Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT
for
HIGHWAY 400 BAYFIELD STREET STORM DRAIN INSTALLATION AND CULVERT EXTENSION
RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-002
BARRIE, ONTARIO
G.W.P. 2100-13-00

PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO

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Index No.: 010FIR and 011FDR
GEOCRES No.: 31D-582
November 17, 2014

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for
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Installation and Culvert Extension
Retainer Assignment – Task No. 2013-E-0039-002
Barrie, Ontario
GWP 2100-13-00

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1. INTRODUCTION

This report summarizes the results of a foundation investigation carried out on Highway 400 near Bayfield Street for the installation of a new storm sewer, replacement of an existing storm sewer and extension of an existing culvert. The site is located in the City of Barrie, Ontario. The study was carried out by Peto MacCallum Ltd. (PML) for the Ministry of Transportation of Ontario (MTO).

The purpose of this report is to summarize the subsurface stratigraphy encountered at the site of the proposed works during the investigation.

2. SITE DESCRIPTION AND GEOLOGY

The site lies on the west side of Highway 400 between the Highway 400 southbound E/W-S ramp at Bayfield Street and Sunnidale Road in the City of Barrie. Land use in the vicinity of the site includes the Highway 400 transportation corridor, a stormwater control facility with a large berm west of the transportation corridor and dense stands of trees beyond the berm to the west. A channel from the stormwater control facility extends between the existing box culvert under Highway 400 and the stormwater control facility culvert outlet.

The local topography is undulating but generally governed by the Highway 400 transportation corridor. The ground surface is generally slopes downwards from the north to the south and also slopes downwards both east and west of the existing Highway 400 embankment. West of Highway 400 ditch line the ground slopes upwards towards the top of the large berm.

The project site is located within the physiographic region known as the Simcoe Uplands. The Simcoe Uplands comprise a series of broad, rolling glacial till plains (locally sand till), separated by steep-sided flat floored valleys.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out on July 13, 2014 and comprised 4 boreholes drilled to depths of 3.4 to 3.5 m for the proposed storm drain installation (BH's 2 to 5 inclusive), and 2 boreholes drilled to depths of 9.6 and 19.1 m for the proposed culvert extension and storm sewer replacement (BH's 1 and 1A). The locations of the boreholes are shown on appended Drawings B-1 and B-2.

The borehole locations were strategically located to provide soils data for the proposed works while minimizing the impact on the existing Highway 400 traffic. The borehole locations and elevations were surveyed in the field by Rudy Mak Surveying. All elevations in this report are expressed in metres.

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

Standard penetration tests and dynamic cone penetration test were conducted to assess the strength characteristics of the substrata. Soil samples were recovered from the boreholes at regular 0.75 and 1.5 m intervals following standard penetration testing. Soils were identified in accordance with 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.

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

The recovered soil samples were returned 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 (46)
- Grain size distribution analyses (11)
- Atterberg limit test (3)

The figures prepared to present the results of the laboratory grain size distribution analyses and Atterberg Limit Test are presented in Figures B-GS-1 to B-GS-5 and B-PC-1 to B-PC-2, respectively. 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 1A and 1 to 5 for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration test data, dynamic cone penetration test data and groundwater observations. The results of laboratory grain size distribution analyses, Atterberg limit test and moisture content determinations are also shown on the Record of Borehole sheets.

The borehole locations and stratigraphic profile prepared from the borehole data are shown on Drawings B-1 and B-2. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, these boundaries are assumed and may vary.

In summary, the subsurface stratigraphy revealed in borehole 1A drilled at the culvert extension location, comprised a 1.4 m thick surficial silty sand and topsoil layer over a 3.3 m thick compact sand deposit, above a 4.9 m thick very stiff clayey silt deposit. At the embankment location, directly east of the proposed culvert extension, borehole 1 revealed a 10 m thick compact to dense sand fill layer, above a 2.5 m thick very stiff clayey silt layer, overlying an approximately 7.6 m thick compact to very dense sand deposit. At the location of the culvert extension, the slope is covered by large boulders with diameters in the order of 1 m.

Boreholes 2 to 5, drilled for the proposed storm drain along the Hwy 400 west shoulder generally revealed pavement structure (locally topsoil in borehole 5) over sand or sand till to the 3.4 to 3.5 m exploration depth.

Details of the soil stratigraphy are provided below:

4.1 Pavement Structure

The pavement structure encountered in boreholes 1 to 4 which were drilled through Highway 400 and the Highway 400 E/W-S ramp, included 150 and 250 mm of asphaltic concrete, underlain by 520 to 650 mm of sand and gravel.

4.2 Topsoil

A 100 mm thick layer of topsoil was encountered at the surface at BH#5 and extended to elevation 259.9. A 400 mm thick layer of topsoil was also encountered beneath the silty sand fill at 1.0 m (elevation 244.1) at BH#1A that extended to a for a thickness of 1.4 m (to elevation 243.7).

4.3 Fill

A 0.7 to 9.1 m thick fill unit was encountered beneath the pavement structure at depths of 0.7 and 0.9 m (elevation 254.7 and 251.5) in boreholes 2 and 1, respectively. The fill was also contacted beneath the topsoil at a depth of 0.1 m (elevation 259.9) in borehole 5 and surficially in borehole 1A. The fill unit extended for a thickness of approximately 10.0 m (elevation 242.4) in borehole 1 and for thicknesses ranging from 0.5 m to 1.4 m (elevation 244.1 to 259.5) in boreholes 1A, 2 and 5. The fill was typically loose to compact, with SPT-‘N’ values ranging from 7 to 28. However the fill was locally very loose and dense in borehole 1 and 1A. The fill was moist to wet with moisture contents of 5 to 23%. Clayey silt layers, topsoil layers, cobbles and boulders and organic inclusions were noted within the fill. The results of an Atterberg Limit Test performed on a sample of the fill is presented on Figure B-PC-1 and the results of grain size distribution analyses performed on 4 samples of the fill are presented on Figures B-GS-1 and B-GS-2.

4.4 Clayey Silt

A 2.5 and 4.9 m thick clayey silt deposit was contacted beneath the fill at depth of 10.0 m (elevation 242.4) in borehole 1 and beneath the sand at a depth of 4.7 m (elevation 240.4) in borehole 1A. The clayey silt extended to a depth of 12.5 m (elevation 239.9) in borehole 1 and to a depth of greater than 9.6 m (below elevation 235.5), which was the termination depth in borehole 1A. The clayey silt was typically very stiff (locally hard at the bottom of borehole 1A) with SPT-'N' values of ranging from 17 to 27.

The results of grain size distribution analyses and Atterberg Limit Tests performed on two samples of the clayey silt are presented on Figures B-GS-3 and B-PC-2, respectively. Atterberg Limit Testing indicated that the clayey silt had liquid limits ranging from 25 to 28, plastic limits ranging from 14 to 15, and plasticity indices ranging from 11 to 13. The moisture content of the clayey silt was between the plastic limit and liquid limit with moisture contents ranging from 18 to 24%.

4.5 Sand

A 2.1 to 6.6 m thick sand deposit was contacted beneath the clayey silt at a depth of 12.5 m (elevation 239.9) in borehole 1, beneath the topsoil at a depth of 1.4 m (elevation 243.7) in borehole 1A and beneath the fill at a depth of 1.4 m (elevation 254.0) in borehole 2. The sand extended to the clayey silt at 4.7 m (elevation 240.4) in borehole 1A and to the 3.5 and 19.1 m (elevation 251.9 and 233.3) exploration depth in boreholes 2 and 1, respectively. The sand was loose to very dense with SPT-'N' values of 8 blows to 83 blows for 23 cm. The material was wet in boreholes 1 and 1A (moisture contents ranging from 18 to 23%) and moist in borehole 2 (moisture contents ranging from 3 to 6%). The results grain size distribution analyses performed on 3 samples of the sand are presented on Figure B-GS-4.

4.6 Sand Till

A 2.7 to 3.0 m thick sand till layer was contacted beneath the pavement structure at depths of 0.5 and 0.7 m (elevations 256.1 to 259.5) in boreholes 3 to 5 that extended to depths of 3.4 to 3.5 m (elevation 253.4 to 256.5, which was the borehole exploration depth. The till was typically compact to very dense, although locally loose in the upper portion of the layer in borehole 5, with SPT-'N' values typically between 21 and 106. The till was moist, having moisture contents of 3 to 14%. Cobbles and boulders were noted within the layer. The results of grain size distribution analyses performed on 3 samples of the layers are presented on Figure B-GS-5.

4.7 Groundwater

In the process of augering, water strikes were observed at depths of 1.5 and 8.8 m (elevation 243.6) and in boreholes 1A and 1 respectively. Upon completion of augering, groundwater was measured at a depth of 1.5 m (elevation 243.6) in boreholes 1A.

The water level in the stormwater drainage channel at the location of the proposed culvert extension and adjacent to borehole 1A was at elevation 243.7 on July 13, 2014.

The groundwater levels at the site are subject to seasonal fluctuation.

5. CLOSURE

Mr. A. Lo and Mr. P. Portela carried out the field investigation for this study under the supervision of Mr. A. DeSira, MEng, P.Eng. Walker Drilling supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This Foundation Investigation report was prepared by Mr. A. DeSira, MEng, P.Eng., and reviewed by Mr. D. Dundas, P.Eng. Mr. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact conducted a quality review of the report.

Yours very truly

Peto MacCallum Ltd.

