Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT
for
NEW SNOWMOBILE CULVERT
HIGHWAY 11 SOUTHBOUND LANES STATION 21+985
SITE 44-371/C2
TOWNSHIP OF SOUTH HIMSWORTH
NORTH BAY AREA, ONTARIO
G.W.P. 323-00-00

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PML Ref.: 10TF013A-C5S
Index No.: 348FIR and 349FDR
GEOCRES No.: 31L-169
April 3, 2013

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for
New Snowmobile Culvert
Highway 11 Southbound Lanes Station 21+985
Site No. 44-371/C2
Township of South Himsworth
North Bay Area, Ontario
GWP 323-00-00

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed new Snowmobile Culvert under the existing Highway 11 Southbound Lanes (SBL) as part of the south entrance to Powassan project. The study was carried out by Peto MacCallum Ltd. (PML) for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The proposed culvert is at approximate Sta. 21+985, Highway 11 SBL chainage in the Township of South Himsworth (ref. General Arrangement Drawings 'Hwy 11 SBL Snowmobile Culvert at Sta. 21+985 prepared by AECOM dated February 2012).

The purpose of this report was to summarize the subsurface stratigraphy encountered at the proposed culvert site.

2. SITE DESCRIPTION AND GEOLOGY

The contemplated structure is proposed below the existing Highway 11 SBL about 40 m south of the existing Highway SBL / Purdon Line intersection in the Municipality of Powassan. The site is about 34 km south of the City of North Bay in the Geographic Township of South Himsworth.

Land uses include the Highway 11 transportation corridor, farming and residences.

Locally, the Highway 11 median is approximately 50 m wide. The local topography of the site is generally undulating with overall down slopes towards the existing creek located approximately 30 m south of the proposed snowmobile culvert location. The ground cover is grass in the vicinity of the culvert site.

The project is situated in glaciofluvial outwash deposits of kame formation including sand and gravel soils which overlies Precambrian age monzonitic rock granite formation.

3. INVESTIGATION PROCEDURES

The field work for this investigation was carried out during the period of January 25 to January 27, 2012. A total of three boreholes (CSS-1 to CSS-3) were drilled for the proposed culvert to 9.9 to 12.0 m at the locations shown on Drawings S-1, appended.

The reference working points were laid out by exp Geometics. The locations of the boreholes relative to the reference points were selected at each structure by PML accounting for site accessibility and presence of underground utilities. The ground surface elevations at the borehole locations were established by PML using the ground surface elevations at the reference points. All elevations in this report are expressed in metres.

The boreholes were advanced using continuous flight hollow stem augers through the soil cover with a track-mounted D-50 drill rig, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor.

Soil samples were recovered from the boreholes at regular 0.75 and 1.5 m depth intervals using the standard penetration test method. Standard penetration tests were conducted to assess the strength characteristics of the substrata. Following the auger refusal in borehole CSS-1, a Dynamic Cone Penetration Test was conducted about 2 m north of borehole CSS-1 extending below the fill. Soils were identified in accordance with the MTO soil classification manual procedures.

The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, where encountered, by measuring the groundwater level in the open holes.

The boreholes were backfilled with a bentonite/cement mixture where required in accordance with the MTO guidelines and MOE Reg. 903 regulations for borehole abandonment.

The recovered soil samples were transported to our laboratory in Toronto for detailed visual examination, laboratory testing and classification. The laboratory testing program included the following tests.

- Natural moisture content determinations (34)
- Grain size distribution analyses (8)

The laboratory grain size distribution charts are presented in Figures CSS-GS-1 to CSS-GS-4. All of the test results are summarized on the Record of Borehole Sheets.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole Sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration test results, dynamic cone penetration test results and groundwater observations. The results of laboratory particle size distributions and moisture content determinations are also shown on the Record of Borehole Sheets.

The borehole locations, soil stratigraphic profile and cross-sections prepared from the borehole data are shown on Drawing S-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the three boreholes drilled at the southbound culvert site generally included fill or surficial topsoil overlying cohesionless sandy silt and silt mantling bedrock. The bedrock surface was contacted / inferred at 9.9 to 12.0 m (elevation 252.0 to 253.5).

4.1 Topsoil

Layers of 150 and 200 mm thick topsoil were encountered surficially in boreholes CSS-1 and CSS-2, extending to 0.2 m (elevation 263.8 and 262.7).

4.2 Fill

Surficially in borehole CSS-3 and below topsoil in boreholes CSS-1 and CSS-2, a 2.5 to 4.3 m thick fill unit was encountered and extended to 2.7 to 4.3 m (elevation 260.3 to 259.9). The fill unit includes a mixture of cohesionless sand, trace to some silt, trace clay, trace gravel and occasional cobbles. N values ranged from 5 to 30 indicating loose to compact relative density.

The results of a grain size distribution analysis for a fill sample are included in Figure CSS-GS-1. The moisture content determinations ranged from 9 to 21%.

4.3 Upper Sandy Silt

An upper cohesionless sandy silt deposit was encountered below the fill at 3.7 and 2.7 m (elevation 260.3 and 260.2) in the boreholes CSS-1 and CSS-2, respectively. The deposit was 0.6 and 1.6 m thick extending to 4.3 m (elevation 259.7 and 258.6). N values ranged from 7 to 19 indicating loose to compact relative density.

The moisture content determinations ranged from 20 to 37%.

4.4 Silt

A cohesionless silt deposit was encountered below the fill at 4.3 m (elevation 259.9) in borehole CSS-3 and below the upper sandy silt layer at 4.3 m (elevation 259.7 and 258.6) in boreholes CSS-1 and CSS-2. The deposit was 3.9 and 2.4 m thick in boreholes CSS-1 and CSS-2, extending to 8.2 and 6.7 m (elevation 255.8 and 256.2), respectively and at least 6.4 m thick in borehole CSS-3 which was terminated within the silt deposit at 10.7 m (elevation 253.5). N values ranged from 9 to 24, locally 3 in borehole CSS-3, indicating loose to compact relative density.

The results of grain size distribution analysis for silt samples are included in Figure CSS-GS-2 and CSS-GS-3. The moisture content determinations ranged from 18 to 31%.

4.5 Lower Sandy Silt

A second lower cohesionless sandy silt deposit was encountered below the silt layer at 8.2 and 6.7 m (elevation 255.8 and 256.2) in boreholes CSS-1 and CSS-2, and extended to the borehole termination depths of 12.0 and 9.9 m (elevation 252.0 and 253.0), respectively. N values generally ranged from 10 to 11, locally 50 blows per 25 cm in borehole CSS-1, indicating compact to very dense relative density. The low N values (3 to 5) were probably due to hydrostatic disturbance during sampling.

The result of grain size distribution analysis for a lower sandy silt sample is included in Figure CSS-GS-4. The moisture content determinations ranged from 19 to 30%.

4.6 Probable Bedrock

A probable bedrock surface was inferred in all of the boreholes by refusal to augering at the borehole termination depths of 9.9 to 12.0 m (elevation 252.0 and 253.5).

4.7 Groundwater

Groundwater was observed in all of the test holes during the course of the field work in January 2012 at the levels list below.

