

**FOUNDATION INVESTIGATION AND DESIGN REPORTS  
PROPOSED BORDEN RIVER CULVERT REPLACEMENT  
HIGHWAY 101 EAST OF HIGHWAY 129, ONTARIO  
WP 5077-09-01 SITE NO. 46-330/C  
G.W.P. 5077-08-00  
MTO GEOCRE NO. 410-12**

Prepared for:

**MCINTOSH PERRY CONSULTING ENGINEERS**

By:

**SPL CONSULTANTS LIMITED**

Project: 750-1001 (Borden River)  
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 Borden Lake on Highway 101 approximately 3.7 km east of Highway 129 near Chapleau, 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 RFQ and the initial foundation investigation (in June 2011) the proposed culverts were to be constructed in the same location as the existing culverts. Subsequent to completion of the field investigation, the location of the proposed culverts was shifted approximately 5 m to the east.

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 the north end of Borden Lake on Highway 101 approximately 3.7 km east of Highway 129, near Chapleau, Ontario (see Drawing 1). The existing structure is made up of twin Structural Plate Corrugated Steel Pipe (SPCSP) culverts with a width of 2.69 m, a height of 2.08 m, and an overall length of about 38 m. The fill cover over top of the existing culverts is approximately 2.5 m in depth.

The elevation of the natural ground in the general vicinity of the culvert crossing is approximately 421 m to 422 m. The elevation of the highway (top of pavement) at the crossing is approximately 427 m (the embankment is approximately 5 m to 6 m high at the crossing).

## **3. INVESTIGATION PROCEDURES**

The initial foundation investigation was carried out in June, 2011 and followed by a supplementary investigation in November 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 and/or glaciofluvial deposits. These deposits generally would be expected to include silt, sand and gravel deposits, as well as potentially cobbles and boulders.

Bedrock geology maps of the general area indicate the bedrock to be foliated to gneissic tonalite and granodiorite, as well as metasedimentary rocks of paragneiss and migmatites and metavolcanic rocks of granitic gneiss.

### **3.2 Field Investigation**

Field investigations were carried out on June 12 and 13, 2011 as well as November 22 to 25, 2013. The investigations included drilling a total of six boreholes at the crossing location (BH11-1 through BH11-4, BH13-1 and BH13-2). As noted previously, additional shallow boreholes were advanced at the same time for the geotechnical (pavement) portion of the work; the results of those boreholes are submitted with the geotechnical (pavement) investigation report under separate cover.

In June 2011, boreholes were advanced using a truck-mounted drill rig supplied and operated by George Downing Estate Drilling Limited of Hawkesbury, ON. These boreholes (BH11-1 through BH11-4) were drilled using hollow-stem auger drilling to depths ranging from 3.7 m to 9.0 m below the existing pavement surface. In November 2013, two additional boreholes (BH13-1 and BH13-2) were advanced using hand portable drilling equipment supplied and operated by OGS Inc. of Almonte, ON. These boreholes were drilled to depths ranging from 4.5 m to 7.3 m below the existing ground surface. During both drilling programs, sampling and in-situ testing (including Standard Penetration [SPT] Testing and Dynamic Cone Penetration [DCPT] Testing) were carried out.

A standpipe piezometer was installed in Borehole BH11-1 to allow for subsequent measurement of the groundwater level 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 Drawings 2A and 2B. Borehole logs are included in Appendix A.

### **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**

A total of four boreholes (BH11-1 through BH11-4) were drilled on the shoulder of the existing highway and encountered a layer of asphalt approximately 50 mm to 60 mm thick.

#### **4.1.2 Topsoil**

Boreholes BH13-1 and BH13-2 were drilled at the base of the embankment, near the inlet/outlet of the existing and proposed culverts. These boreholes encountered a layer of topsoil ranging in thickness from 120 mm to 190 mm.

#### **4.1.3 Granular Fill**

The asphalt in boreholes BH11-1 through BH11-4 and the topsoil in BH13-1 are underlain by granular fill, which forms the pavement structure of the highway, as well as the existing highway embankment.

The granular fill ranged from silty sand to sand and gravel. Grain size curves for a number of samples of the granular fill are presented in Drawing No. 3. A summary of the grain size distribution of these samples is also presented in Table 1 below. It should be noted that these grain size distribution tests were carried out on samples obtained through SPT testing, which does not recover coarse gravel, cobble and boulder sized particles. Because of this the grain size distributions shown on Drawing No. 3 may be finer overall than some portions of the materials in the field. Cobbles and boulders may also be present in the granular fill.

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

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH11-1	SS-3	6	89	5	
BH11-1	SS-5	10	74	13	3
BH11-2	SS-2	1	81	14	4
BH11-2	SS-5	1	76	19	4
BH11-3	SS-3	26	71	3	
BH11-4	SS-4	0	81	14	5
BH13-1	SS1	4	83	13	

The density of the fill material (as interpreted based on SPT “N” values) typically ranged from loose to very dense, with localized areas being very loose to loose.

In the boreholes drilled on the shoulder of the existing highway the fill material extended to a depth of 3.7 m to 5.6 m below the existing road surface. This corresponds to elevations of 424 m to 421.5 m. In the two boreholes drilled on the shoulder adjacent to the existing culverts the fill material was found to be 5.6 m thick (to elevation 421.4 m to 421.5 m). In Borehole BH13-1 drilled near the outlet of the eastern existing culvert, the fill material was found to be 1.5 m thick (to elevation 422.2 m). No fill material was encountered in Borehole BH13-2 drilled near the culvert inlet. Borehole BH11-3 was terminated in the fill due to auger refusal encountered at a depth of 3.7 m.

#### 4.1.4 Native Silt, Sand and Gravel

The fill material and the topsoil in Borehole BH13-2 was underlain by native soils which include a variable deposit of silt, sand and gravel. Detailed descriptions of the native soils encountered at each of the borehole locations is provided in the borehole records included in Appendix A. This deposit was encountered in five of the six boreholes drilled at the site, including the four boreholes drilled adjacent to the existing culverts (Borehole BH11-3 to the west of the culvert encountered refusal at shallow depth and did not encounter the native soils). This material extended to the depth of drilling in all boreholes except BH11-3 (7.8 m to 10.6 m below the existing road surface).

The grain size distributions of representative samples of the native soil are presented in Table 2 below and are also included in Drawings Nos. 4 and 5.

**Table 2 – Results of Grain Size Analyses for Native Silt, Sand and Gravel**

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH11-1	SS-7	44	53	3	
BH11-1	SS-8	41	54	3	2
BH11-2	SS-7	0	7	84	9
BH11-2	SS-8	5	80	12	3
BH11-4	SS-6	2	89	5	4
BH11-4	SS-8	0	13	79	8
BH13-1	SS-4	9	72	19	
BH13-1	SS-7	15	67	18	
BH13-1	SS-9	1	49	47	2
BH13-2	SS-3	26	65	9	
BH13-2	SS-5	19	44	34	3
BH13-2	SS-7	7	75	23	

The consistency of the native silt, sand and gravel (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. SPT “N” values are also included on the Soil Strata included in Drawing Nos. 2A and 2B.

#### 4.1.5 DCPT/Auger Refusal

Bedrock was not cored in any of the boreholes drilled as part of this investigation. Auger refusal was encountered in Boreholes BH11-1 through BH11-4. At Borehole BH11-3 to the west of the proposed culverts, refusal was encountered at a depth of 3.7 m. In Boreholes BH11-1, BH11-2 and BH11-4 the depth to refusal ranged from 8 m to 9 m below the road surface. In Borehole BH13-2, the borehole advanced near the inlet of the eastern existing culvert, DCPT refusal was encountered at a depth of 4.5

m below existing ground surface. Borehole BH13-1 was drilled to a depth of 7.3 m below the existing ground surface and did not encounter refusal.

