



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 7-NEW EBL AND WBL OVER HOPEWELL CREEK
HIGHWAY 7-NEW, KITCHENER TO GUELPH
G.W.P. 408-88-00**

GEOCRES No. 40P9-57

Latitude 43.515747 °, Longitude -80.355691 °

Report

to

WSP

Date: April 28, 2020
Thurber File No: 11375



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the site of two proposed bridges to carry Highway 7-New Eastbound lane and Westbound lane (EBL and WBL) over Hopewell Creek in the Regional Municipality of Waterloo, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, cross sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions under the potential foundation footprint was developed from the data obtained in the course of the previous and current investigations.

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

Reference has been made to information on subsurface conditions contained in a previous foundation report prepared for this site during the preliminary design phase. The title of the report is:

- Preliminary, Foundation Investigation and Design Report, Highway 7 EBL and WBL over Hopewell Creek, Highway 7-New, Kitchener to Guelph, G.W.P. 408-88-00, Geocres No. 40P8-153, Report to Ministry of Transportation Ontario West Region, File: 15-64-17, dated November 10, 2009. (Reference 1).

2. SITE DESCRIPTION

At the site, the Highway 7-New alignment runs parallel to the existing Highway 7 alignment and 150 m to the north. The site lies approximately 6 km to the northeast of a developed area of the City of Kitchener.



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

Hopewell Creek runs north to south and crosses the proposed Highway 7 alignment near station 25+840. The creek is approximately 9.0 m wide within the extent of the proposed structures.

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

3. INVESTIGATION PROCEDURES

A preliminary foundation investigation was carried out between May 26 and August 8, 2008. Four boreholes, 08-130 to 08-133, were drilled for the proposed Highway 7-New Eastbound Lane (EBL) and Westbound Lane (WBL) bridges. Boreholes 08-130 and 08-131 were drilled for the WBL bridge, and Boreholes 08-132 and 08-133 were drilled for the EBL bridge. One borehole was drilled at each bridge abutment of the possible one-span structure arrangements. The depths of the boreholes ranged from 12.2 m to 13.9 m (Elevations 301.3 to 299.6) and, to 26.0 m depth (Elevation 291.2) in Borehole 08-132. The Record of Borehole sheets for the boreholes drilled during the previous investigation are included in Appendix B. The elevations on the Record of Borehole sheets was updated since the preliminary report was issued based on new information obtained during the current investigation.

A detailed geotechnical investigation was conducted between July 28 to August 8, 2017, and November 28 to December 1, 2017. Nine boreholes (numbered HC16-01 to HC16-08 and RW-25) were drilled during the detailed investigation. Boreholes HC16-01 and HC16-02 were located at the proposed west approaches, and Boreholes HC16-07 and HC16-08 were located at the proposed east approaches. Boreholes HC16-03 to HC16-06 were drilled near the proposed west and east abutments of the Highway 7-New WBL and EBL structures. Borehole RW-25 was drilled near the north end of a proposed retaining wall, which extends north from the east abutment of the Highway 7-New WBL. The depths of the boreholes ranged from 3.1 m to 18.5 m (Elevations 311.0 to 297.9). The Record of Borehole sheets for the boreholes drilled during the present investigation are included in Appendix A.



The approximate locations of the boreholes from the previous and current investigations are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix C. The coordinates and elevations of the current and previous boreholes are given on the drawings and on the individual Record of Borehole Sheets in Appendices A and B, respectively.

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

Prior to commencing the site investigation, utility clearances were obtained for all borehole locations.

During the current investigation, a track mounted D52 drill rig equipped with hollow-stem augers were used to advance the boreholes. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

The drilling, sampling and in-situ testing operations were supervised on a full-time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Results of field drilling and sampling of the investigation are presented on the Record of Borehole sheets in Appendices A and B.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Four standpipe piezometers were installed in selected boreholes (08-130, 08-133, HC16-04 and HC16-05). Each piezometer consisted of a 25 mm diameter Schedule 40 PVC pipe with a 1.5 m or 3.0 m long slotted screen enclosed in a column of filter sand to permit groundwater level monitoring. Piezometer installation details, groundwater level observations, and water level readings are shown on the Record of Borehole sheets. Upon completion of the drilling operations, the boreholes without piezometers were abandoned in general accordance with Ontario Regulation 903. The details of standpipe piezometer installation and borehole completion are summarized in Table 3.1. Upon completion of the investigation and monitoring of the piezometers, the piezometers were decommissioned as per O.Reg. 903.



Table 3.1 – Borehole Completion Details

Foundation Unit		Borehole Number	Borehole Ground Surface Elevation	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
WBL	West Approach	HC16-01	314.6	9.8/304.8	None Installed	Borehole backfilled with auger cuttings to surface.
	West Abutment	08-130	314.3	13.8/300.5	13.4/300.9	25 mm diameter piezometer with 1.5 m slotted screen installed with sand filter to 11.6 m, holeplug from 11.6 m to 11.3 m, grout from 11.3 m to 0.2 m, then holeplug to ground surface.
		HC16-03	313.6	15.7/297.9	None Installed	Borehole backfilled with auger cuttings to surface.
	East Abutment	08-131	313.5	12.2/301.3	None Installed	Bentonite benseal to 0.3 m, then holeplug to ground surface.
		HC16-05	313.8	13.9/299.8	13.8/299.9	25 mm diameter piezometer with 3.0 m slotted screen installed with a sand filter to 9.1 m, bentonite holeplug from 9.1 m to ground surface.
	East Approach	HC16-07	314.1	9.1/305.0	None Installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	Retaining Wall (north side)	RW16-25	312.9	12.4/300.5	None Installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
EBL	West Approach	HC16-02	317.4	6.4/311.0	None Installed	Borehole backfilled with auger cuttings to surface.
	West Abutment	08-132	317.2	26.0/291.2	None Installed	Borehole backfilled with grout to 0.6 m, then holeplug to ground surface.
		HC16-04	316.5	18.5/298.0	18.3/298.2	25 mm diameter piezometer with 3.0 m slotted screen installed with a sand filter to 13.7 m, holeplug from 13.7 m to 10.6 m, bentonite seal and auger cuttings from 10.6 m to ground surface.



Foundation Unit		Borehole Number	Borehole Ground Surface Elevation	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
	East Abutment	08-133	313.5	13.9/299.6	13.9/299.6	25 mm diameter piezometer with 1.5 m slotted screen installed with a sand filter to 11.6 m, holeplug from 11.6 m to 11.3 m, bentonite seal from 11.3 m to 0.3 m, then holeplug to ground surface.
		HC16-06	313.4	13.9/299.6	None Installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	East Approach	HC16-08	313.9	3.1/310.8	None Installed	Borehole backfilled with auger cuttings to surface.

4. LABORATORY TESTING

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

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

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendices A and B. Details of the encountered soil stratigraphy along the proposed alignment are presented in these appendices and on the "Borehole Locations and Soil Strata" drawings in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes consisted of topsoil and/or



recent alluvium overlying silt, sand, sand and gravel layers, and both cohesive and cohesionless till deposits. Descriptions of the individual strata are presented below.

5.1 Topsoil

Topsoil was identified at ground surface in Boreholes 08-131, 08-133, HC16-01 to HC16-08 and RW16-05. The topsoil thickness ranged from 75 mm to 700 mm. Moisture content measured in the topsoil ranged from 25 percent to 83 percent.

The topsoil encountered in Borehole HC16-08 has some sand, some silt and trace gravel and has a compact state, based on an SPT 'N' value of 16 blows per 0.3 m of penetration.

The topsoil thickness may vary between and beyond the borehole locations, and the data is not intended for the purpose of estimating quantities.

5.2 Recent Alluvium

Dark brown to brown recent alluvium containing some silt, trace clay, trace sand and occasional organics was encountered surficially in Boreholes 08-130 and 08-132, and below the topsoil in Boreholes HC16-03 to HC16-05 and RW16-25. The alluvium thickness ranged from 0.5 m to 1.5 m.

The alluvium is in a very loose to loose state, based on SPT 'N' values of 2 to 8 blows per 0.3 m of penetration. An SPT 'N' value of 31 blows per 0.3 m of penetration, indicating a dense state, was measured in Borehole RW16-25. Moisture content ranged from 15 percent to 53 percent.

5.3 Sandy Silt

A layer of native dark brown to brown sandy silt containing trace gravel, trace clay and occasional organics, rootlets and cobbles, was encountered below the topsoil and recent alluvium in Boreholes 08-131, HC16-01, HC16-02 and HC16-04. The thickness of the sandy silt ranged from 1.2 m to 3.0 m.

The depth to the base of the sandy silt varied from 1.4 m to 1.5 m (Elevations 315.9 to 312.0) and was 4.4 m (Elevation 312.0) in Borehole HC16-04.

The sandy silt is described as loose to dense, based on SPT 'N' values ranging from 4 to 32 blows per 0.3 m of penetration. The moisture content of this layer ranged from 10 percent to 33 percent.



5.4 Sand and Gravel

A layer of brown sand and gravel containing trace to some silt, trace to some clay and occasional cobbles was contacted at depths ranging from 0.2 m to 1.5 m (Elevations 315.9 to 312.0) in all the boreholes, except in Borehole HC16-01. In Borehole HC16-04, the sand and gravel layer was contacted at 5.9 m depth (Elevation 310.5). The thickness of the sand and gravel ranged from 0.7 m to 4.9 m.

The depth to the base of the sand and gravel ranged from 1.4 m to 5.6 m (Elevations 314.4 to 307.3), and at 7.0 m (Elevation 309.5) in Borehole HC16-04.

A lower layer of sand and gravel was contacted in Borehole 08-132 at 15.7 m depth (Elevation 301.5). The thickness of the lower sand and gravel layer was 2.1 m. The depth to the base of the lower sand and gravel was at 17.8 m (Elevation 299.4).

SPT 'N' values in the sand and gravel layer ranged from 9 to 100 blows per 0.3 m of penetration, typically 20 to 47, indicating a loose to very dense state. An SPT 'N' value in the lower sand and gravel layer of 100 blows per 0.225 m was recorded, indicating a very dense state. Moisture contents ranged from 3 percent to 16 percent.

Grain size distribution test results from sand and gravel samples are presented on the Record of Borehole sheets and on Figures A1 and Figure B1 of Appendices A and B. The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	34 to 57
Sand	28 to 46
Silt & Clay	11 to 24

5.5 Sandy Silt to Silty Sand Till

A deposit of native brown to grey cohesionless till described as sandy silt till, silty sand till and sand and silt till containing trace to some gravel, trace to some clay and occasional cobbles was contacted at depths ranging from 1.4 m to 7.2 m (Elevations 314.4 to 305.7), except in Borehole HC16-04, 08-130, and 08-132. Where fully penetrated, the thickness of the cohesionless till ranged from 1.6 m to 5.3 m. The depth to the base of the upper cohesionless till, where fully penetrated, ranged from 3.0 m to 7.5 m (Elevations 311.6 to 306.1).



A lower layer of grey silty sand to sandy silt till containing some clay and trace to some gravel was contacted in Boreholes 08-132, HC16-03 and HC16-04 at depths ranging from 12.0 m to 17.8 m (Elevations 301.6 to 299.4).

Boreholes 08-131, 08-133, HC16-02, HC16-05 to HC16-08 and RW16-25 were terminated within the upper cohesionless till at depths ranging from 3.1 m to 13.9 m (Elevations 311.0 to 299.6). Boreholes 08-132, HC16-03 and HC16-04 were terminated within the lower cohesionless till at depths ranging from 15.7 m to 26.0 m (Elevations 298.0 to 291.2).

SPT 'N' values in the cohesionless till layer, generally ranged from 30 blows per 0.3 m of penetration to higher than 100 blows per 0.025 m of penetration indicating a dense to very dense relative density. SPT 'N' values of 6, 11, and 17 blows per 0.3 m of penetration were measured in Boreholes HC16-01 and HC16-03 indicating a loose to compact relative density. The measured moisture content varied from 5 percent to 21 percent.

Grain size distribution test results for cohesionless till samples are presented on the Record of Borehole sheets and on Figures A2, A3 and B4 of Appendices A and B. The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 18
Sand	28 to 60
Silt	18 to 55
Clay	6 to 18

Clayey zones were contacted in the sandy silt till near Elevation 306.6 in Borehole 08-133 and near Elevation 307.2 in Borehole 08-131. Atterberg Limits test results are presented on Figure B6 of Appendix B. The results of the laboratory tests are summarized as follows:

Liquid Limit	18
Plastic Limit	10

The above results show that the clayey zones within the cohesionless till are of low plasticity with a group symbol of CL-ML.

Glacial till layers typically contain cobbles and boulders which may account for some high blow counts and resistance to augering.



5.6 Sand

Brown to grey sand containing trace gravel to gravelly, trace to some silt, trace to some clay and occasional cobbles and boulders was encountered at depths ranging from 3.0 m to 6.1 m (Elevations 311.1 to 307.3) in Boreholes 08-130, 08-133, HC16-06, HC16-07 and RW16-25. The thickness of the sand layer ranged from 1.5 m to 2.6 m. The depth to the base of the sand ranged from 5.6 m to 7.6 m (Elevations 308.5 to 305.7).

SPT 'N' values in the sand ranged from 10 to 52 blows per 0.3 m of penetration, indicating a compact to very dense relative density. Moisture content ranged from 5 percent to 20 percent.

Grain size distribution test results for sand samples are presented on the Record of Borehole sheets and on Figures A4 and B2 of Appendices A and B. The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 22
Sand	63 to 90
Silt & Clay	9 to 23

5.7 Silty Clay Till

A native layer of brown to grey cohesive till described as silty clay till containing trace gravel, trace to with sand and occasional cobbles was encountered at depths ranging from 2.5 m to 7.5 m (Elevations 312.0 to 306.1) in Boreholes 08-130, 08-132, HC16-01, HC16-03 and HC16-04. Where fully penetrated, the thickness of the silty clay till ranged from 4.5 m to 12.2 m.

The depth to the base of the silty clay till, where fully penetrated, ranged from 12.0 m to 16.6 m (Elevations 301.6 to 299.8).

Boreholes 08-130 and HC16-01 were terminated within the silty clay till at 13.8 m and 9.8 m depth (Elevations 300.5 and 304.8), respectively.

SPT 'N' values in silty clay till generally ranged from 11 blows per 0.3 m of penetration to higher than 100 blows per 0.125 m of penetration, typically 20 to 79 blows, indicating a typically very stiff to hard consistency. The natural moisture contents generally lay in the range of 9 percent to 24 percent.



Grain size distribution test results for silty clay till samples are presented on the Record of Borehole sheets and on Figures A5 and B3 in Appendices A and B. The results of laboratory tests carried out on silty clay till samples were as follows:

Soil Particles	Silty Clay Till (%)
Gravel	0 to 3
Sand	10 to 31
Silt	38 to 55
Clay	25 to 46

The results of Atterberg Limits are presented on the Record of Borehole sheets and in Figures A6 and B5 included in Appendices A and B. The results of Atterberg Limits testing are summarized below:

Liquid Limit	26 to 38
Plastic Limit	13 to 16

The above results show that the silty clay till is of low to medium plasticity with group symbols of CL and CI.

Glacial tills inherently contain cobbles and boulders.

5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations, and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes 08-130, 08-133, HC16-04 and HC16-05 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometers are summarized below, in Table 5.1.

Table 5.1 – Water Level Measurements

Foundation Unit		Borehole	Date	Water Level (m)		Comment
				Depth	Elevation	
WBL	West Approach	HC16-01	July 28, 2017	6.1	308.5	Open borehole



Foundation Unit		Borehole	Date	Water Level (m)		Comment
				Depth	Elevation	
	West Abutment	08-130	August 22, 2008	0.4*	314.7*	Piezometer
		HC16-03	August 2, 2017	3.0	310.6	Open borehole
	East Abutment	08-131	May 26, 2008	1.1	312.4	Open borehole
		HC16-05	December 1, 2017	2.4	311.4	Open borehole
			December 18, 2017	0.7*	314.5*	Piezometer
			December 21, 2017	0.7*	314.5*	Piezometer
EBL	East Approach	HC16-07	November 28, 2017	2.4	311.7	Open borehole
	Retaining Wall	RW16-25	November 30, 2017	2.4	310.5	Open borehole
	West Approach	HC16-02	July 28, 2017	0.0	317.4	Open borehole
	West Abutment	08-132	August 6, 2008	Dry	-	Open borehole
		HC16-04	July 31, 2017	6.1	310.4	Open borehole
			November 27, 2017	3.0	313.5	Piezometer
	East Abutment	08-133	July 15, 2008	0.7*	314.2*	Piezometer
			August 22, 2008	0.9*	314.4*	Piezometer
	East Approach	HC16-06	November 29, 2017	2.1	311.3	Open borehole
	East Approach	HC16-08	August 8, 2017	2.1	311.8	Open borehole

*Measured above ground surface (artesian conditions)

Available information indicates that the water level at Hopewell Creek is as follows:

- 2-year water level – Elevation 314.7
- 100-year water level – Elevation 315.9

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the sand and gravel from Borehole HC16-05 was submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix A.

Table 6.1 – Analytical Test Results⁷

Parameter	Units (Soil)	Test Results
		HC16-05 SS 3 Depth 1.5 m
		(Soil Sample)
Sulphide	%	<0.02
Chloride	µg/g	71
Sulphate	µg/g	22
pH	No unit	9.06
Electrical Conductivity	µS/cm	128
Resistivity	Ohms.cm	7810
Redox Potential	mV	314

7. MISCELLANEOUS

Altech Drilling & Investigative Services of Elmira, Ontario supplied a D52 track-mounted drill rig for the current investigation and conducted the drilling, sampling and in-situ testing operations.

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

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

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical



laboratory testing was carried out by SGS Canada Inc.

Details of the previous investigation, conducted in 2008, are presented in Reference 1.

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

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



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report presents an interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to select and design a suitable foundation system for the two new bridge structures to carry the proposed Highway 7-New Eastbound lanes (EBL) and Westbound lanes (WBL) over Hopewell Creek in the Regional Municipality of Waterloo, Ontario.

The preliminary General Arrangement (GA) drawings, provided by WSP, dated July 2012, indicate that each bridge will be a single-span structure supported on two abutments. The proposed length and width of each bridge are 44.0 m and 14.1 m, respectively. The east and west abutments of each bridge are designed to be supported on a single row of driven steel H-piles.

Based on proposed finished grade levels of Highway 7-New EBL and WBL structures and the existing ground surface near the proposed bridge abutments, the anticipated heights of the west and east approach embankments are presented in Table 8.1.

Table 8.1 – Anticipated Approach Embankment Height

Foundation Unit		Borehole	Proposed finished grade elevation of Highway 7-New ⁽¹⁾	Existing ground surface ⁽²⁾	Approximate Approach Embankment Height (m)
Hwy 7-New EBL	West abutment	08-132 HC16-04	320.7	317.2 to 316.5	3.5 to 4.2
	East abutment	08-133 HC16-06	320.6	316.0 to 313.4	4.6 to 7.2
Hwy 7-	West abutment	08-130 HC16-03	320.7	316.0 to 313.6	4.7 to 7.1

Foundation Unit		Borehole	Proposed finished grade elevation of Highway 7-New ⁽¹⁾	Existing ground surface ⁽²⁾	Approximate Approach Embankment Height (m)
New WBL	East abutment	08-131 HC16-05	320.6	315.1 to 313.8	5.5 to 6.8

⁽¹⁾ Finished grade level of Highway 7-New at the abutments, obtained from the GA drawings

⁽²⁾ Ground surface elevation at the proposed abutment, obtained from boreholes drilled at this site

The forward and side embankment slopes are proposed to be at inclination of 2H:1V.

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

The discussion and recommendations presented in this report are based on the information provided by WSP and on the factual data obtained in the course of the current and previous investigations.

9. STRUCTURE CLASSIFICATION

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

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

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



10. STRUCTURE FOUNDATIONS

The stratigraphy identified in the geotechnical investigations consisted primarily of topsoil and recent alluvium over layers of native silts and sands, sand and gravel, over cohesionless and cohesive till deposits. The groundwater levels measured in the piezometers ranged from 0.9 m (Elevation 314.4) above ground surface, indicating flowing artesian conditions, to 3.0 m (Elevation 313.5) below the ground surface.

