

**FOUNDATION INVESTIGATION AND DESIGN REPORTS  
PROPOSED WEST BEATON RIVER TRIBUTARY CULVERT REPLACEMENT  
HIGHWAY 631 NORTH OF HIGHWAY 17, ONTARIO  
WP 5079-09-01 SITE NO. 38N-013/C  
G.W.P. 5270-08-00  
MTO GEOCRETS NO. 42C-26**

Prepared for:

**MCINTOSH PERRY CONSULTING ENGINEERS**

By:

**SPL CONSULTANTS LIMITED**

Project: 750-1001 (West Beaton)  
January 2014



**SPL Consultants Limited**  
Geotechnical Environmental Materials Hydrogeology

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**PART A**  
**FOUNDATION INVESTIGATION REPORT**  
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## **1. INTRODUCTION**

SPL Consultants Limited (SPL) was retained by McIntosh Perry Consulting Engineers to conduct a foundation investigation as part of the proposed culvert replacement at a tributary of the West Beaton River located on Highway 631 approximately 70.4 km north of Highway 17 between White River and Hornepayne, Ontario.

The terms of reference (TOR) for this investigation are outlined in the Request for Quotation (RFQ) issued by the Ministry of Transportation (MTO) under Agreement No. 5010-E-0001 dated April, 2010 and SPL's subsequent proposal No. P10.06.018 dated June, 2010. At the time of the initial foundation investigation (June 2011) the proposed culvert was to be located at the same location as the existing culvert. Subsequent to completion of the initial investigation the proposed culvert location was moved approximately 10 m to the south.

The purpose of the foundation investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the foundation investigation carried out at the site, as well as general comments and recommendations for the design and construction of the proposed culvert replacement.

As part of this project a geotechnical (pavement) investigation was also carried out at the site concurrent with the foundation investigation. The results of the pavement investigation are presented under separate cover.

## **2. SITE DESCRIPTION**

The site is located at a tributary of the West Beaton River, between White River and Hornpayne, ON on Highway 631 approximately 70.4 km north of Highway 17 (see Drawing 1). The existing structure is made up of a single plate Structural Plate Corrugated Steel Pipe (SPCSP) culvert with a width of 3.4 m, a height of 2.01 m, and an overall length of about 28 m. The fill cover is approximately 1.5 m in depth above the top of the culvert.

The elevation of natural ground in the general vicinity of the culvert crossing is approximately 324 m. The elevation of the highway (top of pavement) at the crossing is approximately 328.5 m (the embankment is approximately 4 m to 5 m high at the crossing).

## **3. INVESTIGATION PROCEDURES**

The initial foundation investigation was carried out in June 2011 followed by a subsequent investigation in November/December 2013. The scope of work for this assignment included a desk study, field investigations, laboratory testing, analysis and preparation of this report.

### 3.1 Desktop Study

Surficial geology in the area comprises glacial till (silt sand and gravel as well as potentially cobbles and boulders), as well as glaciofluvial (sand and gravel) and glaciolacustrine (silt and sand) deposits.

Bedrock geology maps of the general area indicate the bedrock to be foliated to gneissic tonalite and granodiorite.

### 3.2 Field Investigation

Field investigations were carried out on June 10 and 11, 2011 as well as November 28 to December 2, 2013 and included drilling a total of 6 boreholes at the crossing location (BH11-1 through BH11-4, BH13-1 and BH13-2). Two shallow auger holes (AH13-1 and AH13-4 ; AH13-2 and AH13-3 were advanced mid-slope to supplement the pavement investigations and are discussed in the Pavement Design Report) were advanced in the ditch, west of the existing highway. As mentioned previously, additional shallow boreholes were advanced at the same time for the geotechnical (pavement) portion of the work; the results of these boreholes are submitted with the geotechnical (pavement) investigation report under separate cover.

The boreholes drilled on the existing highway were advanced using a truck-mounted drill rig supplied and operated by George Downing Estate Drilling Limited of Hawkesbury, ON. The boreholes were drilled using hollow-stem auger drilling as well as dynamic cone penetration testing, to depths ranging from 5.4 m to 15.2 m below the existing ground surface. During drilling, sampling and in-situ testing [including Standard Penetration (SPT) Testing and Dynamic Cone Penetration (DCPT) Testing] were carried out. In November/December 2013 additional boreholes were drilled using hand portable drilling equipment supplied and operated by OGS Inc. of Almonte, ON. Boreholes BH13-1 and BH13-2 were drilled using a combination of continuous sampling and wash boring and were drilled to a depths of 7.9 m and 6.7 m, respectively, below the existing ground surface. Auger holes AH13-1 and AH13-4 were drilled through continuous sampling by a manual hammer to depths ranging from 1.2 m to 1.7 m below the existing ground surface. During drilling, sampling and in-situ testing [including SPT<sup>1</sup> and shear vane testing] were carried out.

A standpipe piezometer was installed in Borehole BH11-2 to allow for subsequent measurement of stabilized groundwater levels at the site. All boreholes were backfilled with bentonite and soil cuttings and were sealed at the ground surface. All boreholes were drilled and abandoned in accordance with Ontario Regulation 903.

Borehole locations are shown in Drawing 2. Borehole logs are included in Appendix A.

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<sup>1</sup> SPT sampling was carried out using a non-standard hammer. SPT “N” values recorded on the borehole log for AH13-1 and AH13-4 have been corrected for this non-standard energy.

### **3.3 Laboratory Testing**

During drilling and in-situ testing, soil samples were obtained for further examination and classification. A laboratory testing program, including determination of natural water content, grain size distribution (sieve and hydrometer) and chemical analyses, was carried out on selected representative soil samples.

The results of natural water content tests are included on the relevant borehole logs in Appendix A. The results of determination of grain size distribution are summarized on the individual borehole logs, and are also presented in Drawings 3 through 5.

Chemical testing to determine sulphate content, chloride content, pH and soil resistivity was carried out on selected soil samples obtained during drilling. The results of these tests are included in Appendix B.

## **4. SUBSURFACE CONDITIONS**

The subsurface conditions at the site are discussed in the following sections. Detailed descriptions of the soil and groundwater conditions encountered at each of the borehole locations are included in the individual borehole logs in Appendix A.

### **4.1 Soil Conditions**

#### **4.1.1 Asphalt**

Boreholes BH11-1 through BH11-4 were drilled on the existing highway. Boreholes BH11-1 and BH11-3 were drilled on a paved section of the shoulder and encountered a layer of asphalt 125 mm and 80 mm thick, respectively. Boreholes BH11-2 and BH11-4 were drilled on the unpaved shoulder and did not encounter any asphalt.

#### **4.1.2 Granular Fill**

The asphalt is underlain by granular fill, which forms the pavement structure of the highway, as well as the existing highway embankment.

The uppermost portion of the granular fill was found to be sand and gravel, while the lower portions of the fill were primarily sand. The density of the fill material (as interpreted based on SPT and DCPT "N" values) typically ranged from loose to compact, with localized areas being very loose or dense.

In the boreholes drilled on the existing highway, the fill material extended to a depth of 3.1 m to 4.7 m below the existing road surface. This corresponds to elevations of 325 m to 323.9 m. In the two boreholes on the existing roadway drilled adjacent to the existing culvert the fill material was found to be 4.6 m to 4.7 m thick (to elevation 323.7 m to 323.9 m). Fill was also encountered in the boreholes (BH13-1 and BH13-2) drilled near the inlet/outlet of the proposed culvert. The fill material extended to a depth of 0.9 m to 2.4 m below the existing ground elevation. This corresponds to elevations of 324.9 m to 324.3 m.

The grain size distributions of representative samples of the fill material are presented in Table 1 below. The grain size distribution curves are also included in Drawings 4.

**Table 1 – Results of Grain Size Analyses for Fill**

Borehole No.	Sample No.	Grain Size Distribution		
		% Gravel	% Sand	% Fines
BH13-2	SS-2	6	84	10

#### 4.1.3 Peat/Organic Soil

A layer of peat/organic soil was encountered in Boreholes BH11-1 and BH13-1 drilled at the culvert crossing as well as in the two auger holes drilled in the ditch west of the existing highway (AH13-1 and AH13-4).

In Auger holes AH13-1 and AH13-4 peat was encountered underlying the surface and had a thickness of 1.1 m and 1.7 m, respectively. This corresponds to elevations of 325.4 m and 324.9m.

In Borehole BH11-1, a layer of peat was encountered at the base of the fill and had a thickness of 0.3 m. In Borehole BH13-1, a layer of peat mixed with silty sand was encountered, again, at the base of the fill and had a thickness of 0.6 m. The base of this peat/organic soil in Boreholes BH11-1 and BH13-1 has elevations of 323.6 m and 324.3 m, respectively.

