THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 401 / HIGHBURY AVENUE
INTERCHANGE RECONSTRUCTION
CITY OF LONDON, ONTARIO
G.W.P. 3032-11-00

GEOCRES No. 40I14-165

Report

to

Ministry of Transportation of Ontario

Date: April 26, 2016
File: 10552

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the reconstruction of the Highbury Avenue Interchange on Highway 401 in the City of London. Ontario. The proposed reconstruction works include replacement of the existing underpass structure, a grade raise and widening of the approach embankments, and realignment of high fill embankments for ramps.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location plans and soil strata drawings, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Thurber carried out the investigation as a consultant to the Ministry of Transportation Ontario (MTO) under the MTO Agreement Numbers 3012-E-007 and 3012-E-008.

2. SITE DESCRIPTION

The site is located at the Highway 401 and Highbury Avenue interchange, in the City of London, Ontario. The existing underpass structure carries Highbury Avenue over Highway 401 at the interchange. At the project site, Highway 401 runs approximately in the southwest-northeast direction, while Highbury Avenue runs generally north-south. For the purpose of this report, Highway 401 is assumed to run west-east. Highbury Avenue consists of two lanes of traffic in each direction, and Highway 401 is a six-lane (three lanes in each direction) divided freeway. The interchange is a six-ramp partial cloverleaf, including loop ramps in the northeast and southwest quadrants (S-W and N-E ramps respectively).

The existing underpass was constructed in 1960 and consists of a 61.6 m long three-span, concrete structure. The piers are supported on spread footings and the abutments are supported on piles.

The surrounding lands are generally open fields, with industrial and commercial properties located to the south and west of the site.

Photographs in Appendix E show the general nature of the interchange and the existing bridge.

The site lies within the physiographic region known as the Mount Elgin Ridges, which is generally characterized by undrumlinized till plains (Chapman and Putnam, 1984). The quaternary geology typically consists of Port Stanley till (silt to sandy silt matrix becoming silt to silty clay) and glaciolacustrine deposits of sand, gravelly sand, and gravel (M2556, 1991). The bedrock in the area consists of limestone, dolostone and shale of the Dundee Formation (MRD126-Rev 1, 2011). Based on bedrock topography mapping (P.482, 1968), the bedrock surface in the area is at an approximate elevation of 205 m, which is greater than 65 m deeper than the ground surface elevation at the interchange.

3. INVESTIGATION PROCEDURES

The field investigation for this project was carried out between February 8 and 24, 2016, and consisted of drilling and sampling nine (9) boreholes, designated as Boreholes 16-01 to 16-09. Boreholes 16-01 and 16-02 were drilled near the proposed alignment of the S-W ramp, Boreholes 16-03 to 16-07 were drilled at the proposed bridge foundation and approach embankment locations, and Boreholes 16-08 and 16-09 were drilled along the existing N-E ramp. Due to access constraints, Boreholes 16-08 and 16-09 could not be drilled along the proposed new N-E ramp alignment. Therefore, to supplement the boreholes drilled on the existing ramp, hand-dug pits were excavated at the proposed ramp location, which are designated as 16-08A and 16-09A. Boreholes 16-03, 16-04, 16-06 and 16-07 were drilled on Highbury Avenue, and Borehole 16-05 was drilled at the median of Highway 401 on the south shoulder of the westbound lanes.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings provided in Appendix D.

A track-mounted Diedrich D50T drill rig supplied and operated by London Soil Test Ltd. of London, Ontario was used to advance the boreholes using hollow stem augers. The boreholes were advanced to depths between 15.8 m and 40.2 m. Boreholes 16-04 and 16-06 were extended beyond 40.2 m depth by conducting Dynamic Cone Penetration Tests (DCPTs) to depths of 42.4 to 43.3 m. In all boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

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

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Standpipe piezometers were installed in two of the boreholes (Boreholes 16-04 and 16-06) to permit monitoring of the groundwater levels at the site. Each standpipe piezometer consisted of a 19 mm diameter PVC pipe, with a slotted screen sealed at selected depths within the boreholes. The boreholes, in which no standpipe piezometers were installed, were backfilled in general accordance with Ontario Regulation 903.

Completion details of the boreholes and piezometers are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Location	Borehole Number	Borehole Depth/Base Elevation (m)	Piezometer Tip Depth/ Elevation (m)	Completion Details
S-W Ramp	16-01	15.8/ 256.8	None installed	Bentonite holeplug and cuttings to surface.
S-W Ramp	16-02	15.8/ 256.7	None installed	Bentonite holeplug and cuttings to surface.
North Approach	16-03	15.8/ 266.2	None installed	Bentonite holeplug and cuttings to 1.5 m, bentonite holeplug to 0.9 m and concrete to surface.
North Abutment	16-04	40.2/ 242.3 43.3/ 239.2 (DCPT)	39.6/ 242.9	Filter sand to 37.2 m, bentonite holeplug to 34.7 m, bentonite holeplug and cuttings to 1.2 m, bentonite holeplug to 0.6 m and concrete to surface.
Central Pier	16-05	18.9/ 257.2	None installed	Bentonite holeplug and cuttings to 1.5 m, concrete to 0.2 m and asphalt patch to surface.
South Abutment	16-06	40.2/ 242.3 42.4/ 240.2 (DCPT)	39.6 / 242.9	Filter sand to 37.5 m, bentonite holeplug to 36.6 m, bentonite holeplug and cuttings to 1.5 m, concrete to 0.6 m and asphalt patch to surface.
South Approach	16-07	15.8/ 266.3	None installed	Bentonite holeplug and cuttings to 1.5 m, bentonite holeplug to 0.9 m and concrete to surface.

Borehole Location	Borehole Number	Borehole Depth/Base Elevation (m)	Piezometer Tip Depth/ Elevation (m)	Completion Details
N-E Ramp	16-08	18.9/ 261.4	None installed	Bentonite holeplug and cuttings to 0.9 m, concrete to 0.2 m and asphalt patch to surface.
N-E Ramp	16-09	18.9/ 258.9	None installed	Bentonite holeplug and cuttings to 0.9 m, concrete to 0.2 m and asphalt patch to surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing fill or native soil from each bridge foundation location (for a total of three samples) was submitted to AGAT Laboratories in Mississauga, Ontario for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the "Borehole Locations and Soil Strata" drawings included in Appendix D. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

A 2012 Preliminary Foundation Investigation and Design report by Infrastructure Engineering Group Inc. (Geocres No. 40I14-148) includes two boreholes, designated as 1 and 2, that were drilled on the west side of the existing bridge. The subsurface information is generally consistent with the data collected during the current investigation. The Record of Borehole sheets are included in Appendix C, and the borehole locations and subsurface stratigraphy are shown on the drawings in Appendix D.

In general, the subsurface conditions encountered in the boreholes from the current investigation consisted of concrete or asphalt pavement overlying granular fill and embankment fill, which was in turn underlain by native soil consisting of upper deposits of silty clay till and silty sand to sandy silt, underlain by a silt layer and silty clay lenses, a lower silty sand deposit, and a lower silty clay till deposit. Topsoil was also noted in the locations where there was no fill. Descriptions of the individual strata are presented below.

5.1 Concrete / Asphalt

Boreholes 16-03, 16-04, 16-06 and 16-07 were drilled through the existing concrete pavement on Highbury Avenue. The concrete thickness measured in the boreholes ranged from 263 to 375 mm.

Borehole 16-05 was drilled through the asphalt shoulder of Highway 401. The asphalt was measured to be 75 mm thick.

Boreholes 16-08 and 16-09 were drilled through the asphalt shoulder on the N-E ramp. The asphalt thickness measured in the boreholes ranged from 100 to 275 mm.

5.2 Fill

Granular fill materials ranging from gravelly sand to sand and gravel were encountered below the concrete or asphalt in Boreholes 16-03 to 16-09. The granular fill ranged from 0.5 to 1.4 m thick except at Boreholes 16-04 and 16-06 at the bridge abutments, where the fill was 5.4 m thick and extended to depths of 5.7 to 5.8 m (Elev. 276.7 to 276.8 m). SPT 'N' values within the granular fill ranged from 24 to 89 blows per 0.3 m penetration, indicating a compact to very dense relative density. The measured moisture content ranged from 3% to 18%. The results of grain size analyses conducted on samples of the granular fill are presented on the Record of Borehole sheets included in Appendix A and on Figures B1 and B2 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	18 to 64
Sand	27 to 63
Silt and Clay	9 to 19

A silty clay embankment fill containing some sand to sandy and trace gravel was encountered below the granular fill in Boreholes 16-03, and 16-07 to 16-09. A zone of sandy silt fill was also encountered above the silty clay fill in Borehole 16-08. The silty clay and sandy silt embankment fill ranged in thickness from 2.2 to 5.1 m, and extended to depths ranging from 3.0 to 5.9 m (Elev. 272.4 to 279.1 m). SPT 'N' values in the silty clay fill ranged from 6 to 19 blows per 0.3 m penetration, indicating a firm to very stiff consistency. The measured moisture content ranged from 12% to 27%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay fill are presented on the Record of Borehole sheets included in Appendix A and on Figures B3 and B14 in Appendix B. The results are summarized in the following table:

Soil Particle	**Percentage (%)**
Gravel	0 to 4
Sand	18 to 29
Silt	37 to 46
Clay	30 to 38
Index Property	**Percentage (%)**
Plastic Limit	15 to 18
Liquid Limit	28 to 38

The Atterberg Limits test results indicate that the silty clay fill is typically of low to intermediate plasticity, with group symbols of CL to CI.

Underlying the granular fill and silty clay fill, a layer of cohesionless embankment fill ranging in composition from silt with some sand to gravelly sand with trace to some silt was encountered in Boreholes 16-03, 16-04, and 16-06 to 16-08. The cohesionless fill ranged in thickness from 1.3 to 4.6 m, and extended to depths ranging from 7.0 to 9.1 m (Elev. 273.3 to 275.1 m). SPT 'N' values in the cohesionless fill ranged from 6 to 89 blows per 0.3 m penetration, indicating a loose to very dense relative density. The measured moisture content ranged from 3% to 20%. The results of grain size analyses conducted on samples of the cohesionless fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B4 in Appendix B. The results are summarized in the following table:

Soil Particle	**Percentage (%)**
Gravel	0
Sand	36 to 52
Silt	42 to 47
Clay	6 to 17

5.3 Topsoil

Boreholes 16-01 and 16-02, as well as hand-dug pits 16-08A and 16-09B were excavated through topsoil along the alignments of the proposed S-W and N-E ramps respectively. The measured topsoil thickness ranged from 150 to 200 mm. The topsoil thickness may vary in other areas of the site and this limited data should not be relied upon for estimating stripping quantities.

5.4 Upper Silty Clay Till

Underlying the embankment fill in Boreholes 16-06 and 16-07, and the topsoil in Boreholes 16-01 and 16-02, a layer of silty clay till with some sand and trace gravel was encountered. The upper silty clay till ranged in thickness from 0.8 to 3.1 m, and extended to depths ranging from 1.5 to 10.7 m (Elev. 270.4 to 273.4 m). The silty clay till was also encountered below the topsoil in hand-dug pits 16-08A and 16-09A, which were terminated within the till at a depth of 0.9 m (Elev. 271.7 to 272.3 m).

SPT 'N' values within the upper silty clay till ranged from 6 to 24 blows per 0.3 m penetration, indicating a firm to very stiff consistency. The measured moisture content ranged from 15% to 32%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay till are presented on the Record of Borehole sheets included in Appendix A and on Figures B5 and B15 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	10 to 16
Silt	42 to 49
Clay	39 to 47
Index Property	**Percentage (%)**
Plastic Limit	17 to 18
Liquid Limit	34 to 36

The Atterberg Limits test results indicate that the silty clay till is typically of low to intermediate plasticity, with group symbols of CL to CI.

Glacial tills inherently contain cobbles and boulders.

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5.5 Upper Silty Sand to Sandy Silt

A deposit of silty sand to sandy silt was encountered in all of the boreholes underlying the granular fill, embankment fill and silty clay layers. The deposit varied in composition and included zones of silty sand, sandy silt, silt and sand, and sand with trace silt. The silty sand to sandy silt deposit ranged in thickness from 9.9 to 15.3 m, and extended to depths from 10.7 to 24.4 m (Elev. 257.8 to 261.4 m). Boreholes 16-03, 16-07 and 16-08 were terminated within the deposit at depths from 15.8 to 18.9 (Elev. 261.4 to 266.3 m). A 5.1 m thick zone of silt with trace sand and trace clay was encountered within the silty sand to sandy silt deposit in Borehole 16-06 at a depth of 11.7 m.

SPT 'N' values within the silty sand to sandy silt deposit typically ranged from 12 to 90 blows per 0.3 m of penetration, indicating a compact to very dense relative density. Occasional SPT 'N' values of 6 to 8 blows per 0.3 m penetration were also recorded, indicating the presence of loose zones. Measured moisture contents within the deposit varied between 7% and 33%.

The results of grain size distribution analyses conducted on selected samples of the deposit are presented on the Record of Borehole sheets included in Appendix A and on Figures B6 to B8 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	17 to 89
Silt	9 to 79
Clay	2 to 6

5.6 Silt to Clayey Silt

A layer of silt ranging in composition from trace sand and trace clay to clayey was encountered below the silty sand to sandy silt deposit in Boreholes 16-01, 16-02, 16-04 to 16-06, and 16-09. The silt layer ranged in thickness from 1.8 to 7.6 m, and extended to depths from 15.2 to 24.4 m (Elev. 257.3 to 259.6 m). A 5.1 m thick zone of silt was also encountered within the silty sand to sandy silt deposit in Borehole 16-06 at a depth of 11.7 to 16.8 m (Elev. 265.8 to 270.8 m).

SPT 'N' values within the silt ranged from 26 to 92 blows per 0.3 m penetration, indicating a dense to very dense relative density for the non-plastic portion of the silt and very stiff to hard consistency for the clayey silt. The measured moisture content of the silt ranged from 18% to 27%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silt are presented on the Record of Borehole sheets included in Appendix A and on Figures B9 to B10 and B16 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 to 10
Silt	79 to 90
Clay	4 to 21
Index Property	**Percentage (%)**
Plastic Limit	14
Liquid Limit	20

The Atterberg Limits test result indicates that the silt is typically of low plasticity to non-plastic, with a group symbol of CL-ML.

5.7 Silty Clay

Lenses of silty clay were encountered below the silt in Boreholes 16-01, 16-02, 16-05, and 16-09. The thickness of the silty clay lenses was not established, as each borehole was terminated within the silty clay at depths from 15.8 to 18.9 m (Elev. 256.7 to 258.9 m).

SPT 'N' values recorded in the silty clay lenses ranged from 27 to 53 blows per 0.3 m penetration, indicating a very stiff to hard consistency. The measured moisture content ranged from 20% to 35%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay are presented on the Record of Borehole sheets included in Appendix A and on Figures B11 and B17 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	43 to 52
Clay	48 to 57
Index Property	**Percentage (%)**
Plastic Limit	15 to 18
Liquid Limit	30 to 38

The Atterberg Limits test results indicate that the silty clay is typically of low to intermediate plasticity, with group symbols of CL to CI.

5.8 Lower Silty Sand

A lower layer of silty sand with trace clay was encountered below the silt in Boreholes 16-04 and 16-06. The silty sand layer was 10.3 m thick, and extended to a depth of 34.7 m (Elev. 247.8 m).

SPT 'N' values within the silty sand ranged from 24 to 103 blows per 0.3 m penetration, indicating a compact to very dense relative density. The measured moisture content of the silty sand ranged from 16% to 19%. The results of grain size distribution analyses conducted on selected samples of the silty sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B12 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	72 to 75
Silt and Clay	25 to 28

5.9 Lower Silty Clay Till

A lower silty clay deposit was encountered below the lower silty sand in Boreholes 16-04 and 16-06. The borehole sampling operations were terminated within the till at depths of 40.2 m (Elev. 242.3 m).

SPT 'N' values recorded in the lower silty clay till ranged from 25 to 67 blows per 0.3 m penetration, indicating a very stiff to hard consistency. The measured moisture content ranged from 11% to 15%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the lower silty clay till are presented on the Record of Borehole sheets included in Appendix A and on Figures B13 and B18 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	21 to 22
Silt	50 to 54
Clay	24 to 29
Index Property	**Percentage (%)**
Plastic Limit	11 to 12
Liquid Limit	20 to 21

The Atterberg Limits test results indicate that the silty clay till is typically of low plasticity, with a group symbol of CL.

Glacial tills inherently contain cobbles and boulders.

5.10 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes 16-04 and 16-06 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometers are summarized in Table 5.1 below. Groundwater levels measured in the Boreholes 1 and 2 from the 2012 investigation are also included.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-01	February 8, 2016	3.0	269.7	Open borehole
16-02	February 9, 2016	1.4	271.2	Open borehole
16-03	February 16, 2016	12.2	269.9	Open borehole
16-04	February 23, 2016 April 1, 2016	17.9 16.4	264.6 266.1	Standpipe piezometer Standpipe piezometer
16-05	February 22, 2016	5.8	270.3	Open borehole
16-06	February 23, 2016 April 1, 2016	10.8 10.0	271.7 272.5	Standpipe piezometer Standpipe piezometer
16-07	February 18, 2016	10.3	271.9	Open borehole
16-08	February 23, 2016	9.0	271.3	Open borehole
16-09	February 23, 2016	6.2	271.6	Open borehole
1	May 31, 2012	11.5	263.5	Standpipe piezometer
2	May 31, 2012	4.5	270.9	Standpipe piezometer

The groundwater levels above are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the granular fill from Borehole 16-04 and samples of the native soil from Boreholes 16-05 and 16-06 were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units	Test Results		
		16-04, SS#6, 10'-12'	16-05, SS#5, 10'-12'	16-06, SS#9, 30'-32'
		Granular Fill, Elev. 279.5 to 278.8 m	Silt & Sand, Elev. 273.1 to 272.4 m	Silty Sand, Elev. 273.4 to 272.7 m
Sulphide	%	<0.05	<0.05	<0.05
Chloride	µg/g	2220	709	494
Sulphate	µg/g	43	13	21
pH	pH Units	8.95	9.65	8.72
Electrical Conductivity	mS/cm	3.53	1.25	0.868
Resistivity	ohm.cm	283	800	1150
Redox Potential	mV	238	216	279

7. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained subsurface utility clearances prior to drilling.

London Soil Test Ltd. of London, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. George Azzopardi of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

The coordinates and ground surface elevations at the borehole locations were established by Thurber with a Trimble Pathfinder ProXRT differential GPS unit.

Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was carried out at AGAT Laboratories. Interpretation of the field data and preparation of this report was carried out by Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for the proposed underpass bridge replacement, a grade raise and widening of the approach embankments, and realignment of high fill embankments for ramps at the Highway 401 and Highbury Avenue interchange in the City of London, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

A preliminary General Arrangement (GA) drawing, prepared by Dillon dated May 2013 and provided by MTO, indicates that the replacement bridge is to assume the same centreline alignment as the existing Highbury Avenue Bridge over Highway 401. The new bridge has two spans with a total length of 87.4 m (between ends of wingwalls) and approximately 36.3 m in width, supported by two abutments and one pier. A 6.5 to 6.9 m wide approach slab with sleeper slab is to be located behind each abutment. Each of the two integral abutments are designed to be supported by a single row of driven steel H-piles, and the centre pier is to be supported on a spread footing. The new abutment centrelines will be approximately 6 m behind those of the existing bridge. The existing approach fills are in the order of 6 to 6.5 m in height, which will be raised by approximately 1 to 1.5 m to reach a final height of up to 8 m above the Highway 401 grade. The existing bridge will be removed as part of this project.

Retained Soil Systems (RSS) walls are proposed for the new abutment walls. The new forward slopes and approach slopes will have inclinations of 2H: 1V.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the current investigation and selected data obtained from a previous investigation (Reference 1). The plans and profiles used for preparation of this report were provided by MTO.

9. FOUNDATION DESIGN

In general, the subsurface conditions at this site consist of a pavement structure, embankment fill and surficial very stiff silty clay till overlying extensive deposits of compact to very dense sands and silts. The silts and sands are underlain by very stiff to hard silty clay till. The groundwater level in the vicinity of this interchange typically ranges between 2 and 5 m depths below the highway grade. Details on evaluation of foundation alternatives are presented in Section 9.2 below.

9.1 Structure Classification

In accordance with the currently applicable CHBDC CSA S6-14, the analysis and design of structures depend on its importance category and consequence classification. Such designations are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation (MTO).

An MTO classification has not been provided at the time of preparation of this report. For the purpose of reporting, this structure has been classified as a Major-Route Bridge with Typical Consequence based on CHBDC S6-14 Sections 4.4.2 and 6.5.2, respectively.

Based on the above classification and Table 6.1 in Section 6.5.2 in the CHBDC, a consequence factor, ψ, of 1.0 has been used for assessing ULS and SLS geotechnical resistances. Should the consequence classification changes, the geotechnical assessment and recommendations will need to be reviewed and revised as necessary.

9.2 Foundation Alternatives

Consideration has been given to alternate foundation options taking into consideration the general layout of the site, subsurface stratigraphy and the proposed works. These options are listed below:

- Spread footings
- Driven steel H-piles
- Driven steel pipe piles
- Augered caissons (drilled shafts)

At the pier location, consideration may be given to using shallow spread footings founded on native subgrade above the groundwater table if space constraint is not considered an issue within the median of the Highway 401 corridor. Roadway protection systems will need to be used to support the vertically sided excavations. Spread footings are not considered feasible for the abutments due to the requirements of high abutment walls and deep excavations.

According to the preliminary GA drawing, it is understood that integral abutments are proposed to be used for this bridge. From a foundation engineering perspective, it is considered feasible to use integral abutments founded on a single row of steel H-piles driven to achieve the design ultimate resistance. Augered caissons (drilled shafts) are a typical alternative to driven piles if integral abutments are not to be used. At this site, however, the presence of extensive sand and silt deposits under water pressure will result in caisson installation difficulties including basal and sidewall instability which requires the use of specialized installation techniques. Since caissons are not being considered currently, foundation recommendations are not developed for this option.

Driven H-piles are feasible for providing foundation support to the pier. This option requires excavation for pile cap construction within roadway protection systems.

Steel pipe piles are not suitable for use to support integral abutments due to the high stiffness. Furthermore, driven pipe piles are expected to cause higher vibration and noise levels than H-piles during installation. It may also encounter difficulties during driving if oversize obstructions such as cobbles and boulders are encountered. Since integral abutments are currently being proposed, recommendations for driven pipe piles have not been developed.

More detailed comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix F.

9.3 Driven H-Piles

9.3.1 Axial Resistance

Foundations for the new bridge including the widening may be supported on steel H-piles driven into the underlying very stiff to hard silty clay till. A standard HP 310 x 110 section or a heavier HP 360 x 132 section may be used. Tills and other glacially derived soils inherently contain cobbles and boulders. The pile tips should, therefore, be reinforced to enhance driving (see Section 9.3.4).

The elevations at which the H-piles are anticipated to develop the required resistance, and the vertical, factored geotechnical resistances at Ultimate Limit States (ULS) and geotechnical resistances at Serviceability Limit States (SLS) for the two pile sections driven into the lower silty clay till are presented in Table 9.1 below.

Table 9.1 – Estimated Pile Tip Elevations and Axial Geotechnical Resistances of Driven H-Piles

Foundation Location	Borehole Number	Estimated Pile Tip Elevation	HP 310 x 110		HP 360 x 132	
			Factored			
			ULS (kN)	SLS (kN)	ULS (kN)	SLS (kN)
South Abutment	16-06	240	1,200	1,000	1,400	1,200
North Abutment	16-04	240				

The SLS values correspond to a pile settlement up to 25 mm.

The structural capacity of a pile must not be exceeded and should be confirmed by the structural designer.

The pile tip elevations shown in Table 9.1 should be used for estimating purposes only. The actual pile tip elevations will be controlled during pile driving as described in Section 9.3.4 Pile Installation.

9.3.2 Downdrag Loads

Since the piles are expected to behave as friction piles, downdrag is not considered as a design issue at this site.

9.3.3 Lateral Resistance

Lateral bridge loadings can be geotechnically resisted by the driven H-piles through passive pressure developed along the embedded portion of the piles below the CSPs under the abutment stems.

For lateral resistance design, soil-pile interaction analyses may be carried out using the geotechnical parameters provided in Table 9.2 below.

The lateral resistance of a pile may be calculated using values for the coefficient of horizontal subgrade reaction (k_s) and the lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance, p_{ult}, values given in the following relationships.

<u>Fill, Sands and Silts</u>

	k_s	=	$n_h \cdot z / B$	(kN/m^3)
	p_{ult}	=	$3 \cdot \gamma' \cdot z \cdot K_p$	(kPa)
where	p_{ult}	=	ultimate lateral resistance mobilized by a pile, kPa	
	z	=	depth of embedment of pile, m	
	B	=	pile width, m	
	n_h	=	coefficient related to soil density, kN/m^3	
	γ'	=	submerged unit weight of soil, kN/m^3	
	K_p	=	passive earth pressure coefficient	

<u>Silty Clay / Silty Clay Till</u>

	k_s	=	$67\ C_u / D$	(kN/m^3)
	p_{ult}	=	$9\ C_u$	(kPa)
where	C_u	=	undrained shear strength of cohesive soils, kPa	
	γ	=	total unit weight of soil, kN/m^3	
	B	=	pile width, m	

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Table 9.2
Recommended Geotechnical Parameters for Lateral Resistance Design

Foundation Unit	Borehole Number	Approx. Elevation (m)	Undrained Shear Strength C_u (kPa)	n_h (kN/m^3)	K_p	Unit Weight γ (kN/m^3)	Soil Conditions
South Abutment	16-06	275* to 273	100	-	-	19	Silty Clay Till (very stiff)
		273 to 258	-	5,000	3.4	11**	Silty Sand to Sandy Silt (compact to very dense)
		258 to 248	-	4,000	3.2	10**	Silty Sand (compact to dense)
		248 to 242	200	-	-	20	Silty Clay Till (very stiff to hard)
North Abutment	16-04	275* to 273	-	3,000	3.0	20	Silt and Sand Fill (dense)
		273 to 258	-	8,000	3.8	12**	Silty Sand to Sandy Silt (dense to very dense)
		258 to 248	-	7,000	3.7	11**	Silty Sand (dense to very dense)
		248 to 242	150	-	-	20	Silty Clay Till (very stiff to hard)

* Underside elevation of CSP

** Buoyant unit weight for cohesionless soil below the water table.

The spring constant, K, for analysis may be obtained by the expression, $K = k_s \times d_z \times B$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3), B is the pile width (m), d_z is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance on any one segment of pile, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult} \times d_z \times B$. This represents the ultimate load at the contact between the soil and the pile above which additional load cannot be supported at greater displacements.