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

1. Spread footings bearing on native soil
2. Spread footings on engineered fill pads
3. Augered Caissons in very dense/hard glacial till (drilled shafts)
4. Steel H-piles or open ended pipe piles driven into the very dense/hard glacial till soils

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

10.1 Spread Footing on Native Soil

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

The spread footings must bear on native undisturbed compact to very dense sand and gravel, dense sandy silt or dense to very dense silty sand to silty sand till. Provided a minimum footing width of 2 m is maintained and the front edge of the footing is set back a minimum horizontal distance of twice the footing width behind the forward slope, footings founded on the above recommended strata, may be designed in accordance with the elevations and bearing resistances given in Table 10.1.

Table 10.1 – Bearing Resistances for Spread Footings

Foundation Unit		Borehole	Depth (m)	Approx. Founding Elevation ⁽¹⁾ (m)	Founding Stratum	Factored ULS _f (kPa)	Factored SLS _f (up to 25 mm settlement) (kPa)
Hwy 7- New EBL	West abutment	08-132 HC16-04	4.5 to 5.2	312.0	Dense sandy silt / compact sand and gravel	600	400
	East abutment	08-133 HC16-06	1.4 to 1.5	312.0	Dense to very dense sand and gravel	600	400
Hwy 7- New WBL	West abutment	08-130 HC16-03	2.1 to 2.8	311.5	Dense to very dense sandy silt to silty sand till	450	300
	East abutment	08-131 HC16-05	1.5 to 1.8	312.0	Compact to very dense sand and gravel	450	300

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

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

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



The sliding resistance of cast-in-place concrete placed on the native, undisturbed soils may be computed based on an ultimate coefficient of friction, $\tan \delta$, of 0.45. A resistance Factor of 0.8 should be applied for cohesionless soils, as indicated in Table 6.2 in the CHBDC (2014).

Founding elevations presented in Table 10.1, are below the groundwater level measured in the piezometers with the exception of the west abutment of the WBL. The groundwater level was measured at 3.0 m (Elevation 313.5) below ground surface and at 0.4 m to 0.9 m above ground surface (Elevations ranging from 316.9 to 314.5), indicating flowing artesian conditions. The GA drawing indicates that the creek level varies from Elevation 315.9 to 314.6. Therefore, temporary excavations required to construct these footings will extend below the water table, and groundwater control will be required prior to excavation to construct the footing in the dry, to prevent sloughing of the sides and to prevent disturbance of the footing base due to the inflow of groundwater.

The contractor must implement groundwater control measures prior to excavating below the groundwater level and during construction. The design of the groundwater control system is the responsibility of the contractor. However, two systems that might be considered are:

- Vacuum well-points installed around the proposed excavation.
- Interlocking steel sheet piling installed as a cut-off around the foundation excavation with sumps and pumps

The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the footing grade level to avoid base boiling in the native soils.

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

Scour protection should be provided for the spread footing at all the abutments.

10.2 Spread Footing on Engineered Fill

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



If an engineered fill pad is used, all topsoil, alluvium, organics, or other deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material. Subexcavation of existing surficial topsoil and recent alluvium will be required. The engineered fill will bear on native compact to very dense sand and gravel and silty sand, and the highest permitted founding/base elevations at which engineered fill pads may be placed, are given in Table 10.2.

Table 10.2 – Highest Founding Elevations for Engineered Fill Pads

Foundation Unit		Borehole	Founding Stratum	Approx. Founding Elevation
Hwy 7-New EBL	West abutment	08-132 HC16-04	Compact to Dense Sandy Silt	314.0
	East abutment	08-133 HC16-06	Compact to Very Dense Sand and Gravel	312.0
Hwy 7-New WBL	West abutment	08-130 HC16-03	Compact to Very Dense Silty Sand Till	311.5
	East abutment	08-131 HC16-05	Compact to Very Dense Sand and Gravel	312.5

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

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

Factored Geotechnical Resistance at ULS

900 kPa



Factored Geotechnical Resistance at SLS

350 kPa

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

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

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

Founding elevations presented in Table 10.2 are below the groundwater level measured in the piezometers, with the exception of the west abutment of the WBL. Groundwater control will be required prior to excavation to construct the engineered fill pad in the dry, to prevent sloughing of the sides of the excavation and to prevent disturbance of the base of the excavation due to the inflow of groundwater.

Scour protection should be provided for the spread footings at all the abutments.

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

10.3 Augered Caissons (Drilled Shafts)

Augered caisson (drilled shaft) foundations founded on very dense cohesionless till or hard cohesive till were considered for the support of structural loads at this site. However, augered caissons (drilled shafts) are not recommended for use as foundation support at this site due to high groundwater level conditions, including flowing artesian conditions, and potential caisson installation difficulties through a deep deposit of water bearing largely cohesionless till deposit. Sealing of the caisson liner into the founding stratum will be difficult, and base boiling may also be encountered. Based on these expected difficulties this option is not developed further in this report.



10.4 Steel H-Piles

From a foundation engineering perspective, it is feasible to support the structure on steel H-piles or open ended pipe piles driven to practical refusal. It should be noted that pipe piles driven into hard/very dense till deposits are more prone to pile tip damage in comparison to H-piles.

It is recommended that the H-piles or pipe piles be driven to achieve resistance in the very dense cohesionless till encountered at this site.

The GA drawing indicates that the underside elevation of the abutment stems at the east and west abutments are 315.5 and 315.6, respectively, at the proposed Highway 7-New WBL. At the proposed Highway 7-New EBL, the underside elevation of the abutment stems at the east and west abutments are 315.6 and 315.7, respectively.

10.4.1 Axial Resistance

The axial resistances of HP 310 X 110 and HP 360 x 132 steel piles, and 324 mm x 9.5 mm and 356 mm x 9.5 mm pipe piles driven to refusal in very dense till were assessed based on the subsurface conditions encountered at the abutment locations. The estimated Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS), as well as the recommended pile tip elevations, are summarized in Tables 10.3 and 10.4.

Table 10.3 – Estimated Axial Geotechnical Resistance and Pile Tip Elevation for H-piles

Foundation Unit		Borehole	Pile length	Approx. Pile Tip Elevation (m)	Pile Section HP 310 X 110		Pile Section HP 360 X 132	
					Factored ULS (kN)	Factored SLS (kN)	Factored ULS (kN)	Factored SLS (kN)
Hwy 7-New EBL	West abutment	08-132 HC16-04	16.2	299.5	1,400	1,200	1,600	1,400
	East abutment	08-133 HC16-06	13.6	302.0	1,400	1,200	1,600	1,400
Hwy 7-New WBL	West abutment	08-130 HC16-03	16.7	299.0	1,400	1,200	1,600	1,400
	East abutment	08-131 HC16-05	12.6	303.0	1,400	1,200	1,600	1,400

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

Foundation Unit		Borehole	Pile length	Approx. Pile Tip Elevation (m)	Pile Section 324 mm x 9.5 mm		Pile Section 356 mm x 9.5 mm	
					Factored ULS (kN)	Factored SLS (kN)	Factored ULS (kN)	Factored SLS (kN)
Hwy 7-New EBL	West abutment	08-132 HC16-04	16.2	299.5	1,115	1,000	1,300	1,100
	East abutment	08-133 HC16-06	13.6	302.0	1,115	1,000	1,300	1,100
Hwy 7-New WBL	West abutment	08-130 HC16-03	16.7	299.0	1,115	1,000	1,300	1,100
	East abutment	08-131 HC16-05	12.6	303.0	1,115	1,000	1,300	1,100

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

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

10.4.2 Downdrag

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

10.4.3 Lateral Resistance

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

Silty Clay Till (cohesive soils)

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

$$p_{ult} = 9 C_u \quad (\text{kPa}) \text{ at and below a depth of } 3B \text{ reduced to zero at the ground surface}$$

$$\text{where } p_{ult} = \text{ultimate lateral resistance mobilized by a pile, kPa}$$



C_u	=	undrained shear strength of cohesive soils, kPa
γ	=	unit weight of soil, kN/m ³
B	=	width of pile, m

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

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

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

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

For pile lateral resistance design below the flexible zone, soil-pile interaction analyses may be carried out using the coefficient of horizontal subgrade reaction values provided in Table 10.5 below.

Table 10.5 – Recommended Geotechnical Parameters for Lateral Resistance Design

Location	Reference Boreholes	Approx. Elevation (m)	Undrained Shear Strength C_u (kPa)	Unit Weight γ (kN/m ³)	K_p	n_h (kN/m ³)	Soil Conditions
Hwy 7- New EBL and WBL East Abutments	08-131 08-133 HC16-05 HC16-06	313.5 to 310.0	-	11*	3.3	3,500	Compact to very dense sand and gravel
		310.0 to 307.0	-	10*	3.4	4,000	Dense sand
		307.0 to 299.5	-	11*	3.5	7,500	Dense to very dense sand and silt till/sandy silt till
Hwy 7- New EBL and WBL West Abutments	08-130 08-132 HC16-03 HC16-04	315.0 to 312.0	-	11*	3.4	3,500	Compact to dense silty sand, sandy silt, compact to very dense sand and gravel
		312.0 to 309.0	-	10*	3.4	6,000	Very dense sandy silt till
		309.0 to 301.0	200	10*	-	-	Hard silty clay till
		301.0 to 299.0	-	11*	3.5	7,000	Very dense sand and gravel
		299.0 to 291.0	-	11*	3.5	8,000	Very dense sandy silt till, silty sand till, sand and silt till

* Buoyant unit weight below water table

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

10.4.4 Pile Installation

All piles shall be installed in accordance with OPSS 903 and SP 109F57.

Pile driving must be controlled in accordance with Standard Provision SS103-11 (Hiley Formula), and an ultimate pile resistance must be specified by the designer. The Hiley formula does not



need to be used until the pile tip is within 2 m of the design tip elevation. The appropriate pile driving note to be shown on the contract drawing is “Piles to be driven in accordance with Standard SS103-11 using an ultimate geotechnical resistance of R kN per pile” where “R” must have a minimum value of twice the factored design load at ULS. It is recommended that Pile Driving Analysis (PDA) testing be conducted in conjunction with the Hiley tests at this site, to ensure the integrity of the pile and to verify pile ultimate geotechnical resistance.

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

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

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

Three of the piezometers show water levels above the ground surface. Flowing artesian pressure has the potential to cause flow up the pile shaft, with accompanying loss of fines which may lead to loss of vertical and horizontal pile capacity. To reduce the risk of loss of fines, it is recommended that the backfill around the pile be designed to act as a filter to allow any future upward seepage to dissipate without removal of a significant quantity of fines. Reference should be made to Appendix H when designing the inverted filter. To reduce the risk of loss of fines, it is recommended that a minimum 0.5 m thick layer of select graded granular fill filter be placed below the pile cap and/or around the piles (or CSPs for integral abutment design) immediately against the native soil surface. The filter should consist of 19 mm HL-3 coarse aggregate completely wrapped in non-woven (Class I) geotextile to limit the potential for removal of native fine soils. 100 mm perforated subdrain wrapped in fabric should be installed near the base of the inverted filter around its perimeter to provide relief of artesian flow and pressure to the ditch. Prior to placing loose sand in the CSPs, bentonite (e.g. holeplug) should be placed to a depth of 1 m inside and at the bottom of the CSP to form a clay plug against artesian flow within the CSPs.



10.5 Abutment Design Considerations

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

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

10.6 Frost Cover

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

10.7 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended abutment foundations for the proposed Hwy 7-New Hopewell Creek WBL and EBL bridges consist of steel H-piles driven into the very dense silt and sand till/silty sand till/sandy silt till native soils.

11. RETAINING WALLS

The GA drawing dated July 2012 proposes a retaining wall (armour stone wall) located on the east abutment of the Hwy 7 New WBL. The proposed armour stone wall will extend to the north and it is proposed to be approximately 35 m long and 1.5 m high.

The soil conditions encountered on site are generally suitable for the support of the proposed retaining wall. To provide an acceptable foundation performance, the wall should be founded on a minimum 500 mm thick OPSS Granular A engineered fill pad resting on the native compact sand and gravel. The engineered fill pad should extend a minimum 500 mm beyond the footprint of the wall. The permitted base levels of the engineered fill pads and the geotechnical resistances for the retaining wall are as presented in Table 11.1.

Table 11.1 – Highest elevation for Armour Stone Wall and Bearing Resistance

Borehole	Depth below existing ground surface (m)	Approx. Founding Elevation (m)	Founding Stratum	Bearing Capacity (kPa)	
				Factored ULS	Factored SLS
RW16-25	1.4	311.5	Dense Sand and Gravel	400	300

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

Topsoil, recent alluvium, disturbed soils and deleterious material must be stripped from the footprint of the armour stone wall. The subgrade under the wall foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the armour stone wall and placement and compaction of the granular fill must be carried out in the dry. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below grade level to avoid base boiling in the native soils.

The wall must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall or engineered granular fill in contact with native compact sand and gravel may be estimated using an ultimate friction coefficient of 0.55. Resistance Factor of 0.8 should be applied for cohesionless soils, as indicated in Table 6.2 in the CHBDC (2014).

Wall backfill and embankment behind the retaining wall should be free draining granular material satisfying OPS Granular A or Granular B Type II. Wall backfill should be placed in maximum 200 mm lifts and compacted to 98% of SPMDD. Compaction behind the armour stone wall should be carried out using light hand-operated equipment to avoid potential damage to the wall.

Lateral earth pressures acting on the wall should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

A geotextile filter fabric must be incorporated in the wall design to prevent loss of fines from granular material behind the wall subject to fluctuating water level. Since the wall will be constructed adjacent to a creek, the wall may be subjected to flooding.

A perforated drain should be installed at the wall base beneath the granular backfill, and directed to a suitable outlet. In addition, the topography upslope of the wall should be graded to avoid concentrating surface flow toward the walls. If required, a suitable surface water drainage system should be installed to intercept and convey surface water away from the wall.

12. LATERAL EARTH PRESSURES

Earth pressures acting on a structure (e.g. abutment or retaining wall), may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC 2014 but are generally given by the expression:

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

where: p_h = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Table 12.1)
 γ = unit weight of retained soil (see Table 12.1)
 h = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa).

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

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 12.1.

Table 12.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48



At rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive (Movement Towards Soil Mass)	3.7	-	3.2	-

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

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

The factors in Table 12.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in the design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

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

13. APPROACH EMBANKMENTS

Based on the GA drawings, the finished grade level of Highway 7-New EBL and WBL structures at the west abutments will be at about Elevation 320.7, and at approximate Elevation 320.6 at the east abutments. At the west abutments of the EBL and WBL structures, the ground surface ranges from 317.2 to 313.6, resulting in approach embankments of about 3.5 m to 7.1 m. At the east abutments of the EBL and WBL structures, the ground surface ranges from 315.1 to 313.4, resulting in approach embankments of about 5.5 m to 7.2 m.

Based on the boreholes drilled at the site, a layer of recent alluvium was encountered surficially and below the topsoil in Boreholes 08-130, 08-132, HC16-03 to HC16-05 and RW16-25. The thickness of this layer ranged from 0.5 m to 1.5 m. In order to prevent settlement due to the placement of the new fill, it is recommended that the recent alluvium be stripped within 20 m of the abutment prior to placing fill.

The approach embankments will be constructed over native, loose to compact sandy silt/sandy silt, compact to very dense sand and gravel, compact to very dense sandy silt till/silty sand till/sand and silt till, and very stiff to hard silty clay till.

13.1 Slope Stability

The global, internal and surficial stability of the approach embankment fills will depend on the slope geometry and also to a large degree, on the material used to construct the embankments. Embankments constructed using Granular A or Granular B Type II, will have stable side slopes at inclinations of up to 2H:1V.

For the purpose of embankment stability analyses a commercially available slope stability program GEO-SLOPE was used. The Morgenstern-Price method was employed.

Global stability analyses were conducted for a 7.5 m high Granular A or Granular B Type II embankment with a slope of 2H:1V. The stability of the embankments was also checked under seismic loading assuming an acceleration of 0.08g. The computed factors of safety are as shown in Table 13.1. Slope stability computation outputs are included in Appendix F.

Table 13.1 Computed Factors of Safety

Location / Material	Condition	Factor of Safety	Figure (Appendix F)
Hwy 7-New WBL - West and East Approaches – up to 7.5 m high embankment			
Granular A or Granular B Type 2	Drained	1.5	1F, 3F
Granular A or Granular B Type 2	Seismic = 0.08g	1.2	2F, 4F
Hwy 7-New Retaining Wall (Armour Stone Wall at WBL East Abutment)			
Granular A or Granular B Type 2	Drained	1.5	5F
Granular A or Granular B Type 2	Seismic = 0.08g	1.3	6F

A F.S. of 1.5 is acceptable for long term (drained) conditions after excess pore pressures generated in the foundation soil caused by fill placement have dissipated. In the case of normal loading, the factor of safety against global failure was 1.5 for the embankment slope and 1.5 for the armour stone retaining wall. Under the assumed seismic loading, the minimum factor of safety calculated was 1.2 for the embankment slope and 1.3 for the armour stone retaining wall. These factors of safety are considered to be acceptable for the proposed embankment bearing on non-cohesive soil.



13.2 Settlement

It is estimated that at the Hwy 7 WBL, east and west embankments, and Hwy 7 EBL, east embankment, immediate settlements up to 35 mm will occur in the foundation soils under the loading imposed by approximately 7.2 m of the new approach fill. This settlement will be immediate and essentially complete when construction of the fill is completed.

13.3 Embankment Design and Construction

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

It is recommended that MTO approved Select Subgrade Material (SSM), granular materials or non-cohesive earth fill, be used for constructing the approach embankments at this site. Within 50 m of the abutment needs to be Granular A or Granular B Type II to maintain global stability. These materials will have stable side slopes at inclinations of up to 2H:1V.

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

14. TEMPORARY EXCAVATION

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

Excavation for foundation construction will be extended through the recent alluvium, sand and gravel and silty sand/sandy silt and into the sandy silt till.

For the purposes of the OHSA, the native soils above the water table are classified as Type 3, and the glacial till above the water table may be classified as Type 2. Cohesionless soils below the water table are classified as Type 4.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should regularly be inspected for evidence of instability if they have been left open for extended periods



of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to maintain the stability of the excavation and the safety of workers.

15. BACKFILL TO ABUTMENTS

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

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

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

16. GROUNDWATER AND SURFACE WATER CONTROL

The groundwater levels measured in the piezometers ranged from 0.4 m to 0.9 m (Elevations 316.9 to 314.5) above ground surface, indicating artesian condition. A piezometric reading was taken at 3.0 m (Elevation 313.5) below the ground surface. Seasonal fluctuations of the groundwater level are to be expected.

The General Arrangement (GA) drawings provided by WSP indicate that the water levels at Hopewell Creek are estimated to be at following elevations:

- 100-year water level – Elevation 315.9
- 2-year water level – Elevation 314.7

The abutments will be constructed at the edge of the creek. Temporary excavation for footing/engineered fill pad construction (if applicable) or pile cap (if applicable) will extend below the measured groundwater levels and within the permeable recent alluvium, silty sand and sand and gravel. Additional, to the artesian conditions were observed at this site, seepage or perched water from the granular layers is to be expected. Excavation of the cohesionless native soils below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.



The design of the dewatering system that may be required is the responsibility of the Contractor, and the Contract Documents must alert him to this responsibility. The design the dewatering system must take account of the maximum creek level likely to occur during construction. Suitable systems that might be considered to maintain an unwatered condition at this site include sheeted excavation (cofferdam) or vacuum well-points. Filtered sumps must be properly designed to control loss of fines/ground loss. Suggesting wording for an NSSP in this regard is included in Appendix G.

The groundwater and surface (flood) water must be controlled during construction to maintain a stable excavation and to allow concrete to be placed in an unwatered excavation. Any accumulation of water from the base of the excavation should be removed prior to placing concrete or compacting granular fill. Placement of concrete or compacting engineered fill must be done in the dry. Unwatering must remain operational and effective until the footings are constructed and backfilled.

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

Soil	Permeability, k (cm/sec)
Sandy silt till/Silty sand till	1×10^{-4} to 7×10^{-6}
Sand and Gravel	5×10^{-3}
Sand	5×10^{-3}

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

A Ministry of Environment (MOE) Permit to Take Water (PTTW) or requesting with Environmental Activity and Sector Registry (EASR), may be required prior to construction and should be anticipated by the Contractor.

Water discharged from unwatering operations or displaced during concrete placement may not be suitable for direct discharge to the creek. The contract documents must alert the contractor to this fact and include an item for treatment of the water to the satisfaction of MOE, Ministry of Natural Resources (MNR), Department of Fisheries and Oceans (DFO) or other agencies having jurisdiction, prior to discharge to the creek.



17. SCOUR AND EROSION PROTECTION

If spread footings are selected, scour protection for footing base below the scour depth, such as suitably sized rip-rap (crushed stones), should be provided for the abutments.

