



THURBER ENGINEERING LTD.

**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
O'BRIEN ROAD INTERCHANGE
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F-216

Report to:

Ministry of Transportation Ontario

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) under Assignment No. 4018-E-0009 to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street in the Renfrew area.

This report addresses the proposed O'Brien Road (Highway 60) Interchange at Highway 17 in Renfrew, Ontario. The existing Highway 17 alignment will become the future Highway 17 westbound lanes, new eastbound lanes and interchange ramps will be constructed. New structures are required to convey Highway 17 over O'Brien Road.

This section of the report presents the factual findings obtained from a foundation investigation completed at the future Highway 17/O'Brien Road Interchange. Thurber carried out the investigation under Ministry of Transportation (MTO) Retainer Agreement No. 4068-09-00, Assignment No. 4018-E-0009.

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

Previous foundation information from a preliminary investigation completed in 2003 for the currently proposed structures was available under Geocres 31F-128.

2 SITE DESCRIPTION

2.1 General

The site is located on Highway 17 at the existing O'Brien Road (also known as Highway 60) intersection northeast of the Town of Renfrew. At the location of the proposed structures, Highway 17 is oriented southeast to northwest with O'Brien Road oriented in a southwest to northeast direction terminating at the T-intersection with Highway 17. For project purposes,



Highway 17 and O'Brien Road are herein described as oriented east-west and north-south respectively.

The land use adjacent to the site generally consists of low-density commercial to the south and west and forests and agricultural fields to the north and east. The terrain is relatively flat near the existing intersection with land west of the intersection gradually sloping downward toward the Bonnechere River valley northwest of the site. A small tributary creek within a 14 m deep ravine crosses O'Brien Road approximately 250 m southwest of the intersection and crosses Highway 17 approximately 150 m west of the intersection. The creek flows towards the Bonnechere River.

Highway 17 in this area consists of a two-lane undivided highway with paved shoulders and a posted speed limit of 90 km/hr. The AADT for this section of Highway 17 was 11,000 and 14,200 to the west and east of the intersection in 2008. O'Brien Road has one lane in each direction and had a reported AADT of 6550 in 2008. The T-intersection is controlled with traffic lights. A west bound left turn lane is present on Highway 17. A west to south ramp and a south to east ramp facilitate right turn movements.

Photographs showing the existing conditions in the area of the site at the time of the field investigation are included in Appendix D for reference.

2.2 Site Geology

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand. Base mapping by the Ontario Geological Survey indicates the bedrock in the area is carbonate metasedimentary rocks, marble, calc-silicate rocks, skarn, tectonic breccias of the Grenville Supergroup and Flinton Group.

3 SITE INVESTIGATION AND FIELD TESTING

The current site investigation and field-testing program was carried out between September 9th, 2019 and March 10th, 2020. The field investigation consisted of advancing 19 boreholes identified as Boreholes OBR19-1 through OBR19-16 and Boreholes CV-7, CV-8 and CV-9. Boreholes OBR19-10 and OBR19-11 were completed as Seismic Cone Penetration Tests (SCPTu). Additional details regarding the SCPTu testing equipment and methodology are provided in Appendix E. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Previously drilled Boreholes BRN-1, BRN-2, BRN-4 and BRN-5 were completed by Thurber in December 2003 as part of a preliminary investigation for the structures required for the twinning of Highway 17. Data from these boreholes has been fully incorporated into this report.

The locations of 2019/2020 boreholes were surveyed by Thurber for both location and elevation with a Trimble Catalyst DA1 antenna with centimeter accuracy. The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in



Appendix A, the individual Record of Borehole sheets in Appendix B, and in Table 3-1 below. The site is located within MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
BRN-1	EBL O/P West Abutment	5 038 049.1 (45.482273)	293 357.3 (-76.646373)	129.8	27.1
BRN-2	WBL O/P East Abutment	5 038 074.4 (45.482502)	293 421.5 (-76.645553)	128.4	27.4
BRN-4	WBL O/P West Abutment	5 038 084.7 (45.482594)	293 399.3 (-76.645837)	128.4	27.4
BRN-5	EBL O/P East Abutment	5 038 028.3 (45.482086)	293 364.2 (-76.646285)	129.8	28.2
OBR19-1	EBL O/P West Abutment	5 038 041.3 (45.482202)	293 345.5 (-76.646524)	129.9	26.9
OBR19-2	EBL O/P East Abutment	5 038 037.1 (45.482166)	293 370.9 (-76.646199)	129.8	25.2
OBR19-3	WBL O/P West Abutment	5 038 071.2 (45.482472)	293 371.2 (-76.646196)	129.9	30.5
OBR19-4	WBL O/P East Abutment	5 038 055.8 (45.482335)	293 400.5 (-76.645821)	130.2	28.9
OBR19-5	WBL O/P West Abutment	5 038 081.2 (45.482563)	293 388.9 (-76.645971)	129.8	25.3
OBR19-6	WBL O/P East Abutment	5 038 067.6 (45.482441)	293 414.2 (-76.645645)	130.0	25.2
OBR19-7	O'Brien Rd 10+050 Cut	5 038 025.6 (45.482061)	293 335.9 (-76.646647)	129.8	20.4
OBR19-8	O'Brien Rd 10+000 Cut	5 038 049.6 (45.482278)	293 383.7 (-76.646036)	130.0	20.4
OBR19-9	O'Brien Rd 9+950 Cut	5 038 085.1 (45.482598)	293 413.7 (-76.645653)	128.3	18.9
OBR19-10	WBL O/P West Abutment	5 038 072.3 (45.482482)	293 367.7 (-76.646241)	129.9	15.0
OBR19-11	EBL O/P East Abutment	5 038 038.5 (45.482178)	293 374.5 (-76.646153)	129.8	18.0
OBR19-12	W-S Ramp Cut	5 038 043.4 (45.482219)	293 182.2 (-76.648626)	131.5	12.8
OBR19-13	W-S Ramp Cut	5 038 088.3 (45.482623)	293 159.3 (-76.648907)	131.8	12.8
OBR19-14	W-S Ramp Cut	5 038 130.9 (45.483006)	293 126.1 (-76.649333)	132.2	14.3
OBR19-15	W-S Ramp Cut	5 038 164.8 (45.483311)	293 088.4 (-76.649816)	129.1	12.8



Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
OBR19-16	W-S Ramp Cut	5 038 190.7 (45.483542)	293 049.7 (-76.650316)	127.9	15.2
CV-7	W-S Ramp Fill / Culvert	5 037 953.0 (45.481406)	293 202.0 (-76.648358)	117.0	6.2
CV-8	W-S Ramp Fill / Culvert	5 037 972.4 (45.481581)	293 214.7 (-76.648196)	116.5	7.9
CV-9	W-S Ramp Fill / Culvert	5 038 001.6 (45.481843)	293 212.5 (-76.648224)	116.2	9.3

The current investigation was carried out using both truck and track-mounted CME 55 drill rigs equipped with hollow-stem augers and rotary diamond drilling equipment.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In-situ vane shear testing was completed in cohesive soils with an MTO 'N' sized vane. Select boreholes were advanced approximately 3 m into bedrock, with NQ sized coring equipment.

Standpipe piezometers, 19 mm in diameter, were installed in Boreholes BRN-1, BRN-2, BRN-4, OBR19-1, OBR19-2, OBR19-6, OBR19-9, OBR19-12 and CV-8. Monitoring wells, 38 mm and 50 mm in diameter, were installed in Boreholes OBR19-3 and OBR19-15, respectively. The installation details are illustrated on the respective Record of Borehole sheets provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg 903, as amended). The monitoring wells installed in 2019 are to be utilized during an upcoming hydrogeological study and will be subsequently decommissioned by Thurber.

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

4 LABORATORY TESTING

Laboratory testing was selected in accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. At least 25% of the recovered soil samples were subjected to grain size distribution analysis and Atterberg limits tests, where appropriate. The testing was carried out to MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. Unconfined Compressive Strength (UCS) testing was carried out on selected bedrock samples. Chemical analysis for determination of pH, conductivity, resistivity, sulphide, sulphate and chloride was carried out on soil samples from Boreholes OBR19-1, OBR19-2, OBR19-4 and OBR19-5.



The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. The SCPTu data is provided in Appendix E. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations. Soil classification is in accordance with ASTM D2487. Cohesive soils from the 2019/2020 boreholes are described per current MTO protocols.

In general terms, the site was found to have a surficial layer of topsoil or asphalt/fill overlying a native silty clay to clayey silt deposit, which is underlain by a deposit of silty sand to sand with silt over glacial till over bedrock.

5.1 Topsoil

Topsoil was encountered at surface in boreholes CV-8, and OBR19-12 through OBR19-16 which were drilled along the proposed W-S ramp and in boreholes OBR19-9, and BRN-2 through BRN-4 which were drilled north of the existing westbound lanes. Where encountered the topsoil thickness was found to range between 50 mm and 150 mm. The topsoil thickness may vary between or beyond the borehole locations.

5.2 Asphalt

Asphalt was encountered in boreholes OBR19-1, OBR19-2, OBR19-3, OBR19-4, OBR19-5, OBR19-7, OBR19-8, BRN-1 and BRN-5 which were drilled through the existing paved shoulder or paved gore areas. The asphalt was found to range between 75 mm and 150 mm in thickness.

5.3 Fill

A granular fill layer consisting of gravel with sand to silty sand with gravel was encountered at surface or below the asphalt in select boreholes on the existing highway platform near the intersection. A clay/silt/sand mixed fill was encountered either below the asphalt or upper granular fill in most boreholes drilled at the existing intersection. The underside of the granular fill was encountered at depths ranging from 0.8 m to 1.5 m (Elevations 128.3 m to 129.4 m). The thickness of the clay/silt/sand fill ranged from 0.6 m to 1.0 m and it extended to elevations ranging from 128.2 m to 129.1 m.

SPT tests conducted in the clay/silt/sand fill layer gave N-values ranging from 6 to 15 blows, indicating a firm to stiff consistency.

The moisture content of the fill samples tested ranged from 2 to 29%. The results of grain size analysis tests conducted on eight samples of the fill material are summarized below and are illustrated on Figures C1 to C2 in Appendix C.

Summary of Grain Size Distribution Testing – Granular Fill

Soil Particle	Percentage (%)
Gravel	34 – 57
Sand	38 – 57
Silt and Clay	4 – 18

Summary of Grain Size Distribution Testing – Mixed Fill

Soil Particle	Percentage (%)
Gravel	7 – 21
Sand	23 – 27
Silt	29 – 42
Clay	24 – 27

The results of Atterberg Limits testing carried out on the fines from two samples of the mixed clay/sand fill material are summarized below and are illustrated on Figure C16 in Appendix C. The laboratory results indicate that the fines from the mixed fill material is generally a clay of intermediate to low plasticity (CI to CL).

Summary of Atterberg Limit Testing – Mixed Clay/Sand Fill

Parameter	Value
Liquid Limit	32 – 39
Plastic Limit	17
Plasticity Index	15 – 22

5.4 Silty Clay (CI/CH) to Clayey Silt (CL)

A native deposit generally ranging in composition from silty clay to clayey silt was encountered below the fill or topsoil in Boreholes OBR19-1 through OBR19-9 and BRN-1 through BRN-5. Within these boreholes, this layer ranged in thickness from 7.1 m to 11.2 m with an underside elevation ranging from 117.4 m to 122.0 m. Sand and silty sand seams were noted throughout this deposit with thicknesses ranging from a few millimeters to upwards of 300 mm. The frequency of the sand seams increased with depth.

SPT tests conducted within this layer gave N-values ranging from weight of hammer to 23. In-situ shear vane tests in several locations indicated undrained shear strengths of 34 to greater than 100 kPa indicating a firm to very stiff consistency. Sensitivity ranged from 2.2 to 10.0.



The undrained shear strength of the deposit inferred from the SCPTu data ranged from about 50 to 200 kPa.

The moisture content of the samples tested ranged from 16 to 47%. The results of twenty-eight grain size analysis tests conducted on samples of this material are summarized below and are illustrated on Figures C3 to C7 in Appendix C.

Summary of Grain Size Distribution Testing – Silty Clay to Clayey Silt

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	0 – 24
Silt	50 – 70
Clay	22 – 48

The results of Atterberg Limits testing carried out on twenty-six samples of this material are summarized below and are illustrated on Figure C17 to C20 in Appendix C. The laboratory results indicate that the material is generally a silty clay of intermediate to low plasticity (CI to CL). There was one test result (OBR19-6 SS5) indicating a clay of high plasticity (CH) as well as one test result (BRN-3 SS10) indicating a silt/clayey silt (CL-ML). In general, the upper portion of this layer was found to have a higher plasticity than the lower portion. It should be noted in accordance with the MTO Guideline for Foundation Engineering Services (October 2020) this cohesive deposit could be described as a “clayey silt” where Atterberg limits tests indicate a CL material.

Summary of Atterberg Limit Testing – Silty Clay to Clayey Silt

Parameter	Value
Liquid Limit	19 – 57
Plastic Limit	13 – 22
Plasticity Index	5 – 35

5.5 Silty Sand to Sand with Silt to Gravel with Silt and Sand (SP-SM, SM, SW-SM, GP)

A glaciofluvial deposit of silty sand to sand with silt to gravel with silt and sand was encountered in all boreholes. This sand deposit was encountered beneath the clay/clayey silt in Boreholes OBR19-1 through OBR19-9 and BRN-1 through BRN-5 and at/near surface in Boreholes OBR19-12 through OBR19-16 and CV-7 through CV-9. In Boreholes OBR19-12, OBR19-13 and OBR19-14 this deposit had a noticeably greater gravel content with OBR19-14 having occasional to frequent cobbles. Clay seams were noted in numerous boreholes particularly in the upper portions of this unit. Silt layers were observed in Borehole BRN-2. Organic material was observed near ground surface in Borehole CV-8.

In the boreholes drilled in vicinity of the existing intersection which fully penetrated this layer, the thickness ranged from 8.5 m to 16.7 m and the underside of this layer ranged from elevation 103.3

m to 108.1 m. In boreholes drilled along the proposed W-S ramp the observed thicknesses ranged from 3.1 m to greater than 14.2 m and the underside elevation ranged from 110.9 m to 119.7 m.

SPT tests conducted in this layer gave N-values ranging from 2 to greater than 100 blows for 125 mm of penetration, indicating a very loose to very dense relative density, but was typically compact to dense.

The moisture content of this unit ranged from 3 to 44%. The results of grain size distribution testing carried out on forty-one samples of the sand are summarized below and are illustrated on Figures C8 to C14 in Appendix C.

Summary of Grain Size Distribution Testing – Glaciofluvial Sand

Soil Particle	Percentage (%)
Gravel	0 – 62
Sand	32 – 92
Silt and Clay	5 – 47

5.6 Clayey Silt (CL)

A clayey silt layer was observed beneath the silty sand to sand with silt in Borehole OBR 19-15. The layer was observed to be at least 3.3 m thick. The base was at elevation 116.4 m. There is silty sand below the clayey silt.

SPT test results ranged from 3 to 17. An undrained shear strength of 84 kPa was measured indicating a stiff consistency. The sensitivity was determined to be 8.0.

Moisture content test results ranged from 11% to 55%. The liquid limit was found to be 32% and the plastic limit 19%, indicating a CL classification, see Figure C21 in Appendix C. Grain size distribution test results on one sample indicated it contained 2% sand, 64% silt and 34% clay sized particles, see Figure C15 in Appendix C.

5.7 Gravel, Cobbles and Boulders, Glacial Till

A basal till deposit consisting of gravel, cobbles and boulders was encountered beneath the sand deposit in Boreholes OBR19-4, BRN-2, BRN-5 and CV-9. Penetration through this layer required the use of coring techniques. Where encountered the thickness ranged from 0.4 m to 3.3 m and the elevation of the underside of the layer ranged from 104.5 m to 110.5 m. Boulders up to 800 mm and 500 mm in size were cored in Boreholes OBR19-4 and BRN-2, respectively.

SPT tests were generally not completed due to the high frequency of cobbles and boulders. One SPT test was conducted at the surface of this layer in Borehole OBR19-4 and gave an N-value of 34, indicating a dense relative density for the soil matrix. This single sample was predominately gravel and had a moisture content of 5%.

5.8 Refusal and Bedrock

Boreholes OBR19-2, OBR19-5 and OBR19-6 were terminated on SPT refusal. Bedrock was proven by coring in Boreholes BRN-1, BRN-2, BRN-4, BRN-5, OBR19-1, OBR19-3, OBR19-4, CV-7, CV-8 and CV-9. The bedrock encountered consisted of slightly weathered to fresh, medium strong, white to grey marble. Photographs of the bedrock cores are provided in Appendix C. The following table summarizes the rock core quality:

Summary of Rock Core Quality

Parameter	Range	Average
Total Core Recovery (TCR), %	63 to 100	98
Solid Core Recovery (SCR), %	19 to 100	75
Rock Quality Designation (RQD), %	0 to 100	76
Fracture Index	0 to >10	-

Based on the average RQD value, the bedrock is classified as fair quality. Unconfined compressive strength (UCS) testing was carried out on three samples of the bedrock in Boreholes OBR19-1, OBR19-3 and OBR19-4; the results ranged from 36 MPa to 40 MPa. Based on the unconfined compressive strength testing the bedrock is medium strong. It should be noted that the UCS values provided on the 2003 borehole logs were estimated from point load tests which can significantly overestimate the bedrock strength.

A summary of the bedrock surface information is provided in Table 5-1 below:

Table 5-1: Summary of Bedrock Depth/Elevation

Borehole No.	Depth to Bedrock Surface (mbgs)	Bedrock Surface Elevation (m)
BRN1	23.9	105.9
BRN2	23.9	104.5
BRN4	24.5	103.9
BRN5	25.3	104.5
OBR19-1	23.2	106.7
OBR19-2	25.2*	104.6*
OBR19-3	26.6	103.3
OBR19-4	25.4	104.8
OBR19-5	25.3*	104.5*
OBR19-6	25.2*	104.8*
CV-7	3.1	113.9
CV-8	4.2	112.3
CV-9	5.7	110.5

Note: * - Inferred from SPT Refusal, which could also occur due to boulders and cobbles



5.9 Groundwater

Standpipe piezometers and monitoring wells with diameters ranging from 19 mm to 50 mm were installed in eight of the current boreholes and three previously drilled boreholes. Groundwater levels recorded in the piezometers are presented in Table 5-2 below:

Table 5-2: Summary of Groundwater Levels

Borehole No.	Bottom of Screen Elevation (m)	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
OBR19-1	106.7	19.3	110.6	2019.09.26
		19.3	110.6	2020.04.21
OBR19-2	104.6	19.9	109.9	2019.09.26
		19.6	110.2	2020.04.21
OBR19-3	103.3	20.1	109.8	2019.09.26
		20.1	109.8	2020.04.21
OBR19-6	105.0	20.1	109.9	2019.09.26
		20.2	109.8	2020.04.21
OBR19-9	109.9	Dry to 18.4	Dry to 109.9	2020.04.21
OBR19-12	118.8	Dry to 12.6	Dry to 118.9	2020.04.21
OBR19-15	119.8	8.0	121.1	2020.02.07
		Dry to 6.3	Dry to 122.8	2020.04.21
CV-8	112.3	Dry to 4.2	Dry to 112.3	2019.11.26
		3.6	112.9	2020.04.21
		Dry to 4.2	Dry to 112.3	2020.09.29
BRN-1	106.0	19.7	110.1	2003.10.22
		19.4	110.4	2003.12.16
		19.4	110.4	2004.02.04
BRN-2	101.0	19.3	109.1	2003.10.22
		19.1	109.3	2003.12.16
		18.9	109.5	2004.02.04
		19.3	109.1	2020.04.21
BRN-4	101.0	18.9	109.5	2003.12.16
		18.7	109.7	2004.02.04



At the time of the site visits and field investigation carried out for the proposed W-S Ramp crossing of the Bonnechere River tributary creek, east of O'Brien Road, nominal surficial creek flow, less than about 0.3 m deep, was observed.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.10 Analytical Testing

Four samples of the native soils were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity and conductivity. The analysis results are summarized in Table 5-3. Copies of the test results are provided in Appendix C.

Table 5-3: Results of Chemical Analysis

Borehole	OBR19-1	OBR19-2	OBR19-4	OBR19-5	CV-9
Sample	SS5	SS3	SS4	SS3	SS3
Depth (m)	3.0 – 3.6	1.5 – 2.1	2.3 – 2.9	1.5 – 2.1	1.5 – 2.1
Chloride (µg/g)	277	36	434	74	11
Sulphate (µg/g)	35	13	53	2460	10
Sulphide (%)	0.03	0.03	0.03	0.03	< 0.02
pH (-)	7.4	7.6	7.6	7.9	8.0
Resistivity (Ohm-cm)	1,800	5,440	1,140	239	9,750
Conductivity (µS/cm)	555	184	876	4180	103



6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevation of the boreholes were surveyed by Thurber following completion of the field program. The elevation survey was carried out with reference to geodetic elevation benchmarks provided by the MTO.

Marathon Underground of Greely, Ontario and Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated the drilling equipment and carried out the drilling, soil sampling, in-situ testing, piezometer installation and borehole decommissioning. ConeTec of Toronto, Ontario completed the cone penetration tests onsite. The field investigation was supervised on a full-time basis by Sean O'Bryan, Nick Weil and Michel Johnston of Thurber. Overall supervision of the investigation program was provided by Justin Gray, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Unconfined Compressive Strength Testing of the bedrock was carried out by Thurber's laboratory in Oakville. Analytical testing was completed by Paracel Laboratories in Ottawa.

Overall project management and direction of the field program was provided by Fred Griffiths, P.Eng. Interpretation of the factual data and preparation of this report were carried out by Justin Gray, P.Eng. and Fred Griffiths, P.Eng. The report was reviewed by P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
O'BRIEN ROAD INTERCHANGE
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F-216

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber for the construction of foundation elements for the proposed eastbound and westbound Highway 17 overpass structures, retaining walls and deep cuts/high fills. The site is located on Highway 17 at the intersection of O'Brien Road (Highway 60) in Horton Township, Renfrew County. At the site, the existing Highway 17 will become the future westbound lanes while the new future eastbound alignment will be located approximately 40 m south of the existing alignment. The interchange will be designed to a combination trumpet/diamond configuration. O'Brien Road will be lowered approximately 6 m from existing grade and pass beneath the Highway 17 eastbound and westbound structures. Retaining walls beyond and between the structures will likely be required. Cuts as deep as 7 m and fills as high as 13 m will be required for the W-S ramp.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. 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 factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide geotechnical recommendations for the construction of foundation elements for the proposed structures and retaining wall as well as the deep cut and high fills on-site. The discussions and recommendations presented in this report are based on the information provided by the Ministry of Transportation of Ontario (MTO) and on the factual data obtained during the course of this investigation.

7.1 Proposed Structures

For project purposes, Highway 17 and O'Brien Road are herein described as oriented east-west and north-south, respectively.



Per the Terms of Reference for this assignment, the new structures to convey Highway 17 over O'Brien Road will consist of two reinforced concrete rigid frames separated by approximately 40 m centreline to centreline. The structures will have a single, clear span of 12.0 m and a vertical clearance of 4.85 m. A copy of the preliminary General Arrangement Drawing from the Structural Planning Report is provided in Appendix G. A copy of an updated GA prepared by Parsons with a modification date of June 15, 2021 is also provided in Appendix G.

The finished grade of Highway 17 will remain approximately the same at its current elevation of approximately 130.0 m. The roadway width at the eastbound structure will be approximately 15.25 m to allow for two 3.75 m lanes, a 3.75 m future inside lane, a 3.0 m wide outside shoulder and a 1.0 m wide inside shoulder. The roadway width at the westbound structure will be approximately 18.75 m to allow for two 3.75 m lanes, a 3.75 m future inside lane, a ramp speed change lane of variable width, and a 2.5 m wide outside shoulder and a 1.0 m wide inside shoulder.

The finished grade of O'Brien Road will have a low point of approximately elevation 123.8 m below the structures. The road will be approximately 12.0 m wide to accommodate two 3.5 m lanes and two 2.5 m shoulders. O'Brien Road and the associated Highway structures will be constructed at a skew of approximately 20 degrees from perpendicular.

It is anticipated that retaining walls will be required at both ends of both structures to retain the cut slopes. As many as eight retaining walls are anticipated onsite.

Significant cut and fill operations are anticipated along the W-S Ramp. A non-structural culvert will be placed to facilitate creek flow at approximate Station 21+155 on the W-S Ramp. The proposed culvert is to be a concrete box culvert with a 2.2 m span and a 2.7 m rise, based on the 2004 Preliminary Design Report.

7.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-19.

In accordance with CHBDC, the analysis and design of a structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

It is understood that the new Highway 17 bridge structures are being designed to the "Major Route" importance category.

It is assumed that the proposed underpass structures have a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances for these structures.



The degree of site and prediction model understanding for this site has been assessed to be typical understanding (Section 6.5.3 of CHBDC).

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). The seismic hazard for this site has been obtained from the GSC online calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values ($S_a(T)$) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.22 g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class.

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the measured shear wave velocities from the SCPTu tests as presented in Appendix E, this site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC.

As per Table 4.8 of the CHBDC, Site Class D yields a PGA_{ref} of 0.179 g and $F(PGA)$ of 1.14 for the site. These values give a factored Site Class D PGA of 0.26 g.

8.3 Seismic Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Boulanger and Idriss (2007)ⁱ criteria using measured undrained shear strengths. The results of the analysis indicate the cohesive material is not susceptible to cyclic mobility.

The susceptibility of the cohesionless soils at the site to experience liquefaction was assessed using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)ⁱⁱ. The cohesionless foundation soils are not considered to be susceptible to liquefaction.



9 STRUCTURE FOUNDATION ALTERNATIVES

9.1 Foundation Alternatives

At the time of preparation of this report, it is understood that the new overpasses are to consist of two reinforced concrete rigid frame structures, each with a single interior span of 12.0 m and a vertical clearance of 4.85 m. It is assumed that the width of the structures will be greater than 15.0 m and 18.5 m in order to accommodate the planned and future lanes. A total of eight retaining walls will be required along O'Brien. Drainage along O'Brien Road will be based on an urban cross-section at the structures and a storm sewer system.

It is anticipated that the underside of the abutments will be at approximate elevation 122 m. Based on the ten boreholes near the four abutments (OBR 19-1 through 6 and BRN-1, 2, 4 and 5), the soil conditions at that elevation general consist of clayey silt (CL) with a firm to very stiff consistency over a compact to dense sand to silty sand over a glacial till layer over bedrock. The clayey silt extends 0 m to 4.6 m beneath the underside of the abutments with an average of 2.9 m. A summary figure presenting the in-situ and laboratory test results and other pertinent information for the clayey silt/clay and underlying sand deposit is presented as Figure I-1 in Appendix I. Groundwater was observed at elevations ranging from 109.1 m to 110.6 m. Bedrock was encountered or inferred at elevations ranging from 103.3 m to 106.7 m. Cobbles and boulders were observed in the glacial till layer over the bedrock in five of the ten boreholes.

Given the soil stratigraphy encountered, the following options have been considered from a geotechnical perspective for the support of the bridge abutments:

- Spread footings,
- Caissons (drilled shafts), and
- Steel piles (H-piles, pipe piles).

The foundation alternatives are presented below and evaluated from a geotechnical perspective in terms of their respective advantages, disadvantages, risks and consequences. The evaluation is summarized in the table provided in Appendix G.

- Spread Footings

Spread footings would be founded below the base of the abutment which is estimated to be at an elevation of 122 m. The foundation soils at the founding elevation for spread footings would generally consist of firm to very stiff silty clay to clayey silt which would offer low bearing resistance. Furthermore, the thickness of the clayey silt beneath the underside of the abutments varies significantly from abutment to abutment, thus generating differential settlements between founding units. Alternatively, to achieve higher bearing resistances and reduced differential settlement, the native silty clay and clayey silt could be sub-excavated to the underlying sand layer and replaced with engineered fill, however this would result in excavations as deep as 4.6 m below footing level and large quantities of excess material and the need for temporary protection systems. Spread footings do not allow for construction of integral abutments.

It is not recommended to support the new bridges on spread footings; however, it may be feasible to support retaining walls on spread footings.

- Caissons

Caisson foundations, particularly when they are socketed into bedrock, offer high geotechnical resistance. The high lateral stiffness of caissons is not compatible with integral abutments. The deep groundwater level observed during the field investigation supports the ability to drill caissons through much of the cohesionless soils, however possible unbalanced hydraulic pressure heads and caisson base boiling at lower elevations would require the use of temporary liners and synthetic slurry to counterbalance groundwater pressure. Cobbles and boulders in the till layer above the bedrock were encountered in five of the boreholes and could present additional installation difficulties. Founding caissons on dissimilar stratigraphy (e.g. some on bedrock and some in boulders) could result in differential settlements.

It is not recommended to support the new bridges on caissons.

- Steel piles

Based on the foundation soils encountered as part of the current investigation, driven steel piles are considered feasible for the support of the new abutments. Driven piles will typically reduce the volumes of excavation required when compared to shallow foundations. The use of H-Piles with reinforced tips is the option with the least risk given the cobbles and boulders in the till layer above the bedrock observed at this site. Pipe piles are more likely to meet effective refusal early in the cobbles and boulders at the site and would not provide enough lateral flexibility to accommodate integral abutments.

It is recommended to support the new abutments on driven steel H-Piles.

9.2 Construction Methodology

At the time of preparation of this report, it is understood that a two stage construction plan has been developed. During the first stage, traffic on O'Brien Road will be diverted onto a temporary alignment leading to a new intersection with Highway 17 to the west of the existing while the new eastbound structure is constructed. During the second stage, Highway 17 traffic will be diverted onto the new eastbound lanes while the new westbound structure is constructed. The foundation recommendations presented herein have been prepared based on the assumption that construction will be carried out under full road closure conditions with no requirement for temporary roadway protection.



10 FOUNDATION DESIGN RECOMMENDATIONS

The abutments may be supported on steel H-piles driven to refusal in the till layer above bedrock. Approximate key elevations are as follows:

- | | |
|--|------------------|
| • Proposed top of pavement Highway 17, assumed | 130.2 m |
| • Proposed top of pavement O'Brien 10+000, assumed | 123.8 m |
| • Underside of pile cap, assumed | 122.0 m |
| • Groundwater elevation | 109.1 to 110.6 m |
| • Clay/Sand interface | 117.4 to 122.0 m |
| • Bedrock surface | 103.3 to 106.7 m |

10.1 Driven Steel H-Piles

10.1.1 Axial Geotechnical Resistance and Founding Elevation

Bedrock was proven by coring in Boreholes OBR19-1, OBR19-3, OBR 19-4, BRN-1, BRN-2, BRN-4 and BRN-5, which were advanced near the abutments, with bedrock surface elevations ranging from 103.3 to 106.7 m. Cobbles and boulders were observed in the glacial till layer over the bedrock in five of the ten boreholes. Coring was required to advance through this layer of cobbles and boulder. It is anticipated that a number of piles will not be able to penetrate this layer to bedrock. Accordingly, pile recommendations are based on driving the piles to refusal in this cobble and boulder layer; some of the piles will fully penetrate the till and reach bedrock.

Steel HP 310x110 piles driven to practical refusal in the till layer may be designed with a factored geotechnical ULS resistance for axial compression of 1,800 kN. For long piles driven to refusal in the cobbles and boulders, consideration may be given to using an H-pile with a heavier pile section such as an HP 310x132. The structural resistance of the pile under static and seismic conditions must be checked by a structural engineer. The factored geotechnical resistance at SLS will not govern for steel H-piles founded at practical refusal in the cobble and boulder layer. Likewise, H-piles founded at practical refusal in the cobble and boulder layer will not experience differential settlement. The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2) of $\phi_{gu} = 0.4$ (static analysis; typical degree of understanding)

The estimated pile tip elevations for H-piles end bearing at practical refusal in the cobble and boulder layer are summarized in Table 10-1.

Table 10-1 Axial Geotechnical Resistances for HP310x110

Foundation	Location	Bedrock Elevation (m)	Estimated Pile Refusal Elevation (m)
Westbound Structure, East Abutment	OBR19-4	104.8	106.1 cobbles & boulders 108.1
	OBR19-6	104.8 (inferred)	104.8 cobbles at 105.4
	BRN-2	104.5	104.5 cobbles & boulders 106.0
Westbound Structure, West Abutment	OBR19-3	103.3	103.3
	OBR19-5	104.5 (inferred)	104.5
	BRN-4	103.9	104.6 cobbles from 106.6
Eastbound Structure, East Abutment	OBR19-2	104.6 (inferred)	104.6
	BRN-5	104.5	104.5 cobbles & boulders 105.7
Eastbound Structure, West Abutment	OBR19-1	106.7	106.7
	BRN-1	105.9	105.9

The geotechnical axial resistance was selected assuming that the H-piles meet refusal 2 m into the glacial till layer or on bedrock. Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance should be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of MTO's Structural Manual. Dynamic load testing (PDA) should be carried out to confirm pile capacity during construction. It is recommended the capacity of at least one pile per abutment is verified by PDA testing.

Steel H-piles (Grade 350W steel) at this site may be designed with 540 kN for factored geotechnical resistances for static axial tension. Similarly, the same H-piles can be designed with 1,800 kN of factored geotechnical resistance for seismic axial tension. The factored geotechnical resistances in tension include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2) of $\phi_{gu} = 0.3$ (static analysis; typical degree of understanding)
- Geotechnical resistance factors (CHBDC Table 6.2) of $\phi_{gu} = 1.0$ (seismic analysis; typical degree of understanding)



10.1.2 Downdrag

Time dependant settlement of the cohesive foundation soils is not expected to occur as O'Brien Road will be in a cut and the grades for Highway 17 will not change from existing; thus there will be a reduction in stress on the underlying soils and downdrag on the piled foundations is not expected.

10.1.3 Lateral Geotechnical Resistance and Group Effects

Piles can be installed with a batter to resist lateral loads for a conventional or semi-integral abutment.

The lateral resistance for the soil adjacent to a vertical pile is developed on the face of the pile embedded in the foundation soils and estimated using p-y curves.

The p-y curves for static conditions are shown in Appendix H to allow for calculation of the *ultimate* lateral capacity of an individual pile. A geotechnical resistance factor of 0.5 (ϕ_{gu}) and 0.8 (ϕ_{gs}) as per Table 6.2 of the CHBDC (static analysis – typical understanding) should be applied to the *ultimate* ULS and SLS values, respectively.

Where lateral spacing between an adjacent pile or another structural element is less than four equivalent pile diameters, the lateral resistance will also need to be further reduced based on the center-to-center spacing. The reduction factors to be used can be obtained from Figures C6.22, C6.23, and C6.24 of the Commentary to the CHBDC.

10.1.4 Pile Tips

It is expected the pile installation will encounter cobbles and boulders. Care must be exercised not to damage the piles while driving into layers with cobbles and boulders and to bedrock. The tips of all piles must be protected from damage when driving and should be fitted with a Titus Steel (standard H-Point) or approved equal.

10.1.5 Pile Driving

Pile driving must be carried out in accordance with OPSS.PROV 903 and Special Provision 109F57 for piles driven to refusal in the cobble and boulder layer. Pile testing need not be used until piles are within 2 m of the design tip elevation. The appropriate pile driving note is "Piles to be driven to an ultimate resistance of "R" kN per pile". "R" must have a minimum value of twice the design load at ULS. The designer fill-in (*) in Section 903.07.02.07.03.01 shall be *High-Strain Dynamic Testing*. Piles meeting effective refusal and end-bearing on very dense glacial till or bedrock are not anticipated to have significant capacity increase due to soil setup. Pile re-tapping should be carried out as per OPSS 903.

10.1.6 Abutment Type

The subsurface conditions at this site are considered suitable for conventional, semi-integral or integral abutments. The primary criterion for integral abutment foundations is the need to support the abutments on relatively flexible piles. If integral abutments are adopted, casing of the upper



portion of the piles in a sand-filled corrugated steel pipe (or similar) would be required to ensure the suitable flexibility of steel H-piles.

10.2 Wingwalls and Retaining Walls

Based on preliminary design documents, it is understood that a combination wingwall/retaining wall system installed along O'Brien at each structure is the preferred method to retain the cut slopes between and beyond each structure. Consideration could also be given to installing a continuous wall between the structures to further mitigate erosion issues. Preliminary design drawings suggest the concrete retaining walls would be supported on driven steel piles similar to the abutments. Spread footing foundations and RSS Walls are also considered feasible.

10.2.1 Deep Foundations

Foundations supported on driven piles for the retaining walls should follow recommendations discussed in Section 10.1.

10.2.2 Shallow Foundations

Shallow foundations for the retaining walls are feasible at this site and can be founded directly on the native silty clay to clayey silt at or below elevation 121 m with a minimum 1 m thick Granular A bedding layer.

Shallow footings between 3 m and 5 m in width and constructed as outlined above may be designed based on the following factored geotechnical resistances:

- Factored geotechnical resistance at ULS 250 kPa
- Factored geotechnical resistance at SLS 150 kPa

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.2 and Clause 6.10.5. The factored geotechnical resistance at SLS corresponds to total footing settlement of up to 25 mm.

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 11.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. An unfactored coefficient of friction of 0.35 can be assumed for the interface between the Granular 'A' and the silty clay.



The subgrade soils may become disturbed when saturated and should be protected by prompt placement of a geotextile separator (Class II non-woven geotextile with a maximum FOS of 150 μ m: OPSS.PROV 1860) and the bedding layer placed immediately after excavation and inspection.

10.2.3 RSS Walls

Retained soil system (RSS) walls are considered feasible at this site. The design of proprietary RSS walls is the responsibility of the supplier. Typically, such systems do not require full frost protection as they are able to tolerate some movement due to frost heave. The RSS system should be designed in accordance with the MTO RSS Design Guidelines. Once the location and height of the wall is established, the following recommendations should be confirmed:

Performance	H
Appearance	H
Acceptance	A

RSS walls should have a minimum embedment of 0.8 m. The underside elevation of the RSS wall is anticipated to be at approximately 123.0 m. A minimum 1 m thick engineered fill pad constructed on the underlying undisturbed native soils should be provided below the RSS wall as well as under the reinforced retained soil. The engineered fill pads should consist of OPSS Granular A placed and compacted in accordance with OPSS.PROV 501. Engineered fill pads should be constructed with 1H:1V sides slopes with the crest of slope a minimum of 1 m from the edge of footing and reinforced retained soil on all sides. The subgrade soils may become disturbed when saturated and should be protected by prompt placement of a geotextile separator (Class II non-woven geotextile with a maximum FOS of 150 μ m: OPSS.PROV 1860) and the engineered fill pad placed immediately after excavation and inspection.

The lateral pressure comments provided Section 10.3 may be used in RSS design. Bearing resistances provided in section 10.2.2 may be used for RSS design. Please also refer to Section 10.7 for comments on Global Stability.

It should be noted that these RSS walls are estimated to be between 4.0 m and 6.2 m high. Before selecting the RSS wall, discussions should be held with RSS wall suppliers whether RSS walls are feasible based on the relatively low bearing capacities available in the silty clay.

10.3 Backfill and Lateral Earth Pressures

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 and SP110S06 specifications. Large scale direct shear box testing on samples of Granular A from numerous nearby aggregate sources was completed for this project. The results indicate that for design of structural backfill for this project, an internal angle of friction of 40 degrees can be used for Granular B Type II and quarry-sourced Granular A in this area provided the vertical pressure on the material is less than 150 kPa (Geocres Memorandum 31F-213). An Operational Constraint will be required in the contract restricting the source of



Granular A to quarries. Throughout this report, the term “Granular A” is defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

The backfill must be in accordance with OPSS.PROV 902 and placed to the extents shown on OPSD 3101.150. The backfill should be compacted and compaction equipment to be used adjacent to the structure must be restricted in accordance with OPSS.PROV 501.

The design of the abutments and wingwalls/retaining walls, where required, must incorporate a subdrain as shown in OPSD 3101.150. A geosynthetic drainage blanket is recommended to be placed vertically on the back wall of the abutment leading to the subdrain to enhance drainage.

Lateral earth pressure parameters provided in Table 10-2 and Table 10-3 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design. Where back slopes are horizontal or 2.5H:1V, the corresponding coefficients provided in Table 10-2 and Table 10-3 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

10.3.1 Static Lateral Earth Pressure

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

$$\sigma_h = K * (\gamma h + q)$$

where:

σ_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) (K_a for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for backfill are shown in Table 10-2.

Table 10-2: Static Earth Pressure Coefficients

Condition	Quarry-Sourced OPSS Granular A and Granular B Type II $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$		Pit-Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	2.5H:1V Slope Behind Wall	Horizontal Surface Behind Wall	2.5H:1V Slope Behind Wall
Coefficient of At Rest Earth Pressure, K_o (Restrained Wall)	0.36	0.49	0.43	0.58
Coefficient of Active Earth Pressure, K_A (Unrestrained Wall)	0.22	0.27	0.27	0.35

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for any wingwalls or unrestrained walls. For rigid structures, at-rest horizontal earth pressures would apply for design.

10.3.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14.7.2 of the CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14.7.2 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- $k_h = \frac{1}{2} * F(\text{PGA}) * \text{PGA}$, for structures that allow 25 to 50 mm of movement, and
- $k_h = F(\text{PGA}) * \text{PGA}$, for non-yielding walls

Table 10-3: Combined Static and Seismic Earth Pressure Coefficients

Condition	Quarry-Sourced OPSS Granular A and Granular B Type II $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$		Pit-Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	2.5H:1V Slope Behind Wall	Horizontal Surface Behind Wall	2.5H:1V Slope Behind Wall
Coefficient of Active Earth Pressure, K_{AE} (Restrained Wall)	0.37	0.58	0.44	0.87
Coefficient of Active Earth Pressure, K_{AE} (Unrestrained Wall)	0.28	0.39	0.35	0.51



The coefficients of horizontal earth pressure for combined static and seismic loading presented in Table 10-3 may be used. The provided earth pressure coefficients are calculated using a site-adjusted PGA of 0.26 g, based on a Seismic Site Class D, a reference (Site Class C) PGA with a 2% probability of exceedance in 50 years of 0.22 g (Geological Survey of Canada – Fifth Generation), and a F(PGA) of 1.14 as per Table 4.8 of the CHBDC.

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

$$\sigma_h = K * \gamma * d + (K_{AE} - K_A) * \gamma * (H - d)$$

where:

σ_h	=	lateral earth pressure at depth d (kPa)
d	=	depth below the top of the wall (m)
K	=	static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, use submerged unit weight below groundwater level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.4 Frost Depth

The depth of frost penetration at this site is estimated to be 1.9 m (as per OPSD 3090.101); storm sewers, footings and pile caps for the abutments and retaining walls should be founded at or below this depth or provided with equivalent insulation. It is not necessary to found RSS walls at a depth below frost penetration.

10.5 Earth Cuts

Earth cuts deeper than 4.5 m below existing grades are proposed for O'Brien Road between approximate Stations 9+950 and 10+090 with a maximum cut of approximately 6.2 m and between approximate Stations 20+920 and 21+080 on the new W-S Ramp with a maximum cut of approximately 6.8 m.

The O'Brien Road cut at its deepest will penetrate through existing fills and stiff to very stiff silty clay. Twenty-five vane shear tests were carried out in the clay unit and all yielded values in excess of 100 kPa. Below the base of the cut the soils consist of a firm to very stiff clayey silt to silty clay (CL to CI) over a loose to dense sand to silty sand. Thirty vane shear tests in the cohesive deposits below the cut yielded results from 35 to greater than 100 kPa with an average of approximately 90 kPa. SPT N-values in the non-cohesive layer to 6 m below the base of the



cut ranged from 9 to 47 and averaged 21. The ground water level was noted to be deeper than 13 m below the base of the cut.

The W-S Ramp cut at its deepest will penetrate through compact silty sand to sand with silt to gravel with sand and silt. Standard Penetration N-values in these soils ranged from 4 to 38 with an average of 14. Below the base of the cut the soils are generally similar however denser with N values ranging from 8 to 100 with an average of 27. A clayey silt was noted in in one borehole (OBR 19-15) at a depth of 9.4 m below ground surface or approximately 5 m below the base of the proposed cut. The ground water level was noted to be deeper than 1.5 m below the base of the cut.

Global stability for the earth cut slopes for O'Brien Road and the W-S Ramp were evaluated using GeoStudio 2020 Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the SPT N values, undrained shear strength values and the results of laboratory testing. The following additional parameters were used in the analysis:

- Estimated soil stratigraphy based on the nearest boreholes
- O'Brien Road: maximum cut depth of 6.2 m at Station 9+980
- W-S Ramp: maximum cut depth of 6.8 m at Station 20+980
- Cut slopes of 2H:1V
- A traffic surcharge has not been applied in the analyses as there will be no traffic at the top of the cut slopes
- Site adjusted PGA value of 0.127 g, equal to $\frac{1}{2}$ of the site adjusted PGA value (0.255 g) was used for seismic analysis, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2 above

Copies of the output from the stability analyses are provided in Appendix I, Figures I-2 and I-3. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis.

The stability analyses generated the following factor of safety values:

Table 10-4: Stability Analyses Factors of Safety, Earth Cuts

Condition	Case	O'Brien Road Station 9+980	W-S Ramp Station 20+980
Permanent	Short Term (Undrained)	4.2	1.7
	Long Term (Drained)	1.7	
Temporary (Seismic)	Pseudo-Static (Undrained) 0.127g	2.9	1.3

Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a Ψ of 1.0 generates minimum Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions



respectively. These criteria have also been applied to the cut slopes for this assignment. All of the static results presented in the table above meet or exceed the target Factors of Safety.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and Ψ of 1.0, a target Factor of Safety of 1.1 for this temporary condition with a typical degree of understanding is appropriate for the pseudo-static seismic analysis. The pseudo-static result presented in the table above, exceeds the target Factor of Safety for seismic design. It is noted that some displacement of the slope can occur where the pseudo-static Factor of Safety is less than 1.3. However, as noted in the table above this criterion has also been satisfied for both cases.

The 2H:1V earth cut slopes are considered stable under both static and seismic conditions. For earth slopes in excess of 6 m in total height, a 2 m wide mid-height bench must be provided along the length of the earth cut.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the earth cut slopes. Normally slope vegetation should be established as soon as possible after completion of the earth cut slopes in order to control surficial erosion in general accordance with OPSS.PROV 804. The exposed soils at the O'Brien Road cut are considered to be moderately erodible (K of 0.34 to 0.46) based on the Wischmeier Nomograph) while those at the W-S Ramp cut should be considered non-erodible (K of 0.02 to 0.14).

The finished earth cut slopes should be inspected for ongoing seepage emerging from the cut slopes. Gravel sheeting or rock protection may be required to provide drainage of the seepage to prevent erosion of the slope face.

Portions of the materials generated from the O'Brien Road cut may be re-useable as earth borrow. Portions of the materials generated from the W-S Ramp cut may be re-useable as Select Subgrade Material (SSM). In both cases re-use of material depends on the moisture content at the time of placement as it will affect compaction and could reduce the proportion of re-useable materials.

10.6 Non-Structural Culvert, W-S Ramp

It is noted that a non-structural culvert will be placed to facilitate creek flow at approximate Station 21+155 on the W-S Ramp. The culvert is proposed to be a concrete box culvert with a 2.2 m span and a 2.7 m rise, based on the 2004 Preliminary Design Report. An embankment fill greater than 4.5 m in height will be constructed between Stations 21+120 and 21+180 on the W-S Ramp with a maximum height of approximately 12.5 m. The embankment fill is required to establish the design profile across the ravine incised into the overall relatively flat terrain by a tributary to the Bonnechere River.

The three boreholes drilled in the existing ravine (CV-7, CV-8, and CV-9) indicate a silty sand to sand deposit over an intermittent gravel layer over marble bedrock at depths ranging from 3.1 m to 5.7 m. N-values from the seventeen SPTs carried out in the silty sand to sand ranged from 2 to



35 with an average of 10 blows per 0.3 m of penetration. Groundwater was observed to be as high as elevation 112.9 m in the standpipe piezometer installed in Borehole CV-8.

The proposed invert elevation for the new culvert is not yet known; however, it is anticipated to match the low point in the existing ravine at approximate elevation 116.0 m.

10.6.1 Culvert Foundation Bearing Resistances

The subgrade soils within the culvert footprint will be subjected to the additional loads from the proposed infilled embankment with a fill thickness of up to 12.5 m. Further discussion on the estimated elastic settlement of the underlying native soils is provided in Section 10.7.2. The subgrade should be prepared as described in Section 10.6.2.

The recommended factored geotechnical resistance at ULS for a 2.0 to 3.0 m wide (exterior) pre-cast closed-bottom, box culvert with the underside of culvert base slab at or below approximate elevation 116.0 m, installed on a bedding layer with a minimum thickness of 0.3 m placed on a prepared subgrade is 350 kPa. Due to the additional loads from the embankment infill, settlement greater than 25 mm is expected and geotechnical resistance at SLS does not apply. Further discussion on the estimated elastic settlement of the underlying native soils is provided in Section 10.7.2.

The factored geotechnical resistance at ULS includes the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factor (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)

The bearing resistance value is for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.3) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A reduction factor of 0.8 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the culvert and Granular A.

Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

10.6.2 Subgrade Preparation, Bedding and Backfilling

This non-structural culvert should be constructed in accordance with OPSS 422, OPSD 803.010 and OPSD 3920.100. The bedding material, leveling course and cover material should consist of OPSS Granular A material meeting the OPSS.PROV 1010 and SP110S06 specifications. The culvert bedding should be 300 mm thick.



10.7 Embankment Fill, W-S Ramp

Embankment construction after culvert placement should be carried out in accordance with OPSS.PROV 206. The fill should be placed and compacted in accordance with OPSS.PROV 501.

10.7.1 Embankment Stability

An embankment with fill greater than 4.5 m in height will be constructed between Stations 21+120 and 21+180 on the W-S Ramp with a maximum height of approximately 12.5 m. The embankment fill is required to establish the design profile across a ravine incised into the overall relatively flat terrain by a tributary to the Bonnechere River.

The three boreholes drilled in the existing ravine (CV-7, CV-8, and CV-9) indicate a silty sand to sand deposit over an intermittent gravel layer over marble bedrock at depths ranging from 3.1 m to 5.7 m. N-values from the seventeen SPTs carried out in the silty sand to sand ranged from 2 to 35 with an average of 10 blows per 0.3 m of penetration.

Global stability of the side slopes have been assessed for two different embankment materials: Select Subgrade Material (SSM) and Compacted Rock Fill. It is noted that fill geometry must include a 2 m wide bench for earth fills equal to or greater than 8 m in height while rock fill must incorporate a 2 m wide bench for fills equal to or greater than 10 m in height.

Slope stability for the high fill embankment scenarios for the W-S Ramp was evaluated using GeoStudio 2020 Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the SPT N values and the results of laboratory testing. The following additional parameters were used in the analysis:

- Estimated soil stratigraphy based on the nearest boreholes
- Maximum W-S Ramp embankment fill height of 12.5 m at Station 21+155
- Side slopes of 2H:1V and 2.5H:1V for SSM Fill and 1.25H:1V for Rock Fill
- A traffic surcharge of 17 kPa applied as a temporary load
- Site adjusted PGA value of 0.127 g, equal to ½ of the site adjusted PGA value (0.255 g) was used for seismic analysis for a 1 in 2475 year event, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2 above
- Site adjusted PGA value of 0.049 g, equal to ½ of the site adjusted PGA value (0.097 g) was used for seismic analysis for a 1 in 475 year event, as per Section 4.4.3.3, of the CHBDC

Copies of the output from the stability analyses are provided in Appendix I, Figures I-4 to I-6. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis.

The stability analyses generated the following factor of safety values:

Table 10-5: Stability Analyses Factors of Safety, W-S Ramp Embankment

Condition	Case	Select Subgrade Material 2H:1V	Select Subgrade Material 2.5H:1V	Rock Fill 1.25H:1V
Permanent	Short Term (Undrained)	1.4	1.8	1.6
	Long Term (Drained)			
Temporary (Traffic)	Short Term (Undrained)	X	1.8	1.6
Temporary (Seismic)	Pseudo-Static (Undrained) 0.127 g	X	1.3	1.2
Temporary (Seismic)	Pseudo-Static, (Undrained) 0.049 g	X	N/A	1.4

X - not assessed, N/A - not required

Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a Ψ of 1.0 generates minimum Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions respectively. The static results presented in the table above meet or exceed the target Factors of Safety for the 2.5H:1V SSM and 1.25H:1V rock fill scenarios. The 2H:1V SSM slope does not meet the long term stability target and will not be further considered.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and Ψ of 1.0, a target Factor of Safety of 1.1 for this temporary condition with a typical degree of understanding is appropriate for the pseudo-static seismic analysis. The pseudo-static results presented in the table above, exceeds the target Factor of Safety for seismic design for the 2.5H:1V SSM and 1.25H:1V Rockfill scenarios. It is noted that some displacement of the slope can occur where the pseudo-static Factor of Safety is less than 1.3. This criterion has been satisfied for the 2.5H:1V SSM scenario but not for the 1.25H:1V Rock Fill scenario.

It is noted that there is no embankment bridge interface zone for this non-structural culvert installation. Furthermore, based on Table 4.10 of the CHBDC and a Site Class D S(0.2) value of 0.390 g for a 2% probability of exceedance, and assuming a fundamental period of less than 0.5 seconds, the seismic performance Category for a major route is 3. Section 6.14.2.3 of the CHBDC indicates that geotechnical systems outside the bridge approach embankment interface zone for major routes within seismic performance Category 3 shall have at least one lane available for use following ground motions with a return period of at least 475 years. An additional analysis has been completed for the 1.25H:1V Rock Fill scenario considering a return period of 475 years. The result is a Factor of Safety exceeding 1.3 which indicates that displacement of the slope is unlikely, thus the performance requirement to have at least one lane available for use following ground motions with a return period of at least 475 years has been satisfied for 1.25H:1V Rock Fill.



Both the 2.5H:1V SSM and 1.25H:1V Rockfill scenarios are acceptable for this site. It may also be possible that installation of a toe berm or widening of the mid-height bench could improve stability conditions to an acceptable level for the 2H:1V SSM slope.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankments constructed with SSM, see Section 11.4 below.

10.7.2 Embankment Settlement

Elastic compression of the soils beneath the embankment along the W-S Ramp that will be constructed to infill the ravine over the proposed culvert at Station 21+155 should be anticipated.

It is estimated that the loose to compact silty sand to sand deposit beneath the embankment will settle as much as 150 mm. The settlement will occur rapidly and will be virtually complete at the end of embankment construction. It is noted that the design of the culvert proposed at the base of the fill will need to consider this movement and include either an appropriate camber or modified internal rise to ensure drainage.

An assessment of the settlement that would result from construction of the W-S Ramp embankment across the infilled ravine was carried out using Rocscience's Settle3 modelling software with a Boussinesq stress distribution. The soil stratigraphy was defined based on borehole data and the water table was defined based on piezometer readings. It is noted that results of the in-situ testing and engineering judgment and experience were used to select the material properties of the site soils.

The creek ravine is at a skew of approximately 50 degrees from perpendicular to the proposed W-S Ramp alignment. Based on the anticipated width of the ramp and the relative skew to the ravine, the total length along the ravine required to be at the ramp grade (i.e. infilled to full height to accommodate the road platform) was estimated to be about 30 m.

The following has been assumed for the infilled embankment geometry:

- Maximum Height = 12.5 m
- Length = variable, see Table 10-6
- Platform Width = 30 m
- Side slopes (SSM) = 2.5H:1V
- Side Slopes (Rockfill) = 1.25H:1V

The geotechnical parameters used in the settlement analyses were based on the results in-situ testing and engineering judgment and experience and considered an elastic modulus of 10 MPa for the native silty sand.

The maximum calculated settlement that would occur beneath the culvert at the W-S Ramp center line is shown in the table below. The table includes the estimated length of culvert required to span the width of the W-S Ramp and the side slopes extending from the crest at the ramp to the toe of slopes at the creek bottom. Retaining walls constructed at or beyond the embankment crest

would reduce the required culvert length; however, due to the anticipated magnitudes of settlement that will occur, retaining walls are not considered feasible from a geotechnical perspective.

Table 10-6: Estimated Settlement, W-S Ramp Culvert

Embankment Type	Unit Weight of Fill	Side Slopes	Approx. Culvert Length	Maximum Settlement (at Ramp C/L)
Select Subgrade Material	21 kN/m ³	2.H:1V	N/A	N/A
		2.5H:1V	97 m	150 mm
Rock Fill	17 kN/m ³	1.25H:1V	66 m	125 mm

Based on the results of the settlement analyses, the settlement profile anticipated along the culvert alignment may be defined as:

- The Maximum Settlement outlined in Table 10-6 for the section of culvert between the embankment crests (i.e. directly below the W-S Ramp road platform); and,
- Decreasing from Maximum Settlement outlined in Table 10-6 at the embankment crests to zero at the embankment toes (i.e. at the creek level).

In addition, there will be self settlement of the embankment material itself. For embankments constructed with compacted rock fill the short term settlement will be approximately 130 mm (up to 1 year after completion of construction with 90% of this value occurring in the first six months). In addition, rock fill embankments continue to settle after the first year with an estimate of an additional 15 mm. Similarly, an embankment constructed of SSM material will undergo approximately 200 mm of self settlement with the majority of that complete within the one year of completion of construction. Embankments must be overbuilt to compensate for the estimated settlement.

10.8 RSS Stability

The global stability for an RSS installation in the median of Highway 17 was evaluated using GeoStudio 2020 Slope/W software for limit equilibrium analysis. Please refer to the soil descriptions provided above in Section 10.5 for the O'Brien Road cut. Input parameters for the analysis are based on the SPT N values, undrained shear strength values and the results of laboratory testing. The following additional parameters were used in the analysis:

- Estimated soil stratigraphy based on the nearest boreholes
- O'Brien Road: maximum cut depth of 6.2 m at Station 9+980
- Retained soil to consist of OPSS Granular B Type II, 4 m in width and supported on a 1 m thick Granular A bedding layer
- Structural backfill behind the RSS to consist of OPSS Granular A
- Horizontal backslope behind RSS

- Site adjusted PGA value of 0.127 g, equal to ½ of the site adjusted PGA value (0.255 g) was used for seismic analysis, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2 above

Copies of the output from the stability analyses are provided in Appendix I, Figures I-7. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis.

The stability analyses generated the following factor of safety values:

Condition	Case	O'Brien Road RSS Station 9+980
Permanent	Short Term (Undrained)	2.6
	Long Term (Drained)	1.9
Temporary (Seismic)	Pseudo-Static (Undrained) 0.127g	2.2

Please refer to discussion in Section 10.5 above concerning target Factors of Safety. The RSS slopes are considered globally stable under both static and seismic conditions.

10.9 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity was carried out on samples of the native materials. The analysis results are summarized in Section 5.10 and a copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 5-3 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and indicate a low to severely corrosive environment at the O'Brien Road cut sections, and a very low corrosive environment in the native soil in the vicinity of the ravine culvert under the W-S Ramp. The test results provided in Section 5.10 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects, where required.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in Table 5-3 were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a low to severe degree of sulphate attack potential on concrete structures at the O'Brien Road cut sections, and a low degree of sulphate attack potential at the culvert under the W-S Ramp.

The corrosive effects of road de-icing salts should also be considered.



11 CONSTRUCTION CONSIDERATIONS

11.1 Temporary Excavations

All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the existing fills at this site may be classified as Type 3 soil. Native silty clay and clayey silt should be considered as Type 2 above and Type 3 below the groundwater table. Native loose to compact non-cohesive soils above the ground water level should be considered as Type 3 soils. Side slopes for excavations through more than one soil type must be entirely based on the highest soil type number. Unsupported excavations made in Type 3 soils must have side slopes no steeper than 1H:1V from the base of the excavation.

Excavations for the footings or pile caps must be carried out in accordance with OPSS.PROV 902 and will be carried out through the existing fill and extend into the underlying native deposits (silty clay to clayey silt). Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Should Temporary Protection Systems be required for excavation support or groundwater control, they must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2. Based on the site stratigraphy and the anticipated depths of excavation, installation of interlocking sheet piles through the silty clay and into the underlying sand deposit is considered to be feasible but may be difficult in areas due to the presence of cobbles within the sand. Alternatively, a soldier pile and lagging system is a feasible option. It may be necessary to predrill for the soldier piles. Deadman anchors, struts and/or raker supports may be required to achieve the specified performance level.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for cobbles and boulders and obstructions within the fill and glacial till. Suggested wording for the NSSP has been included in Appendix J

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. The protection system should be installed at a suitable distance away from the new structures to limit the disturbance to subgrade associated with removal of the protection system following completing of construction. Alternatively, the protection system near the structures could be left in place and cut off in accordance with OPSS.PROV 903 to limit the disturbance of subgrade during removal of the TPS.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design for the structural backfill are provided in Table 10-2. The lateral earth pressure coefficients for the underlying native soils are given below for a vertical wall and a horizontal backslope:

Table 11-1. Earth Pressure Coefficients – Native Soil

Parameter	Silty Clay to Clayey Silt		Sand to Silty Sand
	Drained	Undrained	Drained/Undrained
Unit Weight (kN/m ³)	18		20
K _a	0.36	-	0.31
K _p	2.8	-	3.3
c' (kPa)	5	90	-

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

11.3 Surface and Groundwater Control

Foundation construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. The depth of excavations required to construct the storm sewer, footings or pile caps is not expected to reach the groundwater level observed at the time of the investigation. However, surface runoff and perched groundwater will tend to seep into and accumulate into the excavations. The Contractor must control groundwater, perched groundwater and surface water flow at the site to permit the construction of the footings in a dry and stable excavation.

Excavation, subgrade preparation, placement and compaction of bedding material, placement of the leveling course, installation and backfilling for the non-structural culvert at 21+155 on the W-S Ramp must be carried out in the dry. The depth of excavation required to install the culvert is not expected to reach the groundwater level observed at the time of the investigation. However, surface runoff and perched groundwater will tend to seep into and accumulate into the excavations. The Contractor must control groundwater, perched groundwater and surface water flow at the site to permit the work to proceed in a dry and stable excavation.

Further assessment of the dewatering requirements and the need for a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

It is noted that a Hydrogeological Investigation and Design Report is under preparation for the Highway 17 Twinning Project. Please refer to that document for additional discussion on dewatering with respect to this assignment.

11.4 Erosion Control

The Contractor should provide silt fences and erosion control blankets as per OPSS.PROV 805 throughout the duration of construction to prevent transport of silt/sediment. Slope protection and drainage measures will be required to ensure the long-term surficial stability of the cut and embankment slopes. Slope vegetation should be established as soon as possible after completion of the cut and embankment fills in order to limit surficial erosion. The exposed soils at the O'Brien Road cut are considered to be moderately erodible (K of 0.34 to 0.46) based on the Wischmeier Nomograph) while those at the W-S Ramp cut should be considered non-erodible (K of 0.02 to 0.14).

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

12 CONSTRUCTION CONCERNS

The planned construction methodology includes open cut excavations for the grade lowering of O'Brien Road and the installation of foundation elements of two new underpass structures and associated retaining walls. Deep cuts and high fills are also required along the W-S ramp alignment. Potential construction concerns include, but are not necessarily limited to:

- Excavation difficulties due to the presence of obstructions such as potential for cobbles and boulders may be encountered during excavation in the cut section of the W-S ramp. Provision must be made for the removal of cobbles and boulders.
- Pile achieving refusal at different depths, some on cobbles and boulders, some on bedrock.
- Control of groundwater seepage during excavation and permanent drainage in the cut sections.

The successful performance of the structure installations will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per OPSS.PROV 902 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Justin Gray, P.Eng., Matt Kennedy, P.Eng., and Dr. Fred Griffiths, P.Eng.. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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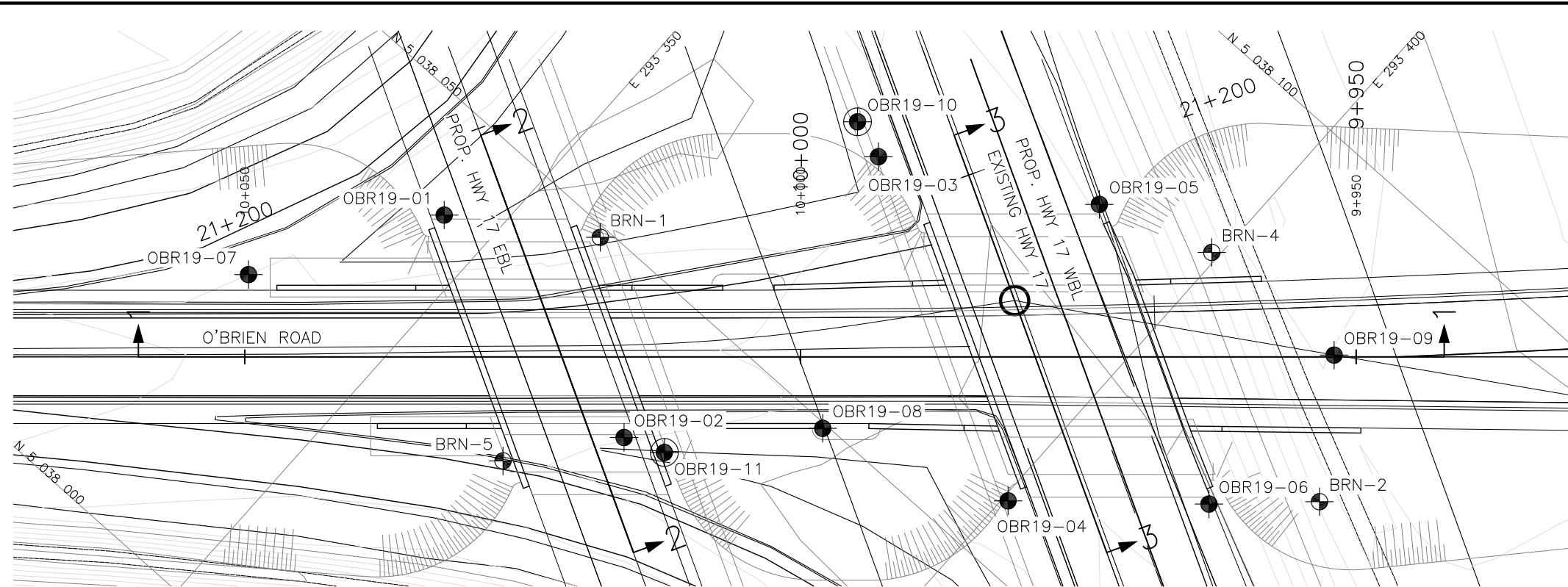
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ⁱ Boulanger, R. W. and Idriss, I. M. (2007). Evaluation of cyclic softening in silts and clays, ASCE, Journal of Geotechnical and Geoenvironmental Engineering, 133(6), 641-652.

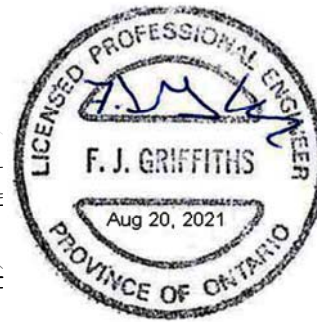
ⁱⁱ Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.

Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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



CONT No
WP No 4068-09-00

HIGHWAY 17 TWINNING
O'BRIEN ROAD
BRIDGES
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

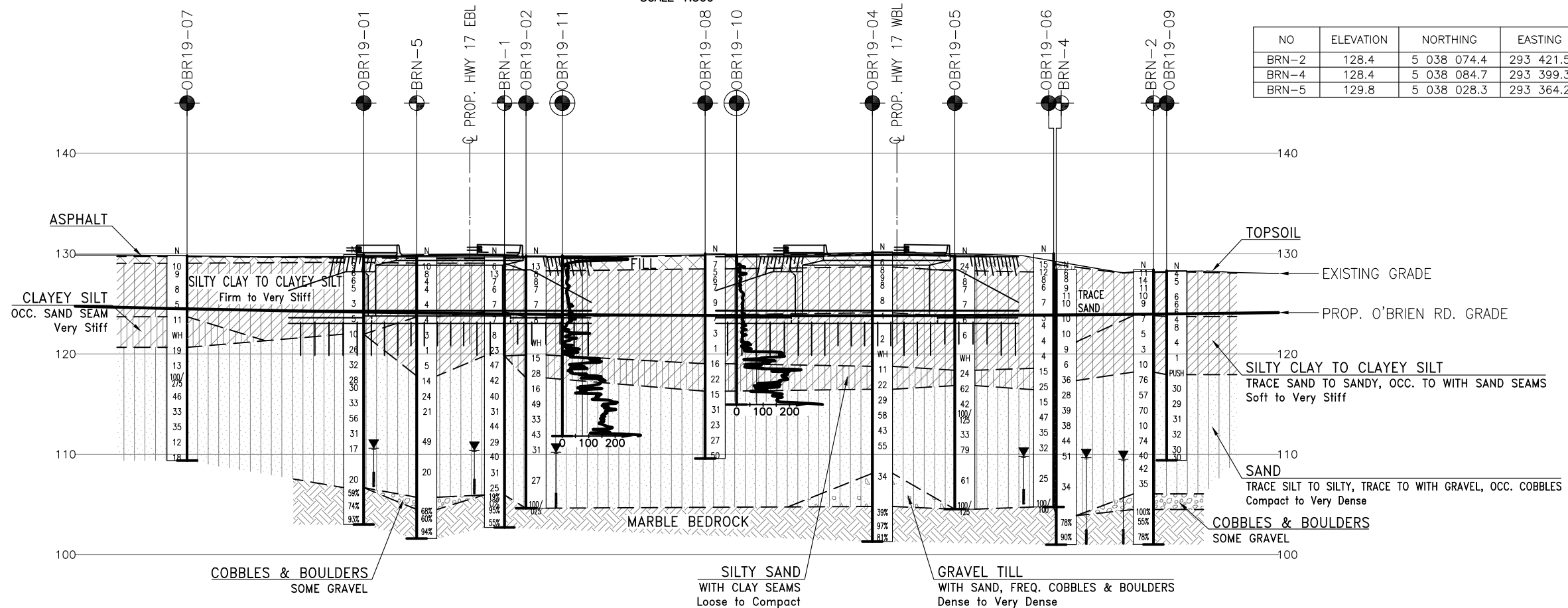
	Borehole/SCPT (2019 Investigation)
	Borehole (2003 Investigation)
	Blows /0.3m (Std Pen Test, 475J/blow)
	Blows /0.3m (60' Cone, 475J/blow)
	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
	Rock Quality Designation (RQD)
	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
OBR19-01	129.9	5 038 041.3	293 345.5
OBR19-02	129.8	5 038 037.1	293 370.9
OBR19-03	129.9	5 038 071.2	293 371.2
OBR19-04	130.2	5 038 055.8	293 400.5
OBR19-05	129.8	5 038 081.2	293 388.9
OBR19-06	130.0	5 038 067.6	293 414.2
OBR19-07	129.8	5 038 025.6	293 335.9
OBR19-08	130.0	5 038 049.6	293 383.7
OBR19-09	128.3	5 038 085.1	293 413.7
OBR19-10	129.9	5 038 072.3	293 367.7
OBR19-11	129.8	5 038 038.5	293 374.5
BRN-1	129.8	5 038 049.1	293 357.3

-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 9.

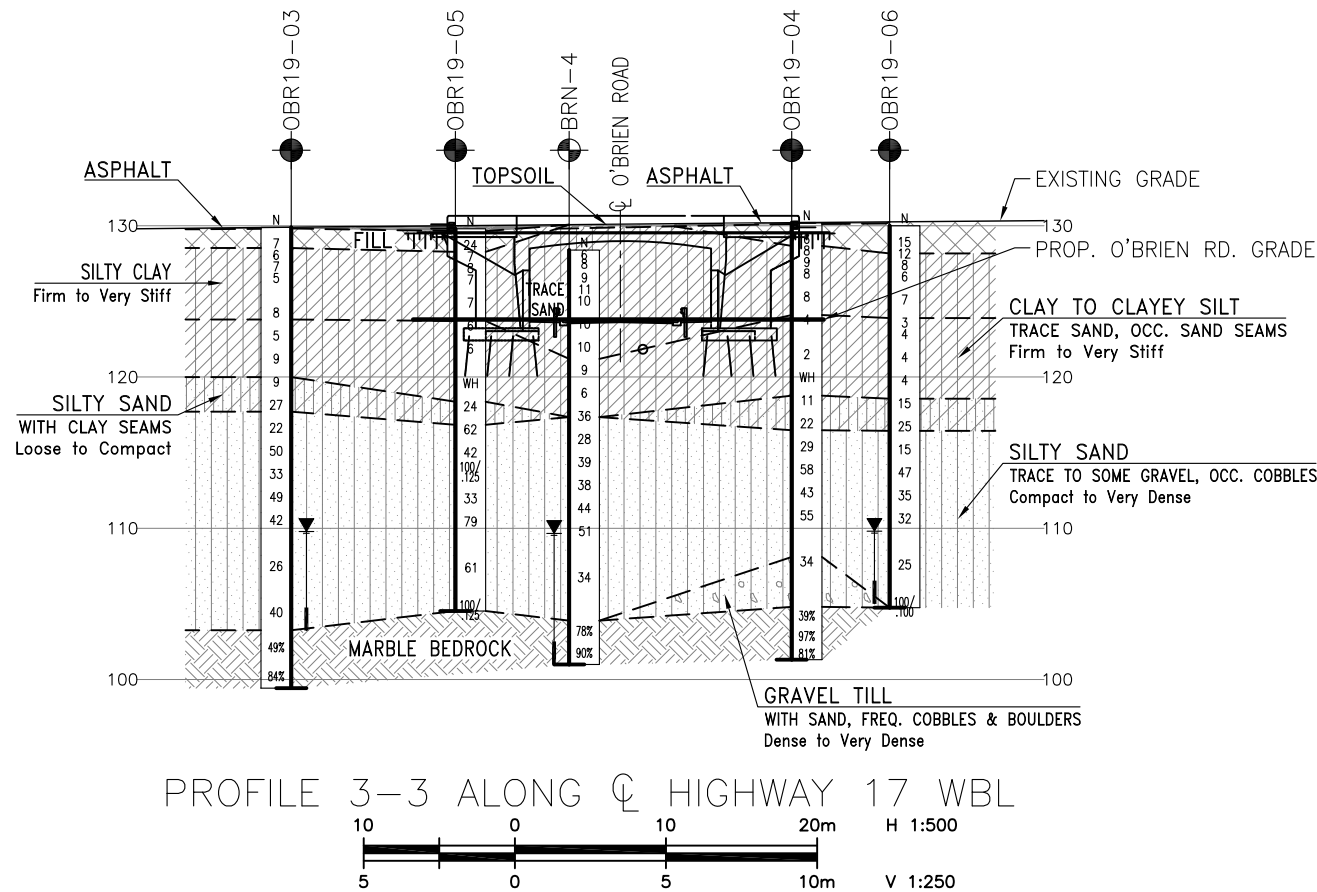
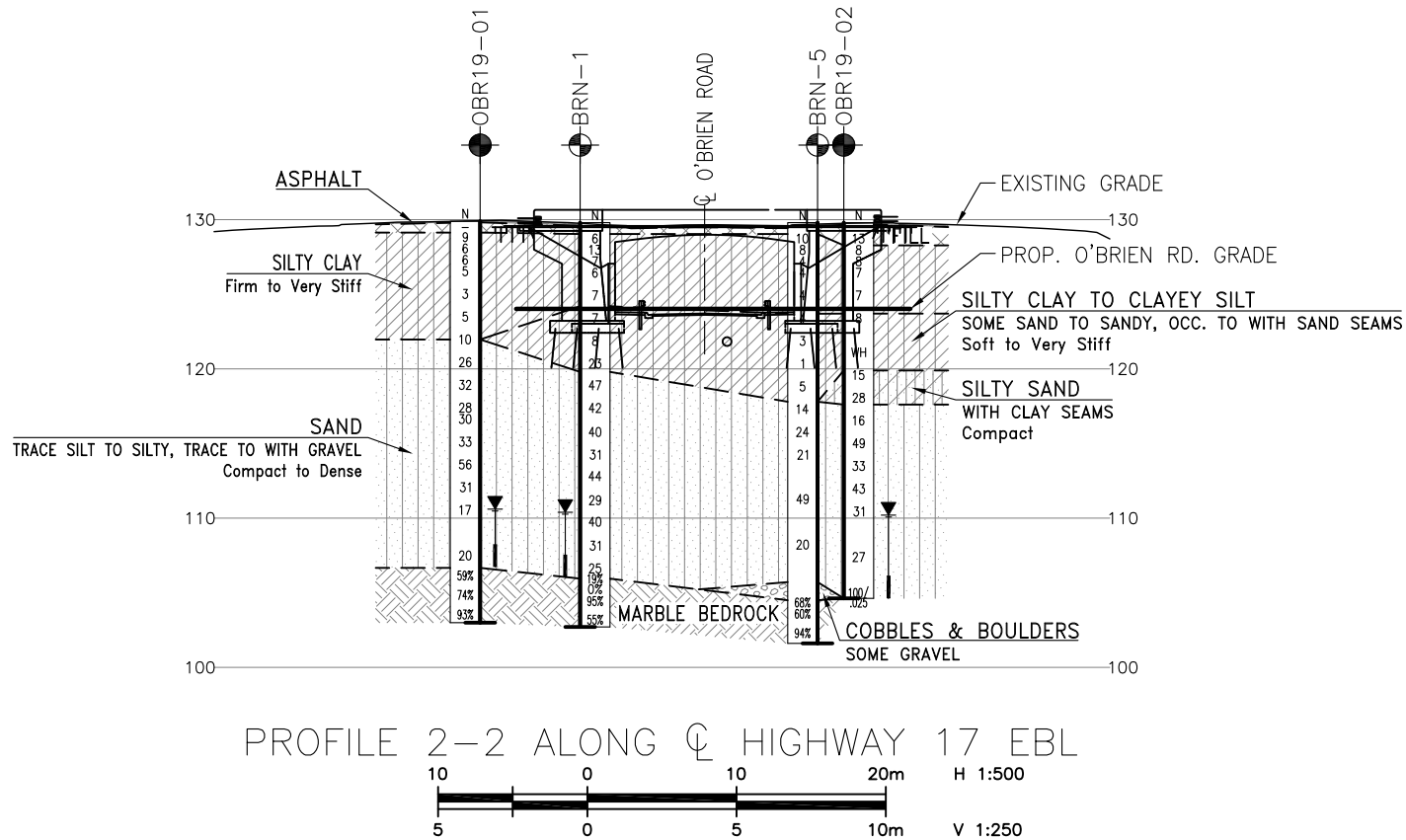
GEORES No. 31F-216



PROFILE 1-1 ALONG C O'BRIEN ROAD



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK -	CODE
DRAWN	MFA	CHK JG	SITE
LOAD			
STRUCT			
DWG	1		
DATE	AUG 2021		



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



CONT No
WP No 4068-09-00

HIGHWAY 17 TWINNING
O'BRIEN ROAD
BRIDGES
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

	Borehole/SCPT (2019 Investigation)
	Borehole (2003 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

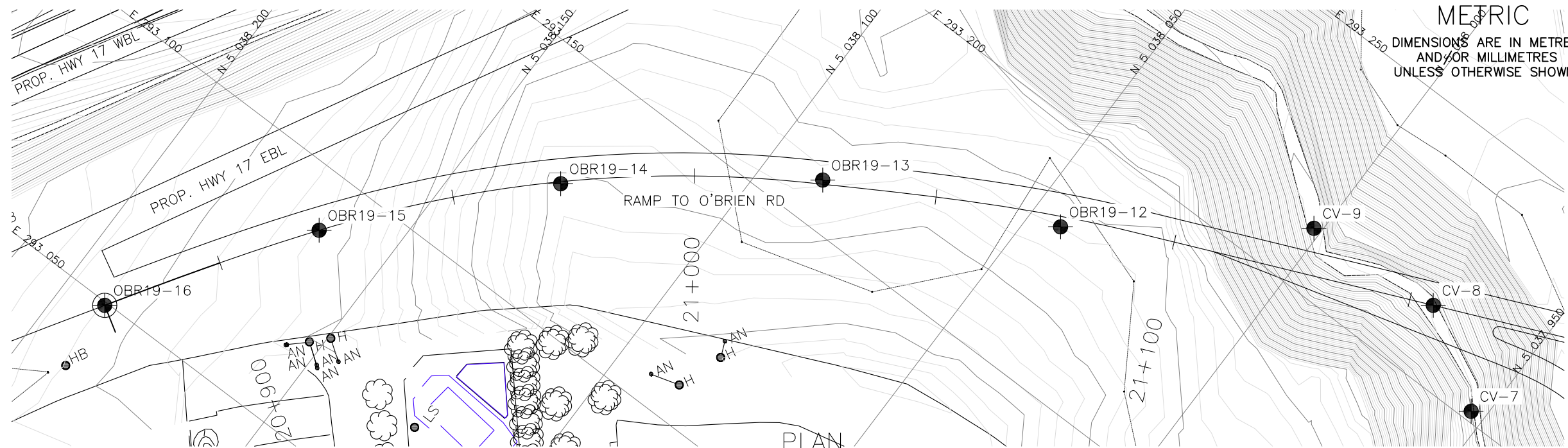
NO	ELEVATION	NORTHING	EASTING
OBR19-01	129.9	5 038 041.3	293 345.5
OBR19-02	129.8	5 038 037.1	293 370.9
OBR19-03	129.9	5 038 071.2	293 371.2
OBR19-04	130.2	5 038 055.8	293 400.5
OBR19-05	129.8	5 038 081.2	293 388.9
OBR19-06	130.0	5 038 067.6	293 414.2
OBR19-07	129.8	5 038 025.6	293 335.9
OBR19-08	130.0	5 038 049.6	293 383.7
OBR19-09	128.3	5 038 085.1	293 413.7
OBR19-10	129.9	5 038 072.3	293 367.7
OBR19-11	129.8	5 038 038.5	293 374.5
BRN-1	129.8	5 038 049.1	293 357.3

-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 9.

GEOCRES No. 31F-216

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK -	CODE
DRAWN	MFA	CHK JG	SITE
LOAD		STRUCT	DWG 2
DATE	AUG 2021		



CONT No
WP No 4068-09-00

HIGHWAY 17 TWINNING
O'BRIEN ROAD
W-S RAMP
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

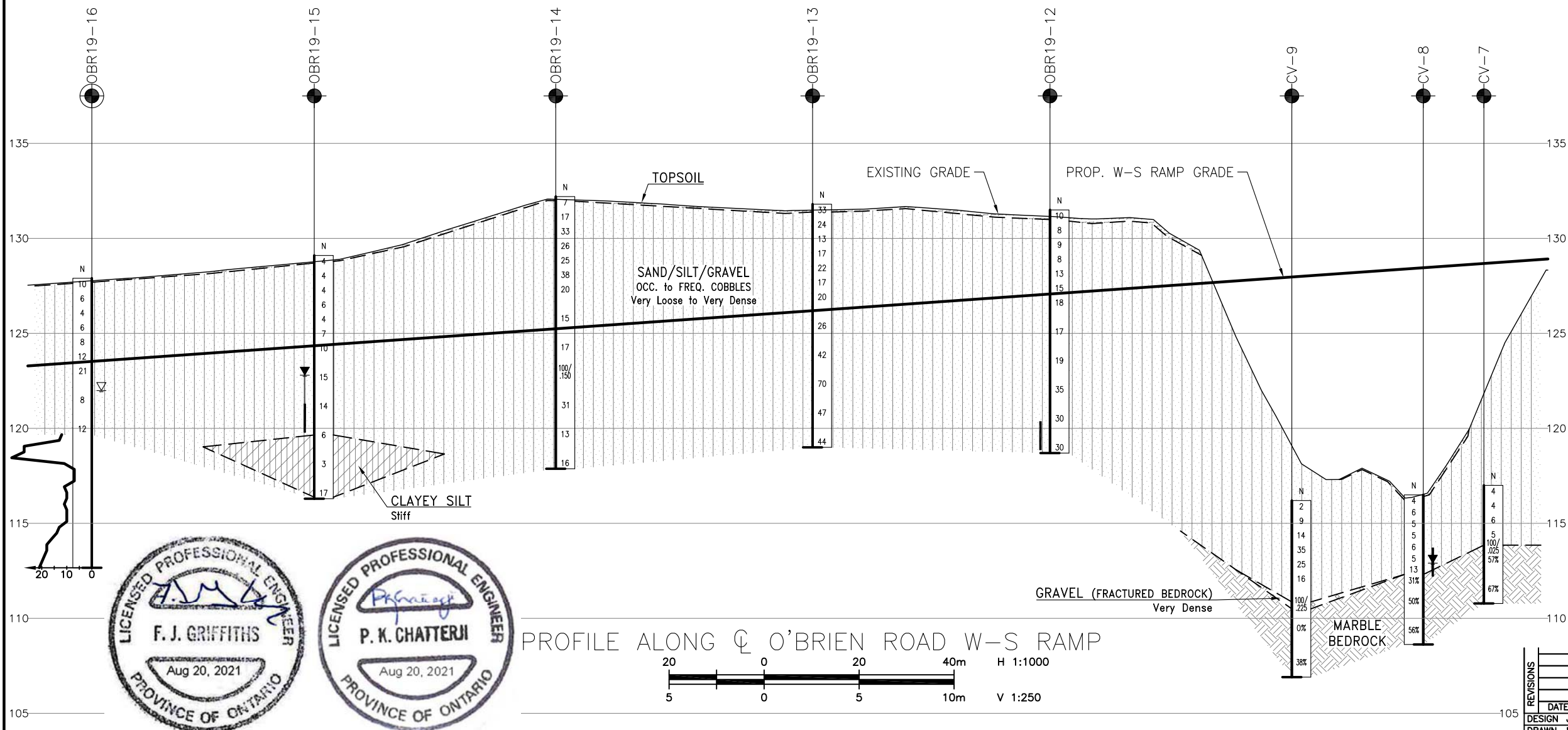
- Borehole/DCPT (2019 Investigation)
- Borehole (2003 Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
OBR19-12	131.5	5 038 043.4	293 181.2
OBR19-13	131.8	5 038 088.3	293 159.3
OBR19-14	132.2	5 038 130.9	293 126.1
OBR19-15	129.1	5 038 164.8	293 088.4
OBR19-16	127.9	5 038 190.7	293 049.4
CV-7	117.0	5 037 953.0	293 202.0
CV-8	116.5	5 037 972.4	293 214.7
CV-9	116.2	5 038 001.6	293 212.5

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F-216



PROFILE ALONG CL O'BRIEN ROAD W-S RAMP

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK -	CODE
DRAWN	MFA	CHK JG	SITE
			LOAD
			STRUCT
			DWG 1
			DATE AUG 2021

Appendix B.

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

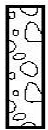
DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

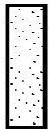


STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel



Sand



Silt



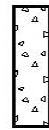
Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	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	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clayey silts of low plasticity, gravelly clays, sandy clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No OBR19-01

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482202°, Long: -76.646524° O'Brien Road N 5 038 041.3 E 293 345.5 ORIGINATED BY SOB
 HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
 DATUM Geodetic DATE 2019.09.09 - 2019.09.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L			
129.9	Pavement Surface												
0.0 0.1	ASPHALT (75 mm) CLAY (Cl) with sand and gravel Brown (FILL)		1	GS	-								21 23 29 27
129.1													
0.8	SILTY CLAY (Cl) Very Stiff Brown		2	SS	9		129						
			3	SS	6		128						0 1 59 40
			4	SS	6		127						
			5	SS	5		126						
			6	SS	3		125						
			7	SS	5		124						0 7 56 37
			8	SS	10		122						
122.0	SILTY SAND to SAND with silt Compact to Dense Brown		9	SS	26		121						0 86 14 (SI+CL)
7.9							120						

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-01

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482202°, Long: -76.646524°
O'Brien Road N 5 038 041.3 E 293 345.5 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
DATUM Geodetic DATE 2019.09.09 - 2019.09.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _p W W _L							
	Continued From Previous Page						20 40 60 80 100					20 40 60							
	SILTY SAND to SAND with silt Compact to Dense Brown		10	SS	32		119						○						
							118							○					
							117							○					
							116												
							115							○					
							114								○				
							113												
							112								○				
							111									○			
							110												

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-01

3 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482202°, Long: -76.646524° O'Brien Road N 5 038 041.3 E 293 345.5 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
DATUM Geodetic DATE 2019.09.09 - 2019.09.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page							20 40 60 80 100							
	SILTY SAND to SAND with silt Compact to Dense Brown														
			17	SS	20										0 79 21 (SI+CL)
106.7															
23.2	MARBLE BEDROCK Slightly Weathered to Fresh White, Grey and Red Medium Strong -Vertical fractures throughout		1	RUN										FI 6 2 >10	RUN #1 TCR=100% SCR=19% RQD=59% UCS=37.8MPa
	-Silt seam from 24.6 m to 24.8 m														
			2	RUN										1 3 3 3	RUN #2 TCR=100% SCR=70% RQD=74%
			3	RUN										1 0 0 3	RUN #3 TCR=100% SCR=93% RQD=93%
103.0															
26.9	End of Borehole Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2019.09.26 19.3 110.6 2020.04.21 19.3 110.6 2020.09.29 19.5 110.4														

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-02

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482166°, Long: -76.646199° O'Brien Road N 5 038 037.1 E 293 370.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.11 - 2019.09.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
129.8	Pavement Surface															
0.0	ASPHALT (75 mm)															
0.1	GRAVEL with silt and sand Brown (FILL)		1	GS												57 38 5 (SI+CL)
129.0	CLAYEY SILT with sand Stiff Brown (FILL)		2	SS	13		129									
0.8																
128.3	SILTY CLAY (CI) Very Stiff Brown to Grey		3	SS	8		128									
1.5																
			4	SS	8		127									
			5	SS	7											0 1 61 38
							126									
			6	SS	7		125									
							124									
123.7	CLAYEY SILT(CL) with sand seams Very Stiff Brown to Grey		7	SS	8		123									
6.1																
							122									
			8	SS	WH		121									0 4 59 37
119.9							120									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-02

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482166°, Long: -76.646199° O'Brien Road N 5 038 037.1 E 293 370.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.11 - 2019.09.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%) W _p W W _L				GR	SA	SI	CL
9.9	Continued From Previous Page SILTY SAND with clay seams Compact Brown		9	SS	15		119											
			10	SS	28		118											
117.6																		
12.2	SILTY SAND to SAND with silt Compact to Dense Brown						117											
				11	SS		16											
				12	SS		49		115									
			13	SS	33		114											
			14	SS	43		113											
			15	SS	31		112											
							111											
							110											

Continued Next Page

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

RECORD OF BOREHOLE No OBR19-02

3 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482166°, Long: -76.646199° O'Brien Road N 5 038 037.1 E 293 370.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.11 - 2019.09.11 CHECKED BY FG

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								
	Continued From Previous Page							20	40	60	80	100				
	SILTY SAND to SAND with silt Compact to Dense Brown															
				16	SS	27										
104.6			17	SS	100/											
25.2	End of Borehole on Inferred Bedrock Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2019.09.26 19.9 109.9 2020.04.21 19.6 110.2 2020.09.29 19.9 109.9				25mm											

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-03

1 OF 4

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482472°, Long: -76.646196° O'Brien Road N 5 038 071.2 E 293 371.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing/ NQ coring COMPILED BY JP
DATUM Geodetic DATE 2019.09.18 - 2019.09.19 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
							WATER CONTENT (%)								
							20 40 60								
129.9	Pavement Surface														
0.0	ASPHALT (75mm)														
0.1	SILTY SAND with gravel Compact Brown (FILL)		1	GS										34 48 18 (SI+CL)	
129.1															
0.8	CLAYEY SILT (CL) with sand, trace gravel Firm Brown		2	SS	7		129							7 27 42 24	
128.5															
1.4	SILTY CLAY (CI/CH) Very Stiff Brown		3	SS	6		128								
			4	SS	7		127							0 2 52 46	
			5	SS	5		126								
							125								
			6	SS	8		124								
123.8															
6.1	CLAYEY SILT (CL), occasional sand seam Very Stiff Brown						123								
			7	SS	5		122								
							121							1 7 60 32	
120.0			8	SS	9		120								

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-03

2 OF 4

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482472°, Long: -76.646196° O'Brien Road N 5 038 071.2 E 293 371.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing/ NQ coring COMPILED BY JP
DATUM Geodetic DATE 2019.09.18 - 2019.09.19 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)			
								<div><div><div></div><div></div><div></div><div></div><div></div></div><div>20406080100</div></div> <div>○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE</div>						<div><div><div></div><div></div><div></div><div></div><div></div></div><div>204060</div></div> <div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W_P W W_L</div>			
9.9	Continued From Previous Page SILTY SAND with clay seams Loose to Compact Brown		9	SS	9		119										
			10	SS	27		118										
117.7																	
12.2	SILTY SAND (SM) Compact to Dense Brown																
			11	SS	22		117										
			12	SS	50		115										
			13	SS	33		114										
			14	SS	49		112										
			15	SS	42		111										
							110										

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-03

3 OF 4

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482472°, Long: -76.646196° O'Brien Road N 5 038 071.2 E 293 371.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing/ NQ coring COMPILED BY JP
DATUM Geodetic DATE 2019.09.18 - 2019.09.19 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W _p	W	W _L	
								20 40 60 80 100	WATER CONTENT (%)			GR SA SI CL
	SILTY SAND (SM) Compact to Dense Brown		16	SS	26		109					
							108					
							107					
							106					
							105					
			17	SS	40		104					
103.3							103					
26.6	MARBLE BEDROCK Slightly Weathered Grey and White Medium Strong Coarse Grained		1	RUN			102					
							101					
			2	RUN			100					

RUN #1
TCR=100%
SCR=84%
RQD=49%

RUN #2
TCR=100%
SCR=97%
RQD=84%
UCS=39.7MPa

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-03

4 OF 4

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482472°, Long: -76.646196° O'Brien Road N 5 038 071.2 E 293 371.2 ORIGINATED BY SOB
 HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing/ NQ coring COMPILED BY JP
 DATUM Geodetic DATE 2019.09.18 - 2019.09.19 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
99.4	MARBLE BEDROCK Slightly Weathered Grey and White														4		
30.5	Medium Strong Coarse Grained End of Borehole Monitoring well consists of 38mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2019.09.26 20.1 109.8 2020.04.21 20.1 109.8 2020.09.29 20.3 109.6														0		

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-04

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482335°, Long: -76.645821° O'Brien Road N 5 038 055.8 E 293 400.5 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
DATUM Geodetic DATE 2019.09.12 - 2019.09.13 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W P W W L							
130.2	Pavement Surface						20	40	60	80	100								
0.0 0.1	ASPHALT (75 mm)																		
	GRAVEL with sand Brown (FILL)		1	GS									○					57 39 4 (SI+CL)	
129.4																			
0.8	CLAYEY SILT with sand Firm Brown (FILL)		2	SS	6								○						
128.7																			
1.5	SILTY CLAY (CI/CH) Very Stiff Brown		3	SS	8								○						
			4	SS	9								○						
			5	SS	8														
			6	SS	8														

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-04

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482335°, Long: -76.645821° O'Brien Road N 5 038 055.8 E 293 400.5 ORIGINATED BY SOB
 HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
 DATUM Geodetic DATE 2019.09.12 - 2019.09.13 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _P	W	W _L		WATER CONTENT (%)	GR	SA	SI	CL
								20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
	Continued From Previous Page																		
			9	SS	WH		120										0 14 59 27		
118.8							119												
11.4	SILTY SAND with clay seams Loose to Compact Brown		10	SS	11		118												
			11	SS	22		117										0 66 34 (SI+CL)		
116.5							116												
13.7	SILTY SAND Compact to Very Dense Brown		12	SS	29		115												
			13	SS	58		114												
			14	SS	43		113												
							112												
			15	SS	55		111										0 85 15 (SI+CL)		

Continued Next Page

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

RECORD OF BOREHOLE No OBR19-04

3 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482335°, Long: -76.645821°
O'Brien Road N 5 038 055.8 E 293 400.5 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NQ coring COMPILED BY MW
DATUM Geodetic DATE 2019.09.12 - 2019.09.13 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								20 40 60 80 100					
	Continued From Previous Page												
108.1	SILTY SAND Compact to Very Dense Brown						110						
22.1	GRAVEL with Sand, frequent cobbles and boulders (TILL) Dense to Very Dense - 800mm boulder at elevation 107.4 m		16	SS	34		108						
							107						
			17	NQ			106						
							105						
104.8	MARBLE BEDROCK Slightly Weathered to Fresh Grey Medium Strong Coarse Grained, some banding		1	RUN			104						
25.4			2	RUN			103						
			3	RUN			102						
101.3													
28.9	End of Borehole												

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

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

RECORD OF BOREHOLE No OBR19-05

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482563°, Long: -76.645971° O'Brien Road N 5 038 081.2 E 293 388.9 ORIGINATED BY SOB
 HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
 DATUM Geodetic DATE 2019.09.16 - 2019.09.16 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)		
129.8	Pavement Surface							20	40	60	80	100							
0.0	ASPHALT (150 mm)							20	40	60	80	100							
0.2	SILTY SAND with gravel Compact Brown (FILL)		1	GS			129										38 47 15 (SI+CL)		
			2	SS	24														
128.3																			
1.5	SILTY CLAY (Cl) Very Stiff Brown		3	SS	7		128												
			4	SS	8		127												
			5	SS	7														
			6	SS	7		125										0 1 62 37		

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-05

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482563°, Long: -76.645971°
O'Brien Road N 5 038 081.2 E 293 388.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.16 - 2019.09.16 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20 40 60 80 100	W _p	W	W _L								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
	Continued From Previous Page																		
118.4	SILTY CLAY (CI) , occasional sand seam Very Stiff Brown to Grey		9	SS	WH		119						○						
11.4	SILTY SAND with clay seams Compact Brown		10	SS	24		118						○						
116.8							117												
13.0	SILTY SAND with gravel Dense to Very Dense Brown		11	SS	62		116						○						
							115						○						
							114												
			12	SS	42		113												
			13	SS	100/ 125mm		112						○						
							111												
			14	SS	33		110						○						
			15	SS	79														

