

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
STRUCTURAL CULVERTS  
HIGHWAY 69 FOUR-LANING  
FROM THE SOUTH JUNCTION OF HIGHWAY 529 NORTHERLY 15 KM  
G.W.P. 5076-06-00  
SOUTH SECTION – HIGHWAY 529 TO NAISCOOT LAKE**

**Geocres Number: 41H-130**

**Report to**

**MMM Group Limited**

**Thurber Engineering Ltd.**  
2010 Winston Park Drive, Suite 103  
Oakville, Ontario  
L6H 5R7  
Phone: (905) 829 8666  
Fax: (905) 829 1166

August 21, 2014  
File: 19-5161-21

## TABLE OF CONTENTS

### **PART 1      FACTUAL INFORMATION**

1	INTRODUCTION.....	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	4
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	4
5.1	Culverts 313 and 314 (Station 19+303 NBL and 19+299 SBL).....	4
5.2	Culverts 317 and 318 (Station 19+830 NBL and SBL).....	8
5.3	Culvert 330 (Station 11+890 Naiscoot Access Rd).....	11
5.4	Culvert 332 (Station 12+357, Naiscoot Access Rd).....	14
6	MISCELLANEOUS.....	17

### **PART 2      ENGINEERING DISCUSSION AND RECOMMENDATIONS**

7	INTRODUCTION.....	18
8	FOUNDATION DESIGN .....	19
8.1	Culverts 313 and 314.....	19
8.2	Culvert 330 .....	20
8.3	Culverts 317 and 318.....	21
8.4	Culvert 332 .....	23
9	BACKFILL AND LATERAL EARTH PRESSURES .....	23
10	SEISMIC CONSIDERATIONS.....	25
11	SCOUR PROTECTION AND EROSION CONTROL .....	26
12	EXCAVATION AND GROUNDWATER CONTROL .....	26
13	CONSTRUCTION CONCERNS.....	27
14	CLOSURE.....	28

## **Appendices**

Appendix A	Culverts 313 and 314
Appendix B	Culverts 317 and 318
Appendix C	Culvert 330
Appendix D	Culvert 332

Appendices A to D include:

- Record of Borehole Sheets
- Laboratory Test Results
- Borehole Locations and Soil Strata Drawings

**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**STRUCTURAL CULVERTS**  
**HIGHWAY 69 FOUR-LANING**  
**FROM THE SOUTH JUNCTION OF HIGHWAY 529 NORTHERLY 15 KM**  
**G.W.P. 5076-06-00**  
**SOUTH SECTION – HIGHWAY 529 TO NAISCOOT LAKE**

**Geocres Number: 41H-130**

**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted for the proposed structural culverts required along a section of the Highway 69 four-laning project extending from Highway 529 northerly approximately 3.8 km to north of Naiscoot Lake. Two of the culverts associated with this project are required along the proposed Naiscoot Access Road (existing Highway 69), located to the west of the proposed Highway 69.

The report is one of two reports addressing a larger section of the four-laning project extending from the south junction of Highway 529 northerly for 15 km in the Townships of Harrison and Wallbridge, Ontario. The report deals with the culverts in the south part of this section; the remaining culverts in the north part of the section are dealt with in a separate report.

The purpose of the investigation was to explore the subsurface conditions at the proposed culvert locations and, based on the data obtained, to provide record of borehole sheets, borehole location plans, stratigraphic profiles, laboratory test results, and a generalized description of the subsurface conditions at each location. This information provides a model of the anticipated geotechnical conditions influencing design and construction of the structural culverts.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM) under the Ministry of Transportation Ontario (MTO) Agreement Number 5006-E-0030.

**2 SITE DESCRIPTION**

Highway 69 in the study section (Highway 529 northerly approximately 3.8 km to north of Naiscoot Lake) is currently a two lane undivided roadway. The proposed four-lane alignment will run roughly parallel to the existing alignment, with a new median centreline approximately 130 m west of the current alignment at the south project limit, before crossing to the east side and running approximately 70 m to the east. Both northbound and southbound lanes will be on new alignment

in this section. The existing Highway 69 will become Naiscoot Access Road as part of the four-laning project.

The roadway corridor typically has a rolling topography with frequent bedrock outcrops of generally low relief, separated by low-lying swamp areas, water bodies, and small streams. In general, the area is heavily wooded except in swamp areas.

The site lies within the physiographic region known as the Georgian Bay Fringe, characterized by very shallow soils and bare rock knobs and ridges. Where present, the overburden materials consist of sand, silt and clay. Recent organic deposits of peat and muck occur in abundance in bedrock hollows and valleys. The area is underlain by strongly foliated and highly to intermediately deformed rocks of Precambrian age, primarily migmatitic rocks and gneisses.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for the six (6) culverts in the south section were carried out in two phases. The first phase consisted of drilling and sampling eleven boreholes located off of the existing Highway 69 between February 11 and March 8, 2011. During the first phase of drilling one Dynamic Cone Penetration Test (DCPT) was performed from surface and a second DCPT was conducted at the base of one of the boreholes. The second phase of drilling was completed during June 2012 and consisted of two boreholes drilled on Highway 69 through the existing highway embankment. During the second phase of drilling a DCPT was conducted from the base of one of the boreholes. In addition to these boreholes and DCPTs specific to the culverts, four boreholes drilled in 2009 for the swamp crossings and high fill embankments investigation (BH10-02, BH11-02, BH13-07, and BH14-08) are included in this report for a total of seventeen boreholes and three DCPTs (one from surface and two from the base of a borehole).

The boreholes drilled at each culvert are listed in Table 3.1 along with additional information regarding the culvert location. In general, one borehole was located at each of the proposed culvert inlets, outlets, and mid points. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawings included in Appendices A through D.

The boreholes were advanced to depths of 1.1 m to 19.8 m (Elev. 191.4 to 179.0 m). The DCPT performed from surface extended to a depth of 13.1 m (Elev. 178.4 m). The two DCPTs conducted from the bottom of a borehole extended to depths of 12.5 m and 27.6 m (Elev. 179.0 and 172.3 m). All of the boreholes and DCPTs were terminated upon refusal on probable bedrock, except for boreholes C330-1 and C330-2 which were extended with a DCPT to refusal and borehole C332-2 which was advanced 1.2 m into bedrock to confirm the rock fill – bedrock interface.

The borehole locations were established by Thurber relative to culvert centreline staking by MMM Group Limited. Ground elevations at the borehole locations were approximated from survey data and detailed topographic plans provided by MMM Group Limited.

**Table 3.1 – Summary of Culvert Locations and Corresponding Boreholes**

Culvert	Site Number	Location		Boreholes/DCPTs	Appendix
		Station	Road/Direction		
313 314	44-600/C1 44-600/C2	19+303 19+299	Hwy 69 NBL Hwy 69 SBL	C313-1 to 3, C314-1 & 2, BH10-02, and BH11-02	A
317 318	44-603/C1 44-603/C2	19+830 19+830	Hwy 69 NBL Hwy 69 SBL	C317-1 & 2, C318-1, BH13-07, and BH14-08	B
330	44-601/C	11+890	Naiscoot Access Rd	C330-1 & 2, C330-2D and C314-2	C
332	44-602/C	12+357	Naiscoot Access Rd	C332-1 to 3	D

Prior to commencement of drilling, utility clearances were obtained for all borehole and DCPT locations.

Where accessible, a CME-45 track-mounted drill rig equipped with hollow stem augers was used to advance the boreholes. Wash-boring methods with casing and portable tripod were employed where drilling was conducted on ice. A truck-mounted drill rig was used for boreholes drilled on the existing Highway 69 platform. Hollow stem augers, HQ casing, and NQ coring techniques were used to advance these boreholes.

Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the fill and native soils. Where firm to soft cohesive soils were encountered, in situ vane shear testing was carried out to assess the undrained shear strength of soft to firm cohesive deposits.

Where practical, groundwater conditions were observed in the open boreholes during the drilling operations. Standpipe piezometers were installed in selected boreholes to monitor groundwater levels. The standpipe piezometers consisted of 19 mm diameter PVC pipe with a 1.5 m long slotted screen enclosed in filter sand. A bentonite seal was placed above the filter sand and the remainder of the borehole was backfilled with bentonite and/or cuttings to the ground surface. Boreholes without piezometer installations were backfilled with bentonite and/or auger cuttings upon completion. The piezometers installation details are summarized in Table 3.2 and are shown on the Record of Borehole sheets in Appendices A to D.

**Table 3.2 – Piezometer Installation Details**

<b>Borehole</b>	<b>Piezometer Tip Depth/ Elevation (m)</b>	<b>Installation Details</b>
C317-2	4.3 / 188.1	Piezometer with 1.5 m slotted screen installed, sand filter from 4.3 to 2.5 m, bentonite seal from 2.5 to 2.0 m, cuttings from 2.0 to 0.6 m, bentonite from 0.6 to 0.3 m, then cuttings to surface.
C330-2	9.1 / 182.4	Piezometer with 1.5 m slotted screen installed, sand filter from 9.5 to 7.3 m and bentonite from 7.3 m to ground surface.

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

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are presented on the Record of Borehole sheets included in Appendices A to D.

Selected samples were also subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of the testing program are summarized on the Record of Borehole sheets and figures included in Appendices A to D.

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

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and the Borehole Locations and Soil Strata Drawings included in Appendices A to D of this report. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in this section. However, the factual data presented in the borehole logs takes precedence over this general description and interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

The specific conditions encountered at individual sites vary. Generalized descriptions of the individual strata at each culvert site are presented below.

##### **5.1 Culverts 313 and 314 (Station 19+303 NBL and 19+299 SBL) (Appendix A)**

###### **General**

This site consists of a pond. The site stratigraphy below the pond bottom generally consists of layers of silty clay and peat overlying sand and gravel at the eastern extent of

the site and a thin layer of peat overlying silty sand to sand and gravel at the western extent of the site. Probable bedrock was encountered below these overburden deposits.

### **Ice and Water**

Ice and water were encountered at surface at all seven borehole locations. In general, the ice was approximately 0.3 m thick at the time of drilling. The depth of the ice and water ranged from 1.2 m to 1.6 m.

### **Peat**

A thin layer of peat (25 to 50 mm) was encountered at the ground surface, below the ice and water in Boreholes C313-2, C314-1 and C314-2. The thickness of surficial peat material may vary between and beyond the borehole locations.

A thicker layer of peat was also encountered below a layer of silty clay in Boreholes C313-1 to 3, and BH10-02. This layer of peat was typically fibrous and had a dark brown colour. The peat contained trace sand at some locations.

The thickness of this buried layer of peat ranged from 0.6 m to 1.5 m and the lower boundary of this layer was encountered at depths of 1.3 m to 2.5 m below the pond bottom (Elev. 190.7 to 189.3 m).

SPT ‘N’ values recorded in the peat layer ranged from 0 to 2 blows for 0.3 m penetration, indicating a very soft to soft consistency.

Moisture contents of the peat ranged from 119 to 663%.

### **Silty Clay**

Silty clay was encountered below the water or thin peat layer in five of the seven boreholes drilled along the proposed alignment of the culverts. In three of these boreholes, a second clay layer was encountered below an interlaying layer of peat. The clay layers ranged in thickness from 0.2 to 1.3 m, and the lower boundary of the lowest layers was encountered at depths of 1.6 to 5.2 m below the ice surface, 0.3 to 3.8 m below the pond bottom (Elev. 191.6 to 188.0 m).

SPT ‘N’ values recorded in the silty clay ranged from 0 to 4 blows for 0.3 m penetration, indicating a very soft to soft consistency. A SPT ‘N’ value of 50 blows for 0.125 m penetration was recorded in the silty clay in Borehole C313-2 at the silty clay-bedrock interface.

Moisture contents of the silty clay ranged from 22% to 76%.

Three samples of the silty clay underwent laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are plotted on Figure A1, Appendix A.



Gravel %	0
Sand %	18 to 21
Silt %	50 to 55
Clay %	27 to 29

### **Silt and Sand**

A layer of silt and sand was encountered locally in Borehole C313-3, below the peat. The silt and sand was grey and contained trace clay.

The layer of silt and sand was 1.0 m thick with the lower boundary of this layer encountered at a depth of 2.3 m below the pond bottom (Elev. 189.7 m).

A SPT ‘N’ value of 7 blows for 0.3 m penetration was recorded in the silt and sand layer, indicating a loose relative density.

The moisture content of one sample of the silt and sand was measured to be 15%.

One sample of the silt and sand underwent laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curve for this sample is plotted on Figure A2 of Appendix A.

Gravel %	0
Sand %	42
Silt %	54
Clay %	4

### **Sand**

A layer of sand was encountered below the silty clay in Boreholes C314-1 and BH10-02, below the silt and sand in Borehole C313-3, below the thin peat layer in Borehole C314-2, and at ground surface (below the ice and water) in Borehole BH11-02. The sand was typically grey and contained trace silt to silty, trace gravel to gravelly, and trace clay.

The thickness of the sand layer ranged from 0.5 to 1.3 m, with the lower boundary of the sand layer encountered at depths of 0.8 to 3.7 m below the pond bottom (Elev. 191.1 to 188.0 m).

SPT ‘N’ values recorded in the sand layer ranged from 3 to 17 blows for 0.3 m penetration, indicating a very loose to compact relative density. Higher ‘N’ values were also recorded in the sand layer upon refusal on probable bedrock and are not indicative of the relative density of the sand.

Natural moisture contents of the sand ranged from 14 to 43%. The higher moisture contents (> 23%) were measured in samples collected just below the pond bottom and may reflect an organic component.

One sample of the sand underwent laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curve for this sample is plotted on Figure A3 of Appendix A.

Gravel %	5
Sand %	73
Silt %	20
Clay %	2

### **Sand and Gravel**

A layer of sand and gravel was encountered below the lower layer of silty clay in Borehole C313-1 and below the sand in Borehole C314-2. The sand and gravel was brown to grey and contained trace silt as well as occasional cobbles.

The sand and gravel layer was 4.2 m thick in Borehole C313-1, with the lower boundary of this layer encountered at a depth of 8.0 m below the pond bottom (Elev. 183.8). In Borehole C314-2, the sand and gravel layer was 0.8 m thick with the lower boundary at a depth of 2.2 m below the pond bottom (Elev. 189.4).

SPT ‘N’ values recorded in the sand and gravel generally ranged from 7 to 9 blows for 0.3 m penetration, indicating a loose relative density. ‘N’ values of greater than 50 blows for less than 0.3 m penetration were also recorded in the sand and gravel layer at refusal on probable bedrock.

Natural moisture contents of the sand and gravel ranged from 9 to 15%.

Two samples of the sand and gravel underwent laboratory grain size analysis testing. The results of these tests are summarized below and are presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are plotted on Figure A4 of Appendix A.

Gravel %	39 to 53
Sand %	40 to 55
Silt and Clay %	6 to 7

### **Bedrock**

The boreholes were terminated at depths ranging from 0.8 m to 8.0 m below the pond bottom (Elev. 191.1 to 183.8 m) upon refusal on probable bedrock. The depths and elevations of the probable bedrock surface at the borehole locations are summarized in Table 5.1.

**Table 5.1 – Depth/Elevation of Probable Bedrock**

Borehole	Probable Bedrock Surface	
	Depth below Pond Bottom (m)	Elevation (m)
C313-1	8.0	183.8
C313-2	3.4	188.4
BH10-02	3.7	188.0
C313-3	2.8	189.2
C314-1	0.8	191.1
BH11-02	1.1	190.6
C314-2	2.2	189.4

### **Groundwater Conditions**

Water levels were not observed in the open boreholes as water was introduced into the boreholes during the drilling process.

The ice surface was at Elevation 193.2 m at the time of drilling. The water level in the pond will fluctuate subject to seasonal variations, rainfall patterns, and possible beaver dams.

## **5.2 Culverts 317 and 318 (Station 19+830 NBL and SBL) (Appendix B)**

### **General**

The stratigraphy at this site generally consists of peat and/or organics overlying silty clay and silty sand to sand, underlain by probable bedrock. At one borehole location (C317-1) no silty clay was encountered and at one borehole location (C317-2) no sand was encountered.

### **Peat and Organics**

A layer of fibrous peat and/or organics was encountered at surface in all five boreholes. This layer was dark brown to black and occasionally contained trace sand.

The thickness of the surficial peat/organic layer ranged from 0.1 m to 0.3 m.

A natural moisture content of 91% was measured in one sample.

The thickness of peat and organics may vary between and beyond the borehole locations.