For lateral soil-pile group interaction analysis, the values for k_s should be reduced based on pile spacing.

Where a pile group is oriented ***perpendicular*** to the direction of loading, group action may be considered by reducing values of k_s using a reduction factor R as follows:

Pile Spacing Perpendicular to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
4 D	1.00
1 D	0.50

Where B is the diameter of the pile, and spacing is measured centre to centre.

Where a pile group is oriented parallel to the direction of loading, group action may be considered by reducing values of k_S using a reduction factor R as follows:

Pile Spacing Parallel to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
8 D	1.00
6 D	0.70
4 D	0.40
3 D	0.25

Intermediate values may be obtained by interpolation.

For integral abutments, the flexibility of the pile can be increased by providing a corrugated steel pipe (CSP) system. The preliminary GA drawing indicates a concentric CSP system which involves installing the pile through a 600 mm diameter, 3 m long, CSP, which is itself inside an outer 800 mm diameter CSP, below the abutment wall. The annular void between the pile and the sidewall of the 600 mm diameter CSP is to be backfilled with uncompacted uniformly graded sand. The sand for filling the hole should meet the gradation requirements presented in Table 9.3 and should be placed after driving the pile through the CSP.

Table 9.3 – Integral Abutment Sand Grading

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

9.3.4 Pile Installation

All piles shall be installed in accordance with OPSS 903.

The appropriate pile driving note to be shown on the contract drawing is "Piles to be driven in accordance with Standard SS103-11 using an ultimate geotechnical resistance equal to two times the maximum factored design load at ULS, but must be driven below elevation 241.0 m.

To facilitate pile installation, embankment fill through which piles will be driven must not contain any material with particle sizes greater than 75 mm.

Glacially derived soils inherently contain cobbles and boulders. In order to be able to penetrate boulders, cobbles and hard/very dense zones to achieve the required tip elevations and soil resistance, it is recommended that the pile tips be reinforced with driving shoes such as the Titus Standard Points for H Piles or approved equivalent.

9.4 Spread Footings

Where space permits at the pier location, consideration may be given to using spread footings founded below the fill on the compact silt and sand above the groundwater level. Roadway protection (temporary shoring) will be required during new footing construction. The preliminary GA drawing indicates that the footings be founded just below Elevation 274 m.

9.4.1 Vertical and Lateral Resistance

The recommended founding depths and elevations for spread footings for the pier are given in Table 9.4.

Table 9.4 – Recommended Highest Footing Founding Depths and Elevations

Foundation Unit	Borehole	Footing on Native Undisturbed Soil		
		Founding Elevation (m)	Depth Below Ground Surface (m)	Soil
Pier	16-05	274	2.1	Silt and Sand (compact)

Provided a minimum footing width of 2 m is maintained, the pier footings as outlined above may be designed for the following values:

- Factored geotechnical resistance of 375 kPa at Ultimate Limit States (ULS)
- Factored geotechnical resistance of 250 kPa at Serviceability Limit States (SLS)

The geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be calculated as illustrated in the CHBDC Clause 6.7.3 and Clause 6.7.4.

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction. Differential settlements are not expected to exceed 20 mm across the width of the structure.

The sliding resistance of mass concrete placed on the native, undisturbed compact silt and sand may be computed on the basis of an ultimate coefficient of friction at the interface of 0.4. This is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.

All footings should be provided with a minimum of 1.2 m of earth cover, or its thermal equivalent, over the footing base (founding elevation) as protection against frost action.

9.4.2 Footing Construction

The base of the footing excavation should be inspected by a geotechnical engineer to confirm that the footing subgrade is in the native, undisturbed, compact silt and sand conforming to the design requirements and has been adequately prepared to receive concrete. Concrete or mud slab should be placed within 24 hours following completion of excavation to prevent deterioration of the approved subgrade. The mud slab should be at least 100 mm thick and formed with the same class of concrete as that of the footings. Where sub-excavation is required to remove unsuitable material from below the design founding level, the founding surface should be re-established using engineered fill or mass concrete of the same class as the footing.

All footing construction procedures should follow the guidelines provided in OPSS 902. The measured and observed groundwater levels are below the recommended highest footing base at Elevation 274 m. The native silt and sand is prone to disturbance, and water seepage from perched water within the fill as well as accumulation of precipitation and surface runoff. It is recommended that the roadway protection also serves as partial groundwater cutoff in order to facilitate construction of the footings in the dry and to prevent sloughing of the sides or disturbance of the base of the excavation due to the inflow of groundwater. Consideration may be given to using steel interlocking sheet piles. Suggested wording for an NSSP to this effect is presented in Appendix H.

10. RETAINED SOILS SYSTEM (RSS) WALL

The preliminary GA drawing indicates that an RSS retaining wall is proposed for the abutments. Design of the RSS walls should be in accordance with MTO's RSS Design Guidelines (2008). The walls are in the order of 8 m in height. Design recommendations for RSS walls are provided in the following paragraphs.

RSS walls used on this project must be specified to be "High Performance" and "High Appearance". The soil conditions encountered at the abutment areas are generally suitable for the support of RSS walls. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of an RSS is dependent, among other factors, on the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass should be founded below Elevation 275 m at the south abutment on the undisturbed, native, very stiff silty clay till, and below Elevation 274 m at the north abutment on the undisturbed, native, very dense silty sand. An RSS wall founded at these levels may be designed using a factored geotechnical resistance at ULS of 375 kPa and a factored geotechnical resistance at SLS of 250 kPa. It is recommended that the concrete levelling pads for supporting the panels of the RSS be founded on engineered fill resting on the subgrade discussed above. Engineered fill with a minimum thickness of 300 mm must consist of OPSS Granular “A” compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered fill must laterally extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC CSA S6-14, Clauses 6.7.3 and 6.7.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.4 for a native subgrade.

Organics, loose/soft fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any loose/soft spots sub-excavated and replaced with compacted granular materials prior to constructing the RSS block.

The proprietary RSS system must meet the Ministry’s specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site. RSS walls founded on the very stiff or very dense soils at this site, and having a maximum height of 8.0 m, would satisfy global stability requirements.

11. LATERAL PRESSURES

Should conventional abutment walls and retaining walls be used at this site, the backfill to these walls should be in accordance with OPSS 902 and placed to the extents shown in OPSD 3101.150 where applicable. Any backfill to the walls should consist of Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

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

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

where:

p_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see Table 10.1)
γ	=	unit weight of retained soil (see Table 10.1)
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa).

For non-draining or partially drained backfill conditions, it is recommended that full hydrostatic pressure be included in the design.

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 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.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 11.1.

Table 11.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A and Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°$, $\gamma = 21.2$ kN/m^3		Existing Embankment Fill $\phi = 30°$, $\gamma = 20.0$ kN/m^3	
	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	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	-	0.47	-	0.50	-
Passive (Movement towards soil mass)	3.7	-	3.3	-	3.0	-

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 10.1 are "ultimate" values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

It is recommended that perforated sub-drains and 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.

12. HIGH FILLS

12.1 Settlement

Proposed reconstruction of the Highway 401 at Highbury Avenue interchange involves the realignment of S-W ramp in the northeast quadrant and N-E ramp in the southwest quadrant. Information provided by MTO is summarized as follows:

- New fills on the S-W Ramp including high fills up to 8 m in height along an approximately 150 m long section.
- New fills on the N-E Ramp including high fills up to 8 m in height along an approximately 150 m long section.
- New fills for widening the underpass bridge approaches including high fills up to 8 m in height.
- Overall grade raise up to the order of 1.5 to 2 m.

The assessment of the high fills has been carried out based on the following assumptions:

- The new fills will be constructed with side slopes not steeper than 2H: 1V, unless RSS is used such as those for the abutments.
- Subgrade preparation will be carried out as per OPSS.PROV 206.
- The high fills will be constructed using OPSS 1010 (SSM) or granular materials and compacted to OPSS 501 requirements.

In general, the stratigraphy at the new ramp locations consists of embankment (silty clay, silt, sand to gravelly sand) fill overlying surficial firm to very stiff silty clay till, which is underlain by compact to very dense silty sand to sandy silt. The groundwater level is typically within 1 to 2 m depth below existing ground surface.

Based on this information, it is anticipated that the settlement induced by the new fill will consist of immediate (elastic) compression of the sand and silt deposits and recompression of the over-consolidated silty clay till. Estimated settlements at the 2 m grade raise, the widening areas and the new ramp alignments are 25 mm, 45 mm and 60 mm, respectively. It is anticipated that the immediate settlement would essentially be completed by the end of fill placement and that post construction foundation settlement would not exceed 25 mm.

Compression of well compacted granular and SSM embankments should be considered negligible. For approved inorganic earth fill, compression under its self-weight could be up to 0.5% of the embankment height and is expected to be completed within one to two years after construction. The settlement within an 8 m high embankment consisting of inorganic earth fill is expected to be up to the order of 40 mm.

12.2 Global Stability

Actual new fill cross-sections are unavailable at the time of preparation of this report. Based on assumed 2H: 1V slopes for the new ramp and widening fills, limit equilibrium stability analyses were carried out using the commercially available slope stability program GEO-SLOPE, employing the Morgenstern-Price method.

Table 12.1 – Estimated Factors of Safety

High Fill Location	Maximum Embankment Height (m)	Case	Estimated Factors of Safety		Figure
			Gran. A or B Type II	SSM	
			Φ' = 35°	Φ' = 30°	
Ramp S-W	8	Drained	-	1.6	G1
		Undrained	-	1.4	G2
Ramp N-E	8	Drained	-	1.5	G3
South Approach	8	Drained	1.9	-	G4
		Undrained	2.3	-	G5
North Approach	8	Drained	1.9	-	G6
		Undrained	1.9	-	G7

The computed factors of safety for selected high fill locations are as shown in Table 12.1 above. Global embankment stability computation outputs are included in Figures G1 to G7 of Appendix G.

As per typical MTO requirements, a Factor of Safety (F.S.) of 1.3 is acceptable for short term (undrained) conditions. A F.S. of 1.5 is acceptable for long term (drained) conditions after excess pore pressures generated in the foundation soil caused by fill placement have dissipated. The results indicate that these acceptance criteria are generally satisfied for the cases analysed.

12.3 Embankment Design and Construction

The performance of the new fills will need to satisfy the requirements stipulated in the MTO document titled “Embankment Settlement Criteria for Design” dated July 2010.

It is recommended that MTO approved SSM or granular materials satisfying OPSS.PROV 1010 requirements be used for constructing the new fills. Based on the above analyses, the high fills constructed using these materials will be stable at a slope inclination not steeper than 2H: 1V. Typical MTO design requires that a mid-height berm of at least 2 m in width be incorporated where the total fill height is 8 m or higher. The proposed maximum fill height at this site is about 8 m. A mid-height berm may be incorporated in the design, but it should be noted that such a berm is not required to maintain the minimum F.S. as discussed above. Embankments less than 4.5 m in height will be stable at a slope inclination not steeper than 2H: 1V.

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 sub-excavated. 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.

All embankment fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and 501 requirements. Earth borrow in compliance with OPSS.PROV 212 may be used although it should be noted that cohesive soils are expected to undergo larger post construction settlement than SSM or granular. Clayey materials are not recommended for embankment construction at this site due to potentially higher post construction settlement, difficulties in achieving the specified compaction and potential embankment stability issues.

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13. EXCAVATION

Temporary excavations will be required during construction at this site. All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA).

At the pier, excavation for footing construction will extend through the existing pavement structure into the underlying native silt and sand. At the abutments, excavation for construction will extend predominantly through the gravelly sand to sandy gravel embankment fill into the upper portion of the underlying native soils. For the purpose of OHSA, the existing fills and native soils above the groundwater level may be classified as Type 3 soils. Any soil below the water level may be classified as a Type 4 soil. Based on existing information, the excavations are not likely to extend below the groundwater level.

All excavations must be carried out in a manner that avoids undermining or destabilising the foundations of the existing bridge, existing slopes, the adjacent ramp and other structures.

Pier footing construction will need to be carried out in conjunction with roadway protection (temporary shoring) such as a sheet pile enclosure which are discussed in more details in the Section 14 below. Roadway protection will also be required during abutment construction.

Where space permits at some locations, temporary excavation may be formed with temporary side slopes not steeper than 1H: 1V. Flatter slopes may be required at locations where the soils are less competent than what is assumed during design or where water seepage affects surficial stability.

Excavation and backfilling for foundation construction should be carried out with reference to the requirements in OPSS 902.

14. GROUNDWATER AND SURFACE WATER CONTROL

The water table at the foundation element locations is within 3 to 5 m depth below ground surface. It is anticipated that perched water will be encountered within the existing fills. Groundwater from water-bearing interlayers within the upper silty clay till should also be expected. Moreover, groundwater seepage from sands and silts should be expected. Since the excavations are not expected to extend below the groundwater level, groundwater control will likely be limited to diverting surface runoff and preventing precipitation from entering the excavations supplemented by sump pumping. Filtered sumps must be designed properly so that construction drainage water containing eroded soil and fines do not flow onto existing roadways and watercourses.

At the pier, it is anticipated that the use of partial groundwater cut-off such as interlocking sheet piles supplemented by sump pumping inside the excavation would be required to maintain a dry excavation during footing construction. Alternatively, a vacuum well point system may be used such that the footing can be constructed in the dry.

The design of any dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist.

15. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the granular fill and native soil at the foundation locations indicates the following conditions at the locations tested:

- The fill and native soils are considered to be potentially corrosive to steel, cast iron, and other metals, which is mainly due to the low resistivity of the soils.

- The fill and native soils are considered to be potentially corrosive to structural elements (steel reinforcement in concrete), due to the high chloride concentrations in the soils.

- The potential for sulphate attack on concrete foundations from the surrounding fill or native soil is considered to be negligible due to the low concentration of sulphate in the samples tested.

- Appropriate protection measures are recommended to address the potential for corrosion on metal and metal structural elements.

16. ROADWAY PROTECTION

Roadway protection will be required during construction of the pier footing and the abutments. An item titled “Protection System” as per OPSS 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 an interlocking steel sheet pile wall. It is anticipated that the sheet piles will need to be extended through existing fill into the compact to very dense sands and silts to develop the required toe resistance. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

A sheet pile 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 (approach fills and native silty clay till)
= 0.3 (native sands/silts)

K_p = 3.0 (approach fills and native silty clay till)
= 3.3 (native sands/silts)

The designer of the roadway protection system should check whether the depth of sheet pile is sufficient to provide base fixity and partial groundwater cut-off.

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs.

17. SEISMIC CONSIDERATIONS

According to Clause 4.4.4 of the CHBDC, an earthquake with a 2475-year return period or 2% probability of exceedance in 50 years should be used for seismic design. The peak ground acceleration (PGA) associated with the design earthquake is 0.067g for Site Class C.

Based on the encountered soil conditions, this site is assessed to be Site Class 'D' for seismic site response according to Table 4.1 of the CHBDC. The above PGA value should be modified by a site coefficient of 1.29 based on Table 4.8 of the CHBDC.

In accordance with Clause 4.6.5 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls under seismic loading, the coefficients of horizontal earth pressure in Table 17.1 may be used:

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Table 17.1 – Earth Pressure Coefficient for Earthquake Loading

Loading Condition	Granular A or Granular B Type II $\phi = 35°$; $\gamma = 22.8$ kN/m^3	OPSS Granular B Type I or Type III $\phi = 32°$; $\gamma = 21.2$ kN/m^3
Active (K_{AE})*	0.30	0.34
At Rest (K_{0E})**	0.54	0.59
Passive (K_{PE})	3.6	3.1

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

** After Woods (1973).

The compact to very dense sandy silt to silty sand and dense to very dense silt underlying the fill is considered not susceptible to liquefaction under seismic loading.

18. CONSTRUCTION CONCERNS

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

- Piles driven through the hard or 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 ended prematurely.
- Although there was little direct evidence of their presence during borehole drilling, glacially derived deposits inherently contain cobbles and boulders, 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.
- 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.
- Footings must be constructed in the dry and dewatering may be required to achieve that.
- <u>Impact of excavation on the existing pavement surface</u>
  Daily visual inspection of the pavement surface must be carried out in the vicinity of the remedial 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.
- Disturbance of the subgrade within the sub-excavation footprint.

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- Confirmation that the backfill materials 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 depth of sub-excavation and subgrade conditions, these provisions should require the Contractor to retain qualified geotechnical personnel to assess the site conditions and to alert the Contract Administrator.

19. CLOSURE

Stability and settlement analysis was carried out by Mr. Michael Eastman, E.I.T. and reviewed by Dr. Sydney Pang, P.Eng. Engineering assessment and preparation of this report was carried out by Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

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

P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

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RECORD OF BOREHOLE No 16-01

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 183.3 E 412 612.8	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.08 - 2016.02.08	CHECKED BY	MEF

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
272.7	GROUND SURFACE
0.0	**TOPSOIL:** (150mm)
0.2	Silty **CLAY**, some sand, trace gravel Firm to Very Stiff Brown Moist (TILL)(CL)
270.4 / 2.3	Silty **SAND** Loose Brown Wet
269.7 / 3.0	Sandy **SILT**, trace clay Compact Brown Wet
267.1 / 5.6	Silty **SAND**, trace clay Dense to Compact Brown Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	10				
2	SS	6	0	16	45	39
3	SS	22				
4	SS	8				
5	SS	18				
6	SS	26	0	25	69	6
7	SS	30				
8	SS	28				
9	SS	23	0	78	20	2

GROUND WATER CONDITIONS: water level symbol at approx. elev. 269.6

ELEVATION SCALE: 272, 271, 270, 269, 268, 267, 266, 265, 264, 263

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

Continued Next Page

+ 3, × 3 : Numbers refer to Sensitivity

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

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-01

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 183.3 E 412 612.8 | ORIGINATED BY GA

HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.02.08 - 2016.02.08 | CHECKED BY MEF

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

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
	Silty **SAND**, trace clay Very Dense Brown Wet						262				
			10	SS	64		261				
260.5 / 12.2	**SILT**, trace sand, trace clay Very Dense Brown Wet		11	SS	86		260	0	10	84	6
			12	SS	51		259, 258				
257.5 / 15.2	Silty **CLAY** Very Stiff Grey Wet		13	SS	27		257				
256.8 / 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 3.0m. 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

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RECORD OF BOREHOLE No 16-02

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 158.1 E 412 555.7 | ORIGINATED BY GA

HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.02.09 - 2016.02.09 | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
272.6	GROUND SURFACE					
0.0	**TOPSOIL:** (175mm)					
0.2	Sandy **SILT**, Loose, Brown, Moist	1	SS	6	272	
271.9 / 0.7	Silty **CLAY**, some sand, Stiff, Brown, Moist (TILL)	2	SS	10		0 11 42 47
271.0 / 1.5	Silty **SAND**, Compact, Brown, Wet	3	SS	16	271	
		4	SS	23	270	
269.5 / 3.0	**SILT**, some sand, trace clay, Dense, Brown, Wet	5	SS	34	269	0 17 79 4
		6	SS	49	268, 267	
266.5 / 6.0	Silty **SAND**, trace clay, Dense to Very Dense, Brown, Wet	7	SS	44	266	
		8	SS	51	265	0 62 34 4
		9	SS	62	264, 263	

Ground water level symbol shown at approx. elevation 271.2.

Columns: 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 16-02

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 158.1 E 412 555.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.09 - 2016.02.09	CHECKED BY	MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	Silty **SAND**, trace clay Very Dense Brown Wet				262					
		10	SS	72		w				
					261					
260.4 12.2	Clayey **SILT** Hard to Very Stiff Grey Wet (CL-ML)	11	SS	45	260	wP, w	0	0	79	21
					259					
		12	SS	26		w				
					258					
257.3 15.2	Silty **CLAY** Hard Grey Wet (CI)	13	SS	53	257	wP, w, wL	0	0	43	57
256.7 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 1.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.									

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

+3, ×3: Numbers refer to Sensitivity

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

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THURBER

RECORD OF BOREHOLE No 16-03

METRIC

W.P. 3032-11-00 LOCATION N 4 756 084.2 E 412 562.8 ORIGINATED BY GA

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.02.16 - 2016.02.16 CHECKED BY MEF

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
282.1	GROUND SURFACE					
0.0	**CONCRETE:** (300mm)					
281.8 / 0.3	**SAND** and **GRAVEL**, some silt, Dense, Brown, Moist (FILL)	1	SS	30	○	48 40 12 (SI+CL)
281.3 / 0.8	Silty **CLAY**, some sand, trace gravel, Stiff to Very Stiff, Brown, Moist (FILL)(CL)	2	SS	14	○	
		3	SS	11	○	
		4	SS	17	○ (with Wp–WL range)	0 22 46 32
		5	SS	19	○	
		6	SS	13	○	
276.1 / 5.9	**SILT** and **SAND**, some clay, Dense, Grey, Moist (FILL)	7	SS	40	○	0 45 45 10
274.5 / 7.6	Gravelly **SAND**, some silt, Compact, Brown, Moist (FILL)	8	SS	26	○	
273.4 / 8.7	Silty **SAND**, trace clay, Dense to Very Dense, Brown, Moist	9	SS	40	○	

Elevation scale: 282, 281, 280, 279, 278, 277, 276, 275, 274, 273

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

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-03

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 084.2 E 412 562.8 | ORIGINATED BY GA
HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN
DATUM Geodetic | DATE 2016.02.16 - 2016.02.16 | CHECKED BY MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Silty **SAND**, trace clay Dense to Very Dense Brown Moist						272					
			10	SS	48		271	○	0	76	21	3
	becoming Wet					▽	270					
			11	SS	60		269	○				
			12	SS	59		268	○				
							267					
			13	SS	39			○				
266.2 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 12.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 1.5m, BENTONITE HOLEPLUG TO 0.9m, THEN CONCRETE TO SURFACE.											