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

METRIC

SOIL PROFILE						SAMPLES									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
								20 40 60 80 100	W _P	W	W _L			WATER CONTENT (%)	GR SA SI CL
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
107.7	SILTY SAND with gravel Dense to Very Dense Brown		16	SS	61		109							0 88 12 (SI+CL)	
22.1							108								
							107								
							106								
104.5			17	SS	100/		105								
25.3	End of Borehole on Inferred Bedrock				125mm										

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OBR19-06

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482441°, Long: -76.645645° O'Brien Road N 5 038 067.6 E 293 414.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.17 - 2019.09.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
130.0	Ground Surface																		
0.0	SAND with gravel Compact Brown (FILL)		1	GS											39 57 4 (SH+CL)				
129.2																			
0.8	CLAYEY SAND, some gravel Compact Brown		2	SS	15		129												
128.2																			
1.8	CLAY (CH) Very Stiff Grey to Brown		3	SS	12		128												
			4	SS	8														
							127												
			5	SS	6										0 1 51 48				
							126												
			6	SS	7														
							125												
							124												
123.9																			
6.1	CLAYEY SILT (CL), occasional sand seam Very Stiff Brown		7	SS	3														
			8	SS	4		123								0 8 59 33				
							122												
			9	SS	4														
							121												

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

METRIC

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	20			40	60	80	100	W _P	W		W _L	GR	SA	SI	CL
	Continued From Previous Page																			
118.6	CLAYEY SILT (CL) , occasional sand seam Very Stiff Brown		10	SS	4							o								
11.4																				
116.4	SILTY SAND with clay seams Compact Brown		11	SS	15							o								
13.6	SILTY SAND Compact to Dense Brown		12	SS	25							o								
			13	SS	15							o								
			14	SS	47							o								
			15	SS	35							o								
			16	SS	32							o								

+³, ×³: Numbers refer to Sensitivity

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-06

3 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482441°, Long: -76.645645° O'Brien Road N 5 038 067.6 E 293 414.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA/NW casing COMPILED BY JP
DATUM Geodetic DATE 2019.09.17 - 2019.09.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
Continued From Previous Page							20 40 60 80 100				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L			
							20 40 60 80 100				WATER CONTENT (%) 20 40 60			
104.8 <														

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-07

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482061°, Long: -76.646647° O'Brien Road N 5 038 025.6 E 293 335.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA COMPILED BY MW
DATUM Geodetic DATE 2019.09.09 - 2019.09.09 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L							
								20 40 60 80 100	20 40 60								
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
129.8 0.0 0.1	Pavement Surface ASPHALT (75 mm) SAND, some clay Compact Brown (FILL)		1	GS													
129.0 0.8	SILTY CLAY (CI) Very Stiff Brown		2	SS	10		129										
			3	SS	9		128							0 1 63 36			
							127										
			4	SS	8		126										
							125										
			5	SS	5		124										
123.7 6.1	CLAYEY SILT (CL), occasional sand seam Very Stiff Brown to Grey		6	SS	11		123							1 24 52 23			
			7	SS	WH		122							0 6 63 31			
							121										
120.7 9.1	SILTY SAND Compact to Very Dense Brown		8	SS	19		120										

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-07

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482061°, Long: -76.646647° O'Brien Road N 5 038 025.6 E 293 335.9 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA COMPILED BY MW
DATUM Geodetic DATE 2019.09.09 - 2019.09.09 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR SA SI CL							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)											
	Continued From Previous Page							20	40	60	80	100											
	SILTY SAND Compact to Very Dense Brown		9	SS	13		119																
			10	SS	100/ 275mm		117														0 73 27 (SI+CL)		
			11	SS	46		116																
			12	SS	33		114																
			13	SS	35		113																

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OBR19-08

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482278°, Long: -76.646036° O'Brien Road N 5 038 049.6 E 293 383.7 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA COMPILED BY MW
DATUM Geodetic DATE 2019.09.11 - 2019.09.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR SA SI CL			
								20 40 60 80 100	○ UNCONFINED + FIELD VANE			WATER CONTENT (%)							
						20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE												
130.0	Pavement Surface																		
0.0 0.1	ASPHALT (75 mm)																		
	SAND with silt and gravel Compact Brown (FILL)		1	GS									○					43	51 6 (SI+CL)
129.2																			
0.8	CLAY with sand Firm Brown (FILL)		2	SS	7		129						○						
128.5																			
1.5	SILTY CLAY (CI) Very Stiff Brown		3	SS	5		128						○						
			4	SS	6								○						
							127												
			5	SS	7														
							126												
			6	SS	9								○						
							125												
							124												
123.9																			
6.1	CLAYEY SILT (CL) Stiff to Very Stiff Brown		7	SS	7		123						○						
							122						○						
			8	SS	3														
							121												
			9	SS	1								○						

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-08

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482278°, Long: -76.646036°
O'Brien Road N 5 038 049.6 E 293 383.7 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, HSA COMPILED BY MW
DATUM Geodetic DATE 2019.09.11 - 2019.09.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100	20	40	60		GR SA SI CL			
119.0	CLAYEY SILT (CL) Stiff to Very Stiff Brown																			
11.0	Silty SAND with clay seams Compact Brown		10	SS	16		119													
							118													
			11	SS	22												0 70 30 (SI+CL)			
							117													
116.3																				
13.7	SILTY SAND Compact to Dense Brown		12	SS	15		116													
							115													
				13	SS	31		114												
				14	SS	23		113									0 85 15 (SI+CL)			
								112												
			15	SS	27															
							111													

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OBR19-09

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482598°, Long: -76.645653° O'Brien Road N 5 038 085.1 E 293 413.7 ORIGINATED BY NW
HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JG
DATUM Geodetic DATE 2020.03.09 - 2020.03.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								○ UNCONFINED + FIELD VANE				
								● QUICK TRIAXIAL × LAB VANE				
128.3	Ground Surface						20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
0.0	TOPSOIL (50 mm)											
0.1	SILTY CLAY (CI) Very Stiff Brown		1	SS	4		128					
			2	SS	5		127					
			3	SS	6		126					
			4	SS	6		125					
			5	SS	6		124					
123.7	CLAYEY SILT (CL) Firm to Stiff Brown		6	SS	4		123					
4.6			7	SS	8		122					
			8	SS	4		121					
			9	SS	1		120					
							119					

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-09

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482598°, Long: -76.645653° O'Brien Road N 5 038 085.1 E 293 413.7 ORIGINATED BY NW
HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JG
DATUM Geodetic DATE 2020.03.09 - 2020.03.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				WATER CONTENT (%)			
								20 40 60 80 100				20 40 60							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
Continued From Previous Page																			
117.9			1	ST	PUSH		118												
10.4	SILTY SAND, with 50 mm clay seams Compact Brown						117												
			10	SS	30														
				11	SS	29													
114.7							115												
13.6	SAND with silt Compact to Dense Brown						114												
			12	SS	31														
							113												
				13	SS	32													
							112												
							111												
			14	SS	30		110												
			15	SS	30														
109.4																			
18.9	End of Borehole Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2020.04.21 dry to 18.4m																		

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

Continued Next Page

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

RECORD OF BOREHOLE No OBR19-09

3 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482598°, Long: -76.645653°
O'Brien Road N 5 038 085.1 E 293 413.7 ORIGINATED BY NW
HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JG
DATUM Geodetic DATE 2020.03.09 - 2020.03.10 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page 2020.09.29 18.4 109.9													

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-12

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482219°, Long: -76.648626° O'Brien Road W-S Ramp N 5 038 043.4 E 293 181.2 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.07 - 2020.02.07 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)		
131.5	Ground Surface							20	40	60	80	100							
0.0	TOPSOIL (150mm)							20	40	60	80	100							
0.2	SAND with silt to SAND with silt and gravel Loose to Dense Brown		1	SS	10														
			2	SS	8														
			3	SS	9														
			4	SS	8														
			5	SS	13														

Continued Next Page



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

RECORD OF BOREHOLE No OBR19-12

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482219°, Long: -76.648626° O'Brien Road W-S Ramp N 5 038 043.4 E 293 181.2 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.07 - 2020.02.07 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)
	Continued From Previous Page							20 40 60 80 100									
118.7	SAND with silt to SAND with silt and gravel Loose to Dense Brown						121									0 91 9 (SI+CL)	
			11	SS	30												
							120										
118.7			12	SS	30		119										
12.8	End of Borehole																
	Borehole Dry Upon Completion Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2020.04.21 dry to 12.6m 2020.09.29 dry to 12.6m																

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

RECORD OF BOREHOLE No OBR19-13

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482623°, Long: -76.648907° O'Brien Road W-S Ramp N 5 038 088.3 E 293 159.3 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.06 - 2020.02.06 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR SA SI CL				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)								
131.8	Ground Surface						20 40 60 80 100													
0.0	TOPSOIL (150 mm)						20 40 60 80 100													
0.1	SAND with silt to SAND with silt and gravel Compact to Very Dense Brown		1	SS	33								○							
			2	SS	24								○						7 84 9 (SI+CL)	
			3	SS	13								○							
			4	SS	17								○							
			5	SS	22								○						14 78 8 (SI+CL)	
			6	SS	17								○							
			7	SS	20								○							
			8	SS	26								○							
			9	SS	42								○						23 69 8 (SI+CL)	
			10	SS	70								○							

Continued Next Page

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


DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-13

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.482623°, Long: -76.648907° O'Brien Road W-S Ramp N 5 038 088.3 E 293 159.3 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.06 - 2020.02.06 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W P W W L						
	Continued From Previous Page							20	40	60	80	100		20	40	60		
119.0	SAND with silt to SAND with silt and gravel Compact to Very Dense Brown																	
			11	SS	47													
			12	SS	44													
12.8	End of Borehole Borehole dry upon completion						119											

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-14

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483006°, Long: -76.649333° O'Brien Road W-S Ramp N 5 038 130.9 E 293 126.1 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.05 - 2020.02.05 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								WATER CONTENT (%)					
132.2	Ground Surface												
0.0 0.1	TOPSOIL (50 mm)												
	Silty SAND Loose to Compact Brown		1	SS	7								
			2	SS	17								
130.7													
1.5	SAND with silt and gravel to GRAVEL with silt and sand Occasional to Frequent Cobbles Compact to Very Dense Brown		3	SS	33								
			4	SS	26								
			5	SS	25								
			6	SS	38								
	-grinding while augering		7	SS	20								
	-poor sample recovery below elevation 126 m		8	SS	15								
			9	SS	17								
	-very heavy grinding while augering		10	SS	100/ 150mm								

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

Continued Next Page


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

RECORD OF BOREHOLE No OBR19-14

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483006°, Long: -76.649333° O'Brien Road W-S Ramp N 5 038 130.9 E 293 126.1 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.05 - 2020.02.05 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20 40 60 80 100									20 40 60			
	Continued From Previous Page																			
	SAND with silt and gravel to GRAVEL with silt and sand Occasional to Frequent Cobbles Compact to Very Dense Brown		11	SS	31		122									62 32 6 (SI+CL)				
							121													
							120													
							119													
							118													
117.9			13	SS	16															
14.3	End of Borehole Borehole dry upon completion																			

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-15

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483311°, Long: -76.649816° O'Brien Road W-S Ramp N 5 038 164.8 E 293 088.4 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.06 - 2020.02.06 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100	20 40 60	W _p W W _L				
129.1	Ground Surface														
0.0	TOPSOIL (50 mm)														
	SILTY SAND to SAND with silt Loose to Compact Brown		1	SS	4										
			2	SS	4										
			3	SS	4										0 85 15 (SH+CL)
			4	SS	6										
			5	SS	4										
			6	SS	7										
			7	SS	10										
			8	SS	15										3 86 11 (SH+CL)
			9	SS	14										

Continued Next Page

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

RECORD OF BOREHOLE No OBR19-15

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483311°, Long: -76.649816° O'Brien Road W-S Ramp N 5 038 164.8 E 293 088.4 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.06 - 2020.02.06 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
	Continued From Previous Page												
	CLAYEY SILT (CL) Stiff Brown												
			11	SS	3								
			12	SS	17								
116.4													
116.3	SILTY SAND Compact Brown End of Borehole Monitoring well consists of 50mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2020.02.07 8.0 121.1 2020.04.21 6.3 122.8 2020.09.29 6.9 122.2												
12.8													

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

RECORD OF BOREHOLE No OBR19-16

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483542°, Long: -76.650316° O'Brien Road W-S Ramp N 5 038 190.7 E 293 049.4 ORIGINATED BY NW
HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
DATUM Geodetic DATE 2020.02.05 - 2020.02.05 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
127.9	Ground Surface						20	40	60	80	100	WATER CONTENT (%)						
0.0	TOPSOIL (50 mm)						20	40	60	80	100	20	40	60				
	SILTY SAND Loose Brown		1	SS	10										○			
			2	SS	6											○		
			3	SS	4												○	
			4	SS	6											○		0 64 21 15
			5	SS	8											○		
124.1	SAND with silt Loose to Compact Brown																	
6			SS	12										○				
7			SS	21											○		0 91 9 (SI+CL)	
	- running sands below 5.8 m																	
			8	SS	8											○		
			9	SS	12											○		5 90 5 (SI+CL)
119.7	Begin DCPT at 8.2 m																	
8.2																		

Continued Next Page

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

DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No OBR19-16

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.483542°, Long: -76.650316° O'Brien Road W-S Ramp N 5 038 190.7 E 293 049.4 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME 55 Trackmount, HSA COMPILED BY JP
 DATUM Geodetic DATE 2020.02.05 - 2020.02.05 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	DCPT continued						117							
							116							
							115							
							114							
							113							
112.7	DCPT ended													
15.2	End of Borehole													



DOUBLE LINE 24726 O'BRIEN ROAD GINT.GPJ 2012TEMPLATE(MTO).GDT 21/7/29

RECORD OF BOREHOLE No CV-7

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.481406°, Long: -76.648358°
Culvert 21+155 Ramp N 5 037 953.0 E 293 202.0 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE CME45 Track COMPILED BY MW
DATUM Geodetic DATE 2019.10.15 - 2019.10.15 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)								
117.0								20	40	60	80	100									
0.0	SAND with silt Very Loose to Loose Brown		1	SS	4																
			2	SS	4																
			3	SS	6																
			4	SS	5																
113.9			5	SS	100/																
3.1	MARBLE BEDROCK Slightly Weathered Grey and White Medium Strong to Strong Highly fractured with calcite infill from 3.6 m to 3.8 m				25 mm																
			1	RUN																	
			2	RUN																	

DOUBLE LINE 24726 CULVERT 21+055 RAMP GINT.GPJ 2012TEMPLATE(MTO).GDT 6/5/20

RECORD OF BOREHOLE No CV-8

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.481581°, Long: -76.648196°
Culvert 21+155 Ramp N 5 037 972.4 E 293 214.7 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE CME45 Track COMPILED BY MW
DATUM Geodetic DATE 2019.10.16 - 2019.10.16 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
116.5								20	40	60	80	100					
0.0	TOPSOIL							20	40	60	80	100					
0.1	Silty SAND , organics to 1.2 m Loose Brown		1	SS	4		116							o			2 76 22 (SI+CL)
			2	SS	6									o			
			3	SS	5		115							o			
			4	SS	5									o			
			5	SS	6		114							o			
			6	SS	5									o			
			7	SS	13		113							o			1 78 21 (SI+CL)
112.3																	
4.2	MARBLE BEDROCK Slightly Weathered White/Grey Medium Strong to Strong Foliated		1	RUN			112								FI	RUN #1 TCR=100% SCR=77% RQD=31%	
															5		
															6		
															3		
			2	RUN			111								3	RUN #2 TCR=100% SCR=100% RQD=50%	
															1		
															5		
															3		
							110								3		
			3	RUN			109								6	RUN #3 TCR=100% SCR=90% RQD=56%	
															1		
															3		
108.6																	
7.9	End of Borehole Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2019.11.26 dry - 2020.04.21 3.6 112.9																

DOUBLE LINE 24726 CULVERT 21+055 RAMP GINT.GPJ 2012TEMPLATE(MTO).GDT 6/5/20

RECORD OF BOREHOLE No CV-9

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.481843°, Long: -76.648224°
Culvert 21+155 Ramp N 5 038 001.6 E 293 212.5 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE CME45 Track COMPILED BY MW
DATUM Geodetic DATE 2019.10.15 - 2019.10.15 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE				w _p w w _L				
								● QUICK TRIAXIAL × LAB VANE								
116.2							20	40	60	80	100	20	40	60		GR SA SI CL
0.0																
	SILTY SAND , trace gravel Very Loose to Dense Brown		1	SS	2								○			
			2	SS	9								○			7 75 18 (SI+CL)
			3	SS	14								○			
			4	SS	35								○			4 82 14 (SI+CL)
			5	SS	25								○			
			6	SS	16								○			
110.9																
5.3	GRAVEL , (fractured bedrock) Very Dense Black/Grey/Red		7	SS	100/ 225 mm								○			FI
110.5																
5.7	MARBLE BEDROCK Slightly Weathered White/Grey medium strong Moderately fractured Moderately weathered from 5.9 m to 7.7 m		1	RUN												RUN #1 TCR=63% SCR=31% RQD=0%

DOUBLE LINE 24726 CULVERT 21+055 RAMP GINT.GPJ 2012TEMPLATE(MTO).GDT 6/5/20

RECORD OF BOREHOLE No BRN-1

1 OF 3

METRIC

W.P. 647-92-00 LOCATION N 1.0 E 1.0 (N 5 038 049.1 E 293 357.3) O'Brien Road ORIGINATED BY JL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 06.10.03 - 07.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
								20 40 60 80 100							20 40 60	
								20 40 60 80 100							20 40 60	
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%)							
129.8																
129.6	ASPHALT (150mm)															
0.2	SAND and GRAVEL Brown (FILL) (SP)		1	GS												
129.0																
0.8	Silty CLAY to Clayey SILT Stiff Grey - Brown Moist (CI)		1	SS	6		129									
			2	SS	13		128									
			3	SS	7		127									
			4	SS	6		126									
	occasional sand lenses, wet		5	SS	7		125					0 2 50 48				
124.2																
5.6	Silty CLAY, with numerous sand laminations and layers to 300mm Firm Grey Wet (CL)		6	SS	7		124									
							123									
			7	SS	8		122									
	sand layer from 9.0m to 9.3m		8	SS	23		121									
119.8							120									

Continued Next Page

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

RECORD OF BOREHOLE No BRN-1

2 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 049.1 E 293 357.3) O'Brien Road ORIGINATED BY JL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 06.10.03 - 07.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
10.0	SAND, trace silt, trace to some gravel Dense Brown Moist to Wet (SP)														
			9	SS	47		119								18 56 26 (SI+CL)
							118								
			10	SS	42										
							117								
							116								
			11	SS	40										
							115								
							114								
			12	SS	31										
							113								
			13	SS	44										
							112								
							111								
			14	SS	29										
							110								

Compact, wet

Continued Next Page

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

RECORD OF BOREHOLE No BRN-1

3 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 049.1 E 293 357.3) O'Brien Road ORIGINATED BY JL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 06.10.03 - 07.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
			15	SS	40										
			16	SS	31										
106.9															
22.9	Silty SAND, trace gravel Compact Grey Wet (SM)		17	SS	25										
105.9															
23.9	MARBLE (BEDROCK) Fresh to slightly weathered, light grey, moderately strong		1	RUN											
			2	RUN											
			3	RUN											
			4	RUN											
102.7															
27.1	END OF BOREHOLE AT 27.09m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH (m) 22/10/03 19.72 16/12/03 19.38 04/02/04 19.41														

+ 3, × 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BRN-2

1 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road ORIGINATED BY SL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 01.10.03 - 02.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
128.4 128.8 0.1	TOPSOIL (50mm) Silty CLAY, trace rootlets to 1.4m Very Stiff to Stiff Brown Moist to Wet (CI)		1	SS	11		128								
			2	SS	14		127								
			3	SS	11		126								
			4	SS	10		125								
	with sand laminations		5	SS	9		124								
123.8 4.6	Silty CLAY with interbedded silty sand Firm Brown Wet (CL)		6	SS	7		123							0 8 70 22	
	becoming grey below 6.1m		7	SS	5		122								
			8	SS	3		121								
			9	SS	10		120								
							119								0 17 56 27

Continued Next Page

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

RECORD OF BOREHOLE No BRN-2

2 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road ORIGINATED BY SL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 01.10.03 - 02.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
118.2													
10.2	SAND, fine grained, trace silt, trace gravel Very Dense to Dense Brown Moist to Wet (SP)		10	SS	76		118						
							117						
			11	SS	57		116						
							115						
			12	SS	70		114						
							113						
	some silt (SM) Compact		13	SS	10		112						
							111						
			14	SS	74		110						
							109						
110.1													
18.3	SAND, trace silt, occasional silt and silty sand layers Dense Brown Wet (SP/SM)		15	SS	40								
			16	SS	42								

Continued Next Page

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

ONTMT4 7450BRN.GPJ 19/08/04

RECORD OF BOREHOLE No BRN-2

3 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road ORIGINATED BY SL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 01.10.03 - 02.10.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
106.0	medium grained, with silty fine sand seams		17	SS	35		108						
	Auger refusal at 22.4m.						107						
22.4	Cobbles and Boulders, some gravel, maximum size 500mm		1	RUN			106						
			2	RUN			105						
104.5													
23.9	MARBLE (BEDROCK) Fresh to slightly weathered, light grey, strong		3	RUN			104						
			4	RUN			103						
			5	RUN			102						
101.0							101						
27.4	END OF BOREHOLE AT 7.57m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 2.13m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) 22/10/03 19.30 16/12/03 19.08 04/02/04 18.91												

ONTMT4 7450BRN.GPJ 19/08/04

RECORD OF BOREHOLE No BRN-4

1 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 084.7 E 293 399.3) O'Brien Road ORIGINATED BY SL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 02.12.03 - 03.12.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
128.4														
0.0	TOPSOIL (100mm)													
128.1														
0.3	Silty CLAY, trace sand Firm Brown Moist (CI)		1	SS	6		128							
			2	SS	8									
	Stiff below 1.5m depth						127							
			3	SS	9									
							126							
			4	SS	11									
	occasional oxide staining						125							0 0 54 45
			5	SS	10									
							124							
			6	SS	10									
							123							
			7	SS	10		122							
121.2							121							
7.2	Silty CLAY, trace sand Stiff to Firm Brown Moist (CL)		8	SS	9									
							120							
	with thin sand seams below 9.1m						119							0 10 57 33
			9	SS	6									


Continued Next Page

+ 3 x 3 : Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

ONTMT4 7450BRN.GPJ 19/08/04

METRIC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIMIT MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE			*"N" VALUES		20 40 60 80 100	W _P W W _L		
												
							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100					

Depth (ft)	Soil Type	SS (%)	SP (%)	Notes
117.4				
11.1	SAND, fine grained, some silt Compact to Dense Brown Moist (SM)	10	36	
	with silty clay lenses Compact	11	28	
		12	39	
		13	38	
		14	44	
		15	51	
	Very Dense			

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No BRN-5

1 OF 3

METRIC

G.W.P. 647-92-00 LOCATION (N 5 038 028.3 E 293 364.2) O'Brien Road ORIGINATED BY JL
 HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring COMPILED BY SS
 DATUM Geodetic DATE 17.12.03 - 17.12.03 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
129.8												
129.9	ASPHALT (150 mm)											
0.2	Clayey SILT, sandy, some gravel Dark Brown (FILL)		1	GS								
129.0												
0.8	Silty CLAY, occasional oxide staining Stiff to Firm Brown (CI)		1	SS	10		129					
			2	SS	8		128					
			3	SS	4		127					0 1 52 47
	some sand seams/ partings below 3.0m		4	SS	4		126					
			5	SS	4		125					
							124					
123.7			6	SS	4		123	7.1				
6.1	Silty CLAY, some sand to sandy, occasional sand seams Firm to Soft Brown-Grey (CL)		7	SS	3		122	10				
			8	SS	1		121					
							120					0 12 54 34

Continued Next Page

+ 3, x 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

ONTMT4 7450BRN.GPJ 19/09/04

METRIC

ONTMT4 7450BRN.GPJ 19/08/04

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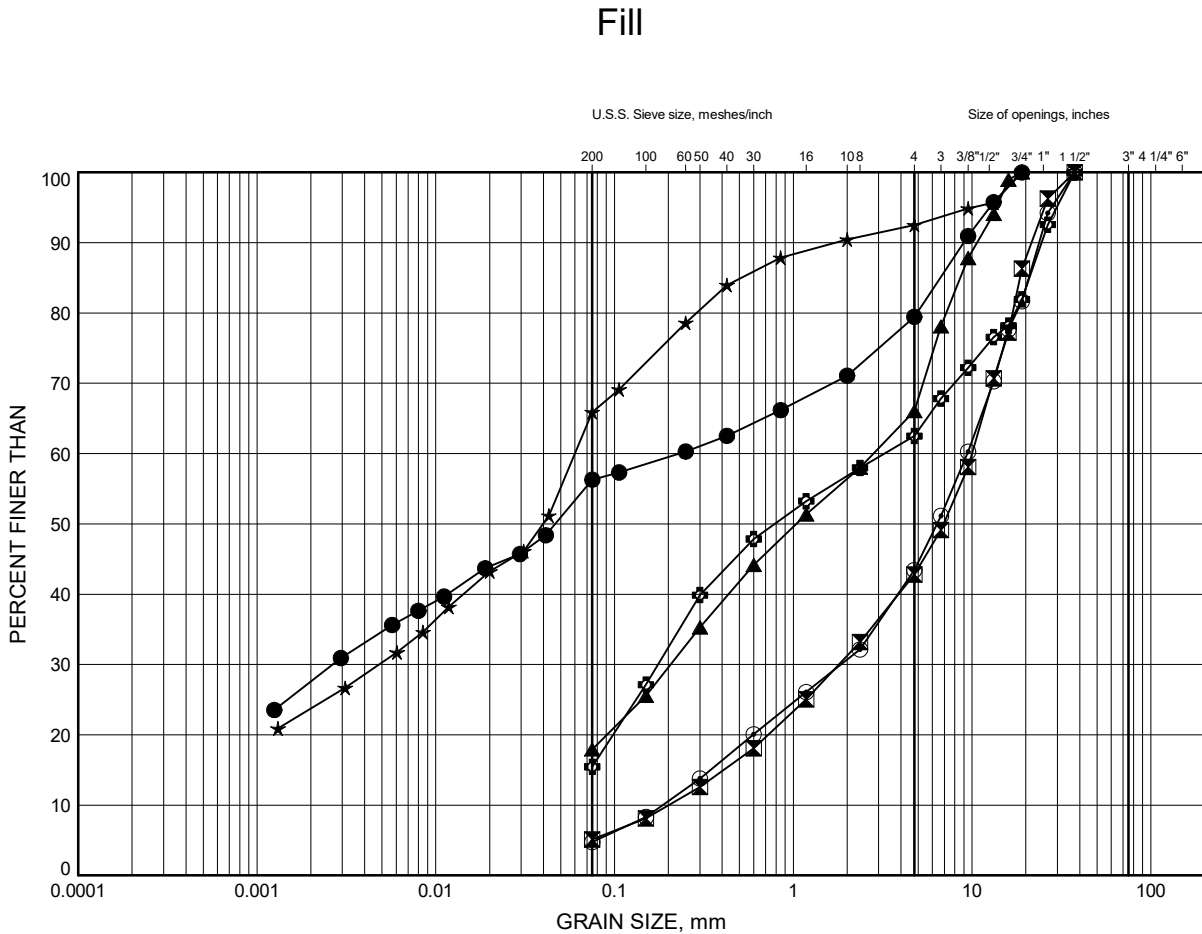
+³, ×³: Numbers refer to Sensitivity

Appendix C.
Laboratory Testing

Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-01	0.4	129.5
⊠	OBR19-02	0.4	129.4
▲	OBR19-03	0.4	129.5
★	OBR19-03	1.1	128.8
⊙	OBR19-04	0.4	129.8
⊕	OBR19-05	1.1	128.7

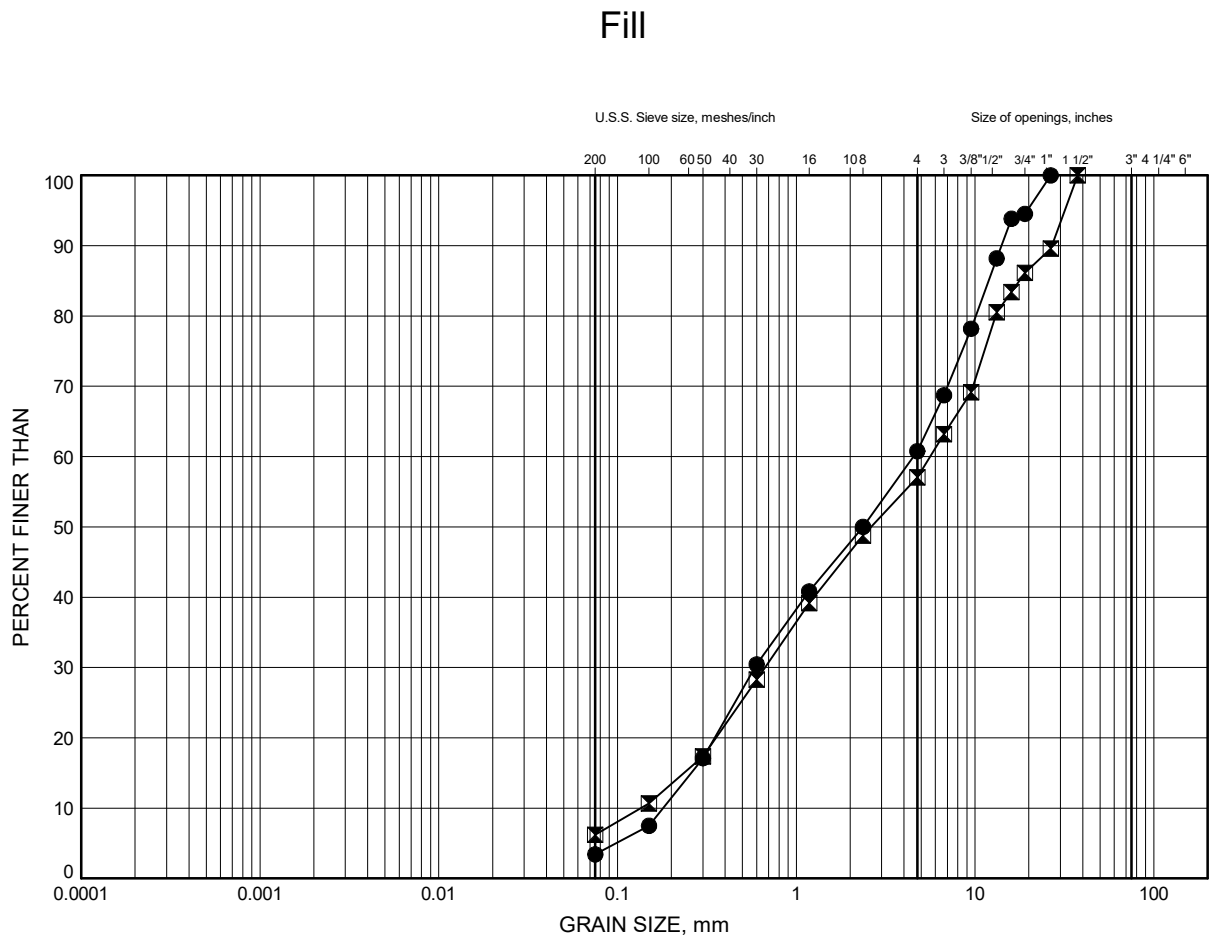
Date April 2020
WP# 4068-09-00



Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-06	0.3	129.7
⊠	OBR19-08	0.4	129.6

Date April 2020
WP# 4068-09-00

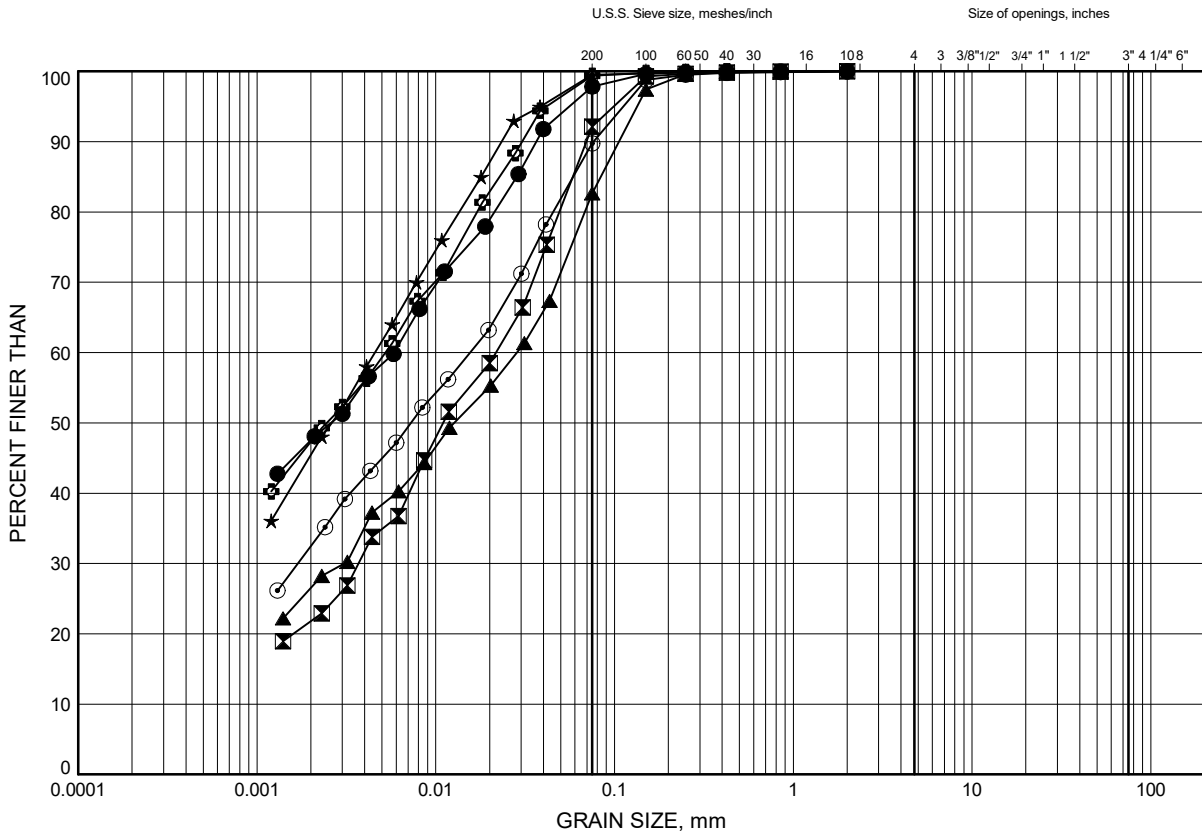


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty Clay to Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BRN-1	4.9	124.9
⊠	BRN-2	4.9	123.5
▲	BRN-2	9.5	118.9
★	BRN-4	3.4	125.0
⊙	BRN-4	9.5	118.9
⊕	BRN-5	2.6	127.2

Date April 2020
WP# 4068-09-00

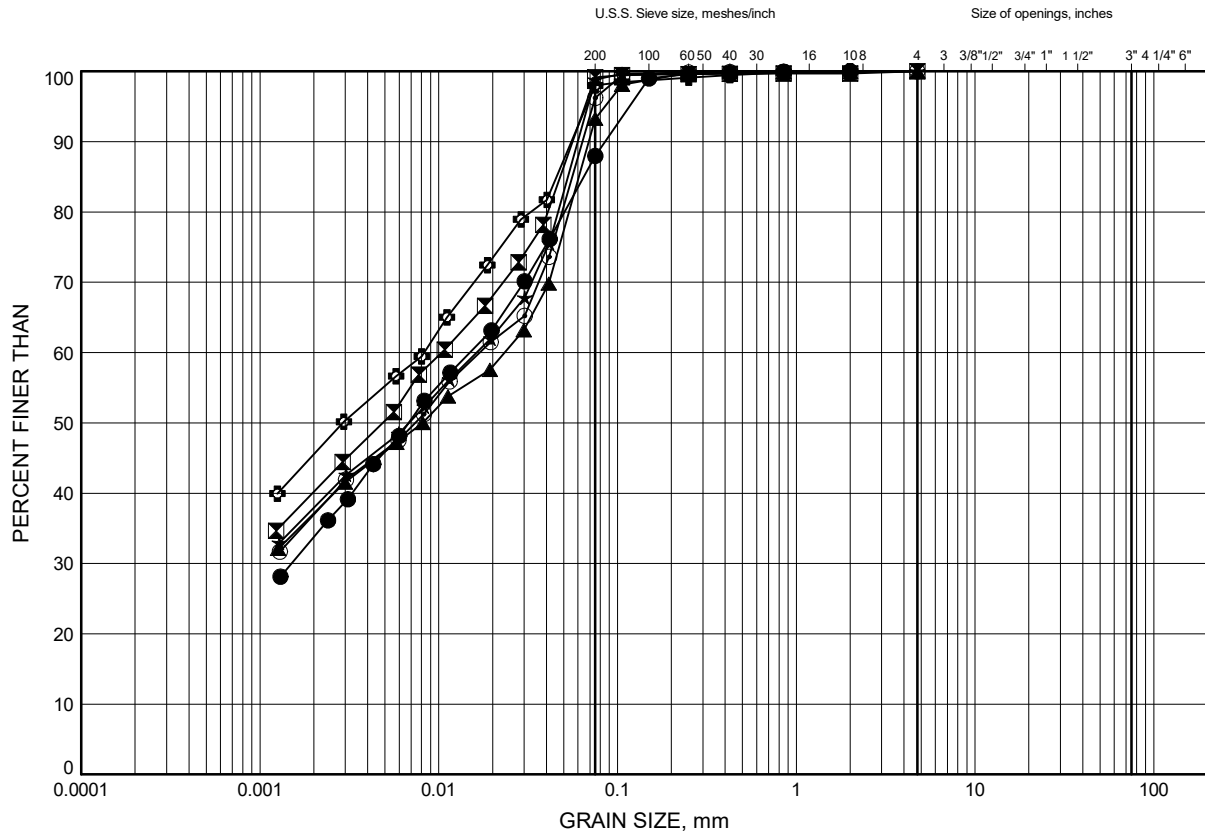


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C4

Silty Clay to Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BRN-5	9.5	120.4
⊠	OBR19-01	1.8	128.1
▲	OBR19-01	6.4	123.5
★	OBR19-02	3.4	126.4
⊙	OBR19-02	8.7	121.1
⊕	OBR19-03	2.6	127.3

Date April 2020
WP# 4068-09-00

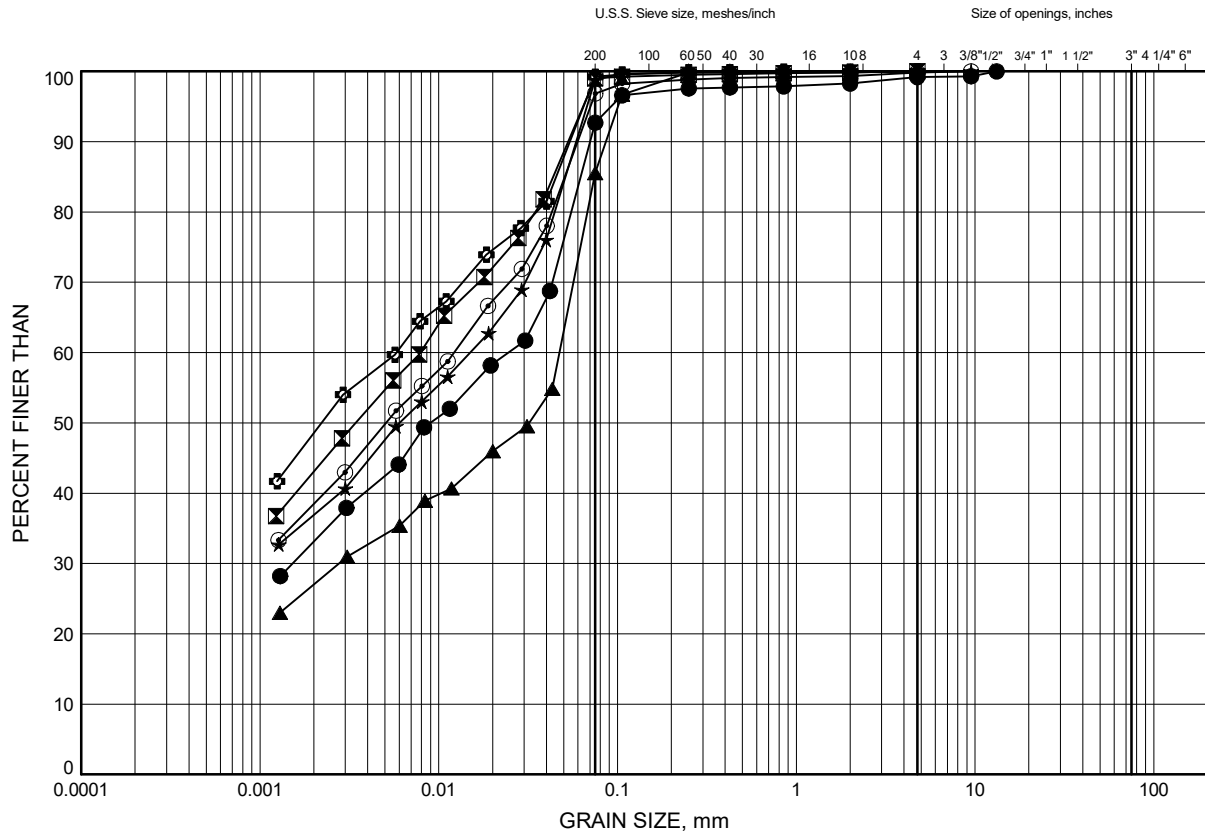


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C5

Silty Clay to Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-03	8.7	121.2
⊠	OBR19-04	3.4	126.8
▲	OBR19-04	10.2	120.0
★	OBR19-05	4.9	124.9
⊙	OBR19-05	7.9	121.9
⊕	OBR19-06	3.4	126.6

Date April 2020
WP# 4068-09-00

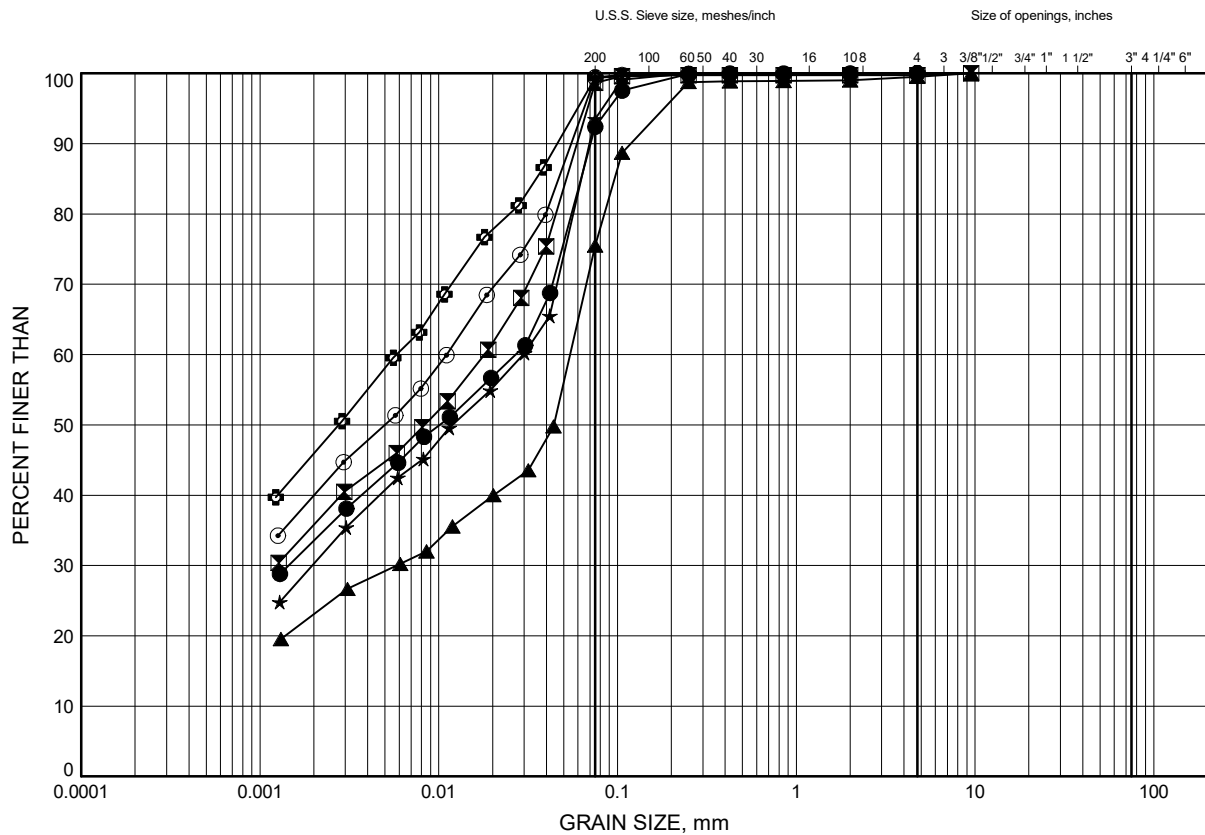


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C6

Silty Clay to Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-06	7.2	122.8
⊠	OBR19-07	1.8	128.0
▲	OBR19-07	6.4	123.4
★	OBR19-07	7.9	121.9
⊙	OBR19-08	3.4	126.6
⊕	OBR19-09	2.6	125.7

Date April 2020
WP# 4068-09-00

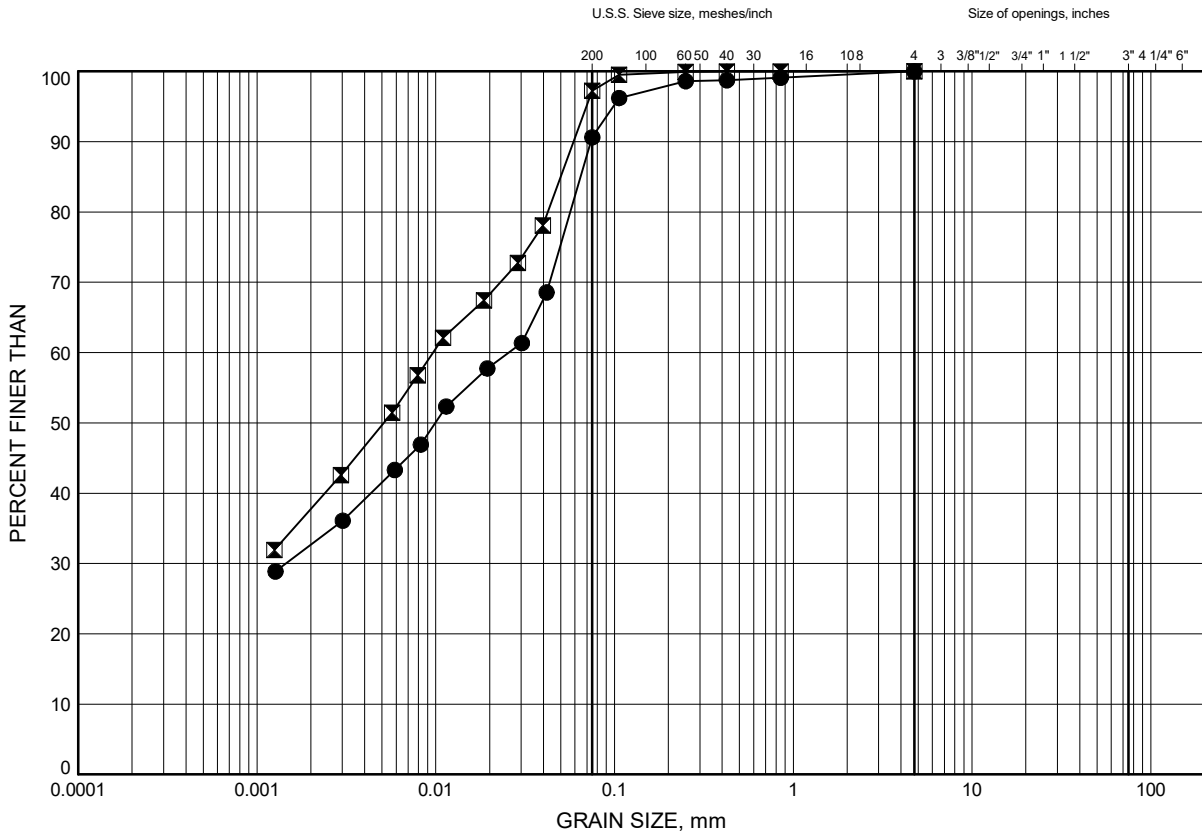


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C7

Silty Clay to Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-09	5.6	122.7
⊠	OBR19-09	8.7	119.6