### **Silty Clay**

A layer of silty clay was encountered below the peat in four of the boreholes; no silty clay was encountered in borehole C317-1. The silty clay was brown to grey and contained trace sand with occasional sandy zones and occasional sand seams.

The thickness of the silty clay layer ranged from 1.4 m to 4.1 with the lower boundary of the silty clay encountered at depths of 1.5 m to 4.3 m (Elev. 191.2 to 188.1 m).

SPT ‘N’ values recorded in the silty clay layer ranged from 0 to 11 blows for 0.3 m penetration, indicating a very soft to stiff consistency. Generally, the ‘N’ value was in the range of 3 to 11 blows for 0.3 m penetration (soft to stiff). The undrained shear strength of the silty clay determined by an in situ vane shear strength test in Borehole C317-2 was 50 kPa (firm to stiff).

The moisture content of samples of the silty clay ranged from 20% to 53%.

Five samples of the silty clay underwent laboratory grain size analysis testing. Four of these samples also underwent Atterberg Limits testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B and are presented below. These results are also plotted on Figures B1 and B3, Appendix B.

Gravel %	0
Sand %	3 to 22
Silt %	40 to 57
Clay %	24 to 56
Liquid Limit	33 to 58
Plastic Limit	16 to 22

The results of the Atterberg Limits tests indicate that the silty clay ranges from low plastic to high plastic with group symbol CL to CH.

### **Silty Sand to Sand**

A layer of silty sand to sand was encountered directly below the peat/organics in Borehole C317-1 and below the silty clay layer in Boreholes BH13-07, BH14-08, and C318-1. The silty sand to sand is brown to grey and contains trace gravel, trace to some clay, and occasional cobbles.

The thickness of the sand layer ranged from 0.2 m to 1.4 m with the lower boundary of the silty sand to sand layer encountered at depths of 1.2 m to 4.8 m (Elev. 191.4 to 187.1 m).

SPT ‘N’ values recorded in the silty sand to sand ranged from 53 blows for 0.3 m penetration to 50 blows for 0.075 m penetration. However, all of the ‘N’ values were recorded at borehole refusal upon probable bedrock and are therefore not representative of the denseness of the silty sand to sand layer.

Natural moisture contents of the silty sand to sand ranged from 15 to 25%.

One sample of the silty sand to sand underwent laboratory grain size analysis testing. The results of this test are summarized below and are presented on the Record of Borehole sheets included in Appendix B. The grain size distribution curve for this sample is plotted on Figure B2 of Appendix B.

Gravel %	6
Sand %	61
Silt %	23
Clay %	10

### Bedrock

The boreholes were terminated at depths ranging from 1.2 m to 4.8 m (Elev. 191.4 to 187.1 m) upon refusal on probable bedrock. The depths and elevations of the probable bedrock surface at the borehole locations are summarized in Table 5.2.

**Table 5.2 – Depth/Elevation of Probable Bedrock**

Borehole	Probable Bedrock Surface	
	Depth below Ground Surface (m)	Elevation (m)
C317-1	1.2	191.4
BH13-07	1.8	190.9
C317-2	4.3	188.1
BH14-08	4.8	187.1
C318-1	2.4	190.5

### Groundwater Conditions

Water levels were observed in the open boreholes upon completion of drilling. A standpipe piezometer was installed in Borehole C317-2 to monitor water levels after completion of drilling. The water levels observed in the boreholes upon completion of drilling and subsequently measured in the piezometer are summarized in Table 5.3.

**Table 5.3 – Water Level Observations**

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
C317-1	Feb. 11, 2011	0.9	191.8	Open borehole
BH13-07	Feb. 12, 2009	0.5	192.2	Open borehole
C317-2	Feb. 22, 2011	0.0	192.4	Piezometer
	Mar. 1, 2011	0.0	192.4	Piezometer
	Mar. 13, 2011	0.0	192.4	Piezometer
	Apr. 27, 2011	0.1	192.3	Piezometer
BH14-08	Feb. 12, 2009	0.0	191.9	Open borehole
C318-1	Feb. 11, 2011	0.6	192.3	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.

### **5.3 Culvert 330 (Station 11+890 Naiscoot Access Rd) (Appendix C)**

#### **Pavement Structure**

Pavement structure consisting of a thin layer of asphalt overlying granular fill was encountered in Borehole C330-1, which was drilled through the existing highway shoulder. The asphalt was 40 mm thick.

The granular fill underlying the asphalt consisted of dark brown sand containing some gravel. The sand fill was 1.0 m thick with the lower boundary of the sand fill encountered at Elevation 198.9 m. The moisture content of one sample of the sand fill was measured to be 2%.

#### **Rock Fill**

Rock fill was encountered below the pavement structure in Borehole C330-1. The rock fill consisted of cobble and boulder sized pieces with some gravel. Coring techniques were required to advance the borehole through the rock fill.

The rock fill was 9.2 m thick, with the lower boundary of the rock fill encountered at a depth of 10.3 m (Elev. 189.6 m).

#### **Ice and Water**

Ice and water were encountered at surface at the location of Borehole C314-2. The ice was 0.3 m thick at the time of drilling. The ground surface was encountered 1.6 m below the top of ice (Elev. 191.6 m).

#### **Peat**

A layer of peat was encountered surficially in Borehole C330-2 and at surface (below the water) in Borehole C314-2. At Borehole C330-2 the peat was 0.7 m thick and at Borehole C314-2 the peat was 50 mm thick. The thickness of peat may vary between and beyond the borehole locations.

A SPT ‘N’ value of 4 blows for 0.3 m penetration was recorded in the peat, indicating a soft consistency.

#### **Silt and Sand**

A layer of silt and sand was encountered locally in Borehole C330-2, below the peat. The silt and sand was brown and contained trace gravel and trace clay.

The silt and sand layer was 1.1 m thick, with the lower boundary of the silt and sand encountered at a depth of 1.8 m (Elev. 189.7).

SPT ‘N’ values recorded in the silt and sand layer ranged from 18 to 25 blows for 0.3 m penetration, indicating a compact relative density.

The moisture content of samples of the silt and sand ranged from 8 to 19%.

One sample of the silt and sand was selected for laboratory grain size analysis testing, the results of which are summarized below. The grain size distribution curve for this sample is plotted on Figure C1, Appendix C.

Gravel %	2
Sand %	41
Silt %	54
Clay %	3

### **Sand**

A layer of brown sand was encountered below the sand and gravel layer in Borehole C330-1 and below the silt and sand layer in Borehole C330-2. The sand was brown and contained trace to some gravel and trace to some silt and clay. A layer of grey sand containing some silt and trace gravel was encountered below the thin layer of peat in Borehole C314-2.

The sand encountered in Borehole C314-2 was 1.3 m thick with the lower boundary of the sand encountered at a depth of 3.0 m below the ice level (Elev. 190.2). The sand encountered in Boreholes C330-1 and C330-2 was not fully penetrated and the sampled boreholes were terminated at depths of 19.8 m and 11.3 m, respectively (Elev. 180.1 and 180.2).

SPT ‘N’ values recorded in the sand layer ranged from 0 to 33 blows for 0.3 m penetration, indicating a variable relative density ranging from very loose to dense. In general, the sand had a loose to compact relative density (‘N’ values of 4 to 28).

Moisture contents of samples of the sand typically ranged from 15 to 23%. A moisture content of 40% was measured in a sample of sand collected from just below the water in Borehole C314-2.

Four samples of the sand underwent laboratory grain size analysis testing. The results of these tests are summarized below and are presented on the Record of Borehole sheets included in Appendix C. The grain size distribution curves for these samples are plotted on Figure C2 of Appendix C.

Gravel %	0 to 5
Sand %	73 to 97
Silt and Clay %	3 to 22

### **Sand and Gravel**

A layer of sand and gravel was encountered below the sand layer in Borehole C314-2 and below the rock fill in Borehole C330-1. The sand and gravel was brown and contained trace to some silt.

The thickness of the sand and gravel layer in Borehole C314-2 was 0.8 m, with the lower boundary of this layer encountered at a depth of 3.8 m below the ice surface (Elev. 189.4 m). In Borehole C330-1, the sand and gravel layer was 1.6 m thick with the lower boundary encountered at a depth of 11.9 m below ground surface (Elev. 188.0 m).

SPT ‘N’ values recorded in the sand and gravel in Borehole C330-1 ranged from 3 to 7 blows for 0.3 m penetration, indicating a very loose to loose relative density. In Borehole C314-2, a SPT ‘N’ value of 61 blows for 0.275 m penetration (very dense) was recorded near refusal on probable bedrock.

The moisture content of samples of the sand and gravel ranged from 9 to 10%.

One sample of the sand and gravel underwent laboratory grain size analysis testing. The results of this test are summarized below and are presented on the Record of Borehole sheets included in Appendix C. The grain size distribution curve for this sample is plotted on Figure C3 of Appendix C.

Gravel %	53
Sand %	40
Silt and Clay %	7

### Bedrock

Borehole C314-2 was terminated upon refusal on probable bedrock. Boreholes C330-1 and C330-2 were terminated within the sand layer and a DCPT was performed from the bottom of each of these boreholes to refusal on probable bedrock. A DCPT was also conducted 3 m west of Borehole C330-2 (designated C330-2D). The depths and elevations of the probable bedrock surface at the borehole locations are summarized in Table 5.4.

**Table 5.4 – Depth/Elevation of Probable Bedrock**

Borehole	Probable Bedrock Surface	
	Depth below Ground Surface (m)	Elevation (m)
C314-2	2.2	189.4
C330-1	27.6	172.3
C330-2	12.5	179.0
C330-2D	13.1	178.4

### Groundwater Conditions

Water levels were not observed in the open boreholes upon completion of drilling since water was introduced into the boreholes during the drilling process. One piezometer was installed at this site, in Borehole C330-2, with a 1.5 m long screen encased with filter sand. The water levels observed in the piezometer are summarized in Table 5.5.



**Table 5.5 – Water Level Observations**

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
C330-2	Mar. 13, 2011	0.0	191.5	Piezometer
	Apr. 27, 2011	0.5	191.0	Piezometer

The above values are short-term observations. The surface water depth and depths to groundwater will vary depending upon seasonal fluctuations, rainfall patterns and swamp outlet conditions such as presented by beaver dams. In particular, water levels may be higher after the spring snowmelt or periods of heavy rainfall.

#### **5.4 Culvert 332 (Station 12+357, Naiscoot Access Rd) (Appendix D)**

##### **General**

The stratigraphy encountered at this site generally consists of peat or organics overlying deposits of silty clay and sand overlying bedrock. At the existing highway embankment, the stratigraphy consists of pavement structure overlying rock fill overlying bedrock.

##### **Pavement Structure**

Pavement structure consisting of a thin layer of asphalt overlying granular fill was encountered in Borehole C332-2, which was drilled through the existing highway shoulder. The asphalt was 50 mm thick.

The granular fill consisted of brown gravelly sand containing some silt. The sand fill was 1.1 m thick with the lower boundary of the sand fill encountered at Elevation 196.1 m. The moisture content of one sample of the sand fill was measured to be 4%.

One sample of the granular fill underwent laboratory grain size analysis testing. The results of this testing are presented on the corresponding Record of Borehole sheets included in Appendix D and are plotted on Figure D1, Appendix D. The laboratory results are summarized as follows:

Gravel %	29
Sand %	59
Silt and Clay %	12

##### **Rock Fill**

Rock fill was encountered below the pavement structure in Borehole C332-2. The rock fill consisted of cobble and boulder sized pieces with some gravel and sand. Coring techniques were required to advance the borehole through the rock fill.

The rock fill was 6.4 m thick, with the lower boundary of the rock fill encountered at a depth of 7.5 m (Elev. 189.7 m).

### **Peat and Organics**

A layer of peat 0.8 m thick was encountered at surface in Borehole C332-3 and a layer of organics (200 mm) was encountered at surface in Borehole C332-1. The thickness of peat and organics may vary between and beyond the borehole locations.

### **Silty Clay**

A layer of silty clay was encountered below the organics in Borehole C332-1, below the rock fill in Borehole C332-2, and below a layer of native sand in Borehole C332-3. The silty clay was brown and generally contained trace sand.

The thickness of the silty clay ranged from 0.1 m to 1.9 m, with the lower boundary of the silty clay encountered at depths of 2.1 m to 7.6 m (Elev. 189.8 to 189.1 m). The layer of silty clay was the thinnest in Borehole C332-2, where it was encountered below the rock fill.

SPT ‘N’ values recorded in the silty clay ranged from 5 to 9 blows for 0.3 m penetration, indicating a firm to stiff consistency. A SPT ‘N’ value of 50 blows for 0.1 m penetration was also recorded in the silty clay in Borehole C332-3 at the silty clay – bedrock interface.

The moisture content of samples of the silty clay ranged from 25% to 37%.

Two samples of the silty clay underwent laboratory grain size analysis and Atterberg Limits testing, the results of which are summarized below. The results of these tests are also summarized on the Record of Borehole sheets included in Appendix D and plotted on Figures D2 and D3, Appendix D.

Gravel %	0
Sand %	5
Silt %	42 to 48
Clay %	47 to 53
Liquid Limit	48 to 52
Plastic Limit	21

The results of the Atterberg Limits tests indicate that the silty clay is medium to high plastic with group symbol CI-CH.

### **Sand**

A layer of brown sand containing some silt to silty was encountered below the silty clay in Borehole C332-1 and below the peat in Borehole C332-3.

The thickness of the sand layer ranged from 0.1 m to 0.6 m, with the lower boundary of the sand layer encountered at depths of 1.4 m to 2.2 m (Elev. 190.2 to 189.7 m). Borehole C332-1 was terminated below the sand layer upon refusal on probable bedrock.

A SPT ‘N’ value of 4 blows for 0.3 m penetration was recorded in the sand in Borehole C332-3, indicating a very loose to loose relative density.

The moisture content of one sand sample was measured to be 19%.

### Bedrock

Boreholes C332-1 and C332-3 were terminated upon refusal on probable bedrock and Borehole C332-2 was advanced 1.2 m into the bedrock to confirm the transition from rock fill to bedrock. The depths and elevations of the probable bedrock surface at the borehole locations are summarized in Table 5.6.

**Table 5.6 – Depth/Elevation of Probable Bedrock**

Borehole	Probable Bedrock Surface	
	Depth below Ground Surface (m)	Elevation (m)
C332-1	2.2	189.7
C332-2	7.6	189.6
C332-3	2.5	189.1

### Groundwater Conditions

Water levels were observed in the open boreholes upon completion of drilling, where possible. The water levels observed during drilling are summarized in Table 5.7.

**Table 5.7 – Water Level Observations**

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
C332-1	Feb. 2, 2011	0.0	191.9	Open borehole
C332-3	Feb. 2, 2011	0.1	191.5	Open borehole

The above values are short-term observations. The surface water depth and depths to groundwater will vary depending upon seasonal fluctuations, rainfall patterns and swamp outlet conditions such as presented by beaver dams. In particular, water levels may be higher after the spring snowmelt or periods of heavy rainfall.

## 6 MISCELLANEOUS

MMM Group survey personnel staked the centreline alignment of the culverts prior to drilling of the boreholes. The borehole locations were established by measuring offset distances from the centreline staking. The approximate ground surface elevations at the boreholes were interpreted from the survey data and contour plan provided by MMM Group Limited.

Eastern Ontario Diamond Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling and sampling equipment for the field program.

Supervision of the field activities, including obtaining utility clearances, was carried out by Ms. Eckie Siu, Mr. Stephane Loranger, Mr. Jason Mei and Mr. Will Ball of Thurber.

Supervision of the field program was carried out by Ms. Lindsey Blaine, E.I.T. and Ms. Rocío Palomeque Reyna, P. Eng. Interpretation of the field data and preparation of the report was performed by Ms. Lindsey Blaine, E.I.T. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

### Thurber Engineering Ltd.

Lindsey Blaine, E.I.T.  
Project Manager

Murray R. Anderson, P.Eng.  
Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.  
Review Principal



**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**STRUCTURAL CULVERTS**  
**HIGHWAY 69 FOUR-LANING**  
**FROM THE SOUTH JUNCTION OF HIGHWAY 529 NORTHERLY 15 KM**  
**G.W.P. 5076-06-00**  
**SOUTH SECTION – HIGHWAY 529 TO NAISCOOT LAKE**

**Geocres Number: 41H-130**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 INTRODUCTION**

This report presents interpretation of the geotechnical data in the factual report and presents foundation recommendations for design of the structural culverts.