Column headings: 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 (%)

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 16-04

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 068.3 E 412 575.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.16 - 2016.02.17	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT	GR	SA	SI	CL
282.5	GROUND SURFACE									
0.0	**CONCRETE:** (375mm)									
282.1 / 0.4	Gravelly **SAND**, some silt, Dense to Compact, Brown, Moist (FILL)	1	GS		282	○	25	60	15 (SI+CL)	
		2	SS	36		○	23	63	14 (SI+CL)	
		3	SS	24	281	○				
	some gravel	4	SS	32	280	○	18	63	19 (SI+CL)	
279.5 / 3.0	Very Dense	5	SS	70	279	○				
278.5 / 4.0		6	SS	34	278, 277	○				
276.7 / 5.8	**SILT** and **SAND**, some clay, Loose to Dense, Brown/Grey, Moist (FILL)	7	SS	6	276	○	0	36	47	17
		8	SS	39	275, 274	○				
273.4 / 9.1	Silty **SAND**, trace clay, Very Dense, Brown, Moist	9	SS	84	273	○				

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

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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

RECORD OF BOREHOLE No 16-04

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 068.3 E 412 575.4 | ORIGINATED BY GA

HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.02.16 - 2016.02.17 | CHECKED BY MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Silty **SAND**, trace clay Very Dense Brown Moist				272					
		10	SS	89						
270.9 11.7	Sandy **SILT**, trace clay Very Dense Brown Moist				271					
		11	SS	90	270		0	27	69	4
	becoming Wet				269					
		12	SS	64	268					
	Dense	13	SS	48	267					
266.2 16.3	Silty **SAND**, trace clay Very Dense to Dense Brown Wet				266 (water level)					
		14	SS	56	265					
		15	SS	48	264		0	75	23	2
263.0 19.5	Sandy **SILT**, trace clay Very Dense Brown				263					

Continued Next Page

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

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

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

RECORD OF BOREHOLE No 16-04

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 068.3 E 412 575.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.16 - 2016.02.17	CHECKED BY	MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Sandy **SILT**, trace clay Very Dense Brown Wet	16	SS	84		○				
					262					
					261					
260.3 22.3	**SILT**, some clay, occasional clay seams Dense Grey/Brown Wet									
					260					
		17	SS	37		○	0	0	83	17
					259					
258.1 24.4	Silty **SAND** Dense Grey Wet									
					258					
					257					
		18	SS	37		○				
					256					
					255					
					254					
		19	SS	37		○				
					253					

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

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No 16-04

METRIC

W.P. 3032-11-00 LOCATION N 4 756 068.3 E 412 575.4 ORIGINATED BY GA

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.02.16 - 2016.02.17 CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m3	GR	SA	SI	CL
	Silty **SAND** Dense Grey Wet				252						
					251						
	Very Dense	20	SS	103		○		0	72	28 (SI+CL)	
					250						
					249						
247.8					248						
34.7	Silty **CLAY**, trace to some sand, trace gravel Very Stiff to Hard Grey Wet (TILL)(CL)	21	SS	26	247	○					
					246						
					245						
		22	SS	39	244	⊢○⊣		0	22	54	24
					243						
		23	SS	60		○					

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; REMARKS & GRAIN SIZE DISTRIBUTION (%)

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

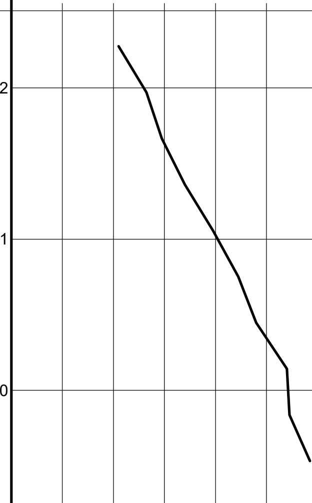
THURBER

RECORD OF BOREHOLE No 16-04

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 068.3 E 412 575.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.16 - 2016.02.17	CHECKED BY	MEF

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L – WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
242.3 / 40.2	End of sampling and start of DCPT						242, 241, 240				
239.2 / 43.3	END OF BOREHOLE AT 43.3m. BOREHOLE OPEN TO 43.3m AND WATER LEVEL AT 10.6m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										



WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2016.02.23	17.9	264.6
2016.04.01	16.4	266.1

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-05

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 042.3 E 412 608.1	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.22 - 2016.02.22	CHECKED BY	MEF

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
276.1	GROUND SURFACE
0.0 / 0.1	**ASPHALT:** (75mm)
	Gravelly **SAND**, trace silt Dense Brown Moist (FILL)
275.3 / 0.8	**SILT** and **SAND**, trace clay Compact Brown Moist becoming Wet
268.9 / 7.2	Silty **SAND** Dense to Compact Brown Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	44				
2	SS	14				
3	SS	22	0	39	57	4
4	SS	28				
5	SS	30				
6	SS	24	0	41	53	6
7	SS	26				
8	SS	39				
9	SS	21				

GROUND WATER CONDITIONS: water level symbol at approx. elevation 270.4

ELEVATION SCALE: 276, 275, 274, 273, 272, 271, 270, 269, 268, 267

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 16-05

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 042.3 E 412 608.1 | ORIGINATED BY GA
HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN
DATUM Geodetic | DATE 2016.02.22 - 2016.02.22 | CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Silty **SAND**, Compact, Brown, Wet				266					
265.4 / 10.7	**SILT**, trace sand, trace to some clay, Dense to Very Dense, Grey, Wet	10	SS	41	265	○	0	6	90	4
		11	SS	50	264 / 263	○				
		12	SS	55	262 / 261	○	0	0	81	19
		13	SS	65	260	○				
		14	SS	71	259 / 258	○				
257.8 / 18.3	Silty **CLAY**, trace sand, Hard, Grey, Wet, (CI)	15	SS	31		wP–w–wL	0	0	43	57
257.2 / 18.9	END OF BOREHOLE AT 18.9m. BOREHOLE OPEN TO 18.9m AND WATER LEVEL AT 5.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 1.5m, CONCRETE									

Continued Next Page

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

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

RECORD OF BOREHOLE No 16-05

METRIC

W.P. 3032-11-00 | LOCATION N 4 756 042.3 E 412 608.1 | ORIGINATED BY GA

HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.02.22 - 2016.02.22 | 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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	TO 0.2m, THEN ASPHALT PATCH TO SURFACE.										

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-06

METRIC

W.P. 3032-11-00	LOCATION N 4 756 002.3 E 412 609.7		ORIGINATED BY GA
HWY 401	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2016.02.18 - 2016.02.18		CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
282.5	GROUND SURFACE					
0.0 / 282.2	**CONCRETE:** (275mm)					
0.3	Gravelly **SAND**, trace to some silt, Compact to Dense, Brown, Moist (FILL)	1	SS	33	282	
		2	SS	24		
		3	SS	33	281	
		4	SS	42	280	
		5	SS	36	279	
	Very Dense	6	SS	89	278	30 52 18 (SI+CL)
276.8 / 5.7	Silty **SAND**, Dense, Brown, Moist (FILL)	7	SS	40	277 / 276	
275.1 / 7.5	Silty **CLAY**, trace sand, Very Stiff, Dark Brown, Moist (TILL)	8	SS	17	275 / 274	
273.4 / 9.1	Silty **SAND**, Dense, Brown, Moist	9	SS	34	273	

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 16-06

METRIC

W.P. 3032-11-00 LOCATION N 4 756 002.3 E 412 609.7 ORIGINATED BY GA

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.02.18 - 2016.02.18 CHECKED BY MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **SAND**, Compact, Brown, Wet				272		
		10	SS	26			
270.8 / 11.7	**SILT**, trace sand, trace clay, Very Dense, Brown, Wet				271		
		11	SS	57	270		0 6 88 6
		12	SS	89	269		
		13	SS	92	268, 267		
265.8 / 16.8	Silty **SAND**, Compact, Brown, Wet	14	SS	24	266		
		15	SS	29	265, 264		
262.7 / 19.8					263		

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

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 16-06

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 002.3 E 412 609.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.18 - 2016.02.18	CHECKED BY	MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILT, trace sand, trace clay Dense Grey Wet	16	SS	89		○ ~19	0	6	90	4
					262					
					261					
					260					
		17	SS	38		○ ~18				
					259					
258.1 24.4	Silty **SAND**, trace clay Compact Grey Wet				258					
					257					
		18	SS	26		○ ~19	0	75	20	5
					256					
					255					
					254					
		19	SS	24		○ ~19				
					253					

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 16-06

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 002.3 E 412 609.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.18 - 2016.02.18	CHECKED BY	MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **SAND**, trace clay Very Dense Grey Wet				252		
					251		
		20	SS	70		○	
					250		
					249		
					248		
247.8 34.7	Silty **CLAY**, trace to some sand, trace gravel Very Stiff to Hard Grey Wet (TILL)(CL)						
		21	SS	25	247	○	
					246		
					245		
		22	SS	53	244	○	
					243		
		23	SS	67		⊢○⊣	0 21 50 29

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

UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-06

METRIC

W.P.	3032-11-00	LOCATION	N 4 756 002.3 E 412 609.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.18 - 2016.02.18	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
242.3 / 40.2	End of sampling and start of DCPT						242, 241				
240.2 / 42.4	END OF BOREHOLE AT 42.4m BOREHOLE OPEN TO 39.6m AND WATER LEVEL AT 10.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2016.02.23	10.8	271.7
2016.04.01	10.0	272.5

Legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-07

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 984.1 E 412 621.1	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.18 - 2016.02.18	CHECKED BY	MRF

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
282.2	GROUND SURFACE
0.0 / 281.9	**CONCRETE:** (263mm)
0.3 / 281.3	Sandy **GRAVEL**, some silt Dense Brown Moist (FILL)
0.8 / 279.1	Silty **CLAY**, some sand to sandy, trace gravel Stiff to Firm Brown Moist (FILL)
3.0 / 276.4	**SILT**, some sand, some clay, trace gravel Compact to Loose Brown Wet (FILL)
5.8 / 274.6	Gravelly **SAND**, trace silt Very Dense Brown Moist (FILL)
7.6	Silty **CLAY**, trace sand Very Stiff Brown Moist (TILL)(CI)

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	40	62	28	10 (SI+CL)	
2	SS	12				
3	SS	12				
4	SS	6	4	29	37	30
5	SS	12				
6	SS	6				
7	SS	89				
8	SS	19	0	10	49	41
9	SS	24				

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (282 – 273); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-07

METRIC

W.P. 3032-11-00 | LOCATION N 4 755 984.1 E 412 621.1 | ORIGINATED BY GA
HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN
DATUM Geodetic | DATE 2016.02.18 - 2016.02.18 | CHECKED BY MRF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Silty **CLAY**, trace sand, Very Stiff, Brown, Moist (TILL)(CI)				▽	272					
271.5 / 10.7	Sandy **SILT**, trace clay, Very Dense, Brown, Wet	10	SS	72			○	0	24	72	4
						271					
		11	SS	55		270	○				
268.9 / 13.3	**SILT** and **SAND**, trace clay, Very Dense, Brown, Wet					269					
		12	SS	80		268	○	0	37	58	5
		13	SS	78		267	○				
266.3 / 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 10.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 1.5m, BENTONITE HOLEPLUG TO 0.9m, THEN CONCRETE TO SURFACE.										

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-08

METRIC

W.P. 3032-11-00 | LOCATION N 4 755 908.3 E 412 657.4 | ORIGINATED BY GA

HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.02.23 - 2016.02.23 | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
280.3	GROUND SURFACE						
0.0	**ASPHALT:** (275mm)						
0.2	Gravelly **SAND**, some silt, Dense, Brown, Moist (FILL)	1	SS	47		~1	
		2	SS	38		~9	27 56 17 (SI+CL)
278.7 / 1.5	Sandy **SILT**, trace gravel, Compact, Brown, Moist (FILL)	3	SS	19		~5	
277.8 / 2.4	Silty **CLAY**, some sand, trace gravel, Stiff, Brown, Moist (FILL)(CL)	4	SS	13		~7 (wP ~8, wL ~15)	3 19 42 36
		5	SS	9		~8	
		6	SS	8		~12	
274.6 / 5.7	**SAND** and **SILT**, trace clay, Compact, Brown, Moist (FILL)	7	SS	14		~6	0 52 42 6
273.3 / 7.0	Sandy **SILT**, trace clay, Compact to Dense, Brown, Wet	8	SS	12		~10	
					∇ (approx. El. 271.6)		
		9	SS	49		~8	

Elevation scale: 280, 279, 278, 277, 276, 275, 274, 273, 272, 271

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 wP — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wL; 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 16-08

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 908.3 E 412 657.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.23 - 2016.02.23	CHECKED BY	MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Sandy **SILT**, trace clay Very Dense Brown Wet				270					
		10	SS	62		~19	0	28	67	5
					269					
268.4 / 11.9	Silty **SAND**, trace clay Very Dense Brown Wet									
					268					
		11	SS	67		~19				
					267					
		12	SS	81		~19				
					266					
					265					
		13	SS	59		~21				
					264					
		14	SS	71		~21	0	74	23	3
					263					
					262					
	Compact	15	SS	28		~20				
261.4 / 18.9	END OF BOREHOLE AT 18.9m. BOREHOLE OPEN TO 18.9m AND WATER LEVEL AT 9.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT PATCH									

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-08

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 908.3 E 412 657.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.23 - 2016.02.23	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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	TO SURFACE.										

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-08A

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 914.0 E 412 628.0	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hand Augers	COMPILED BY	MFA
DATUM	Geodetic	DATE	2016.02.24 - 2016.02.24	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	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
273.2	GROUND SURFACE										
0.0	**TOPSOIL:** (175mm)					▽					
0.2	Silty **CLAY** Brown Wet (TILL)						273				
272.3 0.9	END OF BOREHOLE AT 0.9m. BOREHOLE OPEN TO 0.9m AND WATER LEVEL AT 0.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-09

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 861.7 E 412 595.5	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.23 - 2016.02.23	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
277.8	GROUND SURFACE								
0.0 / 0.1	**ASPHALT:** (100mm)								
	Sandy **GRAVEL** Dense Brown Moist (FILL)	1	SS	44					64 27 9 (SI+CL)
		2	SS	40		277			
276.3 / 1.5	Silty **CLAY**, some sand, trace gravel Stiff to Very Stiff Brown Moist (FILL)(CI)	3	SS	14		276			
		4	SS	12		275			0 18 44 38
		5	SS	19		274			
		6	SS	10		273			0 19 44 37
272.4 / 5.5	Sandy **SILT**, trace clay Compact to Very Dense Brown Wet					272			
		7	SS	35	∇	271			
		8	SS	54		270			0 23 72 5
		9	SS	23		269 / 268			

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

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 10552.GPJ 2015TEMPLATE(MTO).GDT 4/26/16

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-09

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 861.7 E 412 595.5	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.23 - 2016.02.23	CHECKED BY	MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Sandy **SILT**, trace clay Dense Brown Wet	10	SS	36	267					
266.1 11.7	**SAND**, trace silt, trace clay Dense Brown Wet	11	SS	44	266		0	89	9	2
		12	SS	47	265 / 264					
		13	SS	34	263 / 262					
261.4 16.5	**SILT**, some sand Very Dense Brown Wet	14	SS	67	261 / 260					
259.6 18.3	Silty **CLAY** Hard Brown Wet (CL)	15	SS	37	259		0	0	52	48
258.9 18.9	END OF BOREHOLE AT 18.9m. BOREHOLE OPEN TO 18.9m AND WATER LEVEL AT 6.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.9m, CONCRETE									

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

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 16-09

METRIC

W.P.	3032-11-00	LOCATION	N 4 755 861.7 E 412 595.5	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.02.23 - 2016.02.23	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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page TO 0.2m, THEN ASPHALT PATCH TO SURFACE.										

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-09A

METRIC

W.P. 3032-11-00	LOCATION N 4 755 881.0 E 412 592.0		ORIGINATED BY GA
HWY 401	BOREHOLE TYPE Hand Augers		COMPILED BY MFA
DATUM Geodetic	DATE 2016.02.24 - 2016.02.24		CHECKED BY MEF

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
272.6	GROUND SURFACE										
0.0	**TOPSOIL:** (200mm)					▽					
0.2	Silty **CLAY** Brown Wet (TILL)						272				
271.7 0.9	END OF BOREHOLE AT 0.9m. BOREHOLE OPEN TO 0.9m AND WATER LEVEL AT 0.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.										

ONTMT4S 10552.GPJ 2015TEMPLATE(MTO).GDT 4/26/16

+ 3, × 3: Numbers refer to Sensitivity

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

THURBER

Appendix B

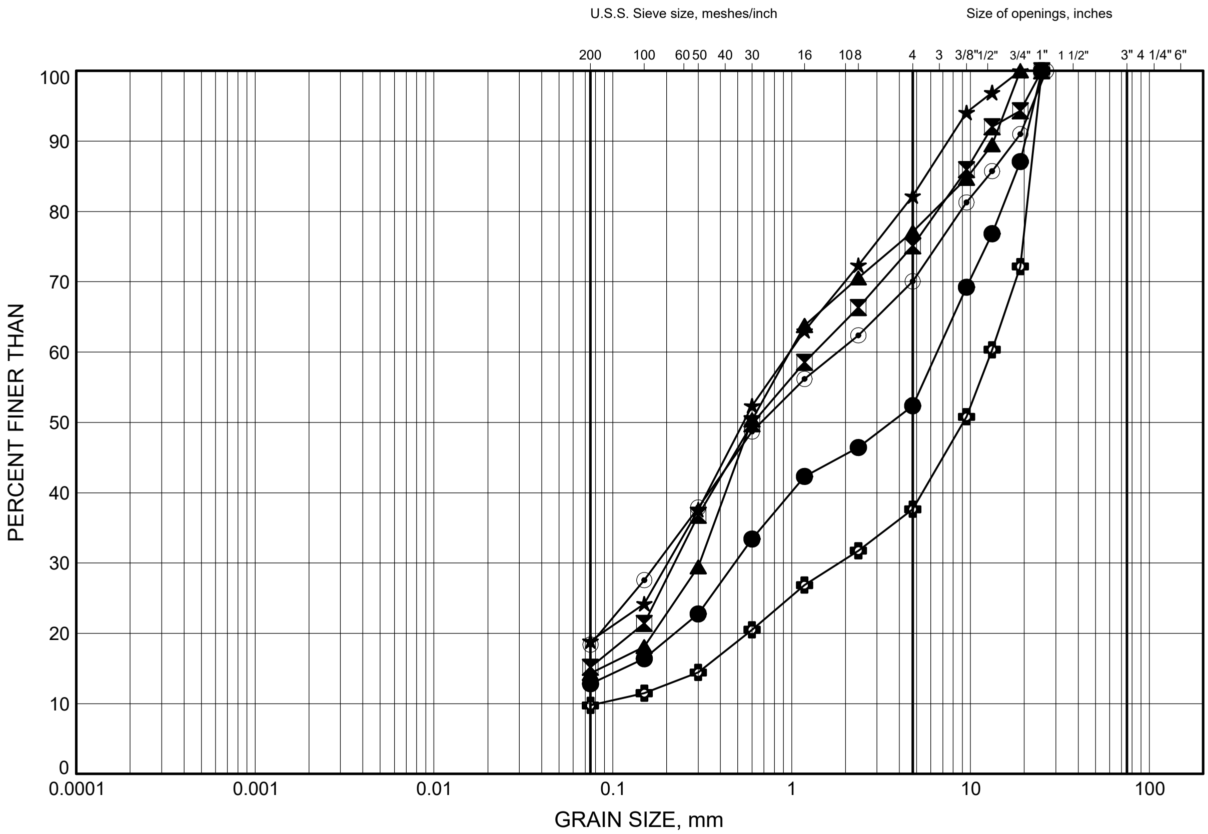
Laboratory Test Results

Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B1

Granular FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	0.53	281.54
⧗	16-04	0.61	281.90
▲	16-04	1.07	281.44
★	16-04	2.59	279.92
⊙	16-06	4.88	277.65
✿	16-07	0.53	281.64

GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

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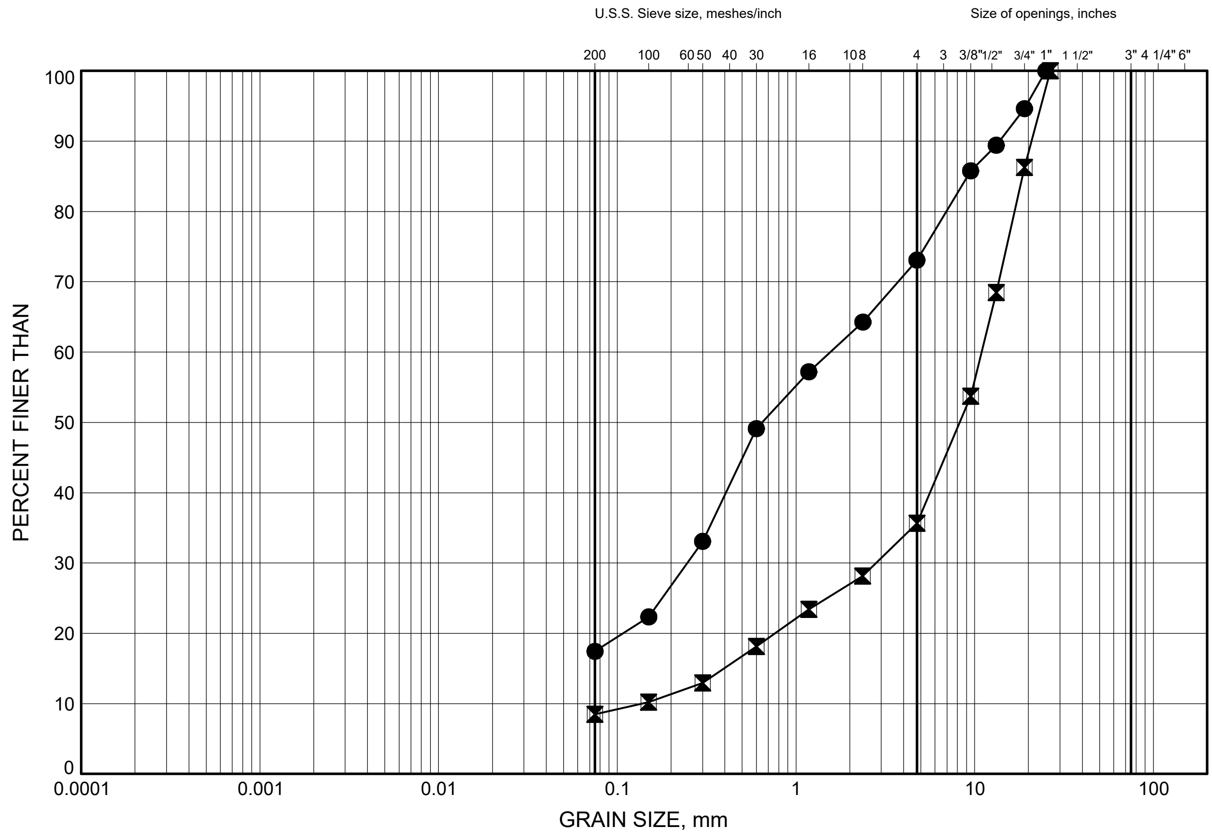
Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B2

Granular FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-08	1.07	279.20
⧗	16-09	0.46	277.38

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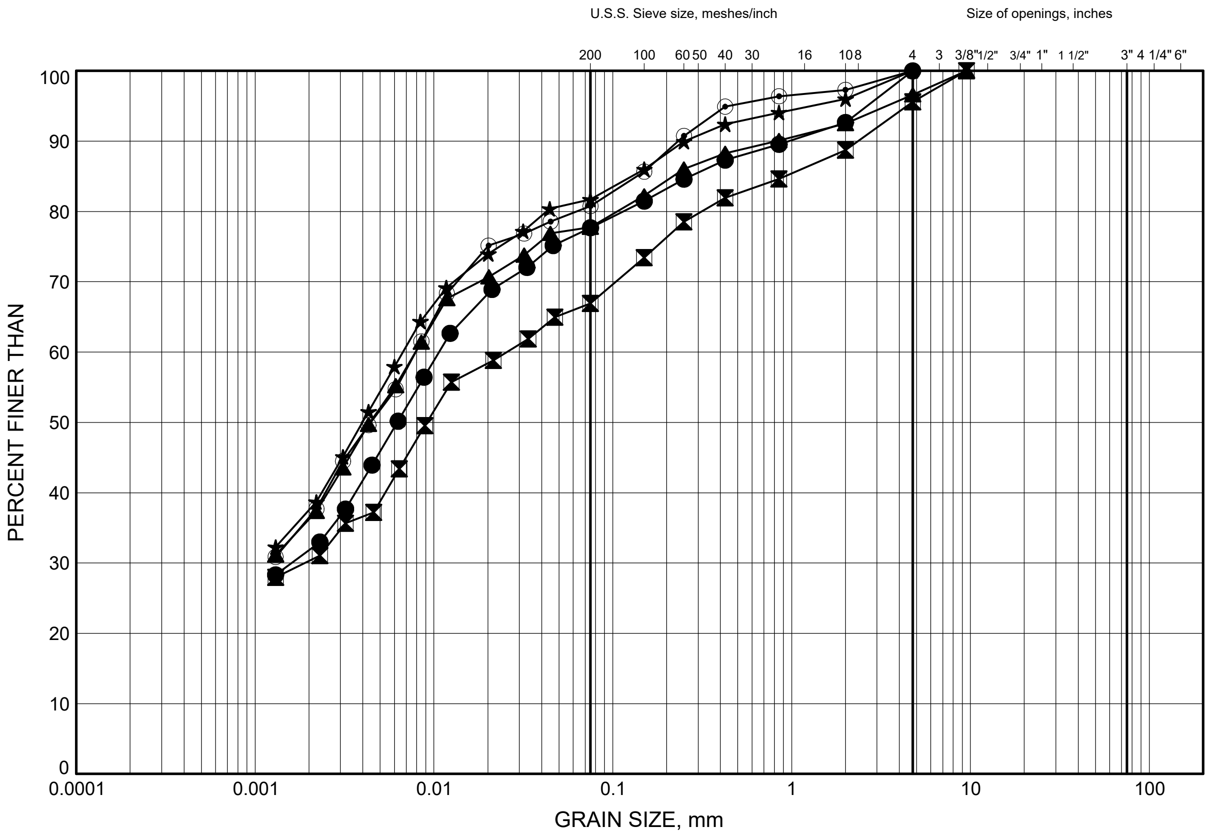
GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	2.59	279.48
⧗	16-07	2.59	279.58
▲	16-08	2.59	277.68
★	16-09	2.59	275.25
⊙	16-09	4.88	272.96

Date April 2016

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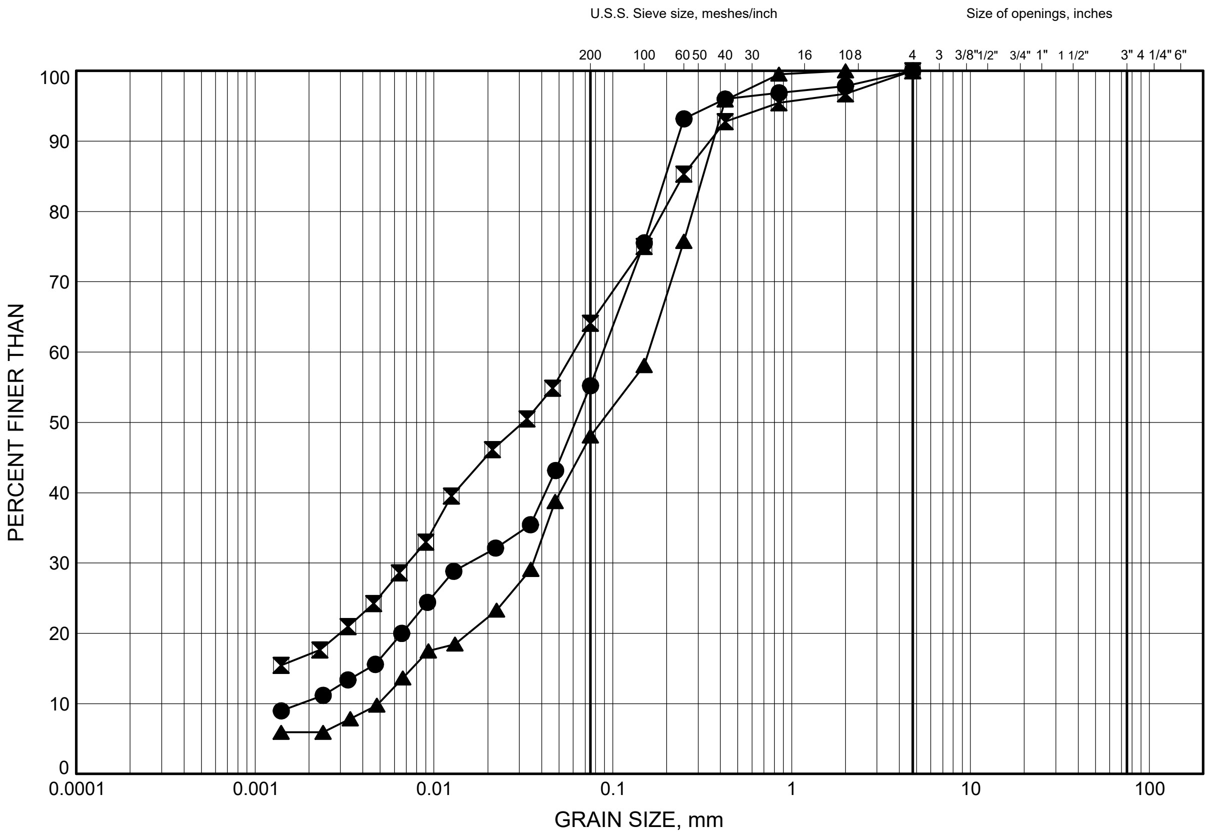
GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILT, Some Sand FILL to Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	6.40	275.67
⧗	16-04	6.40	276.11
▲	16-08	6.40	273.87

