

**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF HIGHWAY 401 UNDERPASS
AT HIGHWAY 19, TOWN OF INGERSOLL
TOWNSHIP OF SOUTHWEST OXFORD
SITE No. 23-210, G.W.P. 3079-09-00
Geocres Number: 40P2-77**

**Submitted to
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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the location of a proposed replacement of the Highway 401 Underpass at Highway 19 in the Town of Ingersoll, Ontario. The replacement of the Highway 19 structure constitutes part of the Highway 401 improvement project. It is noted that Highway 19 is also known as Harris Street to the north of Highway 401 and Plank Line to the south of Highway 401.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to MMM Group Limited (MMM) under the Ministry of Transportation (MTO) Agreement Number 3013-E-0027.

A previous foundation investigation carried out at this site for the preliminary design of the Highway 401 / Highway 19 Interchange improvements was documented in the report "Preliminary Foundation Investigation and Design Report – Highway 19 Underpass, Site 23-210, Highway 401 Structure Replacements and Interchange Improvements" prepared by Stantec, dated February 2013, Geocres No. 40P2-74. The information presented in the above report was reviewed and incorporated in this report.

2 SITE DESCRIPTION

The existing underpass structure carries Highway 19 (Harris Street/Plank Line) over Highway 401 in the Town of Ingersoll. The structure is located approximately 29 km east of the intersection of Highway 401 and Highbury Avenue in London, Ontario. At the project site, Highway 401 runs approximately in the southwest-northeast direction, while Highway 19 runs generally northwest-southeast. For the purpose of this report, Highway 401 is assumed to run west-east, and Highway 19 is assumed to run north-south.

The existing underpass is a single span structure approximately 33 m in length and consists of one lane of traffic in each direction. Highway 401 is a six-lane (three lanes in each direction) divided freeway.

The surrounding land is gently undulating. The land use generally consists of a mixed agricultural land with a commercial property to the north and a parking lot directly west of the structure. The developed area of the Town of Ingersoll lies a short distance to the north. Selected photographs of the site are enclosed in Appendix D.

Based on the Quaternary Geology Map, the site is situated in the till plain characterized by the Tavistock Till (Huron-Georgian Bay lobe) consisting of sandy silt to silt matrix with variable amounts of clay and sand and moderate to high carbonate content. Bedrock of the Detroit River Group, Onondaga Formation consisting of limestone, dolostone and shale underlies the site. Limestone is quarried at the Carmeuse Lime, Beachville operation approximately 4.5 km northeast of the bridge.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out in two stages. The first stage of the investigation carried out between November 5 and 28, 2014 consisted of drilling and sampling a total of seven boreholes denoted as 14-01 to 14-07. Boreholes 14-02 and 14-03 were drilled in the vicinity of the north bridge abutment, Boreholes 14-04 and 14-05 were advanced in the vicinity of the south abutment, and Boreholes 14-01 and 14-06 were drilled within each approach embankment. Borehole 14-07 was advanced within the median of Highway 401, in proximity to the pier of the existing structure. Boreholes were extended to depths ranging from 10.8 to 21.9 m below the existing ground surface. To supplement the existing information, the second stage of the investigation was carried out between June 22 and 25, 2015, when a total of three boreholes denoted as Borehole 14-08 to 14-10 were advanced at the site to depths ranging from 20.3 m to 24.7 m. Borehole 14-08 was drilled at the pier and Boreholes 14-09 and 14-10 were advanced at the north and south abutments, respectively. The borehole completion information is summarized in Table 3-1. The approximate borehole locations are shown on the attached Borehole Location and Soil Strata Drawings included in Appendix E.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations. Drilling was carried out using a truck mounted CME 75 drill rig with hollow stem augers during the 2014 investigation and a D56 drill rig with solid and hollow stem augers was used during the 2015 investigation. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations and again at later dates. Two standpipe piezometers, consisting of 25 mm diameter Schedule 40 PVC pipes with a 1.5 m long slotted screens, were installed at alternate corners of the structure within Boreholes 14-02 and 14-05. The standpipe piezometers installed in Boreholes 14-08 to 14-10 comprised 19 mm diameter Schedule 40 PVC pipe with a 4.6 m long slotted screen.

The piezometer screens were enclosed in filter sand to permit groundwater level monitoring. Boreholes with piezometers were decommissioned following the final water level readings. All boreholes, were backfilled in general accordance with MOE Regulation 903 upon completion, and the details are provided in Table 3-1.

Table 3-1. Piezometer Installation and Backfilling Details

Borehole Number	Drilling Depth/ Elevation (m)	Piezometer Tip Depth/ Elevation (m)	Borehole Backfilling Details
14-01	11.3 / 284.4	N/A	Bentonite holeplug and cuttings from 11.3 to 0.5 m, concrete from 0.5 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-02	16.9 / 278.8	16.8 / 278.9	Piezometer with 1.5 m slotted screen installed, sand filter from 16.9 to 14.9 m, bentonite seal from 14.9 to 14.0 m, bentonite holeplug and cuttings from 14.0 to 0.6 m, concrete from 0.6 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-03	21.9 / 273.9	N/A	Bentonite holeplug and cuttings from 21.9 to 1.0 m, concrete from 1.0 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-04	12.3 / 283.9	N/A	Bentonite holeplug and cuttings from 12.3 to 0.6 m, concrete from 0.6 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-05	14.0 / 282.3	12.2 / 284.1	Piezometer with 1.5 m slotted screen installed, sand filter from 14.0 to 10.4 m, bentonite seal from 10.4 to 9.8 m, bentonite holeplug and cuttings from 9.8 to 0.9 m, concrete from 0.9 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-06	11.0 / 285.4	N/A	Bentonite holeplug and cuttings from 11.0 to 0.6 m, concrete from 0.6 to 0.2 m, asphalt patch from 0.2 m to ground surface
14-07	10.8 / 278.2	N/A	Bentonite holeplug and cuttings from 10.8 to 0.5 m, concrete from 0.5 to 0.2 m, asphalt patch from 0.2 m to ground surface.
14-08	20.3 / 268.7	16.8 / 272.2	Piezometer with 4.6 m slotted screen installed, sand filter from 16.8 m to 11.9 m, bentonite seal from 11.9 m to ground surface.
14-09	21.7 / 274.0	21.0 / 274.7	Piezometer with 4.6 m slotted screen installed, sand filter from 21.0 to 16.0 m, bentonite seal from 16.0 to ground surface.
14-10	24.7 / 271.6	24.4 / 271.9	Piezometer with 4.6 m slotted screen installed, sand filter from 24.4 to 18.0 m, bentonite seal from 18.0 to ground surface.

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.

4 LABORATORY TESTING

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

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the Borehole Locations and Soil Strata Drawing included in Appendix E. 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 interpretation of the site conditions. It should be recognised and expected that soil conditions may vary between and beyond borehole locations.

Subsurface information obtained from the existing Preliminary Foundation Investigation (Geocres No. 40P2-72) was reviewed during preparation of this report. The subsurface conditions documented in the noted report are generally consistent with those observed during the present investigations. Record of Borehole sheets and the Borehole Locations and Soil Strata drawing from that report are enclosed in Appendix F, for reference.

The subsurface stratigraphy below the pavement structure and the existing embankment fill generally consisted of a cohesionless till comprising various proportions of sand and silt underlain by a cohesive till comprising silty clay to clayey silt. Beneath the upper tills was a layers of silty clay underlain by a silt layer. Another layer of cohesionless till, consisting of sand and silt, was encountered on the north side of the site below the silty clay till. Bedrock was not encountered during the investigation. Descriptions of the individual strata are presented below.

5.1 Pavement Structure

Boreholes 14-01 to 14-06, 14-09 and 14-10 were drilled through the existing Highway 19 embankment and Boreholes 14-07 and 14-08 were drilled through the inside shoulder of Highway 401. All boreholes, except for Borehole 14-10, encountered a pavement structure consisting of approximately 100 mm to 150 mm of asphalt overlying granular road base fill.

In Boreholes 14-01 to 06 and 14-09, advanced from Highway 19, the granular road base fill was predominantly sand with significant proportions of gravel and was classified as sand with some gravel to sand and gravel with trace silt and trace clay. The granular fill extended to a depth of 0.7 to 1.7 m below the ground surface (Elev. 294.0 to 295.4).

SPT tests performed in the granular fill gave N-Values between 19 and 47 blows per 0.3 m of penetration, indicating a compact to dense relative density. Moisture contents within this fill varied from 1 to 9%.

In Boreholes 14-07 and 14-08 drilled on Highway 401, the granular road base consisted of sandy gravel and gravelly sand with some silt. This layer extended to a depth of 1.5 m and 1.7 m below the highway grade to Elev. 287.5 and 287.3. In Borehole 14-08, the road base material was placed directly on the native sand and silt till.

SPT tests performed in this fill gave N-Values of 29, 50 and 92 blows per 0.3 m of penetration, indicating a compact to very dense relative density.

Grain size distribution analyses were completed on selected samples of this material. The results are summarized on the Record of Borehole sheets in Appendix A, and the grain size distribution curves for three samples of this fill are included in Figure B1 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	18 to 54
Sand	31 to 57
Silt and Clay	10 to 25

Moisture contents within the granular fill varied from 2 to 5%.

5.2 Embankment Fill

A layer of silty sand fill with trace to some gravel and trace to some clay was encountered below the road base or extending from ground surface in the boreholes drilled from Highway 19, except in Boreholes 14-06. The fill extended to depths of ranging from 1.5 m to 4.5 m below the existing ground surface (Elev. 291.2 to 294.3). In Borehole 14-07 advanced from the shoulder of Highway 401, the road base was underlain by approximately 0.8 m of sand fill extending to a depth of 2.3 m (Elev. 286.7).

SPT tests performed in the silty sand fill under Highway 19 produced N-Values between 0 and 29 blows per 0.3 m of penetration, indicating a very loose to compact relative density. The majority of the N-values ranged from 8 to 24 blows per 0.3 m penetration, with the exception of Borehole 14-09, where N-values of 0 to 7 blows per 0.3 m of penetration were obtained indicating a very loose to loose relative density. Moisture contents within the fill under Highway 19 varied from 2 to 22%.

In Boreholes 14-07, drilled under Highway 401, the SPT N-Value in the fill was 79 blows per 0.3 m of penetration, indicating a very dense relative density. The moisture content of the fill under Highway 401 was 7%.

A grain size distribution analyses were completed on a selected samples of this fill. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are included in Figure B2 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0 to 10
Sand	33 to 55
Silt	23 to 51
Clay	12 to 17

5.3 Upper Cohesionless Till

The fill was underlain by a cohesionless glacial till consisting of a heterogeneous mixture of sand and silt with trace to some clay and trace to some gravel. Silty clay lenses were noted occasionally throughout the deposit. Cobbles and boulders do inherently occur in glacial tills and should be assumed to be present at this site. The thickness of this layer ranged from 6.3 m to 10.7 m in Boreholes 14-02 to 14-05, 14-09 and 14-10, where the deposit was fully penetrated. The base of the deposit was encountered between a depth of 10.4 m (Elev. 285.9) and 12.2 m (Elev. 283.6). In Boreholes 14-07 and 14-08 advanced from Highway 401 grade, which at this location is constructed in a cut, the sand and silt till layer was 2.3 m to 4.1 m thick and extended to a depth of 4.6 m (Elev. 284.4) and 5.8 m (Elev. 283.2). Boreholes 14-01 and 14-06 were terminated in this deposit at 11.3 m depth (Elev. 284.4) and 11.0 m (Elev. 285.4).

SPT tests performed in this till gave N-values from 6 and to in excess of 100 blows per 0.3 m of penetration, indicating a loose to very dense state.

Grain size distribution analyses were completed on selected samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for selected samples are included in Figures B3 to B5 of Appendix B. The results of the grain size distribution testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 14
Sand	12 to 58
Silt	28 to 78
Clay	7 to 22

Atterberg Limits testing was also completed on four cohesive samples of this deposit. The results are presented on the Record of Borehole sheets in Appendix A and the Atterberg Limits plot is included in Figure B11 of Appendix B. The results of the laboratory test indicate silts of low plasticity.

Parameter	Value (%)
Plastic Limit	11 to 19
Liquid Limit	15 to 27
Plasticity Index	4 to 8

Moisture contents measured on samples of the deposit ranged from 2 to 22%, being typically between 5% and 15%.

5.4 Cohesive Till

A deposit of low plasticity silty clay to clayey silt till with sand and trace gravel was encountered below the upper silty sand to sand and silt till in Boreholes 14-02 to 14-05 and in Boreholes 14-07 to 14-10. The till deposit was comprising a significant percentage of sand fraction and at some locations was classified as sandy or with sand. Where fully penetrated in Boreholes 14-02, 14-03 and 14-08 to 14-10, the thickness of the silty clay till ranged from 4.5 to 9.0 m with the lower boundary of the deposit between 15.2 m (Elev. 280.5) and 19.4 m (Elev. 276.9). Boreholes 14-04, 14-05 and 14-07 were terminated within the silty clay/clayey silt till between depths of 10.8 and 14.0 m (Elev. 278.2 to 283.9) below the ground surface.

It should be noted that cobbles and boulders inherently occur in glacial till deposits, and they should be expected within the soil matrix.

SPT N-Values in the till ranged from 25 blows per 0.3 m of penetration to in excess of 100 blows per 0.3 m of penetration indicating a very stiff to hard consistency. The high blow counts may represent presence of cobbles and boulders.

Grain size distribution analyses were completed on selected samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for the samples are included in Figures B6 and B7 of Appendix B. The results of the laboratory tests are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 6
Sand	9 to 41
Silt	37 to 53
Clay	16 to 50

Atterberg Limits tests completed on selected samples of the silty clay till are summarized on the Record of Borehole sheets in Appendix A and in the table, below. The results are also

presented in Figure B12 of Appendix B. The results of the laboratory tests indicate low plasticity of the till deposit.

Parameter	Value (%)
Plastic Limit	10 to 16
Liquid Limit	15 to 31
Plasticity Index	4 to 14

The moisture content of the silty clay till varied between 4% and 22%.

5.5 Lower Cohesionless Till

A deposit of till consisting of silt to sand and silt with trace to some clay and trace gravel was encountered below the silty clay till in Boreholes 14-02, 14-03 and 14-09 between 15.2m (Elev. 280.5) and 18.3 m depth (Elev. 277.5). All three boreholes were terminated within this till deposit between 16.9 m and 21.9 m depth (Elev. 273.9 to 278.8) below the ground surface.

It should be noted that cobbles and boulders inherently occur in glacial till deposits, and they should be expected within the soil matrix.

SPT tests performed in this deposit gave N-values between 37 blows per 0.3 m of penetration and more than 100 blows per 0.3 m of penetration, indicating a dense to very dense relative density. Moisture contents in this layer ranged from 6 to 22%.

Grain size analysis was completed on selected samples of this deposit. The results are presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves are included in Figure B8 of Appendix B. The results of the laboratory test are presented below:

Soil Particles	Percentage (%)
Gravel	0 to 1
Sand	0 to 43
Silt	47 to 86
Clay	9 to 24

5.6 Silty Clay

A layer of silty clay with trace sand was encountered below the cohesive till in Boreholes 14-08 and 14-10. The thickness of the silty clay ranged from 1.8 m to 2.4 m with the lower boundary of the deposit between 13.4 m (Elev. 275.6) and 21.8 m (Elev. 274.5).

SPT N-Values in the clay ranged from 72 blows per 0.3 m of penetration to in excess of 100 blows per 0.3 m of penetration indicating a hard consistency. The moisture content of the silty clay layer varied between 20% and 23%.

Grain size distribution analyses were completed on two samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for the samples are included in Figure B9 of Appendix B. The results of the laboratory tests are summarized below:

Soil Particles	Percentage (%)
Gravel	0
Sand	0 to 5
Silt	43 to 45
Clay	52 to 55

Atterberg Limits tests completed on two samples of the silty clay are summarized on the Record of Borehole sheets in Appendix A and in the table, below. The results are also presented in Figure B13 of Appendix B. The results of the laboratory tests indicate low to medium plasticity of the till deposit.

Parameter	Value (%)
Plastic Limit	16 to 18
Liquid Limit	31 to 37
Plasticity Index	15 to 19

5.7 Silt

A deposit of silt with trace sand and trace to some clay was encountered below the silty clay layer in Boreholes 14-08 and 14-10. Occasional clayey silt lenses were noted in this deposit. Boreholes 14-08 and 14-10 were terminated within this layer at depths of 20.3 m and 24.7 m below the ground surface (Elev. 268.7 to 271.6 m).

SPT tests performed in this deposit gave N-Values between 31 blows per 0.3 m of penetration and more than 100 blows per 0.3 m of penetration, indicating a dense to very dense relative density, typically being very dense.

