



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SPITZIG ROAD UNDERPASS  
HIGHWAY 7-NEW, KITCHENER TO GUELPH  
G.W.P. 408-88-00**

**GEOCRES No. 40P8-249**

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**Report**

to

**WSP**

Date: April 12, 2018  
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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual findings obtained from a detailed foundation investigation conducted at the site of the proposed underpass structure to carry Spitzig Road over Highway 7-New in the Regional Municipality of Waterloo, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, cross sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions under the potential foundation footprint was developed from the data obtained in the course of the investigation. In addition, background information was reviewed at locations where boreholes were not drilled during the current field investigation.

Thurber was retained by WSP to carry out the site investigation under the Ministry of Transportation Ontario (MTO) Agreement Order Number 3014-E-0013.

**2. SITE DESCRIPTION**

At the site, the Highway 7-New alignment runs approximately parallel to the existing Highway 7 alignment and 115 m to the north. The site lies approximately 5.4 km east of the Conestoga Parkway and Wellington Street interchange in the City of Kitchener.



Based on the Ontario Geological Survey Special Volume 2, The Physiography of Southern Ontario, Third Edition by Chapman and Putnam, the site lies within an area referred to as the Guelph Drumlin Field, an area of drumlinized till plain, also mapped as containing eskers. The till is described as stony and the occurrence of surface boulders is noted. Chapman and Putnam give a typical gradation of the till as being 50% sand, 35% silt and 15% clay. Swampy valleys are reported to occur between the drumlins and associated gravel terraces.

The site lies within an area of farms and agricultural lands. There are farmsteads to the east of Spitzig Road, north of the existing Highway 7 alignment.

### **3. INVESTIGATION PROCEDURES**

The geotechnical investigation at the new location of Spitzig Road underpass was carried out between May 11 and 31, 2017. Eight boreholes, numbered SP16-01 to SP16-08, were drilled at the location of the proposed foundation units. SP16-01 and SP16-08 were drilled at the north and south approaches, and extended to 5.2 m depth (Elevations 320.8 and 322.6). Boreholes SP16-02 and SP16-03 were drilled approximately at the north abutment, SP16-04 and SP16-05 at the pier, and SP16-06 and SP16-07 at the south abutment of a possible two-span structure arrangement. The depths of the abutments and pier boreholes ranged from 12.8 m to 20.4 m (Elevations 314.3 to 305.8).

The Record of Borehole sheets for the boreholes are included in Appendix A. The approximate locations of the eight boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix C. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole Sheets in Appendix A.

The ground surface elevations and coordinates of the recent as-drilled boreholes were provided by WSP.

Prior to commencing the site investigation, utility clearances were obtained for all borehole locations. Road occupancy permit was also obtained to complete site investigation.

During the current investigation, a track mounted D20 drill rig was used in conjunction with hollow-stem augers to advance the boreholes. In general, soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Testing (SPT).



The drilling, sampling and in-situ testing 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. Results of field drilling and sampling of the investigation are presented on the Record of Borehole sheets in Appendix A.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In Boreholes SP16-03, SP16-04 and SP16-06 a standpipe piezometer consisting of 25 mm diameter PVC pipe with a slotted screen was installed and enclosed in filter sand to permit longer-term groundwater level monitoring. Boreholes without piezometer installations were backfilled in general accordance with O. Reg. 903. The completion of the boreholes and the standpipe piezometer were carried out in accordance with the requirements of O. Reg. 903. The borehole completion details are also shown in Table 3.1.



**Table 3.1 – Borehole Completion Details**

Foundation Unit	Borehole	Borehole Depth / Base Elevation (m)	Piezometer Tip Elevation (m)	Completion Details
North Approach	SP16-01	5.2/320.8	None Installed	Backfilled with bentonite holeplug and auger cutting to surface
North Abutment	SP16-02	20.4/305.8	None Installed	Backfilled with bentonite holeplug and auger cutting to surface
	SP16-03	18.9/307.2	18.3/307.8	Backfilled with auger cuttings from 18.9 m to 18.3 m, sand from 18.3 m to 14.6 m, bentonite holeplug from 14.6 m to 2.6 m, auger cuttings from 2.6 m to 0.6 m, sand from 0.6 m to ground surface.
Pier	SP16-04	18.9/308.1	18.3/308.7	Backfilled with auger cuttings from 18.9 m to 18.3 m, sand from 18.3 m to 11.0 m, bentonite holeplug from 11.0 m to 4.8 m, auger cuttings from 4.8 m to 0.6 m, sand from 0.6 m to ground surface.
	SP16-05	18.5/308.4	None Installed	Backfilled with bentonite holeplug and auger cutting to surface
South Abutment	SP16-06	12.8/314.3	12.3/314.8	Backfilled with auger cuttings from 12.8 m to 12.3 m, sand from 12.3 m to 8.7 m, bentonite holeplug from 8.7 m to 7.4 m, auger cuttings from 7.4 m to 0.2 m, concrete from 0.2 m to ground surface.
	SP16-07	17.4/309.8	None Installed	Backfilled with bentonite holeplug and auger cutting to surface
South Approach	SP16-08	5.2/322.6	None Installed	Backfilled with bentonite holeplug and auger cutting to surface



#### **4. LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A, and also presented on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing native soil was collected. The sample was submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

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

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

In general, the site has a surficial layer of topsoil underlain by layers of silty sand and an extensive deposit of silty clay till. Layers of sand, sand and gravel and sandy silt till/silty sand till were encountered within the silty clay till. Descriptions of the individual strata are presented below.

##### **5.1 Topsoil**

A surficial layer of soil ranging in thickness from 75 mm to 300 mm in all eight borehole locations. The natural moisture contents generally lay in the range of 29 percent to 31 percent.

##### **5.2 Sandy Silt and Silty Sand**

Layers of native layers of silty sand and sandy silt containing trace to some gravel and some clay, underlain the topsoil layer was contacted in all the boreholes. The sandy silt and silty sand deposit



extended to depths ranging from 0.7 m to 2.2 m (Elevation 327.0 to 323.9), and ranged in thickness from 0.6 to 2.1 m.

The SPT 'N' values of the sandy silt and silty sand layers ranged from 4 to 31 blows per 0.3 m of penetration indicating a loose to very dense relative density. The natural moisture contents generally lay in the range of 11 percent to 29 percent.

Grain size distribution curve of a sandy silt/silty sand sample tested are presented on the Record of Borehole sheets and on Figure B1 of Appendix B. The results of the gradation test carried out on a sand and silt sample are summarized as follows:

Soil Particles	(%)
Gravel	3
Sand	67
Silt	24
Clay	6

### 5.3 Upper Silty Clay Till

Upper brown to grey silty clay till containing some sand to sandy, trace gravel and occasional cobbles was contacted below the silty sand and sandy silt layers at depths ranging from 0.7 m to 2.2 m (Elevations 327.0 and 323.9), in all the boreholes. The thickness of the upper silty clay till layer ranged from 2.0 m to 6.0 m.

The depth to the base of the upper silty clay till ranged from 4.3 m to 7.3 m (Elevations 323.5 to 318.9) in all the boreholes.

Boreholes SP16-01, SP16-06 and SP16-07 were terminated within the upper silty clay till at 5.2 m, 12.8 m and 17.4 m (Elevations 320.8, 314.3 and 309.8), respectively.

SPT 'N' values in the silty clay till ranged from 5 to 100 blows per 0.3 m of penetration, indicating a firm to hard consistency. The natural moisture contents generally lay in the range of 7 percent to 28 percent.



Grain size distribution curves for silty clay till samples tested are presented on the Record of Borehole sheets and on Figures B2 and B3 of Appendix B. The results of gradation tests carried out on selected samples are summarized as follows:

Soil Particles	Silty Clay Till (%)
Gravel	0 to 8
Sand	11 to 39
Silt	39 to 56
Clay	14 to 45

The results of Atterberg Limits are presented on the Record of Borehole sheets and in Figures B9 and B10 included in Appendix B. The results of Atterberg Limits testing are summarized below:

Liquid Limit	16 to 38
Plastic Limit	11 to 20

The above results show that the upper silty clay till is of low plasticity with group symbols of CL-ML and CL. One sample of the silty clay till shows medium plasticity with a group symbol CI.

Although not specifically identified in the boreholes, glacial tills are known to contain cobbles and boulders.

#### 5.4 Silty Clay

Brown to grey silty clay containing some sand was encountered within the upper layer of silty clay till at depths ranging from 3.0 m to 7.3 m (Elevations 323.5 to 319.9), in Boreholes SP16-03, SP16-04, SP16-05, SP16-07 and SP16-08. The thickness of the silty clay ranged from 0.8 m to 1.4 m.

The depth to the base of the silty clay varied from 4.1 m to 8.5 m (Elevations 322.0 to 318.7).

Borehole SP16-08 was terminated within the silty clay at 5.2 m depth (Elevation 322.6).



SPT 'N' values in the silty clay ranged from 13 to 21 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency. The natural moisture contents generally lay in the range of 14 percent to 21 percent.

Grain size distribution curves for silty clay samples tested are presented on the Record of Borehole sheets and on Figure B4 of Appendix B. The results of gradation tests carried out selected samples are summarized as follows:

Soil Particles	Silty Clay (%)
Gravel	0 to 1
Sand	0 to 11
Silt	38 to 52
Clay	48 to 62

The results of Atterberg Limits are presented on the Record of Borehole sheets and in Figure B12 included in Appendix B. The results of Atterberg Limits testing are summarized below:

Liquid Limit	37 to 40
Plastic Limit	18 to 19

The above results show that the silty clay is of medium plasticity with group symbols of CI.

## 5.5 Sand and Gravel

A layer of sand and gravel was contacted at 5.6 m to 7.2 m depth (Elevations 320.5 to 319.6) in Boreholes SP16-03 to SP16-05. The thickness of the sand and gravel was 3.1 m and 3.3 m.

The depth to the base of the sand and gravel was at 8.7 m to 10.5 m (Elevations 317.4 to 316.3).

SPT 'N' values ranged from 18 to 67 blows per 0.3 m of penetration and 100 blows per 0.225 m, indicating a compact to very dense state. The natural moisture contents generally lay in the range of 6 percent to 18 percent.



A grain size distribution curve is presented on the Record of Borehole sheets and on Figure B5 of Appendix B. The results of a gradation test carried out on a sand and gravel sample are summarized as follows:

Soil Particles	Sand and Gravel (%)
Gravel	47
Sand	46
Silt and Clay	7

### 5.6 Sandy Silt Till and Silty Sand Till

Layers of brown to grey sandy silt till and silty sand till were contacted in Boreholes SP16-02 to SP16-05, at depths ranging from 7.3 m to 10.5 m (Elevations 318.9 to 316.3). The thickness of the silty sand till and clayey silt till ranged from 1.2 m to 6.1 m.

The depth to the base of the sandy silt till and silty sand till ranged from 11.7 m to 13.4 m (Elevations 315.3 to 312.8).

SPT 'N' values ranged from 32 to 100 blows per 0.3 m of penetration and 100 blows per 0.225 m of penetration, indicating a dense to very dense relative density. The natural moisture contents generally lay in the range of 10 percent to 28 percent.

Grain size distribution curves are presented on the Record of Borehole sheets and on Figure B6 of Appendix B. The results of a gradation test carried out on a sandy silt till sample are summarized as follows:

Soil Particles	Cohesionless Till (%)
Gravel	0 to 11
Sand	23 to 45
Silt	32 to 73
Clay	4 to 12



## 5.7 Lower Silty Clay Till

A lower deposit of brown to grey silty clay till containing some sand to sandy and trace to some gravel was contacted in Boreholes SP16-02 to SP16-05 at 11.7 m to 13.4 m depth (Elevations 315.3 to 312.8).

Boreholes SP16-02 to SP16-05 were terminated within the lower silty clay till deposit at depths ranging from 18.5 m to 20.4 m depth (Elevations 308.4 to 305.8).

SPT 'N' values in the lower silty clay till ranged from 26 blows per 0.3 m of penetration to 100 blows per 0.1 m of penetration, indicating a very stiff to hard consistency. The natural moisture contents generally lay in the range of 6 percent to 18 percent.

Grain size distribution curves for the lower silty clay till samples tested are presented on the Record of Borehole sheets and on Figures B7 and B8 of Appendix B. The results of grain size distribution tests carried out on a selected sample are summarized as follows:

Soil Particles	Silty Clay Till (%)
Gravel	0 to 5
Sand	10 to 36
Silt	39 to 74
Clay	16 to 36

The results of Atterberg Limits are presented on the Record of Borehole sheets and in Figure B11 included in Appendix B. The results of Atterberg Limits testing are summarized below:

Liquid Limit	18 to 25
Plastic Limit	11 to 13

The above results show that the lower silty clay till is of low plasticity with group symbols of CL-ML and CL. One sample of the silty clay till shows medium plasticity with a group symbol CI.

Although not specifically identified in the boreholes, glacial tills are known to contain cobbles and boulders.



## 5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations, and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes SP16-03, SP16-04 and SP16-06 to monitor the groundwater level at the site. The water levels measured in the piezometer are summarized in Table 5.1, along with the measurements in the boreholes upon completion of drilling.

**Table 5.1 – Water Level Measurements**

Foundation Unit	Borehole	Date	Water Level (m)		Remark
			Depth	Elevation	
North Approach	SP16-01	May 11, 2017	-	Dry	Open borehole
North Abutment	SP16-03	June 13, 2017	5.1	321.0	Piezometer
Pier	SP16-04	June 13, 2017	5.4	321.6	Piezometer
	SP16-05	May 26, 2017	7.6	319.2	Open borehole
South Abutment	SP16-06	June 13, 2017	5.3	321.8	Piezometer
	SP16-07	May 30, 2017	6.1	321.1	Open borehole
South Approach	SP16-08	May 31, 2017	Dry	-	Open borehole

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

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the sand and silt till from Borehole SP16-04 was submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix A.



**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Test Results
		SP16-04 SS 7 Depth 6.1 m
		(Soil Sample)
Sulphide	%	0.06
Chloride	µg/g	7.6
Sulphate	µg/g	356
pH	No unit	8.49
Electrical Conductivity	µS/cm	357
Resistivity	Ohms.cm	2800
Redox Potential	mV	271

## 7. MISCELLANEOUS

Altech Drilling & Investigative Services of Elmira, Ontario supplied a D20 track-mounted drill rig and conducted the drilling, sampling and in-situ testing operations for the present investigation.

The coordinates for the boreholes were obtained with GPS equipment by Thurber, and the elevations were provided by WSP.

The drilling and sampling operations in the field for the current investigation, were supervised on a full-time basis by Thurber field technicians.

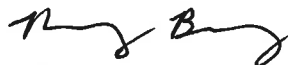
Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc.

Overall supervision of the field program for the present investigation was conducted by Mr. K. Lawes, EIT. Interpretation of the data and preparation of the current report was carried out by Ms. R. Palomeque Reyna, P.Eng. and Dr. Nancy Berg, EIT.



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

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to select and design a suitable foundation system for a new structure to carry Spitzig Road over Highway 7-New in the Regional Municipality of Waterloo, Ontario.

The General Arrangement (GA) drawing provided by WSP, dated July 2012, indicates that the new underpass bridge has two spans, each 41.0 m in length and approximately 13.7 m to 14.2 m in width, supported by two abutments and one pier. Each of the two integral abutments is designed to be supported by a single row of driven steel H-piles, and the centre pier is to be supported on spread footings.

The mainline grade will be in a cut ranging from 3.0 m to 5.0 m deep, and the base of the cut will be at approximate Elevation 323.0 to 321.0. The Spitzig Road grade, within the structure limits, will be between approximate Elevations 330.0 to 330.8.

This foundation investigation and design report, with the interpretation and recommendations, is intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractors must make their own interpretation based on the factual data in Part 1 of the report.



Where comments are made on construction, they are provided only in order to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the information provided as it may affect equipment selection, proposed construction methods and scheduling.

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

## **9. STRUCTURE CLASSIFICATION**

In accordance with the currently applicable Canadian Highway Bridge Design Code (CHBDC) 2014, CSA S6-14, the analysis and design of structures are influenced by its importance category and consequence classification. Such designations are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation Ontario (MTO).