Date April 2020
WP# 4068-09-00



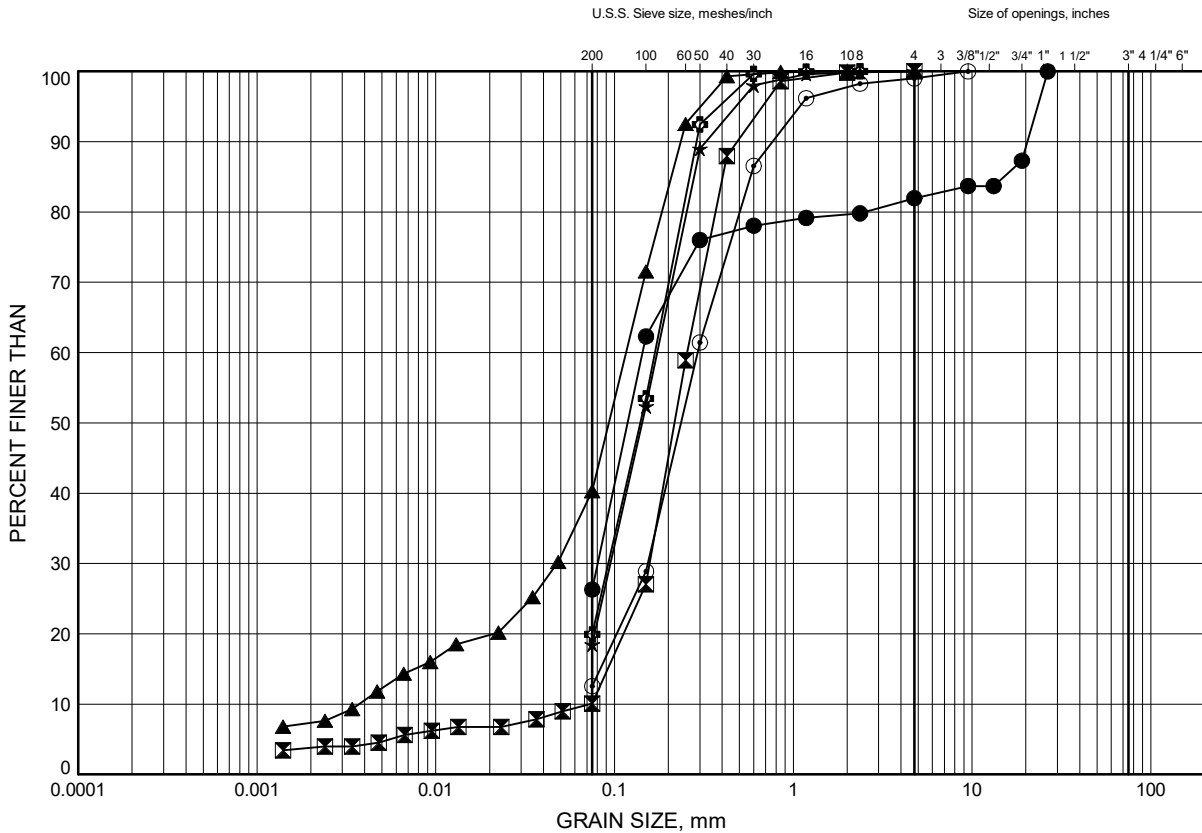
Prep'd JG
Chkd. FG

Highway 17 Twinning

GRAIN SIZE DISTRIBUTION

FIGURE C8

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BRN-1	11.0	118.8
⊠	BRN-2	14.0	114.3
▲	BRN-2	18.6	109.8
★	BRN-4	14.0	114.4
⊙	BRN-4	21.6	106.8
⬢	BRN-5	14.0	115.8

Date April 2020
WP# 4068-09-00

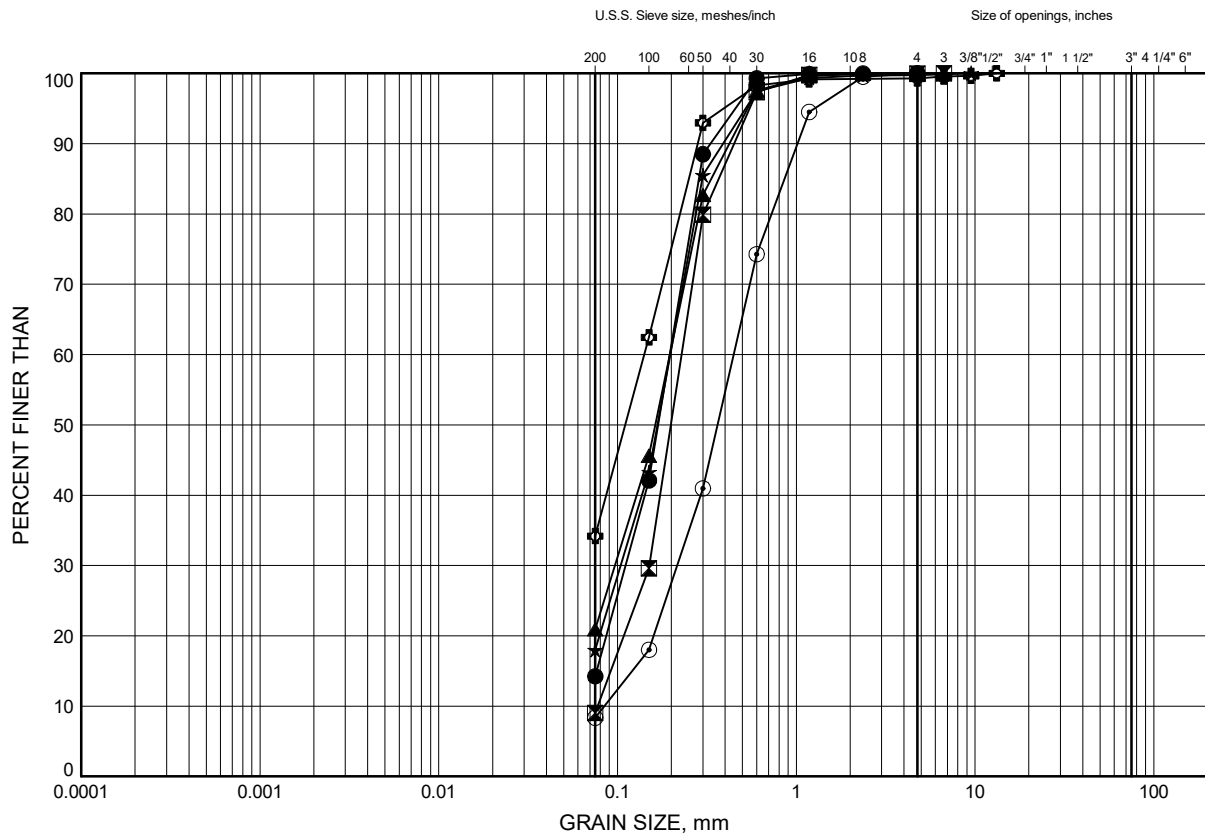


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C9

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-01	9.4	120.5
⊠	OBR19-01	16.3	113.6
▲	OBR19-01	22.4	107.5
★	OBR19-02	14.8	115.0
⊙	OBR19-02	22.4	107.4
⊕	OBR19-03	13.3	116.6

Date April 2020
WP# 4068-09-00

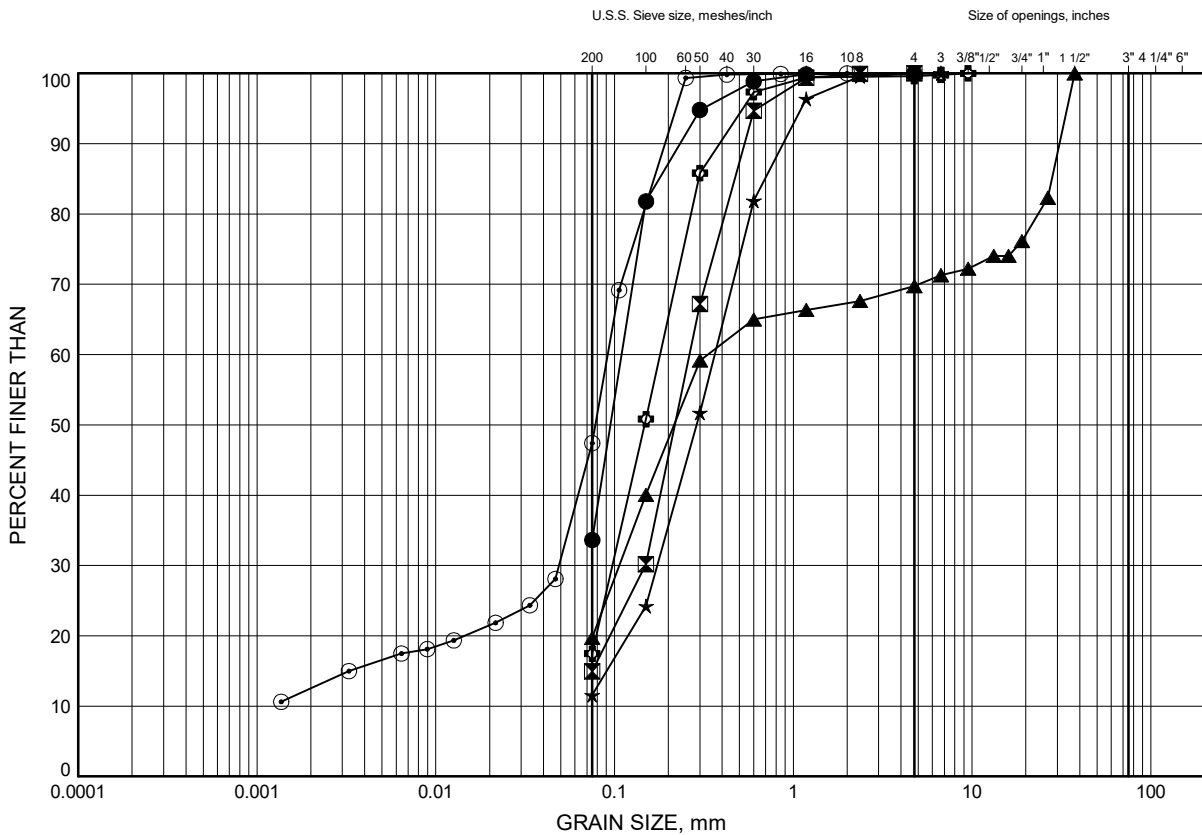


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C10

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-04	13.3	116.9
⊠	OBR19-04	19.4	110.8
▲	OBR19-05	13.3	116.5
★	OBR19-05	22.4	107.4
⊙	OBR19-06	13.3	116.7
⊕	OBR19-06	16.3	113.7

Date April 2020
WP# 4068-09-00

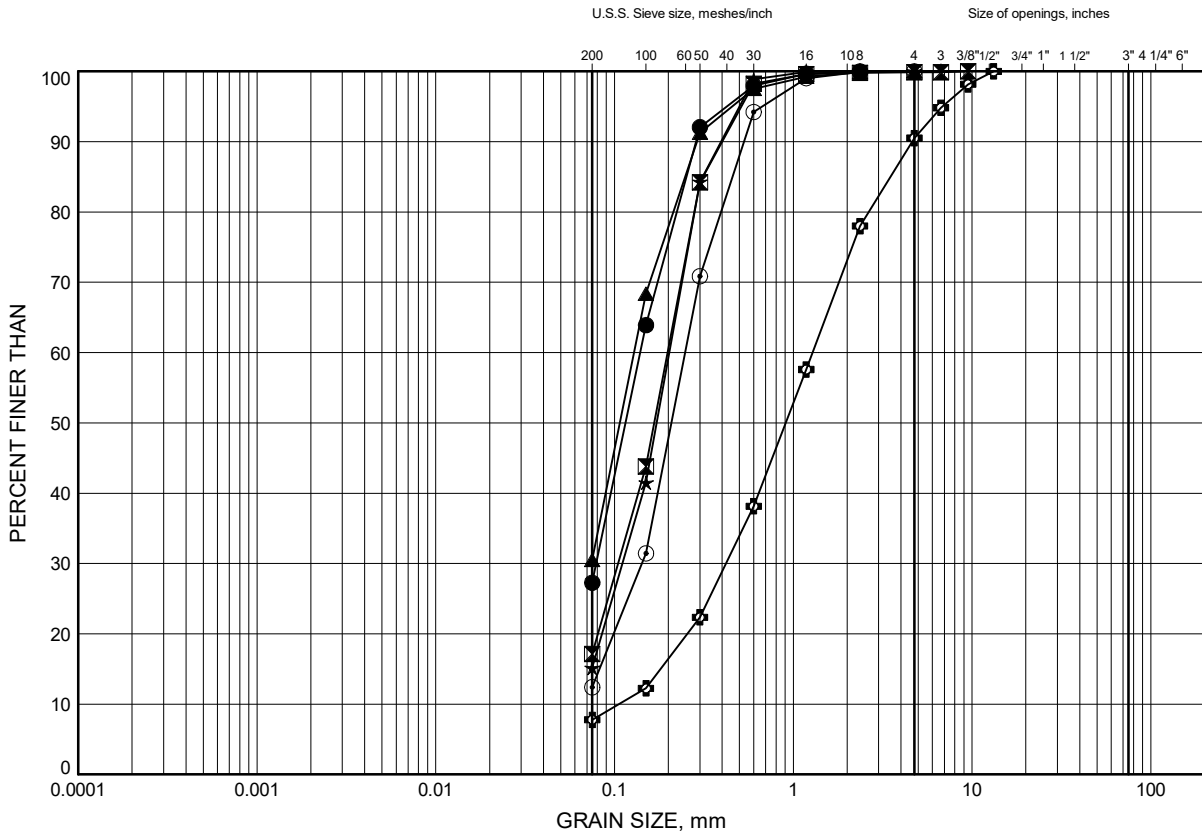


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C11

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-07	12.4	117.4
⊠	OBR19-07	18.6	111.2
▲	OBR19-08	12.5	117.5
★	OBR19-08	17.1	112.9
⊙	OBR19-09	14.8	113.5
⊕	OBR19-12	1.8	129.7

Date April 2020
WP# 4068-09-00



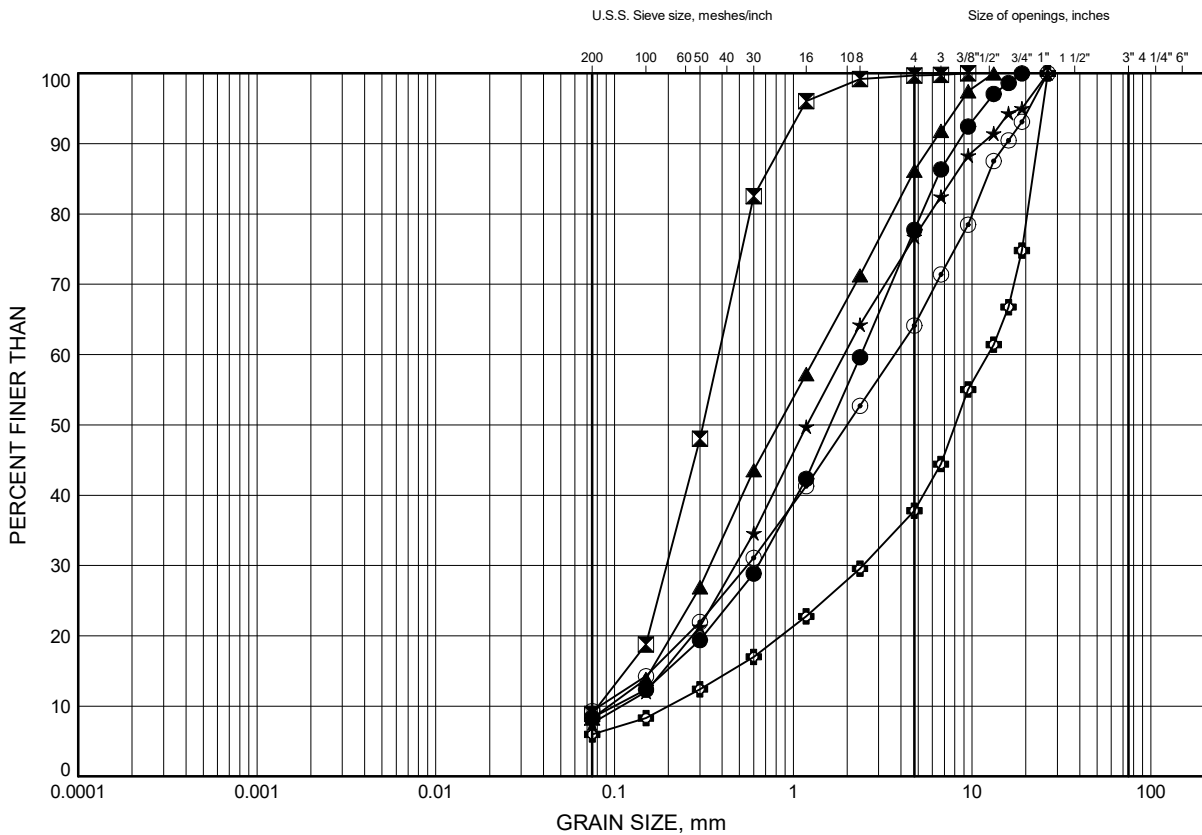
Prep'd JG
Chkd. FG

Highway 17 Twinning

GRAIN SIZE DISTRIBUTION

FIGURE C12

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-12	4.9	126.6
⊠	OBR19-12	11.0	120.5
▲	OBR19-13	3.4	128.4
★	OBR19-13	7.9	123.9
⊙	OBR19-14	2.6	129.6
⊕	OBR19-14	11.0	121.2

Date April 2020
WP# 4068-09-00

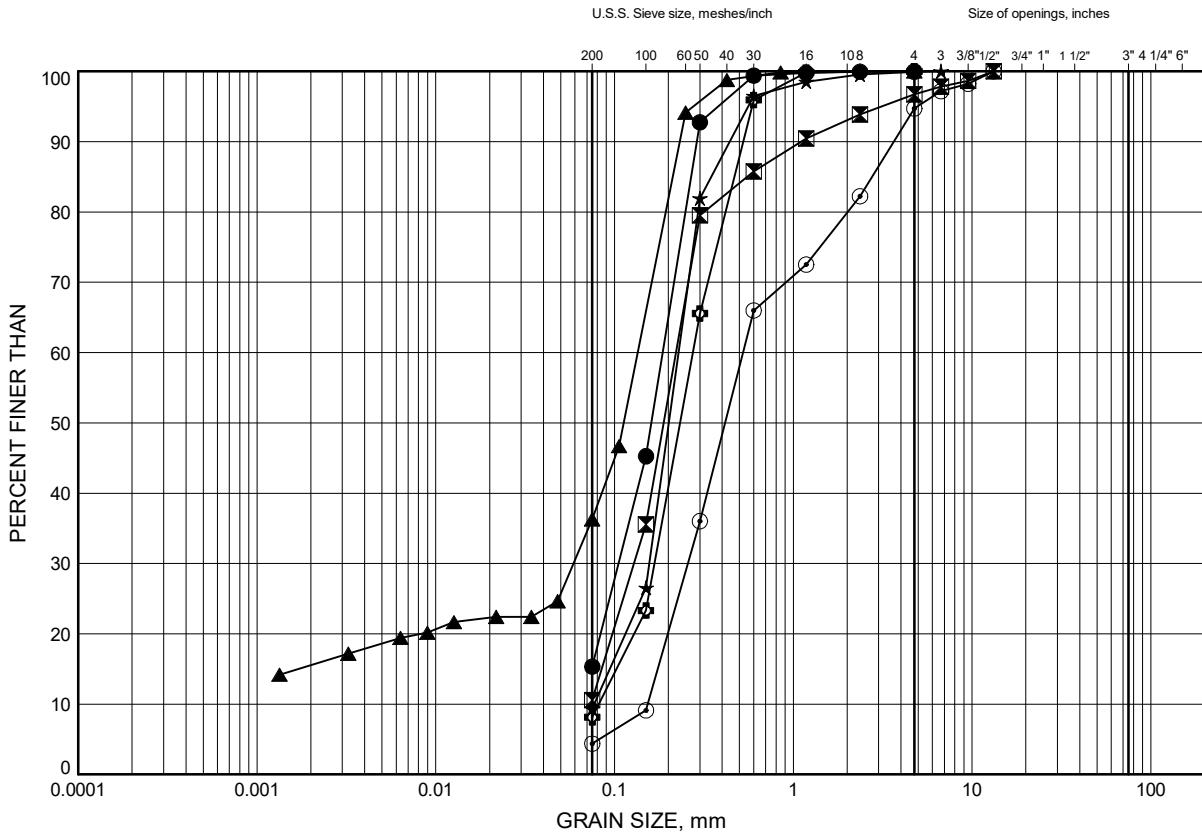


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C13

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-15	1.8	127.3
⊠	OBR19-15	6.4	122.7
▲	OBR19-16	2.6	125.3
★	OBR19-16	4.9	123.0
⊙	OBR19-16	7.9	120.0
⊕	CV-7	1.8	115.2

Date April 2020
WP# 4068-09-00

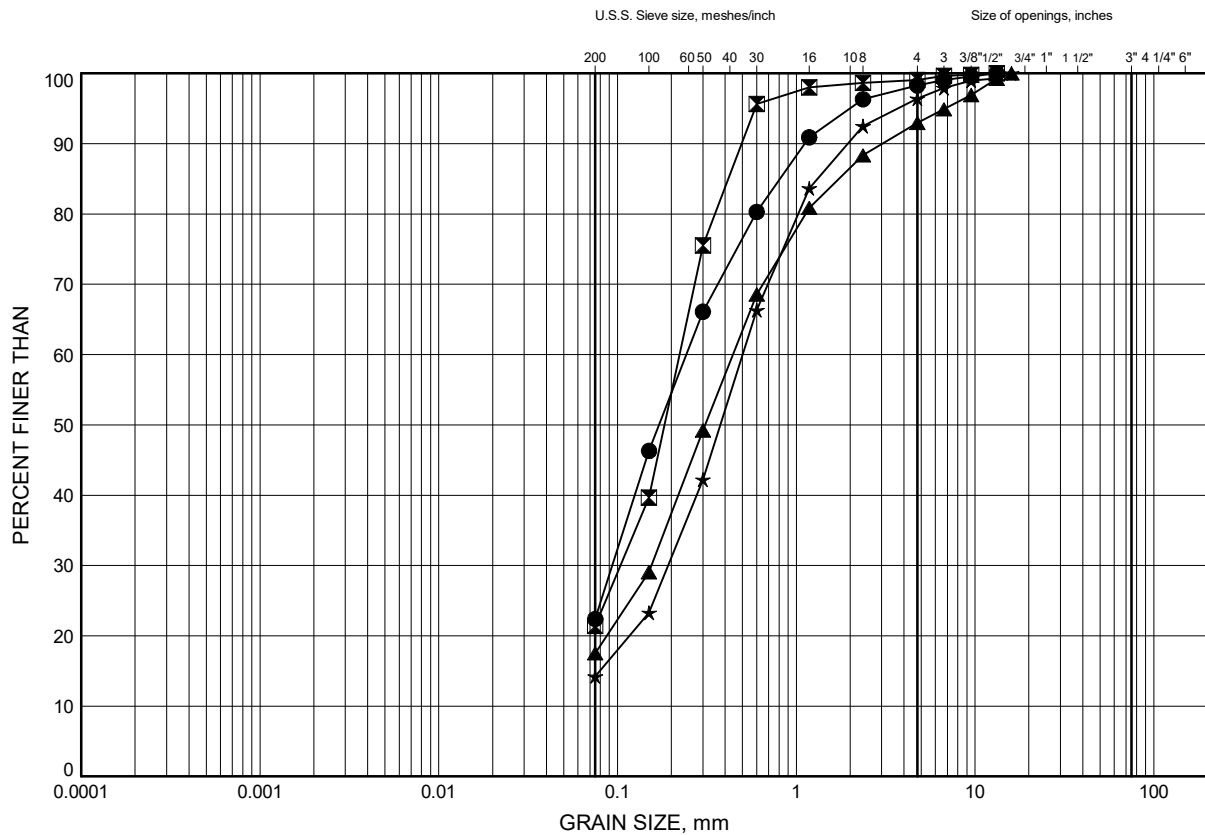


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C14

Silty Sand to Sand with Silt to Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-8	0.3	116.2
⊠	CV-8	3.9	112.6
▲	CV-9	1.1	115.1
★	CV-9	2.6	113.6

Date April 2020
WP# 4068-09-00

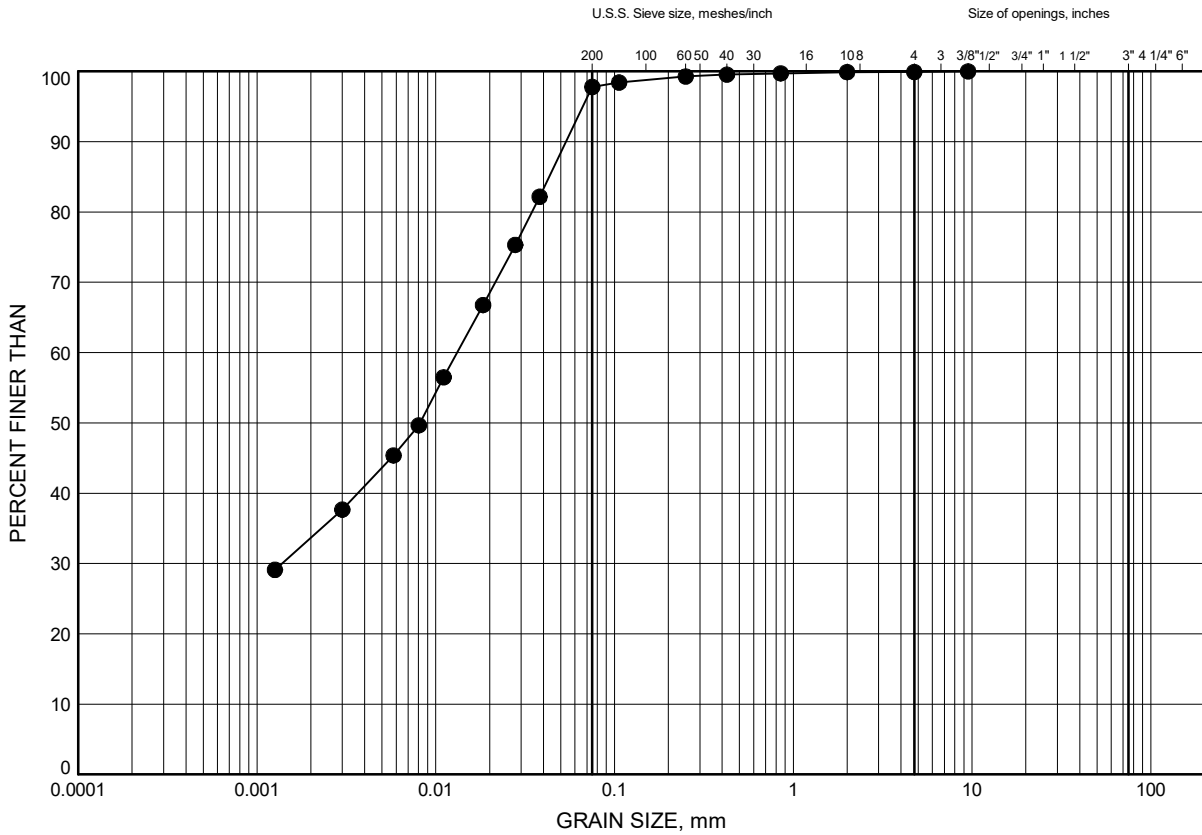


Prep'd JG
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C15

Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-15	11.0	118.1

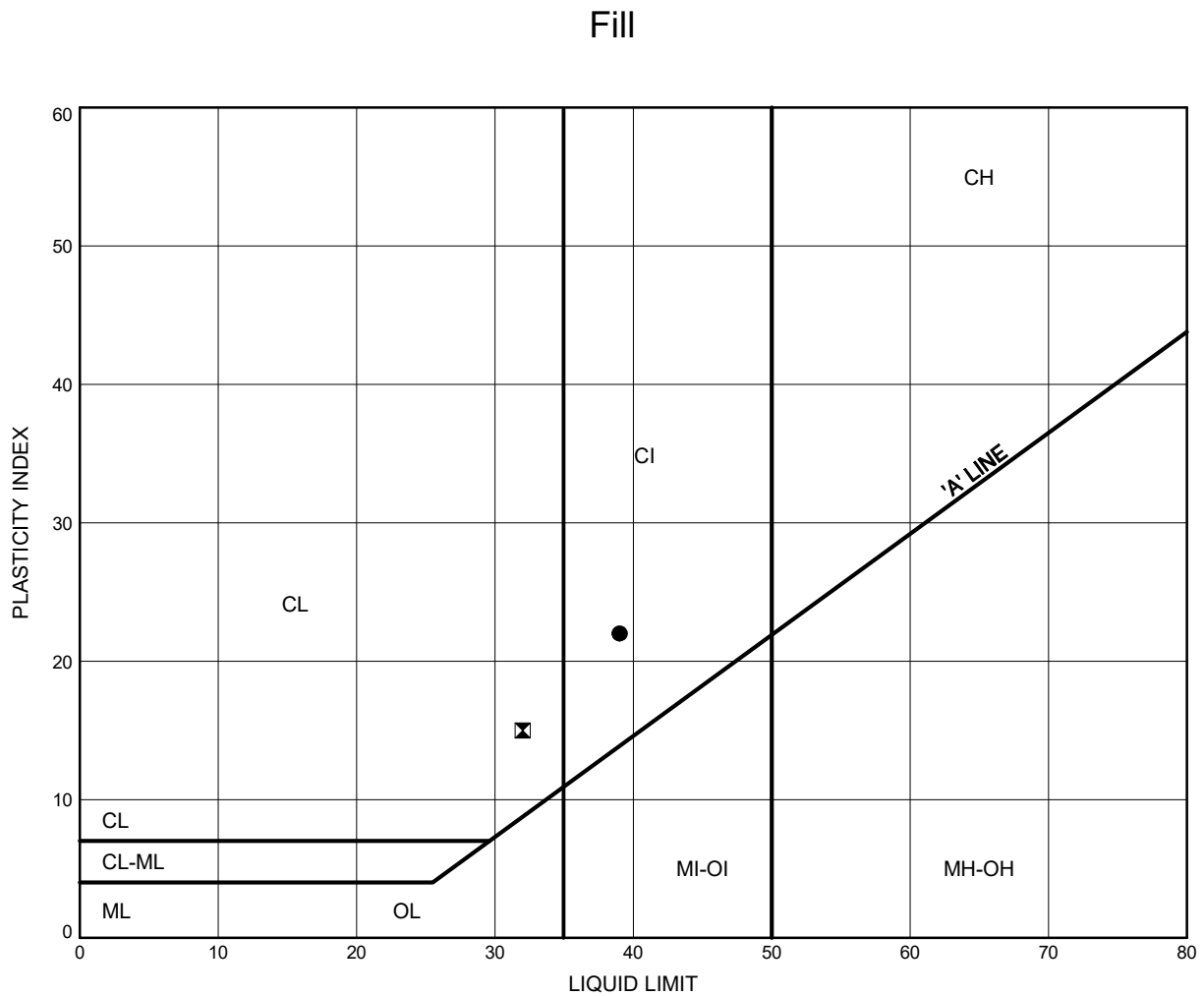
Date April 2020
WP# 4068-09-00



Prep'd JG
Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C16



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-01	0.4	129.5
⊠	OBR19-03	1.1	128.8

Date April 2020
 WP# 4068-09-00

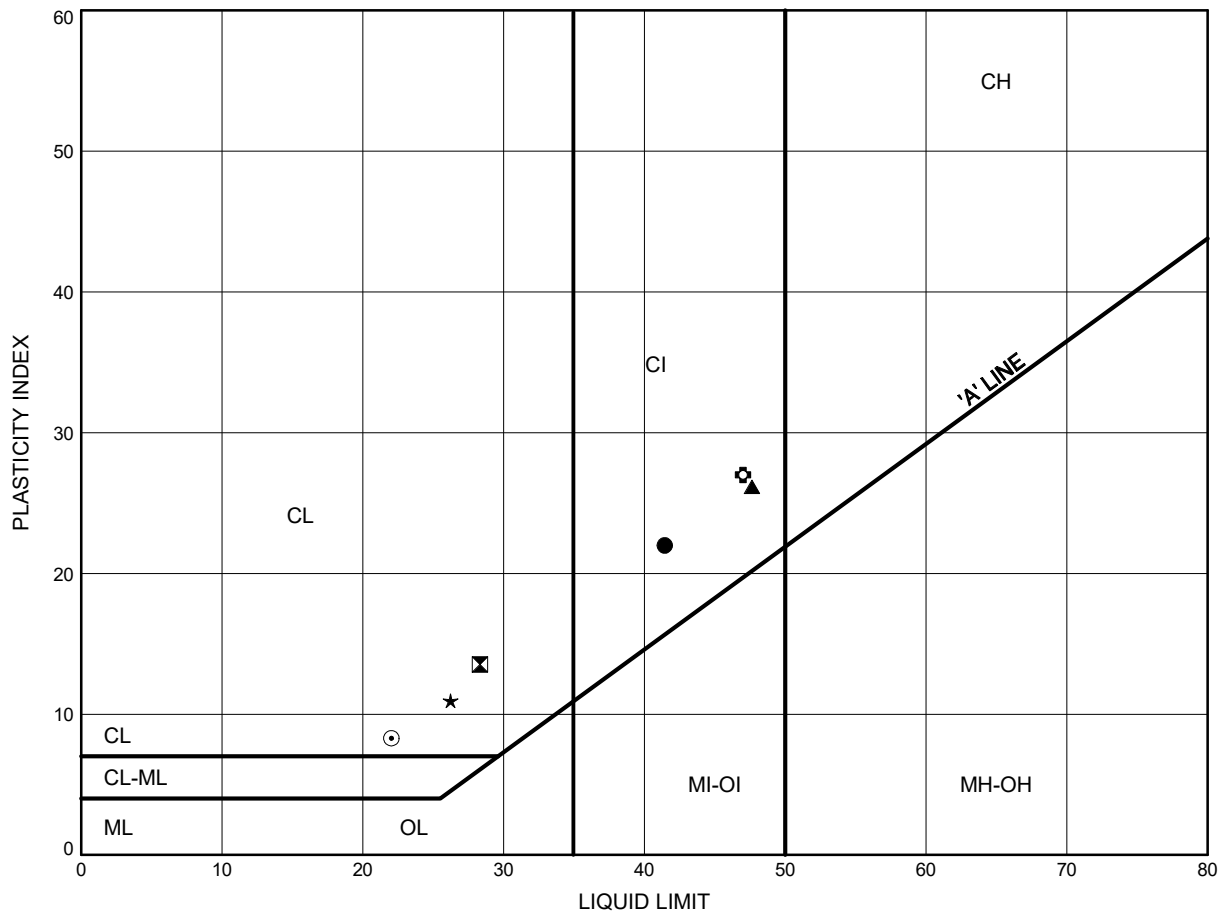


Prep'd JG
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C17

Silty Clay to Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BRN-1	4.9	124.9
⊠	BRN-2	4.9	123.5
▲	BRN-4	3.4	125.0
★	BRN-4	9.5	118.9
⊙	BRN-5	9.5	120.4
⊕	OBR19-01	1.8	128.1

Date April 2020
 WP# 4068-09-00

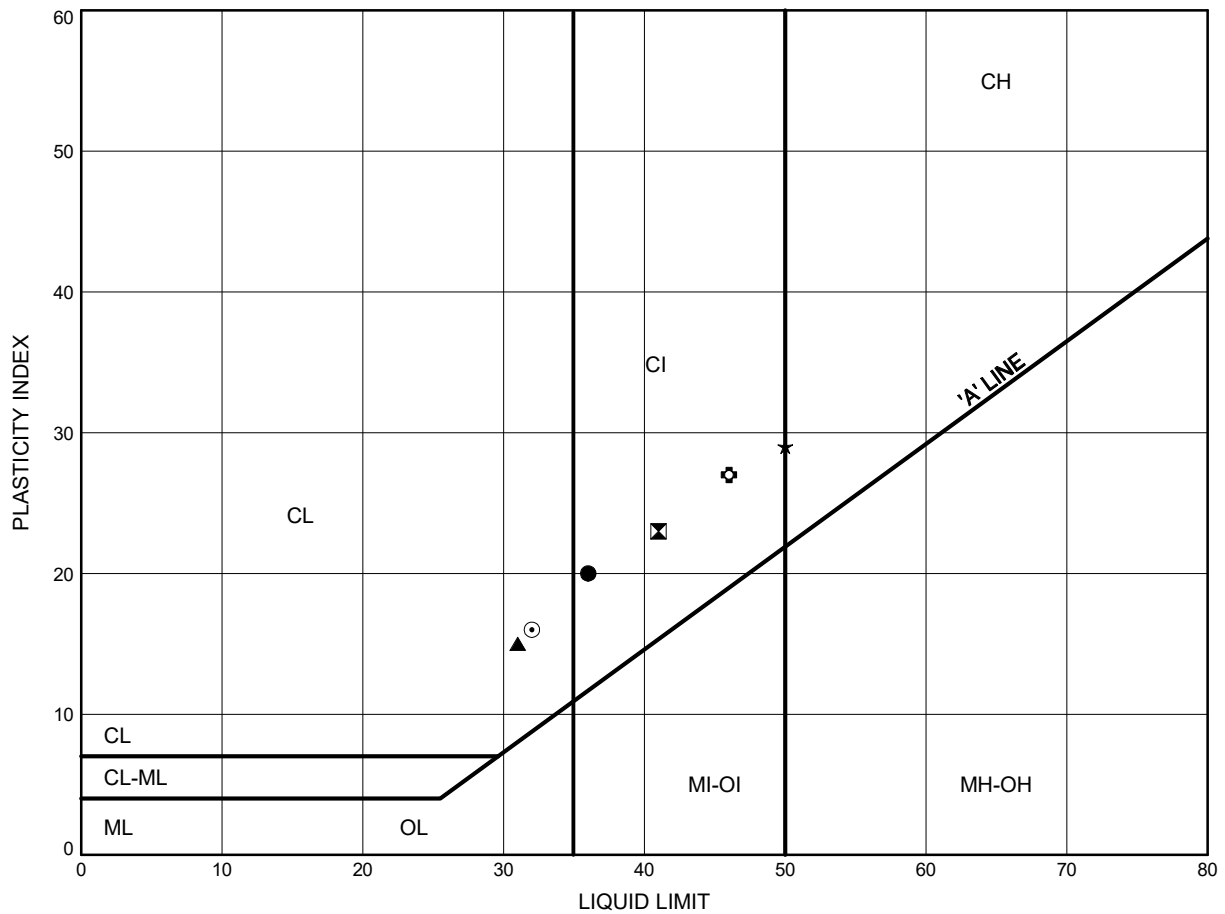


Prep'd JG
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C18

Silty Clay to Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-01	6.4	123.5
⊠	OBR19-02	3.4	126.4
▲	OBR19-02	8.7	121.1
★	OBR19-03	2.6	127.3
⊙	OBR19-03	8.7	121.2
⊕	OBR19-04	3.4	126.8

Date April 2020
 WP# 4068-09-00

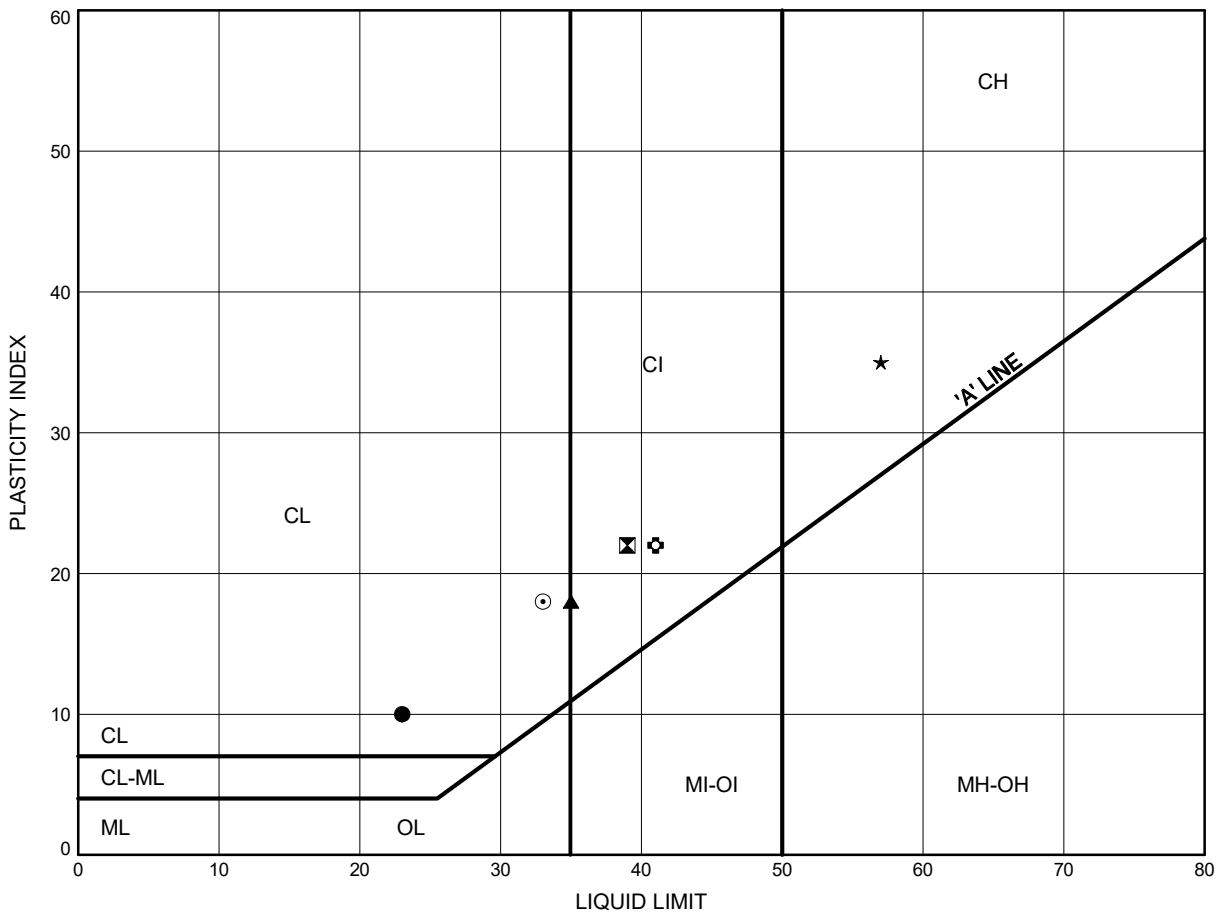


Prep'd JG
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C19

Silty Clay to Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-04	10.2	120.0
⊠	OBR19-05	4.9	124.9
▲	OBR19-05	7.9	121.9
★	OBR19-06	3.4	126.6
⊙	OBR19-06	7.2	122.8
⊕	OBR19-07	1.8	128.0

Date April 2020
 WP# 4068-09-00

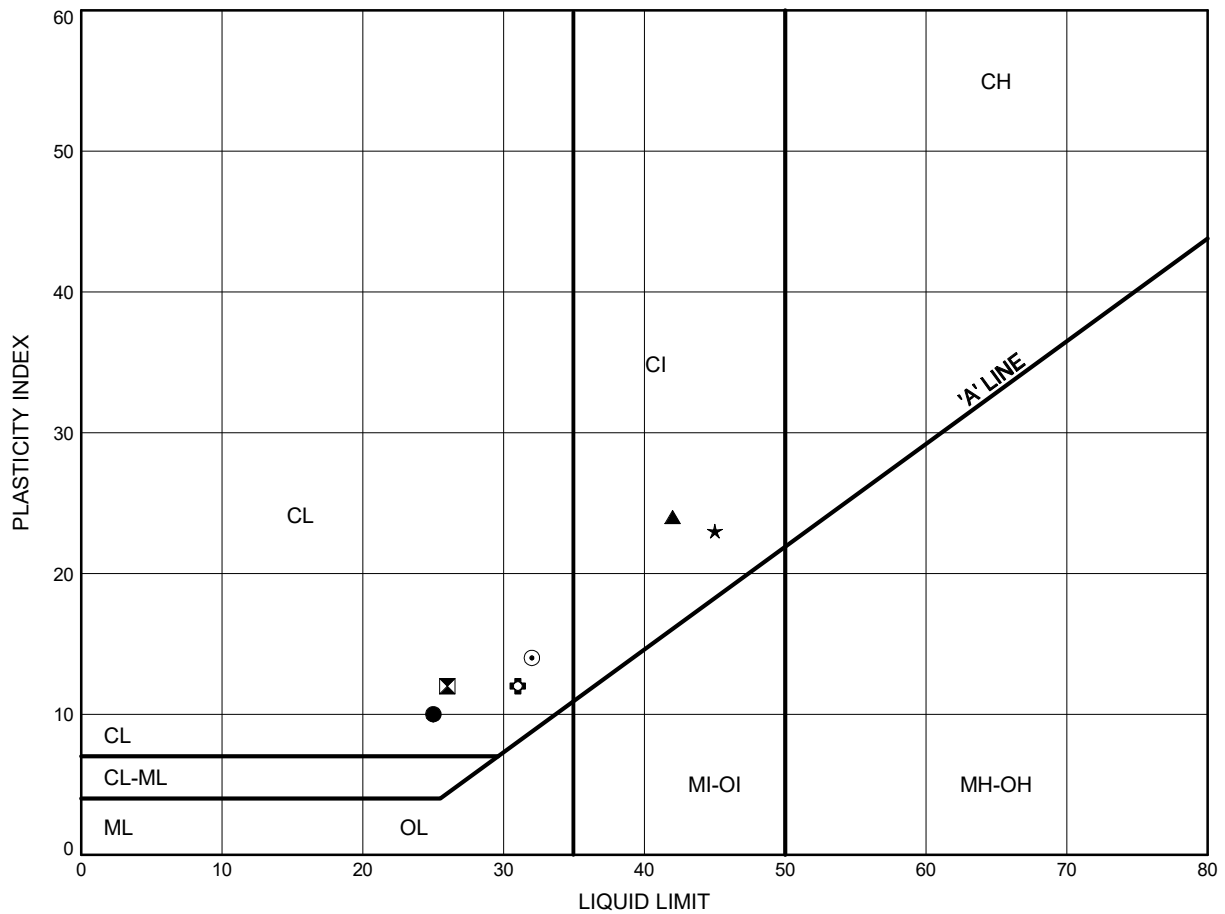


Prep'd JG
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C20

Silty Clay to Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-07	6.4	123.4
⊠	OBR19-07	7.9	121.9
▲	OBR19-08	3.4	126.6
★	OBR19-09	2.6	125.7
⊙	OBR19-09	5.6	122.7
⊕	OBR19-09	8.7	119.6

Date April 2020
 WP# 4068-09-00

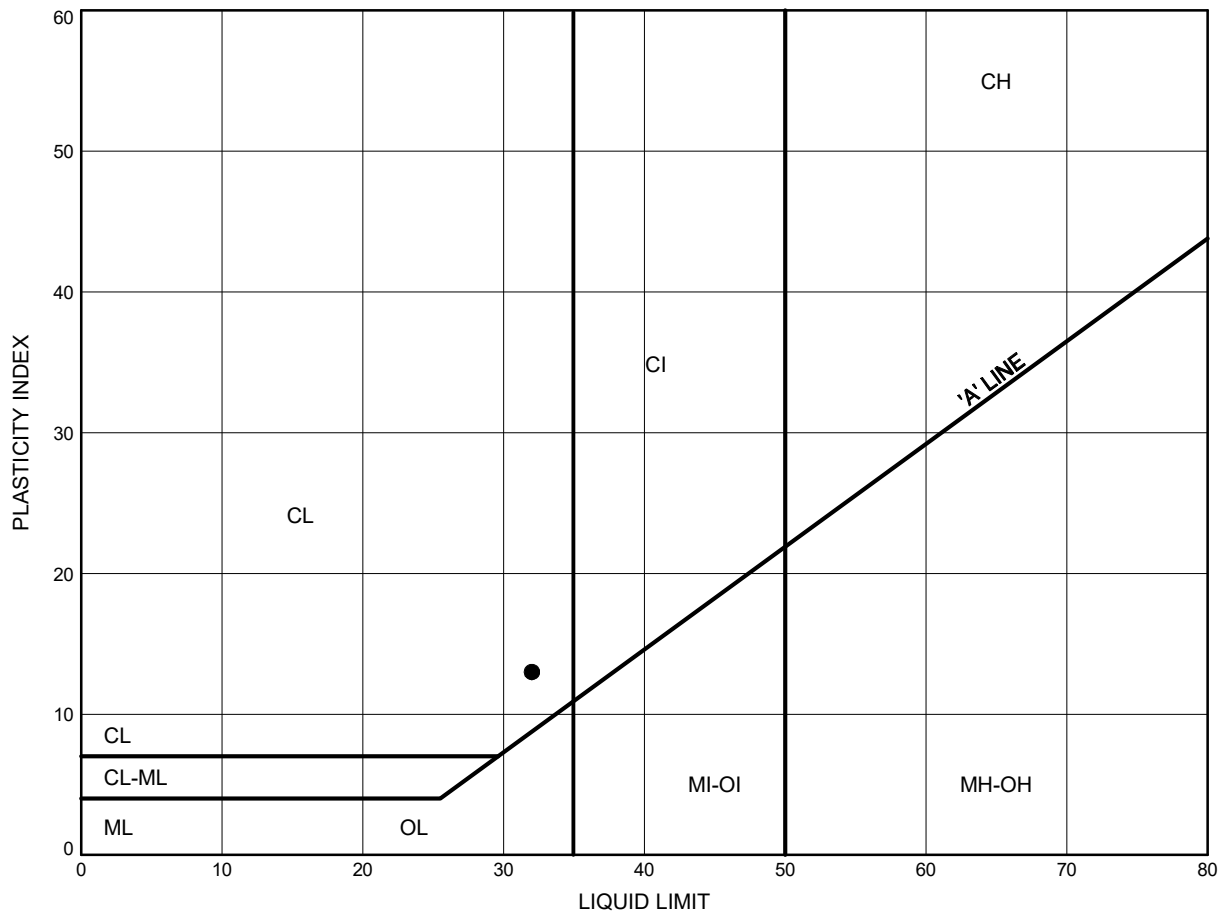


Prep'd JG
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C21

Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OBR19-15	11.0	118.1

Date April 2020
 WP# 4068-09-00



Prep'd JG
 Chkd. FG

Appendix C.2
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Chris Murray

Client PO:
Project: 24726
Custody: 49171

Report Date: 24-Sep-2019
Order Date: 18-Sep-2019

Order #: 1938289

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1938289-01	OBR 19-01, SS5 (10'-12')
1938289-02	OBR 19-04, SS4 (7'6"-9'6")