The south section of the Highway 69 four-laning project, extending from Highway 529 northerly approximately 3.8 km to north of Naiscoot Lake, will require installation of four structural culverts under the new highway alignment and two structural culverts through the existing Highway 69 embankment. A description of the proposed culvert installations is presented in Table 7.1.

**Table 7.1 – Proposed Structural Culverts**

<b>Culvert ID</b>	<b>Station</b>	<b>Description</b>	<b>Box Culvert Size (m)</b>	<b>Proposed Length (m)</b>	<b>Approx. Fill Height Above Top of Culvert (m)</b>
313	19+303	New culvert under future NBL	3.0 x 3.0	38.9	5.7
314	19+299	New culvert under future SBL	3.0 x 3.0	39.0	5.7
330	11+890	Culvert replacement under existing Hwy69 (new Naiscoot Access Rd)	3.0 x 3.0	36.9	5.8
317	19+830	New culvert under future NBL	3.0 x 3.0	35.6	2.3
318	19+830	New culvert under future SBL	3.0 x 3.0	34.3	2.4
332	12+357	New culvert under existing Hwy69 (new Naiscoot Access Rd)	3.0 x 3.0	30.0	3.0

The plans and sections used for preparation of this report were provided by MMM Group. The discussion and recommendations are based on the information provided by MMM Group and the factual data obtained in the course of the investigation.

## **8 FOUNDATION DESIGN**

In general, the proposed culverts will be installed through the existing Highway 69 embankment or within sections of swamp where foundation treatment will be required for construction of the new highway embankments. Recommendations for the treatment of swamp crossings are presented in a separate Foundation Investigation and Design Report: *Swamp Crossings and High Fill Embankments, Highway 69 Four-Laning from the south junction of Highway 529 northerly 15 km, South Section – Highway 529 to Naiscoot Lake*, dated December 13, 2012. This culvert report should be read in conjunction with the swamp crossing report.

Following treatment of the swamps, the culvert subgrade conditions within swamp sections will be different from the conditions shown on the borehole logs. The recommendations presented in this report take into consideration the proposed swamp treatments when discussing the culvert foundation conditions.

As the culvert sites are generally located within swamp areas with standing water or high groundwater levels, closed box culverts are the recommended option to expedite installation, and recommendations regarding foundation treatment for this culvert type are presented below. Comments regarding foundations for open footing culverts are also presented in the event that the design concept changes. A comparison of the technical advantages and disadvantages of the different foundation schemes is provided in Table 8.1 appended at the end of the report text.

Use of precast segmental concrete culverts is preferred over cast-in-place culverts to expedite installation as dewatering below the culvert base level is unlikely to be practical at most locations.

### **8.1 Culverts 313 and 314**

#### **Box Culverts**

Culverts 313 and 314 will extend under the northbound and southbound lanes of Highway 69, respectively. The design invert level will range from Elev. 191.43 at the east end of Culvert 313 to Elev. 191.41 at the west end of Culvert 314. The culverts will be constructed with headwalls at the inlet and outlet.

At present, the existing strata at the culvert base level typically consist of very soft silty clay and peat along Culvert 313 and the east end of Culvert 314, and loose to very loose sand/silt under the remainder of Culvert 314. However, swamp treatment at this location will involve excavation of the peat and clay followed by backfilling with rock fill. Consequently the subgrade for culvert and headwall foundations will vary from rock fill to sand.

The culvert location is currently a pond with water depths of 1.2 to 1.6 m measured at the time of the field investigation. The culvert base level is expected to be approximately 2 m below the water level. Preparation of the culvert subgrade will therefore be carried out

underwater, and compaction and chinking of the rock fill, as well as compaction of granular bedding material, will not be possible.

To provide a uniform subgrade for the conditions at this site, it is recommended that culvert subgrade preparation involve excavation and replacement of all peat and clay with rock fill (as per the proposed swamp treatment) to within 450 mm of the culvert base level, then placement of a uniform 450 mm thick bedding and levelling layer of 53 mm clear stone (OPSS.PROV 1004). To facilitate establishment of a reasonably level rock fill surface below the culvert bedding, the rock fill must be placed in a manner that avoids having large boulders protruding into the bedding layer producing a hard point below the culvert base. The recommended wording for an NSSP addressing this requirement is as follows: “Rock fill placed under the culvert base must have a suitable gradation and be placed in a manner that establishes a reasonably flat, level surface on which to place the culvert bedding material. Care shall be taken to avoid large boulders and rock fragments protruding into the bedding layer.”.

The culvert and headwall foundations founded directly on a 53 mm clear stone bedding layer and subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	450 kPa
Geotechnical Resistance at SLS	=	300 kPa

These resistance values are for vertical, concentric loads. For headwall foundations, where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

Differential settlements in the order of 50 mm may be anticipated due to the variable loading and subgrade conditions along the length of the culverts. The culvert design must be capable of accommodating this magnitude of settlement.

### **Open Footing Culverts**

In view of the water depth and the variable subgrade conditions at this location, use of open footing culverts is not recommended from a foundations perspective, and this option has not been developed further.

## **8.2 Culvert 330**

### **Box Culvert**

Culvert 330 will be installed through the existing Highway 69 embankment consisting of rock fill. The design invert level will be approximately Elev. 191.41. At this level, the

culvert subgrade is expected to consist of rock fill within the embankment, loose to compact sand at the inlet, and peat over compact silt and sand at the outlet (west end).

At the time of investigation, a beaver dam existed along the east side of the existing highway embankment. The water level in the beaver pond to the east of the embankment was at approximate Elev. 193.2, while groundwater was measured at Elev. 191.5 to 191.0 on the west (downstream) side of the embankment. Excavation through the existing embankment and consequent removal of the beaver dam would presumably lower the pond water level to the lower values measured.

Provided the water level is lowered, installation of a box culvert at the proposed level is considered feasible. Preparation of the culvert subgrade should involve excavation to the subgrade level, subexcavation of all peat and organic materials, and placement of a uniform 450 mm thick bedding and levelling layer of 53 mm clear stone (OPSS.PROV 1004).

The culvert founded directly on a 53 mm clear stone bedding layer and subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	300 kPa
Geotechnical Resistance at SLS	=	150 kPa

As the embankment will not be widened or raised, foundation settlement is not expected to be an issue and cambering of the culvert is not considered necessary.

If the water level in the pond must be maintained, installation of a sheet pile cofferdam or earthen dam upstream of the culvert inlet will be required to permit lowering of the water level within the embankment for culvert installation.

### **Open Footing Culvert**

Construction of an open footing culvert at this location would require a dewatering system, possibly including a sheet pile wall enclosure, to permit excavation and dewatering to construct footings below the water level in permeable sands. Further, the geotechnical resistance of the foundation soils is low, variable and unlikely to be adequate for spread footing design. Therefore use of an open footing culvert is not recommended from a foundations perspective and this option has not been developed further.

## **8.3 Culverts 317 and 318**

### **Box Culverts**

Culverts 317 and 318 will extend under the northbound and southbound lanes of Highway 69, respectively. The design invert level will range from Elev. 192.22 at the east end of Culvert 317 to Elev. 191.98 at the west end of Culvert 318.



At present, the existing strata at the culvert base level typically consist of peat and soft to stiff silty clay, with the exception of the east end of Culvert 317 where sand was encountered. Swamp treatment at this location will involve excavation of all peat and clay followed by backfilling with rock fill. Consequently the culvert subgrade will primarily consist of rock fill, locally sand.

It is anticipated that rock fill placement below the culvert base will be carried out by end-dumping of the rock fill below the water level. Preparation of the culvert subgrade will also be carried out underwater, and compaction and chinking of the rock fill, as well as compaction of granular bedding material, will not be possible.

To provide a uniform subgrade for the conditions at this site, it is recommended that culvert subgrade preparation involve excavation and replacement of the peat and clay with rock fill (as per the proposed swamp treatment) to within 450 mm of the culvert base level, then placement of a uniform 450 mm thick bedding and levelling layer of 53 mm clear stone (OPSS.PROV 1004). To facilitate establishment of a reasonably level rock fill surface below the culvert bedding, the rock fill must be placed in a manner that avoids having large boulders protruding into the bedding layer producing a hard point below the culvert base. The recommended wording for an NSSP addressing this requirement is as follows: “Rock fill placed under the culvert base must have a suitable gradation and be placed in a manner that establishes a reasonably flat, level surface on which to place the culvert bedding material. Care shall be taken to avoid large boulders and rock fragments protruding into the bedding layer.”.

The culvert founded directly on a 53 mm clear stone bedding layer and subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	450 kPa
Geotechnical Resistance at SLS	=	300 kPa

Differential settlements in the order of 40 mm may be anticipated due to the variable loading and subgrade conditions along the length of the culverts. The culvert design must be capable of accommodating this magnitude of settlement.

### **Open Footing Culverts**

Construction of an open footing culvert at this location would require placement of the footings on rock fill, preparation of the footing subgrade below the water level, and possibly use of precast footings. Therefore use of an open footing culvert is not preferred from a foundations perspective and this option has not been developed further.

## **8.4 Culvert 332**

### **Box Culvert**

Culvert 332 will be installed through the existing Highway 69 embankment consisting of rock fill. The design invert level will be approximately Elev. 191.5. At this level, the culvert subgrade is expected to consist of rock fill within the embankment, and peat, loose sand or firm silty clay at the ends. The groundwater level observed at the time of the investigation was near the ground surface, at Elev. 191.5 to 192.0.

Based on the borehole data, installation of a box culvert at the proposed level is considered feasible. Preparation of the culvert subgrade should involve excavation to the subgrade level, subexcavation of all peat and organic materials within the footprint of the culvert, and placement of a uniform 450 mm thick bedding and levelling layer of 53 mm clear stone (OPSS.PROV 1004).

The culvert founded directly on a 53 mm clear stone bedding layer and subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	300 kPa
Geotechnical Resistance at SLS	=	150 kPa

As the embankment will not be widened or raised, foundation settlement is not expected to be an issue and cambering of the culvert is not considered necessary.

### **Open Footing Culvert**

Construction of an open footing culvert at this location would require a dewatering system, possibly including a sheet pile wall enclosure, to permit extension of the footings to the bedrock surface. Installation of a dewatering system in the presence of the existing submerged rock fill will be problematic and of uncertain effectiveness. Therefore use of an open footing culvert is not recommended from a foundations perspective and this option has not been developed further.

## **9 BACKFILL AND LATERAL EARTH PRESSURES**

Backfill to the culvert must consist of free-draining granular material conforming to OPSS Granular A or B Type II specifications. The granular material should be placed to the extents shown in OPSD 803.010.

Backfill must be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with SP 105S10.

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

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

where:  $p$  = 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 are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for closed box culvert walls. Active pressures should be used for any wing walls or unrestrained walls.

The parameters presented in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC.

**Table 9.1 – Earth Pressure Coefficients (K)**

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Rock Fill (Limited to 300 mm size) $\phi = 42^\circ, \gamma = 19.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active, $K_A$ (Unrestrained Wall)	0.27	0.40*	0.31	0.48*	0.20	0.28*
At Rest, $K_0$ (Restrained Wall)	0.43	-	0.47	-	0.33	-
Passive, $K_P$	3.7	-	3.3	-	5.0	-

\* For wing walls.

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

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

## 10 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

Velocity Related Seismic Zone	1
Zonal Velocity Ratio	0.05
Acceleration Related Seismic Zone	1
Zonal Acceleration Ratio	0.05

The Soil Profile Type at this site has been classified as Type I. Thus, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” of 1.0 should be used in seismic design.

The seismic earth pressure coefficients for active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) conditions to be used in design at this site are shown in Table 10.1. In accordance with Clause 4.6.4 of the CHBDC, structures should be designed using earth pressure coefficients that incorporate the effects of earthquake loading.

In Table 10.1, the angle of friction between the wall and the backfill,  $\delta$ , is taken as 50% of the angle of internal friction of the backfill,  $\phi$ .

**Table 10.1 – Earth Pressure Coefficients ( $K_E$ ) for Seismic Design**

Condition	Earth Pressure Coefficient (K) for Earthquake Loading					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \delta = 17^\circ$		OPSS Granular B Type I $\phi = 32^\circ, \delta = 16^\circ$		Rock Fill (Limited to 300 mm size) $\phi = 42^\circ, \delta = 21^\circ$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active*, $K_{AE}$ (Unrestrained Wall)	0.30	0.47	0.34	0.58	0.22	0.31
At rest**, $K_{OE}$ (Restrained Wall)	0.53	-	0.57	-	0.43	-
Passive*, $K_{PE}$	3.6	-	3.2	-	4.9	-

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

\*\* After Woods

The potential for liquefaction of the foundation soils has been assessed using the Seed and Idriss (1971) method<sup>1</sup>. Using this method, it was determined that the foundation soils below the culverts are not in danger of liquefaction under earthquake loading.

<sup>1</sup> Seed, H.B. and Idriss, I.M. 1971, “Simplified Procedure for Evaluating Soil Liquefaction Potential” *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 101, No. SM9, pp. 1249 – 1273.

## **11 SCOUR PROTECTION AND EROSION CONTROL**

Erosion protection should be provided at the culvert inlet and outlet areas not comprising rock fill or bedrock. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek 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 accordance with OPSS 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion near the inlet area where the culvert is not installed within rock fill. The clay seal should extend at least 0.3 m above the high water level, have a minimum thickness of 0.5 m, and extend laterally the width of the granular backfill material. The material requirements should be in accordance with OPSS 1205.

## **12 EXCAVATION AND GROUNDWATER CONTROL**

In general, surface vegetation, topsoil, peat, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the culvert area and embankment footprint prior to culvert installation.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purpose of assessing excavation slope requirements in compliance with the OHSA, existing fill and native compact to loose/stiff to firm soils are classified as Type 3 soils above the water table, and Type 4 soil below the water table.

The existing Highway 69 embankment consists of rock fill. Installation of temporary shoring to retain the embankment fill during culvert installation is unlikely to be required or feasible in this material. If required in other areas, temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces. Roadway protection should be supplied in accordance with OPSS 539 and designed for Performance Level 2.

Where possible, temporary stream diversion measures such as impervious dykes should be provided to divert surface water runoff and stream flow away from the culvert excavations at all times during construction. Since the culverts will be installed within rock fill, pond and swamp areas, maintaining a dewatered excavation will generally not be possible and installation of the culverts “in the wet” will be required.

Decisions regarding dewatering, shoring methods and sequencing should be made by the Contractor and submitted to the Contract Administrator for information purposes.

### 13 CONSTRUCTION CONCERNS

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

- Excavation for installation of the culverts in the existing highway embankment will encounter rock fill, and appropriate sized equipment must be supplied for this operation.
- 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 bedding material. The culvert subgrade must be uniformly competent and should be inspected and approved by the Contractor's QVE as per SP 902S01.
- Excavation of soft, loose, organic, peat, wet or otherwise deleterious materials may require flattening of excavation side slopes or installation of temporary shoring. Temporary shoring systems should be properly designed by a Professional Engineer experienced in such designs.
- Care must be exercised during excavation to avoid disturbing the founding subgrade. The exposed subgrade should be protected from physical disturbance, and the granular/clear stone bedding must be placed on the approved subgrade expeditiously following excavation. Temporary stream diversion, in conjunction with sump pumping as required, is essential to maintaining a reasonably dry excavation where culverts will not be placed on rock fill.
- Where the culvert subgrade will be prepared below the water level, care must be exercised to provide a uniform, level bedding surface on which to place the culvert. Rock fill placed in such areas should be limited to a maximum size of 300 mm to facilitate a reasonable level surface on which to place the bedding layer.