For the purpose of reporting, this structure has been classified as a Major-Route Bridge with Typical Consequence based on CHBDC S6-14 Sections 4.4.2 and 6.5.2, respectively.

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

## **10. STRUCTURE FOUNDATIONS**

The stratigraphy identified in the investigations consisted primarily of topsoil overlaying layers of silty sand, sandy silt, upper silty clay, sand and gravel, silty sand till/sandy silt till and lower silty clay till. The groundwater level measured in the piezometers ranged from 5.1 m to 5.4 m below the ground surface (Elevation 321.8 to 321.0).

In the preparation of geotechnical design recommendations, consideration was given to the following foundation types:



1. Spread footings bearing on native soil
2. Spread footings on engineered fill
3. Steel H-piles or steel pipe driven into the very dense/hard soils

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix E.

### 10.1 Spread Footing on Native Soil

Spread footings bearing on native soil generally are a cost effective form of construction and are feasible at this site.

Spread footings should bear on native undisturbed very stiff silty clay till and very dense sand and gravel and compact silty sand. Provided a minimum footing width of 2 m is maintained, spread footings may be designed in accordance with the elevations and bearing resistances given in Table 10.1.

**Table 10.1 – Bearing Resistances for Spread Footings**

Foundation Element	Borehole	Approximately Founding Elevation <sup>(1)</sup> (m)	Factored ULS <sub>f</sub> (kPa)	Factored SLS (up to 25 mm settlement) (kPa)
North Abutment	SP16-02	324.0	300	200
	SP16-03	318.5	500	350
Pier	SP16-04 SP16-05	319.5	600	400
South Abutment	SP16-06	325.0	300	200
	SP16-07	318.0	600	400

<sup>(1)</sup> Potential founding elevation estimated from the GA drawing.



The values of the Factored Geotechnical Resistance at ULS were assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Factored Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The bearing resistances in Table 10.1 are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be adjusted as shown in the CHBDC (2014) Clause 6.10.3 and Clause 6.10.4.

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

The sliding resistance of cast-in-place concrete placed on the native, undisturbed very stiff to hard silty clay till may be computed based on an ultimate coefficient of friction,  $\tan \delta$ , of 0.45 and 0.5 for very dense sand and gravel. Resistance Factor of 0.6 should be applied for cohesive soils and, 0.8 for cohesionless soils, as indicated in Table 6.2 in the CHBDC (2014).

Founding elevations presented in Table 10.1 may be below groundwater level observed during the investigations. If temporary excavations required to construct these footings extend below the water table, dewatering measures will be required to construct the footing in the dry and to prevent disturbance of the footing base.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed subgrade surface conforms to the design requirements and has been adequately prepared to receive concrete. Once approved, the subgrade should be protected by a working mat with a minimum thickness of 100 mm and consisting of mass concrete of the same strength and class as that of the footing. Where subexcavation is required to remove unsuitable material from below the design founding level, the founding surface should be re-established using the same mass concrete.



## 10.2 Spread Footing on Engineered Fill

Spread footings can also be founded on Granular “A” engineered fill pads, where this is beneficial to the overall design. These would be useful in the case of perched abutments on footings.

If an engineered fill pad is used, all topsoil or other deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material. The engineered fill will bear on native silty clay till, silty sand and, sand and gravel, and the permitted founding/base elevations at which engineered fill pads may be founded, are given in Table 10.2.

**Table 10.2 –Highest Founding Elevations for Engineered Fill Pads**

<b>North Abutment (Borehole SP16-02, SP16-03)</b>	<b>Pier (Borehole SP16-04, SP16-05)</b>	<b>South Abutment (Borehole SP16-06, SP16-07)</b>
324.0	319.5	325.5

Provided a minimum footing width of 2 m is maintained footings bearing on the well compacted engineered fill pad, at least 2-m thick, may be designed for the following geotechnical resistances:

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

These resistance values are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

The values of the Factored Geotechnical Resistance at ULS were assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Factored Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

If temporary excavations required to construct the engineered fill pad extend below the water table, local groundwater control will be required to construct the engineered fill pad in the dry and to prevent disturbance of the engineered fill pad base.



For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is expected to not exceed 25 mm. Differential settlements are not expected to exceed 20 mm across the width of the structure.

The sliding resistance of cast-in-place concrete placed on the engineered fill may be computed based on an ultimate coefficient of friction,  $\tan \delta$ , of 0.55. Resistance Factor of 0.8 should be applied for cohesionless soils, as indicated in Table 6.2 in the CHBDC (2014).

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed surface conforms to the design requirements and has been adequately prepared to place the engineered fill. The Granular A for the engineered fill pad must be compacted to 100% Standard proctor maximum dry density (SPMDD) at optimum moisture content  $\pm 2\%$ , and placed in 150 mm lifts. The geometry of the fill pad must conform to the general requirements shown in Figure 1 in Appendix D.

### **10.3 Steel H-Piles and Steel Pipe Piles**

From a foundation engineering perspective, it is feasible to support the structure on steel H-piles driven to practical refusal. Open ended steel pipe piles may also be considered as a suitable foundation option.

It is recommended that the H-piles be driven to achieve resistance in the hard silty clay till encountered at this site. Based on for two H-pile sections (HP 310 X 110 and HP 360 x 132), and two pipe pile sections (and 324 mm diameter and 356 mm diameter), a minimum embedment depth of 6 m is required below the underside of the abutment.

The GA drawing indicates that the underside pile cap elevations at the north and south abutments are 324.4 and 325.4, respectively, and at the pier, if it required, it is at Elevation 318.0.

At the pier, the piles would have to be driven through 100 blow till, therefore, H-pile installation would require pre-augering to achieve sufficient embedment. The pile would have to be driven in 150 mm diameter pre-augered holes to achieve design pile tip elevation. The pre-augering should extend to 2.0 m above the design pile tip elevation and the piles should be driven to capacity to the final 2.0 m.

### 10.3.1 Axial Resistance

The axial resistances of HP 310 X 110 and HP 360 x 132 steel piles and, 324 mm diameter and 356 mm diameter pipe piles driven to refusal in hard/very dense till were assessed based on the subsurface conditions encountered at the abutment and pier locations. The estimated Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS), as well as the recommended pile tip elevations are summarized in Tables 10.3 and 10.4.

**Table 10.3 – Estimated Axial Resistance and Pile Tip Elevation for H-Piles**

Foundation Unit	Borehole	Approx. Pile Tip Elevation (m)	Minimum Pile Length Assumed (m)	Pile Section HP 310 X 110		Pile Section HP 360 X 132	
				Factored ULS (kN)	Factored SLS (kN)	Factored ULS (kN)	Factored SLS (kN)
North Abutment	SP16-02 SP16-03	308.0	16	1,350	1,100	1,600	1,400
Pier	SP16-04 SP16-05	309.0	10	1,150	950	1,500	1,250
South Abutment	SP16-06 SP16-07	310.0	15	1,350	1,100	1,600	1,400

**Table 10.4 – Estimated Axial Resistance and Pile Tip Elevation for pipe piles**

Foundation Unit	Borehole	Approx. Pile Tip Elevation (m)	Minimum Pile Length Assumed (m)	Pile Section 324 mm diameter		Pile Section 356 mm diameter	
				Factored ULS (kN)	Factored SLS (kN)	Factored ULS (kN)	Factored SLS (kN)
North Abutment	SP16-02 SP16-03	308.0	16	1,150	950	1,400	1,200
Pier	SP16-04 SP16-05	309.0	10	1,000	850	1,200	1,000
South Abutment	SP16-06 SP16-07	310.0	15	1,150	950	1,400	1,200

The values of the Factored Geotechnical Resistance at ULS were assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.4 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The SLS values correspond to a maximum pile settlement of 25 mm. The Factored Geotechnical Resistance at SLS was



assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The structural resistance of the pile must be checked by the structural designer.

### 10.3.2 Downdrag

Downdrag on the piles is not an issue at this site.

### 10.3.3 Lateral Resistance

The geotechnical lateral resistance of a pile may be calculated using the coefficient of horizontal subgrade reaction ( $k_s$ ) and the ultimate lateral resistance ( $P_{ult}$ ) as follows:

#### Silty Clay Till (cohesive soil)

$$\begin{aligned}k_s &= 67 C_u / B \quad (\text{kN/m}^3) \\p_{ult} &= 9 C_u \quad (\text{kPa}) \text{ at and below a depth of } 3B \text{ reduced to zero at ground surface} \\ \text{where } p_{ult} &= \text{ultimate lateral resistance mobilized by a pile, kPa} \\ C_u &= \text{undrained shear strength of cohesive soils, kPa} \\ \gamma &= \text{unit weight of soil, kN/m}^3 \\ B &= \text{width of pile, m}\end{aligned}$$

#### Sandy Silt Till/Sand and Silt Till (cohesionless soils)

$$\begin{aligned}k_s &= n_h \cdot z / B \quad (\text{kN/m}^3) \\p_{ult} &= 3 \cdot \gamma' \cdot z \cdot K_p \quad (\text{kPa}) \\ \text{where } z &= \text{depth of embedment of pile, m} \\ B &= \text{pile width, m} \\ n_h &= \text{coefficient related to soil density, kN/m}^3, \text{ Table 10.5} \\ \gamma' &= \text{Bouyant unit weight of soil, kN/m}^3, \text{ Table 10.5} \\ K_p &= \text{passive earth pressure coefficient, Table 10.5}\end{aligned}$$



The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressure obtained from the analysis should not exceed the ultimate lateral resistance.

The spring constant,  $K$ , for analysis may be obtained by the expression,  $K = k_s \times d_z \times B$  (kN/m), where  $k_s$  is the coefficient of horizontal subgrade reaction (kN/m<sup>3</sup>),  $B$  is the pile width (m),  $d_z$  is the length (m) of the pile segment used in the analysis. The ultimate lateral resistance on any one segment of pile,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} \times dz \times B$ . This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

Parameters for lateral pile resistance are shown in Table 10.5.

**Table 10.5– Recommended Geotechnical Parameters for Lateral Resistance Design**

Location	Reference Boreholes	Approx. Elevation (m)	Undrained Shear Strength $C_u$ (kPa)	Unit Weight $\gamma$ (kN/m <sup>3</sup> )	$K_p$	$n_h$ (kN/m <sup>3</sup> )	Soil Conditions
North Abutment	SP16-02 SP16-03	326.0 to 324.0	-	20	3.0	2,500	Loose to dense sand and silt
		324.0 to 320.5	120	19	-	-	Stiff to very stiff silty clay
		320.5 to 317.4	-	20	3.0	2,500	Compact to dense sand and gravel
		317.4 to 312.8	-	11*	3.3	4,500	Dense to very dense sandy silt till/silty sand till
		312.8 to 305.8	250	10*	-	-	Hard silty clay till
Pier	SP16-04 SP16-05	327.0 to 325.5	-	20	3.0	1,500	Loose to compact sandy silt

		325.5 to 321.0	150	20	-	-	Very stiff to hard silty clay till
		321.0 to 319.6	200	19	-	-	Hard silty clay
		319.6 to 316.3	-	11*	3.3	4,000	Very dense sand and gravel
		316.3 to 315.1	-	11*	3.3	4,500	Very dense sandy silt till
		315.1 to 308.1	250	10*	-	-	Hard silty clay till
South Abutment	SP16-06 SP16-07	327.0 to 325.7	-	20	3.0	1,500	Loose to compact sandy silt
		325.7 to 318.0	120	20	-	-	Firm to very stiff silty clay till
		318.0 to 309.8	250	10*	-	-	Hard silty clay till

\* Bouyant unit weight below water table

The group efficiency factors can be calculated based on side-by-side and line-by-line factors shown in Figures C6.11.3(r), C6.11.3(s), and C6.11.3(t) of the CHBDC (2014), S6.1-14 (Commentary).

#### 10.3.4 Pile Installation

All piles shall be installed in accordance with OPSS 903.

Pile driving must be controlled in accordance with Standard Provision SS103-11 (Hiley Formula) and an ultimate pile resistance must be specified by the designer. The Hiley formula does not need to be used until the pile tip is within 2 m of the design tip elevation. The appropriate pile driving note to be shown on the contract drawing is "Piles to be driven in accordance with Standard SS103-11 using an ultimate geotechnical resistance of R kN per pile" where "R" must have a minimum value of twice the factored design load at ULS. It is recommended that Pile Driving



Analysis (PDA) testing be conducted in conjunction with the Hiley tests at this site, to ensure the integrity of the pile and to verify pile ultimate geotechnical resistance.

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

Glacially derived soils inherently contain cobbles and boulders. Hard driving conditions through the hard and very dense soils should be expected. In order to minimize pile damage while driving through boulders, cobbles and harder/dense zones to achieve the required tip elevations and soil resistance, it is recommended that the pile tips be reinforced with Titus steel (Standard H-point).

Pile tip protection should be provided for open ended pipe piles.

The Contract Documents must contain a NSSP alerting the Bidders to the presence of cobbles and boulders in the glacial tills. Suggested texts for the NSSP's are included in Appendix F. The NSSP should contain a requirement to terminate driving before the pile is damaged by overdriving.

#### **10.4 Abutment Design Considerations**

From a geotechnical perspective, the conditions at this site are considered to be suitable for the design of conventional, semi-integral or integral abutments.

For integral abutments, the flexibility of the upper portion of the pile may be provided by a single corrugated steel pipe (CSP) system. Reference should be made to the integral abutment manual for details of this system. Piles should be driven first before pouring in sand.

#### **10.5 Frost Cover**

The design depth of frost penetration for this site is 1.4 m. All footing bases and undersides of pile caps/abutment stems must be provided with at least 1.4 m of soil cover.

#### **10.6 Recommended Foundation**

From a geotechnical perspective, and based on current information, steel H-piles driven into the hard silty clay till are the recommended foundation for the abutments and pier.



## 11. LATERAL EARTH PRESSURES

Earth pressures acting on a structure (e.g. abutment or retaining wall), 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 2014 but are generally given by the expression:

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

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

$K$  = earth pressure coefficient (see Table 11.1)

$\gamma$  = unit weight of retained soil (see Table 11.1)

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

$q$  = value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

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

**Table 11.1 – Earth Pressure Coefficients**

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive (Movement Towards Soil Mass)	3.7	-	3.2	-

Note: Submerged unit weight should be used below the groundwater level.

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

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

The factors in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in the design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

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



## **12. APPROACH EMBANKMENTS**

Based on the GA drawing dated July 2012, the proposed finished grade at the structure will be at about Elevations 330.0 and 330.8 at the north and south abutments, respectively. The finished grade level of the Highway 7 New will be at Elevations 321.5 to 323.0. The existing ground surface at the site, varies from 326.1 to 327.2. Earth cut of about 3.0 m to 5.0 m will be required to achieve the Highway 7 New final grade. As a result, placement of new fill of approximately 3.7 m to 4.0 m will be required for the approaches of the proposed Spitzig Road underpass.

All embankment fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and OPSS.PROV 501 requirements.

The global, internal and surficial stability of the approach embankment fills will depend on the slope geometry and also to a large degree on the material used to construct the embankments. Embankments constructed using granular material, select subgrade material or non-cohesive earth fill will have stable side slopes at inclinations of up to 2H:1V.

It is estimated that at approach embankments, settlements in the order of 25 mm to 30 mm will occur in the foundation soils under the loading imposed by approximately 4.0 m of the new approach fill. This settlement will be immediate and essentially complete when construction of the fill is completed.

No long term settlement or global stability issues are anticipated for approach embankments built at this site.

It is also recommended that all permanent and temporary slope surfaces be vegetated and seeded in accordance with current MTO practice with reference to OPSS.PROV 804. It is important to note that slopes steeper than 2H:1V may be subject to surficial instability which may include sloughing and gullying. Surface runoff and precipitation must be prevented from flowing perpendicularly down any slope surface. Erosion protection measures will have to be taken as necessary to maintain slope stability.