This suggests that the existing highway was not completely stripped prior to placement of the original fill embankment (and possibly the existing culvert structure, although this cannot be confirmed until the existing structure is removed).

In auger holes AH13-1 and AH13-4, in-situ strength of the peat/organic soil was measured during drilling through a combination of SPT testing and field shear vane testing at regular intervals. Shear vane testing yielded shear strengths between 18 kPa to 36 kPa.

#### 4.1.4 Native Silt and Sandy Silt

The fill material and peat/organic soil were underlain by native soils which include a variable deposit of silt and sand. The material generally ranges from gravelly sand to clayey silt. The density of the silt and sand (as interpreted on SPT “N” values and DCPT resistance values) is typically loose to compact. SPT “N” values and DCPT resistance values are presented on the borehole logs included in Appendix A as well as on the Soil Strata included in Drawing Nos. 2A and 2B.

A layer of compact to dense gravelly sand was also encountered in Boreholes BH11-1 and BH13-2. Cobbles and boulders were encountered underlying the fill material in BH11-3. Detailed descriptions of the soils encountered at each of the borehole locations are provided in the borehole records included in Appendix A.



The silt and sand soils extended to the depth of drilling in BH11-1, BH11-2, B11-4, BH13-1 and BH13-2. BH11-3 encountered cobbles and boulders at a depth of 4.6 m, followed by refusal at 5.4 m depth. The grain size distributions of representative samples of the native soils are presented in Table 2 below. The grain size distribution curves are also included in Drawings 3 through 5.

**Table 2 – Results of Grain Size Analyses for Native Soils**

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH11-1	SS-7	40	42	15	3
BH11-1	SS-8	0	8	63	27
BH11-2	SS-8	0	1	85	14
BH11-3	SS-5	10	38	45	7
BH11-4	SS-5	0	6	76	18
BH11-4	SS-8	0	1	85	14
BH13-1	SS-4	0	46	49	6
BH13-1	SS-7	17	66	14	2
BH13-1	SS-10	1	6	76	17
BH13-2	SS-8	0	58	37	5
BH13-2	SS-11	3	4	87	6

#### 4.1.5 Auger Refusal

Auger refusal was encountered in three of the four boreholes (BH11-1, BH11-2 and BH11-3) drilled on the existing highway. Auger refusal may represent the bedrock surface at some of the locations (at BH11-3 south of the culvert the hole was attempted at three locations, and all three attempts met with refusal at roughly the same depth). It may, however, also represent cobbles and boulders which could not be augered through. At Boreholes BH11-1 and BH11-2 DCPT testing could be continued past the point of auger refusal. No refusal was encountered in Boreholes BH13-1 and BH13-2 drilled near the inlet/outlet of the proposed culvert.

## 4.2 Groundwater Conditions

Groundwater was encountered during drilling in all of the boreholes. A standpipe piezometer was installed in BH11-2 adjacent to the existing culvert. The groundwater level at the site was measured in June 2011 and found to be at an elevation of 326.9 m in the piezometer.

It should be noted that the groundwater levels can vary and are subjected to seasonal fluctuations as well as fluctuations in response to major weather events, and in particular for this site, in response to changes in the level of the creek. If construction is carried out at a time when the creek level is higher than the level in June, 2011 a corresponding increase in groundwater levels should be anticipated.

### 4.3 Summary

A summary of the soil and groundwater conditions encountered at the West Beaton River Tributary crossing location is presented in Table 2 below.

**Table 2 – Simplified Stratigraphy and Groundwater Elevations**

Borehole No.	Ground Surface Elevation	Simplified Stratigraphy (Depth)			Measured Ground water Elevation	Notes
		Granular Fill	Peat/ Topsoil	Native Silt & Sandy Silt		
BH11-1	328.5	0.0 – 4.6 m	---	4.6 – 10.7 m	--	Auger refusal at 9.8 m; DCPT continued to 10.7 m
BH11-2	328.4	0.0 – 4.7 m	---	4.7 – 15.2 m	326.9	Auger refusal at 9.8 m; DCPT continued to 15.2 m
BH11-3	329.0	0.0 – 3.1 m	---	3.1 – 5.4 m	---	Auger refusal at 5.4 m
BH11-4	328.1	0.0 – 3.1 m	---	3.1 – 9.8 m	---	Borehole terminated at 5.4 m
BH13-1	326.1	0.0 – 1.2 m	1.2 – 1.8 m	1.8 – 7.9 m	---	Borehole terminated at 7.9 m
BH13-2	326.8	0.0 – 2.4 m	---	2.4 – 6.7 m	---	Borehole terminated at 6.7 m
AH13-1	326.5	---	0.0 – 1.1 m	1.1 – 1.2 m	---	Borehole terminated at 1.2 m
AH13-4	326.6	---	0.0 – 1.7 m	1.7 – 2.4 m	---	Borehole terminated at 2.4 m

## 5. CLOSURE

The field investigations in June 2011 were supervised by Mr. Naeem Ehsan, P.Eng. The field investigations in November/December 2013 were supervised by Mr. Daniel Wall, E.I.T. This report was prepared by Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, P.Eng., SPL's designated MTO contact and Mr. Shaheen Ahmad, P.Eng., SPL's project quality control auditor, provided independent review and quality control of the technical aspects of this report.

We trust that the information contained in this report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

**SPL CONSULTANTS LIMITED**



Chris Hendry, M.Eng., P.Eng.



Fanyu Zhu, Ph.D., P.Eng.



Shaheen Ahmad, M.A.Sc., P.Eng.

*Project: 750-1001 (West Beaton)*


*Foundation Investigation Report GWP 5270-08-00*

*Proposed West Beaton River Tributary Culvert Replacement, Highway 631 North of Highway 17, Ontario Site No. 38N-013/C*

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# Drawings



Client: McIntosh Perry Consulting Engineers		Title: SITE PLAN	
Project#:	750-1001	DWG #:	1
Drawn:	NT	Approved:	CH
Date:	AUG 26-2011	Scale:	N. T. S.
Size:	Letter	Rev:	0
 <b>SPL Consultants Limited</b> Geotechnical Environmental Materials Hydrogeology			



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

CONT No  
WP No 5079-09-01

WEST BEATON RIVER  
TRIBUTARY CULVERT-HWY 631  
BORE HOLE LOCATIONS & SOIL STRATA

SPL Consultants Limited  
Geotechnical • Environmental • Materials • Hydrogeology

KEY PLAN  
NOT TO SCALE

LEGEND

- Bore Hole
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at time of investigation July 2011
- WL in Piezometer
- Piezometer

No	ELEVATION	STATION	OFFSET
BH11-1	328.5	16+714.6	3.5m W
BH11-2	328.4	16+727.9	3.5m E
BH11-3	329.0	16+680.9	3.0m E
BH11-4	328.1	16+760.9	3.5m E
BH13-1	326.1	16+703.6	14.4m W
BH13-2	326.8	16+717.7	5.9m E
AH13-1	326.5	16+693.6	12.4m W
AH13-3	326.6	16+744.4	11.0m W

CROSS-SECTION A-A

SOIL STRATA SYMBOLS

- SAND & GRAVEL FILL
- GRAVELLY SAND
- PEAT
- SILT TO SANDY SILT
- AUGER REFUSAL

NOTES

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

REVISIONS

DATE	BY	DESCRIPTION
Jan14/14	TJC	Revised Final Report
Aug15/12	TJC	Final Revision
Feb16/12	TJC	Revision 1