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 where applicable during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

## 14 CLOSURE

Engineering analysis and preparation of the foundation design report was conducted by Mr. Keli Shi, P.Eng. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Keli Shi, P.Eng.  
Geotechnical Engineer



Murray R. Anderson, P.Eng.  
Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.  
Review Principal



**TABLE 8.1 - COMPARISON OF FOUNDATION ALTERNATIVES**

Closed Box Culvert	Open Footing Culvert on Native Soil
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li><b>i.</b> Ease of construction.</li> <li><b>ii.</b> Minimizes differential settlement.</li> <li><b>iii.</b> Applies lower bearing pressures on foundation soils compared to open footing.</li> <li><b>iv.</b> Compared to open footing, more suited for culvert founded below groundwater table.</li> <li><b>v.</b> Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li><b>i.</b> Requires subexcavation of soft or organic material from streambed if encountered.</li> <li><b>ii.</b> Potential settlement due to embankment loading must be addressed in culvert design.</li> </ul> <p><b>RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li><b>i.</b> Ease of construction.</li> <li><b>ii.</b> Eliminates bedding requirement.</li> <li><b>iii.</b> Potentially less area of subexcavation to remove soft/loose native soil below culvert base.</li> <li><b>iv.</b> Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li><b>i.</b> Higher geotechnical resistance required.</li> <li><b>ii.</b> Additional depth of excavation required to provide frost protection and achieve higher resistance.</li> <li><b>iii.</b> Low geotechnical resistance is available at most sites, possibly resulting in impractical large footings.</li> <li><b>iv.</b> More extensive dewatering required.</li> <li><b>v.</b> Possible differential settlement due to variable subgrade conditions.</li> <li><b>vi.</b> Subexcavation may be required to penetrate upper soft or organic material, if encountered.</li> </ul> <p><b>NOT RECOMMENDED AT THESE CULVERT SITES</b></p>



**Appendix A**

**Culverts 313 and 314**

**Record of Borehole Sheets  
Laboratory Test Results  
Borehole Locations and Soil Strata Drawings**

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

### 1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

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

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

NOTE: Hierarchy of Soil Strength Prediction

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



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

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

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

# UNIFIED SOILS CLASSIFICATION

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

## EXPLANATION OF ROCK LOGGING TERMS


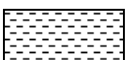

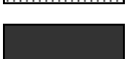

### ROCK WEATHERING CLASSIFICATION

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

### DISCONTINUITY SPACING

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

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

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

### TERMS

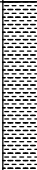



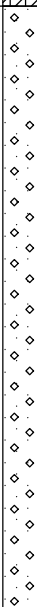
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces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

# RECORD OF BOREHOLE No C313-1

1 OF 2

METRIC

GWP# 5076-06-00 LOCATION N 5 055 317.8 E 235 075.4 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.26 - 2011.02.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60			80	100	PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w
193.2	Pond Surface															
0.0	ICE: (300mm)															
192.9							193									
0.3	WATER															
191.8							192									
1.4	Silty <b>CLAY</b> , trace sand Very Soft Grey		1	SS	0		191									
190.7			2	SS	1											
2.5	<b>PEAT</b> , fibrous Very Soft Dark Brown Wet		3	SS	1		190									
189.3			4	SS	2											
3.9	Silty <b>CLAY</b> , some sand to sandy Soft to Firm Grey		5	SS	4		189									
188.0							188									
5.2	<b>SAND</b> and <b>GRAVEL</b> , trace silt Loose Grey Wet		6	SS	7		187									
			7	SS	9											
			8	SS	7		186									
	occasional cobbles		9	SS	7		185									
			10	SS	73/ 0.250		184									
183.8																
9.4	END OF BOREHOLE AT 9.4m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE															

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C313-1

2 OF 2

METRIC

GWP# 5076-06-00 LOCATION N 5 055 317.8 E 235 075.4 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.26 - 2011.02.26 CHECKED BY RPR

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






ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

# RECORD OF BOREHOLE No C313-2

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 311.2 E 235 056.3 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.26 - 2011.02.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20   40   60   80   100				w <sub>P</sub> w                      w <sub>L</sub>							
						○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      x LAB VANE													
193.2	Pond Surface																		
0.0	ICE: (300mm)																		
192.9							193												
0.3	WATER																		
191.8							192												
191.4	PEAT: (25mm)																		
1.5	Silty <b>CLAY</b> , trace sand Very Soft Grey		1	SS	0		191												
190.6			2	SS	2											23			
2.6	PEAT, trace sand Very Soft Dark Brown Wet						190									46			
189.5			3	SS	1														
3.7	Silty <b>CLAY</b> , some sand Very Soft Grey Wet		4	SS	2		189										0   19   54   27		
188.4			5	SS	50/														
4.8	END OF BOREHOLE AT 4.8m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO SURFACE.				0.125														

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

20  
15  
10

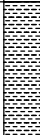



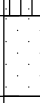

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C313-3

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 304.7 E 235 037.1 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.25 - 2011.02.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
193.2	Pond Surface													
0.0	ICE: (300mm)													
192.9							193							
0.3	WATER													
192.0							192							
1.2	Silty <b>CLAY</b> , some sand Soft Grey		1	SS	2									
191.4														
191.8	<b>SAND</b>													
1.9	<b>PEAT</b> , trace sand Very Soft Dark Brown Wet		2	SS	2		191							
190.7														
2.5	<b>SILT</b> and <b>SAND</b> , trace clay Loose Grey Wet		3	SS	7		190							
189.7														
3.5	<b>SAND</b> , some gravel to gravelly Compact Grey Wet		4	SS	17									
189.2														
4.0	END OF BOREHOLE AT 4.0m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO SURFACE.													

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14






# RECORD OF BOREHOLE No C314-1

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 298.7 E 235 019.2 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.25 - 2011.02.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE									WATER CONTENT (%)
193.2	Pond Surface							20	40	60	80	100					
0.0	ICE: (300mm)						193										
192.9																	
0.3	WATER																
191.9							192										
191.8	PEAT: (50mm)																
191.6	Silty CLAY, trace sand, occasional roots and rootlets		1	SS	4												
1.6	Soft Grey																
191.1			2	SS	50/												
2.1	SAND, fine grained Loose Grey Wet				0.025												
END OF BOREHOLE AT 2.1m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.																	

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

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



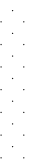
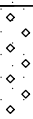
20  
15  
10  
5  
0  
5  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C314-2

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 291.4 E 234 998.4 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.25 - 2011.02.25 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  <b>γ</b>  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 (%) w <sub>P</sub> w      w <sub>L</sub>							
193.2	Pond Surface							20	40	60	80	100						
0.0	ICE: (300mm)						193											
192.9																		
0.3	WATER																	
191.6																		
191.8	PEAT: (50mm)																	
1.7	SAND, some silt, trace gravel Loose to Compact Grey Wet		1	SS	7		191											
			2	SS	16													
190.2																		
3.0	SAND and GRAVEL, trace silt Very Dense Brown Wet		3	SS	61/ 0.275		190											
189.4																		
3.8	END OF BOREHOLE AT 3.8m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO SURFACE.																	

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

# RECORD OF BOREHOLE No BH10-02

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION Harrison Twp., Station 19+301 C/L, NBL ORIGINATED BY WB  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.01 - 2009.03.01 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      x LAB VANE			WATER CONTENT (%) W P      W      W L					
193.2	Pond Surface							20	40	60	80	100				
0.0	ICE and WATER: (1500mm)						193									
							192									
191.7																
1.5	Silty <b>CLAY</b> , some sand, some peat Very Soft Grey		1	SS	0											
191.0							191									
2.2	<b>PEAT</b> , fibrous Very Soft Brown Wet		2	SS	0											
			3	SS	0		190								310	
189.5																
3.7	Silty <b>CLAY</b> , some sand Very Soft Grey		4	SS	0		189									
188.7																
4.5	<b>SAND</b> , trace gravel, trace silt Loose Grey Wet		5	SS	5											
188.0																
			6	SS	50/ .000		188									
5.2	END OF BOREHOLE (SAMPLER BOUNCING) AT 5.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND AUGER CUTTINGS UPON COMPLETION.															

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

# RECORD OF BOREHOLE No BH11-02

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION Harrison Twp., Station 19+301 C/L, SBL ORIGINATED BY WB  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.04 - 2009.03.04 CHECKED BY RPR

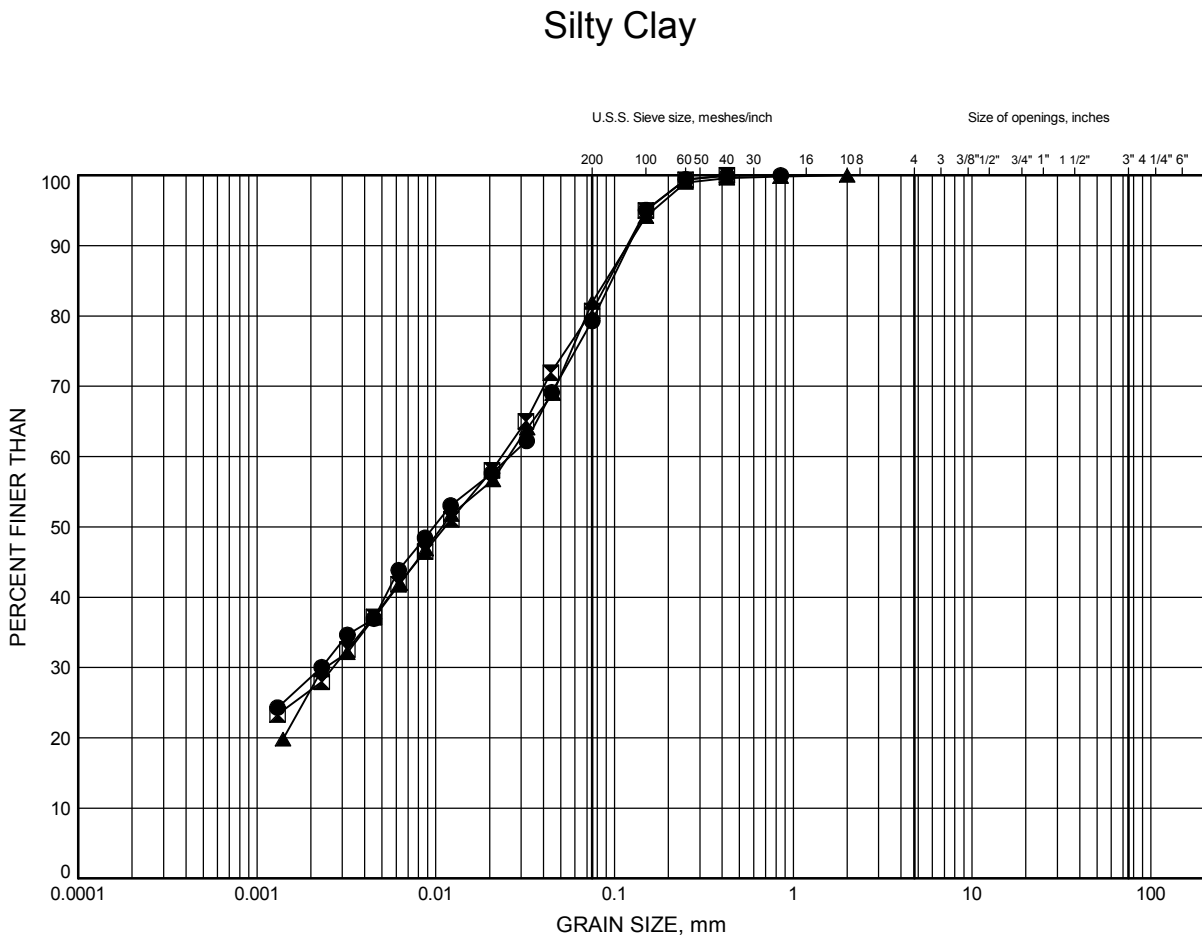
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
193.2	Pond Surface							20	40	60	80	100				
0.0	ICE and WATER: (1500mm)						193									
							192									
191.7																
1.5	Silty SAND, occasional peat and roots Very Loose Brown Wet		1	SS	3		191									
190.6			2	SS	115/ .175											
2.6	END OF BOREHOLE (SAMPLER BOUNCING) AT 2.6m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND AUGER CUTTINGS UPON COMPLETION.															

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

20  
15  
10  
5  
0  
5  
10  
(%) STRAIN AT FAILURE

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE A1



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C313-1	4.78	188.42
⊠	C313-2	4.04	189.16
▲	BH10-02	4.11	189.09