If piles are the selected foundation for the bridges and if a pile cap is designed at creek level, then it is recommended that scour protection measures be designed to prevent undermining of the pile cap. The depth of scour must be determined by a river/creek hydraulics specialist based on Section 1.9 of the CHBDC 2014 and the depth of pile embedment to achieve fixity must be measured from the predicted scour level. Any erosion and scour protection measures developed by the Hydraulics Engineer should be checked by the Foundations Engineer to ensure that they are feasible from a foundations engineering perspective.

Erosion protection should be provided along the toe of any slopes that may be in contact with the creek flow.

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

Erosion and scour protection measures for footings and slopes should be designed by a qualified and experienced professional.

18. SEISMIC CONSIDERATIONS

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

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

Table 18.1 – Earth Pressure Coefficients for Earthquake Loading

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

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

** After Woods

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

19. CORROSION AND SULPHATE ATTACK POTENTIAL

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

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

20. CONSTRUCTION CONCERNS

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

1. Pile Installation

Some possible impacts that must be taken into consideration include, but are not necessarily limited to:



- The presence of cobbles and boulders may result in more arduous driving in the very dense soils. Pile tips must be protected to penetrate through obstructions such as cobbles and boulders.
- Seepage flow along the piles due to artesian groundwater conditions may carry fines with it causing loss of ground and accompanying loss of vertical and horizontal pile capacity. A granular inverted filter should be designed to mitigate this risk.

2. Excavation

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

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

3. Groundwater Control

Excavations will extend below the groundwater levels measured at this site. Flowing artesian conditions were encountered at some of the foundation locations at this site.

The Contractor's unwatering plan must be in place prior to commencing excavation. All footings/pile cap must be constructed in the dry.



21. CLOSURE

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

The report was reviewed by Mr. Jason Lee, P.Eng and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.



Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer



Jason Lee, P.Eng.,
Principal/Senior Geotechnical Engineer



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



Appendix A

Record of Borehole Sheets, Laboratory Test Results for Present Site Investigation and Analytical Laboratory Test Results (Current Investigation)

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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


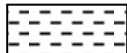



 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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

RECORD OF BOREHOLE No HC16-01

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 525.6 E 231 148.4 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2017.07.28 - 2017.07.28 CHECKED BY RPR

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											
314.6	GROUND SURFACE							20 40 60 80 100											
0.0	TOPSOIL: (100mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
0.1	Sandy SILT, occasional organics, rootlets and topsoil Loose Brown Moist		1	SS	4		314												
			2	SS	6														
313.1							313												
1.4	Sandy SILT, some clay, trace gravel Loose to Compact Brown Moist to Wet (TILL)		3	SS	6														
			4	SS	26		312											0	28 55 17
311.6																			
3.0	Silty CLAY, some sand, trace gravel Stiff to Very Stiff Brown Moist (TILL)		5	SS	19		311												
							310												
	Grey		6	SS	17														
							309												
	Wet		7	SS	13		308												
			8	SS	19		307											3	16 45 36
							306												
	Hard		9	SS	30		305												
304.8																			
9.8	END OF BOREHOLE AT 9.8m.																		

Continued Next Page

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METRIC

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RECORD OF BOREHOLE No HC16-02

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 497.9 E 231 161.8 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2017.07.28 - 2017.07.28 CHECKED BY RPR

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						
317.4	GROUND SURFACE													
0.0	TOPSOIL: (100mm)													
0.1	Sandy SILT , trace gravel, occasional organics Loose to Compact Brown Moist		1	SS	11		317							
			2	SS	9									
315.9							316							
1.4	SAND and GRAVEL Very Dense Brown Moist		3	SS	60									
			4	SS	63		315							
314.4														
3.0	Silty SAND , some gravel, some clay Compact Brown Moist (TILL)		5	SS	29		314							
							313							
	Very Dense		6	SS	79									
							312							
			7	SS	50/									
311.0					.100		311							12 48 28 12
6.4	END OF BOREHOLE AT 6.4m. WATER LEVEL AT SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.													

ONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/16/18

RECORD OF BOREHOLE No HC16-03

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 540.9 E 231 154.8 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2017.08.02 - 2017.08.02 CHECKED BY RPR

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					
313.6	GROUND SURFACE												
0.0	TOPSOIL: (100mm)												
0.1	RECENT ALLUVIUM, some silt, some clay, occasional organics		1	SS	4								
312.9	Loose Dark Brown Moist												
0.7	SAND and GRAVEL Loose to Compact Brown Moist to Wet		2	SS	9								
			3	SS	11								
311.4													
2.2	Silty SAND, some gravel, some clay Very Dense to Compact Grey Wet (TILL)		4	SS	100								
	clayey zone		5	SS	17								
			6	SS	59								
			7	SS	11								
306.1													
7.5	Silty CLAY, some sand, trace gravel Hard to Very Stiff Grey Wet (TILL)		8	SS	47								
			9	SS	21								
	Moist to Wet												

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Sensitivity

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(%) STRAIN AT FAILURE

METRIC

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RECORD OF BOREHOLE No HC16-04

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 511.4 E 231 166.9 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2017.07.31 - 2017.08.01 CHECKED BY RPR

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										
316.5	GROUND SURFACE							20	40	60	80	100						
0.0 0.1	TOPSOIL: (75mm) RECENT ALLUVIUM, some silt, some clay, occasional organics Loose Dark Brown Wet		1	SS	7		316											
			2	SS	8													
315.0							315											
1.4	Sandy SILT, trace gravel, trace clay, occasional organics Compact to Dense Brown Moist		3	SS	18													
			4	SS	32		314											
			5	SS	28		313											
312.0							312											
4.4	Silty CLAY, with sand, occasional cobbles Hard Brown Moist (TILL)		6	SS	98		311											
310.5																		
5.9	SAND and GRAVEL, trace silt, trace clay Dense Grey Wet		7	SS	38		310											
309.5																		
7.0	Grey Wet		8	SS	100/ .100		309											
							308											
			9	SS	100/ .200		307											

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Sensitivity

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(%) STRAIN AT FAILURE

METRIC

ELEV DEPTH	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100					
	Continued From Previous Page.											kN/m ³	GR SA SI CL

Continued from Previous Page		
299.8	16.6	<p>Silty CLAY, some sand, trace gravel, occasional cobbles Hard to Very Stiff Grey Wet (TILL)</p>
306	10	SS 40
305		
304	11	SS 25
303		
302	12	SS 68
301	13	SS 100/.225
300		
299	14	SS 100/.175
298	15	SS 100/.200
18.5	<p>END OF BOREHOLE AT 18.5m. WATER LEVEL AT 6.1m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.11.27 3.0 313.5</p>	

CONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/16/18

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ONTMT4S MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 3/16/18

RECORD OF BOREHOLE No HC16-05

2 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 571.4 E 231 183.7 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.12.01 - 2017.12.01 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
	Continued From Previous Page															
	SAND and SILT , some clay, trace gravel Very Dense Grey Wet (TILL)		10	SS	50/ 100		303									
			11	SS	100/ 225		302									
							301									
299.8			12	SS	100/ 200		300									6 42 38 14
13.9	END OF BOREHOLE AT 13.9m. WATER LEVEL AT 2.4m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.12.18 -0.7 314.5 Artesian 2017.12.21 -0.7 314.5 Artesian (frozen)															

RECORD OF BOREHOLE No HC16-06

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 541.5 E 231 201.0 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.11.29 - 2017.11.29 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ 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	
313.4	GROUND SURFACE						313													
0.0	TOPSOIL: (200mm)																			
0.2	SAND and GRAVEL, trace to some silt and clay, occasional cobbles Loose to Very Dense Brown Wet		1	SS	4															
			2	SS	16															
			3	SS	69															
			4	SS	39															
			5	SS	45															
309.3																				
4.1	SAND, some gravel, trace silt and clay Dense Grey Wet		6	SS	39															
307.0																				
6.4	SAND and SILT, some clay, trace gravel Dense to Very Dense Grey Wet (TILL)		7	SS	45															
			8	SS	82															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

[illegible]

RECORD OF BOREHOLE No HC16-07

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 570.5 E 231 202.0 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.11.28 - 2017.11.28 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20 40 60 80 100				W _P W W _L								
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE														
314.1	GROUND SURFACE																			
0.0	TOPSOIL: (150mm)																			
0.2	SAND and GRAVEL, some silt and clay Compact to Dense Brown Wet occasional cobbles		1	SS	10		314													
			2	SS	38		313													
			3	SS	43		312													
			4	SS	47															
311.1																				
3.0	SAND, some gravel to gravelly, some silt, some clay Dense to Compact Brown Wet		5	SS	34			311												
			6	SS	10	310														
308.5																				
5.6	SAND and SILT, some clay, trace gravel Very Dense Grey Wet (TILL) occasional cobbles						308													
			7	SS	73															
			8	SS	63	307														
305.0																				
9.1	END OF BOREHOLE AT 9.1m UPON AUGER REFUSAL. WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND						306													
							305													

Continued Next Page

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

METRIC

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

[illegible]

RECORD OF BOREHOLE No HC16-08

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 556.9 E 231 216.0 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2017.08.08 - 2017.08.08 CHECKED BY RPR

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											
313.9	GROUND SURFACE																		
0.0	TOPSOIL , some sand, some silt, trace gravel Compact Black Moist		1	SS	16		313												
313.2																			
0.7	SAND and GRAVEL , trace silt, trace clay Dense Brown Moist		2	SS	37														
312.5																			
1.4			Silty SAND , some gravel, trace clay, occasional cobbles Very Dense Brown Moist to Wet (TILL)		3			SS	50/ 0.050	312									
			4	SS	50/ 0.100														
310.8	Auger grinding, slow augering		5	SS	50/ 0.100		311												
3.1	END OF BOREHOLE AT 3.1m UPON AUGER REFUSAL. WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.				0.100														

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RW16-25

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Hopewell Creek, MTM NAD 83 Zone 10: N 4 817 585.5 E 231 178.8 ORIGINATED BY OA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.11.30 - 2017.11.30 CHECKED BY RPR

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											
312.9	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (200mm)							20	40	60	80	100							
0.2	RECENT ALLUVIUM, some silt, some clay, occasional organics and rootlets		1	SS	31														
312.2	Dense Black Moist																		
0.7	SAND and GRAVEL, some silt and clay, occasional cobbles Compact to Very Dense Brown Moist		2	SS	22														
			3	SS	38														
			4	SS	31														
			5	SS	45														
			6	SS	73														
307.3																			
5.6	SAND, some gravel, trace silt and clay Compact Brown Wet		7	SS	11														
305.7																			
7.2	Silty SAND, some gravel, trace clay Very Dense Grey Wet (TILL)		8	SS	59														
			9	SS	86														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

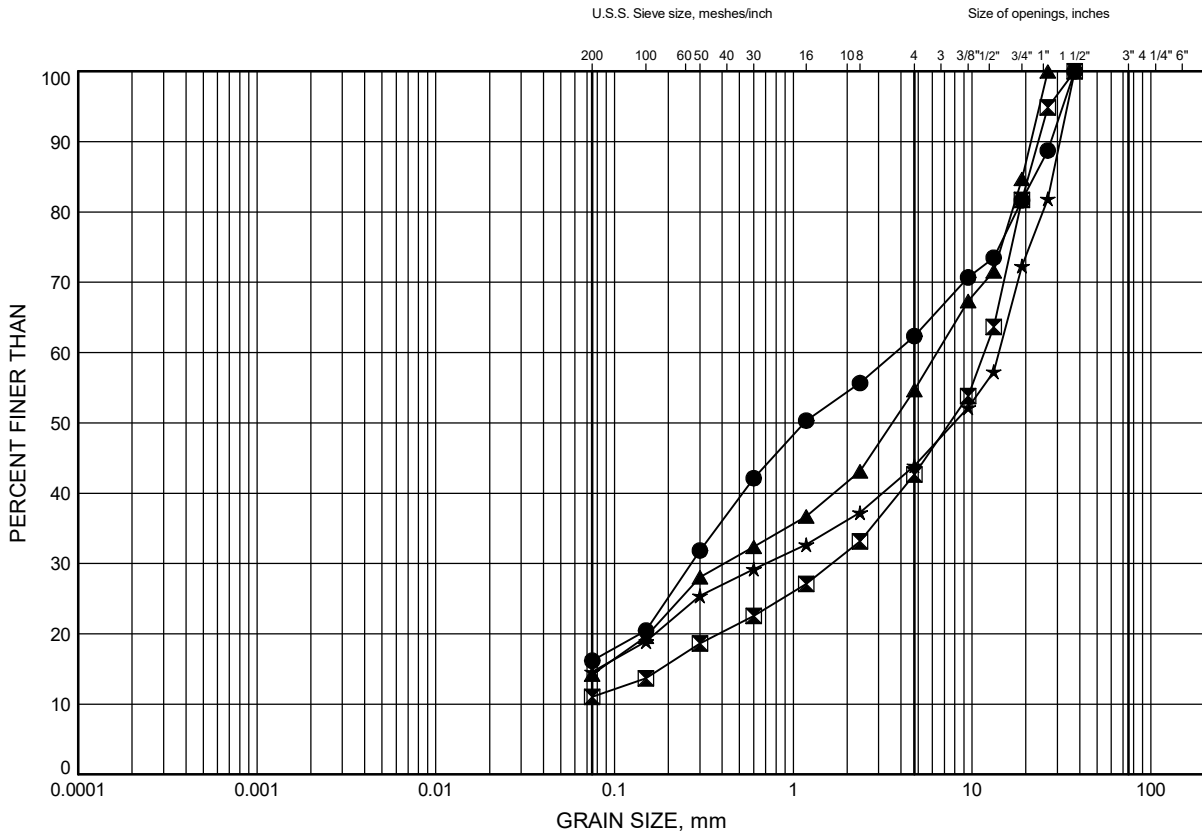
METRIC

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 (%) 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											
	Continued From Previous Page																		
300.5	Silty SAND , some gravel, trace clay Very Dense Brown Wet (TILL)		10	SS	70		302						○			14	56	24	6
							301												
12.4	END OF BOREHOLE AT 12.4m. WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.		11	SS	100/	.175							○						

Hopewell Creek GRAIN SIZE DISTRIBUTION

FIGURE A1

Sand and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-05	3.4	310.4
⊠	HC16-06	2.6	310.9
▲	HC16-07	1.1	313.0
★	RW16-25	2.6	310.3

Date March 2018
GWP# 408-88-00

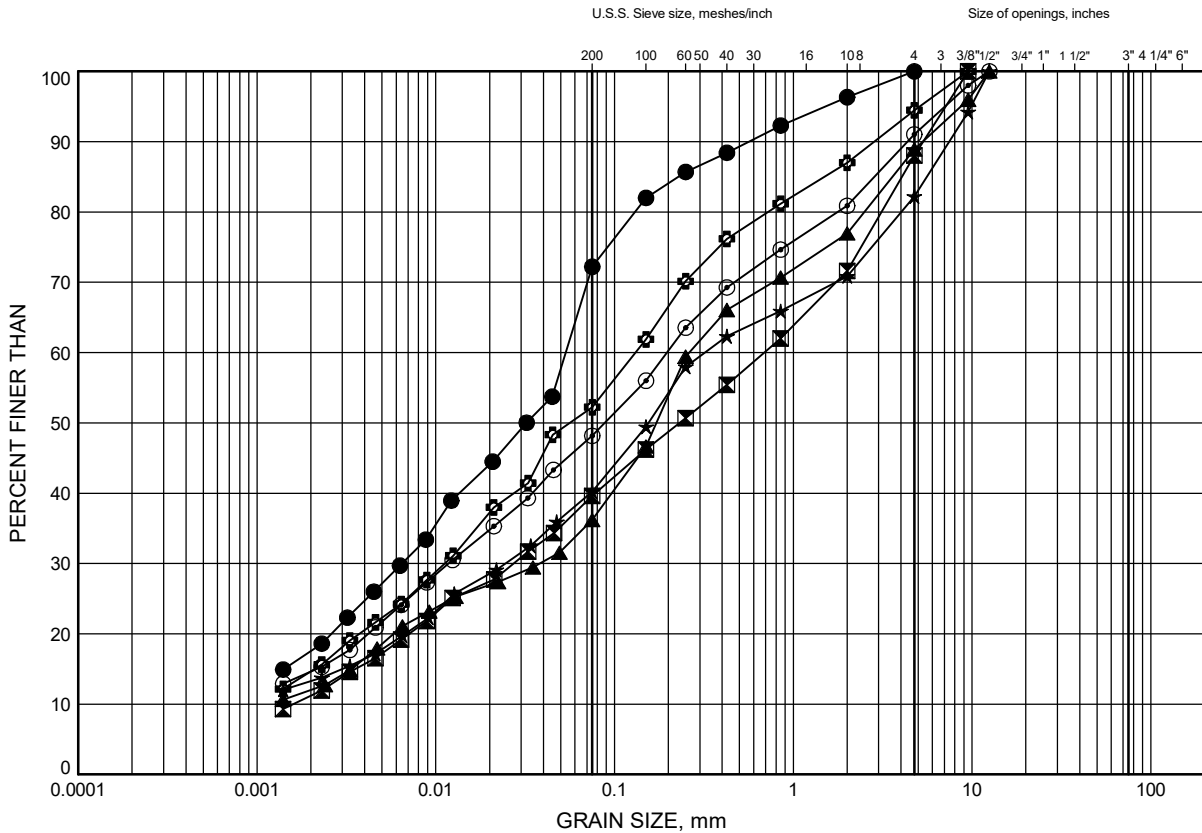


Prep'd MFA
Chkd. RPR

Hopewell Creek GRAIN SIZE DISTRIBUTION

FIGURE A2

Sandy Silt Till to Silty Sand Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-01	2.6	312.0
⊠	HC16-02	6.1	311.3
▲	HC16-03	4.9	308.7
★	HC16-03	14.0	299.6
⊙	HC16-05	9.4	304.3
⊕	HC16-05	13.8	300.0

Date March 2018

GWP# 408-88-00



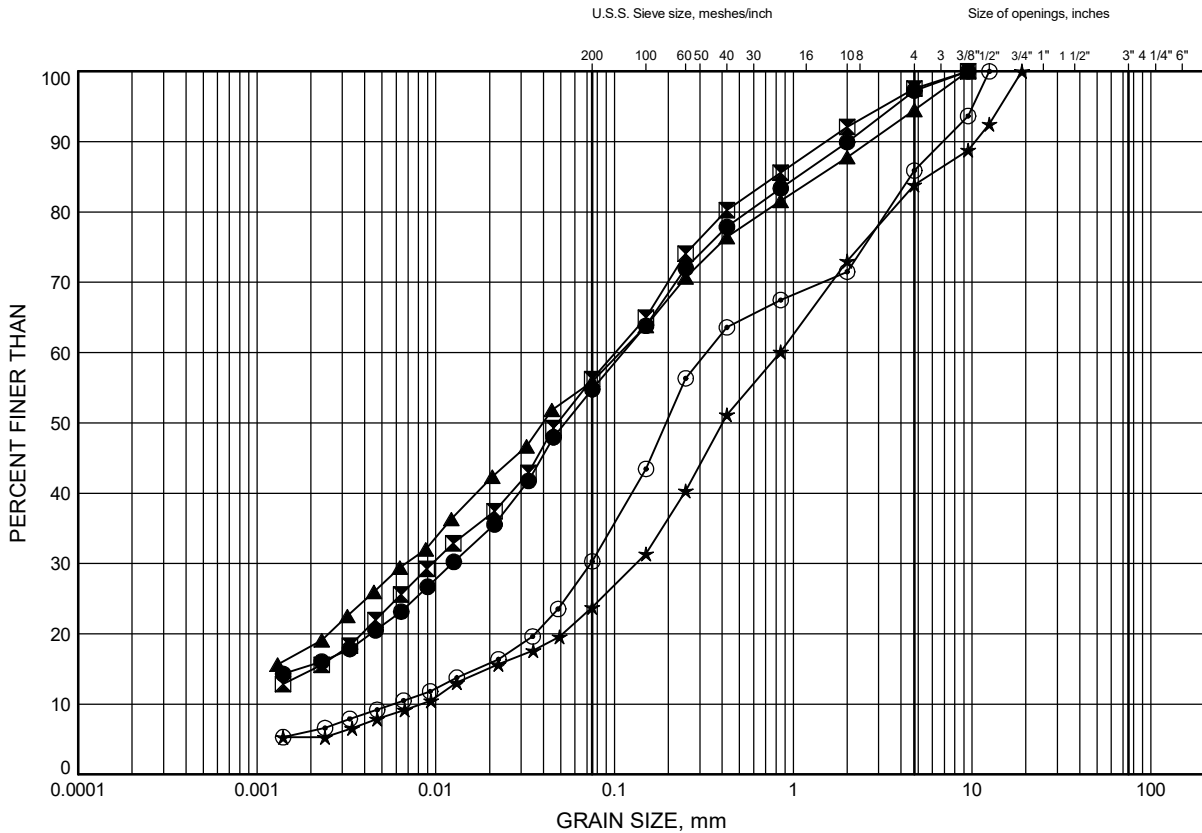
Prep'd MFA

Chkd. RPR

Hopewell Creek GRAIN SIZE DISTRIBUTION

FIGURE A3

Sandy Silt Till to Silty Sand Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-06	11.0	302.5
⊠	HC16-06	13.7	299.7
▲	HC16-07	7.9	306.2
★	HC16-08	2.6	311.3
⊙	RW16-25	11.0	301.9