GROUNDWATER OBSERVATION DETAILS

BOREHOLE NO.	GROUND SURFACE ELEVATION (m)	GROUNDWATER DEPTH (ELEVATION) BELOW EXISTING GROUND SURFACE (m)	
		During Investigation	Upon Completion
CSS-1	264.0	3.7 (260.3)	6.7 (257.3)
CSS-2	262.9	1.2 (261.7)	8.5 (254.4)
CSS-3	264.2	6.7 (257.5)	9.1 (255.1)

In summary, groundwater was observed during augering at 1.2 to 6.7 m (elevation 261.7 to 257.5) in all of the boreholes. Upon completion of drilling, groundwater was measured at 6.7 to 9.1 m (elevation 257.3 to 254.4). The groundwater level is subject to seasonal fluctuation and rainfall patterns.

5. MISCELLANEOUS

Mr. F. Portela carried out the field investigation for this study under the supervision of Mrs. N. S. Balakumaran, P. Eng., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. Walker Drilling Ltd. supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

6. CLOSURE

This Foundation Investigation Report was prepared by Mr. S. K. Shrestha, M.Eng, P.Eng., and reviewed by Mr. B. R. Gray, M.Eng, P.Eng., MTO Designated Principal Contact. Mr. C. M. P. Nascimento, P. Eng., Project Manager conducted an independent review of the report.

Yours very truly

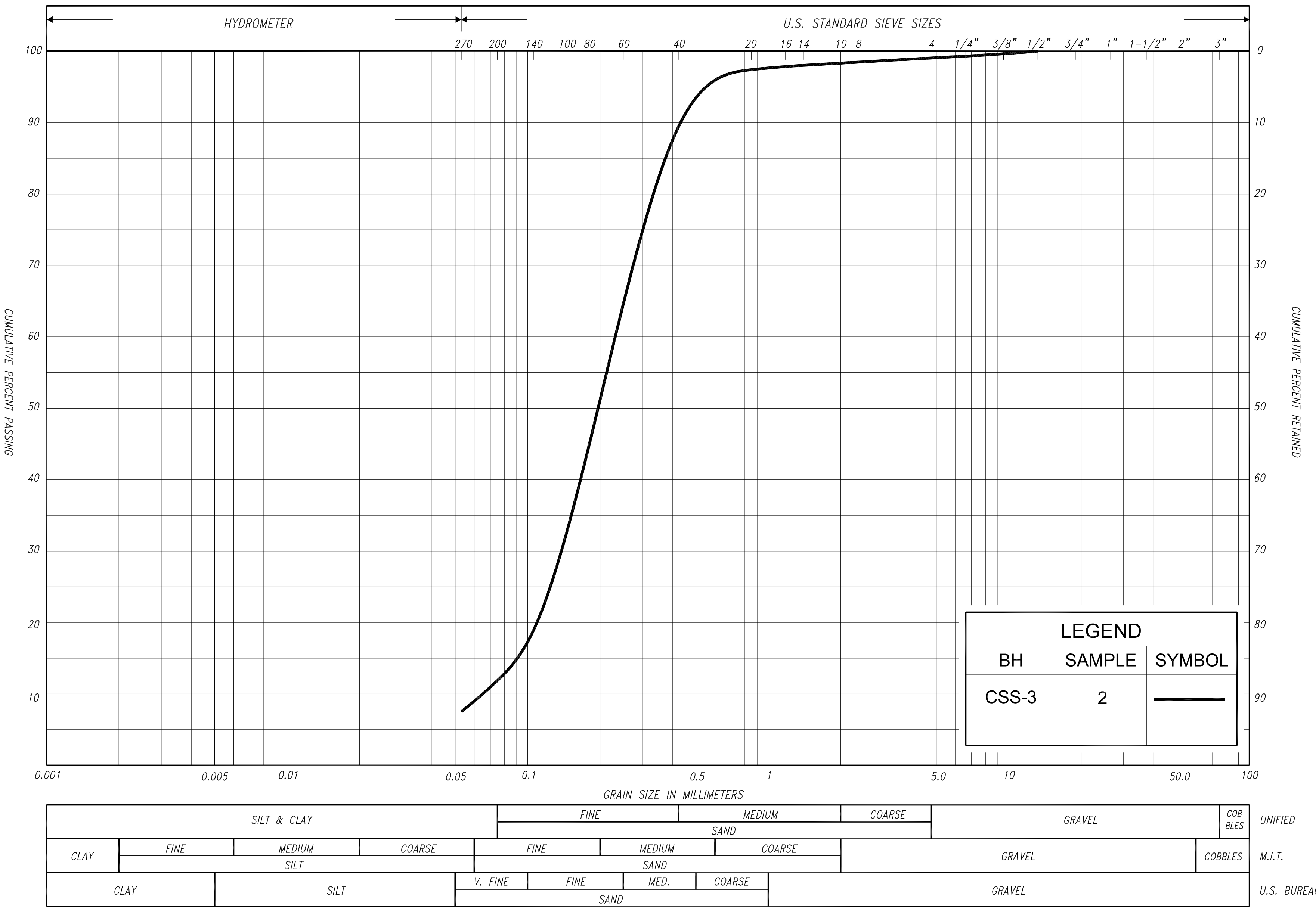
Peto MacCallum Ltd.

Subir K. Shrestha, MEng, P.Eng.
Project Engineer

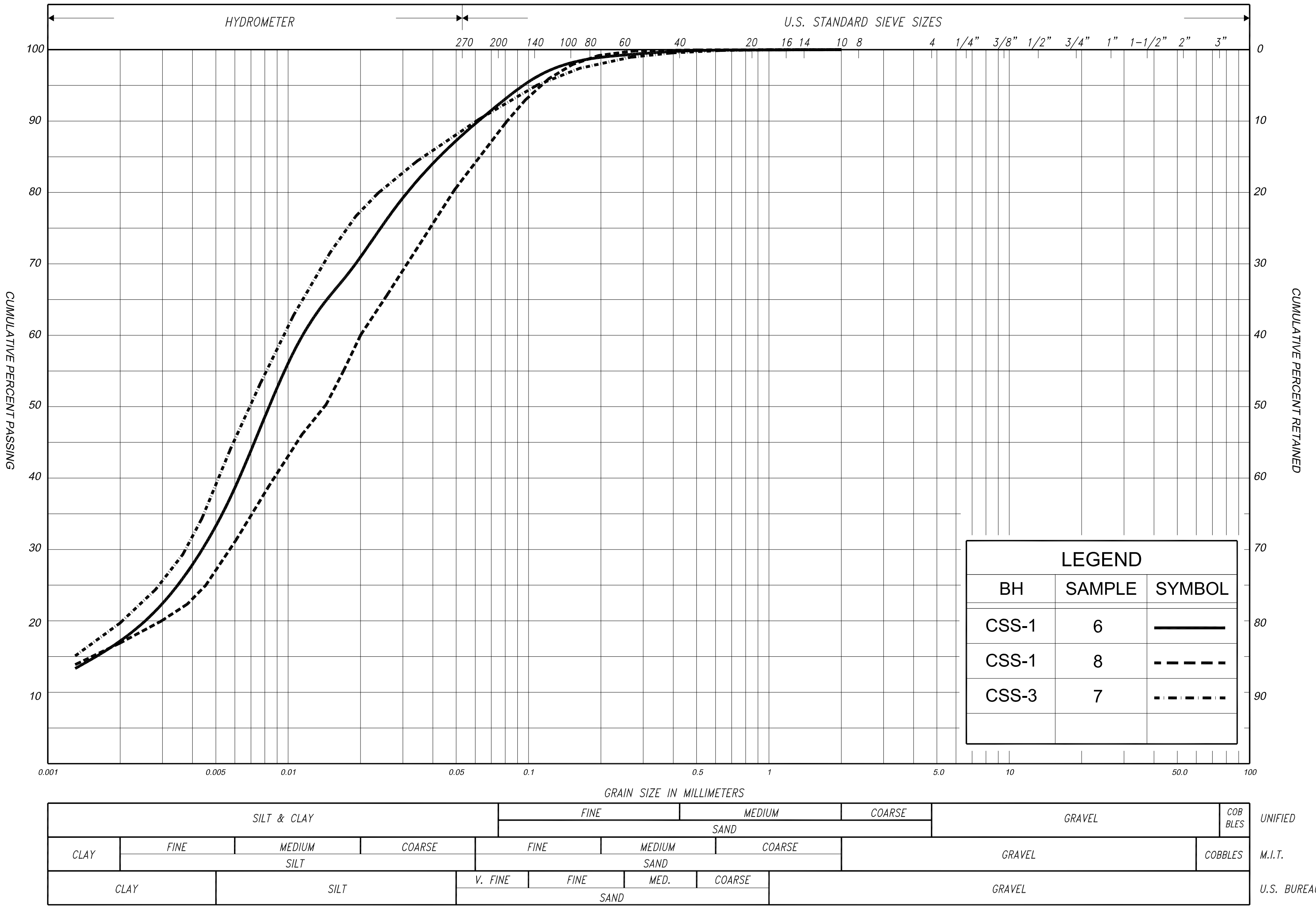
Carlos M. P. Nascimento, P.Eng.
Project Manager