Grain size analyses were completed on selected samples of this deposit. The results are presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves are illustrated in Figure B10 of Appendix B. The results of the laboratory test are presented below:

Soil Particles	Percentage (%)
Gravel	0
Sand	0 to 3
Silt	90
Clay	7 to 10

Moisture contents in this layer ranged from 14% to 25%.

5.8 Groundwater Levels

Water levels were observed during drilling operations and in the open boreholes upon completion of the drilling. As outlined in Table 3-1, standpipe piezometers were installed in Boreholes 14-02, 14-05 and 14-08 to 14-10 to monitor groundwater levels after drilling. The measured groundwater levels are summarized in Table 5-1.

The groundwater level in the piezometer installed into the cohesive till and silt on the south side of the bridge was measured at 6.0 m depth (Elev. 290.3) and 14.0 m depth (Elev. 282.3). The water level in the piezometer sealed into the lower cohesionless till on the north side of the bridge indicated on the upward groundwater flow with the water level raising slowly from 4.5 m below the ground surface to reaching the ground surface (Elev. 295.7) approximately four weeks following the installation of the piezometer. The piezometer was inspected again on June 23, 2015, and the water was removed from the pipe to 16.5 m depth. On July 15, 2015, the water level in the piezometer rose again to 4.3 m depth. In the piezometer installed in Borehole 14-09, located some 12 m to the east on the east side of the embankment, the water level in the piezometer was measured at 10.1 m depth (Elev. 285.6), and seemed to be relatively stable.

The water level in Borehole 14-08 located within the Highway 401 inside shoulder was measured at 7.8 m depth (Elev. 281.2) shortly after the installation of the piezometer in the silt deposit, and three weeks later, the water level was recorded at 1.8 m depth (Elev. 287.2).

The measurements indicate different hydraulic heads at the piezometer locations.

The values shown in Table 5-1 are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation events.

Table 5-1. Measured Groundwater Levels

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
14-01	Nov. 5, 2014	10.7	285.0	Open Borehole
14-02	Nov. 24, 2014	9.8	285.9	Open Borehole
	Nov. 28, 2014	4.5	291.2	Piezometer * On June 23, 2015, water from the pipe was removed to 16.5 m depth below the ground surface; on July 15, 2015, the water level rose to 4.3 m depth.
	Dec. 19, 2014	0.0	295.7	
	Jun. 23, 2015	0.0*	295.7*	
	Jul. 15, 2015	4.3	291.4	
14-03	Nov. 5, 2014	9.1	286.7	Open Borehole
14-04	Nov. 7, 2014	Dry to 12.3 m	-	Open Borehole
14-05	Nov. 28, 2014	6.0	290.3	Piezometer
	Dec. 19, 2014	6.4	289.9	
	Jun. 23, 2015	6.0	290.3	
	Jul. 15, 2015	6.1	290.2	
14-06	Nov. 7, 2014	Dry to 11.0 m	-	Open Borehole
14-07	Nov. 28, 2014	9.5	279.5	Open Borehole
14-08	Jun. 25, 2015	7.8	281.2	Piezometer
	Jul. 15, 2015	1.8	287.2	
14-09	Jun. 23, 2015	10.0	285.7	Piezometer
	Jul. 15, 2015	10.1	285.6	
14-10	Jun. 24, 2015	13.9	282.4	Piezometer
	Jul. 15, 2015	14.0	282.3	

5.9 Analytical Testing

Two representative samples retrieved from the soils at the site were submitted to AGAT Laboratories in Mississauga, Ontario for analysis of pH and soluble sulphates. The analysis results are presented below in Table 5-2.

Table 5-2. Results of Analytical Testing

Location	Borehole	Sample	Depth (m)	pH	Sulphate (µg/g)
North Abutment	14-02	SS-1	0.3	8.1	25
South Abutment	14-04	SS-11	12.5	8.1	33

The results of the analyses are enclosed in Appendix C.

6 MISCELLANEOUS

Borehole locations were selected and marked in the field by an experienced Thurber staff member and were established with a Trimble Pathfinder ProXRT differential GPS unit. The co-ordinates and ground surface elevations at the boreholes were surveyed by MMM Group Limited upon completion of drilling.

Determination Drilling and Soil Investigations Holdings Inc. from Hamilton, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field program. The field investigation was supervised on a full time basis by Mr. George Azzopardi of Thurber. Overall supervision of the investigation program was conducted by Mr. Michael Eastman, EIT and Weiss Mehdawi, P.Eng.

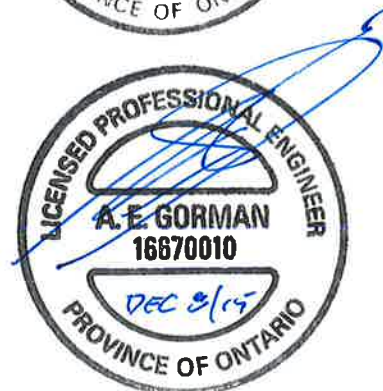
Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario. Interpretation of the data and preparation of this report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and by Dr. P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

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REPLACEMENT OF HIGHWAY 401 UNDERPASS
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PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report presents an interpretation of the geotechnical data in the factual report and provides geotechnical recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed replacement of the Highway 19 Underpass.

The existing underpass is a rigid frame structure with a span of 33 m and carries one lane of traffic in each direction over Highway 401. The underpass is supported on spread footings, based on original design drawings.

The proposed underpass structure, as shown on the preliminary General Arrangement (GA) drawing dated March 2014, is a two span structure with a total span length of 76.0 m and deck width of 12.7 m. The new underpass will carry a single lane of traffic in each direction with similar horizontal alignment as the existing structure. Future widening of Highway 401 is indicated on the General Arrangement drawing. The grades of the approach embankments along the centreline of the structure are specified at approximately Elev. 296.2 and Elev. 296.8 at the north and south abutments/approaches, respectively, which indicates that the grades of the approach embankments would be raised by approximately 0.5 m. The approach embankments are up to 3 m in height above the original ground.

As stated in the RFP for this project, the Highway 19 Underpass will be constructed using the GiGo (Get In – Get out) approach. To accommodate the construction approach, the bridge abutments and pier will be constructed in advance to receive the bridge deck completed off-site.

The discussion and recommendations presented in this report are based on information provided by MMM Group Limited (MMM) and on the factual data obtained in the course of this investigation, in combination with the subsurface information presented in the Geocres 40P2-74 report.

8 STRUCTURE FOUNDATIONS

The subsurface stratigraphy below the pavement structure and the existing embankment fill consists of an extensive glacial till deposit. The till deposit comprises an upper cohesionless till underlain by a very stiff to hard clayey silt/silty clay till, which is further underlain by a lower dense to very dense

cohesionless till. A layer of clay underlain by a layer of silt underlie the cohesive till in the central and southern portion of the site.

The groundwater levels in open boreholes upon completion of drilling were measured from 9.1 m depth to being below 12.3 m depth (borehole open and dry). The groundwater level in the piezometers sealed into the cohesive till on the south side of the bridge was measured at 6.0 m depth (Elev. 290.3) and 14.0 m depth (Elev. 282.3). On the north side of the bridge, the water level in the piezometer sealed into the lower cohesionless till indicated an upward hydraulic gradient in the lower till; the water level rose slowly from 4.5 m below the ground surface to the ground surface (Elev. 295.7) within approximately four weeks following piezometer installation. No upward hydraulic gradient was observed in the piezometer installed in Borehole 14-09, located some 12 m to the east, where the water level in the piezometer was measured at 10.1 m depth (Elev. 285.6) and seemed to be stable.

Based on the conditions encountered at this site, consideration was given to the following foundation types:

- Spread footings:
 - bearing on native soil
 - bearing on engineered fill
- Driven steel H-piles
- Augered caissons (drilled shafts)

A comparison of the foundation alternatives, with advantages and disadvantages of each, are included in Appendix G.

8.1 Spread Footings on Upper Cohesionless Till

The use of spread footings placed on undisturbed upper cohesionless till (sands and silts) is considered feasible to support the abutments and pier.

For design of spread footings bearing on the undisturbed native upper till, the founding elevations, factored geotechnical resistance at Ultimate Limit States (ULS_f) and geotechnical reaction at Serviceability Limit States (SLS) provided in Table 8-1 may be used for an assumed minimum footing width of 3 m.

Table 8-1. Founding Elevation and Bearing Capacities for Spread Footings

Foundation Unit	Referenced Borehole	Highest Founding Elevation (m)	Factored Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa)
North Abutment	14-02 14-03	290.0	550	350
Pier	14-07 14-08	286.7	600	400
South Abutment	14-04 14-05	290.0	550	350

The values of geotechnical reaction at SLS quoted above correspond to 25 mm of settlement of an individual footing and are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2006 Clause 6.7.3 and Clause 6.7.4.

Resistance to lateral forces / sliding resistance between the footing concrete and the till (sands and silts) at the founding level should be evaluated in accordance with the CHBDC, 2006 assuming an ultimate (unfactored) coefficient of friction of 0.4.

The exposed soils at the founding level should be protected from disturbance due to construction traffic and weathering/run off. For protection, a 100 mm concrete slab or a 150 mm layer of Granular B type II should be placed at the footing subgrade as soon as the subgrade is inspected and approved.

The water levels in the open boreholes during the field investigation (Table 5-1) were observed to be below the founding levels. However, the piezometer in Borehole 14-02 indicated water table at the ground surface. Therefore, perched groundwater may be encountered during excavations and local groundwater control will be required to construct the spread footings in the dry and to prevent disturbance of the founding stratum.

Excavation and backfilling for the footings should be in accordance with OPSS 902.

8.2 Spread Footings Bearing on Engineered Fill

Foundations consisting of spread footings founded on engineered fill pads can be considered at the pier on this site, if higher founding elevations than noted in Table 8-1 are required. At the abutments, founding spread footings on engineered fill pads is neither recommended nor beneficial.

The engineered pad at the pier could be placed at or below Elev. 286.7 on very dense silty sand till.

The engineered fill should consist of OPSS Granular "A" or Granular B Type II placed in 150 mm lifts and compacted to 100% of its SPMDD at $\pm 2\%$ of optimum moisture content. The top of the founding pad should be at least 1 m wider than the footprint of the spread footing. The side slopes of the engineered fill pad should be inclined not steeper than 1H:1V. The engineered fill pad arrangement is shown on Figure 1 in Appendix I.

A 3 m wide footing bearing on a minimum 1 m thick pad of engineered fill may be designed for the following capacities:

Factored Geotechnical Resistance at ULS	- 900 kPa
Geotechnical Resistance at SLS	- 350 kPa

The geotechnical resistance at SLS quoted above corresponds to 25 mm of settlement of an individual footing.

The quoted geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design should be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

The lateral resistance of the footings founded on engineered fill may be computed using an unfactored friction coefficient of 0.6.

8.3 Driven H-Pile Foundations

8.3.1 Axial Resistance

The ground conditions at the site are considered to be suitable for the use of driven steel H-pile foundations at the bridge abutments. To develop required capacity, the piles should be driven into hard silty clay till or dense to very dense cohesionless till. The pile tip will be located in the hard/dense to very dense till within the northern part of the site and in the hard silty clay at the pier and south abutment.

At the proposed pier location, the till deposit underlying the fill is very dense/hard and characterized by SPT N-values in excess of 100 blows per 0.3 m of penetration. Installation of H-piles to design depths in these deposits would require pre-drilling, which could be costly; therefore this foundation option is not recommended at the pier location.

The recommended geotechnical resistances and reactions for steel piles HP 310x110 and HP 360x132 driven into the dense to very dense/hard tills and hard silty clay to support abutments are presented in Table 8-2.

Table 8-2. Recommended Geotechnical Resistance and Reaction for H-piles

Foundation Element	Relevant Borehole	Estimated Pile Tip Elevation/ Pile Length* (m)	Factored Geotechnical Resistance at ULS per pile (kN)	Geotechnical Reaction at SLS per pile (kN)
North Abutment	14-02 14-03 14-09	276.0 / 15.2	1600 (HP 310x110) 2000 (HP 360x132)	1400 (HP 310x110) 1800 (HP 360x132)
South Abutment	14-04 14-05 14-10	276.0 / 15.9		

* The pile lengths are based on the preliminary General Arrangement drawing elevations of undersides of the concrete abutments: North - Elev. 291.2, South - Elev. 291.9.

The above pile tip elevations assume that piles are driven to effective refusal and penetrate a minimum 2 m into very dense/hard tills or hard silty clay. Based on Boreholes 14-03 and 14-09 located on the east side of the north abutment, to achieve the above capacities pile tip should be driven to a minimum of Elev. 276.0. However, in Borehole 14-02 drilled on the

west side of the north abutment, practical refusal can be encountered at higher elevation. Borehole 11-01 (Stantec's report, Geocres No. 40P2-74) drilled some 15 m west from the west side of the north abutment indicated a refusal layer at an approximate elevation of 269.0 m. It should therefore be noted that while the recommended pile tip elevation is 276.0, several piles particularly in the western part of the north abutment may have to be driven deeper to reach practical refusal.

If practical refusal is met in the very dense till at shallower depth than required for structural pile performance (flexibility), pre-augering to approximately 2 m above the design pile tip elevation may be needed prior to driving piles. A suggested wording for NSSP addressing requirement for pre-augering is included in Appendix H.

Oversize materials (e.g. greater than 75 mm nominal diameter) should not be used for any new fill through which the piles will be driven.

8.3.2 Pile Tips

Pile tip protection is recommended for driven H-piles to prevent pile damage when setting the piles in the very dense/hard founding stratum or if cobbles or boulders are encountered.

All driven H-piles at the abutments should be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent. The steel H-pile driving shoe presented in OPSD 3000.100 is not recommended, as the reinforcing flange plates to be welded to the outside flange faces would reduce the friction component of the pile resistance.

8.3.3 Pile Installation

Pile installation should be in accordance with OPSS 903. Cobbles and boulders may be encountered during pile installation; a suggested text for NSSP is enclosed in Appendix H.

Pile driving should be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance should be specified by the designer. The Hiley formula need not be used until the piles are within 2.0 m of the design pile tip elevation. The appropriate pile driving note is "*Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile but must be driven below El. 276.0*". "R" should have a minimum value of twice the design load at ULS as calculated by the Structural Engineer.

If the proposed bridge design requires that the deviation at the top of the pile be limited to tight tolerance, a driving template or other means may be required to achieve the specified maximum deviation. A suggested text for NSSP addressing the need for driving templates has been provided in Appendix H.

It is anticipated that new abutment piles will be installed working from the Highway 19 grade, on an excavated grade corresponding to the underside of the abutments stem. For an integral abutment, the following procedure is suggested:

- 1) At each pile centre, auger a hole of sufficient diameter to accept a 600 mm CSP to a depth of 3.0 m below the underside of the abutment stem
- 2) Install the CSP
- 3) Drive the pile taking care to prevent soil or debris from entering the CSP
- 4) After completion of pile driving, fill the CSP using loose uniform sand meeting the requirements of the integral abutment design report.

8.3.4 Pile Lateral Resistance

The geotechnical lateral resistance acting on a pile in cohesionless soil may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

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

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

where

z	=	depth of embedment of pile (m)
D	=	pile width or diameter (m)
n_h	=	coefficient related to soil relative density (kN/m^3)
γ'	=	effective unit weight (kN/m^3)
K_p	=	passive earth pressure coefficient

The geotechnical lateral resistance acting on a pile in cohesive soil may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = 67 S_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 S_u \quad (\text{kPa})$$

where

S_u	=	undrained shear strength (kPa)
D	=	pile width or diameter (m)

The above equations and recommended parameters in Table 8-3 below may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

Table 8-3. Soil Parameters for Lateral Pile Resistance

Location	Soil Strata	Elevation (m)		γ^* (kN/m ³)	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
North Abutment	Sand / Silty Sand Fill / Sand and Silt Till	GS	291.2	21	7,000	2.9	-
	Sand and Silt Till	291.2	284.0	11*	6,000	3.2	-
	Silty Clay/Clayey Silt Till	284.0	280.0	11*	-	-	250
	Sand and Silt Till	280.0	274.0	11*	10,000	3.4	-
South Abutment	Sand and Gravel / Sand / Silty Sand Fill / Sand and Silt Till	GS	290.2	21	7,000	3.2	-
	Sand and Silt Till	290.2	285.9	11*	6,000	3.2	-
	Silty Clay Till/Silty Clay	285.9	274.5	11*	-	-	250
	Silt	274.5	271.6	11*	10,000	3.4	-
Pier	Sand / Gravel Fill	GS	287.3	21	7,000	3.4	-
	Sand and Silt Till	287.3	284.4	11*	9,000	3.4	-
	Silty Clay Till/Silty Clay	284.4	275.6	11*	-	-	250
	Silt	275.6	268.7	11*	10,000	3.4	-

* γ = bulk unit weight; submerged unit weight should be used for soils below the groundwater level.

