



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
PROPOSED STRUCTURAL CULVERTS  
HIGHWAY 7-NEW, KITCHENER TO GUELPH  
G.W.P. 408-88-00**

**Geocres Number: 40P8-269**

**Report**

**To**

**WSP**

Date: February 24, 2020  
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Appendices A to F include:

- Record of Borehole Sheets
- Laboratory Test Results
- Analytical Laboratory Test Results (Only for Culvert C33)
- Slope stability output
- Site Photographs
- Drawing titled “Borehole Locations and Soil Strata”





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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at six (6) proposed culvert sites along the proposed Highway 7-New mainline alignment in the Regional Municipality of Waterloo, Ontario.

The purpose of the investigations was to explore the subsurface conditions at the proposed culvert sites and, based on the data obtained, to provide borehole location plans, records of boreholes, stratigraphic profiles, laboratory test results and written descriptions of the subsurface conditions. Models of the subsurface conditions under the proposed culverts were developed from the data obtained in the course of the investigations.

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

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

- Preliminary, Foundation Investigation and Design Report, Proposed Structural Culverts, Highway 7-New, Kitchener to Guelph, G.W.P. 408-88-00, Geocres No. 40P8-209, Report to Ministry of Transportation Ontario West Region, File: 15-64-17, dated March 20, 2013. (Reference 1).

## 2. SITE DESCRIPTION

The culvert sites addressed in this report are located along the proposed Highway 7-New mainline from 1.4 km west of Regional Road 17 (Ebycrest Road) to approximately 900 m east of Wellington County Road. A total of six (6) structural culverts were identified within this section of the proposed Highway 7-New mainline.

The proposed Highway 7-New alignment generally runs parallel to and to the north of the existing Highway 7.

All the culvert sites lie within areas of farms and agricultural lands. There are farmsteads located near several of the culvert sites.

The designations and approximate locations of the proposed culverts are as follows:

Culvert	Location	Station	MTO Site Number
C8	Approx. 400 m east of Ebycrest Rd.	23+960	33-513/C
C15A	Approx. 460 m east of Greenhouse Rd.	26+207	33-517/C
C16	Approx. 830 m east of Shantz Station Rd.	27+593	33-519/C
C20	Approx. 1 km east of Woolwich Guelph Townline	30+044	33-601/C
C24	Approx. 900 m west of Woolwich Guelph Townline	31+774	35-603/C
C33	Approx. 900 m east of Wellington County road 86	35+895	32-607/C

Photographs of the general nature of the surrounding lands of Culverts C8, C15A, C16, C20 and C24 are included in Appendices A to E.

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. SITE INVESTIGATION AND FIELD TESTING

A preliminary site investigation for five proposed culverts was carried out between January 30 and February 8, 2012 (Reference 1).

A separate site investigation was conducted on June 27 and 28, 2017, and consisted of drilling and sampling three boreholes at the site of the proposed Culvert 33.

A summary of the borehole locations, designations, borehole termination depths and termination elevations for each culvert is provided in Table 3.1. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole Sheets. Record of Borehole Sheets are included in Appendices A and F.

**Table 3.1 – Borehole Designations**

	Station	Borehole	Borehole Ground Surface Elevation (m)	Borehole Termination Depth (m)	Borehole Termination Elevation (m)	Appendix
C8	23+960	C08-1 to C08-4	322.7 to 318.1	9.1 to 14.3	313.4 to 303.8	A
C15A	26+207	C15A-1 to C15A-4	320.3 to 319.5	7.8 to 7.9	311.7 to 312.4	B
C16	27+594	C16-1 to C16-4	323.9 to 323.1	8.0 to 8.2	314.9 to 315.7	C
C20	30+044	C20-1 to C20-3	332.4 to 329.6	7.8 to 8.0	321.6 to 324.6	D
C24	31+774	C24-1 to C24-3	330.1 to 329.9	7.7 to 7.9	322.2 to 322.4	E
C33	35+895	C33-1 to C33-3	340.9 to 340.4	7.0 to 12.2	328.2 to 333.7	F

Three to four boreholes were drilled at each culvert site. The boreholes were drilled along the culvert alignments, generally at both ends and in the middle.

The approximate locations of the boreholes are shown on the drawings included in Appendices A through F.

Prior to commencing the site investigation, utility clearances were obtained for all borehole locations. MTO obtained Permission to Enter (PTE) from all of the owners of the properties accessed by this investigation.



The boreholes were drilled using a track-mounted drill rig and the boreholes were advanced with a combination of hollow stem and solid stem augers. Samples were obtained at selected depth intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the native soils. HQ coring methods were used to advance Borehole C33-01(Culvert 33) into bedrock.

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 to F.

All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined. A photo of the rock cores collected from Borehole C33-01 is included in Appendix F.

Groundwater conditions in the open boreholes were observed during the drilling operations. One piezometer was installed at each culvert site to permit longer term monitoring of groundwater levels. The piezometers consisted of 25 mm diameter PVC pipe with a slotted screen enclosed in filter sand. The locations and completion details of the piezometers are summarized in Table 3.2 along with the borehole completion details. The completion of the boreholes and the standpipe piezometers were carried out in accordance with the requirements of O. Reg. 903 (as amended by O. Reg. 372/07).

**Table 3.2 – Borehole Completion Details**

<b>Culvert</b>	<b>Borehole</b>	<b>Borehole Ground Surface Elevation (m)</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
C8	C08-1	322.7	9.3/313.4	None installed	Borehole caved to 3.3 m. Backfilled with bentonite holeplug from 3.3 m to surface.
	C08-2	321.8	9.1/312.7	None installed	Backfilled with holeplug to 7.0 m, auger cuttings from 7.0 m to 2.4 m, then holeplug to surface.



	C08-3	320.5	14.3/306.2	13.9/306.6	Piezometer with 1.5 m slotted screen installed with sand filter to 11.6 m and bentonite holeplug from 11.6 m to ground surface.
	C08-4	318.1	14.3/303.8	None installed	Backfilled with holeplug to 12.1 m, auger cuttings from 12.1 m to 0.9 m, then holeplug to surface.
C15A	C15A-1	319.5	7.8/311.7	7.6 / 311.9	Piezometer with 1.5 m slotted screen installed with sand filter to 5.6 m and bentonite holeplug from 5.6 m to ground surface.
	C15A-2	320.1	7.9/312.2	None installed	Backfilled with auger cuttings and holeplug to 1.8 m, then holeplug to surface.
	C15A-3	320.1	7.8/312.3	None installed	Backfilled with holeplug to 3.9 m, then auger cuttings from 3.9 m to 1.2 m, then holeplug to surface.
	C15A-4	320.3	7.9/312.4	None installed	Backfilled with auger cuttings to 1.8 m, the holeplug to surface.
C16	C16-1	323.2	8.2/315.0	None installed	Borehole caved to 3.9 m. Backfilled with holeplug to 1.0 m, the auger cuttings to surface.
	C16-2	323.9	8.2/315.7	None installed	Borehole caved to 3.1 m. Backfilled with holeplug to 0.6 m, then auger cuttings to surface.
	C16-3	323.6	8.0/315.6	7.6 / 315.9	Piezometer with 1.5 m slotted screen installed with sand filter to 4.7 m, bentonite holeplug from 4.7 m to 0.9 m, and auger cuttings from 0.9 m to ground surface.
	C16-4	323.1	8.2/314.9	None installed	Borehole caved to 4.0 m. Backfilled with holeplug to 0.9 m, then cuttings to surface.
C20	C20-1	329.6	8.0/321.6	None installed	Borehole caved to 4.9 m. Backfilled with holeplug to 1.6 m, then cuttings to surface.



	C20-2	330.4	7.8/322.6	7.6 / 322.8	Piezometer with 1.5 m slotted screen installed with sand filter to 5.3 m, bentonite holeplug from 5.3 m to 1.3 m, and auger cuttings from 1.3 m to ground surface.
	C20-3	332.4	7.8/324.6	None installed	Borehole caved to 6.3 m. Backfilled with holeplug to 0.9 m, then cuttings to surface.
C24	C24-1	330.1	7.7/322.4	None installed	Backfilled with holeplug to 5.8 m, auger cuttings and holeplug from 5.8 m to 1.2 m, then holeplug to surface.
	C24-2	330.1	7.9/322.2	7.6 / 322.5	Piezometer with 1.5 m slotted screen installed with sand filter to 5.5 m and bentonite holeplug from 5.5 m to ground surface.
	C24-3	329.9	7.7/322.2	None installed	Backfilled with holeplug to 6.1 m, auger cuttings and holeplug from 6.1 m to 1.2 m, then holeplug to surface.
C33	C33-1	340.4	12.2/328.2	None installed	Backfilled with holeplug and auger cutting to surface.
	C33-2	340.9	8.2/332.7	8.2/332.7	Piezometer with 1.5 m slotted screen installed with sand filter to 6.1 m and bentonite holeplug from 6.1 m to 4.6 m, auger cuttings from 4.6 m to ground surface.
	C33-3	340.8	7.0/333.7	None installed	Backfilled with holeplug and auger cutting to surface.

#### 4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing, where appropriate. The results of this testing program are summarized on the Record of Borehole sheets and figures included in Appendix A through F.

Point load tests were carried out on selected samples of intact bedrock of Borehole C33-01, upon arrival at the laboratory to assist in evaluation of the compressive strength of the bedrock. Results of point load tests on the rock core samples are included in Appendix F and on the Record of Borehole sheets in Appendix F.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the native soil from Culvert 33, was collected and submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters. The results of the analytical testing are summarized in this report and also presented in Appendix F (Culvert 33).

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

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendices A to F. Details of the encountered soil stratigraphy along the proposed culvert alignments are presented on the “Borehole Locations and Soil Strata” drawings also included in these appendices. An overall description of the stratigraphy at each culvert site is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

### **5.1 Culvert C8 – Station 23+960 (Boreholes C08-1 to C08-4)**

In general the soil stratigraphy at this site consisted on surficial topsoil overlying a layer of native sand, an upper layer of sand and silt till, gravelly sand, silty clay till and a lower layer of sand and silt till.

#### **5.1.1 Topsoil**

A layer of topsoil was encountered surficially in all four boreholes drilled at this site. The topsoil was silty with some clay to clayey and some sand. It was generally dark brown in colour.

The thickness of the topsoil layer ranged from 0.2 m to 0.8 m. The topsoil thickness may vary between the borehole locations and in other areas of the site.

### 5.1.2 Sand

Native sand was encountered below the topsoil in Borehole C08-1. The sand was brown in colour and contained some gravel to gravelly, some silt and occasional cobbles.

The thickness of the sand layer was 1.6 m, with the lower boundary of the sand encountered at a depth of 2.4 m (Elevation 320.3).

SPT N-values recorded in the sand were 31 and 34 blows for 0.3 m penetration, indicating a dense relative density.

Moisture contents of samples of the sand were 9 percent to 11 percent.

### 5.1.3 Upper Sand and Silt Till

An upper layer of sand and silt till was encountered below the sand layer in Borehole C08-1, and below the topsoil in Boreholes C08-2 to C08-4. The sand and silt till was brown to grey in colour and contained trace to some clay, trace gravel and occasional cobbles.

The thickness of the upper sand and silt till ranged from 1.7 m to 5.3 m, with the lower boundary of this layer encountered at depths of 4.1 m to 6.1 m (Elevation 318.6 and 313.5).

SPT N-values recorded in the upper sand and silt till ranged from 14 to 36 blows for 0.3 m penetration, indicating a compact to dense relative density.

Moisture content of samples of the upper sand and silt till generally ranged from 8 percent to 18 percent.

Samples of the upper sand and silt till underwent laboratory gradation analysis. These results are summarized on the Record of Borehole sheets included in Appendix A and the grain size distribution curves for these samples are plotted on Figure A1 of Appendix A. The results of this testing are summarized as follows:

Soil Particles	Sand and Silt Till (%)
Gravel	1 to 10
Sand	24 to 65
Silt	22 to 55
Clay	3 to 17



Glacial tills inherently contain cobbles and boulders.

#### **5.1.4 Gravelly Sand**

A layer of gravelly sand was encountered below the upper sand and silt till layer in Boreholes C08-1 to C08-3. The gravelly sand was brown and contained some silt and clay.

Boreholes C08-1 and C08-2 were terminated within the gravelly sand layer at depths of 9.3 m and 9.1 m, respectively (Elevations 313.4 and 312.7). In Borehole C08-3, the gravelly sand layer was 3.6 m thick with the lower boundary encountered at a depth of 8.2 m (Elevation 312.3).

SPT N-values recorded in the gravelly sand ranged from 18 blows for 0.3 m penetration to 50 blows for 0.1 m penetration, indicating a compact to very dense relative density. In general, the lower part of the gravelly sand layer was very dense.

Moisture contents of samples of the gravelly sand ranged from 7 percent to 20 percent.

Two samples of the gravelly sand underwent laboratory grain size analysis testing, the results of which are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curves for these samples are plotted on Figure A2, Appendix A.

<b>Soil Particles</b>	<b>Gravelly sand (%)</b>
Gravel	25 to 33
Sand	51 to 54
Silt & Clay	13 to 24

#### **5.1.5 Silty Clay Till**

Silty clay till was encountered below the gravelly sand layer at 8.2 m (elevation 312.3) in Borehole C08-3 and below the upper sand and silt till layer at 4.6 m (elevation 313.5) in Borehole C08-4. The silty clay till was brown to grey and contained some sand to sandy and trace gravel.



The thickness of the silty clay till layer was 1.9 m and 3.9 m, with the lower boundary of the silty clay till encountered at depths of 10.1 m and 8.5 m in Boreholes C08-3 and C08-4, respectively (Elevation 310.4 and 309.6).

SPT N-values recorded in the silty clay till ranged from 18 to 51 blows for 0.3 m penetration, indicating a very stiff to hard consistency.

The natural moisture content of samples of the silty clay till ranged from 10 percent to 15 percent.

Two samples of the silty clay till underwent laboratory gradation analysis and Atterberg Limits testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are plotted on Figure A3 of Appendix A. The results of the Atterberg Limits tests are plotted on Figure A5.

Soil Particles	Silt Clay Till (%)
Gravel	1 to 3
Sand	29 to 31
Silt	40 to 42
Clay	24 to 30

Index Property	
Liquid Limit	22 to 28
Plastic Limit	12 to 14
Plasticity Index	10 to 14

The above results indicate that the silty clay till is low plastic with a group symbol of CL.

It should be noted that glacial tills are known to contain cobbles and boulders.

#### **5.1.6 Lower Silt and Sand Till**

A layer of lower silt and sand till was encountered below the silty clay till at 10.1 m and 8.5 m depth (elevations 310.4 and 309.6) in Boreholes C08-3 and C08-4, respectively. The lower silt and sand till was grey and contained some clay and trace gravel.

Both boreholes were terminated within the lower silt and sand till layer at a depth of 14.3 m (Elevation 306.2 and 303.8).

SPT N-values recorded in the lower silt and sand till in Borehole C08-3 ranged from 13 to 19 blows for 0.3 m penetration indicating a compact relative density. In Borehole C08-4, the SPT N-values ranged from 35 blows per 0.3 m of penetration to 50 blows per 0.25 m of penetration, indicating a dense to very dense relative density.

The moisture content of samples of the lower silt and sand till ranged from 9 percent to 14 percent.

Grain size analysis testing was performed on two samples of the lower silt and sand till. The results of these tests are presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curves for these samples are plotted on Figure A4, Appendix A. The results of the grain size analysis tests are summarized as follows:

Soil Particles	Lower sand and silt till (%)
Gravel	1 to 3
Sand	31 to 37
Silt	46
Clay	16 to 20

It should be noted that glacial tills are known to contain cobbles and boulders.

### 5.1.7 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C08-3, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.1.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.1.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C08-1	Feb. 1, 2012	1.2	321.5	Open borehole
C08-2	Feb. 1, 2012	4.3	317.5	Open borehole
C08-3	Feb. 3, 2012	0.9	319.6	Open borehole
	Feb. 8, 2012	2.6	317.9	Piezometer
	Feb. 27, 2012	2.1	318.4	Piezometer
	Apr. 17, 2012	6.3	314.2	Piezometer
C08-4	Feb. 2, 2012	-	-	Borehole dry upon completion of drilling

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Upon completion of drilling, Borehole C08-1 caved-in at 3.3 m.

Based on data presented on the drawing dated July 2012, the normal water level (2 year design flow) of the stream at this location ranges from Elevation 321.61 on the upstream side to Elevation 311.67 on the downstream side.

## **5.2 Culvert C15A – Station 26+207 (Boreholes C15A-1 to C15A-4)**

The stratigraphy encountered in the boreholes drilled at this site consisted of topsoil overlying layers of native silt, silty sand to sand, silty clay and sand and silt till.

### **5.2.1 Topsoil**

Topsoil was encountered at surface in Boreholes C15A-2 to C15A-4. The thickness of the topsoil ranged from 75 mm to 100 mm. The topsoil thickness may vary between and beyond the borehole locations.

### **5.2.2 Silt**

A layer of silt was encountered at surface locally in Borehole C15A-1. The silt was dark brown and contained some clay and some sand and was mixed with topsoil and occasional roots.

The silt layer encountered in Borehole C15A-1 extended to a depth of 1.2 m (Elevation 318.3).



SPT N-values recorded in the silt layer ranged from 4 to 11 blows for 0.3 m penetration, indicating a loose to compact relative density.

The moisture content of samples of the silt ranged from 35 percent to 38 percent.

### **5.2.3 Silty Sand to Sand**

A layer of silty sand was encountered below the topsoil in Boreholes C15A-2 to C15A-4. The silty sand was dark brown and contained trace gravel and trace clay. Near the surface, the silty sand was mixed with topsoil and organics.

A layer of sand was encountered locally in Borehole C15A-3, below the silty sand at 0.7 m depth (elevation 319.4). The sand was brown and contained some silt and clay and trace gravel.

The thickness of the silty sand and sand layers ranged from 0.7 m to 2.3 m, with the lower boundary of the silty sand and sand encountered at a depth of 0.8 m to 2.4 m (Elevation 319.3 to 317.9).

SPT N-values recorded in the silty sand and sand layers ranged from 3 to 30 blows for 0.3 m penetration, indicating a very loose to compact relative density. In general, the relative density of this layer increased with depth.

The moisture content of samples of the silty sand and sand layers ranged from 13 percent to 36 percent. The samples collected immediately below the topsoil had higher moisture contents.

One sample of the silty sand and one sample of the sand underwent laboratory gradation analysis. The results of this testing are presented on the Record of Borehole sheets included in Appendix B and the grain size distribution curves for these samples are plotted on Figure B1, Appendix B. The results of this test are as follows:

<b>Soil Particles</b>	<b>Silty Sand (%)</b>	<b>Sand (%)</b>
Gravel	5	2
Sand	58	80
Silt	31	-
Clay	6	-
Silt and Clay	-	18



#### 5.2.4 Silty Clay

A layer of silty clay was encountered below the silt and silty sand at depths ranging from 0.8 m to 2.0 m (elevations 319.3 to 318.1), in Boreholes C15A-1, C15A-2, and C15A-3, respectively. Clayey silt layers, 100 mm thick, were also encountered within the silty sand in Borehole C15A-4. The silty clay was brown to grey and contained trace to some sand and trace gravel. A layer of sand (350 mm thick) was encountered within the silty clay in Borehole C15A-3 at a depth of 2.3 m (elevation 317.8).

The thickness of the silty clay layer ranged from 1.0 m to 1.5 m, with the lower boundary of the silty clay encountered at depths of 2.3 m to 3.0 m (Elevation 317.8 to 317.1).

SPT N-values recorded in the silty clay ranged from 23 to 39 blows for 0.3 m penetration, indicating a very stiff to hard consistency.

The moisture content of samples of the silty clay ranged from 16 percent to 25 percent.

Two samples of the silty clay underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix B. The grain size distribution curves for these samples are plotted on Figure B2 of Appendix B and the results of the Atterberg Limits tests are plotted on Figure B4, Appendix B.

Soil Particles	Percentage (%)
Gravel	0 to 1
Sand	10 to 16
Silt	37 to 61
Clay	29 to 46

Index Property	Percentage (%)
Liquid Limit	24 to 28
Plastic Limit	13 to 14
Plasticity Index	11 to 14

Based on the results of the Atterberg Limits tests, the silty clay is low plastic with a group symbol of CL.

### 5.2.5 Silt and Sand Till

Silt and sand till was encountered below the silty clay at depths ranging from 2.3 m to 3.0 m (elevations 317.1 to 317.8) layer in Boreholes C15A-1 to C15A-3 and directly below the silty sand at 2.4 m depth (elevation 317.9) in Borehole C15A-4. The silt and sand till layer was brown to grey and contained some clay and trace to some gravel. Occasional clayey zones were identified within the silt and sand till in Borehole C15A-3. Probable cobbles were also encountered within the silt and sand till, as spoon was bouncing in Borehole C15A-1 near elevations 315.0 and 313.0.

A 900-mm thick layer of very dense sand was encountered within the sand and silt till at 6.1 m depth (elevation 314.2) in Borehole C15A-4.

All four boreholes were terminated within the silt and sand till at depths ranging from 7.8 m to 7.9 m (Elevation 312.4 to 311.7).

SPT N-values recorded in the silt and sand till typically ranged from 22 blows for 0.3 m penetration to 50 blows for less than 0.15 m penetration, indicating a compact to very dense relative density.

The moisture content of samples of the silt and sand till ranged from 7 percent to 19 percent.

Four samples of the silt and sand till underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix B. The grain size distribution curves for these samples are plotted on Figure B3 of Appendix B.

Soil Particles	Silt and sand till (%)
Gravel (%)	2 to 12
Sand (%)	32 to 43
Silt (%)	34 to 43
Clay (%)	12 to 25

Glacial tills inherently contain cobbles and boulders.

### 5.2.6 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C15A-1, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.2.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.2.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C15A-1	Jan. 31, 2012	1.1	318.4	Open borehole
	Feb. 8, 2012	2.1	317.4	Piezometer
	Feb. 27, 2012	1.8	317.7	Piezometer
	Apr. 17, 2012	1.1	318.4	Piezometer
C15A-2	Jan. 31, 2012	6.1	314.0	Open borehole
C15A-3	Jan. 31, 2012	1.4	318.7	Open borehole
C15A-4	Jan. 31, 2012	0.8	319.5	Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Based on data presented on the drawing dated July 2012, the normal water level (2 year design flow) of the stream at this location ranges from upstream Elevation of 320.57 m to downstream Elevation of 320.14 m.

### 5.3 Culvert C16 – Station 27+594 (Boreholes C16-1 to C16-4)

In general the stratigraphy encountered at this site consisted on surficial topsoil, clayey silt and organics overlying layers of native sand and silt till, silt, silty clay to silty clay till, silty sand and sand.





### **5.3.1 Topsoil**

A surficial layer of topsoil was encountered in all the boreholes. The thickness of the topsoil ranged from 150 mm to 700 mm. The topsoil thickness may vary between and beyond the borehole locations.

SPT N-values recorded in the topsoil ranged from 2 to 7 blows for 0.3 m penetration, indicating a very loose to loose relative density.

Moisture contents of topsoil samples ranged from 42 percent to 70 percent.

### **5.3.2 Clayey silt and Organics**

A layer of dark brown to black clayey silt and organics described as peaty and containing occasional rootlets was contacted below the topsoil in Borehole C16-3. The thickness of the clayey silt and organics layer was 1.1 m.

The depth to the base of the clayey silt and organics layer was 1.4 m (elevation 322.2).

SPT N-values recorded in the topsoil ranged from 3 to 7 blows for 0.3 m penetration, indicating a soft to firm consistency.

Moisture content of a sample of the clayey silt and organic layer was 95 percent.

### **5.3.3 Sand and Silt Till**

A layer of brown sand and silt till containing trace to some clay and trace to some gravel was contacted below the topsoil in Boreholes C16-1 and C16-2, below the clayey silt and organics layer in Borehole C16-3 and below the sand layer at 5.2 m (elevation 317.9) in Borehole C16-4. The thickness of the sand and silt till layer ranged from 2.0 m to 3.6 m.

A lower layer of sand and silt till was encountered at 5.8 m depth (elevation 317.8) in Borehole C16-3.

The base of the sand and silt till layer ranged from 3.0 m to 4.9 m depth (elevations 320.9 to 318.7) in Boreholes C16-1, C16-2 and C16-3. In Borehole C16-4, the depth to the base of the sand and silt till was at 7.2 m (elevation 315.9).

Borehole C16-3 was terminated within the lower sand and silt till at 8.0 m depth (elevation 315.6).

Generally, the SPT N-values ranged from 11 to 41 blows per 0.3 m of penetration, indicating a compact to dense relative density. In Borehole C16-1, an SPT N-



value of 5 blows per 0.3 m of penetration, indicating a loose relative density, was measured near elevation 322.3. Higher SPT N-values of 50 blows per 0.3 m of penetration and 100 blows for 0.25 m of penetration, indicating very dense relative density were noted in Boreholes C16-4 and C16-3, near elevation 316.8 and below elevation 317.5, respectively.

The moisture content of samples of the silt and sand till ranged from 9 percent to 17 percent.

Samples of the silt and sand till underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix C and the grain size distribution curves for these samples are plotted on Figure C1.

Soil Particles	Percentage (%)
Gravel	5 to 11
Sand	34 to 65
Silt	22 to 48
Clay	2 to 12

Glacial tills inherently contain cobbles and boulders.

#### **5.3.4 Silt**

A layer of silt was encountered locally in Borehole C16-1, below the sand and silt till at a depth of 4.3 m (elevation 318.9). The silt was grey and contained some sand to sandy and some clay.

The silt was not fully penetrated in Borehole C16-1, which was terminated at a depth of 8.2 m (Elevation 315.0).

SPT N-values recorded in the silt layer ranged from 30 to 42 blows for 0.3 m penetration, indicating a dense relative density. Moisture contents ranged from 10 percent to 19 percent.

One sample of the silt underwent laboratory gradation analysis. The results of this testing are presented on the Record of Borehole sheets included in Appendix C and the grain size distribution curve for this sample is plotted on Figure C2, Appendix C. The results of this test are as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	20
Silt	69
Clay	11

### 5.3.5 Silty Clay and Silty Clay Till

A layer of brown to grey silty clay and silty clay till containing some sand to sandy, sand seams, trace gravel and occasional roots and rootlets were encountered in the boreholes at depths and elevation presented in Table 5.3.1.

**Table 5.3.1 – Depths and Elevations of Silty Clay and Silty Clay Till**

Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)	Soil
C16-2	3.0 to 7.3	320.9 to 316.6	4.3	Silty clay till
C16-3	4.9 to 5.8	318.7 to 317.8	0.9	Silty clay
C16-4	0.2 to 4.1 7.2 to 8.2 <sup>(1)</sup>	322.9 to 319.0 315.9 to 314.9	3.9 >1.0	Silty clay till Silty clay

<sup>(1)</sup> Borehole termination depth

A 0.6-m thick layer of silty sand was encountered within the silty clay till in Borehole C16-2 at 4.3 m depth (elevation 319.6).

SPT N-values recorded within the silty clay and silty clay till ranged from 26 to 46 blows for 0.3 m penetration, indicating a very stiff to hard consistency in Borehole C16-2 and C16-3. SPT N-values recorded in Borehole C16-4 ranged from 5 to 22 blows for 0.3 m penetration, indicating a firm to very stiff consistency.

Moisture contents of samples of the silty clay and silty clay till ranged from 10% to 19%.

Samples of the silty clay and silty clay till underwent laboratory grain size analysis testing and Atterberg Limits testing. The results of these tests are summarized on

the Record of Borehole sheets included in Figures C3 and C4 of Appendix C and are as follows:

Soil Particles	Silty Clay /Silty Clay Till (%)
Gravel	0 to 6
Sand	5 to 34
Silt	28 to 53
Clay	24 to 64

The grain size distribution curves for these samples are plotted on Figure C3, Appendix C.

Index Property	Percentage (%)
Liquid Limit	23 to 38
Plastic Limit	12 to 16
Plasticity Index	11 to 12

The results of the Atterberg Limits tests indicate that the silty clay and silty clay till is low to medium plastic with group symbols of CL to CI.

It should be noted that glacial tills inherently contain cobbles and boulders.

### 5.3.6 Silty Sand

A layer of silty sand was encountered below the silty clay till at 7.3 m depth (elevation 316.6) in Borehole C16-2. The silty sand was grey and contained trace clay and trace gravel.

The silty sand was not fully penetrated in this borehole. Borehole C16-2 was terminated at a depth of 8.2 m (Elevation 315.7) within the silty sand deposit.

A single SPT N-value of 23 blows for 0.3 m penetration was recorded in the silty sand layer, indicating a compact relative density.

The moisture content of one sample of the silty sand was measured to be 16 percent.

### 5.3.7 Sand

A 1.1-m thick layer of brown sand was encountered locally below the silty clay till at 4.1 m (elevation 319.0) in Borehole C16-4. The sand contained some silt and trace gravel. The depth to the base of the sand layer was at 5.2 m (elevation 317.9).

A single SPT N-value of 38 blows for 0.3 m penetration was recorded in the sand layer, indicating a dense relative density.

The moisture content of one sample of the sand was measured to be 14 percent.

### 5.3.8 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C16-3, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.3.2, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.3.2 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C16-1	Feb. 6, 2012	2.2	321.0	Open borehole
C16-2	Feb. 6, 2012	2.0	321.9	Open borehole
C16-3	Feb. 8, 2012	1.4	322.2	Piezometer
	Feb. 27, 2012	1.5	322.1	Piezometer
	Apr. 17, 2012	1.8	321.8	Piezometer
C16-4	Feb. 6, 2012	1.4	321.7	Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Based on data presented on the drawing dated July 2012, the normal water level (2-year design flow) of the stream at this location ranges from upstream Elevation of 322.75 m to downstream Elevation of 322.23 m.

#### **5.4 Culvert C20 – Station 30+044 (Borehole C20-1 to C20-3)**

In general, the stratigraphy encountered in the boreholes drilled at this culvert consists of a surficial layer of topsoil overlying layers of clayey silt, silt and sand till, and clayey silt till (in Borehole C20-3).

##### **5.4.1 Topsoil**

A layer of topsoil was encountered at surface in all three borehole locations at this site. The layer of topsoil was black and contained some roots and rootlets.

The thickness of the layer of topsoil ranged from 150 mm to 300 mm. The topsoil thickness may vary between and beyond the borehole locations.

##### **5.4.2 Clayey Silt**

A layer of clayey silt was encountered below the surficial layer of topsoil in all three boreholes at this site. The clayey silt was dark brown to brown and contained some sand, trace gravel, and trace rootlets.

The thickness of the clayey silt layer ranged from 0.6 m to 1.2 m, with the lower boundary of the clayey silt encountered at depths of 0.8 m to 1.4 m (Elevations 331.0 to 328.2).

SPT N-values recorded in the clayey silt ranged from 3 to 16 blows for 0.3 m, indicating a soft to very stiff consistency. In general, the clayey silt layer became stiffer with increased depth.

Moisture contents of samples of the clayey silt ranged from 10 percent to 28 percent.

##### **5.4.3 Silt and Sand Till**

Silt and sand till was encountered below the clayey silt in all three boreholes. The silt and sand till was brown to grey and contained trace to some clay and trace to some gravel. The presence of occasional cobbles was inferred during drilling.

The silt and sand till was not fully penetrated in Boreholes C20-1 and C20-2. These boreholes were terminated at depths of 8.0 m and 7.8 m, respectively (Elevations 321.6 and 322.6). In Borehole C20-3, the silt and sand till layer was 3.3 m thick, with the lower boundary encountered at a depth of 4.7 m (Elevation 327.7).



SPT N-values recorded in the silt and sand till generally ranged from 11 blows for 0.3 m penetration to 100 blows for 0.125 m penetration, indicating a compact to very dense relative density. In general, the relative density of the silt and sand till increased with depth. An SPT N-value of 4 blows for 0.3 m penetration, indicating a loose relative density, was recorded in Borehole C20-2 at the upper boundary of the silt and sand till layer.

Moisture contents of samples of the silt and sand till typically ranged from 7 percent to 17 percent. A moisture content of 42 percent was measured for a sample from Borehole C20-2 at 7.7 m.

Selected samples of the silt and sand till underwent laboratory grain size analysis testing. The results of these tests are presented on the Record of Borehole sheets included in Appendix D. The grain size distribution curves for these samples are plotted on Figure D1, Appendix D. The results of these tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel (%)	4 to 13
Sand (%)	34 to 54
Silt (%)	26 to 42
Clay (%)	7 to 20

One sample of silt and sand till exhibited sufficient plasticity to perform an Atterberg Limits test. The results of this test are presented below and are summarized on the Record of Borehole sheets included in Appendix D. The results of this Atterberg Limits test are also plotted on Figure D3, Appendix D.

Index Property	Percentage (%)
Liquid Limit	21
Plastic Limit	14
Plasticity Index	7

The results of this Atterberg Limits test indicate that this sample of silt and sand till has a low plasticity.

Glacial tills inherently contain cobbles and boulders



#### 5.4.4 Clayey Silt Till

Clayey silt till was encountered below the silt and sand till at depth of 4.7 m (elevation 327.7) in Borehole C20-3. The clayey silt till was brown to grey and contained some sand to sandy and trace gravel.

Borehole C20-3 was terminated within the clayey silt till at a depth of 7.8 m (Elevation 324.6).

SPT N-values recorded in the clayey silt till were 100 blows for less than 0.3 m penetration, indicating a hard consistency.

Moisture contents of samples of the clayey silt till ranged from 8 percent to 12 percent.

One sample of the clayey silt till underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix D. The grain size distribution curve for this sample is plotted on Figure D2 of Appendix D and the results of the Atterberg Limits tests are plotted on Figure D4, Appendix D.