Brian R. Gray, MEng, P.Eng.
MTO Designated Principal Contact

SS/CN/BRG:ss-mi-nk



Ontario	**GRAIN SIZE DISTRIBUTION** SAND, some silt, trace clay, trace gravel (FILL)	FIG No. CSS-GS-1 HWY: 11 G.W.P. No. 323-00-00

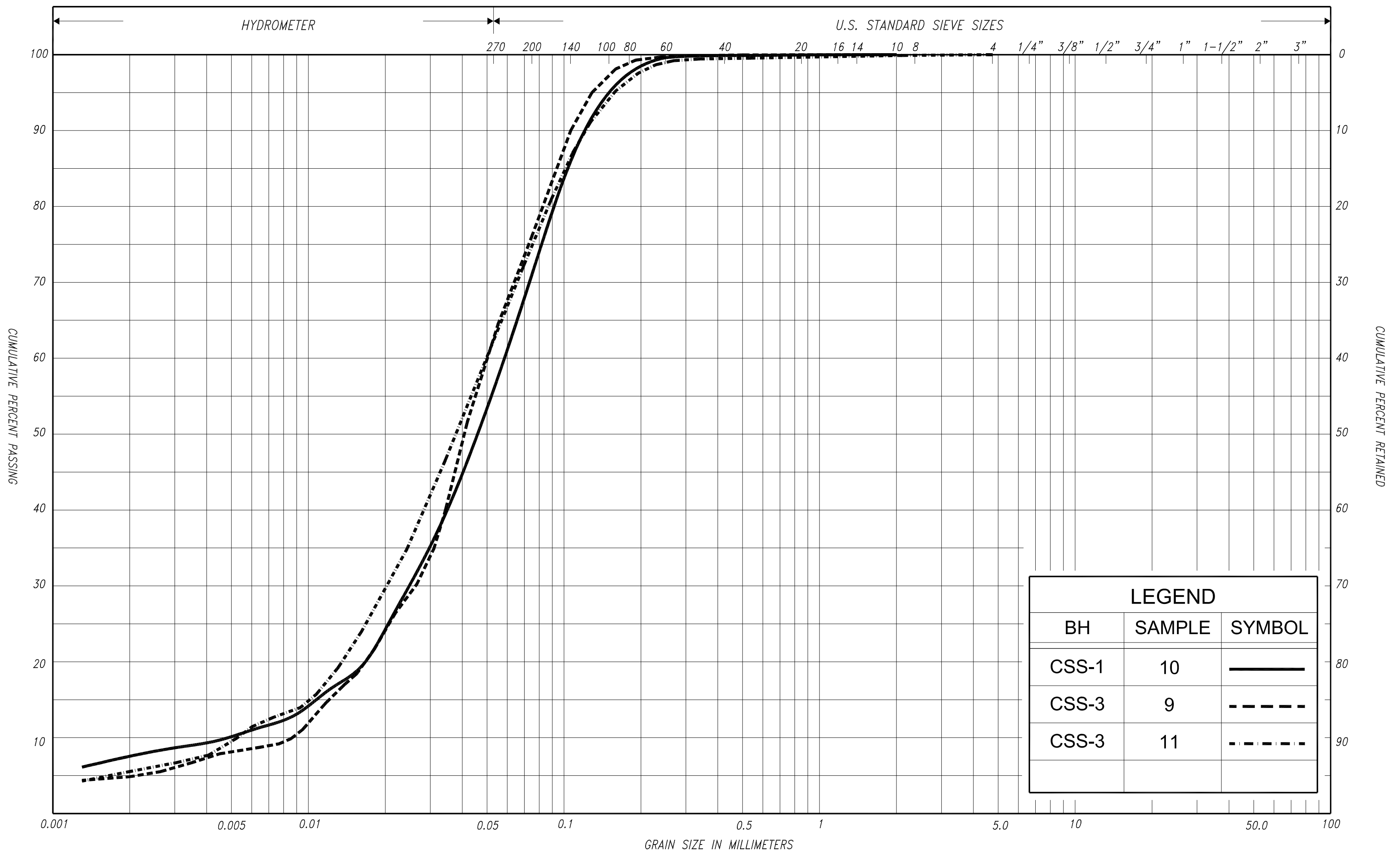


Ontario

GRAIN SIZE DISTRIBUTION

SILT, some clay, trace to some sand

FIG No.	CSS-GS-2
HWY:	11
G.W.P. No.	323-00-00



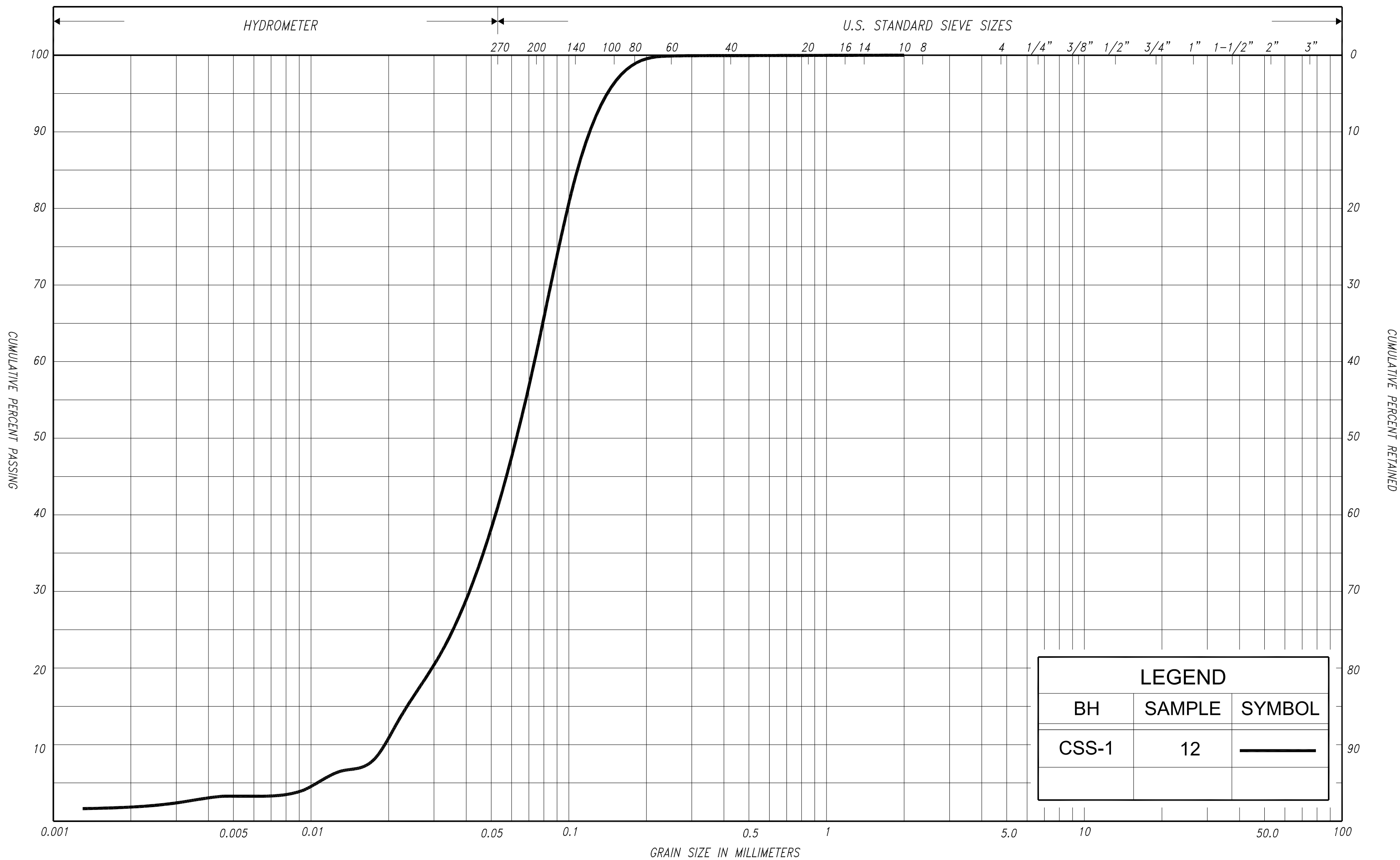
UNIFIED	SILT & CLAY				SAND: FINE		SAND: MEDIUM		SAND: COARSE	GRAVEL		COBBLES
M.I.T.	CLAY	SILT: FINE	SILT: MEDIUM	SILT: COARSE	SAND: FINE		SAND: MEDIUM	SAND: COARSE		GRAVEL		COBBLES
U.S. BUREAU	CLAY	SILT			SAND: V. FINE	SAND: FINE	SAND: MED.	SAND: COARSE		GRAVEL		

Ontario

GRAIN SIZE DISTRIBUTION

SILT, with sand, trace clay

FIG No.	CSS-GS-3
HWY:	11
G.W.P. No.	323-00-00



SILT & CLAY		FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	UNIFIED
CLAY	FINE SILT / MEDIUM SILT / COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	M.I.T.
CLAY	SILT	V. FINE SAND / FINE SAND	MED. SAND	COARSE SAND	GRAVEL		U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT, trace clay

FIG No.	CSS-GS-4
HWY:	11
G.W.P. No.	323-00-00

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 63.5kg, 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 475 J 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.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 – 10	10 – 20	20 – 30	30 – 40	> 40
	TRACE	*SOME*	*WITH*	*ADJECTIVE (SILTY)*	*AND (AND SILT)*

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/0.3 m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL 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 (R Q D), FOR MODIFIED RECOVERY, IS:

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

JOINTING 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

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

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
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	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'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