#### 4.2 Groundwater Conditions

Groundwater seepage was encountered in all of the boreholes drilled below the elevation of the existing watercourse (approximately 423 m; Borehole BH11-3 met refusal at an elevation of approximately 423.9 m - above the expected groundwater table). In June 2011, a standpipe piezometer was installed in BH11-1. The groundwater level in the piezometer was measured the day after completion of drilling and found to be at an elevation of 423.4 m, which is approximately coincident with the water level in the watercourse at the time of the measurement (which would be expected given the granular nature of the soils in the area). In November, 2013 the water level in the watercourse was noted to be 422.8 m.

It should be noted that the groundwater levels can vary and are subject 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 water level in the watercourse. If construction is carried out at a time when the water 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 Borden River culvert location is presented in Table 3 below.

**Table 3 – Simplified Stratigraphy and Groundwater Elevations**

Borehole No.	Ground Surface Elevation	Simplified Stratigraphy (Depth)			Measured Ground water Elevation	Notes
		Topsoil	Granular Fill	Native Silt, Sand and Gravel		
BH11-1	427.0	---	0.0 – 5.6 m	5.6 – 8.0 m	423.4 m	Auger refusal at 8.0 m
BH11-2	427.1	---	0.0 – 5.6 m	5.6 – 9.0 m	---	Auger refusal at 9.0 m
BH11-3	427.6	---	0.0 – 3.7 m	---	---	Auger refusal at 3.7 m
BH11-4	428.1	---	0.0 – 4.1 m	4.1 – 8.9 m	---	Auger refusal at 8.9 m
BH13-1	423.7	0.0 – 0.1 m	0.1 – 1.5 m	1.5 – 7.3 m	---	Borehole terminated at 7.3 m
BH13-2	423.7	0.0 – 0.2 m	---	0.2 – 4.5 m	---	DCPT refusal at 4.5 m

## 5. CLOSURE

The field investigations in June 2011 were supervised by Mr. Naeem Ehsan, P.Eng. The field investigations in November 2013 were supervised by Mr. Daniel Wall, E.I.T. This report was prepared by Mr. Chris Hendry, P.Eng. Quality control and independent review of the technical aspects of this report were provided by Mr. Fanyu Zhu, P.Eng. and Mr. Shaheen Ahmad, P.Eng.

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.

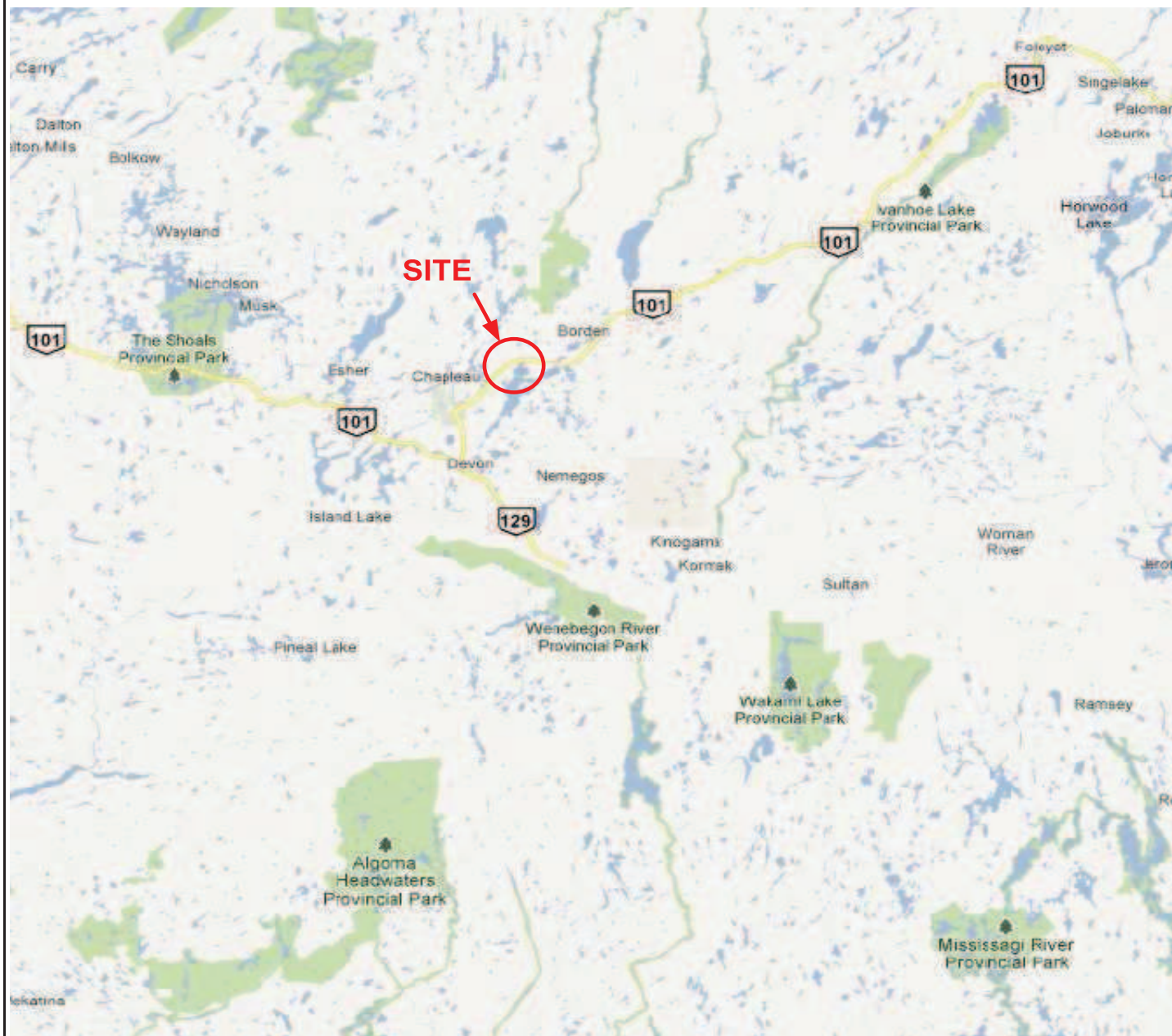



Fanyu Zhu, Ph.D., P.Eng.