The spring constant, K_s , for analysis may be obtained from the expression, $K_s = k_s L D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} L D$. This represents the ultimate load, at which the pile fails and will not support any additional load at greater displacements.

Lateral resistance may be calculated from the given above equations and using parameters in Table 8-3. Alternatively, the values given in the CHBDC Clause 6.8.7.1, Table C 6.4, may be utilized. As an example, in the Table C 6.4, the lateral resistance of an HP310x110 pile driven in the “noncohesive material” is limited to 120 kN at ULS, and 35 kN at SLS for the lateral movement of 10 mm.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8-4. Intermediate values may be obtained by linear interpolation.

Table 8-4. Subgrade Reaction Reduction Factors for Pile Spacing

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

Horizontal loads may be resisted by means of battered piles (i.e. for H-pile case) if load requirements exceed the available lateral pile resistances.

Where downward sloping ground exists in front of a pile, reduction of lateral passive resistance should be taken into account during design. For foundation design at the piles, it can be assumed that full lateral resistance can only be mobilized where the width of the soil in front of the pile is equal to or greater than approximately 4 times the diameter of the piles. The mobilized passive resistance for sloping ground in front of a pile can be estimated using the following reduction factors:

Table 8-5. Passive Resistance Reduction Factors

Slope Inclination	Passive Resistance Reduction Factor
2H:1V	0.60
2.5H:1V	0.65
3H:1V	0.70
4H:1V	0.75

8.3.5 Downdrag Load

Driven H-piles can encounter practical refusal in the very dense/hard till deposit. The existing road grade will be raised by approximately 500 mm. Considering presence of the typically dense to very dense cohesionless till and very stiff to hard cohesive till at this site, negligible consolidation settlements are expected to develop in the glacial till under the weight of the new approach fill placed to raise the grade. In light of the above, the downdrag load on the pile will be negligible at this site.

8.3.6 Integral Abutment

The subsurface conditions at this site are considered suitable for integral, semi-integral or conventional type abutment design. If an integral abutment design is considered, the structure will need to be supported on steel H-piles. The H-pile length below the abutment

should be a minimum of 6.0 m. The pile tip elevations to be used in the design of pile foundations are indicated in Table 8.2, above.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. To provide the required flexibility, the upper 3 m of the piles should be surrounded by a 600 mm diameter column of loose sand as specified by the integral abutment design requirements. A 600 mm diameter CSP may be used to contain the sand.

An NSSP should be included in the contract documents specifying the gradation of the sand according to Table 8-6.

Table 8-6. Integral Abutment Sand Backfill Grading

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

8.4 Caissons

Augered caissons, founded into the hard silty clay till at or below elevations shown in Table 8-7, are considered a feasible foundation alternative for the pier support. The following factored geotechnical resistances at ULS and geotechnical reaction at SLS (for 25 mm of settlements) can be used for the pier caisson design:

Table 8-7. Founding Elevation and Axial Resistance for Caissons at Pier Location

Highest Caisson Founding Elevation (m)	Relevant Borehole	Caisson Diameter (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Reaction at SLS (kN)
279.0	14-07 14-08	0.9	3200	2500
		1.2	6000	4800
		1.5	8800	6000

The above values were obtained considering the base resistance of the caissons in the hard/very dense till deposits. The geotechnical lateral resistance acting on caissons may be calculated using design values provided in Sec. 8.3.4.

The anticipated total loading at the pier at SLS of 3211 kN and at ULS of 4311 kN were provided by the Designer to allow estimate the settlements at the caissons to be installed for the pier support. The settlements were estimated utilizing method proposed by Randolph and Wroth (1978), and H. Poulos (1993). Since the subsurface conditions in Boreholes 14-07 and 14-08 slightly differ, settlements were estimated at each borehole location. Considering the design loading, the total settlements of 4 mm and 8 mm were obtained at the Boreholes 14-07 and 14-08 locations, respectively. Therefore, the differential settlements of 4 mm can be anticipated at the pier.

Construction of the caissons will require the use of a sealed liner and/or slurry methods to control groundwater and to support the sidewalls of the shaft. Each caisson should be concreted and completed within the shift that it was started.

The base of the caissons will be below the groundwater level and dewatering, base cleaning and base inspection will be required, as per OPSS 903.04.02.04.02.01.

The presence of cobbles and boulders within the glacial till deposit is to be expected, and a suggested text for NSSP is enclosed in Appendix H.

8.5 Frost Cover

The depth of frost penetration at this site is 1.3 m. The base of all pile caps, caissons caps or footings, should be provided with a minimum of 1.3 m of earth cover as protection against frost action.

8.6 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended abutment foundation consists of steel H-piles driven into hard/dense to very dense till or hard silty clay deposits, which would allow for the integral abutment design. Caissons or spread footings could be considered for support of the pier. The caisson foundation would be more advantageous from the constructability perspective, as they would allow for minimizing the construction impact on operation of Highway 401, i.e. less excavation and shorter construction time.

9 BACKFILL TO ABUTMENTS

The backfill to the abutment walls should be Granular A or Granular B Type II material meeting the requirements of OPS. PROV 1010. The backfill should be in accordance with OPSS 902 and placed to the extent shown in OPSD 3101.150.

Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

The design of the abutment should incorporate subdrains, as shown in OPSD 3101.150.

10 EARTH PRESSURE

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

$$p_h = K(\gamma h + q) \quad (\text{kN/m}^2)$$

where

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

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of the fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10-1.

Table 10-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active	0.27	0.40	0.31	0.48
Passive	3.7	N/A	3.3	N/A
At Rest	0.43	N/A	0.47	N/A

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.

11 SEISMIC CONSIDERATIONS

11.1 Seismic Design Parameters

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.00

- Acceleration Related Seismic Zone 1
- Zonal Acceleration Ratio 0.00
- Peak Horizontal Acceleration 0.05

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

11.2 Liquefaction Potential

It is expected that under the existing conditions the foundation soils will not be prone to liquefaction. The existing embankments are constructed above the groundwater level and are not considered to be prone to liquefaction.

12 BRIDGE APPROACHES AND EMBANKMENTS

Based on the boreholes drilled within the approach areas, the embankments will be constructed on dense to very dense cohesionless till underlain by very stiff to hard cohesive till. The embankments indicated on the General Arrangement drawing will be up to 3 m in height; however the fore slope will be between 7.2 m to 7.8 m in height. Concrete slope paving is indicated for the fore slopes at this bridge. The embankment slopes constructed of properly compacted earth fill at side slopes of 2H:1V (or flatter) will be stable. Provided proper embankment construction methods are utilized, no long term settlement or global instability is anticipated for approach embankments built at this site.

13 EXCAVATION AND GROUNDWATER CONTROL

Based on the preliminary General Arrangement drawing, the new abutments will be located approximately 18 m behind the existing abutments. Excavations for the construction of the abutments and wing walls will be as much as 7.8 m in depth and will extend through the pavement structure, embankment fill into the compact to dense cohesionless till. The groundwater level encountered in open boreholes upon completion of drilling was generally near the base of excavation for the construction of the new abutments and wing walls. However, perched water within the embankment fill may be encountered and the local water control may be required during construction.

All excavation should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill forming the existing Highway 19 embankment may be classified as Type 3 soils. The underlying dense to very dense cohesionless till may be classified as Type 2 soil.

The sides of temporary excavations should be sloped in accordance with the requirements of the OHSA. Where space does not permit the sides to be sloped, roadway protection should be used.

The design of the dewatering system, if required, is the responsibility of the Contractor and the Contract Documents should be alerted of this responsibility. The Contractor should also be prepared

to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation, as the foundations should be constructed in the dry. Unwatering should remain operational and effective until the foundation is installed and backfilled.

Furthermore, the excavation and backfilling for foundations should be carried out in accordance with OPSS 902.

14 PROTECTION SYSTEM

The new underpass will be constructed using the GiGo approach. The new bridge abutments and pier and supporting foundations will be constructed in advance to receive the deck of the structure, which will be constructed off site.

If protection system is required, it should be implemented in accordance with OPSS 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection).

Conventional steel soldier piles and timber lagging walls is one option to provide temporary support to the soils during excavation. Timber lagging boards should be installed as soon as the soil face is exposed and properly prepared.

The following parameters apply for design of the temporary support system with horizontal backfill.

γ	=	21 kN/m ³	bulk unit weight; submerged unit weight should be used below groundwater table;
K_a	=	0.33	Active pressure coefficient for road embankment fill
	=	0.31	Active pressure coefficient for native soil)
K_p	=	3.0	Passive pressure coefficient for road embankment fill
	=	3.2	Passive pressure coefficient for native soils
h_w	=	289.9 m	(elevation for hydrostatic pressure build-up behind temporary shoring)

Typically, the design of protection system is the responsibility of the Contractor; however due to the nature of the project and need for the re-assessment of the lateral forces, it may be part of the structural design. The actual pressure distribution acting on the protection system is a function of the construction sequence and the relative flexibility of the wall and these factors should be considered when designing the adequate protection system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

Temporary groundwater and surface water control measures will be required during construction.

15 CEMENT TYPE

The water soluble sulphate tests on two samples indicate sulphate concentrations of 25 to 33 µg/g. Soluble sulphate concentrations less than 1000 µg/g indicate a moderate degree of exposure to sulphate attack for concrete in contact with soil and groundwater.

16 CONSTRUCTION CONCERNS

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

- Potential variability of pile lengths due to variation of the density and consistency of the underlying tills and probable presence of cobbles/boulders. Some piles may encounter refusal at shallower depth than the design depth, and will require pre-augering to reach the required pile tip elevation. Proposed wording for the Special Provision is provided in Appendix H.
- Construction of caissons for the pier support should follow the specification in OPSS 903, including careful quality control and good workmanship to ensure that the differential settlement are within the specified limits.
- As the new underpass is designated to be constructed as the GiGo project, the new bridge abutments and pier will have to be constructed in advance to receive the deck of the structure, which will be constructed off-site. Temporary protection system may have to be provided to ensure that the removal of the old deck and installation of the new bridge is safe.
- Protection system to maintain traffic during construction should be properly designed by a Professional Engineer experienced in such designs.
- Excavation below the water level, if required, will involve lowering of the groundwater level below the excavation base to maintain a dry excavation and stable side slopes. A proposed wording for the Special Provision is provided in Appendix H.
- The side embankment slopes should be inspected after construction for surficial disturbance. Where necessary, erosion control measures should be implemented.

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

17 CLOSURE

Engineering analysis and preparation of the report was carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr Alastair Gorman, P.Eng and by Dr. P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

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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.

EXPLANATION OF ROCK LOGGING TERMS


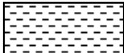



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 14-01

1 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 219.6 E 194 404.7 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.05 - 2014.11.05 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
295.7	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT: (150mm)							20 40 60 80 100					
0.2	SAND, some gravel, trace silt Dense Brown Dry (FILL)		1	SS	46		295						
294.9													
0.8	Silty SAND, trace to some gravel, trace to some clay Compact Brown Dry (FILL)		2	SS	29		294						10 55 23 12
			3	SS	19		294						
293.4													
2.3	SAND and SILT, trace to some clay, trace gravel Compact to Dense Brown Dry to Moist (TILL)		4	SS	44		293						
			5	SS	13		292						0 12 78 10
							291						
			6	SS	13		290						
							289						5 44 39 12
							288						
			8	SS	13		287						
							286						
			9	SS	15								

Continued Next Page

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

RECORD OF BOREHOLE No 14-01

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 219.6 E 194 404.7 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.05 - 2014.11.05 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
284.4		0 4 0 0 4 0	10	SS	19	▽	285										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 11.3m AND WATER LEVEL AT 10.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE TO 0.2m, THEN ASPHALT PATCH TO SURFACE.																

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 14-02

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 209.8 E 194 425.3 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.24 - 2014.11.24 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
								20 40 60 80 100								
Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L WATER CONTENT (%) 20 40 60				
285.0																
10.7	Silty CLAY , some sand, trace gravel, occasional lenses of clayey silt Hard Grey Wet (TILL)		10	SS	45		285									
							284									
			11	SS	55		283									
							282									
			12	SS	106/ 0.150		281									
280.5							280									
15.2	SAND and SILT , trace to some clay, trace gravel Very Dense Grey Wet (TILL)		13	SS	116/ 0.150		279									
278.8			14	SS	110/ 0.150											
16.9	END OF BOREHOLE AT 16.9m. BOREHOLE OPEN TO 16.9m AND WATER LEVEL AT 9.8m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.11.28 4.5 291.2 2014.12.19 0.0 295.7 2015.06.23 16.5* 279.2 2015.07.15 4.3 291.4 * Water observed at ground surface and removed from pipe to 16.5m depth below ground surface.															

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 10/27/15

RECORD OF BOREHOLE No 14-03

1 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 209.0 E 194 414.5 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.05 - 2014.11.05 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>			
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>			
295.8	GROUND SURFACE															
0.0	ASPHALT: (150mm)															
0.2	SAND, some gravel, trace silt Dense Brown Dry (FILL)		1	SS	47											
295.0																
0.8	Silty SAND, trace gravel Compact Brown Dry (FILL)		2	SS	24											
294.3																
1.5	SAND and SILT, trace to some gravel, trace clay Compact to Very Dense Brown to Grey Dry to Moist (TILL)		3	SS	21											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 10/27/15

METRIC

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METRIC

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

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 14-04

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 150.4 E 194 479.9 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.07 - 2014.11.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										20 40 60		
Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE													
285.5							286													
10.7	Silty CLAY , sandy, trace gravel, occasional silty sand and clayey silt lenses Hard Grey Dry (TILL)		10	SS	134		285									0 32 44 24				
283.9							284													
12.3	END OF BOREHOLE AT 12.3m. BOREHOLE OPEN TO 12.3m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.		11	SS	109/ 0.150															

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 14-05

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 144.7 E 194 473.6 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.19 - 2014.11.19 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
	Continued From Previous Page							20	40	60	80	100					
285.6							286										
10.7	Silty CLAY , sandy, trace gravel, occasional silty sand and clayey silt lenses Hard Grey (TILL)		10	SS	109												
							285										
			11	SS	105		284										
282.3			12	SS	110		283										
14.0	END OF BOREHOLE AT 14.0m. BOREHOLE OPEN TO 14.0m AND WATER LEVEL AT 13.7m Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.11.28 6.0 290.3 2014.12.19 6.4 289.9 2015.07.15 6.1 290.2																

RECORD OF BOREHOLE No 14-06

1 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 140.3 E 194 489.8 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.07 - 2014.11.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL	
296.4	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (150mm)							20	40	60	80	100								
0.2	SAND, trace silt, trace clay, trace to some gravel Compact to Dense Dark Grey to Brown Dry (FILL)		1	SS	34		296													
			2	SS	23															
294.9							295													
1.5	SAND and SILT, some clay, trace gravel Loose to Very Dense Brown to Grey Dry to Moist (TILL)		3	SS	10												5	45	36	14
			4	SS	8		294													
			5	SS	6		293										0	32	54	14
							292													
			6	SS	15		291													
			7	SS	48		290										5	46	33	16
							289													
			8	SS	68		288													
			9	SS	101		287													

Continued Next Page

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

RECORD OF BOREHOLE No 14-06

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 140.3 E 194 489.8 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.07 - 2014.11.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W P W W L 20 40 60					
285.4	Continued From Previous Page SAND and SILT , some clay, trace gravel Loose to Very Dense Brown to Grey Dry to Moist (TILL)		10	SS	116		286										
11.0	END OF BOREHOLE AT 11.0m. BOREHOLE OPEN TO 11.0m AND DRY. BOREHOLE BACKILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT PATCH TO SURFACE.																