Date August 2014  
GWP# 5076-06-00

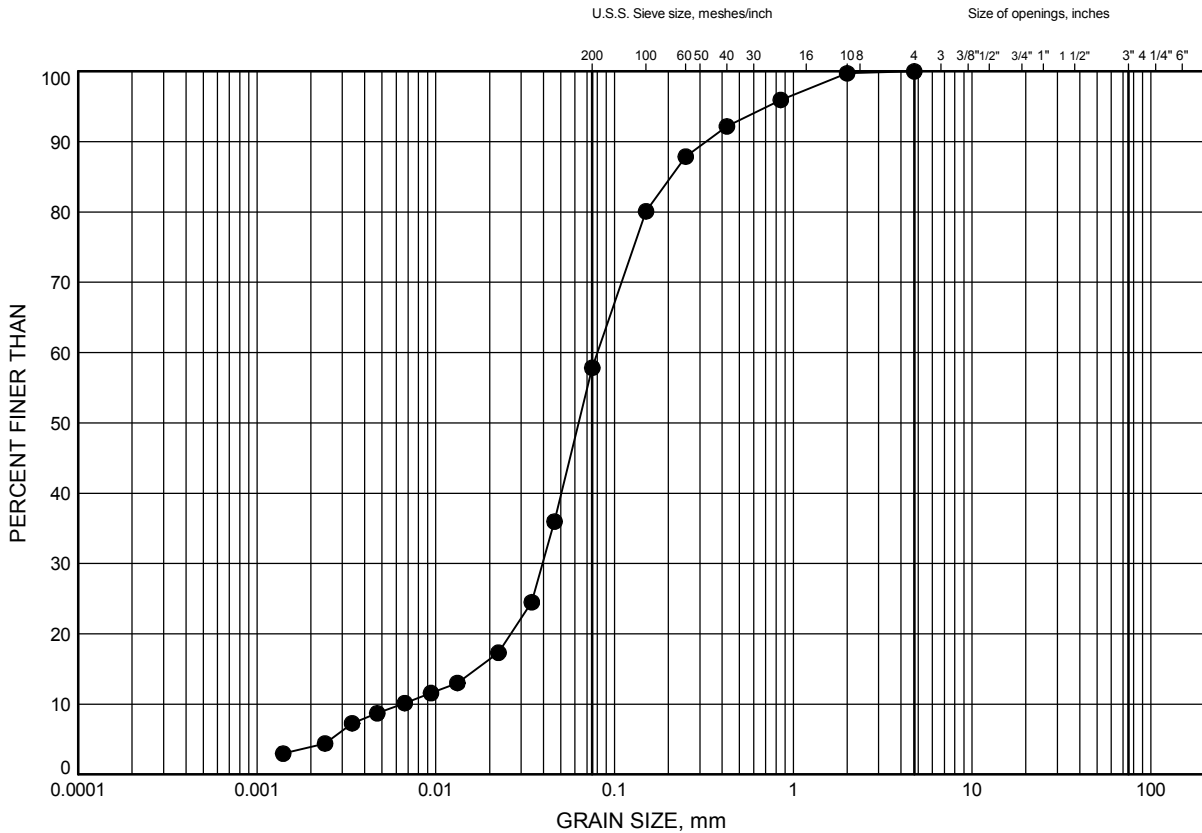


Prep'd MFA  
Chkd. MRA

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE A2

## Silt and Sand



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C313-3	3.05	190.15

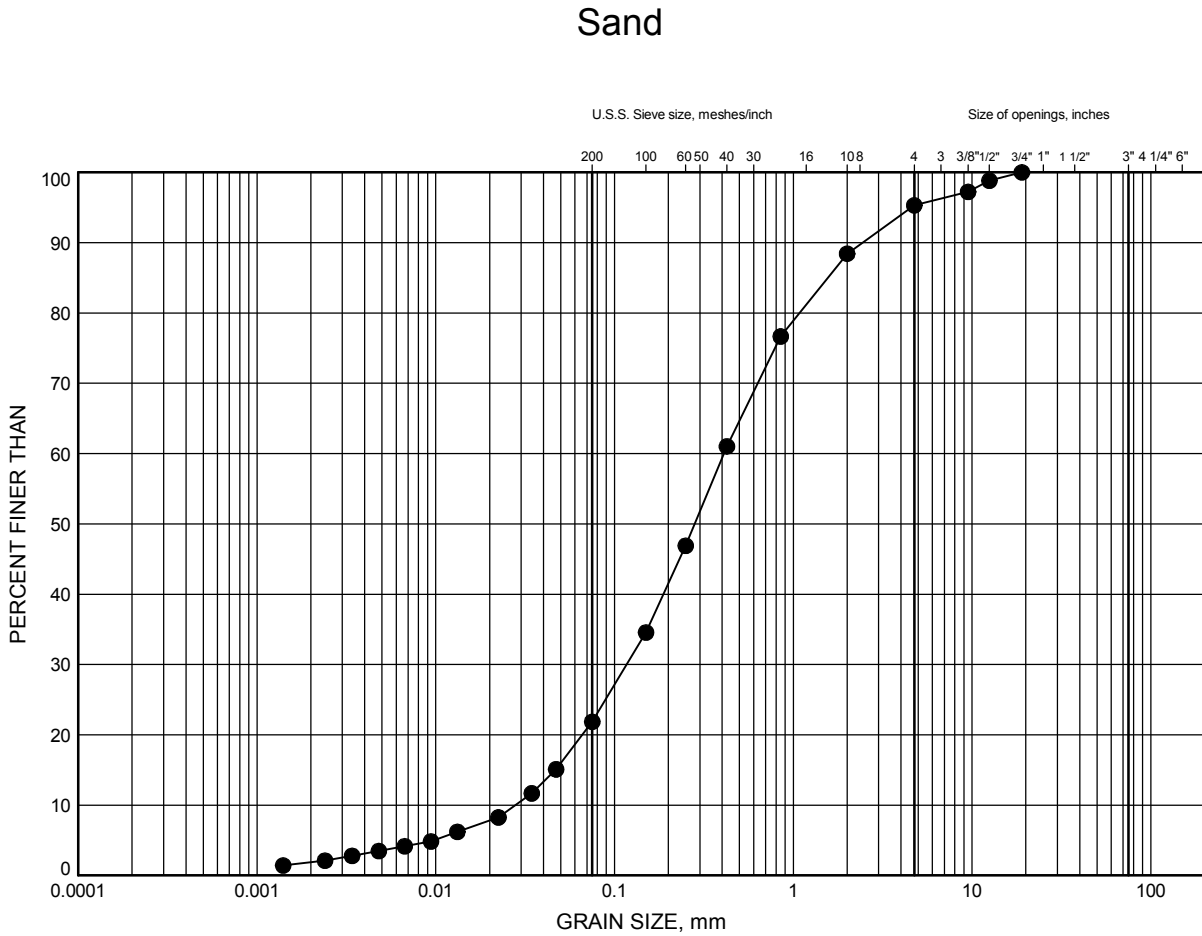
Date August 2014  
GWP# 5076-06-00



Prep'd MFA  
Chkd. MRA

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE A3



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C314-2	2.69	190.51

Date August 2014  
GWP# 5076-06-00

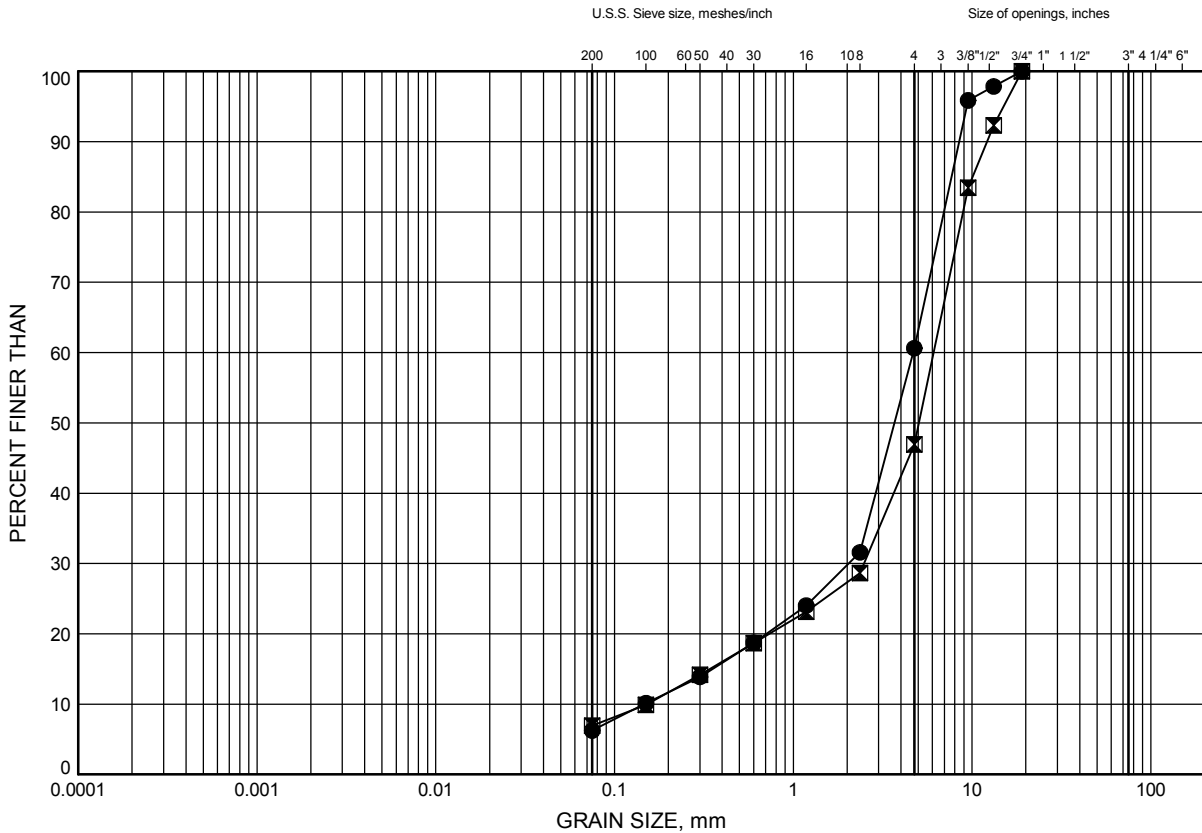


Prep'd MFA  
Chkd. MRA

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE A4

## Sand and Gravel



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C313-1	9.22	183.98
⊠	C314-2	3.36	189.84

Date August 2014  
GWP# 5076-06-00



Prep'd MFA  
Chkd. MRA





**Appendix B**

**Culverts 317 and 318**

**Record of Borehole Sheets**

**Laboratory Test Results**



**Borehole Locations and Soil Strata Drawings**

# RECORD OF BOREHOLE No C317-1

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 827.6 E 234 950.3 ORIGINATED BY SLL  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers (CME 45) COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.11 - 2011.02.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
192.7	Ground Surface																
0.0	PEAT																
0.2	SAND, trace to some silt, trace gravel, occasional cobbles Brown Moist to Wet																
191.4			1	SS	59/ 0.200		192										
1.2	END OF BOREHOLE AT 1.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 0.9m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.																

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

# RECORD OF BOREHOLE No C317-2

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 819.8 E 234 916.4 ORIGINATED BY SLL  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers (CME 45) COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.11 - 2011.02.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE								WATER CONTENT (%)	
192.4	Ground Surface							20	40	60	80	100					
0.0	PEAT Black Wet																
0.2	Silty <b>CLAY</b> , sandy to trace sand Soft to Stiff Brown		1	SS	3		192						10		0	22 54 24	
	Sand seams		2	SS	9		191						20				
			3	SS	3		190						30		0	9 49 42	
	Very Soft		4	SS	0		189						40				
188.1																	
4.3	END OF BOREHOLE AT 4.3m UPON AUGER REFUSAL ON PROBABLE BEDROCK. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) Feb 22/11    0.0            192.4 Mar 01/11    0.0            192.4 Mar 13/11    0.0            192.4 Apr 27/11    0.1            192.3																

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C318-1

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 811.7 E 234 881.7 ORIGINATED BY SLL  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers (CME 45) COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.11 - 2011.02.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
192.9	Ground Surface							20	40	60	80	100		
0.0	PEAT Black							20	40	60	80	100		
0.2	Silty <b>CLAY</b> , trace sand Stiff Brown						192							
			1	SS	9									
			2	SS	8		191							
190.7														
190.7	<b>SAND</b> , trace silt and gravel Brown Wet		3	SS	50/									
2.4	END OF BOREHOLE AT 2.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 0.6m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.				0.075									

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH13-07

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION Harrison Twp., Station 19+826 C/L, NBL ORIGINATED BY JM  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG  
 DATUM Geodetic DATE 2009.02.12 - 2009.02.12 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
192.7	Ground Surface													
0.0 0.1	PEAT: (100mm) Dark Brown Moist		1	SS	2	V	192							
	Silty CLAY, trace sand Soft to Stiff Grey		2	SS	11									0 6 40 54
191.2														
1.5 190.9	Silty SAND, some clay, trace gravel Grey to Brown		3	SS	53		191							
1.8	Moist													
END OF BOREHOLE AT 1.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 0.5m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH AUGER CUTTINGS UPON COMPLETION.														

# RECORD OF BOREHOLE No BH14-08

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION Harrison Twp., Station 19+826 C/L, SBL ORIGINATED BY JM  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG  
 DATUM Geodetic DATE 2009.02.12 - 2009.02.12 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
191.9	Ground Surface							20	40	60	80	100						
0.0	<b>PEAT</b> , fibrous, trace sand Very Soft																	
191.6	Dark Brown Wet (300mm)		1	SS	1													
0.3	Silty <b>CLAY</b> , trace sand Very Soft to Soft Brown to Grey		2	SS	4		191										0	8 57 35
			3	SS	4		190											
			4	SS	2		189											
188.5			5	SS	6													
3.4	Silty <b>SAND</b> , trace clay Loose Grey Moist						188										6	61 23 10
	Occasional cobbles																	
187.1			6	SS	50/													
4.8	END OF BOREHOLE AT 4.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT SURFACE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG AND AUGER CUTTINGS UPON COMPLETION.				.100													

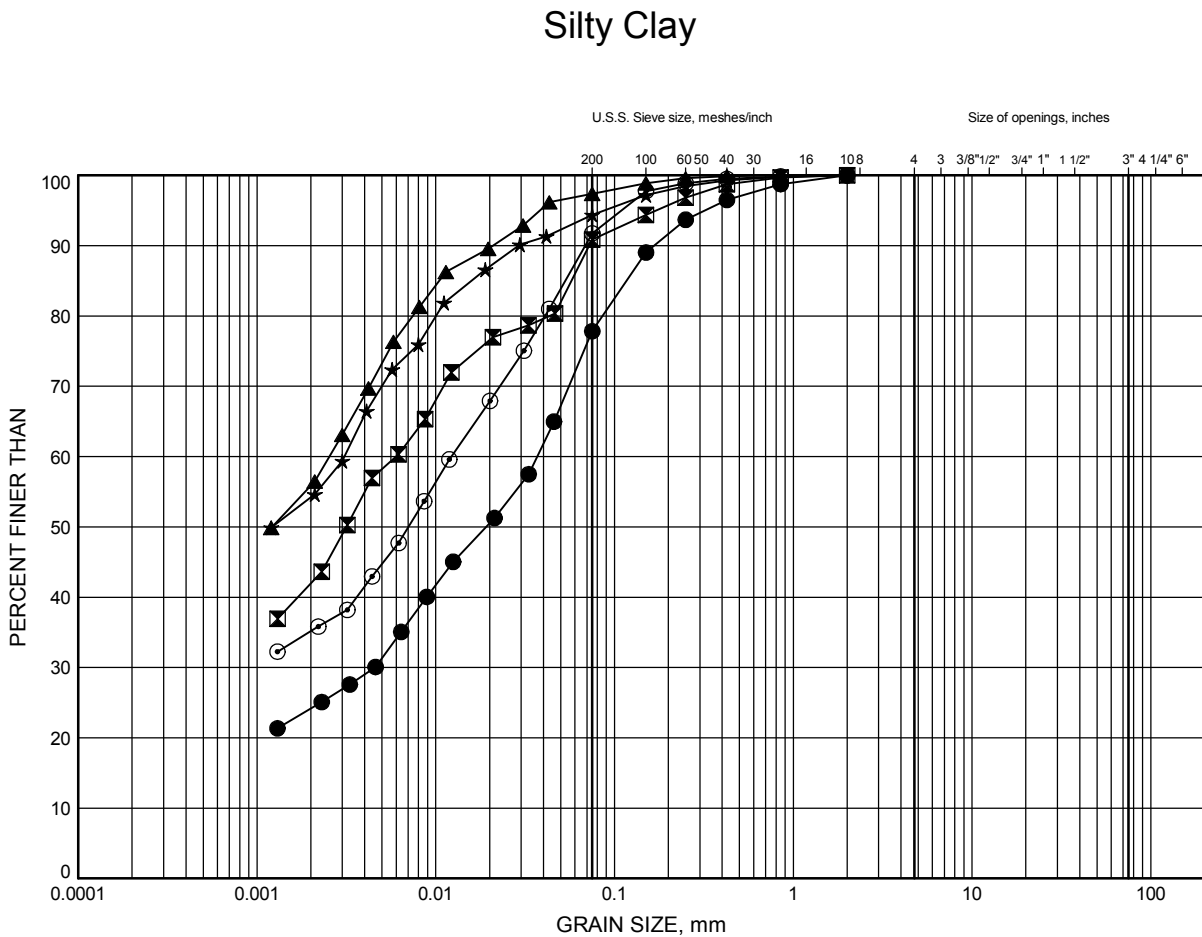
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE B1



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C317-2	1.07	191.33
⊠	C317-2	2.59	189.81
▲	C318-1	1.83	191.04
★	BH13-07	1.07	191.63
⊙	BH14-08	1.07	190.83

