

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 407/BROCK ROAD INTERCHANGE CONNECTION  
STRUCTURE M-3 (SITE 4)  
HIGHWAY 407 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 two new culverts (Structure M-3) that will carry Brougham Creek Tributary 'A' under the new EB and WB lanes of Highway 407 and the W-N/S ramp at the realigned Brock Road, in the City of Pickering, Ontario. The proposed culverts are part of the Highway 407/Brock Road Interchange Connection project.

The purpose of the current 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 culverts run approximately north-south and are located approximately 280 m west of the existing Sideline 16 at Highway 407/Highway 7. The community of Brougham is located approximately 600 m northwest of the proposed culverts.

At the proposed culverts, Brougham Creek Tributary 'A' flows from northwest to southeast. The northern culvert is located within the existing creek channel and the southern culvert is located southwest of the existing channel, in an open agricultural field. Lands surrounding the culvert site consist primarily of agricultural fields and undeveloped areas.

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, interbedded with or 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.

Selected site photographs are included in Appendix D.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this structure were carried out on various dates in August, September, and December 2012. The exact dates are noted on the Record of Borehole sheets included in Appendix A. Seven boreholes, identified as SM3-01 to SM3-07, were drilled and sampled at this site. The boreholes were advanced to depths of 6.6 m to 11.1 m (Elevation 175.3 to 170.3 m).

The boreholes were located along the proposed culvert alignment at approximately 40 m spacing along the northern culvert and 35 m spacing along the southern culvert. Boreholes SM3-01 to SM3-04 were located along the proposed northern culvert and Boreholes SM3-05 to SM3-07 along the proposed southern culvert. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata drawings included in Appendix E.

Two boreholes (M3-1 and M3-2) were previously drilled at this site in December 2010 by Peto MacCallum Ltd. The borehole logs for these two boreholes are included in Appendix C and the approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing included in Appendix E.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. At selected borehole locations, double row silt fencing with straw bales was installed between the drill location and the creek to prevent migration of potential sediment laden water into the adjacent creek. As well, Permission to Enter was obtained for the property accessed during this investigation.

The boreholes were drilled using a B57 track-mounted drill rig and the boreholes were advanced with a combination of hollow stem augers and 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 three boreholes at this site 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>
SM3-01	8.2 / 175.3	A piezometer with 3.0 m slotted screen was installed with filter sand to 4.9 m and bentonite holeplug from 4.9 m surface.
SM3-02	None installed	Backfilled with bentonite holeplug and cuttings to surface.
SM3-03	6.6 / 175.4	A piezometer with 3.0 m slotted screen was installed with filter sand to 3.3 m and bentonite holeplug from 3.3 m to surface.
SM3-04	None installed	Borehole caved to 6.0 m. Backfilled with bentonite from 6.0 to 1.1 m, then cuttings to surface.
SM3-05	None installed	Backfilled with bentonite from 6.6 to 1.8 m, then cuttings to surface.
SM3-06	None installed	Backfilled with bentonite from 7.8 to 1.7 m, then cuttings to surface.
SM3-07	9.5 / 170.3	A 19 mm diameter piezometer with 1.5 m slotted screen was installed with filter sand to 6.3 m, bentonite holeplug from 6.3 to 1.9 m, then 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 “Borehole Locations and Soil Strata” drawings included in Appendix E. 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 overlying silty sand till. More detailed descriptions of the individual strata are presented below.

##### **5.1 Organics**

A thin layer of surficial organics containing roots and rootlets was encountered in all boreholes. The thickness of the surficial organic layer ranged from 75 to 225 mm.

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

## 5.2 Embankment Fill

Embankment fill, consisting of silty sand, was encountered below surficial organics in Borehole SM3-04 which was drilled on the south side of the existing Highway 407 embankment. The silty sand was brown to grey and contained some clay to clayey zones and trace gravel.

The embankment fill was 5.3 m thick, with the lower boundary of the fill encountered at a depth of 5.5 m (Elevation 179.3 m).

SPT N-values recorded in the embankment fill ranged from 18 to 34 blows, indicating a compact to dense relative density. Moisture contents of the fill ranged from 7 to 10%.

One sample of the silty sand fill was selected for laboratory grain size analysis, the result of which is summarized below. The result is also presented on the corresponding Record of Borehole sheets included in Appendix A. The grain size distribution curve for this sample is plotted on Figure B1, Appendix B.

Soil Particles	Percentage (%)
Gravel	1
Sand	46
Silt	35
Clay	18

This sample of the silty sand exhibited sufficient plasticity for Atterberg Limits testing. The results of the Atterberg Limits tests are summarized below and are plotted on Figure B6, Appendix B.

Index Property	Percentage (%)
Liquid Limit	22
Plastic Limit	14
Plasticity Index	8

## 5.3 Clayey Silt

A layer of clayey silt was encountered beneath the organic layer in Boreholes SM3-01 to SM3-03 and SM3-07, and beneath the silty sand fill in Borehole SM3-04. The clayey silt was characterized as dark brown in colour and with organic matters and occasional roots. The layer thickness ranged from 0.3 to 1.2 m with the bottom elevations of the layer ranging from 178.1 to 182.7 m.

SPT N-values recorded in the clayey silt were typically about 2 blows, indicating a very soft to soft consistency. SPT N-values recorded in the clayey silt below the embankment fill

was greater than 100 blows, which may represent an obstruction in the soil. Moisture contents of the clayey silt ranged from 20 to 52%.

#### 5.4 Sandy Silt

A layer of sandy silt with some clay and organics was encountered below the clayey silt layer in Borehole SM3-03. The sandy silt was brownish grey and contained some clay and organics.

The sandy silt layer was 1.7 m thick, with the lower boundary of this layer encountered at a depth of 2.3 m (Elevation 179.7 m).

SPT N-values of 2 blows for 0.3 m penetration, indicating a very loose relative density, were recorded in the sandy silt. The moisture contents of the sandy silt ranged between 40 and 48%.

One sample of the sandy silt was selected for laboratory grain size analysis, the result of which is summarized below. The result is also presented on the corresponding Record of Borehole sheets included in Appendix A. The grain size distribution curve for this sample is plotted on Figure B2, Appendix B.

Soil Particles	Percentage (%)
Gravel	1
Sand	23
Silt	64
Clay	12

#### 5.5 Sand

Sand deposits were encountered below the sandy silt in Borehole SM3-03, below the sandy silt till in Borehole SM3-04 and sandwiched between silty sand till layers in Borehole SM3-06. The sand was not fully penetrated in SM3-04. Layer thickness ranged between 0.5 and more than 0.8 m with the underside elevations ranging from 175.3 to 179.1 m.

SPT N-values recorded in the sand ranged from 14 to greater than 100 blows, indicating a compact to very dense relative density. Moisture contents of the sand ranged from 10 to 36%. The sample with high water content contained some organics.

#### 5.6 Silty Sand to Clayey Sand and Silt Till

A silty sand till layer was encountered below the clayey silt layer in Boreholes SM3-01, SM3-02, SM3-04 and SM3-07, and below the organic layer in Boreholes SM3-05 and SM3-06. The till was found below the sand layer in SM3-03. The silty sand till became clayey sand and silt till at depth in Boreholes SM3-06 and SM3-07. The till was typically brown, becoming grey with depth. The till contained trace clay to clayey and occasional gravelly zones. The presence of occasional cobbles and gravel zones in the till was inferred during drilling.



The till was fully penetrated in Boreholes SM3-01, SM3-02 and SM3-04 with layer thickness ranging from 2.0 to 9.8 m (bottom of layer Elevation 172.9 to 176.1 m). Boreholes SM3-03, SM3-05, SM3-06 and SM3-07 were terminated in the till at elevations ranging from 170.3 to 174.5 m.

SPT N-values recorded in the till ranged from 7 to greater than 100, indicating a loose to very dense relative density. Typical SPT N-values ranged from 50 to greater than 100, indicating a very dense relative density. Moisture contents of the till ranged from 6 to 18%.

Grain size analysis was performed on twelve 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 B3 to B5, Appendix B. Two grain size distribution tests showed high gravel contents (23 to 39% gravel) in the till, indicative of the presence of gravel zones. The results of the grain size analysis tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	1 to 39
Sand	39 to 68
Silt	18 to 43
Clay	7 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 B7, Appendix B.

Index Property	Percentage (%)
Liquid Limit	18
Plastic Limit	10
Plasticity Index	8

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

### 5.7 Lower Sandy Silt

A layer of grey sandy silt was encountered below the silty sand till in Borehole SM3-01.

An SPT N-value of 195 was recorded in the sandy silt, indicating a very dense relative density. Moisture content of the sandy silt was about 15%.