Soil Particles	Percentage (%)
Gravel	1
Sand	23
Silt	51
Clay	25

Index Property	Percentage (%)
Liquid Limit	21
Plastic Limit	12
Plasticity Index	9

The results of the Atterberg Limits tests indicate that the clayey silt is low plastic with a group symbol of CL.

Glacial tills inherently contain cobbles and boulders.



#### 5.4.5 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C20-2, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.4.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.4.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C20-1	Feb. 8, 2012	1.4	328.2	Open borehole
C20-2	Feb. 8, 2012	1.7	328.7	Piezometer
	Feb. 27, 2012	1.4	329.0	Piezometer
	Apr. 17, 2012	0.9	329.5	Piezometer
C20-3	Feb. 8, 2012	2.6	329.8	Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Based on data presented on the drawing dated July 2012, the normal water level (2 year design flow) of the stream at this location ranges from upstream Elevation of 329.9 m to downstream Elevation of 328.8 m.

#### 5.5 Culvert No.24 – Station 31+774 (Boreholes C24-1 to C24-3)

At this location, the stratigraphy encountered in the boreholes generally consisted of a layer of topsoil at surface underlain by a layer of clayey silt and then silt and sand till. A layer of clayey silt till was encountered locally in Borehole C24-3 between the clayey silt layer and the silt and sand till.

##### 5.5.1 Topsoil

Dark brown topsoil mixed with organics was encountered at surface at the location of all three boreholes at this site. The topsoil thickness ranged from 50 mm to 600 mm. The topsoil thickness may vary between and beyond the borehole locations.



Where the topsoil was thicker, SPT N-values of 4 and 5 blows for 0.3 m penetration were recorded, indicating a loose relative density.

The moisture content of samples of the topsoil and organics ranged from 37 percent to 51 percent.

#### **5.5.2 Clayey Silt to Silt**

A layer of clayey silt to silt was encountered below the topsoil in all three boreholes. The clayey silt to silt was brown and contained some sand and trace gravel.

The thickness of the clayey silt layer ranged from 0.5 m to 0.9 m, with the lower boundary of the clayey silt encountered at depths of 0.8 m to 1.5 m (Elevation 329.3 to 328.4).

SPT N-values recorded in the clayey silt to silt ranged from 5 to 14 blows for 0.3 m penetration, indicating a stiff consistency in the clayey silt and loose to compact relative density in the silt.

The moisture content of samples of the clayey silt ranged from 12 percent to 24 percent.

#### **5.5.3 Clayey Silt Till**

A layer of clayey silt till was encountered locally in Borehole C24-3, below the clayey silt. The clayey silt till was brown and contained some sand and trace gravel.

The layer of clayey silt till was 1.5 m thick, with the lower boundary encountered at a depth of 3.0 m (Elevation 326.9).

SPT N-values recorded in the clayey silt till ranged from 26 to 27 blows for 0.3 m penetration, indicating a very stiff consistency.

The moisture content of samples of the clayey silt till ranged from 9 percent to 16 percent.

One sample of the clayey silt till underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix E. The grain size distribution curve for this sample is plotted on Figure E2 of Appendix E and the results of the Atterberg Limits tests are plotted on Figure E3, Appendix B.



Soil Particles	Percentage (%)
Gravel	6
Sand	20
Silt	43
Clay	31

Index Property	Percentage (%)
Liquid Limit	26
Plastic Limit	13
Plasticity Index	13

The results of the Atterberg Limits tests indicate that the clayey silt is low plastic with a group symbol of CL.

#### 5.5.4 Silt and Sand Till

Silt and sand till was encountered below the clayey silt to silt in Boreholes C24-1 and C24-2, and below the clayey silt till in Borehole C24-3. The silt and sand till was brown to grey and contained some clay and trace gravel. Probable cobbles were also encountered within the silt and sand till.

All three boreholes were terminated within the silt and sand till at depths of 7.7 m to 7.9 m (Elevation 322.4 to 322.2).

SPT N-values recorded in the silt and sand till typically ranged from 39 blows for 0.3 m penetration to 50 blows for less than 0.15 m penetration, indicating a dense to very dense relative density below elevation 327.0. Lower N-values of 13 to 25 blows for 0.3 m penetration were recorded in the upper 1.0 m of the silt and sand till indicating that the upper 1.0 m of the silt and sand till has a compact relative density.

The moisture content of samples of the silt and sand till ranged from 5 percent to 12 percent.

Five samples of the silt and sand till underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix E. The grain size distribution curves for these samples are plotted on Figure E1 of Appendix E.



Soil Particles	Percentage (%)
Gravel	5 to 13
Sand	33 to 42
Silt	37 to 43
Clay	12 to 19

Glacial tills inherently contain cobbles and boulders.

#### 5.5.5 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C24-2, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.5.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.5.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C24-1	Jan. 30, 2012	1.8	328.3	Open borehole
C24-2	Jan. 30, 2012	1.3	328.8	Open borehole
	Feb. 8, 2012	0.8	329.3	Piezometer
	Feb. 27, 2012	0.8	329.3	Piezometer
	Apr. 17, 2012	0.9	329.2	Piezometer
C24-3	Jan. 30, 2012	2.7	327.2	Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Based on data presented on the drawing dated July 2012, the normal water level (2-year design flow) of the stream at this location ranges from upstream Elevation of 330.29 m to downstream Elevation of 330.06 m

## **5.6 Culvert C33 – Station 35+895**

At this location, the stratigraphy encountered in the boreholes generally consisted of a layer of topsoil at surface underlain by layers of sand and gravel, silty sand and silty clay till overlying clayey silt till. The overburden soils are underlain by limestone bedrock.

### **5.6.1 Topsoil**

Black topsoil mixed with organics was encountered at surface at the location of all three boreholes drilled at this site. The topsoil thickness was 700 mm. The topsoil thickness may vary between and beyond the borehole locations.

SPT N-values of 2 to 4 blows for 0.3 m penetration were recorded in the topsoil, indicating a loose state.

The moisture content of samples of the topsoil and organics ranged from 55 percent to 90 percent.

### **5.6.2 Silty Sand**

Silty sand was encountered below the topsoil at a depth of 0.7 m (Elevation 340.1) in Borehole C33-03 and within the sand and gravel layer at depths of 1.4 m and 2.2 m (elevation 338.9 and 338.7) in Boreholes C33-01 and C33-02, respectively. The silty sand layer ranged in thickness from 0.7 m to 0.8 m. The silty sand was grey and contained some clay and trace to some gravel.

SPT N-values recorded in the silty sand ranged from 12 to 22 blows per 0.3 m penetration, indicating a compact state.

Moisture contents of samples of the silty sand ranged from 10 percent to 18 percent.

### **5.6.3 Sand and Gravel**

Layers of grey sand and gravel containing some silt, trace to some clay and occasional cobbles was encountered below the topsoil a depth of 0.7 m (Elevation 339.7 and 340.2) in Boreholes C33-01 and C33-02, respectively, and below the silty clay till at a depth of 2.2 m (Elevation 338.5) in Borehole C33-03. A lower layer of sand and gravel was encountered at depths of 2.2 m (Elevation 338.2) and 3.0 (Elevation 337.9) in Boreholes 33-01 and 33-02 respectively.

SPT N-values recorded in the upper sand and gravel layers ranged from 6 to 21 blows per 0.3 m penetration, indicating a loose to compact state, where as the SPT N-values in the lower sand and gravel ranged from 22 to 102 blows per 0.3 m of penetration, indicating a compact to very dense state.

Moisture contents of samples of the sand and gravel ranged from 8 percent to 15 percent.

Three samples of the sand and gravel underwent laboratory gradation analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix F. The grain size distribution curves for these samples are plotted on Figure F1 of Appendix F.

Soil Particles	Percentage (%)
Gravel	50 to 55
Sand	30 to 37
Silt and Clay	13 to 15

#### **5.6.4 Silty Clay Till and Clayey Silt Till**

Grey silty clay till containing some sand to sandy and trace gravel was encountered below the silty sand at a depth of 1.4 m (Elevation 339.3) in Borehole C33-03. The thickness of the silty clay till was 0.8 m.

Grey clayey silt till was encountered below the sand and gravel layer at depths of 4.3 m and 4.1 m (Elevation 336.6) in Boreholes C33-02 and C33-03 respectively. The clayey silt till contained some sand to sandy, trace to some gravel and occasional cobbles.

Boreholes C33-02 and C33-03 were terminated within the clayey silt till at depths of 8.2 m and 7.0 m (Elevations 332.7 and 333.7), respectively.

SPT N-values recorded in the silty clay till/clayey silt till ranged from 12 to more than 100 blows per 0.3 m penetration, indicating a stiff to hard consistency. The high blow counts may represent the presence of cobbles and boulders.

Moisture contents of samples of the silty clay till/clayey silt till ranged from 8 percent to 11 percent.

Two samples of the clayey silt till and one sample of silt clay till underwent laboratory gradation analysis testing, the results of which are summarized below.

These results are also presented on the Record of Borehole sheets included in Appendix F. The grain size distribution curves for these samples are plotted on Figure F2 of Appendix F.

<b>Soil Particles</b>	<b>Silty Clay Till Percentage (%)</b>	<b>Clayey Silt Till Percentage (%)</b>
Gravel	2	7 to 13
Sand	27	39 to 43
Silt	40	32 to 39
Clay	31	12 to 15

Atterberg Limits tests were conducted in the silty clay till/clayey silt till, and the results are presented on the Record of Borehole sheets and on Figure F3 of Appendix F. The results of Atterberg Limits testing are summarized below:

<b>Index Property</b>	<b>Silty Clay Till Percentage (%)</b>	<b>Clayey Silt Till Percentage</b>
Liquid Limit	24	17
Plastic Limit	12	12
Plasticity Index	12	5

The above results show that the silty clay till and clayey silt till are of low plasticity with group symbols of CL and CL-ML, respectively.

Glacial tills inherently contain cobbles and boulders.

### **5.6.5 Bedrock**

The overburden soils described above are underlain by limestone bedrock. Bedrock was encountered at 9.1 m depth (Elevation 331.2) in Borehole C33-01, and it was proved by coring. The bedrock was grey to brown in colour. Occasional mechanical breaks were noted throughout the bedrock cores. The bedrock is generally described as moderately to highly weathered.

Borehole C33-01 was terminated within the bedrock at 12.2 m depth (Elevation 328.2).

Total Core Recovery (TCR) in the bedrock was 20% with Solid Core Recovery (SCR) of 20%. The Rock Quality Designation (RQD) determined from the recovered cores was 3% and 10%, indicating very poor rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, were 3 and 5.

Estimated unconfined compressive strengths (UCS) of the rock ranged from 11 MPa to 97 MPa, indicating the rock is weak to strong. These estimated rock strength values are interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results is presented in Appendix F.

#### 5.6.6 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling.

One standpipe piezometer was installed at this site, in Borehole C33-02, to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.6.1, along with the measurements in the open boreholes upon completion of drilling.

**Table 5.6.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
C33-01	June 27, 2017	3.0	337.4	Open borehole
C33-02	June 28, 2017	2.1	338.8	Open borehole Piezometer
	March 23, 2018	0.3	340.6	
C33-03	June 28, 2017	1.5	339.3	Open borehole

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Based on data presented on the drawing dated July 2012, the normal water level (2-Year design flow) of the stream at this location ranges from upstream Elevation of 341.34 m to downstream Elevation of 340.87 m

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the silty sand from Borehole C33-01, SS3 (Depth of 1.5 m) was submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests



are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix A.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Test Results
		C33-01 <sup>(1)</sup> SS 3 Depth 1.5 m
		(Soil Sample)
Sulphide	%	<0.02
Chloride	µg/g	13
Sulphate	µg/g	68
pH	No unit	8.78
Electrical Conductivity	µS/cm	133
Resistivity	Ohms.cm	7520
Redox Potential	mV	228

<sup>(1)</sup> Borehole C33-01 is identified as CV16-01 in the analytical test results

## 7. MISCELLANEOUS

DBW Drilling of Ajax, Ontario supplied a track-mounted drill rig and conducted the drilling, sampling and in-situ testing operations for the previous phase of drilling.

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

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

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

Other details of the previous investigation, conducted in 2012, are presented in Reference 1.

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



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

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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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
PROPOSED STRUCTURAL CULVERTS  
HIGHWAY 7 – NEW, KITCHENER TO GUELPH  
G.W.P. 408-88-00**

**Geocres Number: 40P8-269**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to select and design suitable foundation systems for six proposed structural culverts associated with Highway 7 - New.

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

The Highway 7 – New Project will involve construction of new divided eastbound and westbound lanes approximately 300 m north of the existing undivided Highway 7. Construction of six new structural culverts have been proposed from 1.4 km west of Ebbycrest Road to about 800 m east of Wellington County Road 86.

Design details of the proposed culverts, as provided by WSP, are presented in Table 8.1. The approximate heights of fill to be placed above the culverts are also included. The drawing provided by WSP, dated July 2012, indicates that the proposed culverts will be rigid frame box culverts.

**Table 8.1 – Proposed Culvert Installations**

Culvert	Site Number	Location (Station)	Invert Elevation (m)		Culvert Size (m) Width x height	Proposed Length (m)	Maximum Depth of Cover (m)
			Inlet	Outlet			
C8 <sup>(1)</sup>	33-513/C	23+960	321.020	311.291	3.0 x 1.5	139.0	13.2
C15A	33-517/C	26+207	320.136	319.617	1.8 x 1.2 <sup>(2)</sup> (each box culvert)	62.4	1.5
C16	33-519/C	27+594	322.170	321.979	3.5 x 1.5	90.8	5.9
C20	33-601/C	30+044	329.450	328.580	4.0 x 1.5	95.7	5.7
C24	33-603/C	31+774	329.530	329.340	2.4 x 1.5 <sup>(2)</sup> (each box culvert)	62.8	3.6
C33	32-607/C	35+895	340.54	340.36	6.0 X 1.8	70.6	1.8

<sup>(1)</sup> Culvert C8 is proposed to have an approximately 7% slope over 139 m, resulting in an approximately 10-m elevation change.

<sup>(2)</sup> Culverts C15A and C24 consist of double concrete box.

The discussions and recommendations presented in this report are based on information provided by WSP and on the factual data obtained during the course of the current investigation.

## 9. CULVERT FOUNDATIONS

This section presents discussions on available types of culverts and foundation alternatives, and provides recommendations on preferred foundation options.

### 9.1 General

A general description of the subsurface stratigraphy and groundwater condition for each culvert is presented below.

#### Culvert C8

The subsurface stratigraphy at the location of the proposed Culvert C8 (Boreholes C08-1 to C08-4) consists of 200 mm to 800 mm of surficial topsoil overlying layers of native dense sand, compact to dense sand and silt till, compact to dense gravelly sand, very stiff to hard silty clay till and a lower layer of sand and silt till.

#### Culvert C15A

The subsurface stratigraphy at the location of the proposed Culvert C15A (Boreholes C15A-1 to C15A-4) consists of 75 mm to 100 mm of surficial topsoil overlying layers of native loose to compact silt, very loose to compact silty sand, soft to hard silty clay, underlain by compact to very dense sand and silt till.

#### Culvert C16

The subsurface stratigraphy at the location of the proposed Culvert C16 (Boreholes C16-1 to C16-4) consists of 200 mm to 700 mm of surficial topsoil over layers of native loose to dense sand and silt, firm to very stiff silty clay till, hard silty clay and dense silt. A 1.1-m thick layer of clayey silt and organics was encountered below the topsoil.

#### Culvert C20

The subsurface stratigraphy at the location of the proposed Culvert C20 (Boreholes C20-1 to C20-3) consists of 150 mm to 300 mm of surficial topsoil over layers of native soft to very stiff clayey silt, loose to very dense sand and silt till and hard clayey silt till. Occasional cobbles were noted in the glacial cohesive till.

#### Culvert C24

The subsurface stratigraphy at the location of the proposed Culvert C24 (Boreholes C24-1 to C24-3) consists of 50 mm to 600 mm of surficial topsoil over layers of native loose to compact silt, stiff clayey silt, very stiff clayey silt till and compact to very dense sand and silt till. Occasional cobbles were noted in the glacial cohesive till.

#### Culvert C33

The subsurface stratigraphy at the location of the proposed Culvert C33 (Boreholes C33-01 to C33-03) consists of 700 mm of surficial topsoil over layers of native compact silty sand, compact to very dense sand and gravel and stiff to hard clayey silt to silty clay till. Occasional cobbles were noted in the sand and gravel layer. The site is underlain by limestone bedrock.

A summary of the groundwater levels measured in the piezometers installed in selected boreholes at the proposed culvert locations is presented in Table 9.1.

**Table 9.1 – Summary of Measured Groundwater Depths/Elevations in Piezometers**

<b>Culvert</b>	<b>Borehole</b>	<b>Date</b>	<b>Measured Groundwater Depth (m)</b>	<b>Measured Groundwater Elevation (m)</b>
C8	C08-3	Feb. 8, 2012	2.6	317.9
		Feb. 27, 2012	2.1	318.4
		Apr. 17, 2012	6.3	314.2
C15A	C15A-1	Feb. 8, 2012	2.1	317.4



		Feb. 27, 2012	1.8	317.7
		Apr. 17, 2012	1.1	318.4
C16	C16-3	Feb. 8, 2012	1.4	322.2
		Feb. 27, 2012	1.5	322.1
		Apr. 17, 2012	1.8	321.8
C20	C20-2	Feb. 8, 2012	1.7	328.7
		Feb. 27, 2012	1.4	329.0
		Apr. 17, 2012	0.9	329.5
C24	C24-2	Feb. 8, 2012	0.8	329.3
		Feb. 27, 2012	0.8	329.3
		Apr. 17, 2012	0.9	329.2
C33	C33-02	Mar. 23, 2018	0.3	340.6

## 9.2 Foundation Design

Foundation design issues that must be considered for culverts consist of subgrade conditions, bearing resistances, groundwater control to maintain dry excavation, settlement of foundation soils under the weight of the new roadway embankment fill, and stability of the new embankments adjacent to the culverts.

The following types of culvert have been considered in this report:

- Concrete closed box culvert supported on native soil
- Concrete open frame culvert with spread footings on native soil
- Concrete Pipe, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)

The design team has indicated that the proposed culverts will be rigid frame box culverts.

A comparison of the technical advantages and disadvantages of the different culvert types listed above from a foundations point of view is presented in Appendix G.

Both pre-cast and cast-in place culvert options were considered. Use of a precast concrete culvert may be preferred over a cast-in-place culvert since installation is likely to be more expedient, reducing the duration of groundwater control requirements during construction. Moreover, a precast concrete culvert is normally installed with less potential for disturbance of the founding soils.



It is understood that wingwalls or headwalls are not planned in the design of these culverts.

From a foundations and constructability perspective, use of the concrete open frame with spread footings founded on native soils or on engineering fill pad, SPCSP, CSP, and precast concrete box culvert are all feasible options, based on the following considerations:

- Precast box culvert or pipe culverts would require shallower depth of excavation compared with the open frame culvert;
- Pre-cast concrete box or pipe culverts can often be installed more expeditiously than cast-in-place open frame culverts, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis;

The culverts must be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

### **9.3 Closed Box Culverts on the Native Soils**

The drawing provided by WSP indicates that the proposed culverts will consist of concrete box culverts. Accordingly, recommendations are provided for installation of closed box culverts on native soils.

Following excavation to the design base level of the culvert, any remaining fill, topsoil, streambed deposits or soft soils within the culvert footprint should be subexcavated to the undisturbed native soils at the elevations shown in Table 9.2 below.

**Table 9.2 – Recommended Founding Levels for Box Culverts**

<b>Culvert</b>	<b>Borehole</b>	<b>Approximate Depth below existing ground surface (m)</b>	<b>Approx. Founding Elevation (m)</b>	<b>Founding Stratum</b>
C08*	C08-1	1.7	321.0	Dense sand
	C08-2	3.8	318.0	Compact sand and silt till
	C08-3	6.0	314.5	Compact to dense gravelly sand
	C08-4	6.6	311.5	Very stiff silty clay till
C15A	C15A-1 C15A-2 C15A-3 C15A-4	1.5 to 2.3	318.0	Very stiff to hard silty clay, and dense sand and silt till
C16	C16-1 C16-2 C16-3 C16-4	2.3 to 3.1	320.8	Compact sand and silt till and very stiff silty clay till
C20	C20-1 C20-2 C20-3	2.1 to 4.9	327.5	Compact to very dense silt and sand till, hard clayey silt till
C24	C24-1 C24-2 C24-3	1.9 to 2.1	328.0	Compact to dense silt and sand till, very stiff clayey silt till
C33	C33-01 C33-02 C33-03	2.4 to 2.9	338.5	Compact to dense sand and gravel

**Note \*:** Due to steep culvert grade the founding elevation varies along the culvert.

The exposed subgrade must be inspected to confirm that the subgrade is uniformly competent. Any fill placed below the culvert to re-establish the founding level should consist of compacted Granular A or B Type II material. This work should be carried out in accordance with OPSS 902.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement



and compaction of the bedding material must be carried out in the dry. 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 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 surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A material. Geotextile should be placed between the founding soils and the granular layer of bedding material. Subgrade preparation should also be conducted as indicated in Section 11.1.

Culverts founded on the native, undisturbed soils at or below the level indicated in Table 9.2, should be designed using a concentric, vertical factored geotechnical resistances as indicated in Table 9.3 below:

**Table 9.3 – Bearing Resistances for Box Culverts**

<b>Culvert</b>	<b>Factored ULS<sub>r</sub> (kPa)</b>	<b>Factored SLS<sub>r</sub> (kPa)</b>
C08	375	250
C15A	400	300
C16	300	200
C20	500	350
C24	480	320
C33	380	250

The above values of the geotechnical resistance and reaction were based on the proposed box culvert widths indicated in Table 8.1.

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

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be

reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The bearing resistances in Table 9.3 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.

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.35.

It is anticipated that the subgrade soils within the culvert footprints will be subjected to loading due to embankment fill. Settlement due to the embankment load is anticipated at the proposed culvert sites. Table 12.1 in Section 12 of this report addresses culvert settlement estimates. The culverts must be designed to accommodate the estimated settlements.

#### **9.4 Open Frame Culvert with Spread Footings on Native Soil**

Consideration was given to open frame culverts supported on spread footings.

Spread footings for open frame culverts should be founded on undisturbed, native compact to dense soils or very stiff to hard cohesive soils. Backfill to subexcavation for reinstating founding elevations must consist of well compacted Granular A or Granular B Type II.

Assuming a footing width of 1.5 m, the geotechnical resistances and founding elevations presented in Table 9.4 are recommended for design of spread footings founded on the native soils.

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

**Table 9.4 – Bearing Resistances and Founding Elevations for Spread Footings**

Culvert	Borehole	Depth below existing ground surface (m)	Approx. Founding Elevation (m)	Founding Stratum	Factored ULS <sub>f</sub> (kPa)	Factored SLS <sub>f</sub> (kPa)
C08	C08-1	3.2	319.5	Compact sand and silt till	480	320
	C08-2	5.1	316.7	Compact sand and silt till		
	C08-3	7.5	313.0	Compact to dense gravelly sand		
	C08-4	7.9	310.2	Hard silty clay till		
C15A	C15A-1 C15A-2 C15A-3 C15A-4	1.5 to 2.3	318.0	Very stiff to hard silty clay and compact sand, and sand and silt till	550	350
C16	C16-1 C16-2 C16-3 C16-4	2.3 to 3.1	320.8	Compact sand and silt till and very stiff silty clay till	350	250
		3.1 to 3.9	320.0	Dense sand and silt till, very stiff silty clay till	480	320
C20	C20-1 C20-2 C20-3	2.1 to 4.9	327.5	Compact to very dense silt and sand till, hard clayey silt till	600	400
C24	C24-1 C24-2 C24-3	1.9 to 2.1	328.0	Compact to dense silt & sand till, very stiff clayey silt till	550	350
C33	C33-01 C33-02 C33-03	2.4 to 2.9	338.5	Compact to dense sand and gravel, compact silty sand	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 typical degree of understanding of the subsurface conditions.

The bearing resistances in Table 9.4 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.

It is anticipated that the subgrade soils within the culvert footprints will be subjected to loading due to embankment fill. Settlement due to the embankment load is anticipated at the proposed culvert sites. Table 12.1 in Section 12 of this report addresses culvert settlement estimates. The culverts must be designed to accommodate the estimated settlements.

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

Based on piezometric readings presented in Table 9.1, the groundwater level at the culvert sites is generally up to 2.6 m above (potentially more at Culvert C8) the founding elevations presented in Table 9.4. 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 effective groundwater control measures during construction and prior to excavating below the groundwater level. 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 inside the enclosure.

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.

Consideration should be given to commencing the application process for a permit to take water (PTTW) prior to contract award.

Scour protection should be provided for the spread footing at the culverts. Design of scour protection must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

## **9.5 Circular Pipe Culvert**

Consideration has been given to circular pipes (concrete pipe, SPCSP or CSP) for the six new culverts.

If this alternative is selected, the SPSCP or CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II. The underside of the bedding layer should be placed at or below elevations presented in Table 9.2, which corresponds to native undisturbed competent soils. Geotextile should be placed between the founding soils and the granular layer of bedding material.

Any remaining organics, loose/soft or deleterious material should be removed from final subgrade level and replaced with compacted granular material. Culvert subgrade preparation and placement and compaction of the granular fill must be carried out in the dry. Adequate preparation of the subgrade will be essential for performance of the culvert.

In general, subgrade preparation, bedding, backfill and compaction requirements for concrete box culvert presented in Section 9.3 should be followed for circular pipes. OPSD 803.030 or OPSD 803.031 should be referenced for circular pipes.

It is anticipated that the subgrade soils within the culvert footprints will be subjected to loading due to embankment fill. Settlement due to the embankment load is anticipated at the proposed culvert sites. Table 12.1 in Section 12 of this

report addresses culvert settlement estimates. The culverts must be designed to accommodate the estimated settlements.

## 9.6 Frost Cover

The design depth of frost penetration for this site is 1.4 m. All footing bases must be provided with at least 1.4 m of soil cover.

## 9.7 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended culvert type for the six culverts is closed box culverts founded on native soils.

## 10. LATERAL EARTH PRESSURES

A triangular distribution of lateral earth pressures acting on the culvert walls may be assumed for design. For a fully drained backfill, 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 below)
$\gamma$	=	unit weight of retained soil (see table below)
$h$	=	depth below top of fill where pressure is computed (m)
$q$	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 10.1 below.

**Table 10.1 – Lateral Earth Pressure Coefficients (K)**

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	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	3.7	-	3.3	-

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

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added.

The design of the culvert must incorporate measures such as weepholes to permit drainage of the culvert backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

## **11. CULVERT CONSTRUCTION CONSIDERATIONS**

### **11.1 Subgrade Preparation**

Performance of the new culverts will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, creek bed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint at the subgrade level must be removed and replaced with well compacted granular materials. A layer

of soft to firm clayey silt encountered below the topsoil at the locations of Culverts C16 and C20 must be removed.

In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction and all subgrade preparation and placement and compaction of granular material must be carried out in the dry.

Construction equipment should not be allowed to travel on the prepared subgrade, which has to be protected from disturbance during construction.

## **11.2 Culvert Bedding and Backfill**

A minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the CSP or box culvert and compacted in accordance with OPSS 501 in the dry. The culvert subgrade preparation, placement and compaction of granular bedding should be carried out in the dry. However, if the dewatering efforts are not fully effective and if the culvert is to be constructed in the remaining wet condition, coarse 53 mm clear stone wrapped in geotextile should be used as backfill in the wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may then be placed and compacted in the dry. The clear stone backfill may be fully enclosed in geotextile. Geotextile should be placed between the founding soils and the granular layer of bedding material for separation purpose.

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.014, and as per the requirements of the CHBDC.



Backfilling for the culvert should be in accordance with OPSS 501, OPSS 902, and as per the CHBDC requirements. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

### 11.3 Excavation and Groundwater Control

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native sand and gravel, sand, clayey silt, silt, silty clay, sand and silt till, and silty clay till at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits and alluvium/muskeg/organics, should be classified as Type 4 soils.

Excavation for culvert construction should be carried out in accordance with OPSS 902. Excavations for the new culverts will be carried out through native sand and gravel, sand, clayey silt, silt, silty clay, sand and silt till, and silty clay till. Organics may be encountered in the creek valleys and flood plains.

The piezometric readings presented in Table 9.1 indicate that the groundwater level varies at each culvert location as follows:

<b>Culvert</b>	<b>Measured Groundwater Depth (m)</b>	<b>Measured Groundwater Elevation (m)</b>	<b>Estimated Culvert Subgrade Elevation (m)</b>
C8	2.6 to 6.3	317.9 to 314.2	320.0 to 310.2
C15A	1.1 to 2.1	317.4 to 318.4	318.0
C16	1.4 to 1.8	322.2 to 321.8	320.8
C20	0.9 to 1.7	328.7 to 329.5	327.5
C24	0.8 to 0.9	329.2 to 329.3	328.0
C33	0.3	340.6	338.0

Based on the above, the groundwater levels are generally above the estimated culvert subgrade levels.

Excavation below the groundwater level without groundwater control is not recommended since the inflow of groundwater will cause boiling and sloughing of

the soil below the water level making it difficult to maintain a dry, sound base on which to work. For any temporary excavation, the Contractor must be prepared to control the groundwater and surface water to permit construction in the dry.

At the culvert sites, the groundwater level is expected to be largely governed by the water level in the creek or water course. In order to construct a pipe, a box culvert or spread footings in the dry, diversion of the water flow will be required. Given the relatively high permeability of the existing native cohesionless soils, water inflow/seepage into the excavation should be anticipated. In order to facilitate the construction works, unwatering methods including, but not necessarily limited to, temporary diversion of creek and other surface water, sandbag and/or sheetpile cofferdams will be required. The Contractor must make provisions to control any water seepage, surface runoff and ponding by measures including the use of sump pumps to maintain dry excavations during the course of the works. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.

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.

At each site, culvert construction must start at the low end and seepage water should be drained using sumps and pumps. Placement of concrete (if required) must be done in the dry. Unwatering must remain operational and effective until the culvert is installed and backfilled.

It is recommended that culvert construction be conducted during the drier season.

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

Soil	Permeability, k (cm/sec)
Sand and silt till, Silt	$2.2 \times 10^{-6}$
Gravelly sand, sand	$5.6 \times 10^{-3}$
Silty sand	$2.5 \times 10^{-5}$
Silty clay till/Clayey silt till	$1 \times 10^{-8}$

Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517, SP 517F01 Amendment to OPSS 517, November 2016 (issued July 2017), and OPSS. PROV 902.

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. Suggesting wording for an NSSP in this regard is included in Appendix G.

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

#### **11.4 Cut at Culvert C8**

Earth cuts are required to construct/install Culvert C8. The earth cut will be formed through about 7.9 m of soils, typically consisting of compact to dense sand and silt till, dense sand and hard silty clay till. It is anticipated that the base of the cut will consist of compact sand and silt till, compact to dense gravelly sand and hard silty clay till. The groundwater levels measured in the piezometer installed in Culvert C8 varied from 2.6 m to 6.3 m (Elevations 317.9 to 314.2).

At the maximum depth, the cut slopes are expected to be stable at inclinations not steeper than 2H:1V. A mid-height bench is required for deep cuts in excess of 8 m in height. The bench should be at least 2.0 m wide.

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

- Storm runoff
- Seepage from the sides of the cut, particularly from the cohesionless soils

Temporary drainage of the cuts should be provided to maintain a relatively dry, stable excavation.

## **12. EMBANKMENT DESIGN AND CONSTRUCTION**

New fill will be placed adjacent to and over the proposed culverts in order to build Highway 7-New embankments.

## 12.1 Settlement

The new embankment fills will induce immediate (elastic) settlement in the sand/silt layers. Settlement of all the proposed culverts are expected to be governed primarily by the settlement of the subgrade under the weight of the new fill.

As previously indicated in the Subgrade Preparation section in this report, the layer of soft to firm clayey silt encountered below the topsoil at the locations of Culverts C16 and C20 must be removed to prevent further settlement.

The actual settlement of the culverts is expected to be controlled primarily by the settlement of the subgrade under the weight of road embankment fill. Post construction settlement (embankment compression) of the fill mass is estimated to be in the order of 0.5% of the embankment height.

Settlement analysis involved computation of the immediate and re-compression (elastic) settlement of the foundation soils under the imposed embankment loading.

The estimated settlements at the culvert foundation level due to the embankment loads and embankment compression are presented in Table 12.1.

**Table 12.1 – Foundation Settlements**

Culvert	Maximum Embankment Height (m)	Estimated Foundation Settlement (mm)	Embankment Compression (mm)	Total settlement (m)
C08	13.2	25	66	91
C15A	1.5	5	8	13
C16	5.9	15	30	45
C20	5.7	15	29	44
C24	3.6	10	18	28
C33	1.8	5	9	14

Due to the non-cohesive nature of the foundation soils at the culvert sites these settlements will be essentially completed when construction of the fill is completed.

Appropriate camber should be provided for the culverts where warranted to accommodate the above foundation settlements.

The embankments should be overbuilt in order to provide the required platform width after the indicated settlements have occurred.

Should a proprietary product be selected for these culverts, the proprietary manufacturer/supplier will need to be consulted to determine if their product can sustain the estimated magnitude of settlement.

## 12.2 Stability

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

Global stability analyses were conducted for Culverts C8, C16 and C20 where high embankments (5.9 m, 5.7 m and 13.2 m high) are anticipated. For the purpose of embankment stability analyses, the commercially available slope stability program GEO-SLOPE and employing the Morgenstern-Price method. For global stability a minimum Factor of Safety (F.S.) of 1.3 is considered appropriate for end of construction conditions.

Global stability analyses were conducted for an SMM or Granular fill embankment inclined at 2H:1V. The stability of the embankments was also checked under seismic loading assuming an acceleration of 0.094g. The computed factors of safety are as shown in Table 12.2. Slope stability computation outputs are also included in figures and appendices indicated in Table 12.2.