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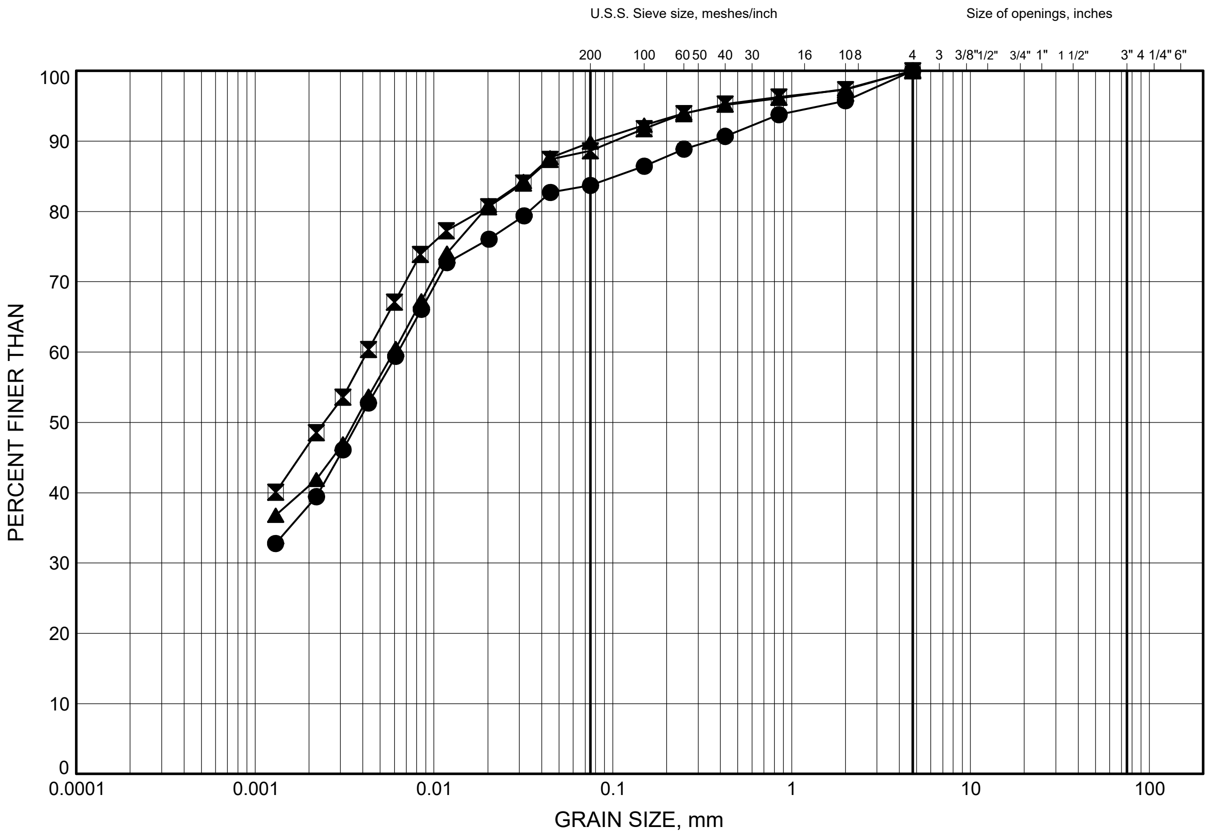
Hwy 401 - Highbury Avenue Interchange **GRAIN SIZE DISTRIBUTION**	FIGURE B5

Upper Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	1.07	271.62
⧗	16-02	1.07	271.49
▲	16-07	7.92	274.25

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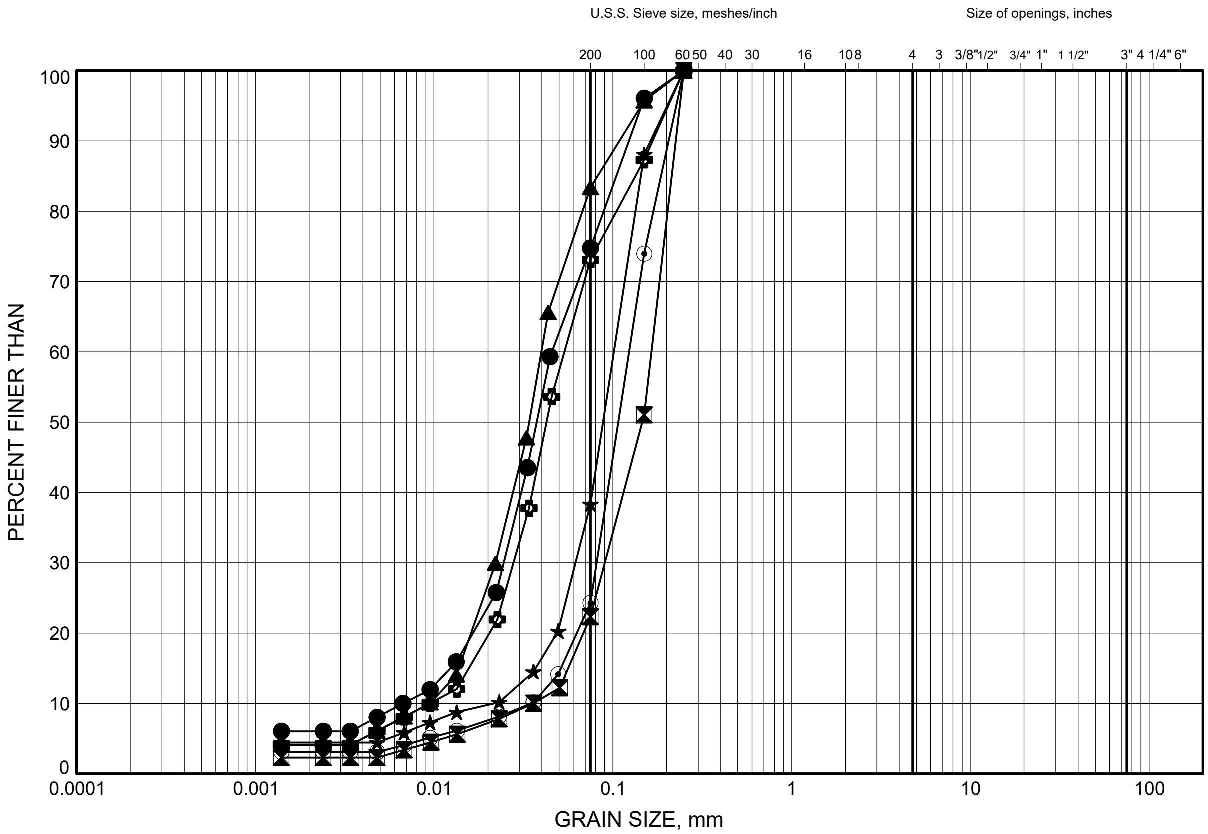
GRAIN SIZE DISTRIBUTION

FIGURE B6

Upper Silty SAND to Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	4.88	267.81
⧗	16-01	9.45	263.24
▲	16-02	3.35	269.21
★	16-02	7.92	264.64
⊙	16-03	10.97	271.10
✿	16-04	12.50	270.01

Date April 2016

W.P. 3032-11-00

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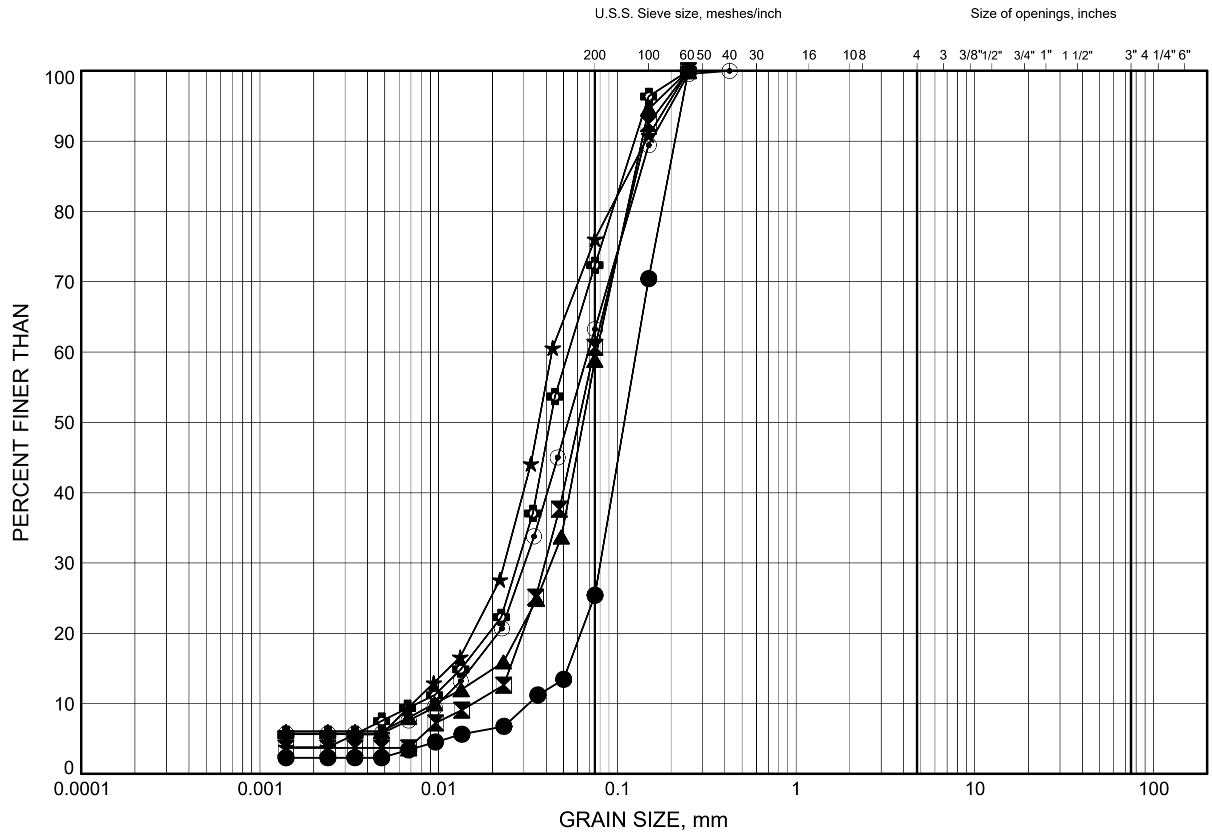
GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B7

Upper Silty SAND to Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	18.59	263.92
⧗	16-05	1.83	274.27
▲	16-05	4.88	271.22
★	16-07	10.97	271.20
⊙	16-07	14.02	268.15
✿	16-08	10.97	269.30

Date April 2016

W.P. 3032-11-00

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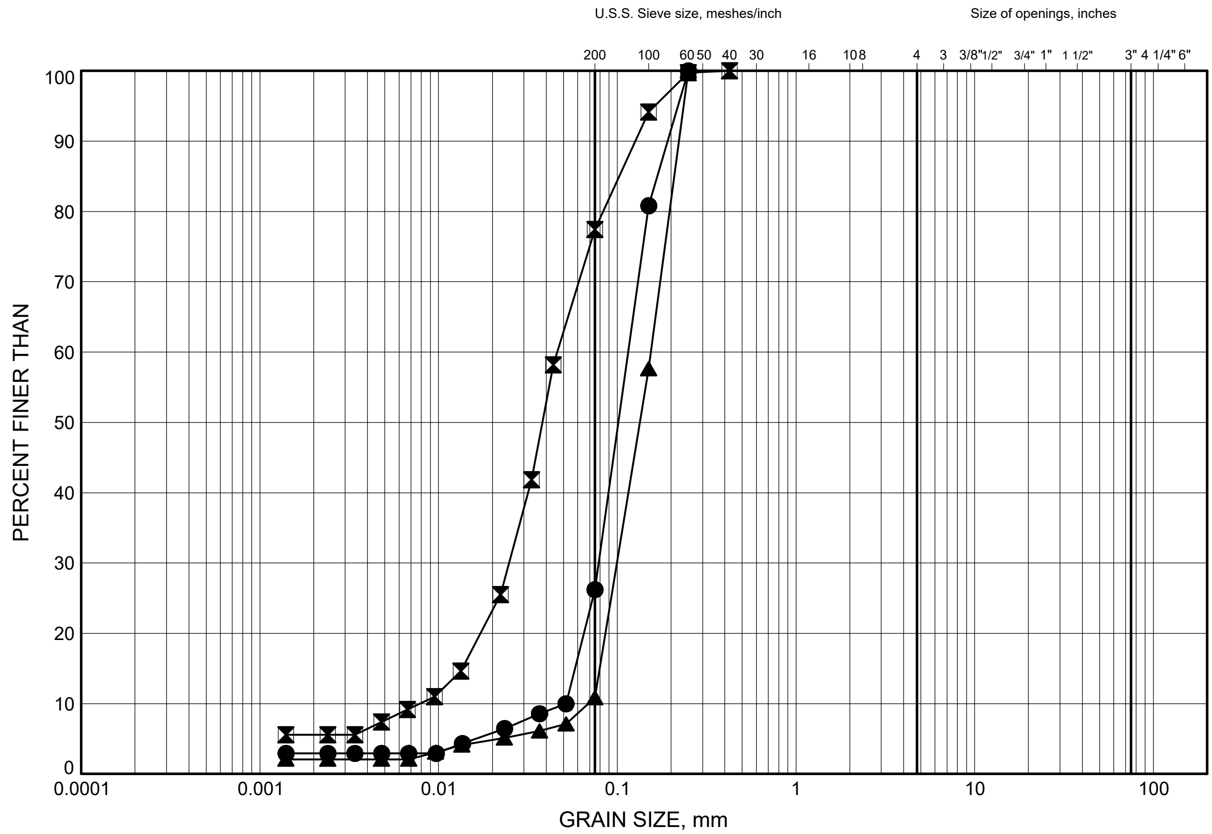
GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B8

Upper Silty SAND to Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-08	17.07	263.20
⧗	16-09	7.92	269.92
▲	16-09	12.50	265.34

GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

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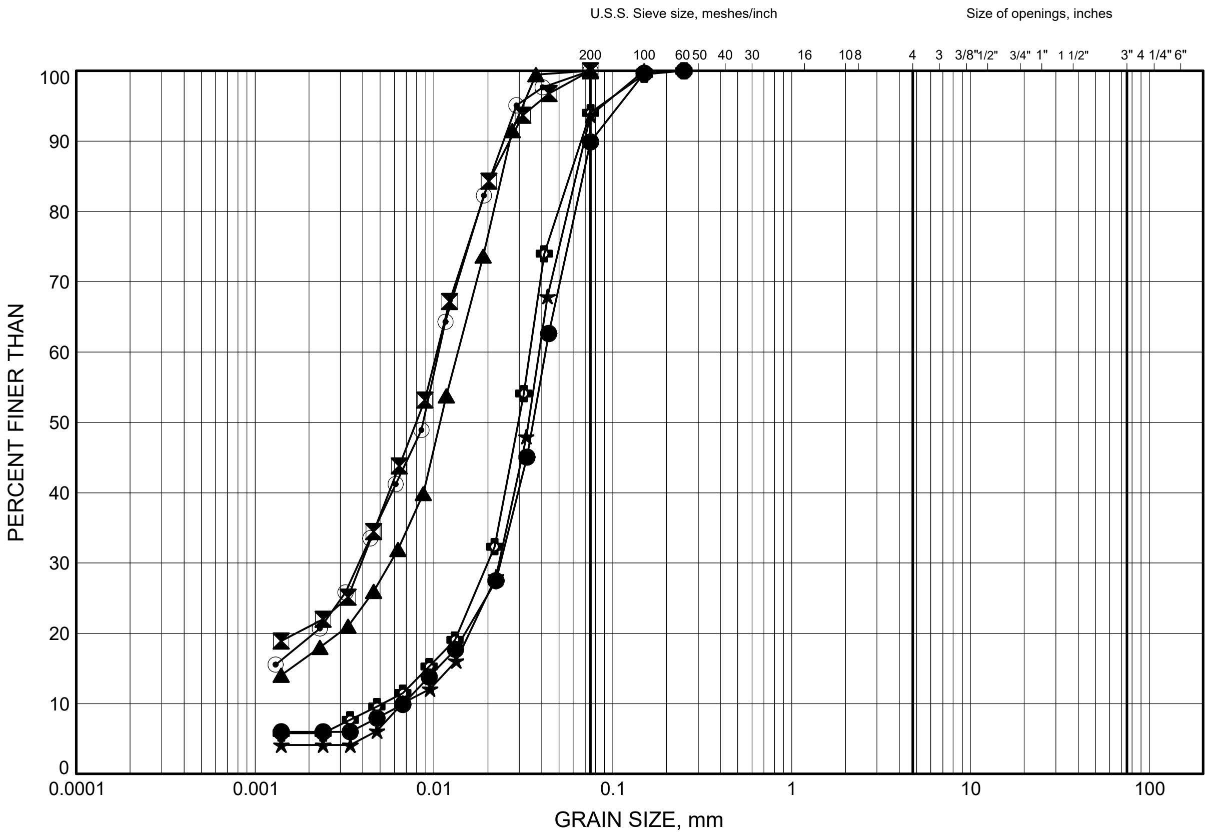
Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	12.50	260.19
⧗	16-02	12.50	260.06
▲	16-04	23.16	259.35
★	16-05	10.97	265.13
⊙	16-05	14.02	262.08
✿	16-06	12.50	270.03

GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

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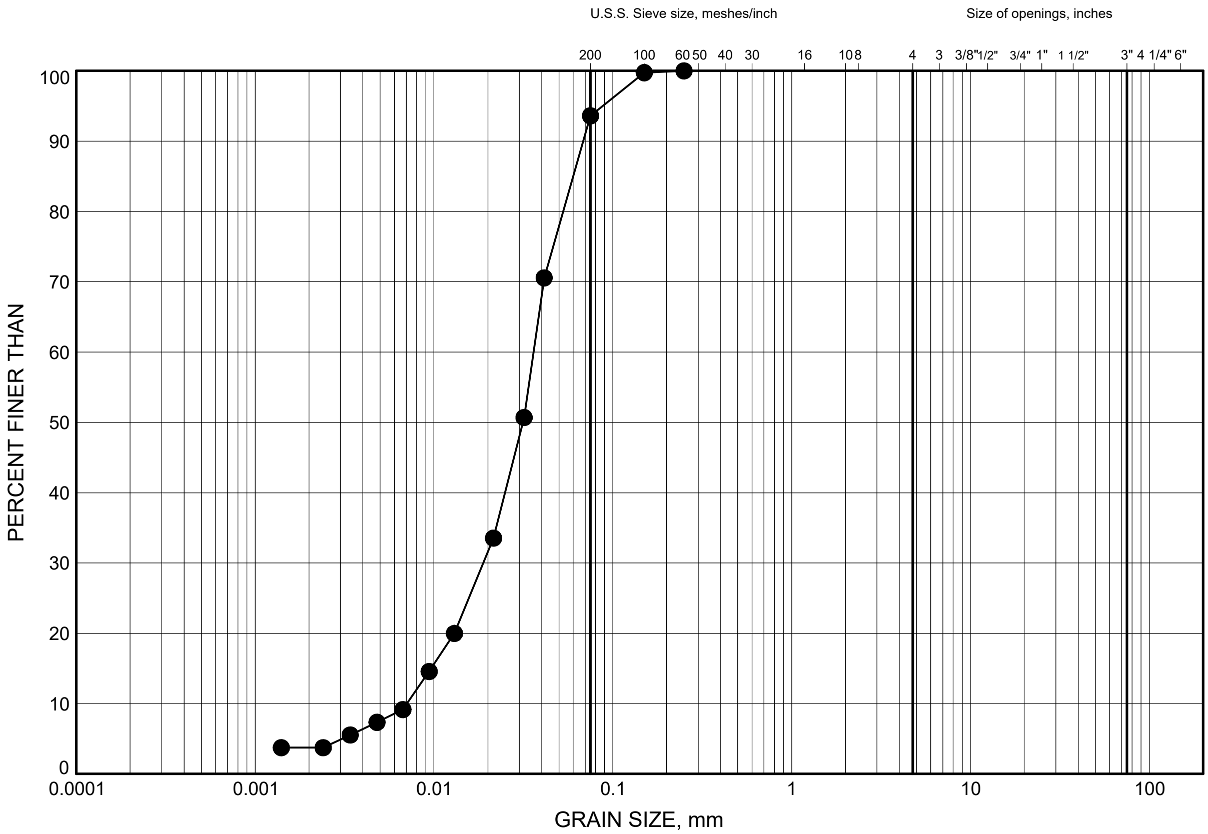
GRAIN SIZE DISTRIBUTION

FIGURE B10

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-06	20.12	262.41

Date April 2016

W.P. 3032-11-00

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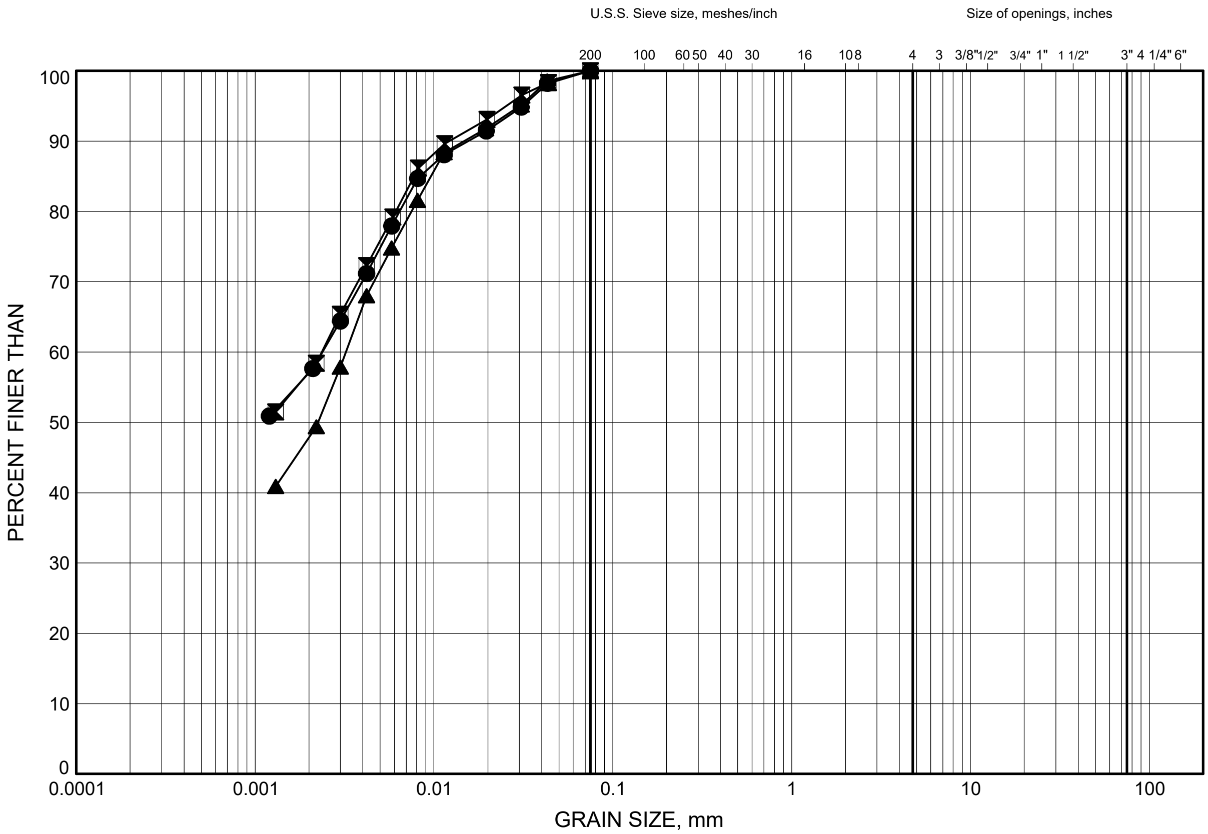
GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B11

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	15.54	257.02
⧗	16-05	18.59	257.51
▲	16-09	18.59	259.25

GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

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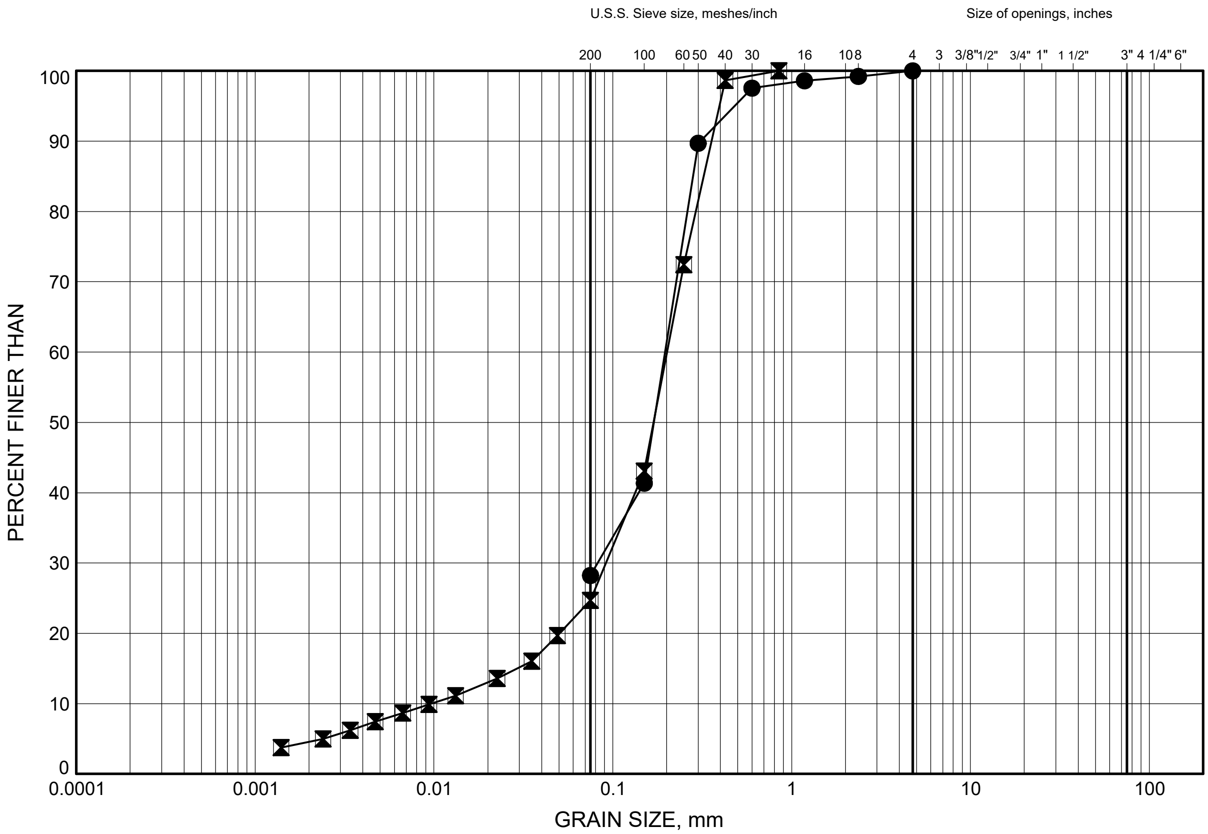
Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B12

Lower Silty SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	32.23	250.28
⧗	16-06	26.21	256.32

Date April 2016

W.P. 3032-11-00

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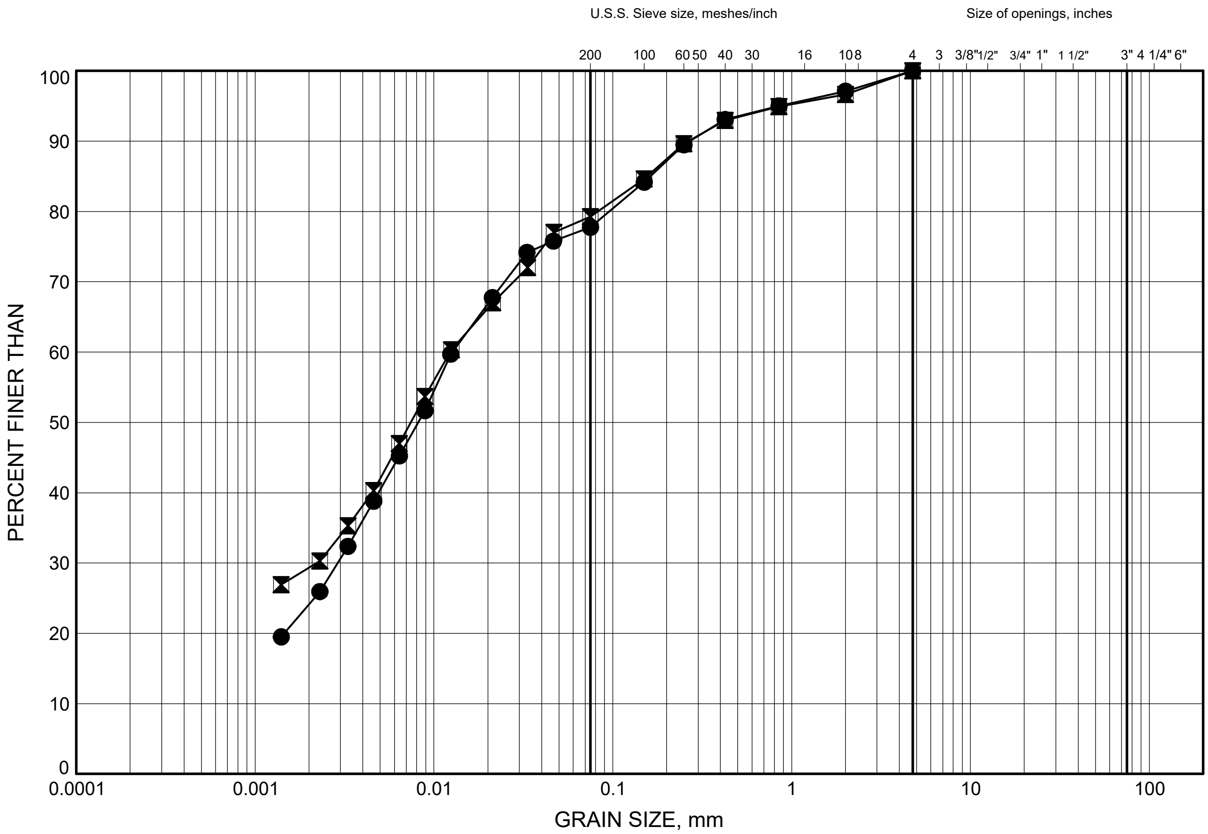
Hwy 401 - Highbury Avenue Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B13

Lower Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	38.40	244.11
⧗	16-06	39.93	242.60

Date April 2016

W.P. 3032-11-00

THURBER

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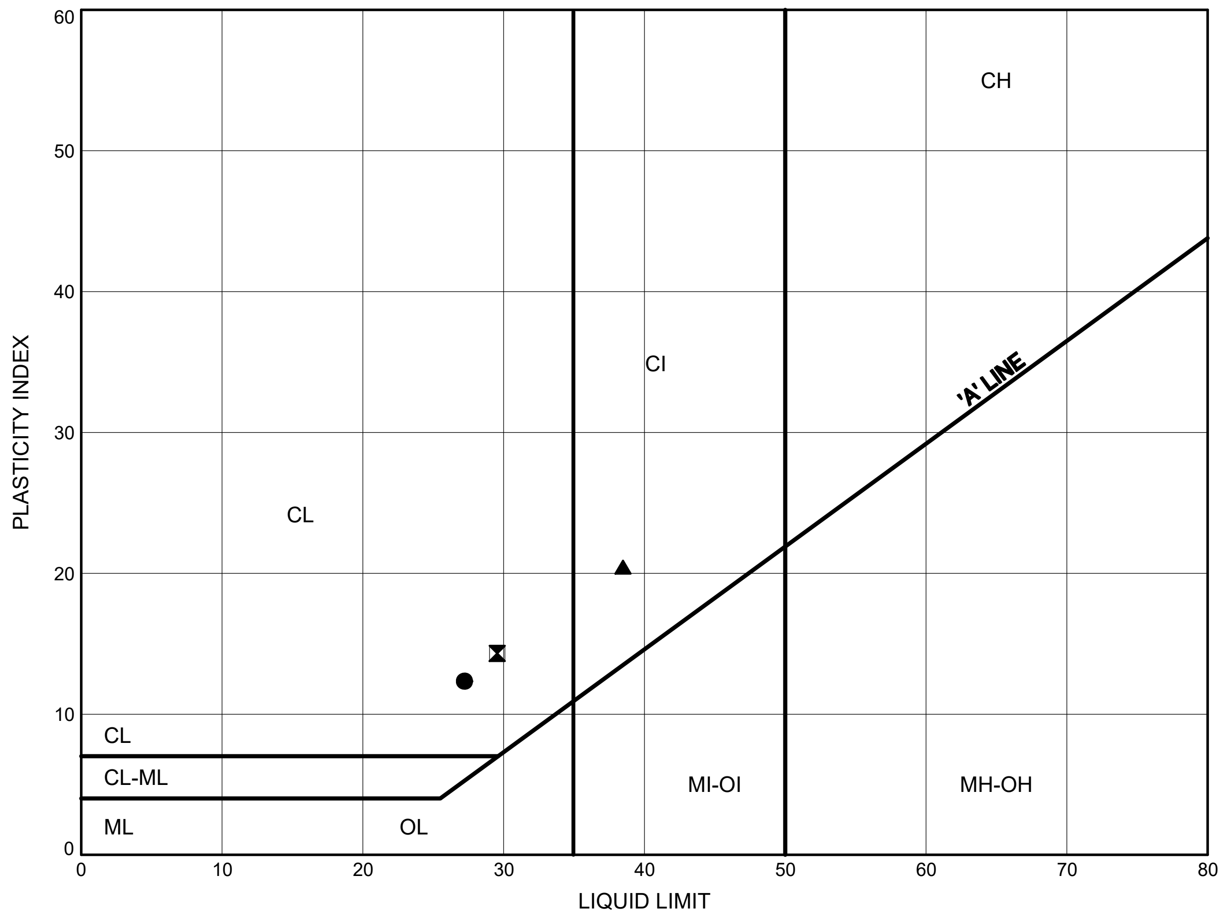
GRAIN SIZE DISTRIBUTION - THURBER 10552.GPJ 4/26/16

Hwy 401 - Highbury Avenue Interchange

ATTERBERG LIMITS TEST RESULTS

FIGURE B14

Silty CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	2.59	279.48
⧗	16-08	2.59	277.68
▲	16-09	4.88	272.96

THURBALT 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

THURBER

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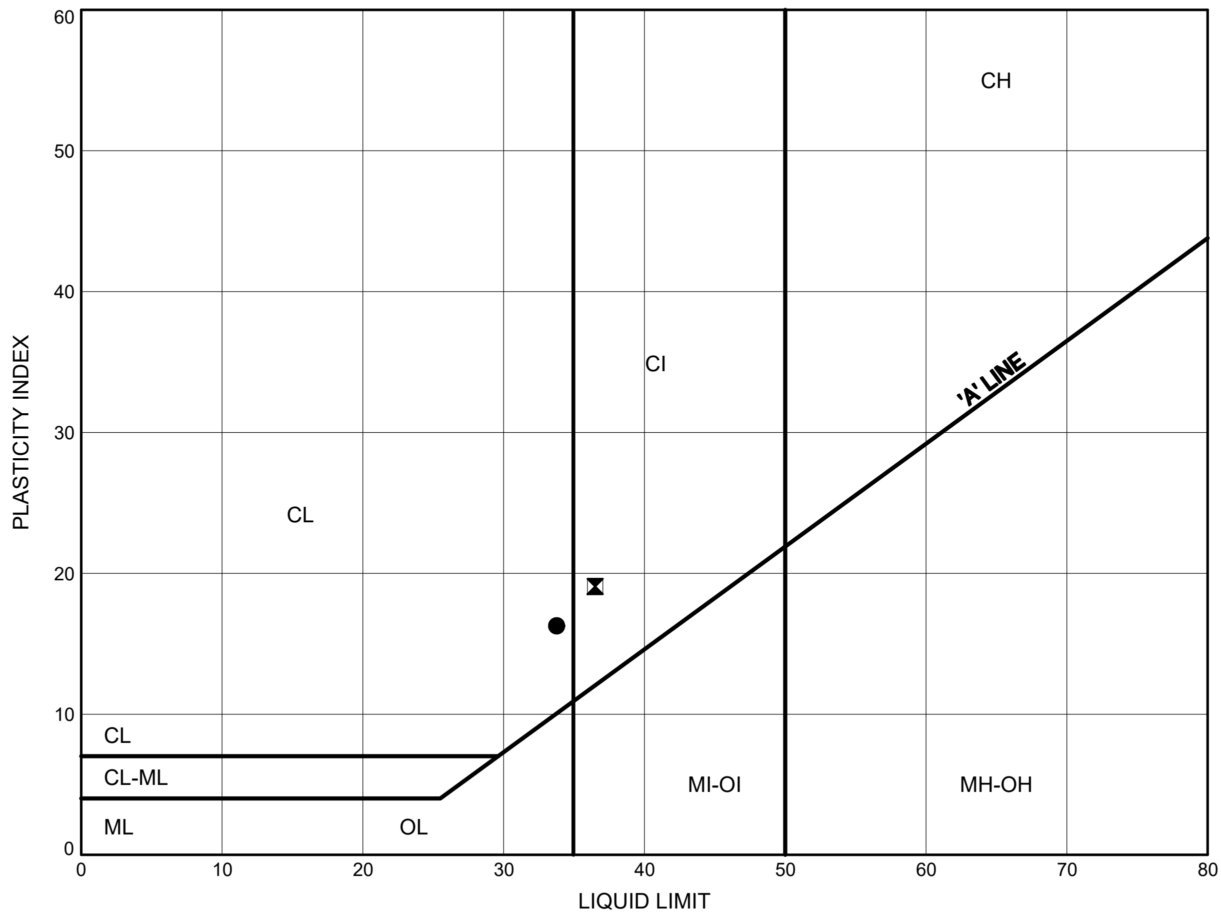
Hwy 401 - Highbury Avenue Interchange

ATTERBERG LIMITS TEST RESULTS

FIGURE B15

Upper Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	1.07	271.62
⧗	16-07	7.92	274.25

THURBALT 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

THURBER

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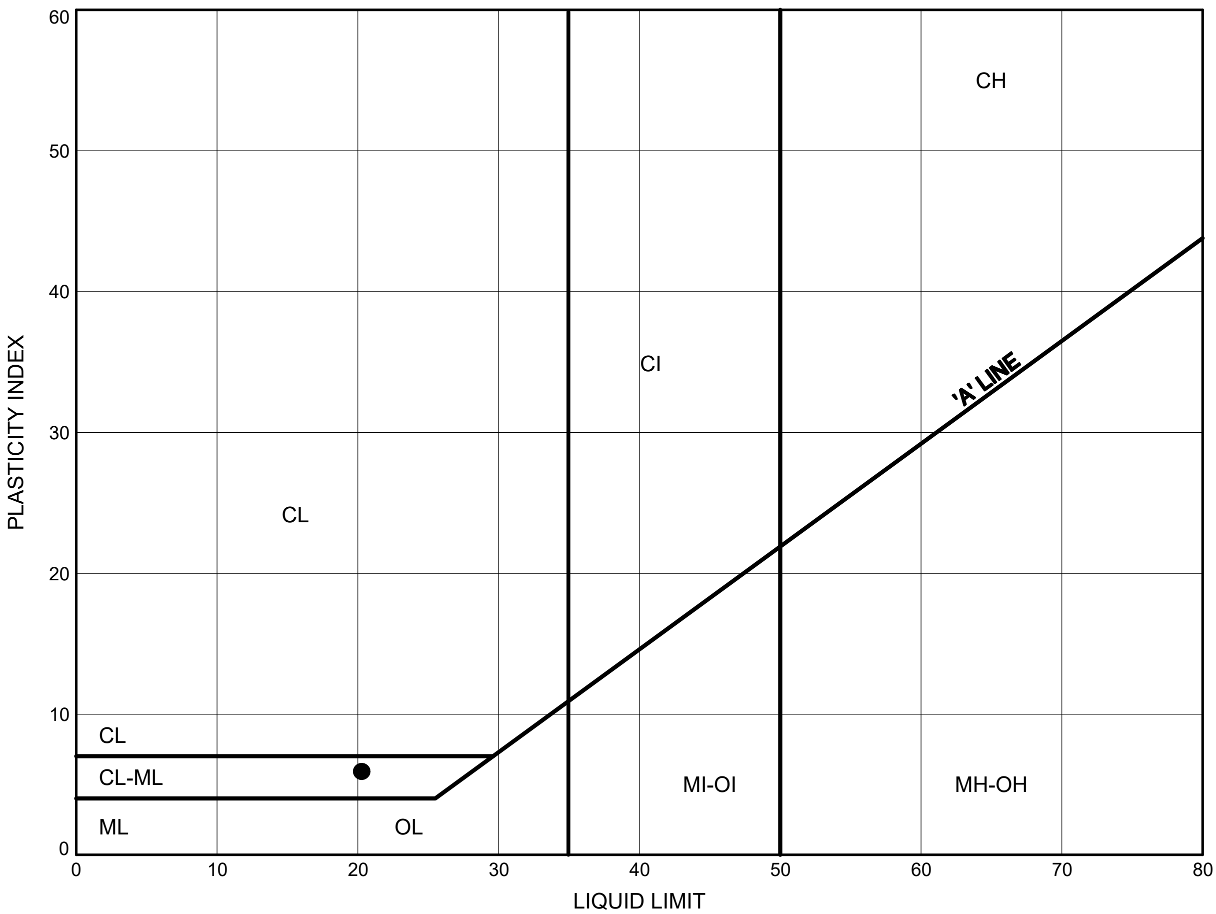
Hwy 401 - Highbury Avenue Interchange

ATTERBERG LIMITS TEST RESULTS

FIGURE B16

SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	12.50	260.06

THURBALT 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

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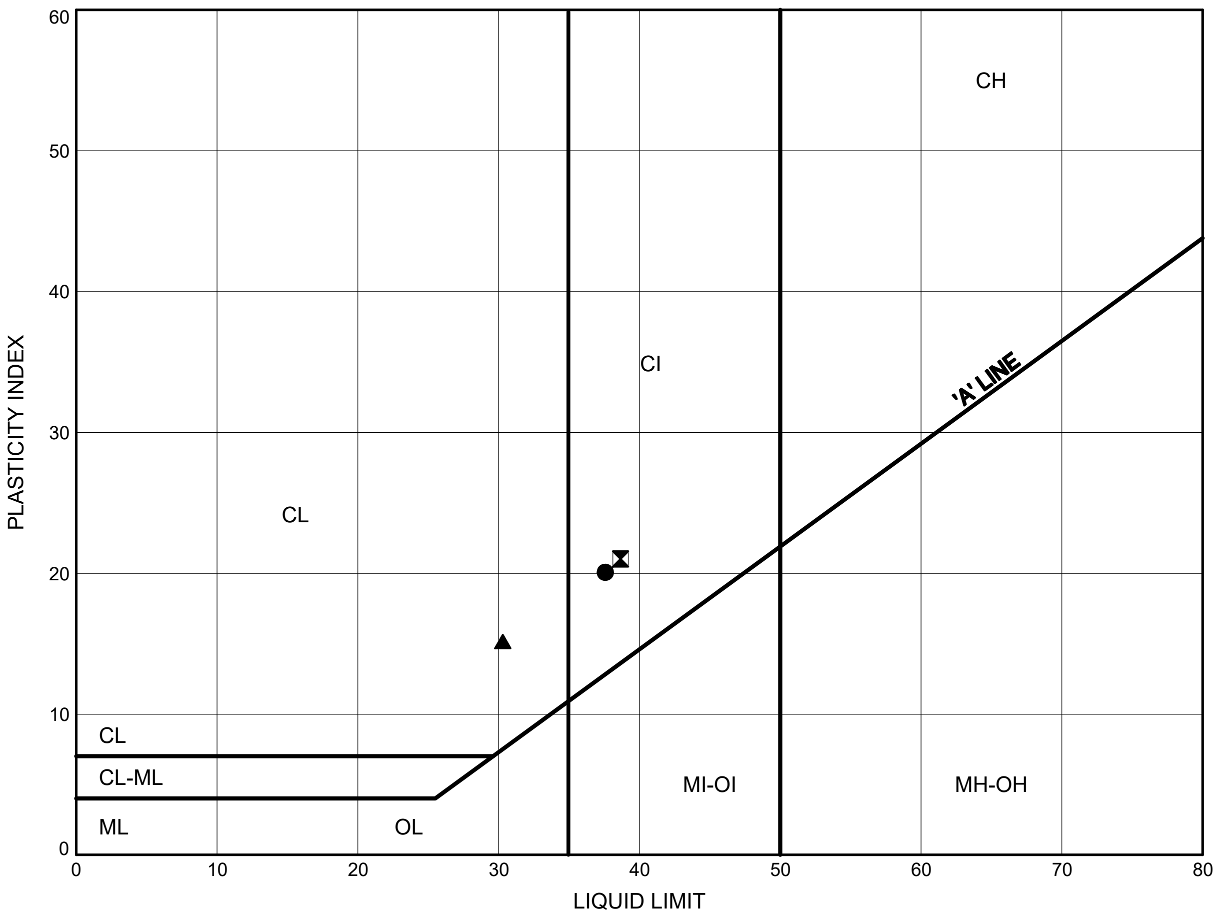
Chkd. MEF

Hwy 401 - Highbury Avenue Interchange

ATTERBERG LIMITS TEST RESULTS

FIGURE B17

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	15.54	257.02
⧗	16-05	18.59	257.51
▲	16-09	18.59	259.25

THURBALT 10552.GPJ 4/26/16

Date April 2016

W.P. 3032-11-00

THURBER

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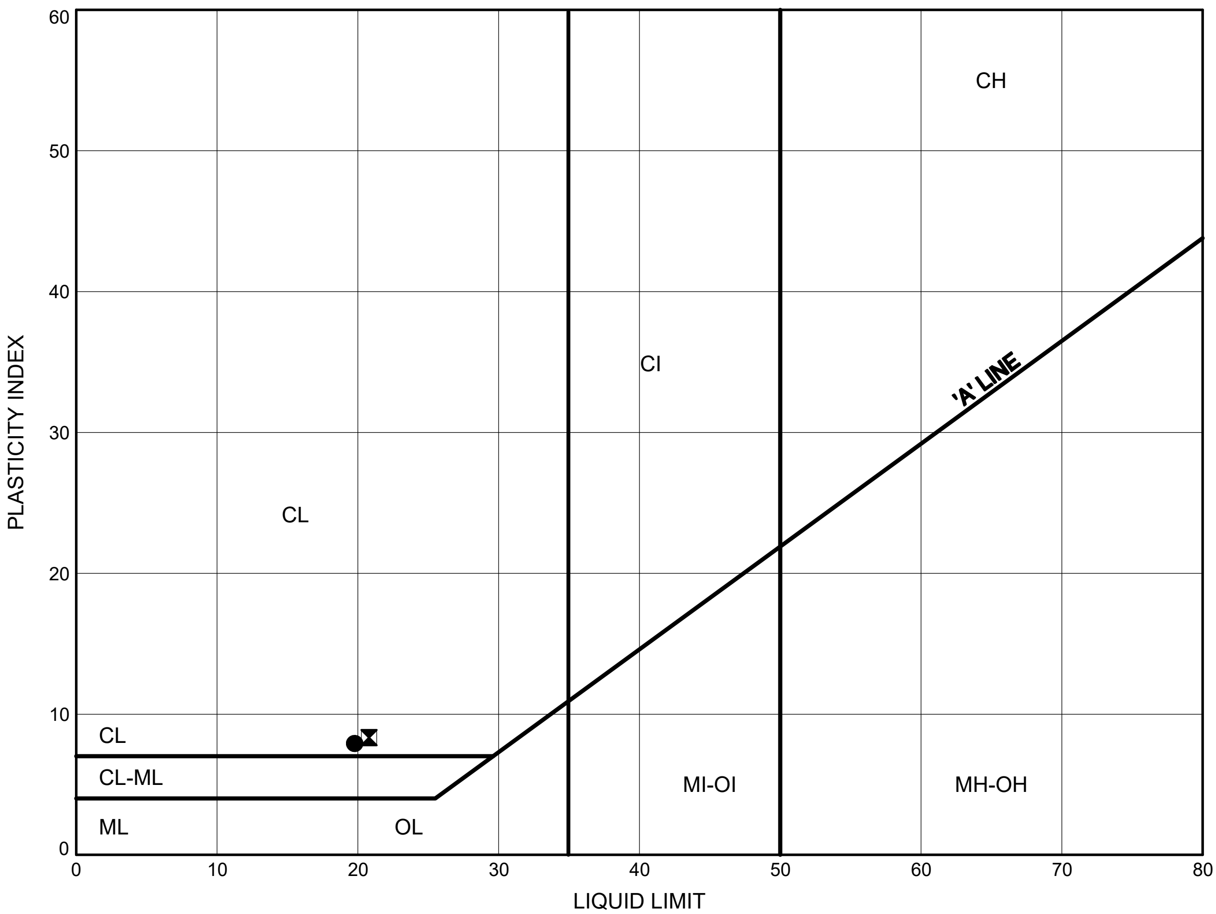
Chkd. MEF

Hwy 401 - Highbury Avenue Interchange

ATTERBERG LIMITS TEST RESULTS

FIGURE B18

Lower Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	38.40	244.11
⧗	16-06	39.93	242.60

Date April 2016

W.P. 3032-11-00

THURBER

Prep'd AN

Chkd. MEF

Certificate of Analysis

AGAT Laboratories

AGAT WORK ORDER: 16T083603

PROJECT: Highbury Ave

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

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: MARK FARRANT

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-04-08

DATE REPORTED: 2016-04-11

Parameter	Unit	G / S	RDL	7476431	RDL	7476443	RDL	7476444
SAMPLE DESCRIPTION:				16-04, SS#6, 15'-17'		16-05, SS#5, 10'-12'		16-06, SS#9, 30'-32'
SAMPLE TYPE:				Soil		Soil		Soil
DATE SAMPLED:				4/7/2016		4/7/2016		4/7/2016
Sulphide	%		0.05	<0.05	0.05	<0.05	0.05	<0.05
Chloride (2:1)	µg/g		8	2220	4	709	2	494
Sulphate (2:1)	µg/g		8	43	4	13	2	21
pH (2:1)	pH Units		NA	8.95	NA	9.65	NA	8.72
Electrical Conductivity (2:1)	mS/cm		0.005	3.53	0.005	1.25	0.005	0.868
Resistivity (2:1)	ohm.cm		1	283	1	800	1	1150
Redox Potential (2:1)	mV		5	238	5	216	5	279

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

7476431-7476443 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
Elevated RDL indicates the degree of sample dilution prior to the analysis for Anions in order to keep analyte within the calibration range of the instrument and to reduce matrix interference.