GEORES No 42C-26

HWY No 631	SUBM'D CH	CHECKED CH	DATE	APPROVED	DIST
			Aug13, 2012	FZ	Algoma

DRAWN TJC

CHECKED CH






APPROVED FZ

DWG 2A

SITE 38N-013/C



SHEET  
24

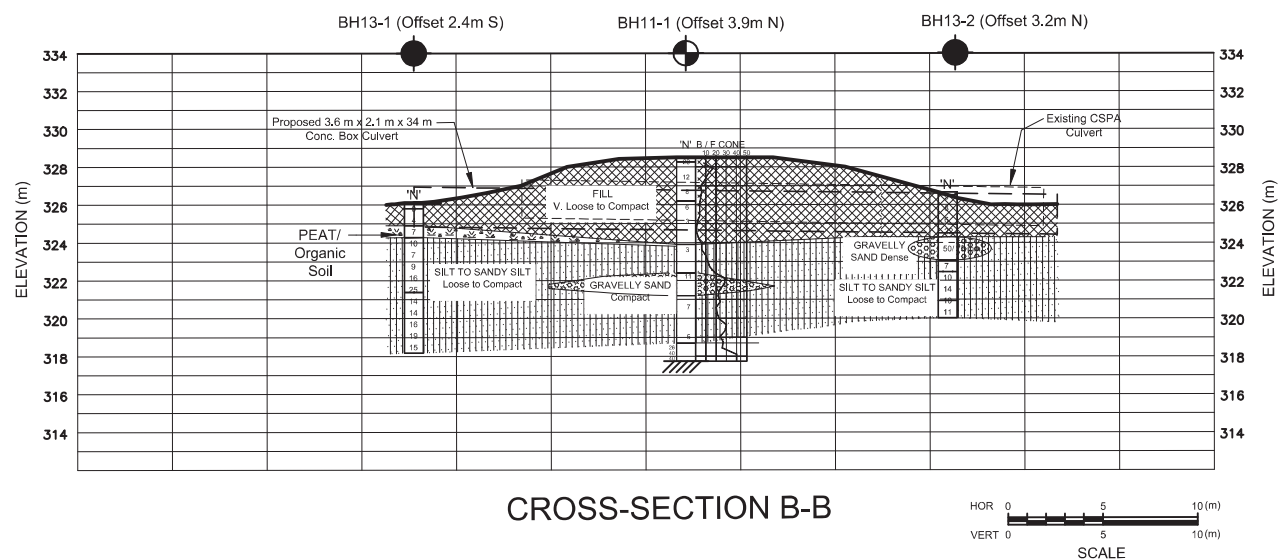
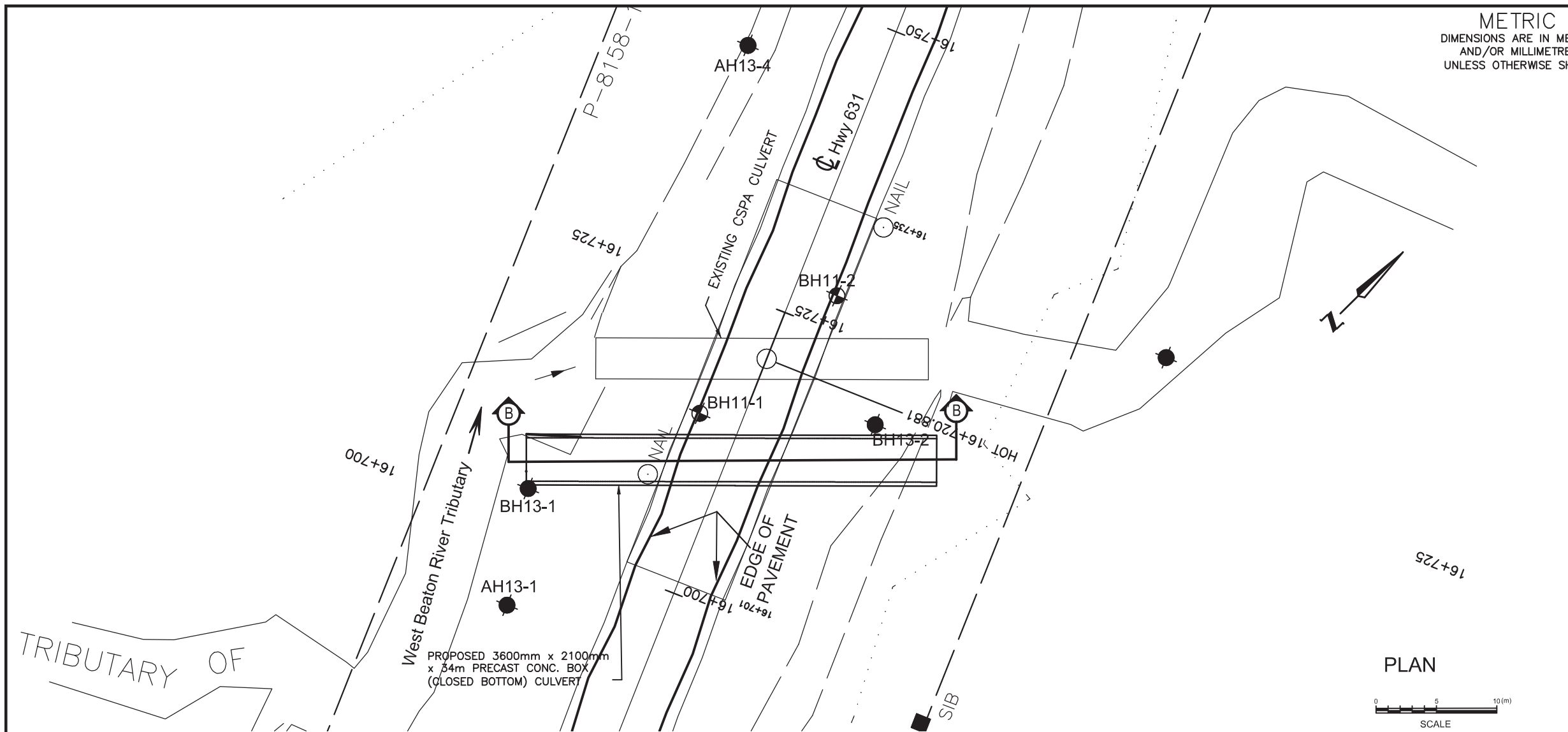
LEGEND	
	Bore Hole
	Bore Hole & Cone
N	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	WL at time of investigation July 2011
	WL in Piezometer
	Piezometer

No	ELEVATION	STATION	OFFSET
BH11-1	328.5	16+714.6	3.5m W
BH11-2	328.4	16+727.9	3.5m E
BH11-3	329.0	16+680.9	3.0m E
BH11-4	328.1	16+760.9	3.5m E
BH13-1	326.1	16+703.6	14.4m W
BH13-2	326.8	16+717.7	5.9m E
AH13-1	326.5	16+693.6	12.4m W
AH13-3	326.6	16+744.4	11.0m W

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

GEOCREs No 42C-26

HWY No 631		DIST Algoma	
SUBM'D CH	CHECKED CH	DATE Aug 13, 2012	SITE 38N-013/C
DRAWN TJC	CHECKED CH	APPROVED FZ	DWG 2A



SOIL STRATA SYMBOLS

	SAND & GRAVEL FILL		GRAVELLY SAND		PEAT
	SILT TO SANDY SILT		AUGER REFUSAL		



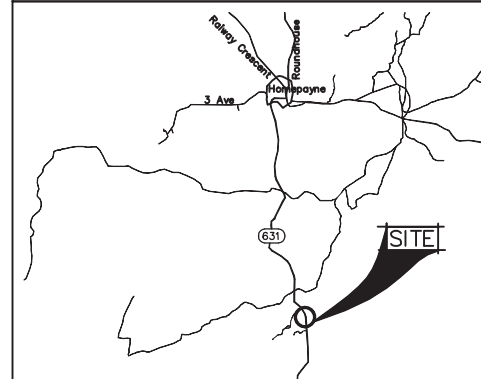
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WP No 5079-09-01



WEST BEATON RIVER  
TRIBUTARY CULVERT-HWY 631  
BORE HOLE LOCATIONS & SOIL STRATA

SHEET  
24

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KEY PLAN  
NOT TO SCALE

#### LEGEND

- ◆ Bore Hole
- ◆ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- ↓ WL at time of investigation July 2011
- ↓ WL in Piezometer
- ▬ Piezometer

No	ELEVATION	STATION	OFFSET
BH11-1	328.5	16+714.6	3.5m W
BH11-2	328.4	16+727.9	3.5m E
BH11-3	329.0	16+680.9	3.0m E
BH11-4	328.1	16+760.9	3.5m E
BH13-1	326.1	16+703.6	14.4m W
BH13-2	326.8	16+717.7	7.1m E
AH13-1	326.5	16+693.6	12.4m W
AH13-4	326.6	16+744.4	11.0m W