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 SUBMERGED 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 = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT

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	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

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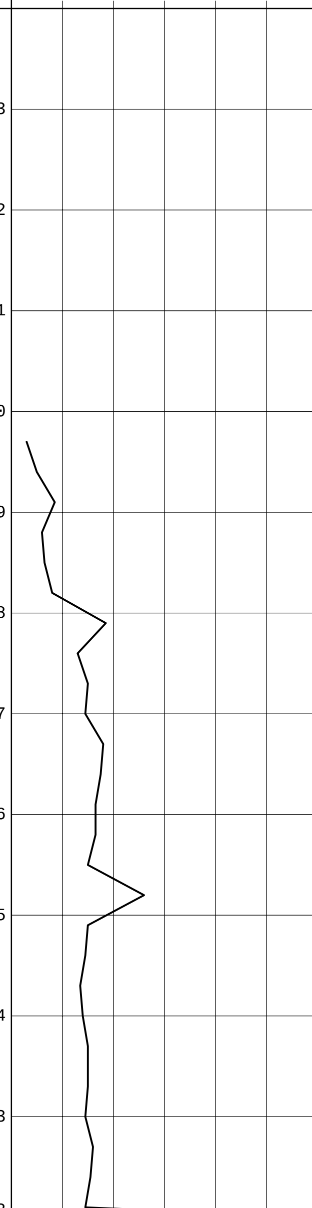
Foundation Design

RECORD OF BOREHOLE No CSS-1

METRIC

G.W.P. 323-00-00	**LOCATION** Co-ords: 5 103 010.2 N ; 316 076.2 E	**ORIGINATED BY** F.P.
DIST North Bay **HWY** 11	**BOREHOLE TYPE** C.F.H.S.A. and Dynamic Cone Penetration Test	**COMPILED BY** S.S.
DATUM Geodetic	**DATE** January 25, 2012	**CHECKED BY** B.R.G.

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); 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	NUMBER	TYPE	"N" VALUES	GROUND WATER	GR SA SI CL
264.0	Ground Surface					
0.0	Topsoil Sand, trace silt Loose to compact Brown Moist (FILL)	1	SS	5		
		2	SS	18		
	trace gravel Wet cobbles	3	SS	27		
		4	SS	22	▽* (approx. 260.4)	
260.3 / 3.7	Sandy silt Compact Grey Wet	5	SS	19		
259.7 / 4.3	Silt, some clay trace to some sand Compact Brown Wet	6	SS	18		0 7 76 17
		7	SS	24		
		8	SS	23	▼* (approx. 257.6)	0 12 71 17
	with sand, trace clay	9	SS	24		
		10	SS	10		0 29 63 8
255.8 / 8.2	Sandy silt, trace clay Compact to very dense Brown Wet	11	SS	5**		
		12	SS	5**		0 39 59 2
		13	SS	11		
		14	SS	50/25cm		
253.2 / 10.8	End of borehole Probable sandy silt					
252.0 / 12.0	End of dynamic cone penetration test Refusal on probable bedrock Sample 14: Sampler bouncing					

Elevation scale: 263, 262, 261, 260, 259, 258, 257, 256, 255, 254, 253, 252

120/8cm

* 2012 1 25

▽ Water level observed during drilling

▼ Water level measured after drilling

C.F.H.S.A. denotes Continuous flight hollow stem augers

NOTE: Auger grinding between 2.7 and 3.1m depth

Remarks:

Dynamic cone test was carried-out 2m north of borehole CSS-1

** Probably hydralic disturbance during sampling

7 5× Numbers refer to Sensitivity

20 / 15—◯—5 / 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No CSS-2

METRIC

G.W.P. 323-00-00 | LOCATION Co-ords: 5 103 006.1 N ; 316 068.2 E | ORIGINATED BY F.P.