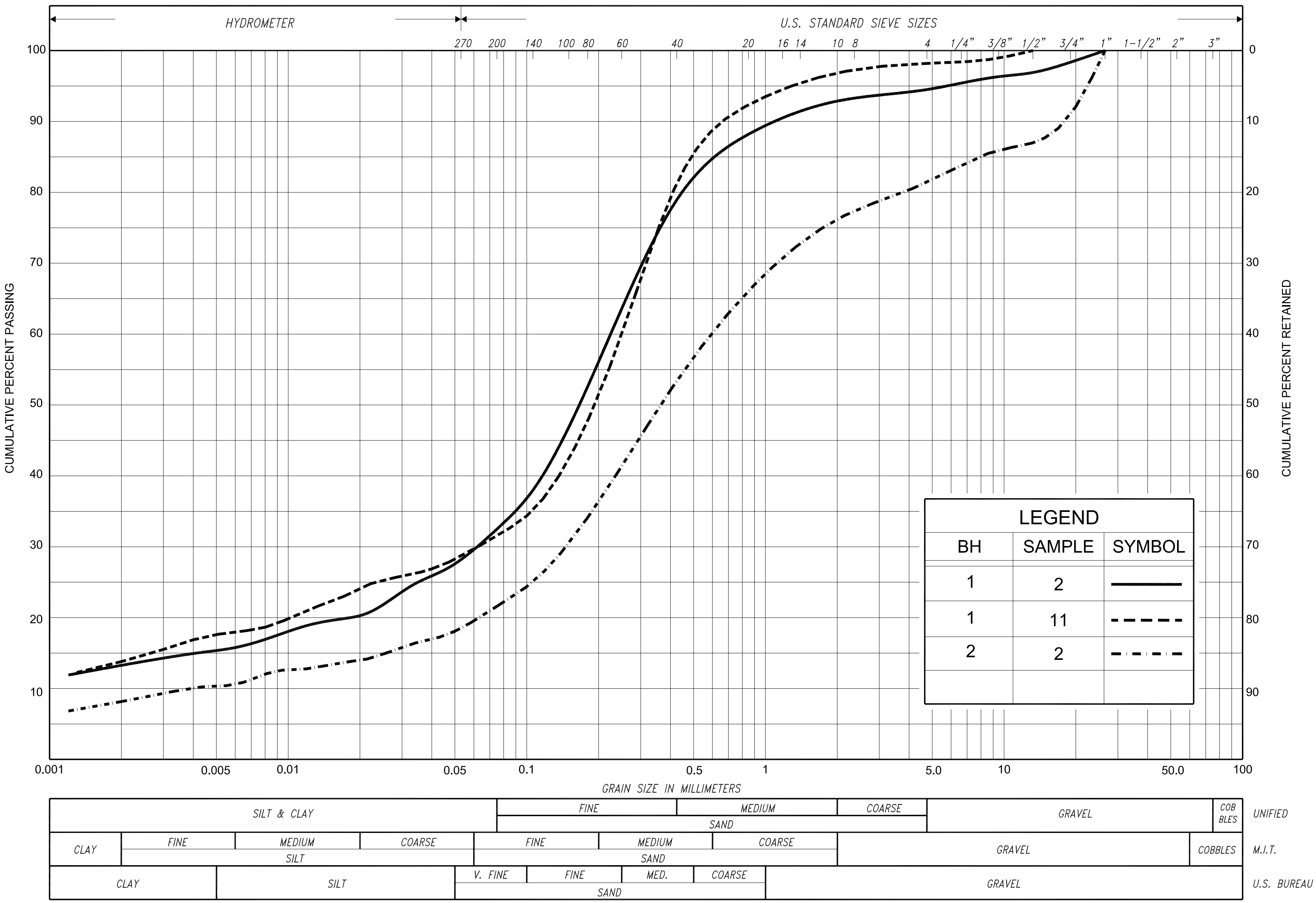
LICENSED PROFESSIONAL ENGINEER
D. H. DUNDAS
November 24, 2014
PROVINCE OF ONTARIO

David Dundas, P.Eng.
Senior Engineer, Geotechnical Services

REGISTERED PROFESSIONAL ENGINEER
C M P Nascimento
Nov. 24, 2014
PROVINCE OF ONTARIO

Carlos Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

AD/CN:ad-mi-nk

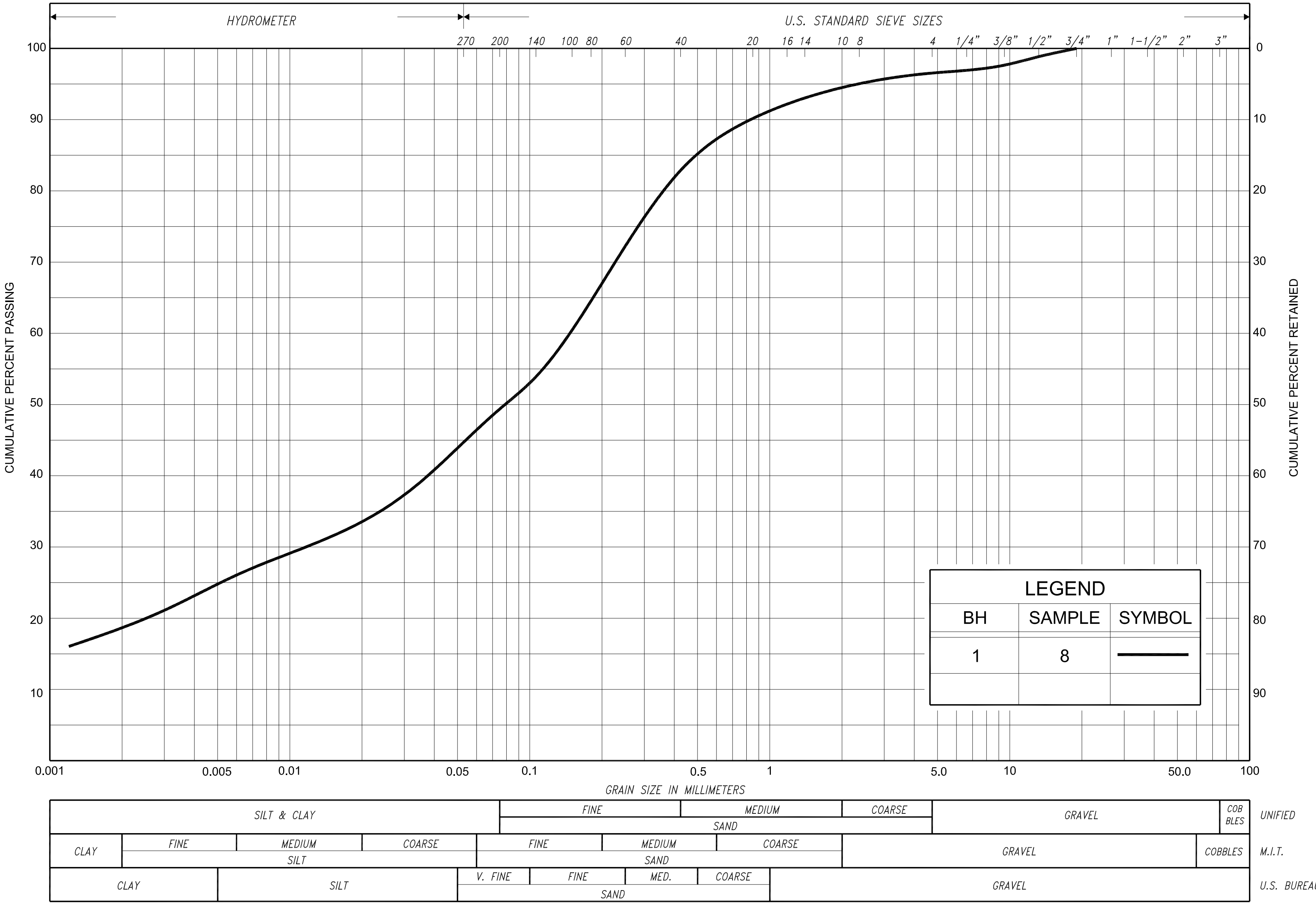


Ontario

GRAIN SIZE DISTRIBUTION

SAND, some silt, trace to some clay, trace to some gravel
(FILL)