#### NOTES

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

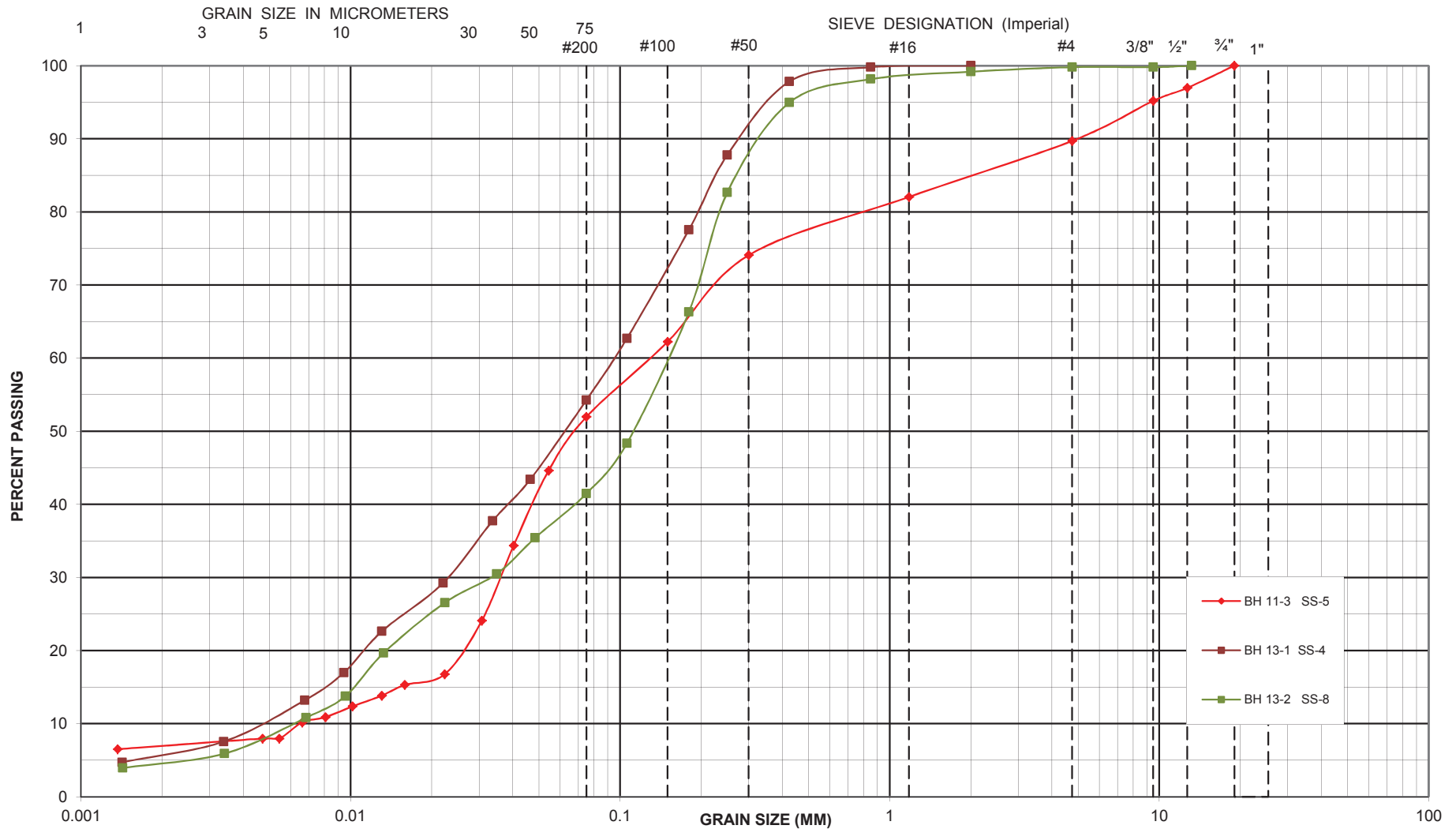
REVISIONS	DATE	BY	DESCRIPTION
Jan14/14	TJC		Revised Final Report
Aug15/12	TJC		Final Revision
Feb16/12	TJC		Revision 1

GEOCRE No 42C-26

HWY No 631		DATE Jan14, 2014	DIST Algoma
SUBM'D CH	CHECKED CH	APPROVED FZ	SITE 38N-013/C
DRAWN ZMO	CHECKED CH		DWG 2B

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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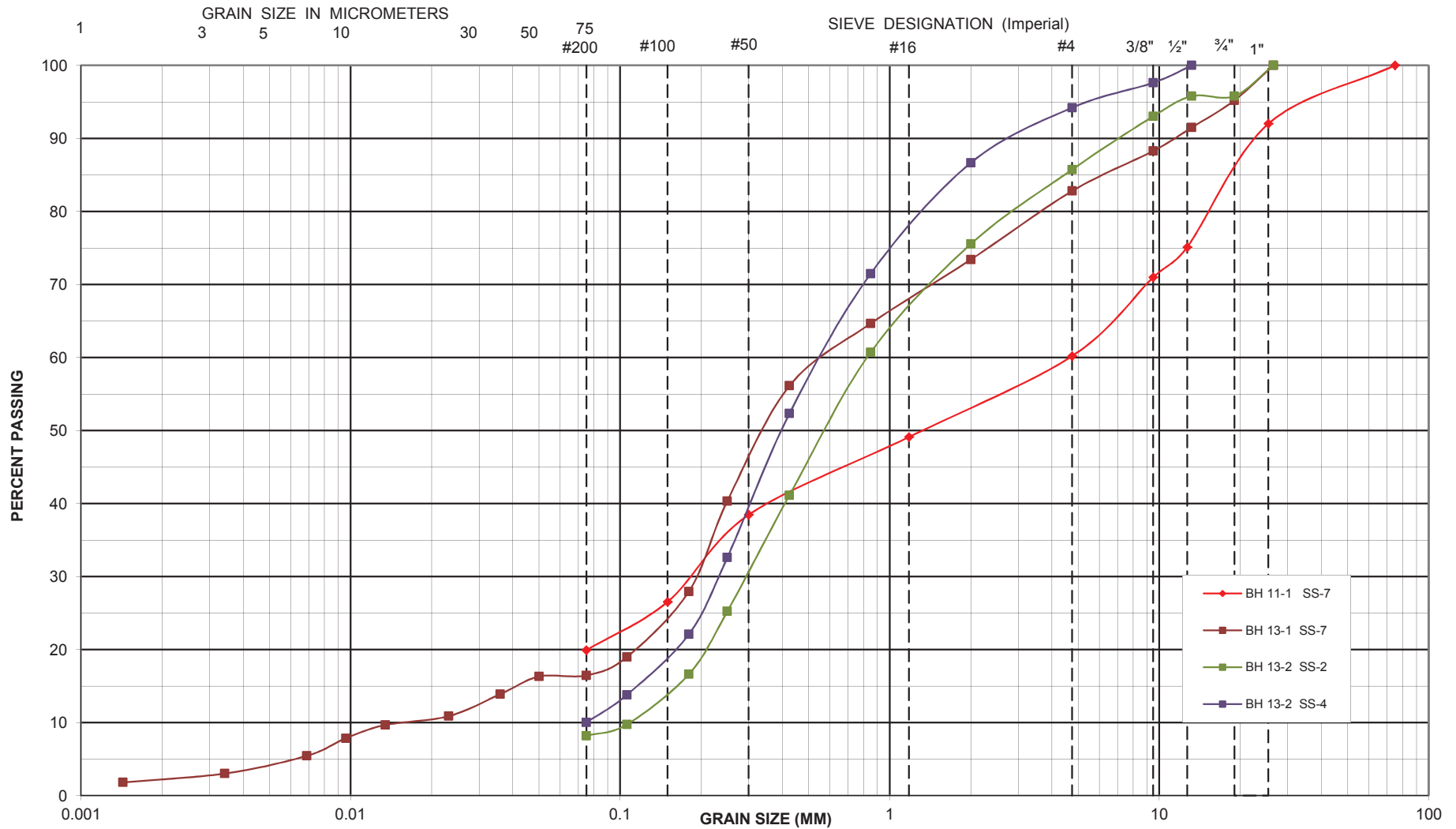
**GRAIN SIZE DISTRIBUTION - SANDY SILT**  
Proposed Culvert Replacement - West Beaton River Tributary