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	23-Sep-19	23-Sep-19
Conductivity	MOE E3138 - probe @25 °C, water ext	24-Sep-19	24-Sep-19
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	19-Sep-19	19-Sep-19
Resistivity	EPA 120.1 - probe, water extraction	24-Sep-19	24-Sep-19
Solids, %	Gravimetric, calculation	18-Sep-19	18-Sep-19

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Client ID:	OBR 19-01, SS5 (10'-12')	OBR 19-04, SS4 (7'6"-9'6")	-	-
Sample Date:	09-Sep-19 09:00	12-Sep-19 09:00	-	-
Sample ID:	1938289-01	1938289-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	79.2	78.0	-	-
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General Inorganics

Conductivity	5 uS/cm	555	876	-	-
pH	0.05 pH Units	7.40	7.55	-	-
Resistivity	0.10 Ohm.m	18.0	11.4	-	-

Anions

Chloride	5 ug/g dry	277	434	-	-
Sulphate	5 ug/g dry	35	53	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	275	5	ug/g dry	277			0.9	20	
Sulphate	34.2	5	ug/g dry	34.6			1.3	20	
General Inorganics									
pH	7.39	0.05	pH Units	7.50			1.5	2.3	
Resistivity	18.2	0.10	Ohm.m	17.2			5.6	20	
Physical Characteristics									
% Solids	77.6	0.1	% by Wt.	79.2			2.1	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	372	5	ug/g	277	94.1	82-118			
Sulphate	142	5	ug/g	34.6	108	80-120			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 24-Sep-2019

Order Date: 18-Sep-2019

Project Description: 24726

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104

Ottawa, ON K1B4S5

Attn: Chris Murray

Tel: (613) 247-2121

Fax: (613) 247-2185

Paracel Report No **1938289**

Client Project(s): **24726**

Client PO:

Reference: **Standing Offer**

Order Date: 18-Sep-19

Report Date: 23-Sep-19

CoC Number: **49171**

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1938289-01	OBR 19-01, SS5 (10'-12')	Sulphide, solid
1938289-02	OBR 19-04, SS4 (7'6"-9'6")	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

23-September-2019

Date Rec. : 19 September 2019
LR Report: CA13704-SEP19
Reference: Project#: 1938289

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		20-Sep-19
2: Analysis Start Time		12:49
3: Analysis Completed Date		20-Sep-19
4: Analysis Completed Time		14:35
5: QC - Blank		< 0.02
6: QC - STD % Recovery		113%
7: QC - DUP % RPD		3%
8: RL		0.02
9: OBR 19-01, SS5 (10'-12')	09-Sep-19	0.03
10: OBR 19-01, SS4 (7'6"-9'6")	12-Sep-19	0.03

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Chris Murray

Client PO:
Project: 24726
Custody: 49174

Report Date: 3-Oct-2019
Order Date: 27-Sep-2019

Order #: 1939628

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1939628-01	OBR19-02, SS3(5'-7')
1939628-02	OBR19-05, SS3(5'-7')

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019
Order Date: 27-Sep-2019
Project Description: 24726

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	30-Sep-19	1-Oct-19
Conductivity	MOE E3138 - probe @25 °C, water ext	30-Sep-19	30-Sep-19
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	1-Oct-19	1-Oct-19
Resistivity	EPA 120.1 - probe, water extraction	30-Sep-19	30-Sep-19
Solids, %	Gravimetric, calculation	27-Sep-19	27-Sep-19

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019

Order Date: 27-Sep-2019

Project Description: 24726

Client ID:	OBR19-02, SS3(5'-7')	OBR19-05, SS3(5'-7')	-	-
Sample Date:	20-Sep-19 09:00	16-Sep-19 09:00	-	-
Sample ID:	1939628-01	1939628-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	75.2	76.1	-	-
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General Inorganics

Conductivity	5 uS/cm	184	4180	-	-
pH	0.05 pH Units	7.55	7.87	-	-
Resistivity	0.10 Ohm.m	54.4	2.39	-	-

Anions

Chloride	5 ug/g dry	36	74	-	-
Sulphate	5 ug/g dry	13	2460	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019
Order Date: 27-Sep-2019
Project Description: 24726

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019
Order Date: 27-Sep-2019
Project Description: 24726

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	8.3	5	ug/g dry	8.7			4.6	20	
Sulphate	24.0	5	ug/g dry	24.9			3.6	20	
General Inorganics									
Conductivity	868	5	uS/cm	861			0.8	5	
pH	7.50	0.05	pH Units	7.50			0.0	2.3	
Resistivity	11.5	0.10	Ohm.m	11.6			0.8	20	
Physical Characteristics									
% Solids	81.3	0.1	% by Wt.	80.8			0.6	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019
Order Date: 27-Sep-2019
Project Description: 24726

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	94.9	5	ug/g	8.7	86.2	82-118			
Sulphate	127	5	ug/g	24.9	102	80-120			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 03-Oct-2019
Order Date: 27-Sep-2019
Project Description: 24726

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Chris Murray

Tel: (613) 247-2121
Fax: (613) 247-2185

Paracel Report No **1939628**

Client Project(s): **24726**

Client PO:

Reference: **Standing Offer**

CoC Number: **49174**

Order Date: 27-Sep-19
Report Date: 4-Oct-19

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1939628-01	OBR19-02, SS3(5'-7')	Sulphide, solid
1939628-02	OBR19-05, SS3(5'-7')	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

04-October-2019

Date Rec. : 01 October 2019
LR Report: CA12036-OCT19
Reference: Project#:1939628

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		04-Oct-19
2: Analysis Start Time		16:08
3: Analysis Completed Date		04-Oct-19
4: Analysis Completed Time		16:27
5: QC - Blank		< 0.02
6: QC - STD % Recovery		111%
7: QC - DUP % RPD		18%
8: RL		0.02
9: OBR19-02, SS3 (5'-7')	20-Sep-19	0.03
10: OBR19-05, SS3 (5'-7')	16-Sep-19	0.03

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Client PO: 24726
Project: Hwy 17, W-N/S Ramp Culvert
Custody: 49177

Report Date: 20-Oct-2019
Order Date: 16-Oct-2019

Order #: 1942180

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1942180-01	CV-9, SS3 (5'-7')

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	17-Oct-19	17-Oct-19
Conductivity	MOE E3138 - probe @25 °C, water ext	17-Oct-19	18-Oct-19
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	18-Oct-19	19-Oct-19
Resistivity	EPA 120.1 - probe, water extraction	17-Oct-19	18-Oct-19
Solids, %	Gravimetric, calculation	17-Oct-19	17-Oct-19

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Client ID:	CV-9, SS3 (5'-7')	-	-	-
Sample Date:	15-Oct-19 09:00	-	-	-
Sample ID:	1942180-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	87.6	-	-	-
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General Inorganics

Conductivity	5 uS/cm	103	-	-	-
pH	0.05 pH Units	7.98	-	-	-
Resistivity	0.10 Ohm.m	97.5	-	-	-

Anions

Chloride	5 ug/g dry	11	-	-	-
Sulphate	5 ug/g dry	10	-	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	120	5	ug/g dry	123			3.1	20	
Sulphate	323	5	ug/g dry	332			2.8	20	
General Inorganics									
Conductivity	114	5	uS/cm	117			2.6	5	
pH	7.30	0.05	pH Units	7.33			0.4	2.3	
Resistivity	87.7	0.10	Ohm.m	85.5			2.6	20	
Physical Characteristics									
% Solids	87.2	0.1	% by Wt.	87.5			0.4	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	215	5	ug/g	123	91.2	82-118			
Sulphate	421	5	ug/g	332	88.8	80-120			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24726

Report Date: 20-Oct-2019

Order Date: 16-Oct-2019

Project Description: Hwy 17, W-N/S Ramp Culvert

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104

Ottawa, ON K1B 4S5

Attn: Justin Gray

Tel: (613) 408-6795

Fax: (613) 247-2185

Paracel Report No **1942180**

Client Project(s): **Hwy 17, W-N/S Ramp Culvert**

Client PO: **24726**

Reference: **Standing Offer**

CoC Number: **49177**

Order Date: 16-Oct-19

Report Date: 20-Oct-19

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID

1942180-01

Client ID

CV-9, SS3 (5'-7')

Analysis

Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

23-October-2019

Date Rec. : 17 October 2019
LR Report: CA15376-OCT19
Reference: Project#: 1942180

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		23-Oct-19
2: Analysis Start Time		14:17
3: Analysis Completed Date		23-Oct-19
4: Analysis Completed Time		14:33
5: QC - Blank		< 0.02
6: QC - STD % Recovery		113%
7: QC - DUP % RPD		4%
8: RL		0.02
9: CV-9, SS3 (5'-7')	15-Oct-19	< 0.02

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety

Appendix C.3
UCS Test Results

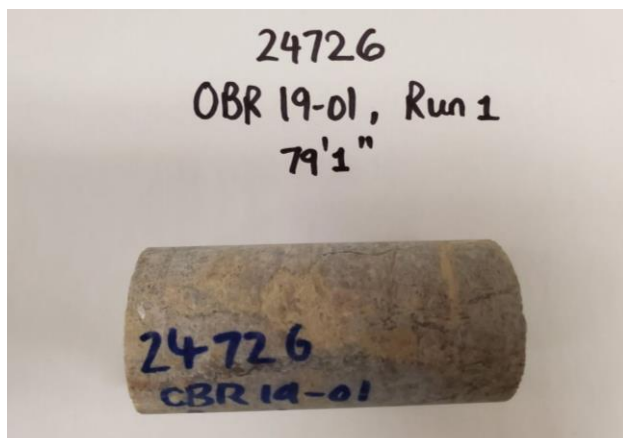
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

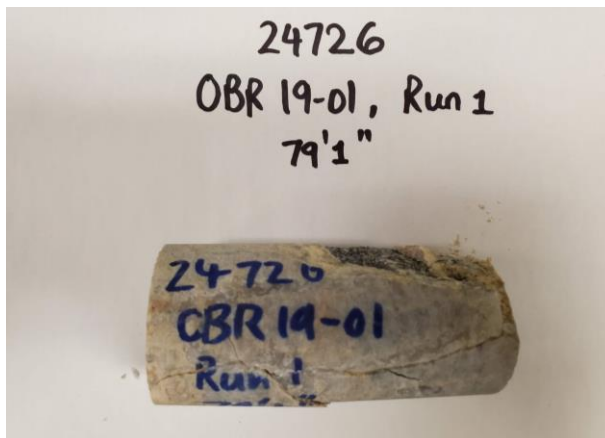
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	24-Mar-20
BOREHOLE No.:	OBR 19-01	TEST DATE:	12-Dec-19
SAMPLE No.:	NQ RUN 3		
SAMPLE DEPTH:	24.1m		
DESCRIPTION:	Marble		

Avg. Height (cm):	9.7	Weight (g):	479.4
Avg. Diameter (cm):	4.8	Wet Density (kg/m ³):	2,731
H. to Dia. Ratio**:	2:1	Dry Density (kg/m ³):	2,731
Cross Sectional Area (cm ²):	18.10	Moisture Content* (%):	N/A
Sample Volume (cm ³):	175.53		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	1.5% / min
MAXIMUM COMPRESSIVE LOAD:	68.4 kN
UNCONFINED COMPRESSIVE STRENGTH:	37.8 MPa

Note: * Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: BS
REVIEWED BY: WM

24726 - OBR 19-01 UCS Run 1, 79'1

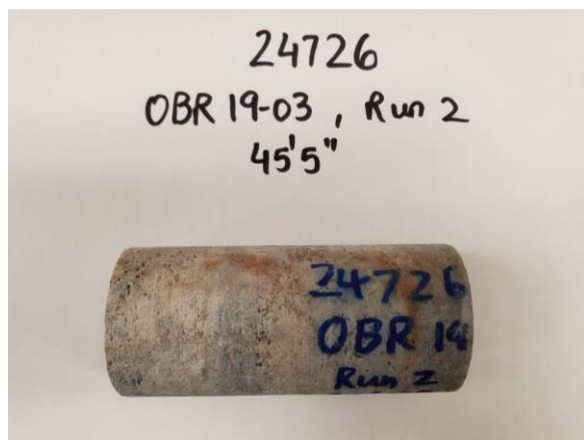
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

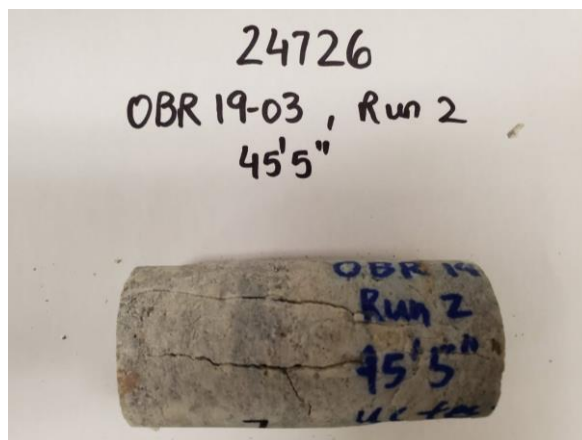
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	24-Mar-20
BOREHOLE No.:	OBR 19-03	TEST DATE:	12-Dec-19
SAMPLE No.:	NQ RUN 2		
SAMPLE DEPTH:	13.8m		
DESCRIPTION:	Marble		

Avg. Height (cm):	9.8	Weight (g):	476.7
Avg. Diameter (cm):	4.8	Wet Density (kg/m ³):	2,688
H. to Dia. Ratio**:	2:1	Dry Density (kg/m ³):	2,688
Cross Sectional Area (cm ²):	18.10	Moisture Content* (%):	N/A
Sample Volume (cm ³):	177.34		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	1.5% / min
MAXIMUM COMPRESSIVE LOAD:	71.9 kN
UNCONFINED COMPRESSIVE STRENGTH:	39.7 MPa

Note: * Dimensions of Specimen conform to ASTM D 4543-04.

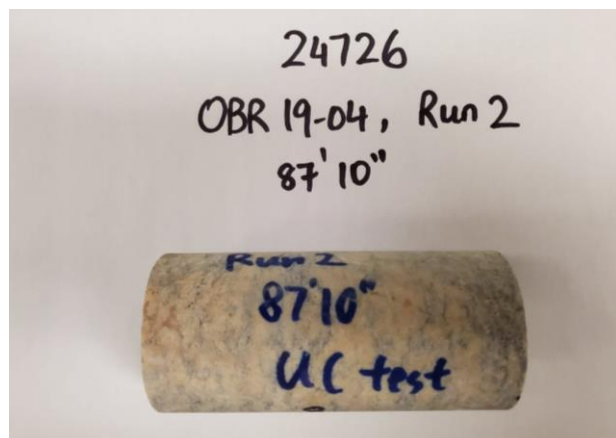
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

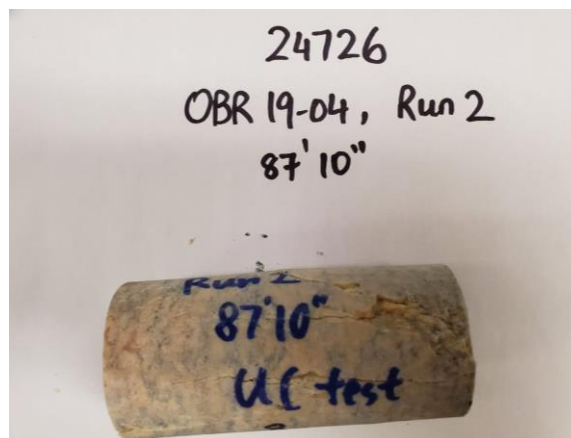
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	24-Mar-20
BOREHOLE No.:	OBR 19-04	TEST DATE:	12-Dec-19
SAMPLE No.:	NQ RUN 2		
SAMPLE DEPTH:	26.8m		
DESCRIPTION:	Marble		

Avg. Height (cm):	9.7	Weight (g):	476.4
Avg. Diameter (cm):	4.7	Wet Density (kg/m ³):	2,831
H. to Dia. Ratio**:	2.1:1	Dry Density (kg/m ³):	2,831
Cross Sectional Area (cm ²):	17.35	Moisture Content* (%):	N/A
Sample Volume (cm ³):	168.29		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	1.5% / min
MAXIMUM COMPRESSIVE LOAD:	62.9 kN
UNCONFINED COMPRESSIVE STRENGTH:	36.3 MPa

Note: * Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: BS
REVIEWED BY: WM

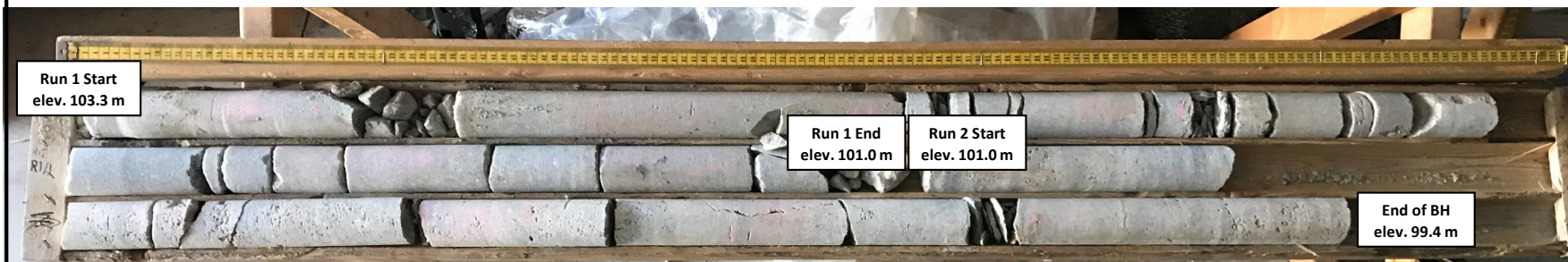
24726 - OBR 19-04 UCS Run 2, 87'10

Appendix C.4
Bedrock Core Photographs

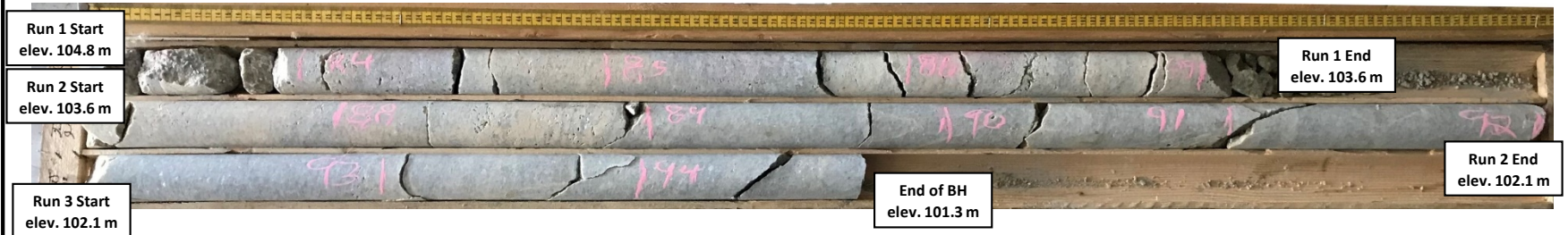
Borehole OBR19-1
Run 1 to 3 (of 3)
Elevation 106.7 m to 103.0 m



Borehole OBR19-3
Run 1 to 2 (of 2)
Elevation 103.3 m to 99.4 m



Borehole OBR19-4
Run 1 to 3 (of 3)
Elevation 104.8 m to 101.3 m



THURBER ENGINEERING LTD.

Geotechnical Investigation
HWY 17 Twinning
Renfrew, Ontario

OBR19-4
Project No.: 24726

Borehole CV-7
Run 1 to 4 (of 4)
Elevation 113.8 m to 110.8 m



Borehole CV-8
Run 1 to 4 (of 4)
Elevation 112.3 m to 108.6 m



Borehole CV-9
Run 1 to 3 (of 3)
Elevation 110.5 m to 106.9 m

Run 1 Start
elev. 110.5 m



Appendix D.
Site Photographs



Photo 1. Looking north from O'Brien Road towards existing intersection (2019/07/03)



Photo 2. Looking west from Highway 17 towards existing intersection (2019/07/03)



Photo 3. Looking east along W-S Ramp alignment at approximate station 20+950. Borehole OBR19-14 and large surficial boulders in foreground (2020/04/22)



Photo 4. Looking south-west in ravine of W-S Ramp at approximate station 21+175 (2020/04/22)

Appendix E.
ConeTec Report

PRESENTATION OF SITE INVESTIGATION RESULTS

Highway 17 and O'Brien Road

Prepared for:

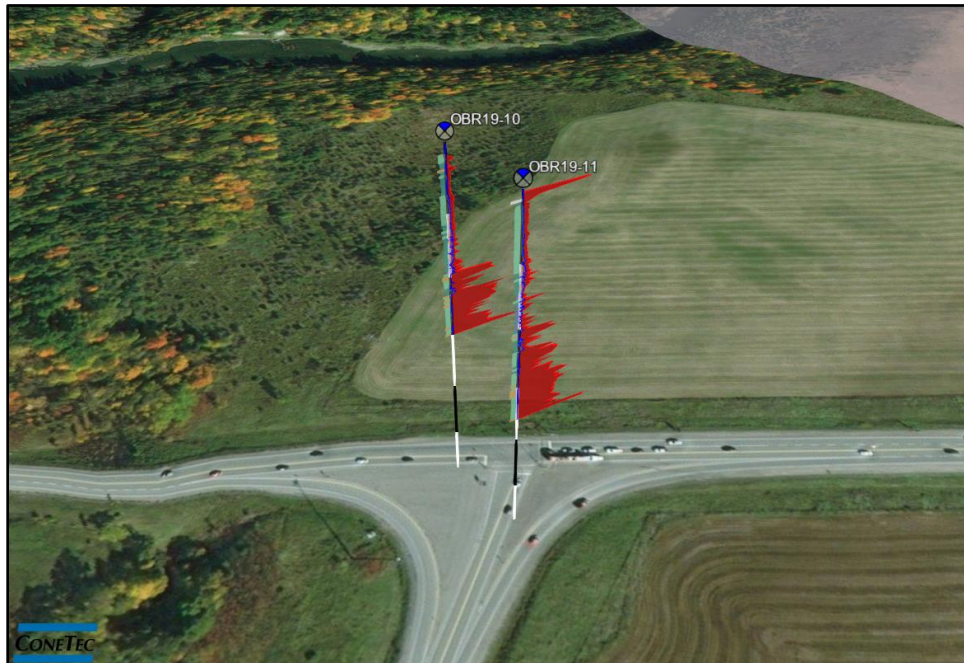
Thurber Engineering Ltd.

ConeTec Job No: 19-05076

Project Start Date: 29-Nov-2019

Project End Date: 29-Nov-2019

Report Date: 05-Dec-2019



Prepared by:

ConeTec Investigations Ltd.
9033 Leslie Street, Unit 15
Richmond Hill, ON L4B 4K3

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Fax: (905) 886-2664
Toll Free: (800) 504-1116

ConeTecON@conetec.com
www.conetec.com
www.conetecdataservices.com



Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Investigations Ltd. for Thurber Engineering Ltd. at Highway 17 and Bruce Street, Renfrew, ON. The program consisted of two seismic cone penetration tests (SCPTu).

Project Information

Project	
Client	Thurber Engineering Ltd.
Project	Highway 17 and O'Brien Road
ConeTec project number	19-05076

An aerial overview from Google Earth including the SCPTu test locations is presented below.



Rig Description	Deployment System	Test Type
CPT track rig (M5T)	14 ton rig cylinder	SCPTu

Coordinates			
Test Type	Collection Method	EPSG Number	Comments
SCPTu	Client Provided	32189	Coordinates and elevations were provided by the client in datum MTM zone 9.

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm ²)	Sleeve Area (cm ²)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
377:T1000F10U500	377	10	150	1000	10	500
Cone 377 was used for all CPT soundings.						

Cone Penetration Test (CPTu)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	<ul style="list-style-type: none"> Advanced plots with I_c, S_u, ϕ and $N1(60)$ Seismic shear wave velocity plots Soil Behaviour Type (SBT) scatter plots

Calculated Geotechnical Parameter Tables	
Additional information	<p>The Normalized Soil Behaviour Type Chart based on Q_{tn} (SBT Q_{tn}) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPTu parameters have been generated and are provided in Excel format files in the release folder. The CPTu parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s) and pore pressure (u_2).</p> <p>Effective stresses are calculated based on unit weights that have been assigned to the individual soil behaviour type zones and the assumed equilibrium pore pressure profile.</p> <p>Soils were classified as either drained or undrained based on the Q_{tn} Normalized Soil Behaviour Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures (zone 4) and sand mixtures (zone 5).</p>

Limitations

This report has been prepared for the exclusive use of Thurber Engineering Ltd. (Client) for the project titled "Highway 17 and O'Brien Road". The report's contents may not be relied upon by any other party without the express written permission of ConeTec Investigations Ltd. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

Cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd., a subsidiary of ConeTec.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in 5 cm², 10 cm² and 15 cm² tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first appendix. The 15 cm² penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm² piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u₂" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meets or exceeds those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

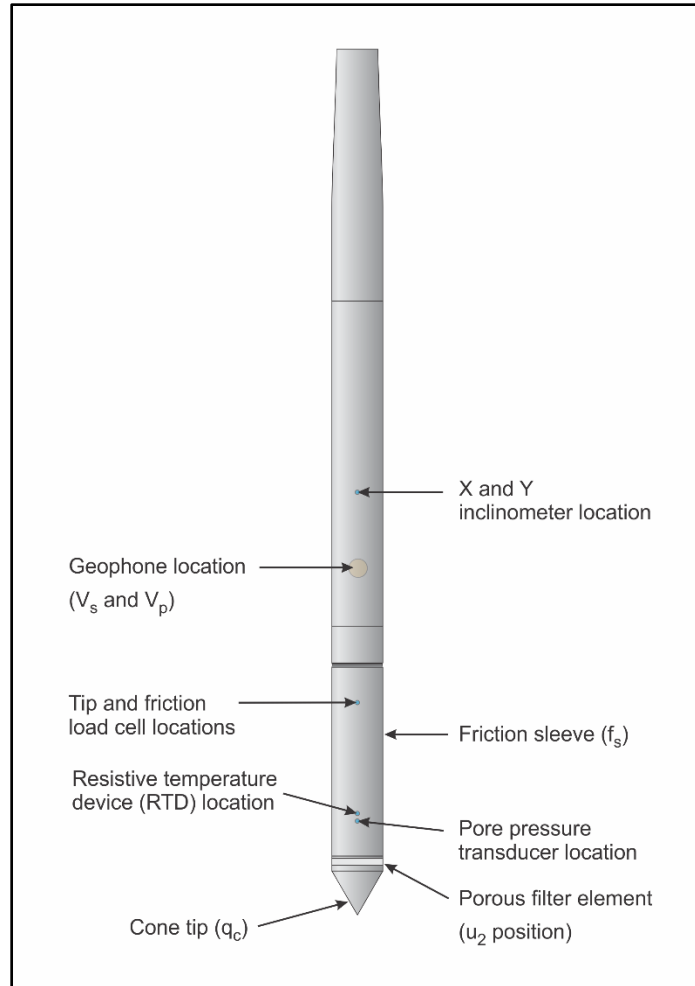


Figure CPTu. Piezocone Penetrometer (15 cm²)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording interval is 2.5 cm; custom recording intervals are possible.

The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerine or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 38.1 mm are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson et al. (1986) and Robertson (1990, 2009). It should be noted that it is not always possible to accurately identify a soil behaviour type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behaviour type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al. (1986):

$$q_t = q_c + (1-a) \cdot u_2$$

where: q_t is the corrected tip resistance

q_c is the recorded tip resistance

u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)

a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (R_f) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

Shear wave velocity (V_s) testing is performed in conjunction with the piezocone penetration test (SCPTu) in order to collect interval velocities. For some projects seismic compression wave velocity (V_p) testing is also performed.

ConeTec's piezocone penetrometers are manufactured with a horizontally active geophone (28 hertz) that is rigidly mounted in the body of the cone penetrometer, 0.2 meters behind the cone tip.

Shear waves are typically generated by using an impact hammer horizontally striking a beam that is held in place by a normal load. In some instances an auger source or an imbedded impulsive source maybe used for both shear waves and compression waves. The hammer and beam act as a contact trigger that initiates the recording of the seismic wave traces. For impulsive devices an accelerometer trigger may be used. The traces are recorded using an up-hole integrated digital oscilloscope which is part of the SCPTu data acquisition system. An illustration of the shear wave testing configuration is presented in Figure SCPTu-1.

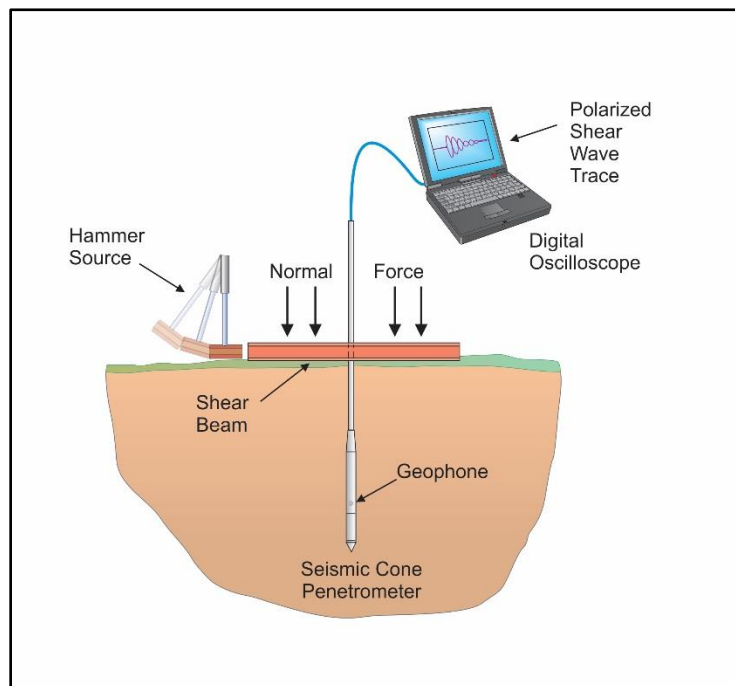


Figure SCPTu-1. Illustration of the SCPTu system

All testing is performed in accordance to ConeTec's SCPTu operating procedures which are in general accordance with the current ASTM D5778 and ASTM D7400 standards.

Prior to the start of a SCPTu sounding, the procedures described in the Cone Penetration Test section are followed. In addition, the active axis of the geophone is aligned parallel to the beam (or source) and the horizontal offset between the cone and the source is measured and recorded.

Prior to recording seismic waves at each test depth, cone penetration is stopped and the rods are decoupled from the rig to avoid transmission of rig energy down the rods. Typically, five wave traces for each orientation are recorded for quality control and uncertainty analysis purposes. After reviewing wave

traces for consistency the cone is pushed to the next test depth (typically one meter intervals or as requested by the client). Figure SCPTu-2 presents an illustration of a SCPTu test.

For additional information on seismic cone penetration testing refer to Robertson et. al. (1986).

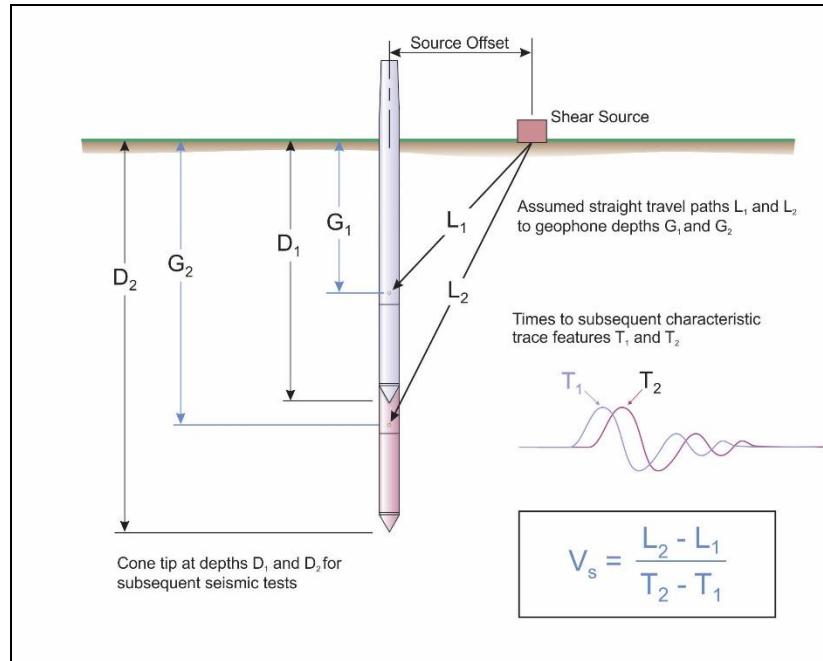


Figure SCPTu-2. Illustration of a seismic cone penetration test

Calculation of the interval velocities are performed by visually picking a common feature (e.g. the first characteristic peak, trough, or crossover) on all of the recorded wave sets and taking the difference in ray path divided by the time difference between subsequent features. Ray path is defined as the straight line distance from the seismic source to the geophone, accounting for beam offset, source depth and geophone offset from the cone tip.

The average shear wave velocity to a depth of 30 meters (V_{s30}) has been calculated and provided for all applicable soundings using an equation presented in Crow et al. (2012).

$$V_{s30} = \frac{\text{total thickness of all layers (30m)}}{\sum(\text{layer traveltimes})}$$

The layer travel times refers to the travel times propagating in the vertical direction, not the measured travel times from an offset source.

Tabular results and SCPTu plots are presented in the relevant appendix.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

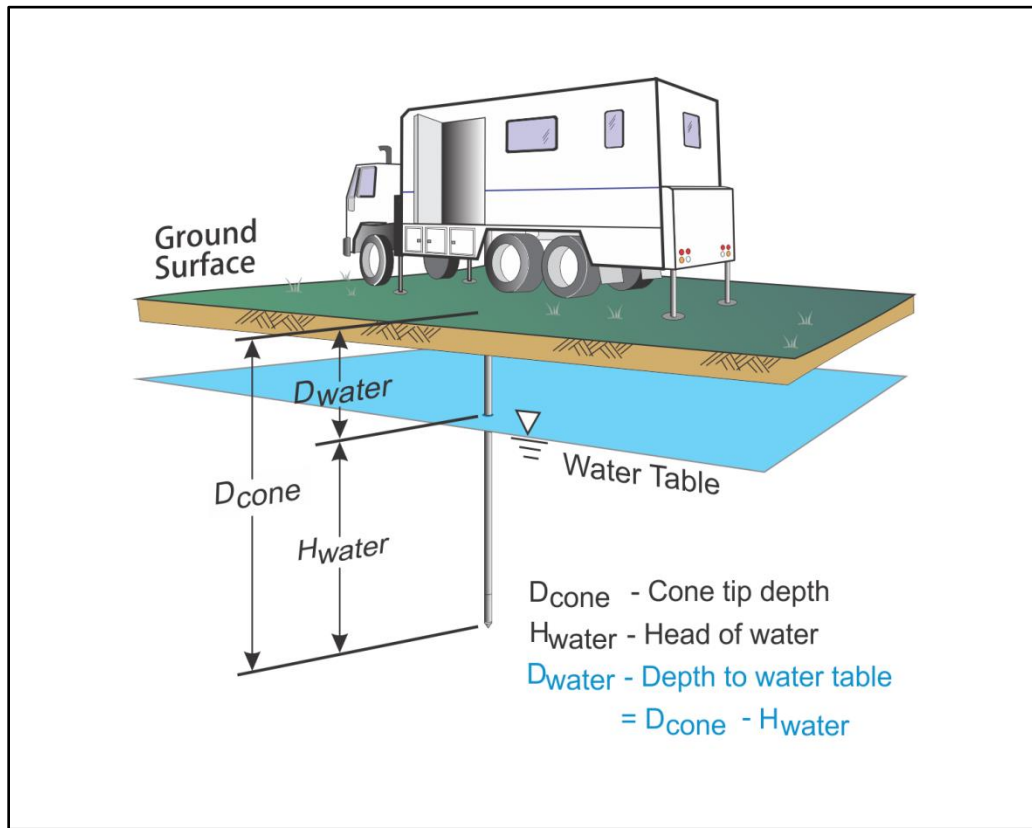


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behaviour.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

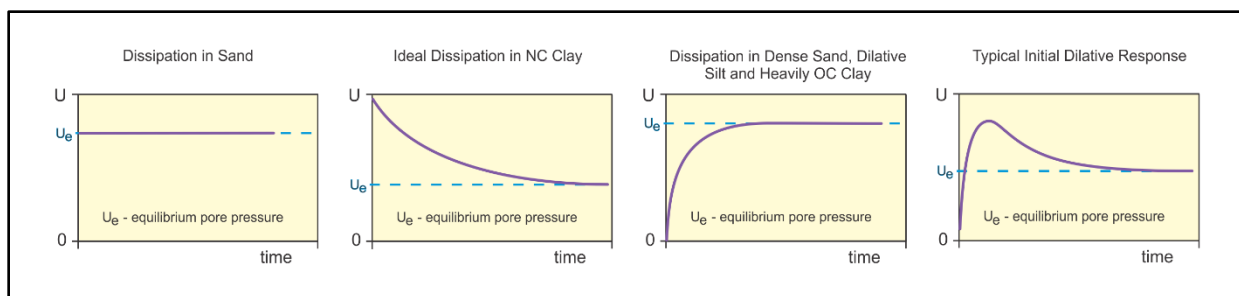


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve in Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100} . In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100} . A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T^*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

- T^* is the dimensionless time factor (Table Time Factor)
- a is the radius of the cone
- I_r is the rigidity index
- t is the time at the degree of consolidation

Table Time Factor. T^* versus degree of dissipation (Teh and Houlsby (1991))

Degree of Dissipation (%)	20	30	40	50	60	70	80
$T^* (u_2)$	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50} , dissipation tests must be taken to a pressure less than u_{50} . The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100} . To estimate u_{50} , both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby (1991)), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50} . In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r , the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50} , other methods should be applied to confirm the results for c_h .

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

REFERENCES

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REFERENCES

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, "An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils", *Canadian Geotechnical Journal*, 36(2): 369-381.

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The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots
- Seismic Cone Penetration Test Plots
- Seismic Cone Penetration Test Tabular Results
- Seismic Cone Penetration Test Shear Wave (V_s) Traces
- Soil Behaviour Type (SBT) Scatter Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

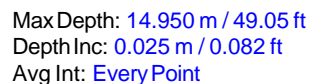


Job No: 19-05076
Client: Thurber Engineering Ltd.
Project: Highway 17 and O'Brien Road
Start Date: 29-Nov-2019
End Date: 29-Nov-2019

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface ¹ (m)	Final Depth (m)	Northing ² (m)	Easting ² (m)	Elevation ³ (m)	Refer to Notation Number
OBR19-10	19-05076_SP10	29-Nov-2019	377:T1000F10U500		14.950	5038072.30	293367.70	129.90	
OBR19-11	19-05076_SP11	29-Nov-2019	377:T1000F10U500		17.975	5038038.50	293374.50	129.80	

1. No phreatic surface detected. Unsaturated conditions were assumed for the calculated parameters.
2. Coordinates and elevations were provided by the client with datum NAD83/MTM Zone 9 North.
3. Elevations are referenced to the existing ground surface at the time of testing.



SBT: [Robertson, 2009 and 2010](#)
 Coords: [MTM9N](#): 5038072.30m E: 293367.70m Elev: 129.90m
 Sheet No: [1 of 1](#)

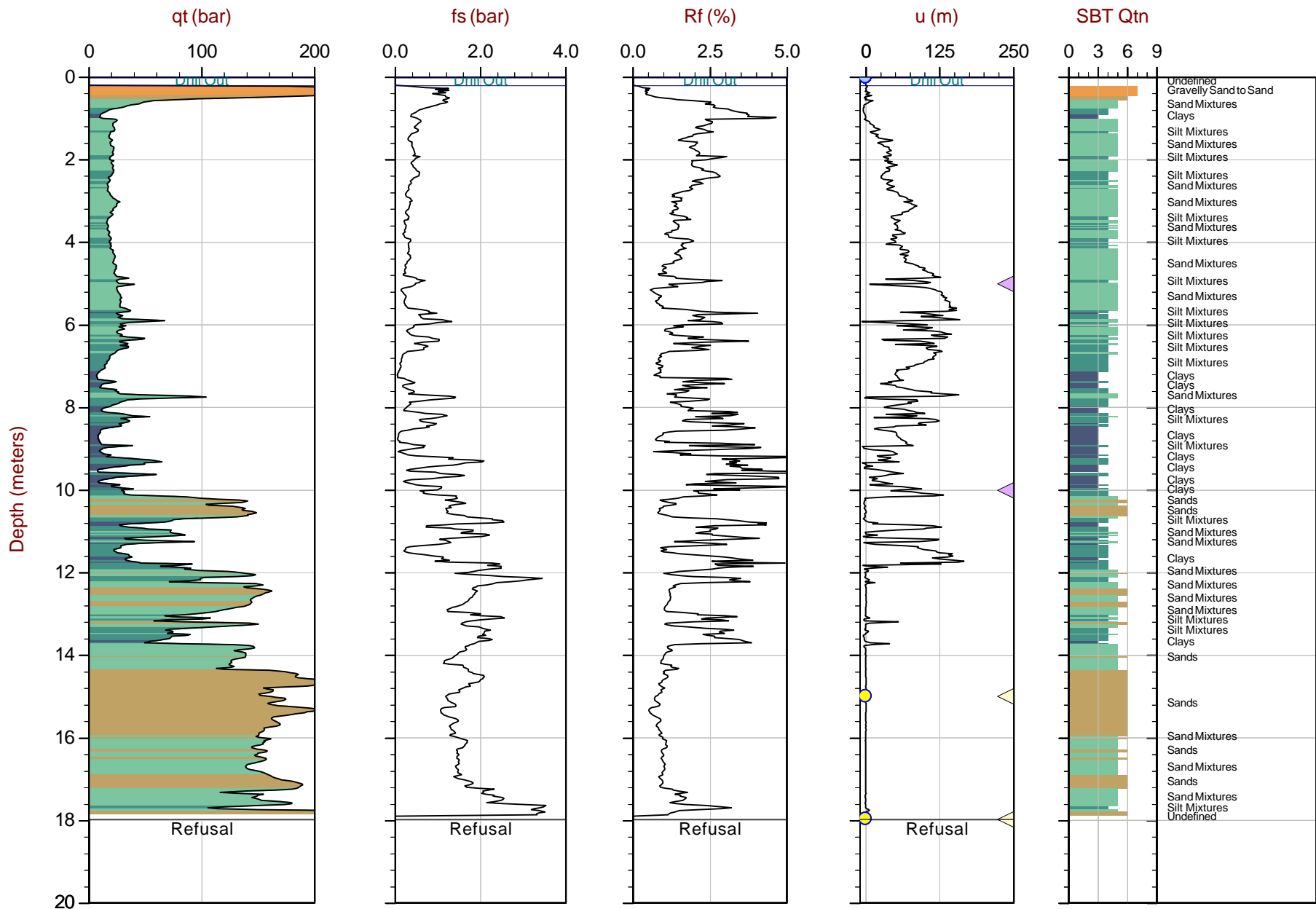
OverplotItem: ● Ueq ● Assumed Ueq ◀ Dissipation, Ueq achieved ◀ Dissipation, Ueq not achieved



Thurber

Job No: 19-05076
Date: 2019-11-29 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500



Max Depth: 17.975 m / 58.97 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-05076_SP11.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: MTM9 N N: 5038038.50m E: 293374.50m Elev: 129.80m
Sheet No: 1 of 1

Overplot Item: ● Ueq ● Assumed Ueq ▲ Dissipation, Ueq achieved ▲ Dissipation, Ueq not achieved

Advanced Cone Penetration Test Plots



Thurber

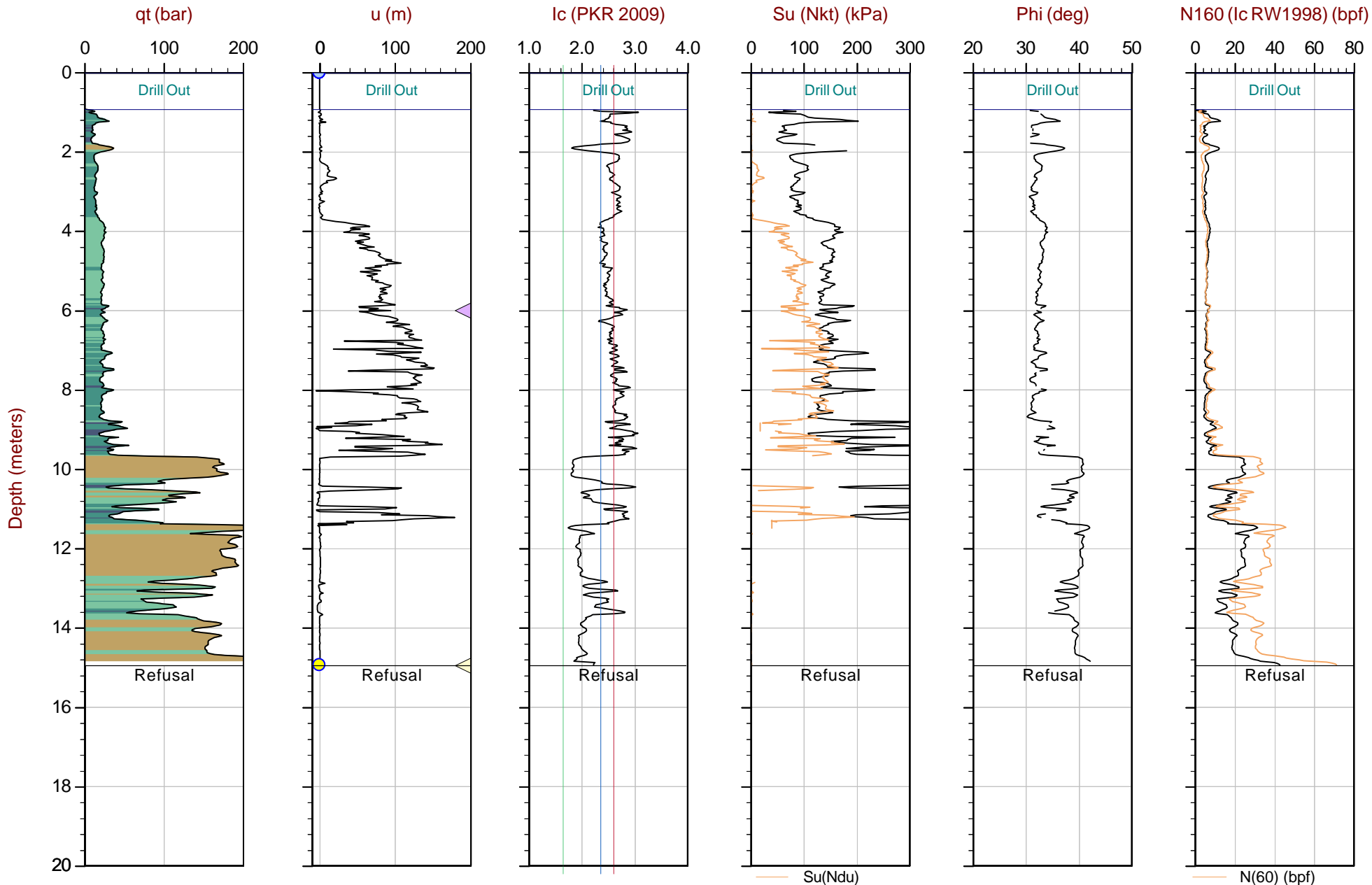
Job No: 19-05076

Date: 2019-11-29 09:33

Site: O'Brien Road

Sounding: OBR19-10

Cone: 377:T1000F10U500



Max Depth: 14.950 m / 49.05 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: Every Point

Overplot Item: ● Ueq ● Assumed Ueq

File: 19-05076_SP10.COR

Unit Wt: SBTQtn(PKR2009)

