FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED CULVERT REPLACEMENT
NEPEWASSI LAKE ROAD NEAR SUDBURY, ONTARIO
SITE NO. 46-419/C
G.W.P. 5022-10-00
MTO GEOCRES NO. 41I-285

Prepared for:

ONTARIO MINISTRY OF TRANSPORTATION

By:

SPL CONSULTANTS LIMITED

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

Project: 1067-710 (Nepewassi Lake Road)
February 2013

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

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1. INTRODUCTION

SPL Consultants Limited (SPL) was retained by the Ontario Ministry of Transportation (MTO) to conduct a foundation investigation as part of a proposed culvert replacement on Nepawassi Lake Road approximately 4.9 km east of Highway 69 near Sudbury, Ontario.

The terms of reference (TOR) for this investigation are outlined in the Request for Proposal (RFP) issued by the MTO under Agreement No. 5011-E-0023 dated November 2011 and SPL's subsequent Proposal No. P11.12.011 dated December 2011.

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.

2. SITE DESCRIPTION

The site is located on Nepawassi Lake Road approximately 4.9 km east of Highway 69, near Sudbury, Ontario (see Drawing 1). The general area is characterized by steeply sloping hills with flat to gently sloping, lowlands. The area is mostly forested, while the low areas along the watercourse are vegetated with grasses and small brush within what appears to be the floodplain of the watercourse.

Flow in the watercourse is from north to south and based on information provided to us the estimated flow velocity during a 5 year storm event is approximately 1.5 m/s with a corresponding flow rate of 6.8 m^3/s. At the time of the investigation the creek was frozen. The top of the ice was at approximately 97.7 m elevation.

The existing structure is a Structural Plate Corrugated Steel Pipe Arch (SPCSPA) approximately 2.7 m high, by 3.9 m wide and 15.1 m long. The culvert has approximately 500 mm of soil cover. The existing road is gravel surfaced and approximately 7.5 m wide. Based on the structural site inspection (completed by others) in 2011 the culvert is in good condition above the high water line and poor condition below the water line. Damage is evident at the inlet of the culvert due to beaver activity and/or removal of beaver dams.

The elevation of the road in the general vicinity of the crossing is approximately 100 m (a local datum has been established by others for this project; the elevation of the top of the existing culvert inlet is 99.54 m in the local datum). The existing embankment is approximately 2 m to 2.5 m high at the crossing.

3. INVESTIGATION PROCEDURES

The foundation investigation was carried out in February/March and December 2012. The scope of work for this assignment included a desk study, field investigations, laboratory testing, analysis and preparation of this report.

3.1 Desk Study

Surficial geology in the area comprises glaciolacustrine (fine-grained) and glaciofluvial (coarse-grained) deposits. These deposits generally would be expected to include clay, silt, sand and gravel deposits, as well as potentially cobbles and boulders.

Bedrock geology maps of the general area indicate the bedrock to be layered biotite gneisses and migmatites of the central gneiss belt.

3.2 Field Investigation

The initial field investigation was carried out between February 28, 2012 and March 5, 2012. The initial field investigation included drilling a total of 5 boreholes at the crossing location (BH-1 through BH-5).

The boreholes were advanced using a truck-mounted drill rig supplied and operated by Landcore Drilling of Chelmsford, ON. The boreholes were drilled using a combination of hollow-stem auger drilling and rock coring to depths ranging from 3.6 m to 15.5 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.

A standpipe piezometer was installed in Borehole BH-3 to allow for measurement of groundwater levels at the site. All boreholes were backfilled with bentonite and soil cuttings and were sealed at the ground surface.

A supplementary field investigation was completed in December 2012. During this supplementary investigation an additional two boreholes (BH12-1 and BH12-2) were advanced at the site. Due to the difficult access, the boreholes were drilled by SPL using hand-portable equipment. The drilling was carried out using driven casing, wash boring and regular sampling with a standard SPT sampler. SPT sampling was completed using a non-standard 31.8 kg hammer; all other aspects of the test were completed in the standard manner. SPT "N" values presented on borehole logs and on the foundation drawings have been corrected for this reduced driving energy.

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

3.3 Laboratory Testing

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

The results of natural water content and soil unit weight testing are included on the relevant borehole logs in Appendix A. The results of grain size distribution testing are summarized on the individual borehole logs and are presented in Drawings 5 through 7. The results of Atterberg limits testing are presented on the plasticity chart included as Drawing 8.

Chemical testing to determine sulphate content, chloride content, pH and soil resistivity was also 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 Fill

Five of the boreholes drilled as part of this investigation (BH-1 through BH-5) were drilled on the existing gravel-surfaced (unpaved) road. At all locations granular fill was encountered which forms the road structure, as well as the existing embankment.

The granular fill was primarily sand and gravel, with finer material (such as sandy silt) near the base of the embankment. Cobbles and boulders were also encountered at some locations within the fill layer (see Borehole records in Appendix A).

The grain size curves for several samples of the fill are presented in Drawing 5. 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 5 and Table 1 may be finer than portions of the materials in the field.

Table 1 – Results of Grain Size Analyses for Fill Material

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt & Clay	
BH-1	1	50	44	6	
BH-1	2	31	64	5	
BH-2	1	9	73	18	
BH-2	2	23	71	6	
BH-3	1	42	51	7	
BH-3	2	29	65	6	
BH-3	3	0	16	75	9
BH-4	1	32	61	7	
BH-4	2	35	53	12	
BH-5	1	40	54	6	
BH-5	3	9	23	57	11
Range		0 - 50	16 – 73	5 - 84	

The density of the fill material (as interpreted based on SPT "N" values) is typically dense within the upper sand and gravel portion and compact within the lower silty sand and sandy silt. Very high "N" values often reflect the presence of cobbles and boulders, rather than a very high density of the soil matrix itself.

The fill material extended to a depth of 1.5 m to 2.3 m below the existing road surface in the boreholes drilled as part of this investigation. This corresponds to elevations of 97.9 m to 98.5 m.

4.1.2 Native Soils

The granular fill layer was underlain by native soils which generally range from silty clay to sandy gravel. The native soils can be broadly separated into two main strata.

<u>Upper Silty Soils</u>

The uppermost native soils include a variable mixture of silty clay, clayey silt, silt and sandy silt. These predominantly silty soils extended from the base of the fill embankment to depths of 4.6 m to 7.6 m and were encountered in all boreholes with the exception of BH-1 (which encountered rock immediately below the fill).

The grain size distributions of several samples of the native soils are presented in Drawing 6, and are summarized in Table 2 below.

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

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH-2	3	0	21	69	10
BH-2	5	0	51	33	16
BH-4	4	0	48	43	9
BH-4	6	3	47	50	
BH-5	4	0	7	76	17
BH-5	5	1	30	58	11
BH-5	6	0	87	13	
BH-5	7	0	12	61	27
Range		0 - 3	7 - 87	13 - 93	

Atterberg limits testing was carried out on four samples of the more cohesive portions of the upper silty native soils. The results of these tests are presented in Table 3 below.

Table 3 – Results of Atterberg Limits (Plasticity) Testing for Native Silty Soils

Borehole No.	Sample No.	Liquid Limit	Plastic Limit	Plasticity Index
BH-2	4	37	29	8
BH-3	5	51	28	23
BH-4	5	43	23	20
BH-5	7	26	17	9
Range		26 - 51	17 - 29	8 - 23

Measurements of soil unit weight carried out on selected cohesive samples from this strata yielded values of 16.3 kN/m^3 to 20.3 kN/m^3.

The silty soils are typically described as loose to very loose or very soft to firm (as interpreted based on SPT “N” values). SPT “N” values and DCPT resistance values are presented on the borehole logs included in Appendix A as well as on the cross-sections provided as Drawings 3 and 4.

Lower Sandy Soils

The lower native soils include predominantly sand and silty sand, with occasional lenses of sandy silt or sand and gravel. These predominantly sandy soils were encountered at an elevation of 92.6 m to 96.1 m below the existing ground surface with the exception of BH-1 (which encountered rock immediately below the fill).

The grain size distributions of several samples of the native soils are presented in Drawing 7, and are summarized in Table 4 below.

Table 4 – Results of Grain Size Analyses for Native Sandy Soils

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH-2	6	6	92	2	
BH-2	7	11	86	3	
BH-3	7	6	41	45	8
BH-3	9	1	73	24	2
BH-3	11	0	37	55	7
BH-4	7	0	54	34	8
BH-4	9	37	33	27	3
BH-5	8	7	43	43	7
BH-5	9	0	82	13	5
BH12-1	4	2	14	79	5
BH12-2	5	24	33	39	4
Range		0 – 37	14 – 82	13 – 55	2 – 8

The sandy soils are typically described as loose to compact (as interpreted based on SPT "N" values). SPT "N" values and DCPT resistance values are presented on the borehole logs included in Appendix A as well as on the cross-sections provided as Drawings 3 and 4.

4.1.3 Bedrock/Auger Refusal

Rock was encountered at Boreholes BH-1 and BH-3 at 2.1 m depth and 13.5 m depth, respectively. These depths correspond to 97.9 m and 86.6 m, respectively. Rock was cored at these two locations using "N" size coring equipment.

The rock at the culvert was found to be fine to medium-grained, red and black very strong, slightly weathered gneissic rock. RQD values of the rock cored ranged from 35% to 65%, indicating poor to fair quality rock.

Auger refusal was also encountered at Borehole BH-4 at a depth of 10.5 m (89.5 m elevation). This refusal may indicate the surface of the bedrock at this location. It could, however, be due to the presence of cobbles/boulders which could not be penetrated by the auger.

4.2 Groundwater Conditions

The creek was frozen at the time of the investigation (late February and early March 2012). The top of the ice was at approximately 97.7 m. The water level in the creek (below the ice) at the time of the investigation was at approximately 97.3 m elevation (or 1.7 m to 1.9 m below the existing road surface). Seepage was noted in Boreholes BH-3 and BH-5, as well as BH12-1 and BH12-2 (which were drilled at the toe of the embankment) during drilling.

A standpipe piezometer was installed in BH-3 during drilling. The groundwater level at the site was found to be at 96.1 m elevation.

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 level of the creek. If construction is carried out at a time when the creek level is higher than the level in February/March 2012, a corresponding increase in groundwater levels should be anticipated.

4.3 Summary

A summary of the soil and groundwater conditions encountered at the crossing location is presented in Table 5 below.

Table 5 – Simplified Stratigraphy and Groundwater Elevations

Borehole No.	Ground Surface Elevation	Simplified Soil Stratigraphy				Measured Groundwater Elevation
		Fill	Upper Silty Soils	Lower Sandy Soils	Bedrock	
BH-1	100.0 m	0.0 – 2.1 m	--	--	2.1 – 3.6 m	--
BH-2	100.0 m	0.0 – 1.5 m	1.5 – 4.6 m	4.6 m – 7.3 m	--	--
BH-3	100.1 m	0.0 – 2.3 m	2.3 – 6.1 m	6.1 – 13.5 m	13.5 – 15.5 m	96.1 m
BH-4	100.0 m	0.0 – 1.5 m	1.5 – 5.0 m	5.0 – 10.5[1] m	--[1]	--
BH-5	100.2 m	0.0 – 2.3 m	2.3 – 7.6 m	7.6 – 9.7 m	--	--
BH12-1	97.9 m	--	0.0 – 1.8 m	1.8 – 6.1 m	--	--
BH12-2	98.3 m	--	0.2 – 2.4 m	2.4 – 6.1	--	--

[1] Auger refusal was encountered at 10.5 m depth.

