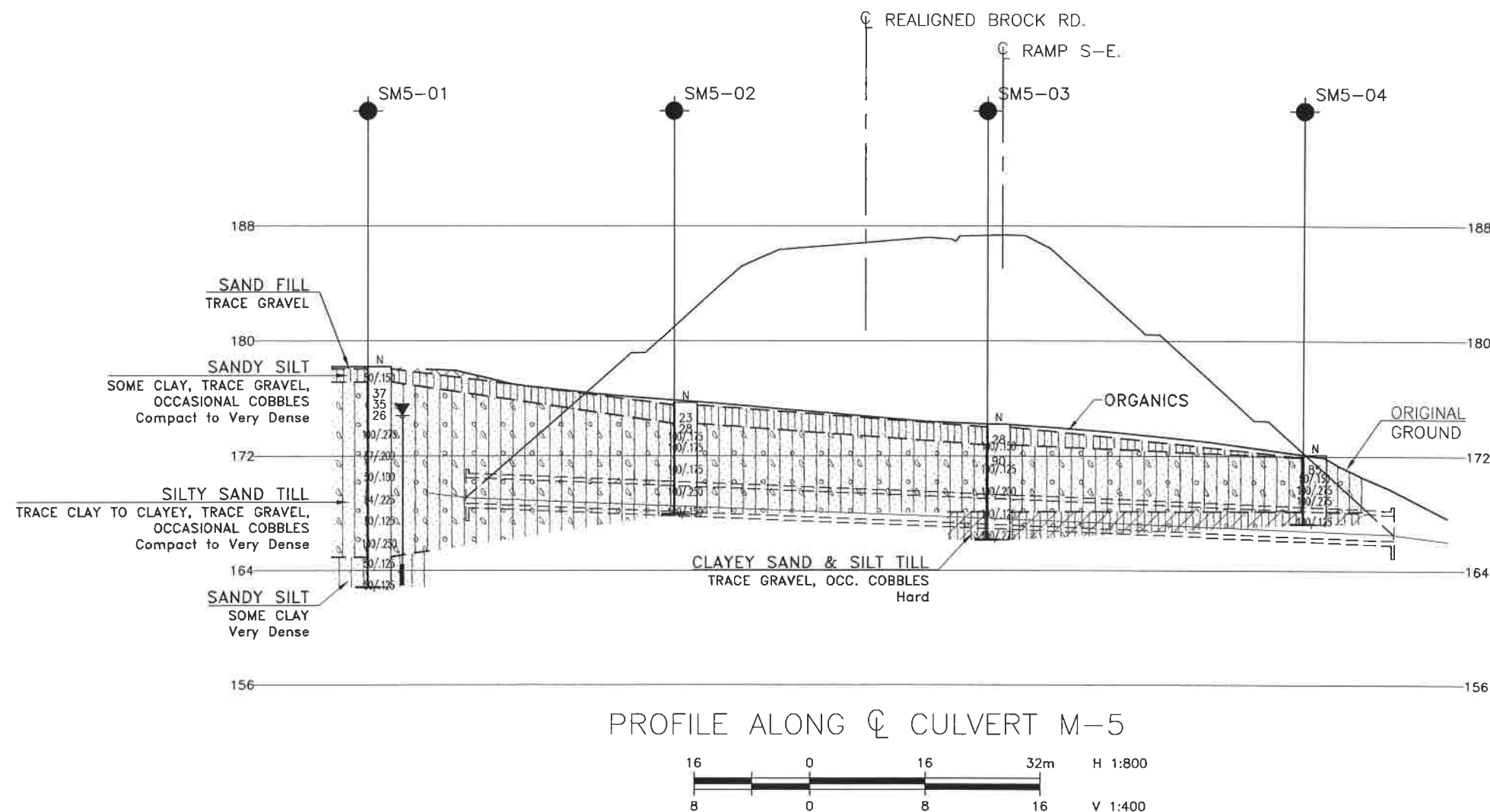
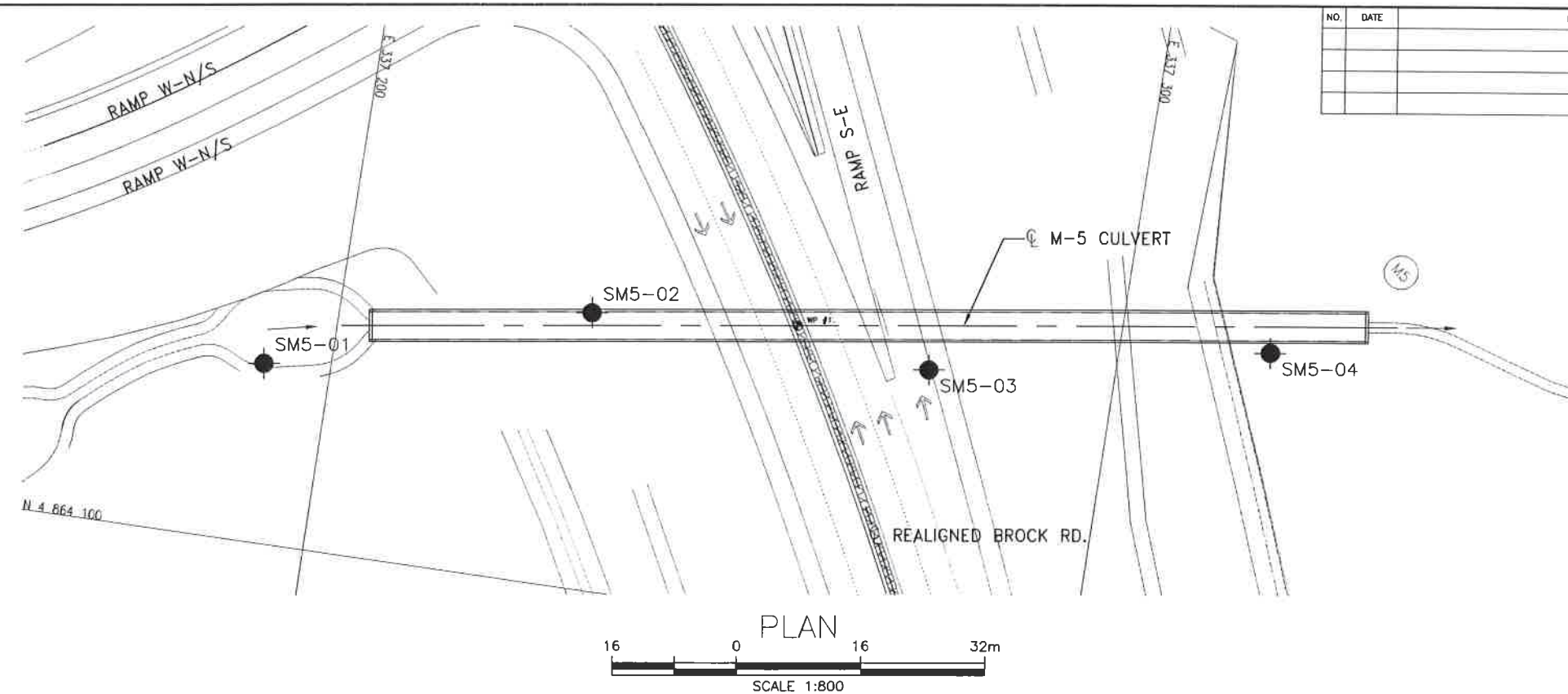
Looking East along Proposed Culvert M-5 Alignment (towards Sideline 16)