### **13. TEMPORARY EXCAVATION**

All excavations at this site must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The excavation and backfilling for foundations must be carried out in accordance with OPSS.PROV 902.

Excavation for foundation construction will be extended through the native silty sand, silty clay till, sand and gravel, silty sand till and sandy silt till/silty sand till.

For the purposes of the OHSA, the silty clay till may be classified as Type 3. The native cohesionless soils (silty sand, sand and gravel) above the water table are classified as Type 3, and below the water table are classified as Type 4.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should regularly be inspected for evidence of instability if they have been left open for extended periods of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to ensure the stability of the excavation and the safety of workers.

### **14. BACKFILL TO ABUTMENTS**

For backfilling immediately behind the new abutment wall, it is recommended that the new fill be Granular A or Granular B Type II materials meeting the gradation and relevant requirements stipulated in OPSS.PROV 1010. Beyond this zone, Granular B Type I may be used.

The backfill should be in accordance with OPSS.PROV 206 requirements and OPSD 3101.150. Compaction equipment to be used adjacent to abutments/retaining structures should must be restricted in accordance to OPSS.PROV 501.

The design of the abutment must incorporate a subdrain as shown in OPSD 3102.100.

### **15. PERMANENT CUT**

Permanent earth cuts are required to construct the Spitzig Road underpass at this site. The earth cut will be formed through about 3 m to 5 m of soils, typically consisting of loose to compact silty sand/sandy silt, stiff to hard silty clay till with occasional cobbles and boulders. It is anticipated that the base of the cut in soil will consist of very stiff to hard silty clay till. The base of this cut will



be stable. A lense of sand and gravel was identified on the highway centreline, just below the base of the cut.

At the maximum depth, the cut slopes are expected to be stable at inclinations not exceeding 2H:1V.

Drainage will be required in the depressed section of the cut to remove water originating from

- Storm runoff
- Seepage from the sides of the cut, particularly from the upper silty sand

Temporary drainage of the cuts should be provided to maintain a relatively dry, stable excavation. Permanent drainage of the cuts must be provided. Roadside ditches are expected to provide an adequate level of surface drainage in most areas. An interceptor ditch should be provided at the top of the earth cuts as per OPSD 200.020 and 201.020.

Vegetative cover should be established on all exposed earth slopes to protect against surficial erosion. Reference may be made to OPSS.PROV 804. Localized sloughing may occur in cut slopes, particularly in the few years following construction and until the vegetation over is well established.

## **16. GROUNDWATER AND SURFACE WATER CONTROL**

Piezometric levels obtained at this site indicate that the groundwater level ranges from Elevation 321.8 to 321.0, or at 5.1 m to 5.4 m depth below the existing ground surface. Seasonal fluctuations of the groundwater level are to be expected. Excavation for footing construction may extend slightly below the groundwater level at some locations.

In general, seepage or perched water from the granular silty sand is to be expected. For temporary foundation excavations at this site, groundwater control will likely be limited to diverting surface runoff and preventing precipitation from entering the excavations and supplemented by sump pumping. Filtered sumps must be properly designed to control loss of fines/ground loss. Unwatering must remain operational and effective until the footings are backfilled.



Temporary excavation of the cohesionless native soils below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

Based on the grain size distribution curves, the coefficients of permeability (k) of the native soils are as follows:

Soil	Permeability, k (cm/sec)
Silty sand	$6.4 \times 10^{-5}$
Silty clay till	$1 \times 10^{-8}$
Sand and Gravel	$3.2 \times 10^{-2}$
Silty sand till/sand and silt till	$2.2 \times 10^{-4}$ to $2.3 \times 10^{-6}$

Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517, SP 517F01 Amendment to OPSS 517, November 216 (issued July 2017), and OPSS. PROV 902.

The design of the dewatering system that may be required is the responsibility of the Contractor, and the Contract Documents must alert him to this responsibility.

## 17. ROADWAY PROTECTION

If roadway protection is required during construction of the proposed underpass, an item titled "Protection System" as per OPSS 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the shoring be specified on the contract drawings.

The design of roadway protection should be the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at this site is a soldier pile and lagging wall.

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



$\gamma$	=	20 kN/m <sup>3</sup>
$\gamma_w$	=	10 kN/m <sup>3</sup>
$K_a$	=	0.31 (sand, sandy silt, cohesionless glacial tills)
	=	0.32 (silty clay till)
$K_p$	=	3.3 (sand, sandy silt, cohesionless glacial tills)
	=	3.2 (silty clay till)

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

## 18. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the averaged soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site, which consists of loose to compact silty sand overlying firm to hard silty clay till or silty clay, and compact to dense sand and gravel, and silty sand till. This would correspond to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.076 g as per the National Building Code of Canada (NBCC). Since this site is classified as Class D the factored PGA for a 2% in 50 year probability of exceedance at this site is 0.094 g.

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 18.1 may be used:

**Table 18.1 – Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.31	0.35
Passive ( $K_{PE}$ )	3.6	3.1
At Rest ( $K_{OE}$ )**	0.55	0.6

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

\*\* After Woods

The site is underlain by typically loose to compact silty sand overlying firm to hard silty clay till or silty clay, and compact to dense sand and gravel, and silty sand till, and liquefaction is not considered to be a concern at this site.

## 19. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the native soils during the current investigation indicates the following conditions at the locations tested:

- The potential for sulphate attack on concrete foundations from the surrounding native soils is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The selection of class of concrete should consider the effects of the road de-icing salts.
- The potential for soil corrosion on metal is considered to be moderate.
- Appropriate protection measures commensurate with the above are recommended if metal structural elements are used. The effects of road de-icing salts should be also considered.



## **20. CONSTRUCTION CONCERNS**

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

### **1. Pile Installation**

The presence of very dense/hard soil containing occasional cobbles, at comparatively shallow depth will limit the length of the pile that can be driven. If the design requires longer piles, pre-augering will be required.

### **2. Excavation**

Hydraulic equipment is expected to be capable of excavating to the required depths at this site. If excavations advance below the existing groundwater level, groundwater control measures may have to be implemented in order to maintain stable sides and base in the excavation.

The glacial tills may contain cobbles and boulders. Equipment selected for excavation must be capable of penetrating, handling and/or removing these obstructions.

### **3. Groundwater Control**

Seepage and perched groundwater may be encountered within the cohesionless fill and native glacial tills. The impact of seepage or surface water could destabilize the sides and or base of the excavation. The Contractor's unwatering plan must be available for rapid implementation should the need arise. Proper groundwater and surface water control measures must be in place prior to commencing excavation. All footings must be constructed in the dry.

## **21. CLOSURE**

Engineering analysis and preparation of the report were carried out by Ms. R. Palomeque Reyna, P.Eng.

The report was reviewed by Mr. Jason Lee, P.Eng, and Dr. P.K. Chatterji, P.Eng., 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 <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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


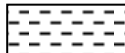



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION

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

## EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>			
<b>Fresh (FR)</b>	No visible signs of weathering.				
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE		
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE		
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE		
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL		
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)		
<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength (MPa) (psi)	Field Estimation of Hardness*	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

# RECORD OF BOREHOLE No SP16-01

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 341.7 E 230 893.3 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.11 - 2017.05.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				
								w P w L			WATER CONTENT (%)				
326.0	GROUND SURFACE														
0.0	TOPSOIL: (300mm)														
325.7			1	SS	4										
0.3	Silty <b>SAND</b> , trace clay, trace gravel Loose to Compact Brown Moist to Wet														
			2	SS	5										
	some gravel														
323.9			3	SS	10										
2.1	Silty <b>CLAY</b> , some sand, trace gravel Very Stiff to Hard Brown Moist (TILL)														
			4	SS	24										
			5	SS	28										
	Hard Grey														
320.8			6	SS	35										
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.														

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

# RECORD OF BOREHOLE No SP16-02

1 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 324.4 E 230 897.9 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.11 - 2017.05.12 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
326.2	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (300mm)																	
325.9			1	SS	9		326											
0.3	Silty <b>SAND</b> , some clay, trace gravel Loose Brown Wet																	
			2	SS	9		325											
324.9																		
1.3	Silty <b>CLAY</b> , with sand, trace to some gravel Firm to Very Stiff Brown Wet (TILL)		3	SS	8		324											
			4	SS	21													
	Grey Moist		5	SS	23		323											
			6	SS	18		322											
							321											
			7	SS	10		320											
							319											
318.9																		
7.3	Silty <b>SAND</b> to Sandy <b>SILT</b> , some gravel, some clay Dense Brown Wet (TILL)		8	SS	32		318											
	Grey																	
			9	SS	48		317											

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SP16-02

2 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 324.4 E 230 897.9 ORIGINATED BY OA  
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
DATUM Geodetic DATE 2017.05.11 - 2017.05.12 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
	Continued From Previous Page							20 40 60 80 100					
	Silty <b>SAND</b> to Sandy <b>SILT</b> , trace clay Very Dense Grey Wet (TILL)		10	SS	100			○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					
								20 40 60 80 100					
			11	SS	100/ .225			20 40 60					
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>P</sub> W W <sub>L</sub>					
								WATER CONTENT (%)					
312.8							316						
13.4	Silty <b>CLAY</b> , sandy to with sand, trace gravel Hard Grey Wet (TILL)		12	SS	47		315						
	Very Stiff		13	SS	26		314						
							313						
	some gravel Hard Moist		14	SS	100/ .275		312						
							311						
							310						
							309						
			15	SS	100/ .225		308						
							307						
			16	SS	100/								

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SP16-02

3 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 324.4 E 230 897.9 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.11 - 2017.05.12 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page				.125		306	20	40	60	80	100					
305.8	Silty <b>CLAY</b> , with sand, trace gravel																
20.4	Hard Grey Moist (TILL)																
	END OF BOREHOLE AT 20.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																

# RECORD OF BOREHOLE No SP16-03

1 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 333.2 E 230 907.4 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.24 - 2017.05.24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
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></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></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></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></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></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></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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Continued Next Page

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

# RECORD OF BOREHOLE No SP16-03

2 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 333.2 E 230 907.4 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.24 - 2017.05.24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							<div>20406080100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>20406080100</div>						
	Sandy <b>SILT</b> , trace clay Dense to Very Dense Grey Wet (TILL)		10	SS	48									
			11	SS	57									
312.9														
13.2	Silty <b>CLAY</b> , some sand, trace gravel Hard Grey Moist (TILL)		12	SS	46									3 16 48 33
	Moist to Wet		13	SS	100/ .225									
			14	SS	100/ .225									0 10 74 16
			15	SS	100/ .200									
307.2														
18.9	END OF BOREHOLE AT 18.9m. WATER LEVEL AT 6.1m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.													

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

ONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/6/18

RECORD OF BOREHOLE No SP16-03

3 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 333.2 E 230 907.4 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.24 - 2017.05.24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
	Continued From Previous Page																
	WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.06.13 5.1 321.0																

ONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/6/18

# RECORD OF BOREHOLE No SP16-04

1 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 293.2 E 230 924.7 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.25 - 2017.05.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	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 <sub>p</sub> w      w <sub>L</sub>				GR	SA	SI	CL
327.0	GROUND SURFACE																		
0.0 0.1	TOPSOIL: (75mm)																		
	Sandy SILT, some clay, trace gravel, occasional organics		1	SS	7								○						
	Loose																		
	Brown																		
326.2	Moist												○						
0.8	Silty CLAY, trace sand, trace gravel		2	SS	60		326						○						
	Hard												○						
	Brown to Grey																		
	Moist to Wet																		
	(TILL)		3	SS	33		325						○						
			4	SS	60		324						○						
	Very Stiff																		
			5	SS	23		323						○						
322.9	Silty CLAY						323												
4.1	Very Stiff																		
	Grey		6	SS	21		322						○				0	0	
	Wet																38	62	
321.4							321												
5.6																			
			7	SS	17		320						○						
319.8							319												
7.2	SAND and GRAVEL, trace silt, trace clay																		
	Very Dense		8	SS	66		318												
	Brown																		
	Wet																		
			9	SS	100/ .250								○						

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SP16-04

2 OF 3

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 293.2 E 230 924.7 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.25 - 2017.05.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
	Continued From Previous Page							20 40 60 80 100					
	<b>SAND</b> and <b>GRAVEL</b> , trace silt, trace clay Very Dense Brown Wet							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					
316.5			10	SS	100/.250		316						0 23 73 4
10.5	Sandy <b>SILT</b> , trace clay Very Dense Brown Wet (TILL)												
315.3													
11.7	Silty <b>CLAY</b> , some sand to sandy, trace to some gravel Hard Grey Wet (TILL)		11	SS	44		315						
							314						
			12	SS	40		313						
							312						
			13	SS	100/.100		311						
							310						
	gravelly, with cobbles		14	SS	100/.125								
							309						
			15	SS	100/.100								5 26 53 16
308.1													
18.9	END OF BOREHOLE AT 18.9m. WATER LEVEL AT 7.6m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.												

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

# RECORD OF BOREHOLE No SP16-05

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 301.7 E 230 928.3 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.26 - 2017.05.26 CHECKED BY RPR

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 (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE	20   40   60   80   100	20   40   60	W <sub>P</sub> W      W <sub>L</sub>					
326.8	GROUND SURFACE															
0.0 0.1	TOPSOIL: (75mm)															
	Sandy SILT, some clay, some gravel, occasional organics Loose to Compact Brown Moist		1	SS	8								○			
			2	SS	11								○			
325.4																
1.4	Silty CLAY, sandy, trace gravel Very Stiff to Hard Brown Moist (TILL)		3	SS	25								○			
			4	SS	46								○			
	Grey		5	SS	33								○			
	Very Stiff		6	SS	21								○			
321.0																
5.8	Silty CLAY Hard Grey Moist		7	SS	33								○			
319.6																
7.2	SAND and GRAVEL, trace silt, trace clay Very Dense Brown Wet		8	SS	60								○			
			9	SS	67								○			

Continued Next Page

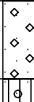




+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SP16-05

2 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 301.7 E 230 928.3 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.26 - 2017.05.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							WATER CONTENT (%) PLASTIC LIMIT    NATURAL MOISTURE CONTENT    LIQUID LIMIT w <sub>P</sub> w                      w <sub>L</sub>				
	Continued From Previous Page							20	40	60	80	100							
316.3	<b>SAND</b> and <b>GRAVEL</b> , trace silt, trace clay Very Dense Brown Wet						316							○					
10.5			Sandy <b>SILT</b> , trace clay Very Dense Grey Wet (TILL)	10	SS	76													
315.1	Silty <b>CLAY</b> , some sand Hard Grey Wet (TILL)						315												
11.7				11	SS	36													
								314											
			Very Stiff Moist to Wet		12	SS	29		313							○			
								312											
	Hard Wet						311								○				
				13	SS	100/ .250		310											
								309											
308.4	Moist														○				
18.5	END OF BOREHOLE AT 18.5m. WATER LEVEL AT 7.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.				.175														

ONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/6/18

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

# RECORD OF BOREHOLE No SP16-06

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 263.8 E 230 949.6 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.26 - 2017.05.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								WATER CONTENT (%)					
327.1	GROUND SURFACE												
0.0	TOPSOIL: (100mm)												
0.1	Sandy SILT, some clay, some gravel Loose Brown Moist		1	SS	6								
326.4													
0.7	Silty CLAY, some sand to sandy, trace gravel Firm to Very Stiff Brown Moist (TILL)		2	SS	5								
			3	SS	25								
			4	SS	24								
	occasional cobbles Moist to Wet		5	SS	15								
	Grey		6	SS	18								
	Wet		7	SS	17								
			8	SS	19								
	Hard		9	SS	100								

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SP16-06

2 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 263.8 E 230 949.6 ORIGINATED BY OA  
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
DATUM Geodetic DATE 2017.05.26 - 2017.05.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	Silty <b>CLAY</b> , sandy, trace gravel Hard Grey Moist to Wet (TILL)		10	SS	100/ .275												
	boulder at 11.9m																
314.3			11	SS	100/ .200												
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 6.1m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.06.13 5.3 321.8																

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# RECORD OF BOREHOLE No SP16-07

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 269.4 E 230 959.1 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.29 - 2017.05.30 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      x LAB VANE				W P      W      W L WATER CONTENT (%)				GR	SA	SI	CL			
327.2	GROUND SURFACE							20	40	60	80	100										
0.0 0.1	TOPSOIL: (75mm)  Sandy SILT, some clay, occasional topsoil Loose to Compact Brown Moist		1	SS	7		327							○								
			2	SS	12		326							○								
325.7																						
1.4	Silty CLAY, some sand, trace gravel Stiff to Very Stiff Brown Moist (TILL)		3	SS	15		325							○								
			4	SS	30		324							○	┌───┐				2	11	46	41
			5	SS	18		324							○								
	Grey		6	SS	18		323							○								
							322															
			7	SS	14		321							○								
319.9							320															
7.3	Silty CLAY Very Stiff Grey Moist		8	SS	15		319							○	┌───┐				0	0	45	55
318.7																						
8.5	boulder at 8.8m  Hard		9	SS	55		318							○								

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No SP16-07

2 OF 2

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 269.4 E 230 959.1 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.29 - 2017.05.30 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL			
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>								
	Continued From Previous Page																						
	Silty <b>CLAY</b> , some sand to sandy, trace gravel Hard Grey Wet (TILL)		10	SS	100/ .200							o											
	Moist		11	SS	43							41						2	15	56	27		
			12	SS	100/ .150							o											
	Wet		13	SS	100/ .150							o											
	with sand Moist to Wet		14	SS	100/ .175							o								2	38	43	17
309.8																							
17.4	END OF BOREHOLE AT 17.4m. WATER LEVEL AT 6.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																						

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# RECORD OF BOREHOLE No SP16-08

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Spitzig Road, MTM NAD 83 Zone 10: N 4 817 258.4 E 230 965.4 ORIGINATED BY OA  
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.05.31 - 2017.05.31 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
327.8	GROUND SURFACE														
0.0	TOPSOIL: (100mm)														
0.1	Sandy SILT, some clay, trace gravel, occasional organics		1	SS	20										
327.0	Compact Brown														
0.8	Moist		2	SS	36										
	Silty CLAY, some sand, occasional cobbles														
	Hard to Stiff														
	Brown														
	Moist (TILL)	3	SS	14											
		4	SS	60											
	Grey														
		5	SS	18											
323.5															
4.3	Silty CLAY, trace sand														
	Stiff														
	Grey														
	Moist to Wet	6	SS	13											
322.6															
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.														