5. CLOSURE

The field investigations were supervised by Mr. Naeem Ehsan, P.Eng. This report was prepared by Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, P.Eng., who is the project manager and SPL's designated MTO contact and Mr. Shaheen Ahmad, P.Eng., who is the project quality control auditor, provided quality control and independent review 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

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F. ZHU
Feb. 14/13
PROVINCE OF ONTARIO

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

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

Site Photographs

Top of Culvert Looking South

Top of Culvert Looking Northwest

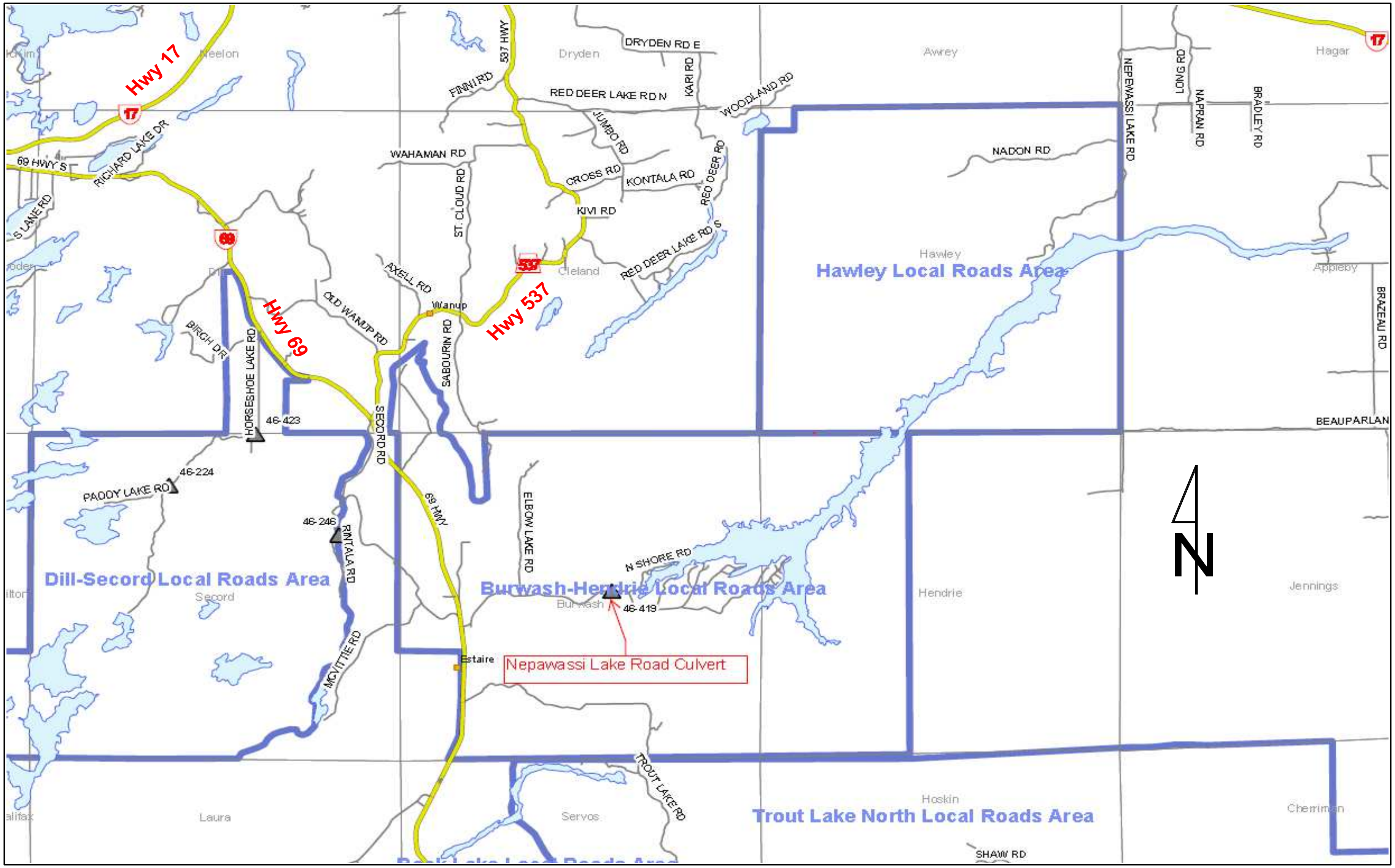
Barrel of Culvert Looking South

Looking East from Culvert (February 2012)

Looking West from Culvert (February 2012)

Looking Northwest at Culvert Inlet (February 2012)

Drawings



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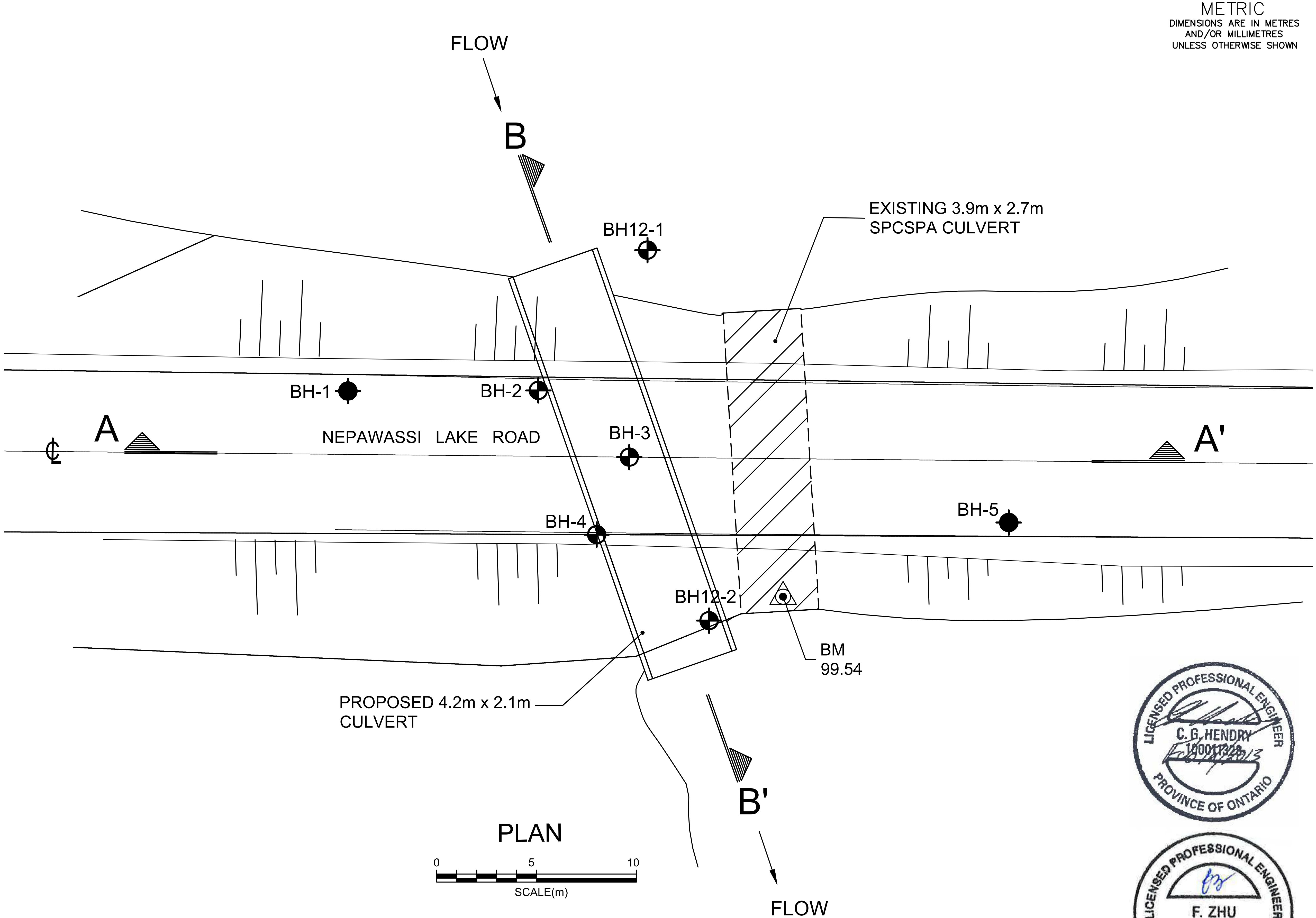
Project#:	1067-710	DWG #:	1	Project:	Geotechnical Investigation - Nepawassi Lake Road Culvert Replacement
Drawn:	NT	Approved:	CH		
Date:	March 2012	Scale:	N. T. S.		SPL Consultants Limited Geotechnical Environmental Materials Hydrogeology
Size:	Letter	Rev:	0		



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

CONT No 2013–5601
WP No 5018–10–01

NEPAWASSI LAKE ROAD
CULVERT REPLACEMENT
BORE HOLE LOCATIONS

SHEET
5

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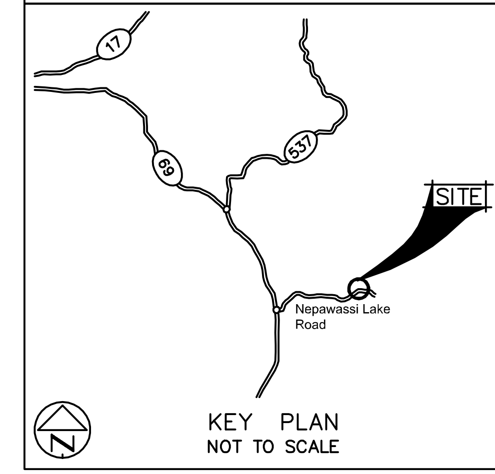

KEY PLAN
NOT TO SCALE

LEGEND

- Bore Hole
- Bore Hole & Cone
- Benchmark (Top of Pipe at Inlet) Elev.=99.54

No	ELEVATION	NORTHING	EASTING
BH–1	100.0	5129662	519552
BH–2	100.0	5129661	519561
BH–3	100.1	5129659	519565
BH–4	100.0	5129659	519564
BH–5	100.2	5129652	519586
BH12–1	97.9	5129669	519566
BH12–2	98.3	5129651	519569

–NOTES–

Borehole elevations are based on local datum.

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REVISIONS		
JAN 2013	ZMO	Revision 03 – Final Report
DEC 2012	TJC	Revision 02 – Revised Draft – Issued for Exec. Review
MAR 2012	NT	Revision 01 – Draft Reprt
DATE	BY	DESCRIPTION

GEOCRES No 411–285

HWY No – –	–		DIST – – –
SUBM'D CH	CHECKED CH	DATE March 2012	SITE 46–419/C
DRAWN NT	CHECKED CH	APPROVED – – –	DWG 2

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

CONT No 2013–5601
WP No 5018–10–01

NEPAWASSI LAKE ROAD CULVERT REPLACEMENT
BORE HOLE LOCATIONS & SOIL STRATA

SHEET 6

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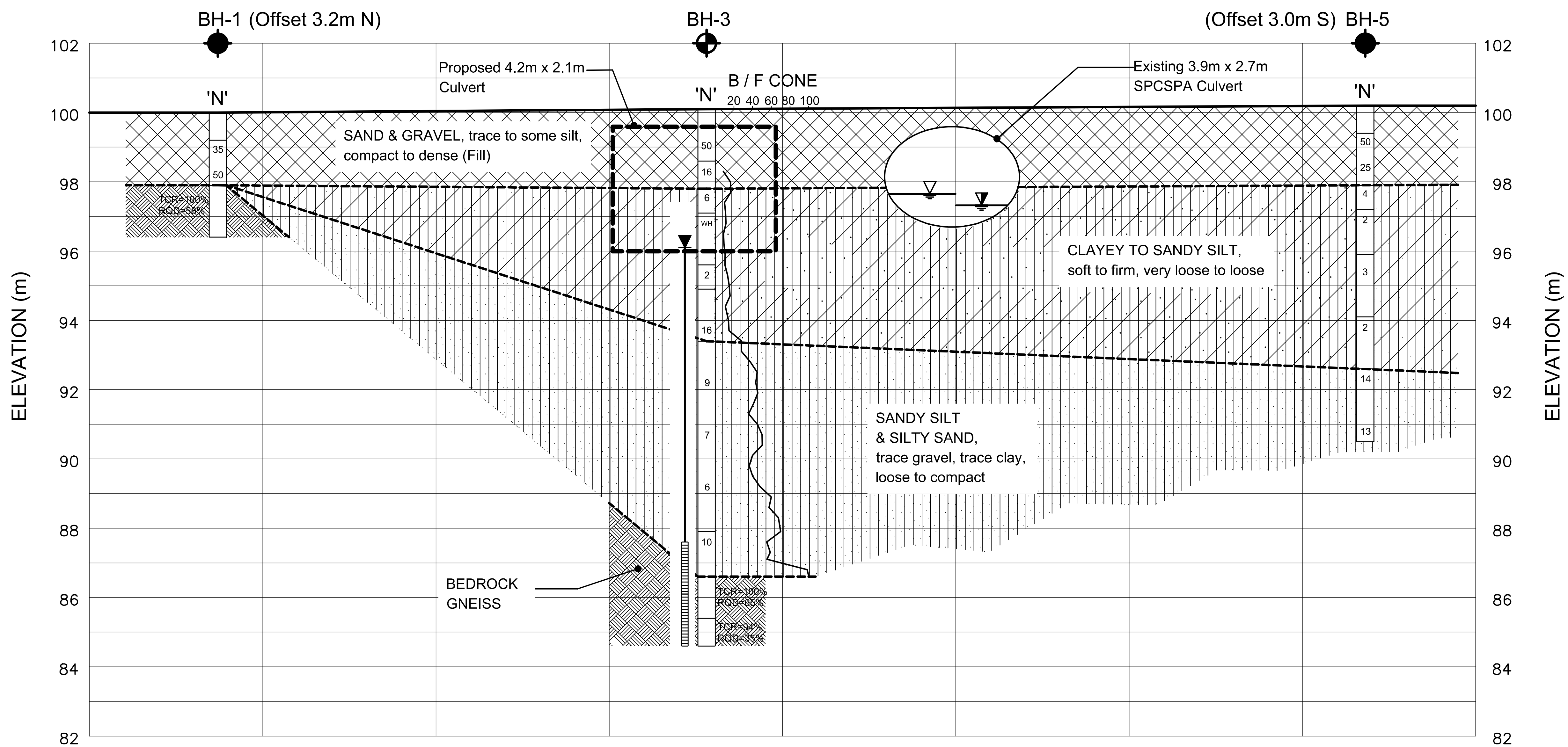
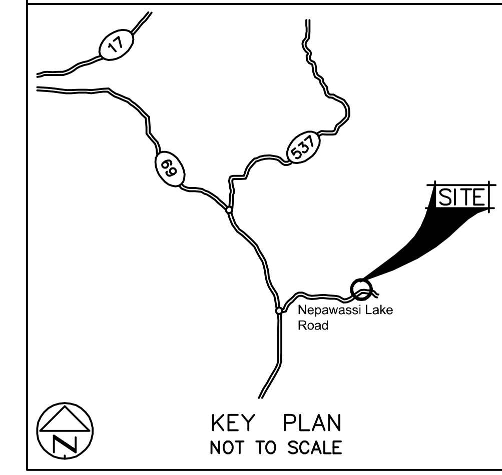


CROSS SECTION A-A'

HOR 0 5 10 (m)
VERT 0 5 10 (m)
SCALE(m)



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 (March 2012)
- WL at time of survey (August 2011)
- WL in Piezometer (March 2012)
- Piezometer

No	ELEVATION	NORTHING	EASTING
BH–1	100.0	5129662	519552
BH–2	100.0	5129661	519561
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BH–5	100.2	5129652	519586
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BH12–2	98.3	5129651	519569

— NOTES —

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

Borehole elevations are based on local datum.