### 5.8 Gravel with some Sand

A layer of gravel with some sand was encountered below the silty sand till in Borehole SM3-02.

SPT N-value of greater than 111 was recorded in the gravel, indicating a very dense relative density. Moisture content of the gravel was about 8%.

## 5.9 Groundwater Conditions

Water levels were observed in the open boreholes during and upon completion of drilling. Three standpipe piezometers were installed at this site 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	
SM3-01	Dec. 18, 2012	0.5	183.0	Piezometer
	Dec. 19, 2012	0.2	183.3	
	Jan. 2, 2013	0.2**	183.3	
SM3-02	Dec. 7, 2012	0.6	182.3	Open borehole
SM3-03	Dec. 18, 2012	-0.2*	182.2	Piezometer
	Dec. 19, 2012	-0.3*	182.3	
	Jan. 2, 2013	-0.3*, **	182.3	
SM3-04	Sept.4, 2012	4.9	179.9	Open borehole
SM3-05	Sept.7, 2012	DRY		Open borehole
SM3-06	Aug.15, 2012	6.6	175.2	Open borehole
SM3-07	Aug.16, 2012	0.3	179.6	Piezometer
	Aug.28, 2012	0.4	179.5	
	Sept. 13, 2012	0.1	179.8	
	Oct.16, 2012	2.6	177.3	
	Nov.26, 2012	2.2	177.7	
	Dec. 19, 2012	0.8	179.1	
	Jan. 2, 2013	2.6	177.3	

\* Negative value denotes artesian conditions.

\*\* Water was frozen inside the standpipe during measurement.

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 for boreholes SM3-04 to SM3-07. Walker Drilling of Barrie, Ontario supplied a D55 track-mounted drill rig and conducted the drilling, sampling and in-situ testing for boreholes SM3-01 to SM3-03.

The drilling and sampling operations in the field were supervised by Mr. Stephane Loranger, C.E.T. and Mr. Alistair Hall 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 Mr. Keli Shi, P.Eng. and Mr. Alastair Gorman, 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 report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for the design of culvert structure M-3.

At the proposed culvert locations, Brougham Creek Tributary 'A' flows from northwest to southeast. The northern culvert (M-3a) is located within the existing creek channel and the southern culvert (M-3b) is located southwest of the existing channel, in an open agricultural field.

The proposed culverts run approximately north-south and are located approximately 280 m west of the existing Sideline 16 at Highway 407/Highway 7. The northern culvert (M-3a) is to be approximately 114 m in length and the southern culvert (M-3b) is to be approximately 71 m in length.

Details of the proposed culvert are presented in Table 7.1.

**Table 7.1 – Proposed Culverts**

<b>Structure No.</b>	<b>Station</b>	<b>Description</b>	<b>Culvert Size (m)</b>	<b>Proposed Length (m)</b>	<b>Maximum Fill Height Above Crown (m)</b>
M-3a	Hwy 407 Sta. 17+656	New Twin Culverts under the proposed N-W Ramp and Hwy 407 embankment	2.4 x 1.5 (Twin)	113.685	4.7
M-3b	W-N/S Ramp Sta. 10+304	New Culvert under the proposed W-N/S Ramp	3.6 x 1.5	71.160	5.7

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 Group Limited.

## 8 FOUNDATION DESIGN

### 8.1 General

Details regarding the invert levels of the proposed culverts were based on the culvert section drawing. Highest groundwater levels at the proposed culvert location, monitored in the installed piezometer, are 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-3a	182.95	180.44	182.3 to 183.3 (Dec. 19, 2012)
M-3b	178.09	176.65	177.3 (Jan. 2, 2013)

Please refer to borehole locations and soil strata drawings for relationship of phreatic surface and the invert elevation.

The subsurface conditions encountered at the proposed culvert locations consist typically of loose sandy silt or soft clayey silt overlying compact to very dense silty sand to clayey silt and sand till. The founding levels of the proposed culverts will be approximately 1 to 5 m below the existing ground surface at the Culvert M-3a and approximately 3 to 6 m below the existing ground surface at the Culvert M-3b. Excavations of the native soils required for culvert installation will be mainly through the clayey silt and sandy silt and partially in the existing sand fill at the Culvert M-3a, and mainly in the silty sand till at the Culvert M-3b.

### 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 culvert types:

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

Based on the site conditions, it is recommended that closed box culverts 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 dense 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 underside of bedding, any remaining fill, topsoil, peat, streambed deposits or soft/loose soils within the culvert footprint must be removed to the underlying undisturbed competent soil. 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 material. This work must 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 glacial till or hard clayey silt.

In order to provide a uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS Granular A requirements must be provided under the base of box culvert. The bedding material must 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 and Elevations of Excavation for Box Culvert**

Structure No.	Location	Borehole	Culvert Invert Elevation (m)	Min. Excavation Depth* / Elevation below GS (m)	Underlying Soil Type
M-3a	Inlet	SM3-01	182.95	1.2 / 182.3	Compact to very dense silty sand till
	Middle	SM3-02	182.11	1.4 / 181.5	
		SM3-03	181.28	3.0 / 179.0	
	Outlet	SM3-04	180.44	5.5** / 179.3	Hard clayey silt
M-3b	Inlet	SM3-05	178.09	3.6 / 177.5	Very dense silty sand till
	Middle	SM3-06	177.37	5.0 / 176.8	
	Outlet	SM3-07	176.65	3.9 / 176.0	

\* To satisfy bedding requirements or removal of unsuitable soil, a 300 mm base slab is assumed.

\*\* Depth measured from top of existing Hwy 407 embankment.

A box culvert founded on bedding placed on the native, undisturbed, compact to very dense silty sand till or hard clayey silt at the anticipated levels should be designed using geotechnical resistances at factored ULS of 450 kPa and at SLS of 300 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 culverts must be founded on the native, undisturbed dense soil to achieve sufficient bearing resistance. Following excavation to the design founding level, any remaining fill, topsoil, peat, streambed deposits or soft/loose soils on and below the bearing surface



must be removed and replaced with well-compacted Granular A material in accordance with OPSS902.

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-3a	Inlet	SM3-01	182.95	2.3	181.2	Very dense silty sand till
	Middle	SM3-02	182.11	2.9	180.0	
		SM3-03	181.28	2.9	179.1	
	Outlet	SM3-04	180.44	5.5*	179.3	Hard clayey silt
M-3b	Inlet	SM3-05	178.09	4.3	176.8	Very dense sandy silt till
	Middle	SM3-06	177.37	5.7	176.1	
	Outlet	SM3-07	176.65	4.5	175.4	

\* Depth measured from top of existing Hwy 407 embankment.

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

Footing Width (m)	Sand and Silt Till	
	<u>0.9</u>	<u>1.2</u>
Factored Geotechnical Resistance at ULS (kPa)	450	475
Geotechnical Resistance at SLS (kPa)	300	325

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.

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 0.55. 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 embankment to be constructed and the type and thickness of foundation soils and subgrade.

The proposed culverts will be founded at depths up to 6 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 settlements along the proposed culverts under the Highway 407 main embankment and W-N/S Ramp are anticipated to be less than 20 mm. The majority of the anticipated settlements will take place during fill placement.

Standard embankment slope inclination of 2H:1V in SSM or granular fill is expected to be stable on the foundation soils consisting of compact 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 and soft clayey silt with organic inclusions. The presence of alluvial and organic deposits should be expected in the vicinities of the watercourse. The depths of organics at borehole locations 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 material placed and compacted in accordance with OPSS902.

## **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 must 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**, $K_{OE}$ (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.

<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.

## **11 SCOUR PROTECTION AND EROSION CONTROL**

Culvert foundations 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.

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 must 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. The existing embankment fill is classified as Type 3 soil, and the clayey silt and sandy silt are also classified as Type 3 soil.

Temporary shoring may be required to retain the existing Highway 407 embankment and 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 passing traffic loads, 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 3 m above the invert levels at the proposed culvert locations. Excavation to reach culvert subgrade will be carried out below the groundwater level. Culvert construction must start at the low end and seepage should be drained using sumps and pumps.

An NSSP should be included in the Contract Documents specifying that an appropriate dewatering operation shall be provided to maintain a stable and 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 subexcavation of the base, 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 must be placed on the approved subgrade as soon as practical following excavation. An effective dewatering plan is essential to maintaining a 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.

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**Appendix A**  
**Record of Borehole Sheets**  
**(Current Investigation)**

# 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 <sup>(1)</sup> '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<sub>pen</sub>

Shear Strength Determination by Pocket Penetrometer


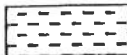



- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration 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
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			



## EXPLANATION OF ROCK LOGGING TERMS

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

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			Field Estimation of Hardness*
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	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

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.