Date August 2014

GWP# 5076-06-00



Prep'd MFA

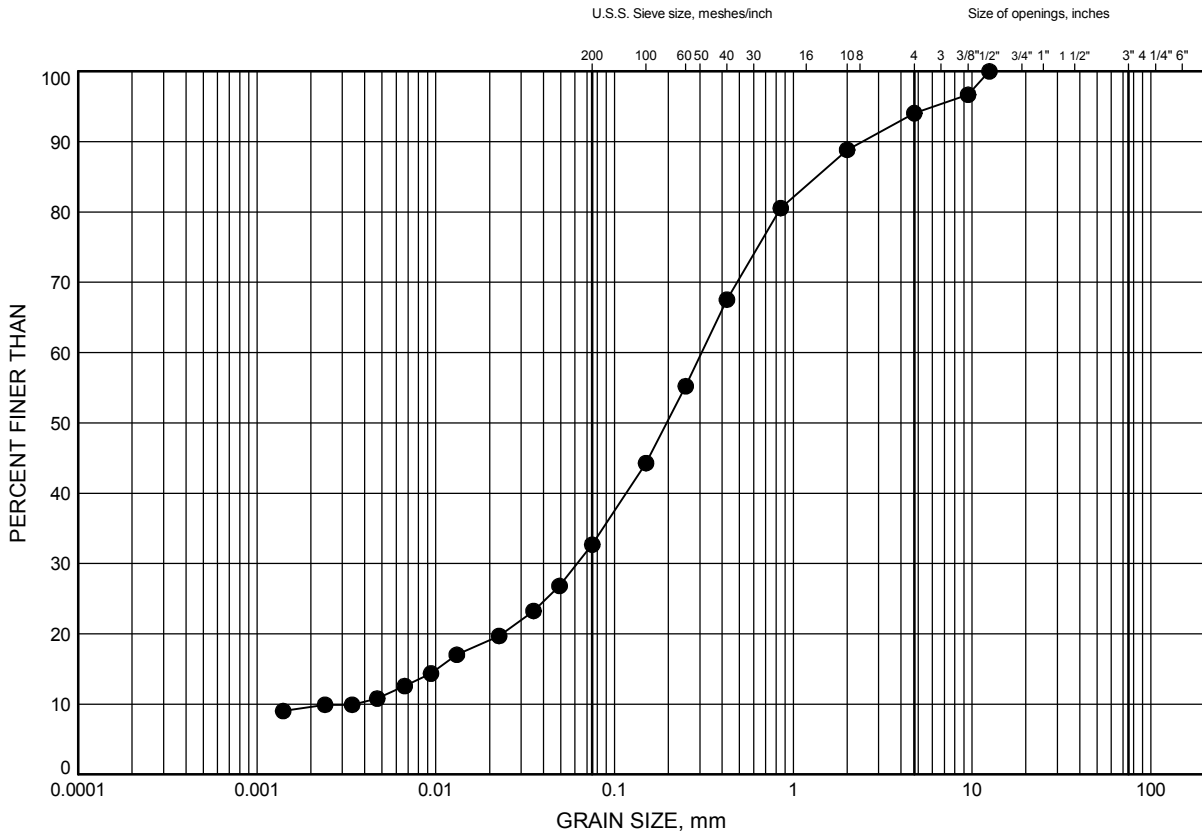
Chkd. MRA



# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE B2

## Silty Sand



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BH14-08	3.51	188.39

Date August 2014  
GWP# 5076-06-00

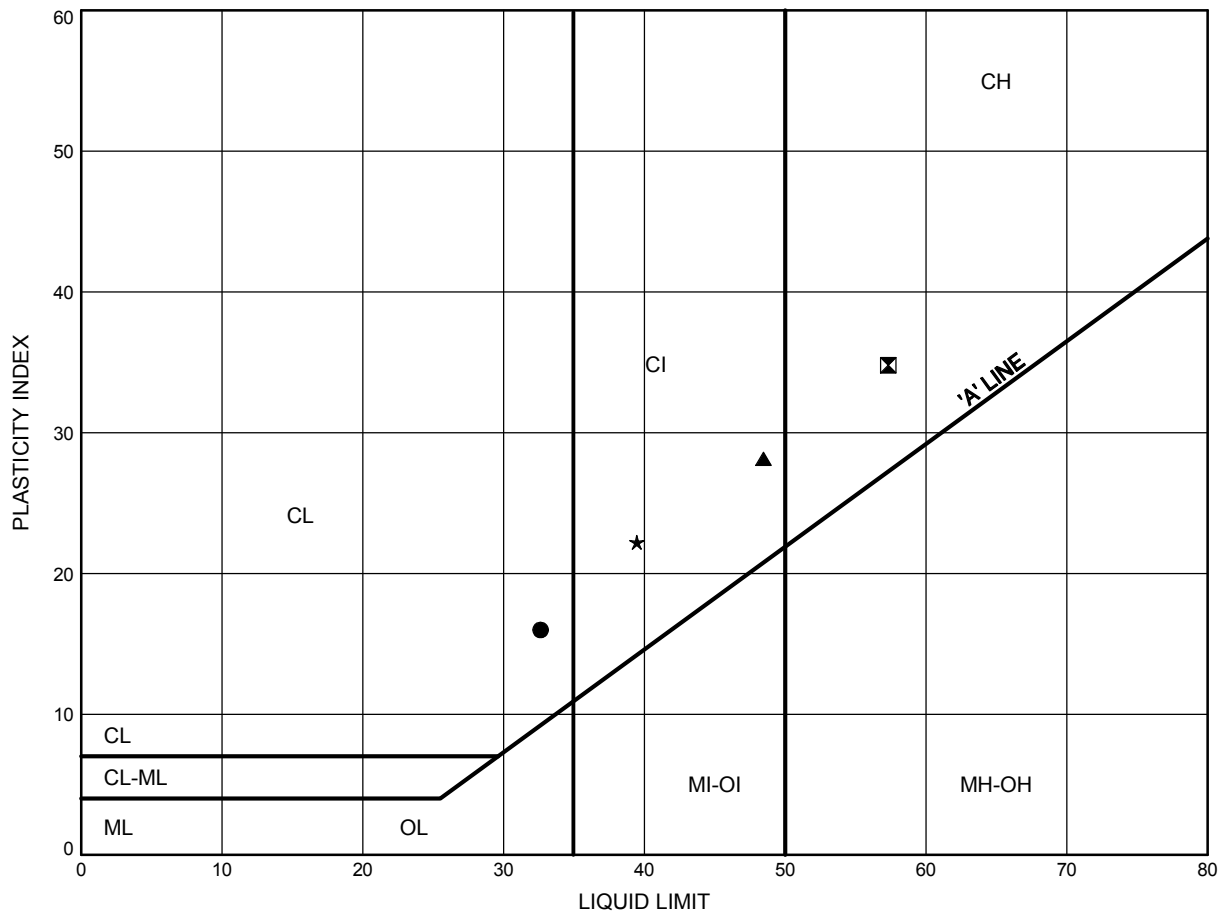


Prep'd MFA  
Chkd. MRA

Hwy 69 Four-Laning North of Hwy 529  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B3

Silty Clay



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C317-2	1.07	191.33
⊠	C318-1	1.83	191.04
▲	BH13-07	1.07	191.63
★	BH14-08	1.07	190.83

Date August 2014  
 GWP# 5076-06-00

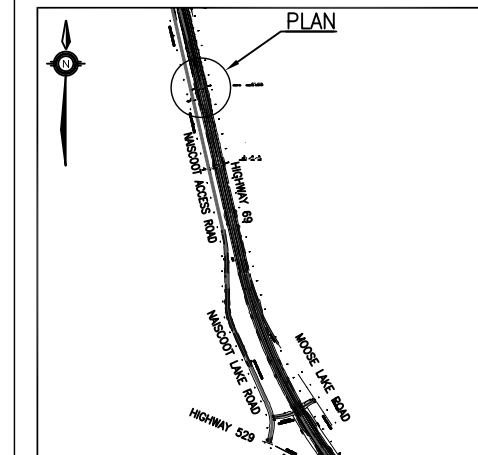


Prep'd MFA  
 Chkd. MRA

A circular professional seal for a Licensed Professional Engineer in the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. In the center, the name "M. R. ANDERSON" is printed. Below the name is a semi-circular stamp containing the handwritten date "Aug 21/14". Above the name is a stylized graphic of a bridge or arch structure.

A circular professional seal for a Licensed Professional Engineer in the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. In the center, the name "P. K. CHATTERJI" is printed. Above the name is a handwritten signature, and below the name is a handwritten date "Aug 21 / 14".

HIGHWAY 69 FOUR-LANING  
SOUTH SECTION  
CULVERT 317 AND 318  
BOREHOLE LOCATIONS AND SOIL STRATA



## KEYPLAN

## LEGEND

- |      |                                       |
|------|---------------------------------------|
|      | Culvert Report Borehole / Cone        |
|      | Other Borehole / Cone                 |
| N    | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60° Cone, 475J/blow)     |
| PH   | Pressure, Hydraulic                   |
|      | Water Level During Drilling           |
|      | Water Level in                        |
|      | Piezometer                            |
| 90%  | Rock Quality Designation (RQD)        |
| A/R  | Auger Refusal                         |

NO	ELEVATION	NORTHING	EASTING
BH13-06L	192.0	5 055 805.3	234 927.0
BH13-07	192.7	5 055 820.3	234 936.4
BH13-08R	192.8	5 055 832.8	234 946.2
BH13-09	193.0	5 055 839.8	234 931.9
BH14-07L	191.9	5 055 796.7	234 890.2
BH14-08	191.9	5 055 811.8	234 899.9
BH14-09R	192.1	5 055 826.7	234 908.8
BH14-10	192.6	5 055 836.2	234 894.2
C317-1	192.7	5 055 827.6	234 950.3
C317-2	192.4	5 055 819.8	234 916.4
C318-1	192.9	5 055 811.7	234 881.7
D13-03R	193.3	5 055 811.0	234 951.5
D13-04L	192.1	5 055 827.2	234 922.1

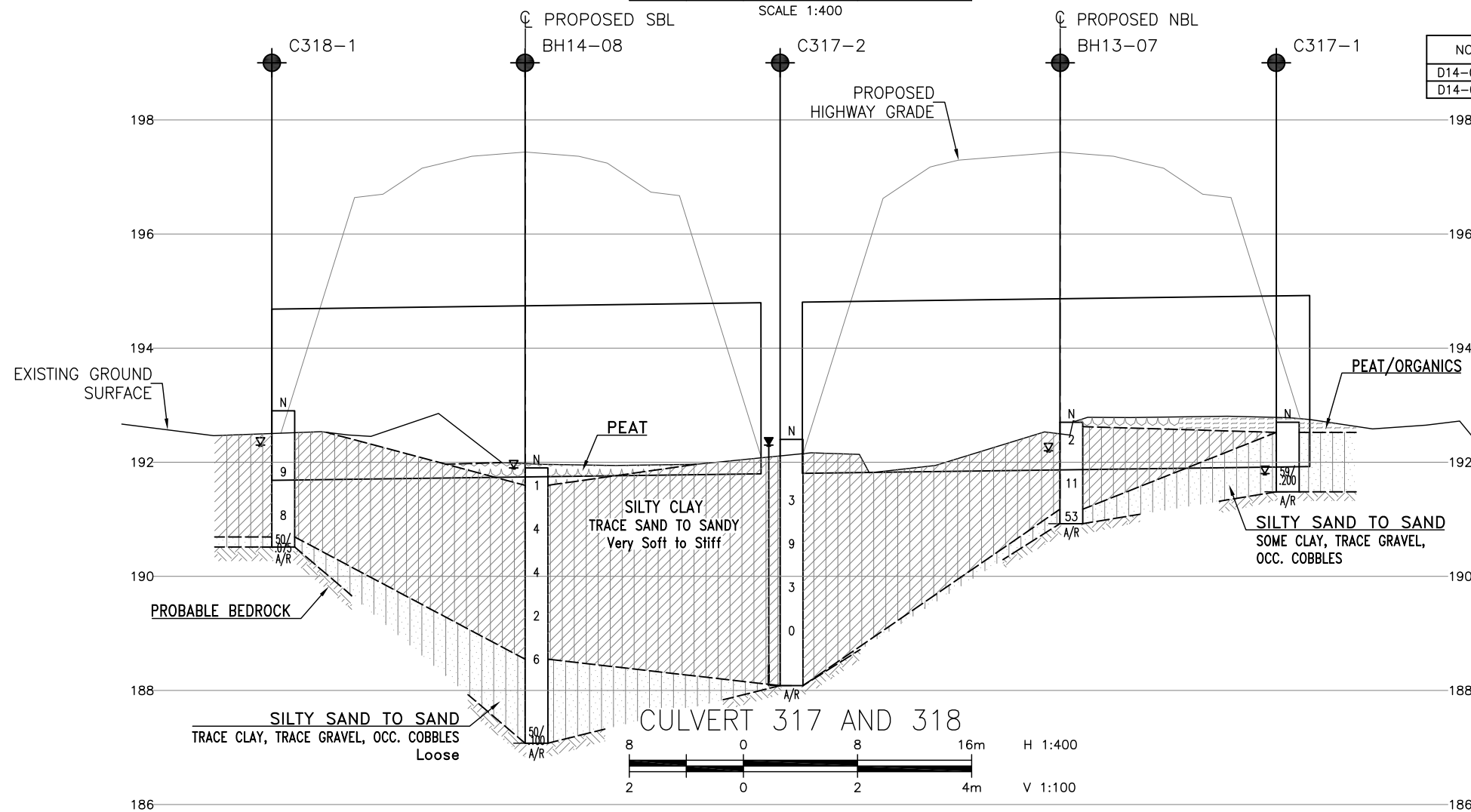
-NOTES-

- 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.

**GEOCRES No. 41H-130**

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	LRB	CHK	MRA	CODE	LOAD		DATE	AUG. 2014	
DRAWN	MFA	CHK	LRB	SITE 44-603/C1&C2	STRUCT	DWG	1		

FILENAME: H:\Drafting\19\5161\21\ted6121-Plan&Sections(Culverts).dwg



**Appendix C**

**Culvert 330**

**Record of Borehole Sheets  
Laboratory Test Results  
Borehole Locations and Soil Strata Drawings**

# RECORD OF BOREHOLE No C330-1

1 OF 3

METRIC

GWP# 5076-06-00 LOCATION N 5 055 288.6 E 234 971.2 ORIGINATED BY ES/GM  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers/HQ/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2012.06.12 - 2012.06.12 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
199.9	Road Surface													
0.0	ASPHALT: (40mm)		1	GS										
198.9	SAND, some gravel Dark Brown Damp (FILL)													
1.0	ROCK FILL		1	RUN										
			2	RUN										
			3	RUN										
			4	RUN										
			5	RUN										

Continued Next Page

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



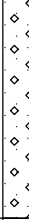

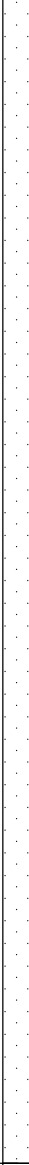
20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C330-1

2 OF 3

METRIC

GWP# 5076-06-00 LOCATION N 5 055 288.6 E 234 971.2 ORIGINATED BY ES/GM  
HWY 69 BOREHOLE TYPE Hollow Stem Augers/HQ/NQ Coring COMPILED BY AN  
DATUM Geodetic DATE 2012.06.12 - 2012.06.12 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  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)								
								20 40 60 80 100			20 40 60								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
Continued From Previous Page																			
189.6	Trace peat																		
10.3	<b>SAND</b> and <b>GRAVEL</b> , some silt, trace rootlets Loose to Very Loose Brown Wet		1	SS	7														
			2	SS	3														
188.0																			
11.9	<b>SAND</b> , trace gravel, some silt Dense to Compact Brown Wet          Occasional cobbles		3	SS	0														
			4	SS	23														
			5	SS	33														
			6	SS	23														
			7	SS	15														
			8	SS	11														
			9	SS	10														
180.1																			
19.8	Start DCPT at 19.8m																		

Continued Next Page

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

# RECORD OF BOREHOLE No C330-1

3 OF 3

METRIC

GWP# 5076-06-00 LOCATION N 5 055 288.6 E 234 971.2 ORIGINATED BY ES/GM  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers/HQ/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2012.06.12 - 2012.06.12 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	WATER CONTENT (%)					
	Continued From Previous Page							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60					
172.3							179							
							178							
							177							
							176							
							175							
							174							
							173							
27.6	END OF BOREHOLE AT 27.6m UPON REFUSAL ON PROBABLE BEDROCK OR BOULDER. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

# RECORD OF BOREHOLE No C330-2

1 OF 2

METRIC

GWP# 5076-06-00 LOCATION N 5 055 278.7 E 234 945.0 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.03.03 - 2011.03.08 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			20 40 60 80 100	20 40 60 80 100	20 40 60	20 40 60		
191.5	Ground Surface												
0.0	PEAT Soft Dark Brown		1	SS	4								
190.8													
0.7	SILT and SAND, trace gravel, trace clay Compact Brown Wet		2	SS	18								2 41 53 4
			3	SS	25								
189.7													
1.8	SAND, trace to some gravel, trace to some silt and clay Loose to Very Loose Brown Wet		4	SS	5								
			5	SS	4								
			6	SS	2								
			7	SS	4								
			8	SS	3								1 86 13 (SI+CL)
			9	SS	2								
			10	SS	5								
	Compact		11	SS	28								
			12	SS	28								0 97 3 (SI+CL)

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No C330-2

2 OF 2

METRIC

GWP# 5076-06-00 LOCATION N 5 055 278.7 E 234 945.0 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.03.03 - 2011.03.08 CHECKED BY RPR

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

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

20  
15  
10

(%) STRAIN AT FAILURE

## METRIC

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

# RECORD OF BOREHOLE No C330-2D

2 OF 2

METRIC

GWP# 5076-06-00 LOCATION N 5 055 278.0 E 234 942.0 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2011.03.08 - 2011.03.08 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	WATER CONTENT (%)					
	Continued From Previous Page						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60						
178.4							181							
178.4							180							
178.4							179							
13.1	END OF BOREHOLE AT 13.1m.													