SOIL STRATA SYMBOLS

- SAND AND GRAVEL FILL
- SILT AND SAND
- CLAYEY TO SANDY SILT
- BEDROCK
- CLAYEY TO SANDY SILT
- BEDROCK

REVISIONS DATE	BY	DESCRIPTION
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GEOCRES No 411–285

HWY No – –	–		DIST – – –
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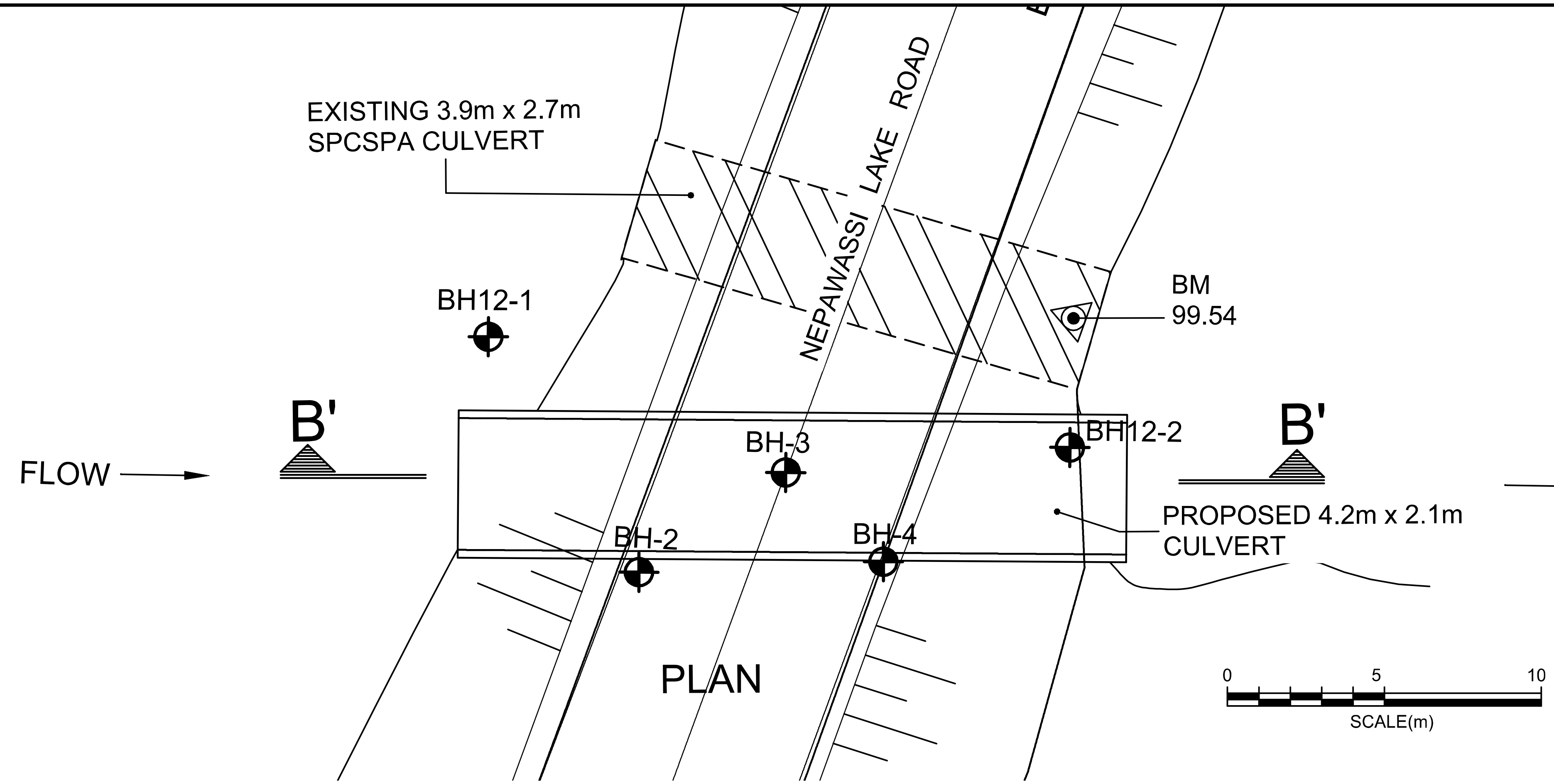
DRAWN NT	CHECKED CH	APPROVED – – –	DWG 3



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CONT No 2013–5601
WP No 5018–10–01

NEPAWASSI LAKE ROAD
CULVERT REPLACEMENT
BORE HOLE LOCATIONS & SOIL STRATA

SHEET 7

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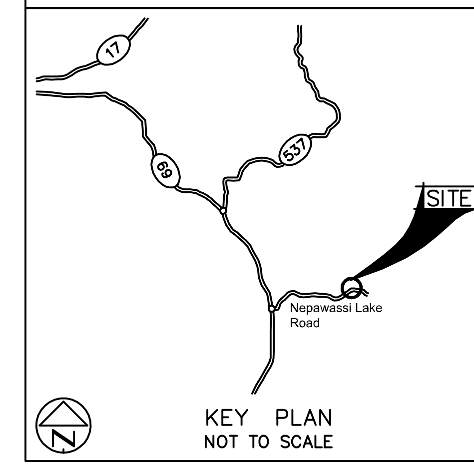

KEY PLAN
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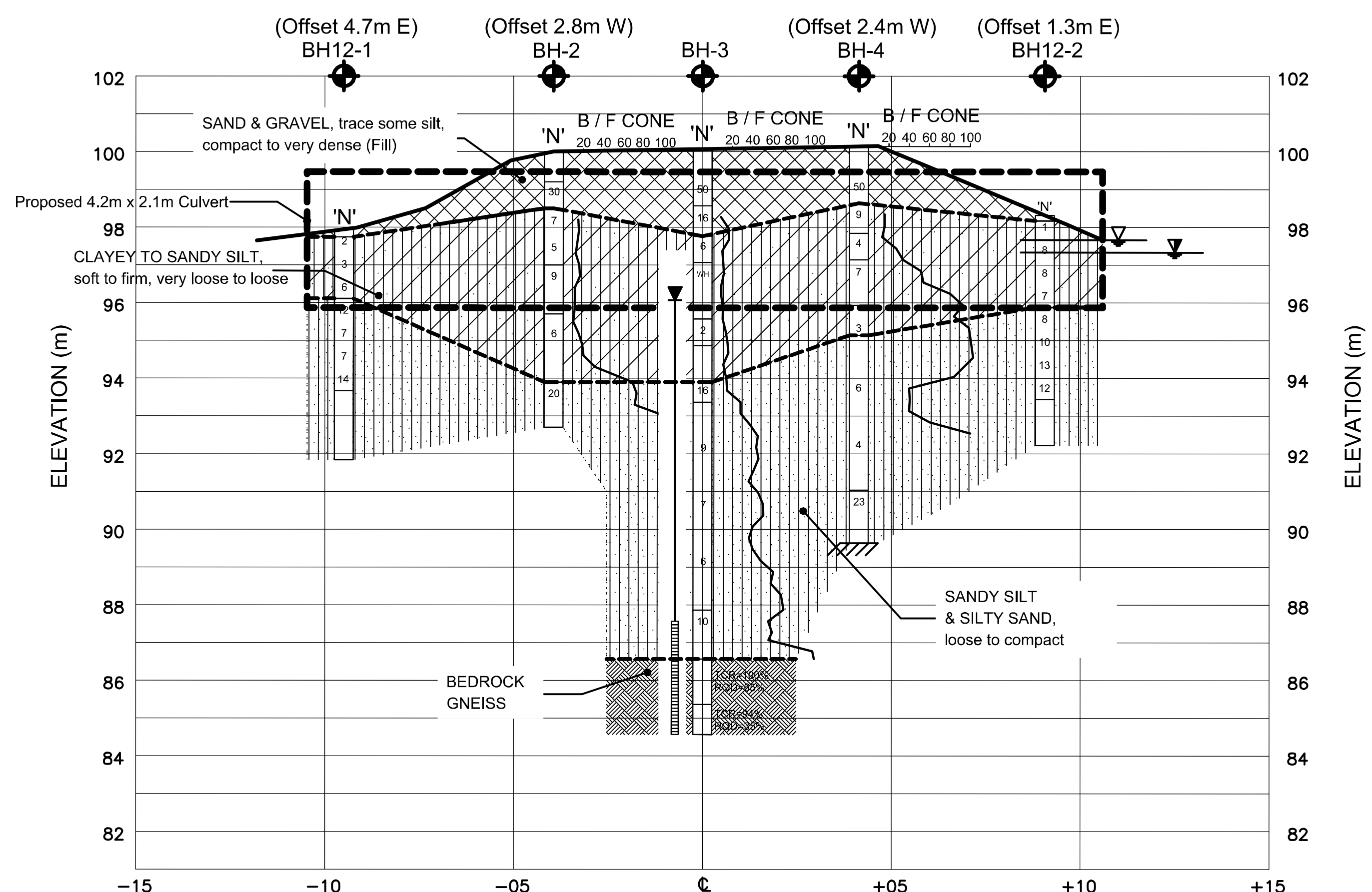

CROSS SECTION B-B'

SOIL STRATA SYMBOLS

- SAND AND GRAVEL FILL
- SILT AND SAND
- CLAYEY TO SANDY SILT
- BEDROCK

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 (March 2012)
- WL at time of survey (August 2012)
- WL in Piezometer
- Piezometer
- Auger Refusal

No	ELEVATION	NORTHING	EASTING
BH–1	100.0	5129662	519552
BH–2	100.0	5129661	519561
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— NOTES —

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

Borehole elevations are based on local datum.

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JAN 2013	ZMO	Revision 03 – Final Report
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MAR 2012	NT	Revision 01 – Draft Reprt