FIG No.	B-GS-1
HWY:	400
W.P. No.	2100-13-00

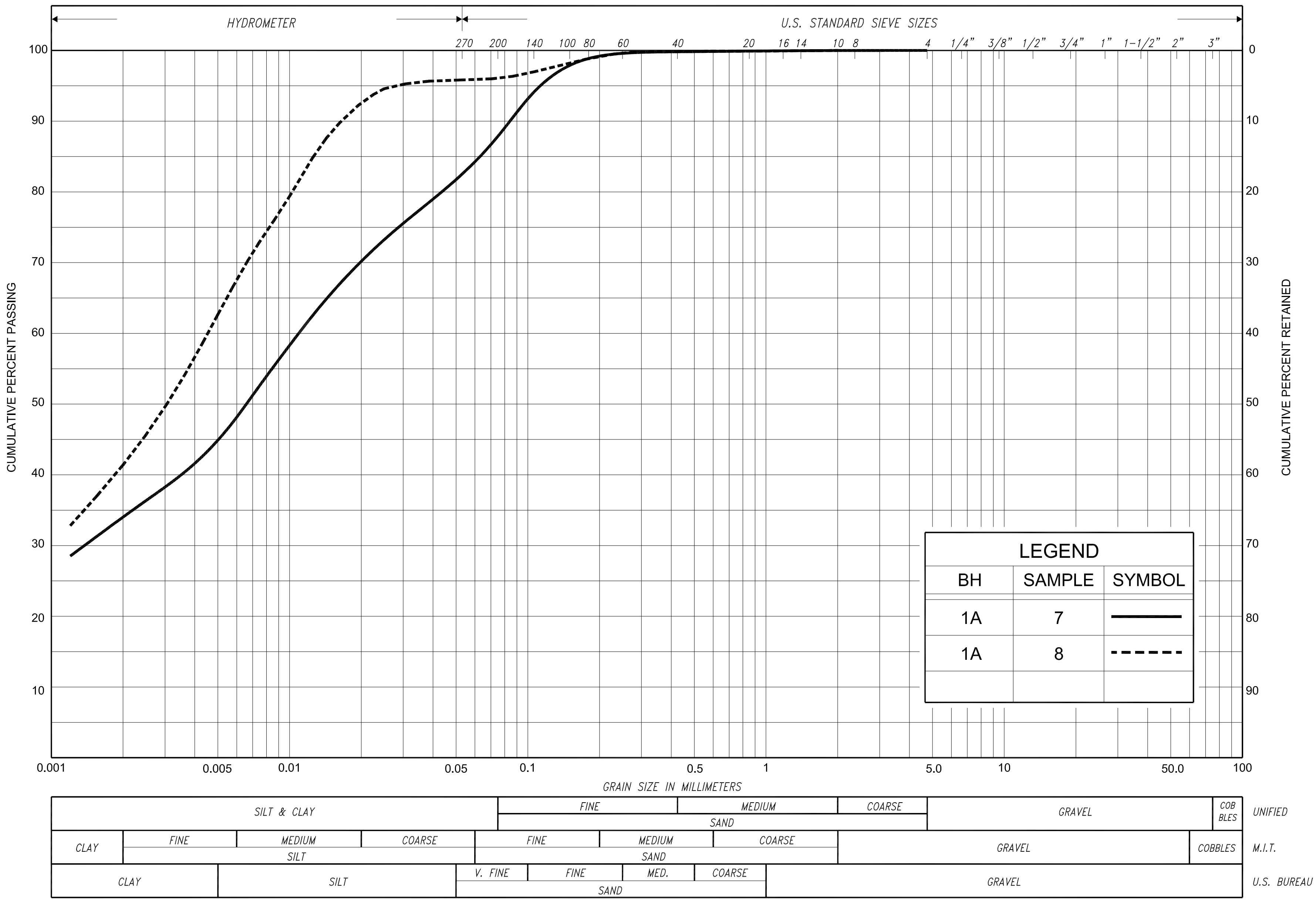


Ontario

GRAIN SIZE DISTRIBUTION

SANDY CLAYEY SILT, trace gravel (CL-ML)
(FILL)

FIG No.	B-GS-2
HWY:	400
W.P. No.	2100-13-00

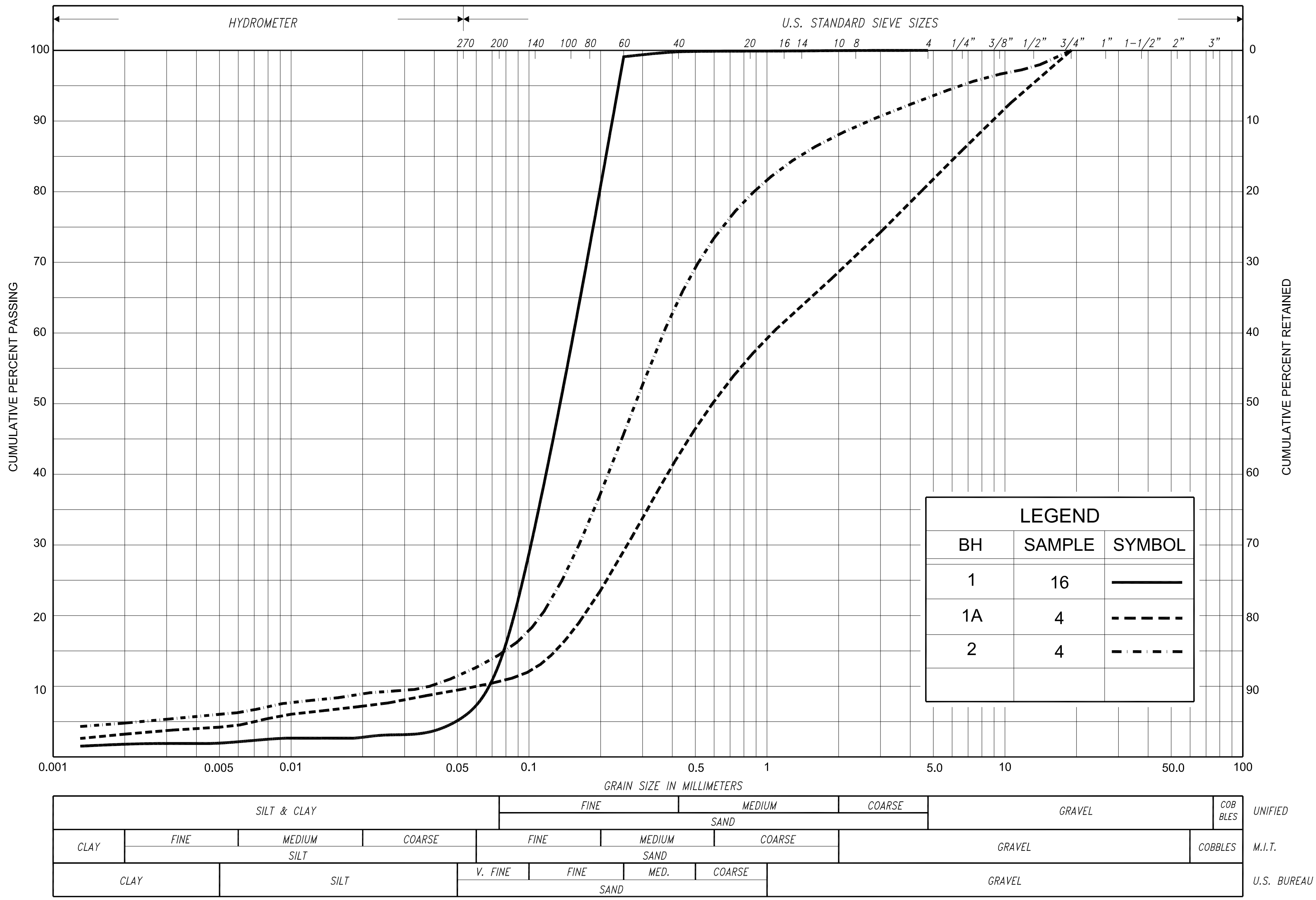


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace to some sand (CL)

FIG No.	B-GS-3
HWY:	400
W.P. No.	2100-13-00

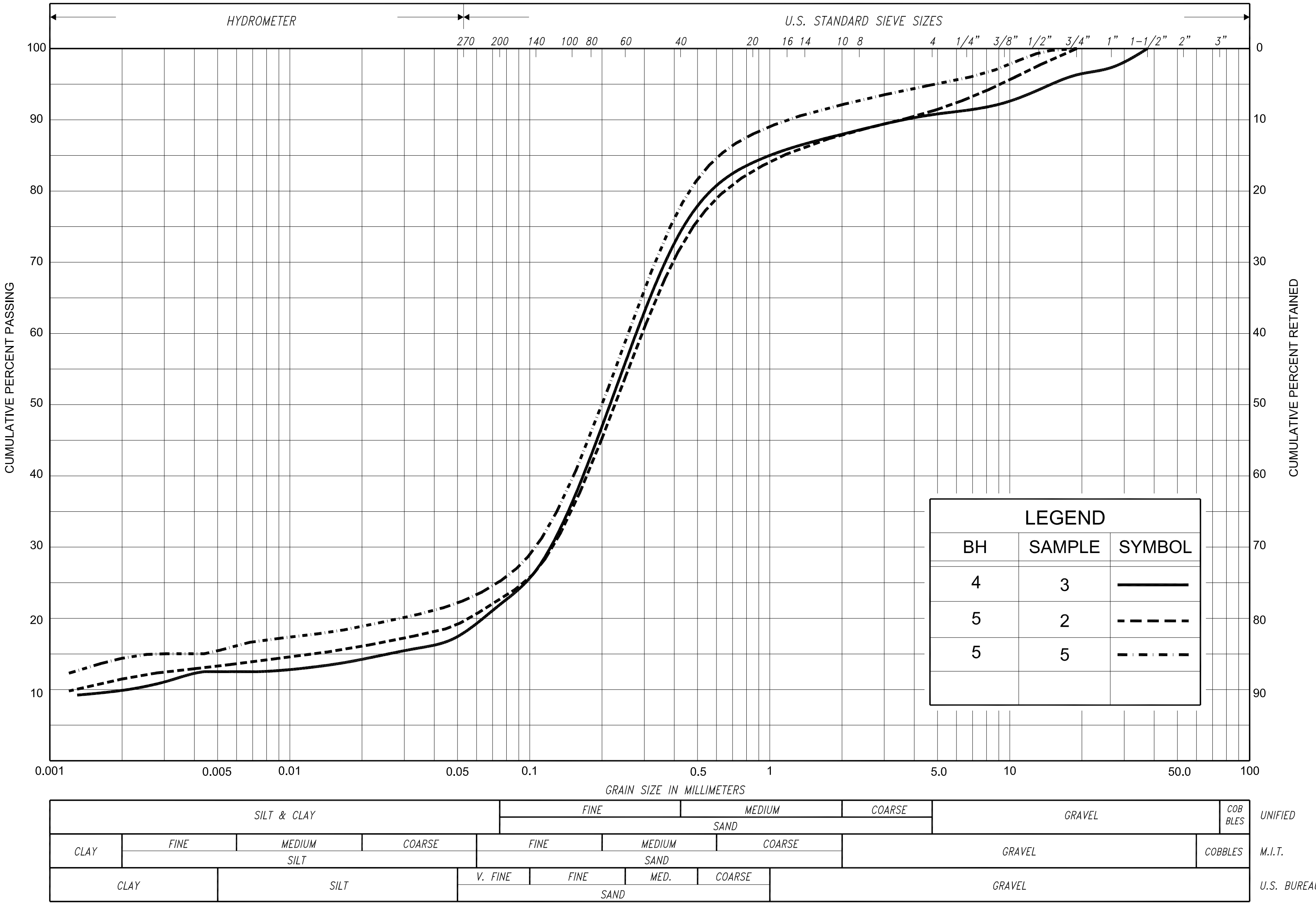


Ontario

GRAIN SIZE DISTRIBUTION

SAND, trace to some gravel, trace to some silt, trace clay

FIG No.	B-GS-4
HWY:	400
W.P. No.	2100-13-00

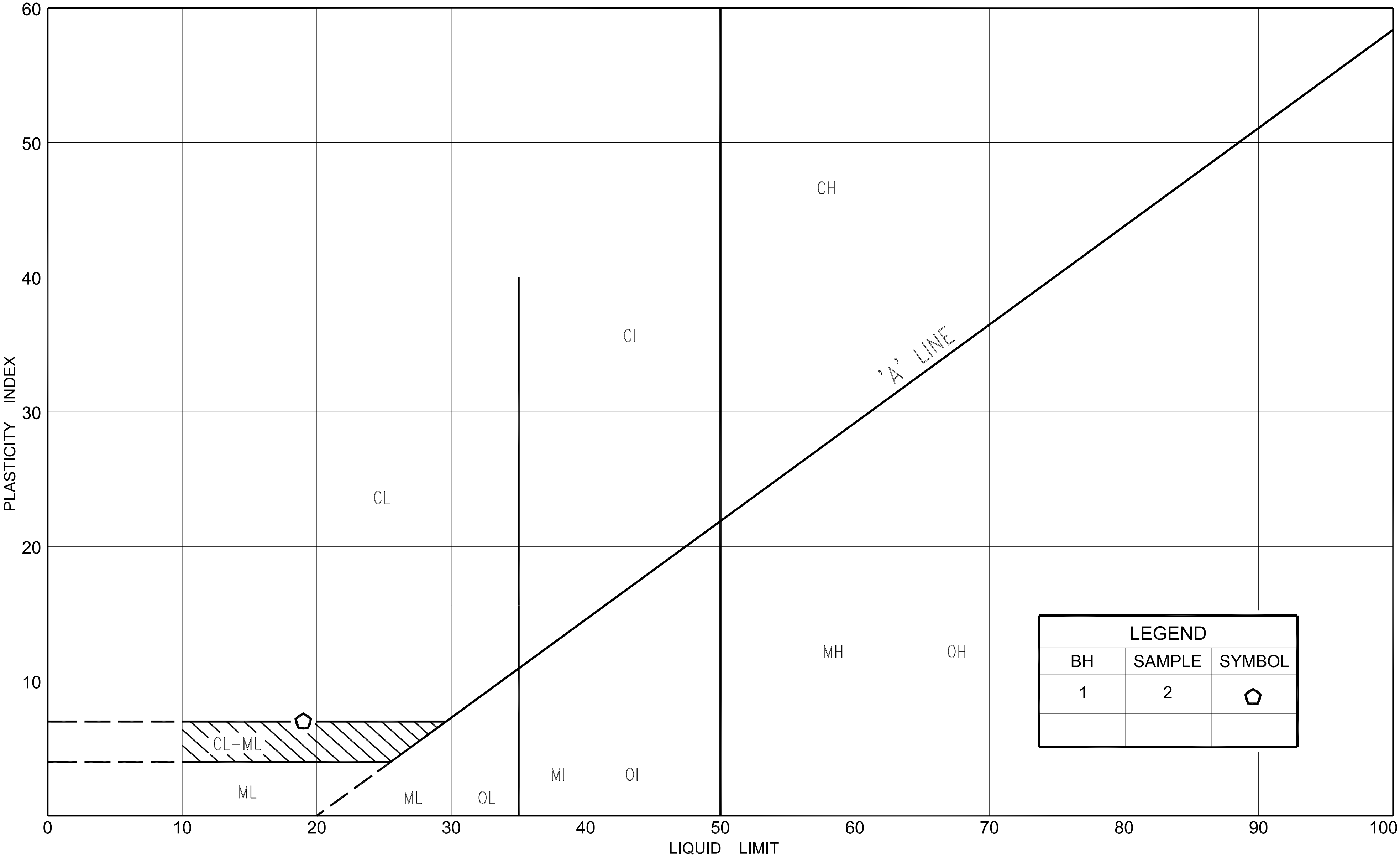


Ontario

GRAIN SIZE DISTRIBUTION

SAND, some silt, some clay, trace gravel
(TILL)

FIG No.	B-GS-5
HWY:	400
W.P. No.	2100-13-00



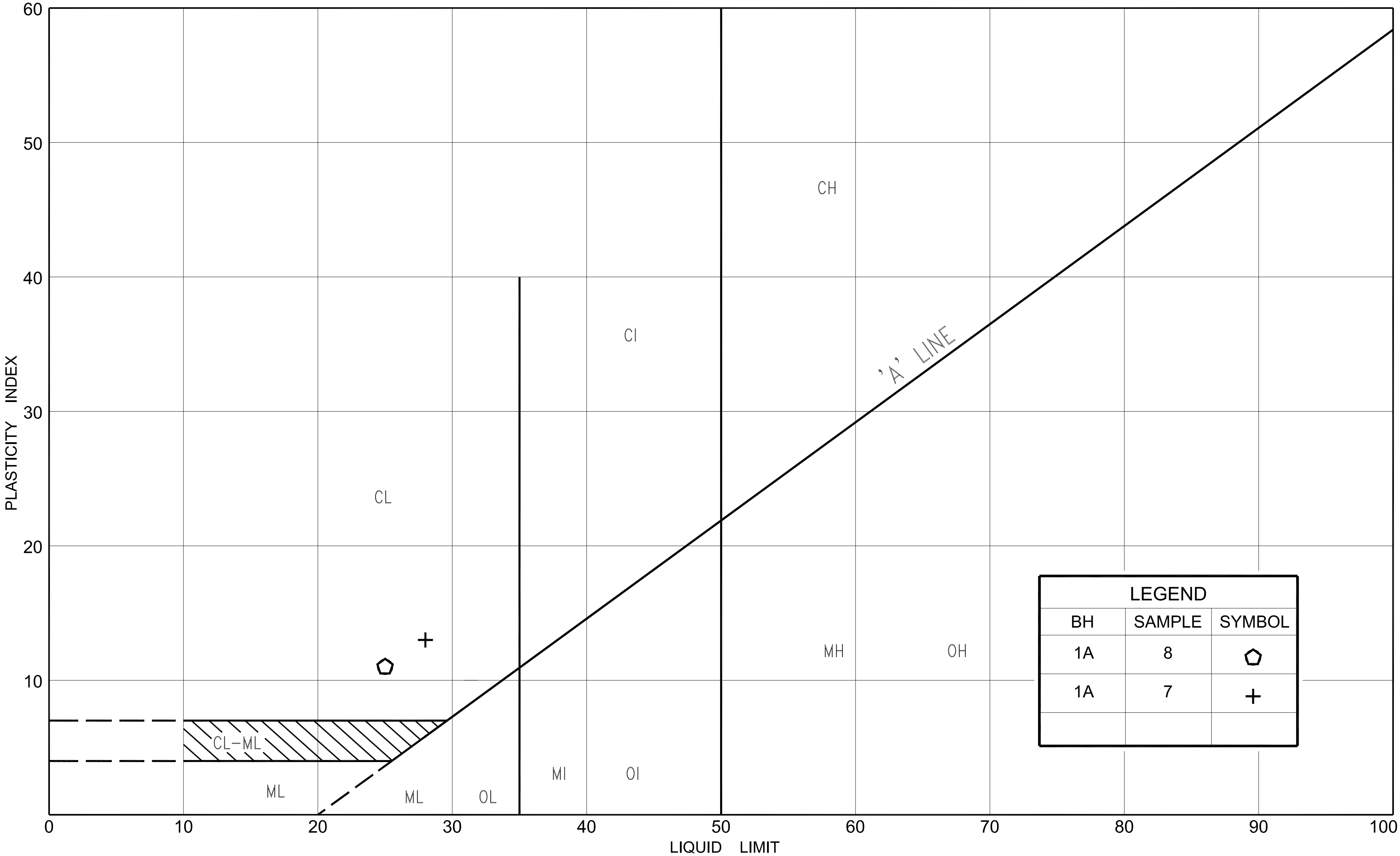
LEGEND		
BH	SAMPLE	SYMBOL
1	2	⬠

PLASTICITY CHART

SANDY CLAYEY SILT, trace gravel (CL-ML)
(FILL)

FIG No.	B-PC-1
HWY:	400
W.P. No.	2100-13-00

Ontario



Ontario

PLASTICITY CHART

CLAYEY SILT, trace to some sand (CL)

FIG No.	BR-PC-2
HWY:	400
W.P. No.	2100-13-00

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 (RQD), 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

Ontario

Peto MacCallum Ltd.
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Foundation Design

RECORD OF BOREHOLE No. 1

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 125.1 N ; 288 637.8 E **ORIGINATED BY** A.L.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
252.4	Ground Surface
0.0	250mm aspahlt over 650mm sand and gravel (PAVEMENT FILL)
251.5 / 0.9	Sand, some silt some clay, trace gravel cobbles and boulders Dense to compact Brown/ grey Moist clayey silt layer sand layer topsoil inclusions Black clayey silt seams/layer clayey silt layer Wet Organic sand Black (FILL)
242.4 / 10.0	Clayey silt, trace sand Very stiff Grey Moist
239.9 / 12.5	Sand some silt, trace clay Compact Grey Wet Cont'd

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	18		
2	SS	47		6 61 19 14
3	SS	28		
4	SS	14		
5	SS	22		
6	SS	16		
7	SS	18		
8	SS	17		3 48 31 18
9	SS	33		
10	SS	15		
11	SS	3**	▽*	2 66 18 14
12	SS	31		
13	SS	17		
14	SS	18		
15	SS	22		
16	SS	30		0 87 11 2

ELEVATION SCALE: 252, 251, 250, 249, 248, 247, 246, 245, 244, 243, 242, 241, 240, 239, 238

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

+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. 1

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 125.1 N ; 288 637.8 E **ORIGINATED BY** A.L.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100)	WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.4	Sand, some silt Compact Grey Wet (Cont'd.)										
			17	SS	11		237		w ≈ 21		
	Very dense						236				
			18	SS	83/23cm		235		w ≈ 19		
			19	SS	17**		234		w ≈ 20		
233.5 18.9	End of borehole							120/23cm			
233.3 19.1	Switched to dynamic cone penetration test Probable sand Very dense End of dynamic cone penetration test										

* 2014 07 13

▽ Water level observed during drilling

** Low 'N' values due to possible hydraulic disturbance during drilling

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L.

+7, ×5 : Numbers refer to Sensitivity; 20 / 15 —○— 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No. 1A

METRIC

G.W.P. 2100-13-00	**LOCATION** Co-ords. 4 917 133.1 N ; 288 616.7 E		**ORIGINATED BY** F.P.
DIST Central	**HWY** 400	**BOREHOLE TYPE** Continuous Flight Solid Stem Augers	**COMPILED BY** A.D.
DATUM Geodetic	**DATE** July 13, 2014		**CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
245.1	Ground Surface					245						
0.0	Silty sand topsoil and clayey silt inclusions (FILL)	1	SS	1			~16					
244.1 / 1.0	Topsoil	2	SS	4		244	~30					
243.7 / 1.4	Sand, some gravel trace silt, trace clay. Loose to compact, Grey, Wet				▽* ▼*							
		3	SS	18		243						
		4	SS	29			~12		19	70	8	3
		5	SS	8		242						
		6	SS	14		241	~21					
240.4 / 4.7	Clayey silt trace to some sand. Very stiff, Grey, Moist	7	SS	20		240	wP–w–wL plotted		0	12	54	34
		8	SS	23		239	wP–w–wL plotted		0	4	54	42
		9	SS	27		238 / 237	~21					
	Hard	10	SS	61		236	~21					
235.5 / 9.6	End of borehole											

* 2014 07 14

▽ Water level observed during drilling

▼ Water level measured after drilling

Legend: 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); REMARKS & GRAIN SIZE DISTRIBUTION (%)

+7, ×5 : Numbers refer to Sensitivity

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

Ontario

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Foundation Design

RECORD OF BOREHOLE No. 2

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 249.8 N ; 288 705.0 E **ORIGINATED BY** F.P.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	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)	WATER CONTENT (%) (PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.4	Ground Surface										
0.0	180mm asphalt over 520mm sand and gravel (PAVEMENT FILL)						255				
			1	SS	14				○		
254.7 / 0.7	Sand, some silt some gravel, trace clay. Compact to loose. Brown. Moist (FILL)		2	SS	9				○		18 60 14 8
254.0 / 1.4	Sand, trace silt trace clay, trace gravel. Compact to very dense. Grey. Moist						254				
			3	SS	17				○		
			4	SS	32		253		○		7 79 9 5
251.9 / 3.5	End of borehole. Refusal on probable bedrock		5	SS	58		252		○		

* Borehole dry

+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. 3

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 307.2 N ; 288 737.2 E **ORIGINATED BY** F.P.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.8	Ground Surface					*				
0.0	150mm asphalt over 550mm sand and gravel (PAVEMENT FILL)		1	SS	21					
256.1 / 0.7	Sand, some silt some clay, trace gravel sand layers		2	SS	21		256			
	Compact to very dense Grey Moist		3	SS	79		255			
	(TILL)		4	SS	106		254			
	clayey silt layers									
253.4 / 3.4	End of borehole		5	SS	60/15cm					

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

* Borehole dry

+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. 4

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 371.3 N ; 288 771.9 E **ORIGINATED BY** F.P.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
258.2	Ground Surface				*						
0.0	150mm asphalt over 550mm sand and gravel (PAVEMENT FILL)	1	SS	14		258	○				
257.5 / 0.7	Sand, some silt some clay, trace gravel; Dense to very dense; Grey; Moist (TILL)	2	SS	49		257	○				
		3	SS	62			○	9	69	12	10
		4	SS	65		256	○				
254.7 / 3.5	End of borehole	5	SS	90		255	○				

* Borehole dry

Legend: 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 (%)

+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. 5

METRIC

G.W.P. 2100-13-00 **LOCATION** Co-ords. 4 917 443.4 N ; 288 807.5 E **ORIGINATED BY** F.P.

DIST Central **HWY** 400 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** A.D.

DATUM Geodetic **DATE** July 13, 2014 **CHECKED BY** D.D.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
260.0	Ground Surface				*							
259.9 / 0.1	Topsoil											
259.5 / 0.5	Silty sand, topsoil inclusions; Loose, Brown, Moist (FILL)	1	SS	7			○					
	Sand, some silt, some clay, trace gravel; Loose to very dense, Grey, Moist; cobbles and boulders (TILL)	2	SS	7		259	○		9	68	11	12
		3	SS	20/8cm		258						
		4	SS	77		257	○					
256.5 / 3.5		5	SS	103			○		5	70	11	14
	End of borehole											

* Borehole dry

Legend: 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); REMARKS & GRAIN SIZE DISTRIBUTION (%)

+7, ×5 : Numbers refer to Sensitivity

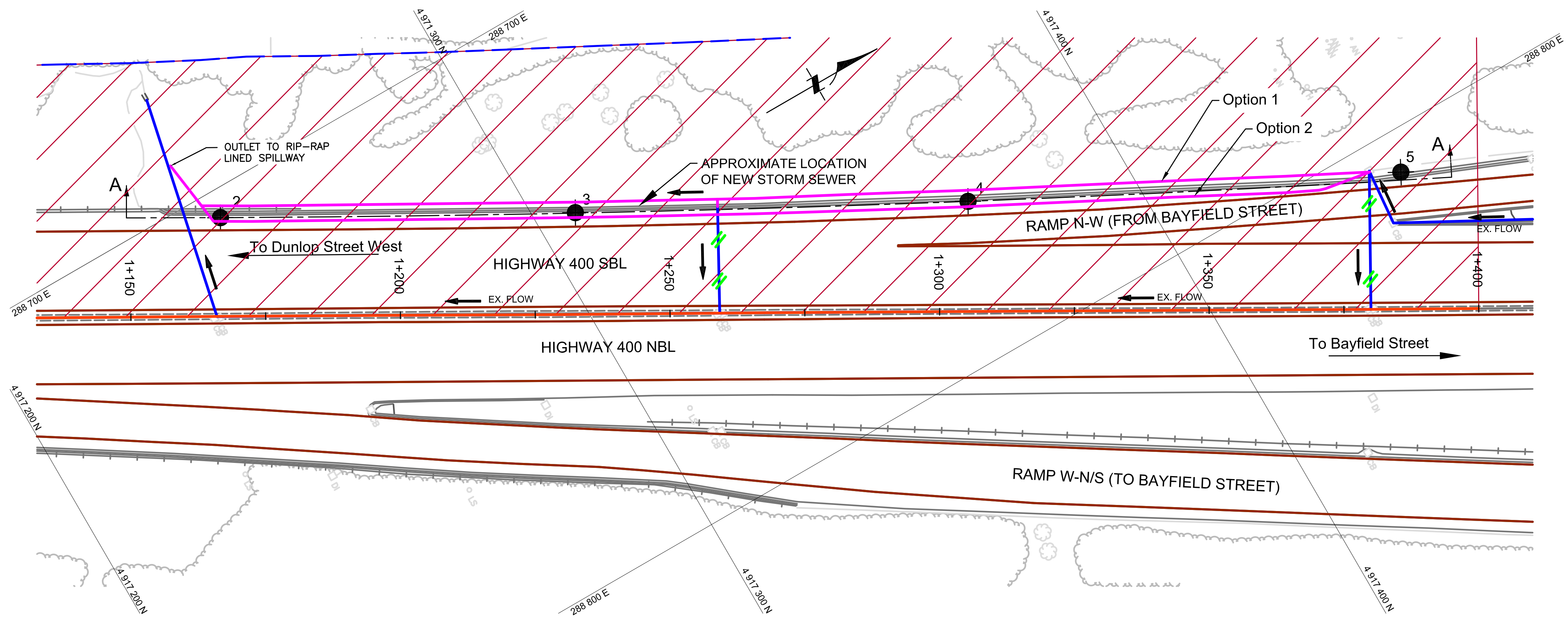
20 / 15 — ○ — 5 / 10 (%) STRAIN AT FAILURE

TASK No. 2013-E-0039-0002
WP No 2100-13-00

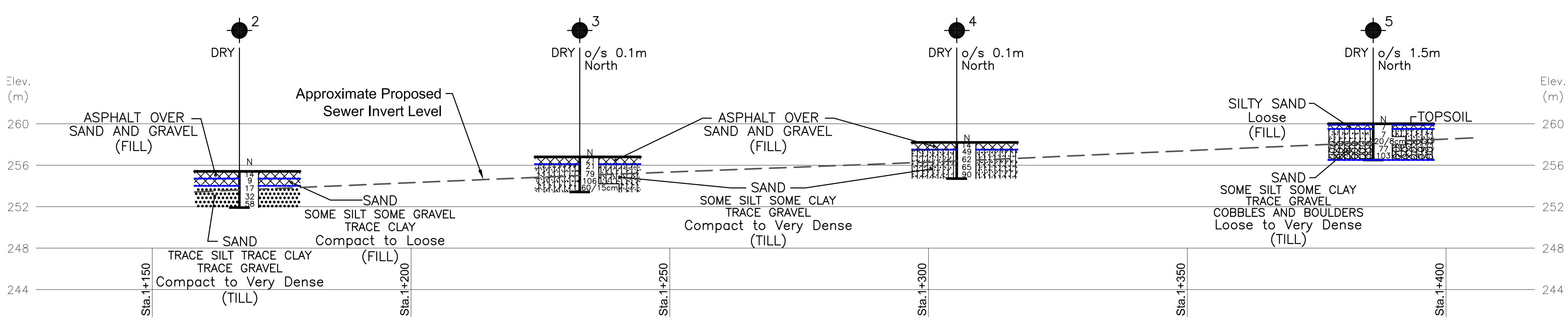
BAYFIELD STORM SEWER
HIGHWAY 400
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

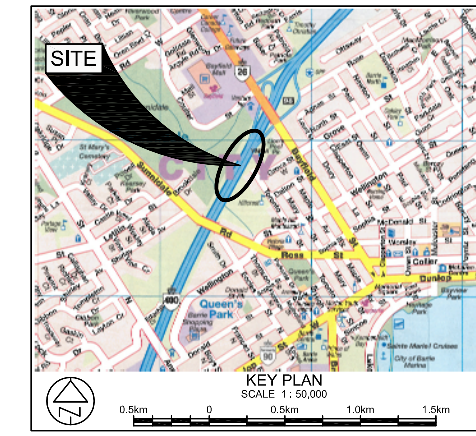
Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN
SCALE



PROFILE A - A
SCALE
HORIZONTAL
VERTICAL



LEGEND

- Borehole
- Borehole and cone
- Cone penetration test
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation June 2014
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	COORDINATES NORTHINGS	COORDINATES EASTINGS
2	255.4	4 917 249.8	288 705.0
3	256.8	4 917 307.2	288 737.2
4	258.2	4 917 371.3	288 771.9
5	260.0	4 917 443.4	288 807.5

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

Reference MTO Drawing:
Bayfield-Plan.dwg; and Base-Gray.dwg both undated

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH RECORD OF BOREHOLES AND REPORT
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.

REVISIONS | DATE | BY | DESCRIPTION

Geocres No. 31D-582

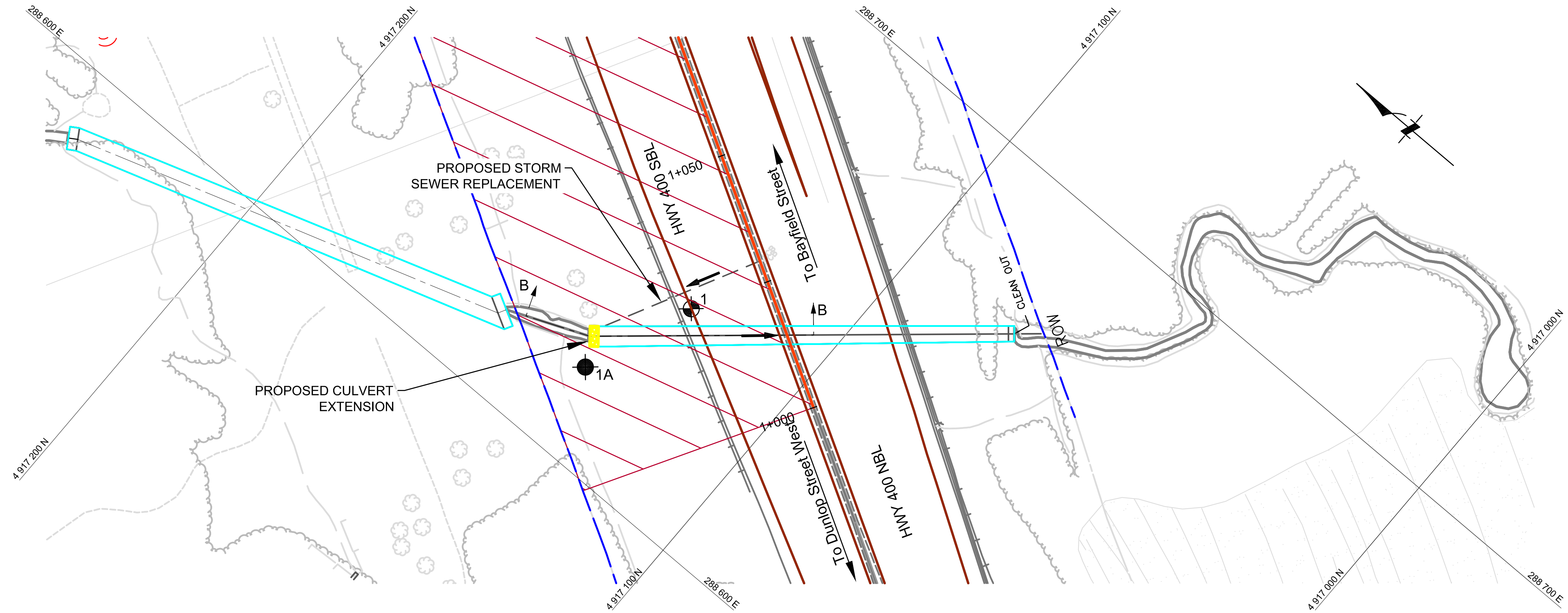
HWY No	400					DIST	CENTRAL
SUBM'D	NA	CHECKED	AD	DATE	NOV. 18, 2014	SITE	
DRAWN	NA	CHECKED	DD	APPROVED	CN	DWG	B-1

TASK No. 2013-E-0039-0002
WP No 2100-13-00

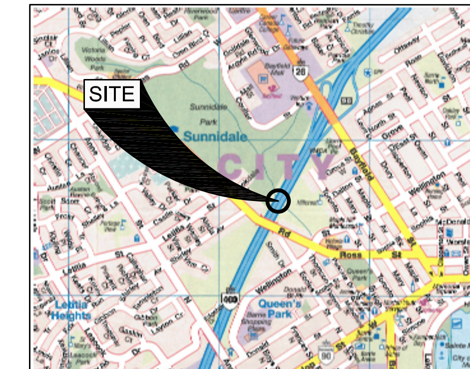
BAYFIELD STORM SEWER
HIGHWAY 400
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN
SCALE
10 0 10 20m

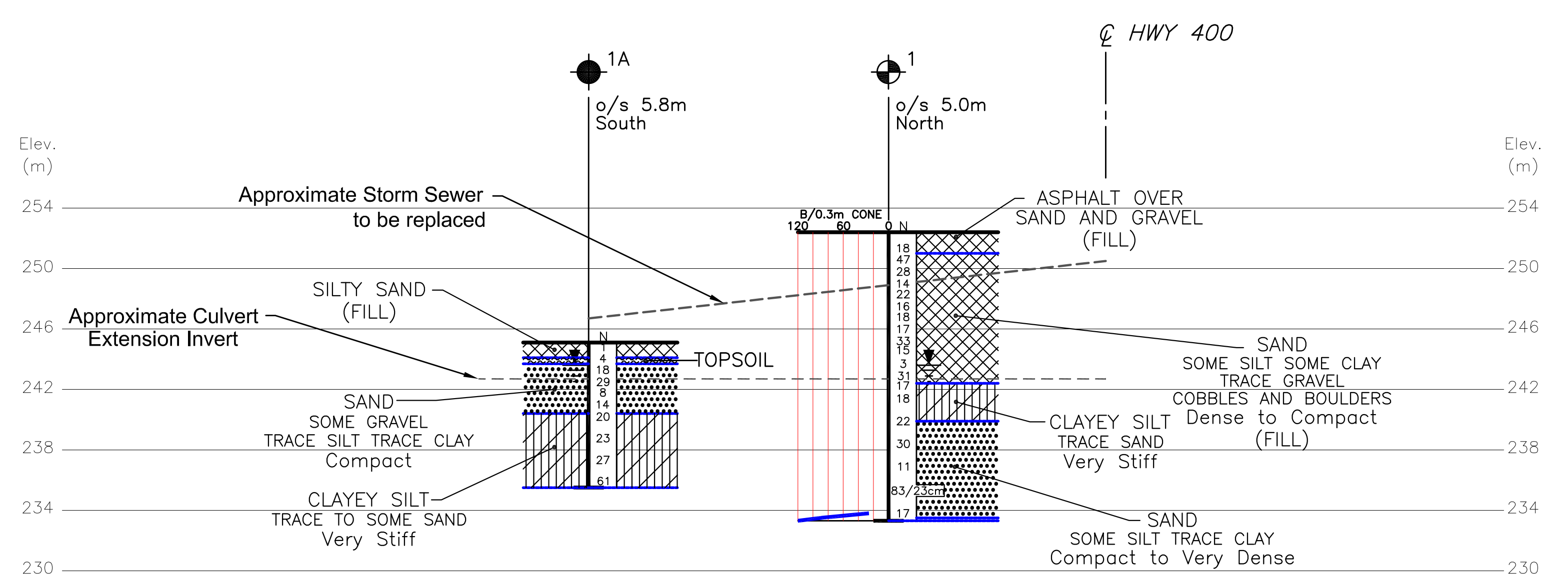


KEY PLAN
SCALE 1 : 50,000
0.5km 0 0.5km 1.0km 1.5km

LEGEND

●	Borehole
⊕	Borehole and cone
⊕	Cone penetration test
N	Blows/0.3m (Std. Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
▽	W L at time of investigation June 2014
▽	Head
	ARTESIAN WATER Encountered
	PIEZOMETER

BH No	ELEVATION	COORDINATES NORTHINGS	COORDINATES EASTINGS
1	252.4	4 917 125.1	288 637.8
1A	245.1	4 917 133.1	288 616.7



PROFILE B - B ALONG ℄ CULVERT
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 RECORD OF BOREHOLES AND REPORT
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.

Reference MTO Drawing:
Bayfield-Plan.dwg; and Base-Gray.dwg both undated

REVISIONS | DATE | BY | DESCRIPTION

Geocres No. 31D-582

HWY No	400					DIST	NORTH BAY
SUBM'D	NA	CHECKED	AD	DATE	NOV. 12, 2014	SITE	
DRAWN	NA	CHECKED	DD	APPROVED	CN	DWG	B-2

Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
HIGHWAY 400 BAYFIELD STREET STORM DRAIN INSTALLATION AND CULVERT EXTENSION
RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-002
BARRIE, ONTARIO
G.W.P. 2100-13-00

PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO

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Index No.: 011FDR
GEOCRES No.: 31D-582
November 17, 2014

TABLE OF CONTENTS

FOUNDATION DESIGN REPORT
For
Highway 400 Bayfield Street Storm Drain
Installation and Culvert Extension
Retainer Assignment – Task No. 2013-E-0039-002
Barrie, Ontario
GWP 2100-13-00

1. INTRODUCTION

This report provides foundation recommendations for the design and construction of the following components sites located between Bayfield Street and Sunnidale Road in Barrie Ontario.

1. Sewers along and across Hwy 400 SBL's and ramp Highway 400 N-W from Bayfield Street (full details of sewer material type, size and depth were not available at the time of reporting) consisting of the following items;

   a. Construction of a new 300 mm diameter concrete storm sewer that will extend for approximately 220 m along ramp Highway 400 N-W from Bayfield Street (from Station 1+380, downstream to Station 1+160), either on the west shoulder or immediately behind the guard rail to be either connected to the existing CSP that extends from the median sewer to outlet on the west side Highway 401 embankment at Station 1+160 or potentially to be outletted directly onto the west side Highway 401 ramp embankment near Station 1+160.

   b. Potential abandonment of 2 existing CSP's (at Station 1+260 and at Station 1+380) that extend from the existing median sewer to outlet at the west side Highway 401 embankment.

   c. Potential replacement of an existing outlet sewer extending from the Highway 400 median to outlet on the west Hwy 400 embankment at Station 1+030 with the east invert near elevation 250.5 m and the west outlet invert near elevation 246.7 m. Based on borehole 1, which was drilled through the Highway 400 embankment near the existing CSP location, it is expected that proposed storm sewer replacement will be founded within the compact to dense sand fill. Groundwater was encountered below the proposed storm sewer at a depth of 8.8 m (elevation 243.6) during augering.

2. Extension of an existing 2.0 m x 1.0 m (width x height) cast-in-place concrete culvert at Station 1+030 by approximately 2 m to the west.

Details for the components identified as 'potential' were not available at the time of reporting and may be beyond the scope of the proposed work.

This report was prepared for the Ministry of Transportation (MTO).

2. GENERAL RECOMMENDATIONS

Refer to the accompanying Foundation Investigation Report for Record of Boreholes illustrating subsurface conditions at borehole locations. The subsurface conditions may vary between boreholes and cobbles and boulders may be present along the planned sewer alignments and at the proposed culvert extension. Refer to Drawings B-1 and B-2 in Foundation Investigation Report for location key plans, location details of proposed installations and associated stratigraphical profiles of subsurface conditions.

Groundwater is not expected to be an issue at the site as all the proposed works are expected to be completed above groundwater level. It is anticipated that any surface run-off or groundwater encountered in excavations can be controlled through conventional sump pumping.

It is expected that temporary protection will be required for open cut installation methods and may be required for tunnelling entry and exit pits. Temporary protection system should be designed by the contractor in accordance with OPSS 539 assuming a minimum performance level 2. The contractor is responsible for the selection, performance and detailed design of the roadway protection.

Earth pressure coefficients provided in Section 4.3 may be used for the design of the temporary protection.

The site is located in Seismic Performance Zone 1. Based on the density of the soils at the site, liquefaction of the subgrade under seismic loading is not anticipated to be a concern for the proposed culvert extension.

All elevations in this report are expressed in metres.

3. SEWERS

Details of sewer pipe material and depth were not available for all proposed installations and work at the time of reporting.

Abandoned cross sewers as described in Section 1.1)b. should be backfilled with hydraulic lean mix concrete to prevent future collapse.

New and replacement sewers can be installed by open cut or by tunnelling.

A range of innovative tunnelling options such as pipe bursting and other innovative techniques were considered but are recommended to be too complex for this project. Consequently, this report focuses on those options that are considered to be appropriate for a site and operation of this nature.

The following table summarizes the advantages, disadvantages, costs and risks of the sewer installation methods considered.

METHOD	ADVANTAGES	DISADVANTAGES	RELATIVE COSTS	RISKS
Open Cut	• Conventional construction	• May require shoring, staged construction and interruption of traffic	• Less than tunnelling options	• Less risk than tunnelling options
Jack and Bore	• Contractor availability • Good for shorter tunnel lengths • Good gradient control	• Requires tunnel shafts • Elevated potential for ground subsidence	• More expensive than open cut depending on shoring requirement	• Conventional installation but more risk than open cut
Pipe Ramming	• Minimal ground water control required along the installation route • Can penetrate soils containing cobbles and boulders	• Requires staging pits • Ground water control is required for the staging pits	• More expensive than open cut depending on shoring requirement	• Conventional installation but more risk than open cut
Horizontal Directional Drilling	• Does not require staging pits • Minimal ground water control required • Alignment can be adjusted to avoid obstructions	• Site grades may require longer bore or staging pits • Potential for inadvertent drilling returns • Larger drilling equipment may be required • Requires drilling fluid to maintain the bore which could allow subsidence	• More expensive than open cut depending on shoring requirement s for open cut	• Conventional installation but more risk than open cut

3.1 Open Cut Installation Method

Installation of the new or replacement storm sewers may be undertaken using open cut installation methods. Open cut may be less feasible for the potential sewer replacement extending from the median to the west embankment described in Section 1. 1)c. than for the other proposed sewers noted due to probable requirements for temporary protection and the possible interruption to traffic that open cutting would require.

3.1.1 Temporary Protection

Temporary excavations can be constructed with side slopes no steeper than 1H:1V. Where road geometry does not permit this excavation geometry, temporary roadway protection would be required. Temporary protection should conform to the requirements of OPSS 539 performance level 2.

3.1.2 Backfill and Bedding

Backfill and bedding for the sewer installed in open cut should be composed of Granular A or B Type II material placed and compacted in compliance with OPSD 3121.150.

3.2 Tunnelling Installation Methods

Installation of the new storm sewer and the potential replacement storm sewer may be undertaken using the tunnelling methods discussed below.

Refer to Ontario Provincial Standard Specifications (OPSS 415), Construction Specifications for Pipeline and Utility Installation by Tunnelling.

From a foundation engineering perspective, the design and construction of any new or replacement sewers should consider the following: over sizing new sewers to permit a future cycle of slip lining before replacement is again necessary, the durability of the sewer material, and the composition of the backfill in order to avoid obstructions to future tunnelling.

Monitoring of tunnelling installations is required as a strategy to mitigate the risks and consequences of settlement or other ground movements at the road surface resulting from tunnelling operations. The Contractor should comply with the guidelines for design and monitoring specified in the Guideline presented in Appendix B.

3.2.1 Jack and Bore

Jack and bore involves the simultaneous advancement of a continuous flight auger and conduit pipe. The auger is used to excavate soil in advance of the casing and transport cuttings back to the entry pit where they are removed. Rotary power to auger and pushing force is provided by a drill rig located within a jacking pit. Jack and bore is a common method of trenchless installation and in appropriate site and soil conditions may be preferable from a cost perspective.

Jack and bore installation(s) should be conducted in accordance with OPSS 416, Construction Specifications for Pipeline and Utility Installation by Jacking and Boring.

The presence of cobbles and boulders will increase the risk for alignment deviations. A significant disadvantage of this method is that the alignment cannot be corrected during pipe advancing.

3.2.2 Pipe Ramming

Pipe ramming installation is analogous to driving an open ended tube pile horizontally. Impact forces from a percussive hammer are used to advance a conduit pipe from an entry pit to a receiving pit. During the advance, most of the soil being penetrated fills the conduit rather than requiring excavation.

The rammed conduit is terminated in a receiving pit at which point the soil contained in the pipe is removed by augering or excavation with a pipe shovel. Augering is expected to be the preferred method provided that cobbles and boulders can be loosened and cleared from between the auger flights. If soil within the pipe cannot be augered, use of a pipe shovel will be necessary. A pipe shovel is essentially a special scoop made from a pipe which fits inside the liner. Excavation via pipe shovel involves advancing the shovel into the soil plug using impact hammer (mole), then pulling the shovel and its contents out with a chain or cable, the process is repeated as required.

Pipe ramming can be conducted though soils with cobbles and boulders. However under these conditions, difficult driving can be expected.

Given the compact to very dense native soils, liquefaction of the soil from pipe ramming is not expected to be a concern.

3.2.3 Horizontal Directional Drilling

HDD involves the boring and enlargement of a near horizontal uncased tunnel which is kept open through use of drilling fluids. Upon completion of boring a conduit pipe is pulled though the bore. The process is initiated by advancing a relatively small diameter pilot hole along the proposed path. During the pilot bore the cutter head at the lead of the drill string is steered. After the pilot hole has been completed the borehole is enlarged using reaming tools until the desired bore diameter is achieved. The conduit is typically pulled through the borehole on the final reaming pass. Water based drilling fluids containing bentonite and/or polymers are used during the pilot bore and reaming processes to convey cuttings out of the borehole and to stabilize the hole.

With HDD there is potential for inadvertent drilling fluid returns to the ground surface via hydro fracture of the soil surrounding the bore or if the bore crosses pre-existing fissures/preferential seepage paths. Inadvertent drilling fluid returns could cause loss of drilling fluid circulation along the bore which may hinder or prevent completion of an HDD installation or cause environmental concerns or safety problems if they coat the pavement. Therefore, prevention and mitigation of inadvertent drilling fluid returns should be part of planning and construction for an HDD installation. There is an elevated potential for inadvertent drilling fluid returns where overburden soils will be thinnest. The presence of cobbles and boulders could also hinder an HDD installation and may necessitate the use of specialized tooling, larger equipment and/or larger tunnel size. Considering that the bore would be unlined during the HDD process, there would be a risk of loss of ground and possible sink holes developing along the alignment.

HDD installations should be carried out in accordance with OPSS 450, Construction Specifications for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling.

4. CULVERT EXTENSION

The existing concrete box culvert will be extended to the west by approximately 2.0 m with the invert elevation matching that of the existing culvert (elevation 242.7 m). The dimensions of the proposed extension will match the 2.0 x 1.0 m (width x height) dimensions of the existing culvert.