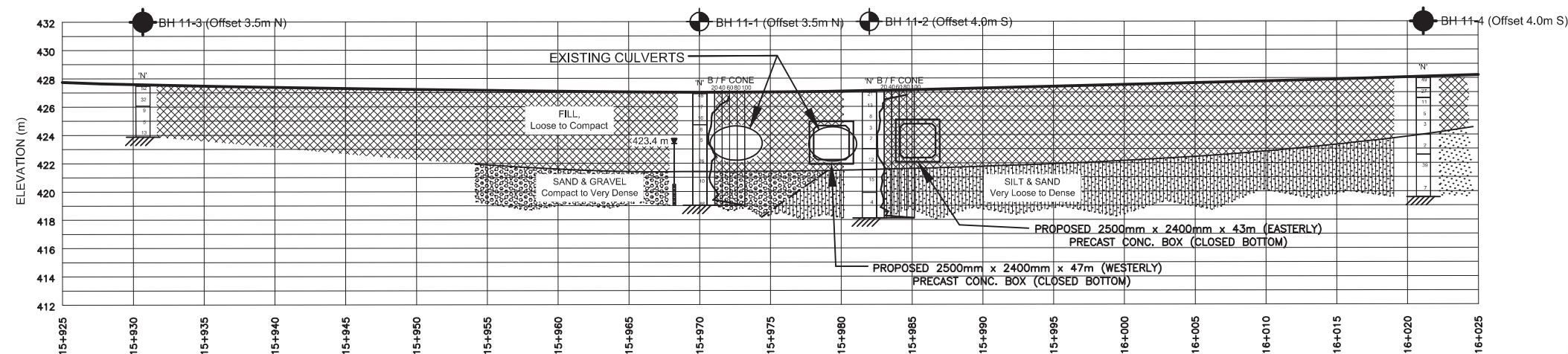
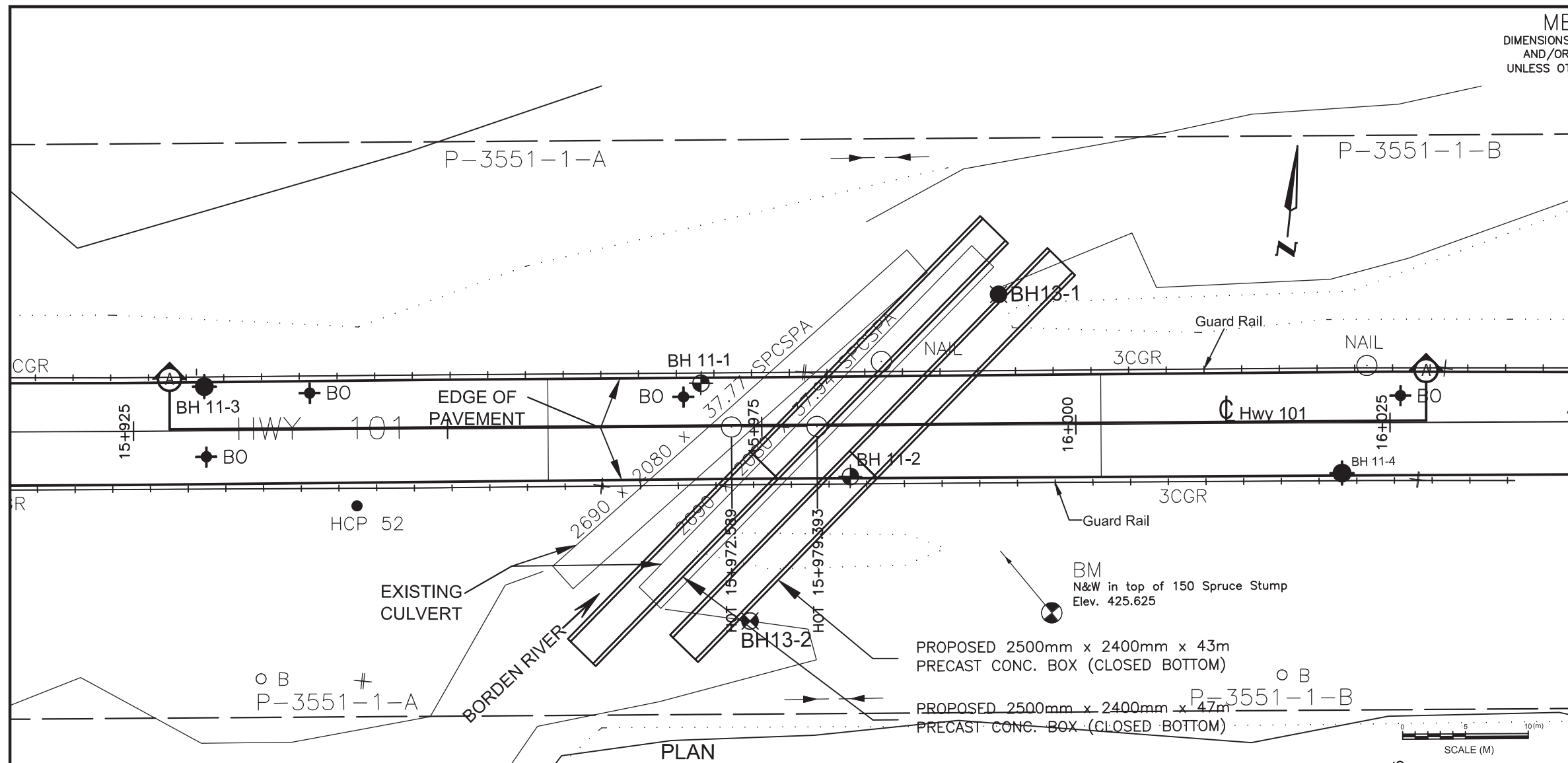


Shaheen Ahmad, M.A.Sc., P.Eng.

# Drawings



Client: McIntosh Perry Consulting Engineers		Title: SITE PLAN	
Project#:	750-1001	DWG #:	1
Drawn:	NT	Approved:	CH
Date:	AUG 31-2011	Scale:	N. T. S.
Size:	Letter	Rev:	0
 <b>SPL Consultants Limited</b> Geotechnical Environmental Materials Hydrogeology			



SOIL STRATA SYMBOLS

CROSS-SECTION A-A'

- GRANULAR FILL
- AUGER REFUSAL
- SILT & SAND
- SAND & Gravel

CONT No  
WP No 5077-09-01

BORDEN RIVER CULVERT  
HIGHWAY 101  
BORE HOLE LOCATIONS & SOIL STRATA

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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	427.0	15+970.2	3.5m N
BH11-2	427.1	15+982.0	4.0m S
BH11-3	427.6	15+930.7	3.5m N
BH11-4	428.1	16+021.1	4.0m S
BH13-1	423.7	15+993.9	10.4m N
BH13-2	423.7	15+974.0	15.5m S

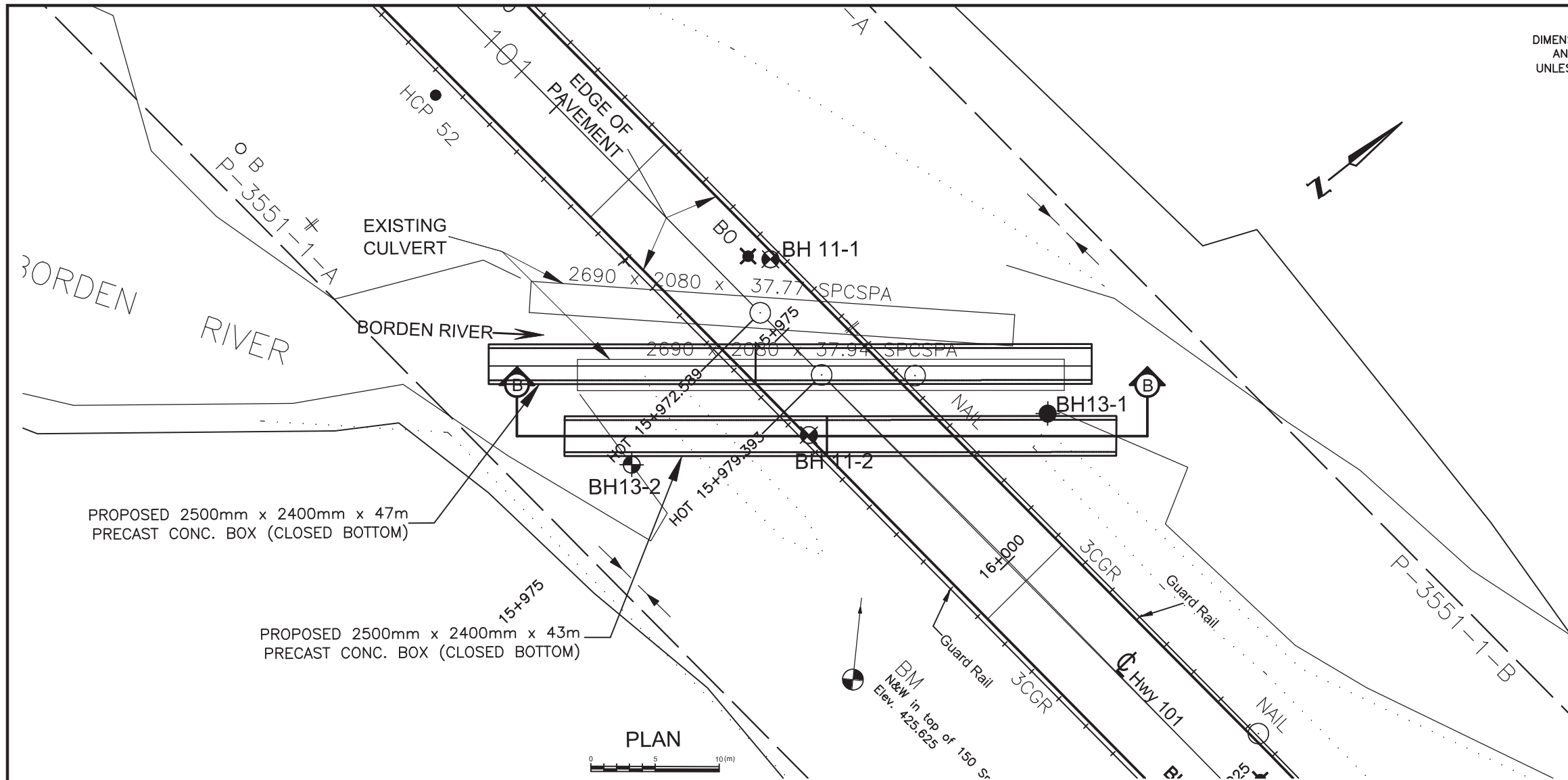
NOTES

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



REVISIONS		Revised Final Report	
1	Jan14/14 TJC		Final Revision
2	Nov15/12 TJC		Revision 1
3	Feb16/12 TJC		Revision 1
4	DATE	BY	DESCRIPTION