GEOCRES No 411–285

HWY No – –	–		DIST – – –
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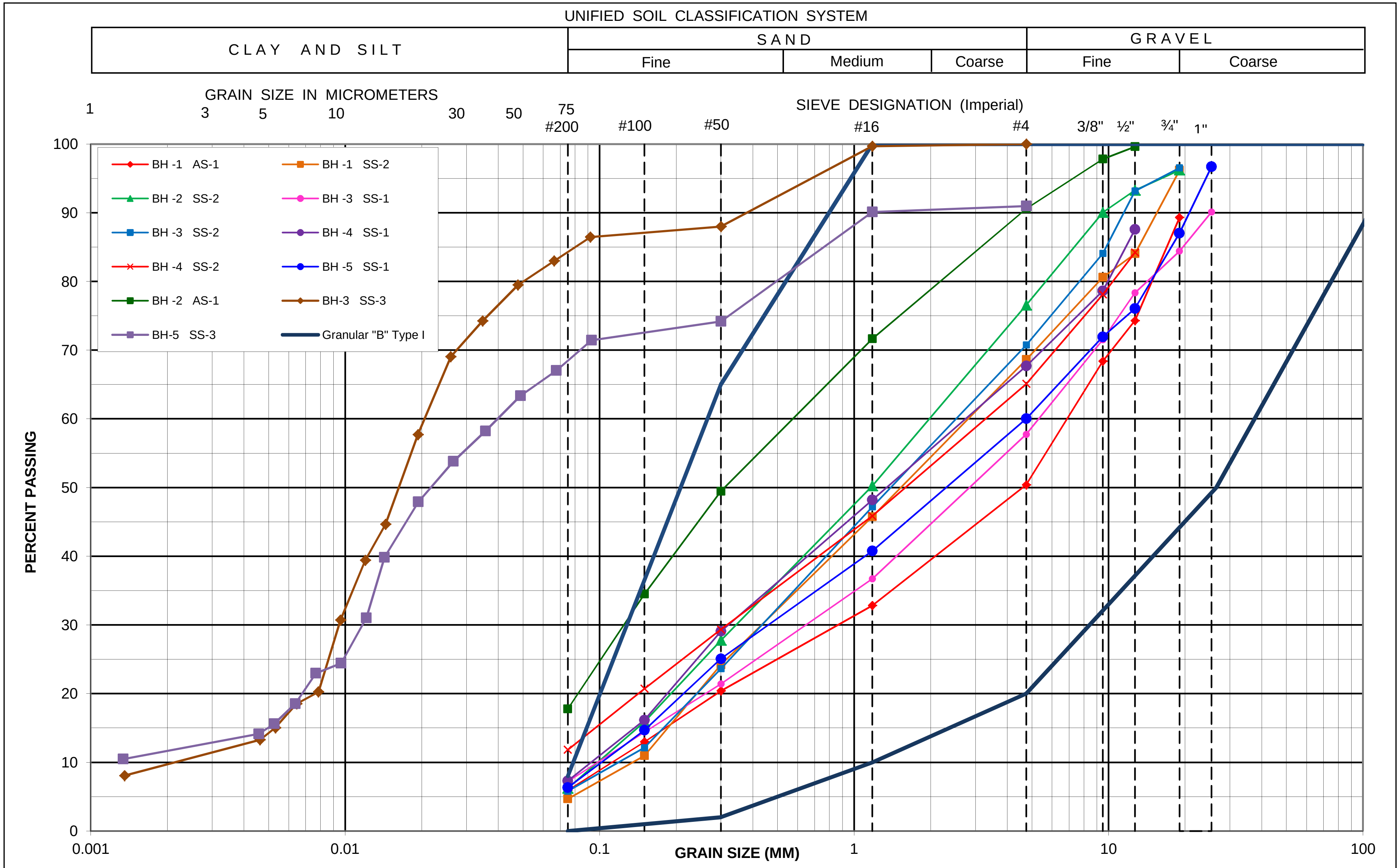
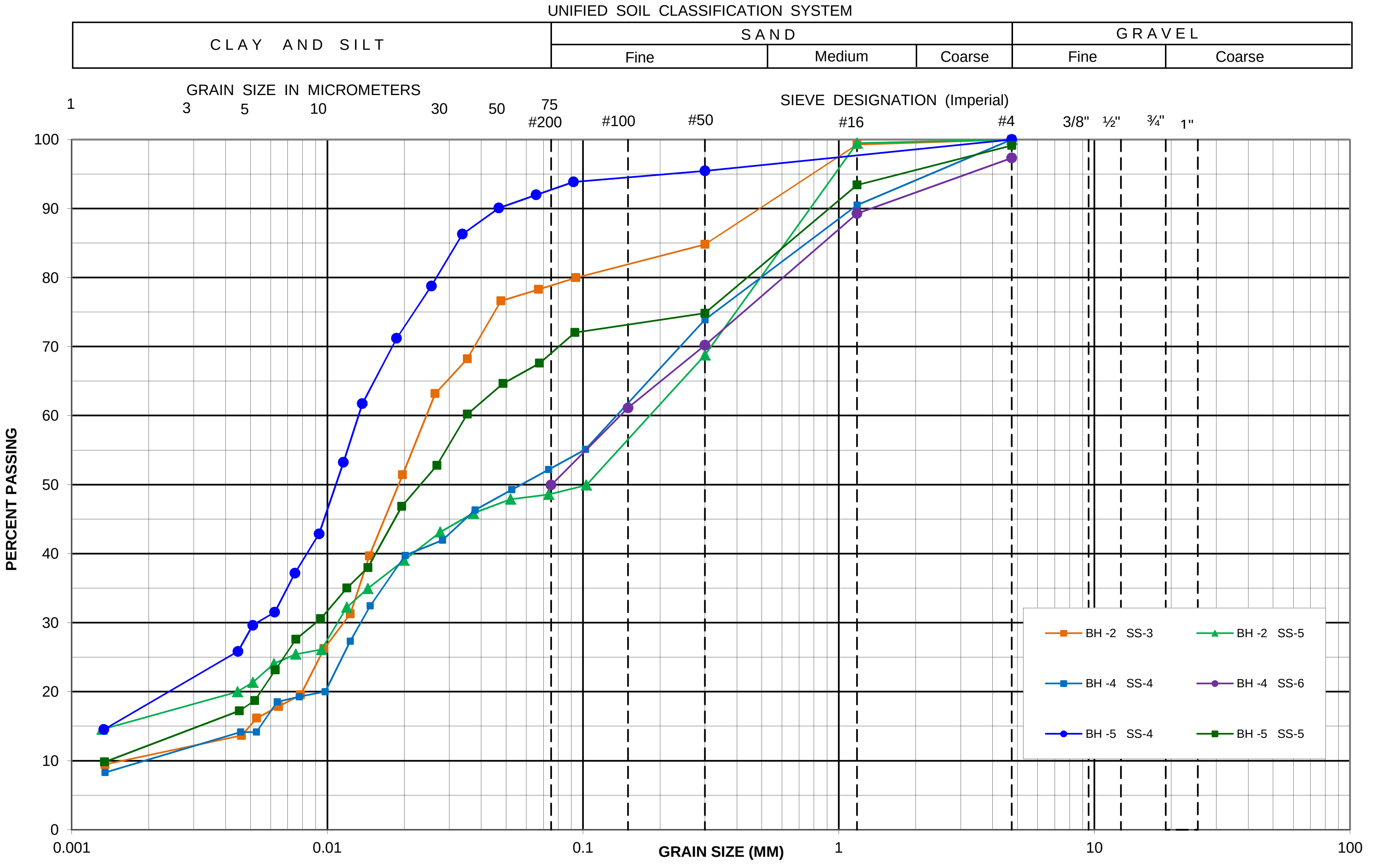
DRAWN NT	CHECKED CH	APPROVED – – –	DWG 4



SPL Consultants Limited Geotechnical Environmental Materials Hydrogeology	GRAIN SIZE DISTRIBUTION - FILL Nepawassi Lake Road Culvert Replacement	Drawing No: 5 Project No. 1067-710 Date : March 2012



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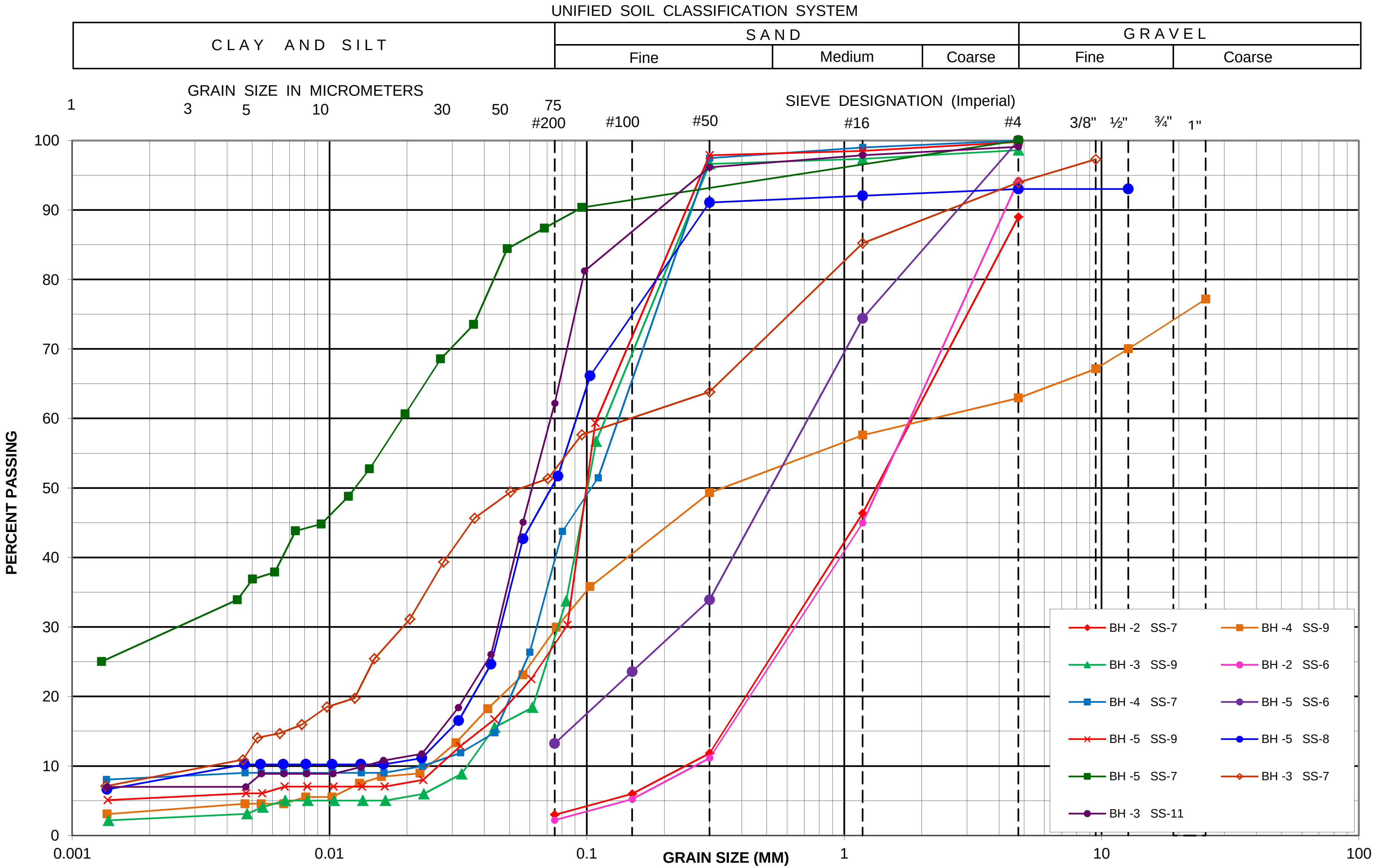
Geotechnical Environmental Materials Hydrogeology

GRAIN SIZE DISTRIBUTION - NATIVE CLAYEY TO SANDY SILT

Nepawassi Lake Road Culvert Replacement

Drawing No:	6
Project No.	1067-710
Date :	March 2012



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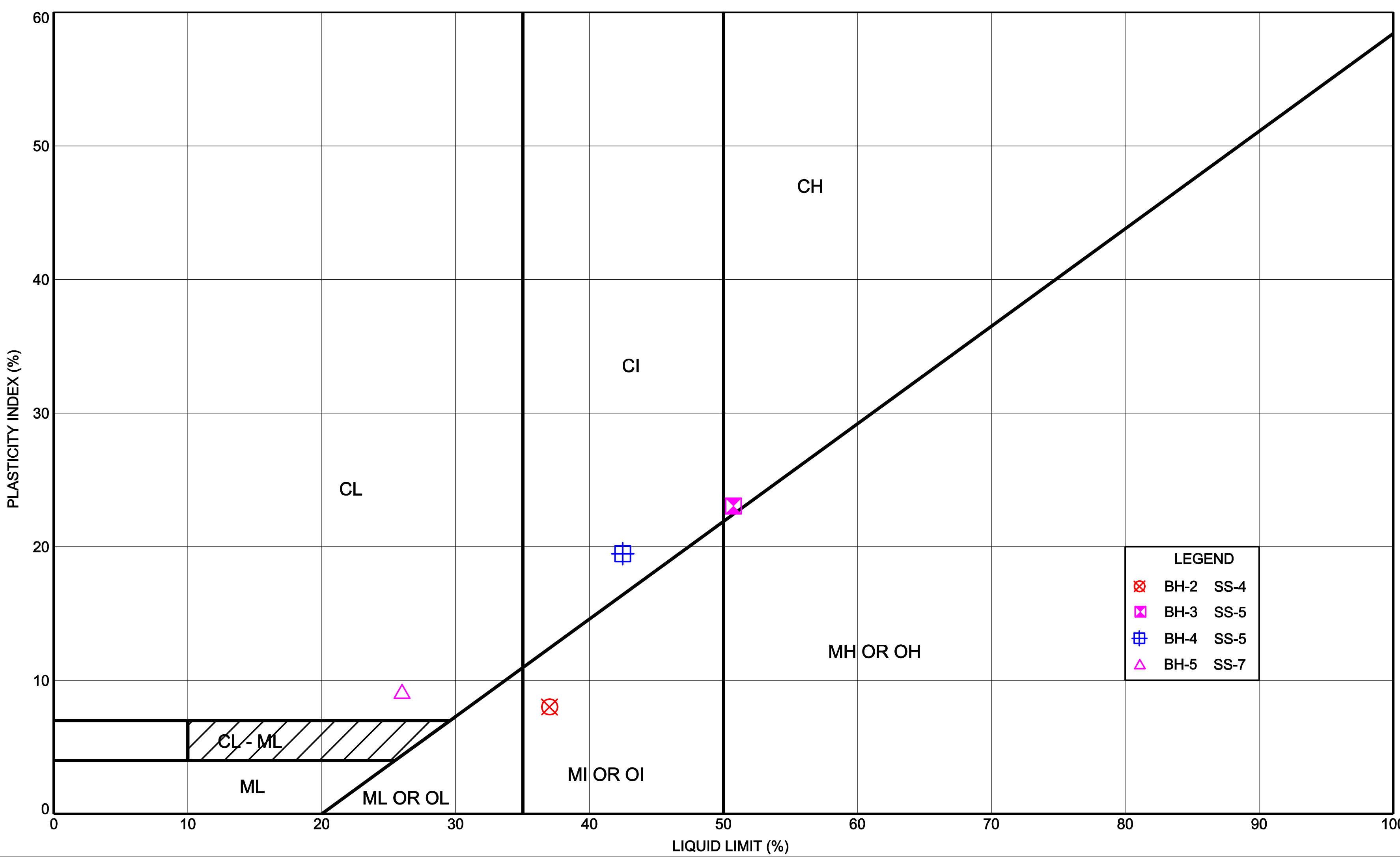
GRAIN SIZE DISTRIBUTION - NATIVE SANDY SILT & SILTY SAND

Nepawassi Lake Road Culvert Replacement

Drawing No:	7
Project No.	1067-710
Date :	March 2012



Client:	Ministry of Transportation Ontario		Title:	PLASTICITY CHART - Clayey Silt & Silty Clay	Project:	Geotechnical Investigation Nepawassi Lake Road Culvert Replacement
Date: March 2012	Drawn: NT		Scale: N/A	Project No.: 1067-710		
Original Size: LETTER	Approved: CH		Rev: 0	Drawing No.: 8	SPL Consultants Limited	Geotechnical • Environmental • Materials • Hydrogeology

Appendix A

Borehole Logs (Record of Borehole Sheets)

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

1067-710

RECORD OF BOREHOLE No BH-1

1 OF 1 **METRIC**

W.P. 5018-10-01 LOCATION Nepawassi Lake Road, (See Borehole Location Plan) ORIGINATED BY NE

DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger and N Size Core COMPILED BY NT

DATUM Local DATE Mar/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.0 / 0.0	**Sandy Gravel,** trace silt brown, moist (Fill)	1	AS			○	50 44 (6)
99.3 / 0.8	**Gravelly Sand,** trace silt cobbles/ boulders noted during drilling brown, moist dense (Fill)	2	SS	35	99	○	31 64 (5)
		3	SS	50/ 50mm			
97.9	Auger refusal				98		
97.9 / 2.1	**Gneiss,** medium to fine grained, red and black, slightly weathered TCR=100% SCR=61% RQD=58%				97		
96.4 / 3.6	**END OF BOREHOLE**						

Other column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (25, 50, 75, 100, 125); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³.