DIST North Bay | HWY 11 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY S.S.

DATUM Geodetic | DATE January 25, 2012 | CHECKED BY B.R.G.

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
262.9	Ground Surface
0.0	Topsoil Sand, trace silt Loose to compact, Brown, Moist Wet (FILL)
260.2 / 2.7	Sandy silt organic inclusions Loose to compact, Brown, Wet
258.6 / 4.3	Silt, trace sand silty sand partings Compact, Brown, Wet
256.2 / 6.7	Sandy silt Compact, Brown, Wet trace gravel Grey oxidized
253.0 / 9.9	End of borehole Refusal on probable bedrock

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	7
2	SS	16
3	SS	7
4	SS	13
5	SS	16
6	SS	21
7	SS	17
8	SS	3**
9	SS	4**
10	SS	11
11	SS	10

GROUND WATER CONDITIONS: ▽* (during drilling, approx. elev. 261.7); ▼* (after drilling, approx. elev. 254.6)

ELEVATION SCALE: 262, 261, 260, 259, 258, 257, 256, 255, 254, 253

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

* 2012 1 25

▽ Water level observed during drilling

▼ Water level measured after drilling

** Probably hydraulic disturbance during sampling

7, 5 × : Numbers refer to Sensitivity

20 / 15 —○— 5 / 10 (%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd.
CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No CSS-3

METRIC

G.W.P. 323-00-00	**LOCATION** Co-ords: 5 103 019.6 N ; 316 095.0 E		**ORIGINATED BY** F.P.
DIST North Bay	**HWY** 11	**BOREHOLE TYPE** Continuous Flight Hollow Stem Augers	**COMPILED BY** S.S.
DATUM Geodetic	**DATE** January 27, 2012		**CHECKED BY** B.R.G.

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
264.2	Ground Surface
0.0	Sand, trace silt cobbles Compact Brown Moist (FILL)
	some silt, trace clay trace gravel
259.9 / 4.3	Silt, trace sand trace to some clay, organics Compact Dark grey Wet
	Very loose
	Compact Grey/ brown
	with sand Brown
	Loose Grey
253.5 / 10.7	End of borehole Refusal on probable bedrock

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	19	
2	SS	21	1 87 (12)
3	SS	30	
4	SS	21	
5	SS	16	
6	SS	3	
7	SS	14	0 8 72 20
8	SS	13	
9	SS	10	0 24 71 5
10	SS	9	
11	SS	9	0 25 69 6

GROUND WATER CONDITIONS: ▽* observed at approx. elev. 257.6; ▼* measured at approx. elev. 255.2

ELEVATION SCALE: 264, 263, 262, 261, 260, 259, 258, 257, 256, 255, 254

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

* 2012 01 27

▽ Water level observed during drilling

▼ Water level measured after drilling

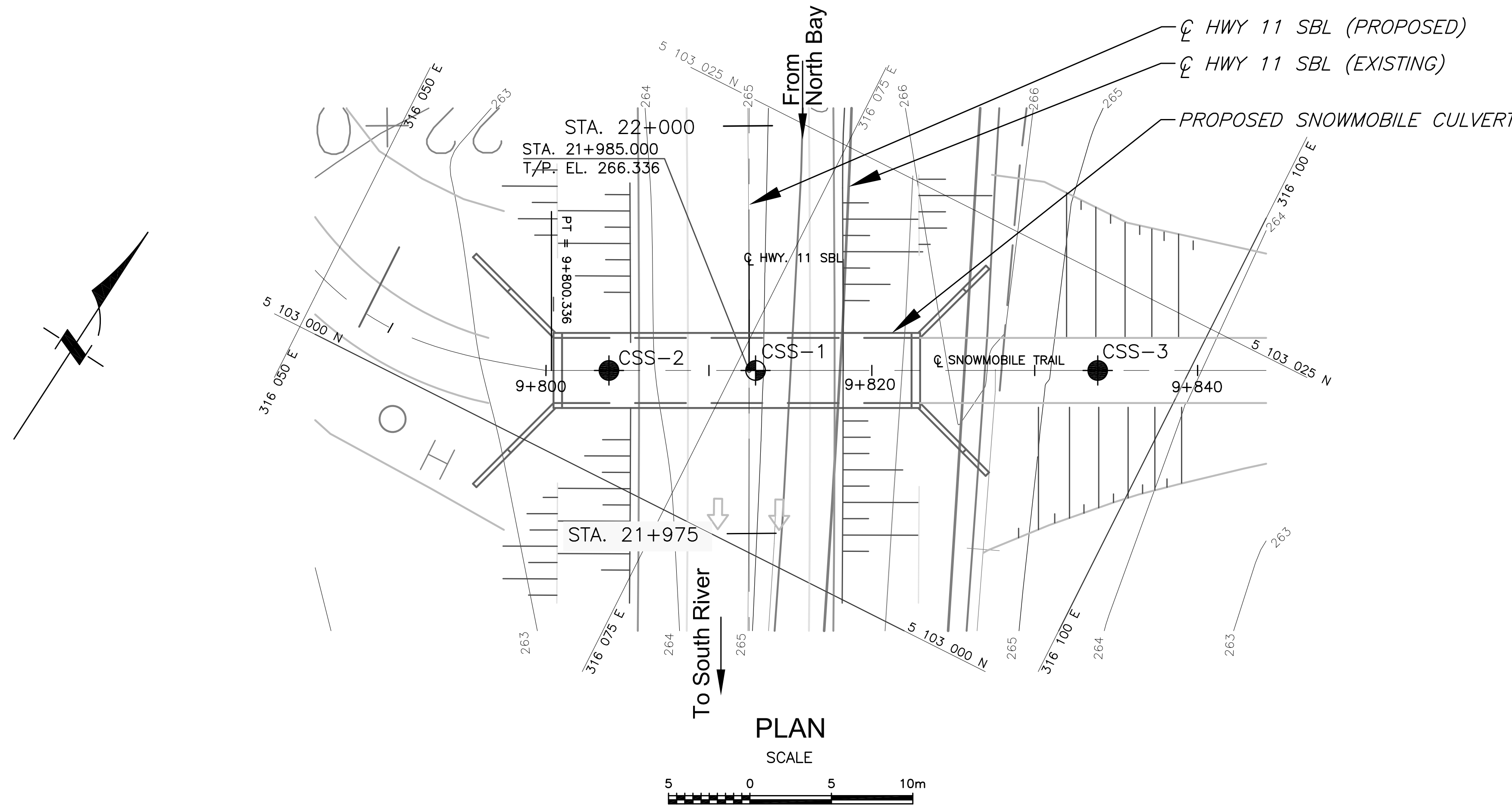
NOTE: Auger grinding betweem 10 and 10.7m depth