RECORD OF BOREHOLE No 14-07

1 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 186.0 E 194 457.2 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.28 - 2014.11.28 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
289.0	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT: (150mm)							20	40	60	80	100							
0.2	GRAVEL, sandy, some silt: (Crusher Run) Very Dense Brown Dry (FILL)		1	SS	50		288												
			2	SS	92														
287.5																			
1.5	SAND, trace silt, trace clay, trace gravel Very Dense Brown Dry (FILL)		3	SS	79		287												
286.7																			
2.3	SAND and SILT, some clay, trace gravel Very Dense Grey Moist (TILL)		4	SS	102/ 0.150		286												
			5	SS	113/ 0.150														
							285												
284.4																			
4.6	Silty CLAY, sandy, trace gravel, occasional silty sand and clayey silt lenses Hard Grey Moist (TILL)		6	SS	116		284												
							283												
			7	SS	69														
							282												
			8	SS	104/ 0.300		281												
			9	SS	108/ 0.150		280												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity


20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-07

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 186.0 E 194 457.2 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.11.28 - 2014.11.28 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page													
278.2	Silty CLAY , sandy, trace gravel Hard Grey Moist (TILL)		10	SS	104/									
10.8	END OF BOREHOLE AT 10.8m. BOREHOLE OPEN TO 10.8m AND WATER LEVEL AT 9.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.				0.150									

RECORD OF BOREHOLE No 14-08

1 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 173.5 E 194 437.9 ORIGINATED BY AN
HWY 401/19 BOREHOLE TYPE Solid Stem Augers COMPILED BY AMP
DATUM Geodetic DATE 2015.06.25 - 2015.06.25 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
289.0	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (100mm)							20	40	60	80	100								
0.1	Gravelly SAND, some silt Compact Brown Dry to Moist (FILL)		1	GS																
			1	SS	29		288													27 57 16 (SI+CL)
287.3																				
1.7	SAND and SILT, some clay, trace gravel Compact to Very Dense Grey Moist to Dry (TILL)		2	SS	21		287													
			3	SS	32															0 38 42 20
			4	SS	74		286													
			5	SS	73		285													
	500mm sand layer at 5m depth.						284													
283.2																				
5.8	Clayey SILT, some sand, becoming sandy, trace gravel Hard Grey Moist (TILL)		6	SS	100/ 0.275		283													4 34 37 25
							282													
			7	SS	70		281													
							280													
			8	SS	100/ 0.175															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

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

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 14-08

3 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 173.5 E 194 437.9 ORIGINATED BY AN
 HWY 401/19 BOREHOLE TYPE Solid Stem Augers COMPILED BY AMP
 DATUM Geodetic DATE 2015.06.25 - 2015.06.25 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	Continued From Previous Page		15	SS	131												
268.7 20.3	END OF BOREHOLE AT 20.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 4.6m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.06.25 7.8 281.2 2015.07.15 1.8 287.2																

RECORD OF BOREHOLE No 14-09

1 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 202.6 E 194 416.4 ORIGINATED BY AN
HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
DATUM Geodetic DATE 2015.06.22 - 2015.06.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
295.7	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (100mm)							20	40	60	80	100						
0.1	Gravelly SAND, some silt Compact Brown Moist (FILL)		1	GS			295											31 53 16 (SI+CL)
			1	SS	19													
294.0							294											
1.7	Silty SAND to SAND and SILT, trace to some clay, trace gravel Very Loose to Loose Brown Moist (FILL)		2	SS	0													
			3	SS	2		293											
			4	SS	7		292											
			5	SS	4													2 45 38 15
291.2							291											
4.5	SAND and SILT, trace to some clay, trace to some gravel Compact Grey Moist (TILL)		6	SS	10		290											
			7	SS	12		289											
			8	SS	19		288											
			9	SS	10		287											10 39 41 10
							286											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-09

2 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 202.6 E 194 416.4 ORIGINATED BY AN
HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
DATUM Geodetic DATE 2015.06.22 - 2015.06.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				
	Continued From Previous Page							20 40 60 80 100								
284.0			10	SS	15		285									
11.7	Clayey SILT and SAND , trace gravel Very Stiff to Hard Grey Moist (TILL)		11	SS	25		284									
							283								6 41 37 16	
							282									
	Clay seam (150mm) at 14.0m		12	SS	26		281									
							280									
			13	SS	69		279									
279.5							278									
16.2	SILT , trace sand, trace to some clay, occasional clayey silt lenses Very Dense Grey Moist to Wet (TILL)		14	SS	68		277								0 0 76 24	
							276									
			15	SS	100/ 0.275											

Continued Next Page

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

RECORD OF BOREHOLE No 14-09

3 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 202.6 E 194 416.4 ORIGINATED BY AN
 HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
 DATUM Geodetic DATE 2015.06.22 - 2015.06.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)	W _p	W	W _L		
	Continued From Previous Page		16	SS	100/									
					0.300									
274.0			17	SS	100/									0 4 86 10
21.7	END OF BOREHOLE AT 21.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 4.6m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.06.23 10.0 285.7 2015.07.15 10.1 285.6				0.175									



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

RECORD OF BOREHOLE No 14-10

1 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 137.8 E 194 477.3 ORIGINATED BY AN
 HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
 DATUM Geodetic DATE 2015.06.23 - 2015.06.24 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
296.3	GROUND SURFACE													
0.0	Silty SAND , some clay, trace gravel Loose to Compact Brown Dry to Moist (FILL)		1	GS										
			1	SS	21									
			2	SS	24									
			3	SS	9									
			4	SS	6									
292.2														
4.1	SAND and SILT , trace to some clay, trace gravel, occasional clayey silt lense Loose to Very Dense Brown to Grey Moist to Wet (TILL)													
			6	SS	8									
			7	SS	27									
			8	SS	67									

Continued Next Page

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

RECORD OF BOREHOLE No 14-10

2 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 137.8 E 194 477.3 ORIGINATED BY AN
 HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
 DATUM Geodetic DATE 2015.06.23 - 2015.06.24 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
285.9	Continued From Previous Page													
10.4	Clayey SILT to Silty CLAY , trace sand, trace gravel Hard Grey Moist (TILL)		9	SS	39									
			10	SS	54									
			11	SS	51									
			12	SS	56									
			13	SS	99									
			14	SS	60									
276.9														
19.4	Silty CLAY , trace sand Hard Grey Moist													

Continued Next Page

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

RECORD OF BOREHOLE No 14-10

3 OF 3

METRIC

GWP# 3079-09-00 LOCATION Hwy 19 Underpass N 4 766 137.8 E 194 477.3 ORIGINATED BY AN
 HWY 401/19 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AMP
 DATUM Geodetic DATE 2015.06.23 - 2015.06.24 CHECKED BY AMP

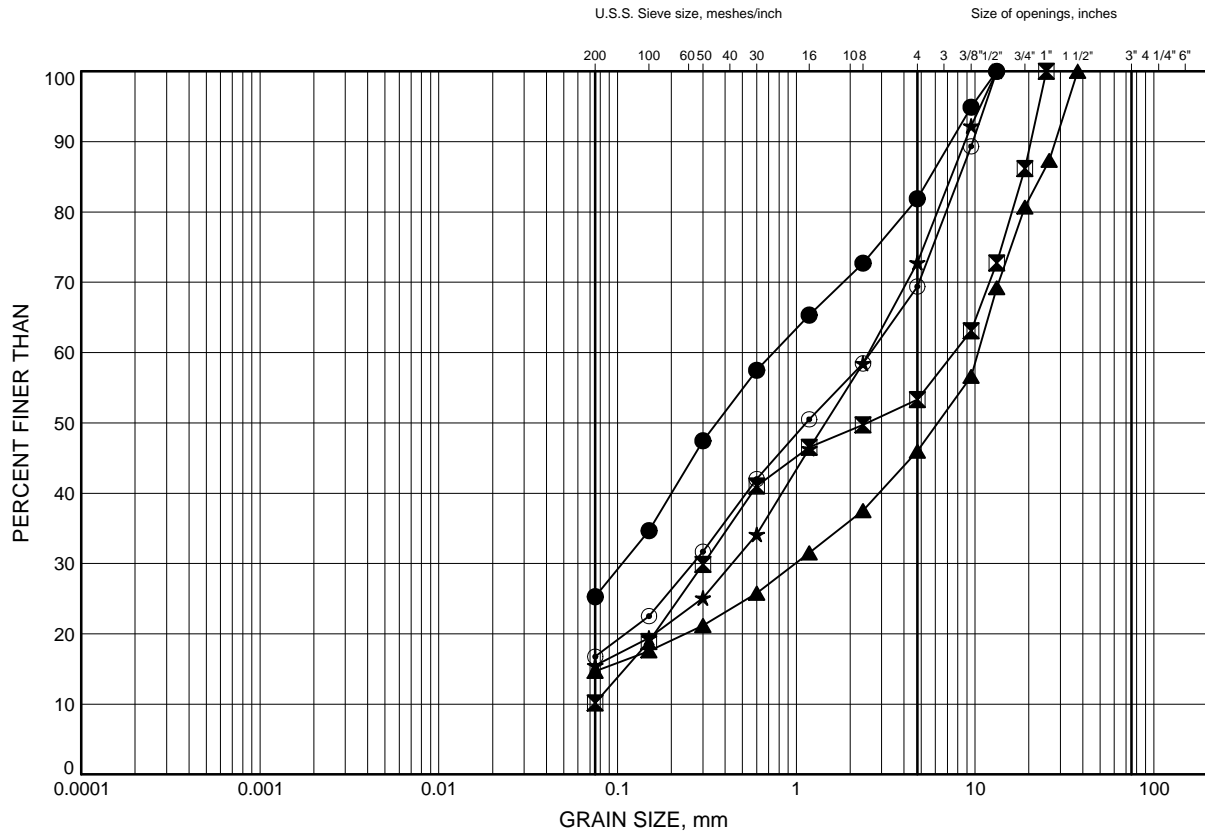
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page		15	SS	72		276								
							275								
274.5			16	SS	103										
21.8	SILT, trace sand, trace to some clay Very Dense Grey Moist to Wet						274								
			17	SS	100/ 0.175		273								
							272								
271.6			18	SS	100/ 0.175										0 0 90 10
24.7	END OF BOREHOLE AT 24.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 4.6m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.06.24 13.9 282.4 2015.07.15 14.0 282.3														

Appendix B
Laboratory Test Results

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to SAND & GRAVEL (FILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	0.38	295.32
⊠	14-04	0.38	295.82
▲	14-07	1.07	287.93
★	14-08	1.07	287.93
⊙	14-09	0.38	295.32

Date ..October 2015.....

GWP# ..3079-09-00.....



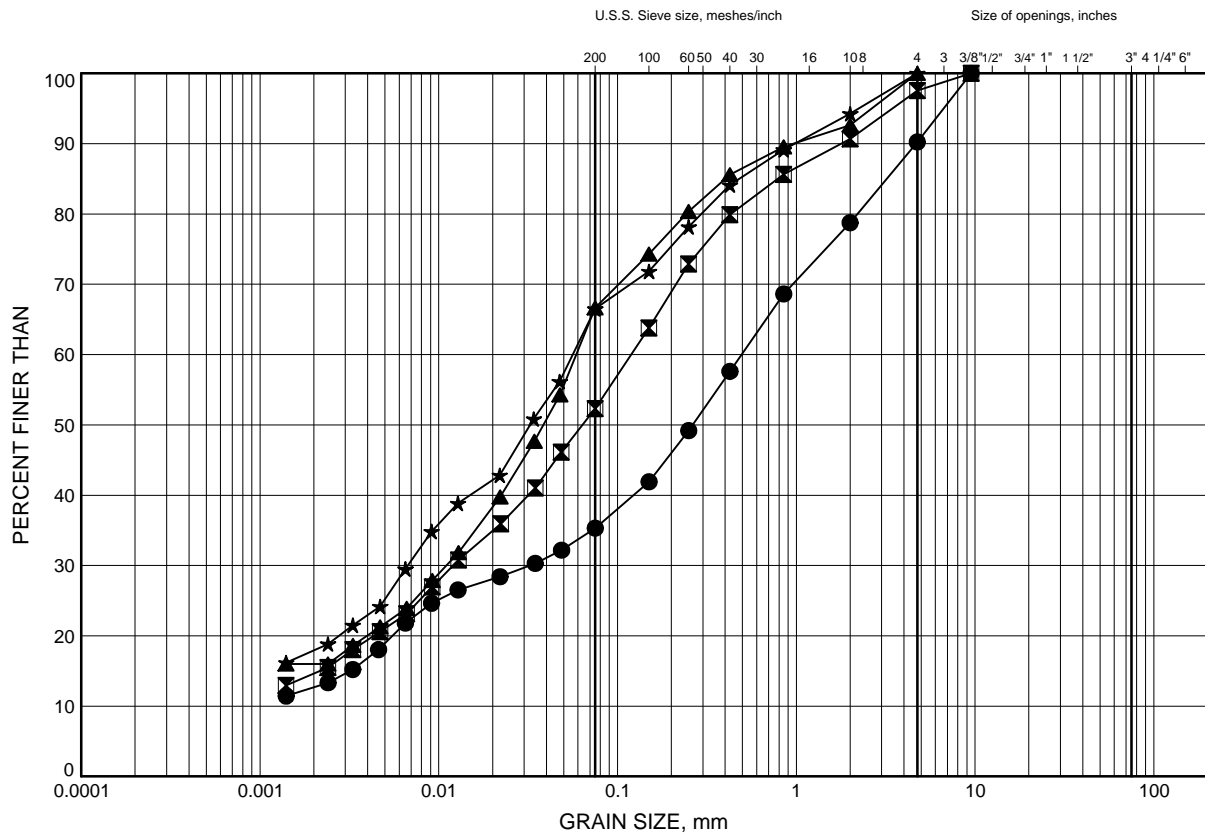
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND to SAND & SILT (FILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	1.07	294.63
⊠	14-09	4.11	291.59
▲	14-10	1.07	295.23
★	14-10	3.35	292.95

Date ..October 2015.....
GWP# ..3079-09-00.....

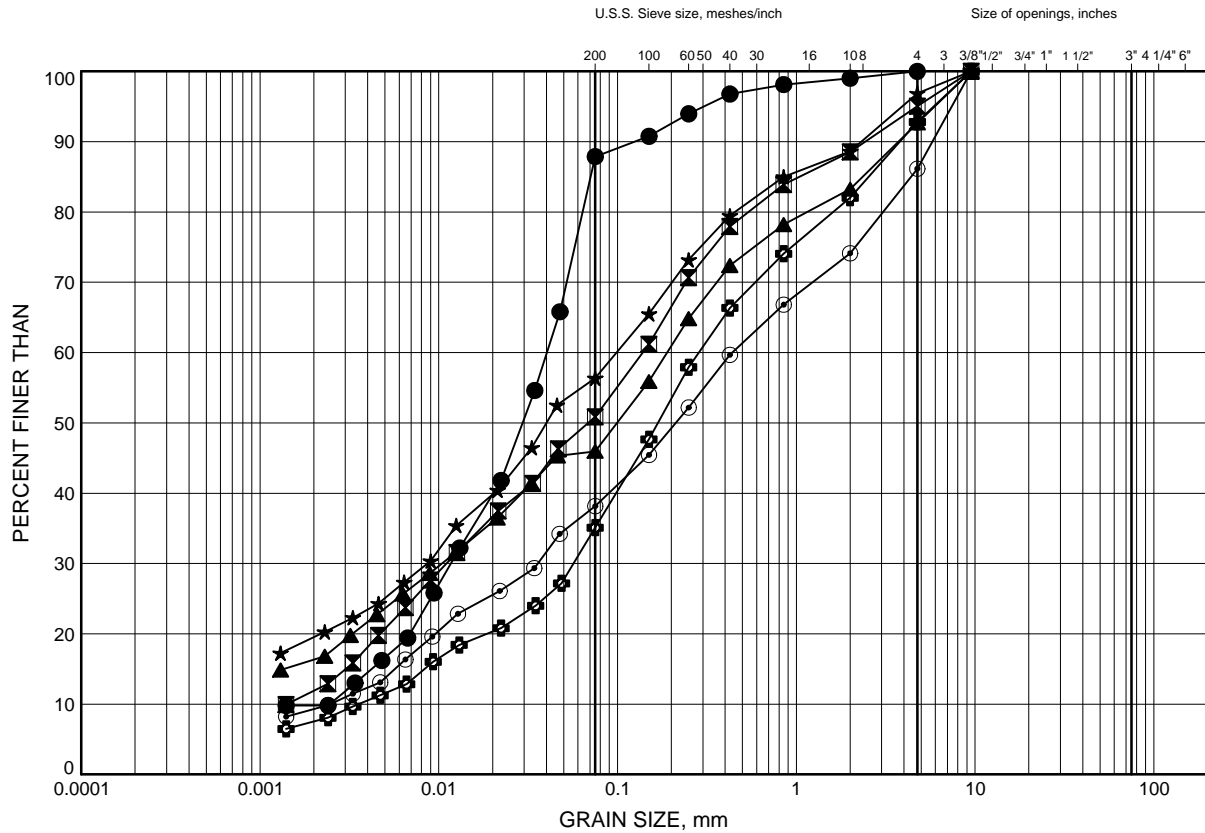


Prep'dAN.....
Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B3

Upper Silty SAND to SAND & SILT (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	3.35	292.35
⊠	14-01	6.40	289.30
▲	14-02	4.88	290.82
★	14-02	9.45	286.25
⊙	14-03	2.59	293.21
⊕	14-03	7.92	287.88

Date ..October 2015.....

GWP# ..3079-09-00.....