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

20  
15  
10

(%) STRAIN AT FAILURE



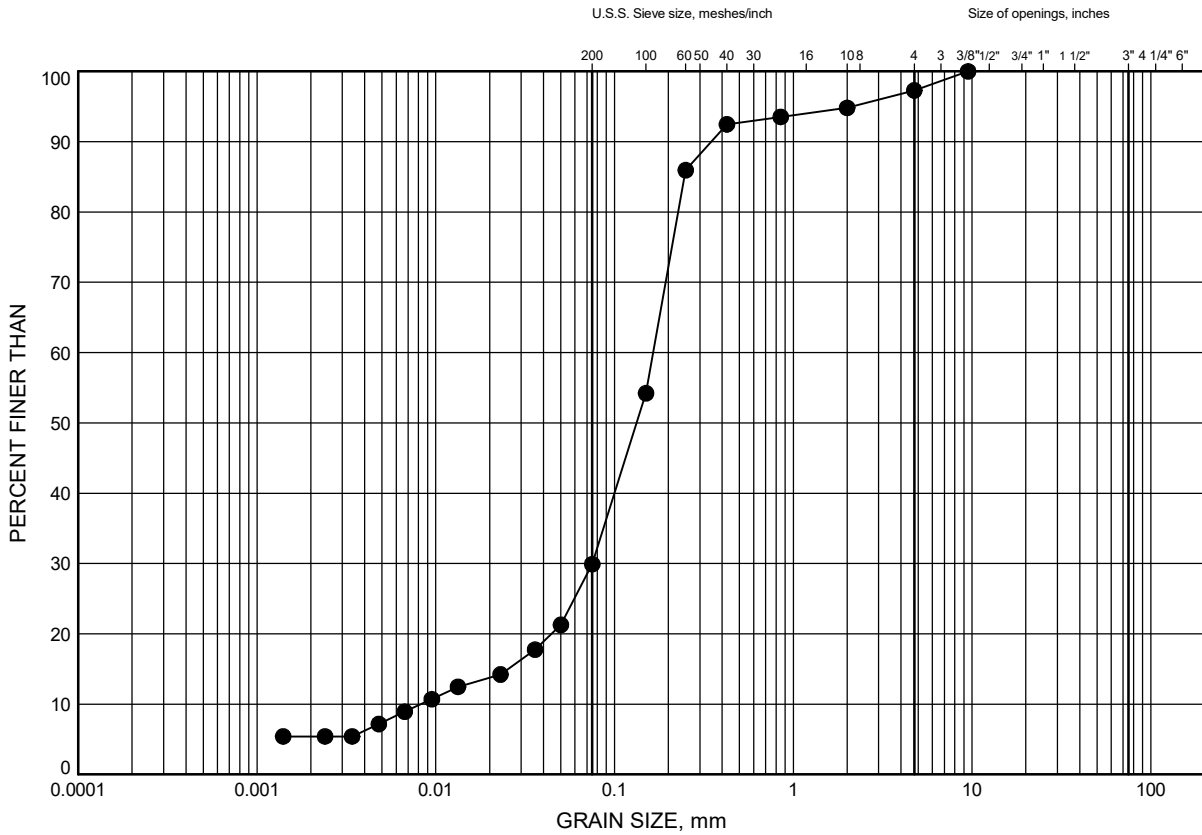
## **Appendix B**

### **Laboratory Test Results and Analytical Laboratory Test Results**

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B1

## Silty Sand



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-01	1.1	325.0

Date January 2018  
GWP# 408-88-00

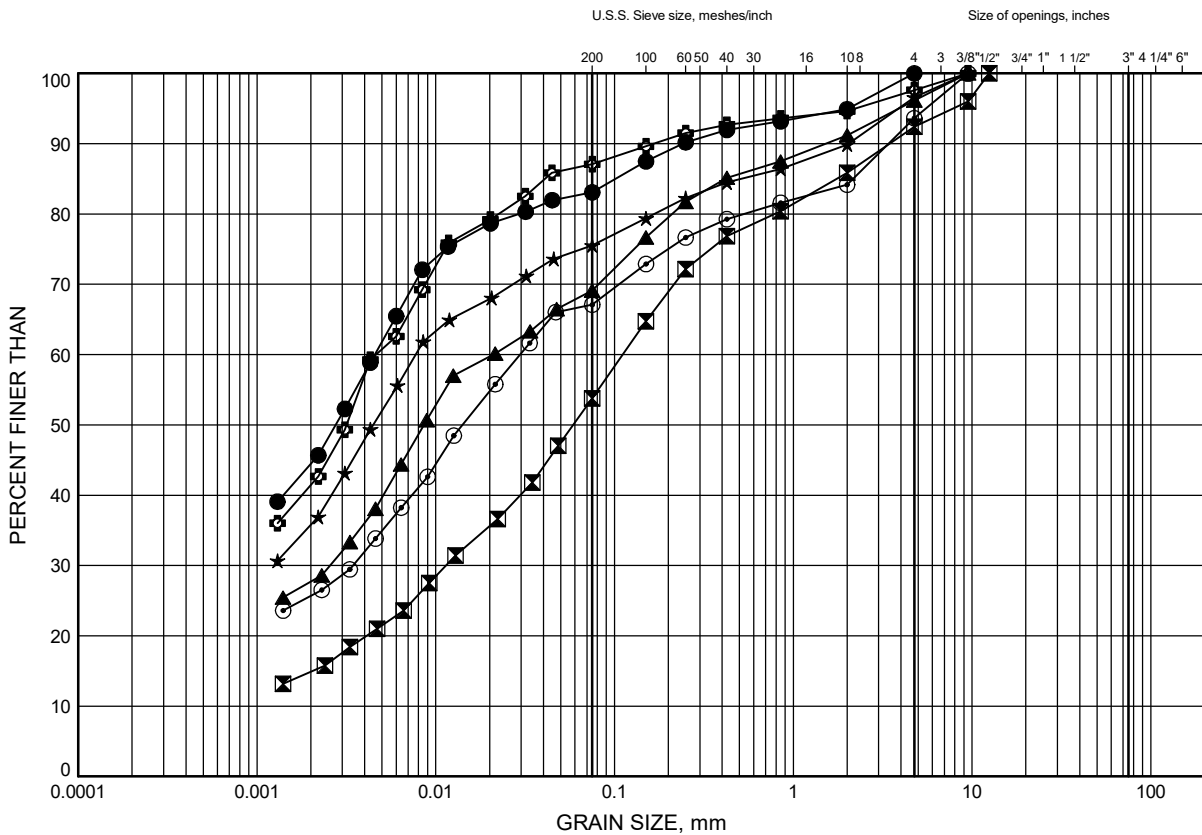


Prep'd MFA  
Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B2

## Upper Silty Clay Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-01	4.9	321.1
⊠	SP16-02	1.8	324.4
▲	SP16-05	1.8	325.0
★	SP16-06	6.4	320.7
⊙	SP16-06	11.0	316.1
⊕	SP16-07	2.6	324.6

Date January 2018

GWP# 408-88-00



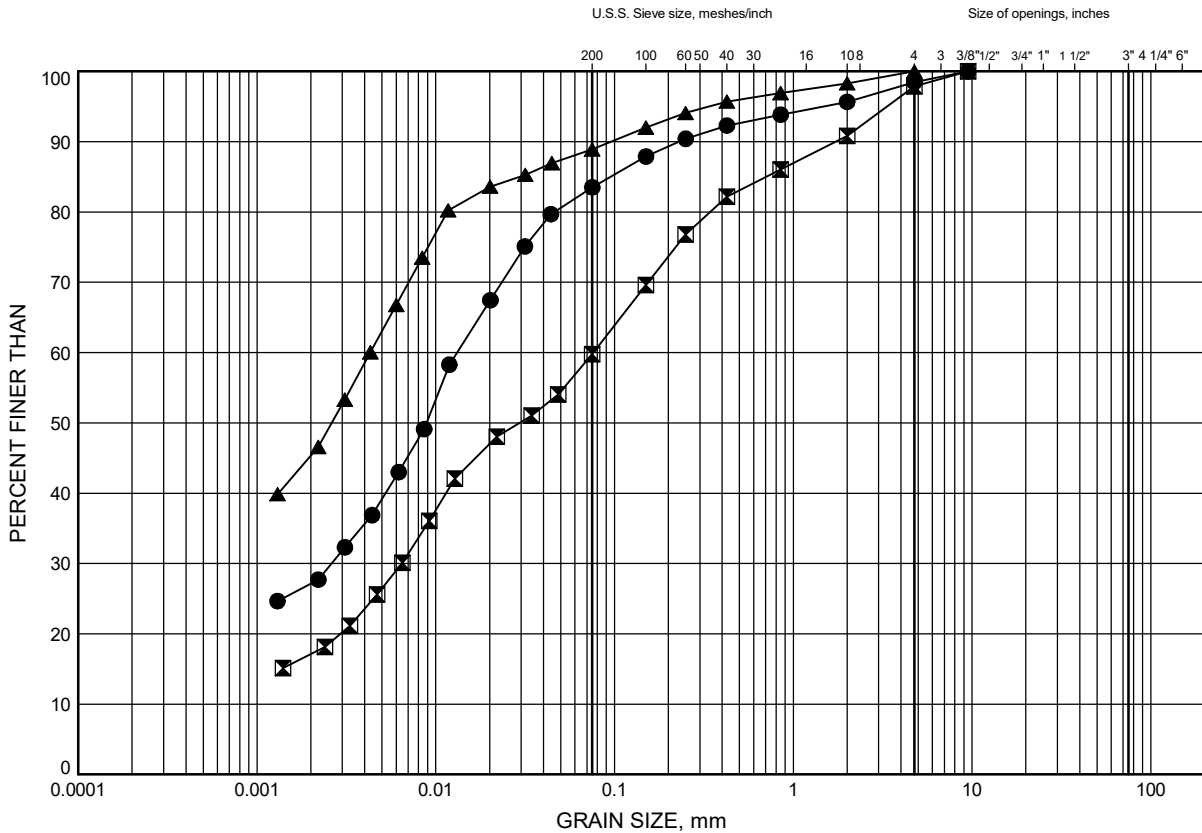
Prep'd MFA

Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B3

## Upper Silty Clay Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-07	12.5	314.7
⊠	SP16-07	17.1	310.1
▲	SP16-08	1.8	325.9

Date January 2018  
GWP# 408-88-00

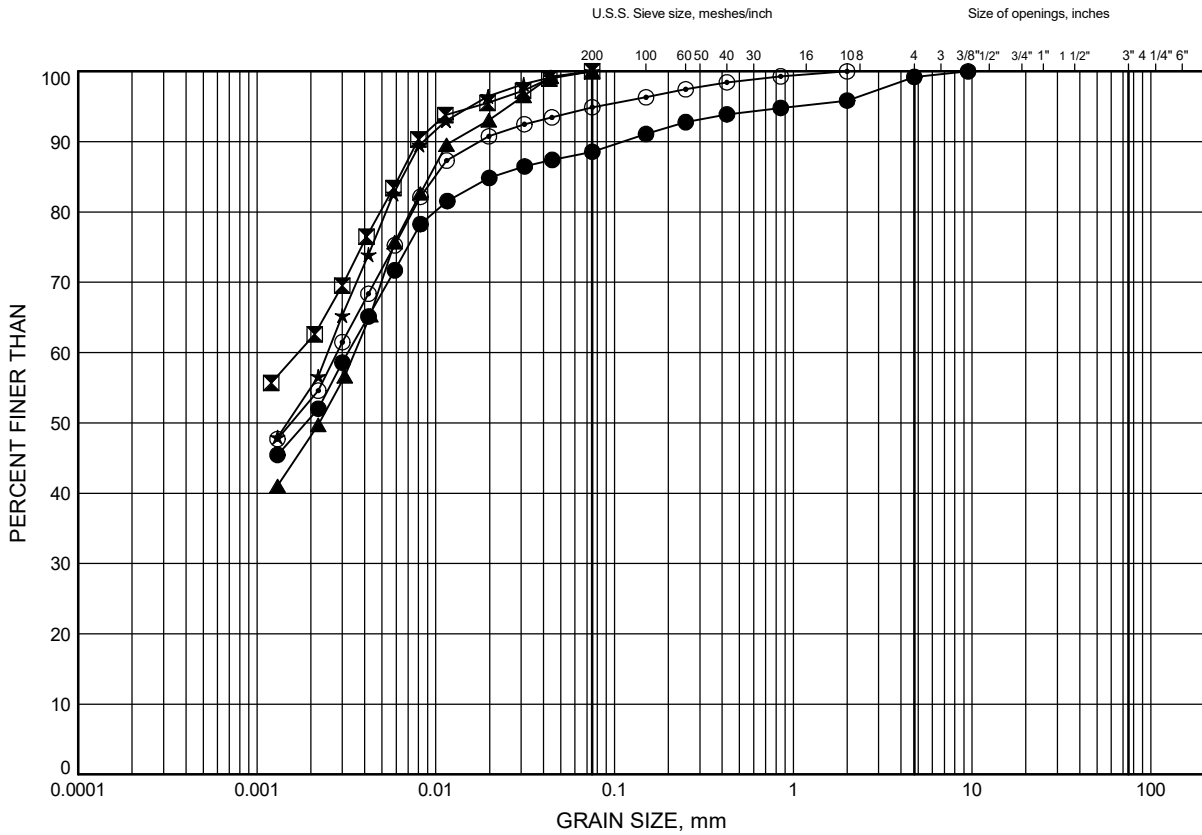


Prep'd MFA  
Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B4

## Silty Clay



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-03	3.4	322.7
⊠	SP16-04	4.9	322.1
▲	SP16-05	6.4	320.4
★	SP16-07	7.9	319.3
⊙	SP16-08	4.9	322.9