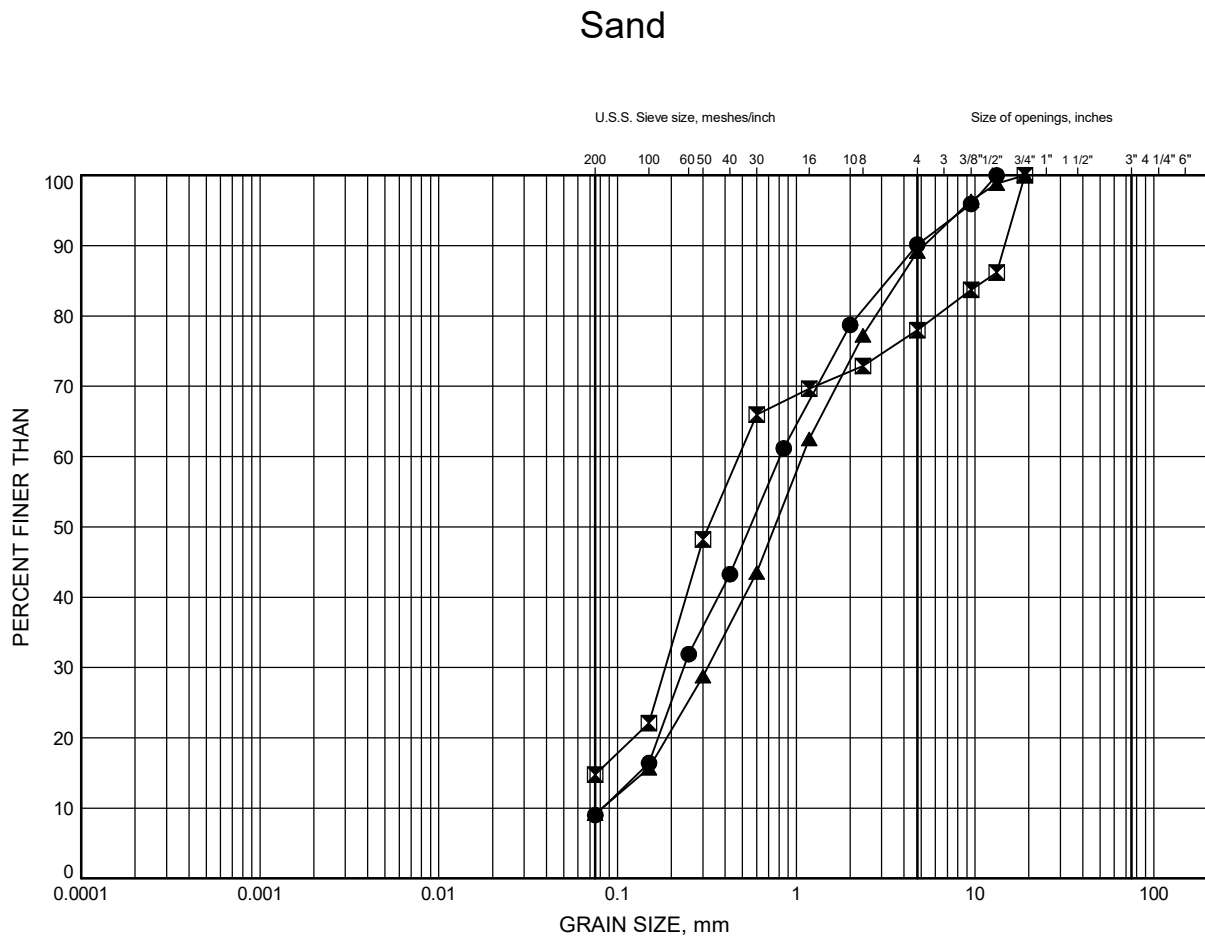
Date March 2018
GWP# 408-88-00



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Hopewell Creek GRAIN SIZE DISTRIBUTION

FIGURE A4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-06	4.9	308.6
⊠	HC16-07	3.4	310.7
▲	RW16-25	6.4	306.5

Date March 2018
GWP# 408-88-00

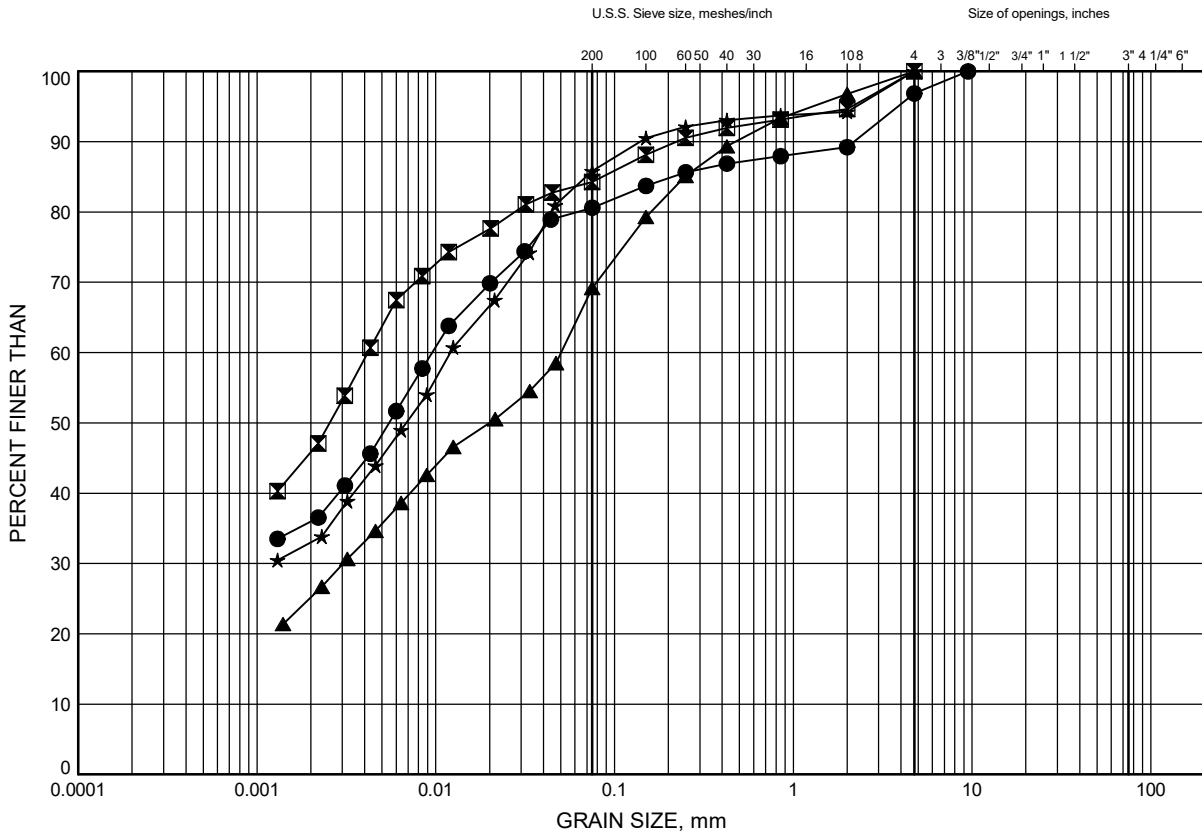


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Hopewell Creek GRAIN SIZE DISTRIBUTION

FIGURE A5

Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-01	7.9	306.6
⊠	HC16-03	9.4	304.1
▲	HC16-04	4.9	311.6
★	HC16-04	11.0	305.5

Date March 2018

GWP# 408-88-00



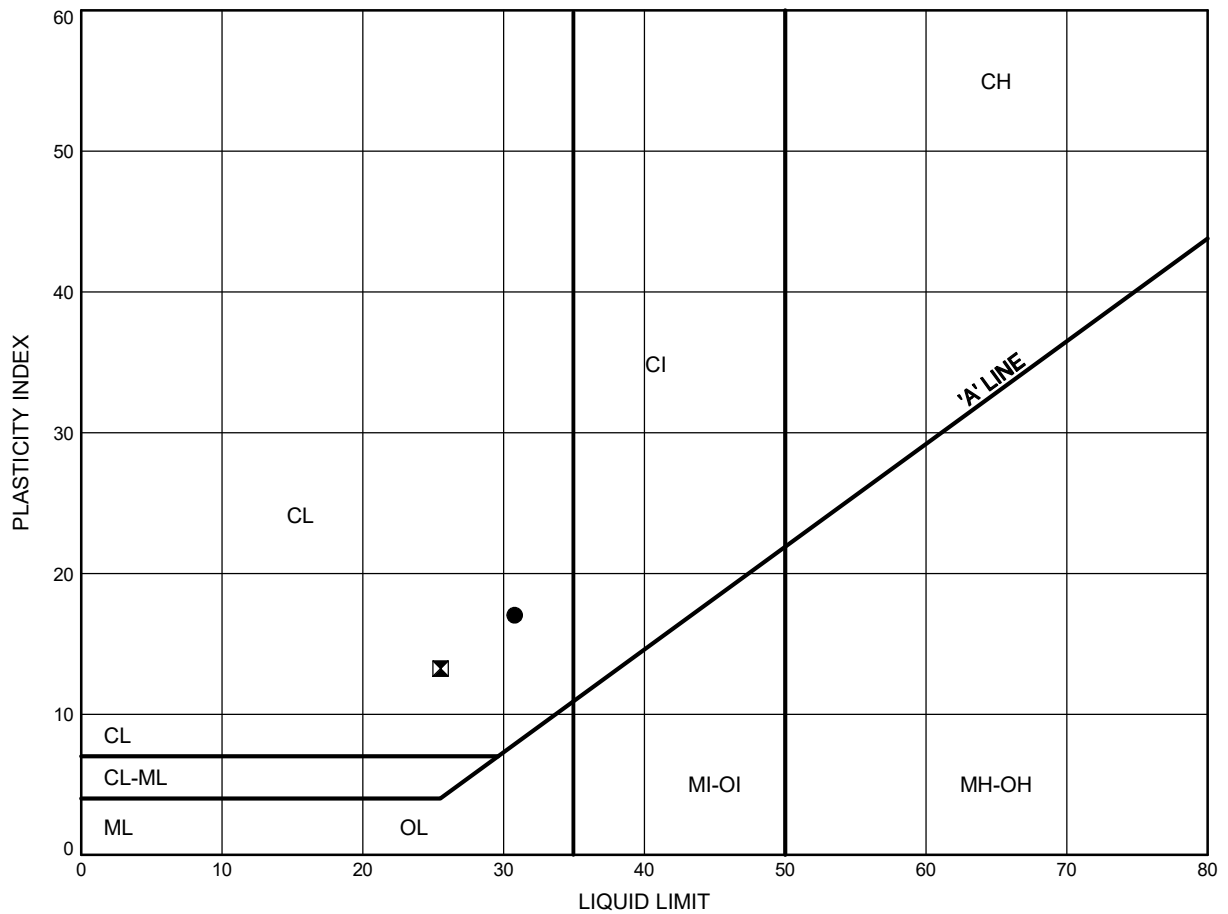
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Hopewell Creek ATTERBERG LIMITS TEST RESULTS

FIGURE A6

Silty Clay Till



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	HC16-01	7.9	306.6
⊠	HC16-04	11.0	305.5

Date March 2018
GWP# 408-88-00



Prep'd MFA
Chkd. RPR



FINAL REPORT

CA14400-MAR18 R

11375

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS

Client Thurber Engineering Ltd.

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

Contact Rocio Reyna

Telephone 905-829-8666 x 263

Facsimile

Email rreyna@thurber.ca

Project 11375

Order Number

Samples Soil (12)

LABORATORY DETAILS

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

Laboratory SGS Canada Inc.

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

Telephone 705-652-2000

Facsimile 705-652-6365

Email deanna.edwards@sgs.com

SGS Reference CA14400-MAR18

Received 03/19/2018

Approved 03/23/2018

Report Number CA14400-MAR18 R

Date Reported 03/23/2018

COMMENTS

Temperature of Sample upon Receipt: 2 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

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

SIGNATORIES

Deanna Edwards, B.Sc, C.Chem





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FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

PACKAGE: - Corrosivity Index (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result	Result
-----------	-------	----	--------	--------	--------	--------	--------	--------	--------	--------

Corrosivity Index

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

PACKAGE: - Corrosivity Index (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result
-----------	-------	----	--------	--------	--------	--------

Corrosivity Index

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



FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

PACKAGE: - General Chemistry (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result	Result
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General Chemistry

Conductivity	uS/cm	2	259	295	216	253	164	357	133	118
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PACKAGE: - General Chemistry (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result
-----------	-------	----	--------	--------	--------	--------

General Chemistry

Conductivity	uS/cm	2	128	99	144	122
--------------	-------	---	-----	----	-----	-----

PACKAGE: - Metals and Inorganics (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result
-----------	-------	----	--------	--------	--------	--------	--------	--------	--------

Metals and Inorganics

Sulphate	µg/g	0.4	140	92	11	69	6.5	356	68	22
----------	------	-----	-----	----	----	----	-----	-----	----	----

PACKAGE: - Metals and Inorganics (SOIL)

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

Parameter	Units	RL	Result	Result	Result	Result
-----------	-------	----	--------	--------	--------	--------

Metals and Inorganics

Sulphate	µg/g	0.4	22	2.4	15	11
----------	------	-----	----	-----	----	----



FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

PACKAGE: - Other (ORP) (SOIL)

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

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

PACKAGE: - Other (ORP) (SOIL)

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

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

PACKAGE: - PHCs (SOIL)

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

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

PACKAGE: - PHCs (SOIL)

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

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

QC SUMMARY

Anions by IC

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

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

Carbon/Sulphur

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

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

Conductivity

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

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



FINAL REPORT

CA14400-MAR18 R

QC SUMMARY

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

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

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

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

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

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

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

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

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

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

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

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.

RL Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

NA The sample was not analysed for this analyte

ND Non Detect

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

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

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

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-- End of Analytical Report --



Request for Laboratory Services and CHAIN OF CUSTODY

No: 1 of 2
Page

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

Laboratory Information Section - Lab use only

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

Received By (signature): [Signature]
Custody Seal Present: ☒ NO
Custody Seal Intact: ☒

Cooling Agent Present: ☒ ICE
Temperature Upon Receipt (°C): 7.0 LAB LIMS #: 707172

REPORT INFORMATION
Company: Thurber Eng.
Contact: Rocio Palomero Reyna
Address: 103-2010 Winstonpark Dr.
Oakville, ON
Phone: 905-829-8666 x260
Fax: [Redacted]
Email: [Redacted]

INVOICE INFORMATION
☒ (same as Report Information)
Company: [Redacted]
Contact: [Redacted]
Address: [Redacted]
Phone: [Redacted]
Email: [Redacted]

PROJECT INFORMATION
Quotation #: 11375 P.O. #: [Redacted]
Project #: [Redacted] Site Location/ID: [Redacted]
TURNAROUND TIME (TAT) REQUIRED
☒ Regular TAT (5-7 days) TAT's are quoted in business days (exclude statutory holidays & weekends).
Samples received after 3pm or on weekends : TAT begins the next business day
☐ RUSH TAT (Additional Charges May Apply) ☐ 1 Day ☐ 2 Days ☐ 3-4 Days
PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION
Specify Due Date: [Redacted] Rush Confirmation ID: [Redacted]

REGULATIONS
Regulation 153 (2011):
Table 1 ☐ Res/Park Soil Texture: ☐ Coarse ☐ Medium ☐ Fine
Table 2 ☐ Ind/Com ☐ Agri/Other
Table 3 ☐ Other Regulations:
Table 4 ☐ Sewer By-Law: ☐ Sanitary ☐ Storm
Municipality: [Redacted]
Other Regulations:
☐ Reg 347/558 (3 Day min TAT)
☐ PWQO ☐ MMER
☐ CCME ☐ Other:
☐ MISA

RECORD OF SITE CONDITION (RSC) <input type="checkbox"/> YES <input type="checkbox"/> NO								ANALYSIS REQUESTED	COMMENTS: Field Filtered (F) Preserved (P)
SAMPLE IDENTIFICATION		DATE SAMPLED	TIME SAMPLED	# OF BOTTLES	MATRIX	ANALYSIS REQUESTED			
1	TR-04 -SSS	← June 2017		1	Soil				
2	SH16-0A SS4	← JULY 2017		1	Soil				
3	GRB16-2A SS4	← Feb 2018		1	Soil				
4									
5									
6									
7									
8									
9									
10									

Observations/Comments/Special Instructions
[Redacted]
Sampled By (NAME): KAMIL FESZAK Signature: [Signature] Date: 03/11/18 (mm/dd/yyyy) Pink Copy - Client
Relinquished by (NAME): Sarah Hashinai Signature: [Signature] Date: --- (mm/dd/yyyy) Yellow & White Copy - SGS
Revision #: 1.0
Date of Issue: 01 June, 2014



Request for Laboratory Services and CHAIN OF CUSTODY

SGS Environmental Services

- Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Toll Free: 877-747-7658 Fax: 705-652-6365

- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361 Web: www.ca.sgs.com

No:

Page 2 of 2

Received By:

Enoch Forster

Received Date (mm/dd/yyyy): 03/17/2018

Received Time: 11:00 AM

Laboratory Information Section - Lab use only

Received By (signature):

Custody Seal Present: ☒

Custody Seal Intact: ☒

Cooling Agent Present: ☒

Temperature Upon Receipt (°C): 7.0, 7.1, 7.2

CA 14400-MAR-18

LAB LIMS #:

5x3

REPORT INFORMATION

Company: Thurber Eng.

Contact: Rogo Palomares Reyna

Address: 103-2010 Winston Dr. W. R. 10.18

Odville, ON L6H 5R7

Phone: 905-824-8666

Fax:

Email: preyna@thurber.ca

INVOICE INFORMATION

☒ (same as Report Information)

Company:

Contact:

Address:

Phone:

Fax:

Email:

PROJECT INFORMATION

Quotation #:

11375

P.O. #:

Site Location/ID:

TURNAROUND TIME (TAT) REQUIRED

TAT's are quoted in business days (exclude statutory holidays & weekends).