## METRIC

[illegible]

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SM3-01

2 OF 2

METRIC

WP# E2-2012 LOCATION N 4 864 219.7 E 336 894.6 ORIGINATED BY AH  
HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.12.06 - 2012.12.06 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 (%)				
								20   40   60   80   100	20   40   60					
	Continued From Previous Page													
172.9							173							
10.6	Sandy SILT Very Dense Grey Moist		10	SS	195									
172.4														
11.1	END OF BOREHOLE AT 11.1m. WATER LEVEL AT 0.9m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE        DEPTH (m)    ELEV. (m) Dec. 18/12   0.5        183.0 Dec. 19/12   0.2        183.3 Jan. 02/13   0.2 (Frozen) 183.3													

## METRIC

[illegible]

# RECORD OF BOREHOLE No SM3-03

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 202.4 E 336 964.0 ORIGINATED BY AH  
 HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.12.05 - 2012.12.05 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 ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE					
182.0								20 40 60 80 100		20 40 60				
0.0	ORGANICS: (200mm)													
0.2	Clayey SILT , with organics		1	SS	2						○			
181.4	Soft													
0.6	Dark Brown													
	Wet													
	Sandy SILT, some clay, some organics		2	SS	2						○		1 23 64 12	
	Very Loose													
	Brownish Grey													
	Wet													
	Sand layer (80mm) at 1.5m		3	SS	2						○			
179.7														
2.3	SAND, some organics		4	SS	14						○			
	Compact													
	Light Brown													
179.1	Moist													
2.9	Silty SAND, some gravel, trace clay, occasional gravelly zones		5	SS	61						○			
	Very Dense													
	Grey													
	Moist													
	(TILL)													
			6	SS	102/ 0.150						○		39 42 19 (SI+CL)	
	Wet													
			7	SS	142						○			
174.4			8	SS	116/ 0.150						○			
7.6	END OF BOREHOLE AT 7.6m. WATER LEVEL AT 1.2m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Dec. 18/12 0.2* 182.2 Dec. 19/12 0.3* 182.3 Jan. 02/13 0.3* (Frozen) 182.3  * Above ground surface (Artesian Condition)													

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

# RECORD OF BOREHOLE No SM3-04

1 OF 2

METRIC

WP# E2-2012 LOCATION N 4 864 163.3 E 336 990.0 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.09.04 - 2012.09.04 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		w <sub>p</sub>	w	w <sub>L</sub>		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE	WATER CONTENT (%)					
184.8							20   40   60   80   100	20   40   60						GR   SA   SI   CL
0.0	ORGANICS, with roots and rootlets: (175mm)													
0.2	Silty SAND, some clay to clayey, trace gravel Compact to Dense Brown Moist (FILL)		1	SS	18									
			2	SS	32									
			3	SS	20									
			4	SS	28									
	Grey													
			5	SS	34									
	Some organics observed on the augers													
179.3														
5.5	Clayey SILT, with some organic matter and wood fragments Hard Dark Brown Moist		6	SS	100/ 0.075									
178.1														
6.7	Silty SAND, some gravel to gravelly Very Dense Grey Moist to Wet (TILL)		7	SS	81									
176.1														
8.7	SAND, trace to some silt, trace cobbles Very Dense Grey Wet		8	SS	100/ 0.250									
175.3														
9.5	END OF BOREHOLE AT 9.5m. BOREHOLE OPEN TO 6.0m AND WATER LEVEL AT 4.9m UPON													

Continued Next Page

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

20  
15-φ 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SM3-04

2 OF 2

METRIC

WP# E2-2012 LOCATION N 4 864 163.3 E 336 990.0 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.09.04 - 2012.09.04 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 $\gamma$ 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 (%)			
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
	Continued From Previous Page															
	COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.1m, THEN CUTTINGS TO SURFACE.															

RECORD OF BOREHOLE No SM3-05

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 136.9 E 337 050.1 ORIGINATED BY SLL  
HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.09.07 - 2012.09.07 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	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	● QUICK TRIAXIAL	× LAB VANE								
181.1																			
0.0	ORGANICS, with roots and rootlets: (175mm)																		
0.2	Silty SAND, trace clay, trace gravel, occasional cobbles, with rootlets Compact to Very Dense Brown Moist (TILL)		1	SS	21											6 68 18 8			
			2	SS	70/ 0.200														
			3	SS	53														
	Grey		4	SS	100														
	Occasional cobbles		5	SS	100/ 0.175											5 42 43 10			
	Sample wet		6	SS	100														
174.5																			
6.6	END OF BOREHOLE AT 6.6m. BOREHOLE OPEN AND DRY ON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.8m, THEN CUTTINGS TO SURFACE.																		

ONTMT4S 1130A.GPJ 1/15/13



RECORD OF BOREHOLE No SM3-06

1 OF 1

METRIC

WP# E2-2012 LOCATION N 4 864 107.8 E 337 072.8 ORIGINATED BY SLL  
HWY 407 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.08.15 - 2012.08.15 CHECKED BY LR8

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	● QUICK TRIAXIAL	× LAB VANE	w <sub>P</sub>	w		
181.8						20	40	60	80	100	20	40	60		
0.0	ORGANICS, with roots and rootlets: (225mm)														
0.2	Silty SAND, some clay to clayey, trace gravel Very Dense Brown Moist (TILL)		1	SS	50										1   50   36   13
			2	SS	100										
179.4															
2.4	SAND, trace silt and gravel Dense Brown Moist		3	SS	39										
178.9															
2.9	Silty SAND, some clay to clayey, trace gravel Very Dense Brown Moist (TILL)		4	SS	100										
	Grey		5	SS	100/ 0.250										
			6	SS	100/ 0.225										3   42   34   21
				</											

ONTMT4S 1130A.GPJ 1/15/13

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

20  
15-5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SM3-07

1 OF 2

METRIC

WP# E2-2012 LOCATION N 4 864 099.1 E 337 108.5 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Hollow Stem Augers/Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.08.15 - 2012.08.15 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  <b>γ</b>  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 (%)				
179.9								20   40   60   80   100						
0.0								20   40   60   80   100						
0.1	ORGANICS, with roots and rootlets: (75mm)													
179.2	Clayey SILT, topsoil stained Dark Brown													
0.7	Moist													
	Silty SAND, some clay to clayey, trace gravel, occasional cobbles Compact to Very Dense Brown Moist (TILL)		1	SS	24		179							
	Grey		2	SS	69		178							
			3	SS	41		177							5   42   36   17
			4	SS	45		176							
			5	SS	52		175							
	Very hard during augering. Switch to SSA.		6	SS	100		174							9   39   34   18
			7	SS	30		172							
			8	SS	100/ 0.250		171							
170.3	END OF BOREHOLE AT 9.6m. Piezometer installation consists of													
9.6														