Date January 2018

GWP# 408-88-00



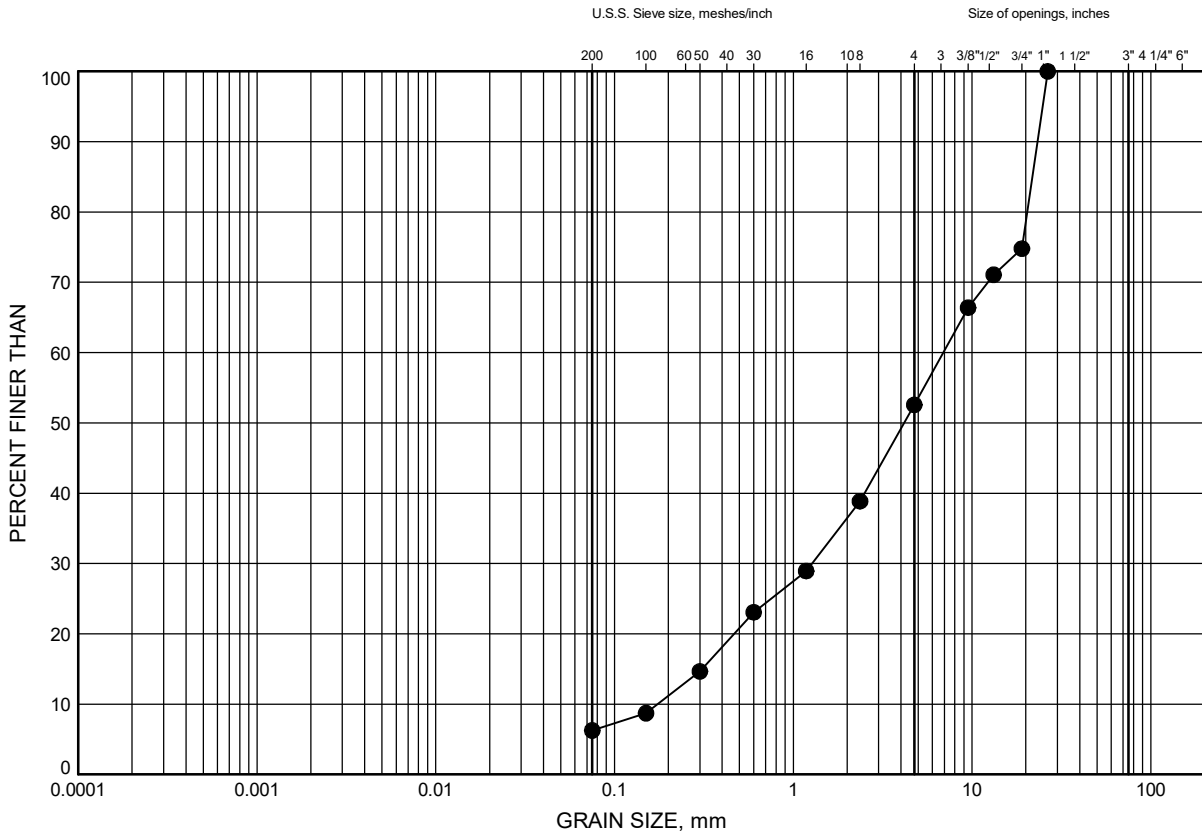
Prep'd MFA

Chkd. RPR

Spitzig Road  
GRAIN SIZE DISTRIBUTION

FIGURE B5

Sand and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-03	7.9	318.2

Date January 2018  
GWP# 408-88-00

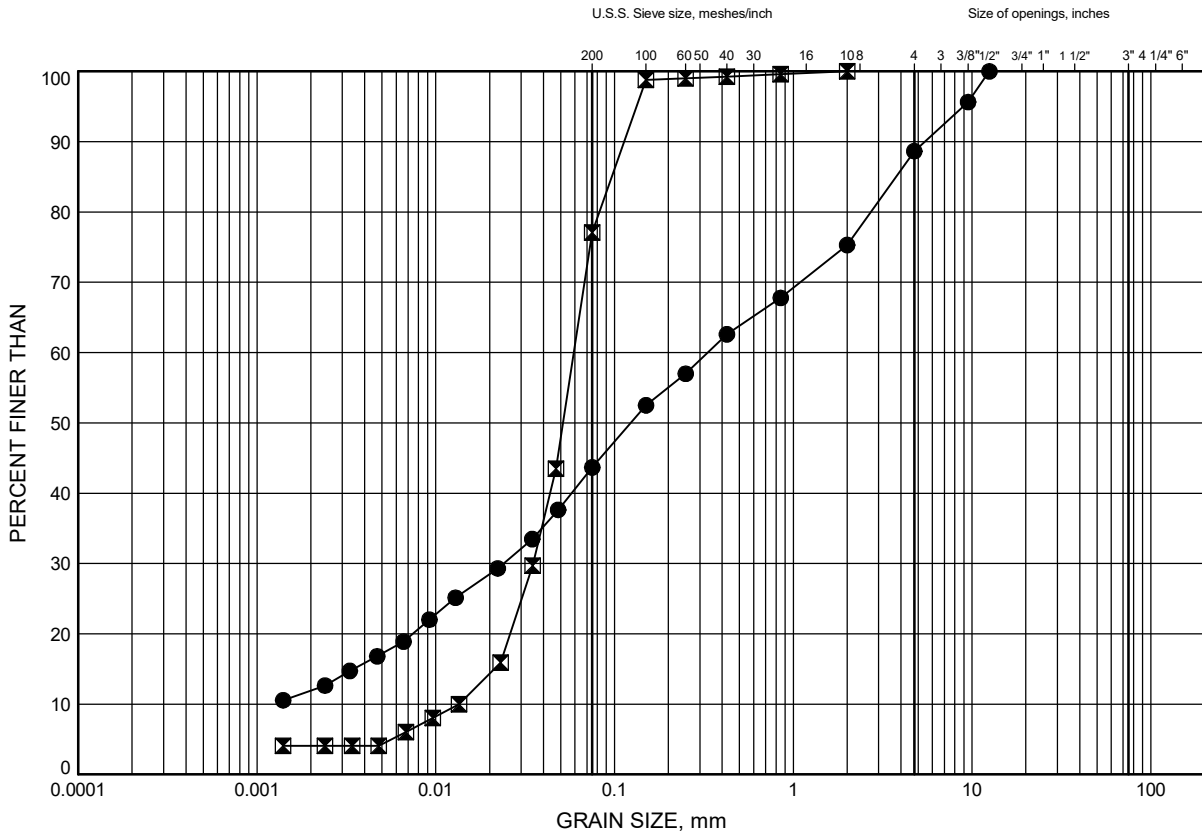


Prep'd MFA  
Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B6

## Silty Sand Till/Sandy Silt Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-02	7.9	318.3
⊠	SP16-04	11.0	316.0

Date January 2018  
GWP# 408-88-00

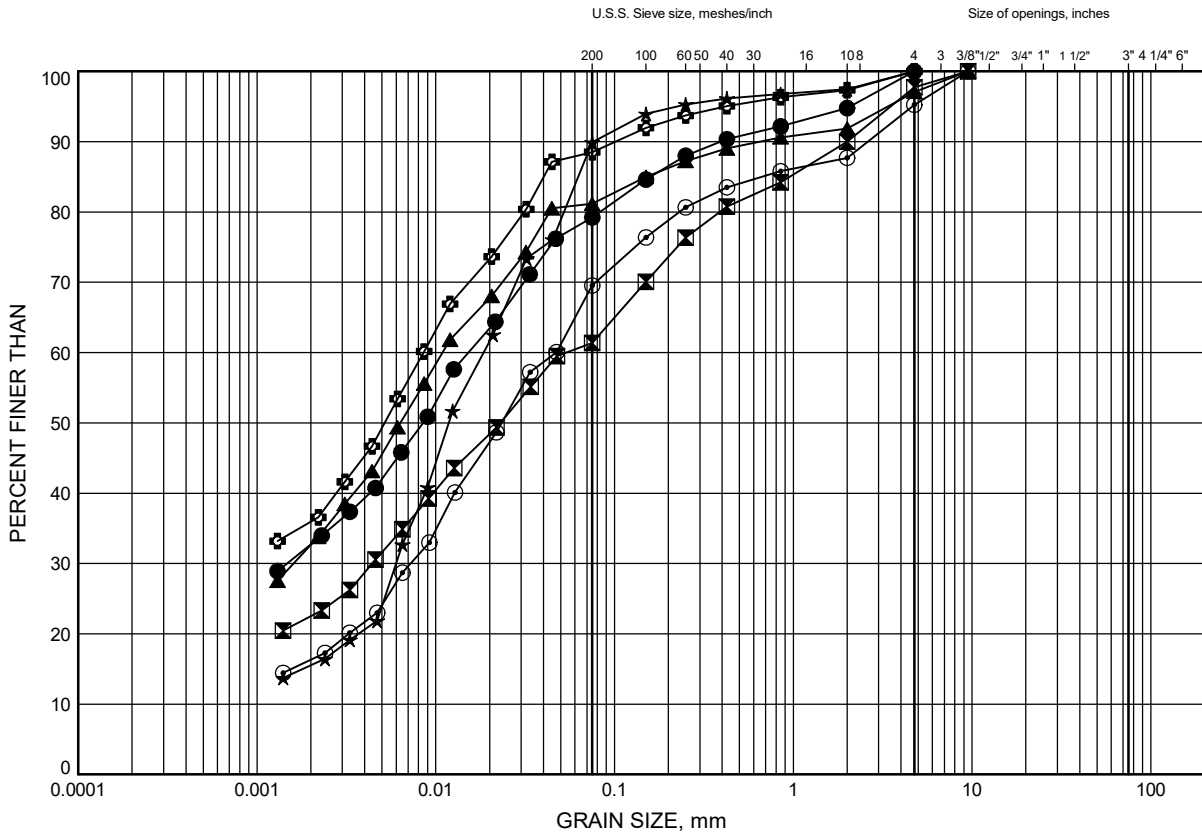


Prep'd MFA  
Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B7

## Lower Silty Clay Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-02	15.5	310.7
⊠	SP16-02	19.9	306.3
▲	SP16-03	14.0	312.1
★	SP16-03	17.1	309.0
⊙	SP16-04	18.6	308.4
⊕	SP16-05	12.5	314.3

Date January 2018

GWP# 408-88-00



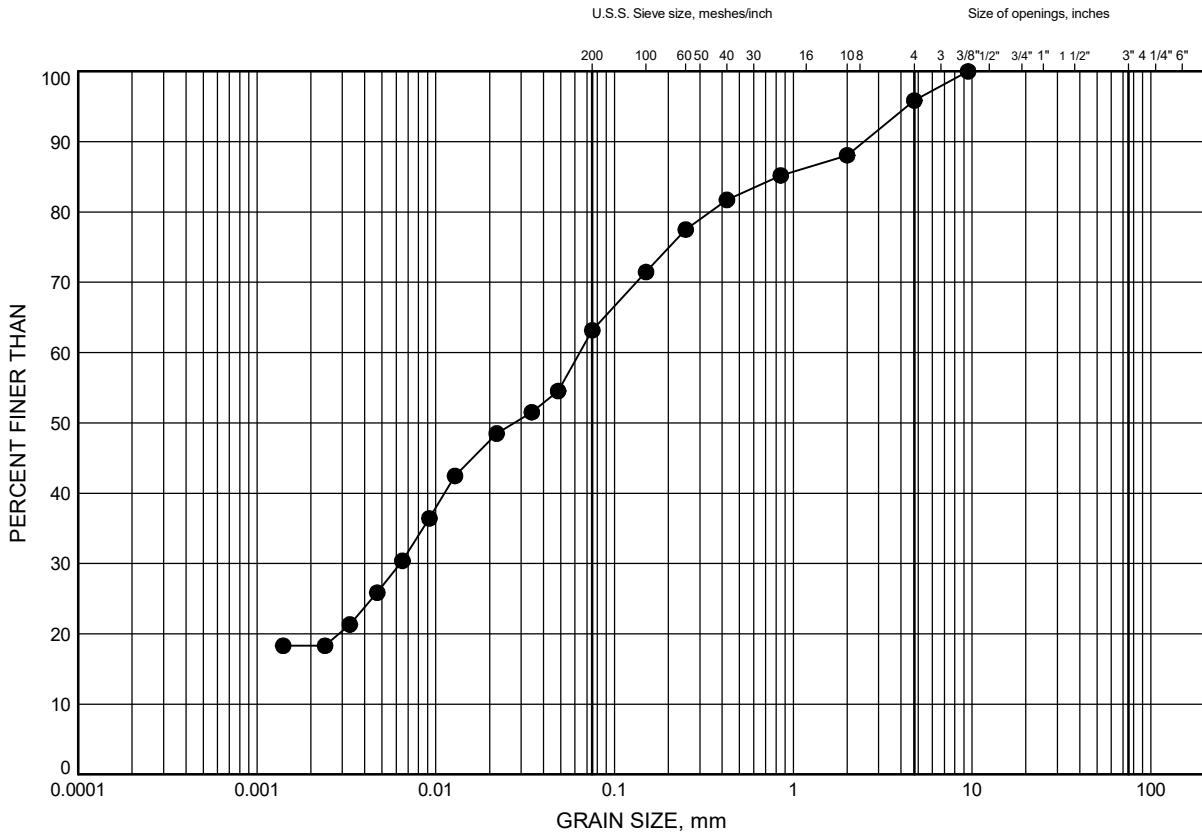
Prep'd MFA

Chkd. RPR

# Spitzig Road GRAIN SIZE DISTRIBUTION

FIGURE B8

## Lower Silty Clay Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-05	17.1	309.8

Date January 2018  
GWP# 408-88-00

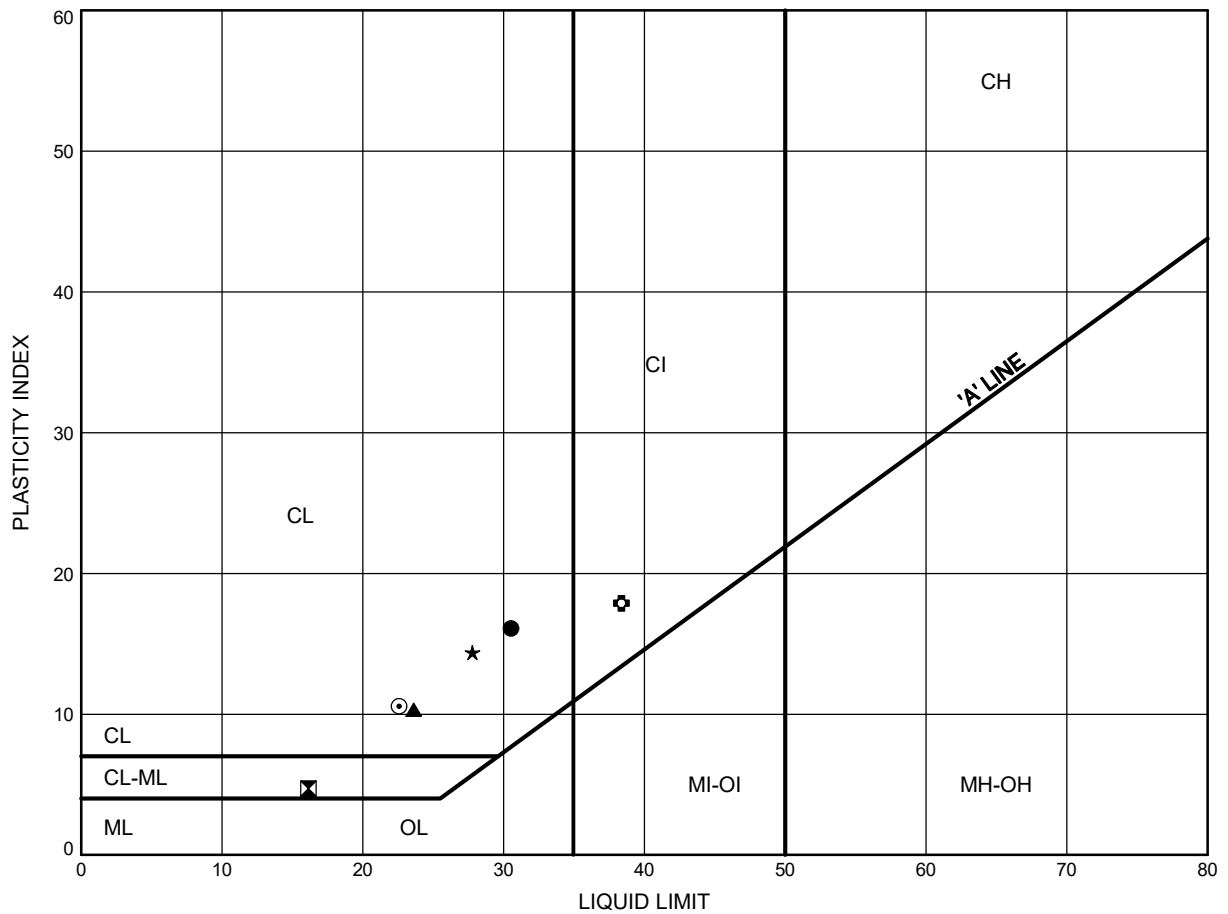


Prep'd MFA  
Chkd. RPR

# Spitzig Road ATTERBERG LIMITS TEST RESULTS

FIGURE B9

### Upper Silty Clay Till



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-01	4.9	321.1
⊠	SP16-02	1.8	324.4
▲	SP16-05	1.8	325.0
★	SP16-06	6.4	320.7
⊙	SP16-06	11.0	316.1
⊕	SP16-07	2.6	324.6