☐ Regular TAT (5-7 days)

Samples received after 3pm or on weekends : TAT begins the next business day

☐ RUSH TAT (Additional Charges May Apply)

☐ 1 Day

☐ 2 Days

☐ 3-4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date:

Rush Confirmation ID:

REGULATIONS

Regulation 153 (2011):

☐ Table 1 ☐ Res/Park ☐ Soil Texture:

☐ Table 2 ☐ Ind/Com ☐ Coarse

☐ Table 3 ☐ Agri/Other ☐ Medium

☐ Table ☐ Fine

Other Regulations:

☐ Reg 347/558 (3 Day min TAT)

☐ PWQO ☐ MMER

☐ CCME ☐ Other:

☐ MISA

Sewer By-Law:

☐ Sanitary

☐ Storm

Municipality:

RECORD OF SITE CONDITION (RSC) ☐ YES ☐ NO

SAMPLE IDENTIFICATION

1 B516-04 S54

2 B516-04 S58

3 RC16-02 S53

4 LR04 S53

5 EB16-03 S55

6 ~~EB16-03 S55~~

7 SP16-04 S57

8 CV16-01 S53

9 GRB16-10 S54

10 HC16-05 S53

DATE SAMPLED

TIME SAMPLED

MATRIX

Soil

✓

✓

✓

✓

✓

✓

COMMENTS:
Field Filtered (F)
Preserved (P)

ANALYSIS REQUESTED

DRINKING WATER SAMPLES (POTABLE WATER FOR HUMAN CONSUMPTION) MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

Observations/Comments/Special Instructions

Sampled By (NAME): KAMIL FESZAK

Relinquished by (NAME): Sarah Hashemi

Signature:

Signature:

Date: 03/19/18

Date: / /

Pink Copy - Client

Yellow & White Copy - SGS

Revision #: 1.0

Date of Issue: 01 June, 2014



SAMPLE INTEGRITY REPORT

Project Number: 11375

ONTARIO REGULATION 153/04

SGS Sample ID CA 14400 - MAR 18

Date / Time Sampled See CoFC

Client Sample ID See CoFC

ALL

Sample Submission General Sample Integrity Violations

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

Sample Specific Sample Integrity Violations

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

Sediment Log

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

Additional Comments/Remarks:

No issues upon receipt



Initials:

KH



Appendix B

Record of Borehole Sheets and Laboratory Test Results (Previous Investigation)

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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



Water Level

C_{pen}



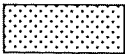


Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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

RECORD OF BOREHOLE No 08-130

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 817 526.71 E 231 156.52 N 4 817 526.7 E 231 156.5 ORIGINATED BY ES
 HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.08.07 - 2008.08.08 CHECKED BY RPR

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						
314.3	GROUND SURFACE							<div>20406080100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>20406080100</div>						
0.0	RECENT ALLUVIUM trace gravel, some silt, trace clay, trace sand, occasional organics Loose Dark Brown Damp		1	SS	5		314							
313.0							313							
1.3	SAND and GRAVEL , some silt Very Dense Brown Moist to Wet		2	SS	80		312							
311.8			3	SS	50									
2.5	Sandy SILT , some clay, trace gravel Very Dense Brown Moist (TILL)		4	SS	45		311							
							310							
	occasional cobbles		5	SS	99									
	Clayey						309							
308.2			6	SS	49		308							
6.1	SAND , fine grained, trace silt, trace clay Dense Brown Moist						307							
306.7	Spoon bouncing at 7.6m													
7.6	Silty CLAY , trace sand, trace gravel Hard Grey (TILL)		7	SS	50/ .125		306							
			8	SS	79		305							

Continued Next Page

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

RECORD OF BOREHOLE No 08-130

2 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 817 526.71 E 231 156.52 N 4 817 526.7 E 231 156.5 ORIGINATED BY ES
 HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.08.07 - 2008.08.08 CHECKED BY RPR

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 (%)						
						20 40 60 80 100 20 40 60 80 100					20	40	60				
	Continued From Previous Page																
	Silty CLAY , trace sand, trace gravel Hard Grey (TILL)		9	SS	105												
	some sand		10	SS	100/ .125												
300.5			11	SS	100/ .125												
13.8	END OF BOREHOLE AT 13.8m. Piezometer installation consists of 25mm diameter schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2008.08.22 0.4* 314.7 2009.04.23 0.7* 315.0 *Above ground level																

METRIC

W.P.	408-88-00	LOCATION	N 4 817 555.39 E 231 188.29 N 4 817 555.4 E 231 188.3	ORIGINATED BY	SLL
HWY	7 - New	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	2008.05.26 - 2008.05.26	CHECKED BY	RPR

[illegible]

Continued Next Page

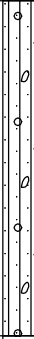
+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 08-131

2 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 817 555.39 E 231 188.29 N 4 817 555.4 E 231 188.3 ORIGINATED BY SLL
 HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.26 - 2008.05.26 CHECKED BY RPR

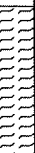


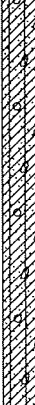
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W _p W W _L 20 40 60				GR SA SI CL		
301.3	Continued From Previous Page Sandy SILT , trace clay, trace gravel Very Dense Grey Moist (TILL)		9	SS	100/ .175		303									○	4 42 47 7
302							302										
12.2	END OF BOREHOLE AT 12.2m. BOREHOLE OPEN TO 11.7m AND WATER LEVEL AT 1.1m ON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE BENSEAL TO 0.3m, THEN HOLEPLUG TO SURFACE.		10	SS	100/ .025												

RECORD OF BOREHOLE No 08-132

1 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 817 498.75 E 231 169.61 ORIGINATED BY WB/ES
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.07.31 - 2008.08.06 CHECKED BY RPR

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 (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					w _P w w _L		
317.2							20 40 60 80 100	20 40 60							
0.0	RECENT ALLUVIUM, some silt, trace clay, trace sand, occasional organics Dark Brown to Brown Damp Loose		1	AS											
			1	SS	5										
315.7															
1.5	SAND and GRAVEL, trace to some silt, trace clay Compact to Dense Brown Damp Auger grinding at 2.1m		2	SS	20										
			3	SS	44										
			4	SS	28										
312.9															
4.3	Sandy SILT, trace to some clay, trace gravel Very Dense Brown Moist (TILL) Wet		5	SS	100/ 200										
			6	SS	73										
310.2															
7.0	Silty CLAY, trace sand, trace gravel Hard Grey (TILL)		7	SS	32										
			8	SS	25										
												</			

Continued Next Page

+ ³ , × ³ : Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

ONTMT4S 6417R.GPJ 9/18/08

RECORD OF BOREHOLE No 08-132

2 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 817 498.75 E 231 169.61 ORIGINATED BY WB/ES
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.07.31 - 2008.08.06 CHECKED BY RPR

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	20 40 60 80 100		
	Continued From Previous Page													
	Silty CLAY , trace sand, trace gravel Hard Grey (TILL)		9	SS	11		307							
			10	SS	40		306							
			11	SS	51		304							
			12	SS	100/ 200		303							
301.5	Auger grinding at 15.5m						302							
15.7	SAND and GRAVEL , trace to some silt, trace clay Very Dense Grey Wet		13	SS	100/ 225		301							46 31 23 (SI+CL)
299.4			14	SS	70		300							
17.8	Sandy SILT , trace gravel, trace clay, cobbles and boulders Very Dense Grey Moist (TILL) Auger grinding at 18.6m						299							
							298							

ONTMT4S 6417R.GPJ 9/18/08

Continued Next Page

+ ³ , × ³ : Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-132

3 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 817 498.75 E 231 169.61 ORIGINATED BY WB/ES
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.07.31 - 2008.08.06 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
	Sandy SILT, trace gravel, trace clay, presence of cobbles and boulders Very Dense Grey Moist (TILL)		15	SS	51		297										
							296										
							295										
			16	SS	100/ .075		294										
							293										
			17	SS	100/ .150		292										
291.2																	
26.0	END OF BOREHOLE AT 26.0m. BOREHOLE OPEN AND DRY TO BOTTOM UPON COMPLETION. BOREHOLE BACKFILLED WITH GROUT TO 0.6m THEN HOLEPLUG TO SURFACE.		18	SS	100/ .125												

ONTMT4S 6417R.GPJ 9/18/08

RECORD OF BOREHOLE No 08-133

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 817 528.39 E 231 194.99 N 4 817 528.4 E 231 195.0 ORIGINATED BY SLL
 HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.26 - 2008.05.26 CHECKED BY RPR

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							WATER CONTENT (%) w _P w w _L			
313.5	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (275mm)																	
313.2	Black																	
0.3	SAND and GRAVEL, trace to some silt, trace clay, occasional cobbles Dense to Very Dense Brown Moist		1	SS	35		313											
			2	SS	45		312											
			3	SS	90		311											
			4	SS	100		310											
309.8																		
3.7	SAND, some silt, trace gravel, trace clay Very Dense Brown Wet		5	SS	52		309											
							308											
307.9																		
5.6	Silty CLAY, some sand, trace gravel Hard Grey (TILL)		6	SS	48		307											
306.2							306											
7.3	Sandy SILT, some clay, trace gravel Very Dense Grey (TILL)		7	SS	100/ .200													
							305											
			8	SS	69		304											

Continued Next Page

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

RECORD OF BOREHOLE No 08-133

2 OF 2

METRIC

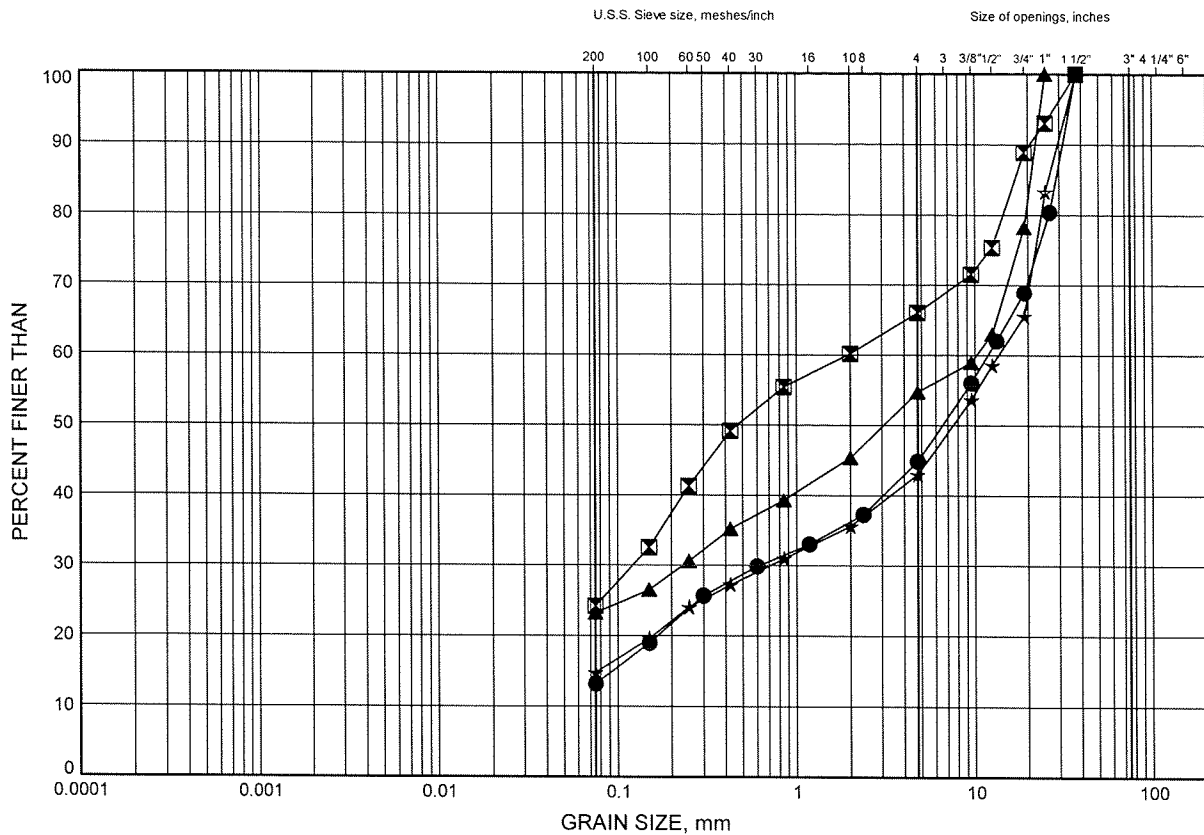
W.P. 408-88-00 LOCATION N 4 817 528.39 E 231 194.99 N 4 817 528.4 E 231 195.0 ORIGINATED BY SLL
 HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.26 - 2008.05.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W _p W W _L 20 40 60					
	Continued From Previous Page																
	Sandy SILT , some clay, trace gravel Very Dense Grey (TILL)		9	SS	100/ .175		303										
			10	SS	100/ .100		301										
299.6			11	SS	100/ .100		300										
13.9	END OF BOREHOLE AT 13.9m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2008.07.15 0.7* 314.2 2008.08.22 0.9* 314.4 *Above ground level																

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand and Gravel



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

LEGEND

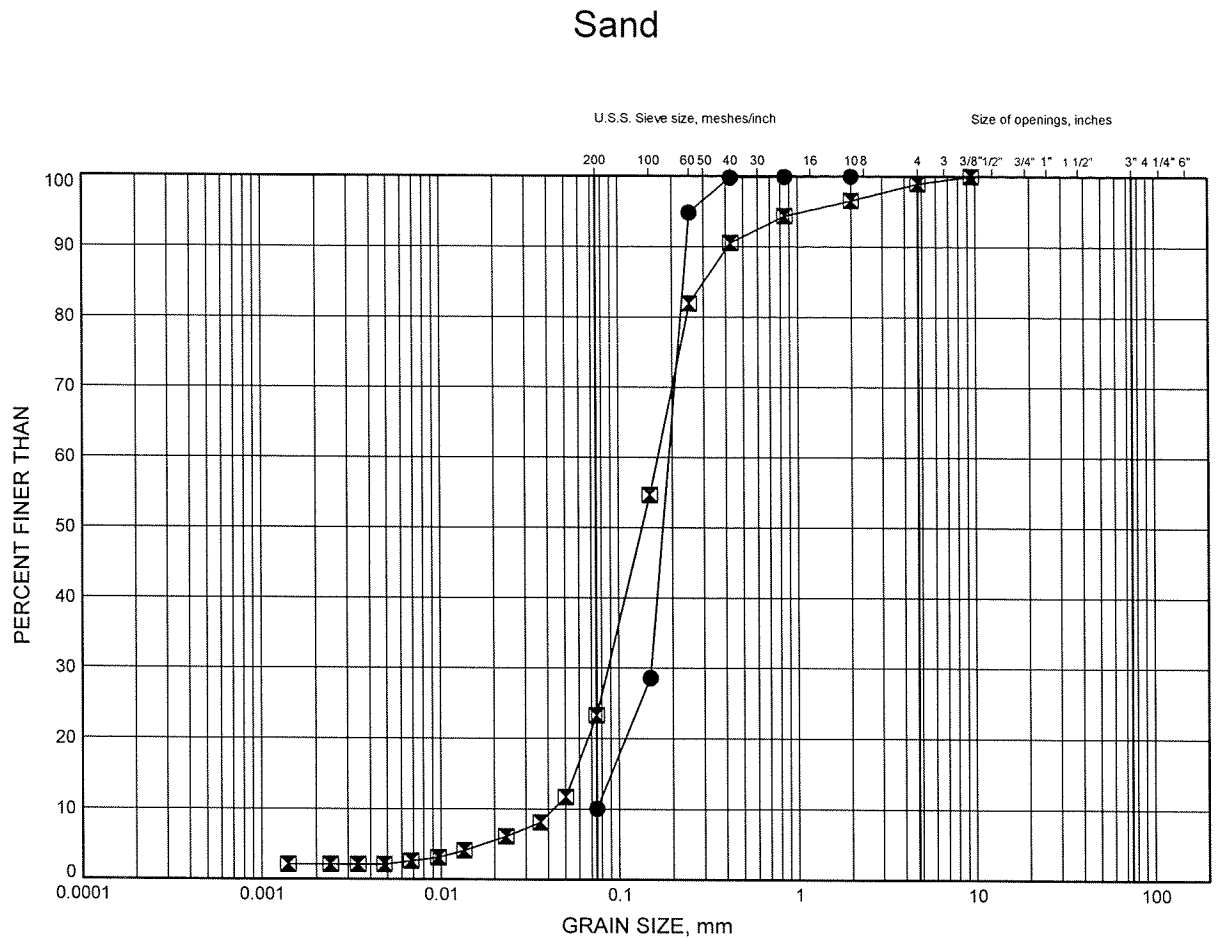
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-131	2.59	312.50
⊠	08-132	1.83	315.39
▲	08-132	16.19	301.03
☆	08-133	2.59	313.38



W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-130	6.40	309.61
×	08-133	4.88	311.09

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 9/15/08

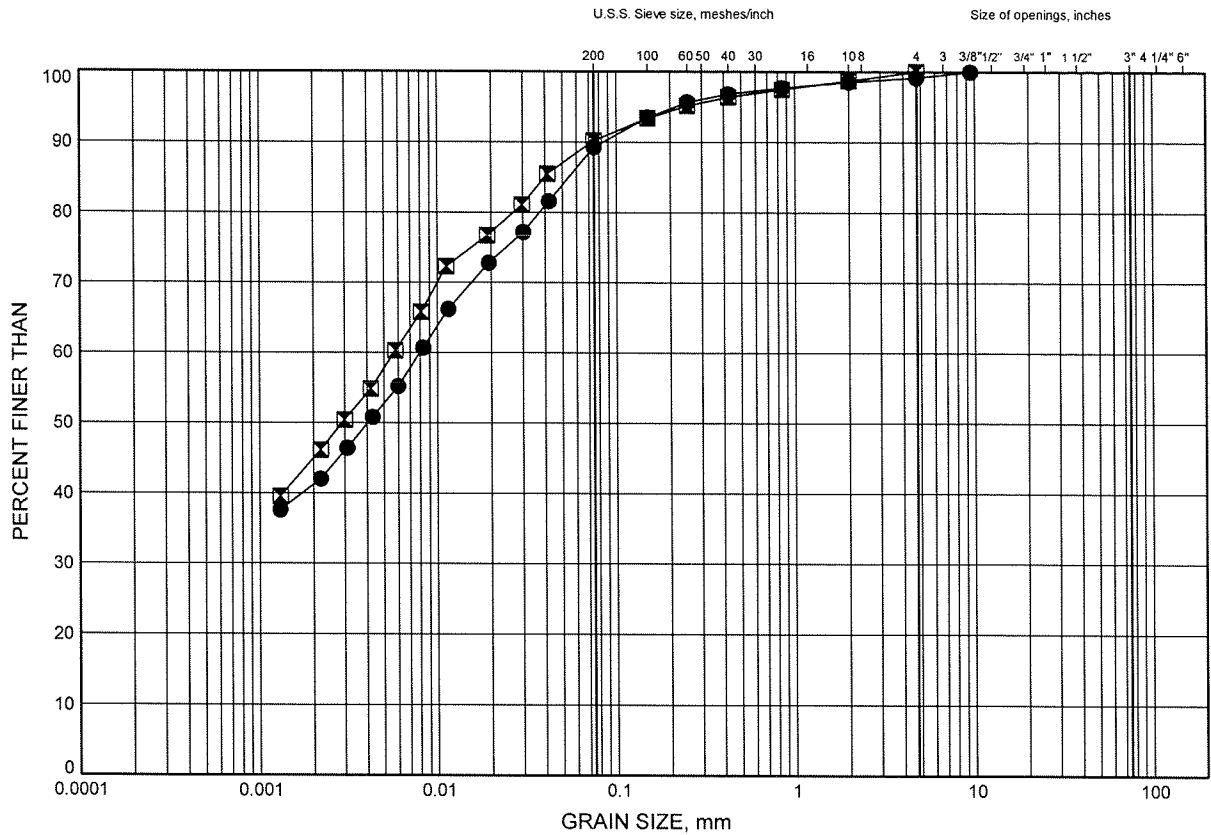
W.P.# 408-88-00
Prepared By MFA
Checked By RPR



Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty Clay Till



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

LEGEND

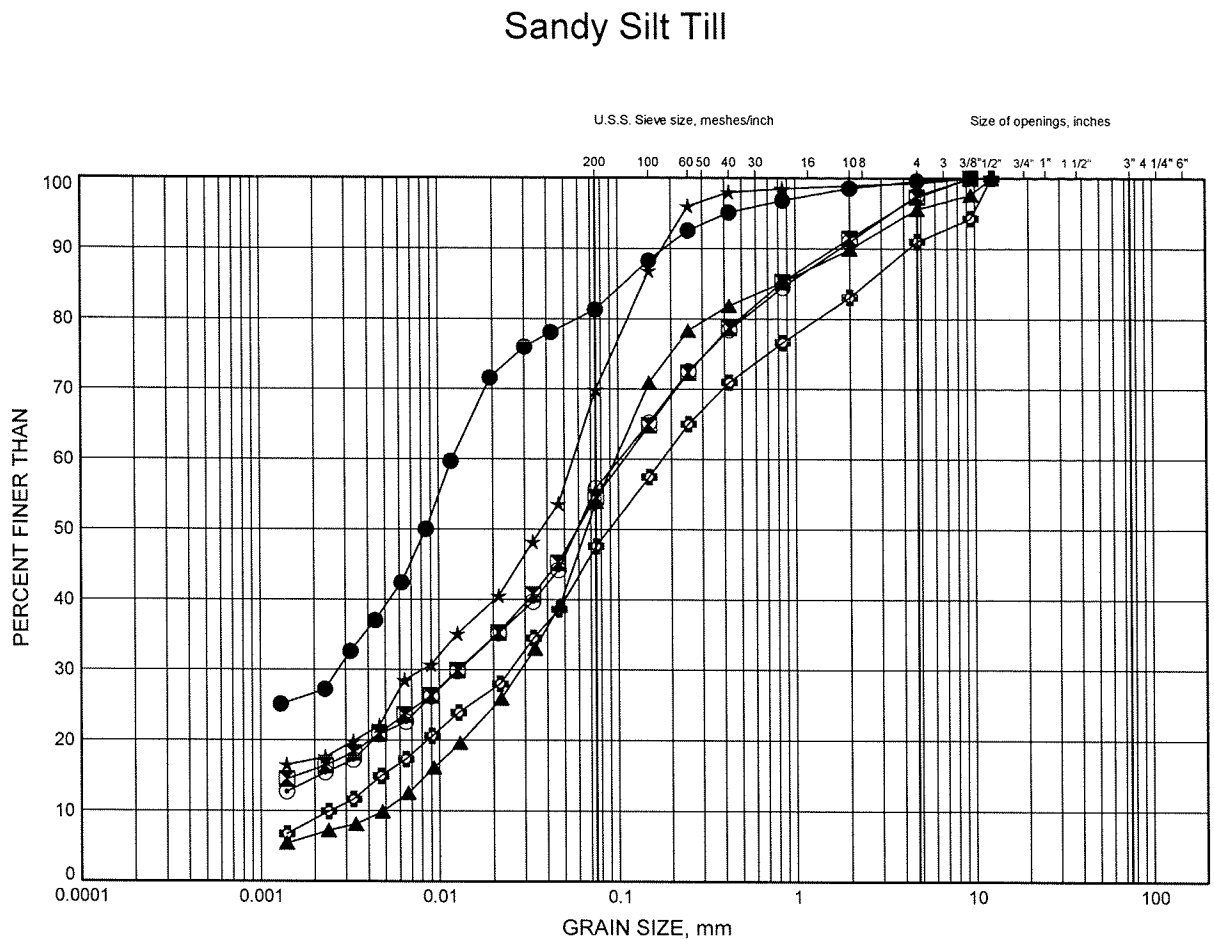
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-130	9.45	306.56
⊠	08-132	9.45	307.77