Su Nkt/Ndu: 15.0 / 9.0

△ Dissipation, Ueq achieved ▲ Dissipation, Ueq not achieved

SBT: Robertson, 2009 and 2010

Coords: MTM9 N N: 5038072.30m E: 293367.70m Elev: 129.90m

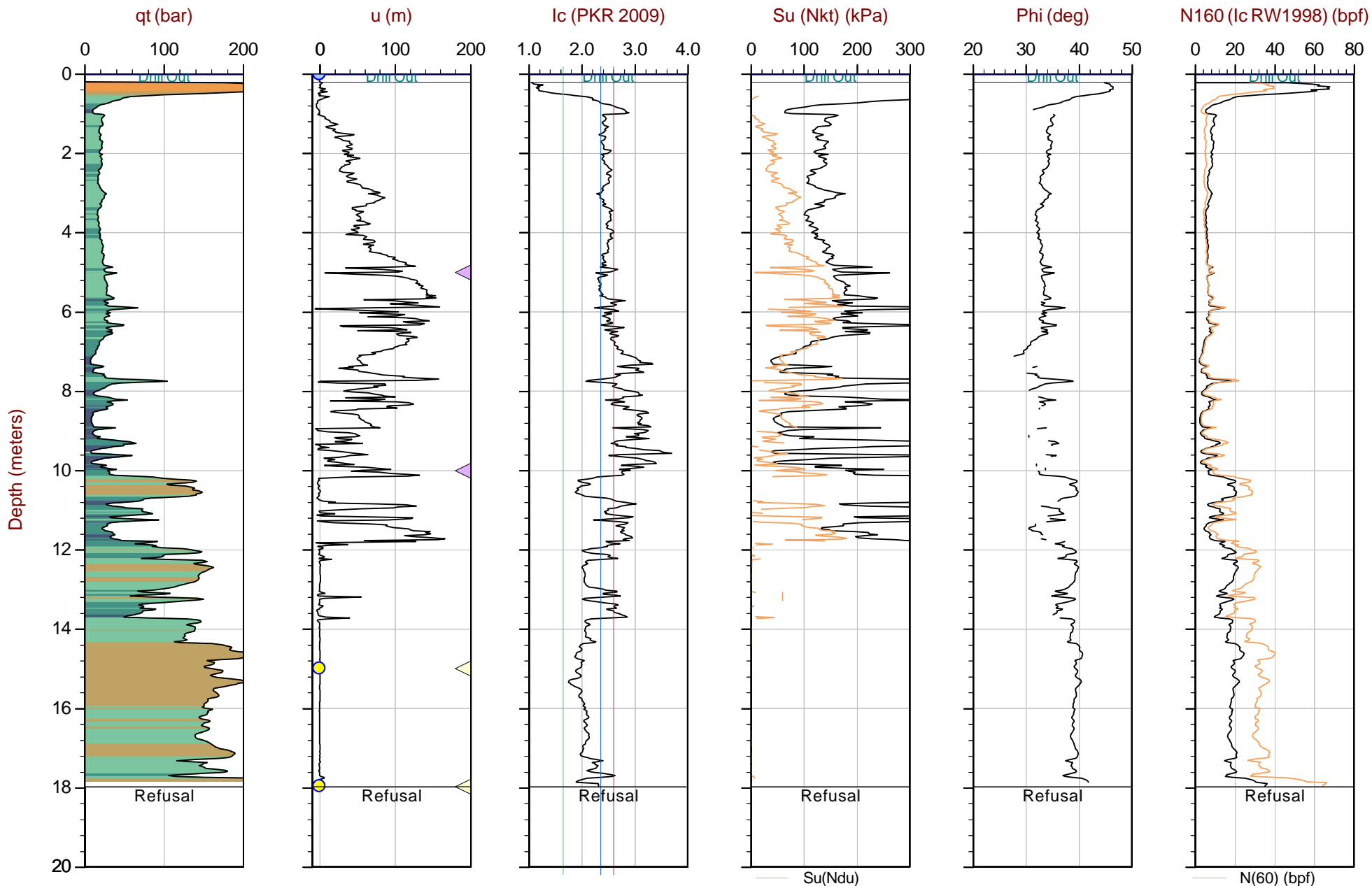
Sheet No: 1 of 1



Thurber

Job No: 19-05076
Date: 2019-11-29 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500



Max Depth: 17.975 m / 58.97 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

OverplotItem: ● Ueq ● Assumed Ueq

File: 19-05076_SP11.COR

Unit Wt: SBTQtn(PKR2009)

Su Nkt/Ndu: 15.0 / 9.0

△ Dissipation, Ueq achieved

◀ Dissipation, Ueq not achieved

SBT: Robertson, 2009 and 2010

Coords: MTM9 N N: 5038038.50m E: 293374.50m Elev: 129.80m

Sheet No: 1 of 1

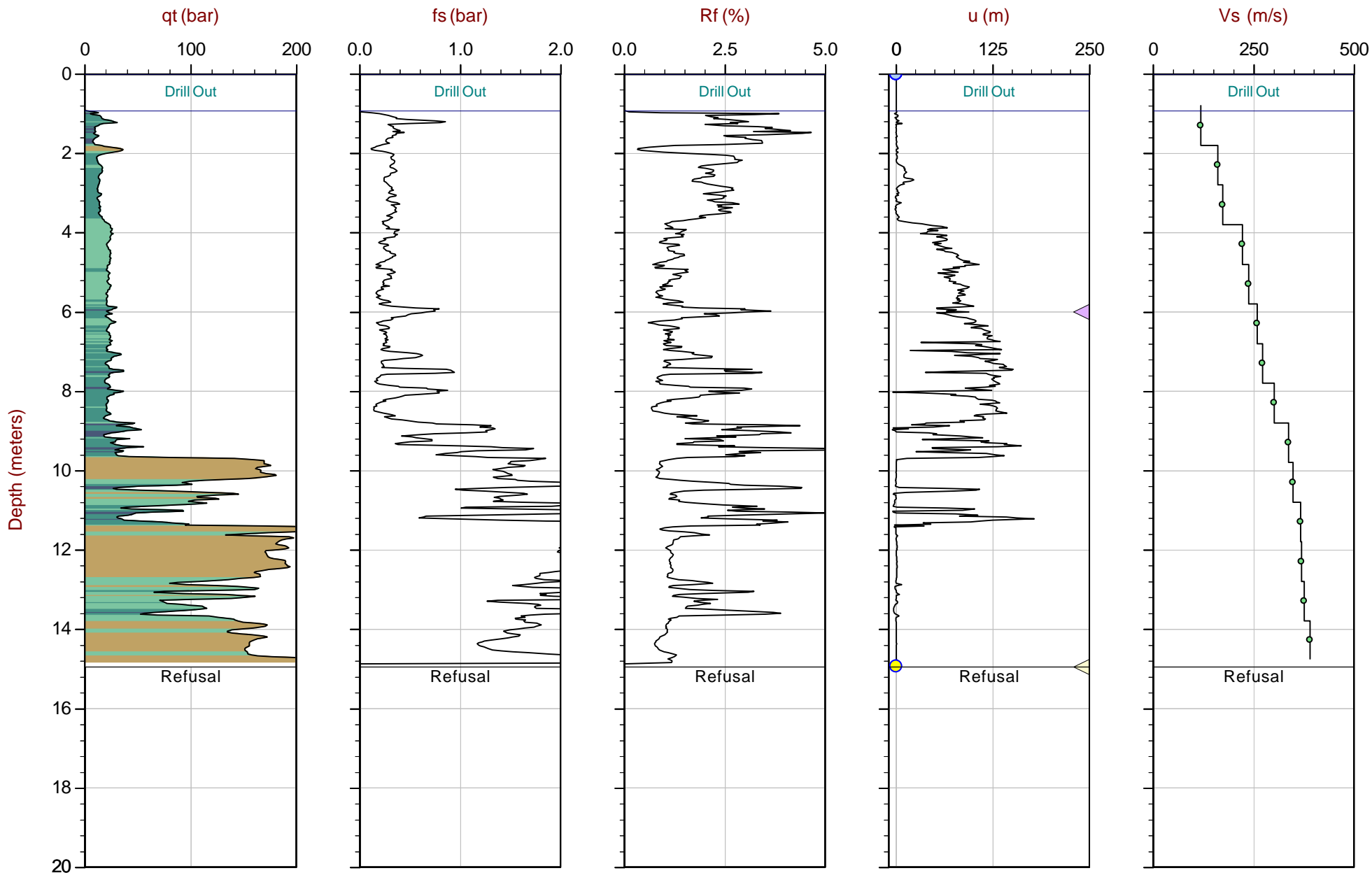
Seismic Cone Penetration Test Plots



Thurber

Job No: 19-05076
Date: 2019-11-29 09:33
Site: O'Brien Road

Sounding: OBR19-10
Cone: 377:T1000F10U500



Max Depth: 14.950 m / 49.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-05076_SP10.COR
Unit Wt: SBTQn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: MTM9 N: 5038072.30m E: 293367.70m Elev: 129.90m
Sheet No: 1 of 1

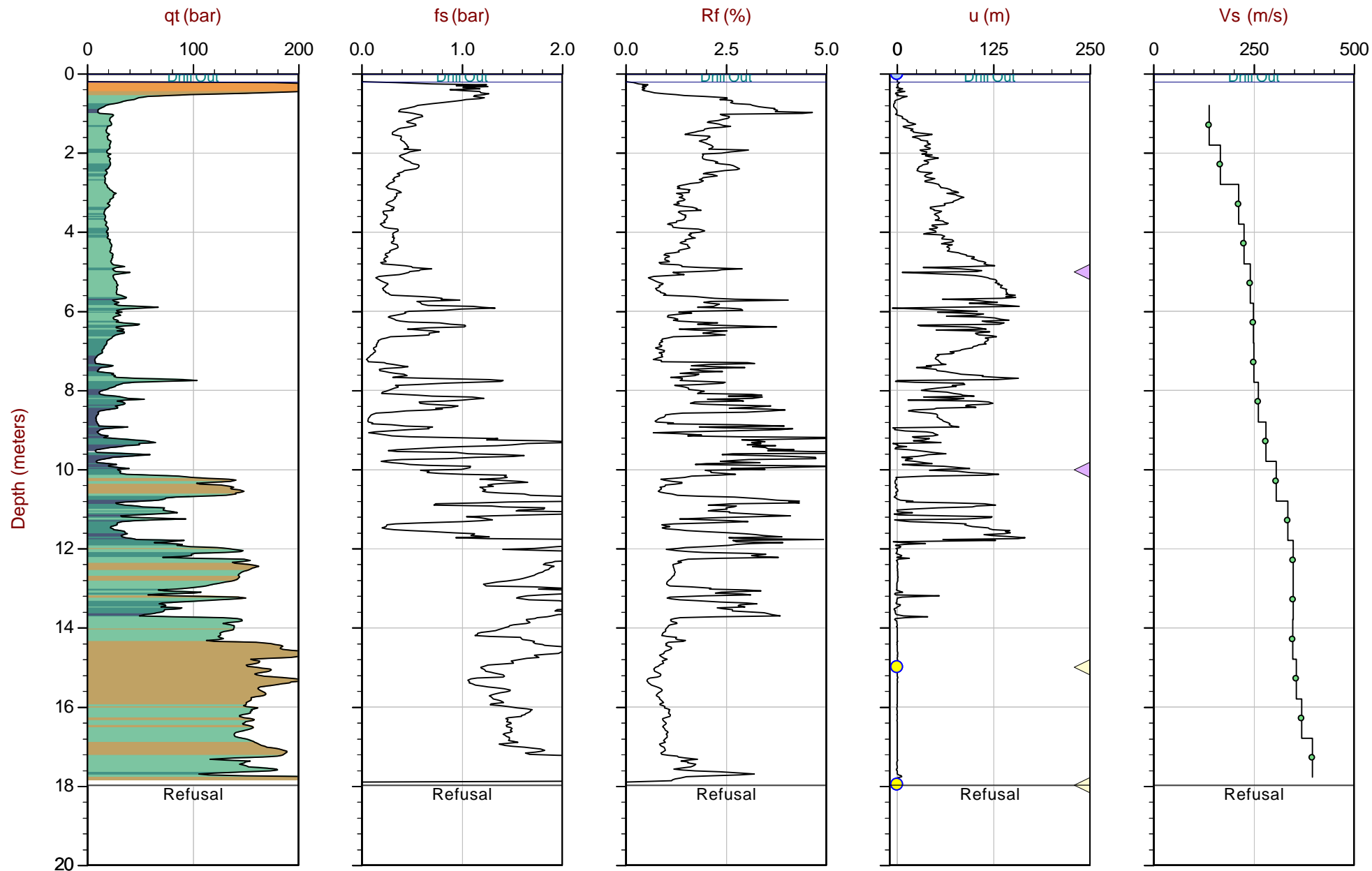
Overplot Item: ● Ueq ● Assumed Ueq ◀ Dissipation, Ueq achieved ▶ Dissipation, Ueq not achieved



Thurber

Job No: 19-05076
Date: 2019-11-29 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500



Max Depth: 17.975 m / 58.97 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-05076_SP11.COR
Unit Wt: SBTQn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: MTM9 N N: 5038038.50m E: 293374.50m Elev: 129.80m
Sheet No: 1 of 1

Overplot Item: ● Ueq ● Assumed Ueq ◀ Dissipation, Ueq achieved ▶ Dissipation, Ueq not achieved

Seismic Cone Penetration Test Tabular Results



Job No: 19-05076
Client: Thurber Engineering Ltd.
Project: Highway 17 and O'Brien Road
Sounding ID: OBR19-10
Date: 29-Nov-2019

Seismic Source: Beam
Seismic Offset (m): 0.75
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.00	0.80	1.10			
2.00	1.80	1.95	0.85	7.19	119
3.00	2.80	2.90	0.95	5.90	161
4.00	3.80	3.87	0.97	5.62	173
5.00	4.80	4.86	0.99	4.44	222
6.00	5.80	5.85	0.99	4.15	239
7.00	6.80	6.84	0.99	3.83	260
8.00	7.80	7.84	1.00	3.64	273
9.00	8.80	8.83	1.00	3.30	302
10.00	9.80	9.83	1.00	2.95	338
11.00	10.80	10.83	1.00	2.86	349
12.00	11.80	11.82	1.00	2.72	368
13.00	12.80	12.82	1.00	2.70	370
14.00	13.80	13.82	1.00	2.65	377
14.95	14.75	14.77	0.95	2.43	391



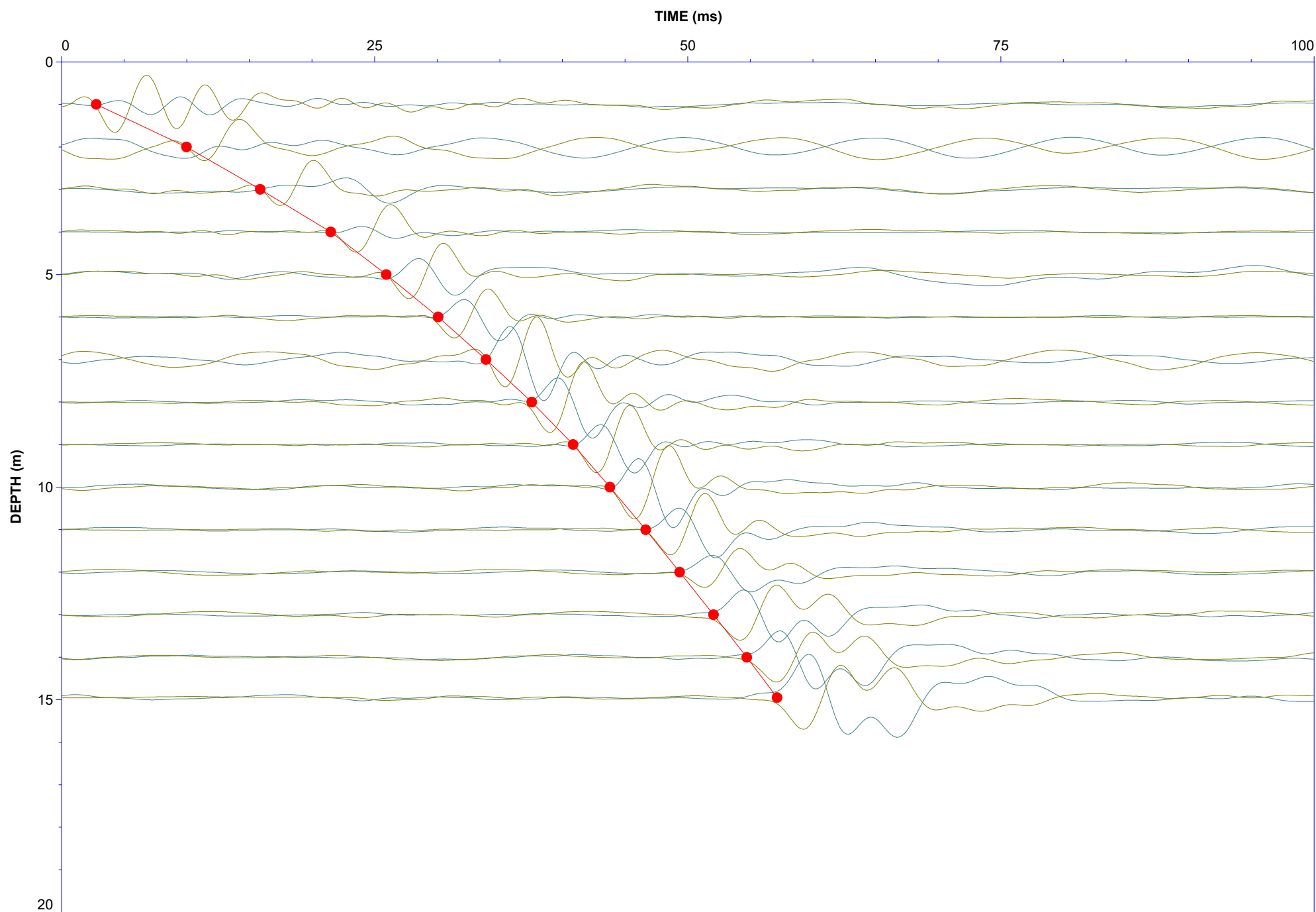
Job No: 19-05076
Client: Thurber Engineering Ltd.
Project: Highway 17 and O'Brien Road
Sounding ID: OBR19-11
Date: 29-Nov-2019

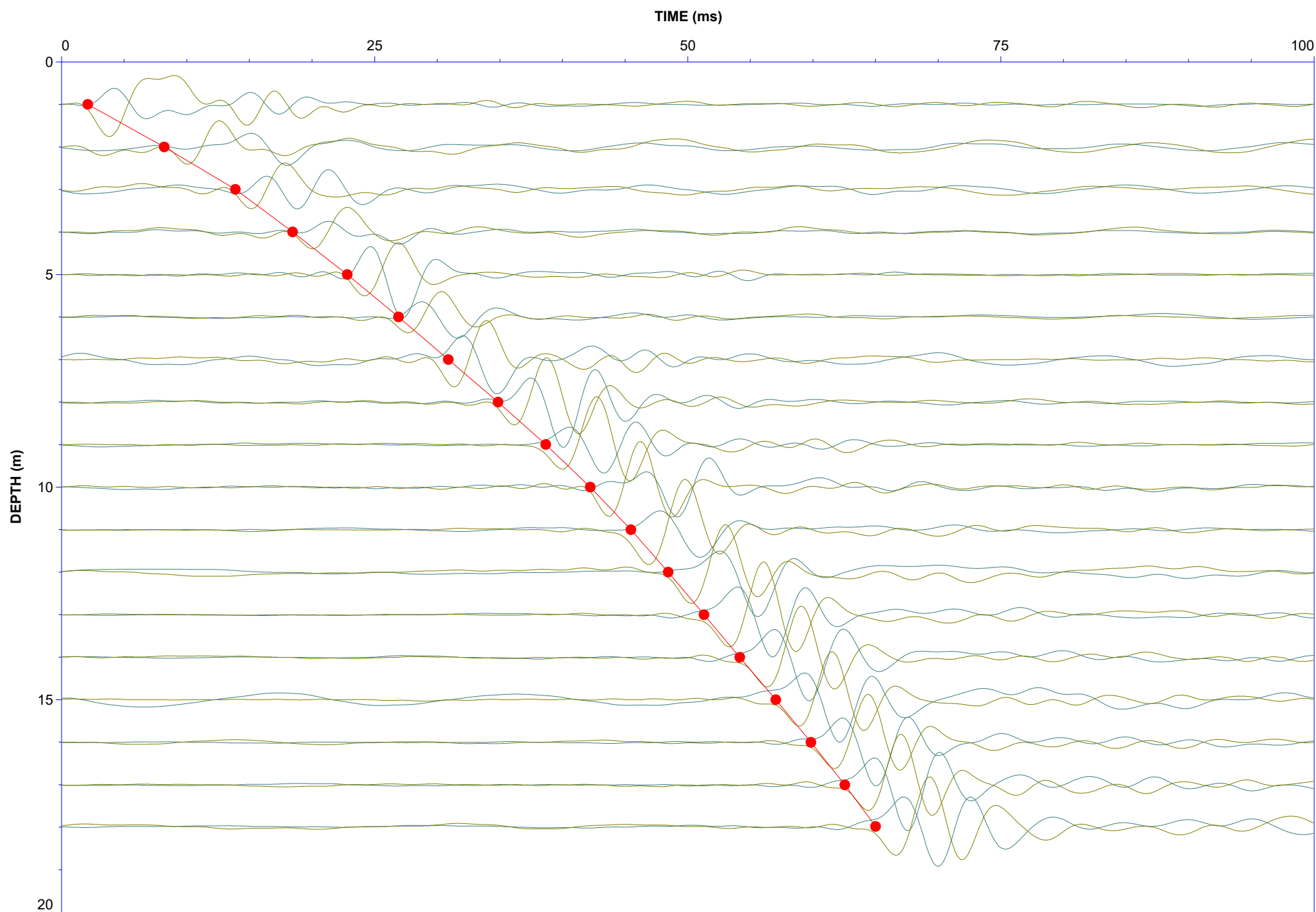
Seismic Source: Beam
Seismic Offset (m): 0.75
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

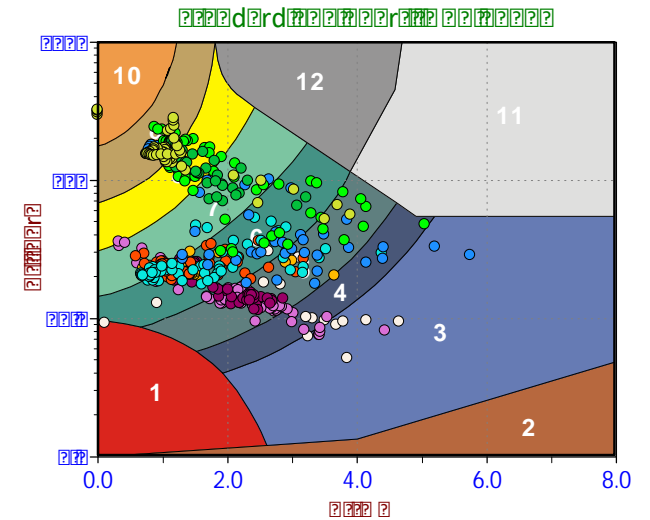
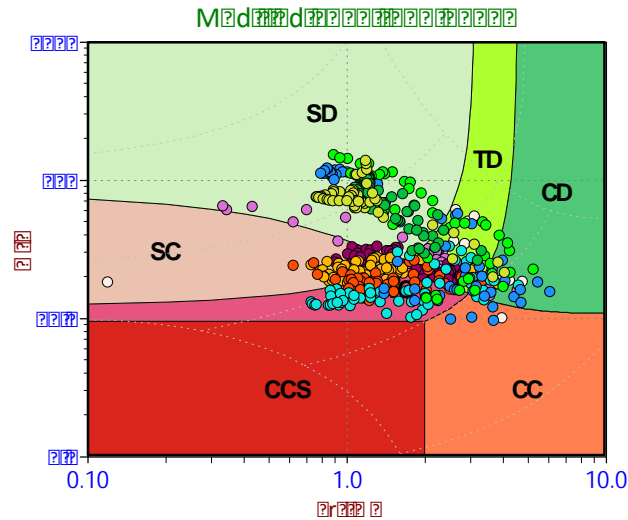
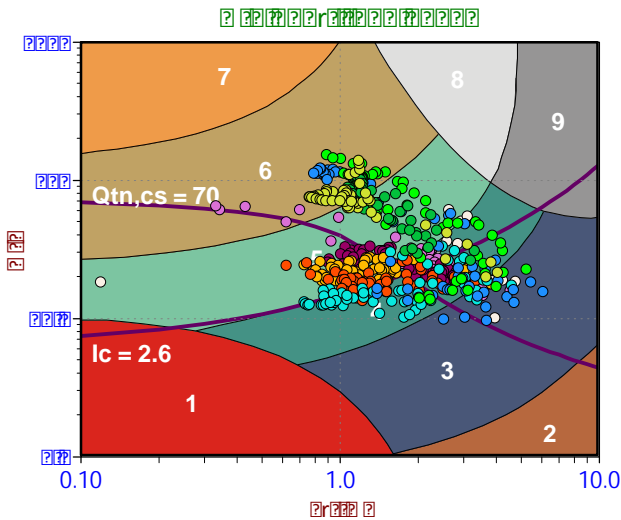
Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.00	0.80	1.10			
2.00	1.80	1.95	0.85	6.12	140
3.00	2.80	2.90	0.95	5.68	167
4.00	3.80	3.87	0.97	4.57	213
5.00	4.80	4.86	0.99	4.35	226
6.00	5.80	5.85	0.99	4.10	241
7.00	6.80	6.84	0.99	3.98	250
8.00	7.80	7.84	1.00	3.96	251
9.00	8.80	8.83	1.00	3.81	262
10.00	9.80	9.83	1.00	3.55	281
11.00	10.80	10.83	1.00	3.26	306
12.00	11.80	11.82	1.00	2.97	336
13.00	12.80	12.82	1.00	2.87	348
14.00	13.80	13.82	1.00	2.86	349
15.00	14.80	14.82	1.00	2.87	348
16.00	15.80	15.82	1.00	2.81	356
17.00	16.80	16.82	1.00	2.70	370
17.98	17.78	17.80	0.98	2.46	397

Seismic Cone Penetration Test Shear Wave (V_s) Traces





Soil Behaviour Type (SBT) Scatter Plots



Depth Ranges

- >0.0 to 1.5 m
- >1.5 to 3.0 m
- >3.0 to 4.5 m
- >4.5 to 6.0 m
- >6.0 to 7.5 m
- >7.5 to 9.0 m
- >9.0 to 10.5 m
- >10.5 to 12.0 m
- >12.0 to 13.5 m
- >13.5 to 15.0 m
- >15.0 m

Legend

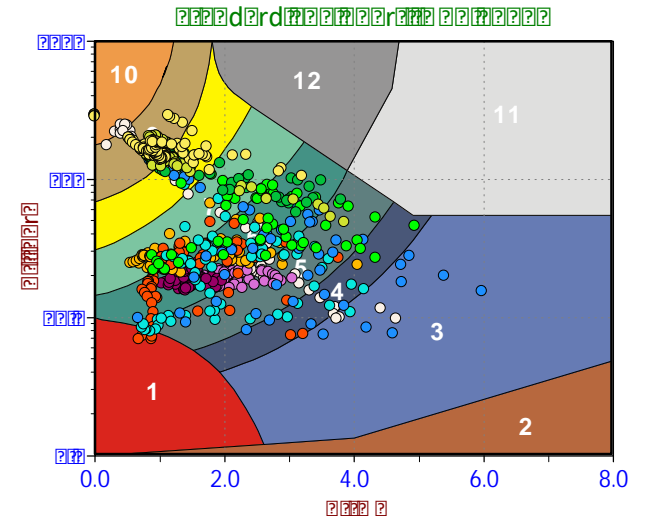
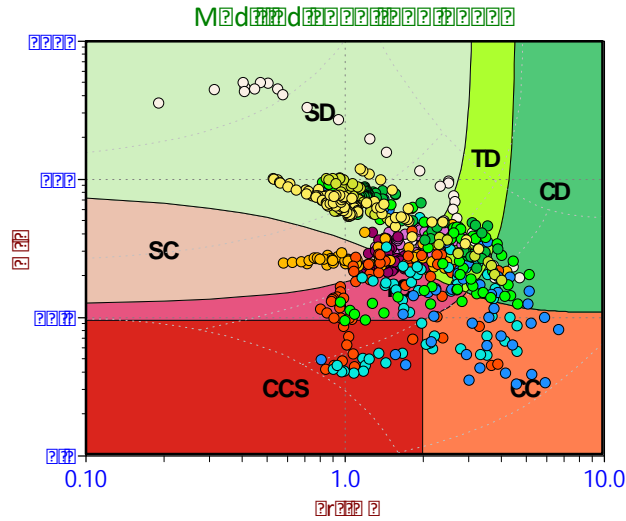
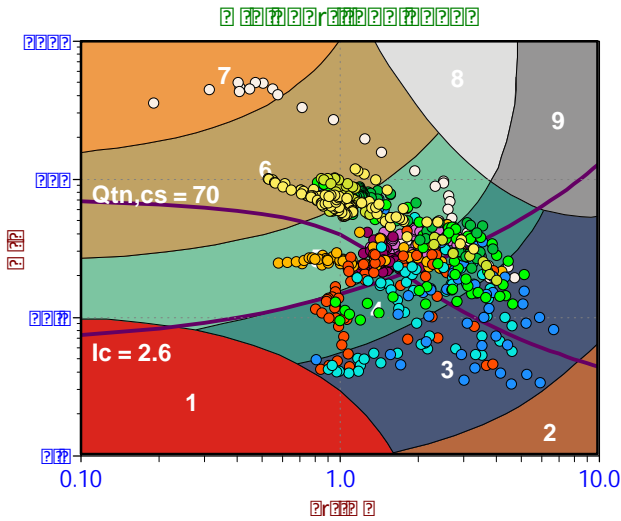
- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand



Depth Ranges

- >0.0 to 1.5 m
- >1.5 to 3.0 m
- >3.0 to 4.5 m
- >4.5 to 6.0 m
- >6.0 to 7.5 m
- >7.5 to 9.0 m
- >9.0 to 10.5 m
- >10.5 to 12.0 m
- >12.0 to 13.5 m
- >13.5 to 15.0 m
- >15.0 m

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots



Job No: 19-05076
Client: Thurber Engineering Ltd.
Project: Highway 17 and O'Brien Road
Start Date: 29-Nov-2019
End Date: 29-Nov-2019

CPT_u PORE PRESSURE DISSIPATION SUMMARY

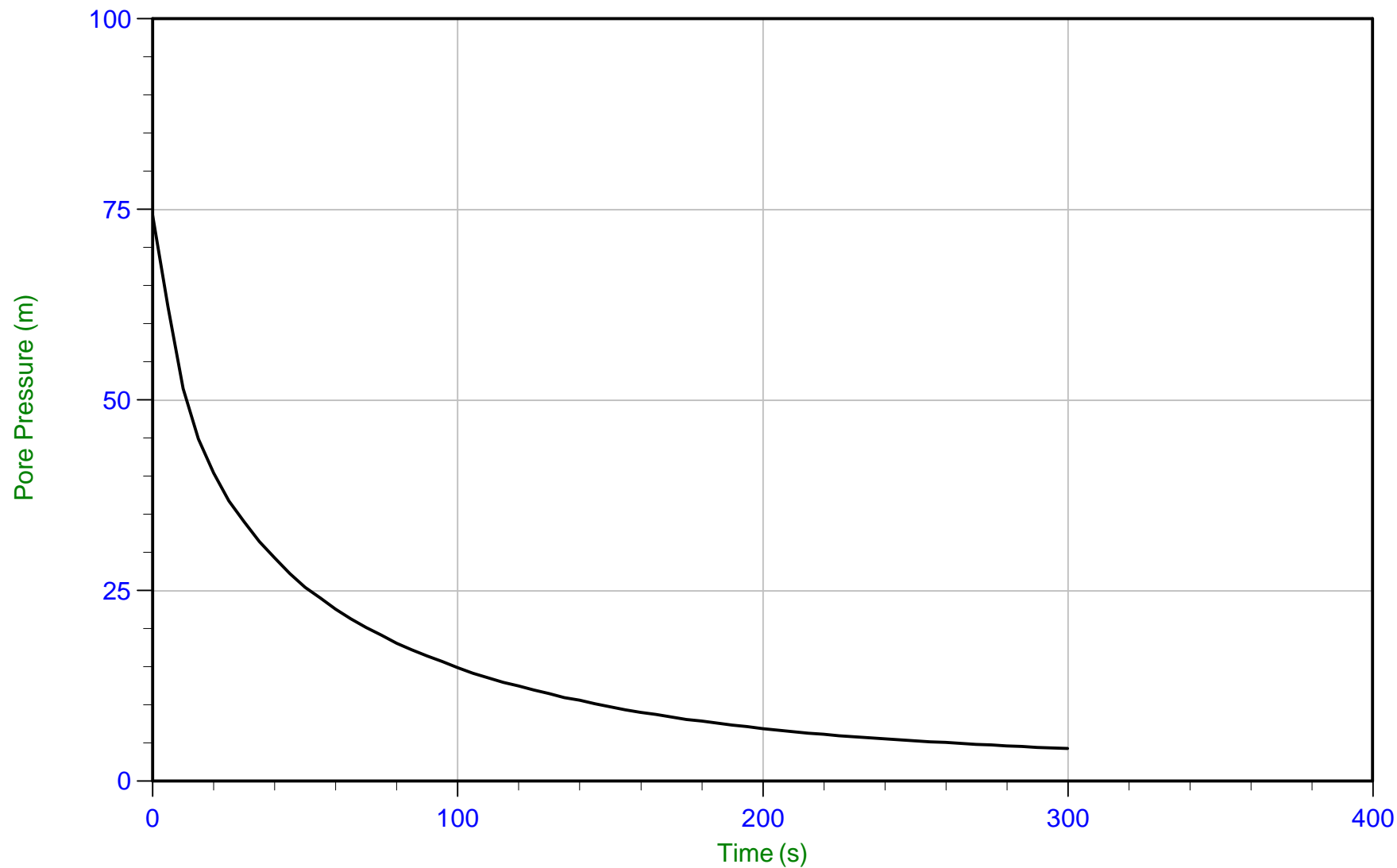
Sounding ID	File Name	Cone Area (cm ²)	Duration (s)	Test Depth (m)	Estimated Equilibrium Pore Pressure U _{eq} (m)	Calculated Phreatic Surface (m)
OBR19-10	19-05076_SP10	10	300	6.000	Not Achieved	
OBR19-10	19-05076_SP10	10	1700	14.950	0.0	
OBR19-11	19-05076_SP11	10	300	5.000	Not Achieved	
OBR19-11	19-05076_SP11	10	300	10.000	Not Achieved	
OBR19-11	19-05076_SP11	10	300	15.000	0.0	
OBR19-11	19-05076_SP11	10	300	17.975	0.0	



Thurber

Job No: 19-05076
Date: 11/29/2019 09:33
Site: O'Brien Road

Sounding: OBR19-10
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP10.PPF
Depth: 6.000 m / 19.685 ft
Duration: 300.0 s

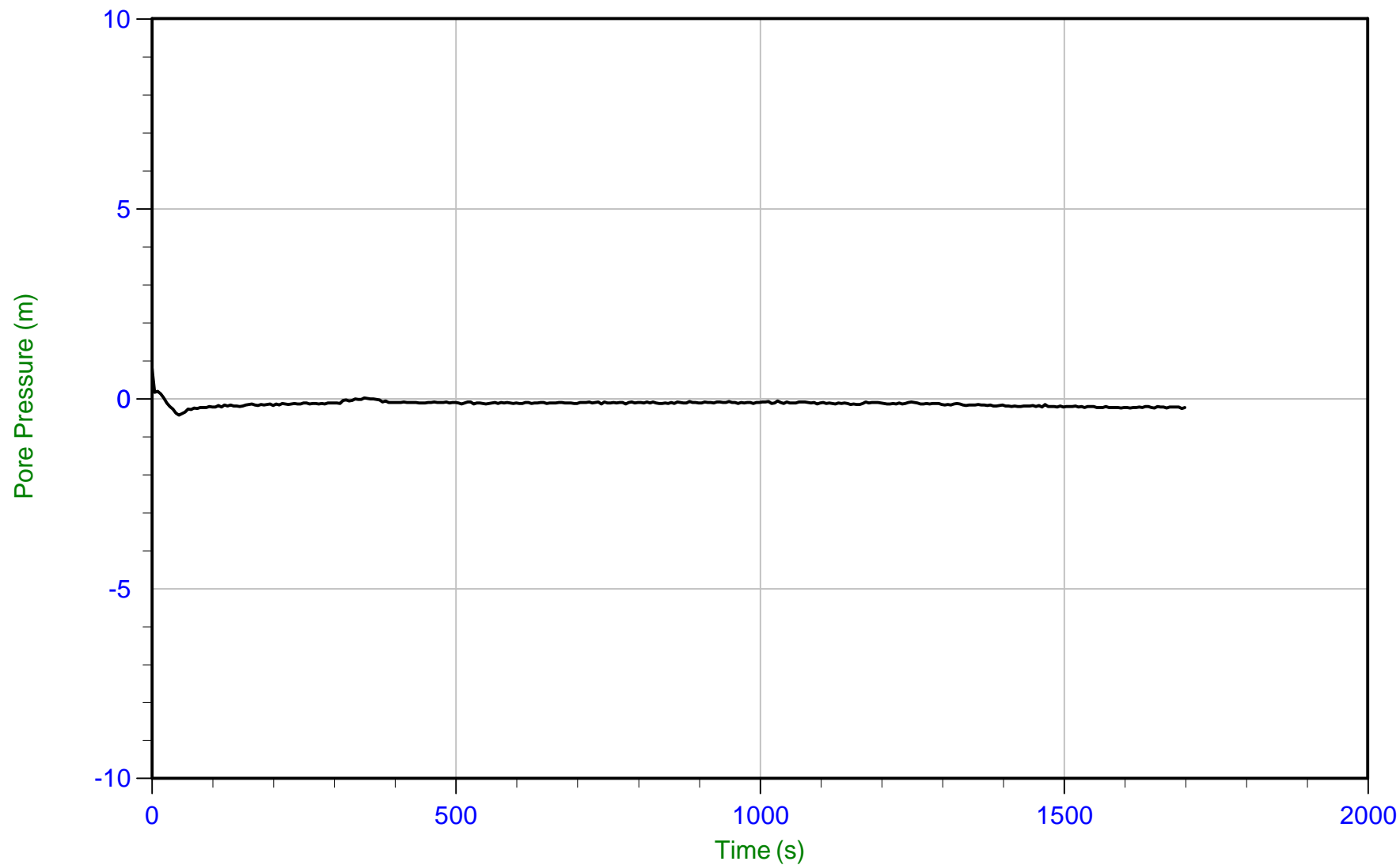
u Min: 4.3 m
u Max: 74.2 m
u Final: 4.3 m



Thurber

Job No: 19-05076
Date: 11/29/2019 09:33
Site: O'Brien Road

Sounding: OBR19-10
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP10.PPF
Depth: 14.950 m / 49.048 ft
Duration: 1700.0 s

u Min: -0.4 m
u Max: 0.8 m
u Final: -0.2 m

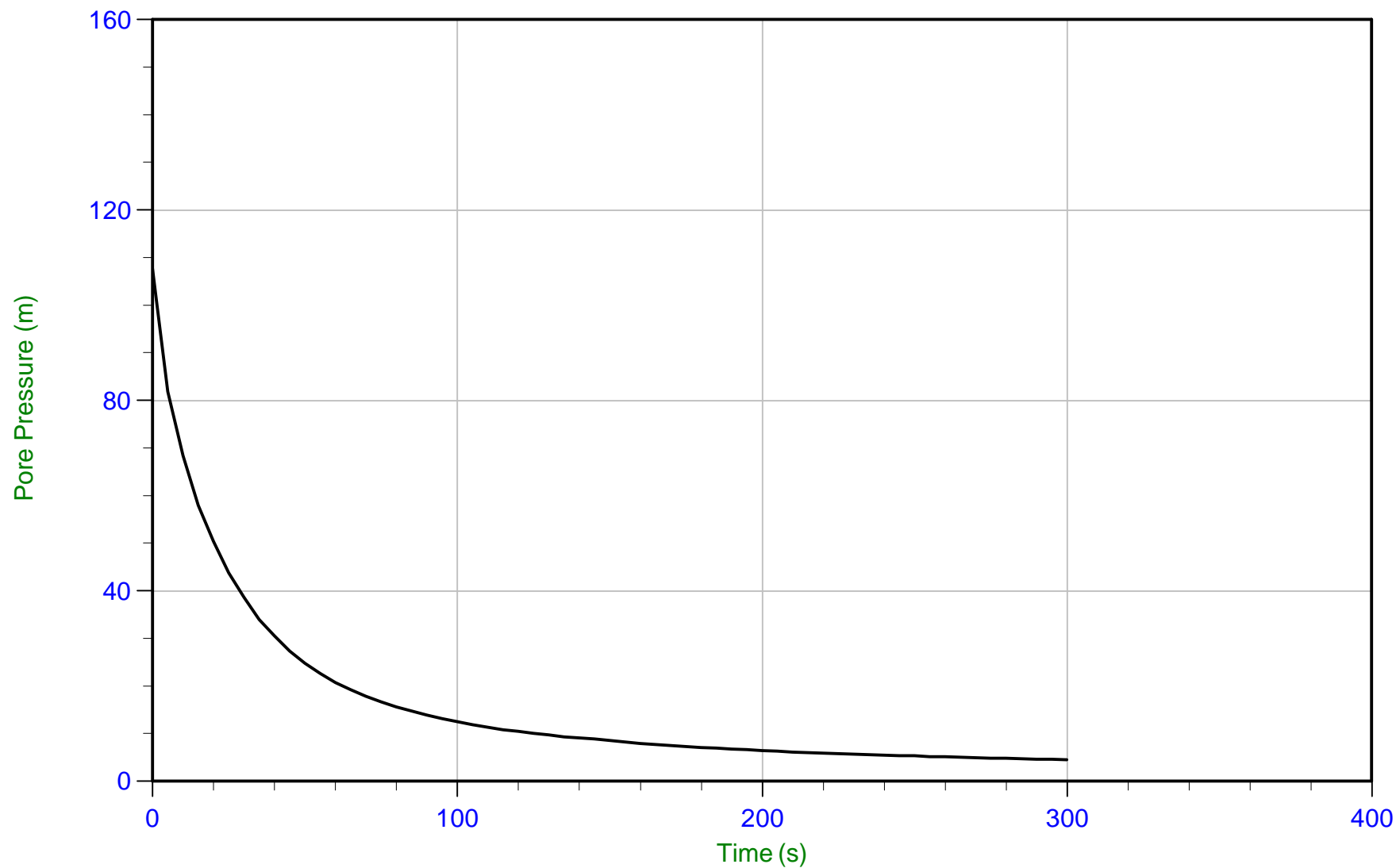
WT: 14.950 m / 49.048 ft
Ueq: 0.0 m



Thurber

Job No: 19-05076
Date: 11/29/2019 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP11.PPF
Depth: 5.000 m / 16.404 ft
Duration: 300.0 s

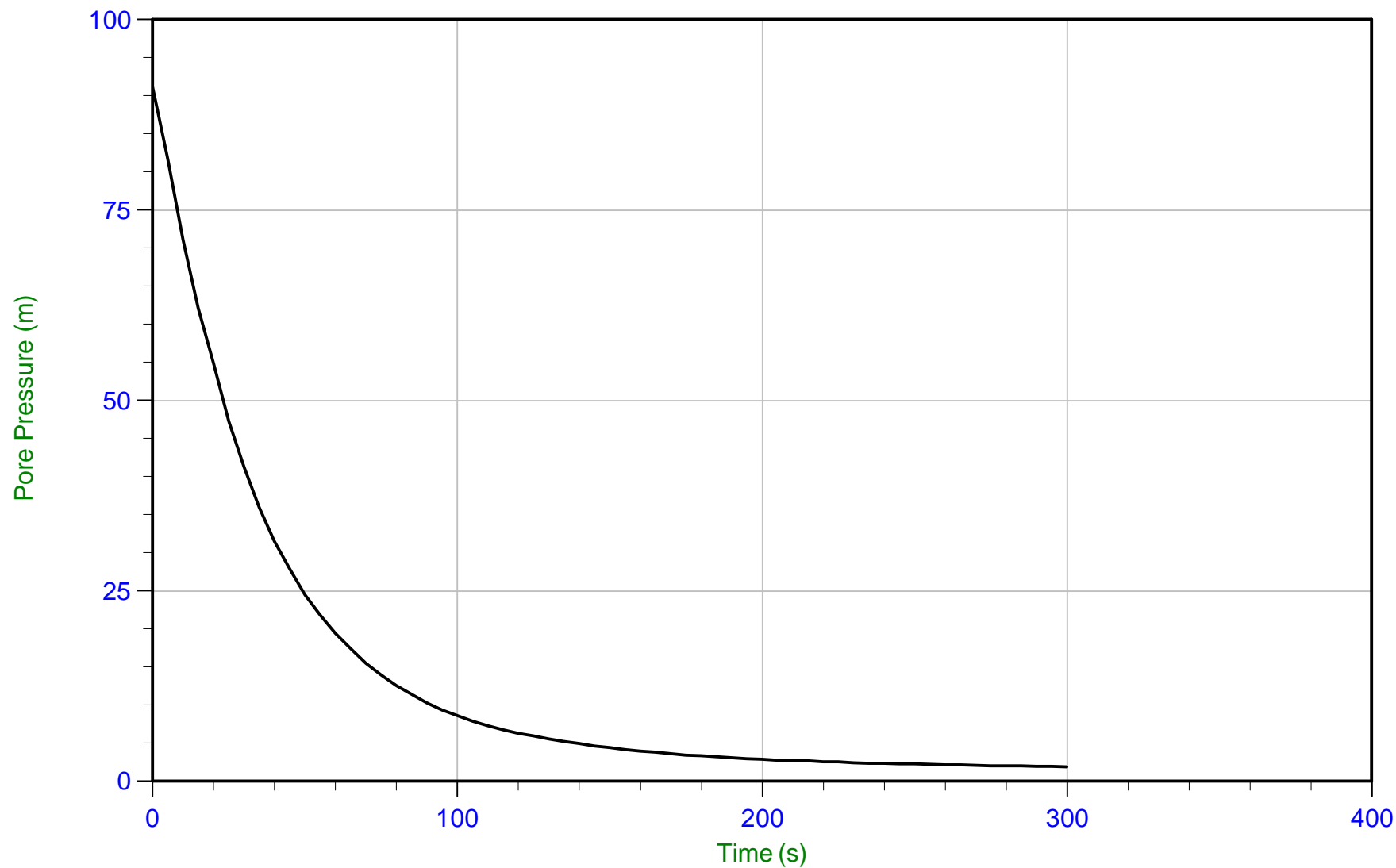
u Min: 4.5 m
u Max: 107.6 m
u Final: 4.5 m



Thurber

Job No: 19-05076
Date: 11/29/2019 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP11.PPF
Depth: 10.000 m / 32.808 ft
Duration: 300.0 s

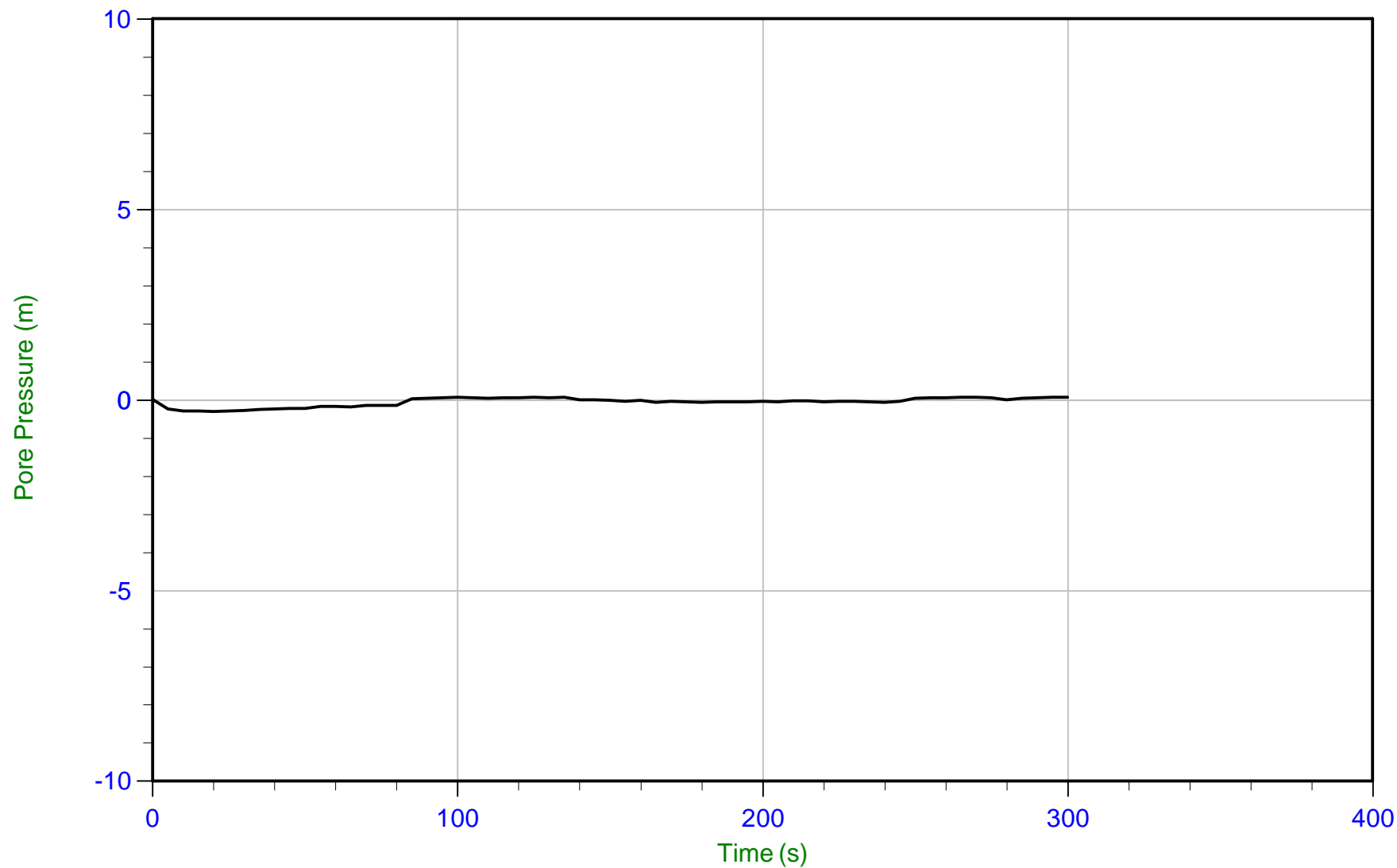
u Min: 1.9 m
u Max: 91.2 m
u Final: 1.9 m