HWY No 101	CHECKED CH	DATE Jan14, 2014	DIST Algoma
SUBM'D CH	CHECKED CH	APPROVED FZ	SITE 46-330/C
DRAWN TJC	CHECKED CH		DWG 2A



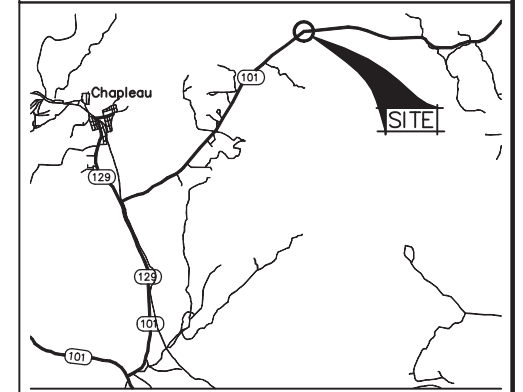
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 5077-09-01

BORDEN RIVER CULVERT  
HIGHWAY 101  
BORE HOLE LOCATIONS & SOIL STRATA

SHEET  
12

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KEY PLAN  
NOT TO SCALE

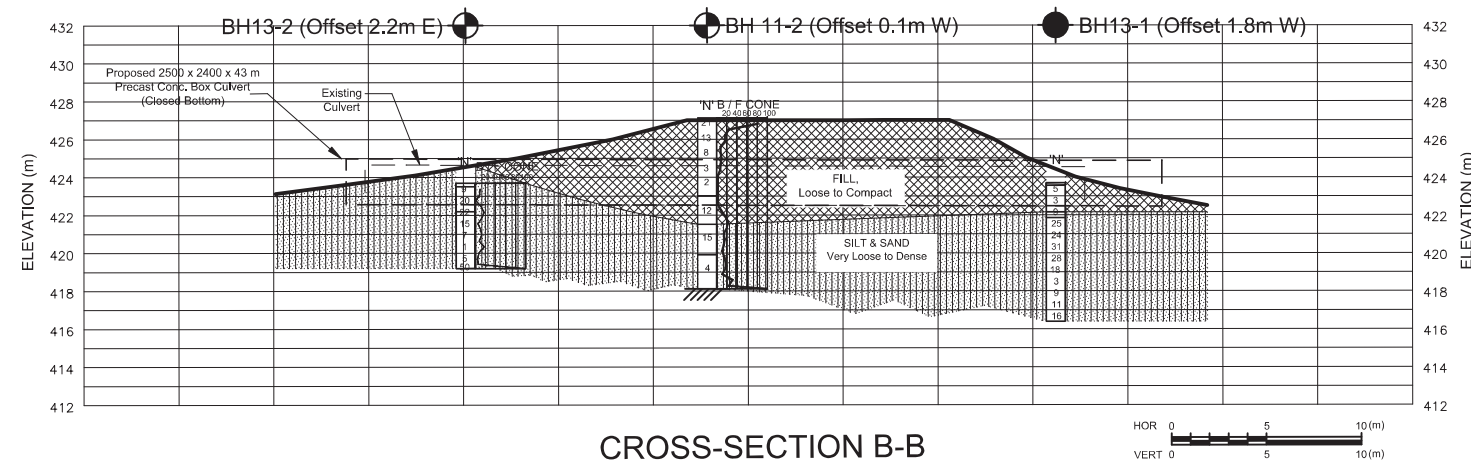
LEGEND

- 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	427.0	15+970.2	3.5m N
BH11-2	427.1	15+982.0	4.0m S
BH11-3	427.6	15+930.7	3.5m N
BH11-4	428.1	16+021.1	4.0m S
BH13-1	423.7	15+993.9	10.4m N
BH13-2	423.7	15+974.0	15.5m S

NOTES

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



CROSS-SECTION B-B

SOIL STRATA SYMBOLS

GRANULAR FILL

SILT & SAND

AUGER REFUSAL

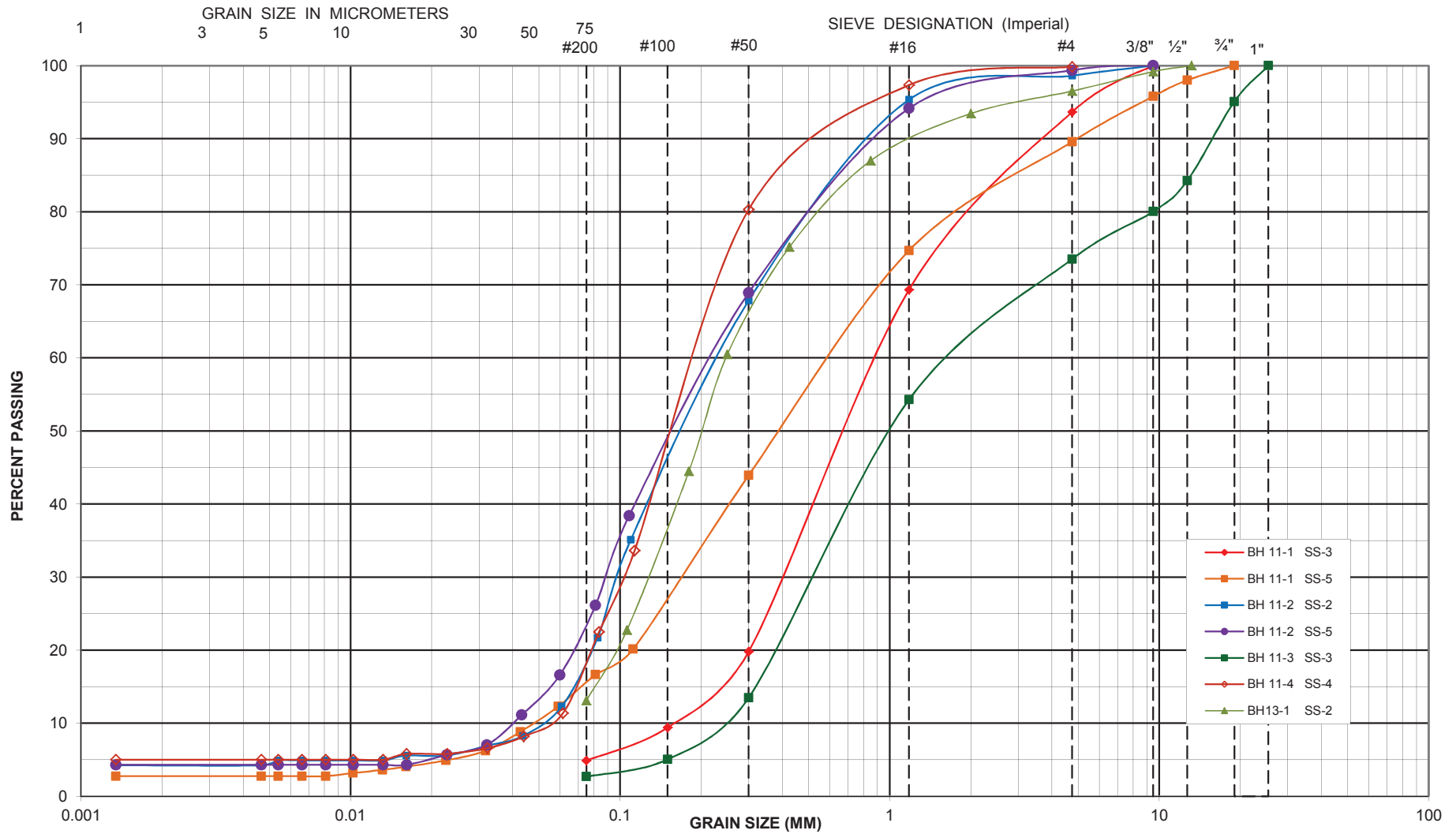
REVISIONS	Jan14/14	CH	Revised Final Report	
	Nov15/12	TJC	Final Revision	
	Feb16/12	TJC	Revision 1	
	DATE	BY	DESCRIPTION	