# RECORD OF BOREHOLE No C314-2

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 291.4 E 234 998.4 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.25 - 2011.02.25 CHECKED BY RPR

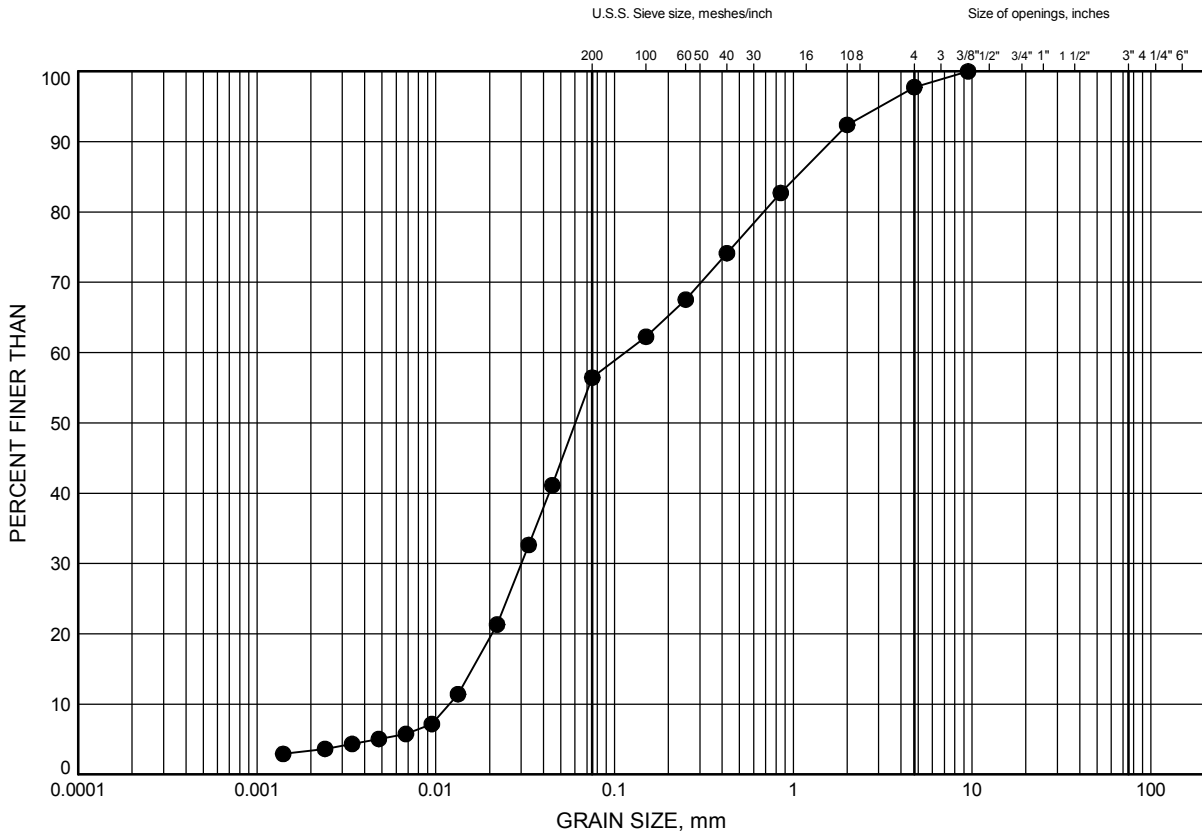
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W <sub>P</sub> W W <sub>L</sub>	WATER CONTENT (%)					
193.2	Pond Surface														
0.0	ICE: (300mm)														
192.9															
0.3	WATER														
191.6															
191.8	PEAT: (50mm)														
1.7	SAND, some silt, trace gravel Loose to Compact Grey Wet		1	SS	7										
			2	SS	16										5 73 20 2
190.2															
3.0	SAND and GRAVEL, trace silt Very Dense Brown Wet		3	SS	61/ 0.275										53 40 7 (SI+CL)
189.4															
3.8	END OF BOREHOLE AT 3.8m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO SURFACE.														

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

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE C1

## Silt and Sand



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C330-2	0.91	190.59

Date August 2014  
GWP# 5076-06-00

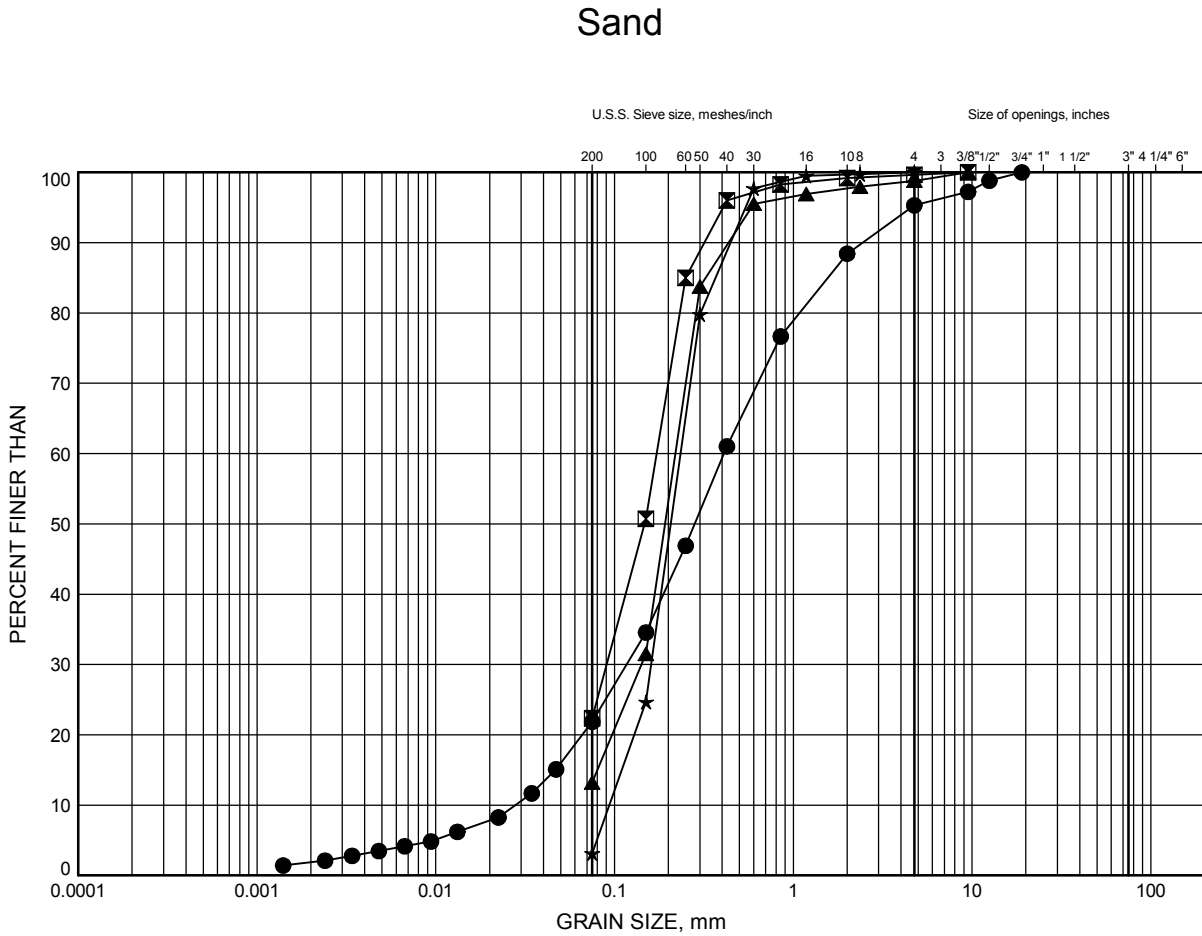


Prep'd MFA  
Chkd. MRA

# Hwy 69 Four-Laning North of Hwy 529

## GRAIN SIZE DISTRIBUTION

FIGURE C2



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C314-2	2.69	190.51
⊠	C330-1	19.51	180.39
▲	C330-2	4.88	186.62
★	C330-2	9.45	182.05

Date August 2014  
GWP# 5076-06-00

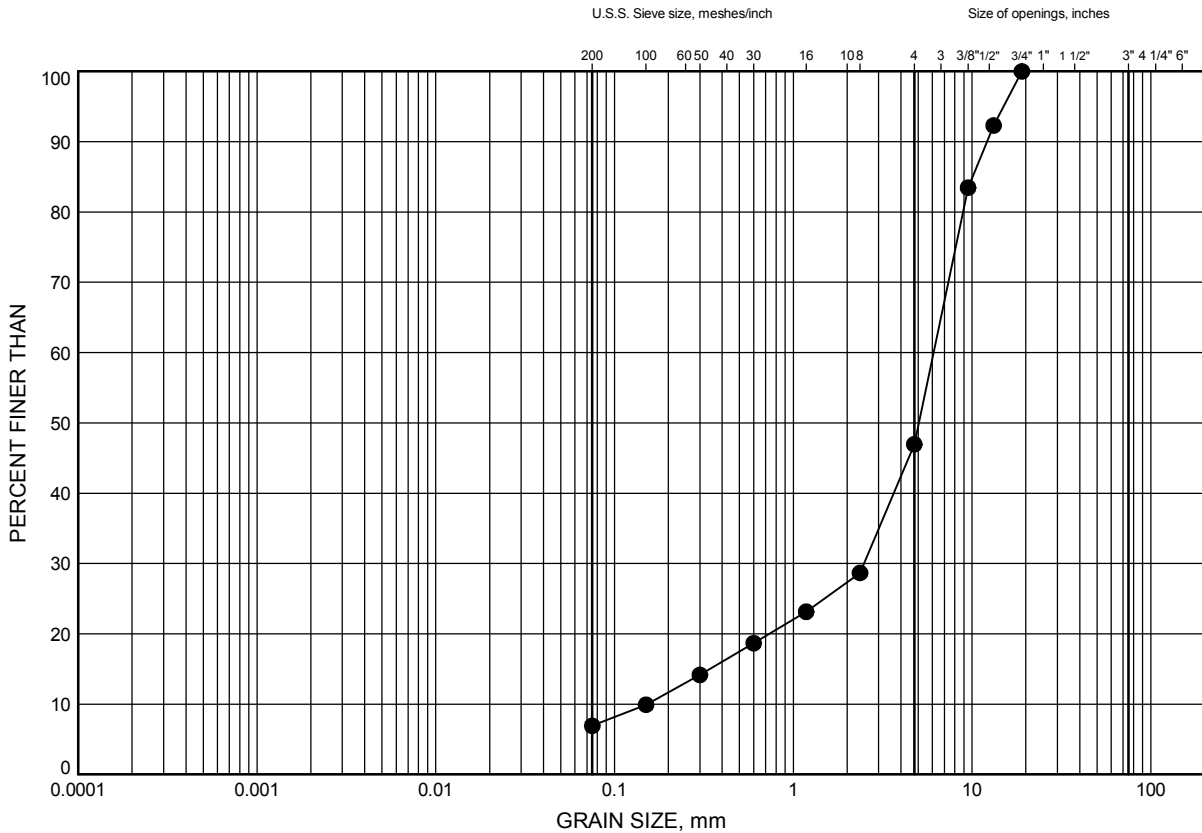


Prep'd MFA  
Chkd. MRA

Hwy 69 Four-Laning North of Hwy 529  
**GRAIN SIZE DISTRIBUTION**

FIGURE C3

**Sand and Gravel**



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

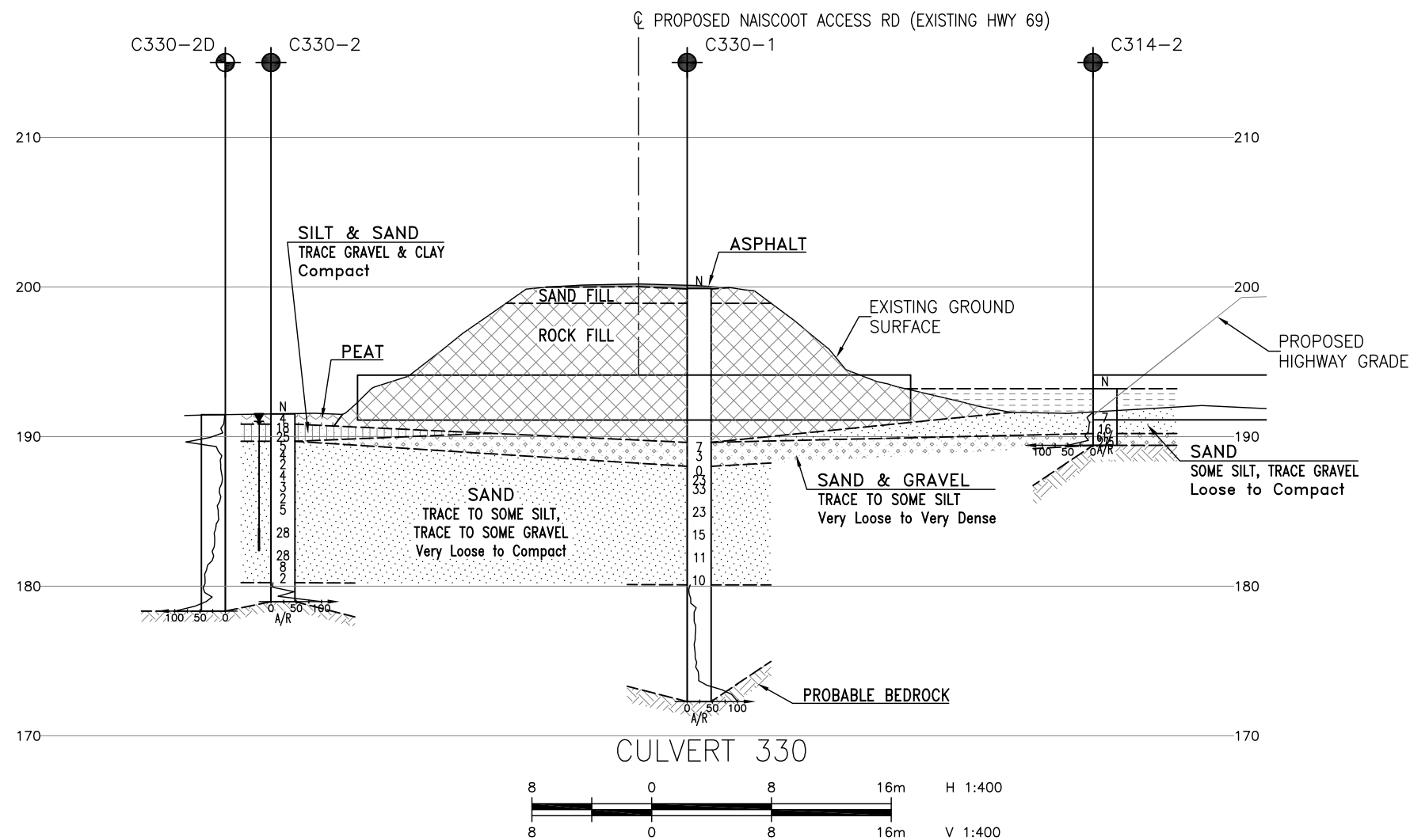
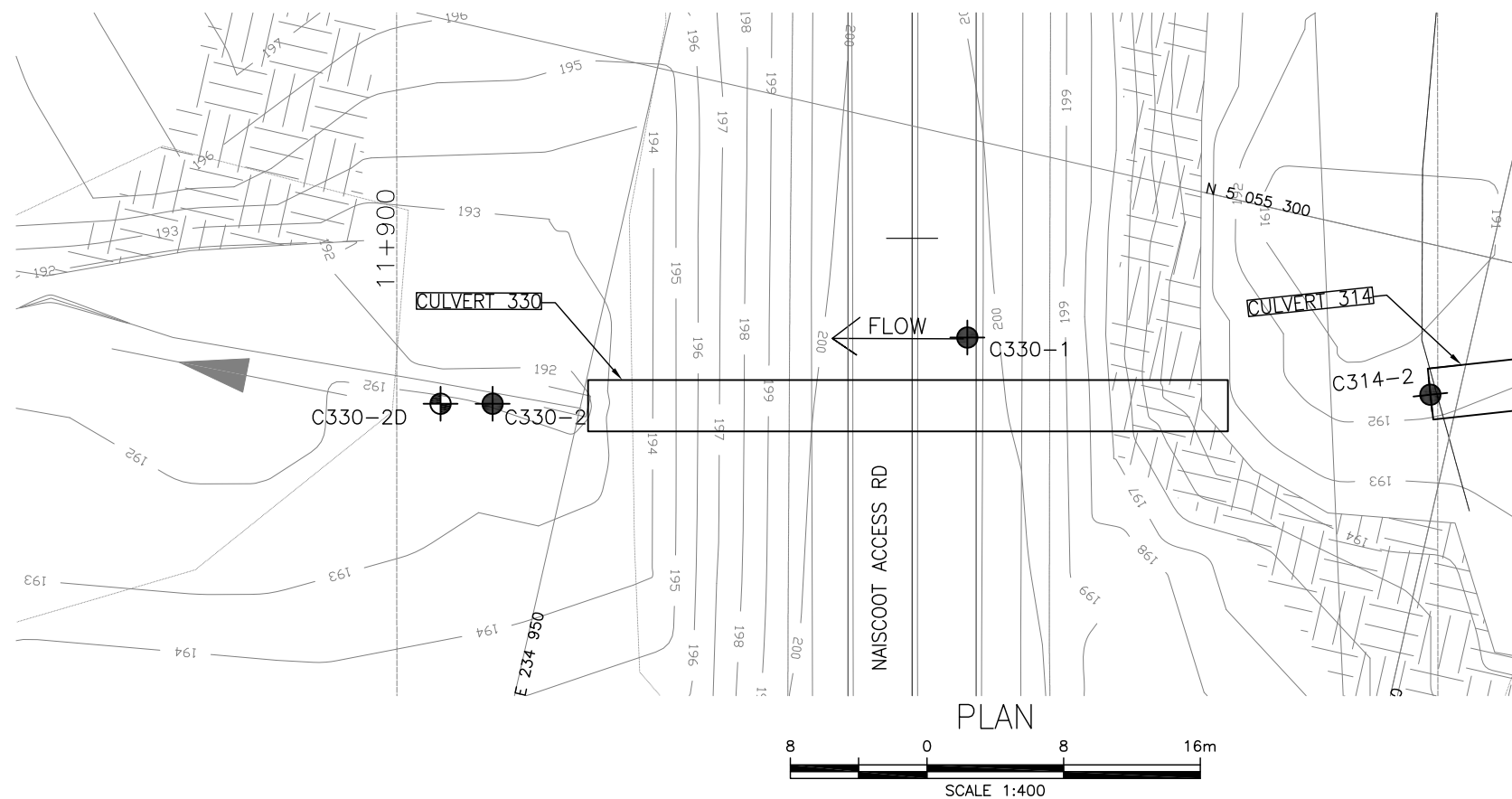
**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C314-2	3.36	189.84

Date August 2014  
 GWP# 5076-06-00



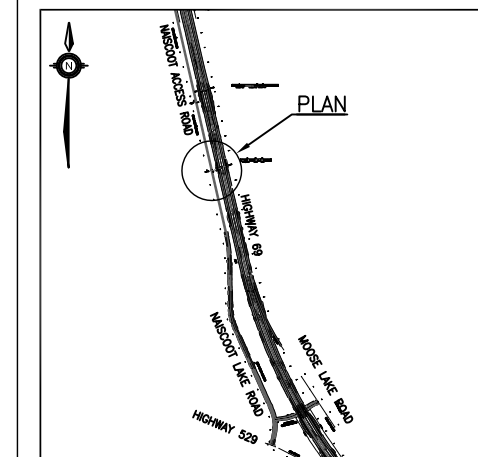
Prep'd MFA  
 Chkd. MRA



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








CONT No  
WP No 5134-12-03  
HIGHWAY 69 FOUR-LANING  
SOUTH SECTION  
CULVERT 330  
BOREHOLE LOCATIONS AND SOIL STRATA



## KEYPLAN

## LEGEND

	Culvert Report Borehole / Cone
	Other Borehole / Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level During Drilling
	Water Level in
	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.