W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New
GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-130	3.35	312.66
⊠	08-131	7.92	307.17
▲	08-131	10.83	304.26
☆	08-132	4.75	312.47
⊙	08-133	9.45	306.52
⊗	08-133	12.32	303.65



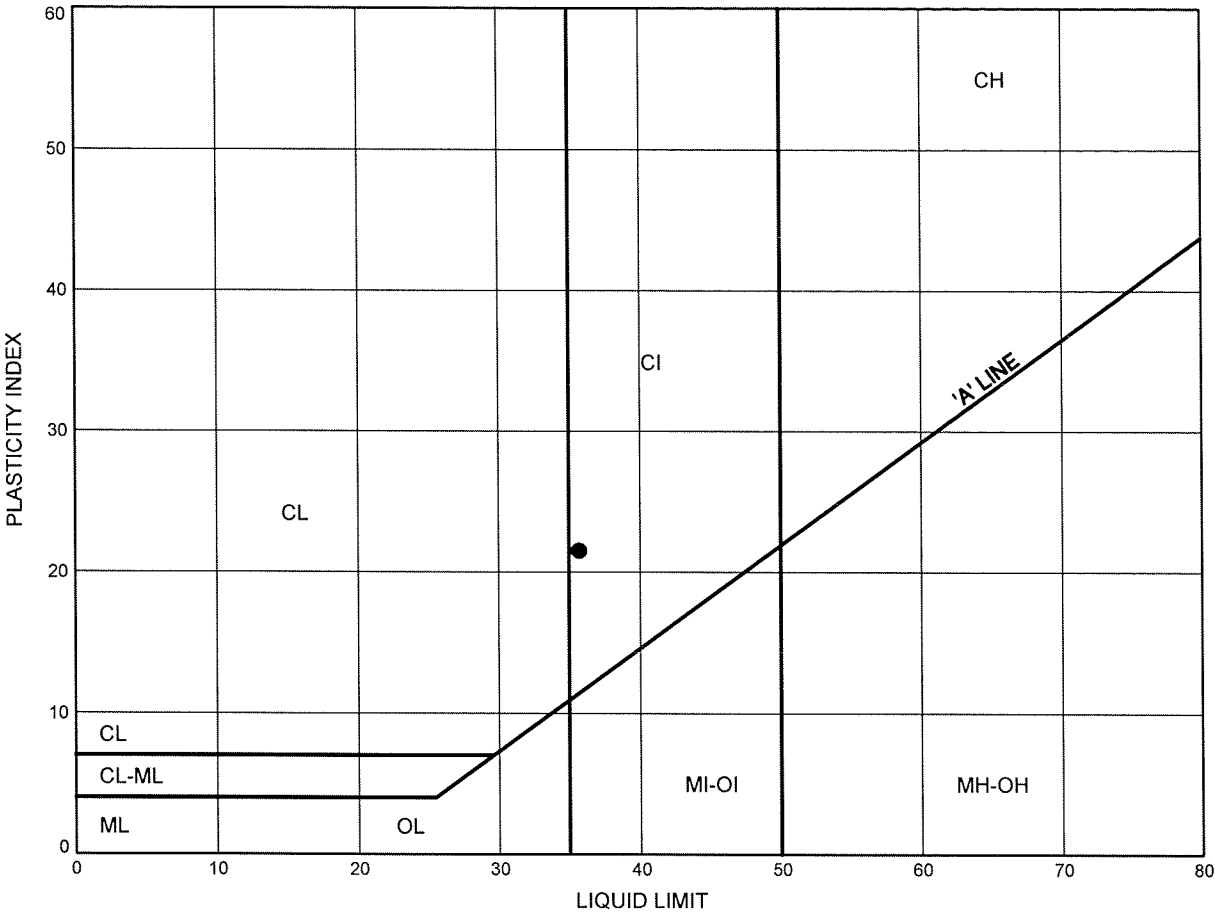
W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay Till



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-132	9.45	307.77

Date September 2008
Project 408-88-00

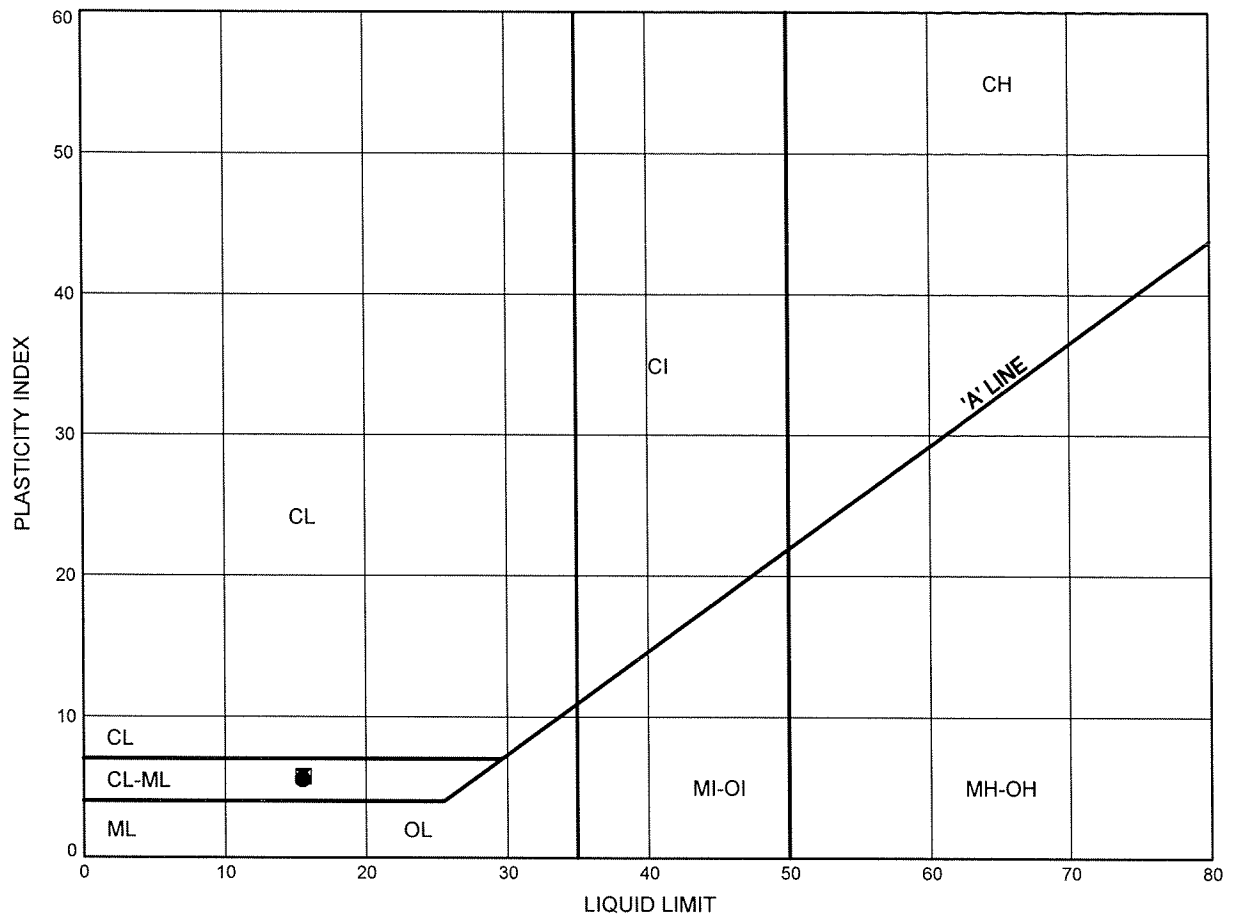


Prep'd MFA
Chkd. RPR

Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Sandy Silt Till



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-131	7.92	307.17
⊠	08-133	9.45	306.52

Date September 2008

Project 408-88-00



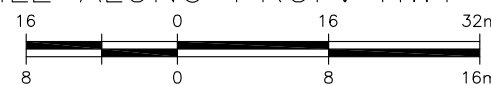
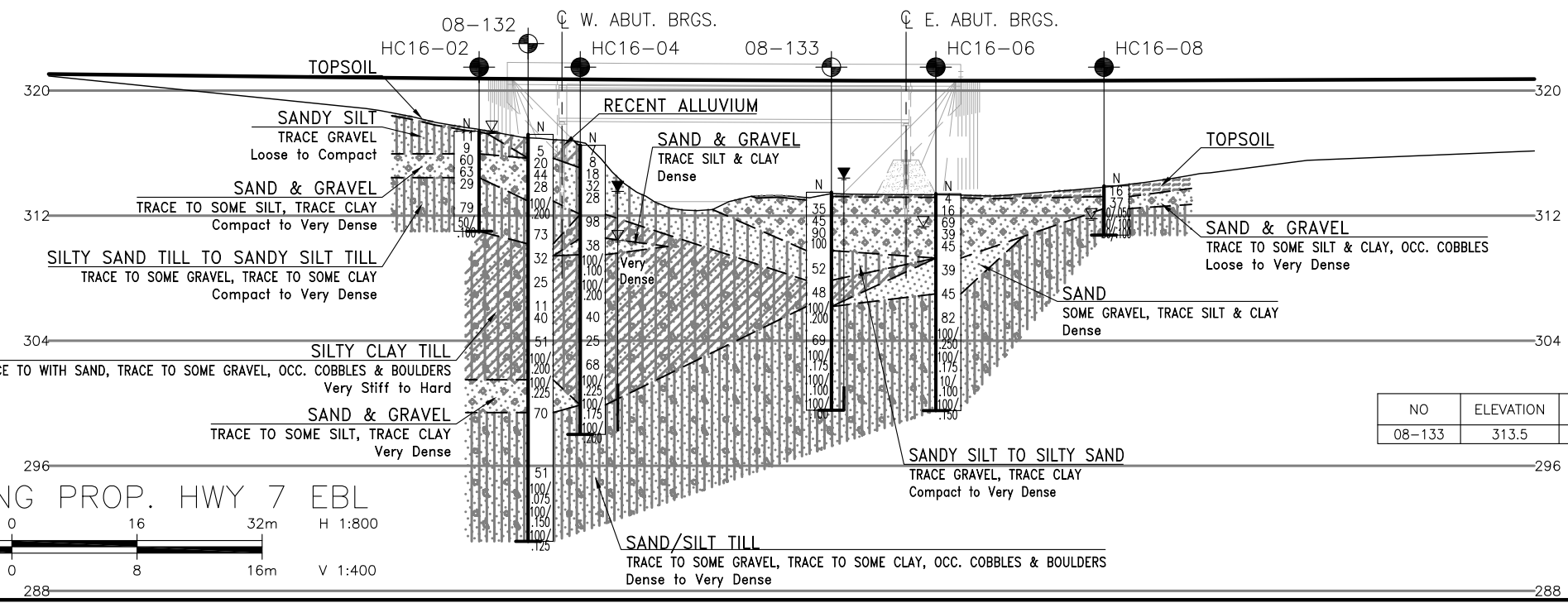
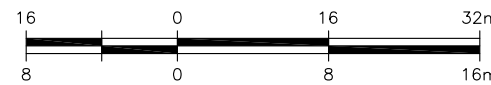
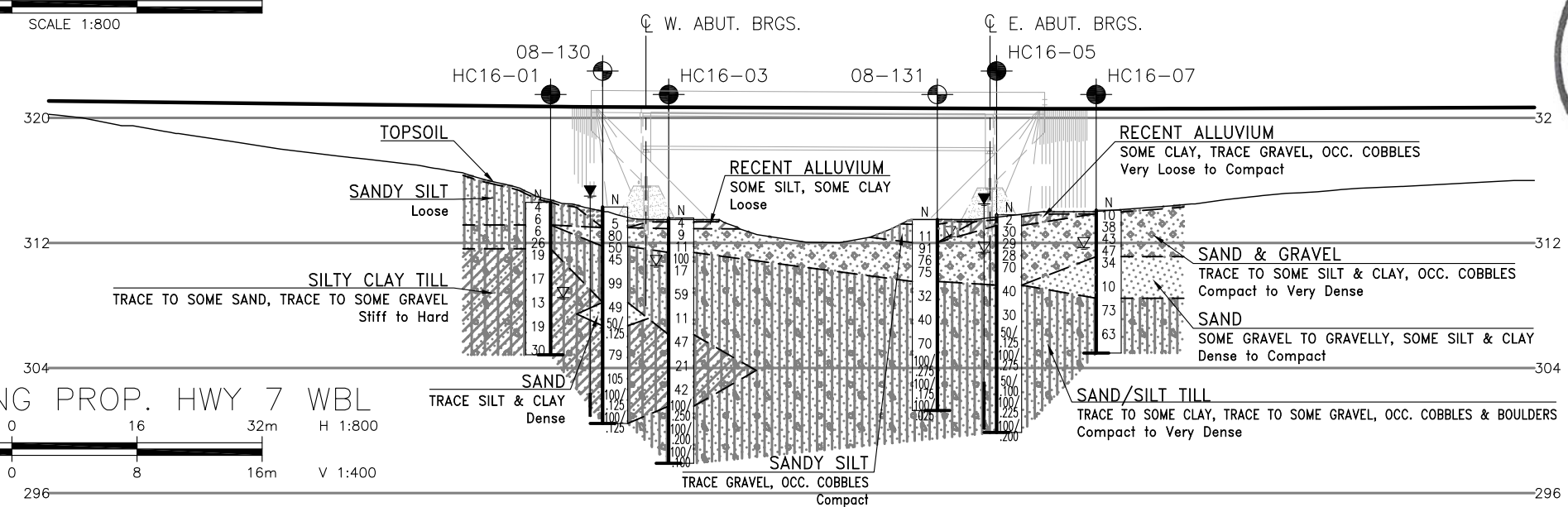
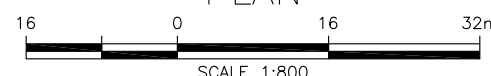
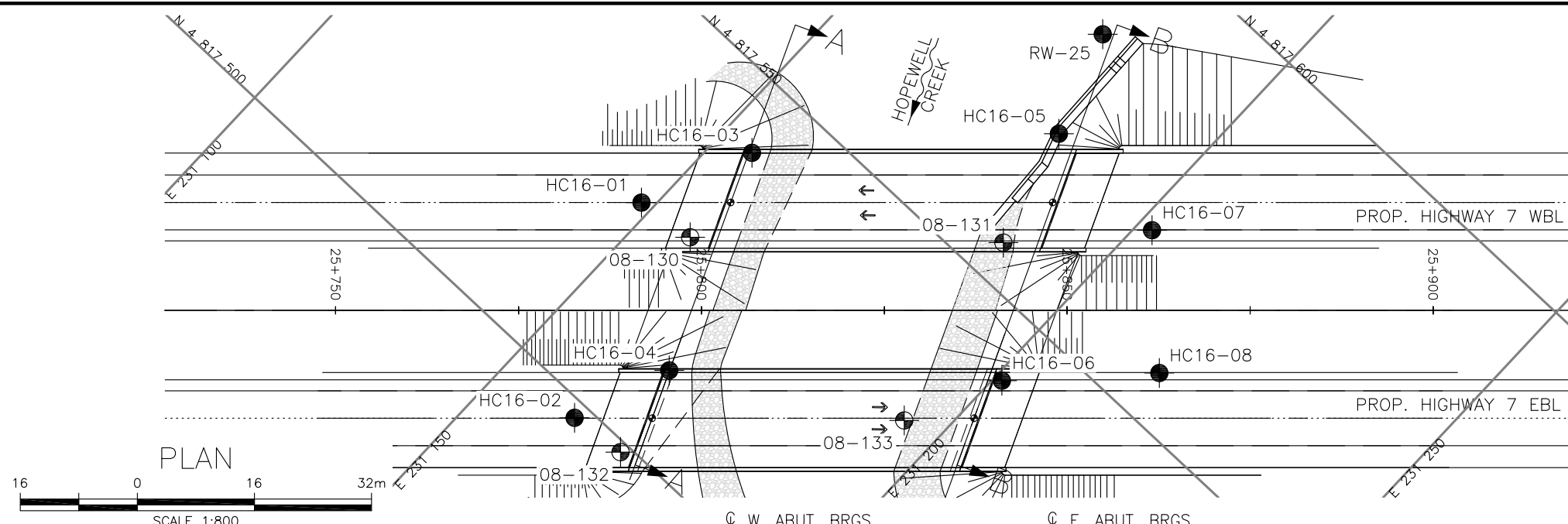
Prep'd MFA

Chkd. RPR



Appendix C

Borehole Locations and Soil Strata Drawing



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

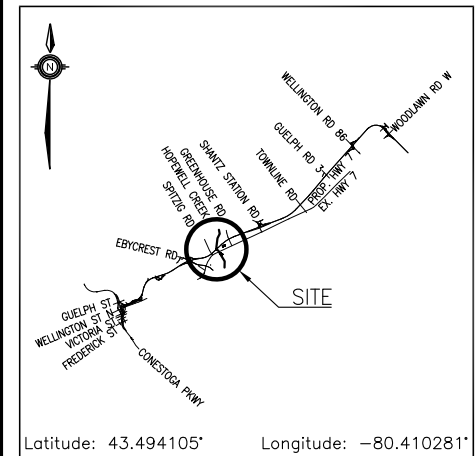


CONT No
GWP No 408-88-00

HIGHWAY 7
HOPEWELL CREEK
PROPOSED BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA








THURBER ENGINEERING LTD



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
HC16-01	314.6	4 817 525.6	231 148.4
HC16-02	317.4	4 817 497.9	231 161.8
HC16-03	313.6	4 817 540.9	231 154.8
HC16-04	316.5	4 817 511.4	231 166.9
HC16-05	313.8	4 817 571.4	231 183.7
HC16-06	313.4	4 817 541.5	231 201.0
HC16-07	314.1	4 817 570.5	231 202.0
HC16-08	313.9	4 817 556.9	231 216.0
RW-25	312.9	4 817 585.5	231 178.8
08-130	314.3	4 817 526.7	231 156.5
08-131	313.5	4 817 555.4	231 188.3
08-132	317.2	4 817 498.7	231 169.6