7476444 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Certified By: Amanjot Bhela

THURBER

Appendix C

Factual Data from 2012 Foundation Investigation Report

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 1

METRIC

W.P. GWP 3032-11-00 | LOCATION Highbury Ave. South Side Northing - 4755997, Easting - 412530 | ORIGINATED BY JL

DIST London HWY 401 | BOREHOLE TYPE 110 mm H/S and Wash Boring | COMPILED BY JL

DATUM Geodetic | DATE 14.2.12 - 16.2.12 | CHECKED BY EC

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
275.04	Ground
0.00	200 mm Asphalt
	710 mm Dark Brown Granular Fill.
274.13 / 0.91	FILL Brown, moist, loose, consisting mainly of silty clay with some sand and gravel, trace organics.
272.75 / 2.29	Silty SAND to SILT, SM to ML Wet to saturated, compact to very dense. Brown – – Grey
260.56 / 14.48	Layered SILT and Clayey SILT, ML to CL-ML, layered Grey, wet to saturated, dense to very dense or hard.

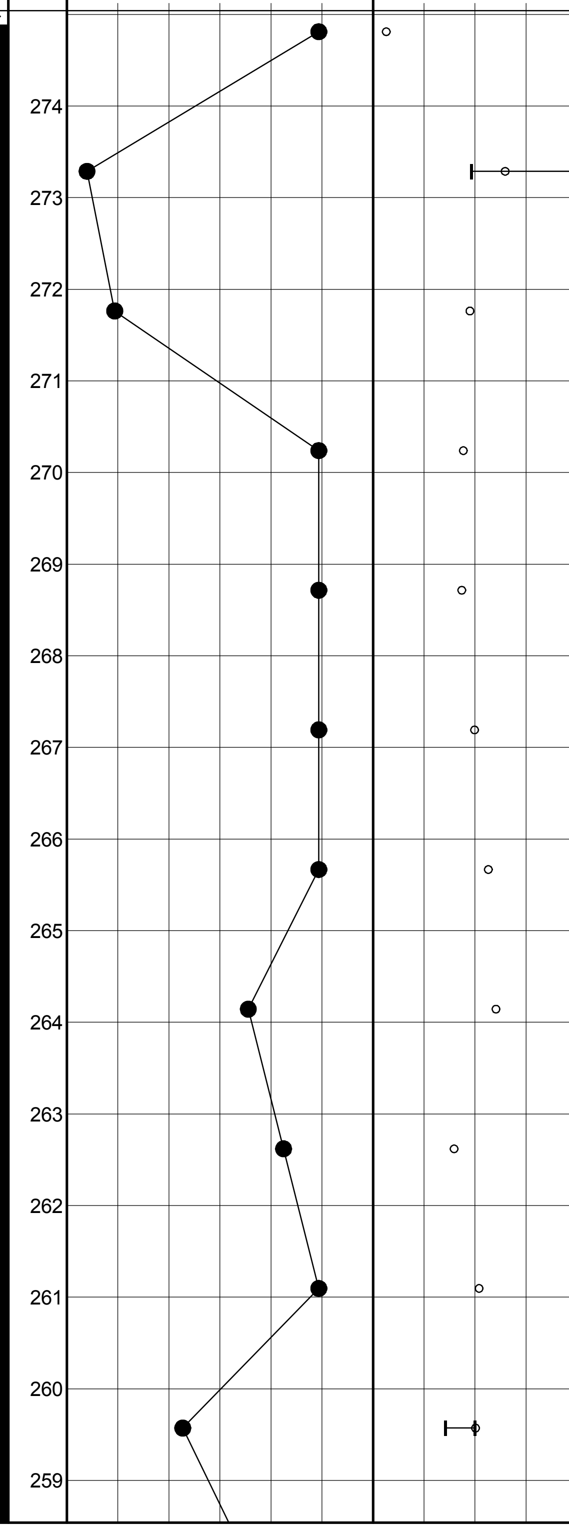
SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SPT	100+	Top of casing @ Elev. 274.98 m.
2	SPT	8	1 11 50 38 (88); Unit weight 15.9 kN/m³; 42
3	SPT	19	0 19 77 4 (81)
4	SPT	100+	0 19 80 2 (81)
5	SPT	100+	1 44 53 2 (55)
6	SPT	100+	0 42 54 4 (58)
7	SPT	100+	0 73 26 2 (27)
8	SPT	72	0 65 34 2 (35)
9	SPT	86	0 3 84 13 (97)
10	SPT	100+	0 6 91 3 (94)
11	SPT	46	0 1 80 19 (99)

Water level measured @ 5.3 m on Feb. 15, 2012

Water level measured @ 11.5 m on May 31, 2012

PENETR. RESISTANCE STANDARD ● DYN. CONE; SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%)



Continued Next Page

+3, ×3: Numbers refer to Sensitivity   ○150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

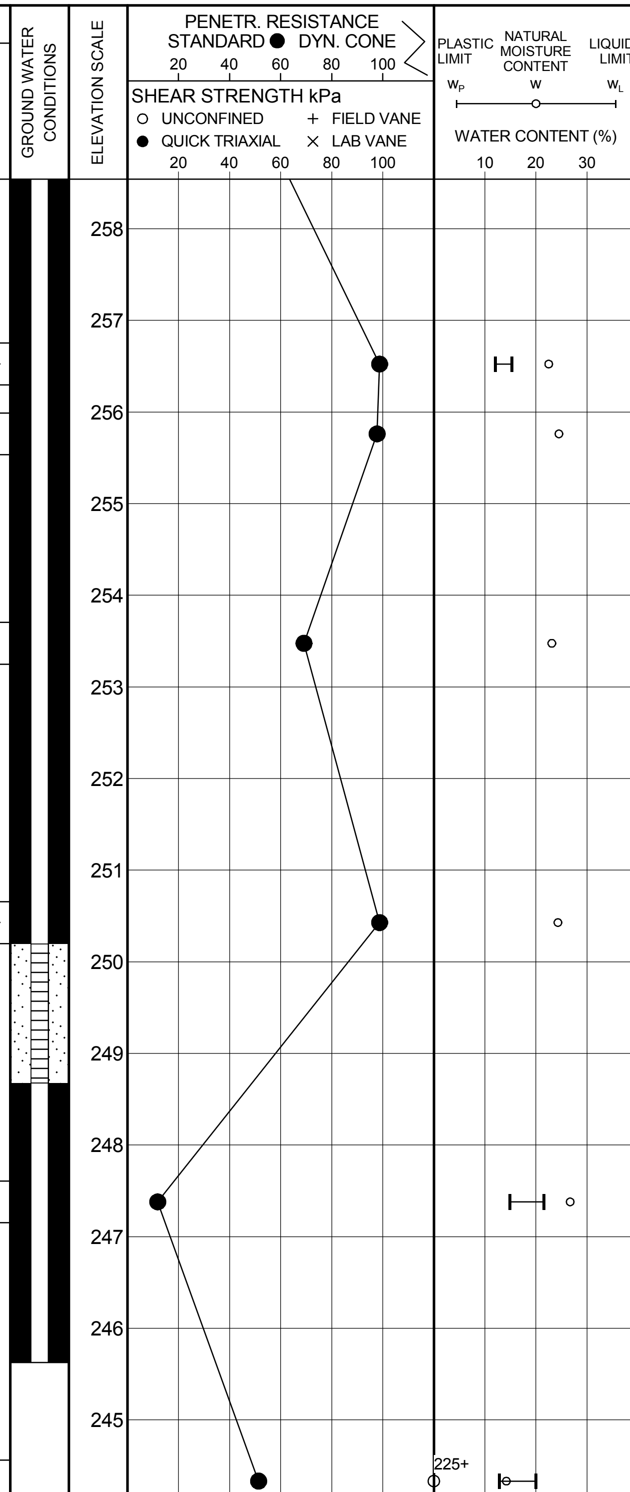
Ministry of Transportation Ontario

RECORD OF BOREHOLE No 1

METRIC

W.P.	GWP 3032-11-00	LOCATION	Highbury Ave. South Side Northing - 4755997, Easting - 412530	ORIGINATED BY	JL
DIST	London HWY 401	BOREHOLE TYPE	110 mm H/S and Wash Boring	COMPILED BY	JL
DATUM	Geodetic	DATE	14.2.12 - 16.2.12	CHECKED BY	EC

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Layered SILT and Clayey SILT, ML to CL-ML, layered Grey, wet to saturated, dense to very dense or hard. *(continued)*	12	SPT	100+	17.3	0	33	39	29 (67)
256.20 / 18.84	SAND to Silty SAND , SP to SM Grey, saturated, very dense.	13	SPT	99		0	95		(5)
		14	SPT	70		0	83	14	3 (17)
		15	SPT	100+		0	75	21	4 (25)
247.61 / 27.43	Clayey Silt, CL-ML Grey, wet to moist, stiff to hard, with embedded sand and gravel (TILL). frequent wet silt seams	16	SPT	12		2	8	68	22 (90)
		17	SPT	52	22.8	4	17	53	26 (79)
244.10 / 30.94	End of borehole								



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

○ [150] UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No 2

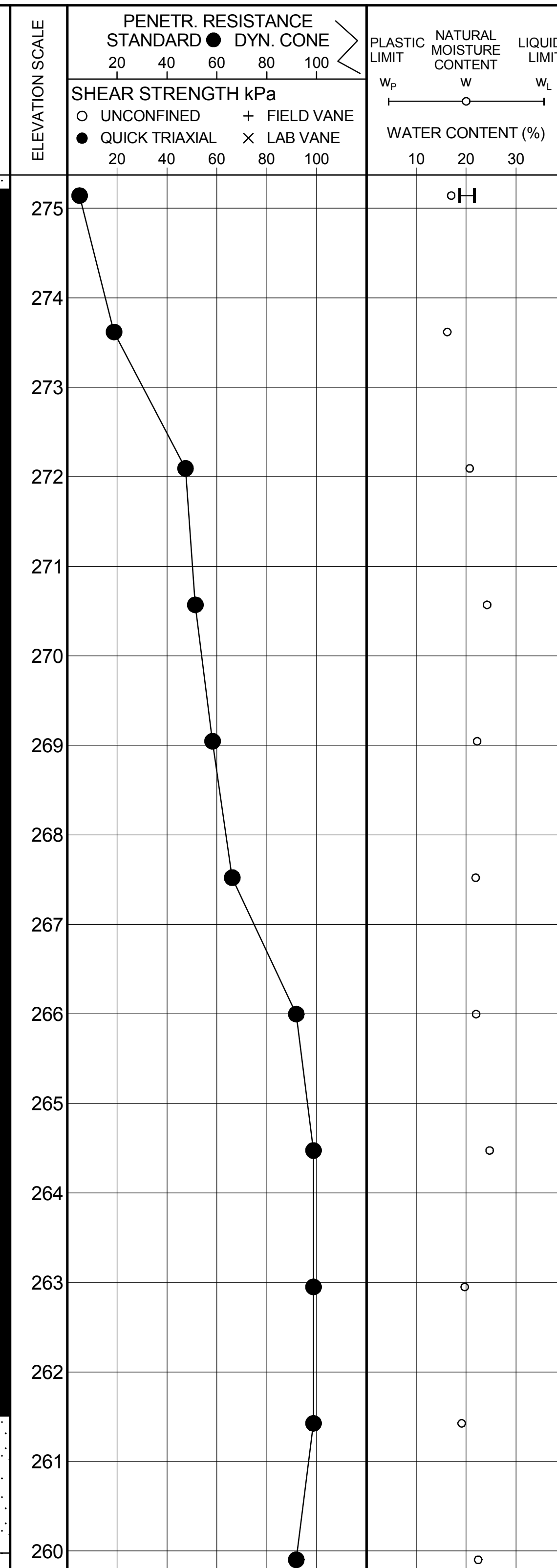
METRIC

W.P. GWP 3032-11-00 LOCATION Highbury Ave. North Side Northing - 4756050, Easting - 412547 ORIGINATED BY JL

DIST London HWY 401 BOREHOLE TYPE 110 mm H/S and Wash Boring COMPILED BY JL

DATUM Geodetic DATE 16.2.12 - 17.2.12 CHECKED BY EC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS	GR	SA	SI	CL
275.37	Ground								
0.00 / 274.91	460 mm silty sand FILL, some gravel.	1	SPT	5		10	46	32	11 (44)
0.46 / 273.69	FILL Brown, moist, loose, consisting mainly of silty clay with some sand and gravel, trace organics.								
1.68	Silty SAND to SILT, SM to ML Moist to saturated, compact to very dense, occasional silty clay seams. Brown	2	SPT	19					
		3	SPT	48	Water level measured at 3.5 m on Feb. 17, 2012.	0	76	22	2 (24)
		4	SPT	52	Water level measured @ 4.45 m on May 31, 2012	2	76	19	4 (23)
		5	SPT	59		0	49	48	2 (51)
		6	SPT	67		0	4	88	8 (96)
		7	SPT	93		0	0	88	12 (100)
		8	SPT	100+		0	80	18	2 (20)
	Grey	9	SPT	100+		0	43	53	4 (57)
		10	SPT	100+		0	13	83	5 (87)
259.67		11	SPT	93		0	0	90	10 (100)
15.70	End of Borehole								



UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity ○150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

THURBER

Appendix D

Borehole Locations and Soil Strata Drawings

MINISTRY OF TRANSPORTATION, ONTARIO

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

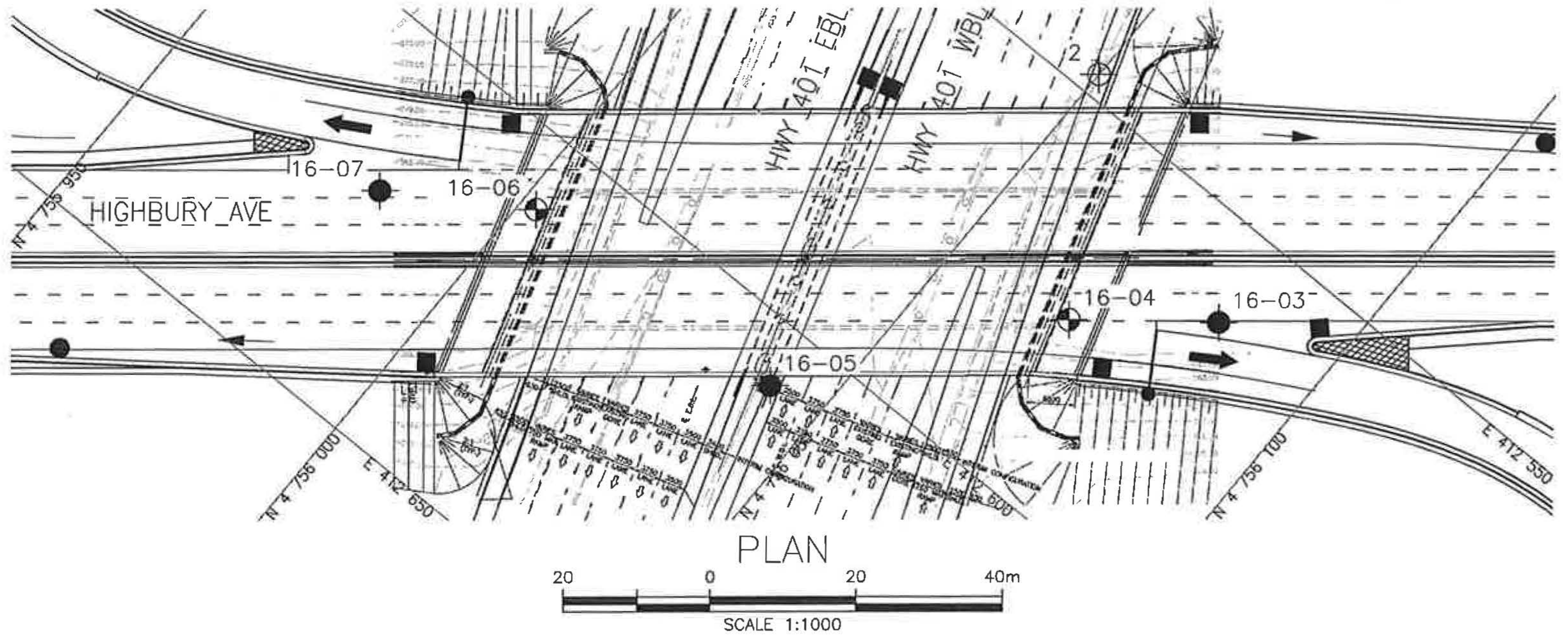
CONT No
WP No 3032-11-00

HIGHWAY 401
HIGHBURY AVENUE
INTERCHANGE – OVERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

THURBER ENGINEERING LTD.



LICENSED PROFESSIONAL ENGINEER
S. PANG
Apr 26/16
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Apr 26/16
PROVINCE OF ONTARIO

KEYPLAN

LEGEND

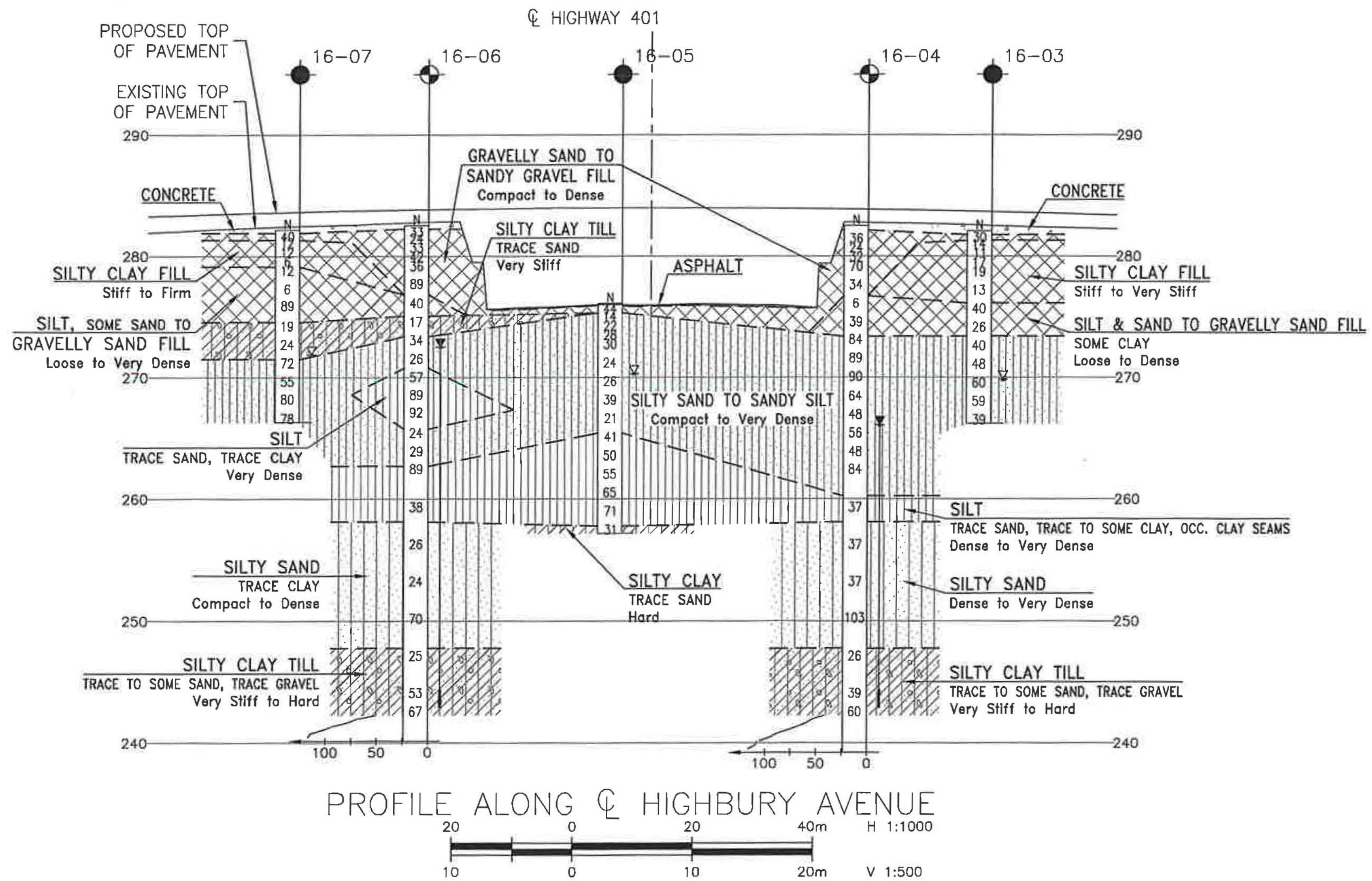
●	Borehole (Present Investigation)
⊕	Borehole and Cone (Present Investigation)
⊕	Borehole and Cone (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
▽	Water Level
▼	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-01	272.7	4 756 183.3	412 612.8
16-02	272.6	4 756 158.1	412 555.7
16-03	282.1	4 756 084.2	412 562.8
16-04	282.5	4 756 068.3	412 575.4
16-05	276.1	4 756 042.3	412 608.1
16-06	282.5	4 756 002.3	412 609.7
16-07	282.2	4 755 984.1	412 621.1
16-08	280.3	4 755 908.3	412 657.4
16-08A	273.2	4 755 914.0	412 628.0
16-09	277.8	4 755 861.7	412 595.5
16-09A	272.6	4 755 881.0	412 592.0
1	275.0	4 755 997.0	412 530.0
2	275.4	4 756 050.0	412 547.0

-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. 40I14-165



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PLOTDATE: 4/21/2016 2:10 PM

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 3032–11–00

HIGHWAY 401
HIGHBURY AVENUE
INTERCHANGE – ABUTMENTS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

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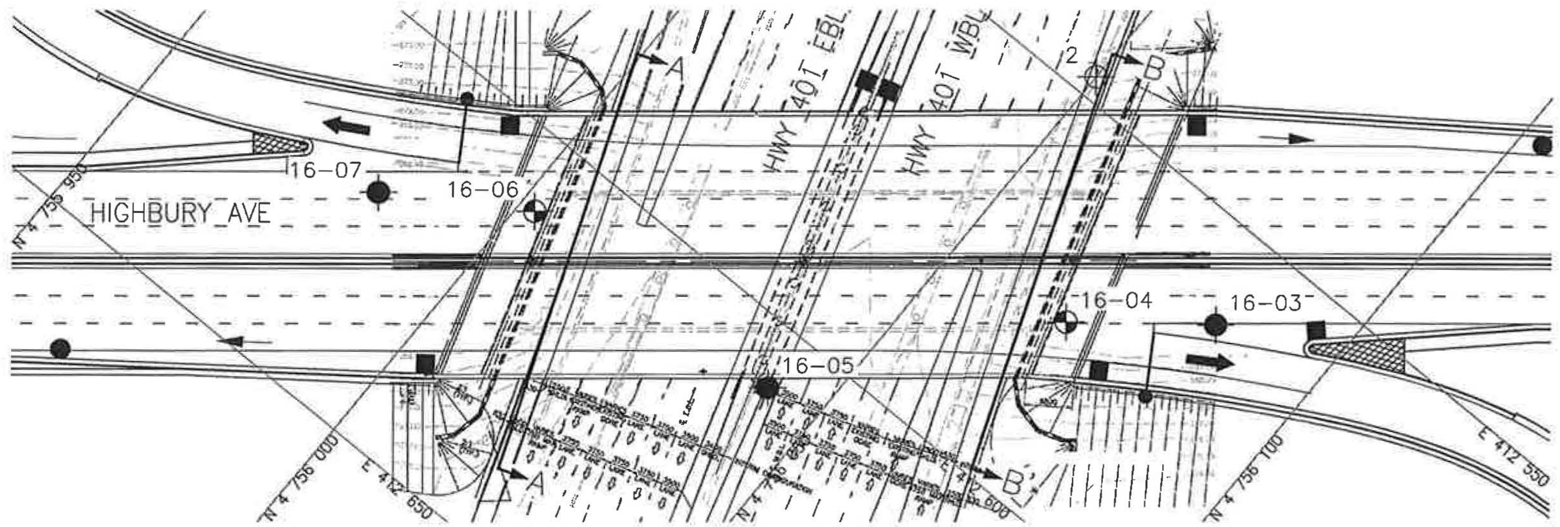
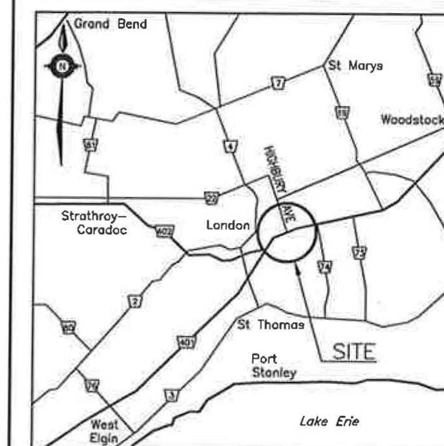
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
April 26/16
PROVINCE OF ONTARIO