GEOCORES No 410-12

HWY No 101		DIST Algoma	
SUBM'D CH	CHECKED CH	DATE Jan 7, 2014	SITE 46-330/C
DRAWN ZMO	CHECKED CH	APPROVED FZ	DWG 2B

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

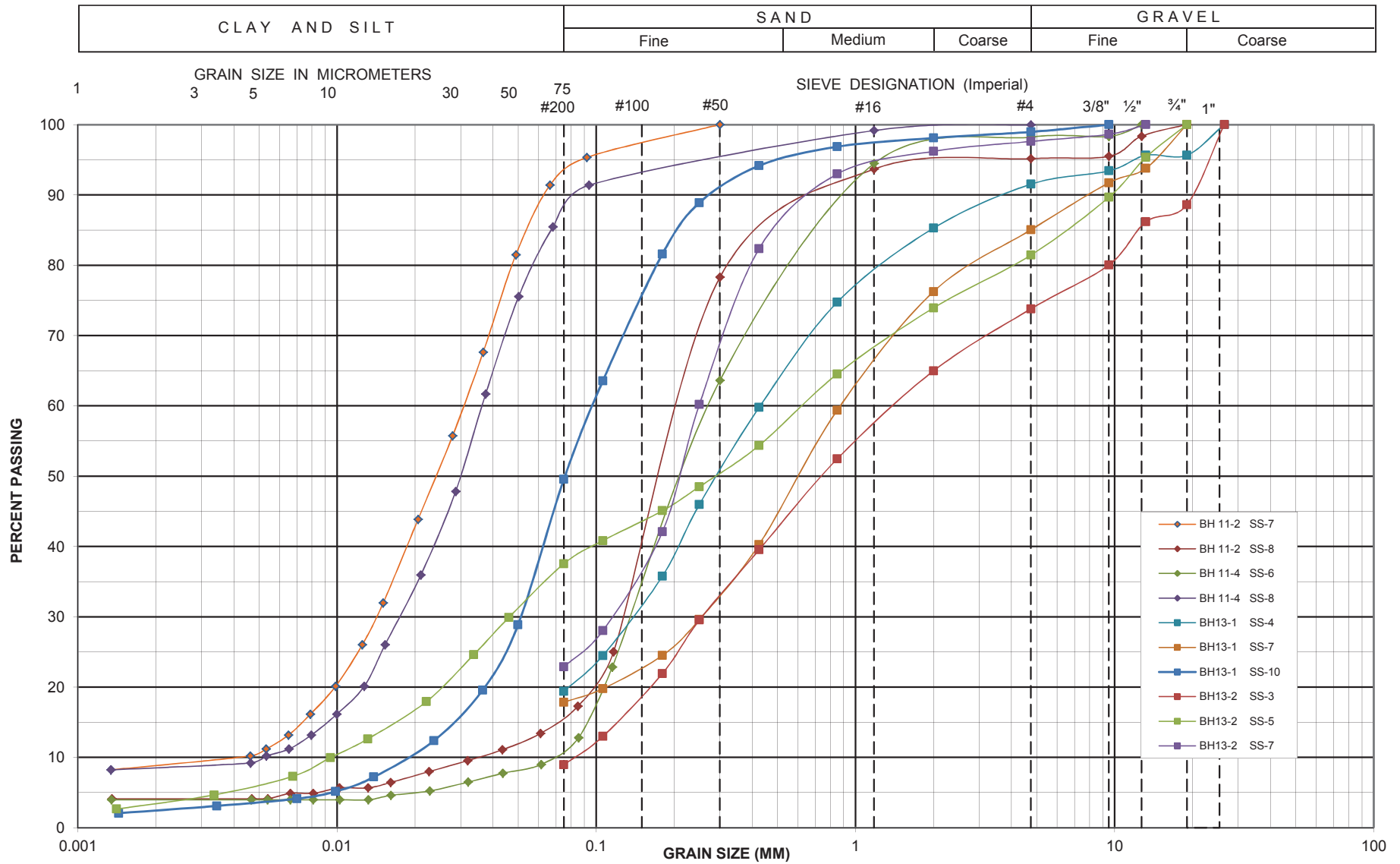


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GRAIN SIZE DISTRIBUTION - FILL  
Proposed Borden River Culvert Replacement

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

# UNIFIED SOIL CLASSIFICATION SYSTEM



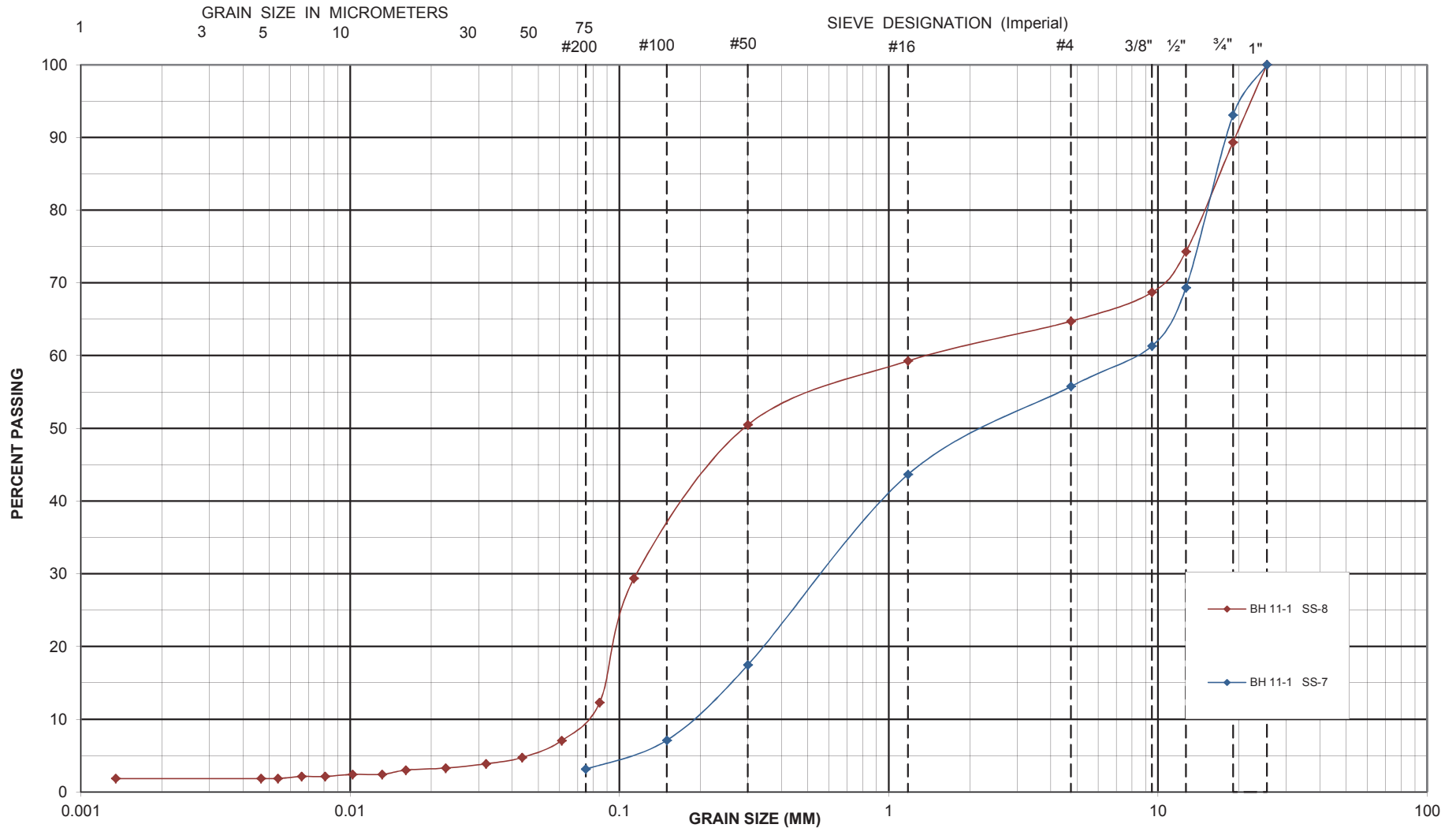
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Geotechnical Environmental Materials Hydrogeology