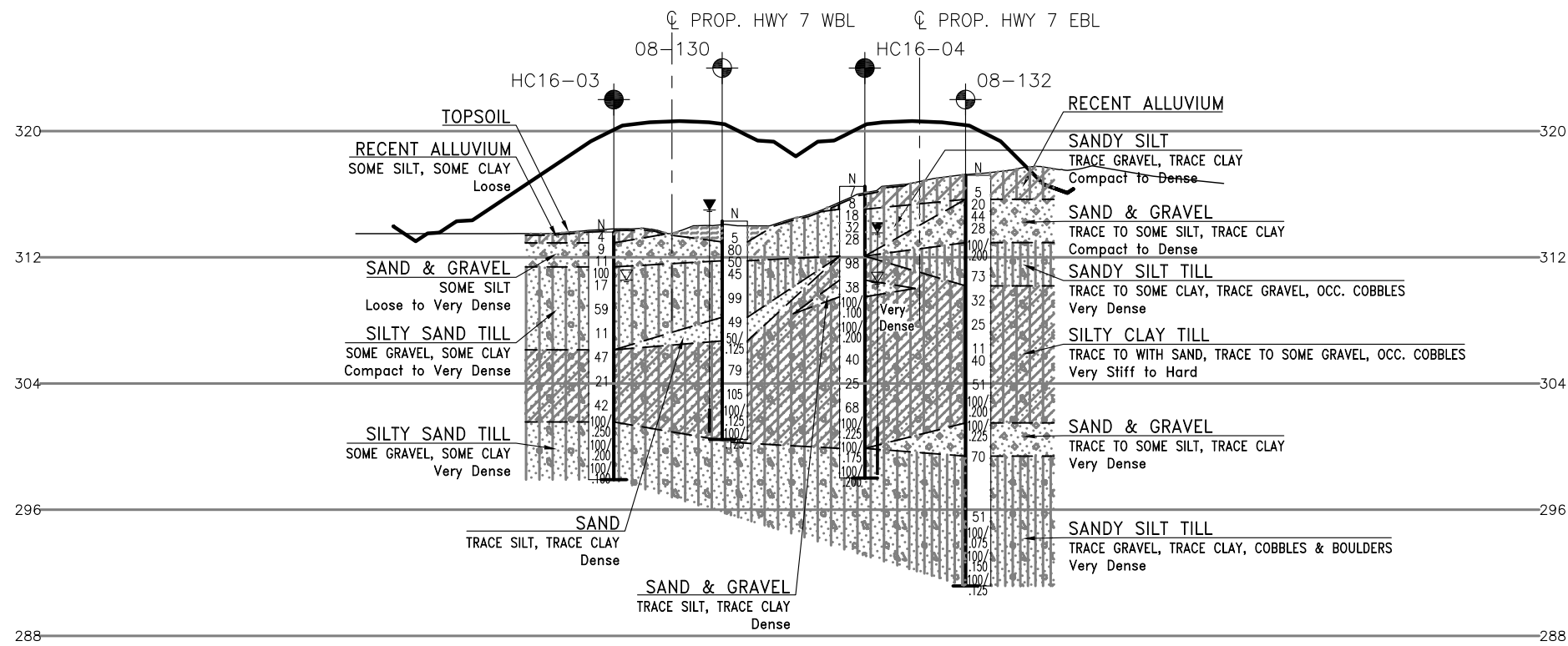
-NOTES-

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

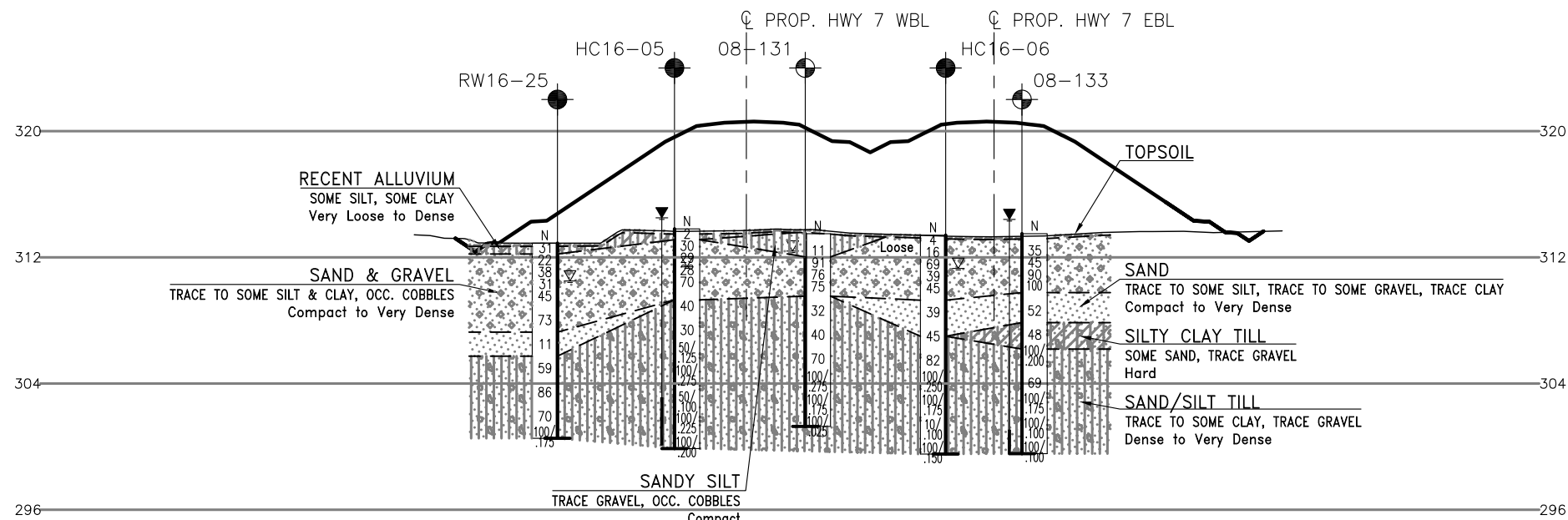
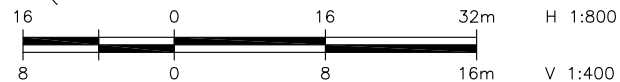
GEOCRES No. 40P9-57

NO	ELEVATION	NORTHING	EASTING
08-133	313.5	4 817 528.4	231 195.0

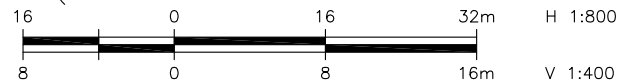
[illegible]



SECTION A-A (WEST ABUTMENTS - WBL & EBL)



SECTION B-B (EAST ABUTMENTS - WBL & EBL)



NO	ELEVATION	NORTHING	EASTING
08-133	313.5	4 817 528.4	231 195.0

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



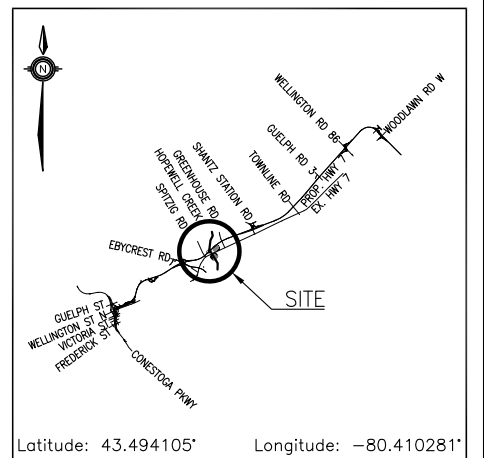
CONT No
GWP No 408-88-00

HIGHWAY 7
HOPEWELL CREEK
PROPOSED BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
HC16-01	314.6	4 817 525.6	231 148.4
HC16-02	317.4	4 817 497.9	231 161.8
HC16-03	313.6	4 817 540.9	231 154.8
HC16-04	316.5	4 817 511.4	231 166.9
HC16-05	313.8	4 817 571.4	231 183.7
HC16-06	313.4	4 817 541.5	231 201.0
HC16-07	314.1	4 817 570.5	231 202.0
HC16-08	313.9	4 817 556.9	231 216.0
RW-25	312.9	4 817 585.5	231 178.8
08-130	314.3	4 817 526.7	231 156.5
08-131	313.5	4 817 555.4	231 188.3
08-132	317.2	4 817 498.7	231 169.6

NOTES

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

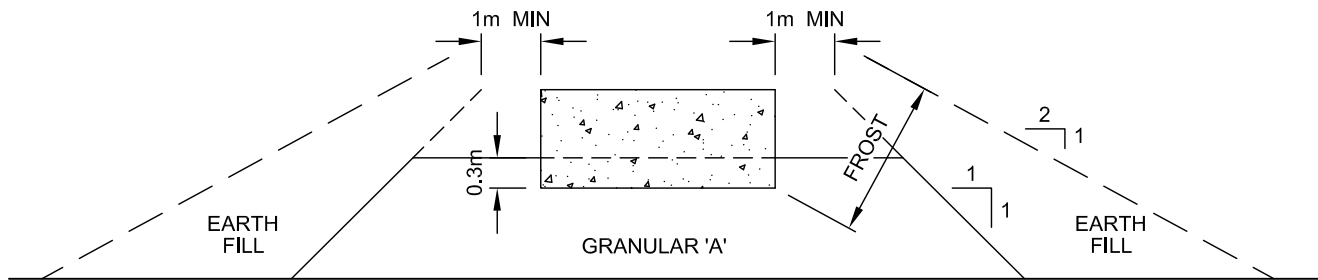
GEOCRES No. 40P9-57

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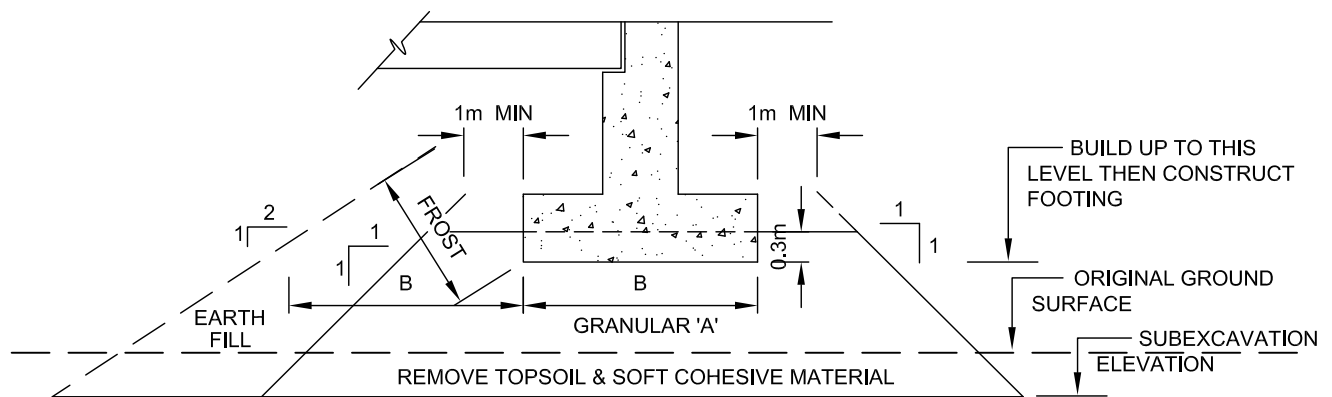


Appendix D

Figure



CROSS-SECTION



LONGITUDINAL SECTION

NOTES:

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

ABUTMENT ON COMPACTED FILL
SHOWING GRANULAR 'A' CORE



THURBER ENGINEERING LTD.

ENGINEER :

-

DRAWN :

MFA

APPROVED :

-

DATE :

SEPTEMBER 2016

SCALE :

N.T.S.

DRAWING No.

FIGURE 1



Appendix E

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Foundation Element	Spread Footings	Spread Footings on Engineered Fill	Driven Piles	Caissons
Abutments	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. ii. High geotechnical resistances available on the compact to very dense native soils. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering will be required. ii. Artesian conditions were encountered at this site. iii. Relatively deep excavations would be required to bear footings on competent soils. iv. Foundations close to water would be at risk of undermining due to scour and erosion. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering will be required, depending on the depth of the excavation. ii. Foundations close to water would be at risk of undermining due to scour and erosion. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense soils. ii. Comparatively short abutment stem. iii. Permit integral abutment design. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense/hard soils may require pre-augering to desire pile tip elevation. iii. When driven into hard/very dense till deposits, pipe piles are more prone to pile tip damage in comparison to H-piles. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Construction of caissons could continue in freezing weather. ii. High geotechnical resistance available for units founded on very dense till. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher cost than spread footings. ii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons under the water table. iii. Potential difficulty in cleaning and inspecting bases.
	FEASIBLE	NOT RECOMMENDED	RECOMMENDED	NOT RECOMMENDED

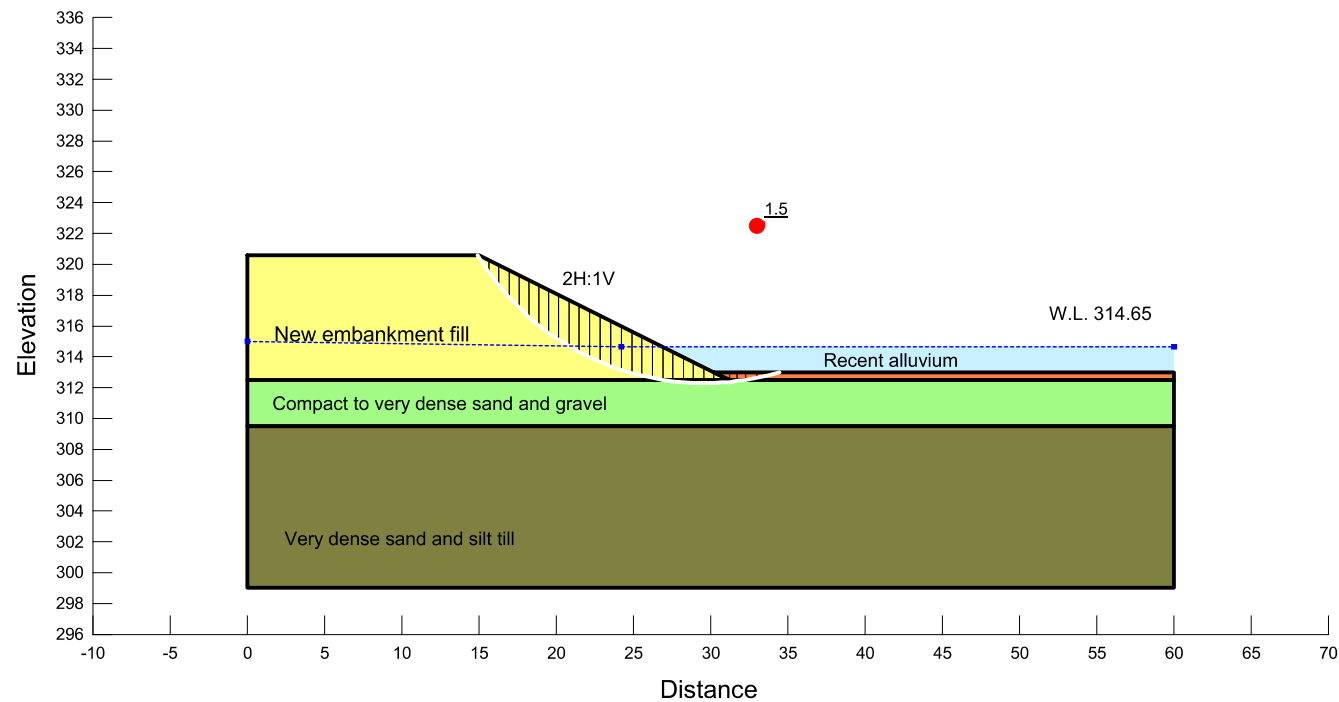


Appendix F

Slope Stability Output

Project Number: 11375
 Highway 7 - New
 Hopewell Creek Bridge
 EBL and WBL bridges
 Embankment height: 7.5 m approx
 Drained Analysis

Name: New embankment fill	Unit Weight: 22 kN/m ³	Cohesion': 0 kPa	Phi': 35 °	Phi-B: 0 °	Piezometric Line: 1
Name: Compact to very dense sand and gravel	Unit Weight: 21 kN/m ³	Cohesion': 0 kPa	Phi': 33 °	Phi-B: 0 °	Piezometric Line: 1
Name: Recent alluvium	Unit Weight: 16 kN/m ³	Cohesion': 0 kPa	Phi': 27 °	Phi-B: 0 °	Piezometric Line: 1
Name: Very dense sand and silt till	Unit Weight: 22 kN/m ³	Cohesion': 0 kPa	Phi': 33 °	Phi-B: 0 °	Piezometric Line: 1

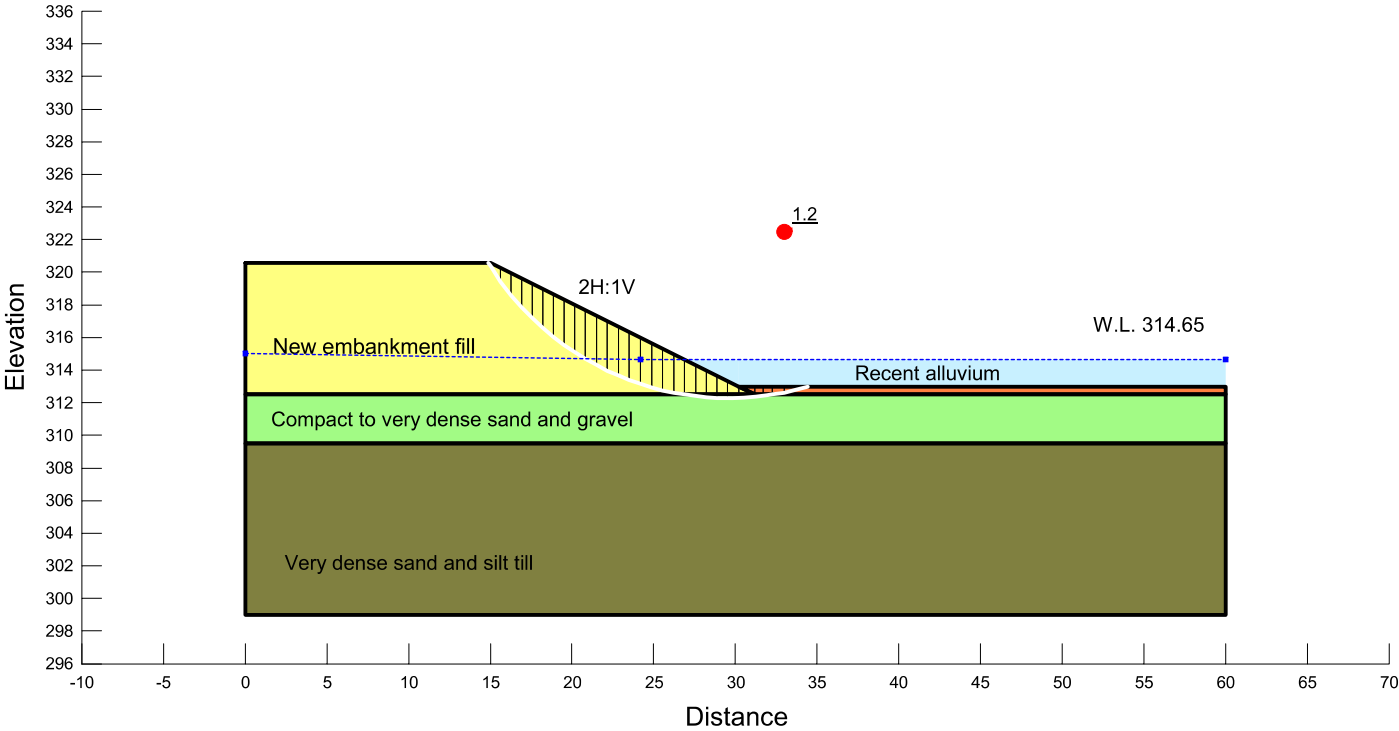


Directory: H:\10000+11375 Hwy 7 New PD and DD Foundations\Reports & Memos\Hopewell Creek\Analysis\Slope Stability\ File Name: 11375- Hopewell - 7.6 m_2.gsz
 Date: 2020-04-27 ,Time: 8:27:08 PM

Figure 1F

Project Number: 11375
Highway 7 - New
Hopewell Creek Bridge
EBL and WBL bridges
Embankment height: 7.5 m approx
Seismic Analysis

Name: New embankment Fill Unit Weight: 22 kN/m³ Cohesion': 0 kPa Phi': 35 ° Phi-B: 0 ° Piezometric Line: 1
Name: Compact to very dense sand and gravel Unit Weight: 21 kN/m³ Cohesion': 0 kPa Phi': 33 ° Phi-B: 0 ° Piezometric Li
Name: Recent alluvium Unit Weight: 16 kN/m³ Cohesion': 0 kPa Phi': 27 ° Phi-B: 0 ° Piezometric Line: 1
Name: Very dense sand and silt till Unit Weight: 22 kN/m³ Cohesion': 0 kPa Phi': 33 ° Phi-B: 0 ° Piezometric Line: 1



Project Number: 11375
 Highway 7 - New
 Hopewell Creek Bridge
 EBL West Abutment
 Embankment height: 2.5 m approx
 Drained Analysis