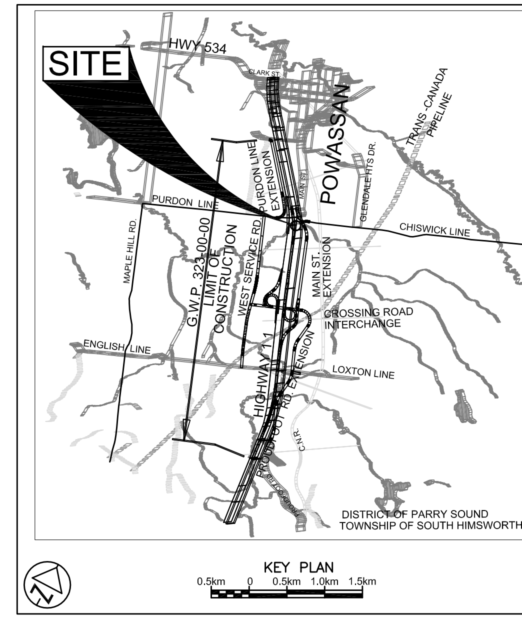
7 , 5 × : Numbers refer to Sensitivity

20 / 15 —○— 5 / 10 (%) STRAIN AT FAILURE

CONT No GWP No 323-00-00 WP No 5415-11-02	
SNOWMOBILE CULVERT HIGHWAY 11 SBL – STA. 21+985 BOREHOLE LOCATIONS AND SOIL STRATA	SHEET

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS

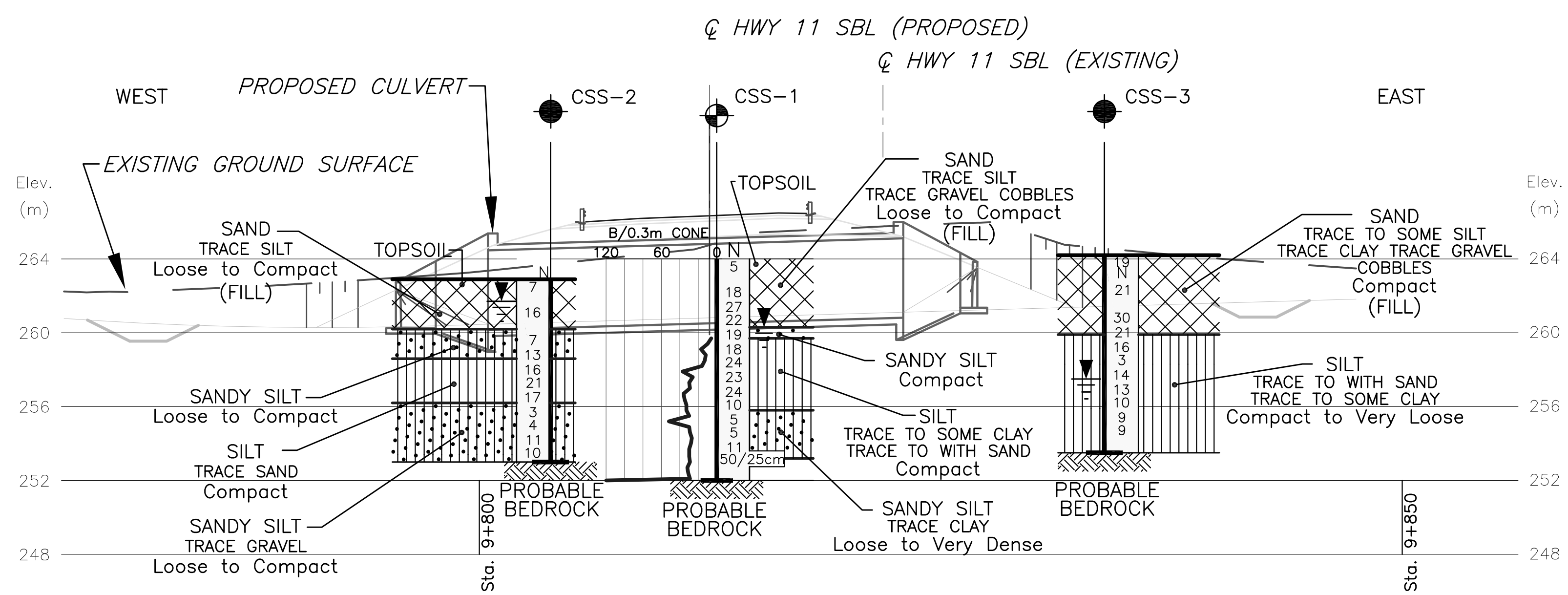




LEGEND

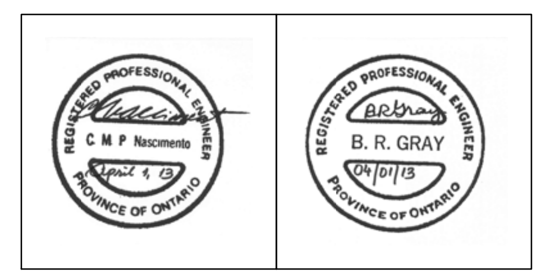
- Borehole
- Borehole and Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation January 2012
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
CSS-1	264.0	5 103 010.2	316 076.2
CSS-2	262.9	5 103 006.1	316 068.2
CSS-3	264.2	5 103 019.6	316 095.0



PROFILE ALONG ℄ SNOWMOBILE CULVERT STA. 21+985 (SBL)

SCALE
5 0 5 10m



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

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
3. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

REF AECOM Drawings:
60157537 Mcgillvary Creek_TriNBL_Creek Culvert Sta. 21+979.dwg dated Dec., 2010; Hwy 11 Base-Trow.dwg; Hwy 11-Deisn.dwg; X-Hwy11-CONTOURS.dwg

REVISIONS		
DATE	BY	DESCRIPTION

Geocres No. 31L-169

HWY No 11			DIST North Bay
SUBM'D NA	CHECKED SS	DATE APR. 01, 2013	SITE 44-371/C2
DRAWN NA	CHECKED BRG	APPROVED CN	DWG S-1

Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
NEW SNOWMOBILE CULVERT
HIGHWAY 11 SOUTHBOUND LANES STATION 21+985
SITE 44-371/C2
TOWNSHIP OF SOUTH HIMSWORTH
NORTH BAY AREA, ONTARIO
G.W.P. 323-00-00

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PML Ref.: 10TF013A-C5S
Index No.: 349FDR
GEOCRES No.: 31L-169
April 3, 2013

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
New Snowmobile Culvert
Highway 11 Southbound Lanes Station 21+985
Site No. 44-371/C2
Township of South Himsworth
North Bay Area, Ontario
GWP 323-00-00

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1. INTRODUCTION

The construction of a new snowmobile concrete box culvert is planned under the existing Highway 11 Southbound Lanes (SBL) as part of the south entrance to Powassan project in the Township of South Himsworth. This report was prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

This foundation design report provides foundation engineering comments and recommendations for the design and construction of the proposed Highway 11 SBL Snowmobile culvert.