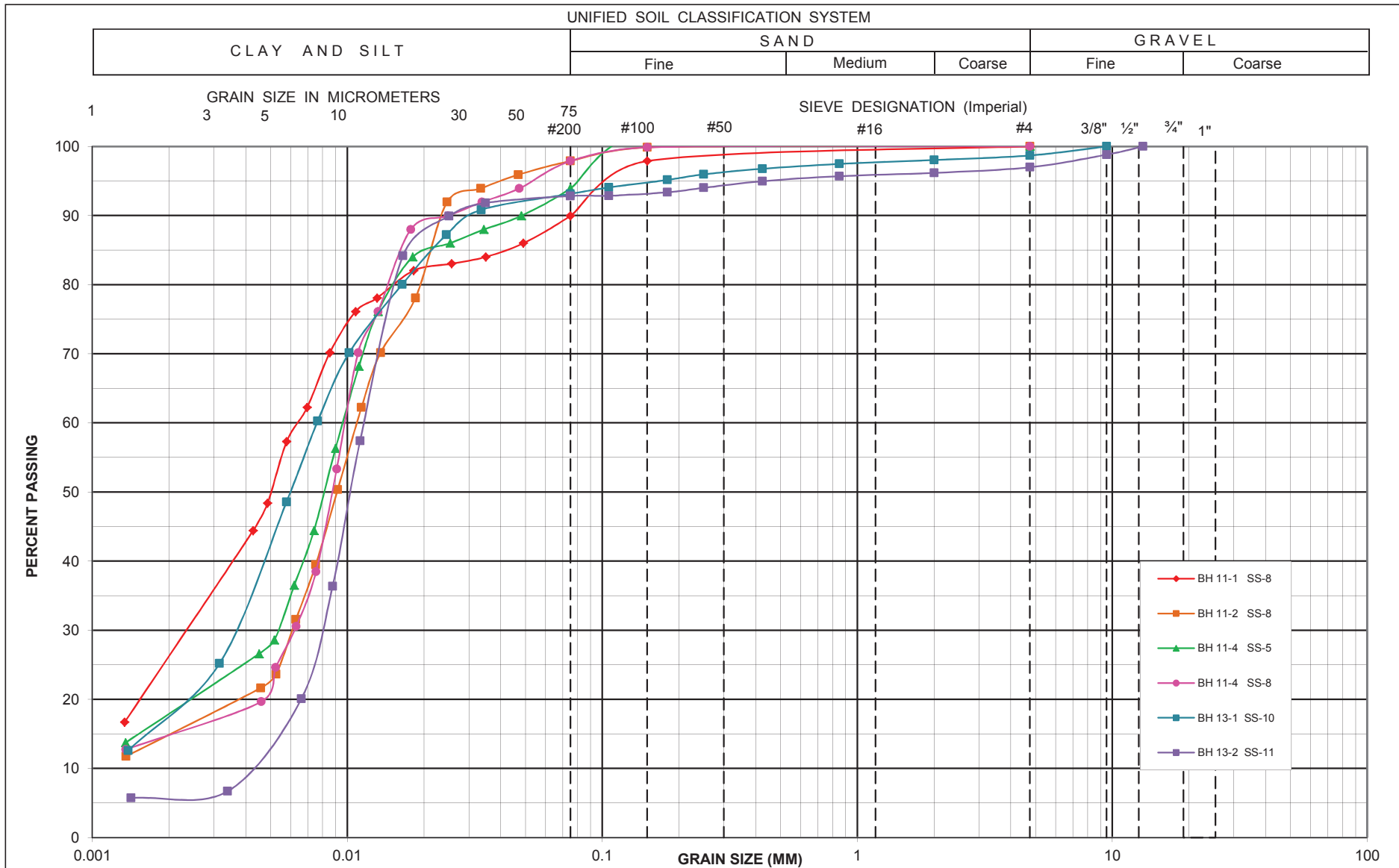
Drawing No: 3  
Project No. 750-1001  
Date: January 2014



# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse





# Appendix A

## Borehole Logs (Record of Borehole Sheets)

**RECORD OF BOREHOLE No BH11-1**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION See Borehole Location Plan, E 1, N 0 ORIGINATED BY NE  
DIST Algoma HWY 631 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NE  
DATUM Geodetic DATE Jun/11/2011 CHECKED BY CH

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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
328.5								25	50	75	100	125				
328.4	ASPHALT: 125 mm		1	SS	23		328									
0.1	Fill: Sand and Gravel brown, moist compact															
	trace gravel		2	SS	12		327									
	loose		3	SS	8		326									
326.2	Fill: Sand brown, wet loose to very loose		4	SS	6		325									
2.3	trace gravel		5	SS	3		324									
323.9	Peat: dark brown, moist		6	SS	3		323									
324.8	Sandy Silt: trace clay, trace rootlets, some organics grey, wet very loose						322									
4.7			7	SS	11		321									
322.4	Gravelly Sand: some silt, trace clay grey, wet compact		8	SS	7		320									
6.1	Silt: trace sand, trace to some clay grey, wet firm		9	SS	5		319									
321.2							318									
7.3	gravelly and sandy at 9.5 m															
318.7	Auger refusal															
9.8																
317.8	End of Borehole															
10.7	Notes: 1. Auger drilling ended at 9.8 m and dynamic cone test ended at 10.7 m. 2. Water level at 3.1 m during drilling. 3. Water level at 4.3 m upon completion.															

ON-MTO-LARGE SCALE SPL-M-MTO-750-JUNE-WEST BEATON RIVER GPJ ON\_MOT\_GDT 13/1/14

**RECORD OF BOREHOLE No BH11-2**

1 OF 2

**METRIC**

W.P. 5079-09-01 LOCATION See Borehole Location Plan, E 2, N 0 ORIGINATED BY NE  
DIST Algoma HWY 631 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NE  
DATUM Geodetic DATE Jun/10/2011 CHECKED BY CH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
328.4 0.0	Fill: Sand and Gravel trace asphalt pieces brown, moist compact		1	SS	15		328										
	some gravel		2	SS	9		327										
326.9 1.5	Fill: Sand brown, wet loose to very loose		3	SS	7		327										
	trace gravel		4	SS	4		326										
			5	SS	1		325										
							324										
323.7 4.7	Silt: trace clay, trace sand grey, wet compact		6	SS	20		323										
	trace rootlets						322										
	loose		7	SS	8		321										
							320										
	some clay		8	SS	8		319										
							318										
318.6 9.8	Auger refusal		9	SS	7		317										
							316										
							315										
							314										
313.2																	

ON-MTO-LARGE SCALE SPL-M-MTO-750-JUNE-WEST BEATON RIVER GPJ ON\_MOT.GDT 13/1/14

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No BH11-2**

2 OF 2

**METRIC**

W.P. 5079-09-01 LOCATION See Borehole Location Plan, E 2, N 0 ORIGINATED BY NE  
DIST Algoma HWY 631 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NE  
DATUM Geodetic DATE Jun/10/2011 CHECKED BY CH

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	25	50	75	100	125	W <sub>p</sub>	W		
15.2	<b>End of Borehole</b> Notes: 1. Auger drilling ended at 9.8 m and dynamic cone test ended at 15.2 m. 2. Water level at 2.3 m during drilling. 3. Water level at 7 m upon completion. 4. 19 mm dia. piezometer was installed to a depth of 9.8 m. 5. water level in piezometer <u>Date</u> <u>Depth (m)</u> <u>Elevation (m)</u> June 11, 2011 1.54 326.86															

ON-MTO-LARGE SCALE SPL-M-MTO-750-JUNE-WEST BEATON RIVER.GPJ ON\_MOT.GDT 13/1/14

**RECORD OF BOREHOLE No BH11-3**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION See Borehole Location Plan, E 3, N 0 ORIGINATED BY NE  
DIST Algoma HWY 631 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NE  
DATUM Geodetic DATE Jun/10/2011 CHECKED BY CH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
329.0																	
328.7	<b>ASPHALT:</b> 80 mm <b>Fill: Sand and Gravel</b> trace asphalt pieces, brown, moist compact		1	SS	23												
	trace gravel		2	SS	12												
327.5	<b>Fill: Sand</b> brown, very moist loose		3	SS	5												
1.5	some silt to silty, some organics, moist to wet, compact		4	SS	25												
325.9	<b>Sandy Silt:</b> trace clay, trace gravel, trace sandstone fragments, wet sand seams, dense		5	SS	36												
3.1																	
324.4	<b>Cobble &amp; Boulder</b> (possibly Bedrock)		6	SS	50/ 25mm												
4.6			7	SS	50/ 0mm												
323.6	<b>End of Borehole</b> Notes: 1. Borehole was drilled 50 m North of rock cut area and got auger refusal at 5.4 m on possible cobble/boulder or possible bedrock. 2. Redrilled three times by moving the borehole 2 to 3 m North and South of the original borehole location and got auger refusal at 5.4 m on possible cobble/boulder or possible bedrock. 3. Water level at 3.6 m upon completion.																
5.4																	

**RECORD OF BOREHOLE No BH11-4**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION See Borehole Location Plan, E 4, N 0 ORIGINATED BY NE  
DIST Algoma HWY 631 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NE  
DATUM Geodetic DATE Jun/10/2011 CHECKED BY CH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
328.1 0.0	Fill: Sand and Gravel trace asphalt pieces brown, moist compact		1	SS	12		328										
327.3 0.8	Fill: Sand brown, moist loose to very loose		2	SS	9		327										
			3	SS	4		326										
	loose, some silt to silty, some organics		4	SS	9		325										
325.0 3.1	Silt: some clay grey, moist stiff		5	SS	22		324										
			6	SS	15		323										
			7	SS	8		322										
			8	SS	5		321										
			9	SS	7		320										
	clay seams, wet seams of sand						319										
318.3 9.8	End of Borehole Notes: 1. Water level at 4.6 m during drilling. 2. Water level at 8.8 m upon completion.																