**Table 12.2 Computed Factors of Safety**

Material	Condition	Factor of Safety	Figure/ Appendix
<b>Culvert C8 , Embankment height 13.2 m</b>			
SMM or Granular fill	Normal	1.5	A1
	Seismic	1.2	A2
<b>Culvert C16, Embankment height 5.9 m</b>			
SMM or Granular fill	Normal	1.6	C1
	Seismic	1.3	C2
<b>Culvert C20, Embankment height 5.7 m</b>			
SMM or Granular fill	Normal	1.3	D1
	Seismic	1.1	D2

The factors of safety of computed for normal conditions and for seismic conditions are considered to be acceptable for the proposed 2H:1V embankment bearing on the soils encountered at this site.

### **12.3 Construction**

Embankment construction should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material.

Where granular or SSM fill embankments are higher than 8 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive grade to shed run-off water.

In general, surface vegetation, alluvium/muskeg/organics, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel must be conducted at this site.

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

## **13. 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. In general, the stratigraphy of the culvert sites consists of surficial topsoil, over layers of native loose to compact silty sand, stiff clayey silt, compact to dense sand, gravelly sand, sand and gravel, sand and silt till, and very stiff to hard clayey silt till/silty clay till.

According with Table 4.1, Clause 4.4.3.2 of the CHBDC, the culvert sites correspond to the Seismic Site Classes C and D, as indicated in Table 13.1.

The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at these culvert sites is 0.076 g as per the National Building Code of Canada (NBCC). Since the sites are classified as Seismic Site Classes C and D, the factored PGA for a 2% in 50-year probability of exceedance are presented in Table 13.1.

**Table 13.1 – Seismic Site Class**

Culvert	Seismic Site Class	PGA (Peak ground acceleration)
C8	D	0.094
C15A	C	0.076
C16	D	0.094
C20	C	0.076
C24	D	0.094
C33	D	0.094

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 for Seismic Site Classes C and D presented in Tables 13.2 and 13.3, respectively, may be used:

**Table 13.2 – Earth Pressure Coefficients for Earthquake Loading  
Seismic Site Class C**

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 ( $K_{AE}$ )*	0.30	0.34
Passive ( $K_{PE}$ )	3.6	3.2
At Rest ( $K_{OE}$ )**	0.53	0.57

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

\*\* After Woods

**Table 13.3 – Earth Pressure Coefficients for Earthquake Loading  
Seismic Site Class D**

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 layers native loose to compact silty sand, stiff clayey silt, compact to dense sand, gravelly sand, sand and gravel, sand and silt till, and very stiff to hard clayey silt till/silty clay till, therefore, liquefaction is not considered to be a concern at this site.

#### **14. SCOUR PROTECTION AND EROSION CONTROL**

Erosion and scour protection should be provided at the culvert inlets and outlets. Design of the erosion and scour protection measures considering hydrologic and hydraulic factors should be carried out by specialists experienced in this field and in accordance with OPSS 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection will be required over all surfaces with which creek/river water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A concrete cut-off wall or a clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should be provided at the inlet and should extend laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

Based on available information to date, Culvert C8 will be installed in an approximately 7% slope over 139 m, resulting in an approximately 10-m elevation change. Therefore, high velocities of the water flow are anticipated at this location. The erosion protection





must be design and properly installed to reduce the velocity and energy of water discharging from the culvert outlet.

## **15. CORROSION AND SULPHATE ATTACK POTENTIAL**

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

- The potential for sulphate attack on concrete foundations from the surrounding native soil is considered to be negligible due to the low concentration of sulphate and chloride in the sample 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.

## **16. CONSTRUCTION CONCERNS**

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

- Excavation for installation of the culverts may encounter soft, loose, organic, wet or otherwise deleterious materials requiring flattening of excavation sideslopes or installation of temporary shoring.
- Soft organic alluvial material may be present in the stream channels extending to greater depths than encountered at the borehole locations. The subgrade exposed at the design level should be examined and any deleterious materials removed and replaced with compacted granular bedding material. The culvert subgrade must be uniformly competent.
- Groundwater was noted above the founding levels in the culverts. If excavation is carried out without implementation of adequate groundwater control measures, there is a risk that the sides and or base of the excavation will be destabilized.

Groundwater control, in conjunction with temporary creek/river/water course diversion might be required to maintain a reasonably dry excavation during the wet seasons.

Accordingly, it must be emphasized to the contractor that proper groundwater and surface water control measures must be in place prior to commencing excavation.



The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.

- Care must be exercised during excavation to avoid disturbing the founding subgrade. The exposed subgrade should be protected from physical disturbance, and the granular bedding must be placed on the approved subgrade expeditiously following excavation.

An effective dewatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.

- The culvert should be designed with a camber and articulated joints where necessary to accommodate the settlements estimated in Section 12.1 of this report.

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

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

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



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## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



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

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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


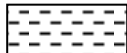



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

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

# UNIFIED SOILS CLASSIFICATION

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

## EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		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	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
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.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				



## **Appendix A**

**Culvert C8 – Station 23+960  
(Boreholes C08-1 to C08-4)**

**Record of Borehole Sheets  
Laboratory Test Results  
Slope stability output  
Site Photographs  
Drawing titled “Borehole Locations and Soil Strata”**

RECORD OF BOREHOLE No C08-1

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 882.3 E 229 491.1, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012 02 01 - 2012 02 01 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      x LAB VANE						
322.7							20 40 60 80 100	20 40 60					GR SA SI CL	
0.0	TOPSOIL, some clay, some sand, occasional roots Very Loose Dark Brown Moist (800mm)		1	SS	3	▽								
321.9														
0.8	SAND, some gravel to gravelly, some silt, occasional cobbles Dense Brown Wet		2	SS	31									
			3	SS	34									
320.3														
2.4	SAND and SILT, some clay, trace gravel Compact Brown Moist (TILL)		4	SS	14								2 44 42 12	
			5	SS	27									
318.6														
4.1	Gravelly SAND, some silt and clay Compact to Very Dense Brown Wet		6	SS	23								33 54 13 (SI+CL)	
			7	SS	52									
			8	SS	50/ 0.100									
313.4			9	SS	50/ 0.125									
9.3	END OF BOREHOLE AT 9.3m. BOREHOLE CAVED TO 3.3m AND WATER LEVEL AT 1.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH													

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE



RECORD OF BOREHOLE No C08-1

2 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 882.3 E 229 491.1, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.01 - 2012.02.01 CHECKED BY LRB

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

RECORD OF BOREHOLE No C08-2

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 837.0 E 229 506.1, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.01 - 2012.02.01 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE	20   40   60   80   100	20   40   60	w <sub>P</sub> w      w <sub>L</sub>			
321.8 0.0	TOPSOIL, silty, some clay to clayey, occasional roots Loose Dark Brown Moist (800mm)		1	SS	4									
321.0 0.8	SAND and SILT, some clay, trace gravel Compact Brown Moist to Damp (TILL)		2	SS	22									
			3	SS	19									
			4	SS	27									1   42   43   14
	Grey		5	SS	23									
	Wet		6	SS	27									7   24   55   14
315.7 6.1	Gravelly SAND, some silt and clay Compact to Very Dense Brown Moist		7	SS	23									
			8	SS	65									25   51   24 (SI+CL)
312.7 9.1	END OF BOREHOLE AT 9.1m. WATER LEVEL AT 4.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 7.0m, AUGER CUTTINGS TO 2.4m THEN													

Continued Next Page

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

RECORD OF BOREHOLE No C08-2

2 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 837.0 E 229 506.1, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.01 - 2012.02.01 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40					
	Continued From Previous Page													
	BENTONITE HOLEPLUG TO SURFACE.													

RECORD OF BOREHOLE No C08-3

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 791.7 E 229 491.5, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.02 - 2012.02.02 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
320.5														
0.0	TOPSOIL, silty, some sand, occasional roots Dark Brown Damp (200mm)		1	SS	6		320							
0.2	SAND and SILT, some gravel, trace clay, occasional cobbles Dense to Compact Brown Damp to Moist (TILL) Sand to silty sand layer at 1.5m		2	SS	33		319							
			3	SS	33		318							10 65 22 3
	Wet		4	SS	20		317							
			5	SS	15		316							
	Coarse grained						315							
315.9							314							
4.6	Gravelly SAND, trace to some silt and clay Compact to Dense Brown Wet		6	SS	22		313							
			7	SS	18		312							
			8	SS	37		311							
312.3														
8.2	Silty CLAY, some sand to sandy, trace gravel Very Stiff Brown to Grey (TILL)		9	SS	24									1 29 40 30

ONTMT4S 6417R.GPJ 1/25/13

Continued Next Page

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

20  
15 5  
10 (%) STRAIN AT FAILURE

## METRIC

[illegible]

ONTMT4S 6417R.GPJ 1/16/13

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

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C08-4

1 OF 2

METRIC

W.P. 408-88-00 LOCATION N 4 816 745.1 E 229 495.8, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.02 - 2012.02.02 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE									
318.1								20	40	60	80	100	20	40	60		
0.0	TOPSOIL, silty, trace roots Loose Dark Brown Moist (600mm)		1	SS	4		318							○			
317.5			2	SS	13		317							C			
0.6	SILT and SAND, trace to some clay, trace gravel, occasional cobbles Compact to Dense Brown Moist (TILL)		3	SS	30		316							C			
			4	SS	20		315							C			10 39 34 17
			5	SS	36		314							○			
313.5			6	SS	21		313							○			
4.6	Silty CLAY, some sand to sandy, trace gravel Very Stiff Grey (TILL)		7	SS	18		312							○			3 31 42 24
			8	SS	51		311							○			
309.6	Hard Occasional cobbles						310										
8.5	SILT and SAND, some clay, trace gravel Dense Grey Damp (TILL)		9	SS	35		309							○			

Continued Next Page

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

20  
15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C08-4

2 OF 2

METRIC

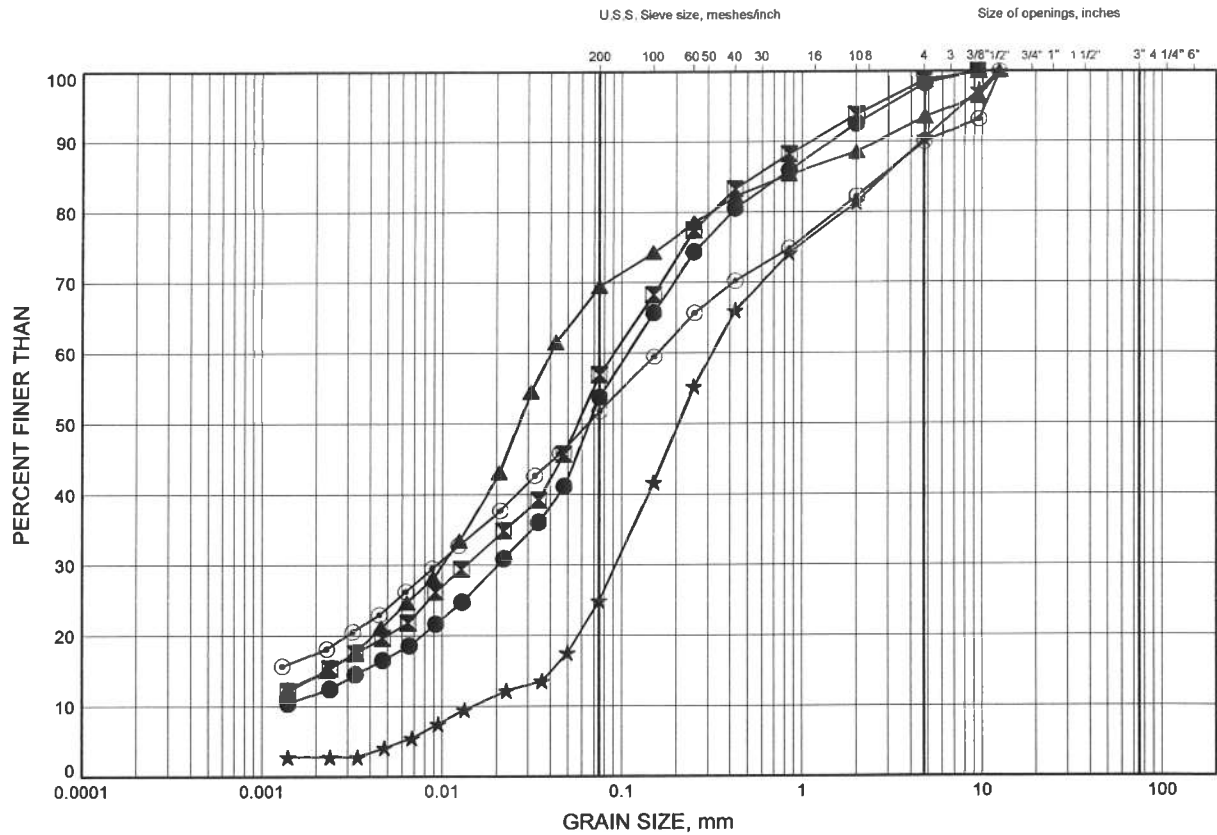
W.P. 408-88-00 LOCATION N 4 816 745.1 E 229 495.8, Culvert C8, Station 23+960 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.02 - 2012.02.02 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20   40   60   80   100	w <sub>p</sub> w                      w <sub>L</sub>					
Continued From Previous Page								○ UNCONFINED                      + FIELD VANE						
	SILT and SAND, some clay, trace gravel Dense to Very Dense Grey Damp (TILL) Occasional cobbles		10	SS	50/ 0.125		308							3   31   46   20
							307							
							306							
							305							
							304							
303.8			11	SS	47									

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE A1

## Upper SAND & SILT TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C08-1	2.59	320.11
■	C08-2	2.59	319.21
▲	C08-2	5.03	316.77
★	C08-3	1.83	318.67
○	C08-4	2.59	315.51

Date January 2013  
W.P. 408-88-00



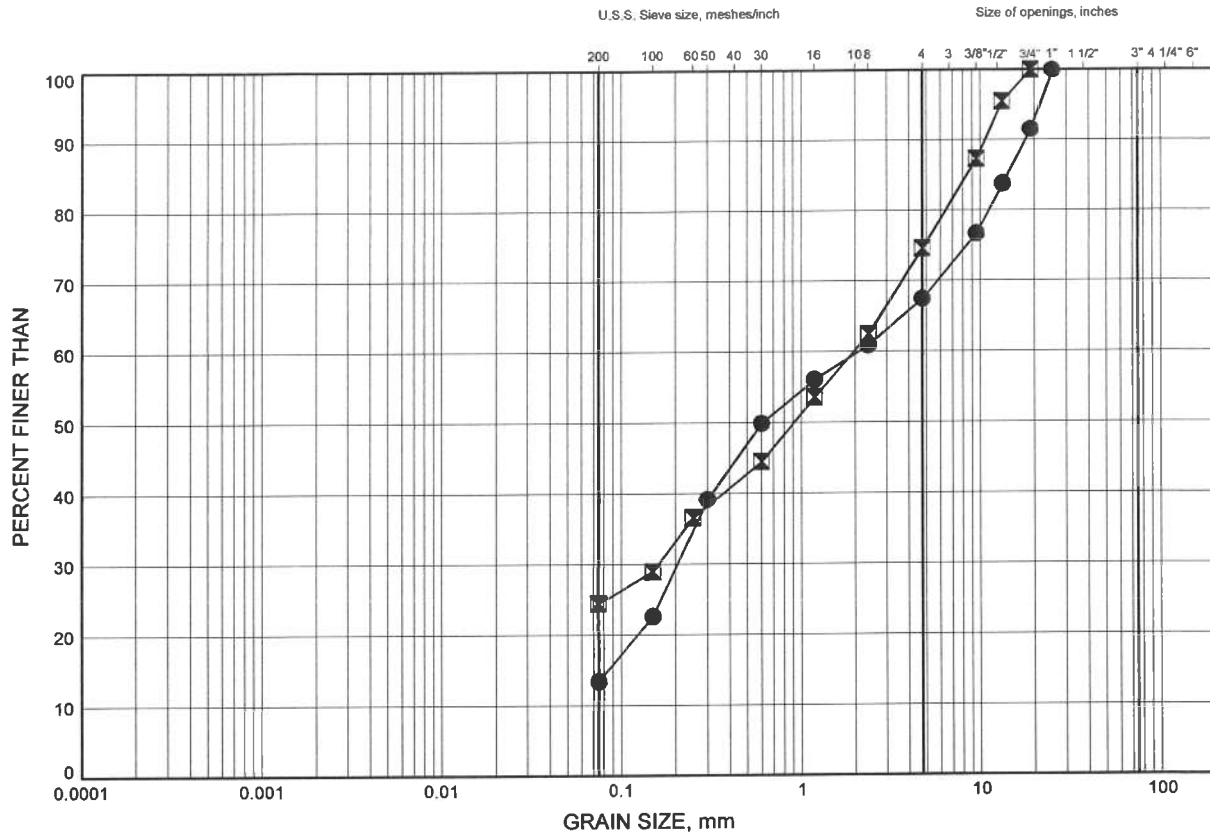
Prep'd AN  
Chkd. RPR



# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE A2

## GRAVELLY SAND



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

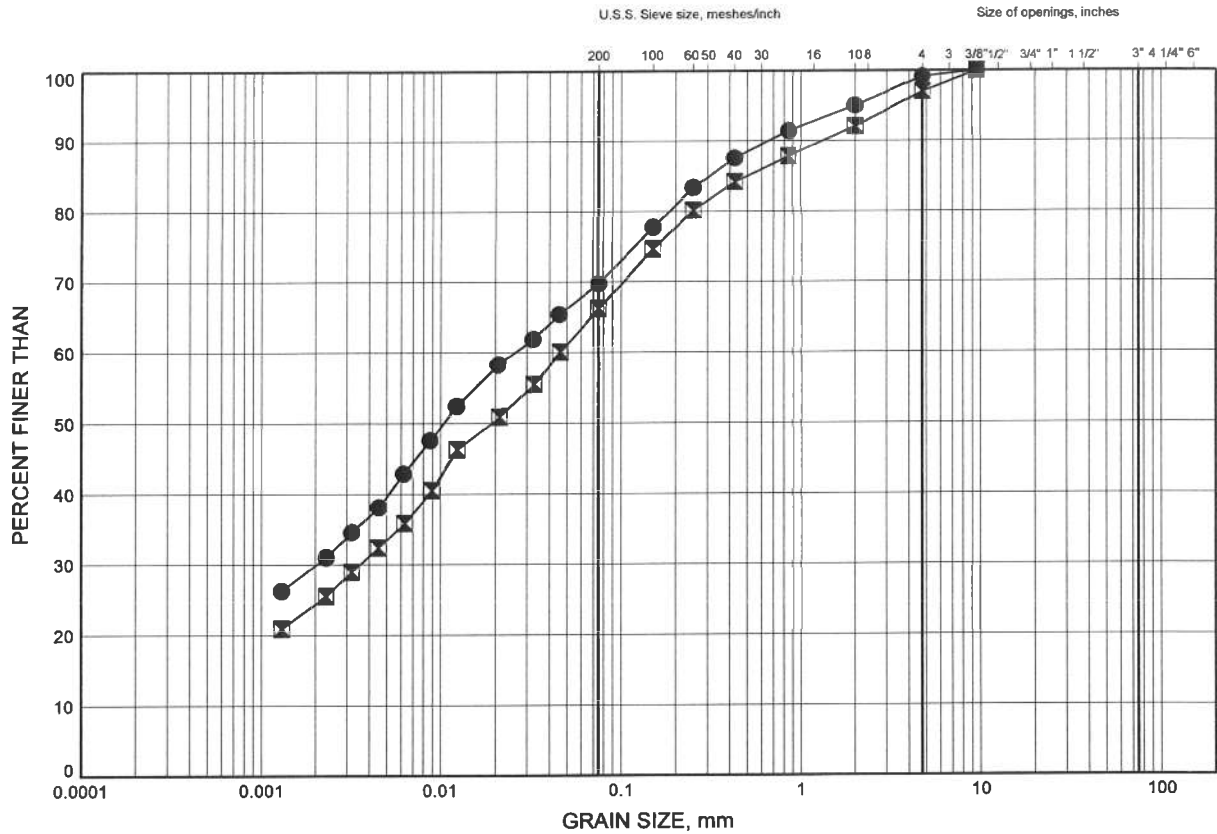
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C08-1	4.88	317.82
■	C08-2	7.92	313.88

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE A3

## SILTY CLAY TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C08-3	9.45	311.05
◻	C08-4	4.88	313.22

Date January 2013  
W.P. 408-88-00

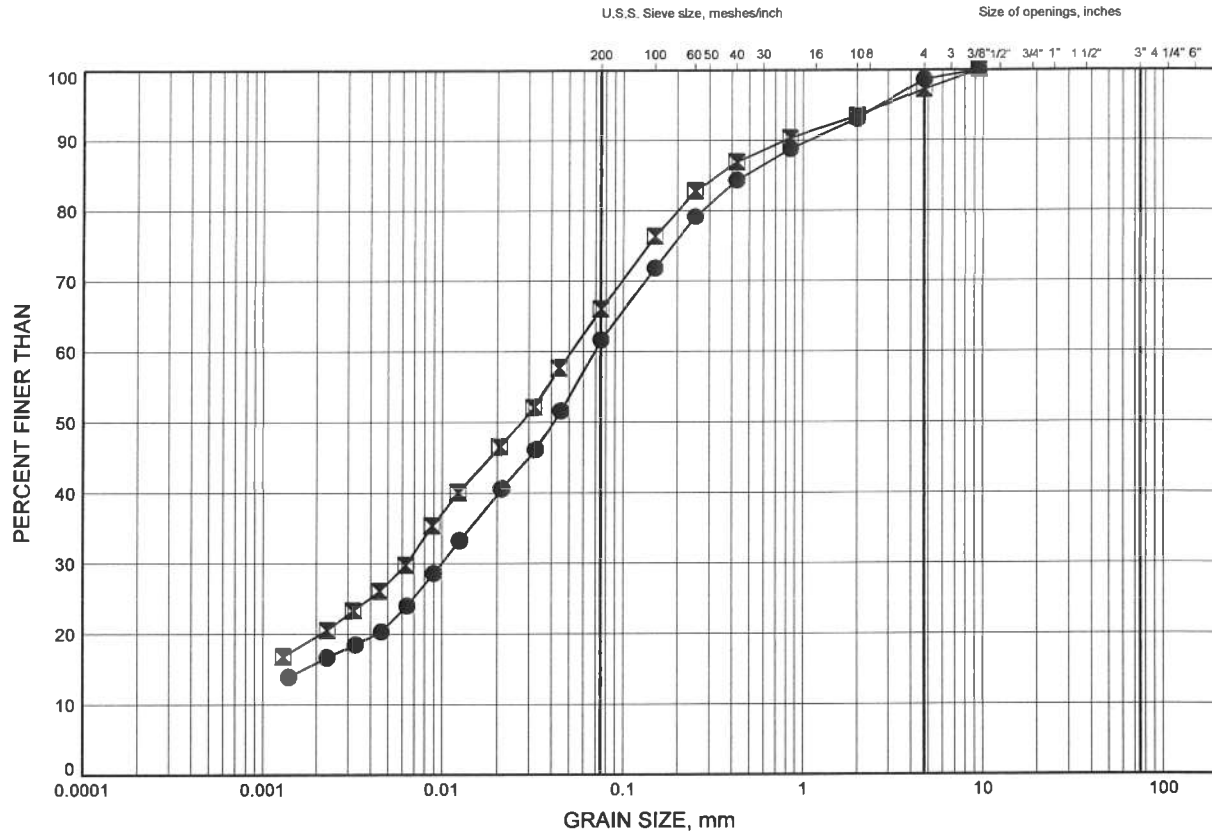


Prep'd AN  
Chkd. RPR

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE A4

## Lower SAND & SILT TILL



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

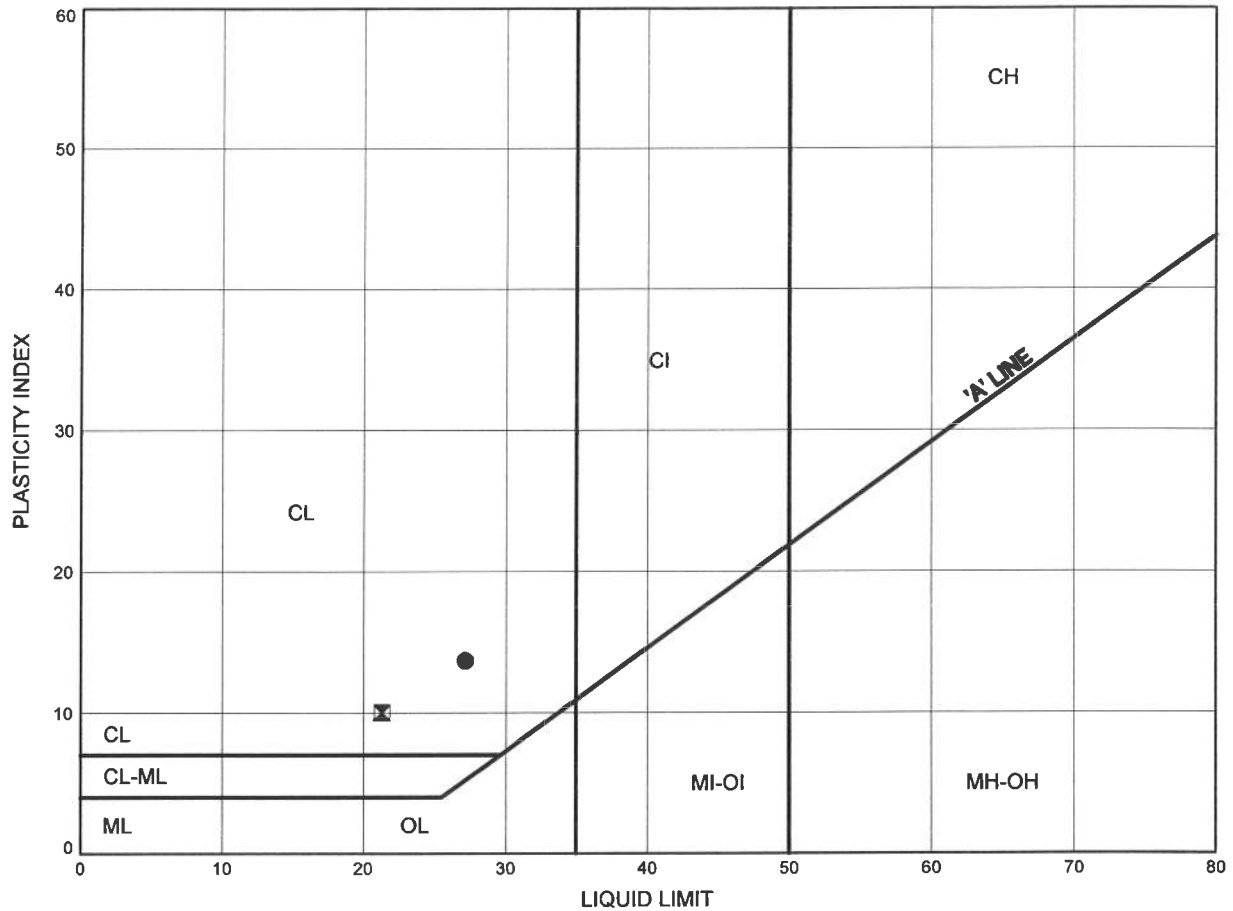
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C08-3	12.50	308.00
■	C08-4	12.42	305.68

# Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE A5

### SILTY CLAY TILL



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C08-3	9.45	311.05
⊠	C08-4	4.88	313.22



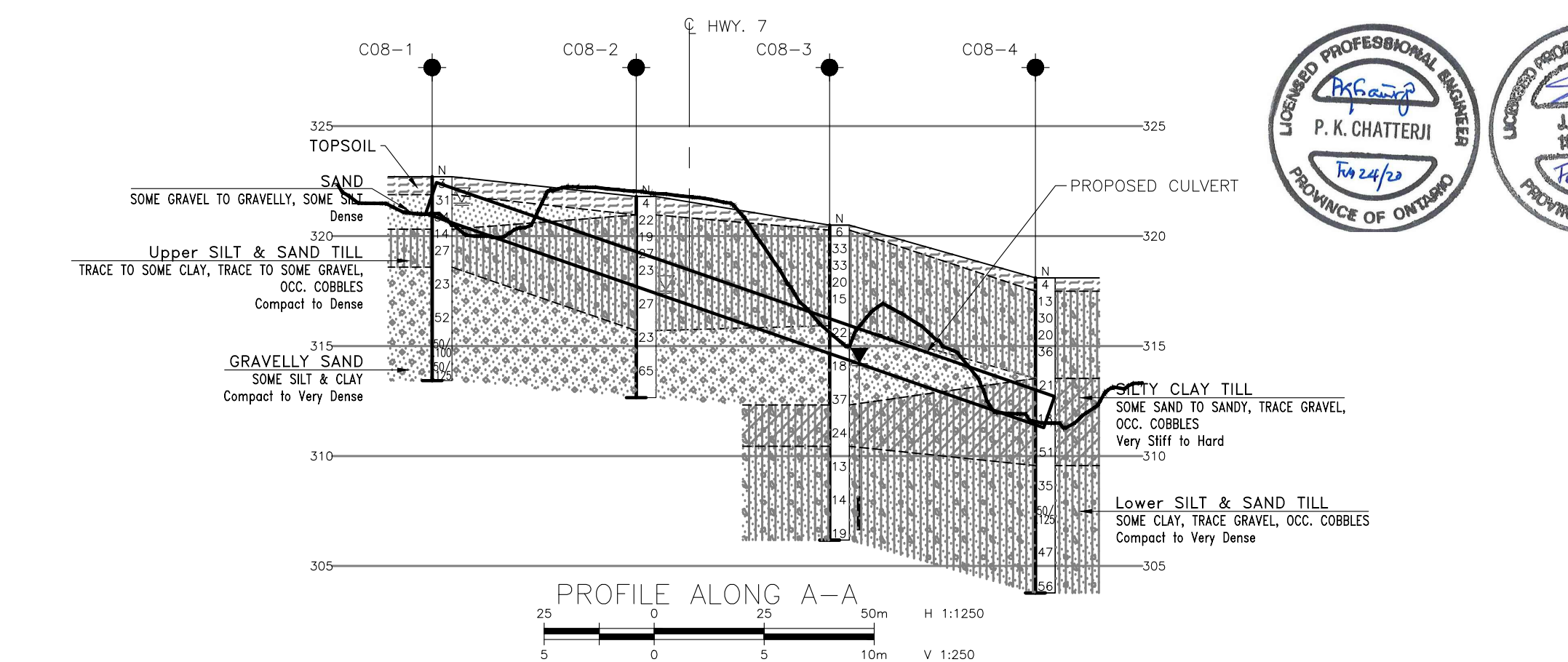
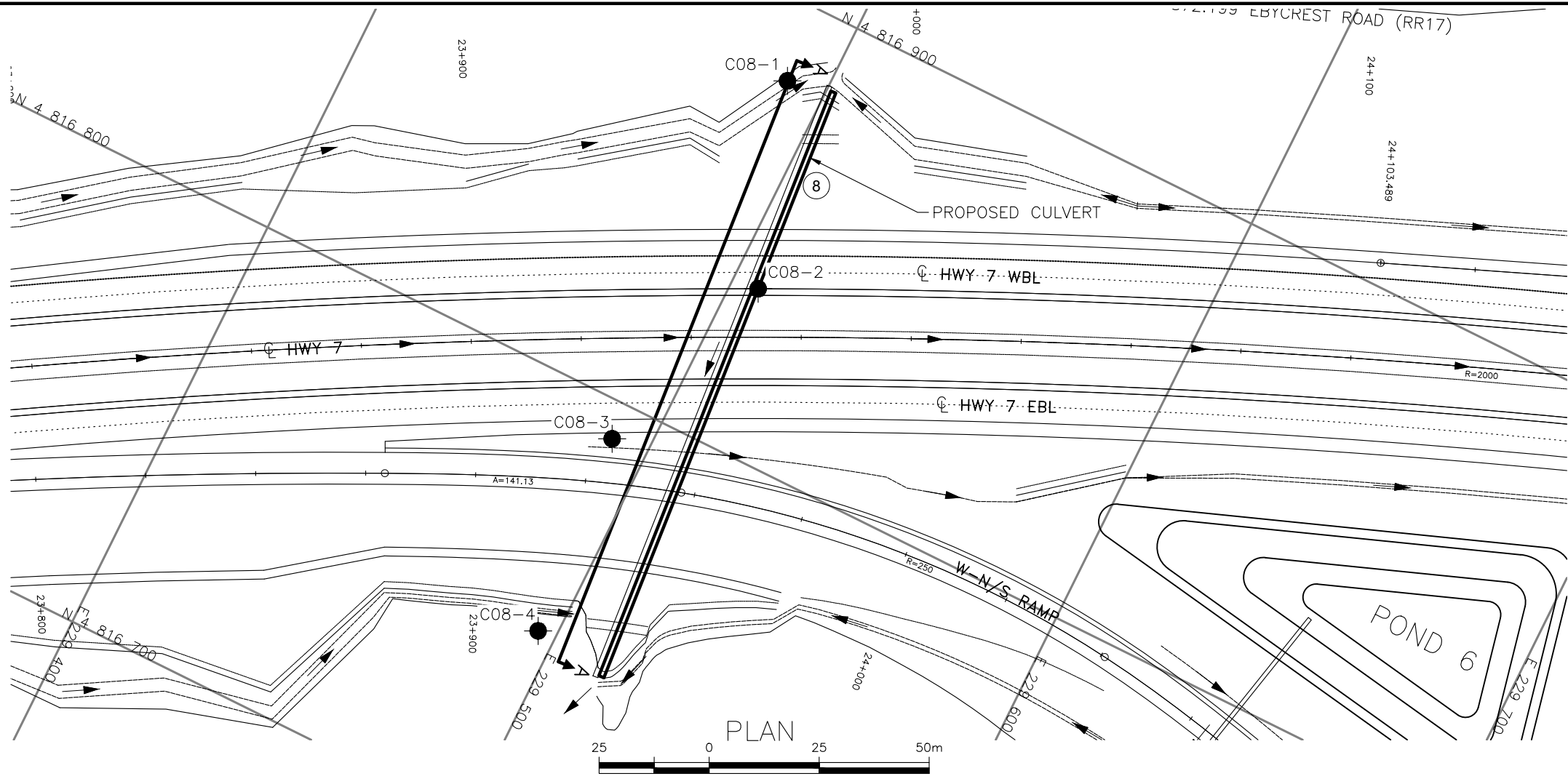
**Photo A1:** Looking north towards Borehole C08-1