Date January 2018  
GWP# 408-88-00

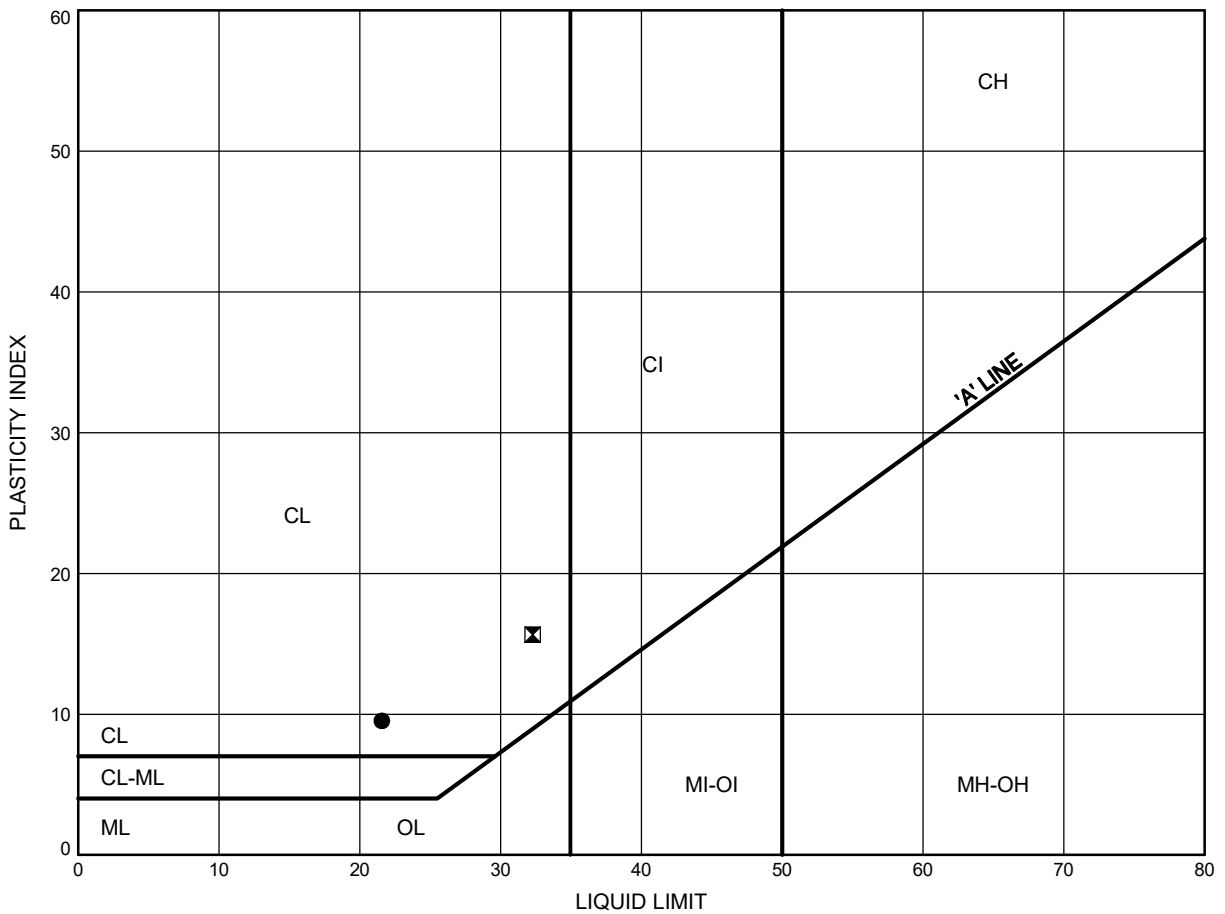


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Chkd. RPR

Spitzig Road  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B10

Upper Silty Clay Till



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-07	12.5	314.7
⊠	SP16-08	1.8	325.9

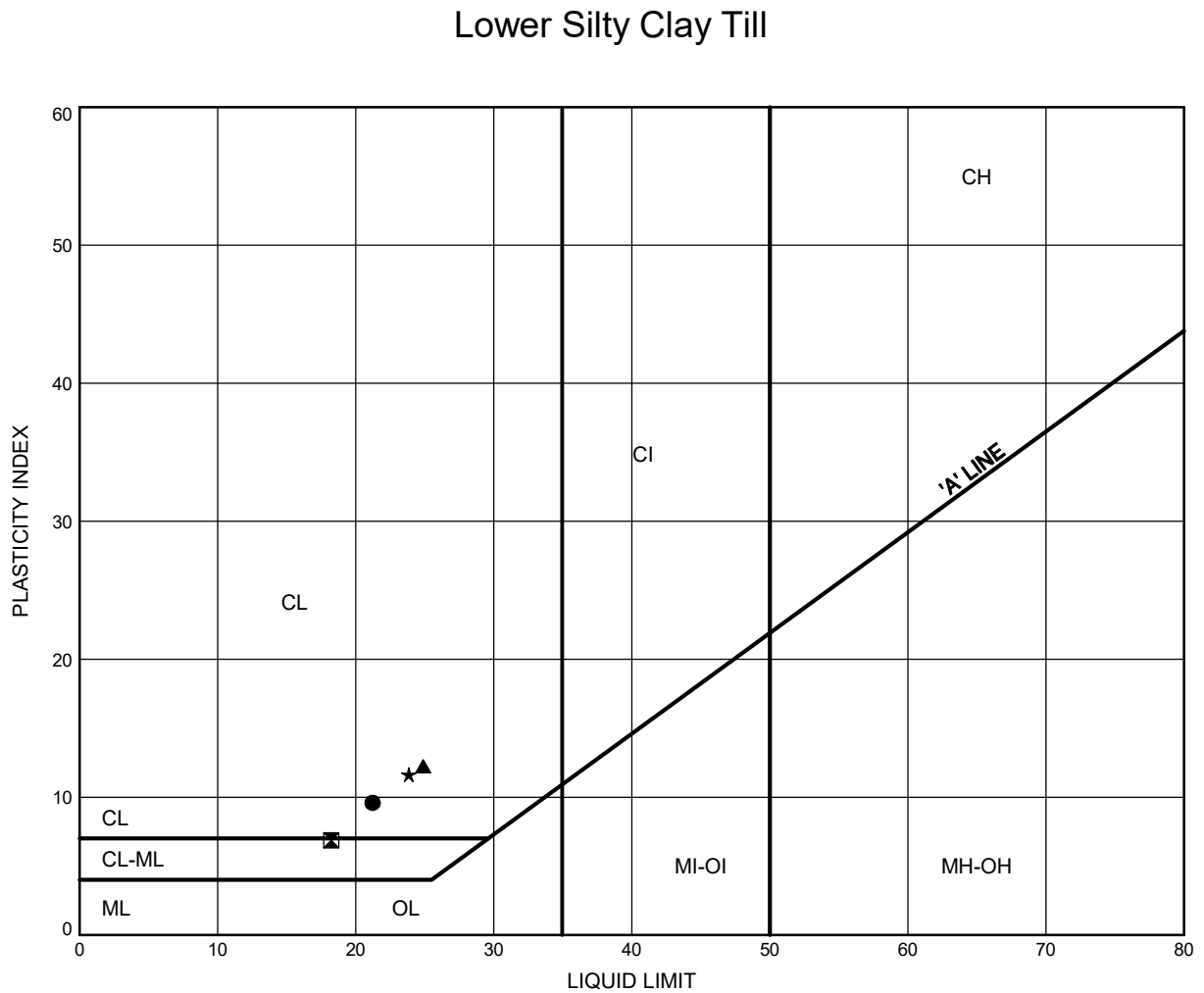
Date January 2018  
 GWP# 408-88-00



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Spitzig Road  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B11



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-02	15.5	310.7
⊠	SP16-02	19.9	306.3
▲	SP16-03	14.0	312.1
★	SP16-05	12.5	314.3

Date January 2018  
 GWP# 408-88-00

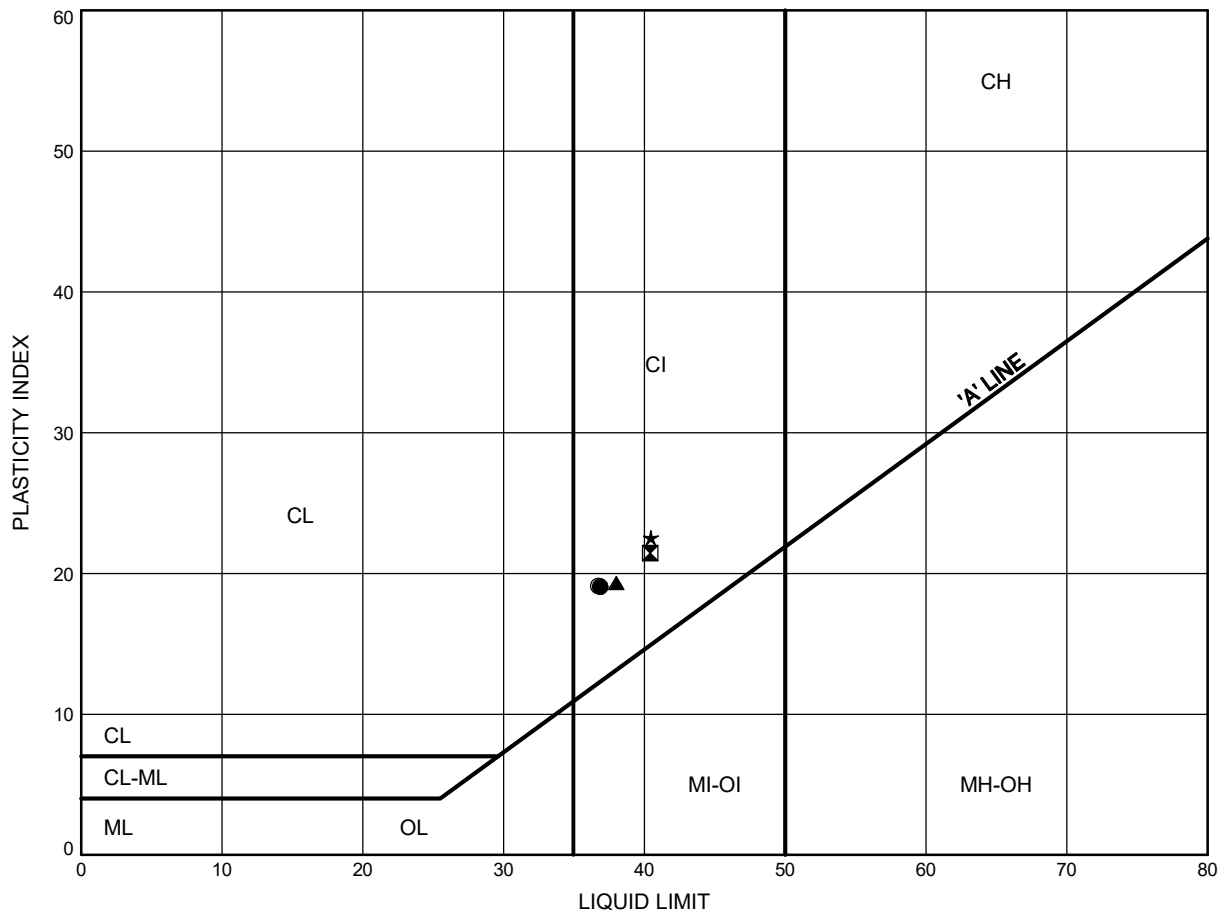


Prep'd MFA  
 Chkd. RPR

Spitzig Road  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B12

Silty Clay



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SP16-03	3.4	322.7
⊠	SP16-04	4.9	322.1
▲	SP16-05	6.4	320.4
★	SP16-07	7.9	319.3
⊙	SP16-08	4.9	322.9

Date January 2018  
 GWP# 408-88-00



Prep'd MFA  
 Chkd. RPR



## FINAL REPORT

CA14400-MAR18 R

11375

Prepared for

**Thurber Engineering Ltd.**

## First Page

## CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7.

Contact Rocio Reyna

Telephone 905-829-8666 x 263

Facsimile

Email rreyna@thurber.ca

Project 11375

Order Number

Samples Soil (12)

## LABORATORY DETAILS

Project Specialist Deanna Edwards, B.Sc, C.Chem

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 705-652-2000

Facsimile 705-652-6365

Email deanna.edwards@sgs.com

SGS Reference CA14400-MAR18

Received 03/19/2018

Approved 03/23/2018

Report Number CA14400-MAR18 R

Date Reported 03/23/2018

## COMMENTS

Temperature of Sample upon Receipt: 2 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

## SIGNATORIES

Deanna Edwards, B.Sc, C.Chem





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# FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

## PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	BS16-04 SS4	GH16-04 SS8	RC16-02 SS3	CR04 SS3	EB 16-03 SS5	SP16-04 SS7	CV16-01 SS3	GRB16-10 SS4
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	21/03/2018							

Parameter	Units	RL		Result	Result	Result	Result	Result	Result	Result	Result
Corrosivity Index											
Corrosivity Index	none	1		4.0	3.0	4.0	4.0	3.0	5.5	4.0	4.0
Soil Redox Potential	mV	-		343	324	305	294	332	271	228	230
Sulphide	%	0.02		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.06	< 0.02	< 0.02
pH	no unit	0.05		9.08	8.73	8.47	8.63	8.60	8.49	8.78	9.14
Resistivity (calculated)	ohms.cm	-9999		3860	3390	4630	3950	6100	2800	7520	8470

## PACKAGE: - Corrosivity Index (SOIL)

Sample Number	13	14	15	16
Sample Name	HC16-05 SS3	TR04-SS5	SH16-04 SS4	GRB16-21 SS4
Sample Matrix	Soil	Soil	Soil	Soil

Parameter	Units	RL		Result	Result	Result	Result
Corrosivity Index							
Corrosivity Index	none	1		4.0	4.0	3.0	4.0
Soil Redox Potential	mV	-		314	250	265	246
Sulphide	%	0.02		< 0.02	< 0.02	< 0.02	< 0.02
pH	no unit	0.05		9.06	8.98	9.11	8.91
Resistivity (calculated)	ohms.cm	-9999		7810	10100	6940	8200



# FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

## PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	BS16-04 SS4	GH16-04 SS8	RC16-02 SS3	CR04 SS3	EB 16-03 SS5	SP16-04 SS7	CV16-01 SS3	GRB16-10 SS4
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	21/03/2018							

Parameter	Units	RL		Result	Result	Result	Result	Result	Result	Result	Result
General Chemistry											
Conductivity	uS/cm	2		259	295	216	253	164	357	133	118