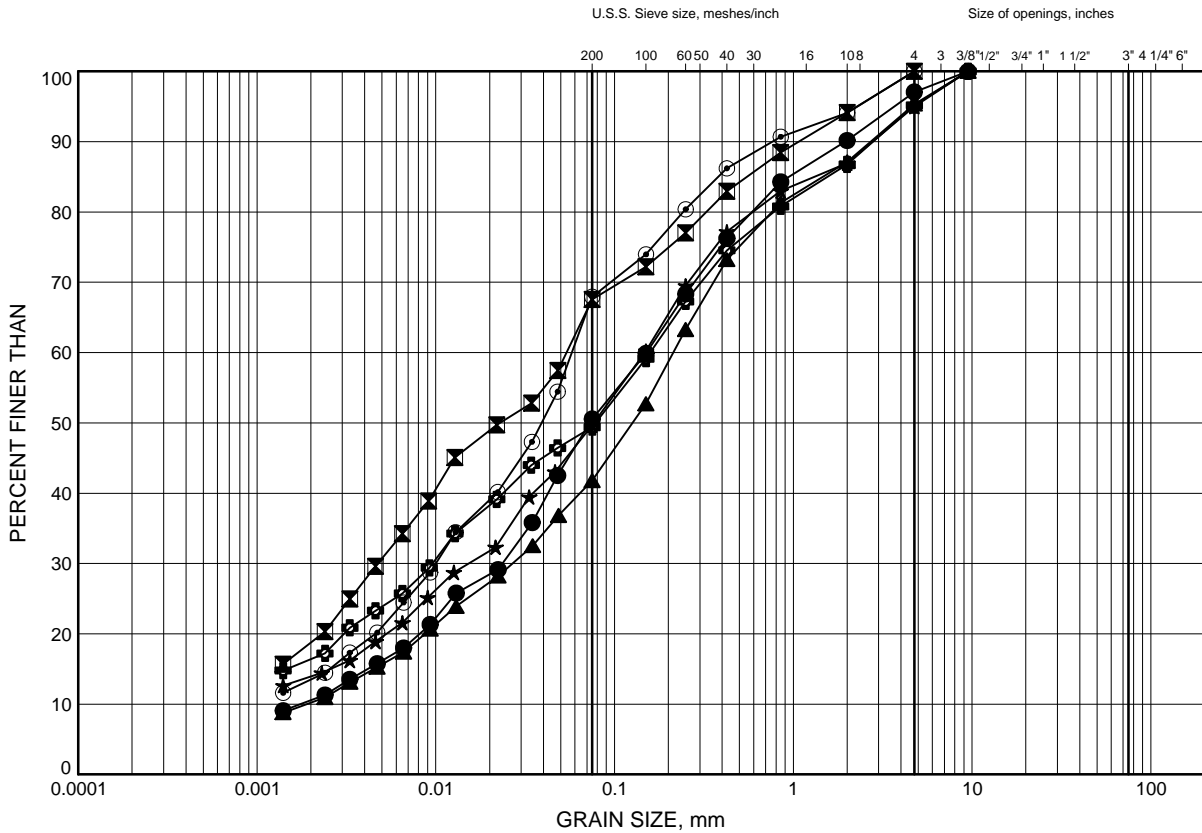
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B4

Upper Silty SAND to SAND & SILT (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-04	4.88	291.32
⊠	14-05	3.35	292.95
▲	14-05	9.45	286.85
★	14-06	1.83	294.57
⊙	14-06	3.35	293.05
⊕	14-06	6.40	290.00

Date ..October 2015.....

GWP# ..3079-09-00.....



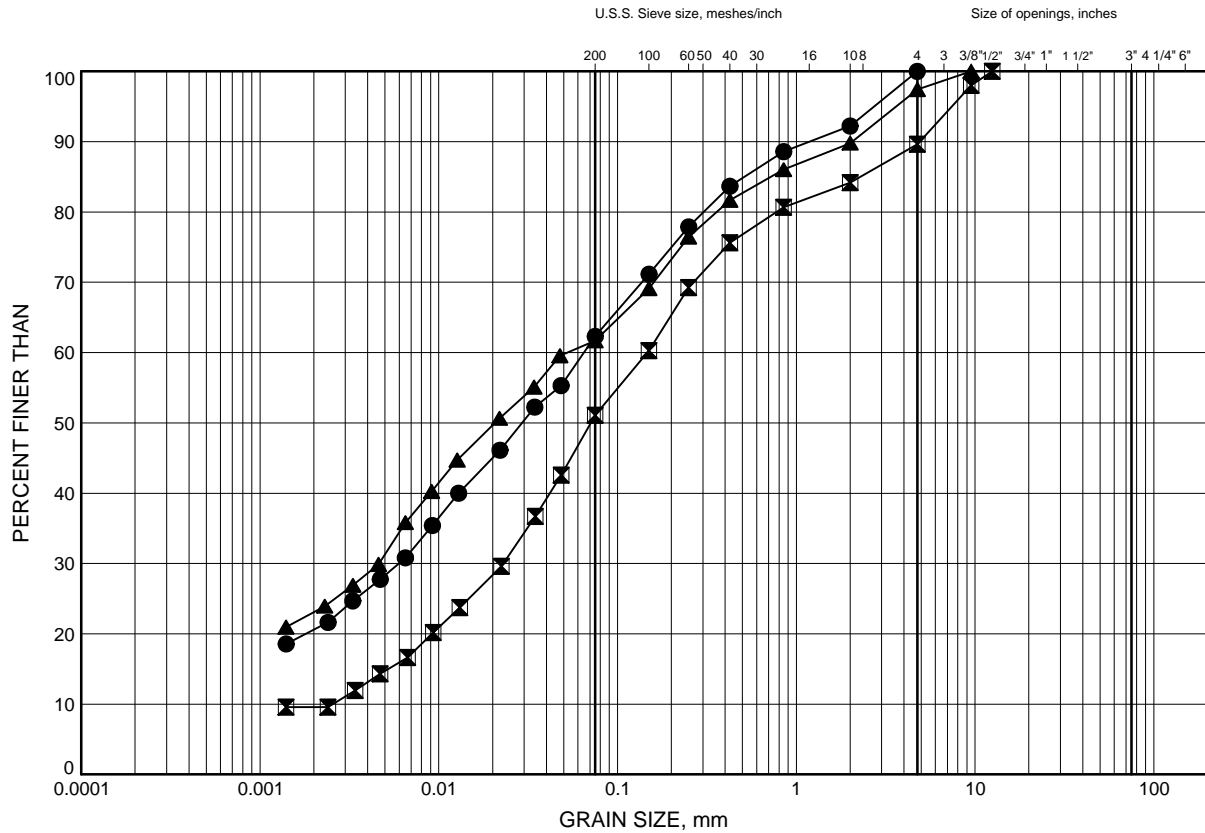
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B5

Upper Silty SAND to SAND & SILT (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-08	2.59	286.41
⊠	14-09	9.45	286.25
▲	14-10	7.92	288.38

Date ..October 2015.....

GWP# ..3079-09-00.....



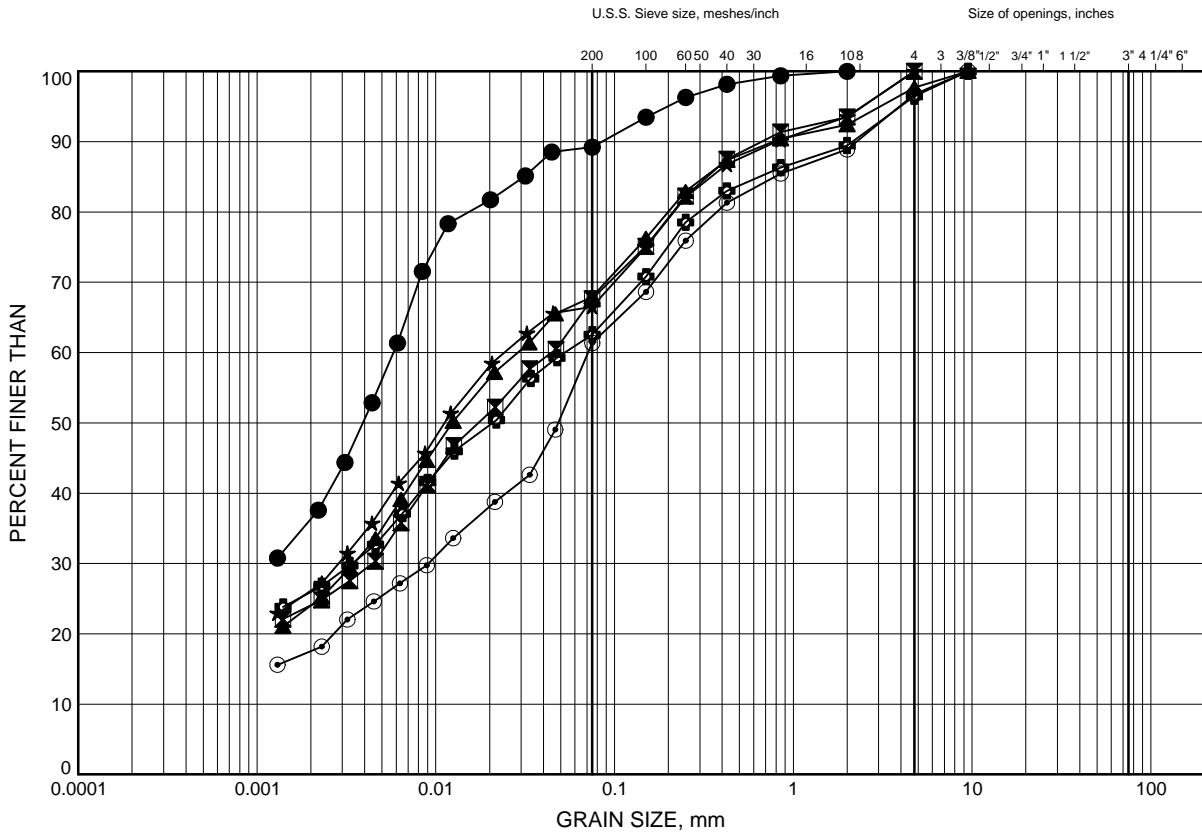
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B6

Clayey SILT / Silty CLAY (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-03	15.54	280.26
⊠	14-04	10.97	285.23
▲	14-05	12.50	283.80
★	14-07	4.88	284.12
⊙	14-07	7.92	281.08
⊕	14-08	6.32	282.68

Date ..October 2015.....

GWP# ..3079-09-00.....



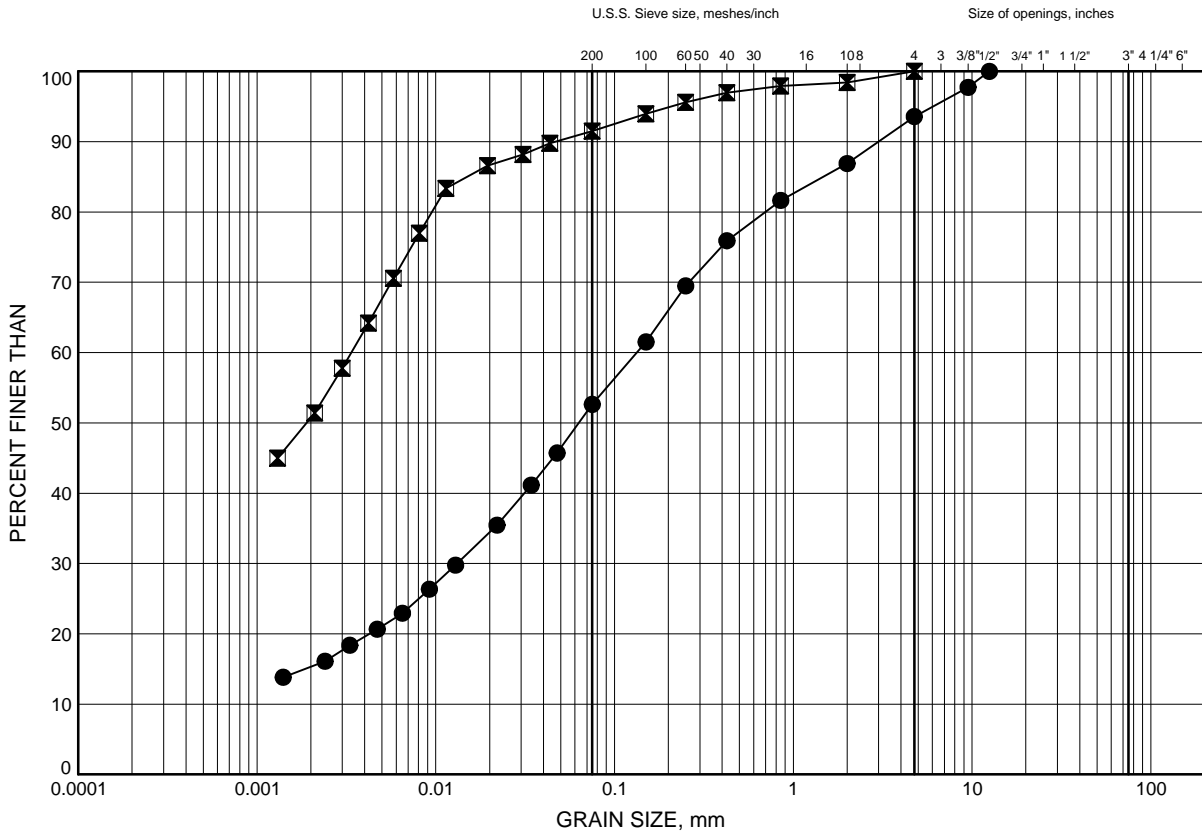
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B7

Clayey SILT / Silty CLAY (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-09	12.50	283.20
⊠	14-10	14.02	282.28

Date ..October 2015.....

GWP# ..3079-09-00.....



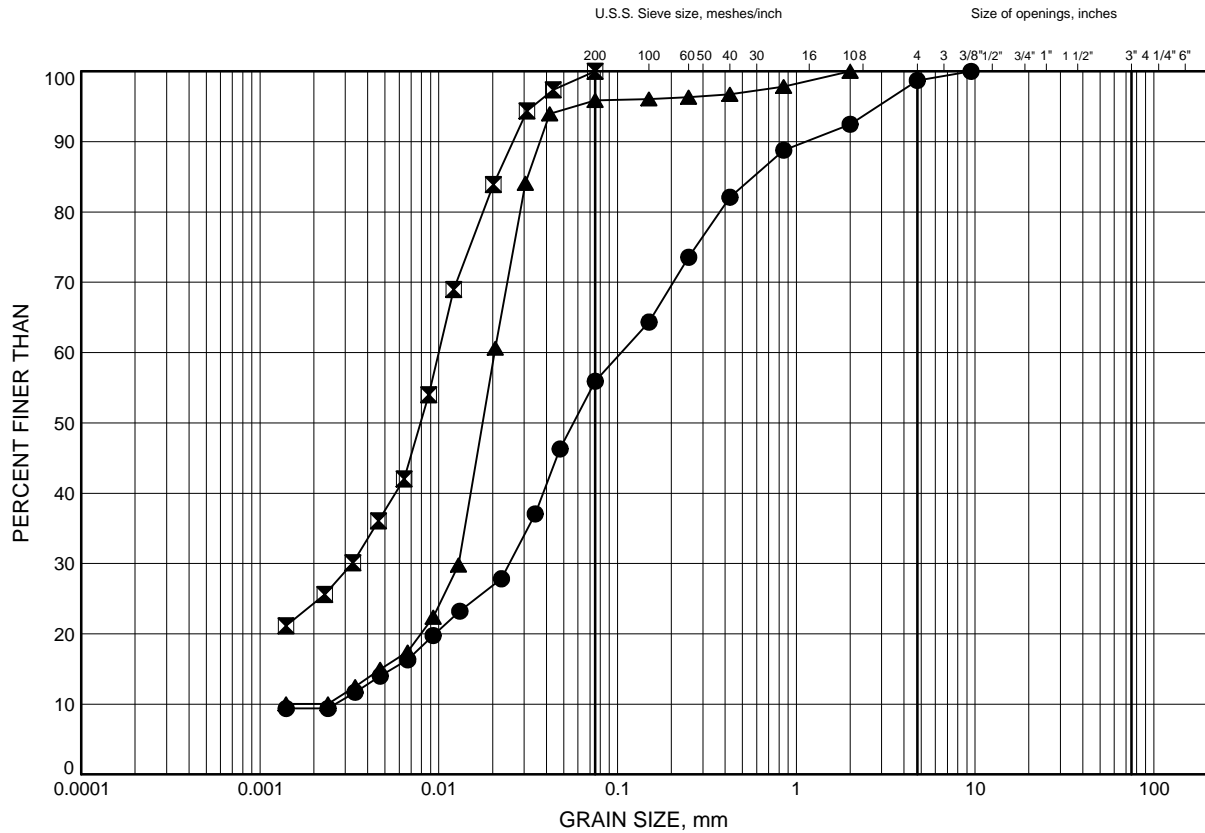
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B8

Lower SAND & SILT (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-03	18.59	277.21
⊠	14-09	18.52	277.18
▲	14-09	21.49	274.21

Date ..October 2015.....

GWP# ..3079-09-00.....