Continued Next Page

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

20  
15 10 5  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SM3-07

2 OF 2

METRIC

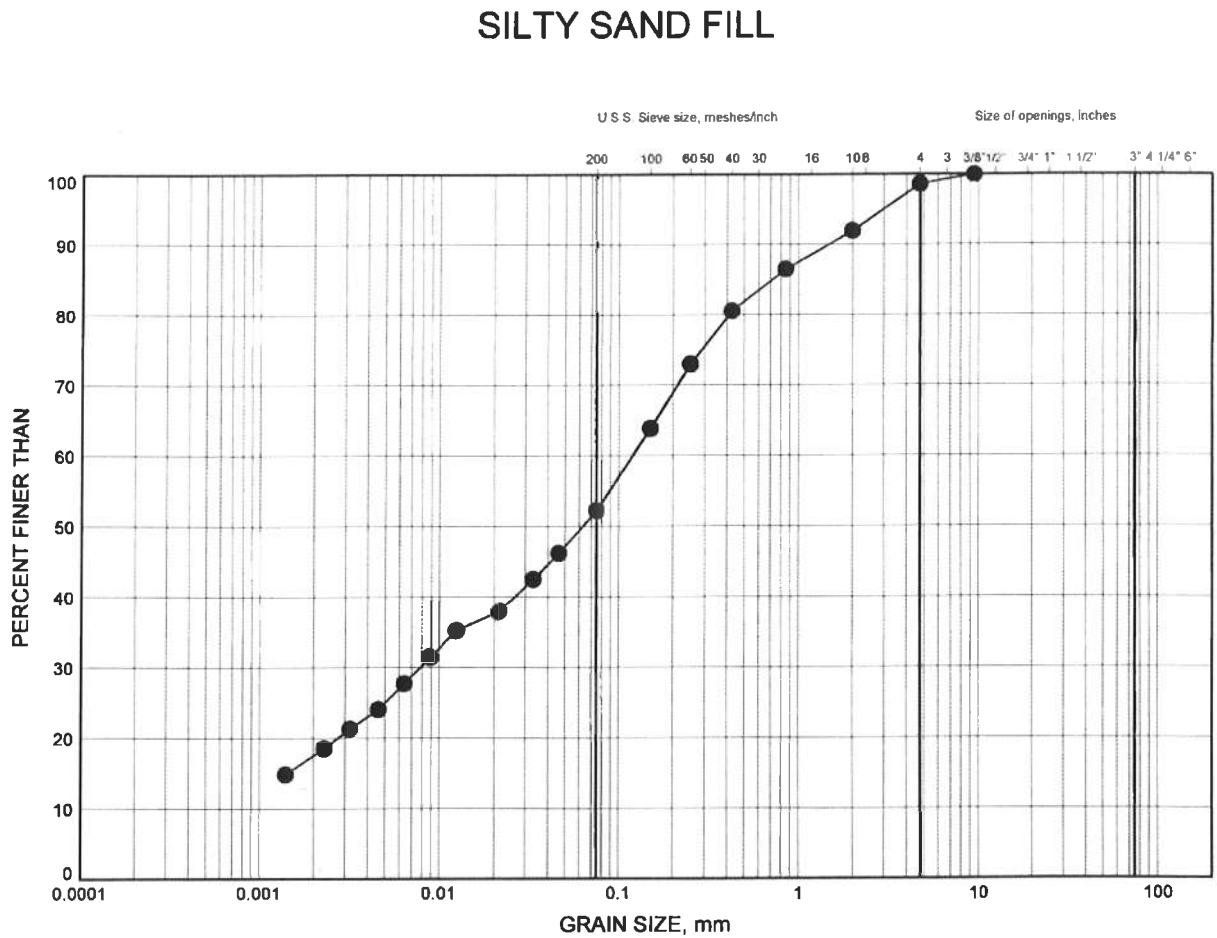
WP# E2-2012 LOCATION N 4 864 099.1 E 337 108.5 ORIGINATED BY SLL  
 HWY 407 BOREHOLE TYPE Hollow Stem Augers/Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.08.15 - 2012.08.15 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ 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 (%)				
							20	40	60	80	100	20	40	60			
	Continued From Previous Page																
	19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																
	WATER LEVEL READINGS:																
	DATE DEPTH (m) ELEV. (m)																
	Aug. 16/12 0.3 179.6																
	Aug. 28/12 0.4 179.5																
	Sep. 13/12 0.1 179.8																
	Oct. 16/12 2.6 177.3																
	Nov. 26/12 2.2 177.7																
	Dec. 19/12 0.8 179.1																
	Jan. 02/12 2.6 177.3																

**Appendix B**  
**Laboratory Test Results**  
**(Current Investigation)**

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		

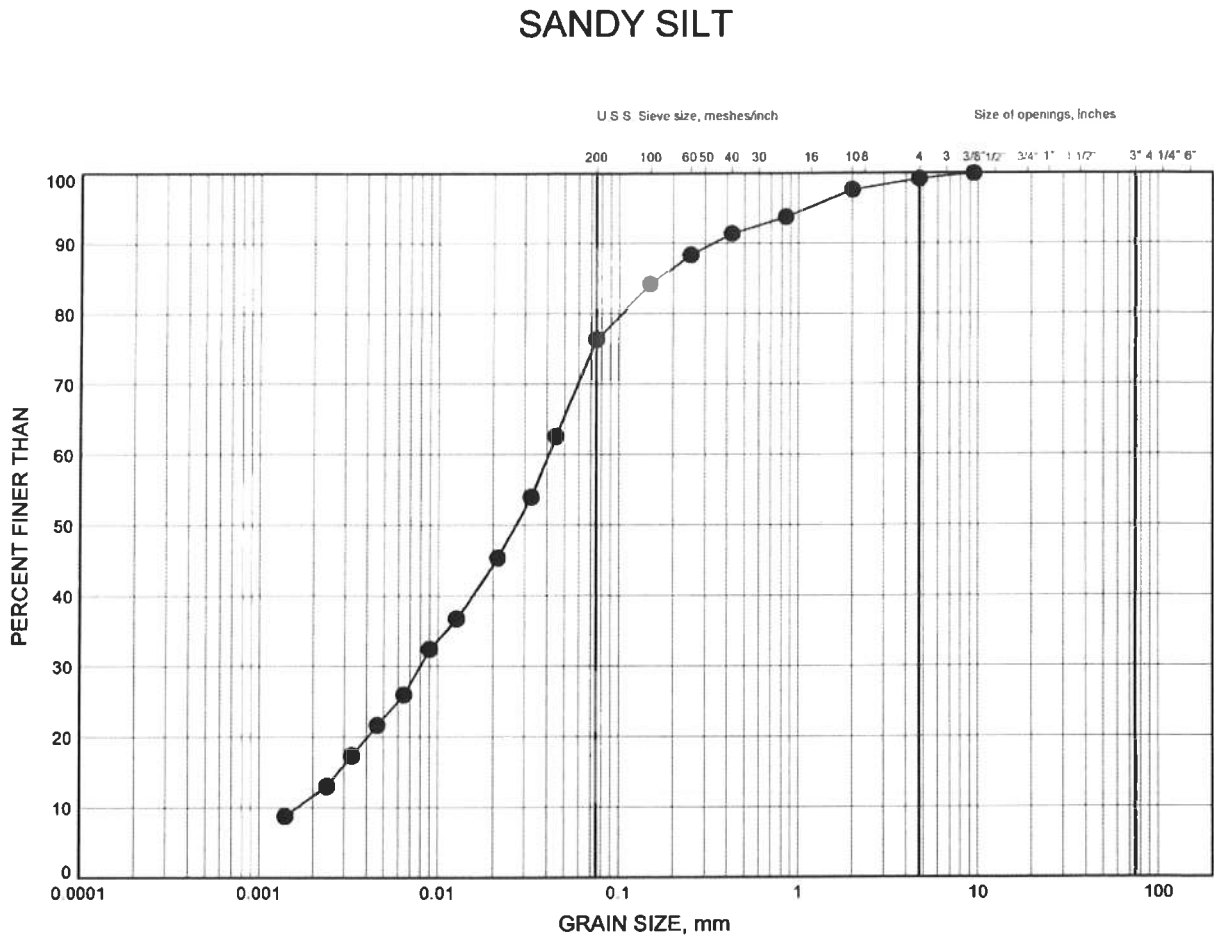
**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-04	2.59	182.21