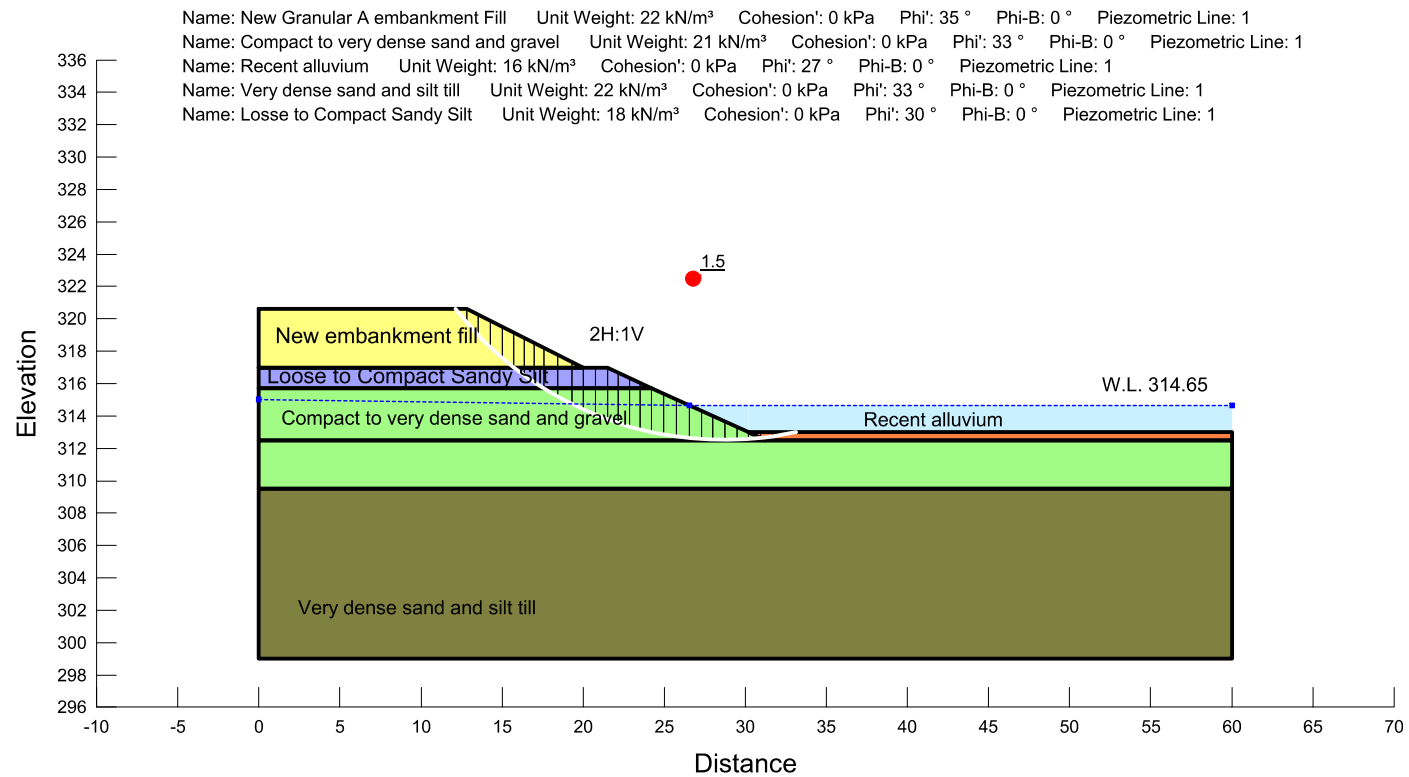


Figure 3F

Directory: H:\10000+11375 Hwy 7 New PD and DD Foundations\Reports & Memos\Hopewell Creek\Analysis\Slope Stability\ File Name: 11375- Hopewell - 7.6 m_east abutment EBL.gsz
 Date: 2020-04-27 ,Time: 7:56:09 PM

Project Number: 11375
 Highway 7 - New
 Hopewell Creek Bridge
 EBL West Abutment
 Embankment height: 2.5 m approx
 Seismic Analysis

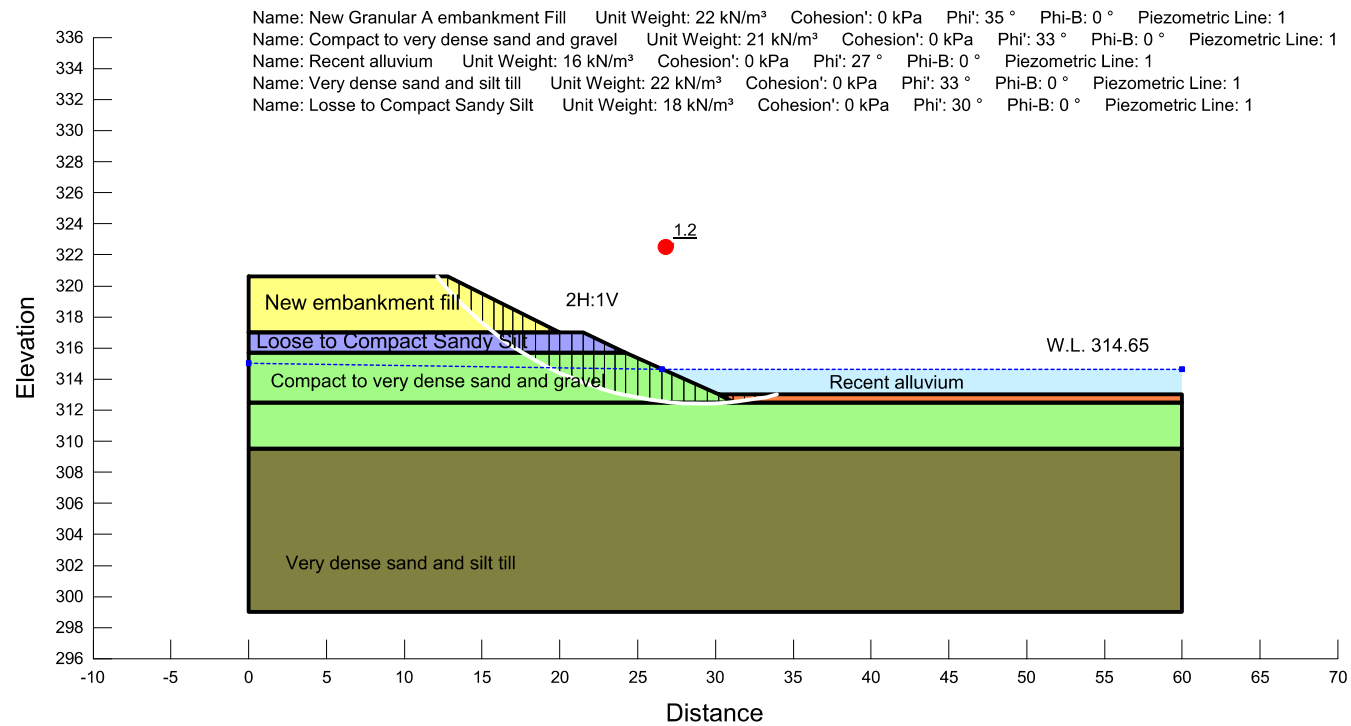
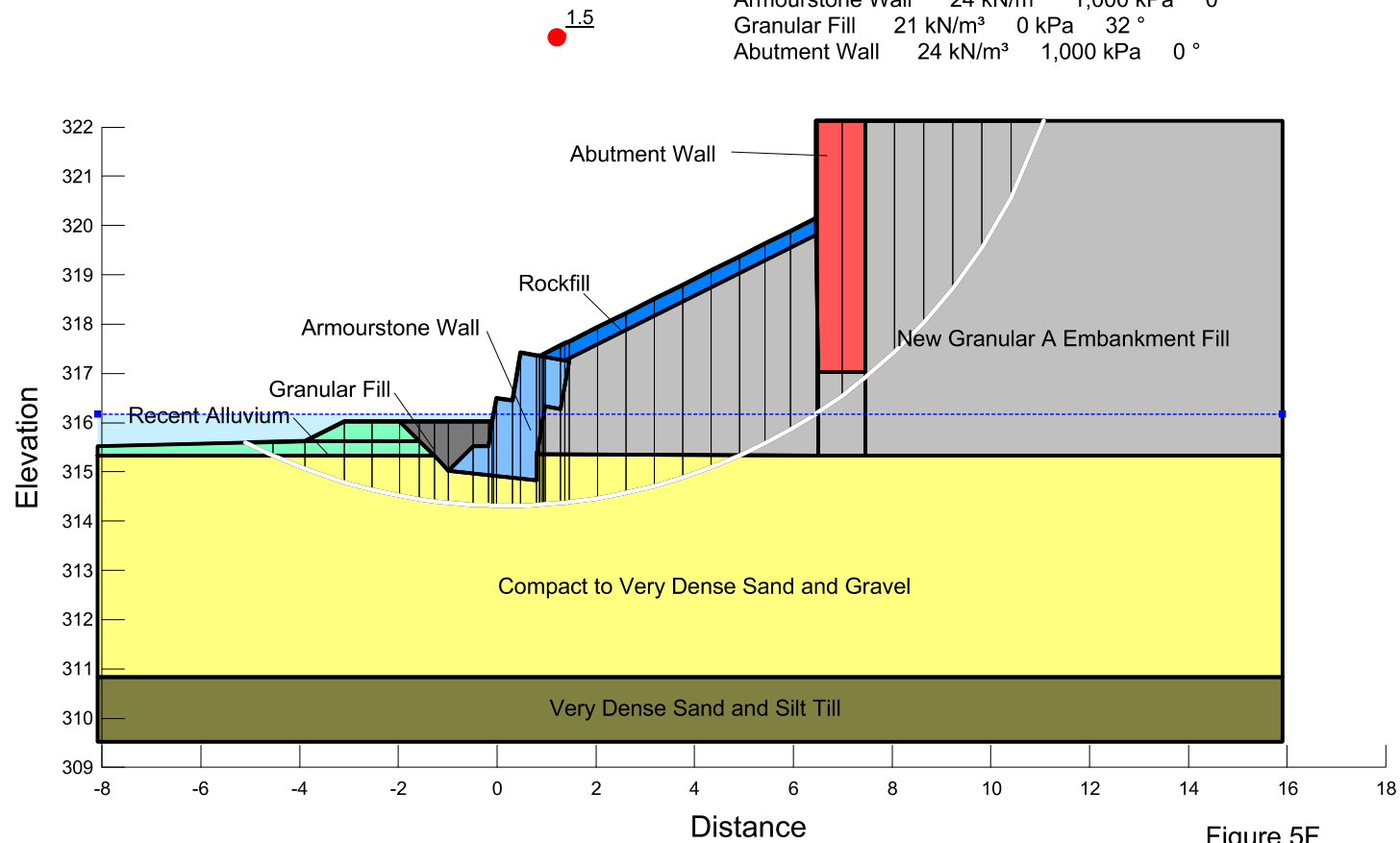


Figure 4F

File Name: Hopewell Armourstone Wall LT 6.gsz
Date: 2020-04-27

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

New Granular A Embankment Fill	22 kN/m ³	0 kPa	35 °
Compact to Very Dense Sand and Gravel	21 kN/m ³	0 kPa	33 °
Very Dense Sand and Silt Till	22 kN/m ³	0 kPa	33 °
Recent Alluvium	16 kN/m ³	0 kPa	27 °
Rock Fill	19 kN/m ³	0 kPa	42 °
Armourstone Wall	24 kN/m ³	1,000 kPa	0 °
Granular Fill	21 kN/m ³	0 kPa	32 °
Abutment Wall	24 kN/m ³	1,000 kPa	0 °



File Name: Hopewell Armourstone Wall LT 6_Seismic.gsz

Date: 2020-04-27

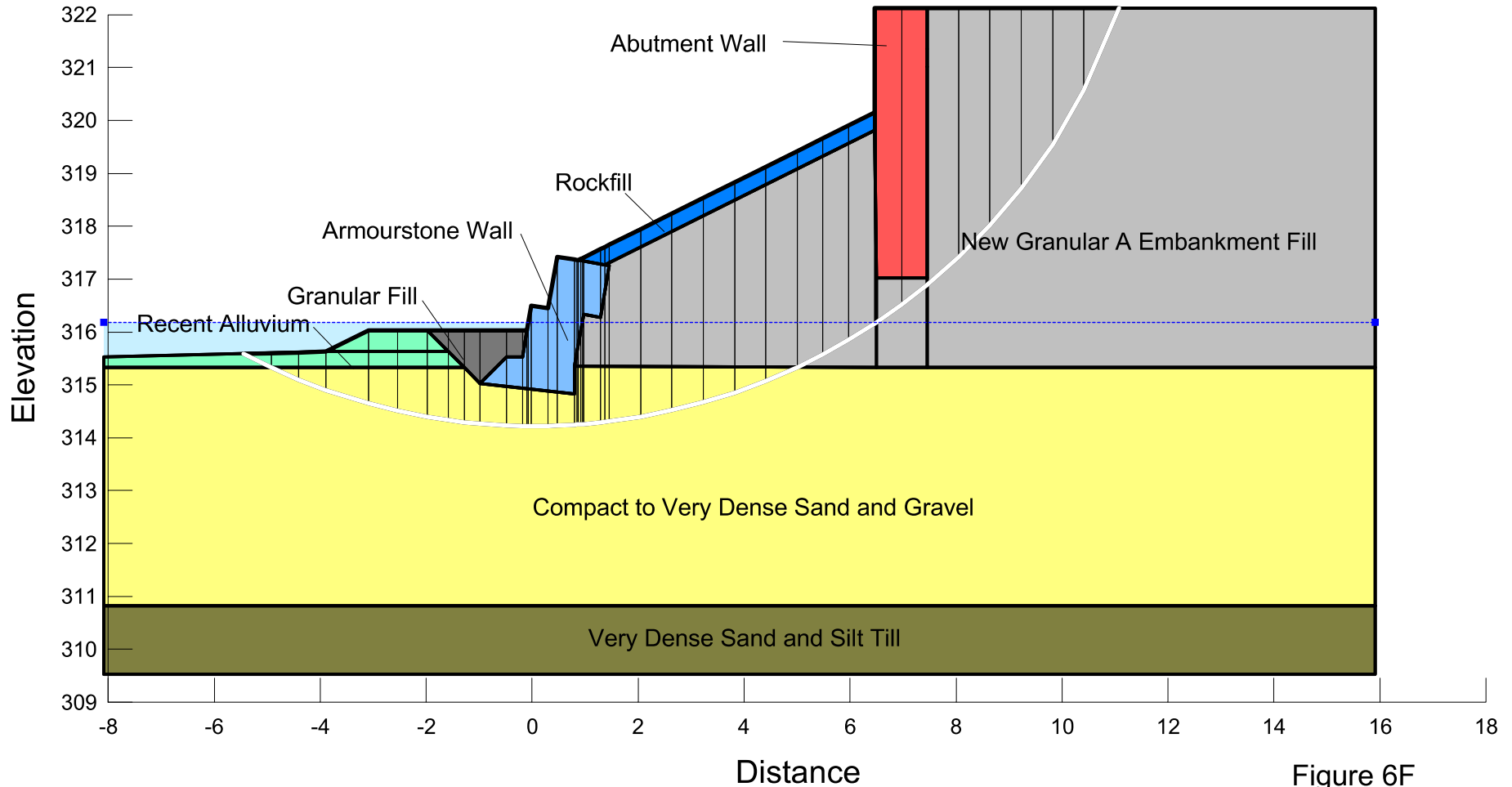
Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

New Granular A Embankment Fill	22 kN/m ³	0 kPa	35 °
Compact to Very Dense Sand and Gravel	21 kN/m ³	0 kPa	33 °
Very Dense Sand and Silt Till	22 kN/m ³	0 kPa	33 °
Recent Alluvium	16 kN/m ³	0 kPa	27 °
Rock Fill	19 kN/m ³	0 kPa	42 °
Armourstone Wall	24 kN/m ³	1,000 kPa	0 °
Granular Fill	21 kN/m ³	0 kPa	32 °
Abutment Wall	24 kN/m ³	1,000 kPa	0 °

1.3





Appendix G

List of OPSS Documents and Nssp Wording



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

- OPSS PROV 206 Construction specification for grading
- OPSS PROV 501 Construction specification for compacting
- OPSS.PROV 517 Construction specification for dewatering
- SP 517F01 Amendment to OPSS 517
- OPSS PROV 539 Construction specification for temporary protection systems
- OPSS PROV 804 Construction specification for seed and cover
- OPSS PROV 902 Construction specification for excavating and backfilling - Structures
- OPSS PROV 903 Construction specification for deep foundations
- SP 109F57 Amendment to OPSS 903
- OPSS PROV 1010 Material specification for aggregates - base, subbase, select subgrade, and backfill material
- OPSD 3102.100 Wall abutments, backfill drain
- OPSD 3101.150 Wall Abutment, Backfill minimum granular requirement

2. Suggested text for a NSSP on Pile Installation

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

- The cobbles may impede the driving of the piles resulting in more arduous driving in the very dense soils.



- Some piles may meet refusal on cobbles that are large enough not to be dislodged or broken by the pile driving.
- As a result of the presence of cobbles, piles may meet refusal at varying depths.
- Pile driving must be controlled according to the criteria specified for the site.

3. Suggested Text for NSSP on Groundwater Control

The soils at this site are predominantly cohesionless and will be readily disturbed by unbalanced water heads or by flow of water. Water seepage due to perched water in the slope, surface runoff and precipitation should be expected. Excavation below the creek and groundwater level will lead to subgrade softening. Flowing artesian conditions were also noted at this site. Effective dewatering shall be designed and provided by the Contractor during excavation to allow the work to proceed in the dry. The design the dewatering system must take account of the maximum creek level likely to occur during construction and the flowing artesian conditions encountered during the site investigation. For temporary excavations at the abutments, groundwater control consisting of sheeted excavation (cofferdam) and/or vacuum well-points will be required due to the cohesionless soils and artesian conditions. Dewatering systems must be installed and made operational prior to excavating below the groundwater level. It is also important to minimize disturbance of the exposed cohesionless till surfaces by limiting construction traffic.

The Contractor must design, install and operate systems that shall:

- Unwater the excavations
- Control the flow of groundwater, surface water and creek water into the excavations
- Prevent the disturbance of the base of the excavation
- Prevent the sloughing of soil into the excavations.

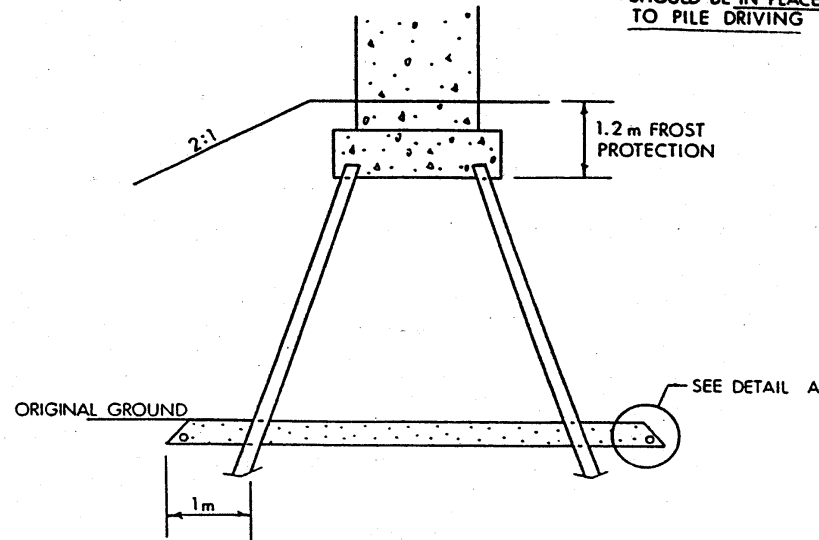
The selection and design of suitable unwatering and shoring systems shall remain the responsibility of the Contractor. However, factors that might influence the selection and design of unwatering and shoring systems include, but are by no means limited to:



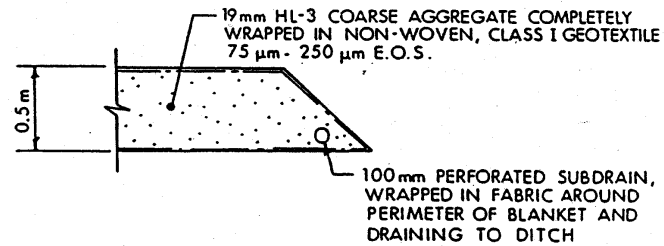
Appendix H

MTO Inverted Filter Design Drawing

NOTE: THE DRAINAGE BLANKETS SHOULD BE IN PLACE PRIOR TO PILE DRIVING



ABUTMENT SECTION (TYP)



DETAIL A.

DRAINAGE BLANKET DETAILS FOR ABUTMENTS AND PIERS