**Photo A2:** Looking south from Borehole C08-2



MINISTRY OF TRANSPORTATION, ONTARIO



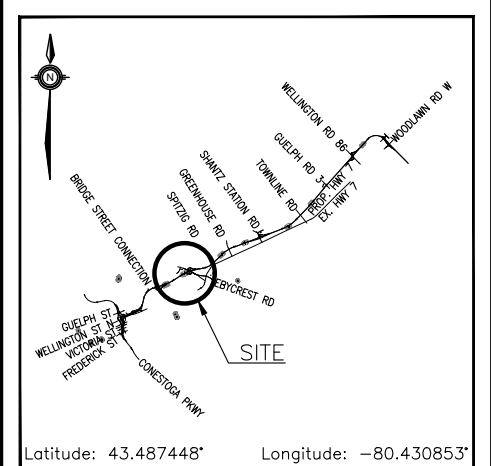
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 408-88-00

HIGHWAY 7 NEW EBL & WBL  
CULVERT C8  
STA. 23+960  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND			
	Borehole		
	Borehole and Cone		
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
C08-1	322.7	4 816 882.3	229 491.1
C08-2	321.8	4 816 837.0	229 506.1
C08-3	320.5	4 816 791.7	229 491.5
C08-4	318.1	4 816 745.1	229 495.8

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

GEOCRES No. 40P8-209			
REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	
CODE	LOAD	DATE	FEB 2020
SITE 33-513/C	STRUCT	DWG	A1



FILENAME: H:\Drafting\1000\11375\1ED-11375-BHPP-CVS.dwg  
PLOTDATE: 2/27/2020 2:33 PM

Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C8, Station 23+960  
Max. Embankment height 13.2 m  
Static Loading Analysis

Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Lin  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Gravelly Sand    Model: Mohr-Coulomb    Unit Weight: 22 kN/m³    Cohesion: 0 kPa    Phi: 33 °    Phi-B: 0 °    Piezometric Line: 1

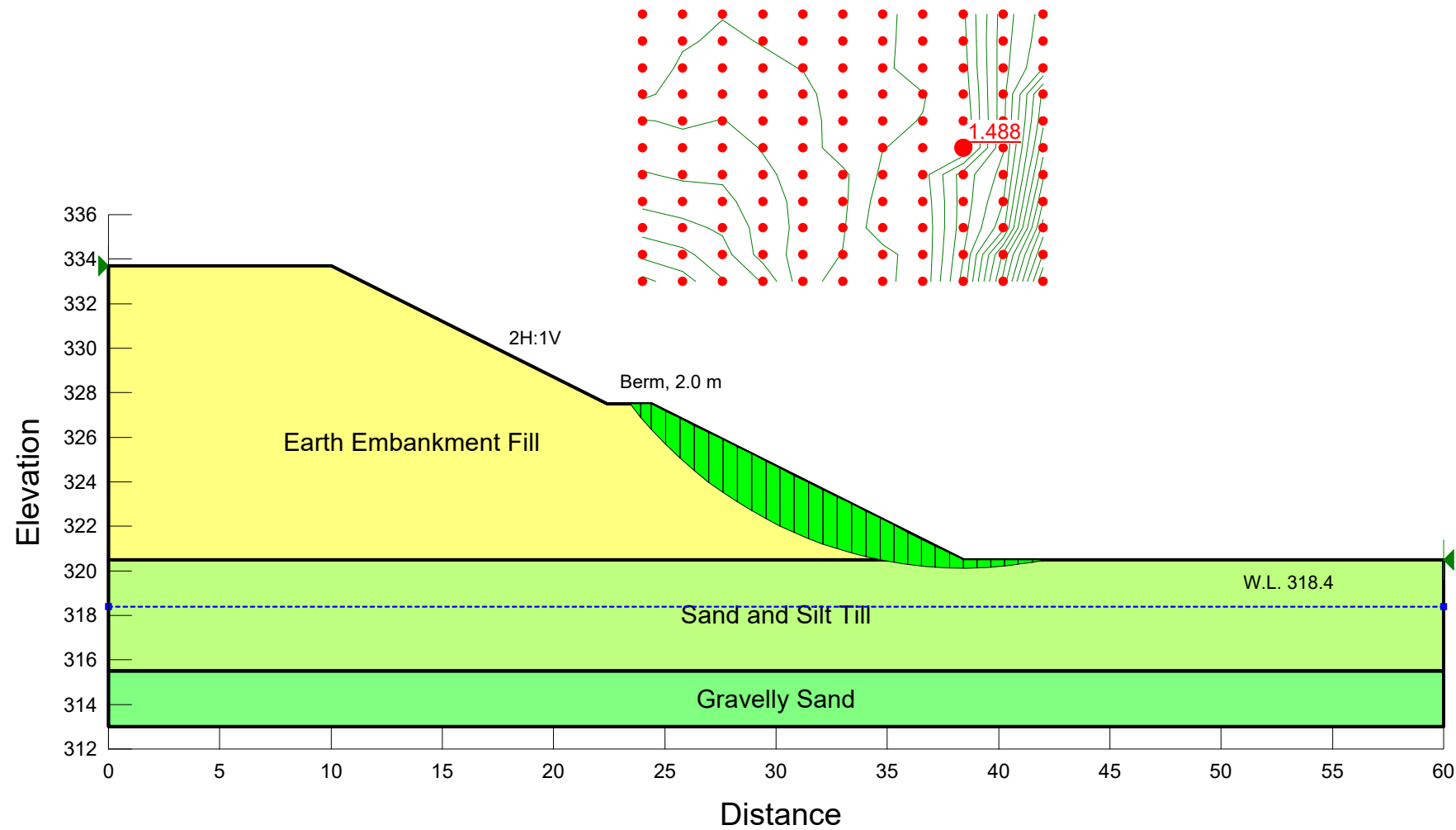
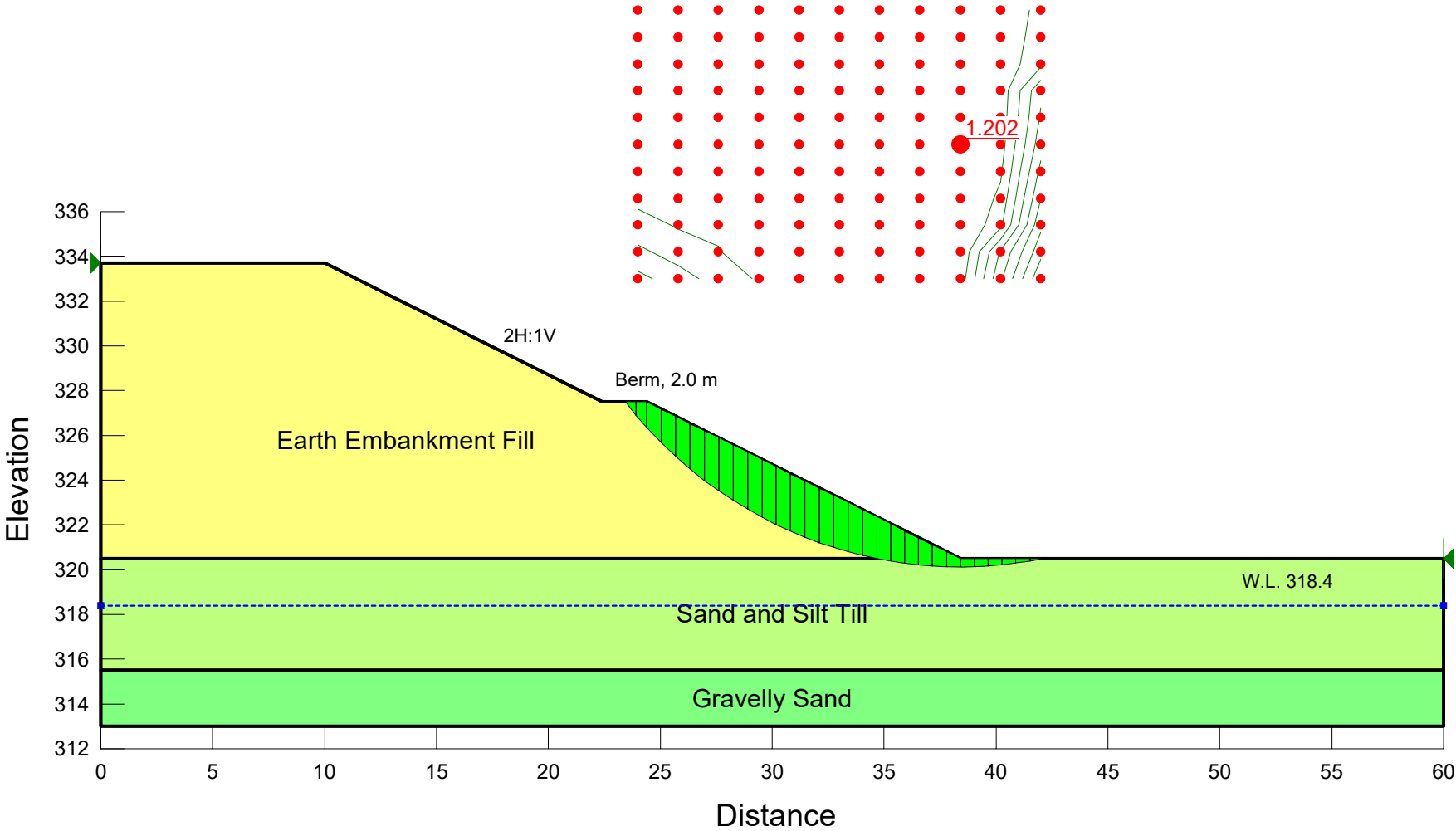


Figure A1

Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C8, Station 23+960  
Max. Embankment height 13.2 m  
Seismic Loading Analysis

Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Lin  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Gravelly Sand    Model: Mohr-Coulomb    Unit Weight: 22 kN/m³    Cohesion: 0 kPa    Phi: 33 °    Phi-B: 0 °    Piezometric Line: 1



Directory: H:\10000+11375 Hwy 7 New PD and DD Foundations\Reports & Memos\Culvert 33\Analysis\Slope stability\File Name: 11375- C8s.gszDate: 2018-05-01Time: 9:31:03 AM

Figure A2





## **Appendix B**

**Culvert C15A – Station 26+207  
(Boreholes C15A-1 to C15A-4)**

**Record of Borehole Sheets  
Laboratory Test Results  
Site Photographs  
Drawing titled “Borehole Locations and Soil Strata”**

# RECORD OF BOREHOLE No C15A-1

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 817 824.4 E 231 446.7, Culvert C15A, Station 26+207 ORIGINATED BY ES  
 HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012 01 31 - 2012 02 31 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>		
319.5													
0.0	SILT, some clay, some sand, mixed with topsoil, occasional roots Loose to Compact Dark Brown Moist to Wet		1	SS	4		319						
318.3			2	SS	11		318						
1.2	Silty CLAY, some sand Stiff to Very Stiff Brown		3	SS	23		317						
317.2			4	SS	22		316						
2.3	SILT and SAND, some clay, trace to some gravel Compact to Very Dense Brown Damp (TILL)		5	SS	37		315						
	Grey		6	SS	50/ 0.050		314						
	Occasional cobbles (Spoon bouncing)		7	SS	50/ 0.125		313						
	(Spoon bouncing)		8	SS	50/ 0.150		312						
311.7													
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE OPEN AND WATER LEVEL AT 1.1m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.												
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Feb.08/12 2.1 317.4 Feb.27/12 1.8 317.7 Apr.17/12 1.1 318.4												

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

# RECORD OF BOREHOLE No C15A-2

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 817 806.8 E 231 452.7, Culvert C15A, Station 26+207 ORIGINATED BY ES  
 HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.01.31 - 2012.01.31 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
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		
320.1 0.0 0.1	TOPSOIL: (75mm)		1	SS	3		320						
319.3 0.8	Silty SAND, trace gravel, trace roots Very Loose Dark Brown Moist		2	SS	29		319						
	Silty CLAY, trace to some sand, trace gravel Very Stiff to Hard Brown		3	SS	34		318						
317.8 2.3	SILT and SAND, some clay, trace gravel Dense to Very Dense Grey Damp (TILL)		4	SS	50		317						
			5	SS	42		316						
	Occasional cobbles		6	SS	77		315						
			7	SS	50/ 0.075		314						10 41 37 12
			8	SS	55/ 0.150		313						
312.2 7.9	END OF BOREHOLE AT 7.9m. BOREHOLE OPEN AND WATER LEVEL AT 6.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS AND HOLEPLUG TO 1.8m THEN HOLEPLUG TO SURFACE.												

ONTMT4S 6417R.GPJ 1/16/13

## METRIC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
			NUMBER TYPE "N" VALUES					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	
320.1						 SKEWED CONE TEST RESULTS ○ UNCONFINED + FIELD VANE      x LAB VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	 WATER CONTENT (%) 20 40 60	γ	GR SA SI CL

DEPTH (m)	SOIL DESCRIPTION	UNIT	SS	SL	CL	GL	WL	REMARKS
0.0	<b>TOPSOIL: (75mm)</b>							
0.1	Silty <b>SAND</b> , trace gravel, trace clay, occasional roots	1	SS	6				
319.4	Loose Dark Brown Moist							
0.7	<b>SAND</b> , some silt and clay, trace gravel	2	SS	10				
	Compact Brown Wet							
318.1		3	SS	30				
2.0	Silty <b>CLAY</b> , trace sand							
	Hard Brown to Grey Sand layer (350mm)	4	SS	39				
317.1								
3.0	<b>SAND and SILT</b> , some clay to clayey, trace gravel	5	SS	50				
	Dense to Very Dense Grey Damp (TILL)							
		6	SS	39				
		7	SS	50/				
				0.150				
312.3		8	SS	55/				
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE OPEN TO 5.2m AND WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 3.9m, AUGER CUTTINGS TO 1.2m THEN HOLEPLUG TO SURFACE.			0.150				

ONTMT4S 6417R.GPJ 1/16/13

+ 3, × 3: Numbers refer to Sensitivity

RECORD OF BOREHOLE No C15A-4

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 817 773.4 E 231 481.7, Culvert C15A, Station 26+207 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.01.31 - 2012.01.31 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
320.3														
0.0	<b>TOPSOIL: (100mm)</b>													
0.1	Silty <b>SAND</b> , mixed with organics, trace gravel Loose to Compact Brown Moist		1	SS	5		320							
	Some clayey silt layers (100mm)		2	SS	19		319							5 58 31 6
			3	SS	28									
317.9							318							
2.4	<b>SAND</b> and <b>SILT</b> , some clay, trace gravel Dense to Compact Brown Damp to Moist (TILL)		4	SS	32									
			5	SS	40		317							2 43 43 12
							316							
			6	SS	29		315							
314.2														
6.1	Layer of <b>SAND</b> , some silt, trace gravel Very Dense Brown Wet (900mm)		7	SS	95		314							
313.3														
7.0	<b>SAND</b> and <b>SILT</b> , trace gravel Very Dense Grey Damp (TILL)						313							
312.4			9	SS	50/									
7.9	END OF BOREHOLE AT 7.9m. BOREHOLE OPEN TO 5.8m AND WATER LEVEL AT 0.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 1.8m THEN HOLEPLUG TO SURFACE.				0.125									

+ <sup>3</sup>/<sub>3</sub> X <sup>3</sup>/<sub>3</sub> : Numbers refer to  
Sensitivity

20  
15  
10

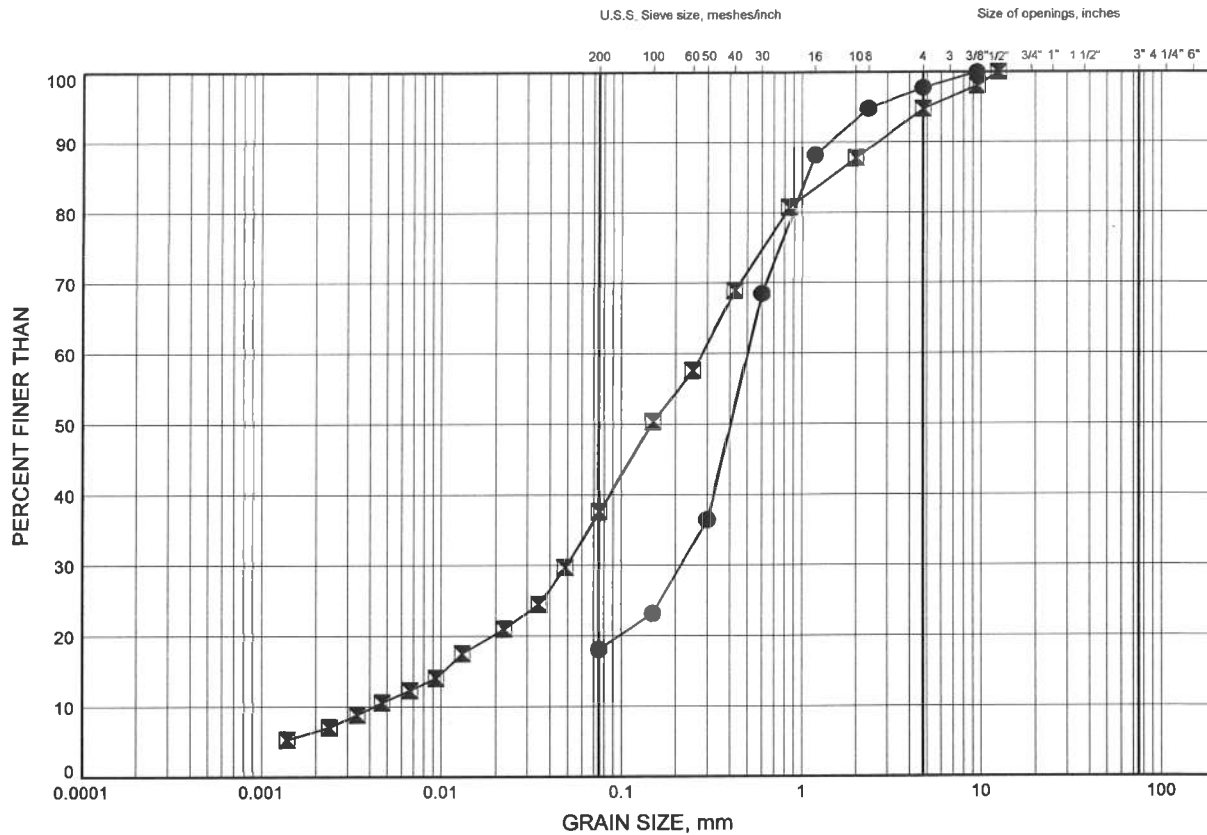
(%) STRAIN AT FAILURE

# Highway 7 - New

## GRAIN SIZE DISTRIBUTION

FIGURE B1

### SAND to SILTY SAND



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

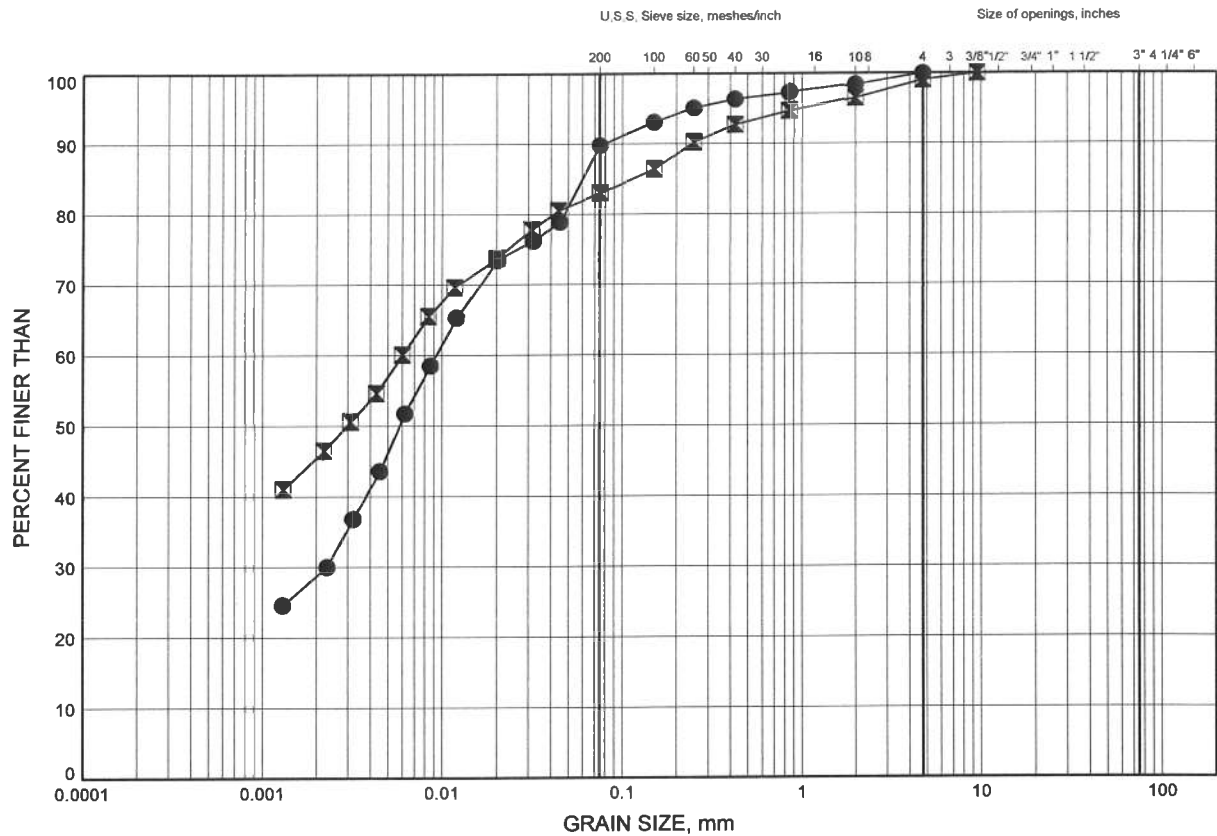
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C15A-3	1.07	319.03
■	C15A-4	1.07	319.23

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2

## SILTY CLAY



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C15A-1	1.83	317.67
■	C15A-2	1.83	318.27

Date January 2013  
W.P. 408-88-00

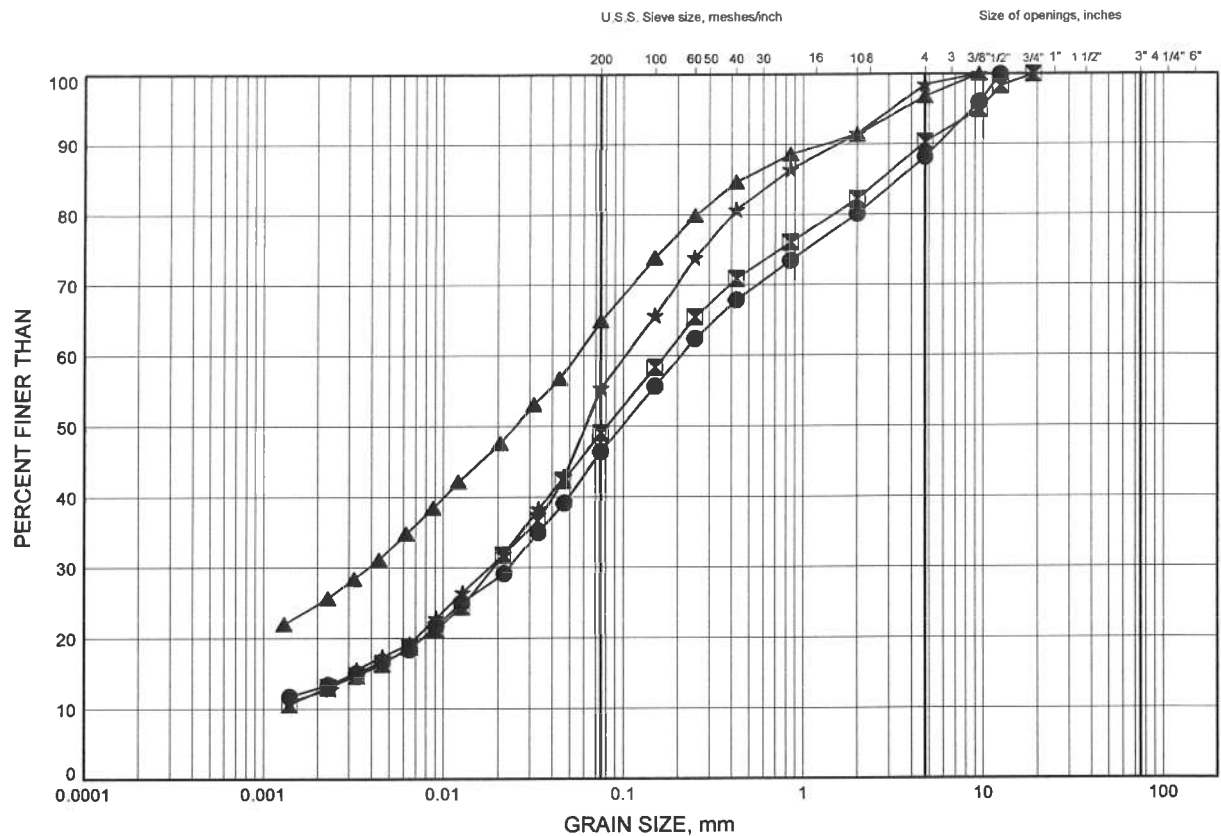


Prep'd AN  
Chkd. RPR

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B3

## SILT & SAND TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C15A-1	7.70	311.80
■	C15A-2	6.21	313.89
▲	C15A-3	4.85	315.25
★	C15A-4	3.35	316.95

Date January 2013  
W.P. 408-88-00



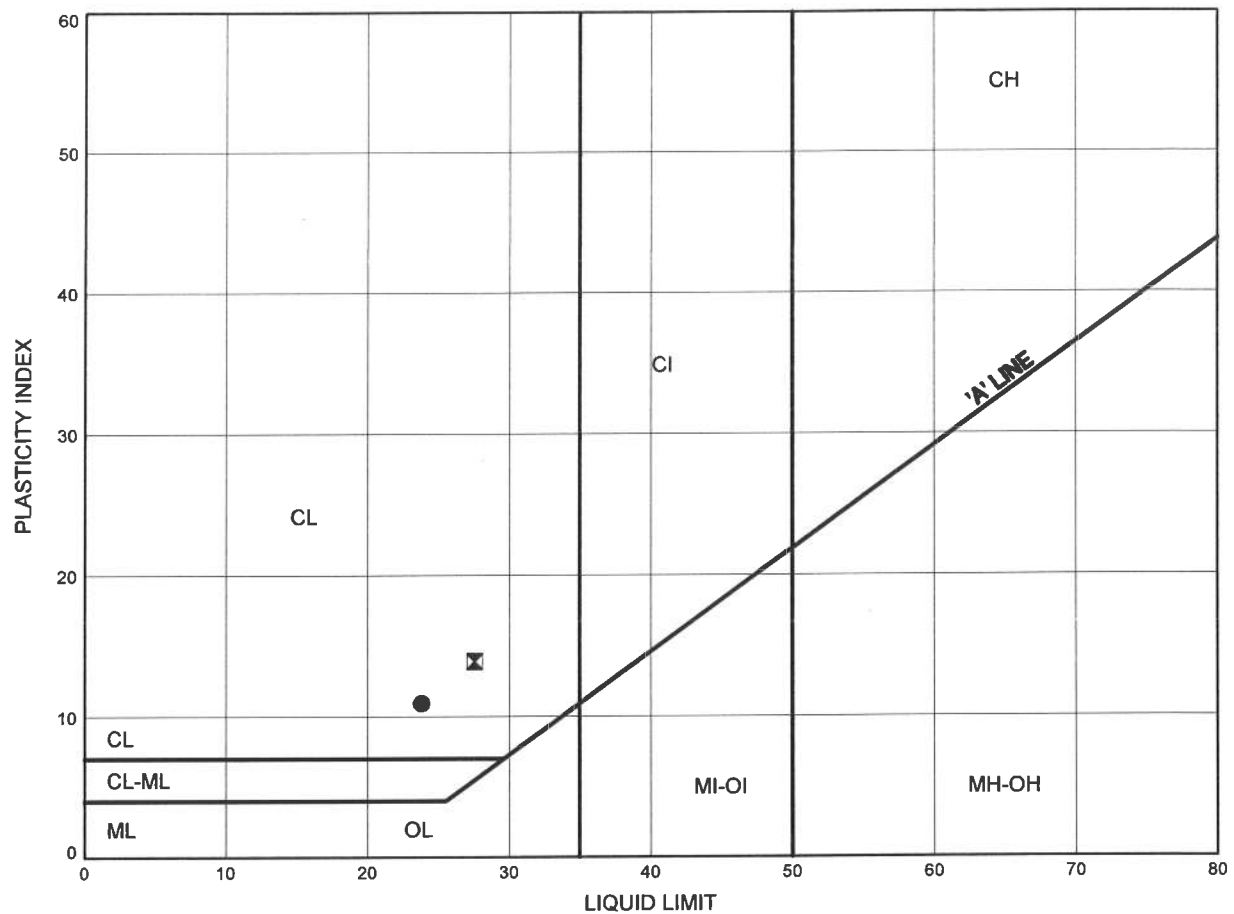
Prep'd AN  
Chkd. RPR



# Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE B4

### SILTY CLAY



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C15A-1	1.83	317.67
⊠	C15A-2	1.83	318.27