Hwy 407 Brock Road Connection - Foundations

# GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-03	1.07	180.93

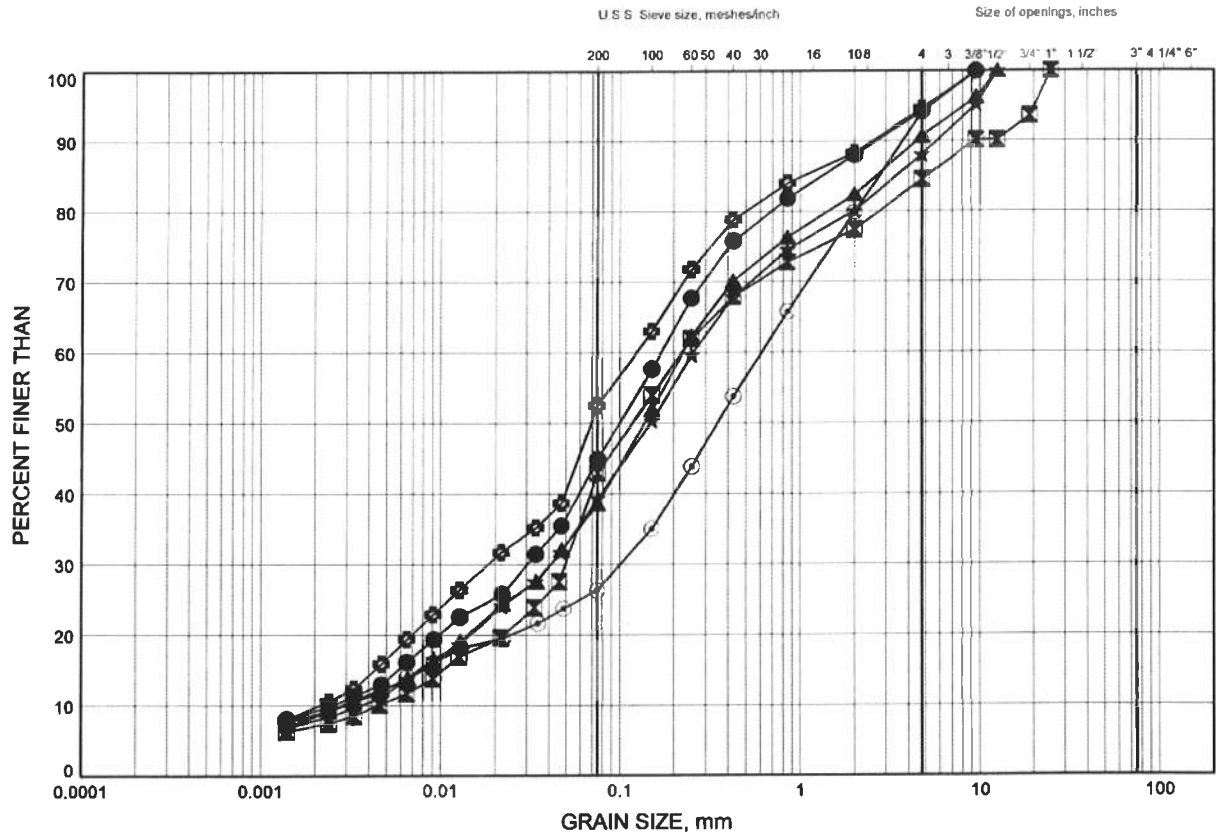


# Hwy 407 Brock Road Connection - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B3

### SILTY SAND TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-01	2.59	180.91
⊠	SM3-01	7.92	175.58
▲	SM3-02	1.83	181.07
★	SM3-02	6.40	176.50
⊙	SM3-05	1.07	180.03
⊕	SM3-05	4.74	176.36

Date January 2013  
 WP# E2-2012

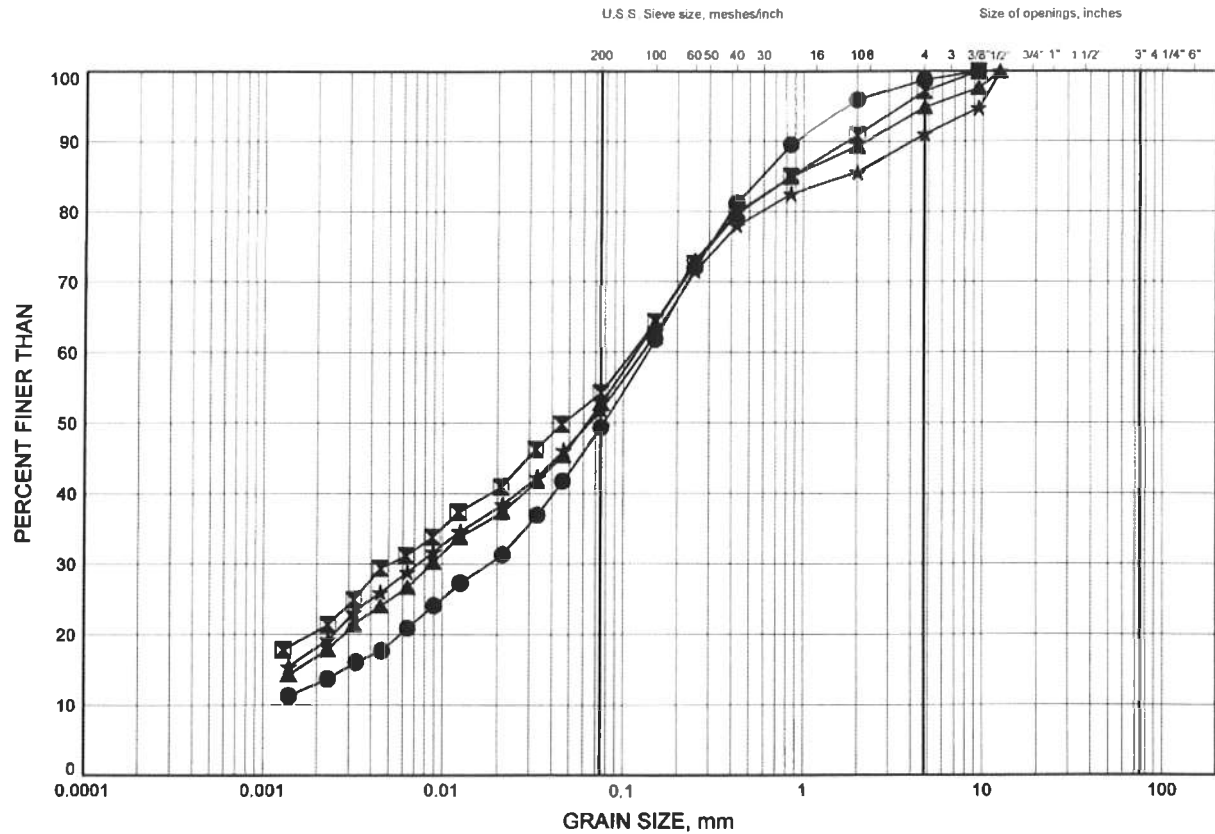


Prep'd AN  
 Chkd. KS

Hwy 407 Brock Road Connection - Foundations  
GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-06	1.07	180.73
■	SM3-06	6.29	175.51
▲	SM3-07	2.59	177.31
★	SM3-07	6.32	173.58

Date January 2013  
WP# E2-2012



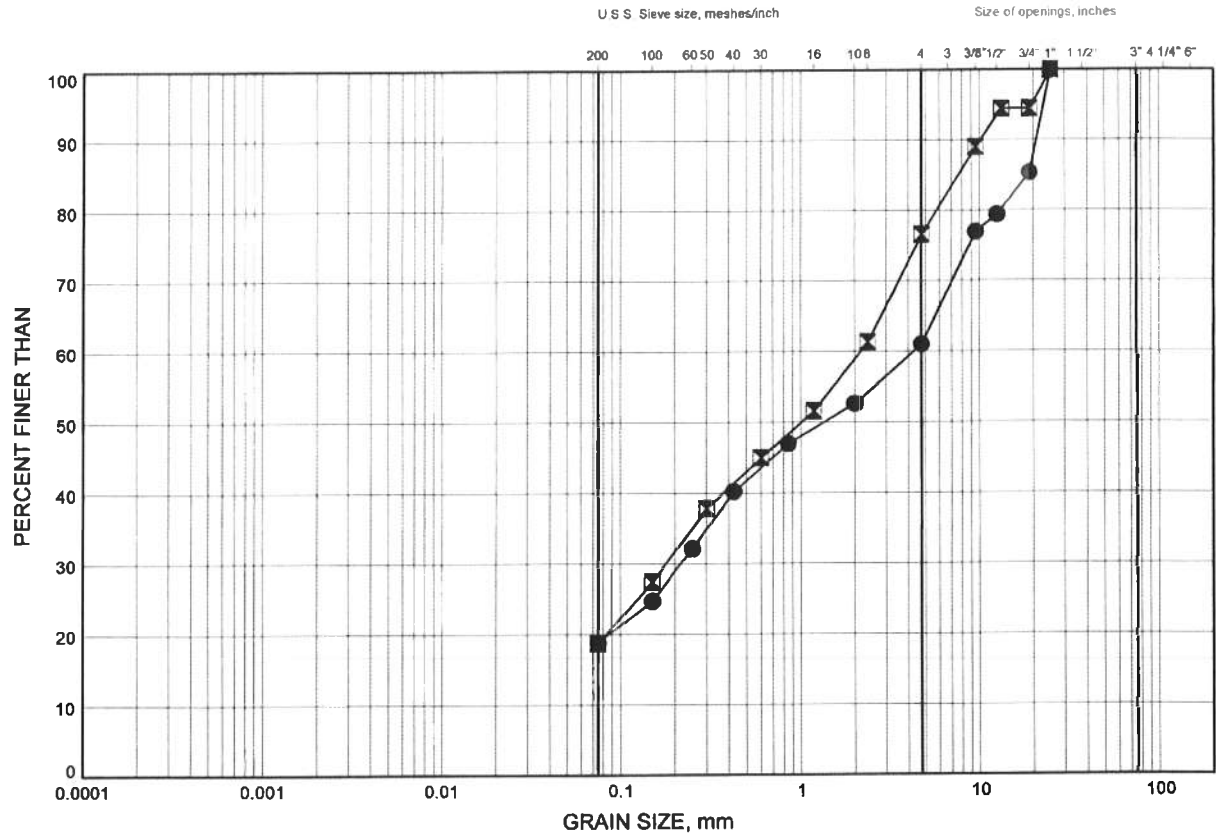
Prep'd AN  
Chkd. KS



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

**FIGURE B5**

**GRAVELLY TILL ZONE**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-03	4.88	177.12
⊠	SM3-04	7.90	176.90

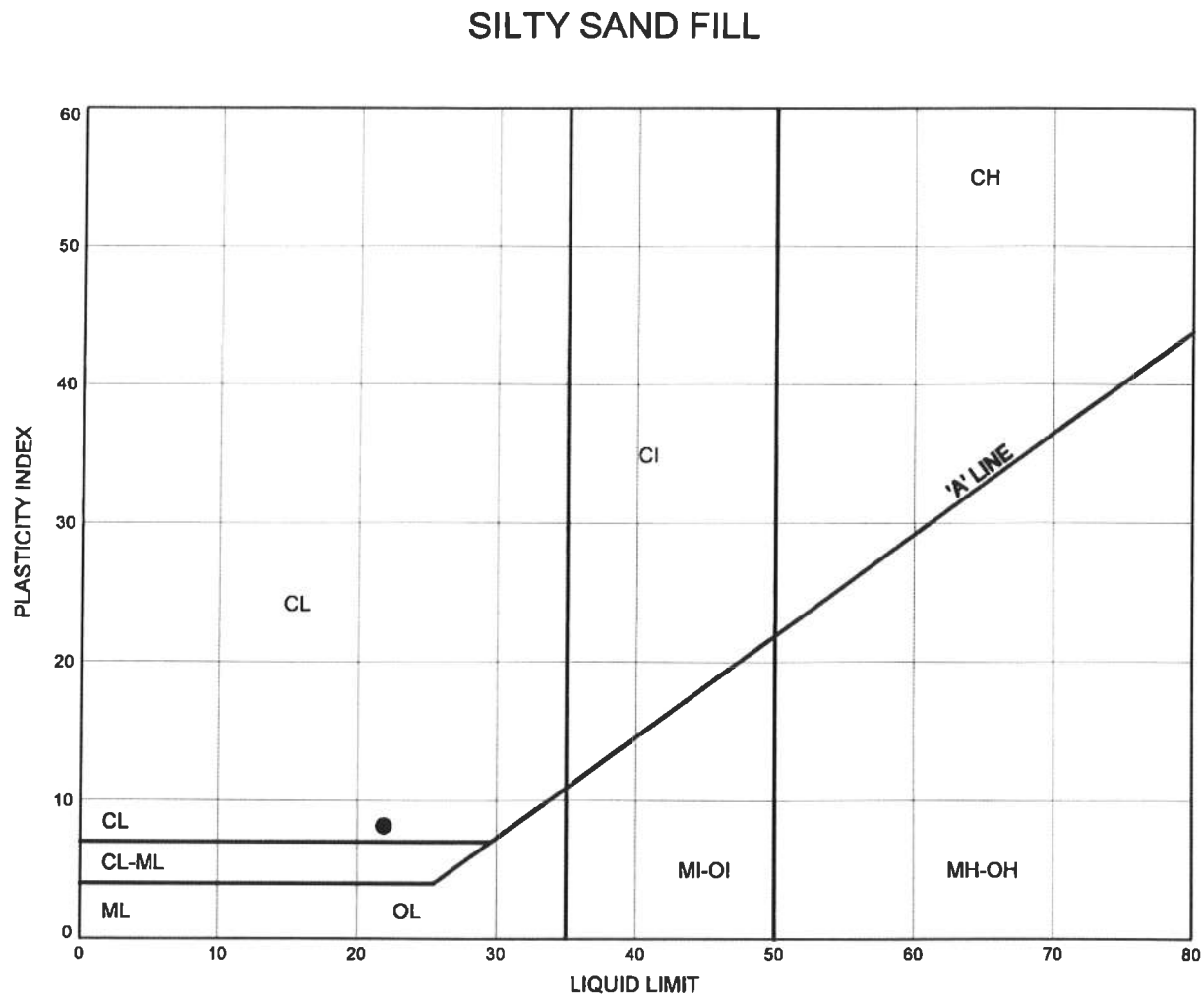
Date January 2013  
 WP# E2-2012



Prep'd AN  
 Chkd. KS

Hwy 407 Brock Road Connection - Foundations  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B6



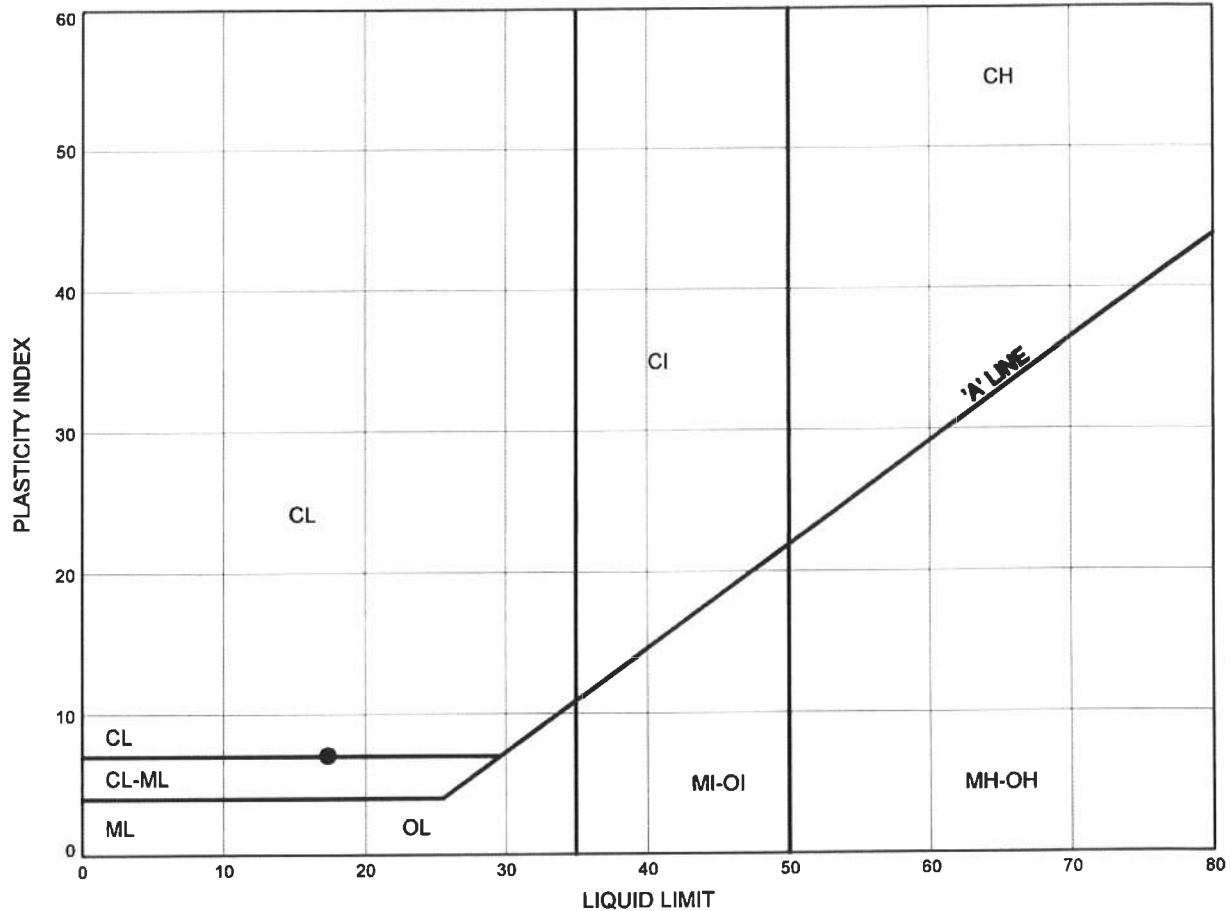
**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-04	2.59	182.21

Hwy 407 Brock Road Connection - Foundations  
**ATTERBERG LIMITS TEST RESULTS**

**FIGURE B7**

**SILTY SAND TILL**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SM3-07	6.32	173.58

Date January 2013  
 WP# E2-2012



Prep'd AN  
 Chkd. KS

**Appendix C**  
**Record of Borehole Sheets**  
**(Previous Investigation)**



**RECORD OF BOREHOLE No M3-2**

1 of 1

**METRIC**

G.W.P. 07-20015 LOCATION Coords: 4 864 160.7 N; 337 013.1 E ORIGINATED BY F.P.  
 DIST Central HWY 407E BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY N.S.B.  
 DATUM Geodetic DATE December 10, 2010 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
182.5	Ground Surface							20 40 60 80 100		20 40 60					
0.0	150mm asphalt over crushed limestone		1	AS	-										
182.0	Grey (PAVEMENT FILL)														
0.5	Sand, with silt some gravel, trace clay		2	SS	51									14 49 27 10	
	Very dense Brown Moist (FILL)		3	SS	50/15cm										
	silty clay layers organic inclusions														
	Compact		4	SS	15										
			5	SS	18										
	Organic clayey silt														
	Dark brown		6	SS	20										
178.2	Silty sand, trace gravel														
4.3	Compact Brown Damp		7	SS	15										
177.3	Silty sand trace clay, trace gravel														
5.2	Compact Brown Moist to wet		8	SS	15									19 45 27 9	
	(TILL)		9	SS	66										
	gravelly sand layers														
	Dense to very dense														
	sandy gravel layers														
	Wet		10	SS	50/15cm										
174.6	End of borehole														
7.9	Probable silty sand														
	Very dense (TILL)														
173.6	End of dynamic cone penetration test														
8.9	Samples 3 and 10: Sampler bouncing														
	2010 12 10														
	Water level observed during drilling														
	Water level measured after drilling														
	C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers														

**Appendix D**  
**Selected Site Photographs**

Structure M-3: Highway 407 over Brougham Creek Tributary 'A'  
Highway 407/Brock Road Interchange Connection

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**Existing Culverts - South side of Highway 407, looking northeast**



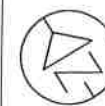
**Looking North along proposed alignment**



**Appendix E**  
**Borehole Locations and Soils Strata Drawings**

NO.	DATE	REVISIONS	BY	CHK	LOAD	PROJ.

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



STRUCTURE M-3 (SITE 4)  
HIGHWAY 407 OVER  
BROUGHAM CREEK TRIBUTARY 'A'  
BOREHOLE LOCATIONS AND SOIL STRATA

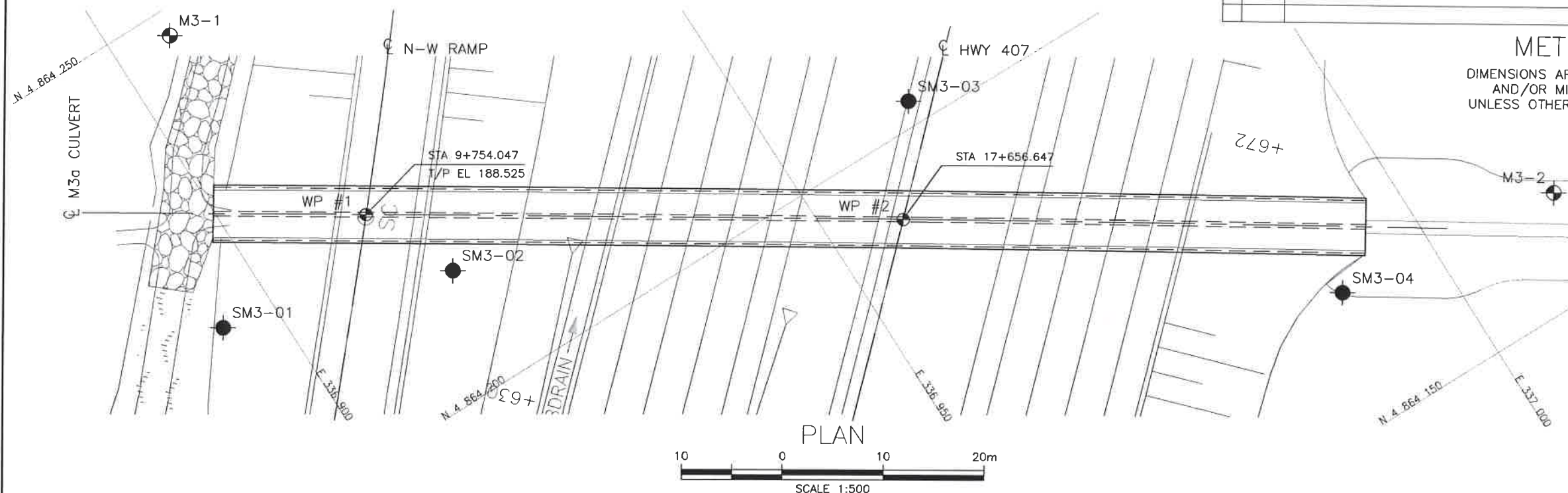
SHEET

**407 ETR**  
Express Toll Route

**MMM GROUP**

**THURBER ENGINEERING LTD.**

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



KEYPLAN

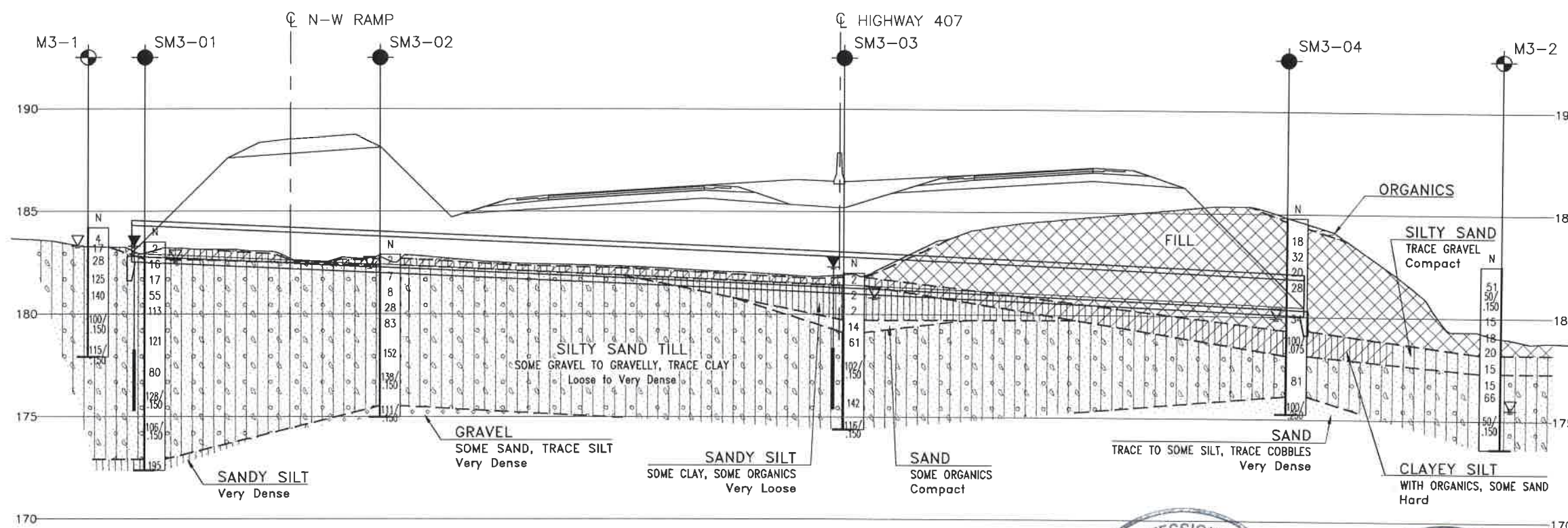
LEGEND

- Borehole (Current Investigation)
- ◆ Borehole (Previous Investigation)
- 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

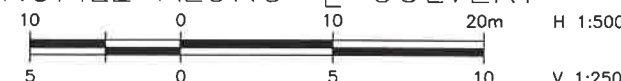
NO	ELEVATION	NORTHING	EASTING
M3-1	184.2	4 864 247.4	336 905.8
M3-2	182.5	4 864 160.7	337 013.1
SM3-01	183.5	4 864 219.7	336 894.6
SM3-02	182.9	4 864 212.2	336 916.9
SM3-03	182.0	4 864 202.4	336 964.0
SM3-04	184.8	4 864 163.3	336 990.0
SM3-05	181.1	4 864 136.9	337 050.1
SM3-06	181.8	4 864 107.8	337 072.8
SM3-07	179.9	4 864 099.1	337 108.5

-NOTES-

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



PROFILE ALONG CULVERT



DRAWING NAME: H:\Drafting\19\5151\130\130-M3-BoreholePlan&Profile.dwg  
CREATED: January 8, 2013  
MODIFIED: January 25, 2013

DESIGN	KS	CHK	AEG	CODE	LOAD	DATE	JAN. 2013
DRAWN	MFA	CHK	KS	SITE 4	STRUCT M-3	DWG 1	



NO.	DATE	REVISIONS	BY	CHK	LOAD	PROJ.

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



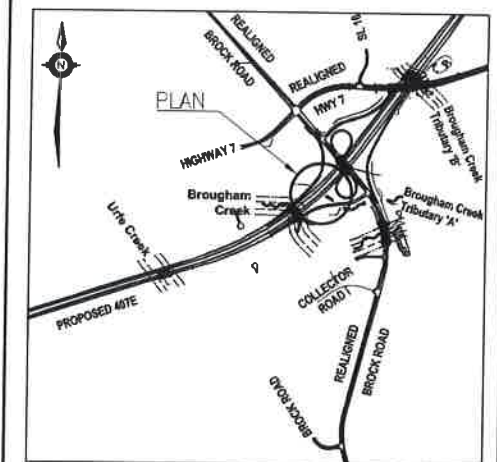
STRUCTURE M-3 (SITE 4)  
HIGHWAY 407 OVER  
BROUGHAM CREEK TRIBUTARY 'A'  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

**407 ETR**  
Express Toll Route

**MMM GROUP**

**THURBER ENGINEERING LTD.**



KEYPLAN

LEGEND

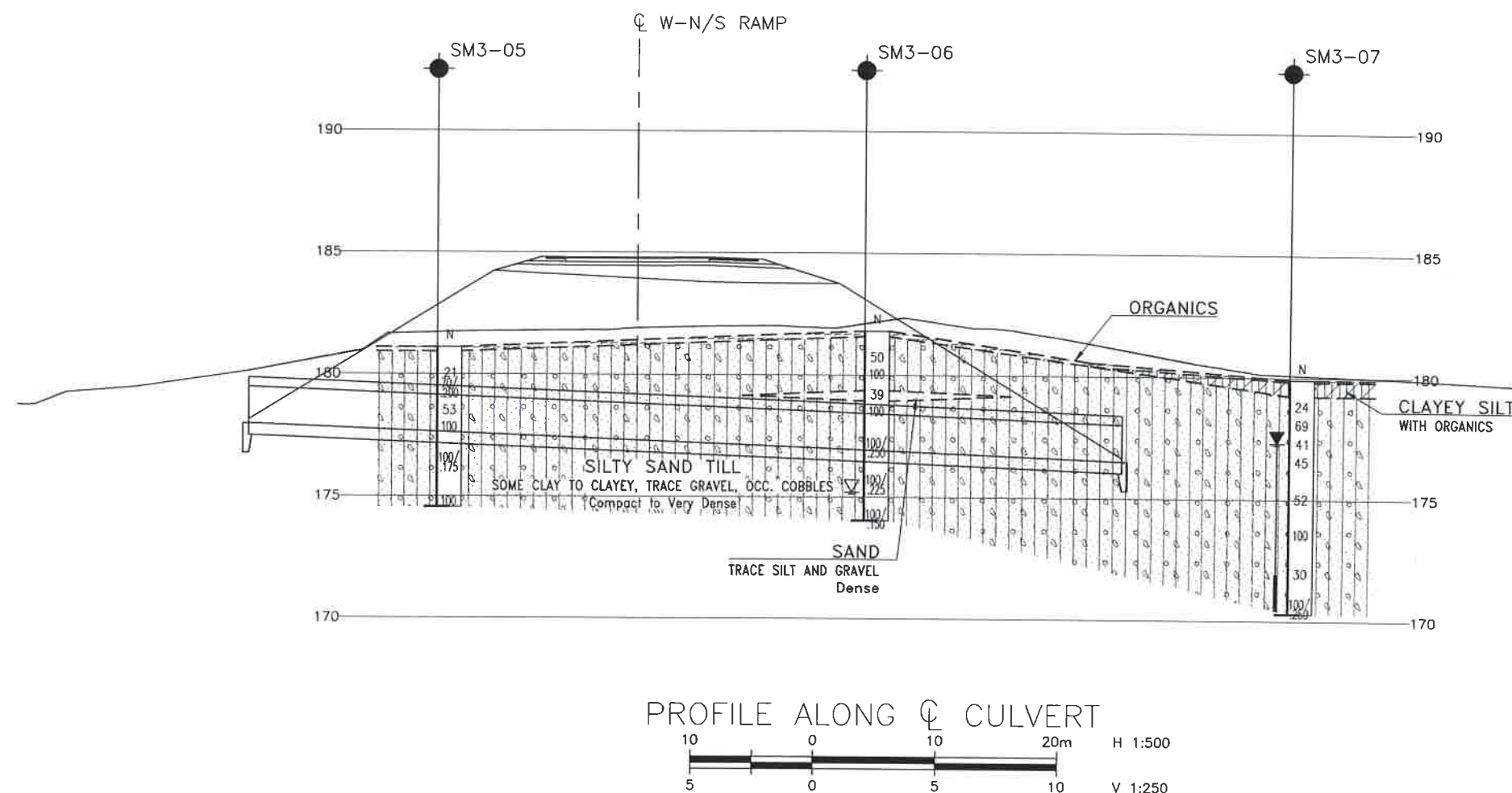
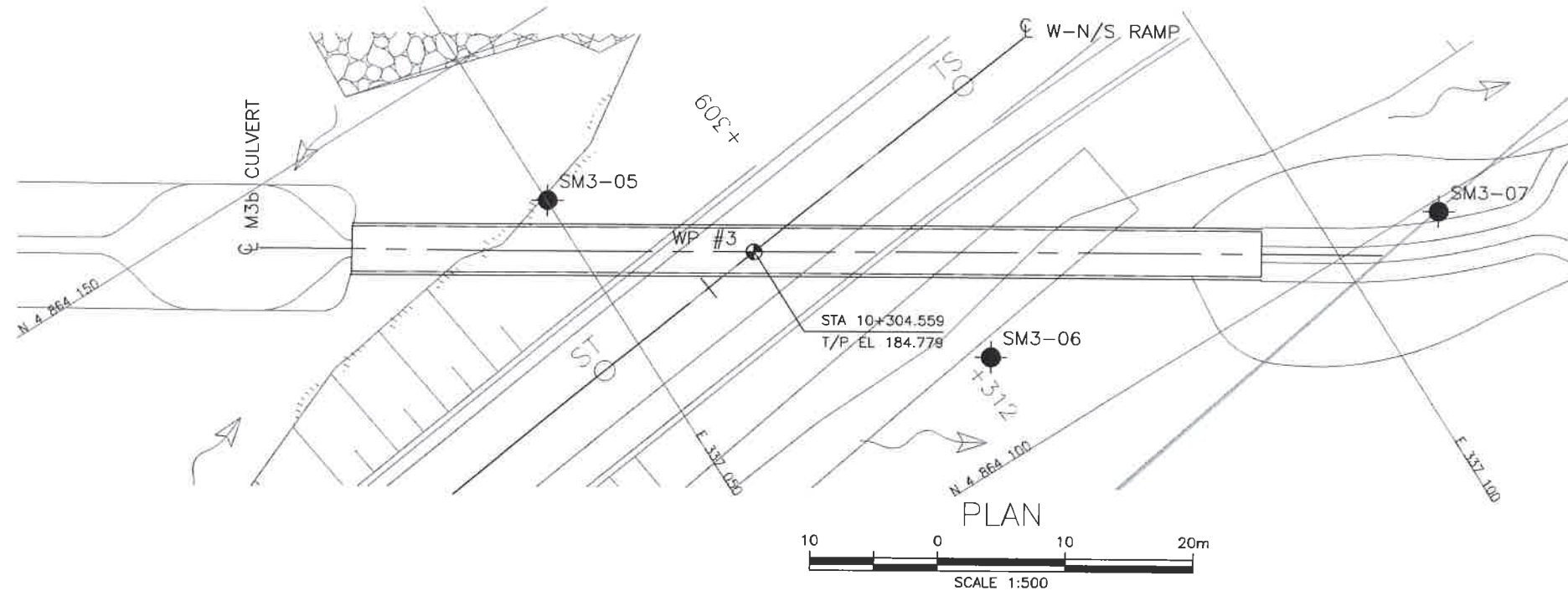
- Borehole (Current Investigation)
- ◊ Borehole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- W Head Artesian Water
- P Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
M3-1	184.2	4 864 247.4	336 905.8
M3-2	182.5	4 864 160.7	337 013.1
SM3-01	183.5	4 864 219.7	336 894.6
SM3-02	182.9	4 864 212.2	336 916.9
SM3-03	182.0	4 864 202.4	336 964.0
SM3-04	184.8	4 864 163.3	336 990.0
SM3-05	181.1	4 864 136.9	337 050.1
SM3-06	181.8	4 864 107.8	337 072.8
SM3-07	179.9	4 864 099.1	337 108.5

**-NOTES-**

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

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



DRAWING NAME: H:\Drafting\19\3161\130\led130A-M3-BoreholePlan&Profile.dwg  
CREATED: January 8, 2013  
MODIFIED: January 25, 2013

DESIGN	KS	CHK	AEG	CODE	LOAD	DATE	JAN. 2013
DRAWN	MFA	CHK	KS	SITE 4	STRUCT M-3	DWG 2	