ON-MTO-LARGE SCALE 1067-710 NEPAWASSI OLD-FEB11-2013.GPJ ON_MOT.GDT 13/2/13

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

1067-710

RECORD OF BOREHOLE No BH-2

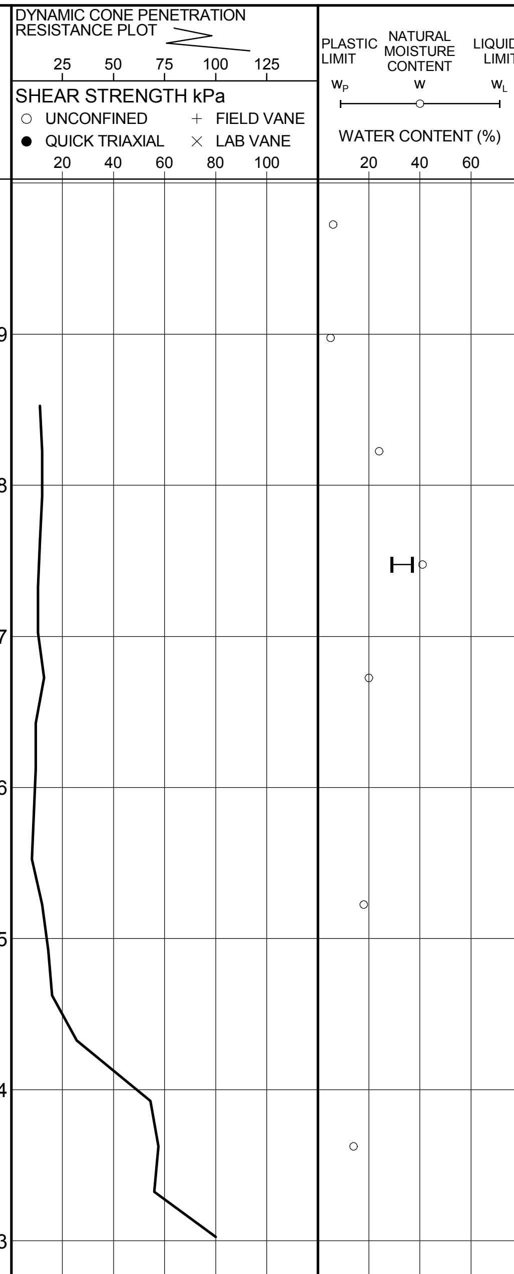
METRIC

W.P. 5018-10-01 LOCATION Nepawassi Lake Road, (See Borehole Location Plan) ORIGINATED BY NE

DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger and Wash Boring COMPILED BY NT

DATUM Local DATE Mar/05/2011 CHECKED BY CH

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
100.0 / 0.0	**Sand,** some silt, trace gravel brown, moist (Fill)	1	AS				9	73	(18)	
99.3 / 0.8	**Gravelly Sand,** trace silt brown, moist compact to dense (Fill)	2	SS	30			23	71	(6)	
98.5 / 1.5	**Sandy Silt,** trace to some clay brown, wet loose	3	SS	7			0	21	69	10
97.8 / 2.3	**Silty Clay,** brown, wet firm	4	SS	5						
97.0 / 3.0	**Silty Sand,** some clay brown, wet loose	5	SS	9		20.6	0	51	33	16
95.5 / 4.5	**Sand,** trace gravel, trace silt brown, wet loose	6	SS	6			6	92	(2)	
93.9 / 6.1	**Sand,** some gravel, trace silt brown, wet compact	7	SS	20			11	86	(3)	
92.7 / 7.3	**END OF BOREHOLE:** Auger refusal									



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

Ministry of Transportation Ontario

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1067-710

RECORD OF BOREHOLE No BH-3

METRIC

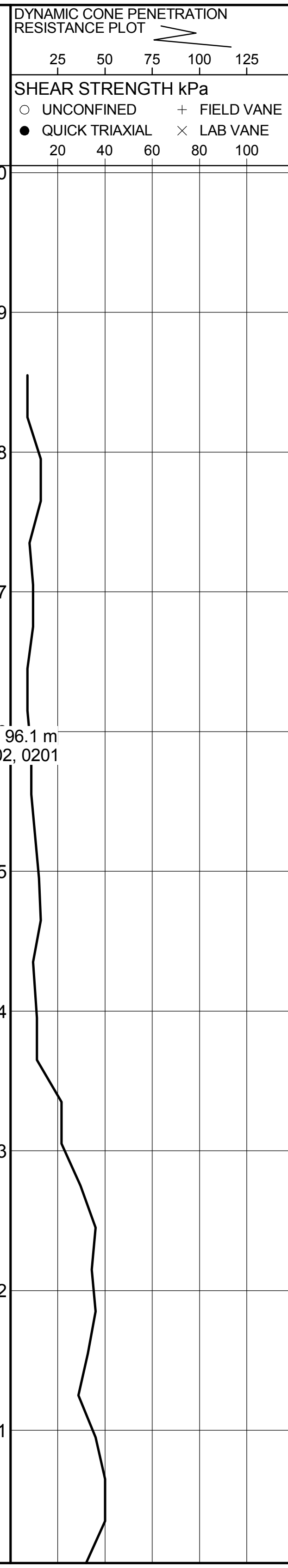
W.P. 5018-10-01 | LOCATION Nepawassi Lake Road, (See Borehole Location Plan) | ORIGINATED BY NE

DIST ____ HWY ____ | BOREHOLE TYPE Hollow Stem Auger and N Size Core | COMPILED BY NT

DATUM Local | DATE Feb/28/2011 | CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT / LIMITS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
100.1 / 0.0	**Gravelly Sand,** trace silt, cobbles/ boulders noted during drilling, brown, moist, very dense (Fill)	1	AS		100	○		42	51	(7)	
		2	SS	50/ 50mm	99	○		29	65	(6)	
98.6 / 1.5	**Sandy Silt,** trace clay, brown, moist, compact (Fill); seepage noted below 2 m	3	SS	16		○		0	16	75	9
97.8 / 2.3	**Clayey Silt,** trace organic material, brown, moist, firm	4	SS	6	98	○					
97.1 / 3.0	**Silty Clay,** trace organic material, brown, moist, soft	5	SS	WH	97	├─○┤	16.9				
95.6 / 4.5	**Sandy Silt,** trace organic material & tree roots, brown, moist, loose	6	SS	2	96 / 95	○	16.3				
94.0 / 6.1	**Sandy Silt,** trace gravel, trace clay, brown, wet, compact	7	SS	16	94	○		6	41	45	8
93.4 / 6.7	**Silty Sand,** trace gravel, trace clay, brown, wet, loose to compact	8	SS	9	93 / 92	○					
	sand heaving inside H.S. auger	9	SS	7	91	○		1	73	24	2

Ground water conditions: W. L. 96.1 m Mar 02, 0201



WATER CONTENT (%): 20 40 60 — PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

Continued Next Page

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

RECORD OF BOREHOLE No BH-3

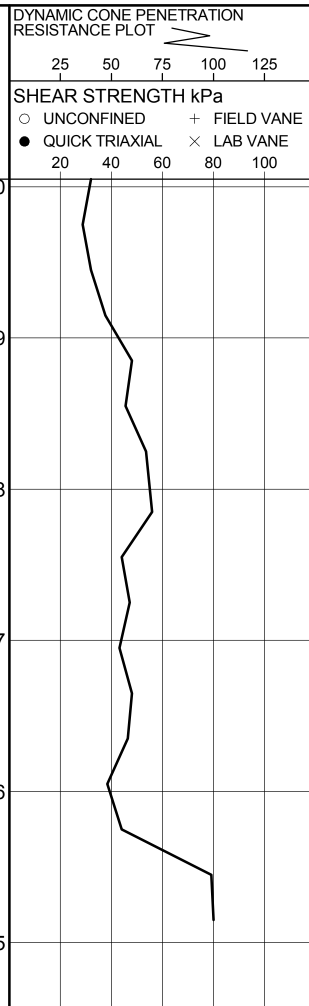
METRIC

W.P.	5018-10-01	LOCATION	Nepawassi Lake Road, (See Borehole Location Plan)	ORIGINATED BY	NE
DIST	HWY	BOREHOLE TYPE	Hollow Stem Auger and N Size Core	COMPILED BY	NT
DATUM	Local	DATE	Feb/28/2011	CHECKED BY	CH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty Sand, trace gravel, trace clay brown, wet loose to compact *(continued)*				90		
		10	SS	6	89	○	
87.9 / 12.2	**Sandy Silt,** trace clay brown, wet loose				88		
		11	SS	10		○	1 37 55 7
86.6	Auger refusal, switched to N size coring				87		
13.5	**Gneiss,** medium to fine grained, red and black, very strong, slightly weathered TCR=100% SCR=65% RQD=65%				86		
85.4 / 14.7	**Gneiss,** medium to fine grained, red and black, very strong, slightly weathered TCR=94% SCR=44% RQD=35%				85		
84.6 / 15.5	**END OF BOREHOLE**						

Note:

1) 19 mm piezometer installed at the end of drilling.
2) Water level at 4.0m below ground surface on March 02, 2012



Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Ministry of Transportation
Ontario

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RECORD OF BOREHOLE No BH-4

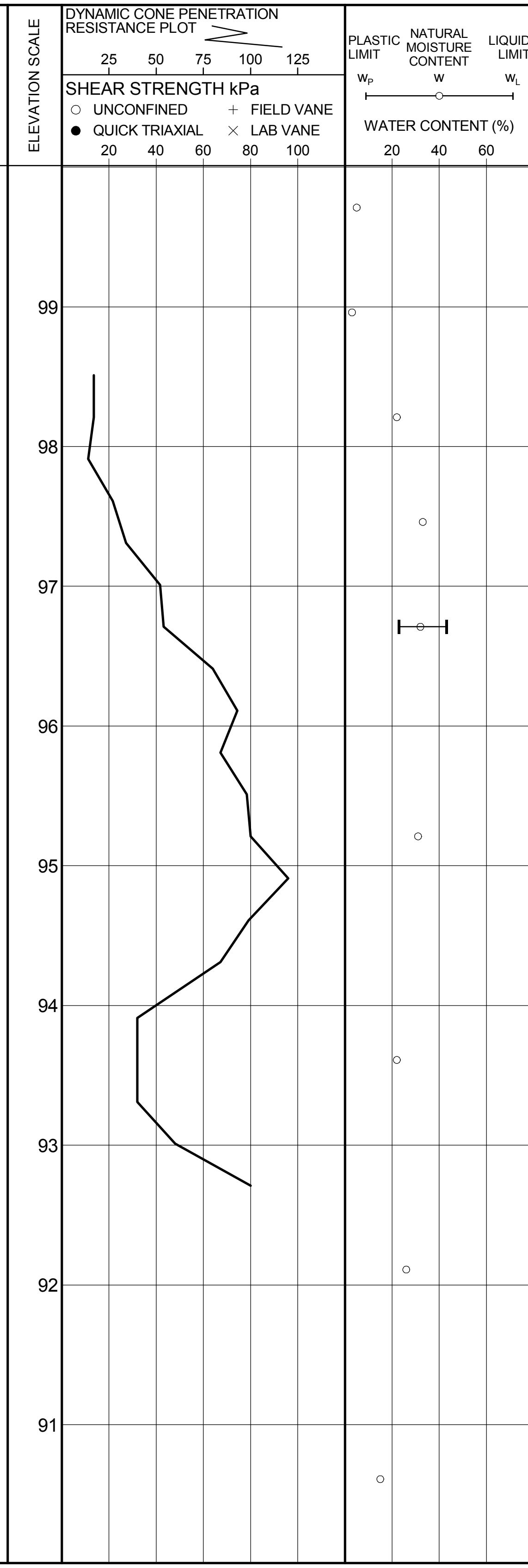
METRIC

W.P. 5018-10-01 | LOCATION Nepawassi Lake Road, (See Borehole Location Plan) | ORIGINATED BY NE

DIST ___ HWY ___ | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY NT

DATUM Local | DATE Mar/05/2011 | CHECKED BY CH

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
100.0 0.0	**Gravelly Sand,** trace to some silt brown, moist very dense (Fill)	1	AS				32	61	(7)	
		2	SS	50/ 25mm			35	53	(12)	
98.5 1.5	**Clayey Silt** brown, moist stiff	3	SS	9						
97.8 2.3	**Silty Sand,** trace gravel, trace clay brown, wet loose to very loose	4	SS	4			0	48	43	9
97.0 3.0	**Silty Clay** brown, moist firm	5	SS	7		17.6				
95.8 4.2	**Silty Sand,** trace gravel, trace clay brown, wet loose	6	SS	3			3	47	(50)	
95.0 5.0	**Silty Sand,** trace clay brown, wet loose to compact	7	SS	6			0	54	34	8
		8	SS	4						
90.9 9.1	**Sandy Gravel,** some silt, trace clay brown, wet compact	9	SS	23			37	33	27	3



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

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1067-710

RECORD OF BOREHOLE No BH-4

METRIC

W.P. 5018-10-01 LOCATION Nepawassi Lake Road, (See Borehole Location Plan) ORIGINATED BY NE

DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger COMPILED BY NT

DATUM Local DATE Mar/05/2011 CHECKED BY CH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (25 50 75 100 125); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
89.5	**Sandy Gravel,** some silt, trace clay brown, wet compact *(continued)*										
10.5	**END OF BOREHOLE:** Auger refusal										

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

Ministry of Transportation
Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

1067-710

RECORD OF BOREHOLE No BH-5

METRIC

W.P. 5018-10-01	LOCATION Nepawassi Lake Road, (See Borehole Location Plan)		ORIGINATED BY NE
DIST	HWY	BOREHOLE TYPE Hollow Stem Auger	COMPILED BY NT
DATUM Local	DATE Feb/28/2011		CHECKED BY CH

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
100.2 / 0.0	**Gravelly Sand,** trace silt, brown, moist (Fill)	1	AS		40	54	(6)	
99.4 / 0.8	**Sandy Silt,** some clay, trace gravel, brown, moist, very dense to compact (Fill)	2	SS	50/ 50mm				
	cobbles / boulders frequent (0.8m to 1.5m)	3	SS	25	9	23	57	11
97.9 / 2.3	**Clayey Silt,** trace sand, brown, wet, firm	4	SS	4	0	7	76	17
97.2 / 3.0	**Sandy Silt,** some clay, trace gravel, brown, wet, very loose	5	SS	2	1	30	58	11
95.9 / 4.3	**Silty Sand,** trace gravel, trace clay, dark brown, wet, very loose; seepage below 4.6 m	6	SS	3	0	87	(13)	
94.1 / 6.1	**Clayey Silt,** some sand, brown, wet, soft	7	SS	2	0	12	61	27
92.6 / 7.6	**Silty Sand,** trace gravel, trace clay, brown, wet, compact	8	SS	14	7	43	43	7
		9	SS	13	0	82	13	5
90.5 / 9.7	**END OF BOREHOLE**							

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (25, 50, 75, 100, 125); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

ON-MTO-LARGE SCALE 1067-710 NEPAWASSI OLD-FEB11-2013.GPJ ON_MOT.GDT 13/2/13

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

RECORD OF BOREHOLE No BH-5

METRIC

W.P. 5018-10-01 LOCATION Nepawassi Lake Road, (See Borehole Location Plan) ORIGINATED BY NE

DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger COMPILED BY NT

DATUM Local DATE Feb/28/2011 CHECKED BY CH

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (25, 50, 75, 100, 125) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20, 40, 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Note: 1) Water at 5.5m in borehole at the end of drilling.										

+3, ×3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH12-1

METRIC

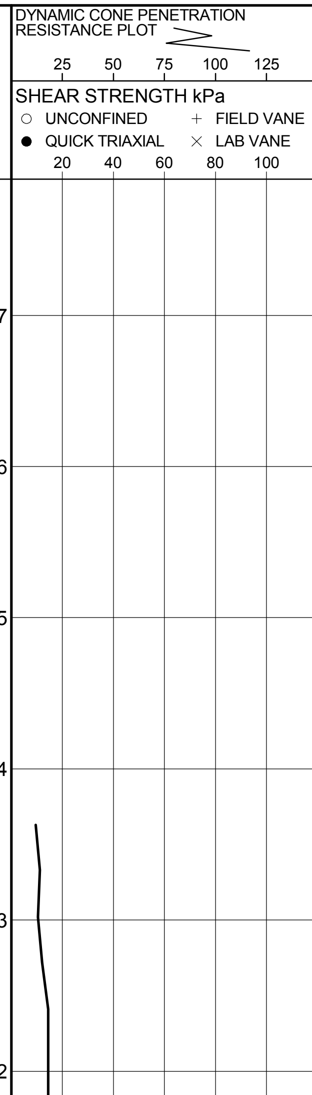
W.P. 5018-10-01 | LOCATION North Side of Nepawassi Culvert - See Borehole Location Plan | ORIGINATED BY PD

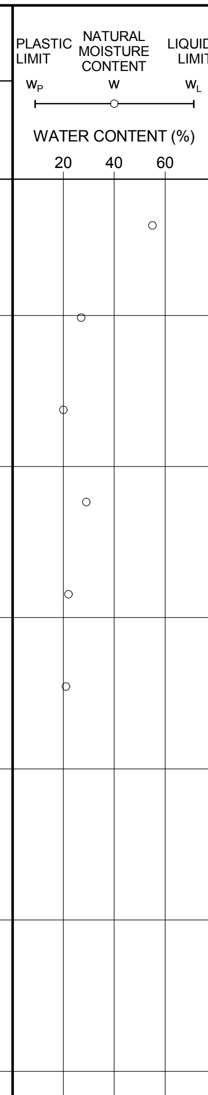
DIST ______ HWY ______ | BOREHOLE TYPE Hand Drilling (Casing and Wash Boring) | COMPILED BY ZO

DATUM Local | DATE Dec/02/2012 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
97.9 / 0.0	**TOPSOIL:** 200mm						
97.7 / 0.2	**CLAYEY SILT TO SILT:** some clay, trace to some sand, grey, wet, soft to firm/ very loose to loose	1	SS	2			
		2	SS	3		97	
	trace gravel, trace organics	3	SS	6			
96.1 / 1.8	**SANDY SILT:** occasional clay seams, trace gravel, grey, wet, loose to compact	4	SS	12		96	2 14 79 5
		5	SS	7		95	
		6	SS	7			
		7	SS	14		94	
93.6 / 4.3						93	
						92	
91.8 / 6.1	**END OF BOREHOLE AND DCPT**						

Notes:
1) Spoon sampling ended at 4.3m. Borehole continued by wash boring.
2) DCPT perfomed from 4.3m to 6.1m.





UNIT WEIGHT γ kN/m³

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

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

1067-710

RECORD OF BOREHOLE No BH12-2

METRIC

W.P. 5018-10-01 LOCATION South Side of Nepawassi Culvert - See Borehole Location Plan ORIGINATED BY PD

DIST ____ HWY ____ BOREHOLE TYPE Hand Drilling (Casing and Wash Boring) COMPILED BY ZO

DATUM Local DATE Dec/02/2012 CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
98.3						
98.2 / 0.0	**TOPSOIL:** 150mm					
0.2	**SILTY CLAY TO CLAYEY SILT:** trace gravel, brown, wet, very soft to stiff	1	SS	1		
		2	SS	8		
		3	SS	8		
		4	SS	7		
95.9 / 2.4	**SILTY SAND TO SANDY SILT:** some gravel, trace clay, grey, wet, loose	5	SS	8		24 33 39 4
	------- compact	6	SS	10		
		7	SS	13		
		8	SS	12		
93.4 / 4.9						
92.2 / 6.1	**END OF BOREHOLE AND DCPT**					

Notes:
1) Spoon sampling ended at 4.9m. Borehole continued by wash boring.
2) DCPT perfomed from 4.9m to 6.1m.

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (98, 97, 96, 95, 94, 93); DYNAMIC CONE PENETRATION RESISTANCE PLOT (25, 50, 75, 100, 125); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Appendix B

Chemical Test Results

EXOVA OTTAWA

Certificate of Analysis

Exova

Client: SPL Consultants Ltd.
146 Colonnade Rd., Unit 17
Ottawa, ON
K2E 7Y1
Attention: Mr. Neem Tavakkoli
PO#: VISA
COC# 156481

Report Number: 1204267
Date Submitted: 2012-03-12
Date Reported: 2012-03-19
Project: 1067-710 Nepawassi

Group	Analyte	MRL	Units	Guideline	945386	945387
				Lab I.D.	945386	945387
				Sample Matrix	Soil	Soil
				Sampling Date	2012-02-28	2012-02-28
				Sample I.D.	BH-3/SS-6	BH-3/SS-7
Agri. - Soil	Electrical Conductivity	0.05	mS/cm		0.21	0.07
	pH	2.0			7.0	7.8
General Chemistry	Cl	0.002	%		0.008	<0.002
	Resistivity	1	ohm-cm		4760	14300
	SO4	0.01	%		0.05	0.03

Guideline = *** = Guideline Exceedence**
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective.

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 $\overline{N}$.

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 COMPOSION 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
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_l, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICALL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
Φ'	$-^o$	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
Φ_u	$-^o$	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
s_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_s	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $(W_L – W_L)$
I_L	1	LIQUIDITY INDEX = $(W – W_P)/ I_P$
I_C	1	CONSISTENCY INDEX = $(W_L – W) / 1_P$
$e_{,max}$	1,%	VOID RATIO IN LOOSEST STATE

e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} – e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	N PERCENT – DIAMETER
C_u	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

FOUNDATION DESIGN REPORT
PROPOSED CULVERT REPLACEMENT
NEPEWASSI LAKE ROAD NEAR SUDBURY, ONTARIO
SITE NO. 46-419/C
G.W.P. 5022-10-00
MTO GEOCRES NO. 41I-285

Prepared for:

ONTARIO MINISTRY OF TRANSPORTATION

By:

SPL CONSULTANTS LIMITED

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

Project: 1067-710 (Nepewassi Lake Road)
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Table of Contents

Appendices

6. DISCUSSION AND RECOMMENDATIONS

6.1 General

The subsurface conditions encountered in the boreholes drilled at the site include a layer of fill ranging from about 1.5 m (98.5 m elevation) to 2.3 m (97.8 m elevation) in thickness which forms the road structure, embankment and backfill around the existing culvert. This fill material is underlain by a variable mix of clayey to sandy silt which would be described as soft to firm and very loose to loose. This layer is underlain by loose to compact silty sand and sandy silt which extended to a depth of 13.5 m at the location of the proposed new culvert. The soils are underlain by strong, slightly weathered gneiss. The depth to rock ranges from 13.5 m (86.6 m elevation) at the proposed culvert location to 2.1 m (97.9 m elevation) at BH-1 to the west of the culvert.

Groundwater levels in the native soils were found to be at an elevation of approximately 96.1 m (in the local datum).

The proposed culvert structure is (based on preliminary General Arrangement drawings provided to us) a 4.2 m wide by 3.0 m high precast concrete box culvert. The invert of the new culvert will be at approximately 96 m, which is about 800 mm lower than the invert of the existing culvert. The replacement culvert will located to the west of the existing culvert, and will be aligned at an angle to the existing road (see Drawing 2).

Based on the borehole information, the existing soils are expected to be adequate to support the proposed new culvert.

6.2 Frost Protection

The depth of frost penetration for the Nepewassi Lake Road site may be assumed to be 2.0 m. The majority of the fill within the frost zone is sand and gravel fill which would be considered to have a low susceptibility to frost heave. The lower portions of the fill embankment (below about 1.5 m) are constructed of sandy silt which would be considered to have a moderate to high susceptibility to frost heaving.

The existing road is a gravel-surfaced rural road, and it is assumed that there are no plans to pave the road in the future. Therefore it is considered that installation of a frost taper is not required, as the road will require seasonal maintenance and re-grading anyway. If there are plans to pave the road and improve the level of service in the near future then consideration can be given to installing a frost taper as per OPSD 803.031.

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

0.02 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 loading, 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 and Bearing Resistance

6.4.1 Foundation Options

The culvert will be replaced with a rigid frame concrete box culvert. This structure could be either a pre-cast concrete culvert or an open bottom box culvert. The existing site soils are considered to be adequate to support either option. Deep foundations are technically feasible but are not required. A comparison of the shallow foundation options is presented in Table 6 below.

6.4.2 Bearing Resistance and Settlement

The culvert structure should be founded on native soils, in an undisturbed condition, with the minimum frost cover indicated above. Based on the preliminary design the new culvert will be a 4.2 m wide pre-cast concrete box culvert founded at an elevation of approximately 96 m.

For individual footings or strip footings (such as for the cut-off walls.) which are approximately 0.4 m wide and are founded below 96 m elevation or lower on native sandy soils:

- The unfactored ultimate geotechnical bearing resistance can be taken as 180 kPa. A resistance factor of 0.5 should be applied to this value, yielding a factored bearing resistance of 90 kPa at ULS (Ultimate Limit States).
- The geotechnical resistance at the Serviceability Limit State (SLS) can be taken as 75 kPa.

For the main culvert which is approximately 4.2 m wide and founded at 96 m elevation or lower on undisturbed native soils:

- The unfactored ultimate geotechnical bearing resistance can be taken as 350 kPa. A resistance factor of 0.5 should be applied to this value, yielding a factored bearing resistance of 175 kPa at ULS (Ultimate Limit States).
- The geotechnical resistance at the Serviceability Limit State (SLS) can be taken as 100 kPa.

Provided that the subgrade is not disturbed during construction the total and differential settlments associated with the above SLS resistance values are expected to be less than 25 mm and 20 mm, respectively.

All bearing surfaces should be checked, evaluated and approved at the time of construction to ensure that the conditions encountered are as anticipated in the preparation of these recommendations.

Table 6: Summary of Foundation Alternatives
Foundation Investigation and Design Report
Proposed Nepewassi Lake Road Culvert Replacement, Site No. 46-419/C

Foundation Option	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Precast Concrete Box Culvert	• Routine excavation and construction procedure • Single stage excavation, excavation support, dewatering, etc. (no separate excavations for footings) • Rapid installation due to pre-cast structure, resulting in less time on site • Wide base distributes load over larger bearing area, reducing the potential for differential settlement • Final culvert may be more tolerant of differential settlement between segments	• May require excavation and replacement of unsuitable material below bedding. • Requires larger excavation volumes and placement of bedding and levelling layers • Will not result in a natural bottom, and therefore the invert may need to be covered with additional material	• Possibly higher for the culvert, but may be offset somewhat by ease of construction	• Risk of difficulties with dewatering and excavation and disturbance of subgrade • Risk of requiring removal of unsuitable soils and replacement with additional engineered fill
Open Bottom Culvert with Cast-in-Place Footings	• Reduces sub-excavation area and eliminates requirements for bedding and levelling layers • Provides a natural soil substrate within the culvert	• Requires additional excavations below frost depth for footings in granular soils below the water table, which will be complicated in terms of excavation support and dewatering	• Structure may be cheaper, but the site work will typically take longer and may be more expensive	• Risk of difficulties with dewatering and excavation and disturbance of subgrade • Risk of requiring removal of unsuitable or disturbed soils below the footings

6.5 Bedding and Backfilling

Bedding for the new culvert should consist of 300 mm of Granular A or Granular B Type II, compacted to 98% SPMDD. Additional Granular A may be used as a levelling course prior to installing the culvert if required.

Backfill for the culvert and any retaining walls should consist of suitable free-draining granular fill (OPSS 1010 Granular A or Granular B) material placed and compacted in accordance with relevant standards, such as OPSS 901 and OPSS 501. The majority of the sand and gravel fill encountered in the upper 1.5 m of drilling would meet the requirements of OPSS 1010 for Granular B type I and would be expected to be suitable for re-use as backfill. Excavated soils should be reviewed during construction and any suitable material stockpiled for re-use. The lower silty soils and any soils below the water table are unlikely to be suitable as backfill (because of high fines content and high water content).

Fill material should be placed in shallow lifts, not exceeding 200 mm loose thickness. Fill immediately below the roadway and adjacent to the culvert should be compacted to a minimum of 100% of Standard Proctor Maximum Dry Density (SPMDD). Remaining fill may be compacted to a minimum of 98% of SPMDD. All compaction should be carried out in accordance with OPSS 501.

To avoid damaging or laterally displacing the structures, care should be exercised when compacting fill adjacent to and immediately on top of the culvert and any retaining wall structures. Compaction equipment should be restricted in size as per MTO convention to prevent damage to the structures. Backfilling should be carried out on both sides of the culvert simultaneously.

6.6 Earth Pressures and Backfilling

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 (ϕ) = 35 degrees (unfactored)
Unit Weight = 22 kN/m^3

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 (ϕ) = 30 degrees (unfactored)
Unit Weight = 21 kN/m^3

Coefficients of Lateral Earth Pressure:

Earth Pressure Coefficient	Level Backfill	Sloping Backfill 3H:1V	Sloping Backfill 2H:1V
K_a	0.33	0.42	0.54
K_b	0.41	0.52	0.64
K_0	0.50	0.66	0.76
K*	0.57	0.74	0.86

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. Where this is not the case then water pressures should also be accounted for and the submerged soil unit weight used below the water table. It will not be feasible to maintain the culvert in a drained condition when the structure is partially submerged by the creek.

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.

According to 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 essentially equal to the earth pressure under static conditions (because A = 0).

6.7 Roadway Widening

Based on staging drawings provided to us, the currently proposed construction staging is as follows:

- Protection systems will be installed on the north and south sides of the road and the north side of the road will be widened slightly. The south side of the new culvert will be installed;

- The south side of the roadway will be widened to the west of the culvert, additional protection systems will be installed approximately along the road centreline and the north side of the new culvert will be installed. The north end of the existing culvert will be removed;

- Traffic will be diverted back to the north side of the road and the south side of the existing culvert will be removed.

Copies of staging drawings for the culvert replacement are included in Appendix D.

The widened portion of the embankment will involve new slopes with normal (2H:1V) slopes. Foundation failures are not anticipated assuming that all organic and 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 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 and compacted in accordance with OPSS 206 and OPSS 501. Borrow material should consist of select suitable inorganic earth, free of objectionable inclusions such as cobbles, boulder, frozen materials, organic soil, etc. Portions of the existing fill material and site soils may be suitable for this purpose provided they are properly moisture conditioned (either dried or wetted). Borrow material should be approved prior to installation from both a geotechnical and environmental perspective.

All embankment construction (including review of stripping, 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 inlet and outlet. The design of erosion protection should be carried out by a specialist who is familiar with the site and the findings of this investigation.

It should also be noted that appropriate cut-off walls, head walls, aprons, etc. will be required to ensure that the flow in the channel is through the culvert and to limit the potential for piping of the bedding, backfill and native soils.

6.9 Construction Considerations

Construction Dewatering

Seepage was encountered during drilling below the level of the creek at the time of the investigation. Given the relatively permeable nature of the embankment fill and the native soils, it should be anticipated that the groundwater level will be very sensitive to changes in the water level in the creek (i.e. if the creek is higher at the time of construction a corresponding increase in groundwater levels should be expected). For this reason it is recommended that if possible construction 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 (or that the existing culvert remain in place to convey the flow during construction and then subsequently removed) to help maintain sufficiently dry conditions for construction.

Even with these 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 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). Deeper excavations will likely require an active dewatering system including well points and/or deep wells.

Given the granular nature of the soils at the site, it is expected that in addition to an above-ground diversion (coffer dam), an underground impervious barrier (such as a sheet pile wall) 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 primarily granular fill in the embankment and pavement structure, as well as soft to firm and very loose to compact native soils. The granular fill material can be classified as Type 3 Soil. The native soils encountered in the boreholes can be classified as Type 3 Soil above water table and as Type 4 Soil below water table.

Temporary protection systems (Performance Level 3) are indicated on the design drawings and will be required to accommodate the construction excavations while maintaining traffic on the road. Protection systems typically consist of interlocking sheet piles, soldier piles and lagging or a similar system. Protection systems will need to be designed to resist earth pressures which are controlled by the type and flexibility of the shoring system chosen. The design of the protection system will be the responsibility of the contractor, however, for preliminary design and evaluation the earth pressure parameters provided in Section 6.6 can be assumed to apply to the granular soils behind the protection system. The deflections associated with a Performance Level 3 would be expected to be sufficient to allow the active earth pressure condition to develop, however, this assumption will need to be verified by the shoring designer based on the proposed shoring system.

It should be noted that cobbles and boulders were encountered during the investigation (particularly in the fill material which forms the embankment) which 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 unduly disturbed during construction. Given the fact that the foundations for the proposed structure will be below the groundwater table in loose-to-compact and soft-to-firm silty soils, 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.

It is also recommended that allowance be made for the need to pour a layer of lean concrete (mud slab) on foundation bearing surfaces immediately after excavation and inspection (before placement of bedding and levelling layers) to minimize foundation disturbance. All excavated surfaces should be kept free of frost, water, etc. during the course of construction.

All excavated surfaces should be inspected and approved prior to placing engineered fill and/or foundations. If disturbed or unsuitable soils are identified in the base of the excavation they may be over-excavated and replaced with additional compacted granular fill.

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.

The test results (soil resistivity) indicate that there is a 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 were supervised by Mr. Naeem Ehsan, P.Eng. This report was prepared by Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, P.Eng., who is the project manager and SPL's designated MTO contact and Mr. Shaheen Ahmad, P.Eng., who is the project quality control auditor, provided quality control and independent review 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. 4th 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

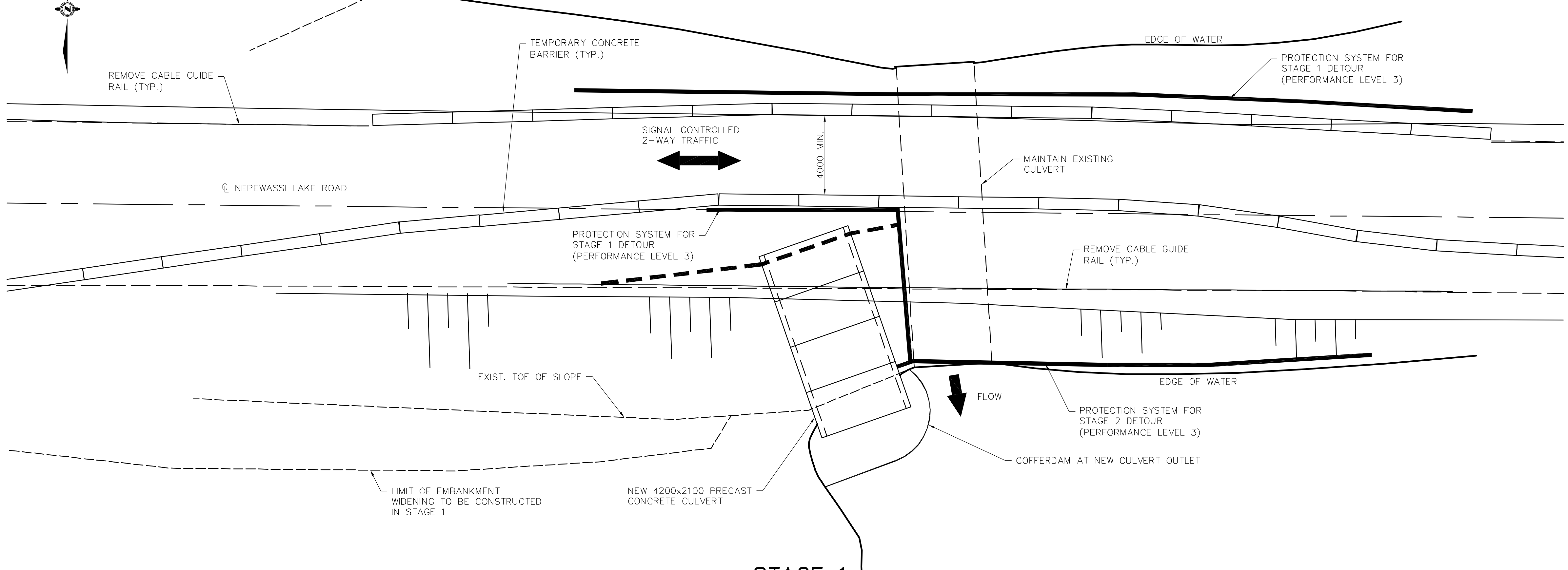
Relevant MTOD's

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

Appendix D

Preliminary Staging Drawings

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



STAGE 1
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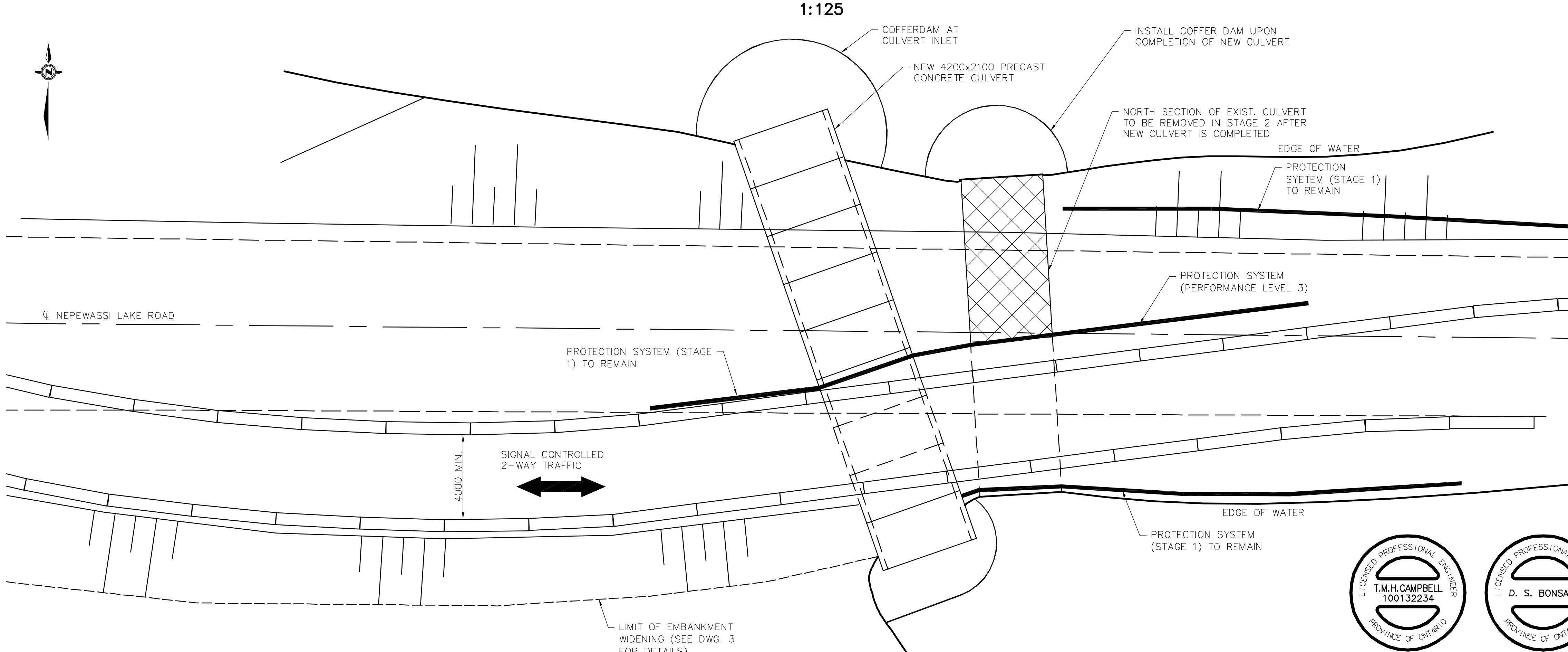

STAGE 2
1:125

CONT No 2013-5601
WP No 5018-10-01

NEPEWASSI LAKE RD.
CULVERT REPLACEMENT

PROPOSED STAGING

SHEET
5

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STAGE 1

1. REMOVE THREE CABLE GUIDE RAIL AND INSTALL PROTECTION SYSTEM ALONG NORTH SIDE OF ROAD. COMPLETE ROAD WIDENING (NORTH) AS REQUIRED;
2. INSTALL TEMPORARY TRAFFIC SIGNALS, TEMPORARY CONCRETE BARRIER AND TRAFFIC STAGING FOR STAGE 1 TRAFFIC;
3. REMOVE THREE CABLE GUIDE RAIL FROM SOUTH SIDE OF ROADWAY;
4. INSTALL PROTECTION SYSTEMS FOR EXCAVATION AND SOUTH SIDE OF ROAD;
5. CONSTRUCT COFFERDAM AT LOCATION OF NEW CULVERT OUTLET;
6. EXCAVATE AND INSTALL SOUTH 4 UNITS OF NEW CULVERT;
7. APPLY WATERPROOFING OVER TOP OF CULVERT;
8. INSTALL PROTECTION SYSTEM AT NORTH END OF NEW CULVERT;
9. BACKFILL SOUTH PORTION OF NEW CULVERT; AND
10. CONSTRUCT ROADWAY WIDENING FOR STAGE 2 TRAFFIC.

STAGE 2

1. RELOCATE TEMPORARY CONCRETE BARRIER AND TEMPORARY TRAFFIC SIGNALS FOR STAGE 2 TRAFFIC;
2. REMOVE NORTHWEST PORTION OF STAGE 1 PROTECTION SYSTEM AT NEW CULVERT;
3. CONSTRUCT COFFERDAM AT LOCATION OF NEW CULVERT INLET;
4. EXCAVATE AND INSTALL NORTH 5 UNITS OF NEW CULVERT;
5. APPLY WATERPROOFING OVER TOP OF CULVERT;
6. BACKFILL NORTH PORTION OF NEW CULVERT;
7. REMOVE COFFERDAMS FROM ENDS OF PROPOSED CULVERT AND ESTABLISH FLOW THROUGH NEW CULVERT;
8. INSTALL COFFER DAM AT EXISTING CULVERT INLET AND EXTEND PROTECTION SYSTEM THROUGH EXISTING CULVERT;
9. EXCAVATE AND REMOVE NORTH HALF OF EXISTING CULVERT; AND
10. REINSTATE PROTECTION SYSTEM ALONG NORTH SIDE OF ROAD AND BACKFILL TO PERMIT STAGE 3 TRAFFIC CONTROL.

LEGEND

—— DENOTES PROTECTION SYSTEM IN CURRENT STAGE

— — DENOTES PROTECTION SYSTEM TO BE INSTALLED PRIOR TO STAGE 2

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DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN TC	CHK DB	CODE CHBDC-2006	LOAD CL-625-ONT	DATE 11/2012
DRAWN JP	CHK TC	SITE 46-419C	STRUCT SCHEME	DWG 2

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2013–5601
WP No 5018–10–01

NEPEWASSI LAKE RD.
CULVERT REPLACEMENT

PROPOSED STAGING

SHEET 6

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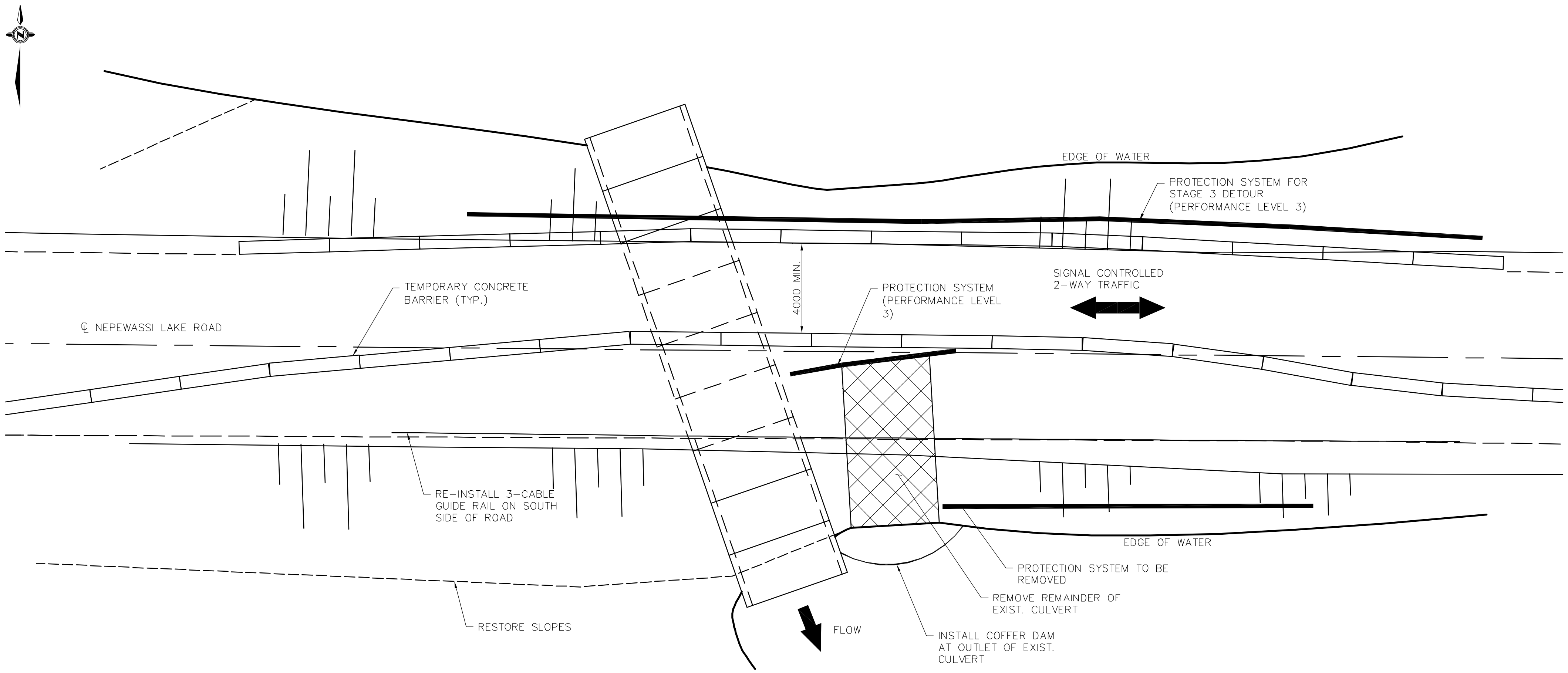
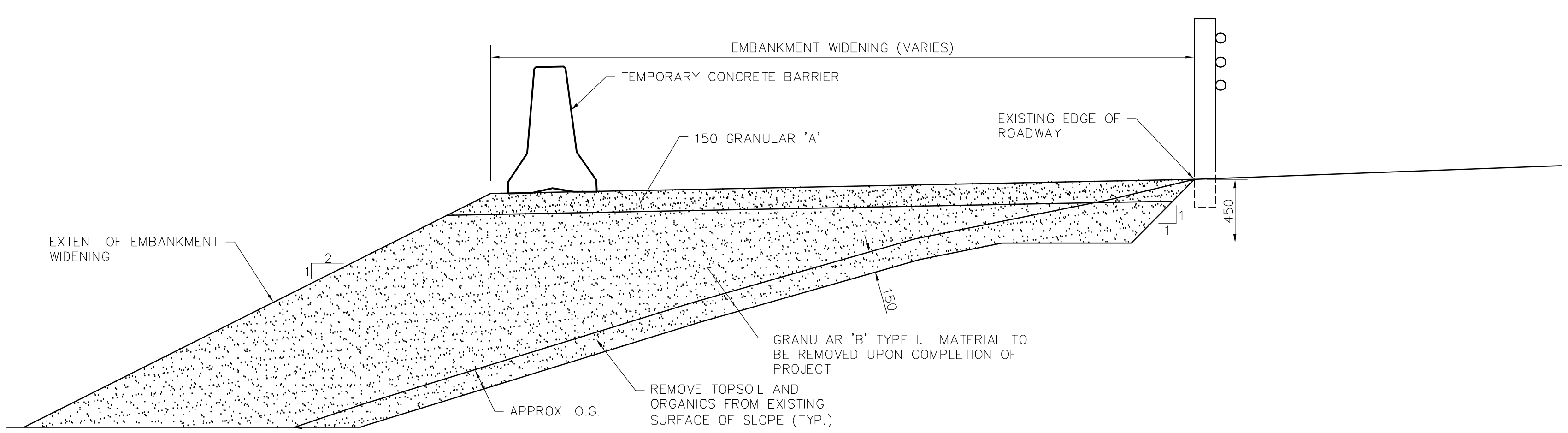


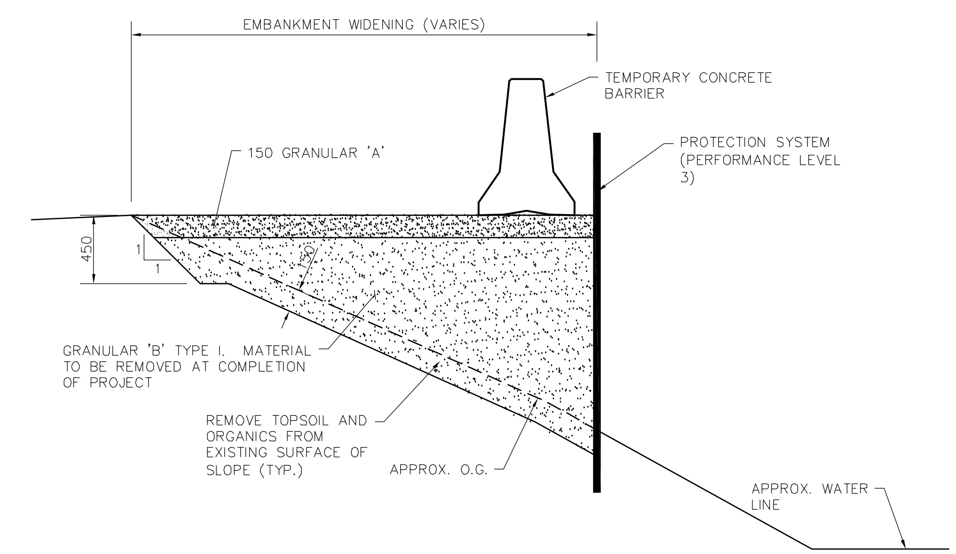
STAGE 3
1:125

STAGE 3

1. RELOCATE TEMPORARY CONCRETE BARRIER AND TEMPORARY TRAFFIC SIGNALS FOR STAGE 3 TRAFFIC;
2. REMOVE PROTECTION SYSTEM FROM STAGE 2 DETOUR AND RESTORE SOUTH SLOPES;
3. INSTALL COFFER DAM AT OUTLET OF EXISTING CULVERT;
4. EXCAVATE AND REMOVE SOUTH HALF OF EXISTING CULVERT;
5. BACKFILL AT LOCATION OF EXISTING CULVERT REMOVAL;
6. REMOVE COFFER DAM AT EXISTING CULVERT OUTLET;
7. REMOVE PROTECTION SYSTEM AT EXISTING CULVERT;
8. RESTORE ROADWAY;
9. INSTALL THREE CABLE GUIDE RAIL ON SOUTH SIDE OF ROADWAY;
10. REMOVE TEMPORARY CONCRETE BARRIERS AND TEMPORARY TRAFFIC SIGNALS AND RESUME TWO–WAY TRAFFIC ON ORIGINAL ROAD ALIGNMENT;
11. REMOVE PROTECTION SYSTEM ON NORTH SIDE OF ROAD AND RESTORE SLOPES; AND
12. INSTALL THREE CABLE GUIDE RAIL ON NORTH SIDE OF ROADWAY.



SOUTH EMBANKMENT WIDENING
1:25



EMBANKMENT WIDENING NEAR WATER
1:25

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DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION		

DESIGN TC	CHK DB	CODE CHBDC–2006	LOAD CL–625–ONT	DATE 11/2012	
DRAWN JP	CHK TC	SITE 46–419C	STRUCT	SCHEME	DWG 3