Looking West Along Proposed Culvert M-5 Alignment



**Appendix D**  
**Borehole Locations and Soil Strata Drawing**



NO.	DATE	REVISIONS	BY	CHK	LEAD DESC	AL

METRIC

DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

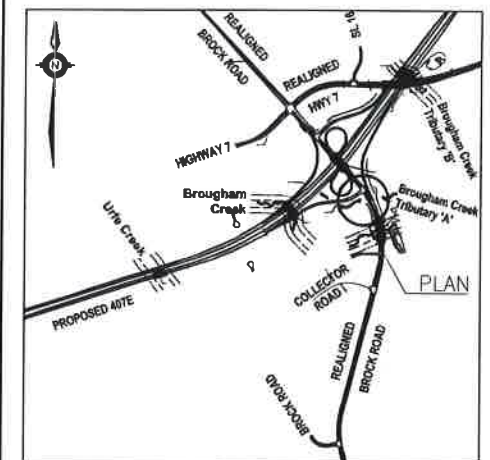
CONTRACT No. E2-2012  
HWY 407/BROCK ROAD  
INTERCHANGE

STRUCTURE M-5 (SITE 5)  
REALIGNED BROCK ROAD OVER  
BROUGHAM CREEK TRIBUTARY 'A'  
BOREHOLE LOCATIONS AND SOIL STRATA

**407 ETR**  
Express Toll Route








**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                         |

[illegible]

**-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.

DRAWING NAME: H:\Drafting\19\5161\130\td130A-M5-BoreholePlan&Profile.dwg  
CREATED: November 19, 2012 MODIFIED: January 25, 2013

DESIGN LRB	CHK LRB	CODE	LOAD	DATE JAN. 2013
DRAWN AN	CHK AEG	SITE 5	STRUCT M-5	DWG 1