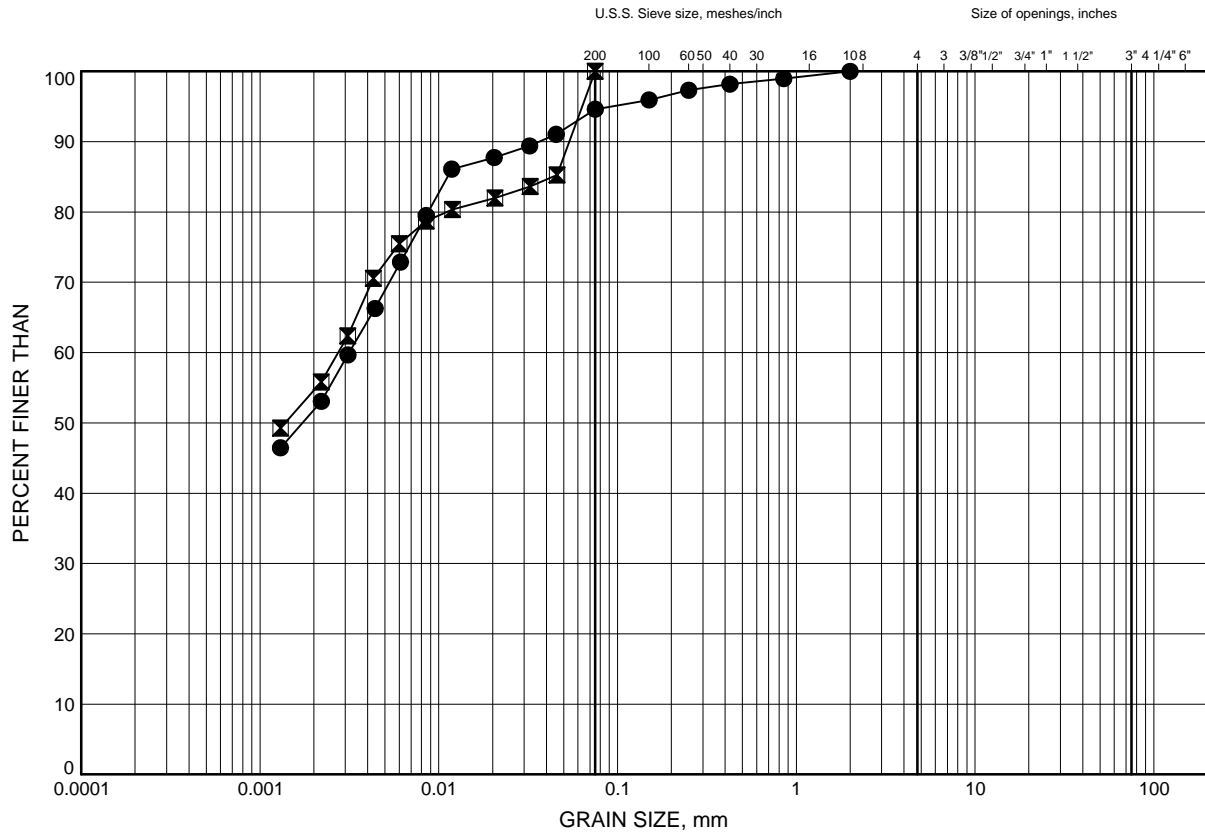
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B9

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-08	12.42	276.58
⊠	14-10	20.10	276.20

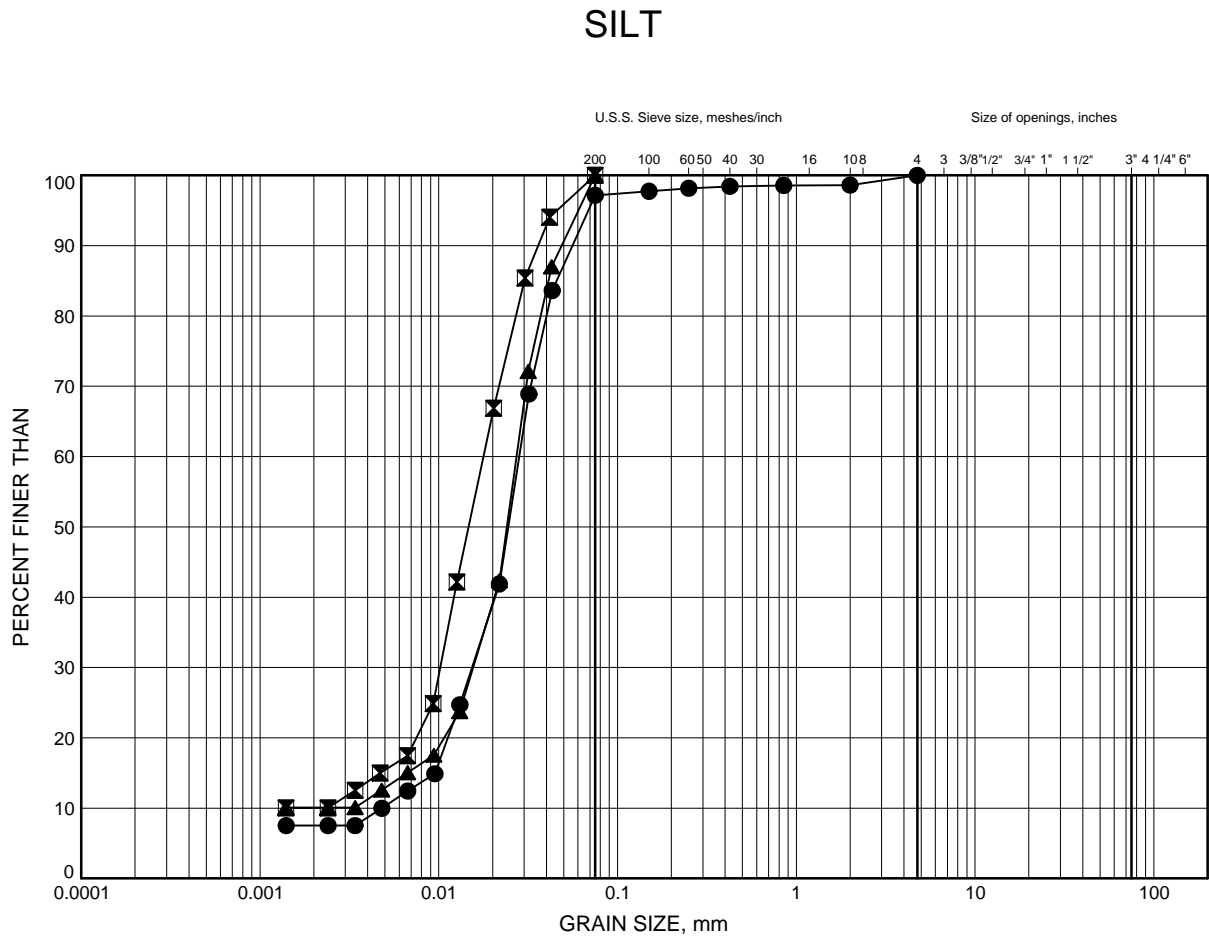
Date ..October 2015.....
GWP# ..3079-09-00.....



Prep'dAN.....
Chkd.AMP.....

Hwy 19 Underpass GRAIN SIZE DISTRIBUTION

FIGURE B10



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-08	15.54	273.46
⊠	14-08	18.59	270.41
▲	14-10	24.54	271.76

Date ..October 2015.....

GWP# ..3079-09-00.....



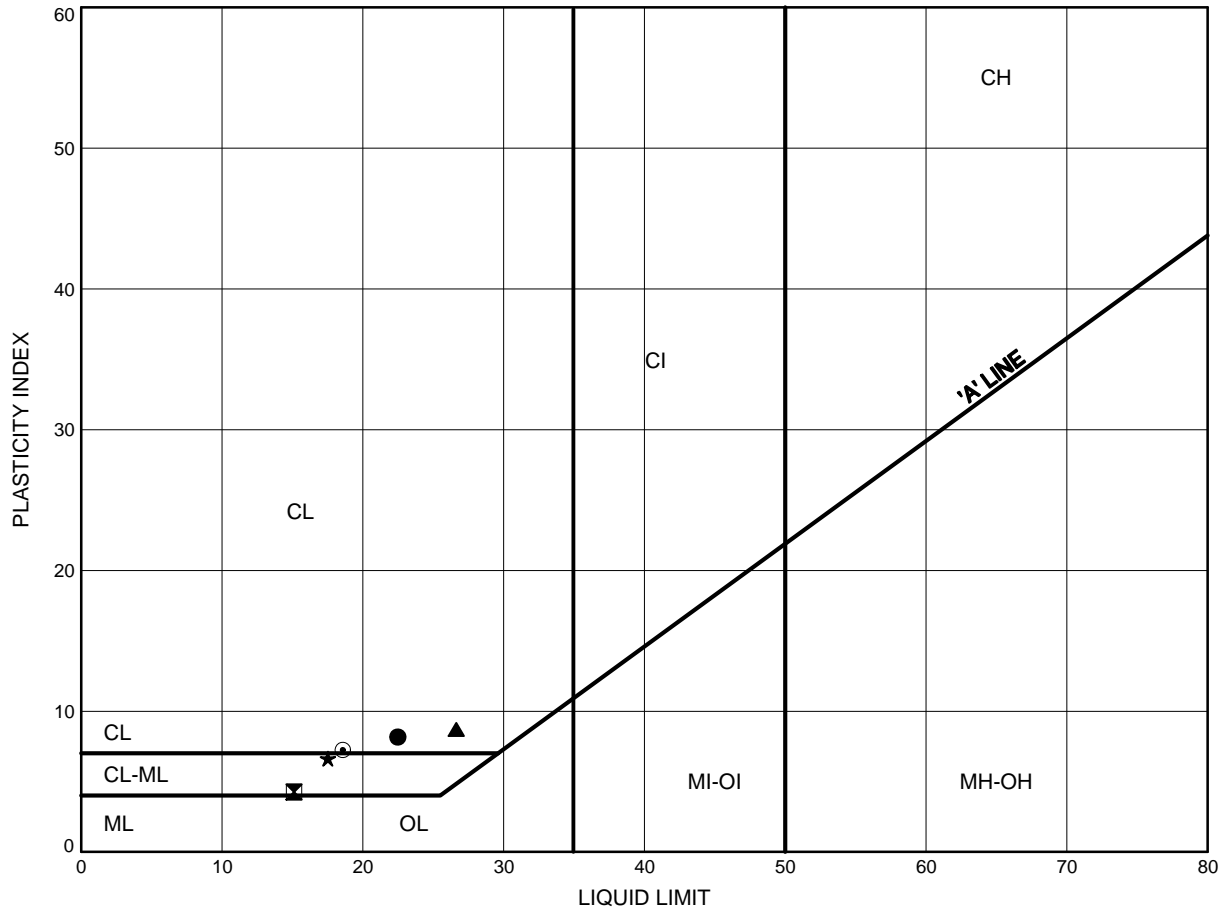
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass ATTERBERG LIMITS TEST RESULTS

FIGURE B11

Upper TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	6.40	289.30
⊠	14-02	9.45	286.25
▲	14-06	3.35	293.05
★	14-08	2.59	286.41
⊙	14-10	7.92	288.38

Date ..October 2015.....

GWP# ..3079-09-00.....



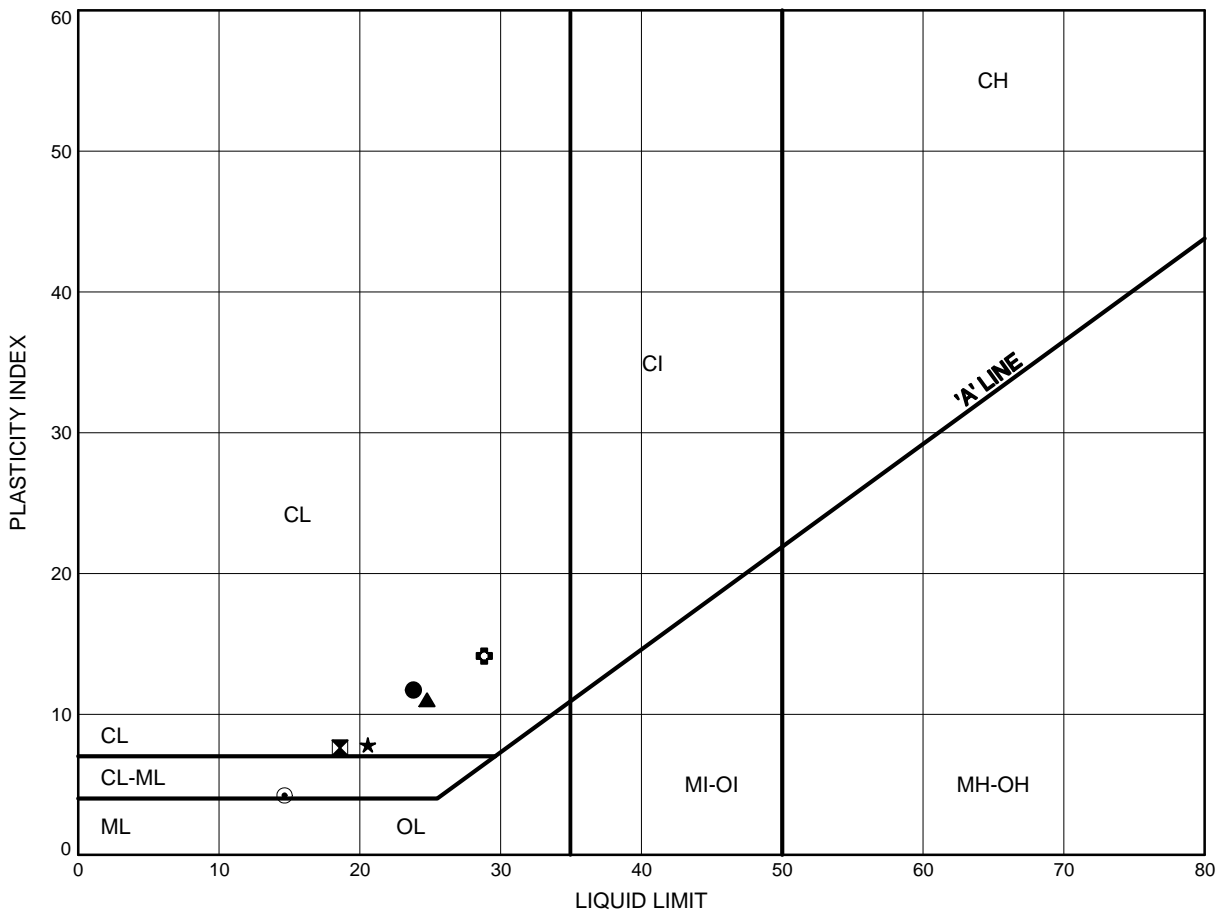
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass ATTERBERG LIMITS TEST RESULTS

FIGURE B12

Clayey SILT / Silty CLAY (TILL)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-03	15.54	280.26
⊠	14-04	10.97	285.23
▲	14-05	12.50	283.80
★	14-07	4.88	284.12
⊙	14-09	12.50	283.20
⊕	14-10	14.02	282.28

Date ..October 2015.....

GWP# ..3079-09-00.....