ON-MTO-LARGE SCALE SPL-M-MTO-750-JUNE-WEST BEATON RIVER GPJ ON\_MOT\_GDT 13/1/14



**RECORD OF BOREHOLE No BH13-1**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION West Beaton Culvert- See Borehole Location Plan ORIGINATED BY DW  
DIST Algoma HWY 631 BOREHOLE TYPE Portable drilling with continuous sampling and wash boring COMPILED BY DW  
DATUM Geodetic DATE Nov/28/2013 CHECKED BY CH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
326.1 0.0	Topsoil - 300 mm						326										
325.8 0.3	Fill: Clayey Silt trace gravel, trace to some roots and organics, dark brown, wet, soft		1	SS	0											93.5	
324.9			2A	SS	4												
324.9 1.2	Peat mixed with Silty Sand: some roots and organics, dark brown, moist, loose		2B	SS	4		325										
324.3 1.8	Sand and Silt: trace clay, brown, wet, loose  - grey below 2.4 m		3	SS	7												
			4	SS	10		324										0 46 49 6
			5	SS	7												
			6	SS	9		323										
322.5 3.7	Sand some gravel, some silt, trace clay, wet, moist, compact		7	SS	16												
			8A	SS	25		322										17 66 14 2
321.4 4.7	Silt: some clay, trace sand, trace gravel, grey, wet, stiff to very stiff		8B	SS	25												
			9	SS	14		321										
			10	SS	14												1 6 76 17
			11	SS	16		320										
			12	SS	19												
			13	SS	15		319										
318.2 7.9	End of borehole 1 - Drilling ends at 7.9 m 2 - Water level at 0.6 m during drilling																

ON-MTO-LARGE SCALE SPL-M-MTO-750-WEST BEATON RIVER- NOV 2013.GPJ ON\_MOT.GDT 13/1/14

**RECORD OF BOREHOLE No BH13-2**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION West Beaton Culvert- See Borehole Location Plan ORIGINATED BY DW  
DIST Algoma HWY 631 BOREHOLE TYPE Portable drilling with continuous sampling and wash boring COMPILED BY DW  
DATUM Geodetic DATE Nov/28/2013 CHECKED BY CH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
326.8	<b>Topsoil - 75 mm</b>																
326.0	<b>Fill: Sand</b> trace to some gravel, trace to some silt, brown, moist, loose to compact (FILL)		1	SS	9												
326.0																	
	- below 0.9 m wet and trace silt		2	SS	8		326										6 84 (10)
			3	SS	6												
			4	SS	22		325										
324.4	<b>Gravelly Sand</b> brown, wet, dense																
324.4			5	SS	50/ 75 mm		324										
323.1	<b>Silty Sand:</b> trace roots and organics, dark brown, wet, loose																
322.5			6	SS	7		323										0 58 37 5
322.5	<b>Silty Sand:</b> trace clay, grey, wet, compact																
322.5			7	SS	10		322										
			8	SS	14												
321.0	<b>Silt:</b> trace clay, trace sand, trace gravel, grey, wet, stiff		9A	SS	10		321										3 4 87 6
321.0			9B	SS	10												
			10	SS	11												
320.1	<b>End of Borehole</b> 1 - Drilling ends at 6.7 m 2 - Casing installed to 3.4 m 3 - Water level at 0.9 m during drilling						320										
320.1																	
							319										

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON-MTO-LARGE SCALE SPL-M-MTO-750-WEST BEATON RIVER- NOV 2013.GPJ ON\_MOT.GDT 13/1/14

**RECORD OF BOREHOLE No AH13-1**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION West Beaton River Tributary Culvert- See location plan ORIGINATED BY DW  
DIST Algoma HWY 631 BOREHOLE TYPE Continuous sampling COMPILED BY DW  
DATUM Geodetic DATE Dec/02/2013 CHECKED BY CH

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			25	50	75	100	125					
326.5	0.0 <b>PEAT</b> Fine Fibrous, some wood and organics, dark brown, moist		1	SS	1		326		2.5								
325.4			2	SS	6				1.6								
325.2	<b>Silt</b> trace sand, grey, wet, loose																
1.2	<b>End of Borehole</b> Notes:																

**RECORD OF BOREHOLE No AH13-4**

1 OF 1

**METRIC**

W.P. 5079-09-01 LOCATION West Beaton River Tributary Culvert- See location plan ORIGINATED BY DW  
DIST Algoma HWY 631 BOREHOLE TYPE Continuous sampling COMPILED BY DW  
DATUM Geodetic DATE Dec/02/2013 CHECKED BY CH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			25	50	75	100	125					
326.6																	
326.8	<b>TOPSOIL - 150 mm</b>																
0.2	<b>PEAT</b> Fine Fibrous, some wood and organics, dark brown, moist		1	SS	2		326										
			2	SS	4				2								
			3	SS	9				1.8								
324.9				VANE			325										
1.7	<b>Silt trace sand, grey, wet, compact</b>		4	SS	17												
324.2	<b>End of Borehole</b> Notes: 1 - Vane will not push past 1.7 m																
2.4																	

ON-MTO-LARGE SCALE 750-1001 - WEST BEATON - TOPSOIL BOREHOLES - DEC 2013.GPJ ON\_MOT.GDT 13/1/14

# Appendix B

## Chemical Test Results



Client: SPL Consultants Ltd.  
146 Colonnade Rd., Unit 17  
Ottawa, ON  
K2E 7Y1  
Attention: Mr. Neem Tavakkoli

Report Number: 1118694  
Date: 2011-08-19  
Date Submitted: 2011-08-15  
Project: 750-1001

Chain of Custody Number: 145782

P.O. Number: VISA  
Matrix: Soil

PARAMETER	UNITS	MRL	LAB ID:		TYPE	LIMIT	UNITS
			Sample Date:	Sample ID:			
Chloride	%	0.002	2011-06-11	BH11-WB-1/SS-9			
Electrical Conductivity	mS/cm	0.05	2011-06-11	BH11-WB-2/SS-6			
pH							
Resistivity	ohm-cm	1					
Sulphate	%	0.01					

MRL = Method Reporting Limit INC = Incomplete AO = Aesthetic Objective OG = Operational Guideline MAC = Maximum Allowable Concentration IMAC = Interim Maximum Allowable Concentration  
Comment:

APPROVAL:   
Lorna Wilson  
Inorganic Lab Supervisor

# Appendix C

## Explanation of Terms used in Report

## EXPLANATION OF TERMS USED IN REPORT

N-VALUE: THE STANDARD PENETRATION TEST (SPT) N-VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N-VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N-VALUE IS DENOTED THUS N.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$C_u$ (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINT AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$c_c$	1	COMPRESSION INDEX
$c_e$	1	SWELLING INDEX
$c_a$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\Phi$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\Phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $c_u / \tau_r$

## PHYSICAL PROPERTIES OF SOIL

$P_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{\min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$P_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF WATER	$s_r$	%	DEGREE OF SATURATION	$D_n$	mm	N PERCENT – DIAMETER
$P$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$P_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\gamma_d$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $(W_L - W_L)$	v	m/s	DISCHARGE VELOCITY
$P_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $(W - W_p) / I_p$	i	1	HYDRAULIC GRADIENT
$\gamma_{\text{sat}}$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	$I_c$	1	CONSISTENCY INDEX = $(W_L - W) / I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
$P'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERED SOIL	$e_{\max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$\text{kN}/\text{m}^3$	SEEPAGE FORCE
$\gamma'$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL						



**PART B**  
**FOUNDATION DESIGN REPORT**  
**PROPOSED WEST BEATON RIVER TRIBUTARY CULVERT REPLACEMENT**  
**HIGHWAY 631 NORTH OF HIGHWAY 17, ONTARIO**  
**WP 5079-09-01 SITE NO. 38N-013/C**  
**G.W.P. 5270-08-00**  
**MTO GEOCRES NO. 42C-26**

Prepared for:

**MCINTOSH PERRY CONSULTING ENGINEERS**

By:

**SPL CONSULTANTS LIMITED**

Project: 750-1001 (West Beaton)  
January 2014



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## **6. DISCUSSION AND RECOMMENDATIONS**

### **6.1 General**

The proposed new culvert structure is a 3.6 m wide by 2.1 m high closed bottom concrete box culvert. The invert new culvert will be approximately 324.4 m to 324.8 m (which is lower than the existing culvert). The new culvert will be approximately 10 m south of the existing culvert. The current design does not include any change in the final embankment height.