According to the General Arrangement drawing dated February 2012, the new Highway 11 SBL snowmobile culvert will be constructed at approximate Sta. 21+985 (Highway 11 SBL chainage) in the Township of South Himsworth. The proposed culvert will be a cast-in-place 4.0 x 4.3 m concrete box culvert with a total length of 22.5 m.

The highway design plan calls for horizontal curve corrections where the culvert will be located. The centreline will be shifted about 9 m westerly and the grades will be raised approximately 0.8 m at the new centreline.

In summary, the subsurface stratigraphy revealed in the southbound three borehole locations generally comprised fill or surficial topsoil overlying cohesionless typically loose to compact sandy silt and silt. All the three boreholes and dynamic cone test were terminated by refusal on probable bedrock at 9.9 to 12.0 m depths (elevation 252.0 to 253.5). The groundwater level observed during the field investigation varied from 1.2 to 6.7 m (elevation 261.7 to 257.5).

Further, the water level in the Tributary to McGillvray Creek located 47 m to the south at approximate Station 21+938 was at elevation 258.0 in January 2011. Therefore, comparing the creek water level with subgrade level of southbound culvert, no major water problem is anticipated during foundation excavation.

From a foundation perspective, the proposed cast-in-place culvert is feasible at the culvert location. However, the cast-in-place culvert can typically tolerate a maximum of 25 mm of settlement, after which, cracking may appear within the culvert. Consideration should be given at the design engineer's discretion, to introduce joints in the culvert to accommodate differential settlement which is larger than 25 mm.

It is understood that SBL of existing Highway 11 will be realigned about 9 m westerly at the proposed culvert location. Due to resulting unloading of the existing overburden pressure, it is anticipated that there will only be negligible post construction settlement at culvert location.

It is understood that the proposed Snowmobile culvert will be of the cast-in-place concrete box culvert type. Therefore, only the recommendations for cast-in-place box culverts are provided and a discussion of the advantages and disadvantages of the open footing culverts or precast box culvert options are not included in this report.

The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the contractor. It is noted that no responsibility or liability is assumed by the consultants or the MTO for alerting the contractor to all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the contractor.

The foundation frost penetration depth at the site is 1.9 m according to OPSD 3090.101.

A list of the standard specifications referenced in this report is compiled in Table 1.

All elevations in this report are expressed in metres.

2. FOUNDATIONS

The invert levels are specified near elevation 260.5 at the west end and near elevation 261.1 at the east end of the culvert. The subgrade level is interpreted to be about 0.8 m below the proposed invert levels allowing for the 650 mm combined thickness of the concrete base and earth fill of the box culvert and 150 mm thick granular bedding or levelling course. Consequently, the subgrade levels will be at elevations 259.7 and 260.3 at the west end and the east end of the culvert, respectively, for an average level of approximately elevation 260.0.

At the proposed culvert location, 0.8 m of grade raise from the existing grade will be required to achieve the proposed centreline grade elevation of 266.3.

The anticipated subgrade soils in the boreholes located from the west to east end along the culvert alignment are relatively uniform and included a 6.7 m thick layer of loose to compact cohesionless soils (borehole CSS-2); a 8.0 m thick layer of compact to very dense cohesionless soils (borehole and cone test CSS-1); and a 0.4 m thick fill over 6.4 m thick loose to compact cohesionless soils (borehole CSS-3). The borehole CSS2, dynamic cone test advanced 2 m north of borehole CSS-1 and borehole CSS-3 terminated by refusal on probable bedrock at elevations 253.0, 252.0 and 253.5, respectively.

The measured groundwater levels (upon completion of drilling) were contacted 2.7 to 5.3 m below the anticipated culvert subgrade levels at the time of investigation. Perched water was found up to 2.0 m above to 2.8 m below the proposed subgrade levels of the culvert in boreholes.

2.1 Concrete Box Culvert

The concrete box culvert subgrade level is anticipated at average elevation 260.0. The subgrade preparation should be carried out as recommended in Section 2.3.1 of this report.

The underlying native cohesionless soils that are in the zone of influence below the design subgrade level are capable of adequately supporting the stress imposed by the concrete box culvert.

Since the average final grade raise is only 2.3 m compared to the average excavation for culvert construction of 4.8 m, there will be a net 2.5 m unloading of the existing overburden pressure. Therefore, it is anticipated that there will only be negligible post construction settlement at this culvert location.

2.2 Geotechnical Bearing Resistance for Box Culvert

The recommended geotechnical bearing resistance at ultimate limit state (ULS) and geotechnical reaction at serviceability limit state (SLS) for the 4.0 m wide cast-in-place concrete box culvert constructed on native sandy silt/silt are as follows:

CULVERT SECTION	SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Entire SBL	Native soils	225	150

The geotechnical resistance at SLS normally allows for 25 mm compression of the founding medium. It is considered that these settlements will likely occur within the culvert and embankment construction periods in view of the underlying cohesionless deposits at the site.

2.3 General Comments

2.3.1 Subgrade Preparation

Preparation of the subgrade for construction of the culverts should be performed and monitored in accordance with OPSS 902. This should include site review by qualified geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the granular fill and during the removal of existing fills and soft materials where applicable.

In particular, loose sandy silt with organics unit in borehole CSS-2 and the 0.3 m thick fill unit contacted in borehole CSS-3 below the subgrade level should be completely excavated along the proposed culvert alignment to the underlying cohesionless deposits.

The excavated soils should be replaced with SP 110S13 Granular A or Granular B Type II material to raise the subgrade to the design level along the proposed culvert alignment. Granular B Type II should be preferred for construction under wet conditions. The placement and compaction should follow the OPSS 501.

Topsoil and any other deleterious soils revealed during the preparation at or below the subgrade should be excavated prior to placement of the granular base below the box culvert and replaced with compacted Granular A or Granular B Type II.

2.3.2 Culvert Bedding and Backfill

For cast-in-place box culvert, it is recommended to provide 150 mm of granular bedding below the culvert. The bedding material should comprise Granular A or Granular B Type II compacted to 100% of the ASTM D-698 (standard Proctor maximum dry density) in conformance to OPSS 501 (Method A).

The cover, backfill and frost treatment for the proposed culvert should be carried out in accordance with OPSD 803.010, OPSS 422 and SP 422S01. A foundation frost penetration depth in the area is at least 1.9 m according to OPSD 3090.101.

2.3.3 Modulus of Subgrade Reaction

The estimated values of the modulus of subgrade reaction for box culvert constructed on the subgrade materials applicable to these sites, such as native sandy silt / silt and compacted granular fill materials (if applicable) are as follows:

SOIL TYPE	**MODULUS OF SUBGRADE REACTION MN/m^3**
Sandy Silt / Silt	10
Compacted Granular A or B Type II Materials	45

2.3.4 Sliding Resistance

It is recommended that the following parameters should be used for sliding resistance of cast-in-place box culvert foundation.

SOIL TYPE	**Friction Angle, (degrees)**	**Cohesion, (kPa)**	**Unit Weight, (kN/m^3)**
Compact Sandy Silt	30	0	19.5
Compact Silt	26	0	17.0
Compacted Granular A or B Type II material	35	0	22.8

The structural designer should use a factor of 0.8 for the above values of friction angle and cohesion when checking the sliding resistance.

2.3.5 Seismic Site Coefficient

The seismic site coefficient for the conditions at the culvert sites is 1.0 – Type I soil profile as per clause 4.4.6 of the CHBDC.