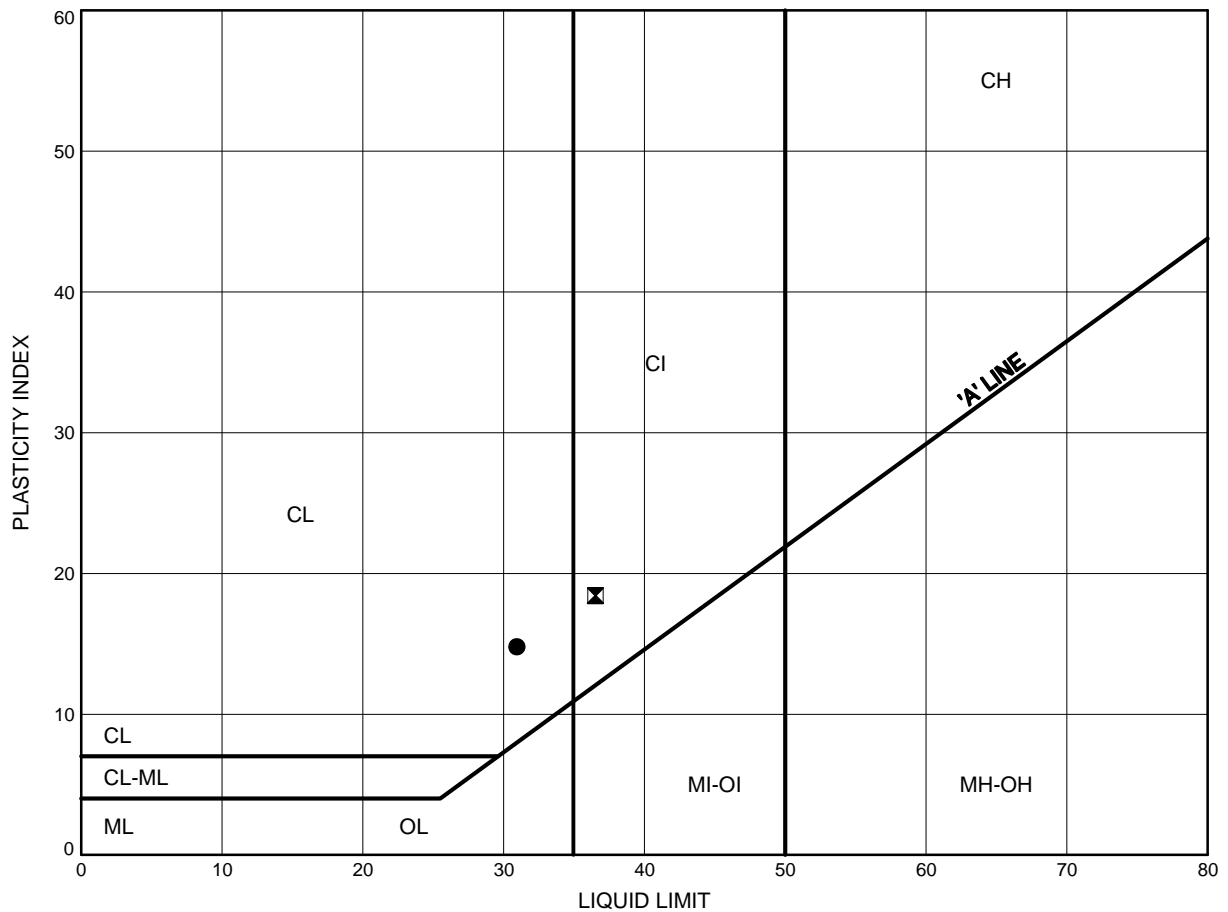
Prep'dAN.....

Chkd.AMP.....

Hwy 19 Underpass ATTERBERG LIMITS TEST RESULTS

FIGURE B13

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-08	12.42	276.58
⊠	14-10	20.10	276.20

Date ..October 2015.....
GWP# ..3079-09-00.....



Prep'dAN.....
Chkd.AMP.....

Appendix C

Analytical Test Results



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 14T925116

PROJECT: 19-5161-224

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

SAMPLING SITE:

ATTENTION TO: Stephen Peters

SAMPLED BY:

pH, Sulphate (Soil)

DATE RECEIVED: 2014-12-05

DATE REPORTED: 2014-12-15

				14-04 SS11	14-02 SS1	NW-02 SS11	NW-04 SS1
SAMPLE DESCRIPTION:				(40'-42')	(6" -2')	(40'-42')	(0'-2')
SAMPLE TYPE:				Soil	Soil	Soil	Soil
DATE SAMPLED:				12/4/2014	12/4/2014	12/4/2014	12/4/2014
Parameter	Unit	G / S	RDL	6157014	6157025	6157026	6157027
pH, 2:1 CaCl2 Extraction	pH Units			8.13	8.12	7.91	7.57
Sulphate (2:1)	µg/g	2		33	25	42	18

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

Certified By:





Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 19-5161-224

SAMPLING SITE:

AGAT WORK ORDER: 14T925116

ATTENTION TO: Stephen Peters

SAMPLED BY:

Soil Analysis

RPT Date: Dec 15, 2014			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
pH, Sulphate (Soil)															
pH, 2:1 CaCl2 Extraction	6157135		7.90	7.91	0.1%	NA	100%	80%	120%	NA			NA		
Sulphate (2:1)	6156506		17	17	3.8%	< 2	99%	80%	120%	103%	80%	120%	102%	70%	130%

Comments: NA signifies Not Applicable.

Certified By: _____



Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 14T925116

PROJECT: 19-5161-224

ATTENTION TO: Stephen Peters

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
pH, 2:1 CaCl ₂ Extraction	INOR-93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH

Appendix D

Site Photographs



Photograph 1 – Looking west onto Highway 401 from bridge deck.



Photograph 2 – Looking east onto Highway 401 from bridge deck.



Photograph 3 – Highway 19 - looking north onto bridge deck.



Photograph 4 – Highway 19 - looking south onto bridge deck.



Photograph 5 – East bridge elevation; looking towards north abutment.

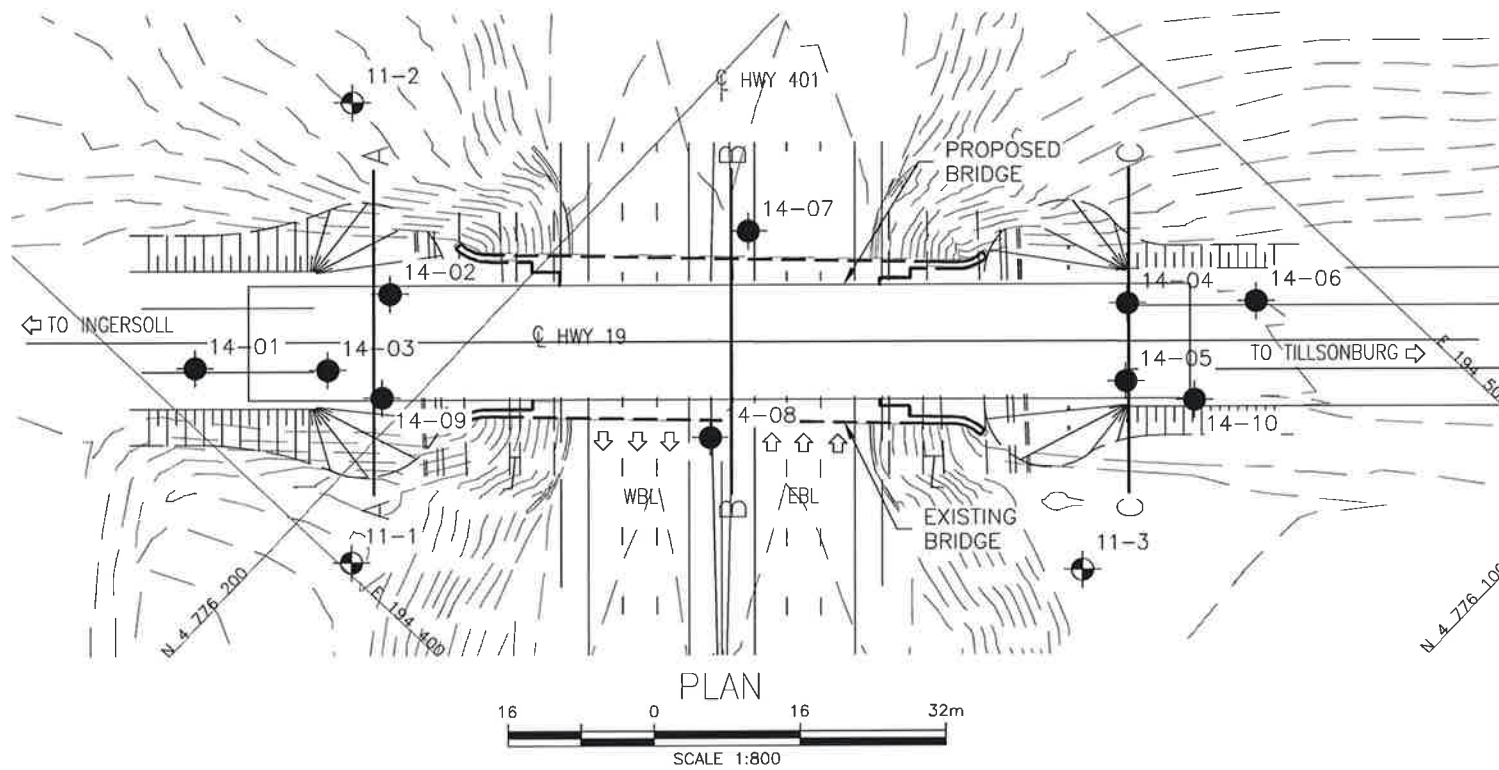


Photograph 6 – Looking towards north bridge abutment

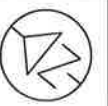
Appendix E

Borehole Location and Soil Strata Drawing

CAD FILE LOCATION AND NAME: H:\Drawing\19\15\12\24\19\15\12\24-BoreholePlan&Profile (Highway 19 Underpass).dwg
MODIFIED: 10/27/2015 8:38:25 AM BY: DBAFTING02
DATE PLOTTED: 12/08/2015 10:14:23 AM BY: DBAFTING02



CONT No
GWP No 3079-09-00

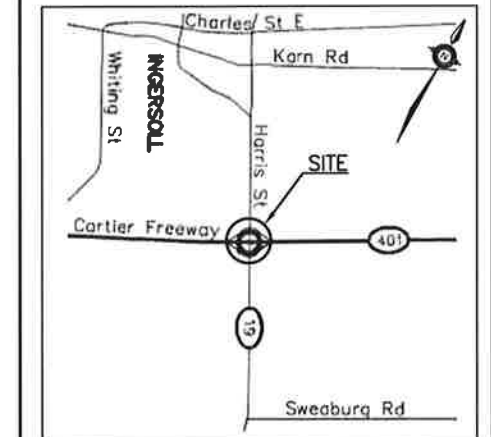


HIGHWAY 401
HIGHWAY 19 UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
127



METRIC



KEYPLAN

LEGEND

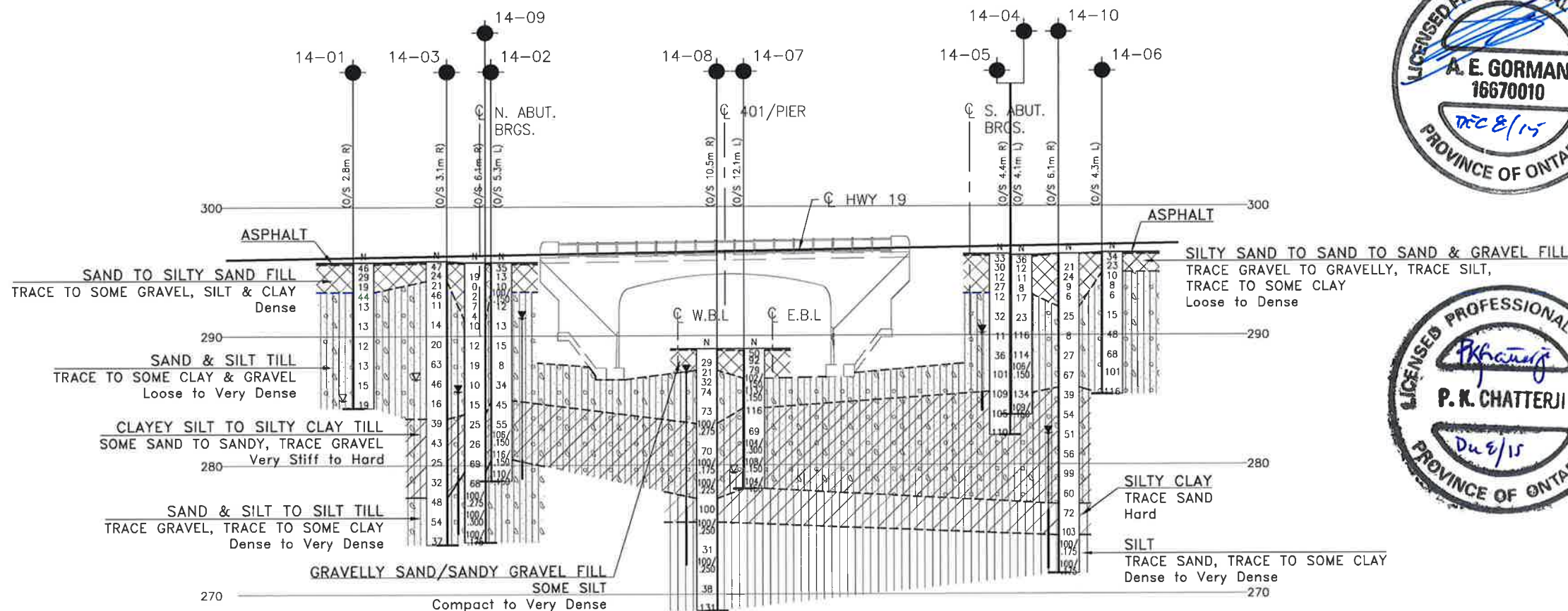
- ◆ Borehole (Current Investigation)
- ◆ Borehole (Previous Investigation, 2013)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level In Open Borehole
- W Water Level In Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
14-01	295.7	4 766 219.6	194 404.7
14-02	295.7	4 766 209.8	194 425.3
14-03	295.8	4 766 209.0	194 414.5
14-04	296.3	4 766 150.4	194 479.9
14-05	296.3	4 766 144.7	194 473.6
14-06	296.4	4 766 140.3	194 489.8
14-07	289.0	4 766 186.0	194 457.2
14-08	289.0	4 766 173.5	194 437.9
14-09	295.7	4 766 202.6	194 416.4
14-10	296.3	4 766 137.8	194 477.3
11-01	293.9	4 766 192.6	194 401.0
11-02	291.7	4 766 227.2	194 437.7
11-03	294.5	4 766 133.9	194 455.4

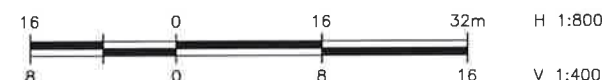
NOTES

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

GEORES No. 40P2-77



PROFILE ALONG C HWY 19



H 1:800

V 1:400

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MKE	CHK	MKE
DRAWN	AN	CHK	SITE
DATE	DEC 2015	DWG	2







DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

[illegible]

A map showing the location of the site. The site is located at the intersection of Harris St and Cortier Freeway. The map includes labels for Charles St E, Korn Rd, Whiting St, INGERSOLL, Harris St, SITE, Cortier Freeway, 401, 19, and Swaburg Rd. A north arrow is also present.

LEGEND

	Borehole (Current Investigation)
	Borehole (Previous Investigation, 2013)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level In Open Borehole
	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
14-01	295.7	4 766 219.6	194 404.7
14-02	295.7	4 766 209.8	194 425.3
14-03	295.8	4 766 209.0	194 414.5
14-04	296.3	4 766 150.4	194 479.9
14-05	296.3	4 766 144.7	194 473.6
14-06	296.4	4 766 140.3	194 489.8
14-07	289.0	4 766 186.0	194 457.2
14-08	289.0	4 766 173.5	194 437.9
14-09	295.7	4 766 202.6	194 416.4
14-10	296.3	4 766 137.8	194 477.3
11-01	293.9	4 766 192.6	194 401.0
11-02	291.7	4 766 227.2	194 437.7
11-03	294.5	4 766 133.9	194 455.4

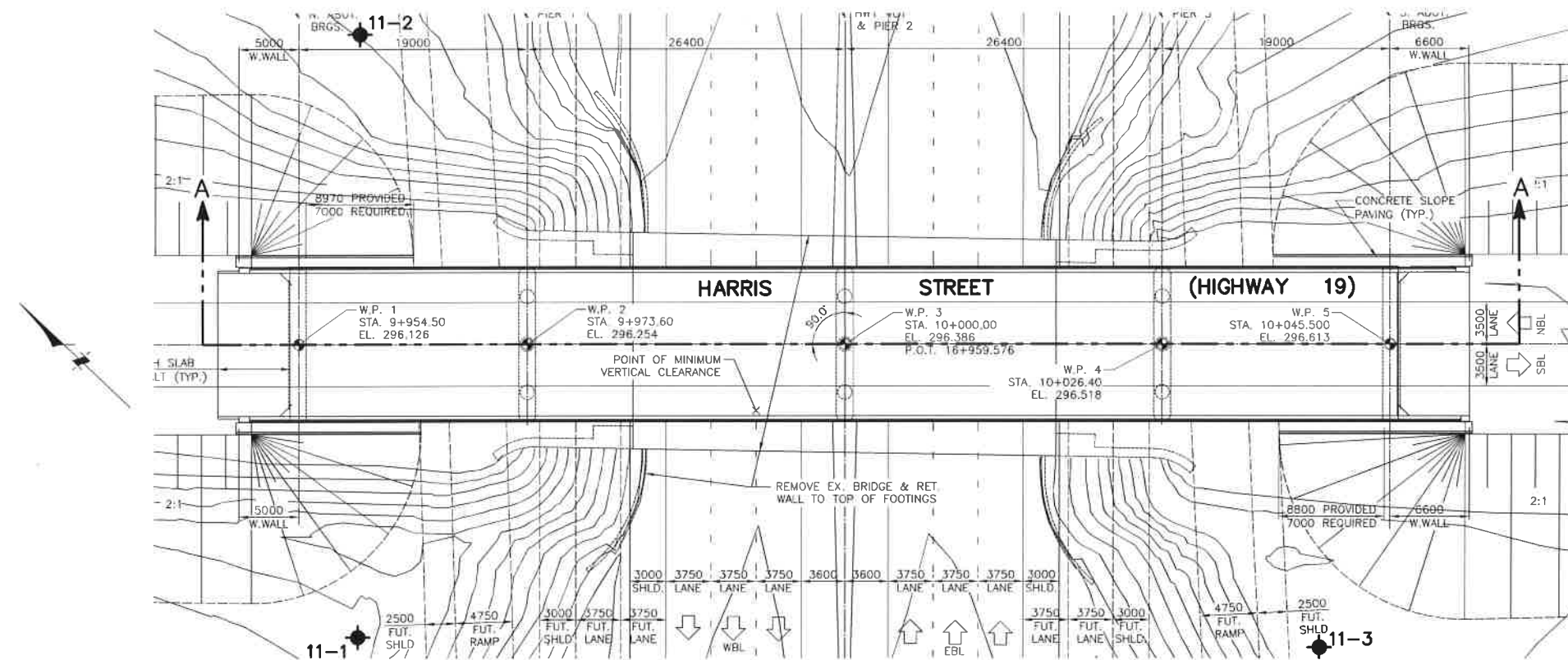
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 40P2-77