The subsurface conditions encountered at the site include a layer of granular fill which forms the road structure, embankment and backfill around the existing culvert. This layer was found to be approximately 4.7 m deep (to El. 323.7 m to 323.9) in the two boreholes drilled on the existing highway at the culvert crossing and 0.9 m to 2.4 m deep (to El. 324.3 m to 324.9) in the two boreholes drilled near the inlet/outlet of the proposed culvert. A layer of peat/organic soil was encountered in one of the two boreholes drilled on the existing road at the culvert crossing as well as in all three of the boreholes drilled west of the existing road.

The fill and peat/organic soil are underlain by native soils consisting primarily of silt and sand and in some locations gravel as well as cobbles and boulders. The native granular soils extended to the depth of drilling and DCPT testing at the culvert location (approximately 15 m below the existing road surface, and 12 m below the culvert invert).

The groundwater level at the site was found in June 2011 to be at approximately elevation 326.9 m, and would be expected to vary seasonally and with the level of the creek.

Based on the borehole information, the culvert and bedding will be founded on loose to compact silt and sandy silt, and potentially some granular fill (the proposed culvert invert is approximately at the transition between the fill and the native soils; some over excavation and replacement may be required ). Either the existing granular fill or the native granular soils are expected to be adequate to support the proposed culvert.

### **6.2 Frost Protection**

The depth of frost penetration for the West Beaton River Tributary site is 2.4 m. The existing fill material within the frost depth is predominantly sand and silty sand and is considered to have a low susceptibility to frost heave. As such, frost tapers are not required for new construction.

### **6.3 Seismic Performance**

The site is located in an area of relatively low seismic activity. The Peak Horizontal Ground Acceleration (PHA) for an earthquake with a 10% chance of exceedance in 50 years (475 year return period event) is 0.011 g. Based on the Canadian Highway Bridge Design Code (CHBDC) this corresponds to a Seismic Performance Zone 1 (assuming the crossing would be classified as an Emergency Route Bridge), and Zonal Acceleration Ratio of  $A = 0$  (CHBDC Section 4.4).

For the purposes of assessing the effects of site conditions under seismic conditions, the site may be assumed to be Soil Profile Type III, which corresponds to a Site Coefficient  $S = 1.5$  (CHBDC Section 4.4.6).

## **6.4 Foundations Design**

### **6.4.1 Foundation Options**

MTO has selected a pre-cast concrete box culvert as the preferred replacement option. The sub-surface conditions at the site are considered to be adequate for the founding of the preferred replacement structure (pre-cast box culvert) on normal foundations (granular bedding placed over native soils or granular fill).

Deep foundations are technically feasible, but are not required as conventional shallow foundations will provide sufficient bearing resistance and settlement performance for the proposed culvert.

### **6.4.2 Bearing Resistance**

The bedding for the new culvert structure will be placed on the native silty soils (or possibly on the existing fill in some areas).

For the new culvert which is 3.6 m wide and will be founded at an elevation of approximately 324.4 m to 324.8 m, the unfactored geotechnical bearing resistance at Ultimate Limit States (ULS) can be taken as 400 kPa. A resistance factor of 0.5 should be applied to this value, yielding a factored bearing resistance of 200 kPa at ULS. This value is for a concentrically loaded foundation. Eccentric loads (if present) should be accounted for by considering an effective bearing area as outlined in the CHBDC.

The geotechnical resistance at the Serviceability Limit State (SLS) can be taken as 150 kPa.

Provided that the subgrade is not disturbed during construction the total and differential settlements associated with the above SLS resistance values are expected to be less than 25 mm and 20 mm, respectively. It is expected that for this level of settlement the new culverts will not require a camber.

### **6.4.3 Sliding Resistance**

For the purposes of evaluating sliding resistance (Section 6.7.5 of the CHBDC) of either the native soils or the granular fill below the foundation the effective cohesion,  $c'$ , should be assumed to be zero. The effective friction angle ( $\phi'$ ) for the silty, sandy native soils may be assumed to be  $30^\circ$ . These values are unfactored values. A resistance factor of 0.8 should be applied to the resulting resistance to obtain the factored sliding resistance as per the CHBDC.

## **6.5 Bedding, Cover and Backfill**

Bedding, cover and backfill details for the new culvert should be as per MTOD 803.021. Bedding for the new culvert may consist of either:

- 500 mm of compacted Granular A or Granular B Type II; or
- 300 mm of compacted Granular A or Granular B Type II placed over a lean concrete working slab.

If constructed properly, either bedding treatment is considered adequate from a foundations perspective.

A 75 mm levelling course of additional Granular A or fine aggregate should also be provided between the bedding and the culvert. In order to minimize the potential for piping and undermining of the culvert foundations the bedding should be wrapped in a non-woven geotextile which meets the requirements of OPSS 1860.

Cover for the new culverts should be a minimum of 300 mm thick as per MTOD 803.021 and may include either Granular A or Granular B with a maximum particle size of 75 mm (as per OPSS 422 and Special Provision 422S01).

Granular backfill may consist of either imported Granular A or B material, or salvageable portions of the existing soils (Granular A or B is preferred for fills below the water table as well as immediately below the pavement structure). Portions of the fill which forms the embankment meet the requirements of OPSS 1010 Granular B Type I. Other portions of the fill meet the requirements of OPSS 1010 for SSM. The excavated soils should be reviewed as excavated and suitable portions may be stockpiled for re-use as backfill (if a cost-effective stockpile location is available). Material from below the water table, as well as the native soils, is unlikely to be suitable for use as granular backfill and there will be a net import of granular fill required for construction.

All bedding, cover and backfill should be placed in lifts not exceeding 200 mm and in accordance with OPSS 206. All fill material should be compacted in accordance with OPSS 422 (as amended by SP422S01), OPSS 501 and OPSS 902.

Heavy equipment should not be used behind the culvert and any other structures within the restricted zone as outlined in OPSS 501.

## **6.6 Earth Pressures**

Computation of earth pressures acting against culvert walls and retaining structures should be in accordance with the Canadian Highway Bridge Design Code (CHBDC). For design purposes, the following properties can be assumed for the backfill:

**Compacted Granular 'A' or Granular 'B' Type II**Angle of Internal Friction ( $\phi$ ) = 35 degrees (unfactored)Unit Weight = 22 kN/m<sup>3</sup>

Coefficients of Lateral Earth Pressure:

Earth Pressure Coefficient	Level Backfill	Sloping Backfill 3H:1V	Sloping Backfill 2H:1V
$K_a$	0.27	0.34	0.40
$K_b$	0.35	0.44	0.50
$K_0$	0.43	0.56	0.62
$K^*$	0.45	0.60	0.66

**Compacted Granular 'B' Type I**Angle of Internal Friction ( $\phi$ ) = 32 degrees (unfactored)Unit Weight = 21 kN/m<sup>3</sup>

Coefficients of Lateral Earth Pressure:

Earth Pressure Coefficient	Level Backfill	Sloping Backfill 3H:1V	Sloping Backfill 2H:1V
$K_a$	0.30	0.38	0.47
$K_b$	0.38	0.48	0.57
$K_0$	0.47	0.61	0.69
$K^*$	0.51	0.67	0.76

Notes:

 $K_a$  is the coefficient of active earth pressure; $K_b$  is the coefficient of active earth pressure for an unrestrained structure including compaction efforts; $K_0$  is the coefficient of earth pressure at rest; $K^*$  is the coefficient of earth pressure at rest for a fully restrained structure including compaction efforts.

The above values assume that the backfill behind the structure is free-draining granular fill, and that proper drainage is provided. Water pressures must also be accounted for in areas below the water table.

The appropriate earth pressure coefficient for design will depend upon whether the retaining structure is restrained or some movement can occur such that the active earth pressure state can develop. The

effect of compaction should also be taken into account when selecting the appropriate earth pressure coefficients.

In accordance with the method outlined in the CHBDC and Commentaries Section 4.6.4, for a Zonal Acceleration Ratio of  $A = 0$  the earth pressure under the design seismic event is equal to the earth pressure under static conditions (the horizontal seismic coefficient,  $k_h$  is 0.5 or 1.5 times the Zonal Acceleration Ratio, and for the design earthquake  $A = 0$ ).

## **6.7 Embankment Widening**

It is understood that the existing roadway embankment may be widened on the west side to facilitate a detour around the construction site, and that this widening would likely be of similar height as the embankment. Based on the conditions encountered in the boreholes, foundation failures are not anticipated for the proposed embankment widening with normal (2H:1V or flatter) slopes, assuming that all organic or unsuitable materials are removed as per normal MTO standards and procedures for stripping and benching prior to placing the embankment fills. In particular this will require removal of the peat/organic soil layer which is present at the existing ground surface west of the embankment and is likely up to 1.7 m thick.