## PACKAGE: - General Chemistry (SOIL)

Sample Number	13	14	15	16
Sample Name	HC16-05 SS3	TR04-SS5	SH16-04 SS4	GRB16-21 SS4
Sample Matrix	Soil	Soil	Soil	Soil

Parameter	Units	RL		Result	Result	Result	Result
Conductivity	uS/cm	2		128	99	144	122

## PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	BS16-04 SS4	GH16-04 SS8	RC16-02 SS3	CR04 SS3	EB 16-03 SS5	SP16-04 SS7	CV16-01 SS3	GRB16-10 SS4
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	21/03/2018							

Parameter	Units	RL		Result	Result	Result	Result	Result	Result	Result	Result
Metals and Inorganics											
Sulphate	µg/g	0.4		140	92	11	69	6.5	356	68	22

## PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	13	14	15	16
Sample Name	HC16-05 SS3	TR04-SS5	SH16-04 SS4	GRB16-21 SS4
Sample Matrix	Soil	Soil	Soil	Soil

Parameter	Units	RL		Result	Result	Result	Result
Sulphate	µg/g	0.4		22	2.4	15	11



# FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	BS16-04 SS4	GH16-04 SS8	RC16-02 SS3	CR04 SS3	EB 16-03 SS5	SP16-04 SS7	CV16-01 SS3	GRB16-10 SS4
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	21/03/2018							

Parameter	Units	RL		Result	Result	Result	Result	Result	Result	Result	Result
Other (ORP)											
Chloride	µg/g	0.4		34	50	12	71	4.8	7.6	13	67

PACKAGE: - Other (ORP) (SOIL)

Sample Number	13	14	15	16
Sample Name	HC16-05 SS3	TR04-SS5	SH16-04 SS4	GRB16-21 SS4
Sample Matrix	Soil	Soil	Soil	Soil

Parameter	Units	RL		Result	Result	Result	Result
Other (ORP)							
Chloride	µg/g	0.4		71	22	94	68

PACKAGE: - PHCs (SOIL)

Sample Number	5	6	7	8	9	10	11	12
Sample Name	BS16-04 SS4	GH16-04 SS8	RC16-02 SS3	CR04 SS3	EB 16-03 SS5	SP16-04 SS7	CV16-01 SS3	GRB16-10 SS4
Sample Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	21/03/2018							

Parameter	Units	RL		Result	Result	Result	Result	Result	Result	Result	Result
PHCs											
Moisture Content	%	0.1		14.5	0.2	12.8	8.6	1.2	19.9	5.5	8.7

PACKAGE: - PHCs (SOIL)

Sample Number	13	14	15	16
Sample Name	HC16-05 SS3	TR04-SS5	SH16-04 SS4	GRB16-21 SS4
Sample Matrix	Soil	Soil	Soil	Soil

Parameter	Units	RL		Result	Result	Result	Result
PHCs							
Moisture Content	%	0.1		12.4	7.1	2.7	10.8



# FINAL REPORT

CA14400-MAR18 R

## QC SUMMARY

### Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0288-MAR18	µg/g	0.4	<0.4	2	20	100	80	120	101	75	125
Sulphate	DIO0288-MAR18	µg/g	0.4	<0.4	15	20	98	80	120	96	75	125

### Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0025-MAR18	%	0.02	<0.02	ND	20	111	80	120			

### Conductivity

Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0284-MAR18	uS/cm	2	< 2	1	10	99	90	110	NA		



QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-|ENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0284-MAR18	no unit	0.05	NA	1		101			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

## LEGEND

### FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --



# Request for Laboratory Services and CHAIN OF CUSTODY

No:

Page 1 of 2

SGS Environmental Services - Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Toll Free: 877-747-7658 Fax: 705-652-6365  
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361 Web: www.ca.sgs.com

Received By:

*Enak Agsey*  
Received Date (mm/dd/yyyy): 03/15/2018 (mm/dd/yyyy)  
Received Time: 11:00 AM

Received By (signature):

Custody Seal Present:

Custody Seal Intact:

Laboratory Information Section - Lab use only

Cooling Agent Present:

Temperature Upon Receipt (°C)

LAB LIMS #:

## REPORT INFORMATION

Company: *Thurber Eng.*

Contact: *Rocio Palomares Reyna*

Address: *103-2010 Winstonpark Dr.*

*Oakville, ON*

Phone: *905-829-8666 x260*

Fax:

Email: *rreynae@thurber.ca*

## INVOICE INFORMATION

☒ (same as Report Information)

Company:

Contact:

Address:

Phone:

Email:

## PROJECT INFORMATION

Quotation #:

Project #:

P.O. #:

Site Location/ID:

## TURNAROUND TIME (TAT) REQUIRED

☒ Regular TAT (5-7 days) TAT's are quoted in business days (exclude statutory holidays & weekends).  
Samples received after 3pm or on weekends : TAT begins the next business day

☐ RUSH TAT (Additional Charges May Apply) ☐ 1 Day ☐ 2 Days ☐ 3-4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date: Rush Confirmation ID:

## REGULATIONS

### Regulation 153 (2011):

☐ Table 1 ☐ Res/Park ☐ Soil Texture:

☐ Table 2 ☐ Ind/Com ☐ Coarse

☐ Table 3 ☐ Agri/Other ☐ Medium

☐ Table ☐ Fine

### Other Regulations:

☐ Reg 347/558 (3 Day min TAT)

☐ PWQO ☐ MMER

☐ CCME ☐ Other:

☐ MISA

### Sewer By-Law:

☐ Sanitary

☐ Storm

Municipality:

## RECORD OF SITE CONDITION (RSC) ☐ YES ☐ NO

### SAMPLE IDENTIFICATION

DATE SAMPLED

TIME SAMPLED

# OF BOTTLES

MATRIX

1 TR-04 -SSS

2 SH16-0A S54

3 GRB16-2A S54

4

5

6

7

8

9

10

Observations/Comments/Special Instructions

## ANALYSIS REQUESTED

COMMENTS:

Field Filtered (F)

Preserved (P)

Sampled By (NAME): *KAMIL FESZAK*

Relinquished by (NAME): *Sarah Hashim*

Signature: *[Signature]*

Signature: *[Signature]*

Date: *03/11/18*

Date: *03/11/18*

Pink Copy - Client

Yellow & White Copy - SGS





# SAMPLE INTEGRITY REPORT

Project Number: 11375

ONTARIO REGULATION 153/04

SGS Sample ID CA 14400 - MAR 18

Date / Time Sampled See CoFC

Client Sample ID See CoFC

ALL

## Sample Submission General Sample Integrity Violations

- |  |                          |
|--|--------------------------|
| Temperature >10 C upon receipt if not sampled same day     | <input type="checkbox"/> |
| No evidence of cooling trend initiated if sampled same day | <input type="checkbox"/> |
| Chain of Custody not submitted                             | <input type="checkbox"/> |
| Chain of Custody incomplete                                | <input type="checkbox"/> |
| Chain of Custody not signed / dated                        | <input type="checkbox"/> |
| Chain of Custody not a current version                     | <input type="checkbox"/> |
| Bottles / Samples listed on CoC but not received           | <input type="checkbox"/> |
| Bottles / Samples received but not listed on the CoC       | <input type="checkbox"/> |
| Sample container received empty                            | <input type="checkbox"/> |

## Sample Specific Sample Integrity Violations

- |   |                          |                          |                          |                          |                          |                          |                          |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Sample received past hold time                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Incorrect preservation (including no preservation where required) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Headspace present in VOC vial (aqueous)                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sample(s) received frozen   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Bottle(s) broken or damaged in transport                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Discrepancy between sample label and chain of custody             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Analysis requirements absent / unclear                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Missing or incorrect sample label(s)                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Inappropriate sample container used                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Insufficient number of bottles received                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Limited sample volume   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Insufficient sample volume  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sample contains multiple phases                                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

## Sediment Log

- |  |                          |                          |                          |                          |                          |                          |                          |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Groundwater samples contain visible sediment / particulate                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Groundwater contains greater than 1cm of sediment / particulate matter in bottle | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

## Additional Comments/Remarks:

No issues upon receipt



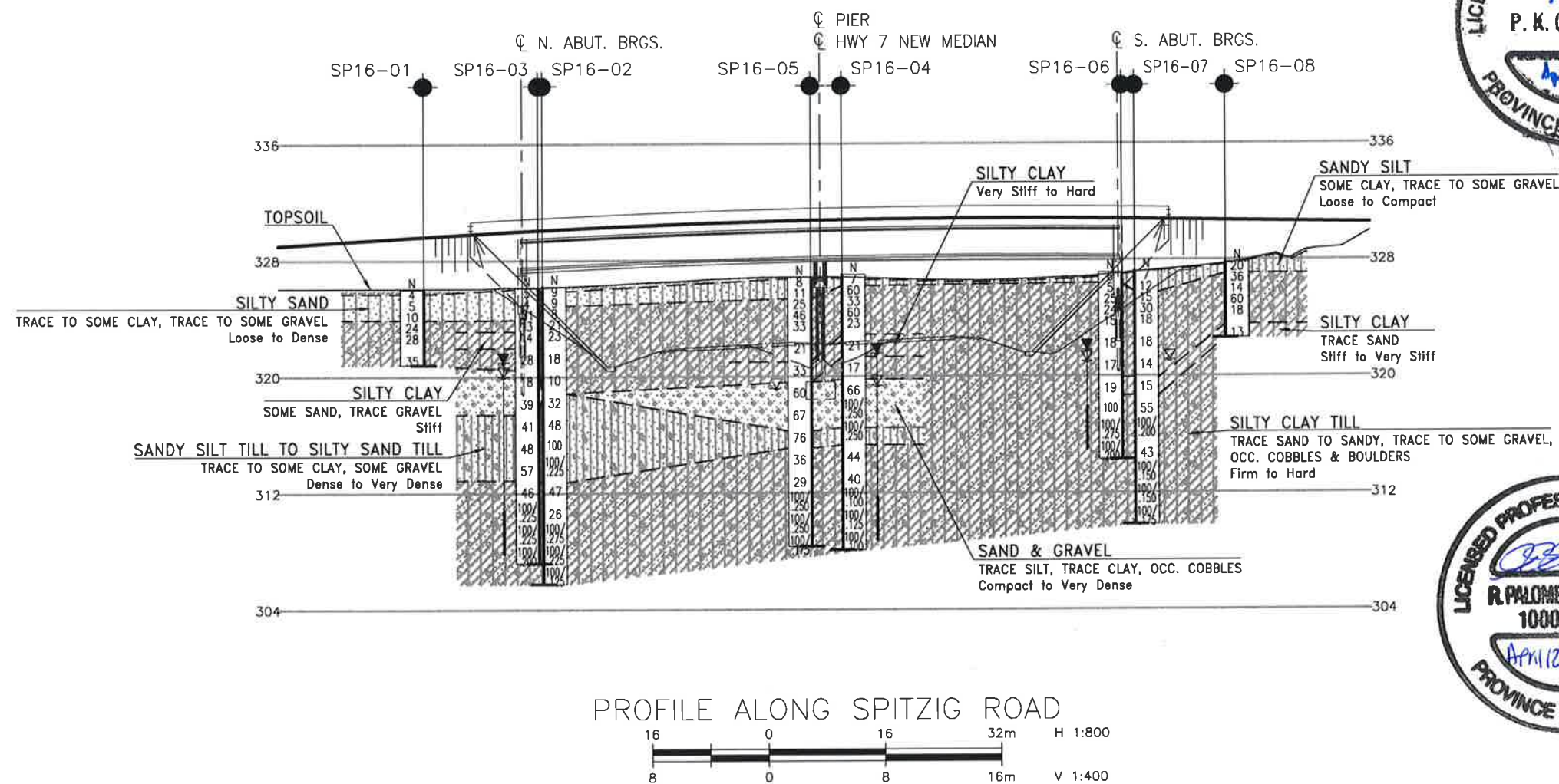
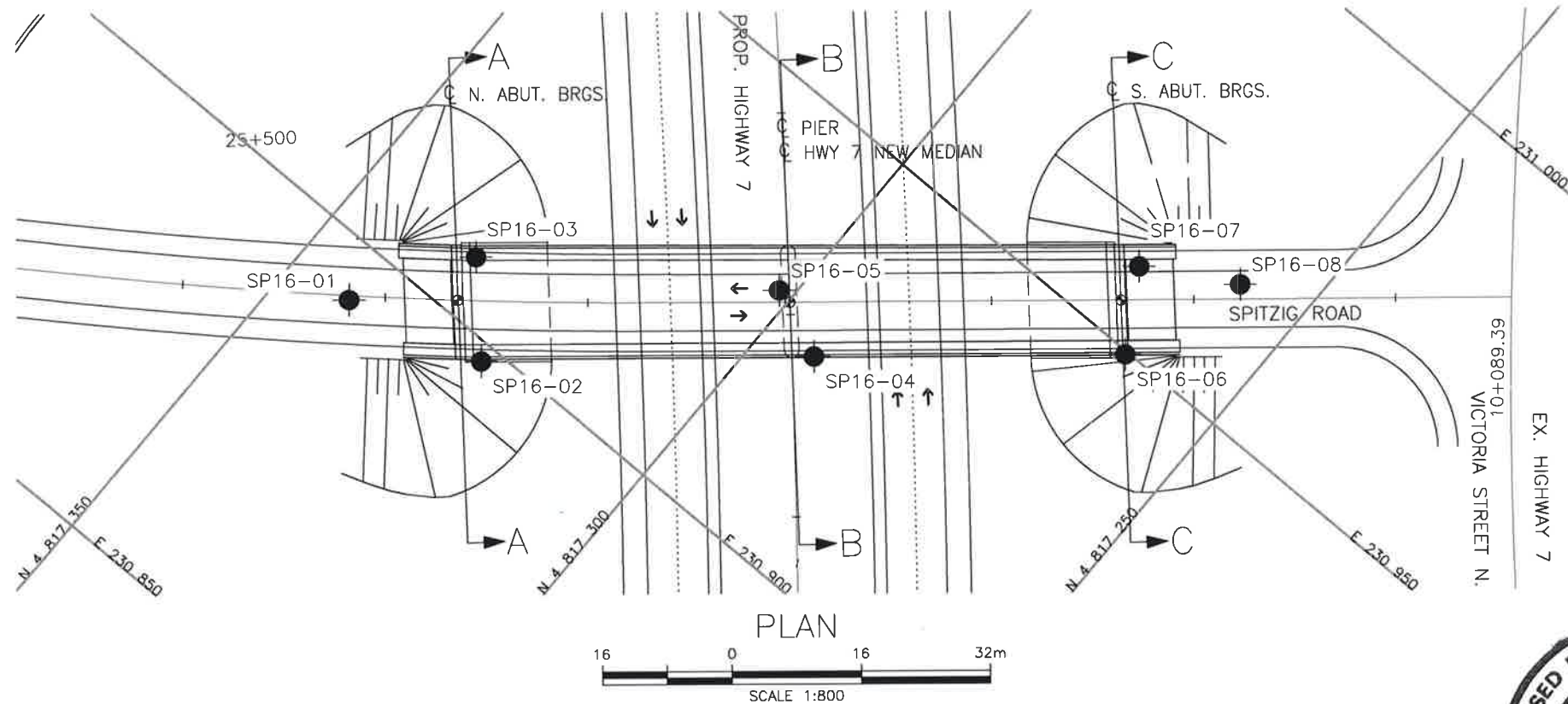
Initials:

KH



## **Appendix C**

### **Borehole Locations and Soil Strata Drawing**



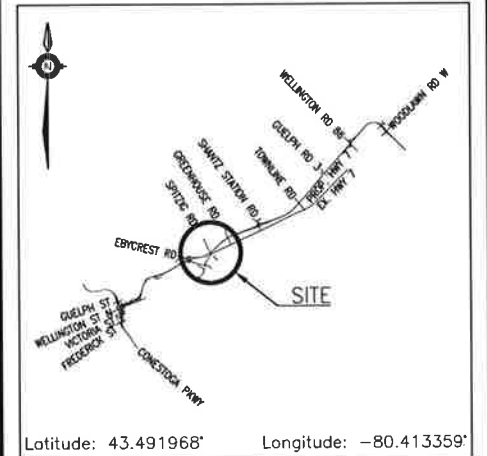
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No 408-88-00