Appendix F

Previous Investigation Borehole Locations and Soil Strata Drawing and Record of Borehole Sheets Geocres No.: 40P2-74



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

PLATE No
CONT
WP 3070-09-00








SHEET

HIGHWAY 401
HIGHWAY 19, INGERSOLL, ONTARIO
BOREHOLE LOCATIONS & SOIL STRATA



 **KEY PLAN**
1 km 0 2 km

LEGEND

- | | |
|---|---|
|  | Borehole (by Stantec) |
|  | Borehole (by others) |
|  | N |
| | Blows/0.3m (Std Pen Test, 475 J/blow) |
|  | WL at time of investigation
March 2011 |
|  | (m NORTH) Offset from Cross Section Line
in metres |

No	ELEVATION	MTM ZONE 11 NORTH	COORDINATES EAST
11-1	293.9	4 766 192.6	194 401.0
11-2	291.7	4 766 227.2	194 437.7
11-3	294.5	4 766 133.9	194 455.4

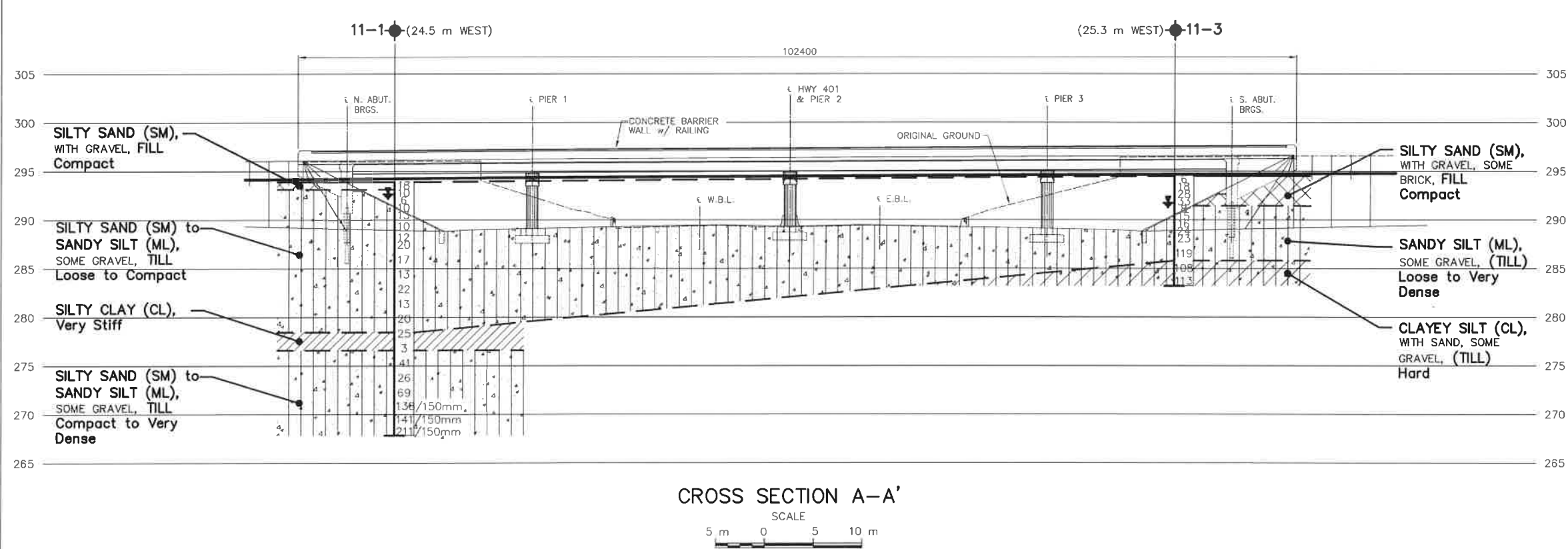
≡NOTES≡

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISION					
DATE	BY	DESCRIPTION			
GEOCES No 40P2-74					
HWY No 401				DIST	
SUBM'D SG	CHECKED	DATE 2012-07-12		SITE	23-210
DRAWN KDM	CHECKED	APPROVED		DWG	1



RECORD OF BOREHOLE No BH 11-1

1 OF 3

METRIC

W.P. GWP 3070-09-00

LOCATION Hwy 401 at Hwy 19, Site 23-210, Ingersoll

N: 4 766 193 E: 194 401

ORIGINATED BY DS

DIST HWY 401

BOREHOLE TYPE Hollow Stem Augers, Spillspoon Sampler

COMPILED BY JF

DATUM Geodetic

DATE 2011 04 04 - 2011 04 05

CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL x LAB VANE	20 40 60 80 100	20 40 60 80 100	w _p w w _L			
293.9	Tall Grass													GR SA SI CL
293.7	Silty sand, some roots, brown, FILL													
0.2	Silty gravel, FILL Compact Brown		1	SS	18									
293.1														
0.8	Silty sand (SM) to sandy silt (ML), some gravel, TILL						293							
	Loose to compact		2	SS	10									
	Brown to grey													
			3	SS	6		292							11 50 (39)
			4	SS	10									Water Flow From Sampler
			5	SS	13		291							Water Flow From Sampler
			6	SS	10		290							
	- wet		7	SS	10		289							11 41 (48)
	- Clayey silt @ 5.6 m		8	SS	12		288							
			9	SS	20									
							287							
	- moist to wet		10	SS	17		286							Water Flow From Sampler
							285							
			11	SS	13									7 39 (54)
283.0							284							Water Flow From Sampler

Continued Next Page

✕ 3. ✕ 3.

Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH 11-2

1 OF 2

METRIC

W.P. GWP 3070-09-00 LOCATION Hwy 401 at Hwy 19, Site 23-210, Ingersoll N: 4 766 227 E: 194 438 ORIGINATED BY DS
DIST HWY 401 BOREHOLE TYPE Hollow Stem Augers, Spitspoon Sampler COMPILED BY JF
DATUM Geodetic DATE 2011 04 04 - 2011 04 04 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								20 40 60 80 100				
								20 40 60 80 100				
291.7	Tall Grass											
290.8	TOPSOIL											
0.2	Silty sand (SM) to sandy silt (ML), some gravel, TILL Loose to dense Brown		1	SS	9							
			2	SS	16							6 42 (52)
			3	SS	4							
			4	SS	6							
			5	SS	15							13 45 (42)
			6	SS	15							
			7	SS	42							
			8	SS	33							8 31 (61)
285.6												
285.4	SAND (SP), compact, brown											
6.1												
6.3	Silty sand (SM) to sandy silt (ML), some gravel, TILL Very dense Grey - with cobbles and boulders - sand infilling augers @ 7.3 m - cobbles and boulders		9	SS	18							Water Flow From Sampler
			10	SS	88							
283.0	Clayey silt (CL) with sand, some gravel, TILL Hard Grey - with cobbles and boulders		11	SS	103							
8.7												
281.7												

Continued Next Page

\times^3, \times^3 Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH 11-3

1 OF 2

METRIC

W.P. GWP 3070-09-00

LOCATION Hwy 401 at Hwy 19, Site 23-210, Ingersoll

N: 4 766 134 E: 194 455

ORIGINATED BY DS

DIST HWY 401

BOREHOLE TYPE Hollow Stem Augers, Splitspoon Sampler

COMPILED BY JF

DATUM Geodetic

DATE 2011 04 05 - 2011 04 06

CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
294.5	Tall Grass							20 40 60 80 100		20 40 60 80 100	10 20 30			
294.1	Silty sand, some roots, brown, FILL		1	SS	6									
	Silty sand (SM) with gravel, FILL													
	Compact		2	SS	18									
	Brown to grey													
			3	SS	28									
			4	SS	33									
	- pieces of red brick													
291.5														
3.1	Sandy silt (ML), some gravel, TILL		5	SS	8									
	Loose to very dense		6	SS	15									
	Brown to greyish brown to grey		7	SS	16									
			8	SS	24									
			9	SS	23									
	- very dense below 7.0 m													
	- occasional cobbles and boulders		10	SS	119									
285.8														
8.7	Clayey silt (CL) with sand, some gravel, TILL													
	Hard													
	Grey		11	SS	108									
	- cobbles and boulders													
284.5														

Continued Next Page

✕ 3, ✕ 3

Numbers refer to Sensitivity

○ 3%

STRAIN AT FAILURE

Appendix G

Comparison of Foundation Alternatives

COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings on Native Soils	Spread Footings on Engineered Fill Pad	Driven H-piles	Caissons / Drilled Shafts
<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. ii. More cost effective than deep foundations. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. ii. More cost effective than deep foundations. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher geotechnical resistance if driven to refusal compared to spread footings ii. Installation less influenced by weather and groundwater compared to spread footing iii. Facilitate the integral abutment design. iv. Requires less excavation than spread footings 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher geotechnical resistance is available for caissons ii. Construction of caissons could continue in freezing weather. iii. Limited extent of excavation and less impact on operation of Highway 401.
<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Potentially deep excavation at abutments ii. May require groundwater control. iii. Not feasible for integral abutment design. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Slightly lower bearing capacity than for footings placed directly on native soils. ii. Potentially deep excavation at abutments iii. May require groundwater control. iv. Not feasible for integral abutment design. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Piles may encounter refusal at varying depth ii. Higher unit costs than spread footings. iii. Piles may require predrilling to achieve design length, complicating installation. iv. Potential difficulties penetrating hard till 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost than for spread footings or H-piles. ii. Temporary liners will be required to install caissons through cohesionless soils. iii. Difficulty in sealing liners at base. iv. Potential difficulties penetrating very dense/hard till layers during augering. v. Difficulties in cleaning and inspecting bases.
Low risk of encountering problems during construction.	Low risk of encountering problems during construction.	High risk of encountering harder layers and cobbles and boulders that would require additional procedures to advance the piles to the desired elevation.	High risk of encountering harder layers, as well as cobbles and boulders that would require additional procedures to advance the augers to the desired elevation.
FEASIBLE	FEASIBLE	RECOMMENDED FOR ABUTMENTS	RECOMMENDED FOR PIER

Appendix H

List of Specifications and Suggested Text for NSSP

The following Standard Specifications and Standard Drawings are referenced in this report:

OPSS 501

OPSS 539

OPSS 804

OPSS 902

OPSS 903

OPSS.PROV 1010

OPSS.PROV 206

OPSD 3090.101

OPSD 601.010

Suggested wording for “NSSP – Presence of Cobbles and Boulders”

Cobbles and boulders shall be expected within the existing embankment fill and native deposits underlying the site. The cobbles and boulders may interfere with H-pile and caissons installation. The Contractor shall be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles/caissons to the specified tip elevation/resistance while meeting the specified deflection tolerances. The Contractor shall have equipment available on site at the time of pile/caisson installation capable of penetrating cobbles and boulders, in the event they are encountered.

Suggested wording for “NSSP – Drilling for Caissons”

Excavation for the caissons installation through the glacial till may encounter cobbles and boulders, and the installation equipment shall be capable of dislodging and removing such obstructions.

The Contractor is responsible for constructing the caisson excavations without disturbing the sides or base of the excavations, and for cleaning of the bases.

Water seepage and /or soil sloughing into the caissons excavation will occur from the fill and cohesionless soils at some locations. The cohesionless soils will be susceptible to disturbance under conditions of unbalanced hydrostatic head. Temporary liners shall be used to support the caissons sidewalls and provide the seepage cut-off, where required.

The base of each caisson excavation shall be inspected either visually or by probing to confirm that the base is clean and all disturbed material has been removed.

Placement of concrete into the caisson excavation shall be conducted by tremie method to the full length of the caisson.

The construction, augering and liner installation for caissons shall not commence until 24 hours has elapsed since the concrete placement of adjacent caissons located within three (3) shaft diameters clear spacing.

Suggested wording for “NSSP – Pre-augering for H-pile Installation”

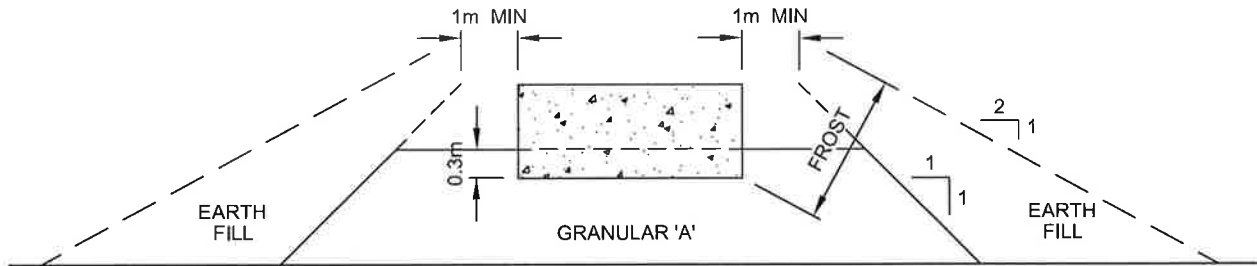
The subsurface stratigraphy below the existing embankment fill consists of extensive glacial till deposits, namely, very stiff to hard cohesive till and dense to very dense cohesionless till. Piles driven through these deposits may encounter practical refusal at higher elevations than the designed pile tip elevations. Pre-augering shall be conducted at the pile locations to achieve the designed pile tip elevations. The Contractor shall allow for pre-augering the holes at the H-pile locations not deeper than 2 m above the designed pile tip elevation prior to driving piles. For pre-augering, the auger shall have an approximate diameter of 200 mm.

Suggested wording for “NSSP – Use of Driving Templates”

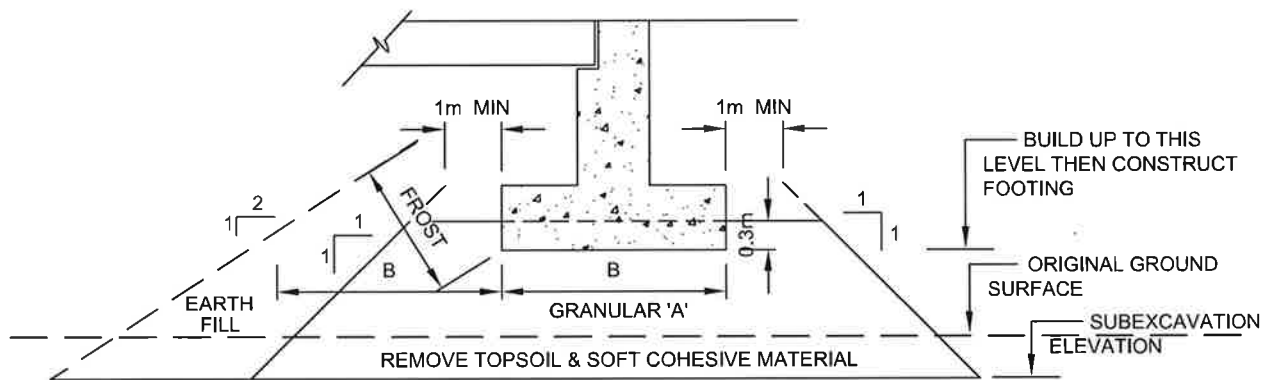
The H-piles will be installed by pre-augering the holes in the very stiff to hard and dense to very dense till deposits. To ensure that the piles at the abutments meet the requirements for tolerances for deviation at the top of the pile, the Contractor shall provide a driving template or other means required to achieve the specified maximum deviation.

Appendix I

Figure 1 – Abutment on Compacted Fill



CROSS-SECTION



LONGITUDINAL SECTION

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

**ABUTMENT ON COMPACTED FILL
SHOWING GRANULAR 'A' CORE**



THURBER ENGINEERING LTD.

ENGINEER :	MRA	DRAWN :	MFA	APPROVED :	-
DATE :	MARCH 2015	SCALE :	N.T.S.	DRAWING No.	FIGURE 1