**GRAIN SIZE DISTRIBUTION - SILT & SAND**  
Proposed Borden River Culvert Replacement

Drawing No. 4  
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 BH 11-1**

1 OF 1

**METRIC**

W.P. 5077-09-01 LOCATION Borden River Culvert - See Borehole Location Plan, E, N ORIGINATED BY NE  
DIST Algoma HWY 101 BOREHOLE TYPE Hollow Stem Augers COMPILED BY FL  
DATUM Geodetic DATE Jun/12/2011 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									
								○ UNCONFINED      + FIELD VANE									
								● QUICK TRIAXIAL      × LAB VANE									
							WATER CONTENT (%)										
427.0							20	40	60	80	100	10	20	30		GR SA SI CL	
426.9	ASPHALT: 50 mm																
	Fill: SAND trace to some gravel, trace to some silt greyish brown, moist dense to compact. some gravel, dense trace gravel, compact		1	SS	48	Holeplug						○					
			2	SS	17		426					○					
			3	SS	16		425					○				6 89 (5)	
424.7	Fill: SAND trace to some gravel, some silt, trace clay greyish brown, moist to saturated loose to compact.		4	SS	6							○					
2.3			5	SS	5	Cutting							○			10 74 13 3	
						W. L. 423.4 m Jun 13, 2011	423									auger grinding at 3.7m	
	some gravel to gravelly, saturated		6	SS	26		422					○				spoon wet at 4.6m	
421.4	SAND & GRAVEL: trace silt and clay, brown, saturated compact to very dense.		7	SS	10	Holeplug	421						○			44 53 (3)	
5.6						Sand											
	inferred cobbles / boulder						420									auger very hard from 7.0m to 7.6m	
						Screen/Sand											
			8	SS	86/ 250mm		419						○			41 54 3 2 spoon bouncing	
419.0	End of Borehole Notes: 1. Auger refusal at 8.02m. 2. Water level at 4.6m during drilling 3. Water level at 4.1m upon completion. 4. 19mm dia. piezometer was installed to a depth of 8.02m. 5. Water level in piezometer Date Depth (m) Elevation (m) June 13, 2011 3.63 423.4																

ON-MTO SPL-M-MTO-750-JUNE-BORDEN CREEK - AUGUST 2012.GPJ ON\_MOT.GDT 4/12/12

**RECORD OF BOREHOLE No BH 11-2**

1 OF 1

**METRIC**

W.P. 5077-09-01 LOCATION Borden River Culvert - See Borehole Location Plan, E, N ORIGINATED BY NE  
DIST Algoma HWY 101 BOREHOLE TYPE Hollow Stem Augers COMPILED BY FL  
DATUM Geodetic DATE Jun/13/2011 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 $\gamma$ 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 (%)
								○ UNCONFINED	+ FIELD VANE							
								● QUICK TRIAXIAL	× LAB VANE							
427.1							20	40	60	80	100	10	20	30		
426.9	ASPHALT: 50 mm															
426.4	Fill: SAND some silt, trace gravel, trace clay greyish brown, moist compact to very loose.		1	SS	21							○				
	contains asphalt pieces														1 81 14 4	
			2	SS	13							○				
			3	SS	8							○				
	very loose		4	SS	3							○				
			5	SS	2								○		1 76 19 4	
423.0	Fill: SAND & GRAVEL some silt, trace clay, with organics dark grey to black, saturated compact.		6	SS	12								○		wet spoon	
421.5	SILT: trace sand, trace clay light grey, saturated compact.		7	SS	15								○		0 7 84 9	
419.9	SAND: trace gravel, some silt, trace clay grey, saturated very loose to very dense.		8	SS	4								○		augering grinding at 7.5m	
418.1	End of Borehole Notes: 1. Auger refusal at 9.0m. 2. Water level at 4.6m during drilling. 3. Water level at 5.93m upon completion.		9	SS	50/ 10mm								○		5 80 11 4	

ON-MTO SPL-M-MTO-750-JUNE-BORDEN CREEK - AUGUST 2012.GPJ ON\_MOT.GDT 4/12/12

**RECORD OF BOREHOLE No BH 11-3**

1 OF 1

**METRIC**

W.P. 5077-09-01 LOCATION Borden River Culvert - See Borehole Location Plan, E, N ORIGINATED BY NE  
DIST Algoma HWY 101 BOREHOLE TYPE Hollow Stem Augers COMPILED BY FL  
DATUM Geodetic DATE Jun/12/2011 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 (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
427.6								20	40	60	80	100								
426.9	ASPHALT: 50 mm Fill: GRAVELLY SAND trace silt greyish brown, moist very dense to dense.		1	SS	52								○							
			2	SS	32								○							
426.1																				
1.5	Fill: GRAVELLY SAND trace silt brown to greyish brown, moist loose to compact.		3	SS	9								○				26 71 (3)			
			4	SS	5								○							
			5	SS	13								○							
423.9	End of Borehole Notes: 1. Auger refusal at 3.7m.																			
3.7																				

**RECORD OF BOREHOLE No BH 11-4**

1 OF 1

**METRIC**

W.P. 5077-09-01 LOCATION Borden River Culvert - See Borehole Location Plan, E, N ORIGINATED BY NE  
DIST Algoma HWY 101 BOREHOLE TYPE Hollow Stem Augers COMPILED BY FL  
DATUM Geodetic DATE Jun/13/2011 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 (%)  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 (%)												
428.1							20	40	60	80	100					
428.0	ASPHALT: 60 mm															
428.0	Fill: SAND some gravel, trace silt greyish brown, moist dense.		1	SS	49								○			
427.3	Fill: SILTY SAND trace gravel, trace clay brown, moist compact.		2	SS	27								○			
426.6	Fill: SAND some silt, trace clay brown, moist compact to very loose.		3	SS	11								○			
	loose		4	SS	5								○			0 81 14 5
	very loose		5	SS	3								○			
424.0	SAND trace silt, trace clay, trace gravel grey, saturated very loose.		6	SS	2									○		wet spoon 2 89 5 4
422.6	SILT trace to some sand, trace clay grey, saturated loose to dense.		7	SS	39									○		
	some sand, loose		8	SS	7									○		0 13 79 8
419.3	End of Borehole		9	SS	50/ 10mm									○		spoon bouncing
8.9	Notes: 1. Auger refusal at 8.85 m. 2. Water level at 4.6m during drilling. 3. Water level at 6.0m upon completion															