3. CULVERT BACKFILL

Backfill adjacent to the culvert should be placed in accordance with OPSD 803.010, OPSD 3121.150, OPSS 422 and MTO SP 422S01.

Backfill should be brought up simultaneously on each side of the box culvert and operation of heavy equipment within 0.5 times the height of the box culvert (each side) should be restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to MTO OPSS 501 for additional comments.

The new culvert must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted by the backfill adjacent to the culvert walls. Recommendations for headwalls and wingwalls are also provided in Section 4 of this report.

The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the CHBDC or employing the following equation assuming a triangular pressure distribution:

$$P = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + Cp + Cs$$

where K = lateral earth pressure coefficient
γ = unit weight of free draining granular material above the design water level (kN/m^3)
γ' = unit weight of backfill submerged below the design water level (kN/m^3)
h_1 = depth below final grade (m), above the design water level
h_2 = depth below the design water level (m)
q = any surcharge load (kN/m^2)
γ_w = unit weight of water equal to 9.8 kN/m^3
Cp = compaction pressure (refer to clause 6.9.3 of CHBDC)

Cs = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)
where Ø = angle of internal friction of retained soil (35º for Granular A or Granular B, Type II)
δ = angle of friction between soil and wall (23.5º for Granular A or Granular B, Type II)

The following parameters are recommended for design:

PARAMETER	GRANULAR A, GRANULAR B TYPE II	EXCAVATED MATERIAL (*)	ROCKFILL
Angle of Internal Friction, degrees	35	30	42
Unit Weight, kN/m^3	22.8	20.0	18.0
Active Earth Pressure Coefficient (K_a)	0.27	0.33	0.20
At-Rest Earth Pressure Coefficient (K_o)	0.43	0.50	0.33
Passive Earth Pressure Coefficient (K_p)	3.69	3.00	5.04

(*) Assumes that excavated materials used for backfill is inorganic cohesionless soils.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls and the active earth pressure coefficient for unrestrained structures.

4. HEADWALLS, WINGWALLS AND RETAINING WALLS

For headwalls and wingwalls design, the previous geotechnical parameters and recommendations for culvert foundations and backfill should be utilized for the design of the foundations. The wall founding levels should match those of the respective culverts where the walls are designed integral with the box culvert structure. For walls designed separately from the culvert structure, the founding levels should be established to provide 1.9 m of earth cover for adequate frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided in Section 2.3.4 for cast-in-place concrete foundations.

Four retaining walls, 2.0 to 5.3 m lengths, were proposed at each end of the wingwalls of the culvert. The walls founding levels should match those of the respective wingwalls. Based on subsurface conditions in the boreholes, the walls should be designed and constructed on native soil using the geotechnical resistances recommended in Section 2.2 of this report. It is assumed that the footing will be a minimum of 2.0 m wide and the groundwater will be at least 1.5 m below the subgrade level of the footings.

For headwalls and wingwalls, a perforated subdrain should be installed to minimise the build-up of hydrostatic pressure behind the wall. The perforated subdrain should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 µm according to OPSS 1860) placed to prevent migration of fines into the system.

5. EXCAVATION

Excavation to the anticipated founding level of the culverts is expected to extend through the existing topsoil and fill into the native cohesionless sandy silt / silt soil deposits . Provision for excavation of cobbles and boulders should be made. Subject to adequate groundwater control, excavations should be feasible using conventional equipment. All excavations should be conducted in accordance with OPSS 902.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the fills and in situ loose to compact sandy silt / silt materials are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V below the water table. Saturated soils are classified as Type 4 soils and should be sloped at 3H:1V or flatter. Where composite soil types exist, the excavation slopes should be cut to the requirements of the soil type with the highest number that is present in the slope according to OHSA.

The excavation at the culvert sites should allow for the backfill cover and frost requirements in accordance with Section 2.3.2 of this report.

6. GROUNDWATER CONTROL

Perched groundwater was contacted up to 2.0 m above the subgrade levels of the culvert (elevations 257.5 to 261.7). The permanent groundwater table is inferred to be below the subgrade of the culvert. Subject to the perched water condition, it will likely be necessary to implement measures to control the perched water during the culvert construction and to permit construction of cast-in-place headwalls and wingwalls that are designed separately. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding levels.

It should be noted that the flow of surface water should be diverted away from the excavations. Conventional procedures such as sump and pump are considered to be adequate. Requirements for a permit to take water (PTTW) will depend on the groundwater levels at the time of construction since these are subject to seasonal fluctuations and precipitation patterns. However, the contractor is responsible for the groundwater control of excavations.

7. EMBANKMENT FILL

Based on the proposed and current road grades , the height of the embankment will be increased up to 1.5 m (elevation 266.3) to accommodate the proposed westerly centreline shift.

The construction specifications for grading in SP 206S03 should be followed. In particular, the topsoil and other excessively loose, soft, organic or otherwise deleterious materials within the new limits of the embankment fill should be subexcavated prior to new fill placement. The new embankment fill should be placed and compacted in accordance with OPSS 501.

A vegetation cover over slope flattening material or other measures should be established to control surface runoff and minimise erosion of the embankment slopes as outlined in Section 8 of this report. A side slope of 2.5H:1V or flatter is recommended for stability of the existing cohesionless embankment fill materials.

8. EROSION CONTROL

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls, etc.) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. Subject to the hydrology engineering studies, the cut-off walls if required, should extend laterally to protect the granular backfill material and to a depth at least equal to the fluctuation of the water level at each culvert location to prevent flow below the culvert that could erode the granular base/bedding material. The requirements of CHBDC clauses 1.9.5.6 and 1.9.11.6.5 should be applied.

Also subject to the Hydrogeology studies, inlet and outlet protection in accordance with OPSS 511, OPSS 1004 and OPSD 810.010 are recommended to prevent erosion adjacent to the culverts as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements concerning the length and width of aprons at the inlet/outlet of the culvert as well as the rock size, apron thickness, height of erosion protection on the embankment slope and type of material should be established by a Hydrology engineer. A non-woven Class II geotextile with an FOS of 75-150 µm according to OPSS 1860 should be placed below the rip-rap to minimise the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the headwalls and wingwalls (if provided) should be covered with topsoil or suitable excess earth material and seeded in accordance with OPSS 802 and 804, as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per OPSS 803) may be placed, as required. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor.

SOIL TYPE	K FACTOR
Sand	0.2
Silt	0.3

9. CLOSURE

This report was prepared by Mr. S.K. Shrestha, MEng, P.Eng. and reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact. Mr. C.M.P. Nascimento, P.Eng., Project Manager, conducted an independent review of the report.

Yours very truly

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SS/CN/BRG:ss-mi

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting
OPSS 802	Construction Specification for Topsoil
OPSS 803	Construction Specification for Sodding
OPSS 804	Construction Specification for Seed and Cover
OPSS 902	Excavation and Backfilling of Structures
OPSS 1004	Material Specification for Aggregates – Miscellaneous
OPSS 1860	Material Specification for Geotextiles
SP 110S13	Material Specification for Aggregates, Base, Subbase, Select Subgrade and Backfill Material
SP 206S03	Construction Specification for Grading
SP 422S01	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls