Appendix J
Foundations Report

THURBER ENGINEERING LTD.

April 19, 2023 File No.: 19-1605-196

HATCH
2800 Speakman Drive
Mississauga, Ontario
L5K 2R7

Attention: Melissa Alexander, B.Sc., MCIP, RPP

FINAL THURBER ENGINEERING REPORTS
WINSTON CHURCHILL BOULEVARD CLASS EA STUDY
HIGHWAY 401 TO EMBLETON ROAD
REGION OF PEEL

Dear Ms. Alexander,

This letter accompanies the final reports submitted by Thurber Engineering Ltd. (Thurber) for the Winston Churchill Boulevard Class EA Study project from Highway 401 to Embleton Road.

As requested by HATCH, Thurber has finalized the following 4 reports, which were last issued in draft form in 2016:

- Contaminated Soil Assessment Report, Winston Churchill Boulevard Class EA Study, Highway 401 to Embleton Road, Region of Peel, Ontario" Report Submitted to Hatch Mott MacDonald, dated March 14, 2016. File No. 19-1605-196.
- Geotechnical Investigation Report, Winston Churchill Boulevard Class EA Study, Highway 401 to Embleton Road, Region of Peel" Report Submitted to Hatch Mott MacDonald, dated May 11, 2016. File No. 19-1605-196.
- Hydrogeology Investigation, Winston Churchill Boulevard, Highway 401 to Embleton Road, City of Brampton, Ontario" Report Submitted to Hatch Mott MacDonald, dated July 25, 2016. File No. 19-1605-196.
- Foundation Investigation and Design Report, Winston Churchill Boulevard Class EA Study, Highway 407 Bridge Widening, Region of Peel" Report Submitted to HATCH, dated August 10, 2016. File No. 19-1605-196.

It is a condition of each report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

The final reports are based on the site and subsurface conditions encountered at the time of Thurber's original investigations in 2015 and 2016 and do not reflect any changes in site conditions that may have occurred since this time. The recommendations provided must be reviewed with respect to any changes in site conditions and updates to relevant specifications, standards, regulations, codes or guidelines that have occurred since 2016.

Furthermore, Thurber's reports were produced prior to completion of the preferred design concept for the Winston Churchill Boulevard corridor and were based on existing site information and preliminary design information that was available at the time of preparation of each report. Accordingly, the factual information and foundation and hydrogeological recommendations (including Permit to Take Water requirements) must be reviewed for their completeness and applicability for the 100% design of the relevant works. Additional investigations may therefore be required to support the 100% design. Some dewatering works may require registration on the Environmental Activity and Sector Registry (EASR).

Thank you and please contact us if you should have any questions.

Yours truly,
Thurber Engineering Ltd.

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

LICENSED PROFESSIONAL ENGINEER
M.E. FARRANT
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PROVINCE OF ONTARIO

Mark Farrant, P.Eng.
Associate, Senior Geotechnical Engineer

Attachment

- Statement of Limitations and Conditions

THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
WINSTON CHURCHILL BOULEVARD CLASS EA STUDY
HIGHWAY 407 BRIDGE WIDENING
REGION OF PEEL

Report

to

HATCH

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August 10, 2016
File: 19-1605-196

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Senior Geotechnical Specialist

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APPENDICES

1. INTRODUCTION

This report presents the results of a geotechnical investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed widening of Winston Churchill Boulevard over Highway 407 at the border of the City of Brampton (Region of Peel) and the Town of Halton Hills (Halton Region), as part of the Winston Churchill Boulevard upgrade between Highway 401 and Embleton Road. The geotechnical investigation was undertaken on behalf of Hatch as part of a Schedule 'C' Class Environmental Assessment (EA) for the Regional Municipality of Peel.

The purpose of this investigation was to assess the geotechnical conditions at the project site and to provide geotechnical recommendations for design and construction of the Winston Churchill bridge expansion over Highway 407. The geotechnical assessment was based on information provided by Hatch for the 30% design of the project. The investigation was carried out in general accordance with Region of Peel's terms of reference (Document 2014-097P) and Thurber's proposal letter dated March 7, 2014.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. PROJECT AND SITE DESCRIPTION

2.1 Background

Winston Churchill Boulevard (Regional Road 19) is a major north-south arterial road that borders the City of Brampton (Region of Peel) and the Town of Halton Hills (Halton Region). It is understood that the Region of Peel is considering corridor improvements (with potential widening) along Winston Churchill Boulevard from Highway 401 to Embleton Road, as part of its Long Range Transportation Plan (LRTP). This will involve widening of the Winston Churchill Boulevard south of Steeles Avenue to a six lane facility, including the existing bridge over Highway 407, in 2021.

Based on the archived General Arrangement (GA) drawing (Dillon's Drawing 9401-3-112-23-0001 Rev. 0 dated January 1997), the existing Winston Churchill Boulevard Bridge over Highway 407 is comprised of a two-span prestressed concrete girder structure supported on a center pier and integral abutments. Both the north and south abutments are supported on a single row of driven HP 310 x 110 steel H-piles. The forward slopes are in the order of 6.5 m to 7.5 m in height and have been designed to have an inclination of 2H:1V. Selected photographs of the existing bridges are included in Appendix E.

Based on available information provided by Hatch, the project involves the widening of the bridge to the east side only. No preliminary General Arrangement (GA) or foundation drawings were available to Thurber at the time of report preparation, therefore the proposed width of the widening and the proposed foundation layout were not known.

It is understood that Winston Churchill Boulevard was last reconstructed in 2013, which included pavement widening from Steeles Avenue to just north of the entrance to the Maple Lodge Farms facility. Project stationing for this study was synchronized with the 2010 construction drawings for the 2013 reconstruction provided by Hatch, which extended from Steeles Avenue (Station 1+000) to Embleton Road (Station 4+000). As a point of reference, Station 1+000 was located at the intersection with Steeles Avenue. It should be noted that base plan and alignment drawing received from Hatch in February 2016, following the field investigation, shows the project stationing to be offset by 292 m from the 2010 construction drawings. The 2010 stationing is used throughout this report, on the borehole location plan, and for identification of borehole locations, where required.

2.2 Physiography

The site is located in the physiographic region known as the Peel Plain, which is characterized by beveled till plains (OGS Map P.2226, 1984).

The Quaternary geologic mapping for the site (OGS Map M.2223, 2005) indicates that the soil conditions mainly consist of red to brown glacial tills ranging in composition from gritty to clayey silt till (Halton Till). The bedrock in the area comprises Upper-Ordovician red shale of the Queenston Formation (Map 2337, 1976). Based on drift thickness mapping for the area (Map 2179, 1969), the depth to the bedrock ranges from approximately 4 to 15 m below the ground surface. Recently, agriculture and road construction activities in the area have likely resulted in placement of anthropogenic (fill) deposits in some areas.

3. INVESTIGATION PROCEDURES

3.1 Field Investigation

The field investigation was carried out during the period of April 25 to May 20, 2016 and consisted of a total of five (5) boreholes:

- Four (4) boreholes advanced from the top of the existing approach embankments of the Winston Churchill Boulevard bridge to depths ranging from 11.0 to 31.4 m; and
- One (1) borehole advanced from the exiting median of Highway 407 to a depth of 15 m.

The drilling included extending three (3) boreholes (407-02, 407-03 and 407-04) into the shale bedrock with rock coring carried out in two (2) of these boreholes (407-02 and 407-04) to collect bedrock samples.

The locations of the boreholes are shown on the Borehole Locations and Soil Strata drawing in Appendix A. The borehole locations were established in the field by Thurber relative to existing site features and using a Trimble ProXRT differential GPS receiver. The locations and ground surface elevations of the boreholes were subsequently checked using the base plans provided by Hatch.

All borehole locations were cleared of utilities and a road occupancy permit was obtained prior to commencement of drilling. The boreholes were repositioned as necessary in consideration of the utility locations and surface features and traffic control was provided during drilling on the roadway.

The boreholes were drilled using D-90 truck-mounted hollow-stem drill rigs supplied and operated by DBW Drilling Limited. Soil samples were obtained at selected depth intervals in conjunction with the Standard Penetration Test (SPT). NQ size rock coring equipment was used to recover shale core samples from Boreholes 407-02 and 407-04.

The field investigation was carried out under full-time supervision of a representative of Thurber's technical staff. All boreholes were logged in the field with the soil samples identified and placed in labelled containers and the rock cores logged (in terms of description, core recovery, Rock Quality Designation, and Fracture Index) and placed in core boxes. All soil and rock samples were transported to Thurber's laboratory for further examination and testing.

Where practical, groundwater conditions were observed in the open boreholes during and immediately after drilling. Monitoring wells were installed in two (2) boreholes (407-02 and 407-05) to measure groundwater levels. Upon completion, all boreholes not containing piezometers were backfilled with a mixture of auger cuttings and bentonite in general accordance with MOE Regulation 903.

Results of the field drilling, sampling and geotechnical laboratory testing are presented on the Record of Borehole sheets in Appendix B.

3.2 Laboratory Testing

Geotechnical laboratory testing consisted of visual classification and natural moisture content determinations of all soil samples. The following laboratory tests were also conducted on selected soil samples:

- Grain size distribution analyses, including hydrometer analysis, where applicable;
- Plasticity (Atterberg) Limits on soil samples with signs of plastic behavior; and
- Point Load Tests on rock samples.

Results of the geotechnical laboratory testing are presented in Appendix C and are summarized on the Record of Borehole sheets in Appendix B.

4. SUMMARY OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and on the Borehole Location and Soil Strata drawings in Appendix A. It should be noted that the Record of Borehole sheets included in Appendix B provide detailed descriptions of the subsurface conditions at the drilled borehole locations and hence must be used in preference to this generalized stratigraphy. It should be also recognized that subsurface conditions may vary between and beyond borehole locations.

The results of the field investigation and the laboratory tests indicate that the subsurface conditions generally consist of asphalt and embankment fill overlying silty clay till, which overlies gravelly sand underlain by shale bedrock. In addition, pockets/layers of intra-till sand and silt were encountered within the silty clay till. Detailed descriptions of the individual strata are presented below.

4.1 Asphalt

Asphalt was encountered in four boreholes drilled from the top of the existing Winston Churchill Boulevard approach embankments (Boreholes 407-01, 407-02, 407-04, and 407-05) and the thickness ranged from 113 to 150 mm.

4.2 Granular Fill

Granular fill was encountered below the asphalt in the four boreholes drilled from the top of the existing Winston Churchill Boulevard approach embankment and at the ground surface in the borehole drilled in the Highway 407 median (Borehole 407-03). The fill extended to depths ranging from 0.7 to 3.4 m (Elevations of 216.4 to 213.6 m in Boreholes 407-01, 407-02, 407-04, and 407-05 and Elevation of 205.7 m in Borehole 407-03) with thickness ranging from 0.6 to 3.25 m.

The granular fill was grey to brown in color and consisted of sand to gravelly sand with traces of gravel. SPT blow counts (N-values) recorded in the granular fill ranged from 9 to 56 blows per 300 mm penetration, indicating loose to very dense fill.

Moisture contents recorded in the granular fill ranged from 2 to 12%. Grain size analysis indicated that gravel, sand, and fine contents ranged from 15 to 47%, from 38 to 83%, and from 2 to 20%, respectively.

4.3 Silty Clay Fill

Silty clay fill was encountered below the granular fill in the four boreholes drilled from the top of the existing Winston Churchill Boulevard approach embankment (Boreholes 407-01, 407-02, 407-04, and 407-05) and extended to depths ranging from 7.2 to 8.7 (Elevations of 210.2 to 207.2 m) with thickness ranging from 4.8 to 7.3 m. Silty clay fill was also encountered within the granular fill in Boreholes 407-02 and 407-03 with thickness ranging from 0.3 to 1.6 m.

The silty clay fill was brown, sandy and with traces of gravel. SPT blow counts (N-values) recorded in the silty clay fill ranged from 5 to 27 blows per 300 mm penetration, indicating firm to very stiff consistency.

Moisture contents recorded in the silty clay fill ranged from 3 to 20%. Grain size analysis indicated that gravel, sand, silt and clay contents ranged from 0 to 4%, from 23 to 33%, from 41 to 47%, and from 22 to 30% respectively. Atterberg Limits testing indicated that the liquid and the plastic limits were in the order of 24 and 15.6%, respectively, indicating low plastic silty clay fill.

4.4 Silty Clay Till

Native silty clay till was encountered below either the silty clay or the granular fill and extended to depths ranging from 19.8 to 21.3 m (Elevations of 197.2 to 196.1 m) in Boreholes 407-02 and 407-04 and to a depth of 12.5 m (Elevation of 196.3 m) in Borehole 407-03 with thickness ranging from 9.5 to 12.6 m. Boreholes 407-01 and 407-05 were terminated within the silty clay till at depths of 12.8 and 11.0 m respectively (Elevations of 202.9 and 206.1 m).

The silty clay till was brown, sandy and with traces of gravel. SPT blow counts (N-values) recorded in the silty clay till ranged from 16 to more than 50 blows per 300 mm penetration, indicating very stiff to hard consistency.

Moisture contents recorded in the silty clay till ranged from 8 to 24%. Grain size analysis indicated that gravel, sand, silt and clay contents ranged from 2 to 8%, from 22 to 37%, from 36 to 48%, and from 14 to 32% respectively. Atterberg Limits testing indicated that the liquid and the plastic limits ranged from 20 to 30.5% and from 14.2 to 19.3%, respectively, indicating low plastic silty clay till.

4.5 Intra-Till Sand

Silty sand pockets with thickness of 1.5 and 3.1 m were encountered within the silty clay till in Borehole 407-02 at depths of 16.8 and 19.8 m (Elevations of 200.2 and 197.2 m), respectively.

The silty sand was grey, with traces to some gravel and traces of clay. SPT blow counts (N-values) recorded in the silty sand ranged from 49 to more than 50 blows per 300 mm penetration, indicating dense to very dense sand.

Moisture contents recorded in the silty sand ranged from 6 to 10%. Grain size analysis indicated that gravel, sand and fine contents ranged from 7 to 13%, from 48 to 52%, and from 39 to 41%, respectively.

4.6 Intra-Till Silt

Silt pockets with thickness ranging from 0.1 to 1.5 m were encountered within the silty clay till in Boreholes 407-03 and 407-04 at depths of 12.5 and 18.3 m (Elevations of 199.1 and 196.3 m), respectively.

The silt was grey, with some sand and traces of clay. SPT blow counts (N-values) recorded in the silt were typically more than 50 blows per 300 mm penetration, indicating very dense silt.

Moisture contents recorded in the silt ranged from 8 to 15%.

4.7 Gravelly Sand

Gravelly sand was encountered below the silty clay till in Boreholes 407-02 and 407-04 and extended to depths ranging from 25.9 to 27.4 m (Elevations of 191.1 to 190 m) with thickness ranging from 3.0 to 6.1 m.

The gravelly sand was grey to brown in color, silty, and with traces of shale fragments. SPT blow counts (N-values) recorded in the gravelly sand ranged from 45 to more than 50 blows per 300 mm penetration, indicating dense to very dense sand.

Moisture contents recorded in the granular fill ranged from 6 to 10%. Grain size analysis indicated that gravel, sand and fine contents ranged from 27 to 31%, from 45 to 55%, and from 18 to 24%, respectively.

4.8 Shale Bedrock

Shale bedrock was encountered below the gravelly sand in Boreholes 407-02 and 407-04 and below the silty clay till in Borehole 407-03; and extended to the end of the boreholes at depths ranging from 15.0 and 31.4 m (Elevations of 193.8 to 186 m).

The shale bedrock was reddish brown, fresh to highly weathered, and thinly bedded. SPT blow counts (N-values) recorded in the shale were typically more than 100 blows per 300 mm penetration.

Total Core Recovery (TCR) of the shale cores was in the order of 100%. Rock Quality Designation (RQD) recorded in the shale bedrock ranged from 90 to 100%, indicating excellent rock mass quality. Fracture Index (FI) of the shale ranged from 0 to 3.

Unconfined Compressive Strength (UCS) values, derived from point load tests on the shale ranged from 18 and 49 MPa, indicating weak to medium strong rock.

4.9 Groundwater Conditions

Information on groundwater levels was collected from the 50 mm diameter monitoring wells installed in Boreholes 407-02 and 407-05 and from open boreholes upon completion of drilling operations. A summary of these levels is presented in Table 4.1 below. The groundwater depth readings are measured from ground surface at the location of each borehole.

Generally, groundwater levels measured in the monitoring wells ranged from 9.4 to 11.8 m below the top of the existing Winston Churchill Boulevard approach embankment (Elevations 207.7 to 205.2 m). These groundwater levels are relatively short-term readings and hence seasonal fluctuations of these levels should be expected, particularly after spring snowmelt and periods of prolonged and/or significant precipitation.

Table 4.1 – Summary of Recorded Groundwater Levels.

Borehole No.	Water Level Depth/Elev. (m)	Date of Reading	Type of Reading[2]
407-02	11.7 / 205.3 11.8 / 205.2	June 15, 2016 June 22, 2016	Monitoring Well Monitoring Well
407-03	2.1 / 206.7	April 25, 2016	Open Borehole
407-04	17.5 / 199.9	May 20, 2016	Open Borehole
407-05	8.2 / 208.9 9.4 / 207.7	June 15, 2016 June 22, 2016	Monitoring Well Monitoring Well

5. FOUNDATIONS RECOMMENDATIONS

5.1 General

Based on archived GA and foundation drawings, the existing structure is a two-span bridge carrying the Winston Churchill Boulevard over Highway 407 WBL and EBL. The bridge is supported on a center pier and two integral abutments with driven HP 310 x 110 piles in the following arrangements:

- North Abutment – One row of 18 vertical piles designed to be 13.5 m in length and driven to a tip elevation of 198.0 m

- South Abutment - One row of 18 vertical piles designed to be 13.5 m in length and driven to a tip elevation of 198.0 m

- Center Pier – Two rows of 15 battered (1H:4V) piles designed to be 7.5 m in length and driven to a tip elevation of 198.0 m. The center row consists of 5 vertical piles and 2 battered (1H:4V) piles designed to be 7.5 m in length and driven to a tip elevation of 198.0 m

Based on the borehole information obtained during the current investigation, the existing driven H-piles are typically embedded within silty clay till and founded within the lower hard silty clay till.

It is important to note that as-built and construction records for the existing structure are not available. As such, it has been assumed that construction had taken place as per the design information on the archived GA and foundation drawings.

It is assumed that the foundations for the existing structures will remain in service and the proposed widening scheme will include one new bridge supported on new pile foundations adjacent to the existing bridge and the new piles will generally align with the existing ones. The existing approach fills have largely been constructed up to the underside of the road pavement. A triangular wedge of new backfill will need to be placed behind each new abutment. No overall grade raise to Winston Churchill Boulevard is anticipated.

The discussions and recommendations presented in this report are based on our understanding of the project and on the factual data obtained during the course of this investigation.

5.2 Structure Foundations

Based on the geotechnical conditions at the project site, feasible foundation solutions for the proposed widening of the Winston Churchill Boulevard Bridge over Highway 407 may include:

- Steel piles driven to the very dense gravelly sand or the shale bedrock;
- Spread footings resting on the native very stiff to hard silty clay till; and
- Augered caissons extending into the shale bedrock.

The information available from the foundations drawings for the existing Winston Churchill Boulevard Bridge (Dillon's Drawing 9401-3-112-23-0002 Rev. 0 dated January 1997) indicated that the existing foundations consisted of HP 310x110 steel driven piles with lengths ranging from 7.5 to 13.5 m and pile design data as follows:

- Factored ULS = 1,300 kN / pile
- SLS = 900 kN / pile

For consistency purposes and to minimize future differential movement between the existing bridge and its expansion, steel driven piles are considered the most suitable foundation type for the bridge expansion/widening. Foundation recommendations for design and construction of steel driven piles are provided in the following sections. Recommendations for other feasible foundation types will not be presented in this report but can be furnished upon request. It is recommended that the new pier pile cap be resting on the native silty clay till at the same elevation of the existing ones at approximately 204.8 m.

5.3 Steel Driven Piles

5.3.1 Axial Resistance

Abutment and pier foundations for the new widening bridge may be supported on steel HP 310x110 piles, similar to the pile type used to support the existing bridge. The available borehole information indicates that piles could be driven to refusal on shale bedrock at South Abutment and Center Pier. At North abutment, the piles could be driven to practical refusal within the gravelly sand where SPT "N" values greater than 100 blows for less than 0.3 m penetration were measured. For an HP 310x110 pile, the estimated pile tip elevations and recommended geotechnical resistances are provided below:

Table 5.1 – Estimated Pile Tip Elevations and Axial Geotechnical Resistances of Driven H-Piles (HP 310 x 110)

Structure	Bearing Stratum	Geotechnical Capacity at ULS_f (kN)	Geotechnical Capacity at SLS (kN) (*)	Estimated Pile Tip Elevation (m)
South Abutment	Shale Bedrock	1800	1500	191.0
Center Pier	Shale Bedrock	1800	1500	196.0
North Abutment	Gravelly Sand	1400	1150	195.0

Note (*) The SLS values correspond to a pile settlement up to 25 mm.

The piles may encounter refusal in the gravelly sand layer or cobbles and shale fragments present in the glacial till above the bedrock at South Abutment and Center Pier. The estimated geotechnical resistances provided above take into account H-piles meeting refusal above the shale bedrock.

The pile tip elevations shown in Table 5.1 may be used for estimating purposes only. The actual pile tip elevations will be controlled during pile driving as described in Section 5.3.6. The design resistance should be confirmed using dynamic pile driving criteria and/or a Pile Driving Analyzer (PDA testing). The possibility exists that driven steel piles meet refusal or achieve the design resistances at varying depths between piles or at elevations other than those indicated in Table 5.1. If pile tip elevations vary by more than 3 m from the anticipated values, it is recommended that the pile driving records be forwarded to Thurber for review prior to acceptance of these piles.

Glacially derived soils above the founding stratum inherently contain cobbles and boulders. The pile tips should, therefore, be reinforced to enhance driving (see Section 5.3.5).

Downdrag is not considered a design issue at this site since the placement of the small amount of fill is expected to induce negligible ground settlement.

5.3.2 Lateral Resistance

The geotechnical lateral resistance of piles in cohesionless soils, including the granular fill, the intra till sand and silt, and the gravelly sand, may be calculated using values for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

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

p_{ult} = 3 γ' z K_p (kPa)

Where z = depth of embedment of pile (m)

D = pile width or diameter (m)

n_h = coefficient related to soil relative density (kN/m^3)

γ' = effective unit weight (kN/m^3)

K_p = passive earth pressure coefficient

The geotechnical lateral resistance of piles in cohesive soils, including the silty clay fill and the silty clay till, may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

k_s = 67 S_u / D (kN/m^3)

p_{ult} = 9 S_u (kPa)

Where S_u = undrained shear strength (kPa)

D = pile width or diameter in metres

The above equations and the recommended parameters in Table 5.2 may be used to analyze the interaction between piles and the surrounding soils. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

Table 5.2 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m^3)	n_h (kN/m^3)	K_p	S_u (kPa)
	From	To				
South Abutment						
Silty clay till (*)	208.3	205.2	20.0	-	-	200
Silty clay till	205.2	200.2	10.0	-	-	200
Intra-till sand	200.2	198.7	10.5	11,000	4.2	-
Silty clay till	198.7	197.2	10.0	-	-	200
Intra-till sand	197.2	194.1	11.0	14,000	4.6	-
Gravelly sand	194.1	191.1	11.0	14,000	4.6	-
Intermediate Pier						
Silty clay till	204.8	196.1	10.0	-	-	150
Silty clay till	198.2	196.1	10.5	-	-	300

North Abutment						
Silty clay till (*)	210.2	207.7	20.0	-	-	150
Silty clay till	207.7	199.1	10.0	-	-	200
Intra-till silt	199.1	197.6	10.0	7,500	3.5	-
Silty clay till	197.6	196.1	10.5	-	-	300
Gravelly sand	196.1	190.0	11.0	14,000	4.6	-

Note (*) above groundwater level

The spring constant, K_s, for analysis may be obtained by the expression, $K_s = k_s\ L\ D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult}\ L\ D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

The modulus of subgrade reaction and ultimate lateral resistance may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 5.3. Intermediate values may be obtained by linear interpolation.

Table 5.3 – Subgrade Reaction Reduction Factors for Pile Spacing

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

5.3.3 Integral Abutment Considerations

The use of H-piles at the abutments allows for design of an integral abutment structure. If integral abutment design is to be considered, adequate flexibility would be required in the upper 3 m of the abutment piles. Due to presence of very stiff to hard silty clay till within this depth range, i.e. within 3 m below the level of the abutment stem base (an approximate average Elevation of 210.8 m), some remedial measures should be taken to achieve the required flexibility. It is recommended that these measures be in the form of pre-drilled 600-mm diameter holes filled with uncompacted uniformly graded sand to reduce resistance to lateral movements and to increase pile flexibility. The sand for filling the hole should meet the gradation requirements presented in Table 5.4 and should be placed after driving the pile through the CSP.

Table 5.4 – Integral Abutment Sand Backfill Grading

MTO Sieve Designation	Percentage Passing
2 mm #10	100%
600 µm #30	80%-100%
425 µm #40	40%-80%
250 µm #60	5%-25%
150 µm #100	0%-6%

5.3.4 Frost Cover

The design depth of frost penetration at this site is 1.2 m.

5.3.5 Impact on Existing Foundations

Piles will be driven adjacent to the existing Winston Churchill Boulevard bridge over Highway 407 for construction of the widening bridge.

The structural designer should select appropriate points on the existing structure and specify a settlement monitoring program for the duration of pile driving (including establishment of adequate benchmarks outside the zone of potential influence and acquirement of baseline readings in advance of pile driving). Settlement monitoring of any buried utilities close to the work areas during construction is also recommended. In addition, vibration monitoring and pre-construction condition survey may also be required.

Overdriving of piles may cause disturbance of the overburden soils and hence must not be permitted, particularly on the potential sloping bedrock at the locations of the south abutment and the intermediate pier. The Contractor should be prepared to maintain the grade of the existing bridge in operation by such means as lifting and shimming of the structure if necessary.

Particular attention should be given to selection of pile driving equipment, particularly the hammer, to avoid formation of soil plug during driving since this could result in pile advancement in the ground as a large displacement pile.

5.3.6 Construction Considerations

Pile installation shall be carried out in accordance with Ontario Provincial Standard Specification OPSS 903: Construction Specification for Deep Foundations.

The tips of all driven H-piles must be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point), or approved equivalent, to prevent pile damage when setting the piles on bedrock or if cobbles or boulders are encountered. The use of rock points (Titus Rock Injector or equivalent) is also recommended for driving piles to the sloping bedrock surface at the South Abutment and the Intermediate Pier.

If the proposed bridge design requires that deviation of the top of pile from its planned/design location be limited to tight tolerance, a driving template or other means may be required to achieve the specified maximum deviation.

6. EXCAVATION AND DEWATERING

Excavation for the proposed widening bridge foundations is anticipated to extend to an Elevations of 204.8 and 210.8 m at the pier and abutment locations, respectively. Excavations are expected to be mainly in the granular fill, the silty clay fill, and the silty clay till and will be partially located below the groundwater level at the pier location.

All excavations must be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the granular and the silty clay fill in addition to the silty clay till may be classified as Type 3 soil above the water table and as Type 4 soil below the water table. Flatter slopes may be required at locations where water seepage affects surficial stability.

All excavations must be carried out in a manner that avoids undermining or destabilising the foundations of the existing bridges and slopes.

Excavation and backfilling for foundations must be carried out in accordance with Ontario Provincial Standard Specification OPSS 902: Construction Specification for Excavating and Backfilling – Structures.

The selection of the method of excavation is the responsibility of the Contractor and must be based on his equipment, experience and interpretation of the site conditions.

Where required, temporary excavation support system should be designed and constructed in accordance with Ontario Provincial Standard Specification OPSS 539: Construction Specification for Temporary Protection Systems. The Contractor should select the wall type and design taking into account the soil conditions encountered in the boreholes.

The groundwater table at the abutment locations is anticipated to be below the base of excavations required for the new abutment construction however it is anticipated that perched water may be encountered within the existing fills. At the new pier location, the water table is approximately 0.5 m above the base of the existing pier pile cap. Since the new pier excavation is expected to extend below the groundwater level, groundwater control may be handled using a sump pumping technique. Other drainage techniques such as ditching are required to divert surface runoff and prevent precipitation from entering the excavations. Filtered sumps must be designed properly so that construction drainage water containing eroded soil and fines do not flow onto existing roadways and ditches.

Dewatering works shall be carried out in accordance with Ontario Provincial Standard Specification OPSS 518: Construction Specification for Control of Water from Dewatering Operations. The design of any dewatering system that may be required is the responsibility of the Contractor.

7. APPROACH EMBANKMENTS

Existing approach embankments within Winston Churchill Boulevard have been constructed to just below pavement structure using silty clay fill. Archived GA drawings indicate that the forward and side slopes have a design inclination of 2H:1V.

As part of the new wall backfill, a wedge of new fill up to about 4 m depth immediately behind the abutment wall will need to be placed on the existing forward slopes immediately behind the new abutments of the widening structure. Provided that the new fill is placed as recommended in this report and a 2H:1V slope inclination is maintained, the forward slopes will remain stable. Given the stress distribution within the embankment fill and the competent ground conditions below, the foundation settlement that will be induced by the placement of the new fill is not expected to impact the existing structure.

Prior to fill placement, the subgrade must be adequately prepared to receive the fill. Within widening areas, all topsoil, organics, soft/loosened or wet soils should be subexcavated. All subgrade should be inspected and approved prior to placing fill. In areas where new fill is to be placed on existing fill, the existing fill surface should be benched in accordance with OPSD 208.01.

Embankment construction should be carried out in accordance with Ontario Provincial Standard Specification OPSS.PROV 206: Construction Specification for Grading.

It is recommended that embankment fill consist of Granular A or B Type II materials be used as new fill conforming to Ontario Provincial Standard Specification OPSS.PROV 1010: Material Specification for Aggregates - Base, Subbase, Select Subgrade, and Backfill Material. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with Ontario Provincial Standard Specification OPSS.PROV 501: Construction Specification for Compacting. The backfill to the abutment walls should be in accordance with Ontario Provincial Standard Specification OPSS 902: Construction Specification for Excavating and Backfilling – Structures.

Vegetation cover should be established on all exposed earth slopes for protection against surficial erosion. Reference should be made to OPSS.PROV 804.

Approach fill conforming to the above requirements may have design forward and side slopes of 2H:1V.

8. LATERAL EARTH PRESSURES

Earth pressures acting on bridge abutments may be assumed to be distributed triangularly and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC) but generally using the following expression:

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

where:

p_h = horizontal pressure on the wall at depth h (kPa)

K = coefficient of lateral earth pressure (see Table 8.1)

γ = unit weight of retained soil (see Table 8.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Typical values for the coefficient of lateral earth pressure for standard granular fills and existing embankment fill are given in Table 8.1.

Table 8.1 – Earth Pressure Coefficients

Condition	**Earth Pressure Coefficient (K)**					
	OPSS 1010 Granular A or Granular B Type II $\phi = 35^\circ$, $\gamma = 22.8$ kN/m^3		**OPSS 010 Granular B Type I or Type III $\phi = 32^\circ$, $\gamma = 21.2$ kN/m^3**		**Embankment Fill (silty clay) $\varphi = 30^\circ$, $\gamma = 20.0$ kN/m3**	
	Horizontal Surface Behind Wall	**Sloping Backfill (2H:1V)**	**Horizontal Surface Behind Wall**	**Sloping Backfill (2H:1V)**	**Horizontal Surface Behind Wall**	**Sloping Backfill (2H:1V)**
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*	0.33	0.54*
At-rest (Restrained Wall)	0.43	-	0.47	-	0.50	-
Passive	3.7	-	3.3	-	3.0	-

* For wing walls.

The use of a material with a high friction angle and low active pressure coefficient, e.g. Granular A, Granular B Type II, is preferred as it results in lower earth pressures acting on the wall.

The factors in Table 8.1 are "ultimate" values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

In accordance with Clause 6.12.3 of the CHBDC, compaction-induced lateral pressure should also be considered in design of bridge abutments. The magnitude of this lateral pressure should vary from 12 kPa at the top of fill to a value of 0 kPa at a depth of 2.0 m for Granular B Type I or III, or at a depth of 1.7 m for Granular A or Granular B Type II. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

It is recommended that perforated sub-drains and/or weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the abutment walls. Reference should be made to OPSD 3102.100.

9. ROADWAY PROTECTION

Roadway protection will be required during foundation construction. An item titled "Protection System" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the roadway protection be specified on the contract drawings.

The design of roadway protection should be the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at this site is a soldier pile and lagging wall. It is anticipated that the protection system will need to be extended predominantly through the existing embankment fill into the underlying native very stiff to hard silty clay till to develop the required toe resistance. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

A soldier pile and lagging wall may be designed using the parameters given below:

γ = 20 kN/m^3
γ_w = 9.8 kN/m^3
K_a = 0.33 (embankment fills)
K_p = 3.0 (embankment fills)
= 3.1 (native silty clay till)

It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC, but generally are given by a triangular distribution. The surcharge should include soil loadings above the top of the pile, construction and highway traffic and other loadings adjacent to the wall. A properly designed and constructed soldier pile and lagging wall will be permeable and therefore water pressure acting on the retained height should be set to zero. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the roadway protection system.

The designer of the roadway protection system should check whether the depth of the soldier piles is sufficient to provide base fixity.

All roadway protection systems should be designed by a Professional Engineer experienced in such designs.

10. SEISMIC CONSIDERATIONS

Based on the undrained shear strength of the silty clay fill and underlying silty clay, Site Class D (stiff soil) should be assumed to evaluate the seismic site response, as per Table 4.1, Clause 4.4.3.2 of the CHBDC 2014.

The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.114g as per the National Building Code of Canada (NBCC). The output of the 2015 National Building Code of Canada seismic hazard calculator for the project site is provided in Appendix D.

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 10.1 may be used:

Table 10.1 – Earth Pressure Coefficients for Earthquake Loading

0.32	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II ϕ = 35° γ = 22.8 kN/m^3	OPSS Granular B Type I ϕ = 32° γ = 21.2 kN/m^3	Silty Clay Fill ϕ = 30° γ = 20 kN/m^3
Active (K_{AE})*	0.32	0.36	0.38
Passive (K_{PE})	3.5	3.1	2.9
At Rest (K_{OE})**	0.58	0.62	0.65

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

** After Woods

The native soils underlying this site are not considered to be prone to liquefaction. Liquefaction is therefore not a concern at this site.

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soil profile:

$\sigma_h = K_a\gamma d + (K_{AE} - K_a)\ \gamma\ (H - d)$

where: σ_h = lateral earth pressure at depth, d (kPa)

d = depth below the top of the wall (m)

K_a = static active earth pressure coefficient

γ = unit weight of the backfill soil (kN/m3)

K_{AE} = combined static and seismic earth pressure coefficient

H = total height of the wall (m)

11. CONSTRUCTION CONCERNS

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

- Piles driven through the very dense soils may achieve the required geotechnical resistance at varying elevations. These elevations must be checked against the design pile tip elevations to confirm that driving is not terminated prematurely.

- Cobbles and boulders are potentially present within glacially derived deposits which may affect installation of H-piles. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the piles to competent foundation levels. Pre-augering a pilot hole prior to driving the pile may be considered as an alternative.

- Settlement monitoring of the existing bridge foundations and buried utilities close to the work areas during construction is recommended. In addition, vibration monitoring and pre-construction condition survey may also be required.

- Pier and abutment construction must be carried out in the dry. Diversion of surface runoff, precipitation and other forms of dewatering may be required.

- Daily visual inspection of the road pavement surface must be carried out in the vicinity of the construction works. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the Contract Administrator for determining as to whether further action is required.

- Confirmation that the backfill to the abutments are adequately placed and compacted to specifications.

It is recommended that provision(s) be included in the contract requiring the Contractor to confirm that the above issues are adequately addressed. Should there be any doubts about issues such as subgrade preparation, compaction of fill materials, pile driving and pile termination, these provision(s) should require the Contractor to retain qualified geotechnical personnel to assess the site conditions and to alert the Contract Administrator.

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

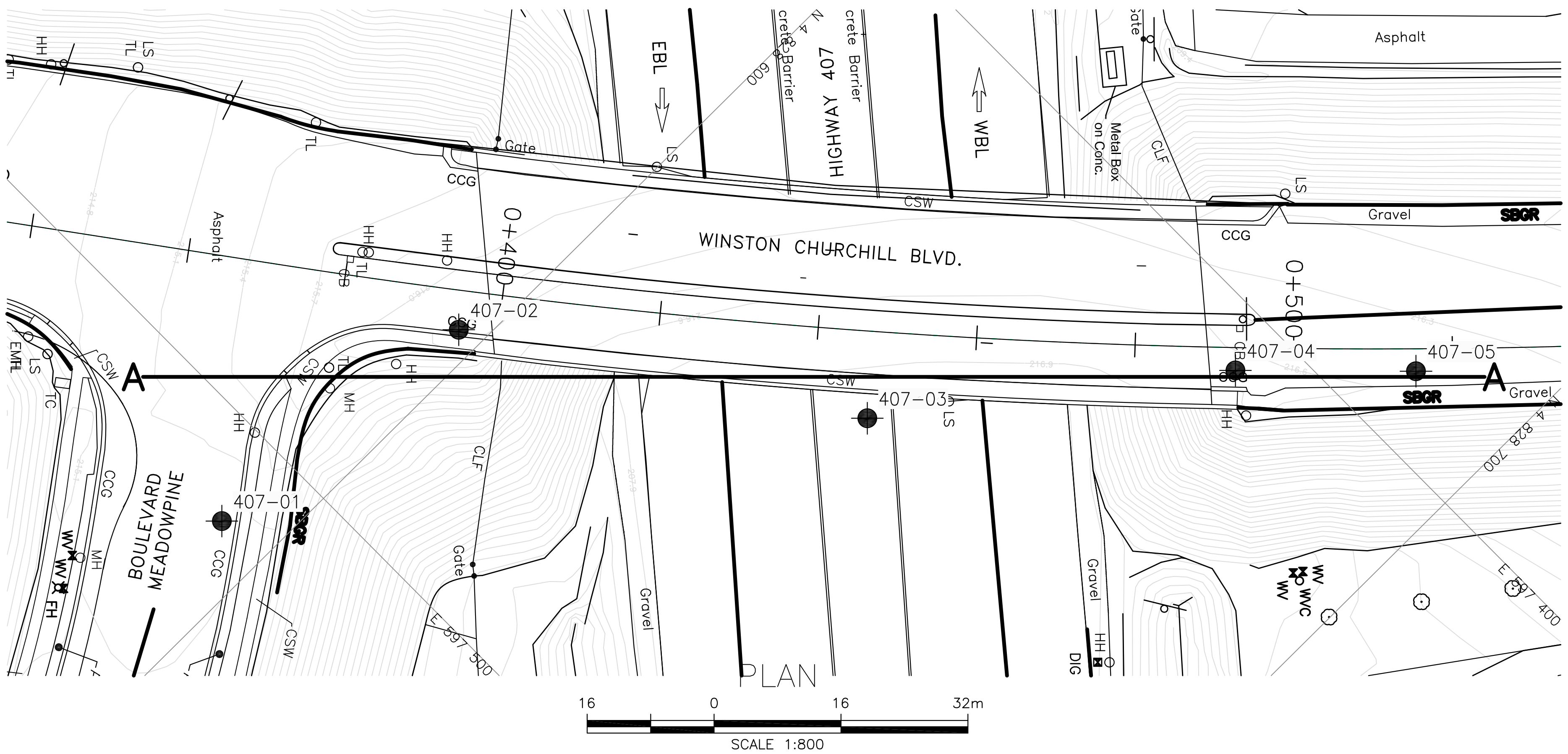
The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

THURBER

APPENDIX A

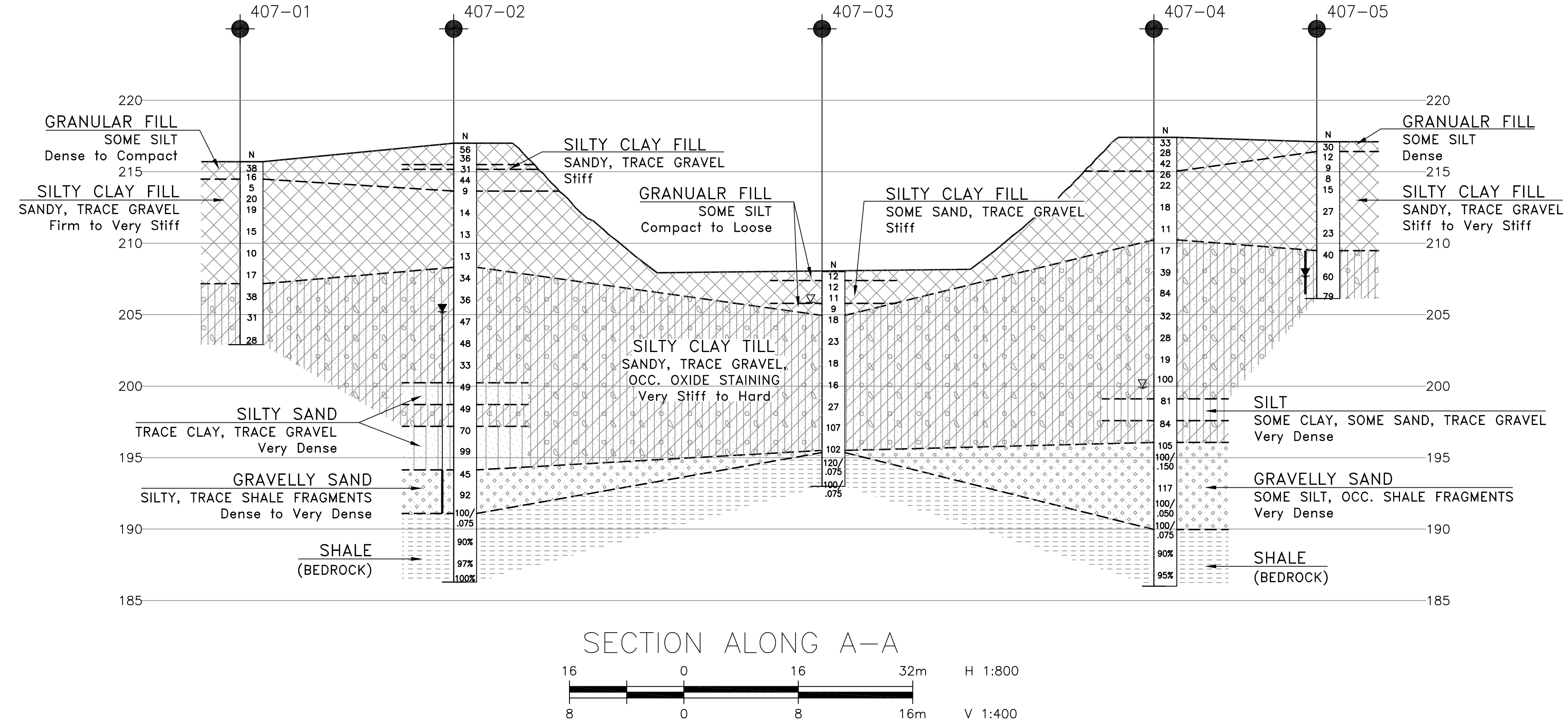
BOREHOLE LOCATION PLAN
AND
STRATIGRAPHIC PROFILE

MINISTRY OF TRANSPORTATION, ONTARIO



METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

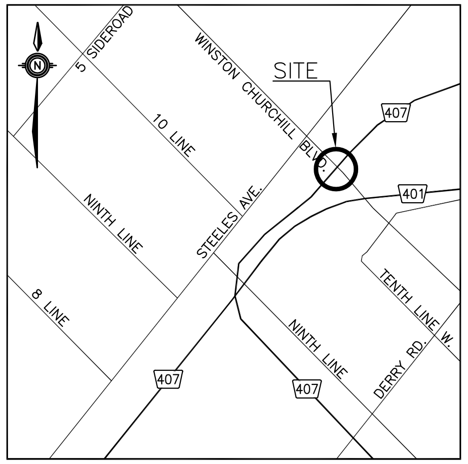


CONT No
WP No

SHEET

HIGHWAY 407 AT
WINSTON CHURCHILL BLVD.
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

THURBER ENGINEERING LTD.



KEYPLAN

L E G E N D

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

NO	ELEVATION	NORTHING	EASTING
407–01	215.7	4 828 593.0	597 511.1
407–02	217.0	4 828 596.9	597 472.9
407–03	208.8	4 828 641.1	597 444.2
407–04	217.4	4 828 669.5	597 407.0
407–05	217.1	4 828 685.6	597 390.9

-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.

GEOCRES No.

REVISIONS

DATE	BY	DESCRIPTION

DESIGN	CHK	CODE	LOAD	DATE AUG 2016
DRAWN AN	CHK	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\19\1605\196\ted5196–BoreholePlan&Profile.dwg
PLOTDATE: 8/10/2016 3:19 PM

APPENDIX B

RECORD OF BOREHOLE SHEETS

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

▨	CLAYSTONE
▤	SILTSTONE
░	SANDSTONE
■	COAL
▦	BEDROCK

STRENGTH CLASSIFICATION

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

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 % 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.

UNIFIED SOILS CLASSIFICATION

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 407-01

1 OF 2

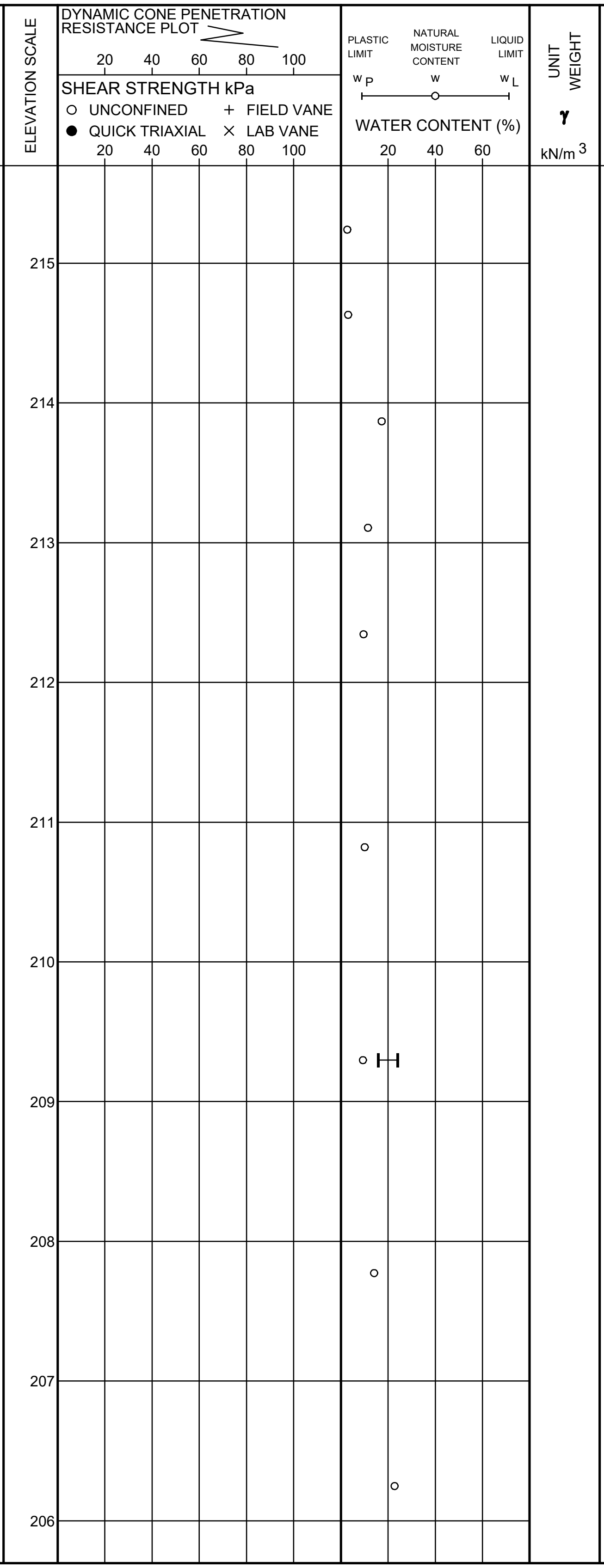
METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 593.0 E 597 511.1 ORIGINATED BY RMT

DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.05.13 - 2016.05.13 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
215.7	GROUND SURFACE							
0.0	**ASPHALT:** (150mm)							
0.2	**SAND** and **GRAVEL**, some silt Dense to Compact Grey to Brown Moist (FILL)	1	SS	38	39	41	20 (SI+CL)	
		2	SS	16				
214.5 1.2	Silty **CLAY**, sandy, trace gravel Firm to Very Stiff Grey to Brown Moist (FILL)(CL)	3	SS	5				
		4	SS	20	2	28	46	24
		5	SS	19				
		6	SS	15				
		7	SS	10	2	30	44	24
		8	SS	17				
207.2 8.5	Silty **CLAY** to Clayey **SILT**, sandy, trace gravel Hard Brown Moist (TILL)(CL-ML)	9	SS	38				



Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 407-01

2 OF 2

METRIC

W.P.

LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 593.0 E 597 511.1

ORIGINATED BY RMT

DIST HWY 407

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY AN

DATUM Geodetic

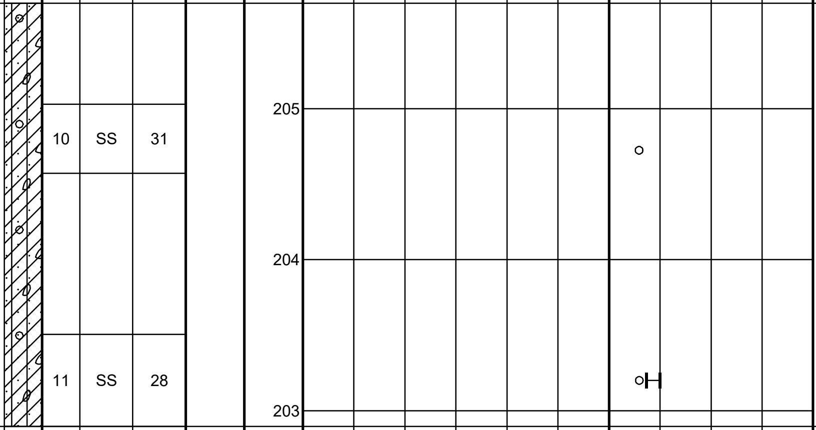
DATE 2016.05.13 - 2016.05.13

LATITUDE

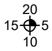
LONGITUDE

CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
							205				
			10	SS	31						
							204				
202.9	Very Stiff		11	SS	28		203				2 31 40 27
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE OPEN TO 12.8m AND BACKFILLED WITH BENTONITE HOLEPLUG TO 0.15m AND ASPHALT PATCH TO SURFACE.										



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



(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 407-02

1 OF 4

METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 596.9 E 597 472.9 ORIGINATED BY RMT/GA

DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

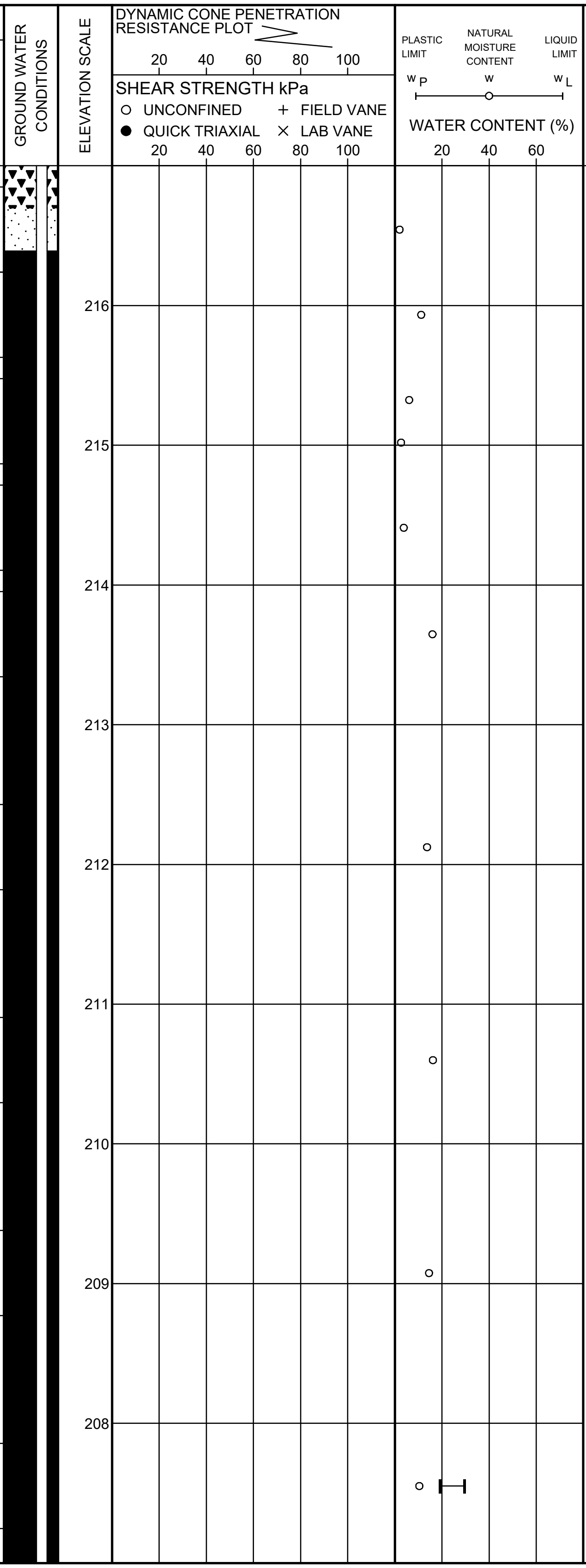
DATUM Geodetic DATE 2016.05.13 - 2016.05.17 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
217.0	GROUND SURFACE
0.0	**ASPHALT:** (150mm)
0.2	Gravely **SAND**, trace silt Very Dense Grey Moist (FILL) Becoming **SAND**, some gravel Dense
215.5 1.5	Silty **CLAY**, with sand, trace gravel Stiff Brown Moist (FILL)
215.2 1.8	Gravelly **SAND**, trace silt Dense Grey Moist (FILL)
213.6 3.4	Silty **CLAY**, with sand, trace gravel Stiff Brown Moist (FILL)
208.3 8.7	Silty **CLAY**, with sand, trace gravel Hard Brown Dry (TILL)(CL)

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	56				
2	SS	36	15	83	2 (SI+CL)	
3	SS	31				
4	SS	44				
5	SS	9	3	33	42	22
6	SS	14				
7	SS	13				
8	SS	13				
9	SS	34	5	22	41	32



UNIT WEIGHT γ kN/m3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 407-02

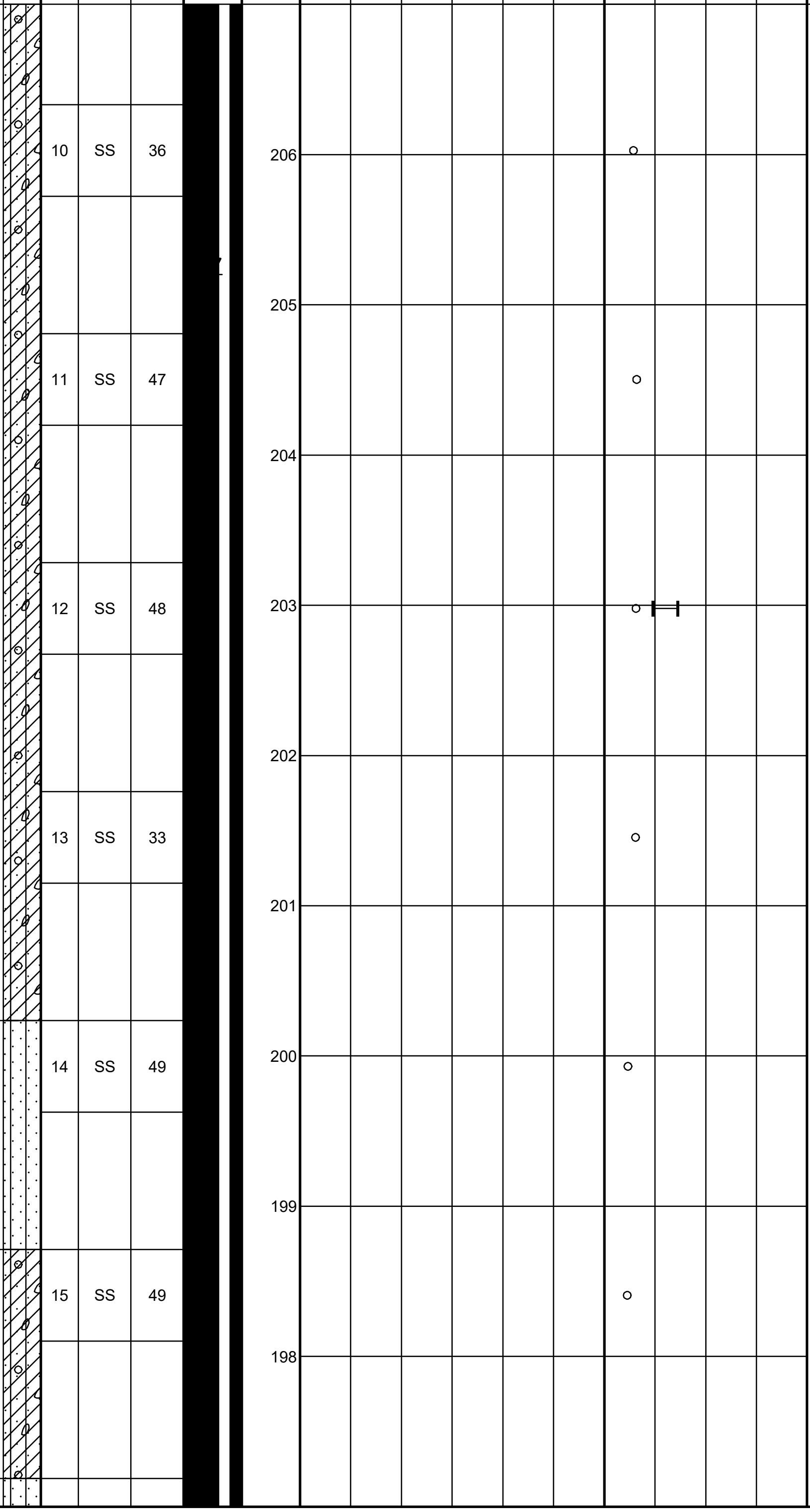
2 OF 4

METRIC

W.P. ____
LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 596.9 E 597 472.9
ORIGINATED BY RMT/GA
DIST ____ HWY 407
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
COMPILED BY AN
DATUM Geodetic
DATE 2016.05.13 - 2016.05.17
LATITUDE ____
LONGITUDE ____
CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, with sand, trace gravel Hard Brown Dry (TILL)(CL)	10	SS	36	
		11	SS	47	
		12	SS	48	4 31 39 26
		13	SS	33	
200.2 16.8	Silty **SAND**, trace clay, trace gravel Very Dense Grey Wet	14	SS	49	7 52 33 8
198.7 18.3	Silty **CLAY**, some sand, trace gravel, occasional shale fragments Hard Brown/Grey Wet (TILL)	15	SS	49	
197.2 19.8					



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+ ³, × ³: Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 407-02

3 OF 4

METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 596.9 E 597 472.9 ORIGINATED BY RMT/GA

DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2016.05.13 - 2016.05.17 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	Continued From Previous Page										
	Silty **SAND**, some gravel, trace clay, occasional shale fragments Very Dense Grey Wet	16	SS	70		○		13	48	29	10
					196						
		17	SS	99		○					
					195						
194.1 22.9	Gravelly **SAND**, silty, trace shale fragments Dense to Very Dense Reddish Brown to Grey Wet	18	SS	45	194	○		31	45	24 (SI+CL)	
					193						
		19	SS	92		○					
					192						
191.1 25.9	**SHALE**, highly weathered to fresh, thinly bedded, weak to medium strong, reddish brown	20	SS	100/ 0.075	191	○					
	Becoming fresh at 27.1m										
	Horizontal joints (50mm) at 27.2m and (225mm) at 28.3m				190		FI				
							2				
	Siltstone interbeds (25mm) at 27.2m, 28.1m and 28.2m, (150mm) at 27.6m and (100mm) at 28.4m	1	RUN				0 0 0	RUN #1 TCR=100% SCR=100% RQD=90% UCS=24MPa (Average)			
					189						
	Siltstone interbeds (25mm to 50mm) at 28.6m, 28.8m, 29.6m, 29.8m and 30.1m						2 2				
					188						
	Horizontal joints (25mm) at 28.8m and 28.9m	2	RUN				0 0 0	RUN #2 TCR=100% SCR=100% RQD=97% UCS=34MPa (Average)			

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 407-02

4 OF 4

METRIC

W.P.	LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 596.9 E 597 472.9		ORIGINATED BY RMT/GA
DIST HWY 407	BOREHOLE TYPE Hollow Stem Augers/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2016.05.13 - 2016.05.17	LATITUDE LONGITUDE	CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
186.3	Siltstone interbeds (25mm) at 30.3m and 30.6m		3	RUN						0 0 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=23MPa (Average)
30.7	END OF BOREHOLE AT 30.7m. BOREHOLE OPEN TO 30.7m AND WATER LEVEL AT 18.0m. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2016.06.15	11.7	205.3
2016.06.22	11.8	205.2

+ ^{3}, × ^{3} : Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

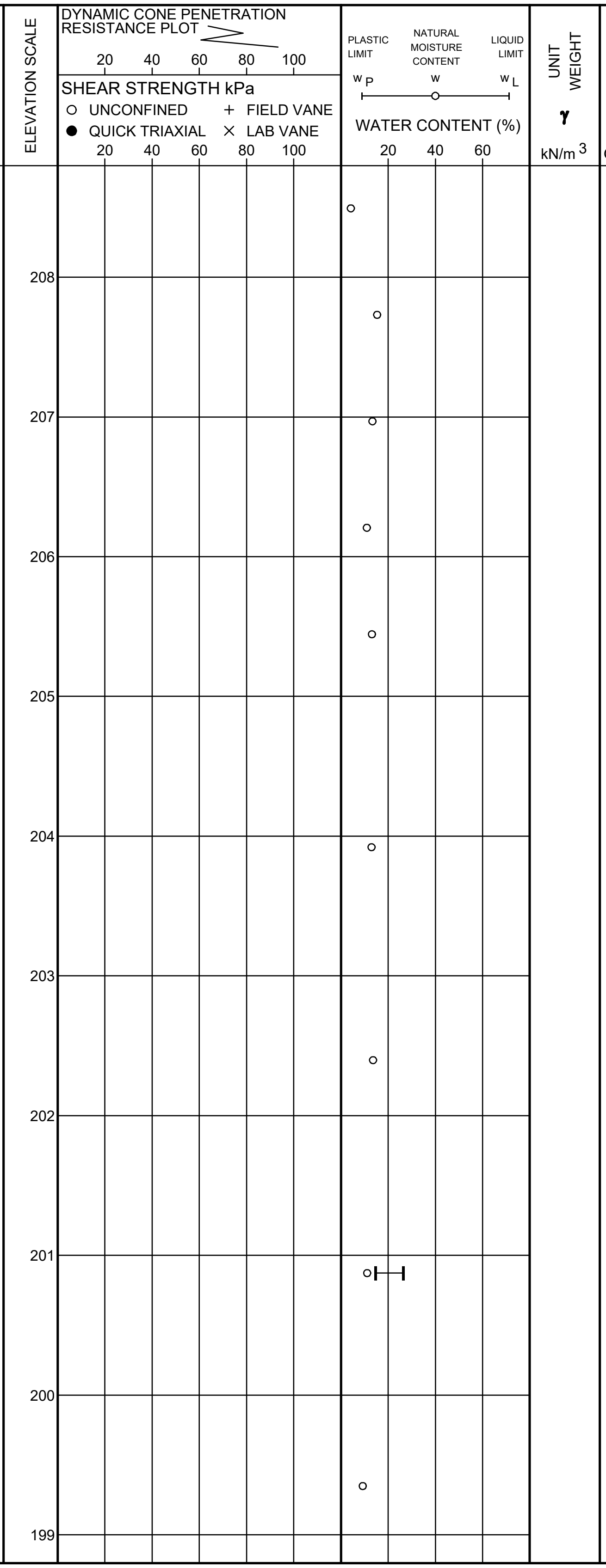
RECORD OF BOREHOLE No 407-03

1 OF 2

METRIC

W.P. ____ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 641.1 E 597 444.2 ORIGINATED BY GA
DIST ____ HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2016.04.25 - 2016.04.25 LATITUDE ____ LONGITUDE ____ CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
208.8	GROUND SURFACE								
0.0 208.2 0.6	**SAND** and **GRAVEL**, some silt: (Crusher Run Limestone) Compact Brown Dry (FILL)	1	SS	12		40	46	14 (SI+CL)	
	Silty **CLAY**, some sand, trace gravel Stiff Brown Dry (FILL)	2	SS	12					
206.6 2.2		3	SS	11	∇				
205.7 3.0	**SAND**, some gravel, some silt: (Limestone Screenings) Loose Grey Wet (FILL)	4	SS	9					
	Silty **CLAY**, with sand, trace gravel, occasional oxide staining Very Stiff Brown Dry (TILL)(CL)	5	SS	18		2	31	39	28
		6	SS	23					
		7	SS	18					
		8	SS	16		2	36	36	26
		9	SS	27					



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+3, ×3: Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 407-03

2 OF 2

METRIC

W.P. ____

LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 641.1 E 597 444.2

ORIGINATED BY GA

DIST ____ HWY 407

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY AN

DATUM Geodetic

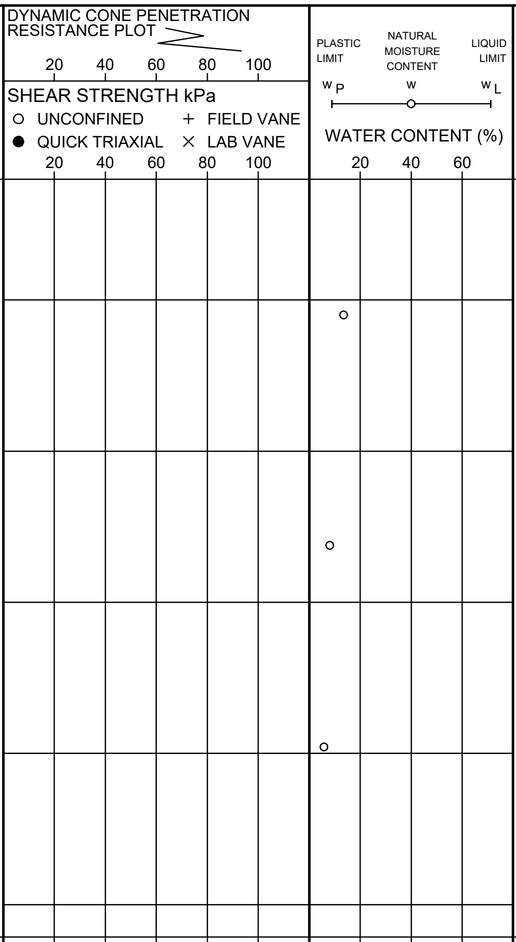
DATE 2016.04.25 - 2016.04.25

LATITUDE ____

LONGITUDE ____

CHECKED BY MEF

SOIL PROFILE			SAMPLES						REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Becoming hard		10	SS	107		198		8	30	48	14
							197					
196.3			11	SS	102							
196.1 12.5	**SILT**, trace clay, some sand Very Dense Grey Wet											
12.6	**SHALE**, highly weathered, thinly bedded Very Dense Brown to Grey						196					
			12	SS	120/ 0.075		195					
							194					
193.8			13	SS	100/ 0.075							
15.0	END OF BOREHOLE ON AUGER REFUSAL AT 15.0m. BOREHOLE OPEN TO 15.0m AND WATER LEVEL AT 2.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.											



+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

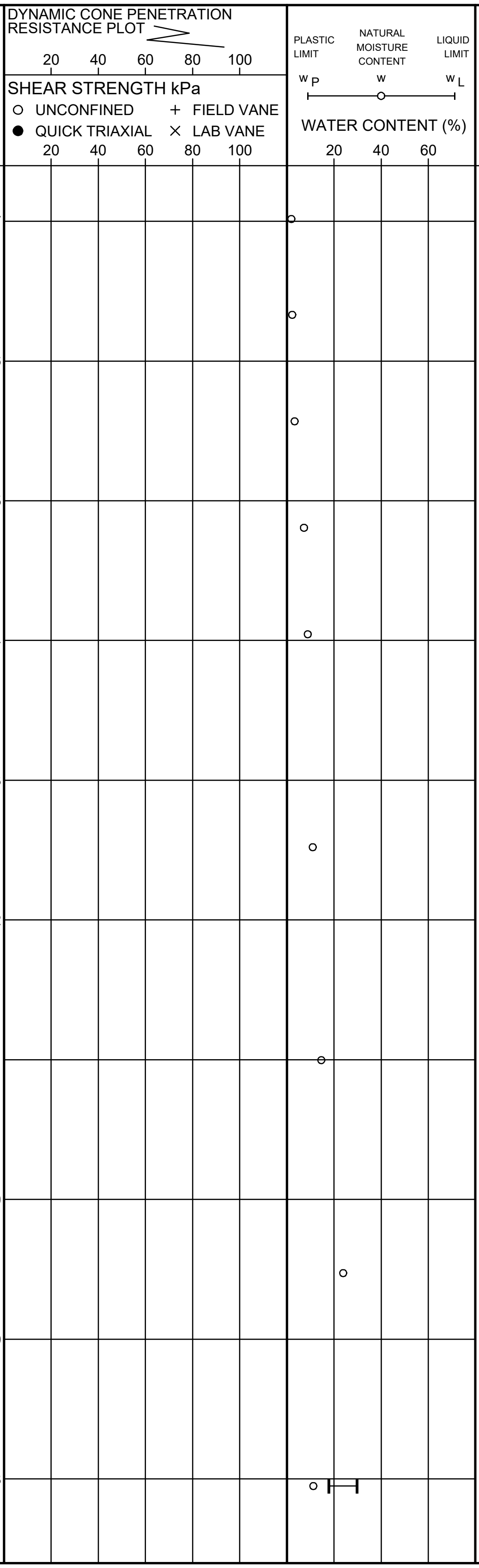
RECORD OF BOREHOLE No 407-04

1 OF 4

METRIC

W.P. ______
DIST ______ HWY 407
DATUM Geodetic
LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 669.5 E 597 407.0
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
DATE 2016.05.19 - 2016.05.20 LATITUDE ______ LONGITUDE ______
ORIGINATED BY GA
COMPILED BY AN
CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
217.4	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	**SAND**, some gravel, some silt: (Crusher Run Limestone) Dense to Compact Brown Dry (FILL)	1	SS	33		217					
		2	SS	28				16	67	17 (SI+CL)	
						216					
		3	SS	42							
215.0 2.4	Silty **CLAY**, with sand, trace gravel Very Stiff Brown Dry (FILL)	4	SS	26		215					
		5	SS	22		214					
						213					
		6	SS	18				4	31	41	24
						212					
	Becoming stiff	7	SS	11		211					
210.2 7.2	Silty **CLAY**, with sand, trace gravel Very Stiff to Hard Brown Dry (TILL)(CL)					210					
		8	SS	17							
						209					
		9	SS	39		208		5	30	48	17



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+3, ×3: Numbers refer to Sensitivity

20 15-⊕-5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 407-04

2 OF 4

METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 669.5 E 597 407.0 ORIGINATED BY GA
DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2016.05.19 - 2016.05.20 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
	Continued From Previous Page									
						207				
		10	SS	84						
						206				
		11	SS	32		205				
						204				
		12	SS	28						
						203				
						202				
		13	SS	19			3	37	45	15
						201				
	Becoming wet	14	SS	100			6	36	45	13
					▽	200				
199.1 18.3	**SILT**, some clay, some sand, trace gravel Very Dense Grey Wet	15	SS	81		199				
						198				
197.6 19.8										

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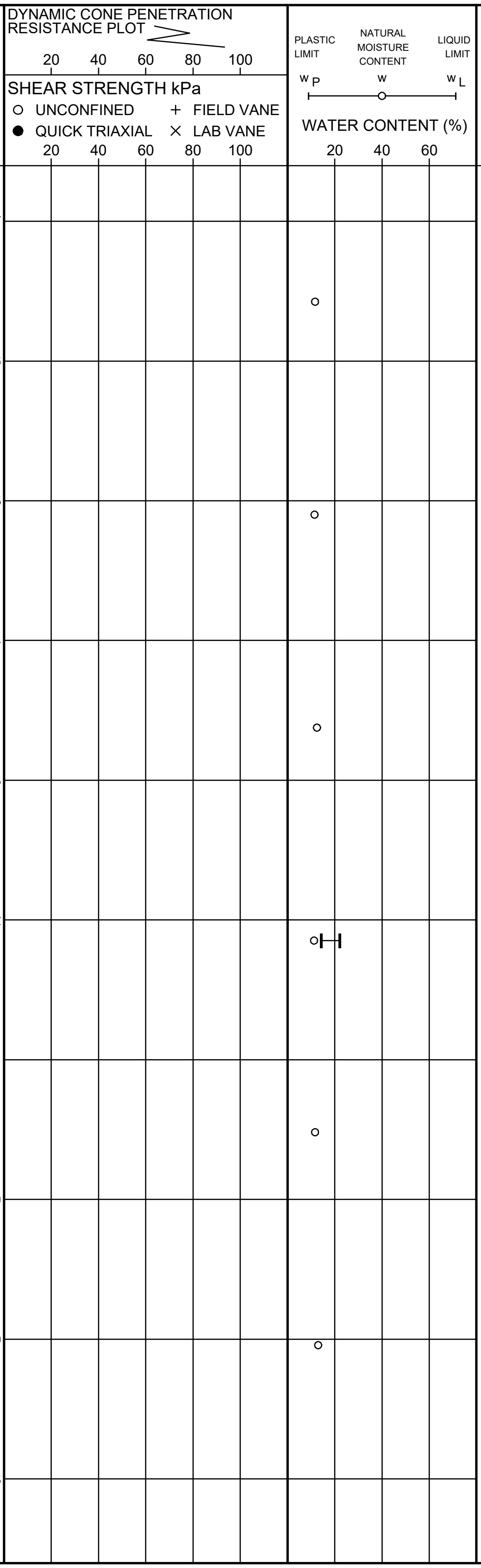


UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ ³, × ³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 407-04 3 OF 4 METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 669.5 E 597 407.0 ORIGINATED BY GA
DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2016.05.19 - 2016.05.20 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, some sand, trace gravel Hard Grey Wet (TILL)	16	SS	84		
196.1 21.3	Gravelly **SAND**, some silt, occasional cobbles and boulders Very Dense Grey Wet	17	SS	105		27 55 18 (SI+CL)
		18	SS	100/ 0.150		
		19	SS	117		
		20	SS	100/ 0.050		
190.0 27.4	**SHALE**, highly weathered to fresh, thinly bedded, weak to medium strong, reddish brown	21	SS	100/ 0.075	FI	
	Siltstone interbeds (25mm) at 28.4m, 28.5m, 28.6m, 28.7m, 29.1m and 29.8m Horizontal joints (25mm) at 29.0m, 29.1m, 29.2m and 29.4m	1	RUN		0 0 2 3 0	RUN #1 TCR=100% SCR=100% RQD=90% UCS=18MPa (Average)

ELEVATION SCALE: 197, 196, 195, 194, 193, 192, 191, 190, 189, 188

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

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

UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 407-04

4 OF 4

METRIC

W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 669.5 E 597 407.0 ORIGINATED BY GA

DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2016.05.19 - 2016.05.20 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
186.0	Siltstone interbeds (25mm to 75mm) at 29.9m, 30.3m, 30.6m, 30.7m, 30.9mm and 31.1m Horizontal joints (25mm) at 30.5m, 30.6m and 30.8m		2	RUN			187			0 0 2 2 0	RUN #2 TCR=100% SCR=100% RQD=95% UCS=49MPa (Average)
31.4	END OF BOREHOLE AT 31.4m. BOREHOLE OPEN TO 31.4m AND WATER LEVEL AT 17.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE FROM 0.5m TO 0.2m, THEN ASPHALT PATCH TO SURFACE.										

+ ³, × ³ : Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 407-05

1 OF 2 **METRIC**

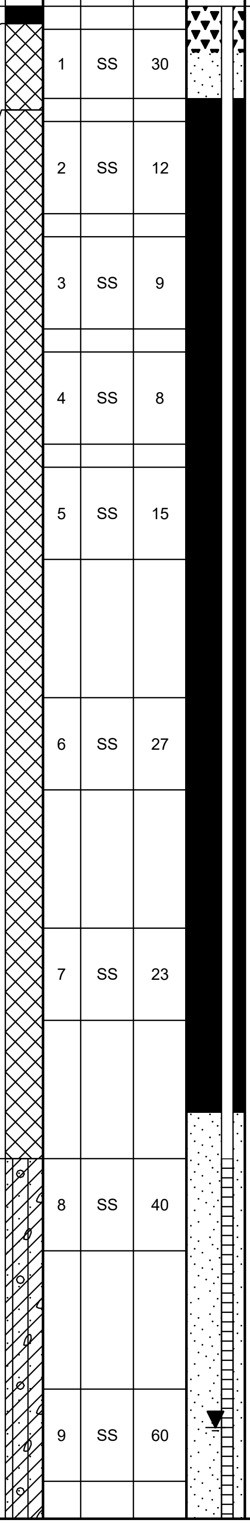
W.P. ______ LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 685.6 E 597 390.9 ORIGINATED BY GA

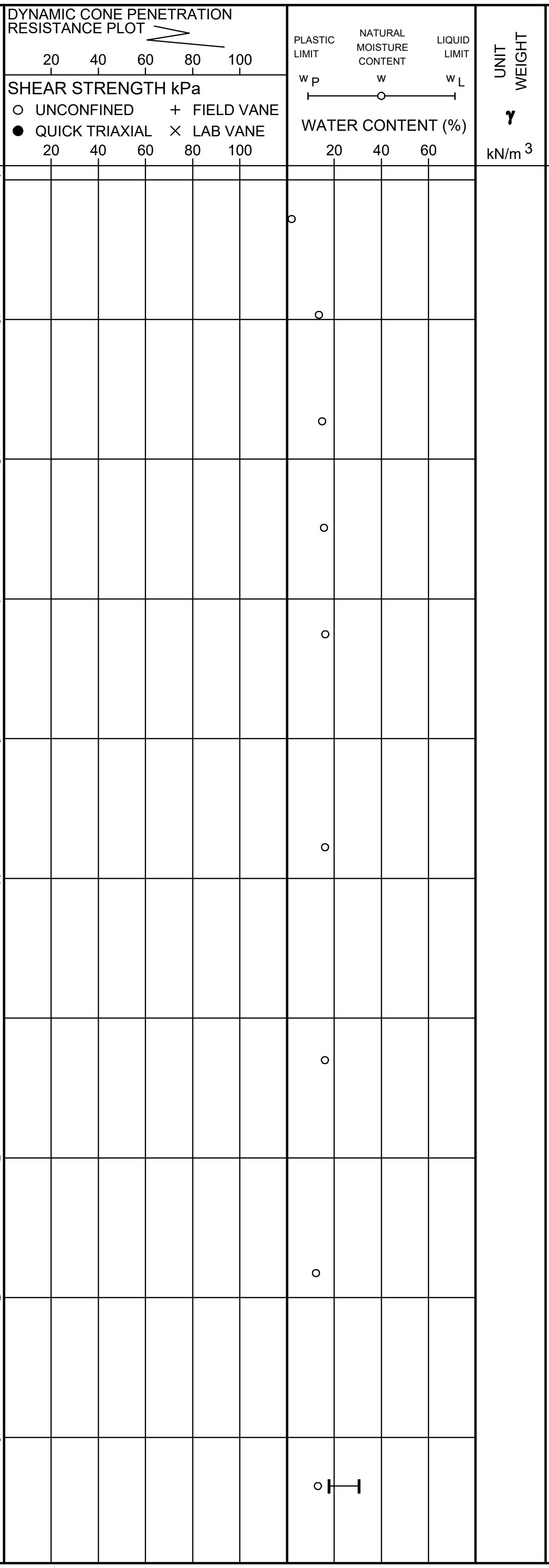
DIST ______ HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.05.18 - 2016.05.18 LATITUDE ______ LONGITUDE ______ CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION
217.1	GROUND SURFACE
0.0	**ASPHALT:** (113mm)
0.1	**SAND** and **GRAVEL**, some silt: (Crusher Run Limestone) Dense Brown Dry (FILL)
216.4 0.7	Silty **CLAY**, sandy, trace gravel Stiff to Very Stiff Brown Dry (FILL)
209.5 7.6	Silty **CLAY**, sandy, trace gravel Hard Brown Dry (TILL)(CL)

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	30	47	38	15 (SI+CL)	
2	SS	12				
3	SS	9				
4	SS	8				
5	SS	15	0	23	47	30
6	SS	27				
7	SS	23				
8	SS	40				
9	SS	60	4	27	43	26





REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 407-05

2 OF 2

METRIC

W.P. ______
LOCATION Winston Churchill Blvd. at HWY 407 N 4 828 685.6 E 597 390.9
ORIGINATED BY GA

DIST ______ HWY 407
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN

DATUM Geodetic
DATE 2016.05.18 - 2016.05.18
LATITUDE ______
LONGITUDE ______
CHECKED BY MEF

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ^{3}	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
206.1			10	SS	79		207		○		
11.0	END OF BOREHOLE AT 11.0m. BOREHOLE OPEN TO 11.0m AND DRY. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2016.06.15	8.2	208.9
2016.06.22	9.4	207.7

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+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

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APPENDIX C

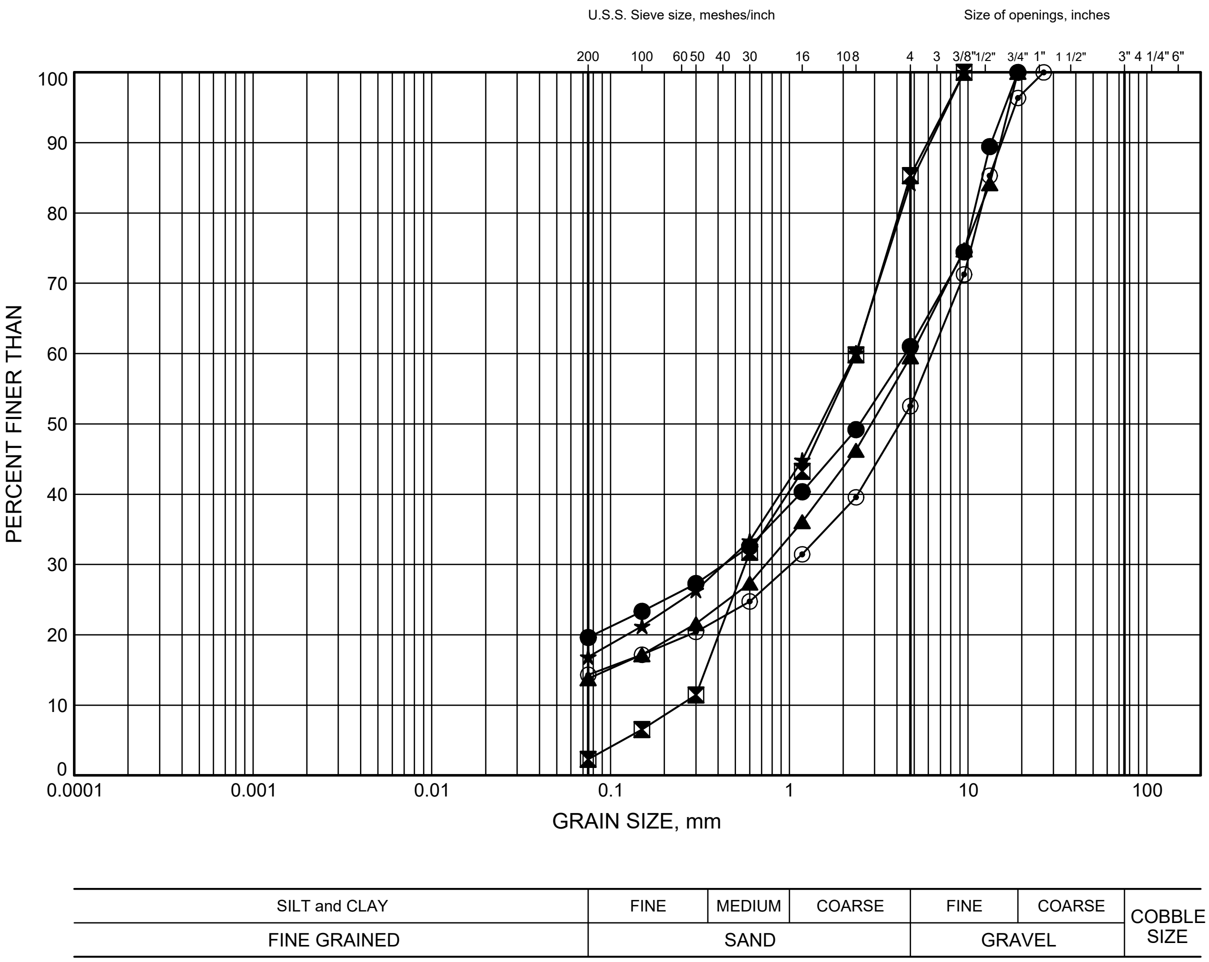
GEOTECHNICAL LABORATORY TEST RESULTS

EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C1

Granular Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-01	0.30	215.39
☒	407-02	1.07	215.93
▲	407-03	0.30	208.49
★	407-04	1.07	216.33
⊙	407-05	0.38	216.72

Date August 2016

W.P.

THURBER

Prep'd MFA

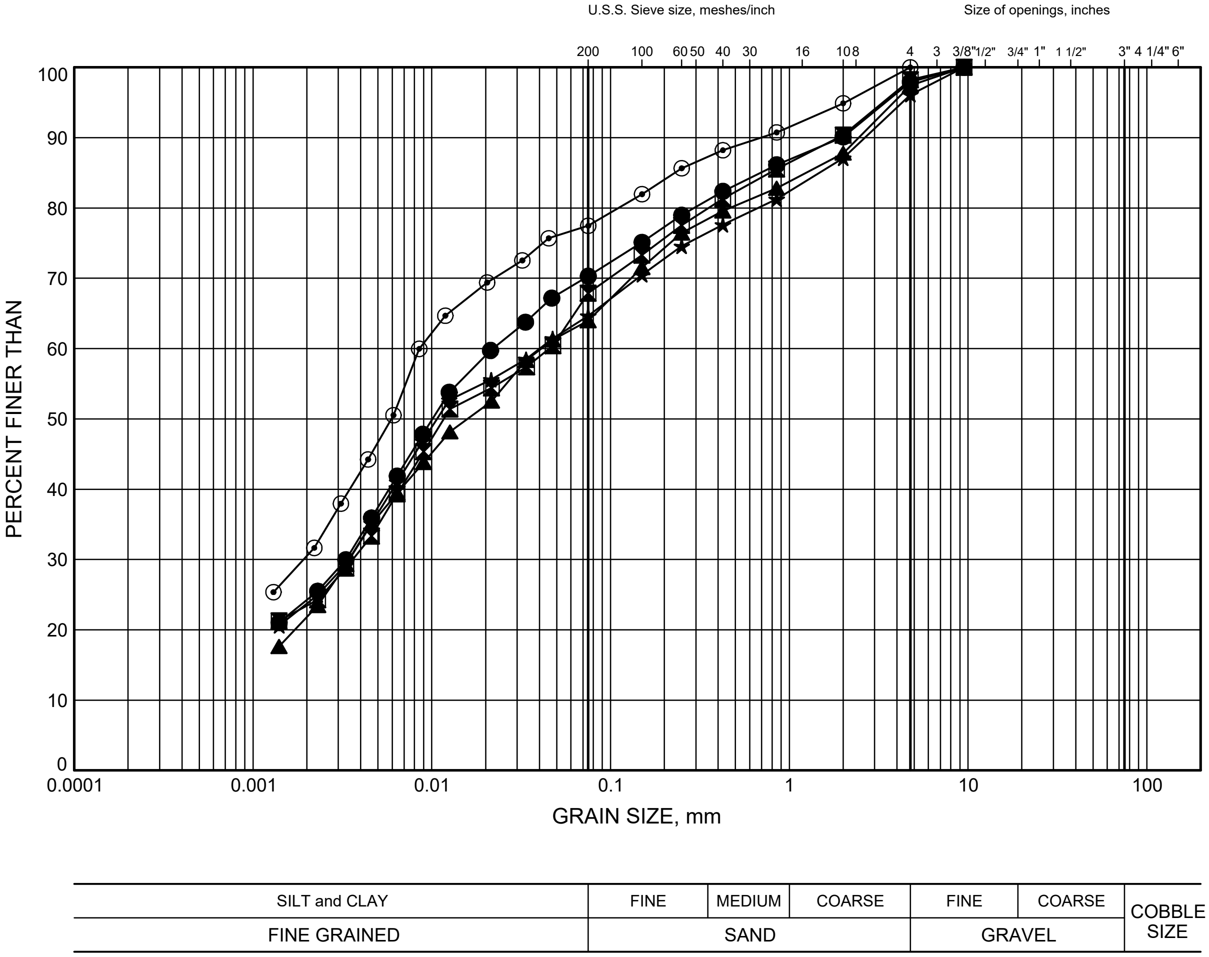
Chkd. TE

EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-01	2.59	213.11
⊠	407-01	6.40	209.30
▲	407-02	3.51	213.49
★	407-04	4.88	212.52
⊙	407-05	3.35	213.75

Date August 2016

W.P.

THURBER

Prep'd MFA

Chkd. TE

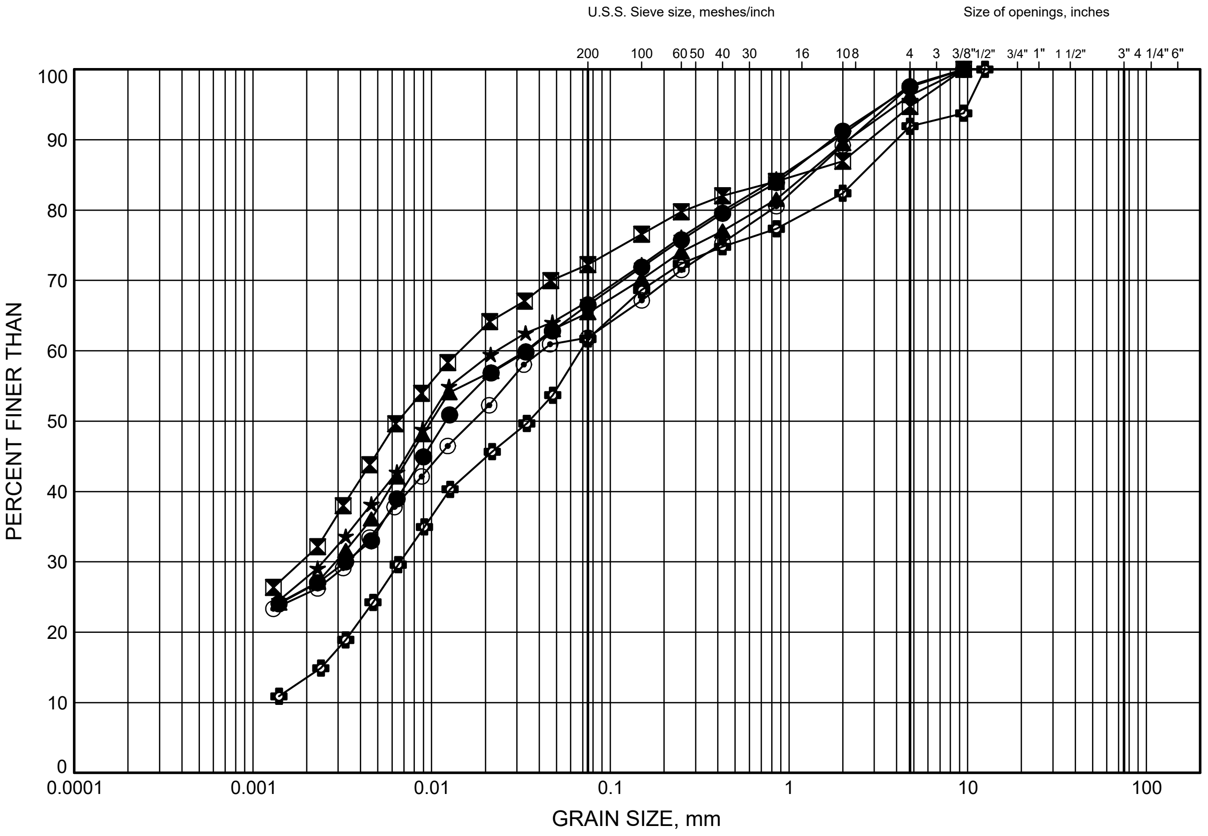
GRAIN SIZE DISTRIBUTION - THURBER 19-1605-196 (FOUNDATION).GPJ 4/19/23

EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-01	12.50	203.20
⧗	407-02	9.45	207.55
▲	407-02	14.02	202.98
★	407-03	3.35	205.44
⊙	407-03	7.92	200.87
✤	407-03	10.97	197.82

Date August 2016

W.P.

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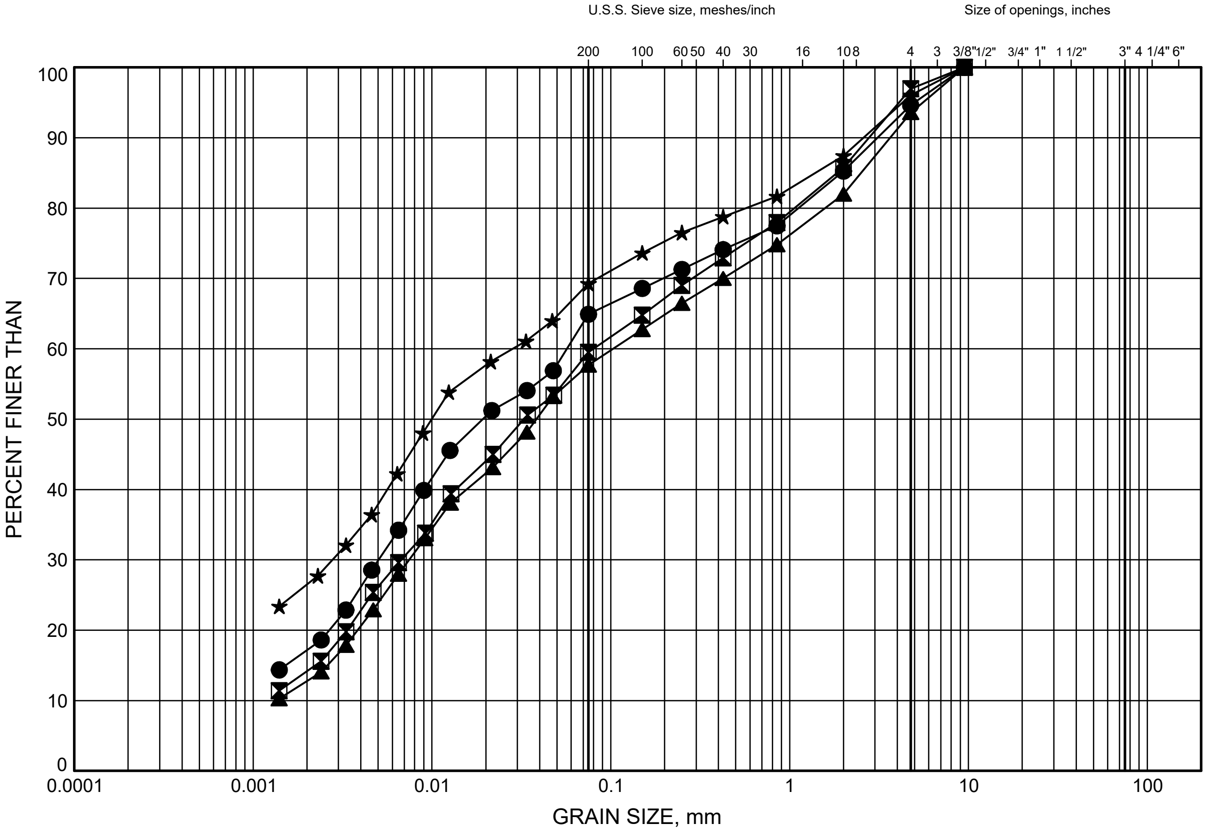
EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C4

Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-04	9.45	207.95
☒	407-04	15.54	201.85
▲	407-04	17.07	200.33
★	407-05	9.45	207.65

Date August 2016

W.P.

THURBER

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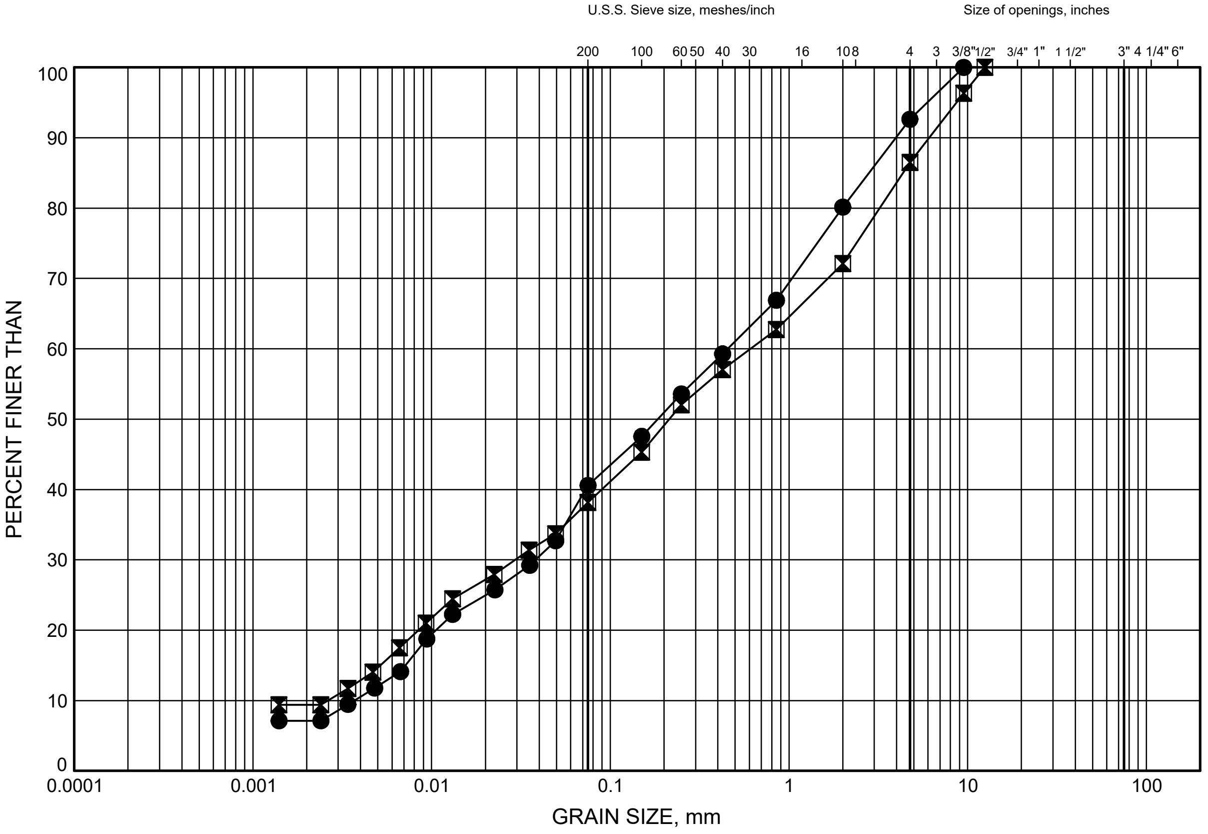
EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C5

Intra-Till Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-02	17.07	199.93
⧗	407-02	20.12	196.88

Date August 2016

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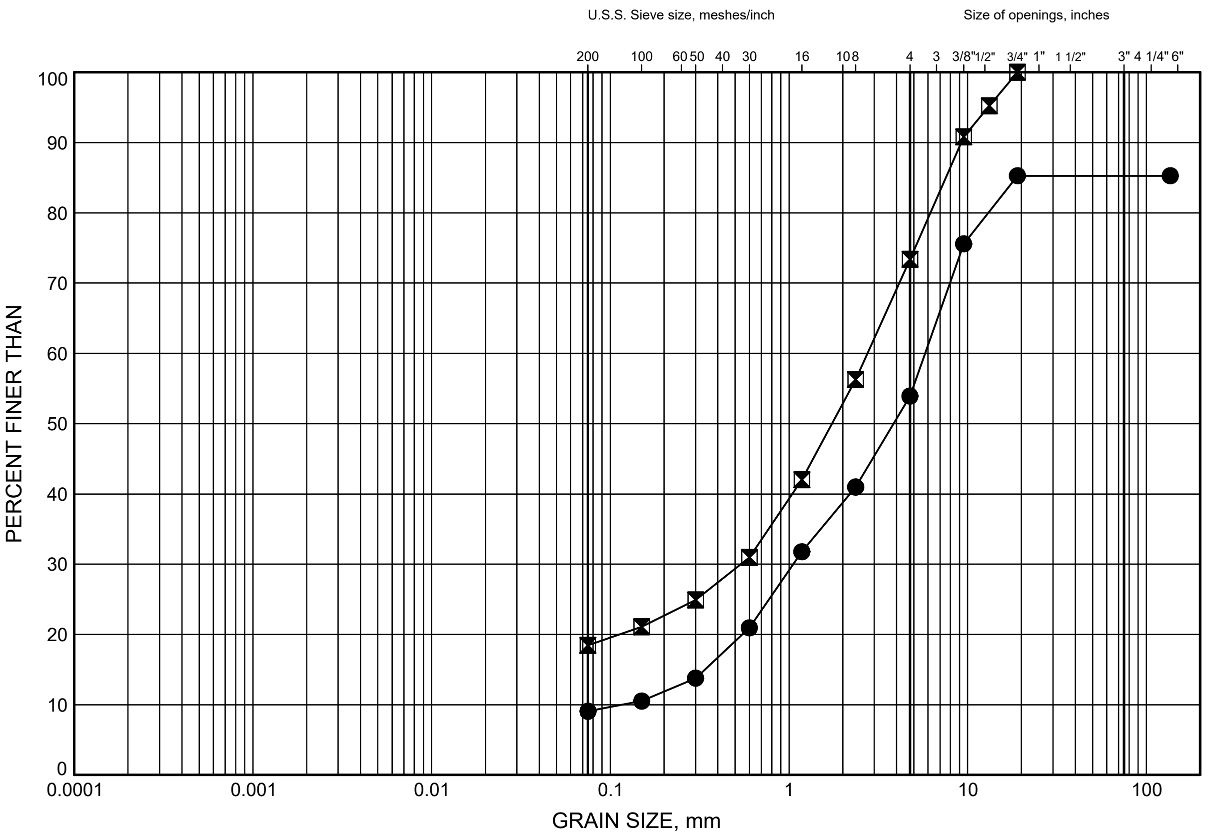
EA for Winston Churchill Blvd Widening

GRAIN SIZE DISTRIBUTION

FIGURE C6

Gravelly Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-02	23.16	193.84
☒	407-04	21.64	195.76

Date August 2016

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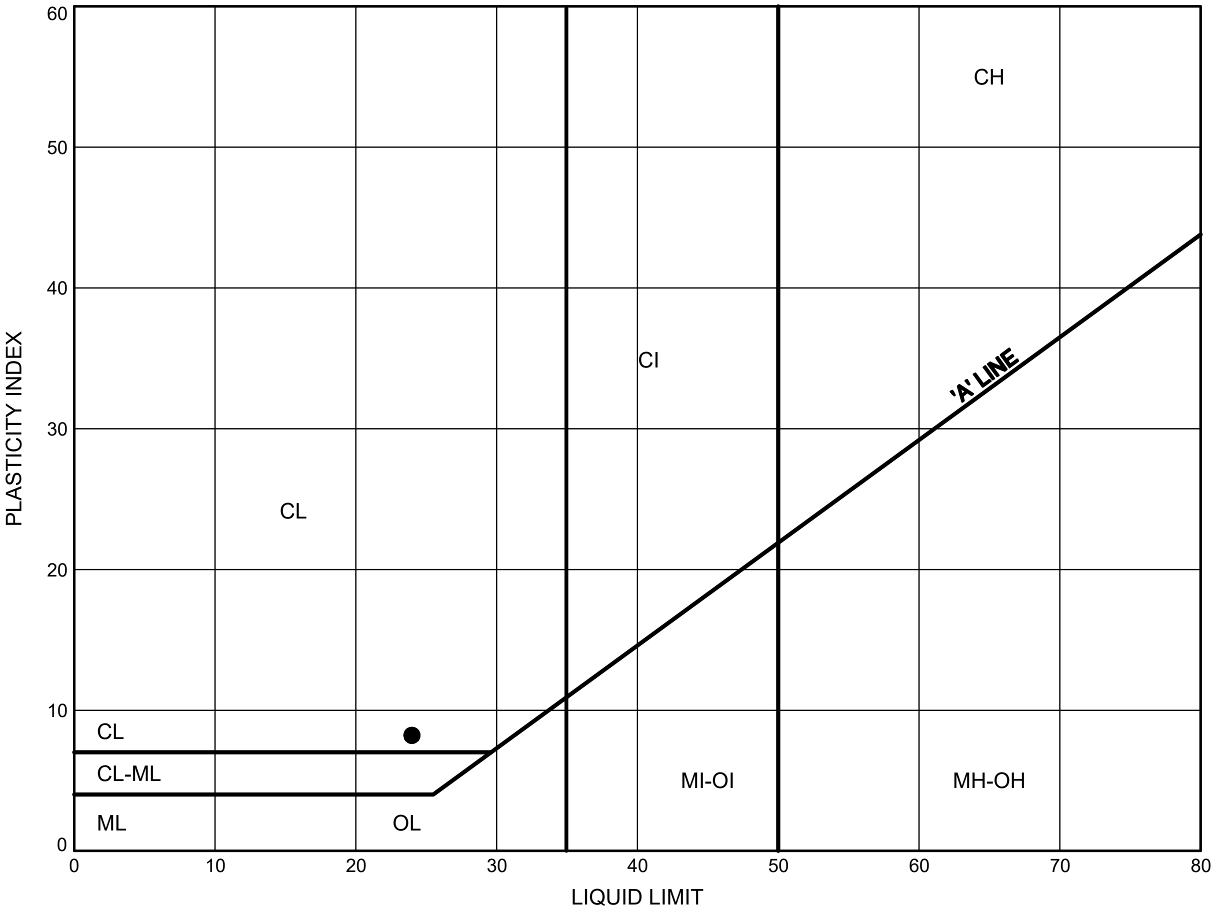
Chkd. TE

EA for Winston Churchill Blvd Widening

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-01	6.40	209.30

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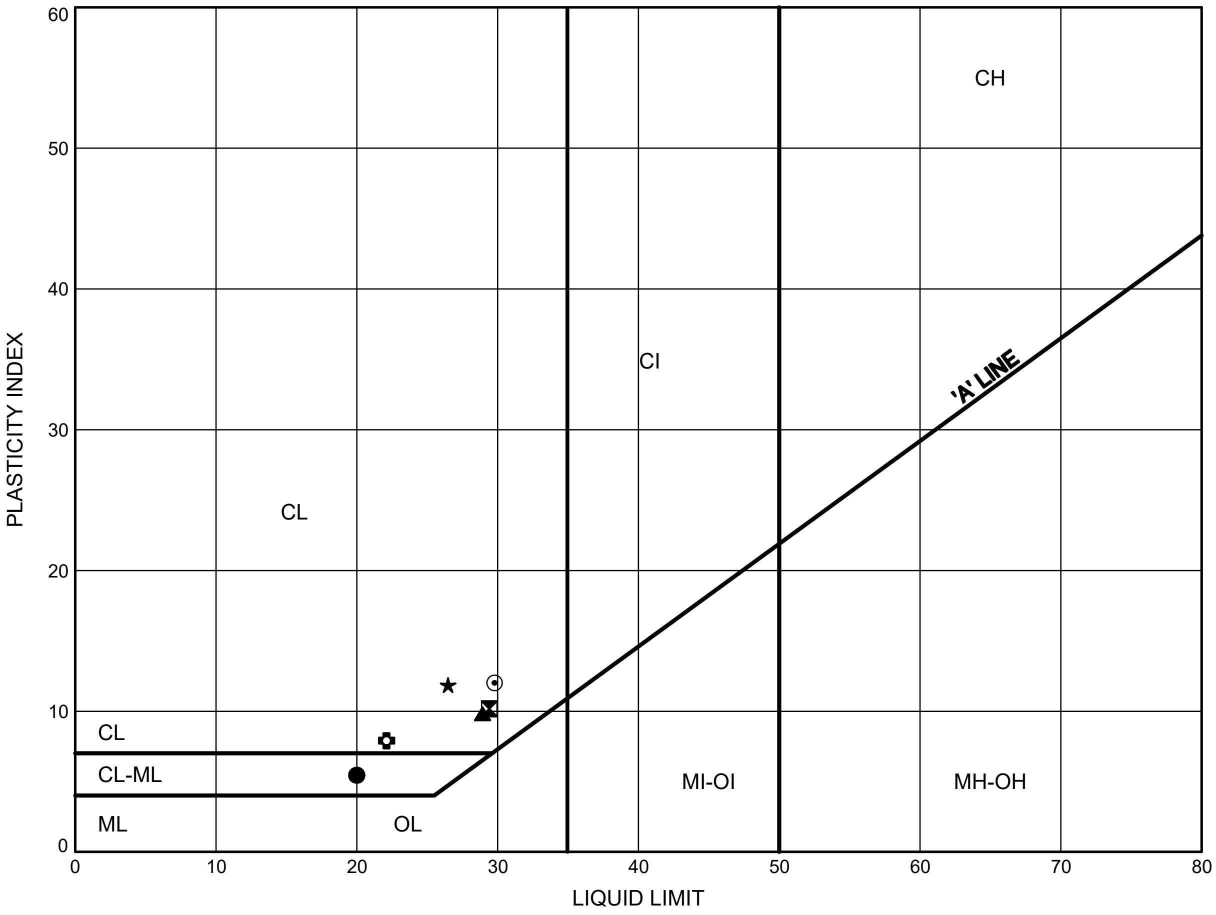
EA for Winston Churchill Blvd Widening

ATTERBERG LIMITS TEST RESULTS

FIGURE C8

Silty Clay Till



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-01	12.50	203.20
⧗	407-02	9.45	207.55
▲	407-02	14.02	202.98
★	407-03	7.92	200.87
⊙	407-04	9.45	207.95
✿	407-04	15.54	201.85

Date August 2016

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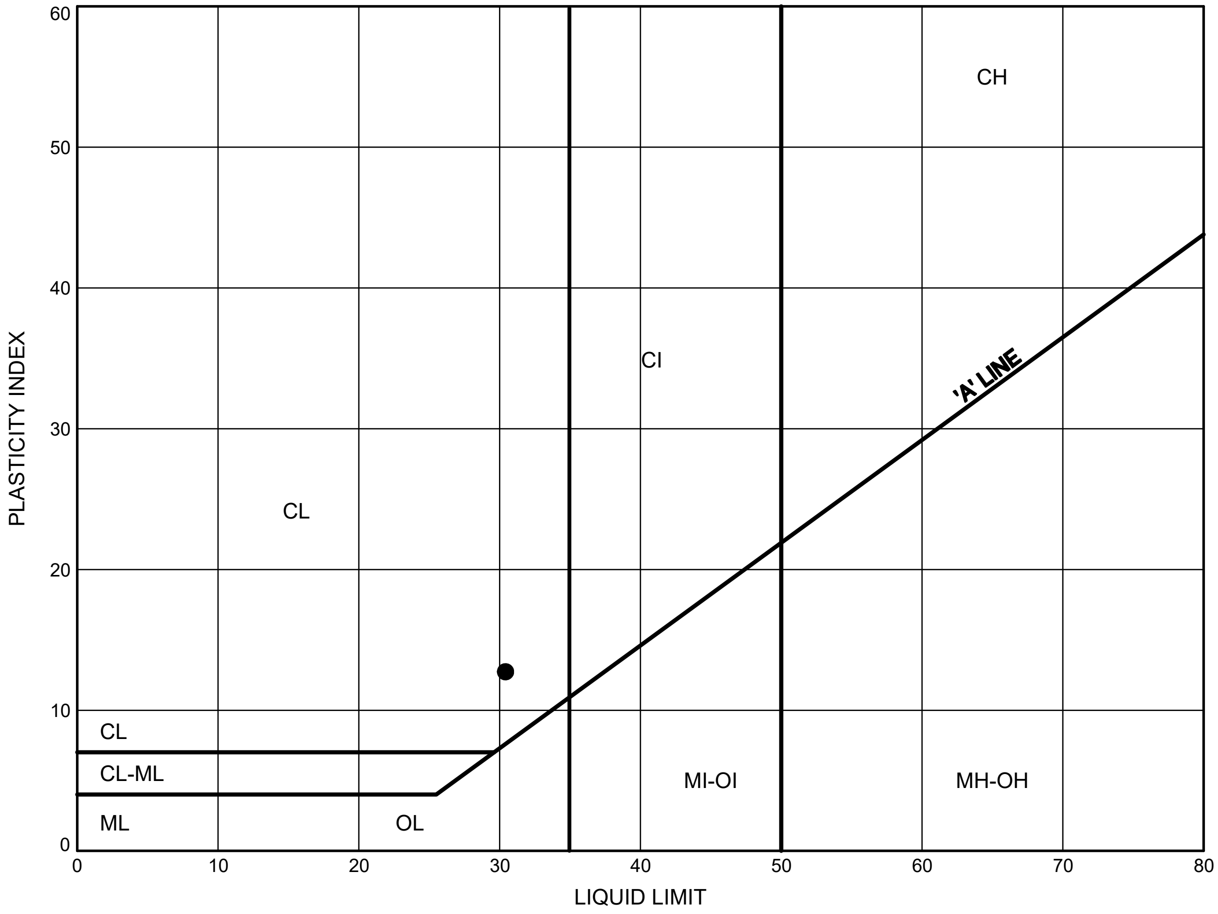
EA for Winston Churchill Blvd Widening

ATTERBERG LIMITS TEST RESULTS

FIGURE C9

Silty Clay Till



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	407-05	9.45	207.65

THURBALT 19-1605-196 (FOUNDATION).GPJ 4/19/23

Date August 2016

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THURBER

Prep'd MFA

Chkd. TE

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 19-1605-196 **Client :** HMM

Date Drilled : 16-May-16

Project Name : EA For Winston Churchill Blvd Widening **Date Tested :** 18-May-16

Core Size : NQ **BH No :** BH 407-2 **Tester :** BT

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	UCS (MPa)	Rock Type	Notes
1	1	27.2	D	0.4	46.9	99.3	4.2	Shale (red)	Very Weak
2	1	27.2	A	3.5	46.9	54.0	25.9	Shale (red)	Medium Strong
3	1	27.7	A	3.8	47.1	55.9	27.7	Shale (grey)	Medium Strong
4	1	27.7	A	4.7	47.0	46.2	39.6	Shale (grey)	Medium Strong
5	1	28.1	A	2.5	47.0	47.3	20.3	Shale (red)	Weak
6	1	28.3	D	1.0	47.1	61.9	9.6	Shale (red)	Weak
7	1	28.2	A	4.1	47.1	51.9	31.6	Shale (red)	Medium Strong
8	1	28.5	A	3.7	47.1	43.5	32.8	Shale (grey)	Medium Strong
9	2	28.8	A	8.4	47.1	50.3	66.1	Shale (red/grey)	Strong
10	2	29.2	A	1.7	47.1	46.1	14.5	Shale (red)	Weak
11	2	29.9	D	2.0	47.1	83.7	19.6	Shale (red/grey)	Weak
12	2	29.9	A	4.5	47.1	50.4	35.0	Shale (red)	Medium Strong
13	3	30.2	D	1.3	47.1	66.7	13.4	Shale (red)	Weak
14	3	30.2	A	2.8	47.1	37.8	27.7	Shale (red)	Medium Strong
15	3	30.5	A	3.7	47.1	51.9	28.7	Shale (red)	Medium Strong
16									
17									
18					Run 1 (Average) =		24.0		Weak
19					Run 2 (Average) =		33.8		Medium Strong
20					Run 3 (Average) =		23.3		Weak
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have 0.7 x D on either side of test point.

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 19-1605-196

Client : HMM

Date Drilled : 20-May-16

Project Name : EA For Winston Churchill Blvd Widening

Date Tested : 20-May-16

Core Size : NQ **BH No :** BH 407-4

Tester : BT

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	UCS (MPa)	Rock Type	Notes
1	1	28.4	D	0.6	46.9	81.5	6.2	Shale (red)	Weak
2	1	28.5	A	1.9	46.9	34.8	19.5	Shale (grey)	Weak
3	1	28.8	A	2.7	46.9	46.6	22.4	Shale (red)	Weak
4	1	29.1	A	2.1	46.2	47.1	18.0	Shale (red)	Weak
5	1	29.4	A	3.1	47.0	53.9	23.0	Shale (red)	Weak
6	1	29.8	A	2.5	46.9	46.1	21.1	Shale (red)	Weak
7	2	30.1	A	3.3	47.0	42.3	30.1	Shale (red)	Medium Strong
8	2	30.4	A	2.7	46.9	58.6	18.8	Shale (red)	Weak
9	2	30.7	D	8.0	46.9	74.0	80.0	Limestone	Strong
10	2	30.7	A	13.5	46.9	53.3	101.6	Shale (red)	Very Strong
11	2	31.0	D	6.2	46.9	94.3	61.9	Shale (red)	Strong
12	2	31.0	A	5.8	46.9	55.6	42.7	Shale (red)	Medium Strong
13	2	31.3	A	4.3	46.9	49.1	34.6	Shale (red)	Medium Strong
14	2	31.2	D	2.2	46.9	75.4	21.9	Shale (red)	Weak
15									
16					Run 1 (Average) =		18.4		Weak
17					Run 2 (Average) =		48.9		Medium Strong
18									
19									
20									
21									
22									
23									
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25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have 0.7 x D on either side of test point.

Last Modified: August 15, 2013

THURBER

APPENDIX D

SEISMIC HAZARD CALCULATION

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

August 05, 2016

Site: 43.6 N, 79.8 W User File Reference:

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.170	0.210	**0.180**	0.138	**0.100**	**0.053**	**0.026**	**0.0063**	**0.0027**	**0.114**	**0.079**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.011	0.049	0.089
Sa(0.1)	0.017	0.067	0.116
Sa(0.2)	0.019	0.062	0.103
Sa(0.3)	0.017	0.051	0.081
Sa(0.5)	0.013	0.039	0.060
Sa(1.0)	0.0063	0.022	0.033
Sa(2.0)	0.0027	0.010	0.016
Sa(5.0)	0.0006	0.0022	0.0037
Sa(10.0)	0.0004	0.0010	0.0016
PGA	0.0096	0.036	0.063
PGV	0.0078	0.029	0.046

References

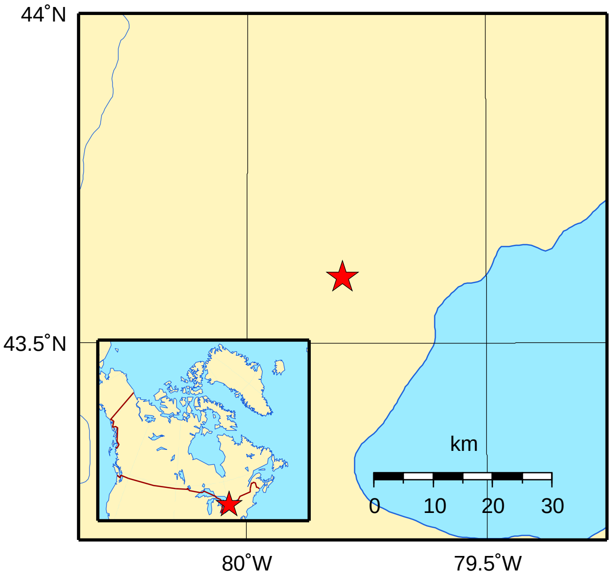
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



APPENDIX E

SELECTED SITE PHOTOGRAPHS

PHOTO 1: Looking west towards east side of Winston Churchill Boulevard bridge over Highway 407

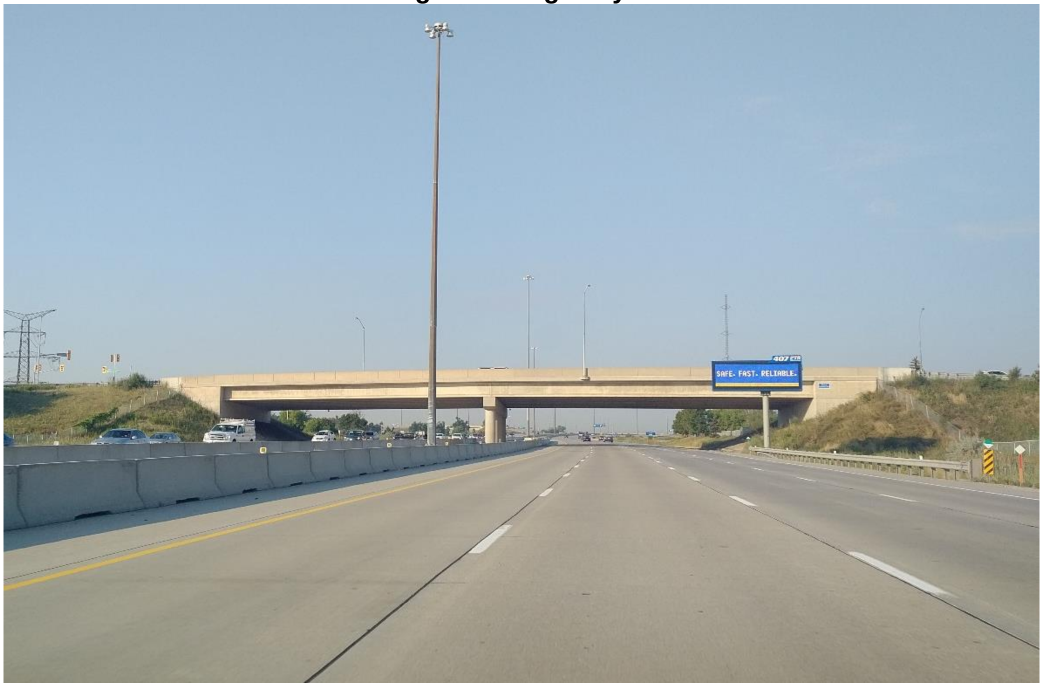


PHOTO 2: Looking southwest towards south abutment and central pier.

PHOTO 3: Looking west towards north abutment and central pier.

PHOTO 4: South abutment, east side

PHOTO 5: North abutment, east side

THURBER ENGINEERING LTD.

WINSTON CHURCHILL BOULEVARD CLASS EA
HIGHWAY 407 BRIDGE WIDENING
SITE PHOTOGRAPHS

PROJECT NO.: 19-1605-196
TAKEN BY: GA
PHOTOS TAKEN: Apr 2016