PLAN

20 0 20 40m
SCALE 1:1000



KEYPLAN

LEGEND

●	Borehole (Present Investigation)
◈	Borehole and Cone (Present Investigation)
⊕	Borehole and Cone (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
⊻	Water Level
⊻	Head Artesian Water
ǀ	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16–01	272.7	4 756 183.3	412 612.8
16–02	272.6	4 756 158.1	412 555.7
16–03	282.1	4 756 084.2	412 562.8
16–04	282.5	4 756 068.3	412 575.4
16–05	276.1	4 756 042.3	412 608.1
16–06	282.5	4 756 002.3	412 609.7
16–07	282.2	4 755 984.1	412 621.1
16–08	280.3	4 755 908.3	412 657.4
16–08A	273.2	4 755 914.0	412 628.0
16–09	277.8	4 755 861.7	412 595.5
16–09A	272.6	4 755 881.0	412 592.0
1	275.0	4 755 997.0	412 530.0
2	275.4	4 756 050.0	412 547.0

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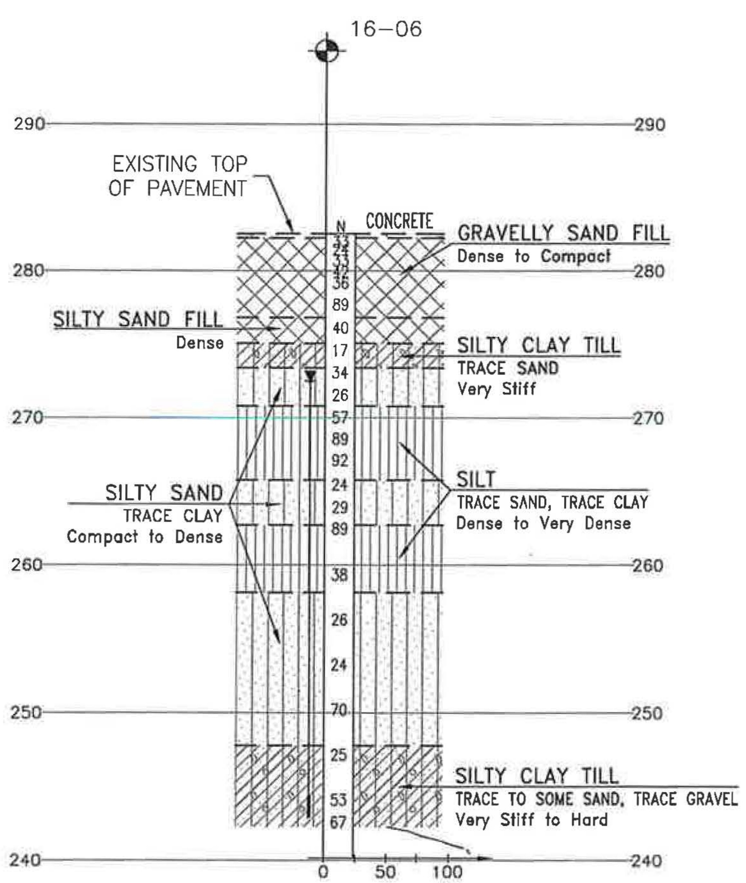
GEOCRES No. 40I14-165



SECTION A–A'

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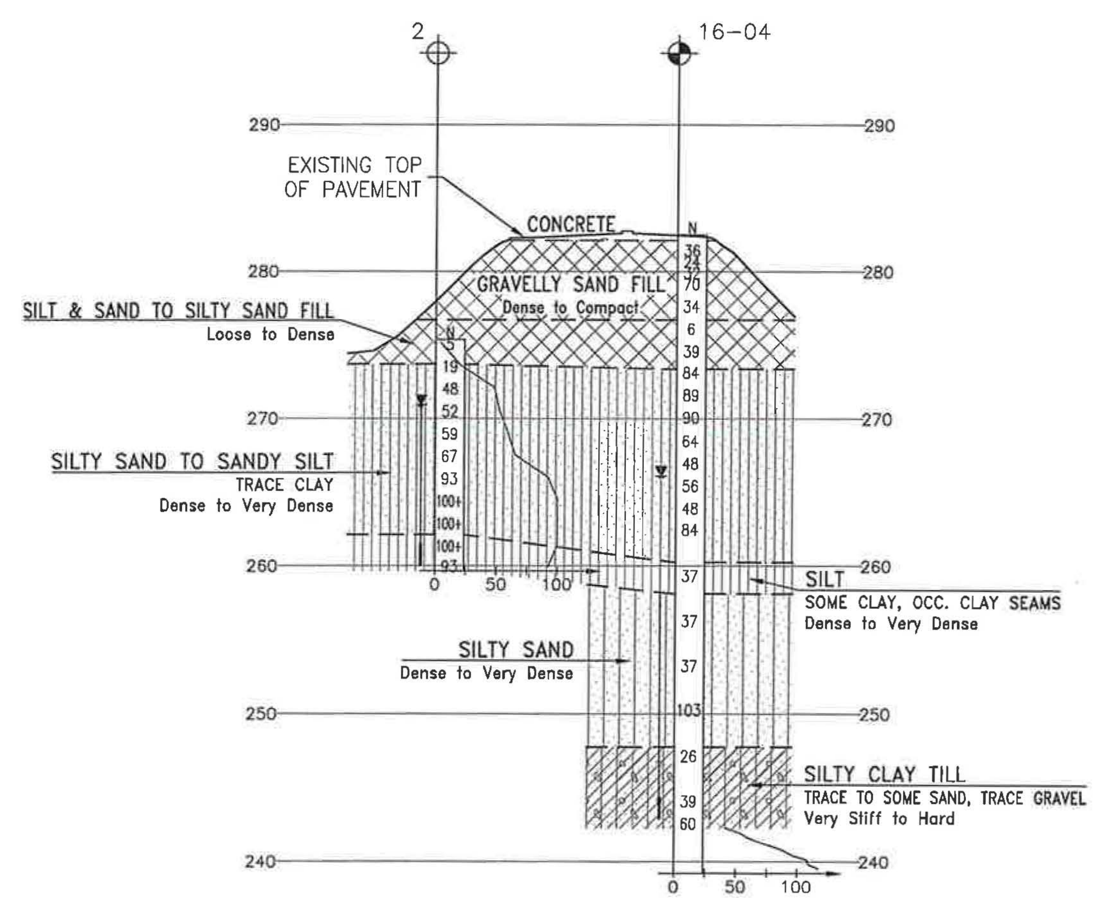
10 0 10 20m V 1:500



SECTION B–B'

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REVISIONS	DATE	BY	DESCRIPTION

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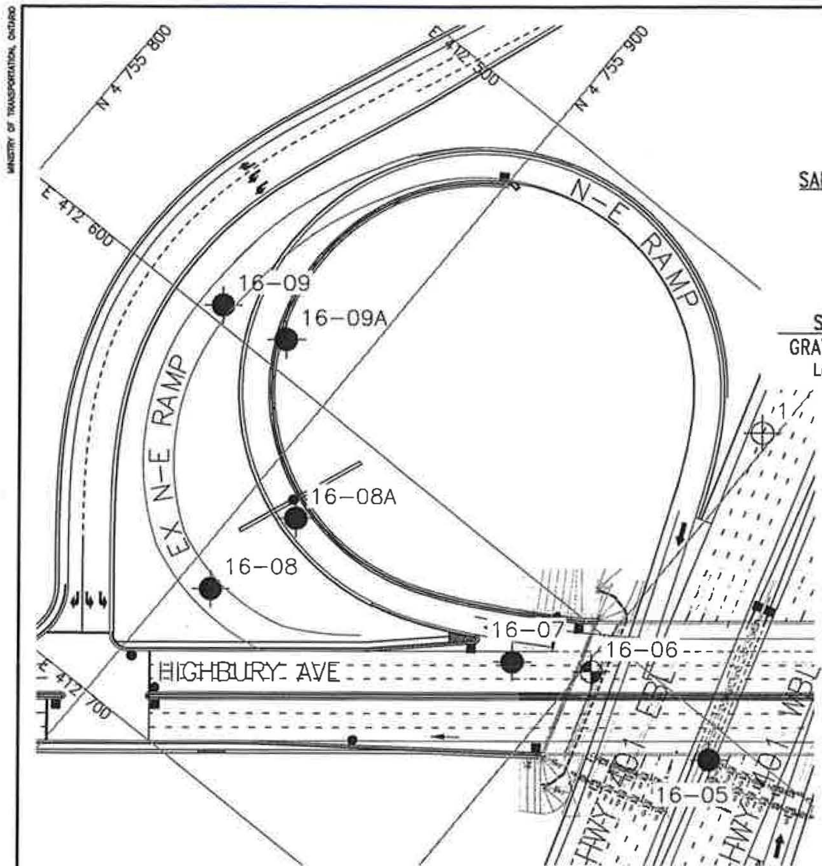
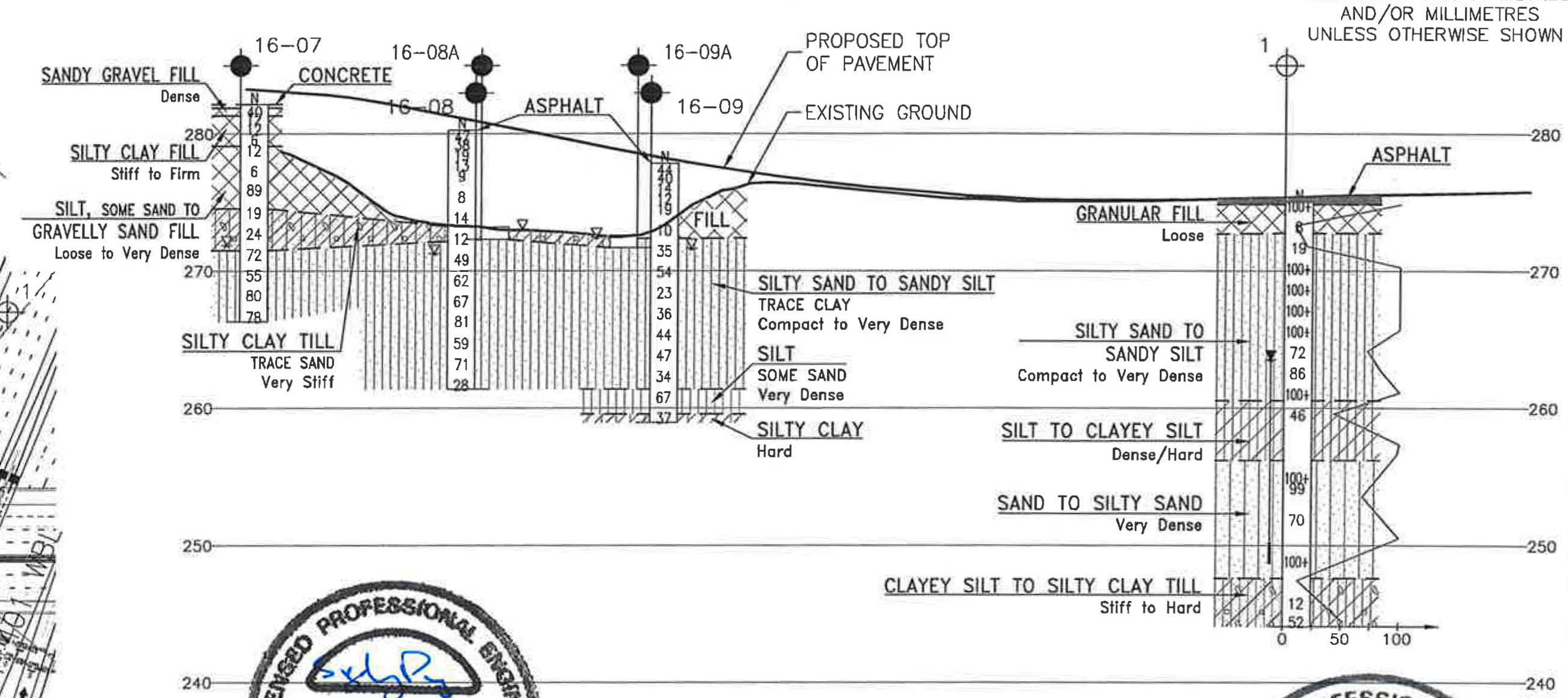


PLAN N-E RAMP

40 0 40 80m

SCALE 1:2000



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PROFILE ALONG ℄ N-E RAMP

40 0 40 80m H 1:2000

10 0 10 20m V 1:500

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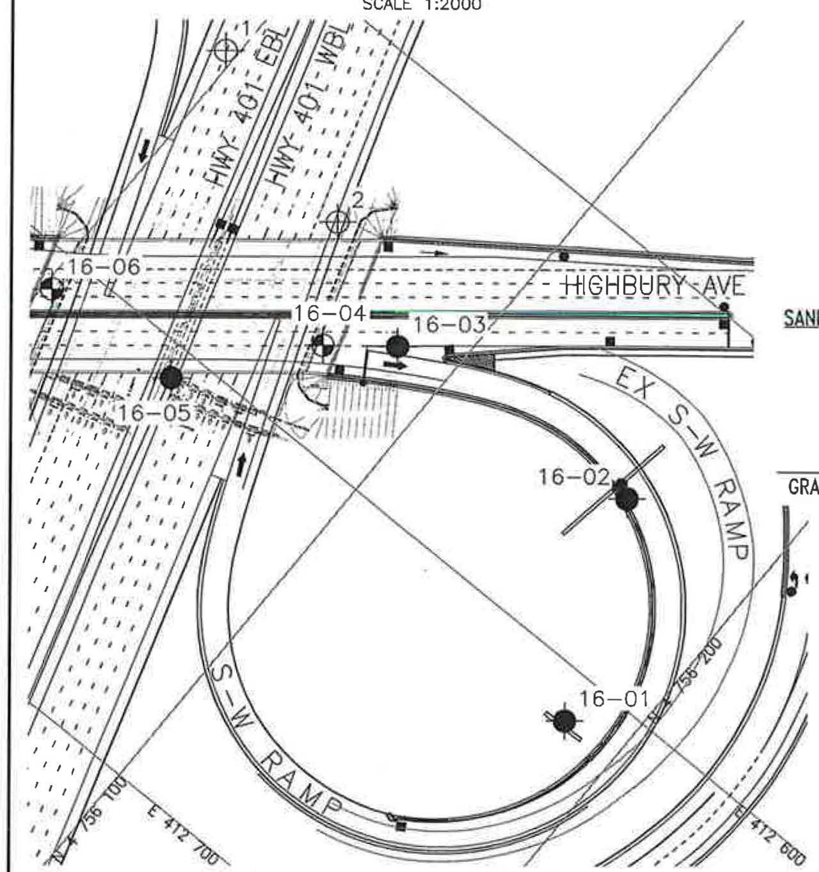
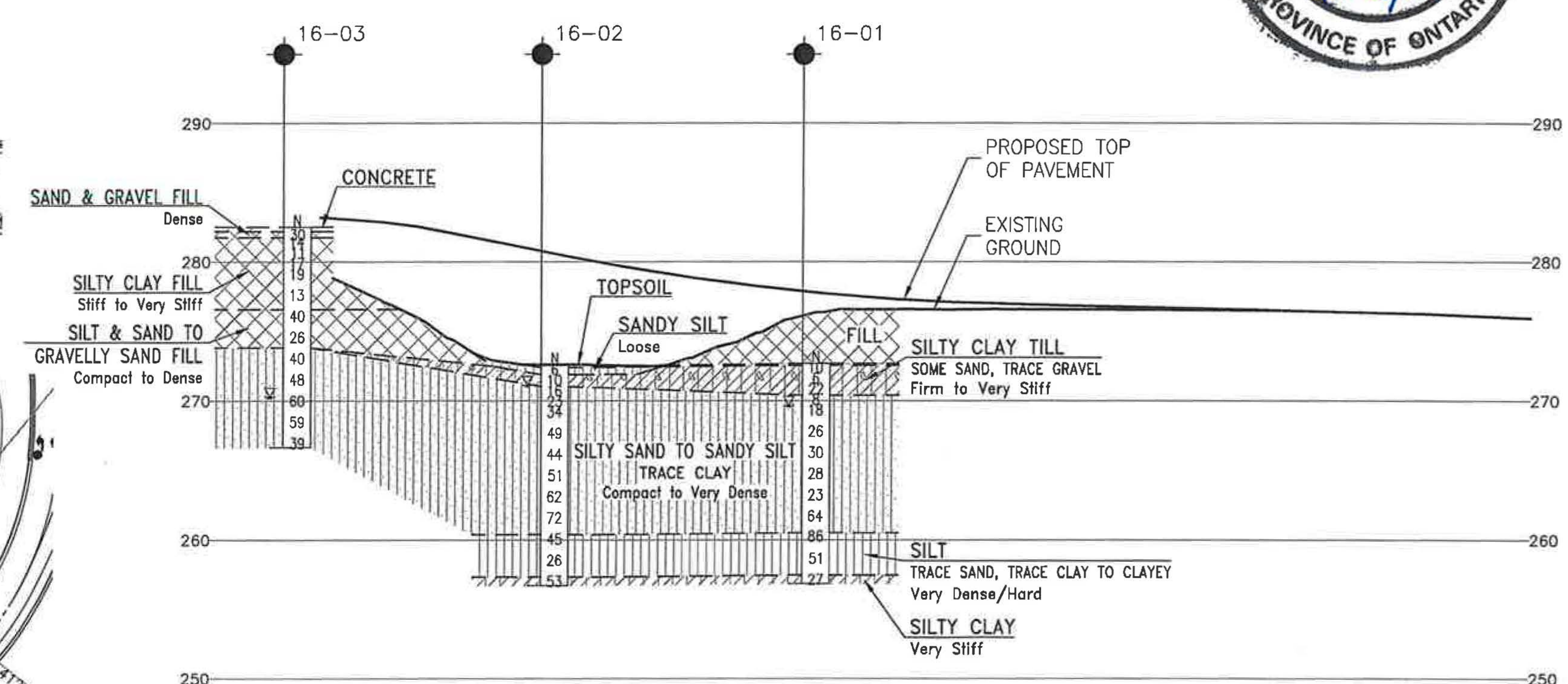
April 26/16
PROVINCE OF ONTARIO



PLAN S-W RAMP

40 0 40 80m

SCALE 1:2000



PROFILE ALONG ℄ S-W RAMP

40 0 40 80m H 1:2000

10 0 10 20m V 1:500

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

WP No 3032-11-00

HIGHWAY 401
HIGHBURY AVENUE
INTERCHANGE – RAMPS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

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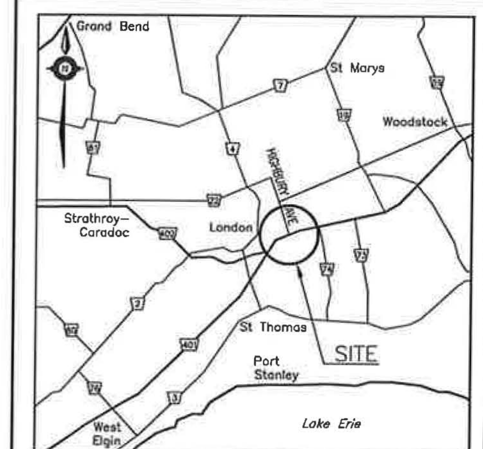

KEYPLAN

LEGEND

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GEOCRES No. 40I14-165

REVISIONS	DATE	BY	DESCRIPTION

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FILENAME: H:\Drafting\10000+\10552\TED-10552-PLPR.dwg
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Appendix E

Site Photographs

Photo 1: Looking west towards east side of the underpass structure.

Photo 2: Looking north towards east side of the north abutment.

Photo 3: Looking south towards east side of the south abutment.

Photo 4: Looking south along east side of north approach embankment

Photo 5: Looking north along west side of south approach embankment

Photo 6: Looking west towards existing S-W ramp embankment

Photo 7: Looking southwest towards existing N-E ramp

Appendix F

Foundation Comparison

THURBER

COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings on Native Soils	Driven Steel H-Pile into Lower Silty Clay Till	Driven Steel Pipe Piles Lower Silty Clay Till	Augered Caissons (Drilled Shafts) into Lower Silty Clay Till
Advantages: i. Ease of construction. ii. Lower cost than deep foundations. ***Disadvantages:*** i. Lower geotechnical capacity than deep foundations. ii. Relatively large excavations and dewatering may be required, depending on depth of excavation and groundwater level at time of construction. iii. May increase requirements for roadway protection.	***Advantages:*** i. Ease of construction. ii. Higher axial resistance than spread footings iii. Required for integral abutments. ***Disadvantages:*** i. Higher unit cost than footings. ii. Cobbles and boulders may be encountered in glacially derived soils that could impede pile penetration to required depths.	***Advantages:*** i. Higher axial resistance than driven H-piles ***Disadvantages:*** i. Not suitable for integral abutments ii. More severe vibrations and noise during pile driving iii. Cobbles and boulders may be encountered in glacially derived soils that could result in damage to pile tips	***Advantages:*** i. Higher lateral resistance than H-piles is available due to higher stiffness. ii. Fewer caissons are required for each foundation element than if steel piles were used. iii. Minimal requirements for sub-excavation of fill and native soils. ***Disadvantages:*** i. Not suitable for integral abutments. ii. Steel liners will be required to install caissons to minimize sidewall sloughing, water seepage and basal instability.
FEASIBLE AT PIER **NOT FEASIBLE AT ABUTMENTS**	**RECOMMENDED AT ABUTMENTS** **FEASIBLE AT PIER**	**NOT RECOMMENDED**	**FEASIBLE IF INTEGRAL ABUTMENTS ARE NOT USED**

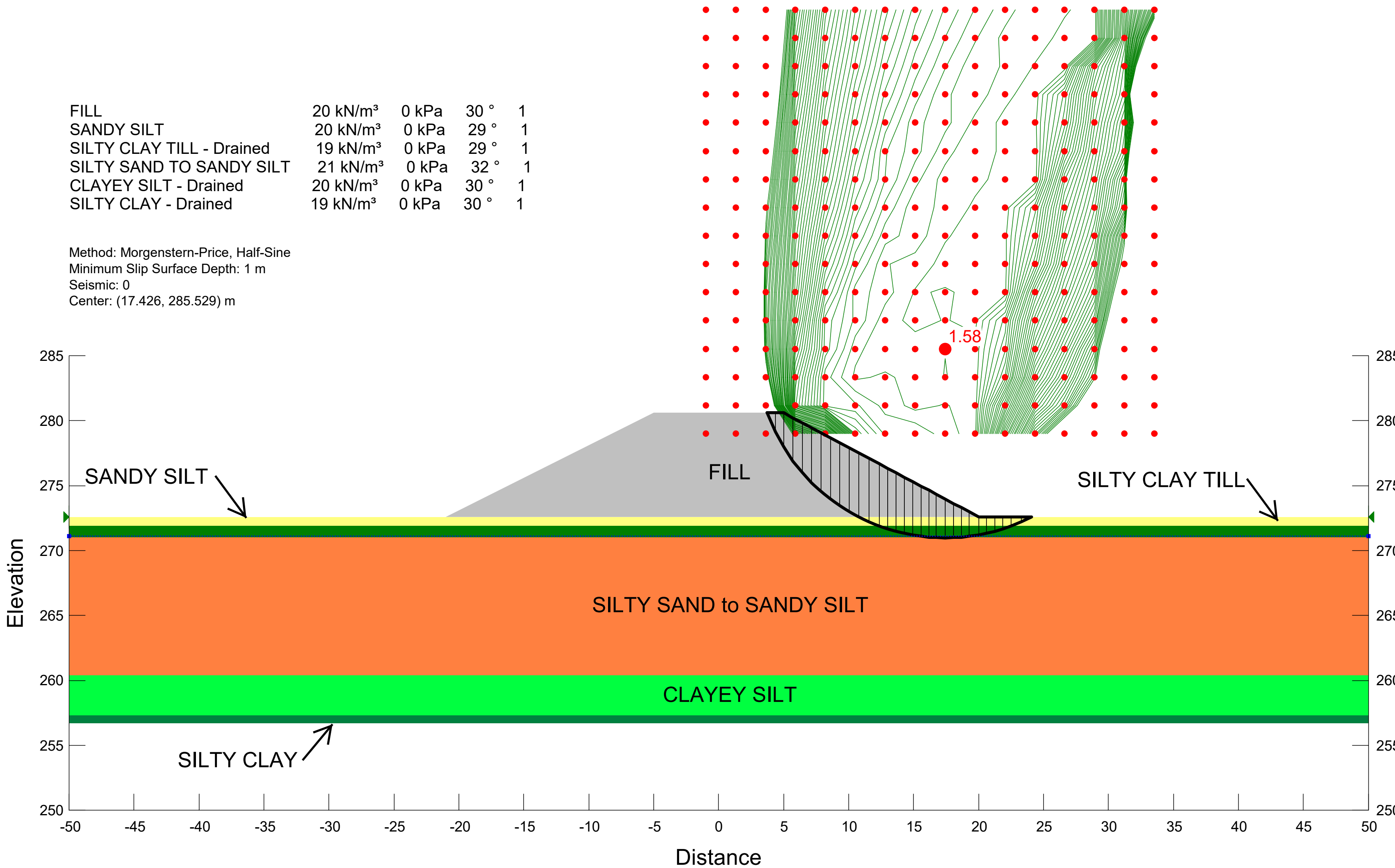
THURBER

Appendix G

Selected Embankment Stability Analyses Results

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
S-W RAMP (DRAINED)

