



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
for  
NEW SNOWMOBILE CULVERT  
HIGHWAY 11 NORTHBOUND LANES STATION 22+009  
SITE 44-371/C1  
TOWNSHIP OF SOUTH HIMSWORTH  
NORTH BAY AREA, ONTARIO  
G.W.P. 323-00-00**

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**Distribution:**

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PML Ref.: 10TF013A-C5N  
Index No.: 351FIR and 352FDR  
GEOCRES No.: 31L-168  
April 3, 2013



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**FOUNDATION INVESTIGATION REPORT**  
for  
New Snowmobile Culvert  
Highway 11 Northbound Lanes Station 22+009  
Site 44-371/C1  
Township of South Himsworth  
North Bay Area, Ontario  
GWP 323-00-00

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**1. INTRODUCTION**

This report summarizes the results of the foundation investigation carried out for the proposed new Snowmobile Culvert under the existing Highway 11 Northbound Lanes (NBL) 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 locations are at approximate Sta. 22+009, Highway 11 NBL chainage, in the Township of South Himsworth (ref. General Arrangement Drawings 'Hwy 11 NBL Snowmobile Culvert at Sta. 22+009' prepared by AECOM dated February 2012).

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

**2. SITE DESCRIPTION AND GEOLOGY**

The contemplated structure is proposed below the existing Highway 11 NBL about 40 m south of the existing Highway NBL / Main Street 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 on December 19, 2011, January 24 and February 1, 2012. A total of three boreholes (CSN-1, CSN-2, and CN-2) were drilled for the culvert to 7.2 to 13.4 m at the locations shown on Drawing N-1, appended.

The reference working points were laid out by exp Geomatics. 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. Due to unstable ground location and presence of utilities, borehole CSN-2 was drilled along the centreline of the proposed culvert, approximately 41 m east of existing centreline of NBL of Highway 11. In addition, borehole CN-2 was located about 20 m away from the culvert location. Although the results of the investigation are considered representative, allowances should be made for variations in subsurface stratigraphy.

The ground surface elevations at the borehole locations were established by PML using the ground surface elevations at reference points as provided by exp Geomatics. 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. 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 (29)
- Atterberg limits (5)
- Grain size distribution analyses (11)

The laboratory grain size distribution charts are presented in Figures CSN-GS-1 to CSN-GS-5 and the Atterberg Limits results are presented in Figures CSN-PC-1 and CSN-PC-2. 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, and groundwater observations. The results of laboratory particle size distributions, Atterberg Limits 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 N-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 boreholes drilled at the northbound culvert site generally included surficial topsoil and fill overlying native silt and clayey silt, which in turn is underlain by cohesionless sand / silty sand. The boreholes were terminated at 7.2 to 13.4 m (elevation 253.5 to 251.4).

#### 4.1 Topsoil

A 200 mm thick topsoil layer was encountered surficially in borehole CSN-2, extending to 0.2 m (elevation 258.9).

#### 4.2 Fill

A 3.7 m thick fill unit was encountered surficially in borehole CSN-1 and extended to 3.7 m (elevation 259.6). In addition, a 6.8 m (elevation 260.1) thick fill unit was encountered in borehole CN-2 drilled on the existing embankment shoulder. The fill unit included mixed cohesionless sand with gravel, clayey silt and sand pockets, occasional cobbles and organics in borehole CSN-1 and cohesionless fill unit in borehole CN-2 has two distinct layers which include sand and silty sand. The sand fill layer extended to 3.8 m (elevation 263.1) and silty sand fill layer extended a further 3.8 m to 6.8 m (elevations 260.1). N values ranged from 3 to 15 indicating very loose to compact relative density.

The results of the grain size distribution analyses for a silty sand fill sample are included in Figure CSN-GS-1. The moisture content determinations ranged from 9 to 19%.

#### 4.3 Silt

A low plasticity silt was encountered below the fill at 3.7 m (elevation 259.6) in borehole CSN-1, below the topsoil at 0.2 m (elevation 258.9) in borehole CSN-2 and below the fill at 6.8 m (elevation 260.1) in borehole CN-2. The deposit was 3.0 to 5.3 m thick (excluding inter-bedded 0.9 m thick clayey silt layer in borehole CSN-2), extending to 4.1 to 11.0 m (elevation 254.3 to 255.9). N values ranged from 3 to 34, indicating very loose to dense relative density.



The results of grain size distribution analysis for silt samples are included in Figure CSN-GS-2. Atterberg Limits chart is presented in Figure CSN-PC-1. The liquid and plastic limits of four of the silt samples ranged from 22 to 29 and 17 to 24, respectively with plasticity index values of 3 to 7. The moisture content determinations ranged from 17 to 32%.

#### 4.4 Sandy Clayey Silt

A cohesive sandy clayey silt layer was encountered within the silt deposit at 2.1 m (elevation 257.0) in borehole CSN-2. The stratum was 0.9 m thick extending to 3.0 m (elevation 256.1). One N value was 2, indicating very soft consistency.

The result of grain size distribution analysis for clayey silt, sandy sample is included in Figure CSN-GS-3. Atterberg Limits chart is presented in Figure CSN-PC-2. The liquid and plastic limits of clayey silt sample were 24 and 13 with a resulting plasticity index value of 11. The moisture content determination was 28%.

#### 4.5 Sand / Silty Sand

A cohesionless sand deposit was encountered below the silt deposit at 9.0 and 4.1 m (elevation 254.3 and 255.0) in boreholes CSN-1 and CSN-2 and extended to the borehole termination depths of 11.9 and 7.2 m (elevation 251.4 and 251.9), respectively. N values typically ranged from 10 to 15, indicating compact relative density. However, higher N values of 40 and over 50 blows for 0.0 mm penetration were recorded in the lower depths of boreholes due to presence of cobbles and boulders.

A silty sand deposit was encountered below the silt deposit at 11.0 m (elevation 255.9) in borehole CN-2. The unit was at least 2.4 m thick containing cobbles and boulders below 12.8 m depth extending to borehole termination depth of 13.4 m (elevations 253.5).

The results of grain size distribution analysis for sand / silty sand sample are included in Figures CSN-GS-4 and CSN-GS-5. The moisture content determinations ranged from 6 to 24%.





#### 4.6 Groundwater

Groundwater was observed in boreholes CSN-1 and CSN-2 during the course of the field work in January and February 2012. No groundwater was encountered in the borehole CN-2 in December 2011. The water levels contacted within the boreholes during and upon completion of drilling are shown in the Table below.

**GROUNDWATER OBSERVATION DETAILS**

BOREHOLE NO.	GROUND SURFACE ELEVATION (m)	GROUNDWATER DEPTH (ELEVATION) BELOW EXISTING GROUND SURFACE (m)	
		During Investigation	Upon Completion
CSN-1	263.3	3.4 (259.9)	6.1 (257.2)
CSN-2	259.1	2.1 (257.0)	5.2 (253.9)
CN-2	266.9	Dry	Dry

In summary, groundwater was observed during augering at 2.1 and 3.4 m (elevation 257.0 to 259.9) in boreholes CSN-1 and CSN-2. Upon completion of drilling, groundwater was measured at 5.2 and 6.1 m (elevation 253.9 to 257.2). No water was encountered in borehole CN-2. 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.



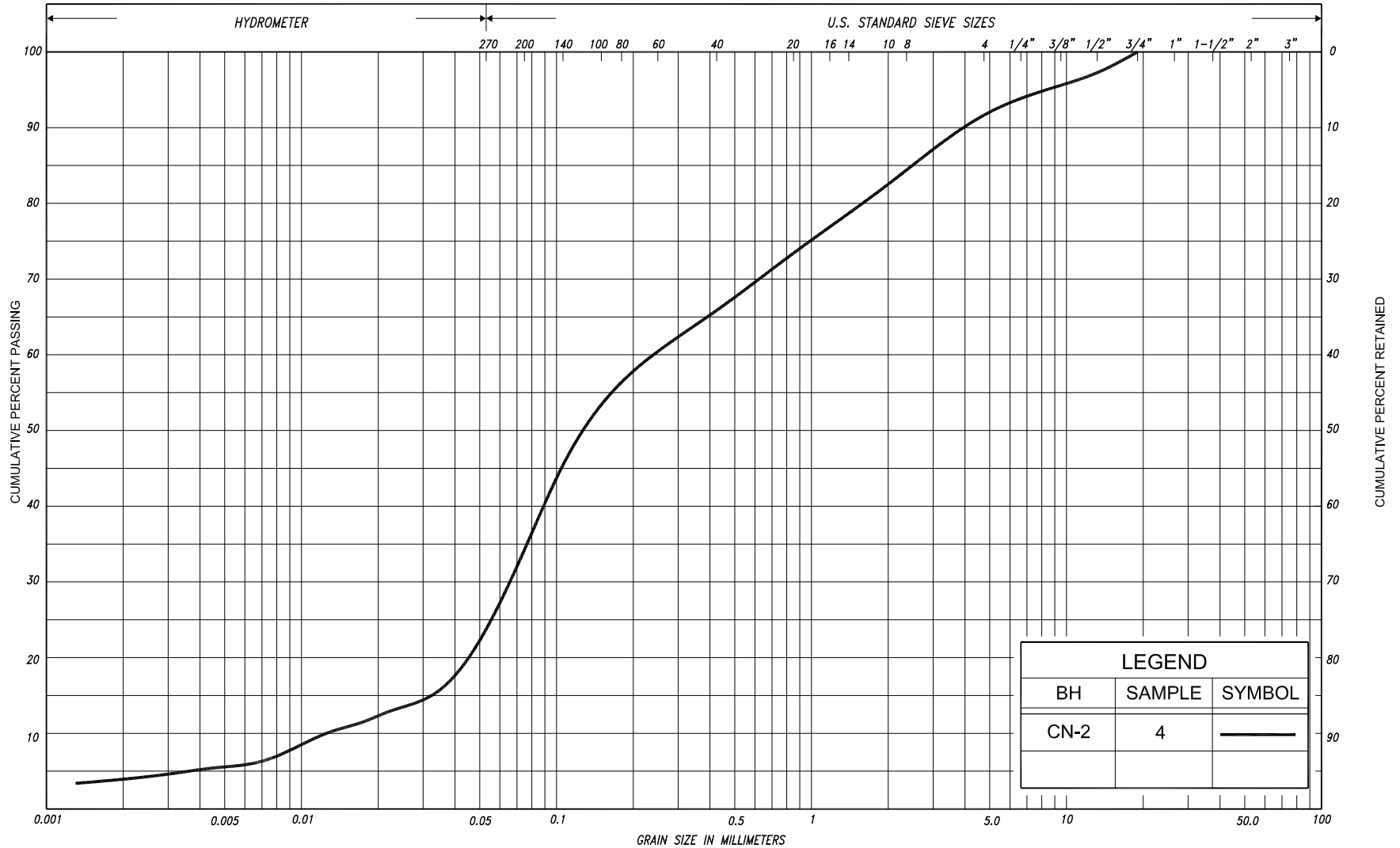
Subir K. Shrestha ,MEng, P.Eng.  
Project Engineer



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



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



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



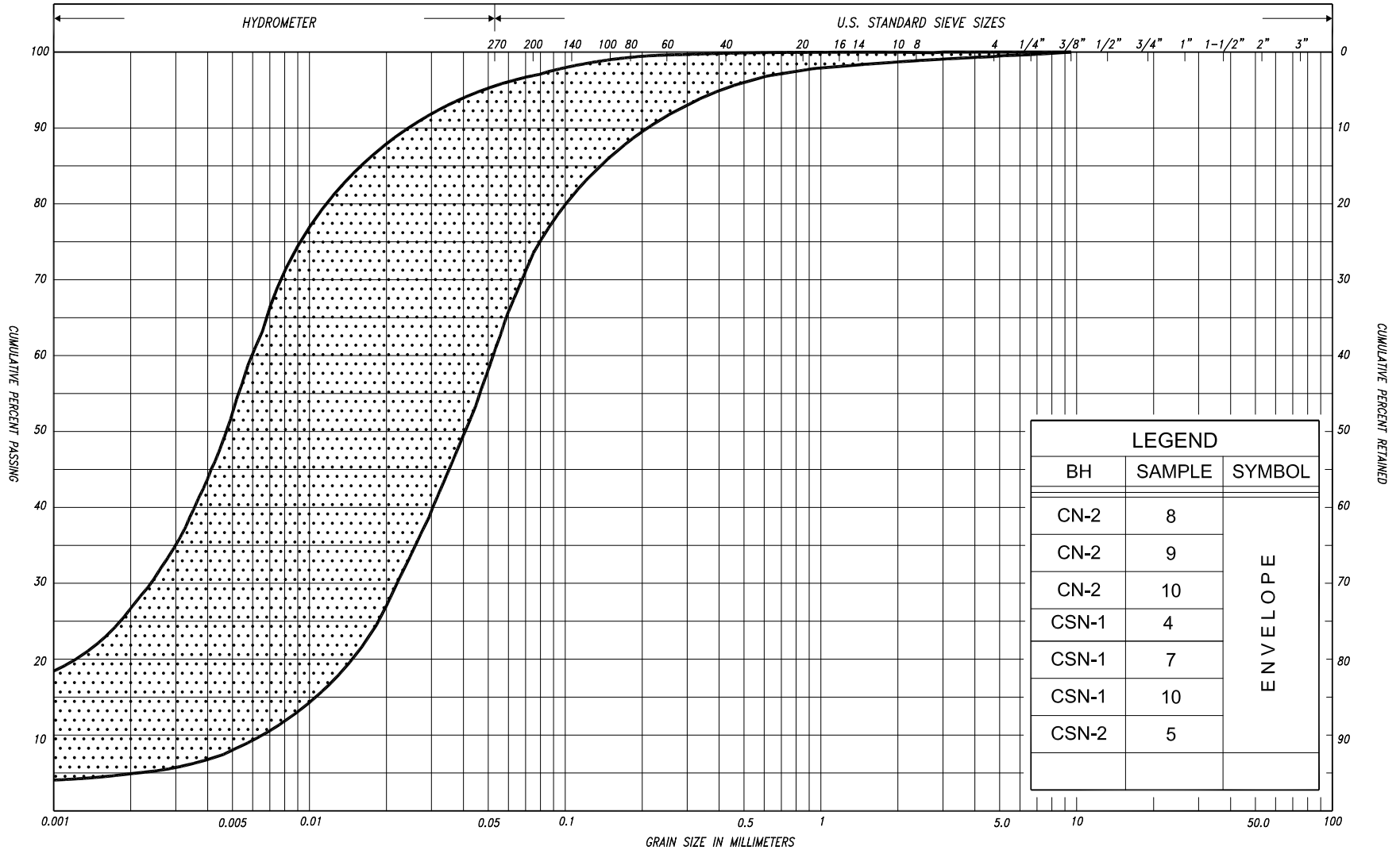
## GRAIN SIZE DISTRIBUTION

SILTY SAND, trace clay, trace gravel  
(FILL)

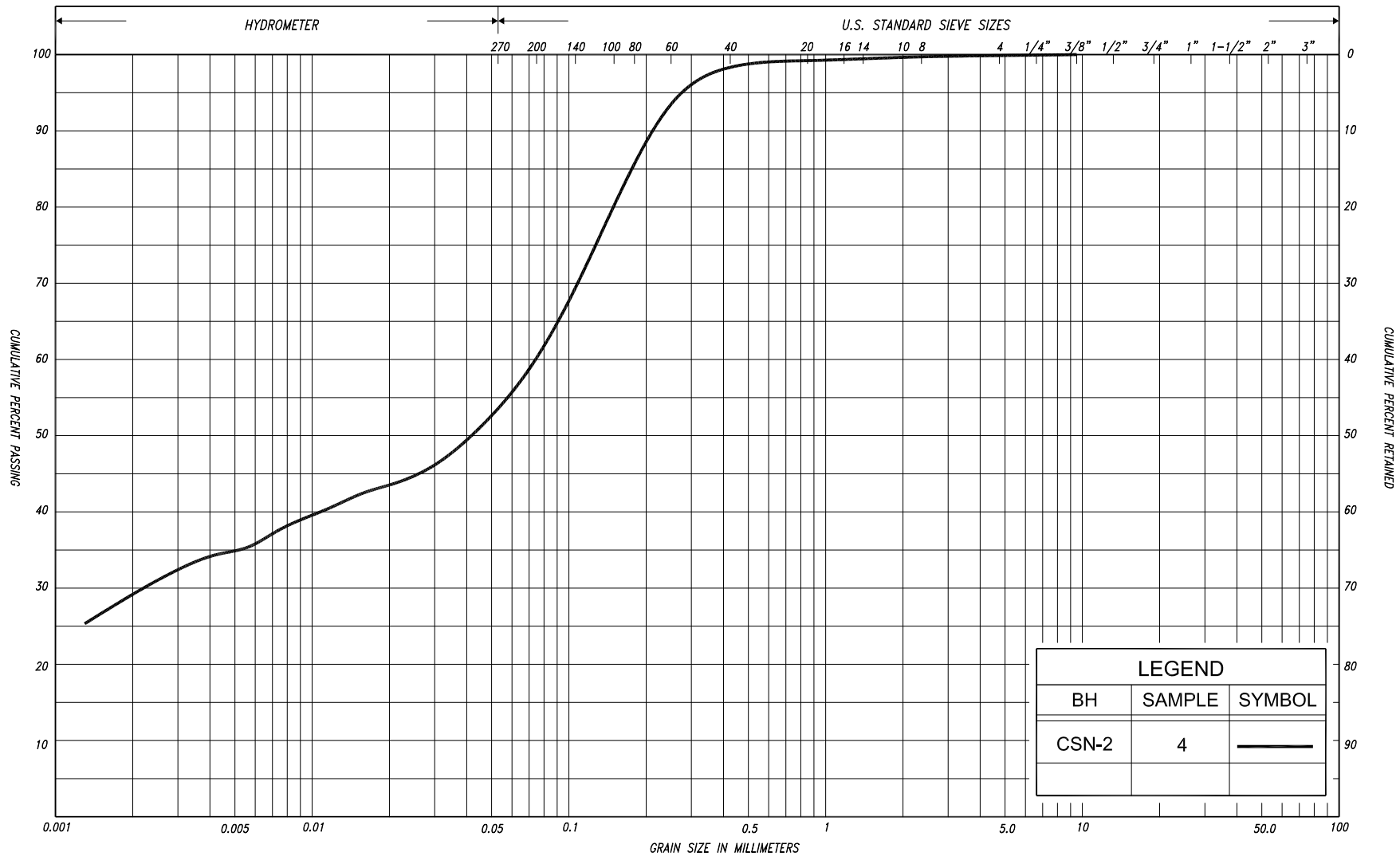
FIG No. CSN-GS-1

HWY: 11

G.W.P. No. 323-00-00



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



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



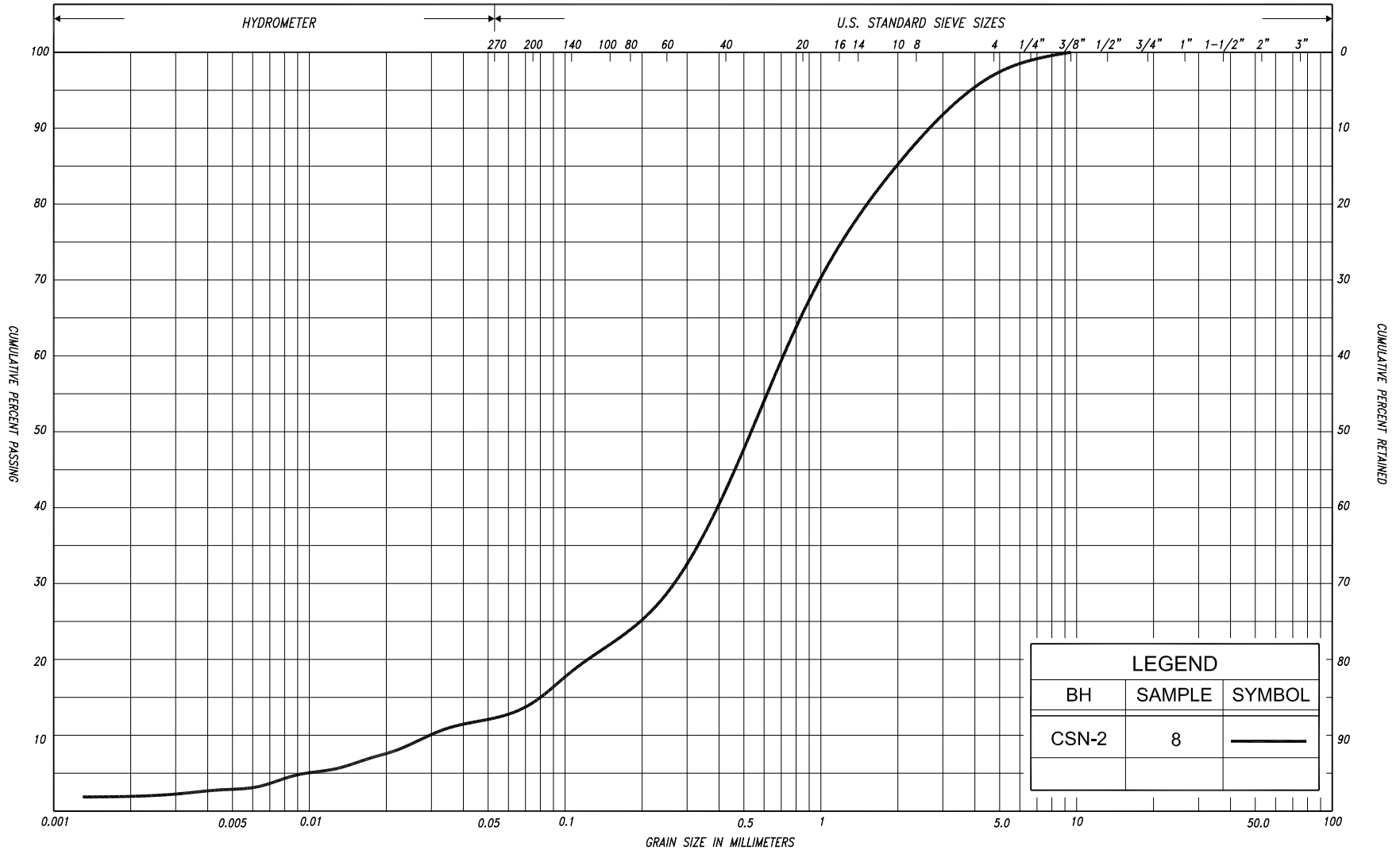
## GRAIN SIZE DISTRIBUTION

### SANDY CLAYEY SILT (CL)

FIG No. CSN-GS-3

HWY: 11

G.W.P. No. 323-00-00



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



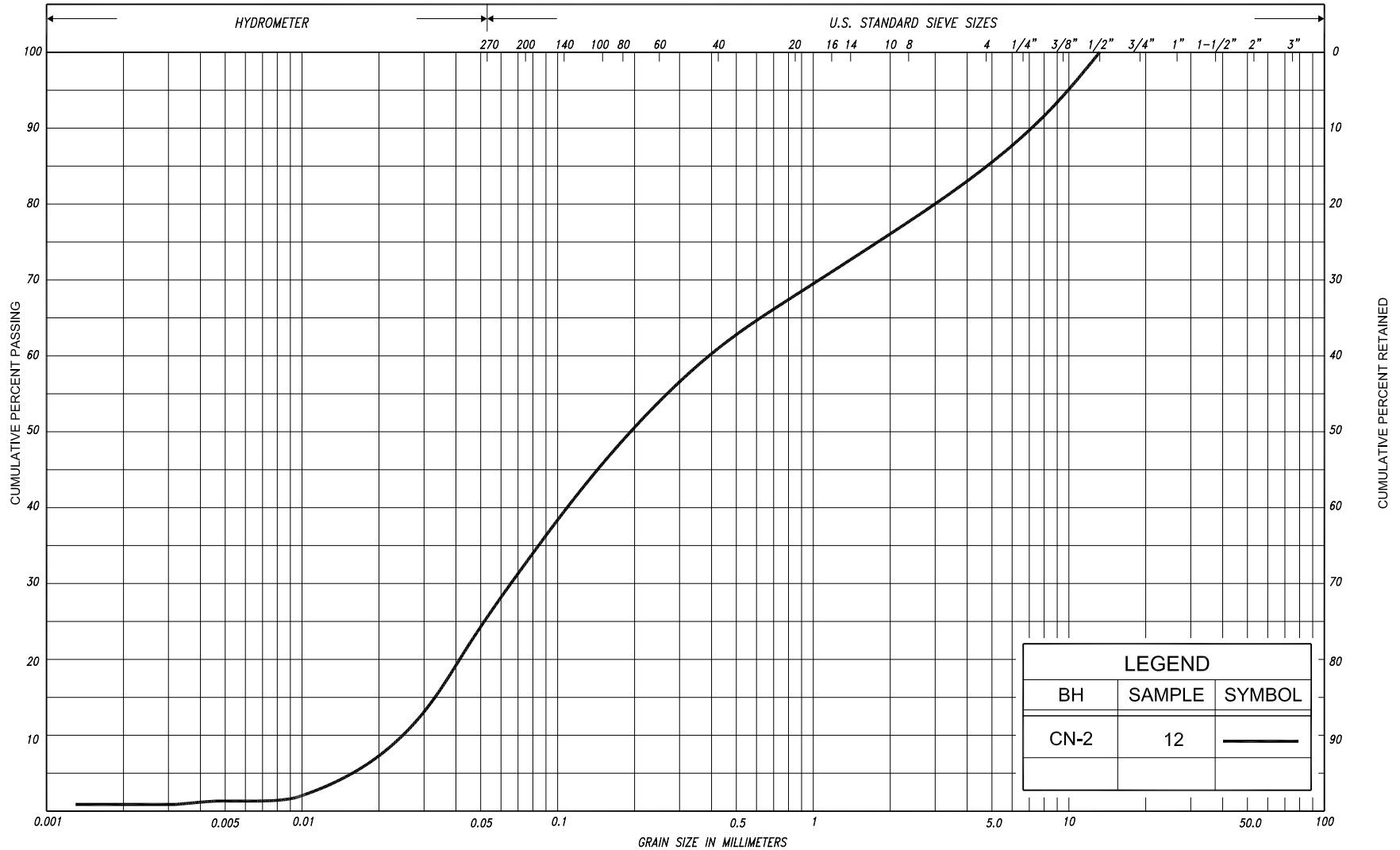
**GRAIN SIZE DISTRIBUTION**

SAND, some silt, trace clay, trace gravel

FIG No. CSN-GS-4

HWY: 11

G.W.P. No. 323-00-00



LEGEND		
BH	SAMPLE	SYMBOL
CN-2	12	—

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



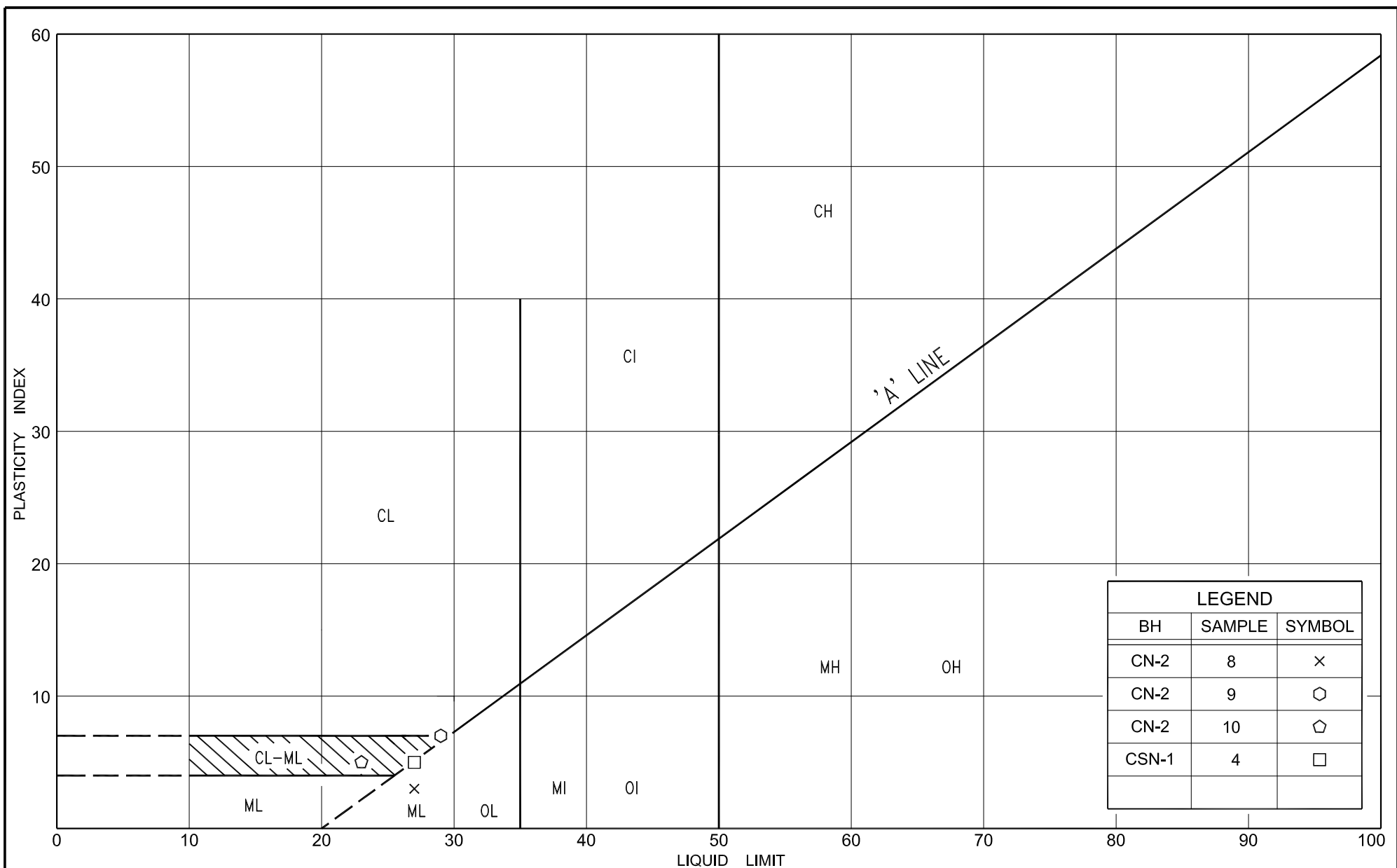
# GRAIN SIZE DISTRIBUTION

SILTY SAND, some gravel, trace clay

FIG No. CSN-GS-5

HWY: 11

G.W.P. No. 323-00-00



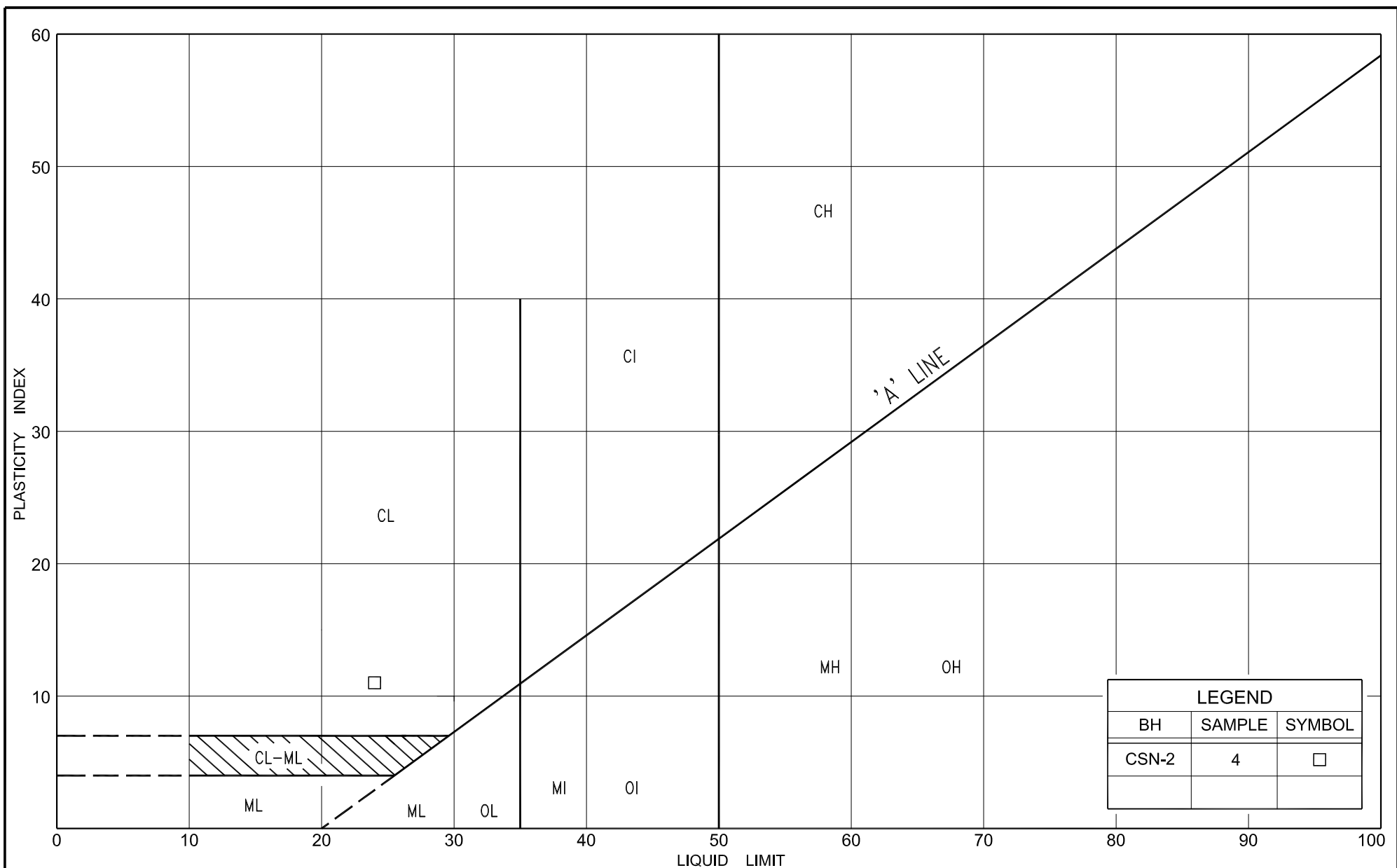
**PLASTICITY CHART**  
SILT, some clay, trace sand (CL - ML)

FIG No. CSN-PC-1

HWY: 11

G.W.P. No. 323-00-00





# PLASTICITY CHART SANDY CLAYEY SILT (CL)

FIG No. CSN-PC-2

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/0.3m)	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:

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

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
$H$	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
$U$	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_i$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	$n$	1, %	POROSITY	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE
$\gamma_s$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	$w$	1, %	WATER CONTENT	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	$S_r$	%	DEGREE OF SATURATION	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$	kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$w_L$	%	LIQUID LIMIT	$D$	mm	GRAIN DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_p$	%	PLASTIC LIMIT	$D_n$	mm	n PERCENT - DIAMETER
$\gamma$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_s$	%	SHRINKAGE LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	$h$	m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$	kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	$q$	m <sup>3</sup> /s	RATE OF DISCHARGE
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	$v$	m/s	DISCHARGE VELOCITY
$\gamma_{sat}$	kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	$i$	1	HYDRAULIC GRADIENT
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	$k$	m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$	kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	$j$	kN/m <sup>3</sup>	SEEPAGE FORCE
$e$	1, %	VOID RATIO						

**RECORD OF BOREHOLE No CSN-1**

1 of 1

**METRIC**

**G.W.P.** 323-00-00      **LOCATION** Co-ords: 5 103 031.8 N ; 316 117.8 E      **ORIGINATED BY** F.P.  
**DIST** North Bay HWY 11      **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers      **COMPILED BY** S.S.  
**DATUM** Geodetic      **DATE** February 01, 2012      **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
263.3	Ground Surface						20	40	60	80	100									
0.0	Sand with gravel cobbles		1	SS	4								○							
	Loose      Brown      Moist (FILL)																			
	clayey silt organics sand pockets		2	SS	12								○							
	Stiff      Dark grey																			
			3	SS	15	▽*							○							
259.6	Wet																			
3.7	Silt some clay, trace sand		4	SS	27								○			0 3 81 16				
	Compact      Brown      Wet to dense																			
			5	SS	34								○							
	Loose to very loose		6	SS	6								○							
	with sand, trace clay oxidized		7	SS	8	▽*							○			0 26 65 9				
			8	SS	3								○							
			9	SS	9								○							
			10	SS	8								○			0 25 70 5				
254.3																				
9.0	Sand, trace silt silty sand seams		11	SS	10								○							
	Compact      Brown      Wet to dense																			
	cobbles and boulders		12	SS	40								○							
251.4																				
11.9	End of borehole																			
	Refusal on probable boulder																			
	*      2012    02    01																			
	▽      Water level observed during drilling																			
	▽      Water level measured after drilling																			
	NOTE: Augers grinding from 10.1 to 10.7m depth																			

## RECORD OF BOREHOLE No CSN-2

1 of 1

**METRIC**

G.W.P.	323-00-00	LOCATION	Co-ords: 5 103 065.4 N ; 316 172.2 E	ORIGINATED BY	F.P.
DIST	North Bay	HWY	11	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers
DATUM	Geodetic	DATE	January 24, 2012	CHECKED BY	B.R.G.

[illegible]

## RECORD OF BOREHOLE No CN-2

1 of 1

## METRIC

<b>G.W.P.</b>	<u>323-00-00</u>	<b>LOCATION</b>	<u>Co-ords: 5 103 029.6 N ; 316 155.4 E</u>	<b>ORIGINATED BY</b>	<u>F.P.</u>
<b>DIST</b>	<u>North Bay</u>	<b>HWY</b>	<u>11</u>	<b>BOREHOLE TYPE</b>	<u>C.F.H.S.A. and 'N' Casing</u>
<b>COMPILED BY</b>					<u>N.S.B.</u>
<b>DATUM</b>	<u>Geodetic</u>	<b>DATE</b>	<u>December 19, 2011</u>	<b>CHECKED BY</b>	<u>B.R.G.</u>

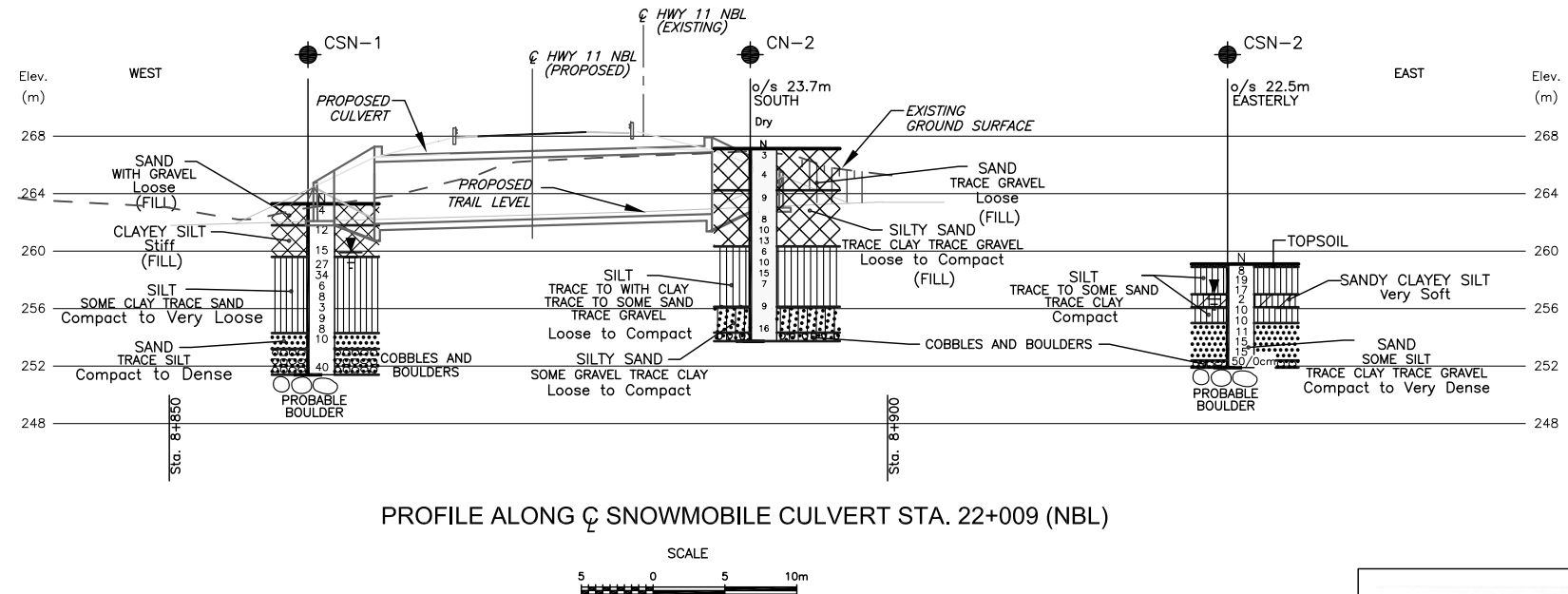
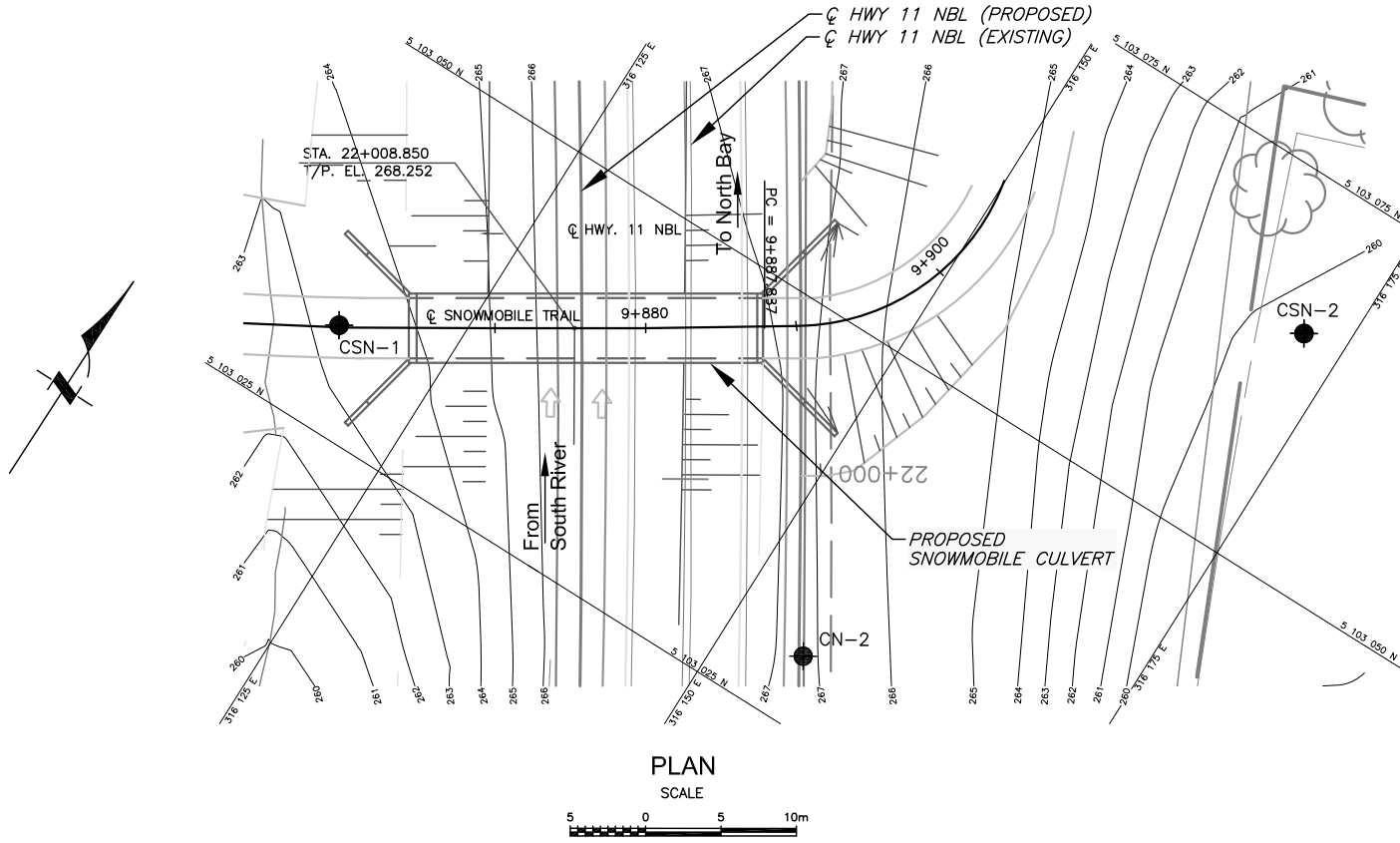
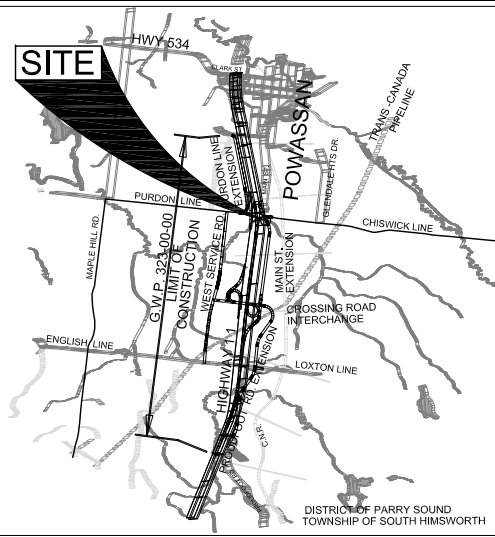
[illegible]

CONT No  
GWP No 323-00-00  
WP No 5415-11-01



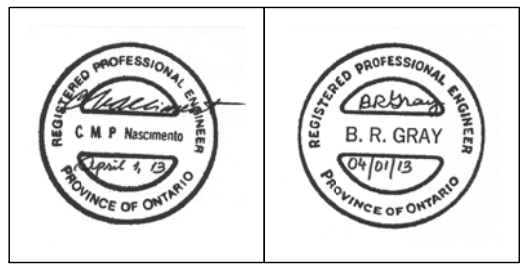
SNOWMOBILE CULVERT  
HIGHWAY 11 NBL - STA. 22+009  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



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	
CSN-1	263.3	5 103 031.8	316 117.8	
CSN-2	259.1	5 103 065.4	316 172.2	
CN-2	266.9	5 103 029.6	316 155.4	

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



REF AECOM Drawings:  
60157537 SNOWMOBILE CULVERT-Sta. 22+008.85-1.GA.dwg  
dated Feb., 2012; Hwy 11 Base-Trow.dwg; Hwy 11-Design.dwg;  
X-Hwy11-CONTOURS.dwg

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 31L-168				
HWY No	11	DATE	APR. 01, 2013	DIST North Bay
SUBM'D	NA	CHECKED	SS	SITE 44-371/C1
DRAWN	NA	CHECKED	BRG	LDWG N-1



**FOUNDATION DESIGN REPORT  
for  
NEW SNOWMOBILE CULVERT  
HIGHWAY 11 NORTHBOUND LANES STATION 22+009  
SITE 44-371/C1  
TOWNSHIP OF SOUTH HIMSWORTH  
NORTH BAY AREA, ONTARIO  
G.W.P. 323-00-00**

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**Distribution:**

- 5 cc: AECOM for distribution to MTO, Project Manager + one digital copy (PDF)
- 1 cc: AECOM for distribution to MTO, Pavements and Foundations Section + one digital copy (PDF) and Drawing (AutoCAD)
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- 1 cc: PML Kitchener
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PML Ref.: 10TF013A-C5N  
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April 3, 2013



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Table 1 – List of Standard Specifications Referenced in Report



**FOUNDATION DESIGN REPORT**  
for  
New Snowmobile Culvert  
Highway 11 Northbound Lanes Station 22+009  
Site 44-371/C1  
Township of South Himsworth  
North Bay Area, Ontario  
G.W.P. 323-00-00

---

**1. INTRODUCTION**

The construction of a new snowmobile concrete box culvert is planned under the existing Highway 11 Northbound Lanes (NBL) 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 NBL Snowmobile culvert.

According to the General Arrangement drawing dated February 2012, the new Highway 11 NBL snowmobile culvert will be constructed at approximate Station 22 + 009 (Highway 11 NBL 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 23.5 m.

The highway design plans call for horizontal curve corrections where the culvert will be located. The existing centreline of the NBL will be shifted about 7 m westerly and the grades will be raised approximately 1.8 m at the new centreline.

In summary, the subsurface stratigraphy revealed in northbound borehole locations generally comprised surficial topsoil / fill overlying native typically loose to dense silt and very soft clayey silt, which in turn are underlain by cohesionless loose to very dense sand / silty sand. The boreholes CSN-1 and CSN-2 were terminated by auger refusal on probable boulders at 11.9 and 7.2 m (elevation 251.4 and 251.9) and the borehole CN-2 was terminated at 13.4 m (elevation 253.5).

The groundwater level measured during the field investigation varied from 2.1 to 3.4 m (elevation 259.9 and 257.0) in boreholes CSN-1 and CSN-2. However, no water was encountered



in borehole CN-2. Upon completion of drilling, groundwater was measured at 5.2 and 6.1 m (elevation 253.9 to 257.2). The groundwater level is subject to seasonal fluctuation and rainfall patterns. Further, the water level in the Tributary to McGillvray Creek located 30 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 levels of northbound culvert, no major water problem is anticipated during foundation excavation.

In view of the anticipated approximately 11.0 m deep excavations (including grade raise changes) for the replacement of the McGillvray Creek Tributary northbound culvert construction, it is recommended that the construction of this culvert under the NBL be co-ordinated to minimize stability construction concerns. We refer to the separate PML Foundation Design Report for the McGillvray Creek Tributary culvert replacement at Sta. 21+978, Site No. 44-366/C1 for further details.

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 NBL of existing Highway 11 will be realigned about 7 m westerly at the proposed culvert location. Due to resulting unloading of the existing overburden pressure at the new NBL culvert, it is anticipated that there will only be negligible post construction settlement at the 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 culvert 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 northbound culvert invert levels are specified near elevation 262.3 at the west end and near elevation 263.0 at the east end of the culvert. The subgrade level for the concrete box culverts 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 culverts and for the 150 mm thick granular bedding or levelling courses. Consequently, the proposed culvert subgrade levels will be at elevations 261.5 and 262.2 at the west end and the east end of the culvert, respectively.

At the proposed culvert location, a 1.8 m of grade raise from the existing grade will be required to achieve the proposed NBL centreline grade elevation of 268.3.

The anticipated culvert subgrade soils in the borehole CSN-1 located at the west end of the northbound culvert alignment included a 1.9 m thick unit of existing fill underlain by a 8.2 m thick layer of compact to dense cohesionless soils. In view of the highway centreline shift 7 m to the west, the subsoil conditions in borehole CN-2 drilled from the shoulder of the highway are considered to be representative for the east end of the culvert. Consequently, it is considered that the east end subgrade soils will include a 2.1 m thick fill unit underlain by a 6.6 m thick layer of loose to compact cohesionless soils.



Comparing the subsurface condition encountered in boreholes CSN-1 and CSN-2, the very soft cohesive soil layer encountered in borehole CSN-2 at approximate depth of 4.8 m below the subgrade level was anticipated not to extend below the proposed culvert location.

The boreholes were terminated by refusal on probable boulders below the cohesionless deposits from west to east end at depths of 10.2 and 10.1 m, elevation 251.4 and 251.9, respectively, below the anticipated northbound culvert subgrade level and soft or loose soils are not anticipated below those levels at the culvert location.

The measured groundwater levels (upon completion of drilling) were contacted 4.3 to 8.3 m below the anticipated culvert subgrade levels at the time of investigation. Perched water was found 1.6 to 5.2 m below the subgrade levels of the culvert.

## **2.1 Concrete Box Culvert**

The concrete box culvert subgrade soils at the anticipated average elevation 261.8 includes the existing uncontrolled embankment fill that is not considered to be adequate to support the proposed culvert. The subgrade preparation for the culvert should include removal of the fill and replacement with structural fill which should be carried out as recommended in Section 2.3.1 of this report.

It is considered that the structural fill (approximately 1.9 to 2.1 m thick compacted OPSS 1010 Granular A or Granular B Type II material) and the underlying cohesionless soils that are in the zone of influence are considered capable of adequately supporting the stress imposed by the concrete box culvert.

Since the average final grade raise is only 2.4 m compared to the average excavation for culvert construction of 4.5 m, there will be a net unloading of 2.1 m of the existing overburden pressure. Consequently, it is anticipated that there will only be a 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 average 2.0 m thick structural fill (Granular A or Granular B Type II fill) over loose to compact native sandy silt/silt are as follows:

CULVERT SECTION	SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Entire NBL Section	Structural fill over native soil	900	350

The geotechnical resistance at SLS normally allows for 25 mm compression of the founding medium. As previously indicated in Section 2.1 only negligible settlements are anticipated.

## **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.



The 1.9 to 2.1 m thick uncontrolled fill unit found below the culvert subgrade level in borehole CSN-1 and CN-2 should be completely excavated along the proposed northbound culvert alignment to the underlying native silt deposits at elevations 259.6 to 260.1.

The excavated soils should be replaced with structural fill made of 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 of the structural fill should follow the OPSS 501. The structural fill should be compacted to 100% of the ASTM D-698 (standard Proctor maximum dry density) in conformance to OPSS 501 (Method A).

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 are as follows:

SOIL TYPE	MODULUS OF SUBGRADE REACTION MN/m <sup>3</sup>
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 <sup>3</sup> )
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 site 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:

$$P = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where  $K$  = lateral earth pressure coefficient

$\gamma$  = unit weight of free draining granular material above the design water level ( $\text{kN/m}^3$ )

$\gamma'$  = unit weight of backfill submerged below the design water level ( $\text{kN/m}^3$ )

$h_1$  = depth below final grade (m), above the design water level

$h_2$  = depth below the design water level (m)

$q$  = any surcharge load ( $\text{kN/m}^2$ )

$\gamma_w$  = unit weight of water equal to  $9.8 \text{ kN/m}^3$

$C_p$  = compaction pressure (refer to clause 6.9.3 of CHBDC)

$C_s$  = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)

where  $\emptyset$  = angle of internal friction of retained soil ( $35^\circ$  for Granular A or Granular B, Type II)

$\delta$  = angle of friction between soil and wall ( $23.5^\circ$  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 <sup>3</sup>	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 to 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 the fill material encountered in the borehole CSN-1, the existing fill should be removed and replaced with structural fill and the wall should be designed and constructed using the geotechnical resistances recommended in Section 2.2 of this report. Alternatively, retaining wall may be designed and constructed at deeper depth on compact native silt soil using 150 kPa of geotechnical reaction at SLS and 225 kPa of geotechnical bearing resistance at ULS. 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 footing.

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 culvert 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 1.6 to 5.2 m below the subgrade of the culvert (elevations 257.0 and 259.9). The permanent groundwater table is inferred to be below the subgrade of the culvert. Subject to the perched water and measured groundwater upon completion of drilling condition, no groundwater problem is anticipated during culvert construction and construction of cast-in-place headwalls and wingwalls that are designed separately.

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. It should be noted that the groundwater levels are subject to seasonal fluctuations and precipitation patterns. However, the contractor is responsible for the groundwater control of excavations.

## **7. EMBANKMENT FILL**

Due to westerly shift of the centreline, the height of the embankment will be increased up to 3.0 m to accommodate the proposed grade rise.

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  $\mu\text{m}$  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 OPSS 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

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



**TABLE 1**  
**LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT**

<b>DOCUMENT</b>	<b>TITLE</b>
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