HIGHWAY 7  
SPITZIG ROAD  
PROPOSED BRIDGE  
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



# LEGEND

●	Borehole (Current Investigation)
⊙	Borehole (2008 Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊖	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SP16-01	326.0	4 817 341.7	230 893.3
SP16-02	326.2	4 817 324.4	230 897.9
SP16-03	326.1	4 817 333.2	230 907.4
SP16-04	327.0	4 817 293.2	230 924.7
SP16-05	326.8	4 817 301.7	230 928.3
SP16-06	327.1	4 817 263.8	230 949.6
SP16-07	327.2	4 817 269.4	230 959.1
SP16-08	327.8	4 817 258.4	230 965.4

## NOTES

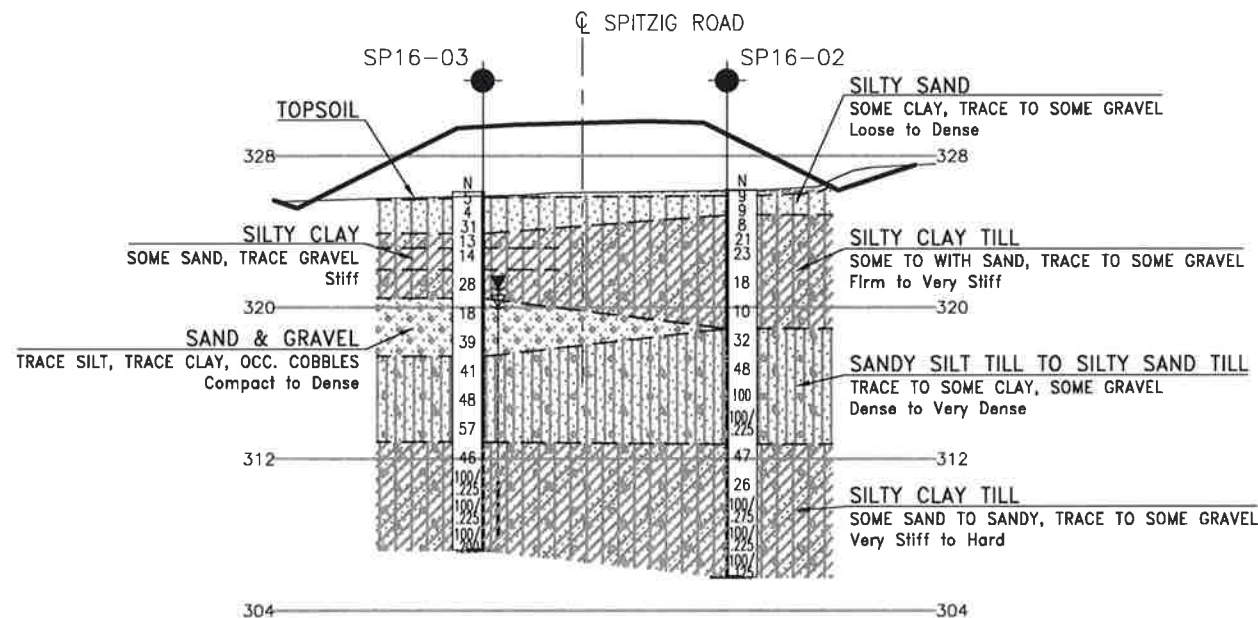
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCREs No. 40P8-249

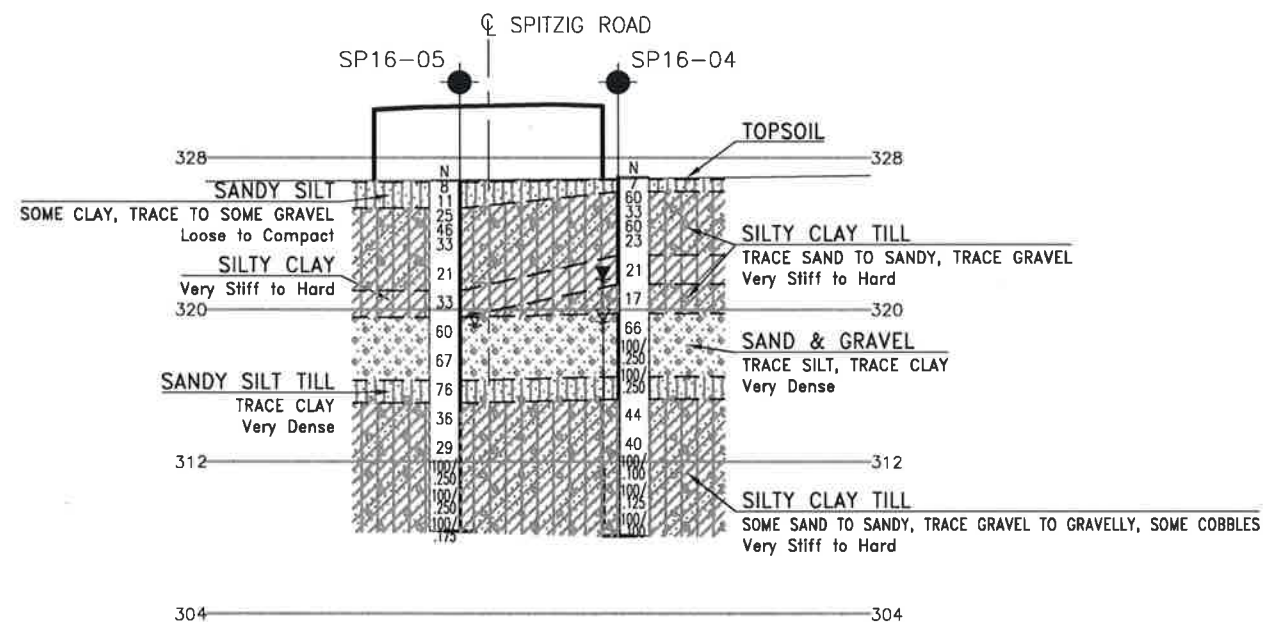


REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK	PKC
DRAWN	MFA	CHK	RPR
DATE	MAR 2018	DATE	MAR 2018
STRUCT	IDWG	1	

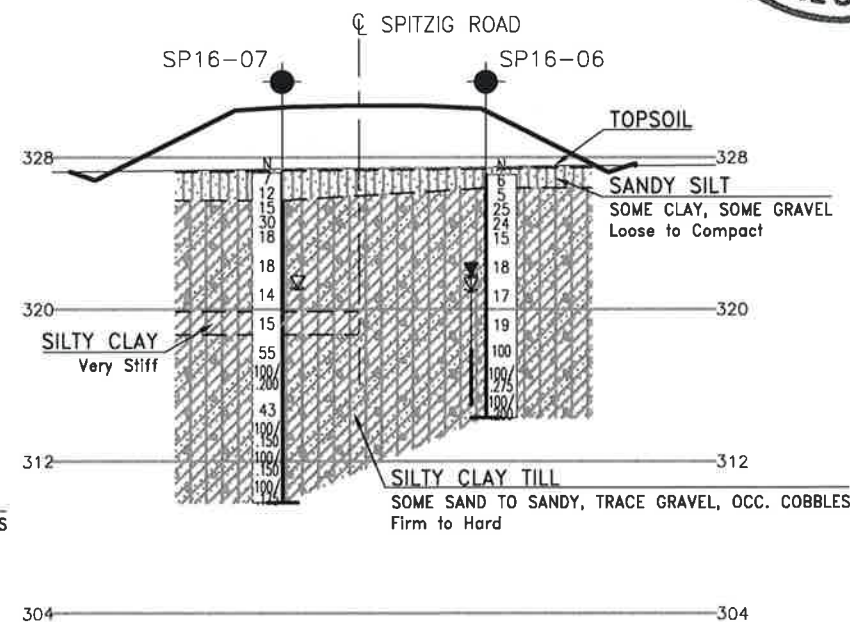
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



SECTION A-A (NORTH ABUTMENT)



SECTION B-B (PIER)



SECTION C-C (SOUTH ABUTMENT)

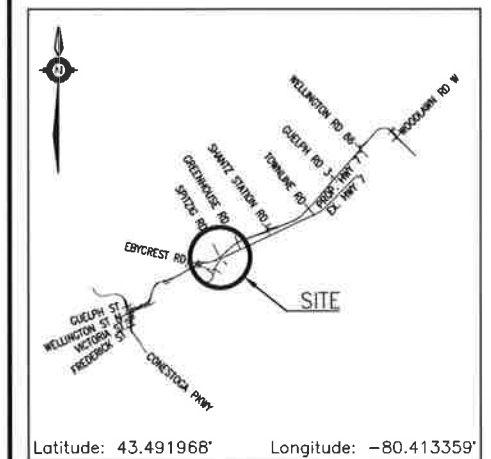


CONT No  
GWP No 408-88-00

HIGHWAY 7  
SPITZIG ROAD  
PROPOSED BRIDGE  
BOREHOLE LOCATIONS AND SOIL STRATA



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KEYPLAN

## LEGEND

●	Borehole (Current Investigation)
○	Borehole (2008 Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
W	Head Artesian Water
P	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SP16-01	326.0	4 817 341.7	230 893.3
SP16-02	326.2	4 817 324.4	230 897.9
SP16-03	326.1	4 817 333.2	230 907.4
SP16-04	327.0	4 817 293.2	230 924.7
SP16-05	326.8	4 817 301.7	230 928.3
SP16-06	327.1	4 817 263.8	230 949.6
SP16-07	327.2	4 817 269.4	230 959.1
SP16-08	327.8	4 817 258.4	230 965.4

## -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.
- Coordinate system is MTM NAD 83 Zone 10.

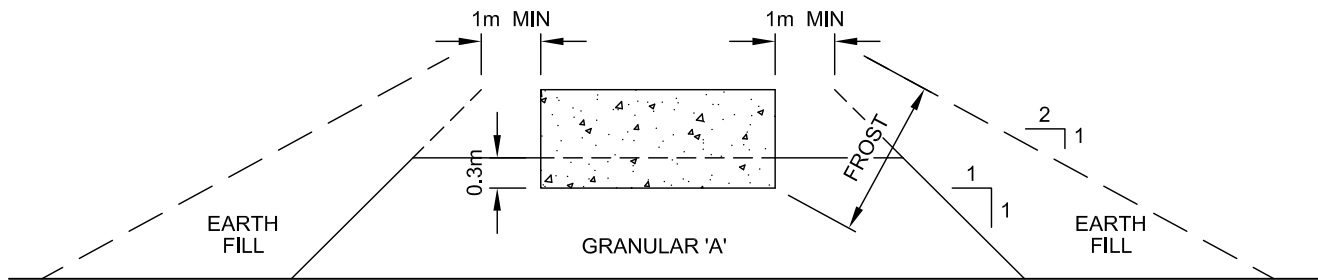
GEOCRES No. 40P8-249

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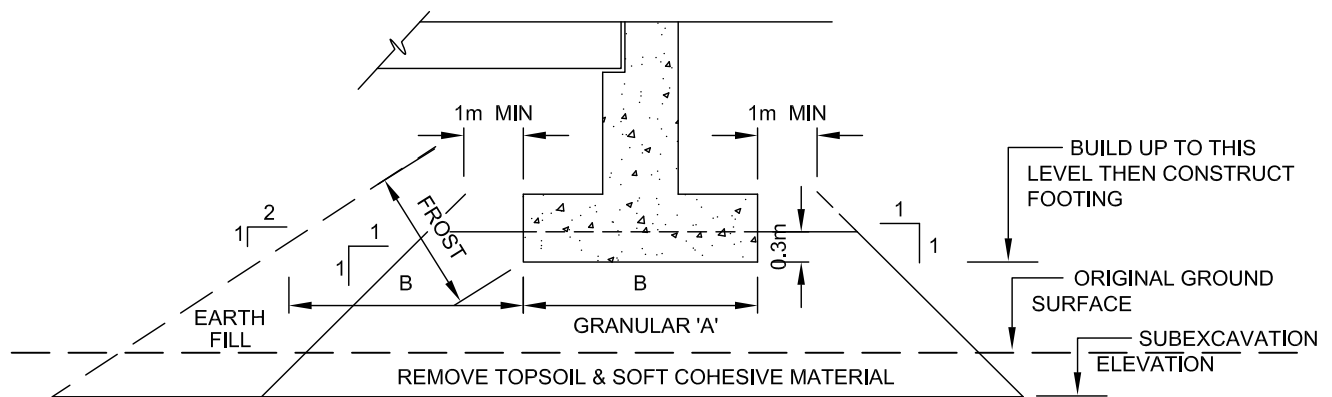


## Appendix D

### Figure



## 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 :	DRAWN :	APPROVED :
-	MFA	-
DATE :	SCALE :	DRAWING No.
SEPTEMBER 2016	N.T.S.	FIGURE 1



## **Appendix E**

### **Foundation Comparison**

**COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT**

Foundation Element	Spread Footings	Spread Footings on Engineered Fill	Driven Piles
<b>Abutments</b>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Lower geotechnical resistance available due to founding on compact soils near the surface.</li> <li>ii. Dewatering will be required, depending on depth of excavation.</li> </ul> <p align="center"><b>FEASIBLE</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Better geotechnical resistance than spread footings on native, but still influenced by the compact soils at the surface.</li> <li>ii. Dewatering may be required, depending on depth of excavation.</li> </ul> <p align="center"><b>FEASIBLE</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance may be developed by driving the piles into very dense soils.</li> <li>ii. Comparatively short abutment stem</li> <li>iii. Permits integral abutment design</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost compared to footings.</li> </ul> <p align="center"><b>RECOMMENDED</b></p>
<b>Pier</b>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Dewatering will be required, depending on depth of excavation.</li> </ul> <p align="center"><b>FEASIBLE</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Dewatering will be required, depending on depth of excavation.</li> </ul> <p align="center"><b>FEASIBLE</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance may be developed by driving the piles into very dense soils.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost compared to footings.</li> <li>ii. Very dense soils at shallow depth will limit length of pile and geotechnical resistance that can be developed.</li> </ul> <p align="center"><b>RECOMMENDED</b></p>



## **Appendix F**

### **List of OPSS Documents and Nssp Wording**



## **1. List of Special Provisions and OPSS Documents Referenced in this Report**

- OPSS PROV 206 Construction specification for grading
- OPSS PROV 501 Construction specification for compacting
- OPSS.PROV 517 Construction specification for dewatering
- SP 517F01 Amendment to OPSS 517
- OPSS PROV 539 Construction specification for temporary protection systems
- OPSS PROV 804 Construction specification for seed and cover
- OPSS PROV 902 Construction specification for excavating and backfilling - Structures
- OPSS PROV 903 Construction specification for deep foundations
- OPSS PROV 1010 Material specification for aggregates - base, subbase, select subgrade, and backfill material
- OPSD 3102.100 Wall abutments, backfill drain
- OPSD 208.010 Benching of earth slopes



## **2. Suggested text for a NSSP on Pile Installation**

The presence of cobbles and boulders will potentially have an impact on the installation of piles at the site. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:

- The cobbles and boulders may impede the driving of the piles resulting in more arduous driving in the very dense soils.
- Some piles may meet refusal on boulders that are large enough not to be dislodged or broken by the pile driving.
- As a result of the presence of boulders, piles may meet refusal at varying depths.
- Pile driving must be controlled according to the criteria specified for the site.

## **3. Suggested Text for NSSP on Groundwater Control**

Water seepage due to perched water in the slope, random fill, surface runoff and precipitation should be expected. For temporary excavations for retaining wall construction at this site, groundwater control will likely be limited to diverting surface runoff and preventing precipitation from entering the excavations supplemented by sump pumping and use of perimeter ditches where required. Filtered sumps must be designed properly so that construction drainage water containing eroded soil and fines do not flow onto the existing roadways. Dewatering systems must be installed and made operational prior to excavating below the groundwater level. It is also important to minimize disturbance of the exposed sandy silt till/sand and silt till surfaces by limiting construction traffic.