All unsuitable materials should be removed and the approved embankment subgrade should be proofrolled. The construction of the new embankment widening may require dewatering and/or groundwater control as discussed in Section 6.9 below where the base of the embankment is below the water table.

The sides of the existing embankment should be benched prior to placing fill material for the embankment widening, as per OPSD 208.01. Fill material should be placed in lifts not exceeding 300 mm in thickness and compacted to 95% SPMD as per OPSS 206 and OPSS 501. Borrow material should consist of select suitable inorganic earth, free of objectionable inclusions such as cobbles, boulders, frozen materials, organic soils, etc. The existing fill material may be suitable for this purpose. Borrow material for the proposed embankment widening should be approved prior to installation from both a geotechnical and environmental standpoint.

Based on the subsurface conditions present, it is expected that the settlement at the surface of the embankment will be less than 50 mm (including settlement of the fill itself as well as the underlying soils) most of which will occur within approximately 6 weeks of construction (assuming predominantly granular fill is used for the embankment). These estimated settlements are typical of this type of construction and considered within acceptable limits.

All embankment construction (including review of exposed subgrade, approval of fill materials, etc.) should be carried out under the review and supervision of a qualified person.

## 6.8 Erosion Protection

The native soils at the site are expected to be susceptible to erosion. Erosion and scour protection such as rip rap treatment similar to OPSD 810.919) will be required at the culvert inlets and outlets. The sizing of erosion protection should be carried out by a specialist who is familiar with the site hydraulics and the findings of this investigation.

The current culvert design includes upstream and downstream cut-off walls on the new culverts. These walls should extend to below the base of the bedding and levelling course to prevent flow of water below the walls through the permeable bedding layer. It is also recommended that the bedding and levelling course be enclosed in a non-woven geotextile (OPSS 1860) in order to reduce the potential for piping and erosion of the culvert bedding.

## 6.9 Construction Considerations

### Construction Dewatering

The groundwater level at the site was found to be approximately equal to the level of the water in the creek at the time of the measurement in June 2011. The groundwater level is expected to be sensitive to changes in the water level in the creek, and for this reason it is recommended that if possible the rehabilitation be carried out in a dry period when the creek would be expected to be at its lowest level. It is also recommended that where possible the water flow in the existing watercourse be diverted away from the construction zone, and the existing culvert remain in place to be used as a by-pass structure, to maintain sufficiently dry conditions for construction.

The replacement will involve excavations below the groundwater table, and even with the above measures, dewatering will likely be required to stabilize the native soils, to maintain a dry working area and to minimize disturbance of the foundation soils during construction. Depending upon the creek level and groundwater conditions at the time of construction, closely spaced filtered sumps may be used for excavations which extend only a short distance below the groundwater table (say 0.5 m or so). The creek level was at approximately 325.5 m at the time of the site survey, and the groundwater level measured in the native soils was at approximately 326.9 m. Excavation will be required to below 324 m elevation when accounting for the culvert itself as well as bedding (1.5 m to 3 m below the likely groundwater level) will be required to accommodate the culvert, bedding, levelling course, etc. These deeper excavations will likely require an active dewatering system including well points and/or deep wells to maintain a dry excavation.

In addition to groundwater control, it is expected that an above-ground diversion (coffer dam and diversion of the existing water course around the site), and an underground impervious barrier (such as a sheet pile wall; the choice of protection systems and cut-off walls will ultimately be the responsibility of the contractor) will also need to be constructed to control groundwater flows into the excavation.



### Temporary Excavations

All excavations should be carried out in accordance with the most recent Occupational Health and Safety Act (OHSA). Part III of Ontario Regulation 213/91 deals with excavations. In addition, the following Ontario Provincial Standard Specifications (OPSS) also deal with temporary excavations:

OPSS 539 – Construction Specification for Temporary Protection Systems

OPSS 902 – Construction Specification for Excavating and Backfilling - Structures

The soils at the site include granular fill in the pavement structure and embankment, underlain by loose to compact native silty soils. Both granular fill and granular native soils can be classified as Type 3 soil above the water table and Type 4 soil below the water table.

Temporary excavations above the water table are likely feasible using sloped excavations in the granular fill. Excavations below the water table will require some form of protection system. It is also noted that the preliminary staging will require excavation in close proximity to the travelled lanes of the highway which will preclude the use of sloped excavations in some areas (as there is not sufficient space).

Temporary shoring would typically consist of soldier piles and timber lagging or interlocking sheet piles. It should be noted that cobbles and boulders were encountered during the investigation. This should be considered when selecting shoring systems and installation methods.

### Foundation Excavations

The bearing capacities provided in Section 6.4 above assume that the subgrade is not excessively disturbed during construction. Given the fact that the foundations for any new structures will be below the groundwater table in loose to compact sand and silt, it will require careful construction control to achieve this condition. Installation and operation of an adequate dewatering system, as discussed above, will be critical to the construction of the foundations.

A layer of lean concrete working slab (mud slab) on foundation bearing surfaces can also be included in the design (see Section 6.5 above). If used, the working slab should be placed immediately after excavation and inspection (before placement of bedding and levelling layers) to minimize foundation disturbance. If excavation conditions are found to be better than anticipated then the requirement for the lean concrete mud slab may be waved at the time of construction. All excavated surfaces should be kept free of frost, water, etc. during the course of construction.

All excavated surfaces should be inspected prior to foundation construction by a qualified individual who is familiar with the findings of this investigation and the design and construction of similar structures.

## **6.10 Corrosion and Cement Type**

Two soil samples were submitted to Exova Accutest for testing related to soil corrosivity and potential exposure of concrete elements to sulphate attack. The results of these tests are included in Appendix B.

The test results indicate that the sulphate content of the native soils is relatively low, and sulphate-resistant Portland cement is not required.

Soil resistivity and acidity test results indicate that there is a low to moderate potential for corrosion of buried steel elements. Appropriate care should be taken in designing the corrosion protection system for any buried steel structures.

## 7. CLOSURE

The field investigations in June 2011 were supervised by Mr. Naeem Ehsan, P.Eng. The field investigations in November/December 2013 were supervised by Mr. Daniel Wall E.I.T. This report was prepared by Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, P.Eng., SPL's designated MTO contact and Mr. Shaheen Ahmad, P.Eng., SPL's project quality control auditor, provided independent review and quality control of the technical aspects of this report.

We trust that the information contained in this report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

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## 8. REFERENCES

The following section provides a general list of references, as well as a list of Ontario Provincial Standard Specifications which are expected to be relevant to the Foundations portion of the proposed work.

### General References

CAN/CSA-S6-06 Canadian Highway Bridge Design Code, 2011

Canadian Foundation Engineering Manual, 2006. 4<sup>th</sup> Edition. Canadian Geotechnical Society

### Relevant Ontario Provincial Standard Specifications

OPSS NO.	TITLE
128	Supply of Pre-Qualified Materials and Products
182	Environmental Protection for Construction in Waterbodies and on Waterbody banks.
201	Clearing, Close Cut Clearing, Grubbing, and Removal of Surface and Piled Boulders
206	Grading
401	Trenching, Backfilling, and Compacting
404	Support Systems
422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
501	Compacting
504	Preservation, Protection and Reconstruction of Existing Facilities
506	Dust Suppressants
510	Removals
511	Rip-Rap, Rock Protection, and Granular Sheeting
514	Trenching, Backfilling, and Compacting
518	Control of Water from Dewatering Operations
539	Temporary Protection Systems
805	Temporary Erosion and Sediment Control Measures
902	Excavating and Backfilling – Structures
1001	Aggregates - General
1010	Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
1860	Geotextiles

Relevant CDED Special Provisions

Provision No.	Title
100S60	Amendment to MTO General Conditions of Contract, April 2010 – use of unlicensed vehicles...
104S04	Amendment to OPSS 401, November 2010
105S21	Amendment to OPSS 501, November 2010
110S13	Amendment to OPSS 1010, April 2004
199S55	Record Drawings for Structures and Foundations
422S01	Precast Concrete Box Culvert
511S01	Rip Rap
539S02	Protection System – Amendment to OPSS 512, April 2011
805F01	Light-Duty Sediment Barriers, etc.

Relevant OPSD's

OPSD No.	Title
803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3 m
810.010	Rip-Rap Treatment for Sewer and Culvert Inlets
810.020	Rip-Rap Treatment for Ditch Inlets
3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Relevant MTOD's

MTOD No.	Title
803.021	Bedding and Backfill for Precast Concrete Box Culverts