ON-MTO SPL-M-MTO-750-JUNE-BORDEN CREEK - AUGUST 2012.GPJ ON\_MOT.GDT 4/12/12

**RECORD OF BOREHOLE No BH13-1**

1 OF 1

**METRIC**

W.P. 750-1101 LOCATION Borden River Culvert - See Borehole Location Plan ORIGINATED BY DW  
DIST Algoma HWY 101 BOREHOLE TYPE Portable drilling with continuous sampling and wash boring COMPILED BY DW  
DATUM Geodetic DATE Nov/22/2013 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			SHEAR STRENGTH kPa									
								○ UNCONFINED      + FIELD VANE									
								● QUICK TRIAXIAL      × LAB VANE									
							25    50    75    100    125					WATER CONTENT (%)					
423.7																	
420.0	Topsoil - 120 mm		1A	SS	5												
0.1	Fill: Sand brown, moist, wet, very loose to loose  - wet below 0.6 m		1B	SS	5												
			2	SS	3												
			3A	SS	9												
422.2																	
1.5	Silty Sand		3B	SS	9												
421.9	dark brown, moist, loose																
1.8	Sand some silt, trace to some gravel, brown, wet, compact to dense      - loose below 4.9 m		4	SS	25												
			5	SS	24												
			6	SS	31												
			7	SS	28												
			8	SS	18												
			9	SS	3												
			418.2														
5.5	Sand and Silt		10	SS	9												
	trace gravel, trace clay, brown, wet, loose to compact		11	SS	11												
			12	SS	16												
416.4																	
7.3	End of Borehole 1. Drilling ended at 7.3 m 2. Casing driven to 3.1 m, wash boring begins 3. Water level at 0.6 m during drilling																

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

ON-MTO-LARGE SCALE SPL-M-MTO-750-BORDEN RIVER-NOV22 2013.GPJ ON\_MOT.GDT 10/1/14

**RECORD OF BOREHOLE No BH13-2**

1 OF 1

**METRIC**

W.P. 750-1101 LOCATION Borden River Culvert - See Borehole Location Plan ORIGINATED BY DW  
DIST Algoma HWY 101 BOREHOLE TYPE Portable drilling with continuous sampling and wash boring COMPILED BY DW  
DATUM Geodetic DATE Nov/23/2013 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					
423.7 0.0	<b>Topsoil - 190 mm</b>																
423.5 0.2	<b>Sand</b> some silt, some root fragments, trace gravel, brown, moist, loose to compact		1	SS	9		423										
			2	SS	20												
422.2 1.5	- wet below 1.2 m <b>Sand</b> some gravel, trace silt, brown, wet, compact		3	SS	22		422										26 65 (9)
			4	SS	15												
421.2 2.4	<b>Silty Sand</b> trace to some gravel, trace clay, brown, wet, loose		5	SS	7		421										19 44 34 3
	- very loose		6	SS	1												
	- loose		7	SS	5		420										2 75 (23)
419.2 4.5	<b>End of Borehole</b> Notes: 1. Sampler refusal at 4.25 m 2. DCPT refusal at 4.5 m 3. Casing driven to 3.1, wash boring begins 4. Water level at 1.2 m during drilling.		8	SS	50/ 0 mm												

# Appendix B

## Chemical Test Results

**CLIENT NAME: SPL BEATTY  
6221 HIGHWAY 7 WEST UNIT 16  
VAUGHAN, ON L4H0K8**

**ATTENTION TO: Naeem Ehsan**

**PROJECT NO: 750-1001**

**AGAT WORK ORDER: 11T507482**

**SOIL ANALYSIS REVIEWED BY: Mike Muneswar, BSc (Chem), Senior Inorganic Analyst**

**DATE REPORTED: Jul 14, 2011**

**PAGES (INCLUDING COVER): 4**

**VERSION\*: 1**

Should you require any information regarding this analysis please contact your client services representative at (905) 712 5100, or at 1-800-856-6261

**\*NOTES**

**All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.**



**AGAT** Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 11T507482

PROJECT NO: 750-1001

5835 COOPERS AVENUE  
MISSISSAUGA, ONTARIO  
CANADA L4Z 1Y2  
TEL (905)712-5100  
FAX (905)712-5122  
<http://www.agatlabs.com>

CLIENT NAME: SPL BEATTY

ATTENTION TO: Naeem Ehsan

### Inorganic Chemistry (soil)

DATE SAMPLED: Jun 12, 2011

DATE RECEIVED: Jul 06, 2011

DATE REPORTED: Jul 14, 2011

SAMPLE TYPE: Soil

Parameter	Unit	G / S	RDL	BH11-MSC-4, S1(0-2) 2521422	BH11-MSC-2, S8(25) 2521424	BH11-BR-2, S1(0-2) 2521425	BH11-BR-4, S6(15) 2521426
Chloride (2:1)	µg/g		2	18	117	7	6
Sulphate (2:1)	µg/g		2	7	17	46	10
pH (2:1)	pH Units		N/A	10.09	8.31	5.90	9.15
Electrical Conductivity (2:1)	mS/cm		0.002	0.154	0.258	0.075	0.083
Resistivity (2:1)	ohm.cm		1	6490	3880	13300	12000

**Comments:** RDL - Reported Detection Limit; G / S - Guideline / Standard

**2521422-2521426** EC,pH,Chloride and Sulphate were determined on the extract obtained from the 2:1 extraction procedure (2 parts DI water: 1 part soil).

**Certified By:**

## Quality Assurance

CLIENT NAME: SPL BEATTY

AGAT WORK ORDER: 11T507482

PROJECT NO: 750-1001

ATTENTION TO: Naeem Ehsan

### Soil Analysis

RPT Date: Jul 14, 2011

RPT Date: Jul 14, 2011			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

#### Inorganic Chemistry (soil)

Chloride (2:1)	1	2521422	18	18	0.0%	< 2	99%	80%	120%	95%	80%	120%	97%	80%	120%
Sulphate (2:1)	1	2521422	7	7	0.0%	< 2	92%	80%	120%	97%	80%	120%	96%	80%	120%
pH (2:1)	1	2521422	10.09	10.00	0.9%	N/A	105%	90%	110%						
Electrical Conductivity (2:1)	1	2521422	0.154	0.148	4.0%	< 0.002	96%	90%	110%						

**Certified By:**



## Method Summary

CLIENT NAME: SPL BEATTY

AGAT WORK ORDER: 11T507482

PROJECT NO: 750-1001

ATTENTION TO: Naeem Ehsan

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
<b>Soil Analysis</b>			
Chloride (2:1)	INOR 1005	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR 1005	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR 1036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR 1036		CALCULATION



## Laboratories

丁

5835 Coopers Avenue  
Mississauga, Ontario; L4Z 1Y2  
Phone: 905-712-5100; Fax: 905-712-5122  
Toll free: 800-856-6261  
[www.agatlabs.com](http://www.agatlabs.com)  
<http://webearth.agatlabs.com>

**LABORATORY USE ONLY**

Arrival Condition: ☐ Good

<input type="checkbox"/>	Poor (complete "notes")
--------------------------	-------------------------

Arrival Temperature: 69

Notes:

## Client Information

Company: SPL Consultants Limited  
 Contact: NAEEM EHSAN  
 Address: 6221, HWY 7, unit 16,  
Vaughan, ON  
 Phone: 905-856-0065 Fax: 905-856-0025  
 Project: 750-1001 PO: \_\_\_\_\_  
 AGAT Quotation #: \_\_\_\_\_

Please note, if quotation number is not provided, client will be billed full price for analysis.

**Invoice To:** Same as Above? ☒ Yes ☐ No (circle)

Company: \_\_\_\_\_  
Contact: \_\_\_\_\_  
Address: \_\_\_\_\_  
Phone: \_\_\_\_\_ Fax: \_\_\_\_\_

**Report Information** - reports to be sent to:

1. Name: NAEEM EHSAN  
Email: nehshan@spcconsultants.ca

2. Name: \_\_\_\_\_  
Email: \_\_\_\_\_

## Regulatory Requirements

<input type="checkbox"/> Regulation 153 Table	<input type="checkbox"/> Sewer Use	<input type="checkbox"/> Regulation 558
(Indicate one)	Region	CCME
<input type="checkbox"/> Ind/Com	<input type="checkbox"/> Sanitary	<input type="checkbox"/> Other (Indicate)
<input type="checkbox"/> Res/Park	<input type="checkbox"/> Storm	

☐ Agriculture  
Soil Texture (check one)

☐ Coarse ☒ Med/Fine

Prov. Water Quality Objectives (PWQO)

**Journal of Management Education**

Is this a drinking water sample (potable water supply) intended for human consumption?