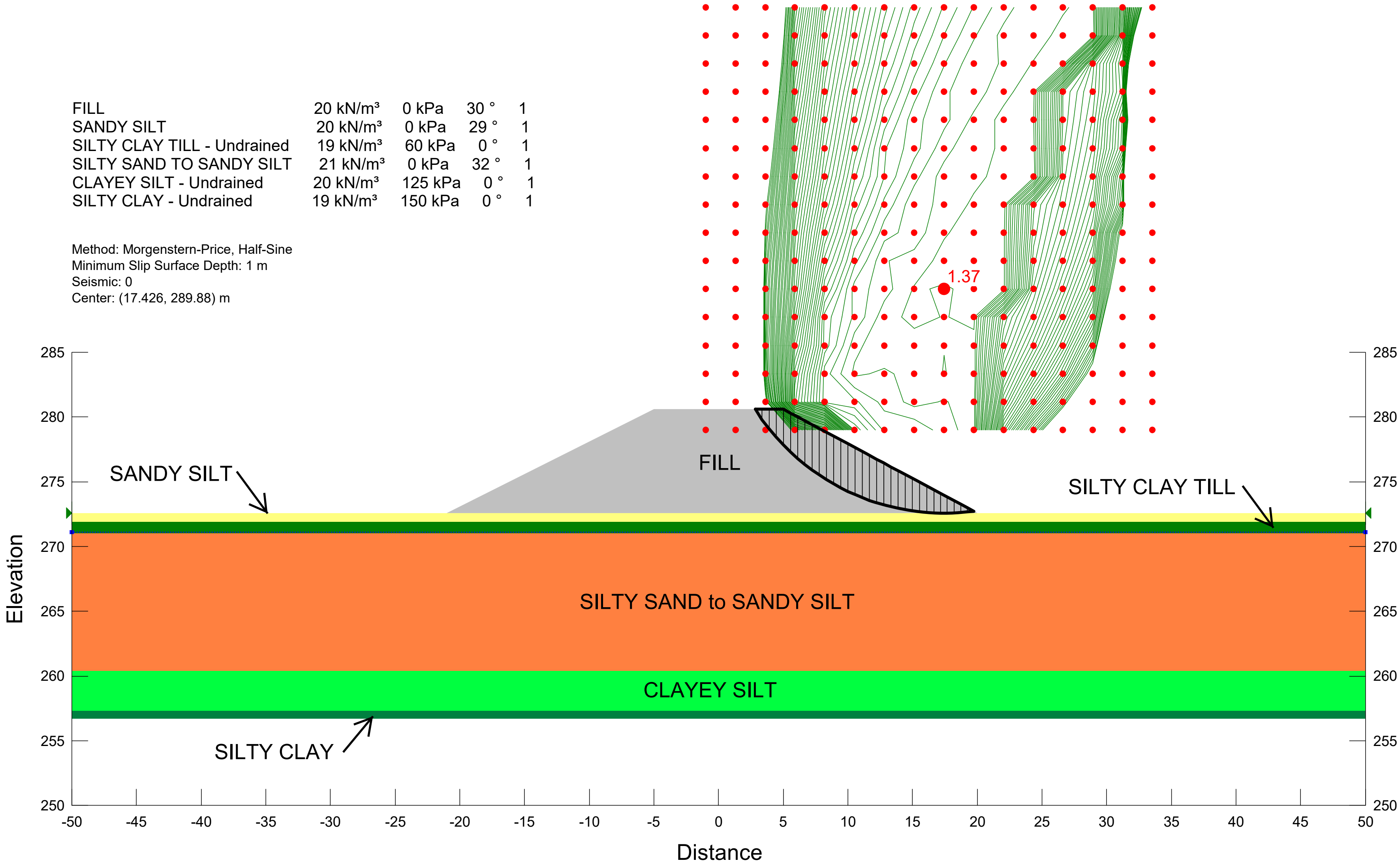
FIGURE G1



Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
S-W RAMP (UNDRAINED)

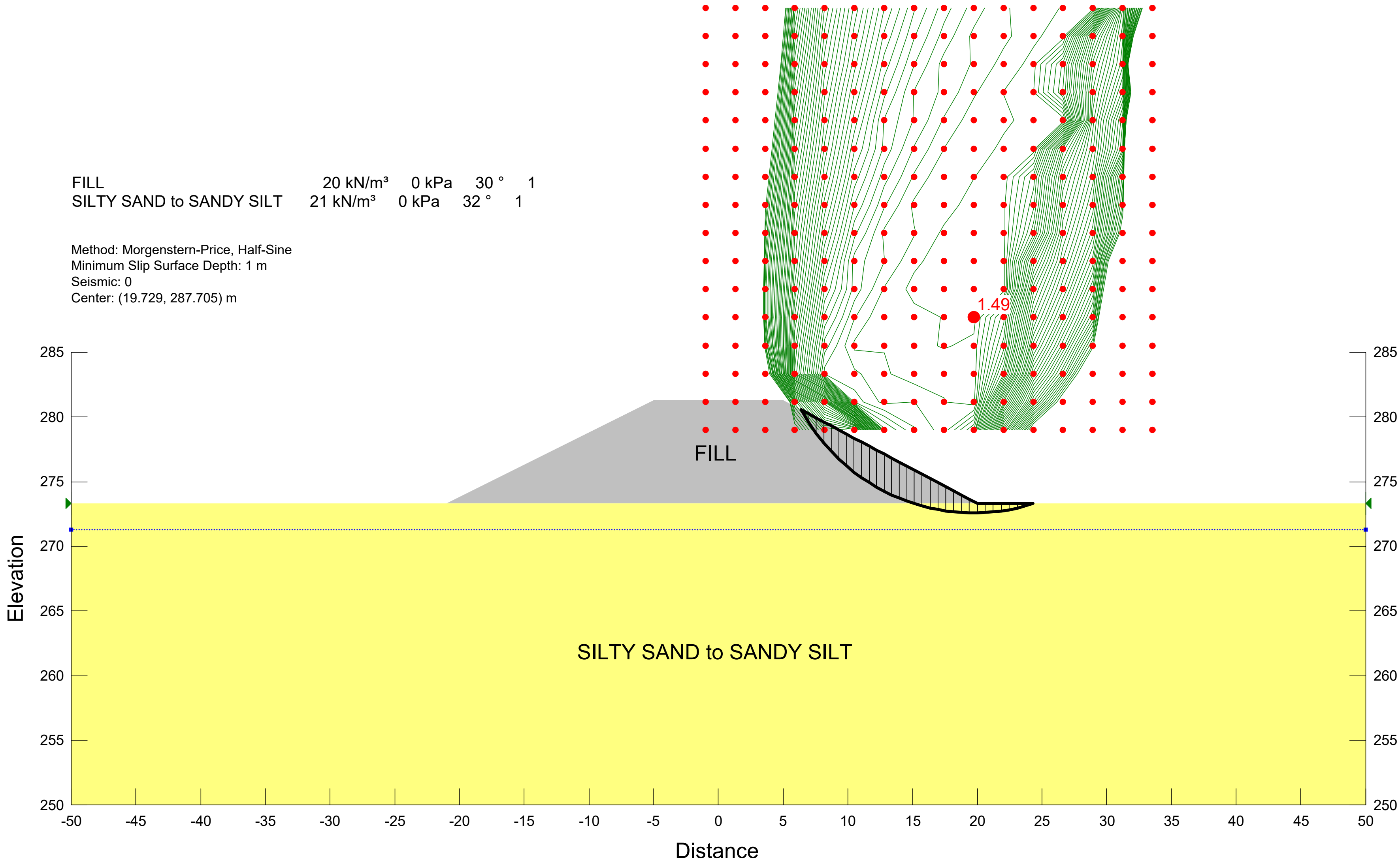


Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
N-E RAMP (DRAINED)

FIGURE G3

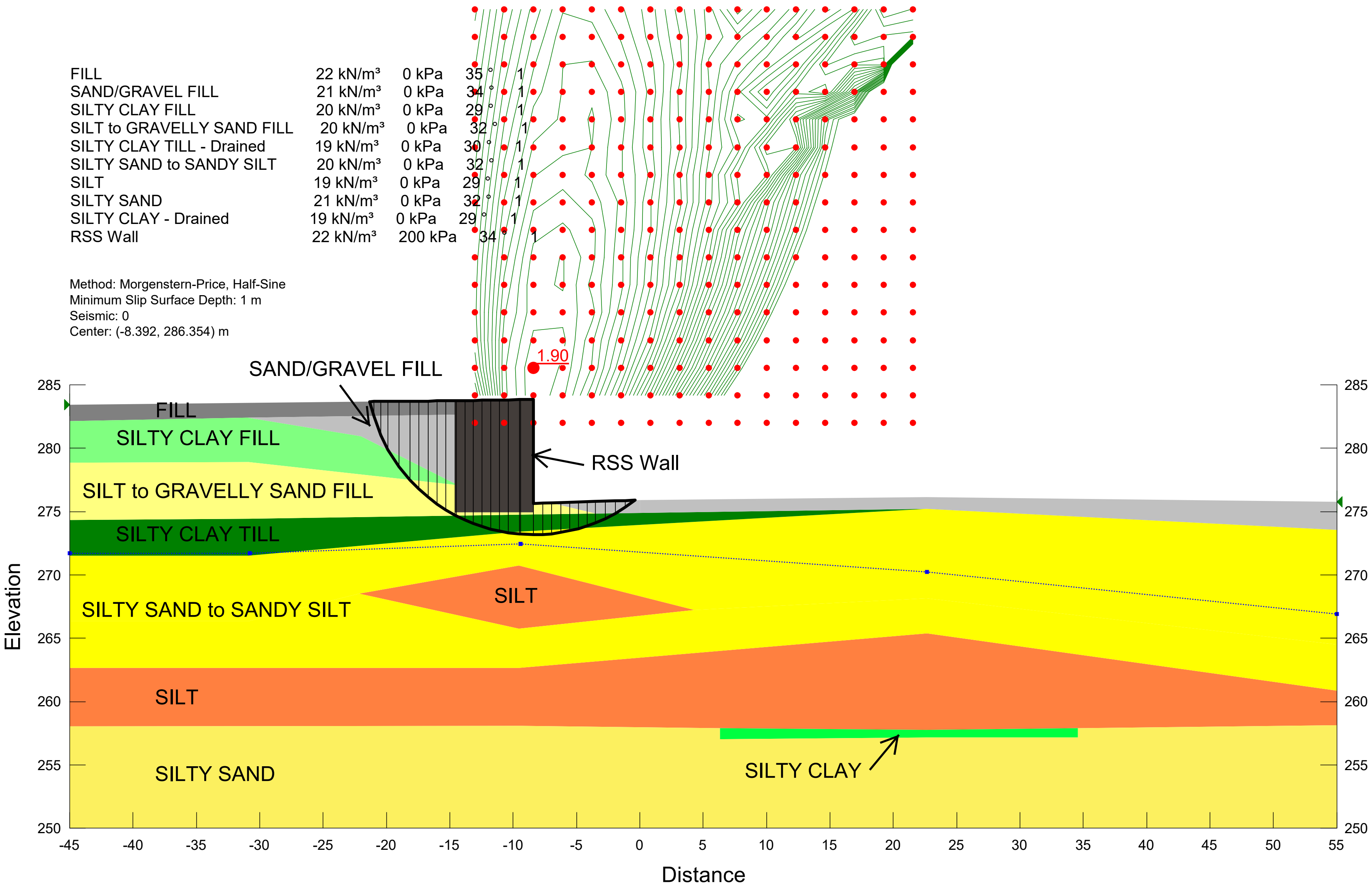


Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
SOUTH APPROACH (DRAINED)

FIGURE G4

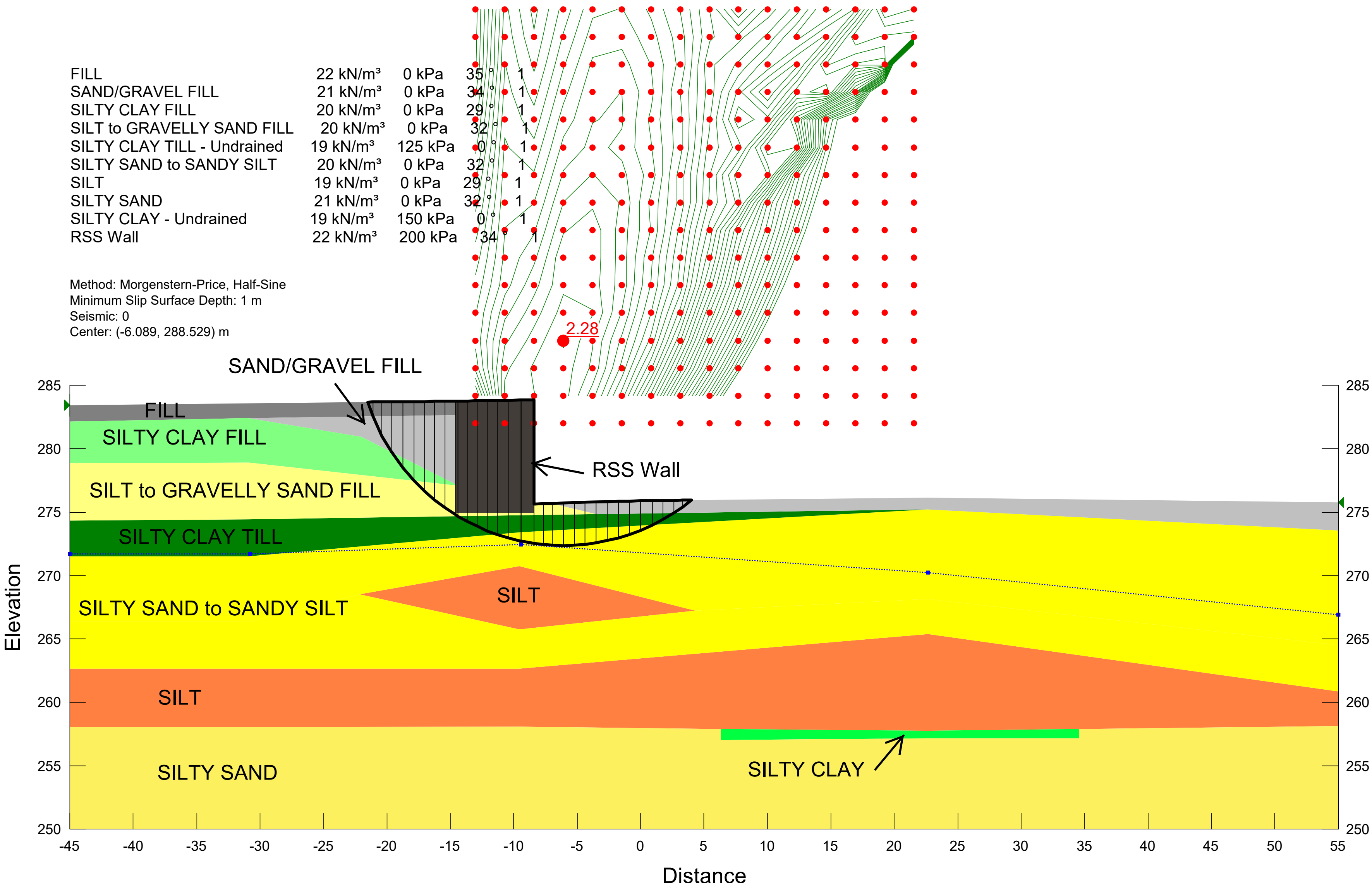


Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
SOUTH APPROACH (UNDRAINED)

FIGURE G5

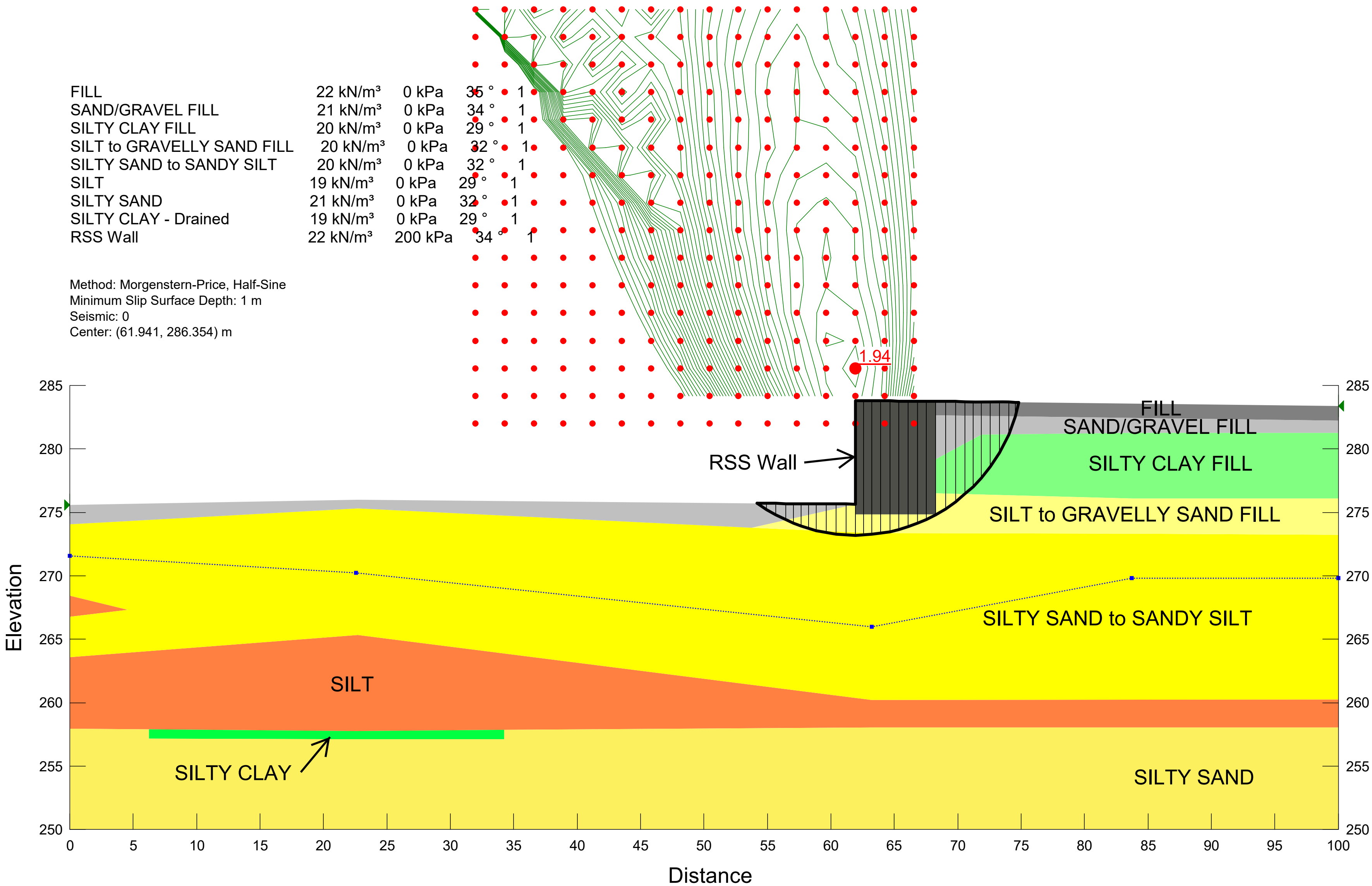


Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
NORTH APPROACH (DRAINED)

FIGURE G6

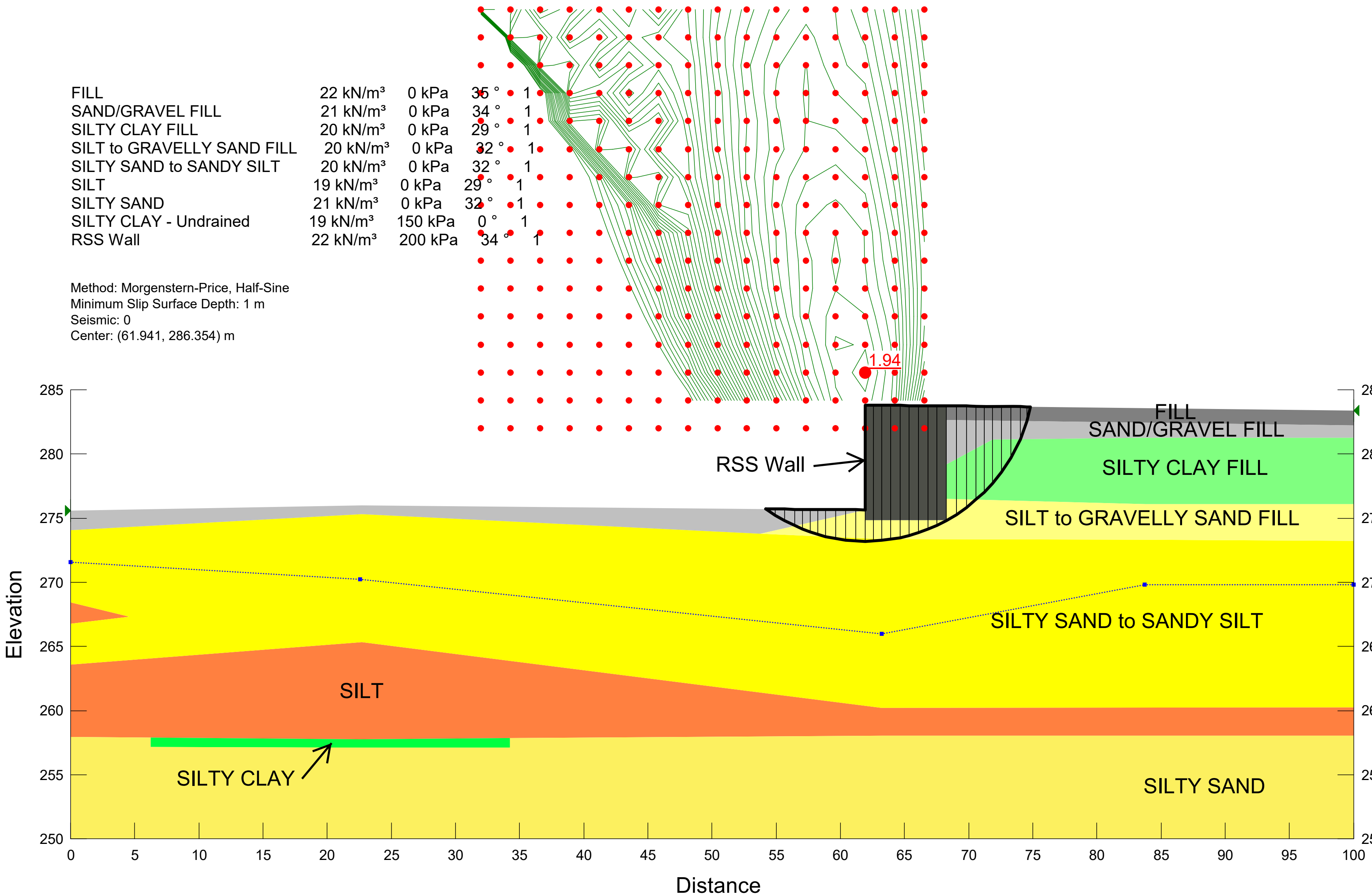


Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

FIGURE G7

HIGHWAY 401 – HIGHBURY AVENUE INTERCHANGE
NORTH APPROACH (UNDRAINED)



Date: April 2016
File No.: 10552

Analysis By: MKE
Reviewed By: SKP

THURBER

Appendix H

List of SPs and OPSS, and Suggested Text for Selected NSSP

THURBER

1. List of OPSS Documents Referenced in this Report

- OPSS 903
- OPSS 206
- OPSS.PROV 804
- OPSS 501
- OPSS.PROV 539
- OPSS 902
- OPSS.PROV 1010
- OPSS.PROV 212

- OPSD 3101.150
- OPSD 3102.100
- OPSD 208.010

2. Suggested Text for NSSP on "Footing Construction"

All footing construction procedures shall follow the guidelines provided in OPSS 902.

The base of the foundation excavation for pier footing construction should be inspected by a geotechnical engineer to confirm that the footing subgrade is in the native, undisturbed, compact silts and sands conforming to the design requirements and has been adequately prepared to receive concrete. Concrete or mud slab should be placed within 24 hours following completion of excavation to prevent deterioration of the approved subgrade. The mud slab should be at least 100 mm thick and formed with the same class of concrete as that of the footings. Where sub-excavation is required to remove unsuitable material from below the design founding level, the founding surface should be re-established using engineered fill or mass concrete of the same class as the footing.

The footing must be constructed in the dry. The native silts and sands are prone to disturbance. Water seepage from below the excavation base, perched water within the fill as well as accumulation of precipitation and surface runoff should be expected. Roadway protection extended to sufficient depth would serve as partial groundwater cutoff and to prevent sloughing of the sides or disturbance of the excavation base due to groundwater inflow. Dewatering prior to and during footing excavation may also be required to construct the footings in the dry.

3. Suggested Text for NSSP on "Monitoring of Existing Bridge"

Monitoring of the existing bridge abutments and piers is required during construction of the new bridge foundations and embankment fills. As a minimum, two reference points must be established on each abutment and pier of the existing structure, and the vertical and lateral positions of these points must be surveyed relative to known, fixed reference datum points on a regular basis.

The suggested monitoring frequency is as follows:

- Three readings on separate days prior to construction to establish a baseline
- Twice daily while any foundation construction or other subsurface construction is in progress
- Daily for one week after completion of foundation construction
- Twice weekly for the following week.

The vertical and horizontal precision of readings should be ±2 mm. All readings must be reported to the Contract Administrator within 24 hours and immediately if any movement exceeds limits set by the structural designers.

The Contract Administrator must be advised of the importance of monitoring and be required to advise the Ministry immediately if the vertical and horizontal movements exceed the specified limits.

4. Suggested Text for NSSP on "Monitoring of Highway 401 Lanes"

During construction, potential impact of excavation and fill placement on the existing pavement surface of Highway 401 should be monitored.

Daily visual inspection of the pavement surface shall be carried out in the vicinity of the fill placement. If cracks form in the pavement or settlement is observed to occur, the observations must be immediately reported to the Contract Administrator for determining whether remedial action is required. Such action may include temporarily re-paving the affected areas.