**GEOCRES No. 41H-130**

REVISIONS								
	DATE	BY				DESCRIPTION		
DESIGN	LRB	CHK	MRA			LOAD	DATE	AUG. 2014
DRAWN	MFA	CHK	LRB			SITE 44-601/C STRUCT	DWG	1



**Appendix D**

**Culvert 332**

**Record of Borehole Sheets  
Laboratory Test Results  
Borehole Locations and Soil Strata Drawings**

# RECORD OF BOREHOLE No C332-1

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 735.4 E 234 849.5 ORIGINATED BY SLL  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers (CME 45) COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.11 - 2011.02.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
191.9	Ground Surface													
0.0	ORGANICS, roots and rootlets													
0.2	Silty CLAY, trace sand Firm Brown		1	SS	7		191							
			2	SS	9		190							
189.8														
188.7	SAND, some silt to silty Brown Wet													
2.2	END OF BOREHOLE AT 2.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT SURFACE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.													

# RECORD OF BOREHOLE No C332-2

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 740.6 E 234 870.1 ORIGINATED BY ES  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2012.06.13 - 2012.06.13 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			SHEAR STRENGTH kPa					
								WATER CONTENT (%)					
197.2	Ground Surface												
0.0	ASPHALT: (50mm)												
	Gravelly SAND, some silt Brown Damp (FILL)		1	GS									29 59 12 (SI+CL)
196.1													
1.1	ROCK FILL												
			1	RUN									
			2	RUN									
			3	RUN									
			4	RUN									
189.7													
189.6	Silty CLAY, some gravel Firm Brown Moist												
7.6	BEDROCK, granite, grey/pink Vertical fracture from 8.4m to 8.7m		5	RUN									RUN #5 TCR=100% SCR=100% RQD=72%
188.4													
8.8	END OF BOREHOLE AT 8.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 6.4m, CUTTINGS TO 1.2m, BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT TO SURFACE.												

ONTMT4S 6121(CULVERTS).GPJ 2012TEMPLATE(MTO).GDT 8/20/14

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C332-3

1 OF 1

METRIC

GWP# 5076-06-00 LOCATION N 5 055 743.5 E 234 881.5 ORIGINATED BY SLL  
 HWY 69 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.02.11 - 2011.02.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
191.6	Ground Surface							20	40	60	80	100		
0.0	PEAT, roots and rootlets													
190.8							191							
0.8	SAND, some silt Loose Brown		1	SS	4									
190.2														
1.4	Silty CLAY, trace sand, occasional rootlets Firm Brown		2	SS	5		190							
189.1			3	SS	50/									
2.5	END OF BOREHOLE AT 2.5m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 0.1m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.				0.100									

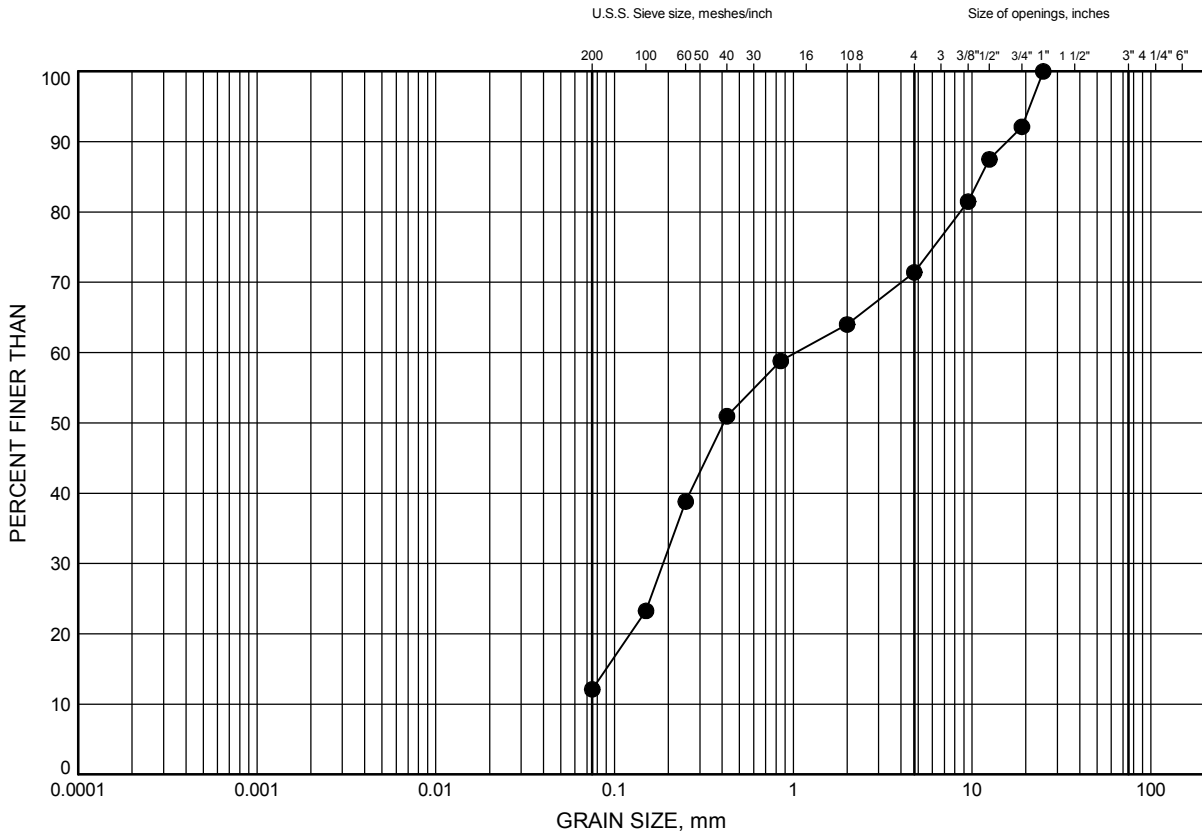
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

Hwy 69 Four-Laning North of Hwy 529  
**GRAIN SIZE DISTRIBUTION**

FIGURE D1

**Gravelly Sand Fill**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C332-2	0.50	196.70

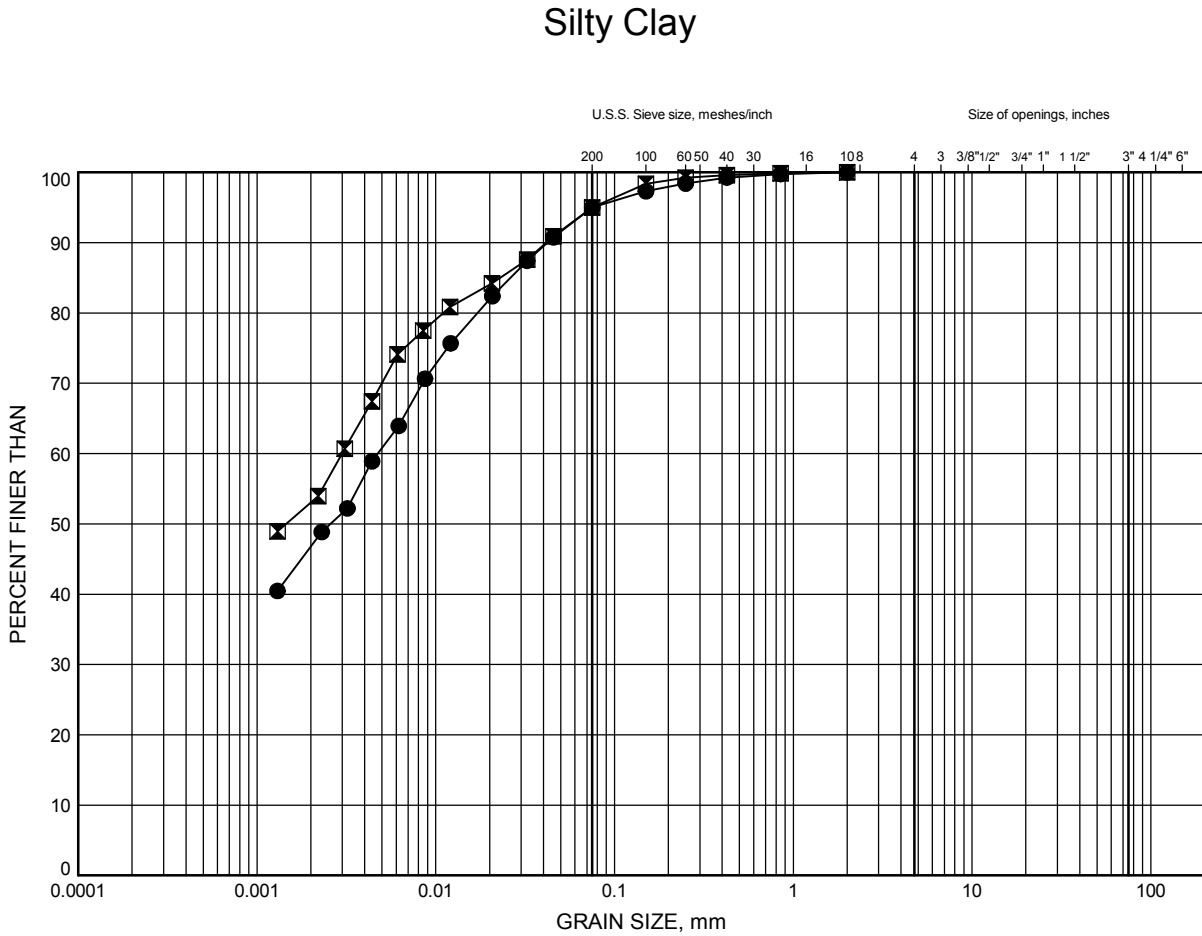
Date August 2014  
 GWP# 5076-06-00



Prep'd MFA  
 Chkd. MRA

# Hwy 69 Four-Laning North of Hwy 529 GRAIN SIZE DISTRIBUTION

FIGURE D2



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C332-1	1.83	190.07
⊠	C332-3	1.83	189.77

Date August 2014

GWP# 5076-06-00



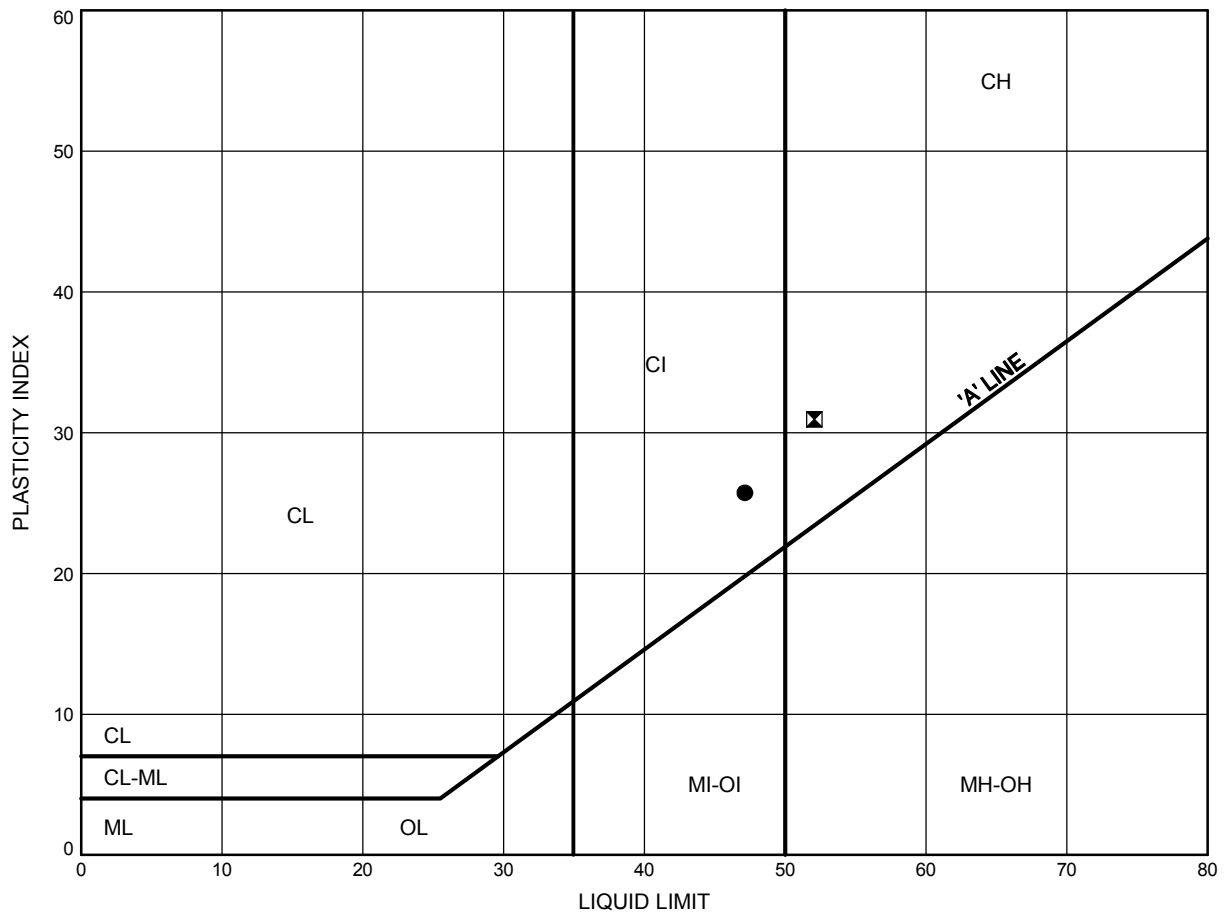
Prep'd MFA

Chkd. MRA

Hwy 69 Four-Laning North of Hwy 529  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE D3

Silty Clay



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C332-1	1.83	190.07
⊠	C332-3	1.83	189.77

Date August 2014  
 GWP# 5076-06-00










Prep'd MFA  
 Chkd. MRA

A circular professional seal for a Licensed Professional Engineer in the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. Inside the ring, there are two horizontal ovals. The top oval contains a handwritten signature, "P. K. Chatterji". The bottom oval contains the handwritten date "Aug 21 / 14". Between the two ovals, the name "P. K. CHATTERJI" is printed in bold capital letters.



## KEYPLAN

### LEGEND

	Culvert Report
	Borehole
	Cone
	Other Borehole
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level During Drilling
	Water Level in
	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.

**GEOCRES No. 41H-130**

[illegible]

FILE NAME: H:\Printing\19\3101\Z1 (reduzi) - Flutuações\Cuvelos).dwg  
 PLOT DATE: 8/22/2014 9:49 AM