☐ Yes ☐ No (If "Yes," please use the Working Water Chain of Custody Record)

Fax:

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Site/ Sample Information	Comments
BH <sup>II</sup> -MSC-A-51(6-2)	June 14, 2011		Soil	1 bag	Machin Shop Creek	
BH <sup>II</sup> -MSC-2, 58(25)	June 14, 2011		Soil	" "	Machin Ship Creek	
<del>BH<sup>II</sup>-BR-4, 56(16)</del>						
<del>BH<sup>II</sup>-BR-2, 57(16)</del>						
BH <sup>II</sup> -BR-2, 51(6-2)	June 12, 2011		" "	" "	Borden River	
BH <sup>II</sup> -BR-4, 56(15)	June 12, 2011		" "	" "	Borden River	
Samples Relinquished By (print name & sign)	Naeem Ehsan					Samples Received By (print name & sign) Naeem Ehsan
Samples Relinquished By (print name & sign)						Samples Received By (print name & sign) Naeem Ehsan

[illegible]

Print name & sign) <i>e/ Joo 7/16/11</i>	Date/Time <i>8:55A</i>	Pink Copy - Client Yellow + Golden Copy - AGAT	PAGE _____ of _____
Print name & sign) <i>Jee 7/16/11</i>	Date/Time <i>9:24A</i>		NO: 152912

Document ID: DIV-78-1511.005

Date Issued: December 6, 2010

# 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  $\bar{N}$ .

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 = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$\rho_w$	$\text{kg}/\text{m}^3$	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
$\rho_d$	$\text{kg}/\text{m}^3$	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
$\rho_{\text{sat}}$	$\text{kg}/\text{m}^3$	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
$\rho'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED 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 BORDEN RIVER CULVERT REPLACEMENT**  
**HIGHWAY 101 EAST OF HIGHWAY 129, ONTARIO**  
**WP 5077-09-01 SITE NO. 46-330/C**  
**G.W.P. 5077-08-00**  
**MTO GEOCRETS NO. 410-12**

Prepared for:

**MCINTOSH PERRY CONSULTING ENGINEERS**

By:

**SPL CONSULTANTS LIMITED**

Project: 750-1001 (Borden River)  
January 2014



**SPL Consultants Limited**  
Geotechnical Environmental Materials Hydrogeology

146 Colonnade Road  
Ottawa, Ontario K2E 7Y1  
Tel: 613.228.0065 Fax: 613.228.0045

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## **6. DISCUSSION AND RECOMMENDATIONS**

### **6.1 General**

The proposed new culverts comprise twin closed bottom concrete box culverts with interior dimensions of 2.5 m wide by 2.4 m high. The culverts will be installed with approximately 3 m of clear space between them and will have invert elevations of approximately 422.5 m and 422.3 m (at their midpoint). These invert elevations are slightly lower than the existing culvert inverts. The location of the proposed new culverts has also been moved about 5 m east of the existing culverts. The current design does not include any change in the final embankment height.

The subsurface conditions encountered in the boreholes drilled on the existing highway include a layer of granular fill ranging from 3.7 m (the fill may be deeper than 3.7 m in BH11 -3 but this could not be determined due to auger refusal) to 5.6 m in thickness which forms the road structure, embankment and backfill around the existing culvert. In the boreholes closest to location of the proposed culverts (BH11-1 and BH11-2) the fill is approximately 5.6 m thick. In Borehole BH13-1, drilled near the outlet of the western proposed culvert, the fill is approximately 1.5 m thick. No fill was encountered in Borehole BH13-2, drilled near the inlet of the eastern proposed culvert.

The fill layer is underlain by native soils consisting of a variable mix of silt, sand and gravel. The native granular soils extended to the depth of drilling at the culvert location. In Boreholes BH11-1 through BH11-4 the boreholes terminated due to auger refusal. With the exception of borehole BH11-3 which terminated at a depth of 3.7 m (El. 423.9 m) refusal was at a depth of approximately 8 m to 9 m (El. 419.3 m to 418.1 m) below the existing road surface. In Borehole BH13-2, drilled near the inlet of the eastern existing culvert the borehole terminated after sampler/DCPT refusal at 4.5 m (El. 419.2 m) below the existing ground surface. In Borehole BH13-1 no refusal was encountered.

The groundwater level at the site was found to be at approximately elevation 423.4 m in June 2011, which is roughly coincident with the level of the water in the watercourse at the time of the measurement.

Based on the borehole information, the culverts and bedding will be founded on loose to compact native silt, sand and gravel, and potentially some granular fill (which extended in some boreholes to slightly below the proposed new inverts. Accounting for the thickness of the culvert and the bedding, the base of the bedding will be at or near the transition between fill and native soils. Either the granular fill or the native granular soils are expected to be adequate to support the proposed culverts.

### **6.2 Frost Protection**

The depth of frost penetration for the Borden Lake site is 2.3 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 heaving. As such, frost tapers are not required for the 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 Foundation Design**

#### **6.4.1 Foundation Options**

MTO has selected a closed-bottom, 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 granular soils or existing 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 structures will be placed on the native granular soils or existing granular fill.

For the new culverts, which are 3.1 m wide and will be founded at approximately 422.0 m elevation, the unfactored geotechnical bearing resistance at Ultimate Limit State (ULS) can be taken as 600 kPa. A resistance factor of 0.5 should be applied to this value, yielding a factored bearing resistance of 300 kPa at ULS (Ultimate Limit States). 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 Section 6.7.2 of the CHBDC.

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

Provided that the subgrade is not unduly 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 the 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 culverts should be as per MTOD 803.021. Bedding for the new culverts 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 and 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 may meet the requirements of OPSS 1010 for Granular B Type I. Other portions of the existing fill embankment may 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 silty soil, is unlikely to be suitable for re-use as 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 vibratory equipment should not be used behind the culvert and retaining walls 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 will be widened slightly to facilitate a detour around the construction site. 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 MTO standards and procedures for stripping and benching prior to placing the embankment fills.

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 OPSS OPSD 208.01. Fill material should be placed in lifts not exceeding 300 mm in thickness and compacted to 95% SPMDD 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 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 in similar to OPSD 810.919) will be required at the culvert inlets and outlets. The sizing of the 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 river at the time of the investigation. The groundwater level is expected to be sensitive to changes in the water level in the river. For this reason it is recommended that if possible construction be carried out in a dry period when the river water level would be expected to be at its lowest level. It is also recommended that one culvert be replaced at a time while the other one is used as a bypass in order to convey the water around the culvert under 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 native soils during construction. Depending upon the river 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 river water level was approximately 423 m elevation both in July 2011 and November 2013 when the investigations were completed. Excavation to an elevation of 421.5 (or at least 1.5 m below the water table) will be required to accommodate the culvert, bedding, levelling course, etc. These deeper excavations will likely require an active dewatering system (such as well points) 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) may 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 granular soil. 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).

If temporary shoring is required it would typically consist of soldier piles and timber lagging or interlocking sheet piles. It is conceivable that a trench box could also be used given the size of the proposed culverts. It should be noted that cobbles and boulders were encountered during the investigation, and refusal was met in several boreholes drilled close to the proposed culverts at approximately 3 m to 4 m below the existing culvert invert. 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 discretion of the CA and QVE. 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 AGAT 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. In particular one test carried out on granular fill (BH11-2, Sample No. 1) indicates the soil is acidic, which can increase corrosion rates. 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 2013 were supervised by Mr. Daniel Wall, E.I.T. This report was prepared by Mr. Chris Hendry, P.Eng. Quality control and independent review of the technical aspects of this report were provided by Mr. Fanyu Zhu, P.Eng. who is SPL's designated MTO contact and Mr. Shaheen Ahmad, P.Eng., who is the project quality control auditor.

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