Date January 2013  
W.P. 408-88-00

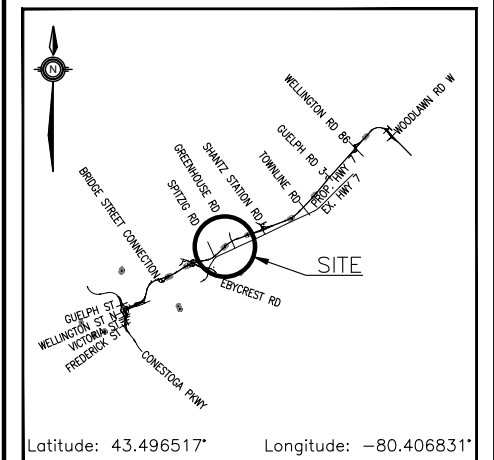


Prep'd AN  
Chkd. RPR








**Photos B1 and B2:** Proposed location of Culvert C15A

HEET



## KEYPLAN

## LEGEND

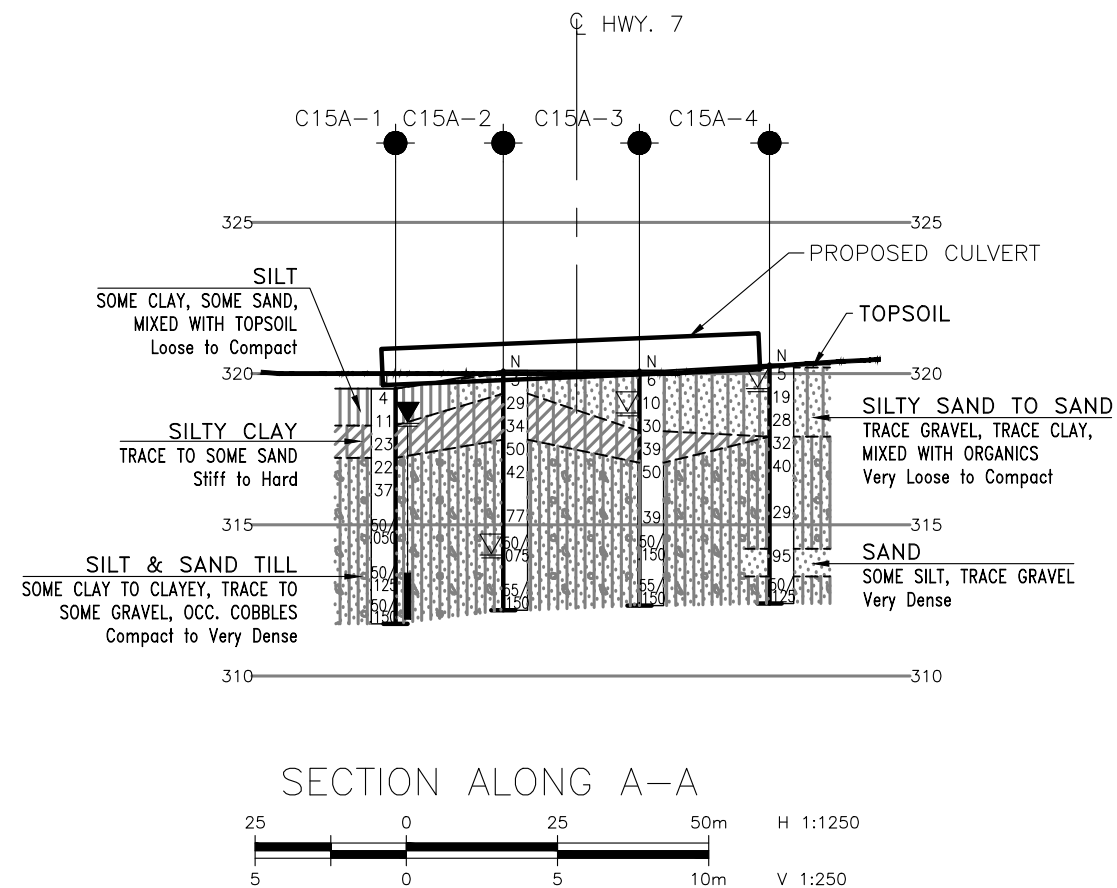
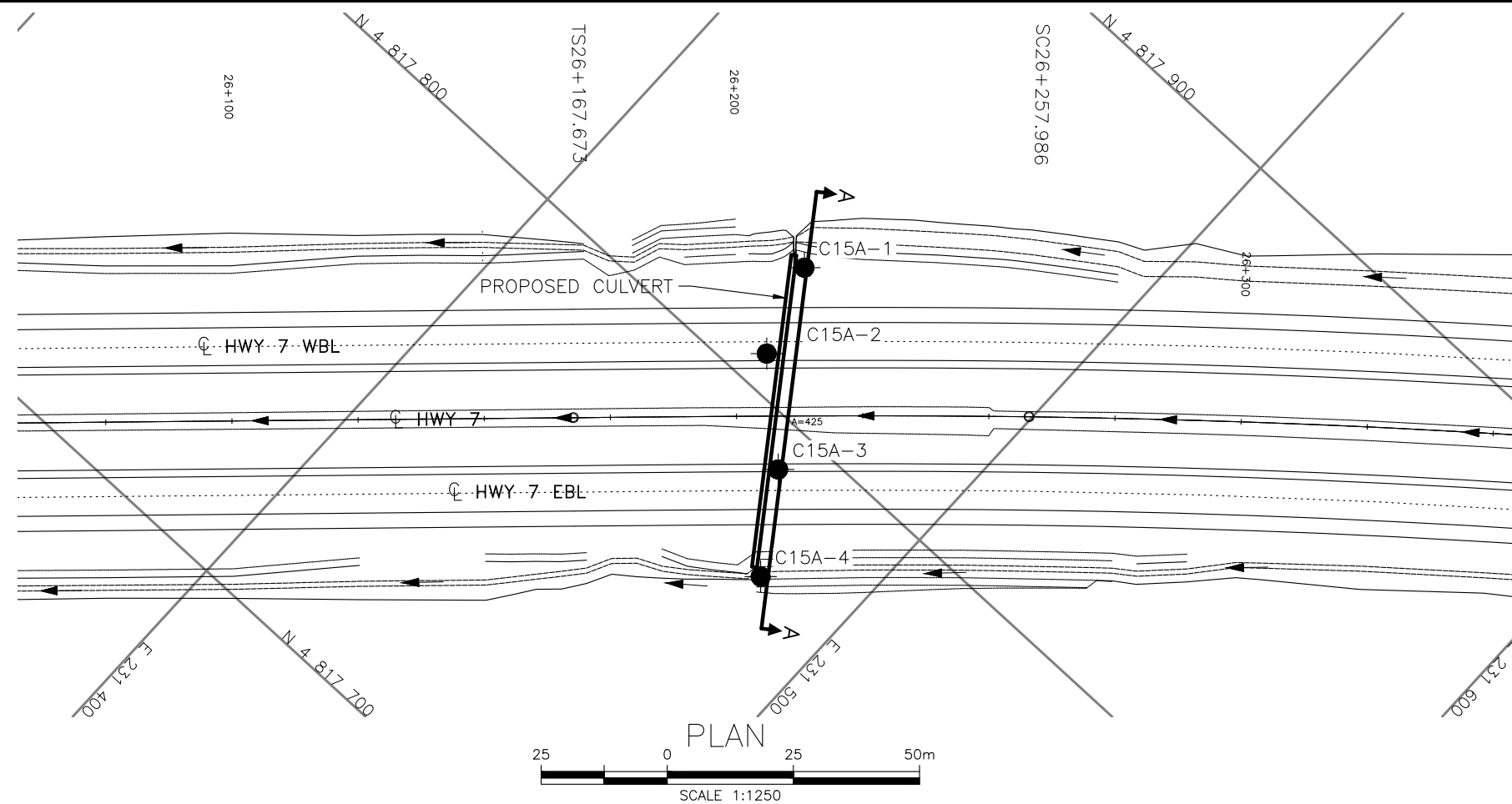
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

[illegible]

-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. 40P8-209**



REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	LRB		CHK	LRB	CODE	LOAD	DATE	FEB 2020	
DRAWN	AN		CHK		SITE 33-517/C	STRUCT	DWG	B1	



## **Appendix C**

**Culvert C16 – Station 27+593  
(Boreholes C16-1 to C16-4)**

**Record of Borehole Sheets  
Laboratory Test Results  
Slope stability output  
Site Photographs  
Drawing titled “Borehole Locations and Soil Strata”**

RECORD OF BOREHOLE No C16-1

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 818 459.3 E 232 657.7, Culvert C16, Station 27+594 ORIGINATED BY SLL  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.06 - 2012.02.06 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
323.2 0.0	TOPSOIL, some peat, some clay Loose Black (700mm)		1	SS	4		323							
322.5 0.7	SAND and SILT, trace clay, trace gravel Loose to Dense Brown Moist to Wet (TILL)		2	SS	5		322							
			3	SS	33		321							
	Wet		4	SS	20		320							5 51 38 6
			5	SS	41		319							
318.9	Boulder (250mm) at 3.9m						318							
4.3	SILT, some sand to sandy, some clay Dense Grey Moist to Wet		6	SS	30		317							0 20 69 11
			7	SS	42		316							
	Trace gravel													
			8	SS	38									
315.0 8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN TO 3.9m AND WATER LEVEL AT 2.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.0m, THEN AUGER CUTTINGS TO SURFACE.													

ONTMT4S 641TR.GPJ 1/17/13

# RECORD OF BOREHOLE No C16-2

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 818 417.4 E 232 669.9, Culvert C16, Station 27+594 ORIGINATED BY SLL  
 HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.02.06 - 2012.02.06 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
323.9 0.0	TOPSOIL, trace roots and rootlets, with some clay Very Loose Black		1	SS	2								
323.3 0.6	Moist (600mm) Moist		2	SS	34								
	SAND and SILT, trace gravel, with clayey pockets Dense to Compact Brown (TILL)		3	SS	30								
	Wet		4	SS	21								
320.9 3.0	Silty CLAY, some sand to sandy Very Stiff Grey (TILL)		5	SS	26								
319.6 4.3	Layer of silty sand (600mm) at 4.3m		6	SS	27								
319.0 4.9			7	SS	46								
316.6 7.3	Silty SAND, trace clay, trace gravel Compact Grey Wet		8	SS	23								
315.7 8.2	END OF BOREHOLE AT 8.2m. BOREHOLE CAVED TO 3.1m AND WATER LEVEL AT 2.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.6m, THEN AUGER CUTTINGS TO SURFACE.												

ONTMT4S 6417R.GPJ 1/17/13



## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI C			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE									
323.6 0.0 323.3 0.3	TOPSOIL, mixed with organics, some peat, trace rootlets Very Loose Black (300mm)	[Pattern]	1	SS	3													
	Clayey SILT and ORGANICS, pealy, clayey, trace rootlets Soft to Firm Dark Brown to Black	[Pattern]	2	SS	7													
322.2 1.4	SAND and SILT, trace to some clay, some gravel Compact to Dense Brown Moist to Wet (TILL)	[Pattern]	3	SS	11													
		[Pattern]	4	SS	18													
		[Pattern]	5	SS	36													
318.7 4.9	Silty CLAY, with sand seams, trace gravel Hard Grey	[Pattern]	6	SS	32													
317.8 5.8	SAND and SILT, some clay, trace gravel Very Dense Grey Moist to Wet (TILL)	[Pattern]	7	SS	100/ 0.250													
		[Pattern]	8	SS	65/ 0.100													
315.6 8.0	END OF BOREHOLE AT 8.0m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																	
WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) Feb.08/12    1.4                 322.2 Feb.27/12    1.5                 322.1 Apr.17/12    1.8                 321.8																		

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

# RECORD OF BOREHOLE No C16-4

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 818 380.1 E 232 709.1, Culvert C16, Station 27+594 ORIGINATED BY SLL  
 HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2012.02.06 - 2012.02.06 CHECKED BY LRB

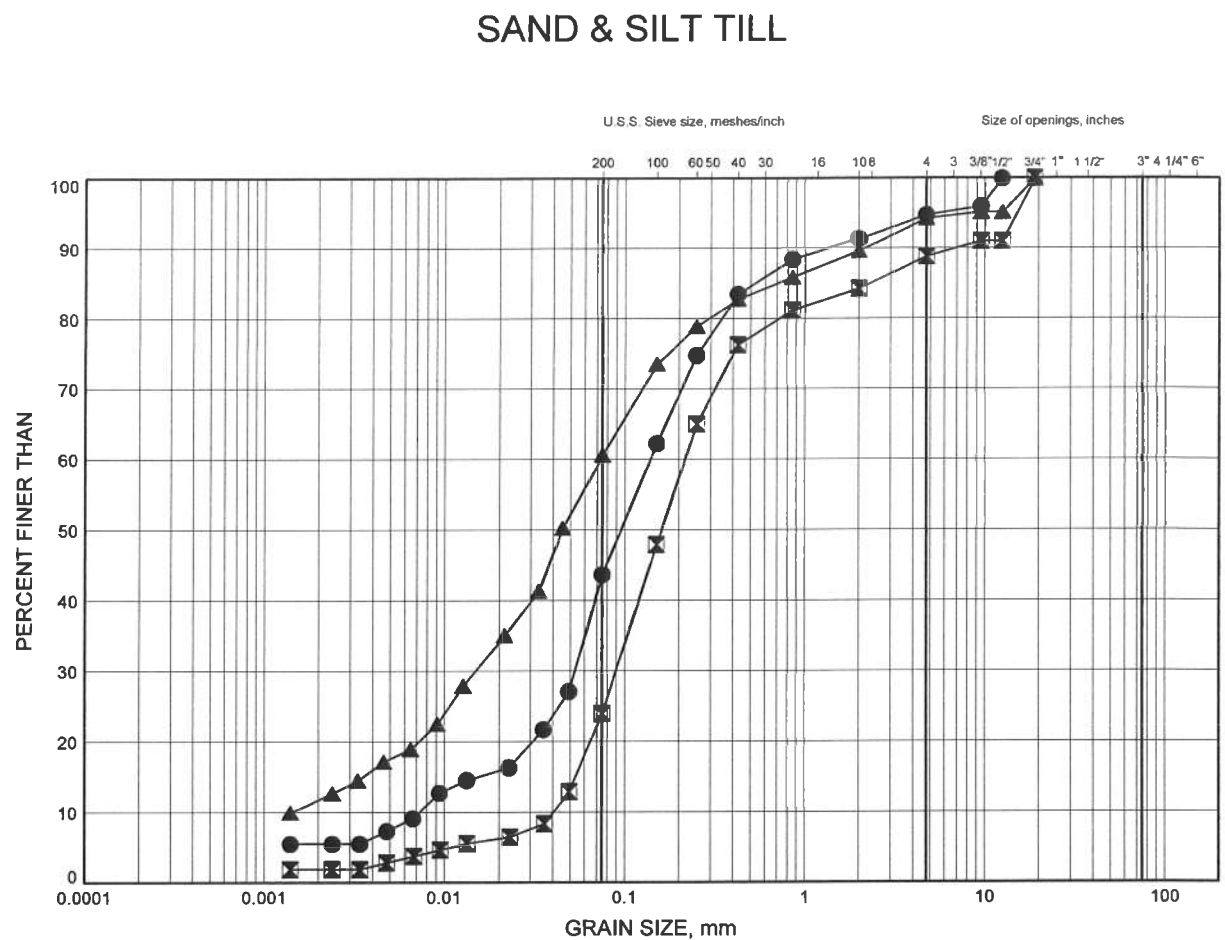
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
323.1 0.0	<b>TOPSOIL</b> , some peat, trace roots and rootlets Black (150mm)		1	SS	7		323						6 34 36 24
0.2	Silty <b>CLAY</b> , some sand to sandy, trace gravel, trace roots and rootlets Firm to Very Stiff Brown (TILL)		2	SS	10		322						
			3	SS	5		321						
			4	SS	18		320						
			5	SS	22		319						
319.0 4.1	<b>SAND</b> , some silt, trace gravel Dense Brown Moist to Wet		6	SS	38		318						1 16 28 55
317.9 5.2	<b>SAND</b> and <b>SILT</b> , trace gravel Very Dense Grey Moist (TILL)		7	SS	50		317						
315.9 7.2	Silty <b>CLAY</b> , some sand, trace gravel Hard Grey		8	SS	40		316						
314.9 8.2	END OF BOREHOLE AT 8.2m. BOREHOLE CAVED TO 4.0m AND WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9m, THEN AUGER CUTTINGS TO SURFACE.						315						

ONTMT4S 6417R.GPJ 1/25/13



# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE C1



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C16-1	2.59	320.61
⊠	C16-3	3.35	320.25
▲	C16-3	6.30	317.30

Date January 2013  
W.P. 408-88-00

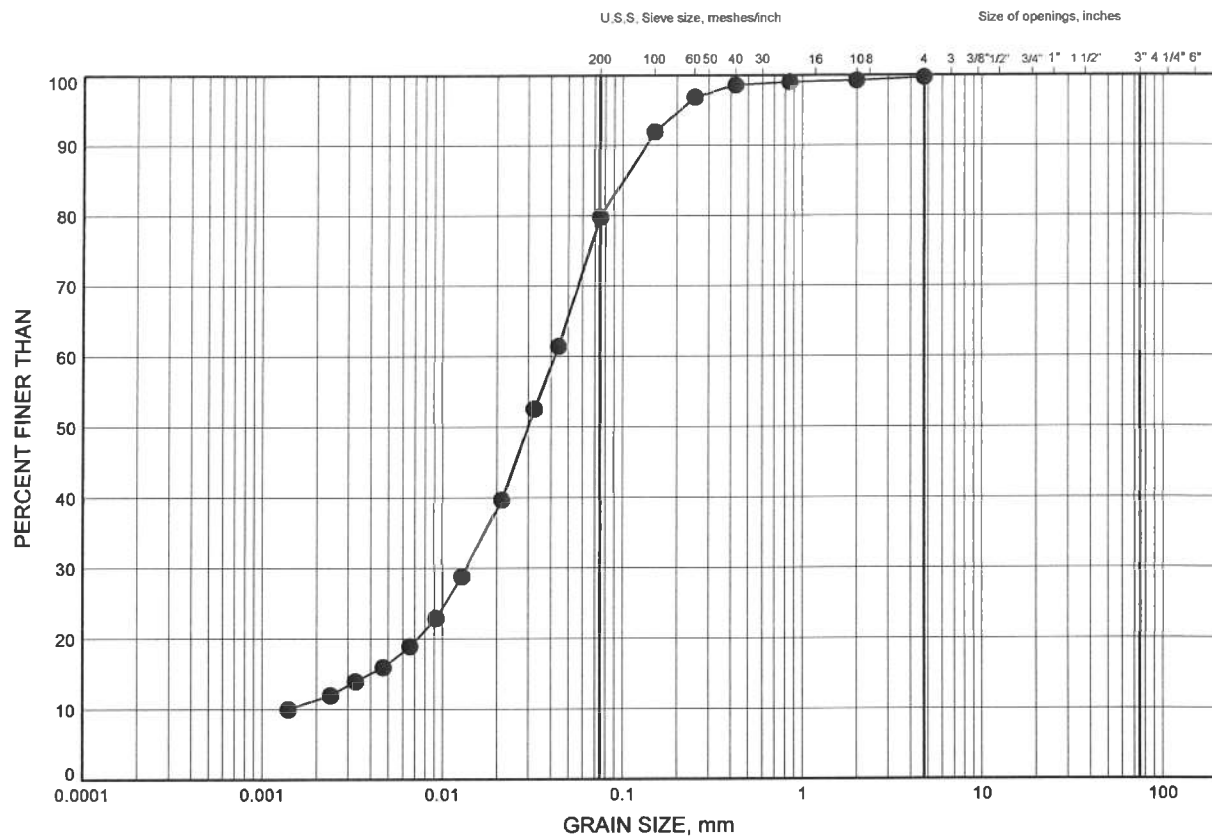


Prep'd AN  
Chkd. RPR

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE C2

## SILT



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C16-1	4.88	318.32

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 1/17/13

Date January 2013  
W.P. 408-88-00

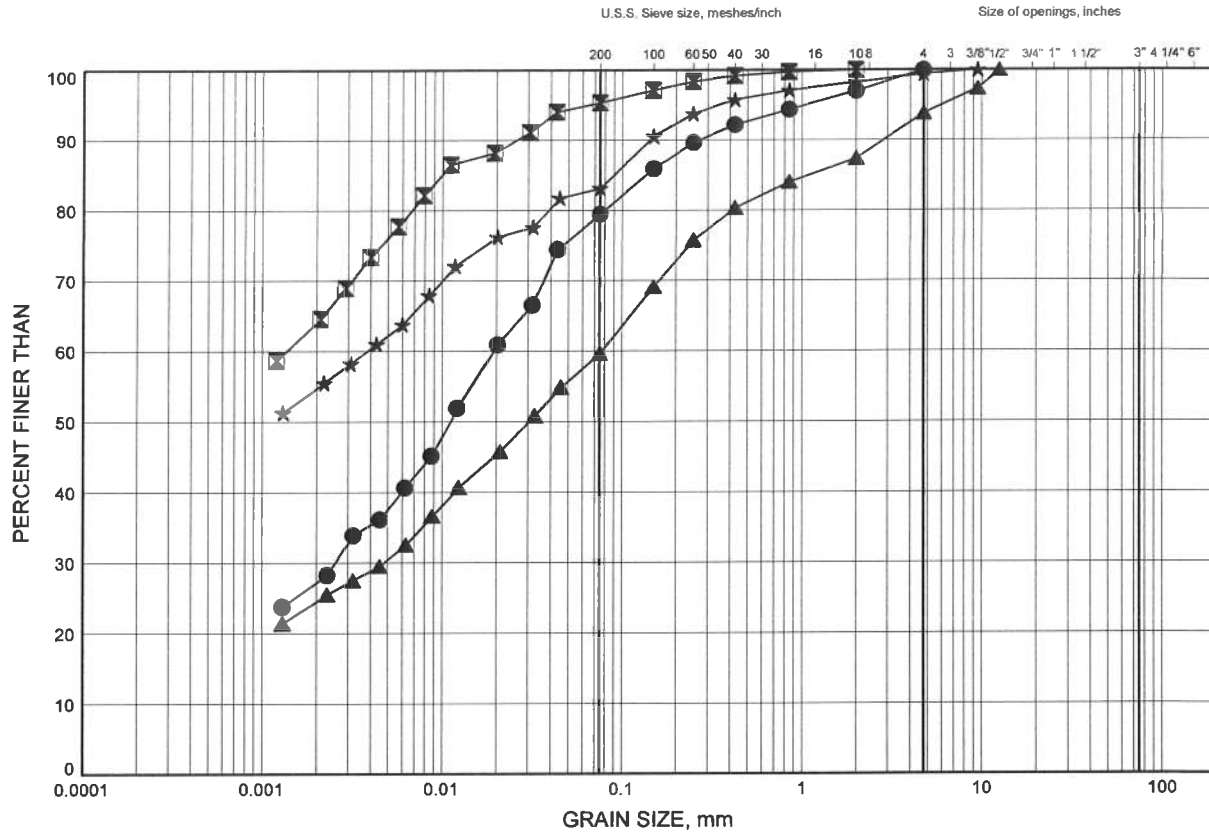


Prep'd AN  
Chkd. RPR

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE C3

## SILTY CLAY & SILTY CLAY TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C16-2	3.35	320.55
■	C16-2	6.40	317.50
▲	C16-4	2.59	320.51
★	C16-4	7.92	315.18

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 1/17/13

Date January 2013  
W.P. 408-88-00

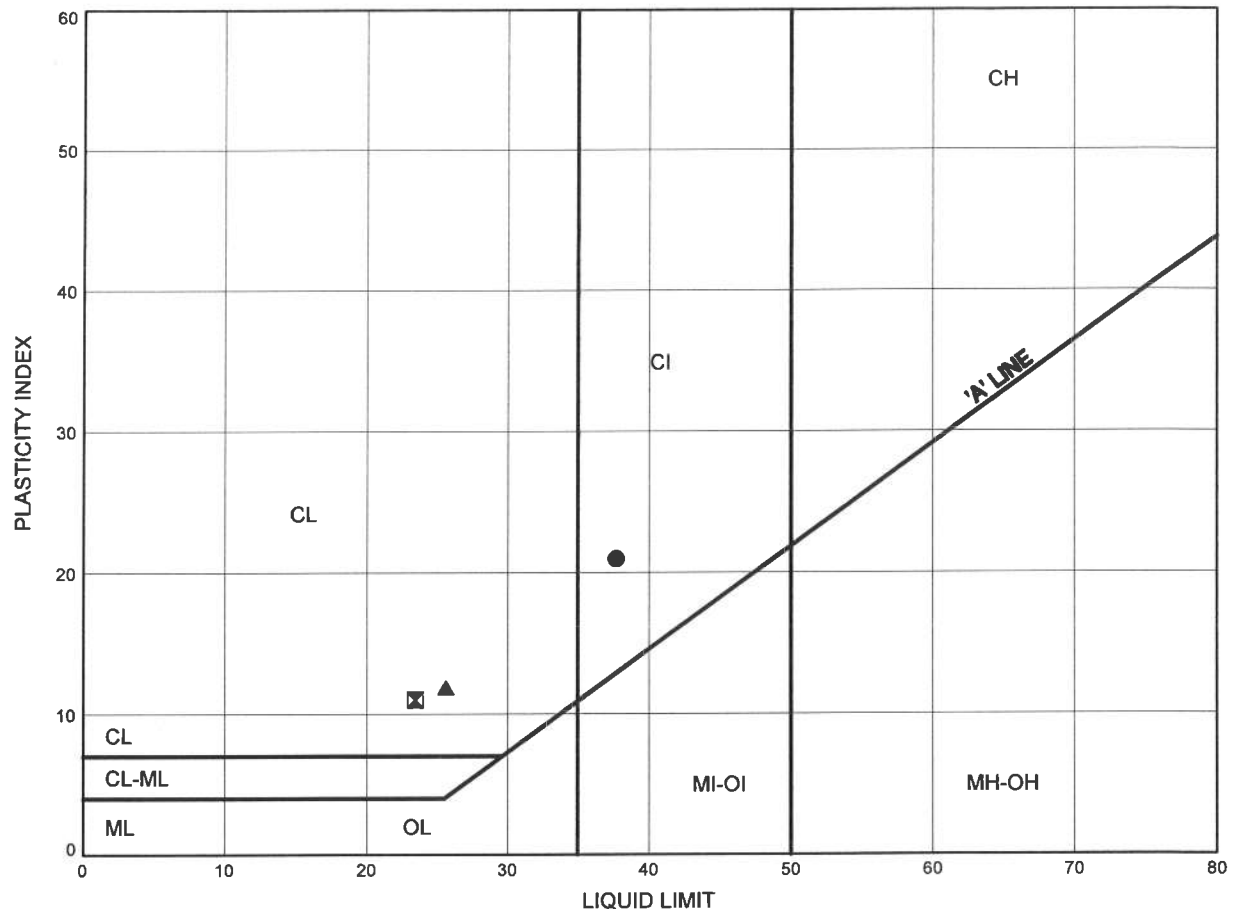


Prep'd AN  
Chkd. RPR

# Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE C4

## SILTY CLAY & SILTY CLAY TILL

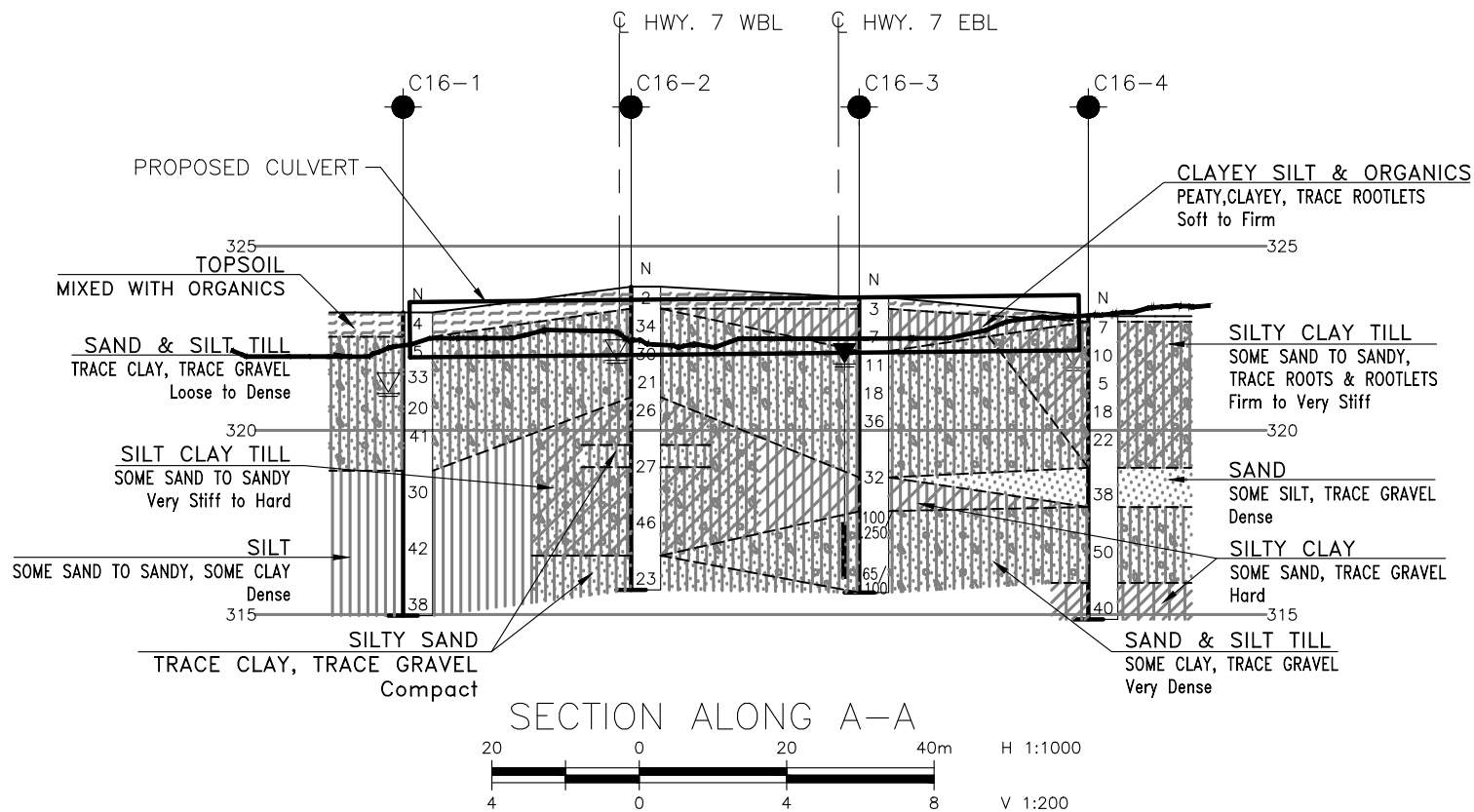
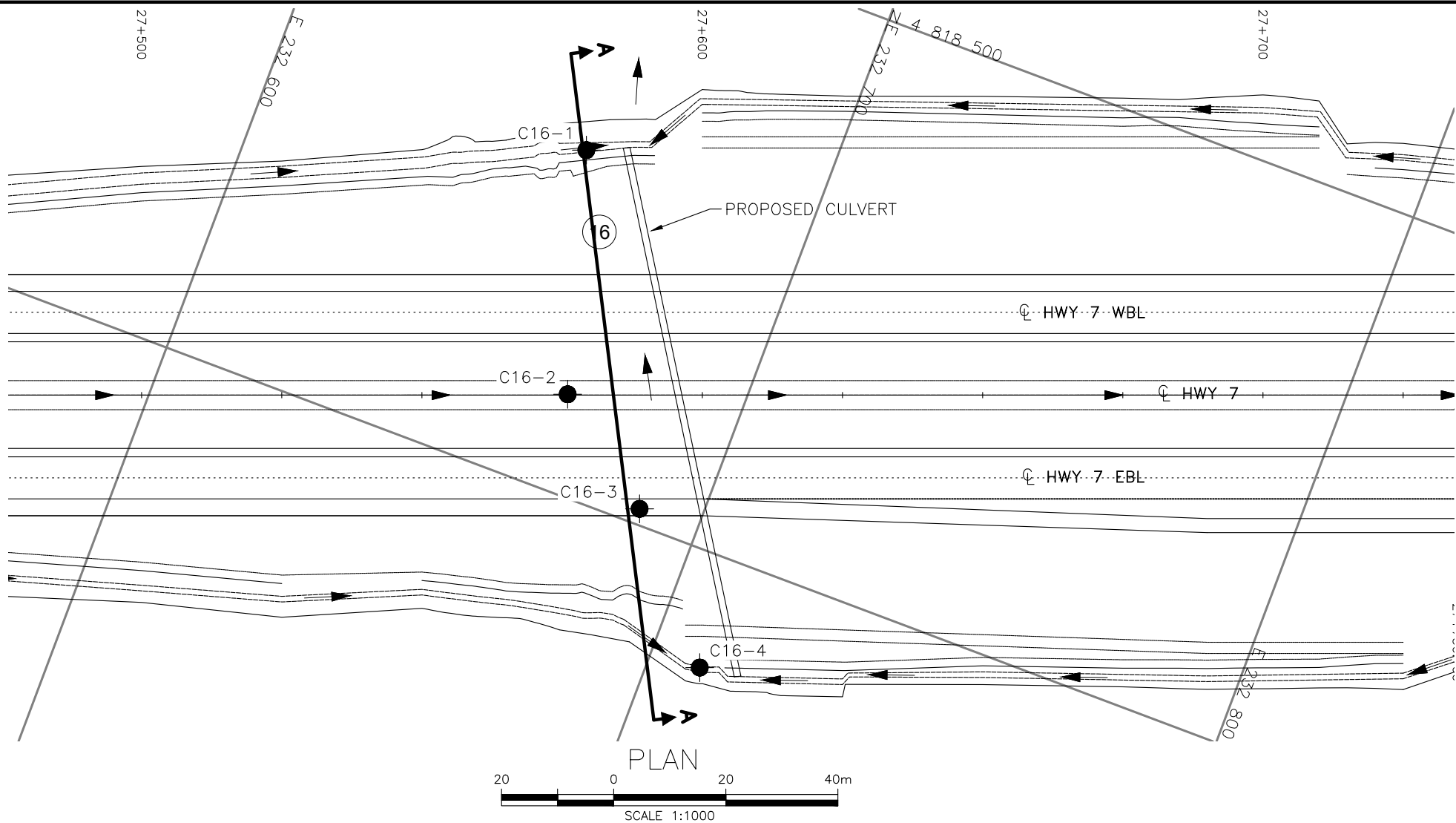


### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C16-2	6.40	317.50
⊠	C16-4	2.59	320.51
▲	C16-4	7.92	315.18



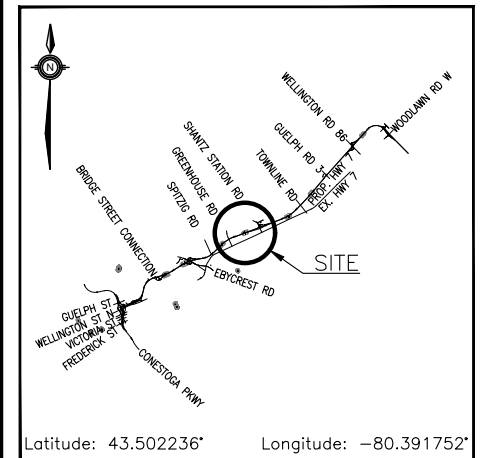
**Photo C1:** Looking north from Borehole C16-3



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

CONT No  
WP No 408-88-00

HIGHWAY 7 NEW EBL & WBL  
CULVERT C16  
STA. 27+594  
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

●	Borehole
●	Borehole and Cone
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
C16-1	323.2	4 818 459.3	232 657.7
C16-2	323.9	4 818 417.4	232 669.9
C16-3	323.6	4 818 402.8	232 689.1
C16-4	323.1	4 818 380.1	232 709.1

-NOTES-

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

GEOCRES No. 40P8-209

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	
CODE	LOAD	DATE	FEB 2020
SITE	33-519/C	STRUCT	DWG C1



Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Silty Clay Till    Model: Mohr-Coulomb    Unit Weight: 19 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 28 °    Phi-B: 0 °    Piezometric Line: 1

Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C16, Station 27+593  
Max. Embankment height 5.9 m  
Static Loading Analysis

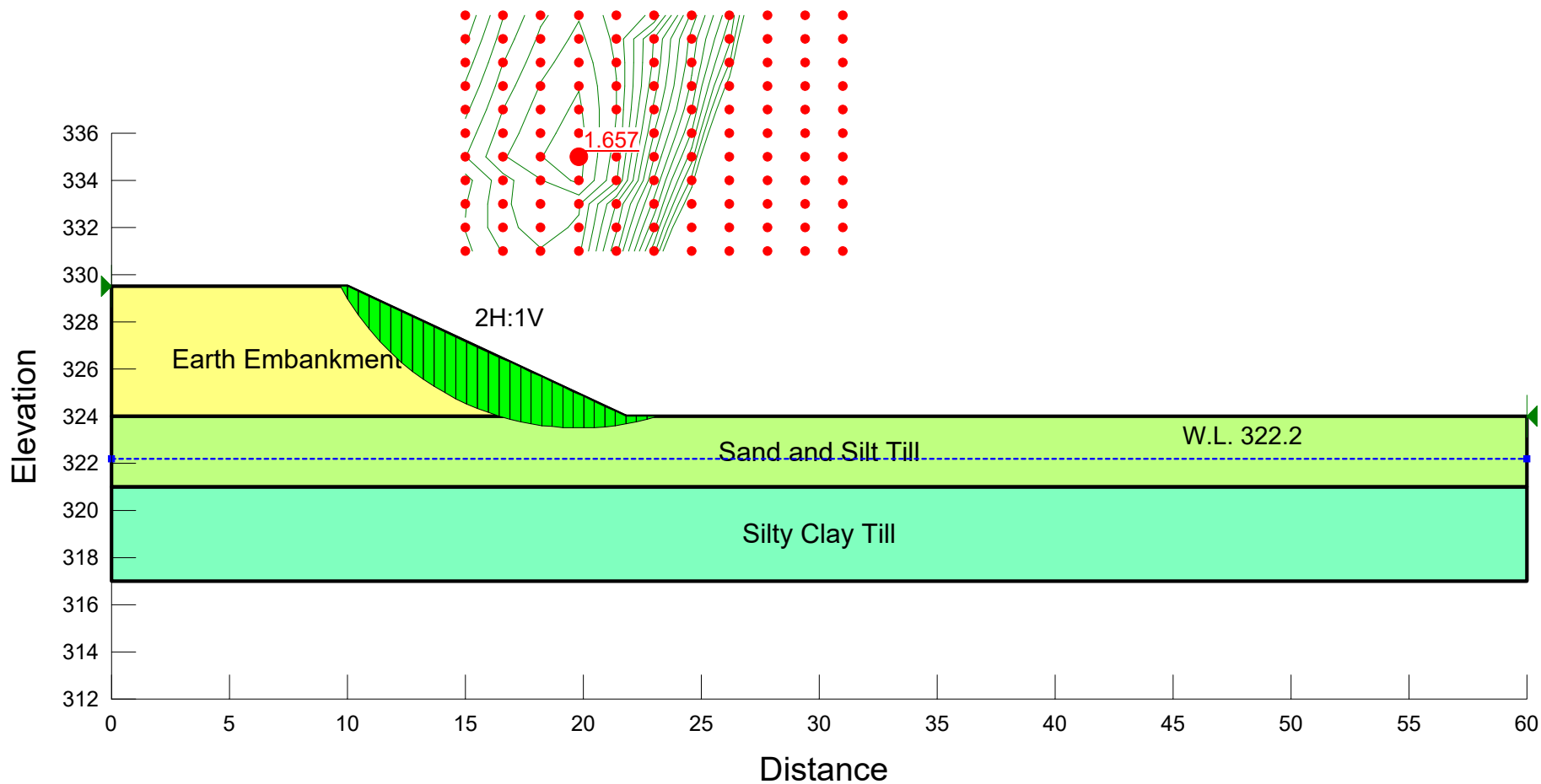


Figure C1

Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C16, Station 27+593  
Max. Embankment height 5.9 m  
Seismic Loading Analysis

Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line:  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Silty Clay Till    Model: Mohr-Coulomb    Unit Weight: 19 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 28 °    Phi-B: 0 °    Piezometric Line: 1

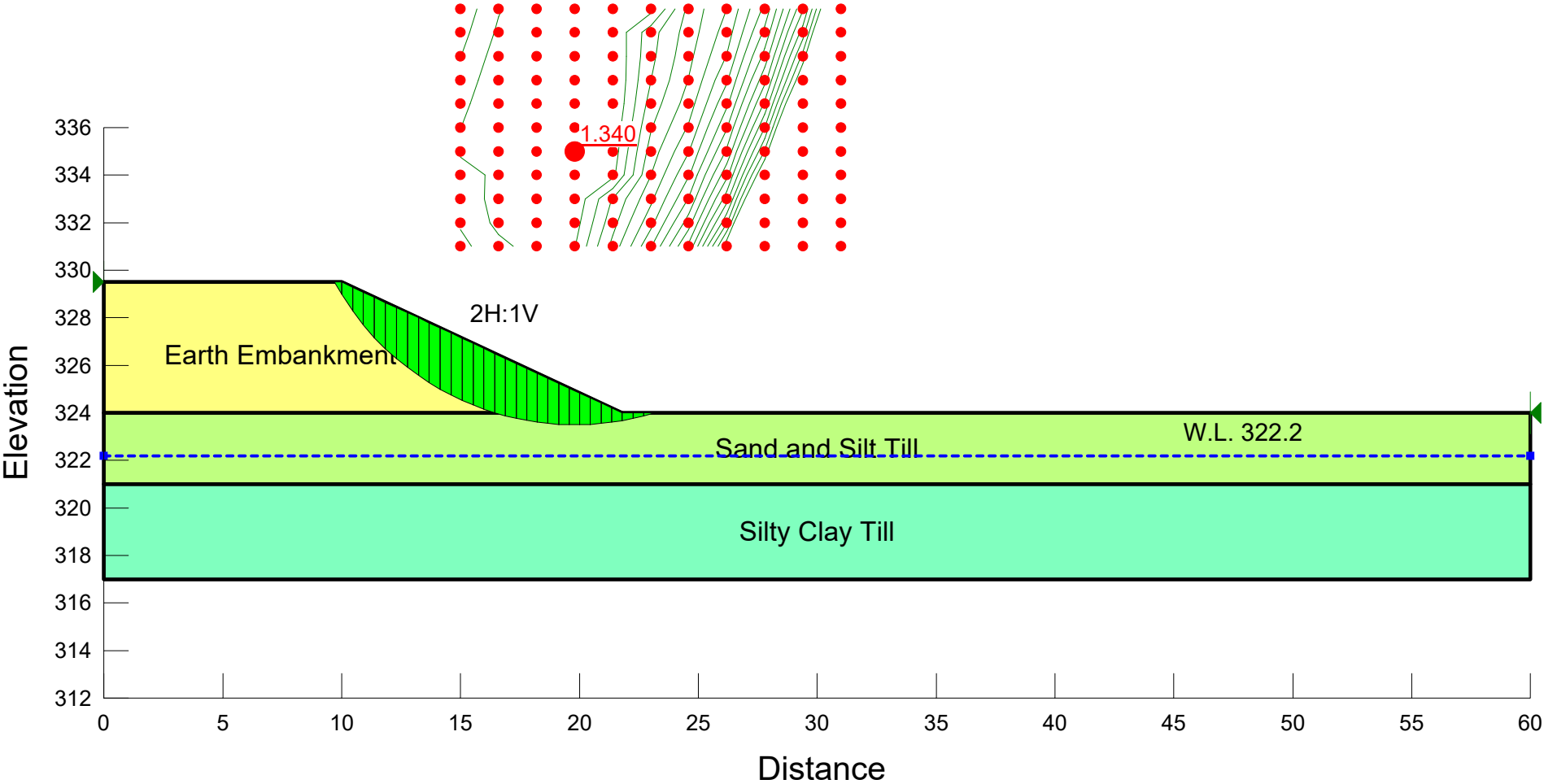


Figure C2





## **Appendix D**

**Culvert C20 – Station 30+044  
(Boreholes C20-1 to C20-3)**

**Record of Borehole Sheets  
Laboratory Test Results  
Slope stability output  
Site Photographs  
Drawing titled “Borehole Locations and Soil Strata”**

## METRIC

[illegible]

+ 3, x 3: Numbers refer to Sensitivity

## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL												
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																			
							SHEAR STRENGTH kPa																	
							○ UNCONFINED    + FIELD VANE																	
							● QUICK TRIAXIAL    × LAB VANE																	
							WATER CONTENT (%)																	
<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT</span> </div> <p>w<sub>p</sub>                  w                  w<sub>L</sub></p>																								
330.4																								
0.0	TOPSOIL, with roots and rootlets		1	SS	4																			
0.2	Black (150mm)																							
329.6	Clayey SILT, trace rootlets		2	SS	4																			
0.8	Firm Dark Brown																							
	SILT and SAND, some clay, trace gravel		3	SS	24																			
	Loose to Compact		4	SS	11																			
	Brown to Grey Moist to Wet (TILL)		5	SS	56																			
	Very Dense		6	SS	100/ 0.275																			
			7	SS	100/ 0.125																			
			8	SS	100/ 0.150																			
322.6	END OF BOREHOLE AT 7.8m.																							
7.8	Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																							
WATER LEVEL READINGS: <table> <tr> <th>DATE</th> <th>DEPTH (m)</th> <th>ELEV., (m)</th> </tr> <tr> <td>Feb 08/12</td> <td>1.7</td> <td>328.7</td> </tr> <tr> <td>Feb 27/12</td> <td>1.4</td> <td>329.0</td> </tr> <tr> <td>Apr. 17/12</td> <td>0.9</td> <td>329.5</td> </tr> </table>													DATE	DEPTH (m)	ELEV., (m)	Feb 08/12	1.7	328.7	Feb 27/12	1.4	329.0	Apr. 17/12	0.9	329.5
DATE	DEPTH (m)	ELEV., (m)																						
Feb 08/12	1.7	328.7																						
Feb 27/12	1.4	329.0																						
Apr. 17/12	0.9	329.5																						

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

RECORD OF BOREHOLE No C20-3

1 OF 1

METRIC

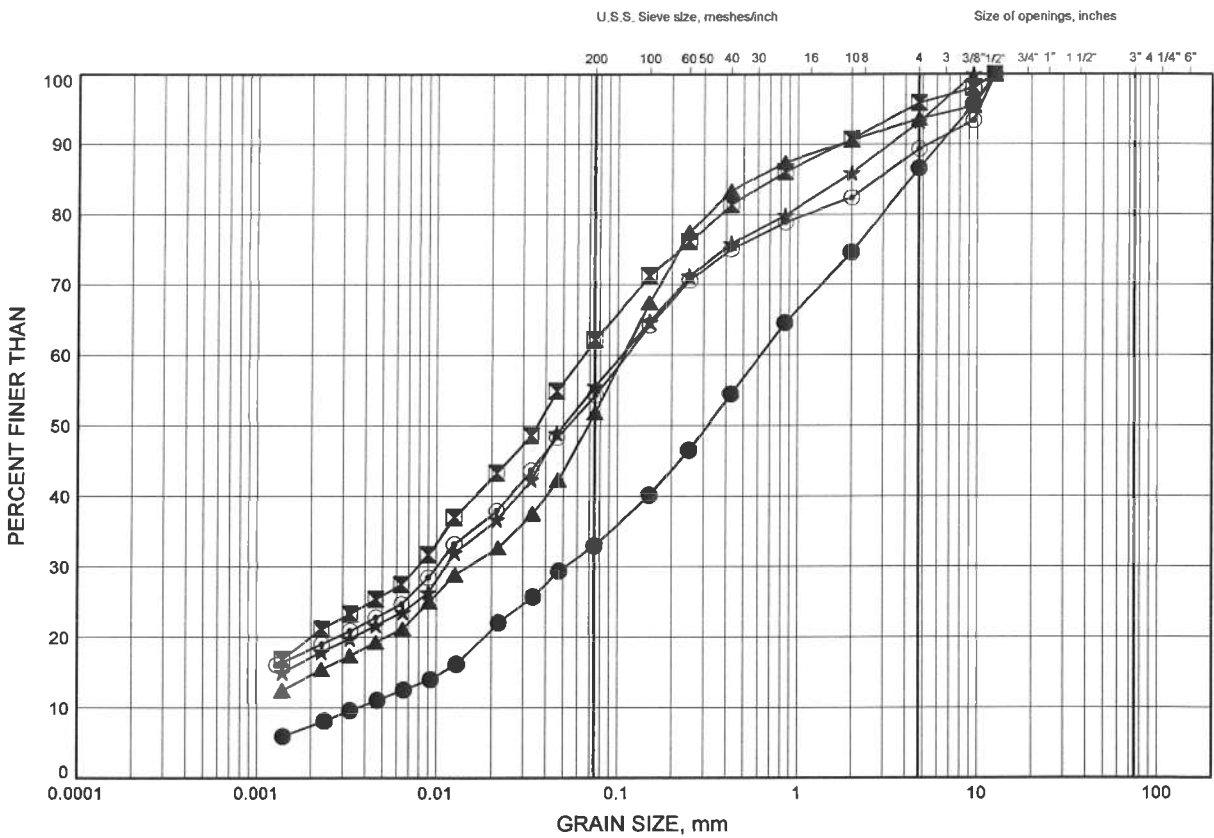
W.P. 408-88-00 LOCATION N 4 819 272.7 E 235 004.7, Culvert C20, Station 30+044 ORIGINATED BY SLL  
HWY 7 - New BOREHOLE TYPE Solid Stern Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.02.08 - 2012.02.08 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	
332.4 0.0	TOPSOIL, trace roots: (200mm)		1	SS	3		332					
0.2	Clayey SILT, some sand, trace gravel Soft to Stiff Brown		2	SS	9							
331.0 1.4	SILT and SAND, some clay, trace to some gravel Dense to Very Dense Brown Moist (TILL)		3	SS	31		331					
			4	SS	41		330					11 35 36 18
			5	SS	100		329					
327.7 4.7	Clayey SILT, some sand to sandy, trace gravel Hard Brown to Grey (TILL)		6	SS	100/ 0.275		328					1 23 51 25
			7	SS	100/ 0.100		327					
							326					
324.6 7.8	END OF BOREHOLE AT 7.8m. BOREHOLE CAVED TO 6.3m AND WATER LEVEL AT 2.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9m THEN AUGER CUTTINGS TO SURFACE.		8	SS	100/ 0.075		325					

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE D1

### SILT & SAND TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C20-1	2.59	327.01
⊠	C20-1	7.79	321.81
▲	C20-2	1.07	329.33
★	C20-2	3.35	327.05
⊙	C20-3	2.59	329.81

Date January 2013  
W.P. 408-88-00

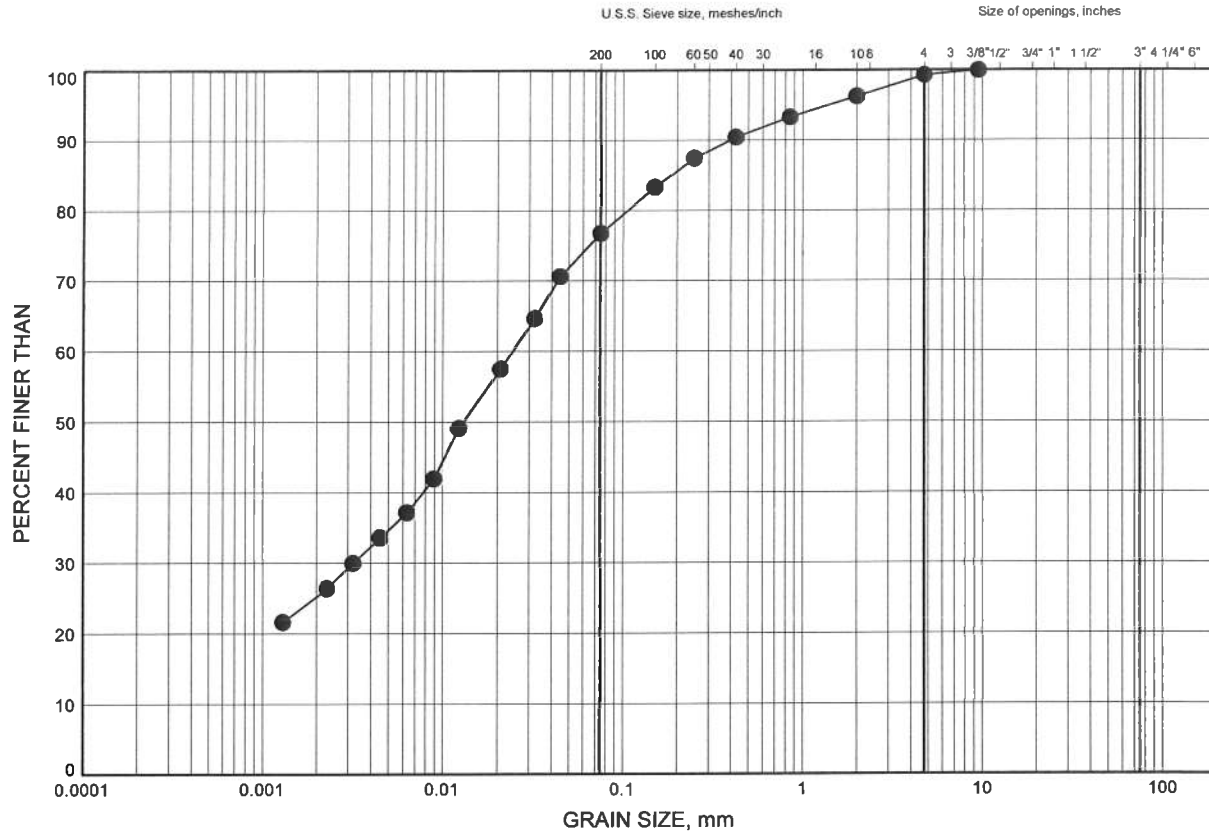


Prep'd AN  
Chkd. RPR

# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE D2

## CLAYEY SILT TILL



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

### LEGEND

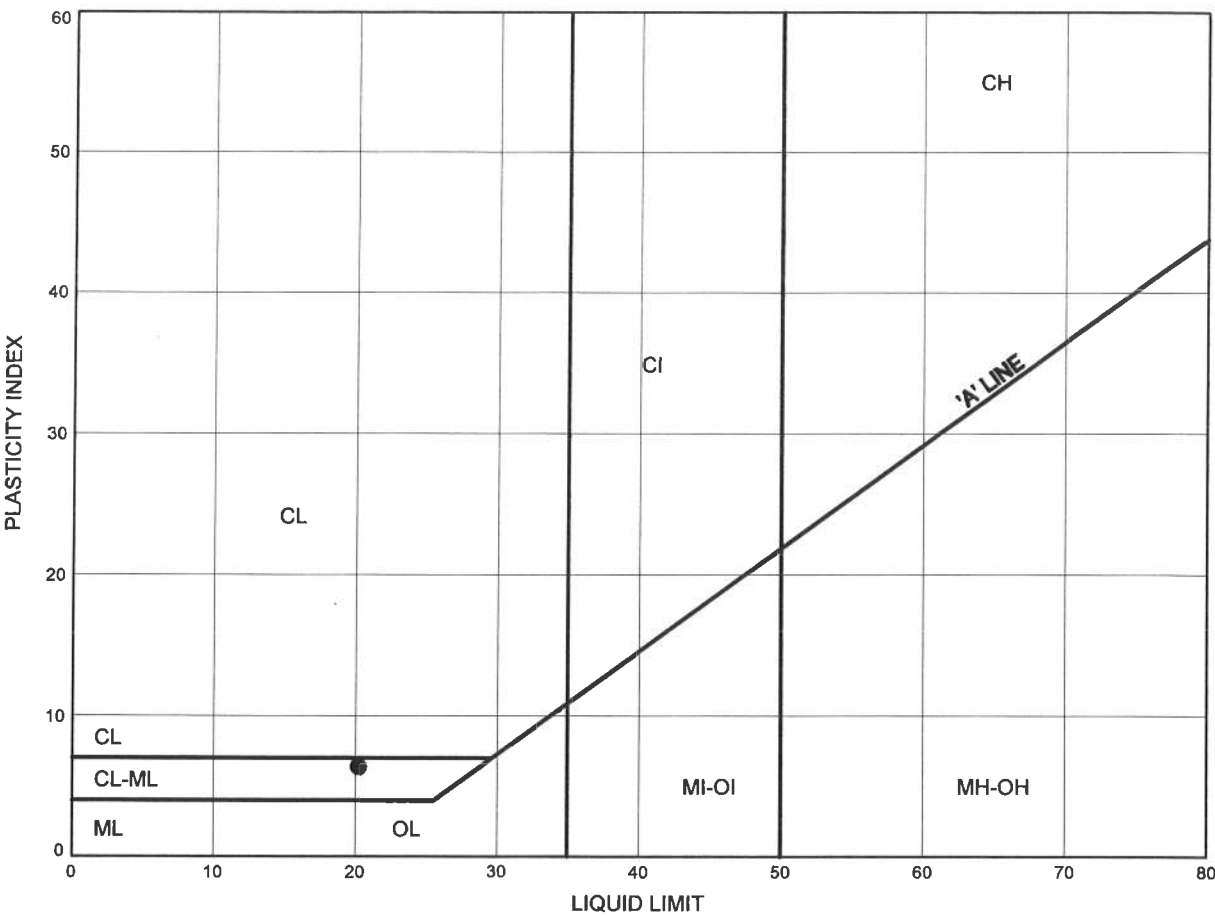
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C20-3	4.80	327.60

Highway 7 - New

# ATTERBERG LIMITS TEST RESULTS

FIGURE D3

SILT & SAND, Some Clay



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C20-2	1.07	329.33

THURBALT 6417R.GPJ 1/17/13

Date January 2013  
W.P. 408-88-00

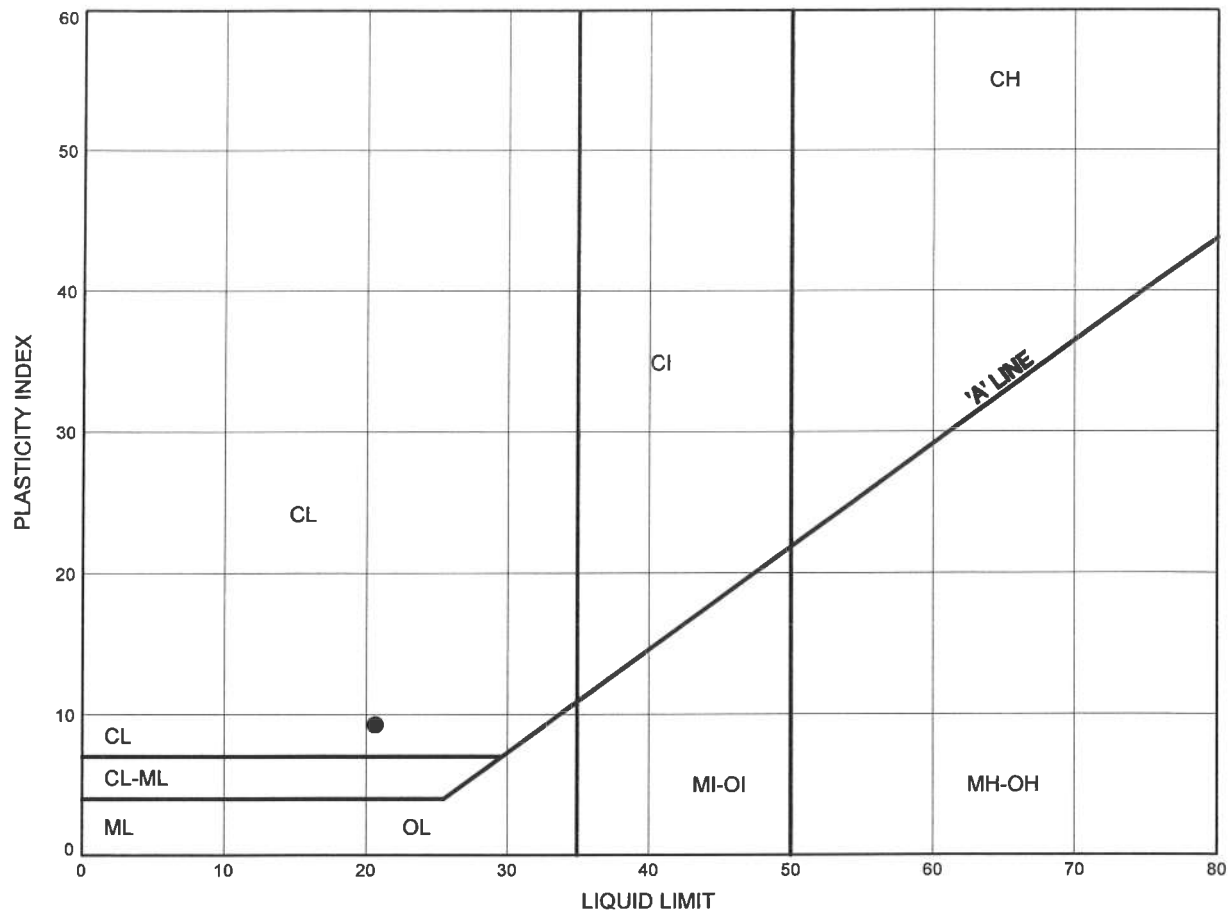


Prep'd AN  
Chkd. RPR

# Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE D4

### CLAYEY SILT TILL



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C20-3	4.80	327.60



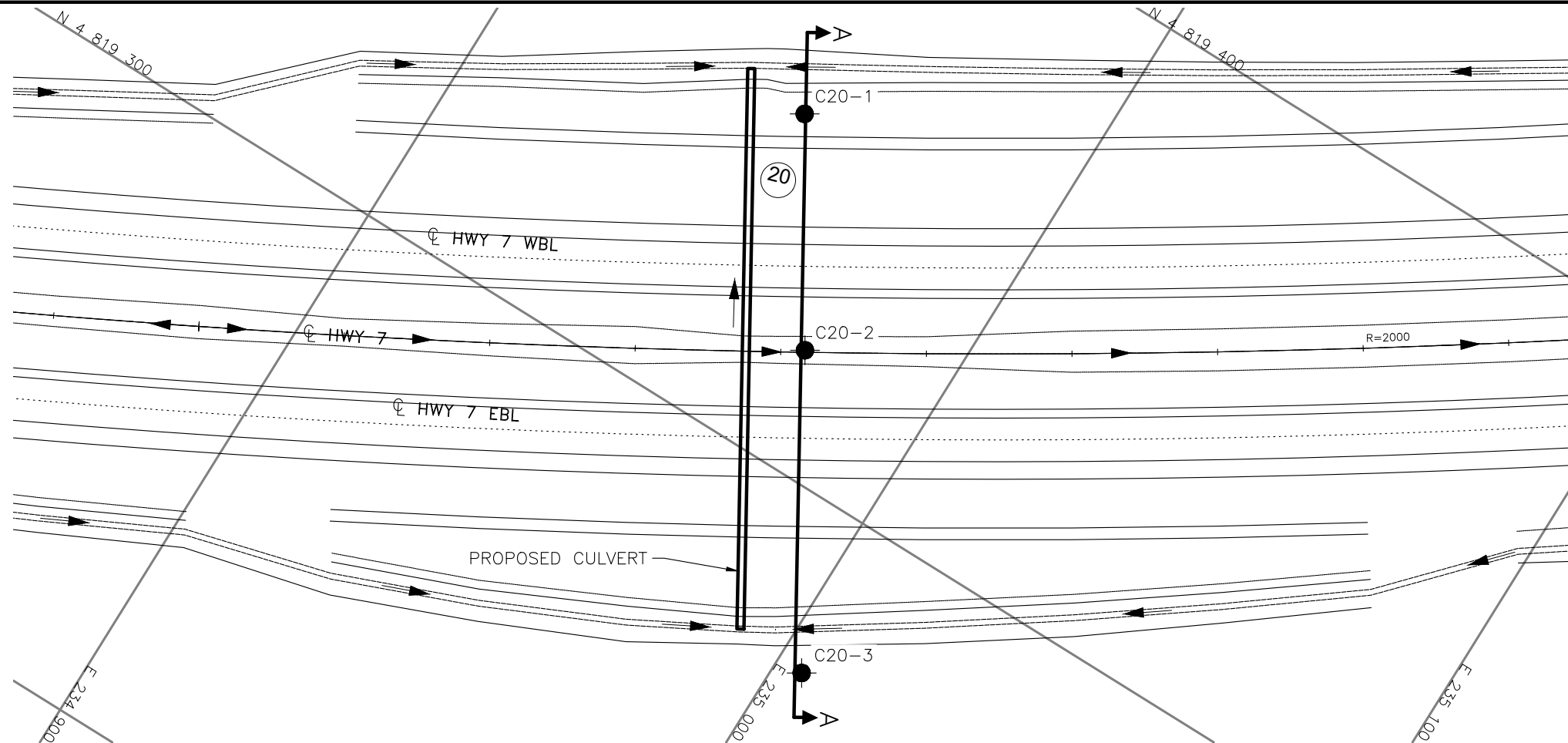


**Photo D1:** Looking north from Borehole C20-2

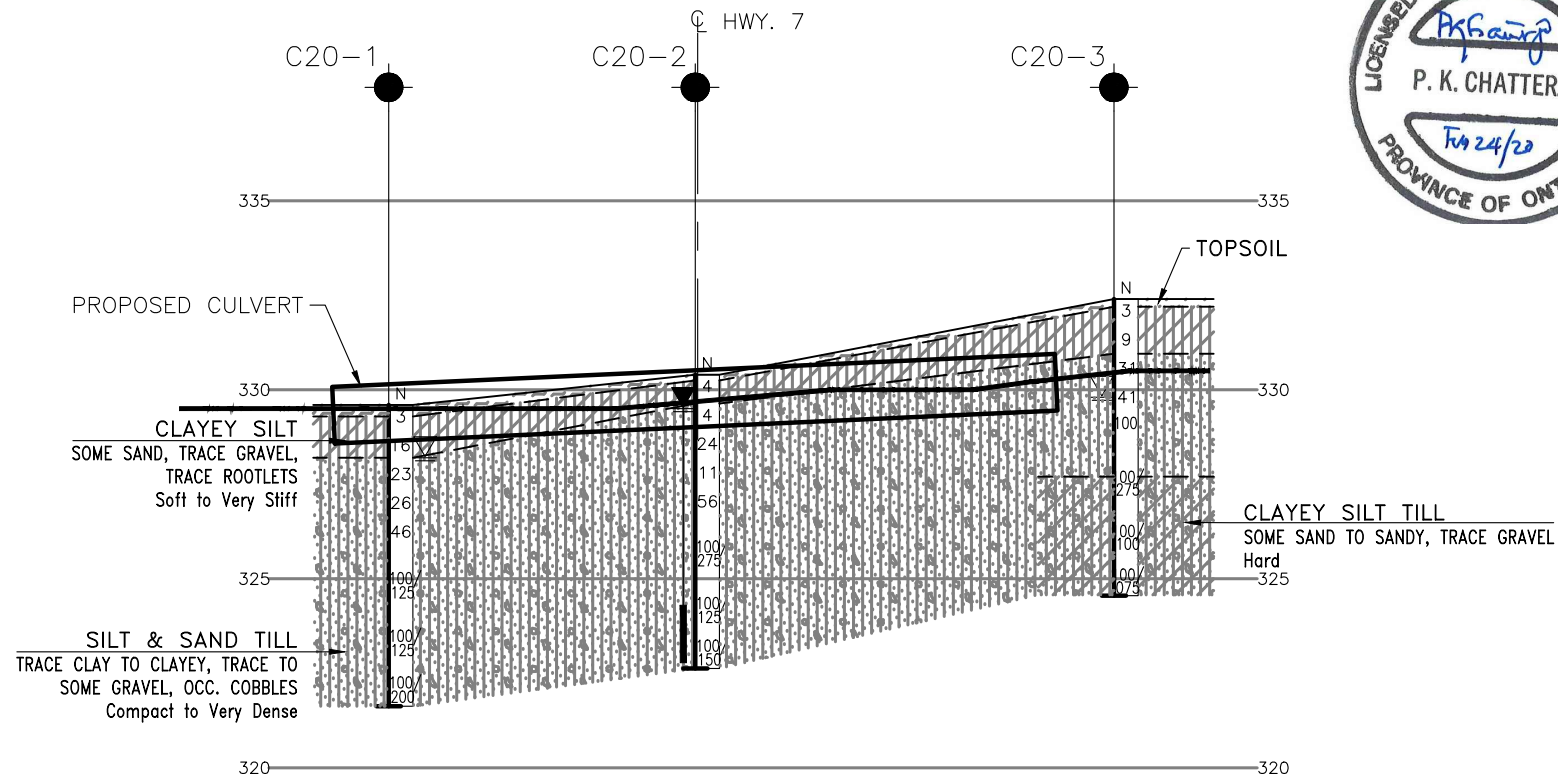
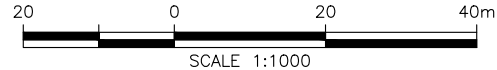


**Photo D2:** Looking south from Borehole C20-2

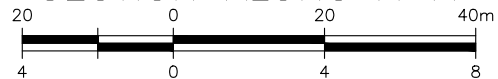
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



PLAN



SECTION ALONG A-A



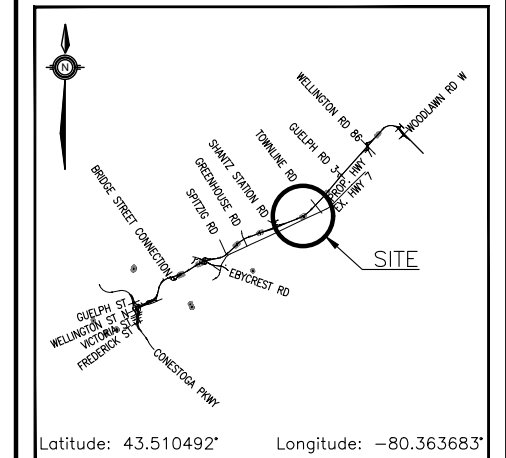
H 1:1000

V 1:200



CONT No  
WP No 408-88-00

HIGHWAY 7 NEW EBL & WBL  
CULVERT C20  
STA. 30+044  
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

●	Borehole
●	Borehole and Cone
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
C20-1	329.6	4 819 354.4	234 954.4
C20-2	330.4	4 819 320.0	234 975.9
C20-3	332.4	4 819 272.7	235 004.7

-NOTES-

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

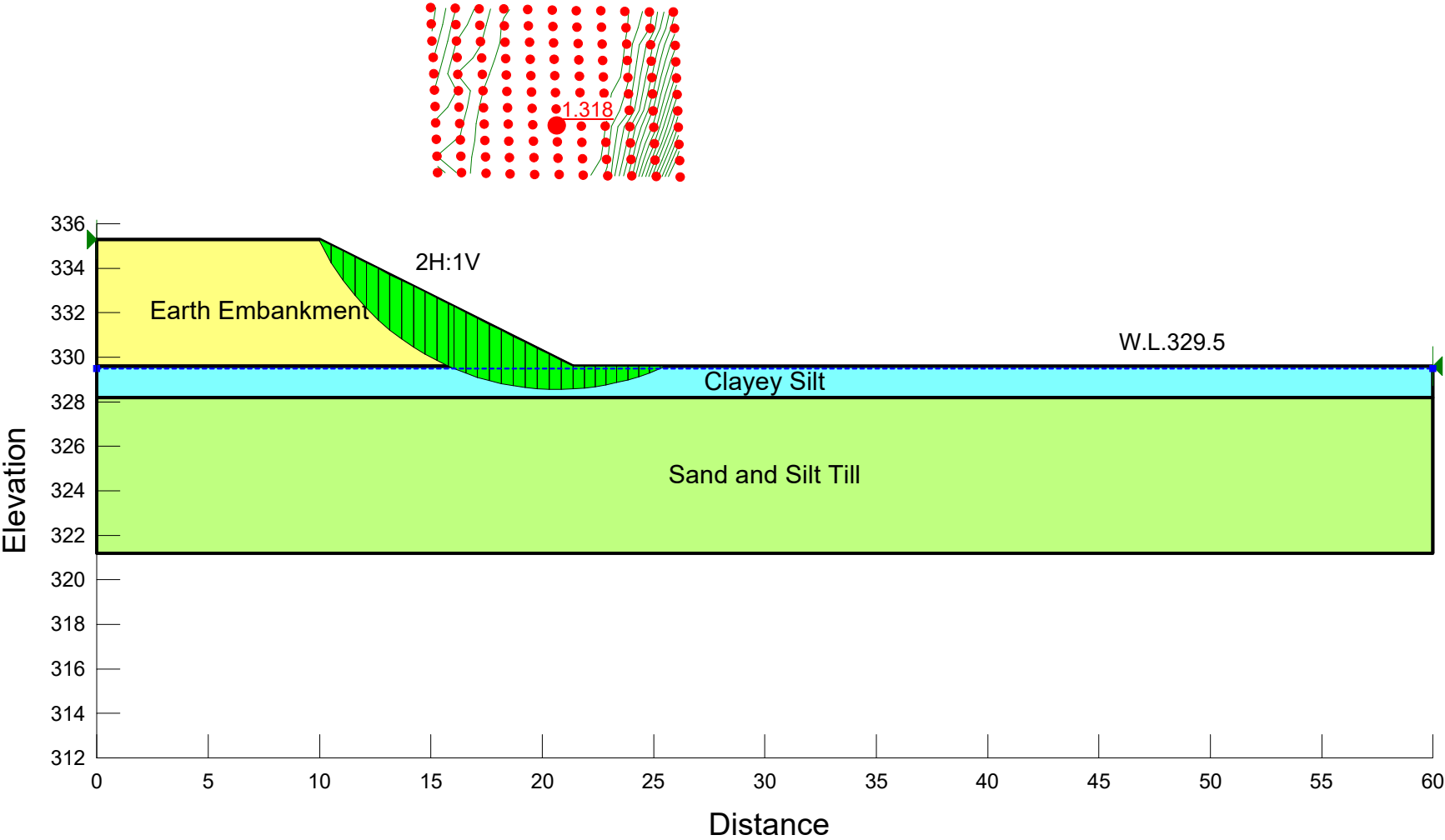
GEOCRES No. 40P8-209

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	
CODE	LOAD	DATE	FEB 2020
SITE	33-601/C	STRUCT	DWG D1



Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C20, Station 30+044  
Max. Embankment height 5.7 m  
Static Loading Analysis

Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Clayey Silt    Model: Mohr-Coulomb    Unit Weight: 18 kN/m³    Cohesion: 0 kPa    Phi: 27 °    Phi-B: 0 °    Piezometric Line: 1



Slope Stability Analysis  
11375  
Highway 7 -New, Kitchener to Guelph  
Culvert C20, Station 30+044  
Max. Embankment height 5.7 m  
Seismic Loading Analysis

Name: Earth Embankment Fill    Model: Mohr-Coulomb    Unit Weight: 22.8 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Sand and Silt Till    Model: Mohr-Coulomb    Unit Weight: 21 kN/m³    Cohesion: 0 kPa    Phi: 32 °    Phi-B: 0 °    Piezometric Line: 1  
Name: Clayey Silt    Model: Mohr-Coulomb    Unit Weight: 18 kN/m³    Cohesion: 0 kPa    Phi: 27 °    Phi-B: 0 °    Piezometric Line: 1

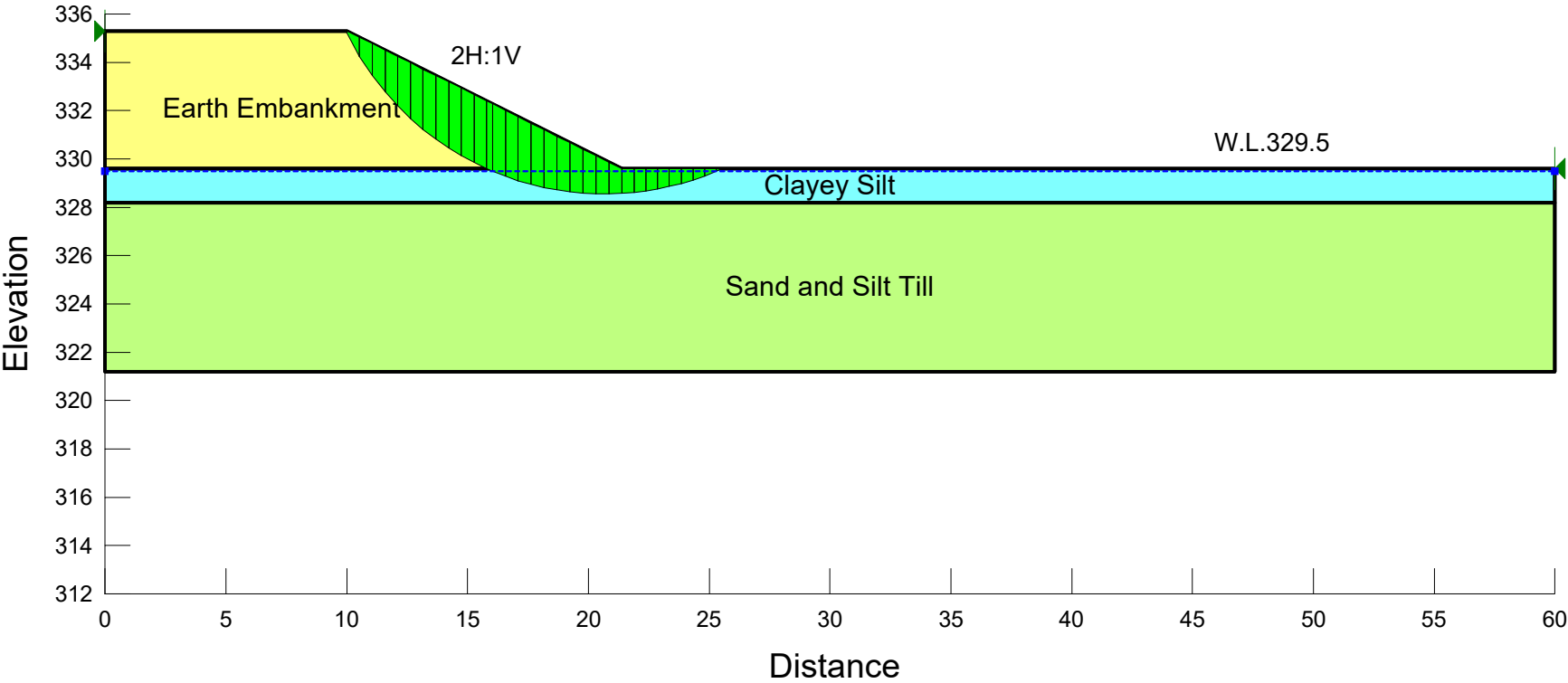
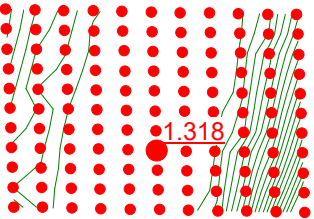


Figure D2



## **Appendix E**

**Culvert C24 – Station 31+774  
(Boreholes C24-1 to C24-3)**

**Record of Borehole Sheets  
Laboratory Test Results  
Site Photographs  
Drawing titled “Borehole Locations and Soil Strata”**

# RECORD OF BOREHOLE No C24-1

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 820 526.8 E 236 176.6, Culvert C24, Station 31+774 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.01.30 - 2012.01.30 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)
								20 40 60 80 100					
								20 40 60 80 100					
330.1													
0.0	TOPSOIL, some clay, trace roots		1	SS	5								
329.6	Loose												
	Dark Brown												
0.5	(500mm)												
329.1	SILT, some clay, some sand, trace												
	gravel												
1.0	Compact		2	SS	14								
	Brown												
	SILT and SAND, some clay, trace												
	gravel												
	Compact to Very Dense												
	Brown		3	SS	13								
	Moist												
	(TILL)												
	Grey		4	SS	39							5 40 39 16	
	Damp												
			5	SS	50/ 0.100								
	Occasional cobbles		6	SS	70							5 37 41 17	

ONTMT4S 6417R.GPJ 1/17/13

# RECORD OF BOREHOLE No C24-2

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 820 508.1 E 236 200.0, Culvert C24, Station 31+774 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.01.30 - 2012.01.30 CHECKED BY LRB

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE								
330.1								20	40	60	80	100	20	40	60		
0.0	TOPSOIL: (50mm)		1	SS	5												
329.3	SILT, some clay, some sand, trace gravel Loose Brown		2	SS	19											9	42 37 12
0.8	SILT and SAND, some clay, trace gravel Compact to Dense Brown to Grey Damp to Moist (TILL)		3	SS	25												
			4	SS	39												
	Very Dense		5	SS	50/ 0.125												
			6	SS	50/ 0.125												
			7	SS	50/ 0.100												
322.2			8	SS	55/ 0.150											5	33 43 19
7.9	END OF BOREHOLE AT 7.9m. BOREHOLE OPEN AND WATER LEVEL AT 1.3m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Feb.08/12 0.8 329.3 Feb.27/12 0.8 329.3 Apr.17/12 0.9 329.2																

ONTMT4S 6417R.GPJ 1/17/13

# RECORD OF BOREHOLE No C24-3

1 OF 1

METRIC

W.P. 408-88-00 LOCATION N 4 820 485.6 E 236 215.4, Culvert C24, Station 31+774 ORIGINATED BY ES  
HWY 7 - New BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2012.01.30 - 2012.01.30 CHECKED BY LRB

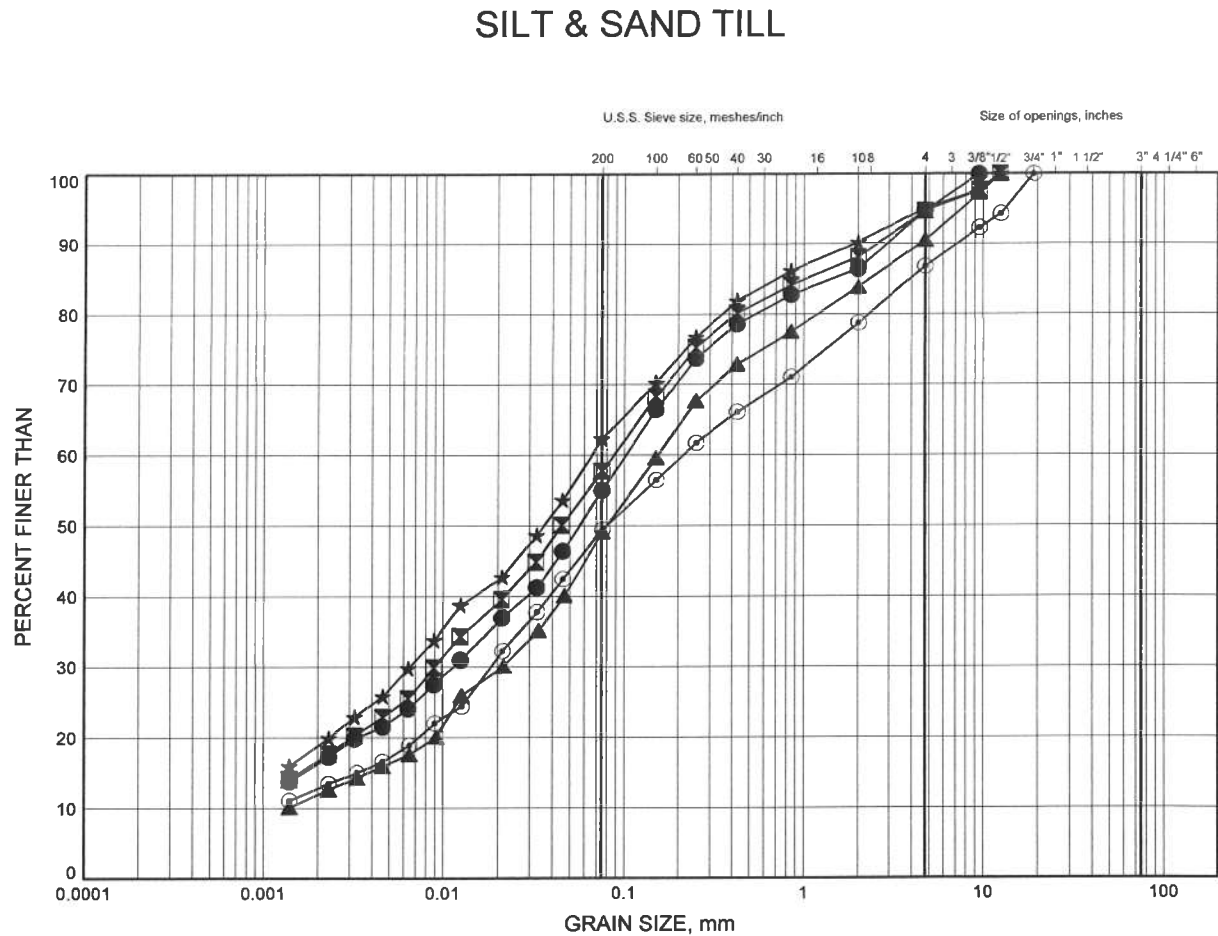
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
329.9 0.0	TOPSOIL Loose Dark Brown Moist (600mm)		1	SS	4									
329.3 0.6	Clayey SILT, some sand, trace gravel Stiff Brown		2	SS	14		329							
328.4 1.5	Clayey SILT, some sand to sandy, trace gravel Very Stiff Brown (TILL)		3	SS	27		328							
			4	SS	26									6 20 43 31
326.9 3.0	SILT and SAND, some clay, trace to some gravel Very Dense Brown to Grey Damp (TILL)		5	SS	83		327							
			6	SS	50/ 0.100		326							13 37 37 13
			7	SS	50/ 0.125		325							
							324							
							323							
322.2 7.7	END OF BOREHOLE AT 7.7m. WATER LEVEL AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 6.1m, AUGER CUTTINGS AND HOLEPLUG TO 1.2m, THEN HOLEPLUG TO SURFACE.		8	SS	50/ 0.075									

ONTMT4S 6417R.GPJ 1/17/13



# Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE E1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C24-1	2.59	327.51
⊠	C24-1	4.80	325.30
▲	C24-2	1.07	329.03
★	C24-2	7.77	322.33
⊙	C24-3	4.62	325.28

Date January 2013  
W.P. 408-88-00



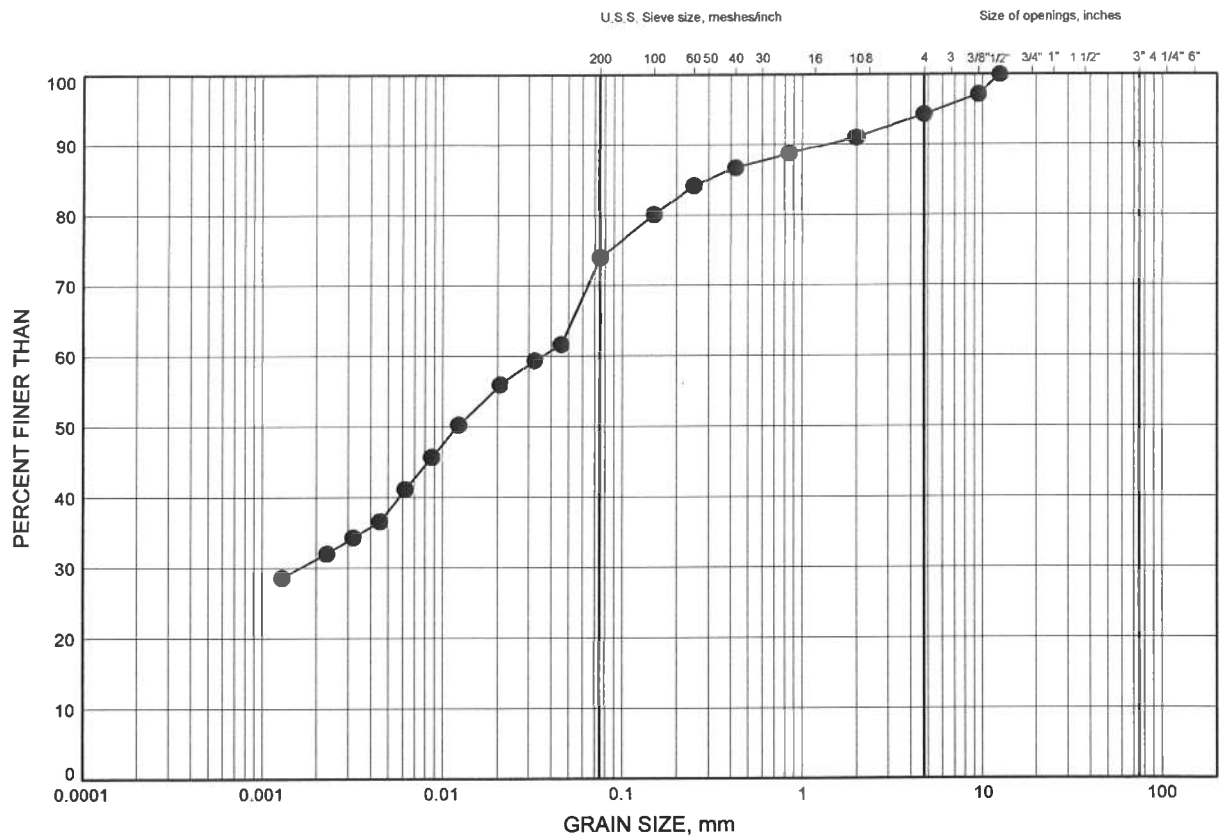
Prep'd AN  
Chkd. RPR

# Highway 7 - New

## GRAIN SIZE DISTRIBUTION

FIGURE E2

### CLAYEY SILT TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C24-3	2.59	327.31

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 1/17/13

Date January 2013  
W.P. 408-88-00

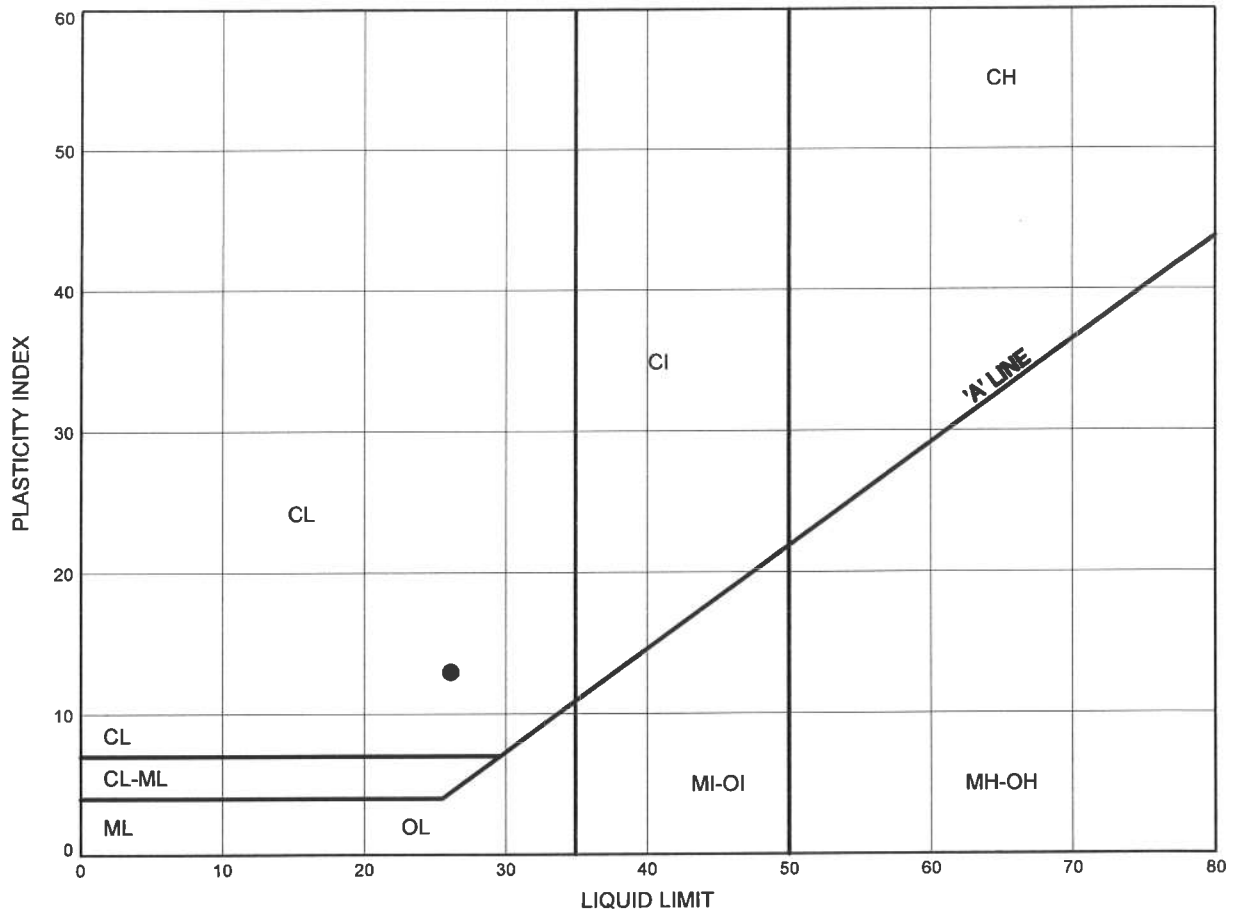


Prep'd AN  
Chkd. RPR

# Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE E3

### CLAYEY SILT TILL

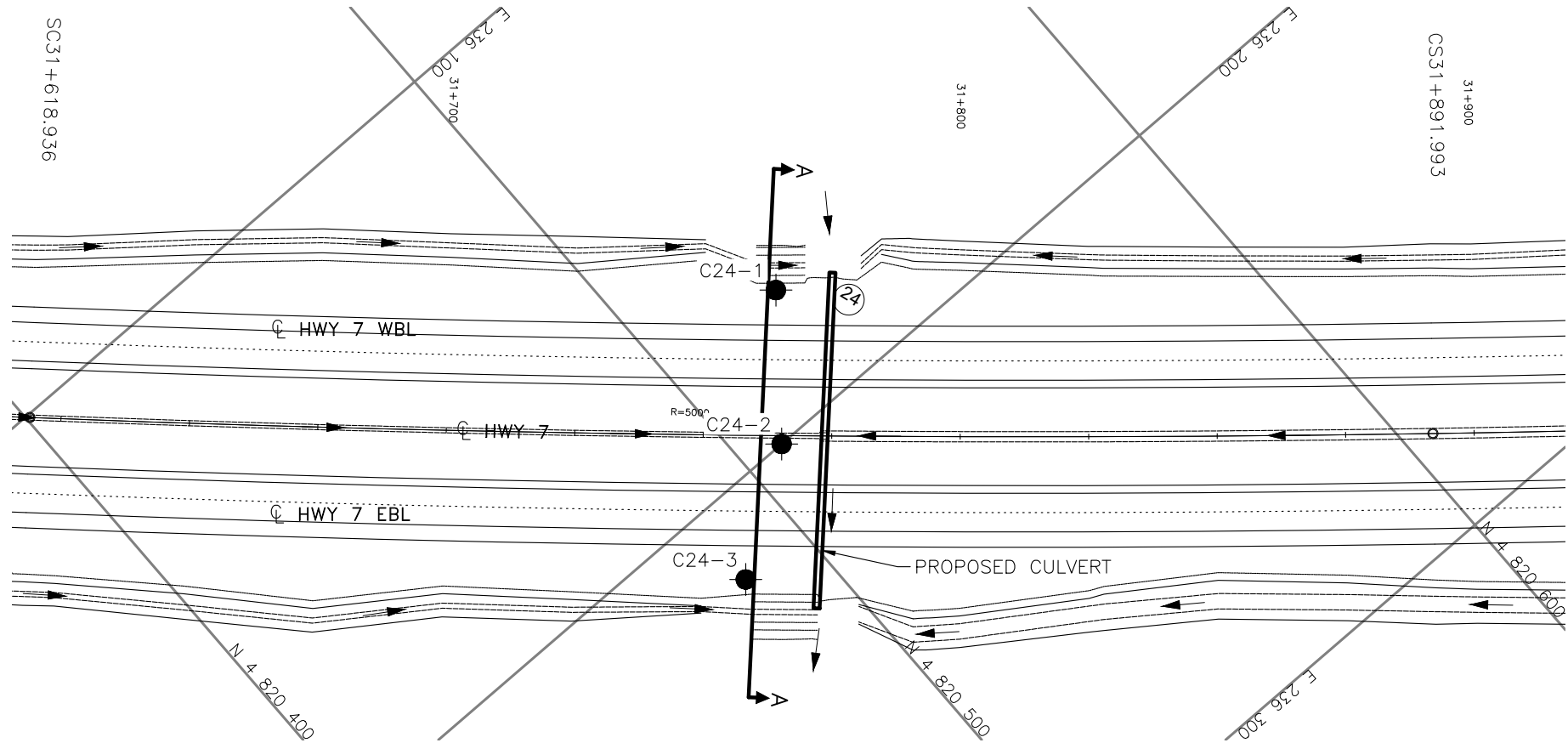


### LEGEND

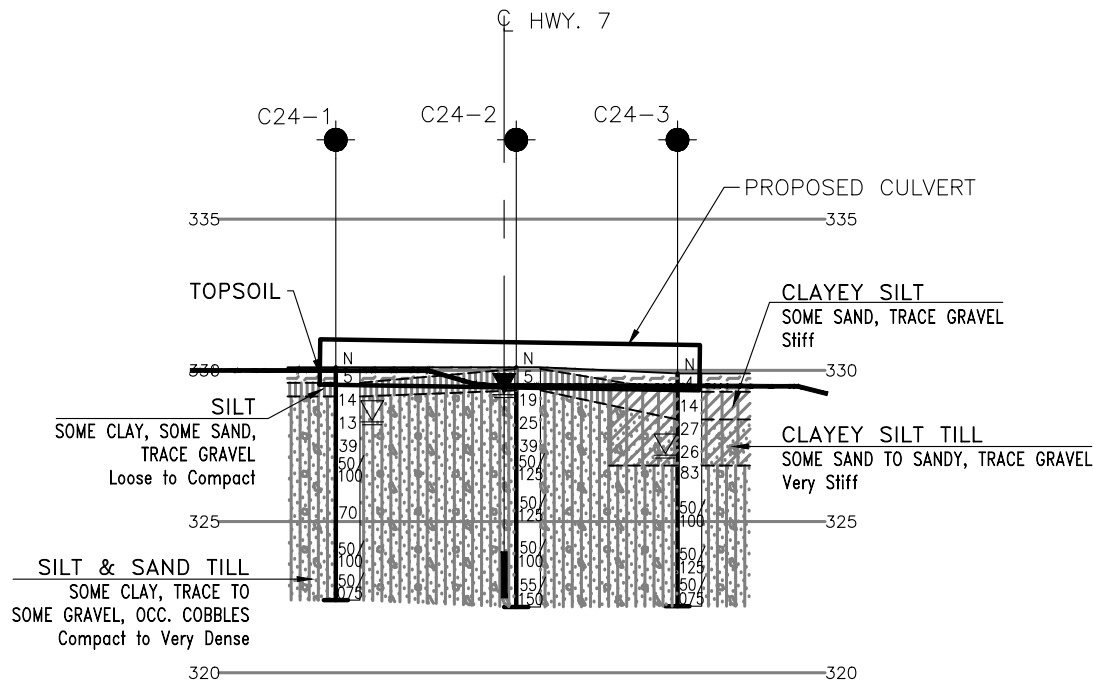
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C24-3	2.59	327.31



**Photo E1:** Looking east from farmers field towards location of proposed Culvert C24.



PLAN  
SCALE 1:1250



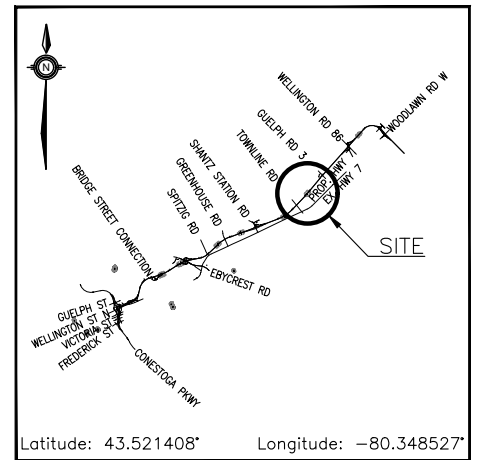
SECTION ALONG A-A

SCALE 1:1250  
SCALE 1:250

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

CONT No  
WP No 408-88-00

HIGHWAY 7 NEW EBL & WBL  
CULVERT C24  
STA. 31+774  
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
C24-1	330.1	4 820 526.8	236 176.6
C24-2	330.1	4 820 508.1	236 200.0
C24-3	329.9	4 820 485.6	236 215.4

-NOTES-

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

GEOCRES No. 40P8-209

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	
CODE	LOAD	DATE	FEB 2020
SITE 35-603/C	STRUCT	DWG	E1



## **Appendix F**

**Culvert C33 – Station 35+890  
(Boreholes C33-1 to C33-3)**

**Record of Borehole Sheets  
Laboratory Test Results  
Analytical Laboratory Test Results  
Drawing titled “Borehole Locations and Soil Strata”**

# RECORD OF BOREHOLE No C33-01

1 OF 2

METRIC

GWP# 408-88-00 LOCATION Culvert 33, MTM NAD 83 Zone 10: N 4 823 628.7 E 238 887.9 ORIGINATED BY GA  
 DIST HWY 7 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY MFA  
 DATUM Geodetic DATE 2017.06.27 - 2017.06.27 LATITUDE 43.549676 LONGITUDE -80.315720 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
340.4	GROUND SURFACE							<div>20406080100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>20406080100</div>					<div>PLASTIC LIMIT</div> <div>NATURAL MOISTURE CONTENT</div> <div>LIQUID LIMIT</div> <div>W P W W L</div> <div>WATER CONTENT (%)</div> <div>204060</div>		GR SA SI CL			
0.0	<b>TOPSOIL</b> , occasional roots Loose Black Wet		1	SS	4		340											
339.7																		
0.7	<b>SAND</b> and <b>GRAVEL</b> , some clay, some silt Loose Grey Moist		2	SS	6													
338.9								339										
1.4	Silty <b>SAND</b> , some clay, some gravel Compact Grey Wet		3	SS	14													
338.2																		
2.2	<b>SAND</b> and <b>GRAVEL</b> , trace to some silt, trace clay Dense Grey Wet		4	SS	36			338										
			5	SS	49			337										
	occasional cobbles																	
							336											
			6	SS	50													
							335											
	Very Dense		7	SS	68		334											
							333											
			8	SS	102													
							332											
331.2	Coring started at 9.1m		9	SS	100													
9.1	<b>BEDROCK</b> , limestone, highly to moderately weathered, grey to brown, mechanical breaks horizontal fracture at 9.4m (50mm)				.050		331											
			1	RUN														

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE

## METRIC

[illegible]



# RECORD OF BOREHOLE No C33-02

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Culvert 33, MTM NAD 83 Zone 10: N 4 823 611.1 E 238 916.3 ORIGINATED BY GA  
DIST HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
DATUM Geodetic DATE 2017.06.28 - 2017.06.28 LATITUDE 43.549520 LONGITUDE -80.315366 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
340.9	GROUND SURFACE							20	40	60	80	100			
0.0	<b>TOPSOIL</b> , occasional roots Soft Black Moist		1	SS	2										
340.2															
0.7	<b>SAND</b> and <b>GRAVEL</b> , some silt, some clay Compact Grey Moist to Wet		2	SS	12		340								
			3	SS	21		339								
338.7															
2.2	Silty <b>SAND</b> , some clay Compact Grey Wet		4	SS	22		338								
337.9															
3.0	Dense Wet		5	SS	34		337								
	cobbles at 4.0m														
336.6															
4.3	Clayey <b>SILT</b> , some gravel, some sand Very Stiff Grey Moist to Wet (TILL)		6	SS	18		336								
	Hard		7	SS	100/ .250		335								
	Wet		8	SS	70/ .075		334								
332.7							333								
8.2	END OF BOREHOLE AT 8.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 2.1m UPON COMPLETION OF DRILLING. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen.  WATER LEVEL READINGS DATE        DEPTH(m)    ELEV.(m) 2018.03.23    0.3        340.6														

ONTMT4S2 MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 11/16/18

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C33-03

1 OF 1

METRIC

GWP# 408-88-00 LOCATION Culvert 33, MTM NAD 83 Zone 10: N 4 823 598.1 E 238 942.7 ORIGINATED BY GA  
 DIST HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA  
 DATUM Geodetic DATE 2017.06.28 - 2017.06.28 LATITUDE 43.549405 LONGITUDE -80.315038 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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								20   40   60   80   100			W P                      W                      W L				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE							
340.8	GROUND SURFACE					▽									
0.0	TOPSOIL, occasional roots Very Loose Black Moist		1	SS	2									83	
340.1															
0.7	Silty SAND, some gravel, some clay Compact Grey Moist to Wet		2	SS	12										
339.3															
1.4	Silty CLAY, some sand to sandy, trace gravel Stiff Grey Moist (TILL)		3	SS	12										2   27   40   31
338.5															
2.2	SAND and GRAVEL, some silt, trace clay Compact Grey Wet		4	SS	28										
			5	SS	22										
336.6															
4.1	Clayey SILT, some sand to sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		6	SS	39									7   39   39   15	
	Wet		7	SS	75										
333.7															
7.0	END OF BOREHOLE AT 7.0m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 1.5m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.														

ONTMT452 MTO-11375.GPJ 2017TEMPLATE(MTO).GDT 11/16/18

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

20  
15  
10

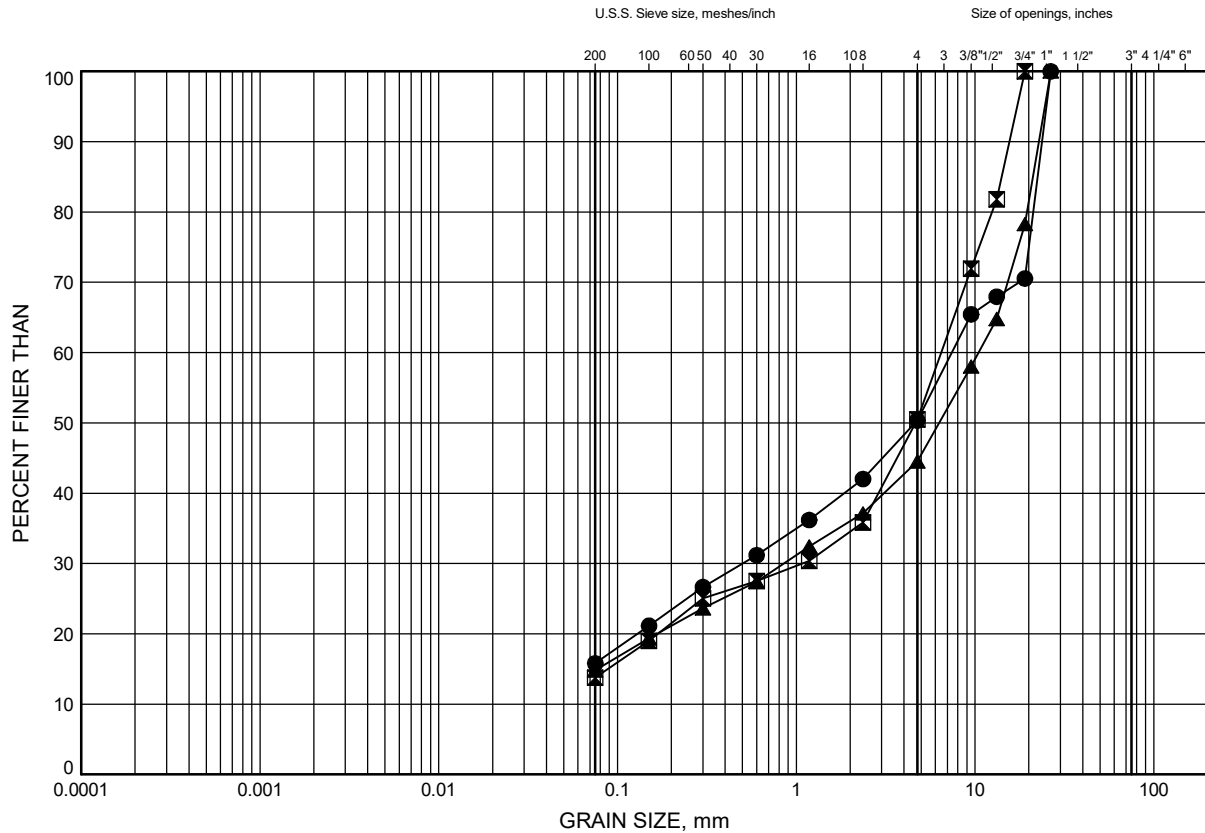
(%) STRAIN AT FAILURE

# Culvert 33

## GRAIN SIZE DISTRIBUTION

FIGURE F1

### Sand and Gravel



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C33-01	3.4	337.0
⊠	C33-01	9.1	331.3
▲	C33-02	3.4	337.5

Date April 2018  
GWP# 408-88-00



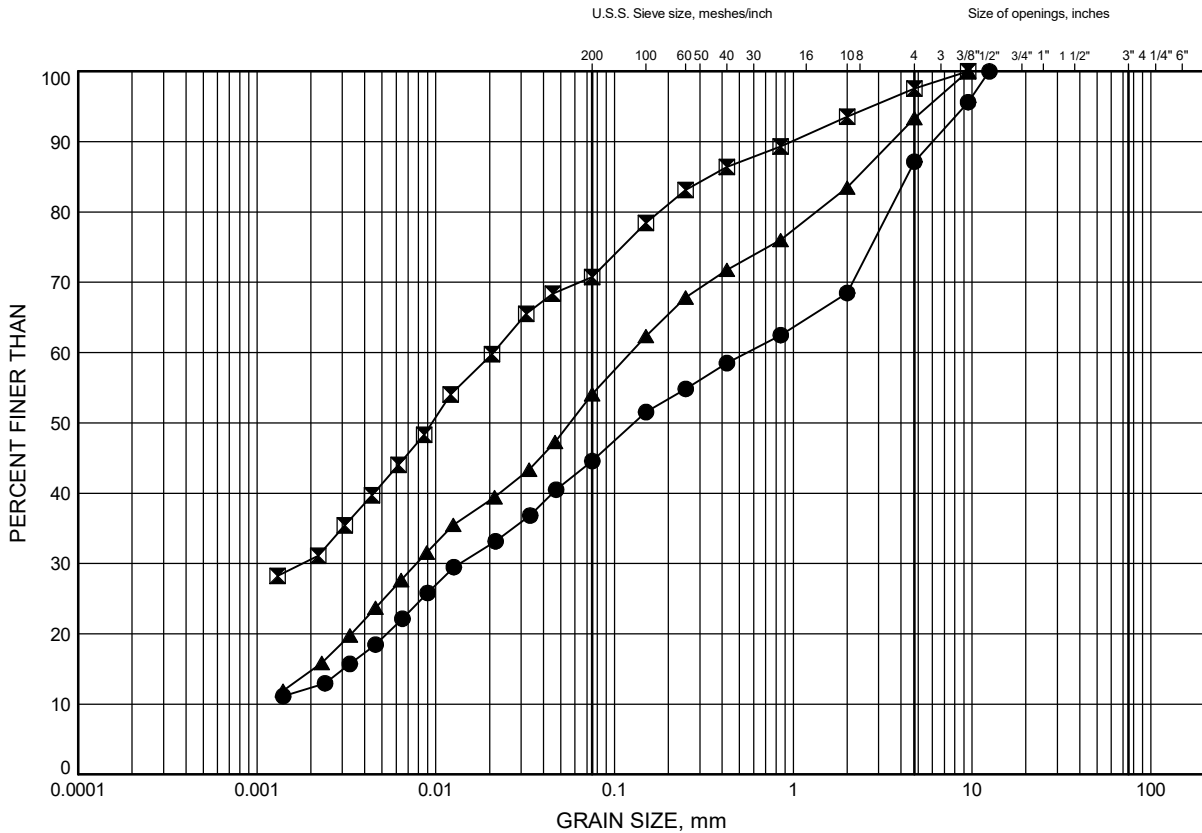
Prep'd MFA  
Chkd. RPR

# Culvert 33

## GRAIN SIZE DISTRIBUTION

FIGURE F2

### Silty Clay to Clayey Silt Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C33-02	6.4	334.5
⊠	C33-03	1.8	338.9
▲	C33-03	4.9	335.9

Date April 2018

GWP# 408-88-00



Prep'd MFA

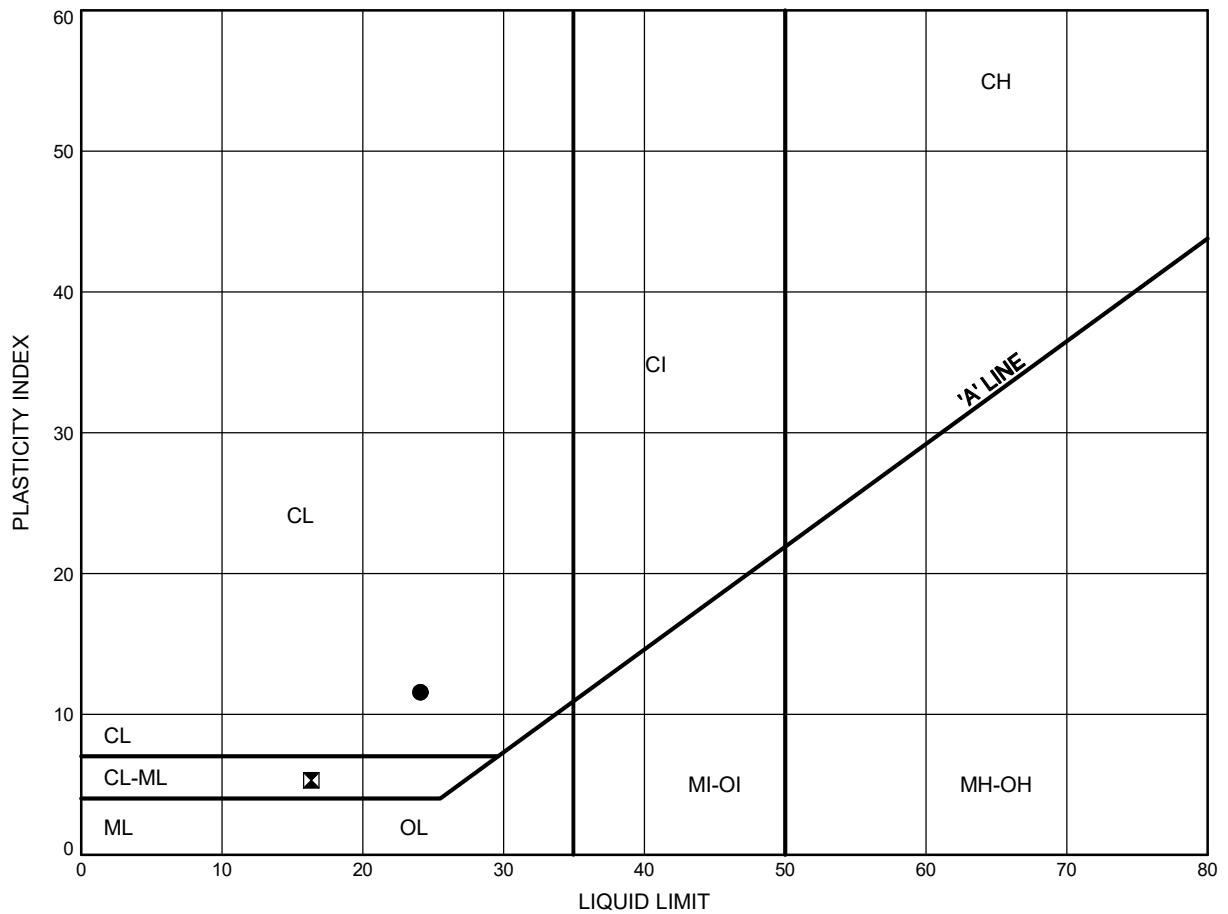
Chkd. RPR

Culvert 33

# ATTERBERG LIMITS TEST RESULTS

FIGURE F3

Silty Clay Till and Clayey Silt Till



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C33-03	1.8	338.9
⊗	C33-03	4.9	335.9

Date April 2018  
GWP# 408-88-00



Prep'd MFA  
Chkd. RPR



## POINT LOAD TEST SHEET

<b>Job No :</b>	11375	<b>Client :</b>	WSP
<b>Project Name :</b>	Highway 7	<b>Date Drilled :</b>	2017-06-27
<b>Core Size :</b>	HQ	<b>Date Tested :</b>	2017-07-06
<b>BH No :</b>	CV16-01	<b>Tester :</b>	ISP

Test No.	Run No.	Depth (m)	Axial or Diametral	Force (kN)	Diameter (mm)	Length (mm)	UCS (MPa)	Rock Type	Notes
1	1	9.3	A	14.4	62.4	84.5	64.1	Limestone	Strong
2	1	9.4	A	12.1	62.1	70.8	62.3	Limestone	Strong
3	2	7.6	A	13.2	62.0	71.0	67.7	Limestone	Strong
4	2	10.9	A	2.3	62.4	77.1	10.9	Limestone	Weak
5	2	11.0	D	14.2	62.3	47.3	96.9	Limestone	Strong
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

\* It is ideal to perform axial test on core specimens with D/L ratio of  $1.1 \pm 0.1$

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

\* Diametral Test should have  $0.7 \times D$  on either side of test point.

\* A conversion factor of 24 was used to calculate the UCS.



Photo 1 – Rock core from Borehole C33-01



## 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
Conductivity	uS/cm	2		259	295	216	253	164	357	133	118

## PACKAGE: - General Chemistry (SOIL)

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

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

## PACKAGE: - Metals and Inorganics (SOIL)

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

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

## PACKAGE: - Metals and Inorganics (SOIL)

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

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



# FINAL REPORT

CA14400-MAR18 R

Client: Thurber Engineering Ltd.

Project: 11375

Project Manager: Rocío Reyna

Samplers: Kamil Feszak

PACKAGE: - Other (ORP) (SOIL)

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

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

PACKAGE: - Other (ORP) (SOIL)

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

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

PACKAGE: - PHCs (SOIL)

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

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

PACKAGE: - PHCs (SOIL)

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

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

## 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-IENVIEWL-LAK-AN-001

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

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

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

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

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

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

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

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

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

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

## LEGEND

## FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

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

**ND** Non Detect

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

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

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

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-- End of Analytical Report --





# Request for Laboratory Services and CHAIN OF CUSTODY

No:

Page 1 of 2

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

Received By:

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

Received By (signature):

Custody Seal Present:

Custody Seal Intact:

Laboratory Information Section - Lab use only

Cooling Agent Present:

Temperature Upon Receipt (°C)

LAB LIMS #:

## REPORT INFORMATION

Company: Thurber Eng.

Contact: Rocio Palomares Reyna

Address: 103-2010 Winstonpark Dr.

Oakville, ON

Phone: 905-829-8666 x260

Fax:

Email: rreynae@thurber.ca

## INVOICE INFORMATION

☒ (same as Report Information)

Company:

Contact:

Address:

Phone:

Email:

## PROJECT INFORMATION

Quotation #:

Project #:

P.O. #:

Site Location/ID:

## TURNAROUND TIME (TAT) REQUIRED

Regular TAT (5-7 days) ☒ Rush TAT (Additional Charges May Apply) ☐ 1 Day ☐ 2 Days ☐ 3-4 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

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date: Rush Confirmation ID:

## REGULATIONS

### Regulation 153 (2011):

☐ Table 1 ☐ Res/Park ☐ Soil Texture:

☐ Table 2 ☐ Ind/Com ☐ Coarse

☐ Table 3 ☐ Agri/Other ☐ Medium

☐ Table ☐ Fine

### Other Regulations:

☐ Reg 347/558 (3 Day min TAT)

☐ PWQO ☐ MMER

☐ CCME ☐ Other:

☐ MISA

### Sewer By-Law:

☐ Sanitary

☐ Storm

Municipality:

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

### SAMPLE IDENTIFICATION

DATE SAMPLED

TIME SAMPLED

# OF BOTTLES

MATRIX

1 TR-04 -SSS

2 SH16-0A S54

3 GRB16-2 S54

4

5

6

7

8

9

10

## ANALYSIS REQUESTED

COMMENTS:

Field Filtered (F)

Preserved (P)

Observations/Comments/Special Instructions

Sampled By (NAME): KAMIL FESZAK

Relinquished by (NAME): Sarah Hashim

Signature: [Signature]

Signature: [Signature]

Date: 03/11/2018

Date: 03/11/2018

Pink Copy - Client

Yellow & White Copy - SGS



# 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 (mm/dd/yyyy)

Received Time: 11:00 AM

## Laboratory Information Section - Lab use only

Received By (signature): [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: Rocio Palomares Reyna

Address: 103-2010 Winston Dr. Oakville, ON

Phone: 905-824-8666

Fax: 905-824-8666

Email: preyna@thurber.ca

## INVOICE INFORMATION

☒ (same as Report Information)

Company:

Contact:

Address:

Phone:

Fax:

Email:

## PROJECT INFORMATION

Quotation #: 11375

Project #: 11375

P.O. #: 11375

Site Location/ID: 11375

## TURNAROUND TIME (TAT) REQUIRED

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

☐ Regular TAT (5-7days)

☐ Rush TAT (Additional Charges May Apply)

☐ 1 Day

☐ 2 Days

☐ 3-4 Days

RUSH TAT (Additional Charges May Apply)

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 ☐ MMR

☐ CCME ☐ Other:

☐ MISA

Sewer By-Law:

☐ Sanitary

☐ Storm

Municipality:

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

### SAMPLE IDENTIFICATION

	DATE SAMPLED	TIME SAMPLED	# OF BOTTLES	MATRIX
1	BS16-04	SS4	1	Soil
2	GH16-04	SS8	1	
3	RC16-02	SS3	1	
4	LR04	SS3	1	
5	EB16-03	SS5	1	
6	<del>EB16-03</del>	<del>SS5</del>	1	
7	SP16-04	SS4	1	
8	CV16-01	SS3	1	
9	GRB16-10	SS4	1	
10	HC16-05	SS3	1	

Observations/Comments/Special Instructions

## ANALYSIS REQUESTED

COMMENTS:  
Field Filtered (F)  
Preserved (P)

Sampled By (NAME): KAMIL FESZAK

Relinquished by (NAME): Sarah Hashemi

Signature: [Signature]

Signature: [Signature]

Date: 03/19/18

Date: 03/19/18

Pink Copy - Client

Yellow & White Copy - SGS





## SAMPLE INTEGRITY REPORT

Project Number: 11375

ONTARIO REGULATION 153/04

SGS Sample ID CA 14400 - MAR 18

Date / Time Sampled See CoFC

Client Sample ID See CoFC

ALL

## Sample Submission General Sample Integrity Violations

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

## 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"/> |

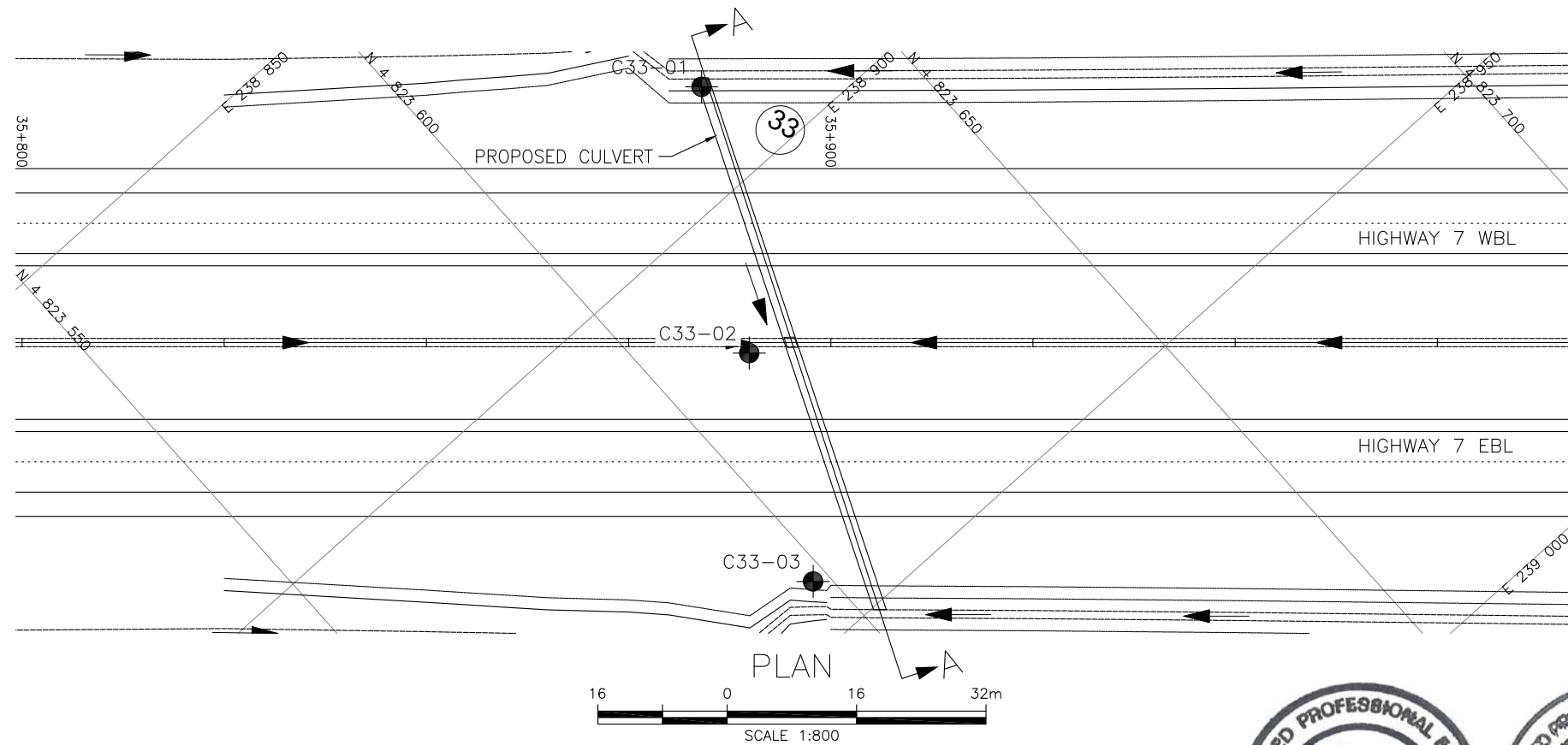
## Additional Comments/Remarks:

No issues upon receipt



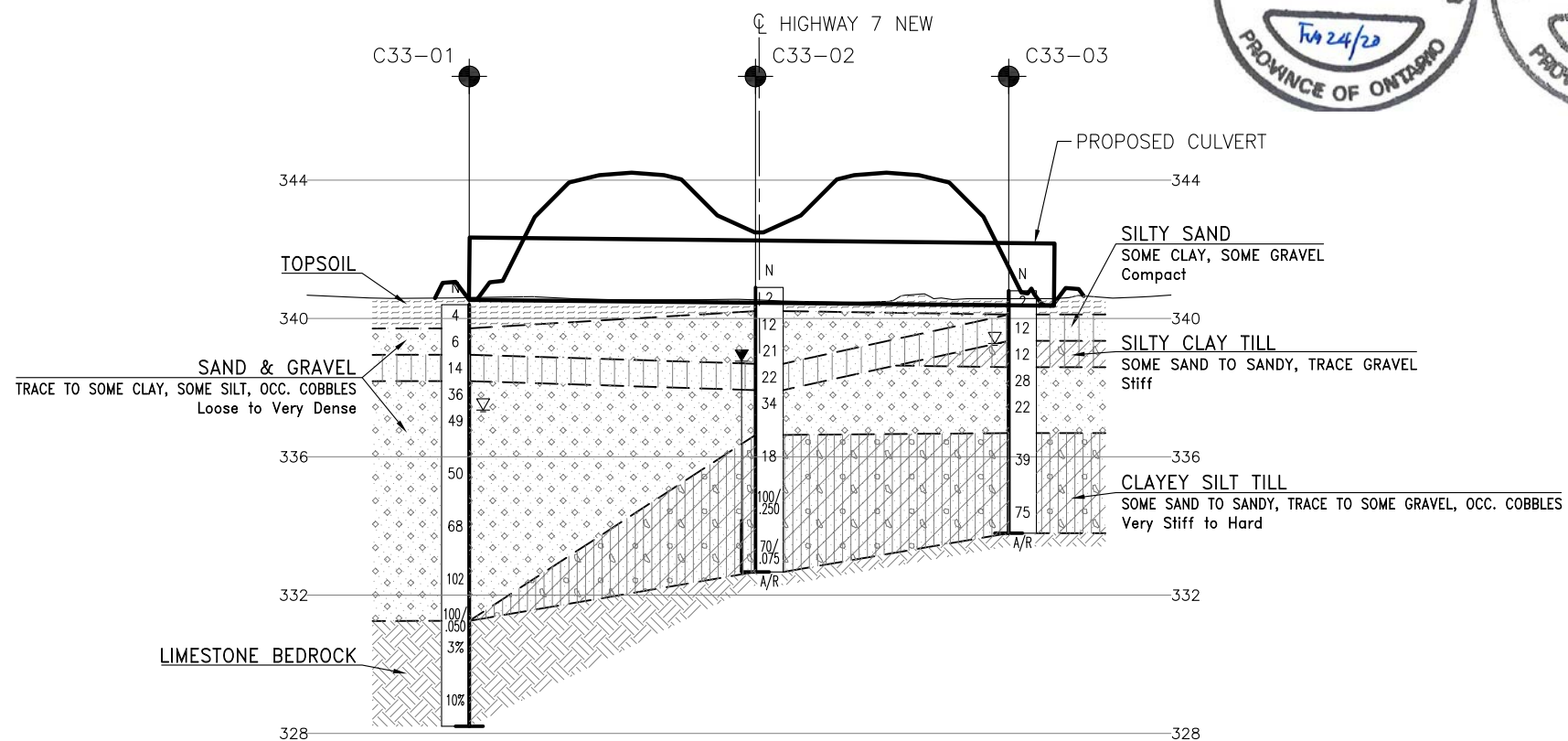
Initials:

KH



PLAN

SCALE 1:800



SECTION A-A (CULVERT 33)

SCALE 1:800  
V 1:200

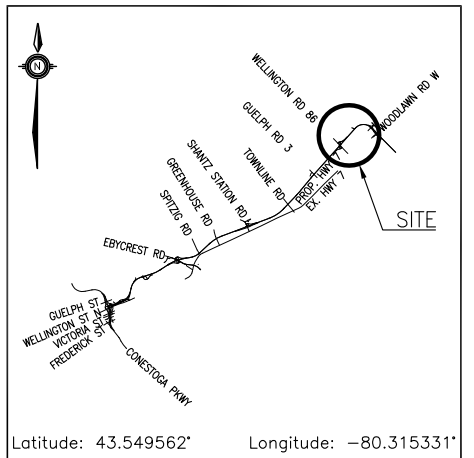
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No 408-88-00

HIGHWAY 7  
STATION 35+895.2  
PROPOSED CULVERT 33  
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
W	Water Level
↑	Head Artesian Water
↓	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
C33-01	340.3800	4823628.6870	238887.8670
C33-02	340.8890	4823611.1110	238916.3350
C33-03	340.7550	4823598.1460	238942.6510

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.

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK PKC	CODE
DRAWN	MFA	CHK RPR	SITE
			LOAD
			DATE
			FEB 2020
			DWG 1



## **Appendix G**

### **Foundation Comparison**

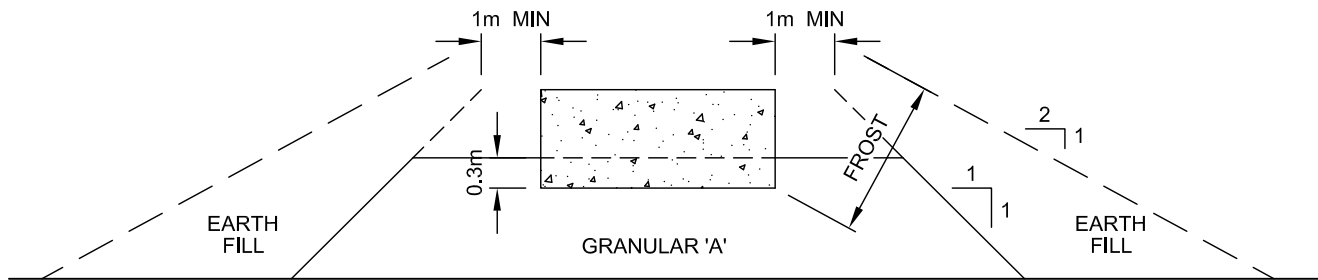
## COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Open Footing Culvert on Native Soil	Footings on Engineered Fill	Closed Box Culvert	Corrugated Steel Pipe (CSP) Culvert
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Eliminates bedding requirement.</li> <li>iii. Lower cost than deep foundations</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Potential settlement due to embankment loading.</li> <li>ii. Subexcavation may be required to penetrate soft or organic material if encountered.</li> <li>iii. Dewatering may be required prior to excavation at some sites. Requires deeper excavation below the groundwater level.</li> <li>iv. Shallow foundations close to water would be at risk due to scour, erosion and undermining problems.</li> <li>v. Potential disturbance of creek/water course during excavation.</li> <li>vi. Cannot tolerate differential settlement.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Would permit use of higher geotechnical resistance than is available on the native soil.</li> <li>ii. Founding level may be placed higher.</li> <li>iii. Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Cost of construction of engineered fill.</li> <li>ii. Potential for settlement in subgrade.</li> <li>iii. Subexcavation may be required to penetrate soft or organic material if encountered</li> <li>iv. Dewatering may be required prior to excavation at some sites.</li> <li>v. Shallow foundations close to water would be at risk due to scour, erosion and undermining problems.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used.</li> <li>ii. Segmental option can accommodate limited amount of potential differential settlement along culvert axis.</li> <li>iii. Less requirement for soil geotechnical resistances as loading is spread over a larger width.</li> <li>iv. Can accommodate and minimizes differential settlement.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. More expensive than a CSP culvert.</li> <li>ii. Requires subexcavation of soft or organic material from streambed if encountered.</li> <li>iii. Culvert subgrade preparation and bedding placement must be carried out in the dry.</li> <li>iv. May require dewatering prior to subexcavation at sites with cohesionless soils and high water table.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. CSP's can accommodate small differential settlement along culvert axis.</li> <li>iii. Steel pipes are likely to be more cost effective than concrete box or open footing culverts.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Multiple pipes may be needed to meet hydraulic requirements.</li> <li>ii. CSP cannot be rehabilitated as concrete culverts.</li> <li>iii. Culvert subgrade preparation and bedding placement must be carried out in the dry.</li> <li>iv. Dewatering is required.</li> <li>v. Requires subexcavation of soft or organic material from streambed if encountered.</li> </ul>
<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>FEASIBLE</b>

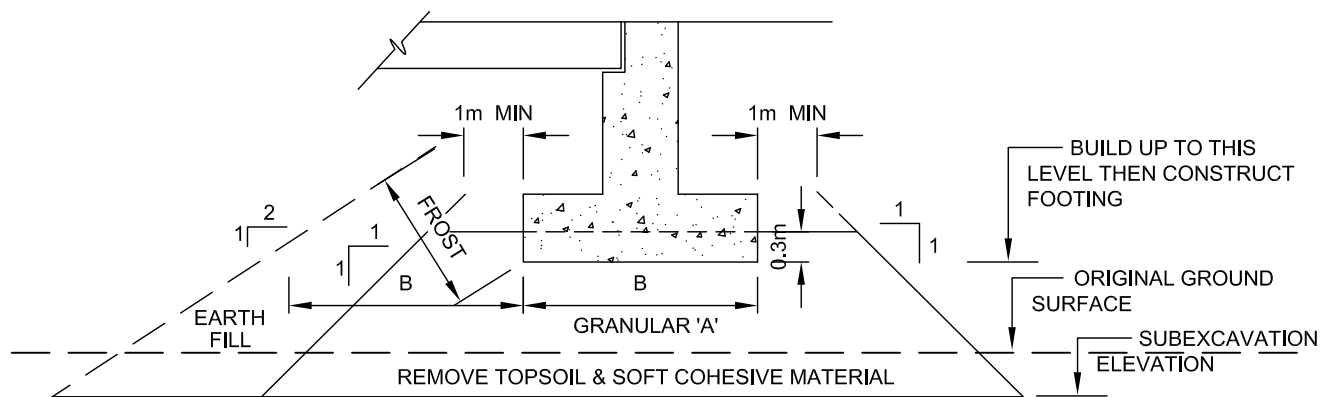


## Appendix H

### Figure 1



## CROSS-SECTION



## LONGITUDINAL SECTION

### NOTES:

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

ABUTMENT ON COMPACTED FILL  
SHOWING GRANULAR 'A' CORE



**THURBER ENGINEERING LTD.**

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





## **Appendix I**

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



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

- |                  |   |
|------------------|---|
| - OPSS PROV 206  | Construction specification for grading  |
| - OPSS PROV 209  | Construction specification for embankments over swamps and compressible soils                 |
| - OPSS PROV 501  | Construction specification for compacting   |
| - OPSS.PROV 511  | Construction specification for rip-rap, rock protection, and granular sheeting                |
| - OPSS.PROV 517  | Construction specification for dewatering   |
| - SP 517F01      | Amendment to OPSS 517   |
| - OPSS PROV 804  | Construction specification for seed and cover   |
| - OPSS PROV 902  | Construction specification for excavating and backfilling – Structures                        |
| -                |   |
| - SP 109S12      | Amendment to OPSS 902   |
|                  | Conformance   |
| - OPSS PROV 1004 | Material specification for aggregates - miscellaneous   |
| - OPSS PROV 1010 | Material specification for aggregates - base, subbase, select subgrade, and backfill material |
| - OPSS PROV 1205 | Material specification for clay seal  |
| - OPSD 802.014   | Flexible pipe embedment in embankment. original ground: earth or rock                         |
| - OPSD 803.031   | Frost treatment – pipe culverts, frost penetration line between top of pipe and bedding grade |
| - OPSD 810.010   | General rip-rap layout for sewer and culvert outlets  |



## **2. Suggested Wording for NSSP on Dewatering**

Effective dewatering shall be designed and provided by the Contractor during culvert excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.