Thurber

Job No: 19-05076
Date: 11/29/2019 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP11.PPF
Depth: 15.000 m / 49.212 ft
Duration: 300.0 s

u Min: -0.3 m
u Max: 0.1 m
u Final: 0.1 m

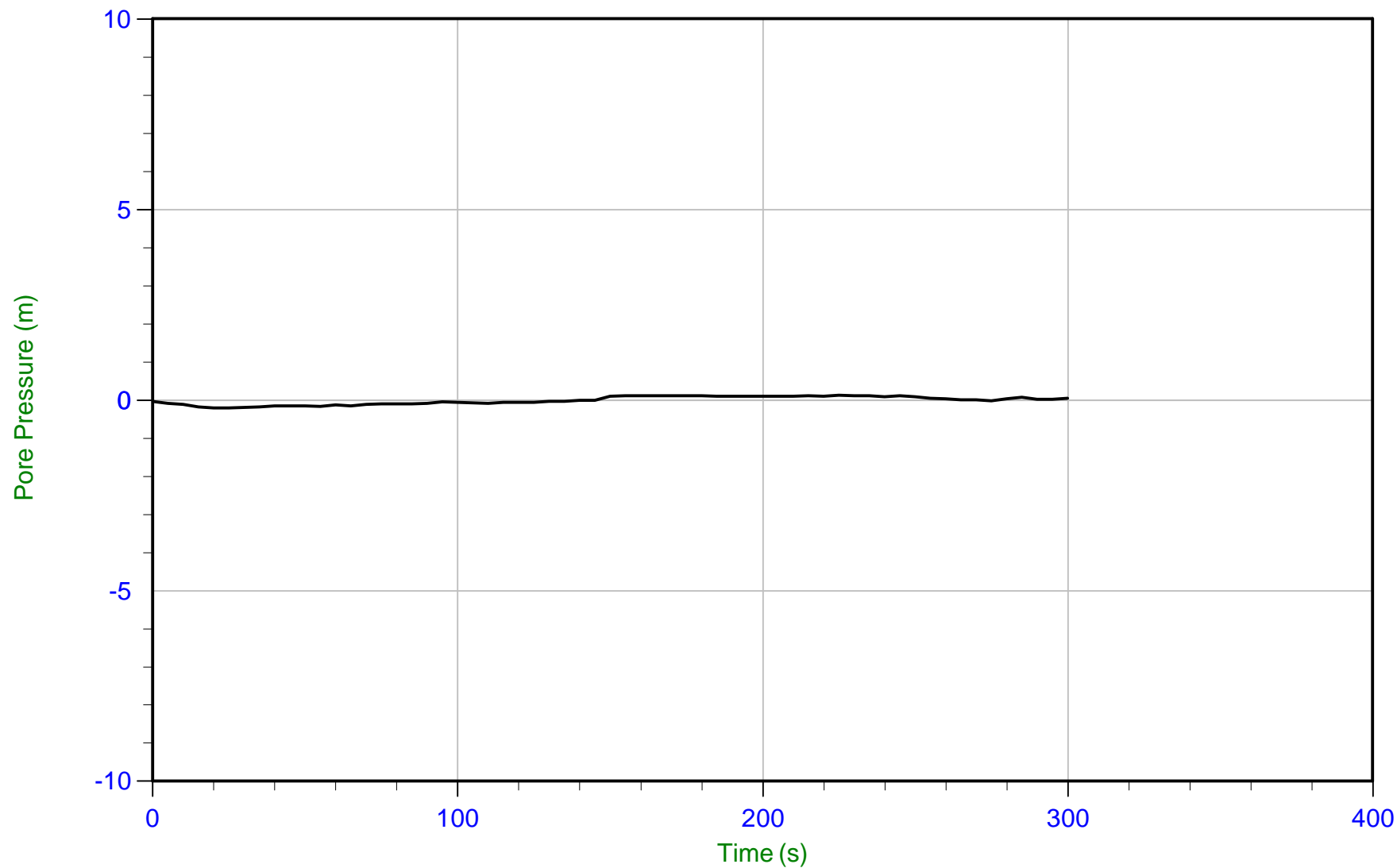
WT: 15.000 m / 49.212 ft
Ueq: 0.0 m



Thurber

Job No: 19-05076
Date: 11/29/2019 11:35
Site: O'Brien Road

Sounding: OBR19-11
Cone: 377:T1000F10U500 Area=10 cm²



Trace Summary:

Filename: 19-05076_SP11.PPF
Depth: 17.975 m / 58.972 ft
Duration: 300.0 s

u Min: -0.2 m
u Max: 0.1 m
u Final: 0.0 m

WT: 17.975 m / 58.972 ft
Ueq: 0.0 m

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

Site: 45.482N 76.646W

User File Reference: O'Brien Road Interchange, Renfrew, Ontario

2020-04-09 01:03 UT

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.351	0.180	0.103	0.031
Sa (0.1)	0.416	0.225	0.136	0.045
Sa (0.2)	0.348	0.195	0.122	0.043
Sa (0.3)	0.265	0.153	0.097	0.035
Sa (0.5)	0.190	0.111	0.072	0.026
Sa (1.0)	0.097	0.058	0.038	0.013
Sa (2.0)	0.047	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.224	0.123	0.075	0.024
PGV (m/s)	0.159	0.089	0.055	0.017

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

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

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

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



Natural Resources
Canada

Ressources naturelles
Canada

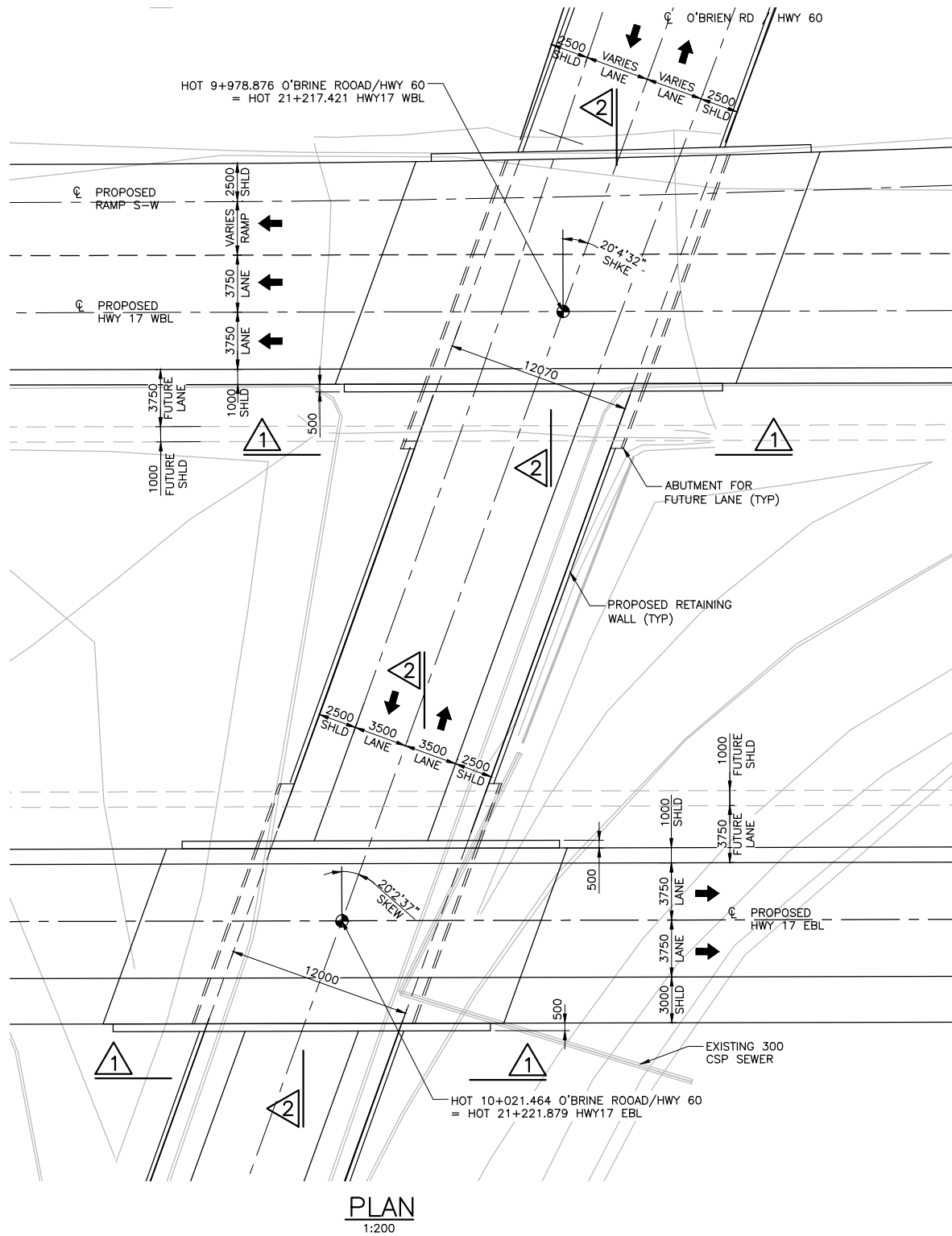
Canada

Appendix G.

**Foundation Comparison
Preliminary General Arrangement Drawings**

Comparison of Alternative Foundation Type, Highway 17 O'Brien Road Overpasses

Shallow Foundation	Caisson (Drilled Shafts)	Driven Steel Piles
Advantages		
Generally less costly construction than deep foundations Requires less specialized construction equipment	Higher geotechnical resistance than spread footings and steel piles Construction can continue in winter weather conditions	Higher geotechnical capacity than spread footings Construction can continue in winter weather conditions Requires less concrete than spread footings and caissons Likely requires less dewatering effort Allows for integral abutments
Disadvantages		
Requires large excavations Lower geotechnical resistance than deep foundations Less efficient for resistance to uplift or overturning Does not allow for integral abutments	Specialized installation measures such as equipment, liners and drilling mud will be required Difficulty in cleaning and inspecting base Does not allow for integral abutments	Lower geotechnical resistance than caissons Has potential to encounter obstructions in the till
Risk/Consequences		
Large Excavation Differential settlement unless clayey silt layer is removed Temporary Protection required to excavate below clay layer	Unbalanced pressure heads and base boiling in the sands below the groundwater table requires liners and/or mud Difficulties advancing through obstructions.	Difficult advancing through obstructions/ design based on refusal in till
Relative Cost		
Moderate	High	Moderate to High
Recommendation		
Not Recommended for support of Abutments Feasible for Retaining Walls	Not Recommended for support of Abutments or Retaining Walls	Recommended for support of Abutments and Retaining Walls



METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

PARSONS

CONT No
WP

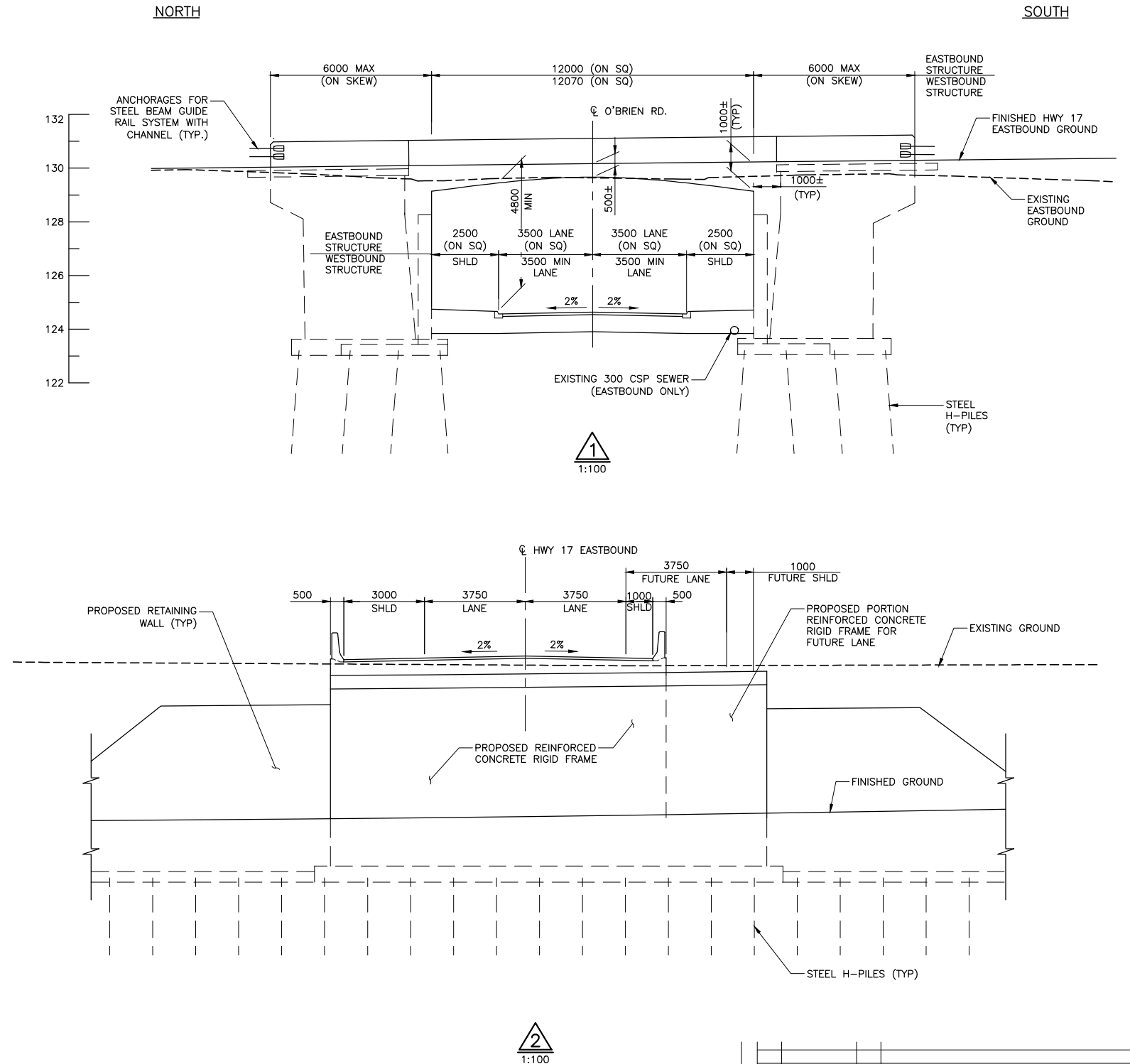
HWY 17 TWINNING
O'BRIEN ROAD OVERPASS

GENERAL ARRANGEMENT



SHEET

-



REVISIONS										
	NO	DATE	BY		DESCRIPTION					
DESIGN	AL	CHK			CODE	CAN/CSA S6-14	LOAD	CL-625-ONT	DATE	
DRAWN	FP	CHK	AL	SITE	29x-0407/B1/B2				DWG	

DOCUMENT CODE:

Appendix H.

P-y Curves



L-Pile Data for P-Y Curves (310x110)
O'Brien Road Interchange

GENERAL NOTES

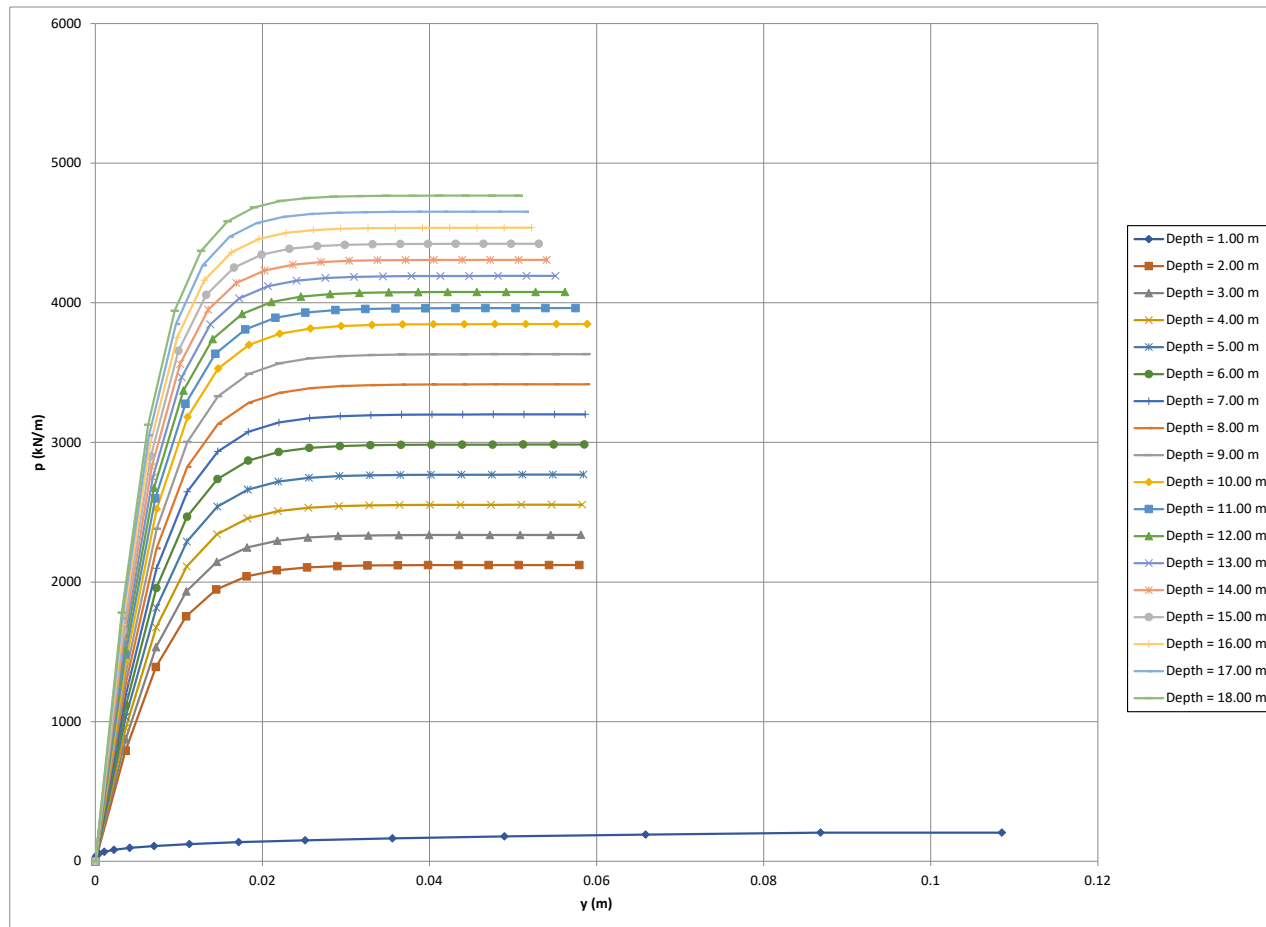
- The values P(kN/m) represent soil reaction per metre of pile length
- The values y(m) represent soil/pile deflection
- The base of the footing is at Elev. 122 m
- The p-y data provided is unfactored. Lateral resistance or deflection calculated based on these parameters should be factored using the geotechnical resistance factors (ϕ_{qu} and ϕ_{qs}) provided in Table 6.2 of the CHBDC (S6-14)
- If lateral spacing between an adjacent pile or another structural element is less than four equivalent pile diameters, suitable reduction factors based on center to center spacing should be applied based on tables C6.11.3(r), C.6.11.3(s) and C6.11.3(t) of the CHBDC (S6-14)

Soil Type	Very Stiff Clayey Silt (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)	
Depth (m)	1		2		3		4		5		6		7		8		9		10	
Elev. (m)	121		120		119		118		117		116		115		114		113		112	
S T A T I C	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0000	13.7	0.0036	793.0	0.0036	873.6	0.0036	954.2	0.0037	1034.8	0.0037	1115.4	0.0037	1196.0	0.0037	1276.6	0.0037	1357.2	0.0037	1437.8
	0.0000	27.3	0.0072	1391.6	0.0073	1533.1	0.0073	1674.5	0.0073	1816.0	0.0073	1957.4	0.0073	2098.9	0.0073	2240.3	0.0074	2381.8	0.0074	2523.2
	0.0001	41.0	0.0109	1754.6	0.0109	1932.9	0.0109	2111.3	0.0110	2289.6	0.0110	2468.0	0.0110	2646.3	0.0110	2824.7	0.0110	3003.0	0.0110	3181.4
	0.0004	54.6	0.0145	1946.2	0.0145	2144.0	0.0146	2341.9	0.0146	2539.7	0.0146	2737.5	0.0147	2935.3	0.0147	3133.1	0.0147	3331.0	0.0147	3528.8
	0.0011	68.3	0.0181	2040.0	0.0182	2247.4	0.0182	2454.7	0.0183	2662.1	0.0183	2869.4	0.0183	3076.8	0.0184	3284.2	0.0184	3491.5	0.0184	3698.9
	0.0022	81.9	0.0217	2084.2	0.0218	2296.1	0.0219	2507.9	0.0219	2719.8	0.0219	2931.6	0.0220	3143.5	0.0220	3355.3	0.0220	3567.2	0.0221	3779.0
	0.0041	95.6	0.0253	2104.7	0.0254	2318.6	0.0255	2532.6	0.0256	2746.5	0.0256	2960.4	0.0257	3174.4	0.0257	3388.3	0.0257	3602.2	0.0258	3816.2
	0.0070	109.3	0.0290	2114.1	0.0291	2329.0	0.0291	2543.9	0.0292	2758.8	0.0293	2973.7	0.0293	3188.5	0.0294	3403.4	0.0294	3618.3	0.0294	3833.2
	0.0112	122.9	0.0326	2118.4	0.0327	2333.7	0.0328	2549.1	0.0329	2764.4	0.0329	2979.7	0.0330	3195.0	0.0330	3410.4	0.0331	3625.7	0.0331	3841.0
	0.0171	136.6	0.0362	2120.4	0.0363	2335.9	0.0364	2551.4	0.0365	2766.9	0.0366	2982.5	0.0366	3198.0	0.0367	3413.5	0.0367	3629.0	0.0368	3844.6
	0.0251	150.2	0.0398	2121.3	0.0400	2336.9	0.0401	2552.5	0.0402	2768.1	0.0402	2983.7	0.0403	3199.3	0.0404	3415.0	0.0404	3630.6	0.0405	3846.2
	0.0356	163.9	0.0434	2121.7	0.0436	2337.3	0.0437	2553.0	0.0438	2768.6	0.0439	2984.3	0.0440	3200.0	0.0440	3415.6	0.0441	3631.3	0.0442	3846.9
	0.0490	177.5	0.0471	2121.9	0.0472	2337.5	0.0474	2553.2	0.0475	2768.9	0.0476	2984.6	0.0476	3200.2	0.0477	3415.9	0.0478	3631.6	0.0478	3847.3
	0.0659	191.2	0.0507	2121.9	0.0509	2337.6	0.0510	2553.3	0.0511	2769.0	0.0512	2984.7	0.0513	3200.4	0.0514	3416.1	0.0514	3631.7	0.0515	3847.4
	0.0868	204.8	0.0543	2122.0	0.0545	2337.7	0.0546	2553.4	0.0548	2769.0	0.0549	2984.7	0.0550	3200.4	0.0550	3416.1	0.0551	3631.8	0.0552	3847.5
	0.1085	204.8	0.0579	2122.0	0.0581	2337.7	0.0583	2553.4	0.0584	2769.1	0.0585	2984.8	0.0586	3200.5	0.0587	3416.1	0.0588	3631.8	0.0589	3847.5

Soil Type	Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Above WT)		Compact to Dense Silty Sand (Below WT)		Compact to Dense Silty Sand (Below WT)		Compact to Dense Silty Sand (Below WT)		Compact to Dense Silty Sand (Below WT)		Compact to Dense Silty Sand (Below WT)		Compact to Dense Silty Sand (Below WT)	
Depth (m)	11		12		13		14		15		16		17		18	
Elev. (m)	111		110		109		108		107		106		105		104	
S T A T I C	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0037	1518.4	0.0037	1599.0	0.0036	1642.0	0.0035	1685.0	0.0035	1727.9	0.0034	1770.9	0.0034	1813.9	0.0033	1856.9
	0.0074	2664.7	0.0074	2806.1	0.0072	2881.5	0.0071	2957.0	0.0069	3032.4	0.0068	3107.9	0.0067	3183.3	0.0066	3258.7
	0.0110	3359.7	0.0111	3538.0	0.0108	3633.2	0.0106	3728.3	0.0104	3823.4	0.0102	3918.5	0.0101	4013.6	0.0099	4108.8
	0.0147	3726.6	0.0147	3924.4	0.0144	4029.9	0.0141	4135.5	0.0139	4241.0	0.0136	4346.5	0.0134	4452.0	0.0132	4557.5
	0.0184	3906.2	0.0184	4113.6	0.0180	4224.2	0.0177	4334.8	0.0173	4445.4	0.0170	4555.9	0.0168	4666.5	0.0165	4777.1
	0.0221	3990.9	0.0221	4202.7	0.0216	4315.7	0.0212	4428.7	0.0208	4541.7	0.0204	4654.7	0.0201	4767.7	0.0198	4880.7
	0.0258	4030.1	0.0258	4244.0	0.0253	4358.1	0.0247	4472.2	0.0243	4586.3	0.0239	4700.4	0.0235	4814.5	0.0231	4928.6
	0.0295	4048.1	0.0295	4263.0	0.0289	4377.6	0.0283	4492.2	0.0278	4606.8	0.0273	4721.4	0.0268	4836.0	0.0264	4950.6
	0.0331	4056.3	0.0332	4271.7	0.0325	4386.5	0.0318	4501.3	0.0312	4616.2	0.0307	4731.0	0.0302	4845.9	0.0297	4960.7
	0.0368	4060.1	0.0369	4275.6	0.0361	4390.6	0.0353	4505.5	0.0347	4620.5	0.0341	4735.4	0.0335	4850.4	0.0330	4965.3
	0.0405	4061.8	0.0406	4277.4	0.0397	4392.4	0.0389	4507.4	0.0382	4622.4	0.0375	4737.4	0.0369	4852.4	0.0363	4967.4
	0.0442	4062.6	0.0442	4278.3	0.0433	4393.3	0.0424	4508.3	0.0416	4623.3	0.0409	4738.3	0.0402	4853.3	0.0396	4968.4
	0.0479	4063.0	0.0479	4278.6	0.0469	4393.7	0.0460	4508.7	0.0451	4623.7	0.0443	4738.7	0.0436	4853.8	0.0429	4968.8
	0.0516	4063.1	0.0516	4278.8	0.0505	4393.8	0.0495	4508.9	0.0486	4623.9	0.0477	4738.9	0.0469	4854.0	0.0462	4969.0
	0.0552	4063.2	0.0553	4278.9	0.0541	4393.9	0.0530	4508.9	0.0520	4624.0	0.0511	4739.0	0.0503	4854.1	0.0495	4969.1
	0.0589	4063.2	0.0590	4278.9	0.0577	4393.9	0.0566	4509.0	0.0555	4624.0	0.0545	4739.1	0.0536	4854.1	0.0528	4969.1



L-Pile Data for P-Y Curves (310x110)
O'Brien Road Interchange



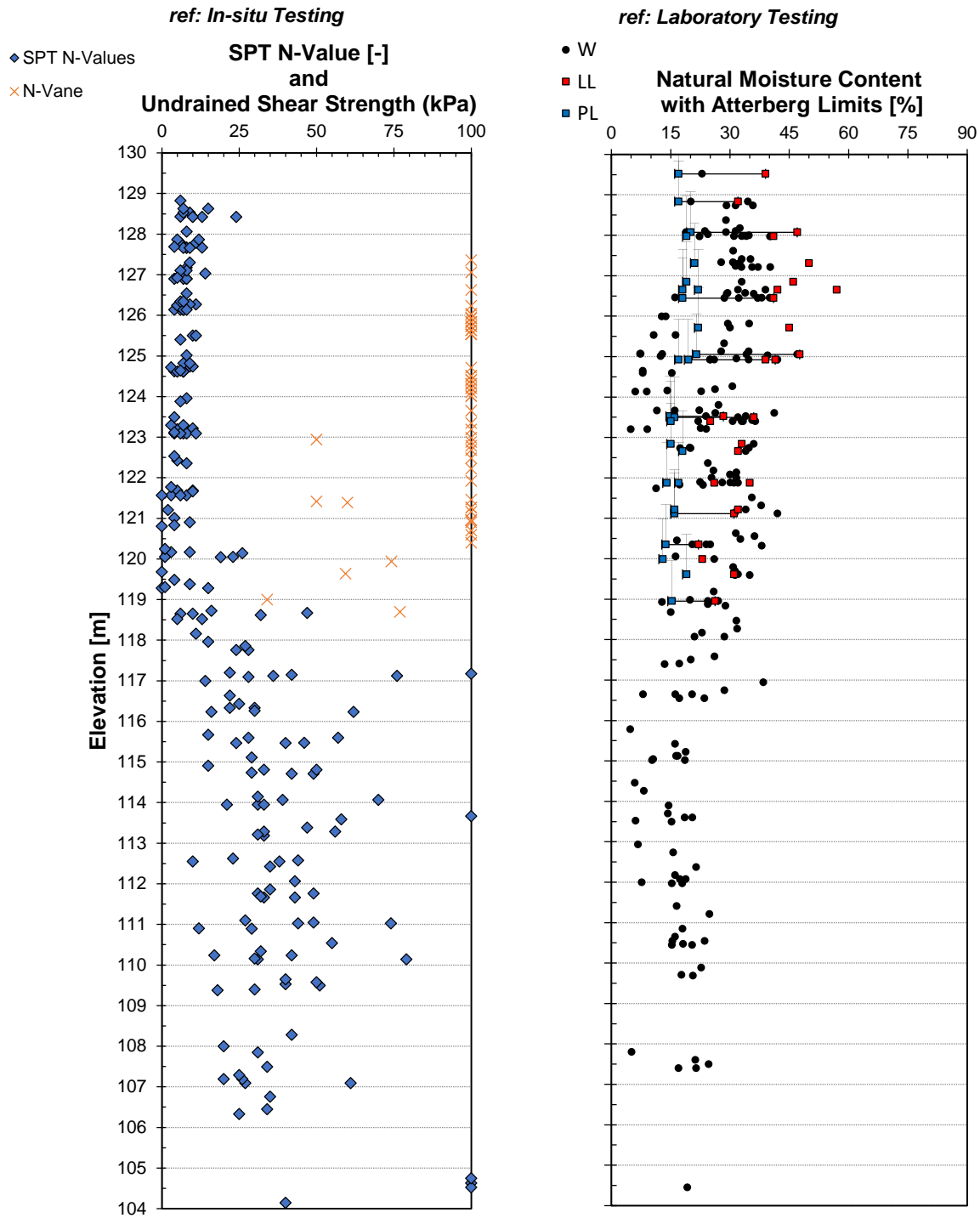
Appendix I.






**Soil Summary Sheet
Slope Stability Analysis Figures**

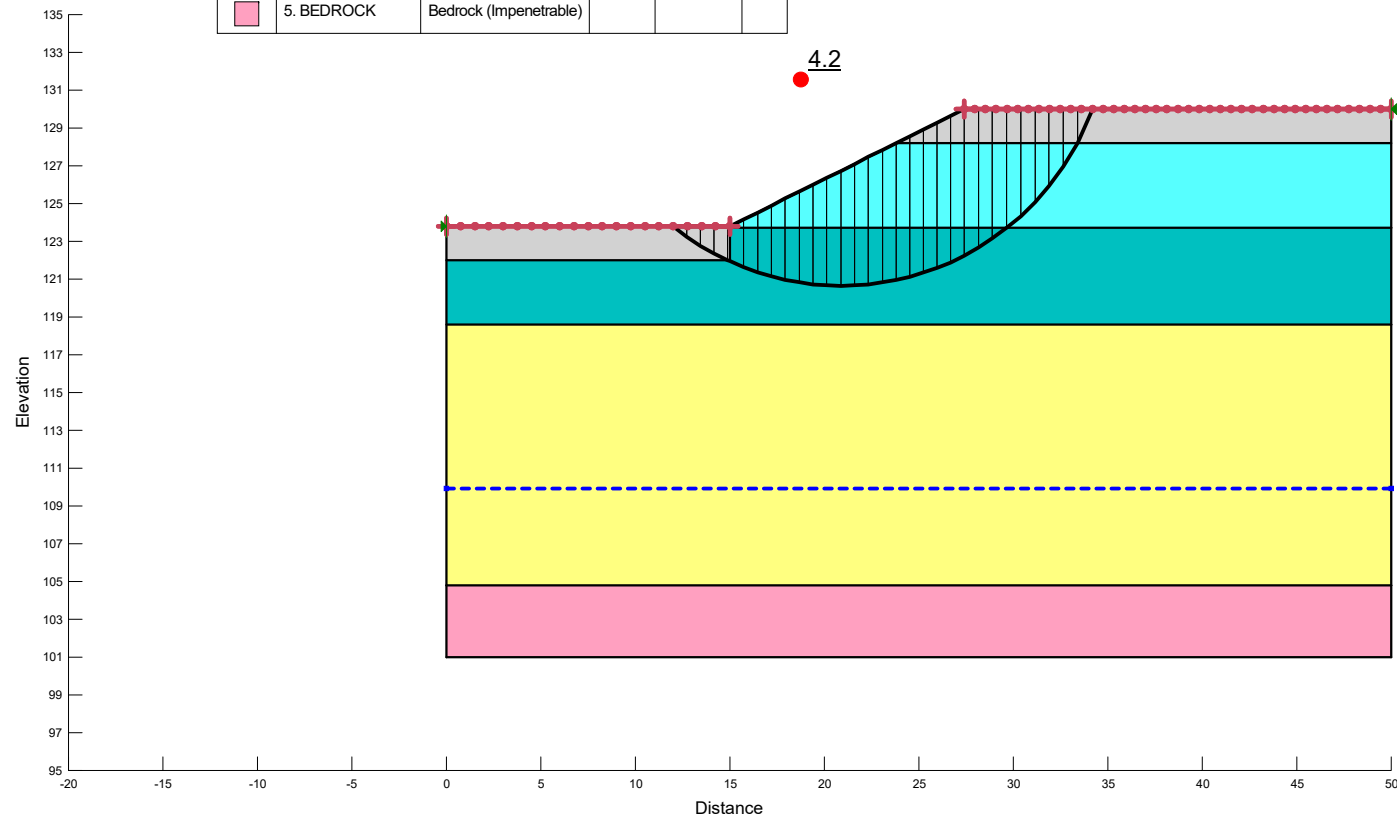
Figure I-1

SOIL SUMMARY SHEET

(OBR19-1 through OBR19-9, BRN-1, BRN-2, BRN-4 and BRN-5)








Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (TSA)	Mohr-Coulomb	18	100	0
	3. CLAYEY SILT (TSA)	Mohr-Coulomb	17	90	0
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			

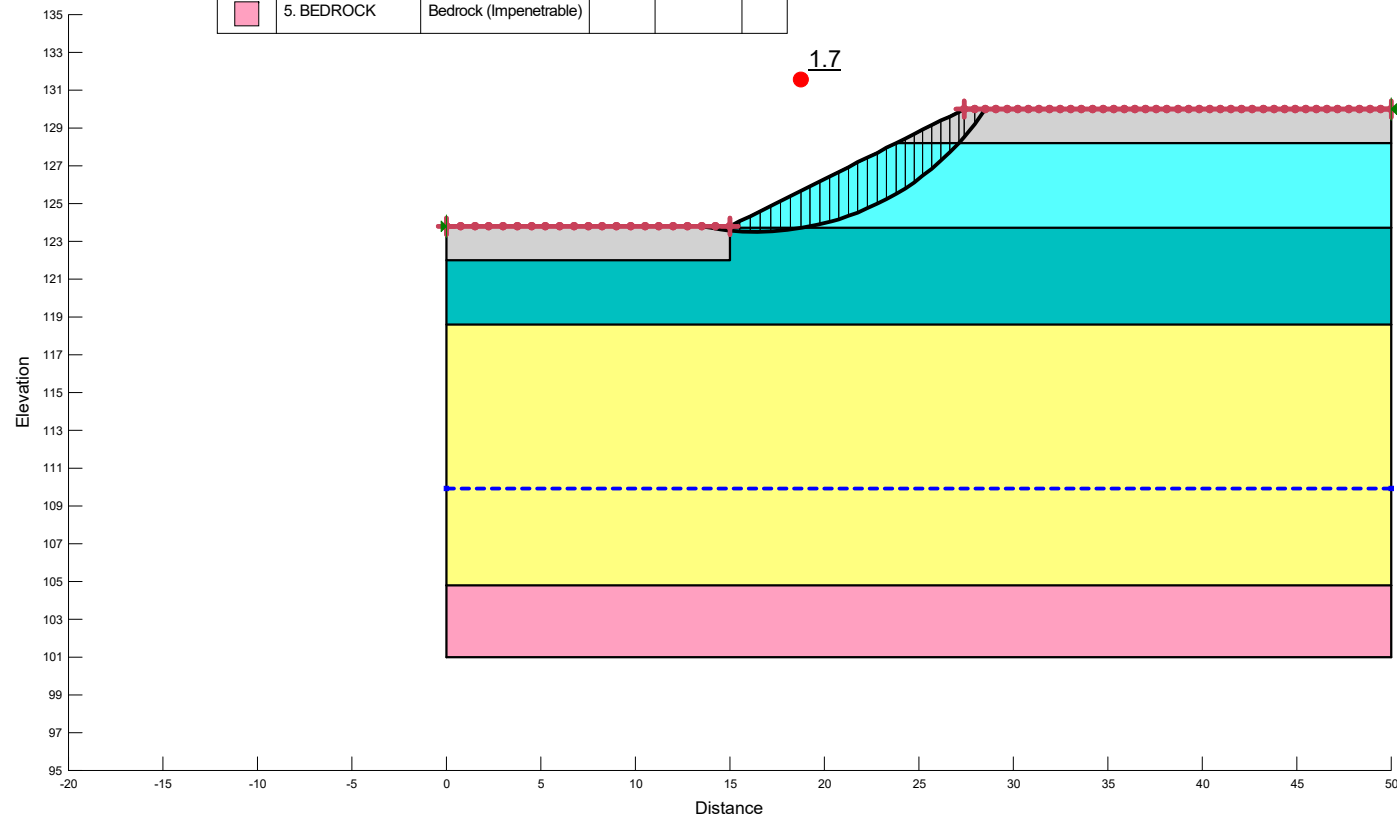


Project O'Brien Road 9+980, 2H:1V Earth Cut		
Analysis 1. Short Term Static (Undrained)		
Seismic Coefficient H: 0g, V: 0g	Last Run 05/09/2020, 05:40:20 PM	Scale 1:400

Additional Details
Name: O'Brien Road 9+980, 2H:1V Earth Cut
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (34.18, 130) m, Exit: (12, 123.8) m
Center: (20.885821, 134.78527) m, Radius: 14.129191 m

Figure I-2.1






Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (ESA)	Mohr-Coulomb	18	7	28
	3. CLAYEY SILT (ESA)	Mohr-Coulomb	17	5	28
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			

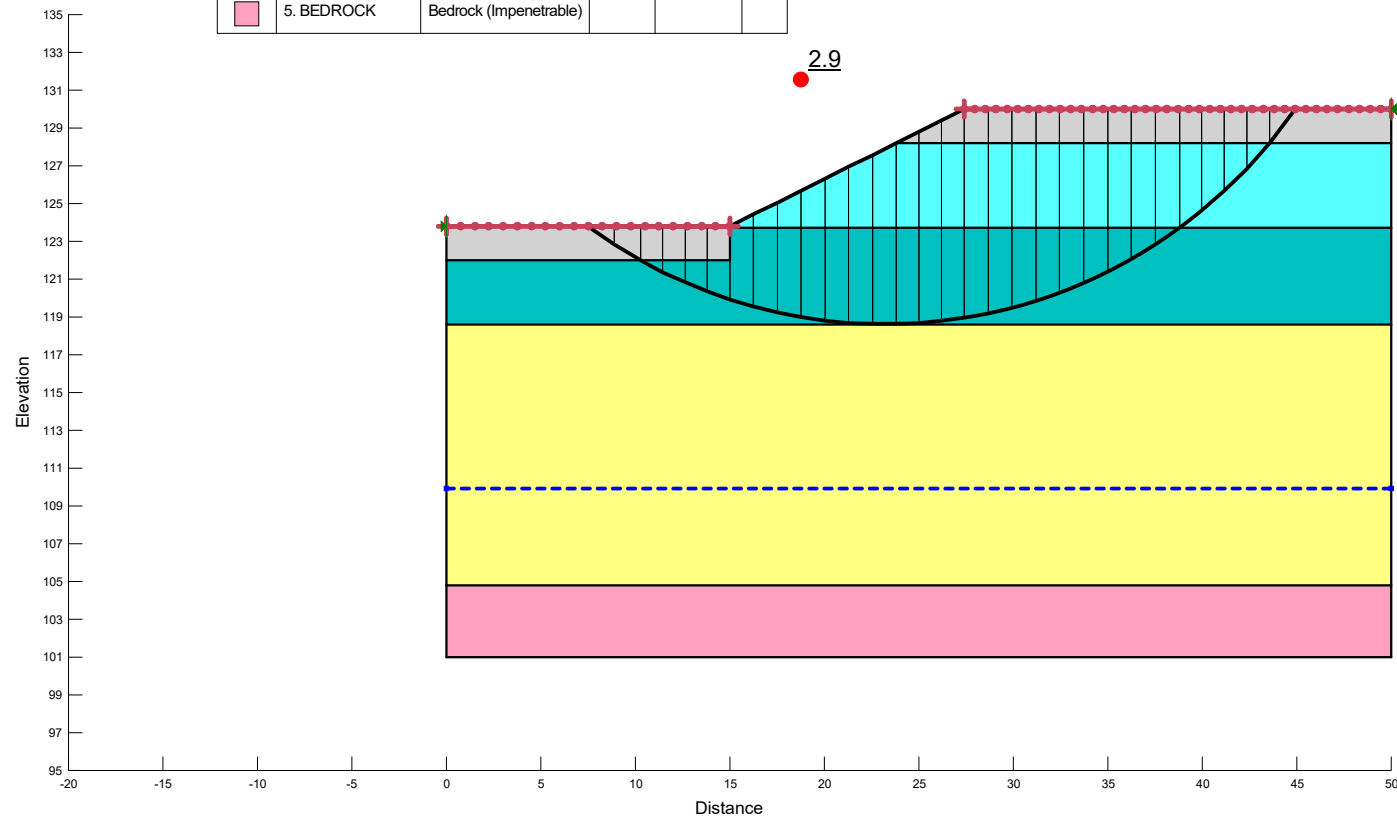


Project		
O'Brien Road 9+980, 2H:1V Earth Cut		
Analysis		
2. Long Term Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	05/09/2020, 05:40:31 PM	1:400

Additional Details
Name: O'Brien Road 9+980, 2H:1V Earth Cut
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (28.53, 130) m, Exit: (13.5, 123.8) m
Center: (16.396677, 138.09571) m, Radius: 14.586227 m

Figure I-2.2




Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (TSA)	Mohr-Coulomb	18	100	0
	3. CLAYEY SILT (TSA)	Mohr-Coulomb	17	90	0
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			

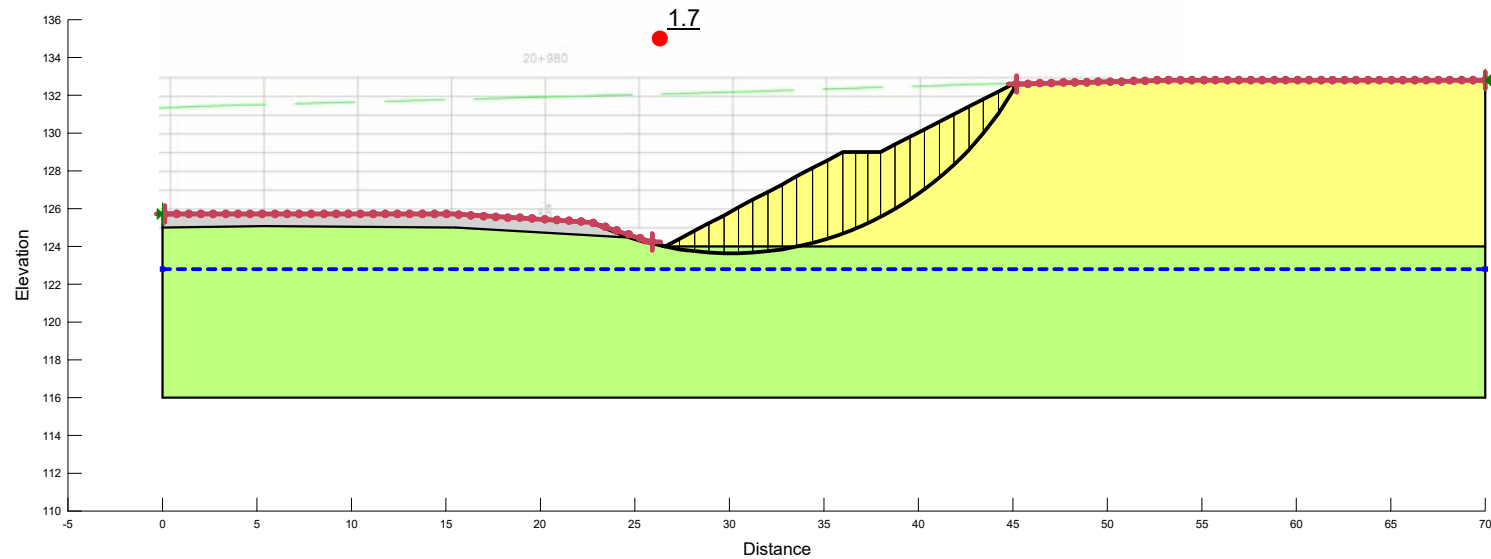


Project O'Brien Road 9+980, 2H:1V Earth Cut		
Analysis 3. Pseudo-Static Seismic (Undrained)		
Seismic Coefficient H: 0.127g, V: 0g	Last Run 05/09/2020, 05:40:26 PM	Scale 1:400

Additional Details
 Name: O'Brien Road 9+980, 2H:1V Earth Cut
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (44.915, 130) m, Exit: (7.5, 123.8) m
 Center: (23.208672, 144.99696) m, Radius: 26.383203 m

Figure I-2.3

Color	Name	Model	Unit Weight (kN/m³)	Phi°
	1. FILL	Mohr-Coulomb	21	33
	2. UPPER SAND TO GRAVEL	Mohr-Coulomb	20	30
	3. LOWER SAND TO GRAVEL	Mohr-Coulomb	21	32



Project
O'Brien Road W-S Ramp 20+980, 2H:1V Earth Cut

Analysis
1. Short/Long Term Static (Undrained/Drained)

Seismic Coefficient
H: 0g, V: 0g

Last Run
05/09/2020, 08:32:37 PM

Scale
1:400

Additional Details

Name: W-S Ramp 20+980, 2H:1V Earth Cut

Comments:




Method: Morgenstern-Price, Half-Sine

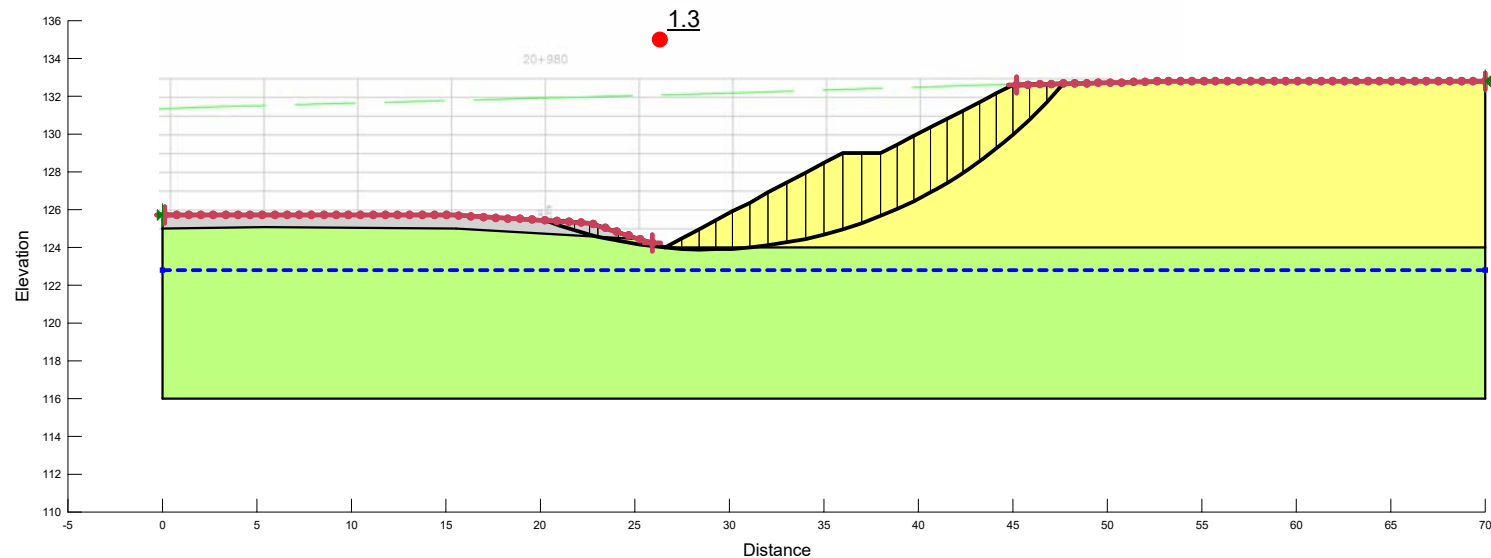
Minimum Slip Surface Depth: 1.52 m

Entry: (45.2, 132.60476) m, Exit: (22.811397, 125.2313) m

Center: (30.057579, 140.906) m, Radius: 17.268568 m

Figure I-3.1

Color	Name	Model	Unit Weight (kN/m ³)	Phi° (°)
	1. FILL	Mohr-Coulomb	21	33
	2. UPPER SAND TO GRAVEL	Mohr-Coulomb	20	30
	3. LOWER SAND TO GRAVEL	Mohr-Coulomb	21	32



Project
O'Brien Road W-S Ramp 20+980, 2H:1V Earth Cut

Analysis
2. Pseudo-Static Seismic (Undrained)

Seismic Coefficient
H: 0.127g, V: 0g

Last Run
05/09/2020, 08:32:46 PM

Scale
1:400

Additional Details

Name: W-S Ramp 20+980, 2H:1V Earth Cut

Comments:




Method: Morgenstern-Price, Half-Sine

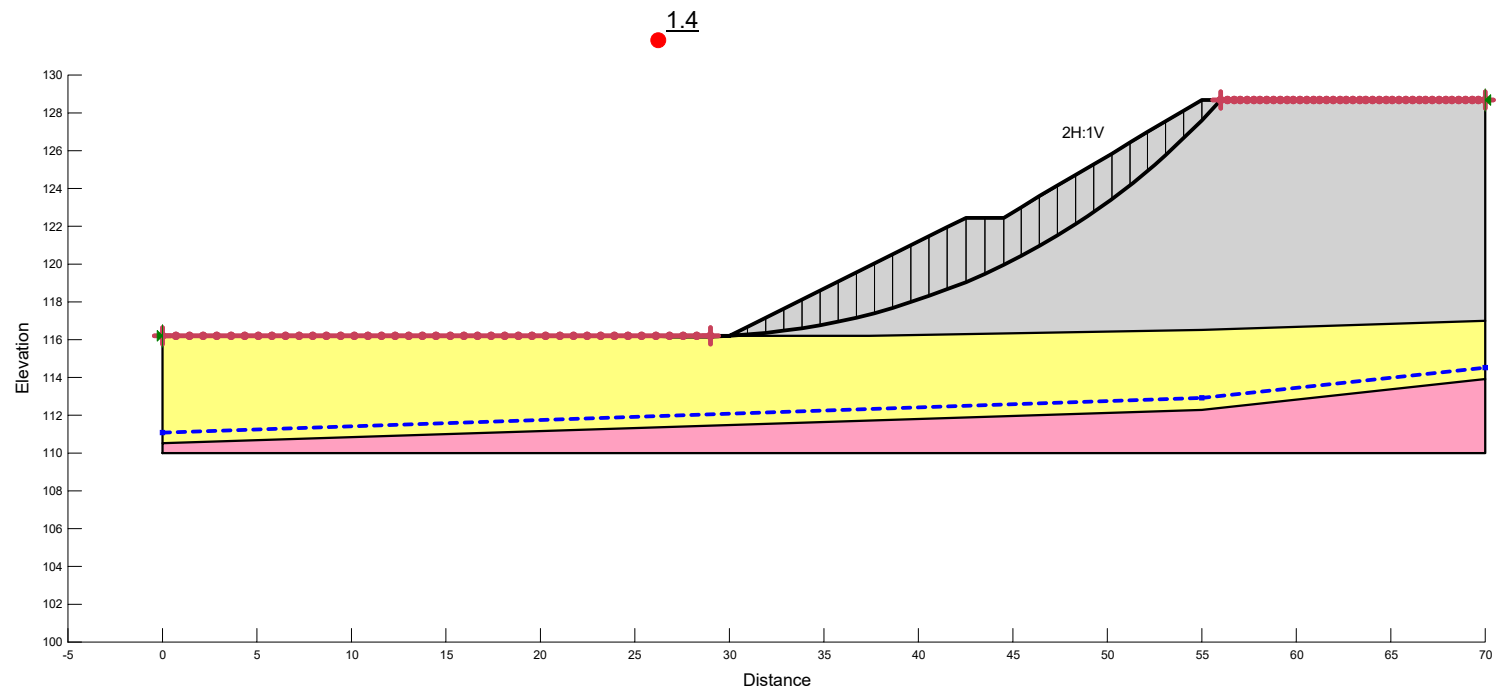
Minimum Slip Surface Depth: 1.52 m

Entry: (47.67953, 132.6638) m, Exit: (20.227838, 125.43179) m

Center: (28.803018, 148.59899) m, Radius: 24.703301 m

Figure I-3.2




Color	Name	Model	Unit Weight (kN/m³)	Phi' (°)
	1. SSM FILL	Mohr-Coulomb	21	32
	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
	3. BEDROCK	Bedrock (Impenetrable)		

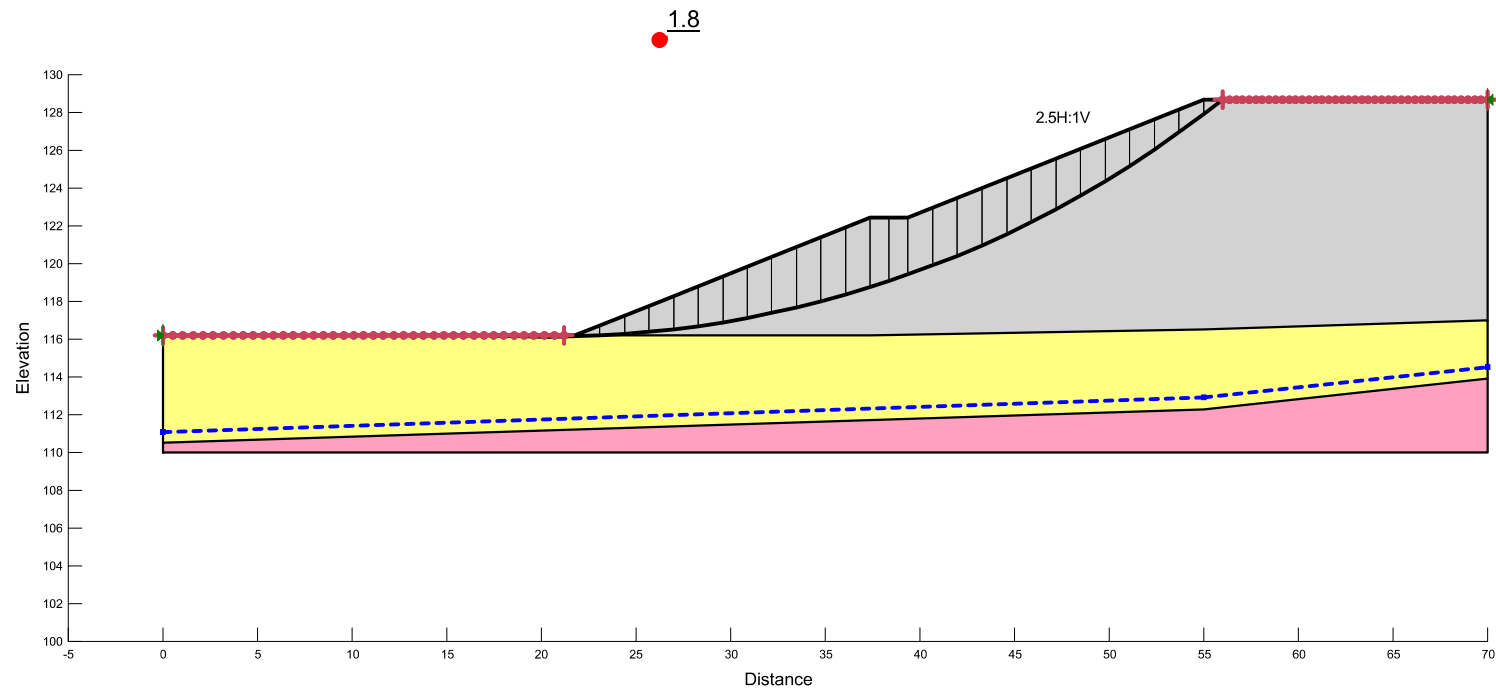


Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
1. Short/Long Term Static (Undrained/Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	05/09/2020, 05:12:34 PM	1:400

Additional Details
Name: W-S Ramp 21+155, 2H:1V Earth Embankment
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (56, 128.7) m, Exit: (26.1, 116.2) m
Center: (28.058881, 153.52476) m, Radius: 37.376124 m

Figure I-4.1




Color	Name	Model	Unit Weight (kN/m³)	Phi°
	1. SSM FILL	Mohr-Coulomb	21	32
	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
	3. BEDROCK	Bedrock (Impenetrable)		

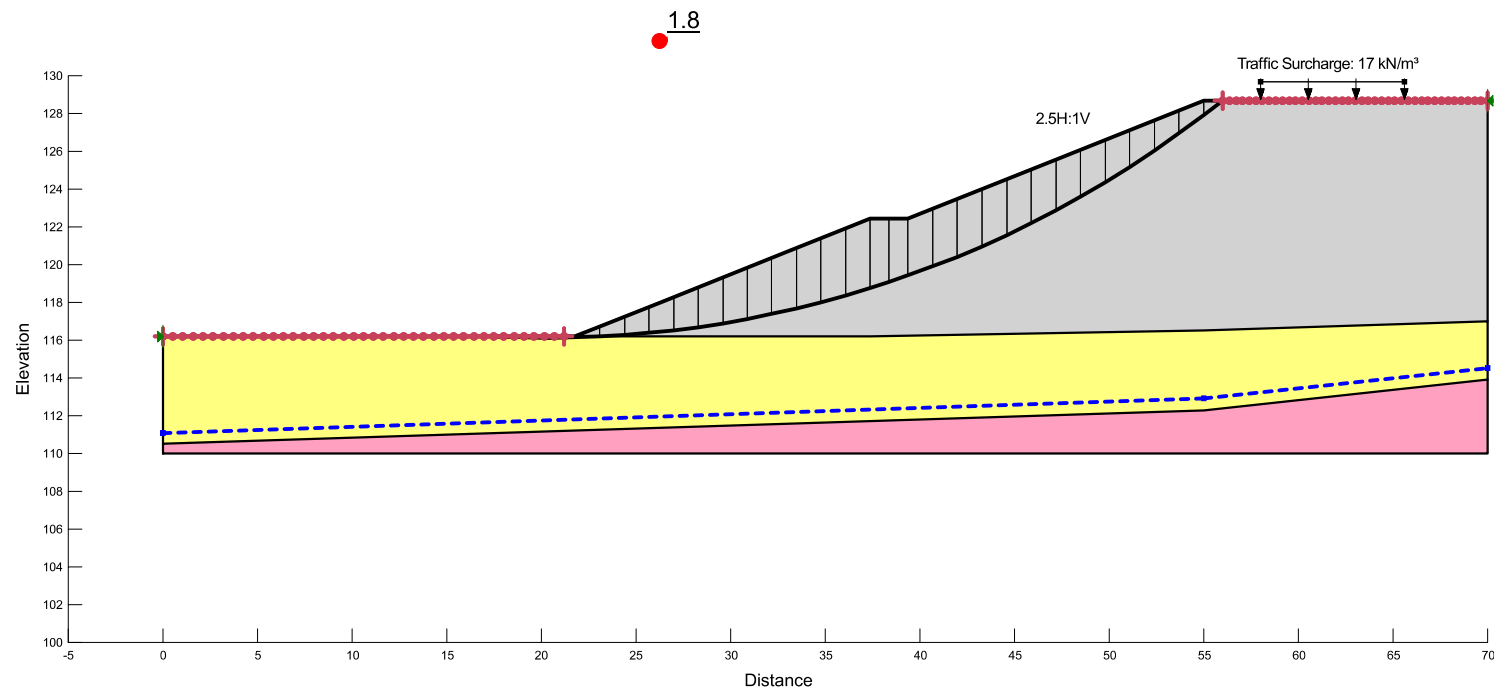


Project O'Brien Road W-S Ramp 21+155		
Analysis 1. Short/Long Term Static (Drained/Undrained)		
Seismic Coefficient H: 0g, V: 0g	Last Run 08/04/2021, 04:58:39 PM	Scale 1:400

Additional Details
 Name: W-S Ramp 21+155, 2.5H:1V Earth Embankment
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (56, 128.7) m, Exit: (17.49, 116.2) m
 Center: (20.289361, 173.14653) m, Radius: 57.015295 m

Figure I-5.1

Color	Name	Model	Unit Weight (kN/m ³)	Phi°
	1. SSM FILL	Mohr-Coulomb	21	32
	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
	3. BEDROCK	Bedrock (Impenetrable)		



Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
2. Short Term Static Traffic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	08/04/2021, 04:59:24 PM	1:400

Additional Details

Name: W-S Ramp 21+155, 2.5H:1V Earth Embankment

Comments:




Method: Morgenstern-Price, Half-Sine

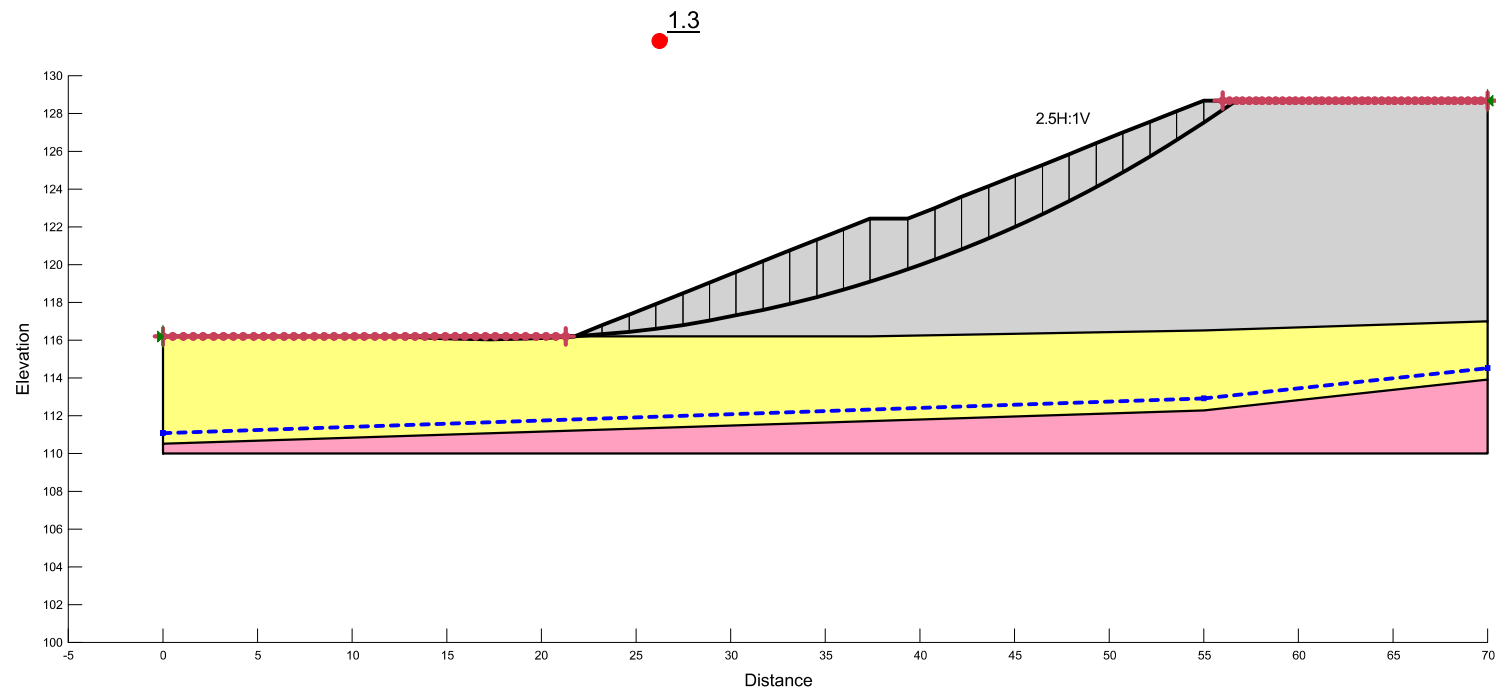
Minimum Slip Surface Depth: 1.52 m

Entry: (56, 128.7) m, Exit: (17.49, 116.2) m

Center: (20.289361, 173.14653) m, Radius: 57.015295 m

Figure I-5.2

Color	Name	Model	Unit Weight (kN/m³)	Phi°
	1. SSM FILL	Mohr-Coulomb	21	32
	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
	3. BEDROCK	Bedrock (Impenetrable)		

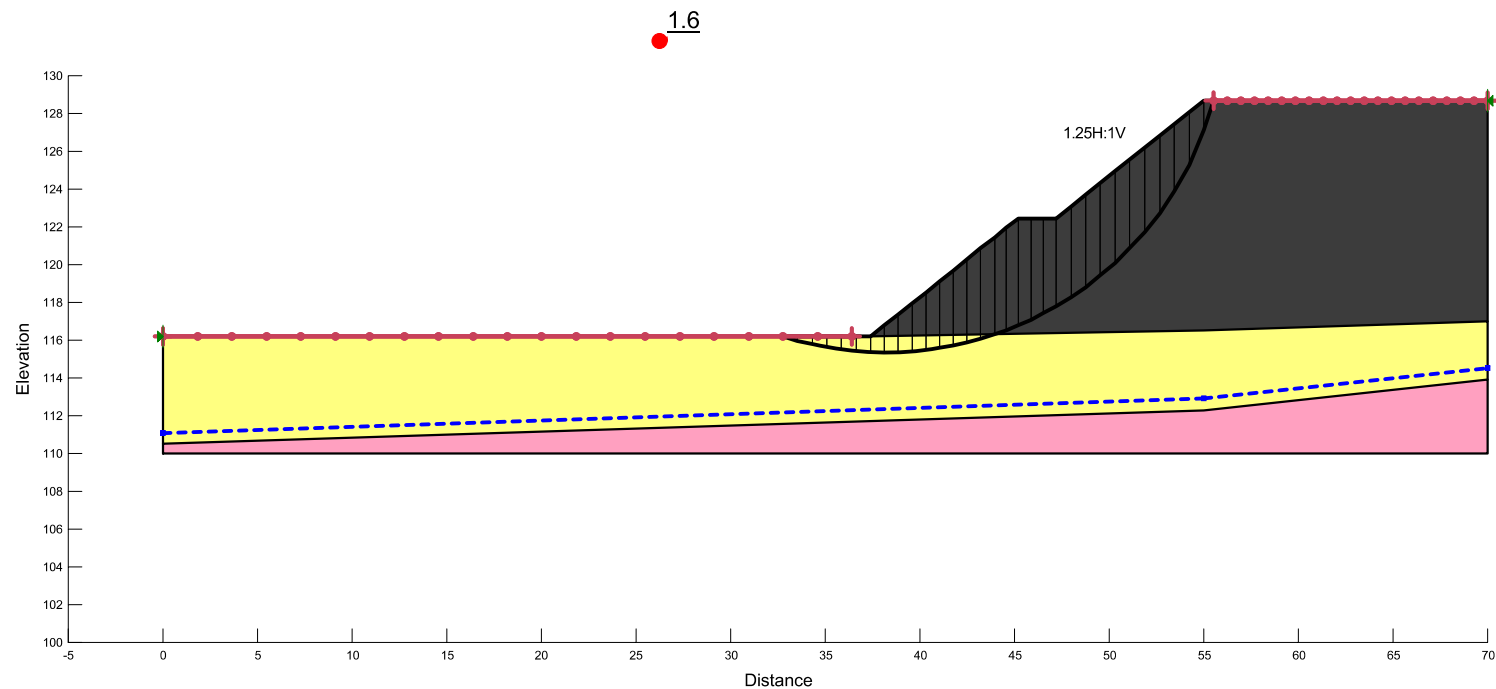


Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
3. Pseudo-Static Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.127g, V: 0g	08/04/2021, 04:59:01 PM	1:400

Additional Details
Name: W-S Ramp 21+155, 2.5H:1V Earth Embankment
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (56.7, 128.7) m, Exit: (12.78, 116.2) m
Center: (17.289242, 183.76498) m, Radius: 67.715289 m

Figure I-5.3

Color	Name	Model	Unit Weight (kN/m³)	Phi° (°)
■	1. ROCK FILL	Mohr-Coulomb	17	42
■	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
■	3. BEDROCK	High Strength	21	



Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
1. Short/Long Term Static (Undrained/Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	08/04/2021, 05:27:40 PM	1:400

Additional Details

Name: W-S Ramp 21+155, 1.25:1V Rock Fill Embankment

Comments: Slope Stability Assessment

Method: Morgenstern-Price, Half-Sine

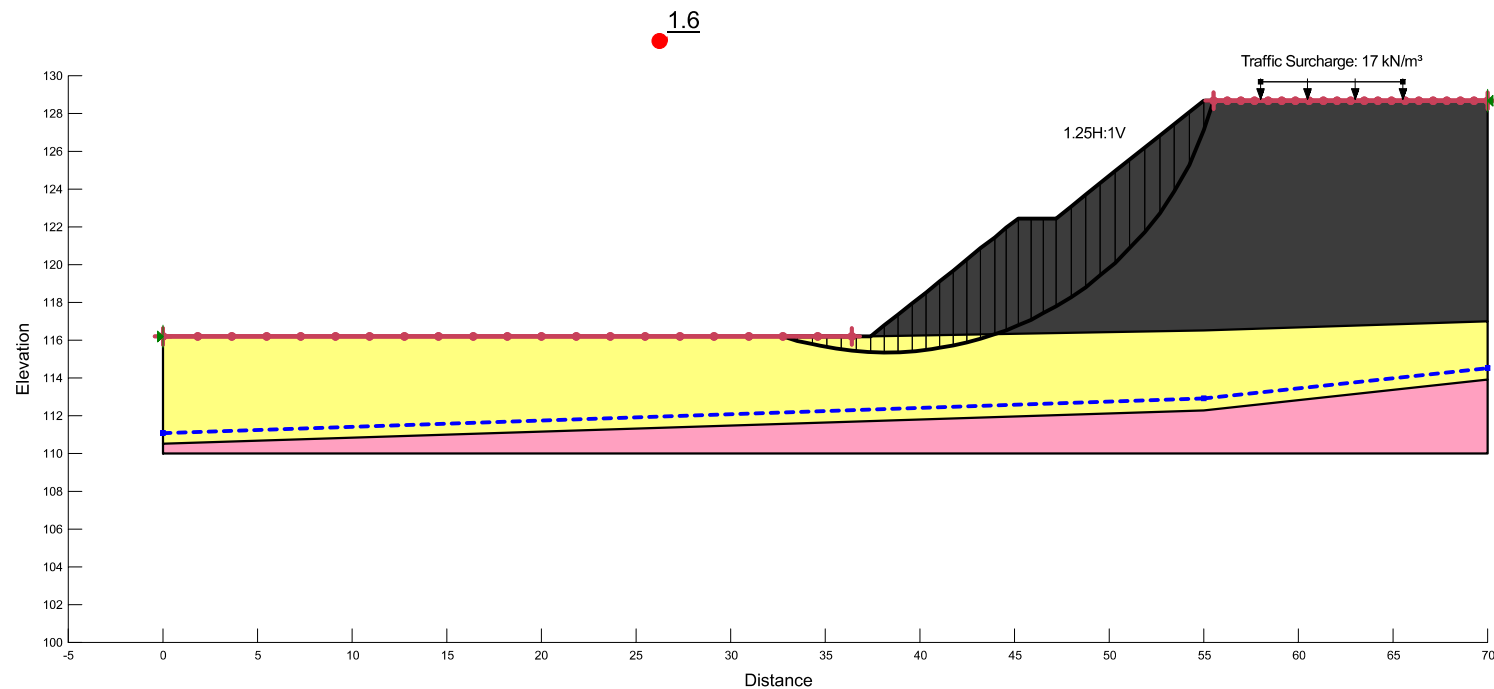
Minimum Slip Surface Depth: 1.52 m

Entry: (55.5, 128.7) m, Exit: (32.76, 116.2) m

Center: (38.181964, 133.27067) m, Radius: 17.91104 m

Figure I-6.1

Color	Name	Model	Unit Weight (kN/m³)	Phi° (°)
■	1. ROCK FILL	Mohr-Coulomb	17	42
■	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
■	3. BEDROCK	High Strength	21	

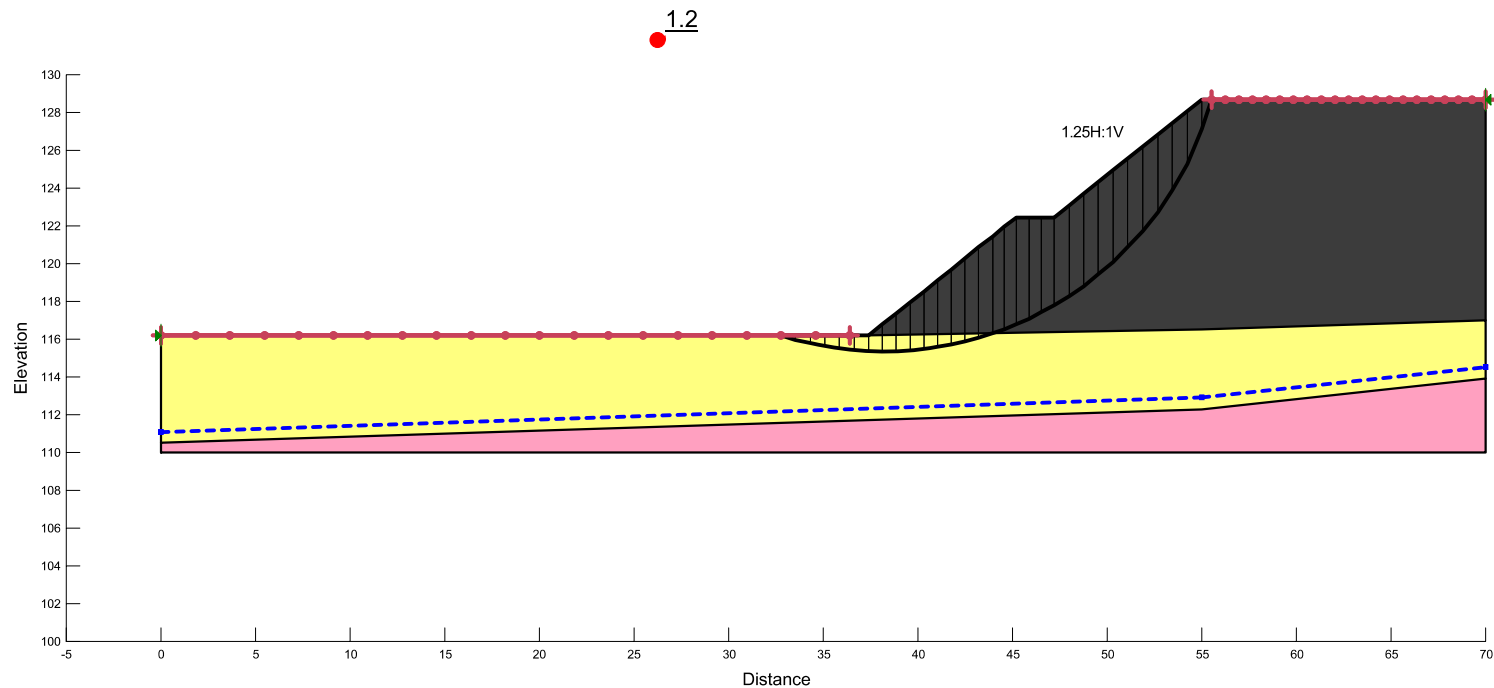


Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
2. Short Term Static Traffic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	08/04/2021, 05:27:43 PM	1:400

Additional Details	
Name: W-S Ramp 21+155, 1.25:1V Rock Fill Embankment	
Comments: Slope Stability Assessment	
Method: Morgenstern-Price, Half-Sine	
Minimum Slip Surface Depth: 1.52 m	
Entry: (55.5, 128.7) m, Exit: (32.76, 116.2) m	
Center: (38.181964, 133.27067) m, Radius: 17.91104 m	

Figure I-6.2

Color	Name	Model	Unit Weight (kN/m³)	Phi° (°)
■	1. ROCK FILL	Mohr-Coulomb	17	42
■	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
■	3. BEDROCK	High Strength	21	



Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
3. Pseudo-Static Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.127g, V: 0g	08/04/2021, 05:27:42 PM	1:400

Additional Details

Name: W-S Ramp 21+155, 1.25:1V Rock Fill Embankment

Comments: Slope Stability Assessment

Method: Morgenstern-Price, Half-Sine

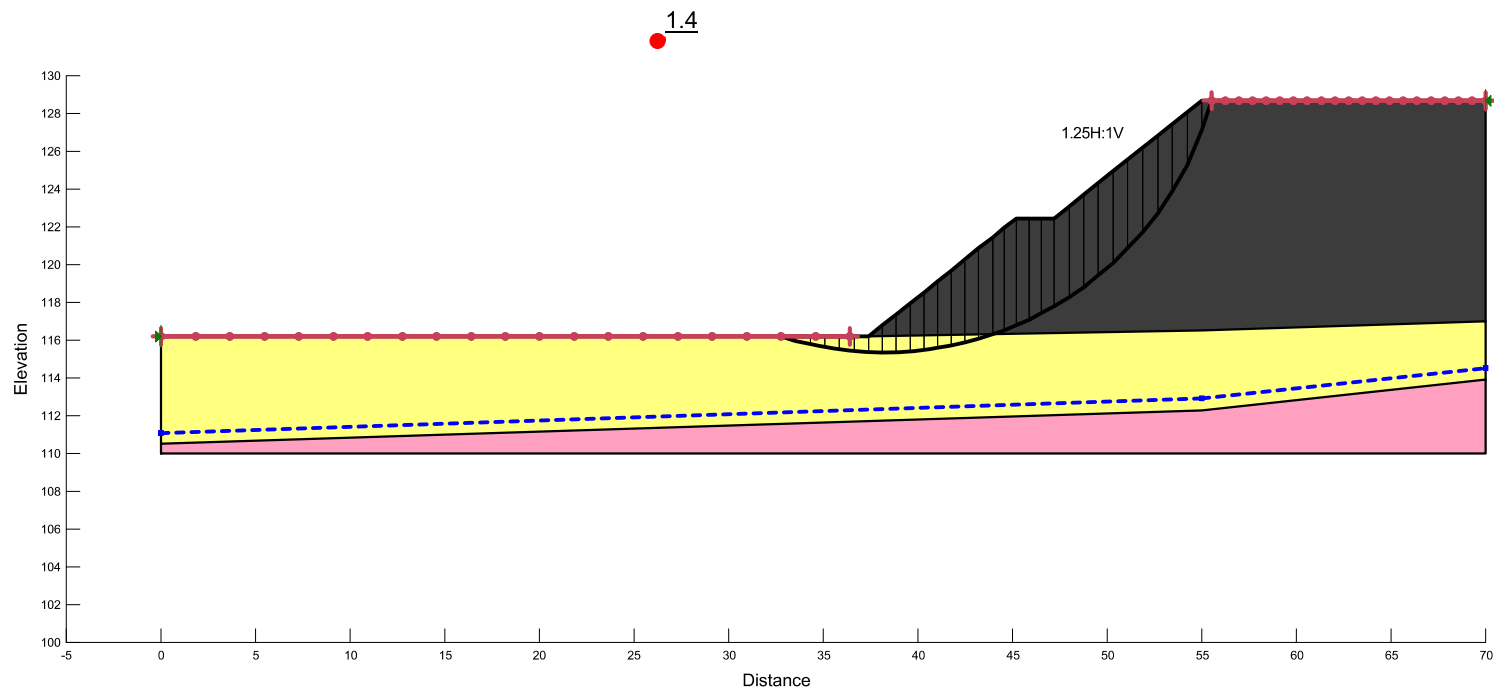
Minimum Slip Surface Depth: 1.52 m

Entry: (55.5, 128.7) m, Exit: (32.76, 116.2) m

Center: (38.181964, 133.27067) m, Radius: 17.91104 m

Figure I-6.3

Color	Name	Model	Unit Weight (kN/m³)	Phi° (°)
■	1. ROCK FILL	Mohr-Coulomb	17	42
■	2. SILTY SAND TO SAND	Mohr-Coulomb	20	30
■	3. BEDROCK	High Strength	21	



Project		
O'Brien Road W-S Ramp 21+155		
Analysis		
4. Pseudo-Static Seismic (Undrained) 1:475		
Seismic Coefficient	Last Run	Scale
H: 0.049g, V: 0g	08/04/2021, 05:38:08 PM	1:400

Additional Details

Name: W-S Ramp 21+155, 1.25:1V Rock Fill Embankment

Comments: Slope Stability Assessment








Method: Morgenstern-Price, Half-Sine

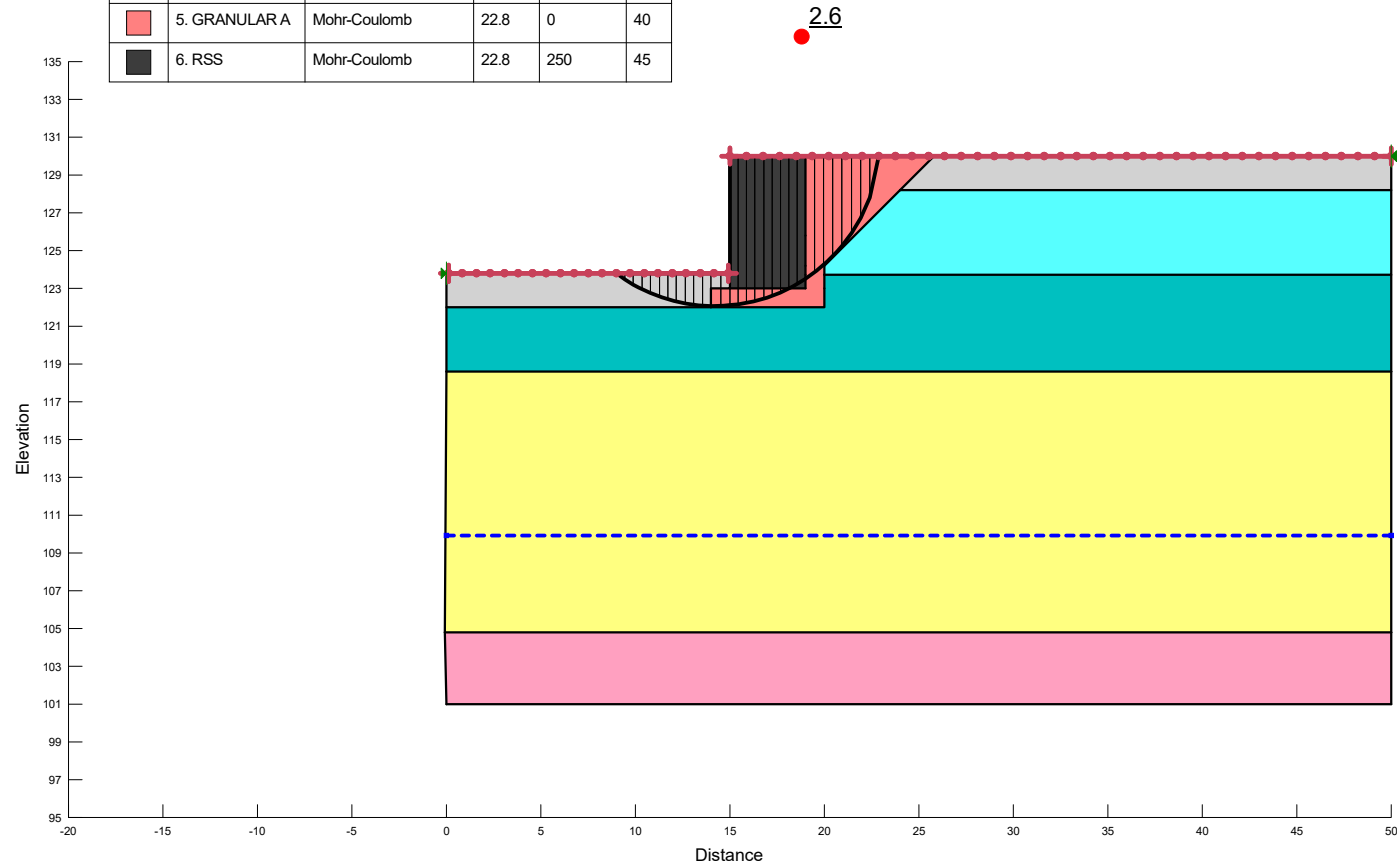
Minimum Slip Surface Depth: 1.52 m

Entry: (55.5, 128.7) m, Exit: (32.76, 116.2) m

Center: (38.181964, 133.27067) m, Radius: 17.91104 m

Figure I-6.4








Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (TSA)	Mohr-Coulomb	18	100	0
	3. CLAYEY SILT (TSA)	Mohr-Coulomb	17	90	0
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			
	5. GRANULAR A	Mohr-Coulomb	22.8	0	40
	6. RSS	Mohr-Coulomb	22.8	250	45

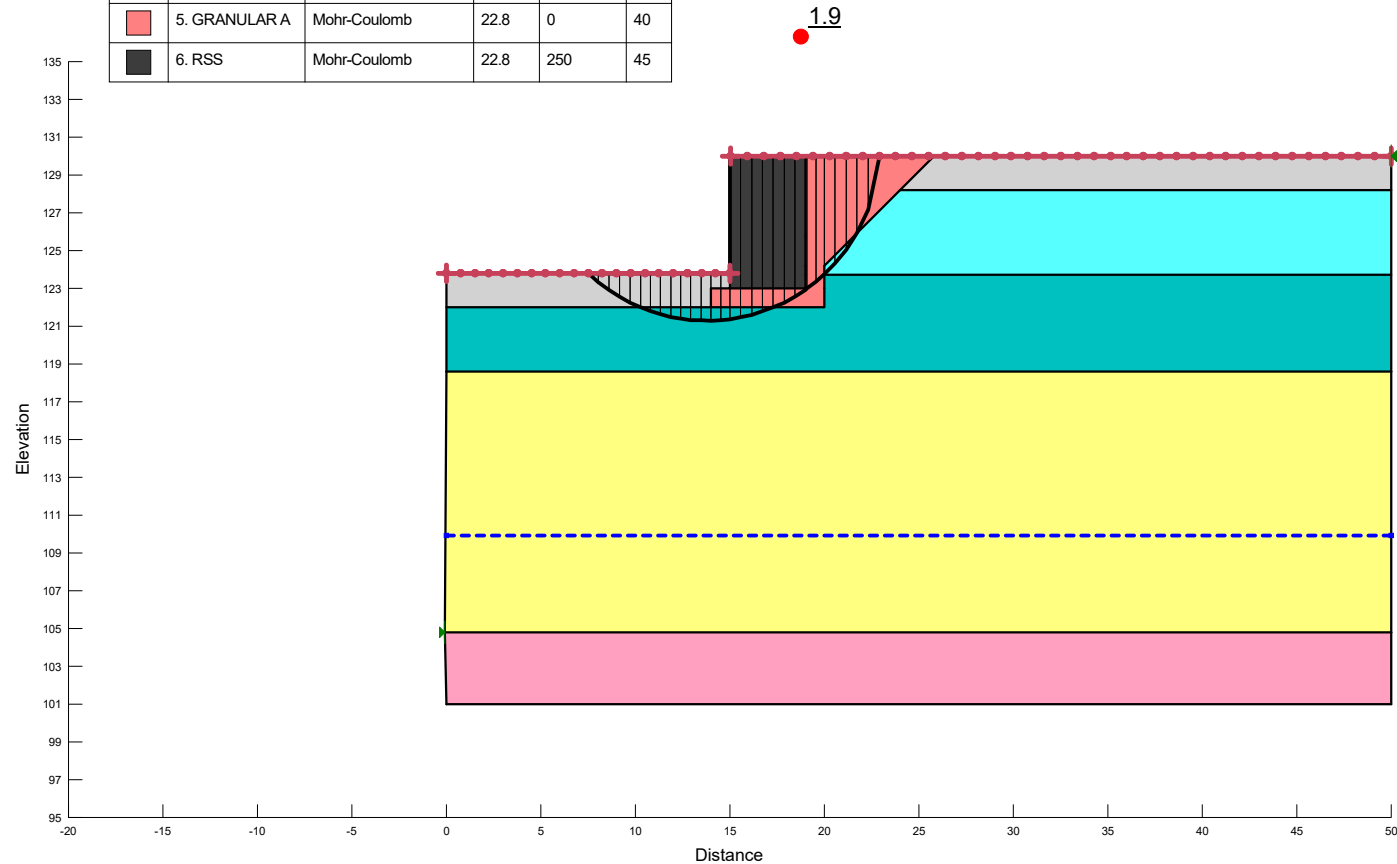


Project O'Brien Road 9+980 RSS Cut Slope		
Analysis 1. Short Term Static (Undrained)		
Seismic Coefficient H: 0g, V: 0g	Last Run 05/09/2020, 05:31:50 PM	Scale 1:400

Additional Details
Name: O'Brien Road 9+980 RSS Cut Slope
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (22.875, 130) m, Exit: (8.98, 123.8) m
Center: (14.197958, 130.77613) m, Radius: 8.7116834 m

Figure I-7.1








Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (ESA)	Mohr-Coulomb	18	7	28
	3. CLAYEY SILT (ESA)	Mohr-Coulomb	17	5	28
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			
	5. GRANULAR A	Mohr-Coulomb	22.8	0	40
	6. RSS	Mohr-Coulomb	22.8	250	45

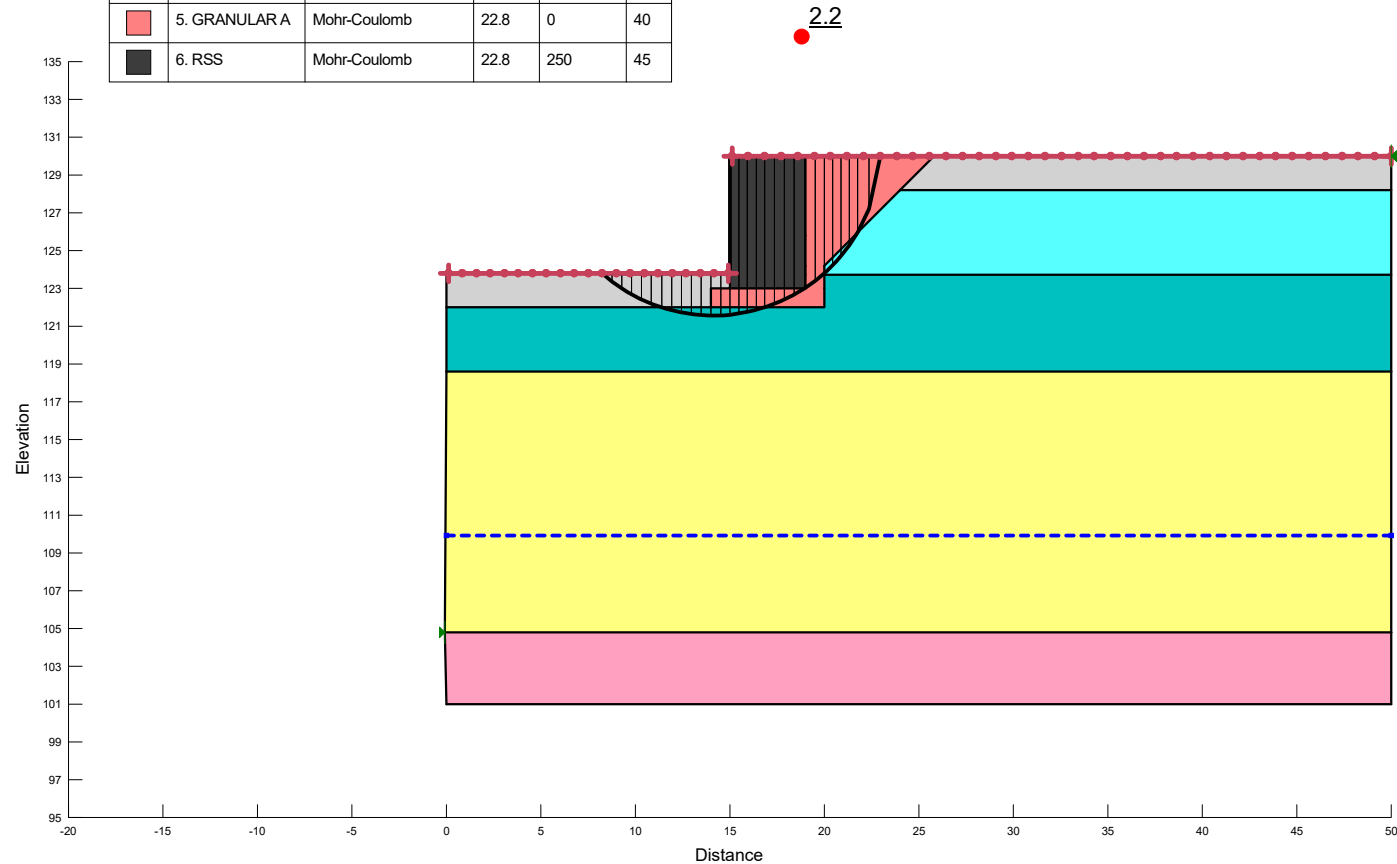


Project		
O'Brien Road 9+980 RSS Cut Slope		
Analysis		
2. Long Term Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	05/09/2020, 05:32:02 PM	1:400

Additional Details
Name: O'Brien Road 9+980 RSS Cut Slope
Comments:
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (22.905225, 130) m, Exit: (7.5, 123.8) m
Center: (13.781863, 130.43016) m, Radius: 9.1334968 m

Figure I-7.2

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1. FILL	Mohr-Coulomb	20	0	30
	2. CLAY TO SILTY CLAY (TSA)	Mohr-Coulomb	18	100	0
	3. CLAYEY SILT (TSA)	Mohr-Coulomb	17	90	0
	4. SILTY SAND TO SAND	Mohr-Coulomb	20	0	32
	5. BEDROCK	Bedrock (Impenetrable)			
	5. GRANULAR A	Mohr-Coulomb	22.8	0	40
	6. RSS	Mohr-Coulomb	22.8	250	45



Project O'Brien Road 9+980 RSS Cut Slope		
Analysis 3. Pseudo-Static Seismic (Undrained)		
Seismic Coefficient H: 0.127g, V: 0g	Last Run 05/09/2020, 05:31:56 PM	Scale 1:400

Additional Details
 Name: O'Brien Road 9+980 RSS Cut Slope
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (22.9525, 130) m, Exit: (8.24, 123.8) m
 Center: (14.115532, 130.41372) m, Radius: 8.8466475 m

Figure I-7.3

Appendix J.

List of Referenced Specifications Non-Standard Special Provisions

1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS 422	Construction Specification for Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
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
OPSS.PROV 1860	Material Specification for Geotextiles
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement
SP 110S06	Amendment to OPSS.PROV 1010

2. Suggested wording for contract documents

Notice to Contractor: “Obstructions”

The Contractor is hereby notified that the native discontinuous tills at the site and as inferred from available information should be expected to contain cobbles and boulders. Considerations of these obstructions must be made in the selection of appropriate equipment and procedures for excavations, installations of deep foundations and temporary protection systems.

Notice to Contractor: “Protection of Sensitive Foundation Soils”

The Contractor is advised that the native clay to clayey silt that will be exposed at the subgrade is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.