In summary, the subsurface stratigraphy revealed in Borehole 1A drilled at the culvert extension location near the toe of the Highway 400 embankment, comprised a 1.4 m thick surficial silty sand and topsoil layer over a 3.3 m thick compact sand deposit, above a 4.9 m thick very stiff clayey silt deposit. Upon completion of augering and during drilling groundwater was noted in borehole 1A at a depth of 1.5 m (elevation 243.6).

At Borehole 1 at the top of the Highway 400 embankment directly east of the proposed culvert extension, the ground consists of a 10 m thick compact to dense sand fill layer above a 2.5 m thick very stiff clayey silt layer overlying an approximately 7.6 m thick compact to very dense sand deposit. Groundwater was at a depth of 8.8 m (elevation 243.6) during drilling.

The foundation frost penetration depth at the site is 1.5 m according to OPSD 3090.101.

The proposed culvert extension is expected to have an invert elevation near 242.7 m. It is considered that the existing fill and topsoil material encountered in Borehole 1A are not adequate to support the proposed culvert extension and these materials should be excavated from the culvert extension subgrade. The proposed extension may be founded on the loose to compact sand that was encountered between elevations 243.7 and 240.4 in borehole 1A.

4.1 Bearing Resistance

The soil encountered at Borehole 1A at the proposed culvert invert level (elevation 224.7 m) comprised loose to compact sand.

The culvert can be founded on a Granular A or Granular B Type II bedding layer with a minimum thickness of 300mm placed on the loose to compact sand using a recommended factored geotechnical bearing resistance at ultimate limit states (ULS) and the geotechnical reaction at serviceability limit states (SLS) as follows:

SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Loose to compact sand	225	150

The recommended geotechnical resistance at SLS value is based on a maximum 25 mm settlement. The provided geotechnical bearing resistances assume a footing width similar to that for the existing culvert.

4.2 Sliding Resistance

The following parameters should be used to compute sliding resistance for a precast box culvert or cast-in-place concrete culvert extension as well as for any retaining or cut-off walls at this location. The design friction angles are provided in the following table.

SOIL TYPE AT CULVERT/GROUND INTERFACE	DESIGN FOUNDATION FRICTION ANGLE, DEGREES	COHESION, kPa	UNIT WEIGHT, kN/m^3
Granular A or Granular B Type II levelling pad	35	0	22.8
Loose to Compact Sand	30	0	19.0

Sliding resistance should be calculated by applying a factor of 0.8 for the friction angle.

4.3 Backfill and Bedding

Backfill and bedding for the proposed culvert should be composed of Granular A or B Type II material placed and compacted in compliance with OPSD 3121.150. The Granular B Type II bedding material should have a maximum particle size of 37.5 mm.

Backfill should be brought up simultaneously in 200 mm thick lifts on each side of the culvert and operation of heavy equipment within 0.5 times the height of the 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 requirements.

The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (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 p = lateral earth pressure (kPa)
K = lateral earth pressure coefficient
γ = unit weight of backfill material above design water level (kN/m^3)
γ' = unit weight of submerged backfill material below design water level (kN/m^3)
= $\gamma - \gamma_w$
γ_w = unit weight of water
= 9.8 kN/m^3
h_1 = depth below final grade (m), above design water level
h_2 = depth below design water level (m)
q = any surcharge load (kPa)
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 Ø = angle of internal friction of retained soil
δ = angle of friction between soil and wall

The following parameters are recommended for estimating the earth pressure for the Granular A or Granular B Type II backfill and existing sand fill:

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	SAND FILL
Angle of Internal Friction, degrees	35	32
Unit Weight, kN/m^3	22.8	21
Coefficient of Active Earth Pressure (K_a)	0.27	0.31
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.47
Coefficient of Passive Earth Pressure (K_p)	3.69	3.25

4.4 Inlet Design

The geometry of the embankment slope at the inlet could consist of either an extended culvert that permits the embankment to spill around the culvert at a slope of 2H:1V or a shortened culvert that terminates within the footprint of the natural slope that would require a head wall structure to retain the embankment and to direct the channel into the culvert inlet.

For the purposes of this report, it has been assumed that the extended culvert/spill though embankment configuration will be selected.

In this case, an inlet seal/cutoff is required to channel the flow through the culvert and eliminate drainage flow under or through the embankment. The seal should consist of clay seal;

- Extending in the longitudinal direction. from a distance of 2 culvert heights upstream from the ultimate culvert inlet along the inlet channel and from that point along the inlet channel and up the upstream highway embankment to the high water level or the obvert of the culvert – whichever is higher
- Extending in the transverse direction, along the bottom of the inlet channel and up its sides and across the upstream embankment for a distance of 2 culvert heights on either side of the culvert
- Erosion protection in the form of a minimum 0.6 m thickness of rock protection with diameters ranging from 150 mm to 300 mm should be placed to cover the clay seal.

5. CONSTRUCTION CONSIDERATIONS

Excavations for the proposed culvert extension, access pits for trenchless storm sewer installation and / or open cut storm sewer installations are expected at this site.

The excavations for the new storm sewer along the E/W-S ramp will extend through surficial fill and topsoil and into the compact to very dense native sand / sand till. The compact to very dense native sand and sand till are considered Type 2 soils as defined in the Occupational Health and Safety Act (OHSA). Excavations within Type 2 soils that are to be entered by workers, may not be excavated steeper than one horizontal to one vertical (1H:1V) from 1.2 m above the bottom of the excavation.

The excavations for the storm sewer replacement and culvert extension will extend through surficial fill, topsoil and locally into the native sand for the culvert extension. The fill and native sand are considered Type 3 soils as defined in the Occupational Health and Safety Act (OHSA). Excavations within Type 3 soils that are to be entered by workers, may not be excavated steeper than one horizontal to one vertical (1H:1V) from the base of the excavation.

Cognizant of the presence of cobbles in the subsurface soils, and relative cost associated with contractor availability, it is recommended that either the open cut method or the jack and bore method be employed. An NSSP (refer to Appendix A) shall be included in the contract documents advising the Contractor that variable mixed fill shall be anticipated at the sewer alignment and that the Contractor shall use methods and equipment that are appropriate for the work and capable of dealing with the conditions encountered.

Refer to Appendix A for a list of the standard specifications and draft NSSP's that should be included in contract documentation.

Where tunnelling is required, refer to Appendix B for Guidelines for Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application MTO Guidelines for requirements for monitoring for tunneling construction.

6. CLOSURE

This Foundation Design Report was prepared by A. DeSira, MEng, P.Eng., and reviewed by D. Dundas, P.Eng. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact conducted a quality review of the report.

Yours very truly

Peto MacCallum Ltd.

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APPENDIX A

List of Ontario Provincial Standard Documents and
Non-Standard Specific Provision (NSSP) Referenced in Report

APPENDIX B

Guidelines for Foundation Engineering –
Tunnelling Specialty for Corridor Encroachment Permit Application

APPENDIX A

List of Ontario Provincial Standard Documents
and Non-Standard Specific Provision (NSSP)
Referenced in Report

DOCUMENT	TITLE
OPSS 415	Construction Specification for Tunneling
OPSS 416	Construction Specifications for Pipeline and Utility Installation by Jacking and Boring
OPSS 450	Construction Specification for Pipeline and Utility Installation in Soil By Horizontal Directional Drilling
OPSS 490	Construction Specification for Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 902	Construction Specification For Excavating and Backfilling –Structures
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
OPSD 3121.150	Walls Retaining, Backfill Minimum Granular Requirement

NON-STANDARD SPECIAL PROVISIONS (NSSP)

NSSP - Variable Mixed Fill and Rock Fill Embankments (Addition to OPSS 902)

The Contractor shall be advised that the highway embankments contain variable mixed fill and rock fill materials and that the Contractor shall use methods and equipment that are appropriate for the work and capable of dealing with the conditions encountered including, but not limited to various tunnelling techniques and ground improvement techniques such as grouting.

NSSP – Obstructions during Tunneling (Addition to OPSS 490)

The contractor shall be advised that cobbles and boulders are present within the embankment fill and native soils. The contractor shall be responsible for selecting tunnelling methods and equipment that will enable tunnelling operations to advance through the embankment fill and/or native soils including zones where cobbles and boulders are encountered.

APPENDIX B

Guidelines for Foundation Engineering – Tunnelling Specialty
For Corridor Encroachment Permit Application

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

Table 1: Complexity Ratings for Tunnelling Specialty Services

<table>
<tr><td rowspan="4">Highway Classification</td><td colspan="6">Tunnel Excavation Diameter (ϕ)</td></tr>
<tr><td colspan="2">≤ 1 m</td><td colspan="2">>1 m & ≤ 2 m</td><td colspan="2">>2 m</td></tr>
<tr><td colspan="6">Minimum Overburden Cover * (m)</td></tr>
<tr><td>≥ 3 ϕ (or 1.5 m whichever is greater)</td><td>< 3 ϕ (or 1.5 m whichever is greater)</td><td>≥ 3 ϕ</td><td>< 3 ϕ (or 1.5 m whichever is greater)</td><td>≥ 3 ϕ</td><td>< 3 ϕ (or 1.5 m whichever is greater)</td></tr>
<tr><td>Kings Highway</td><td>Low</td><td>Medium</td><td>Medium</td><td>High</td><td>High</td><td>High</td></tr>
<tr><td>400 Series Freeway</td><td>Medium</td><td>High</td><td>High</td><td>High</td><td>High</td><td>High</td></tr>
</table>

* Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

Minimum requirements for Subsurface Investigation and Recommendations

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered. Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

Minimum Laboratory Testing Requirements:

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

Borehole Log Preparation and Foundation Drawing:

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

Minimum Requirements for the Foundation Investigation and Design Report:

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD)and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;

- the long-term stability of the tunnel;
- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments.

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Attachment for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO has been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

1. SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement includes settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel within the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

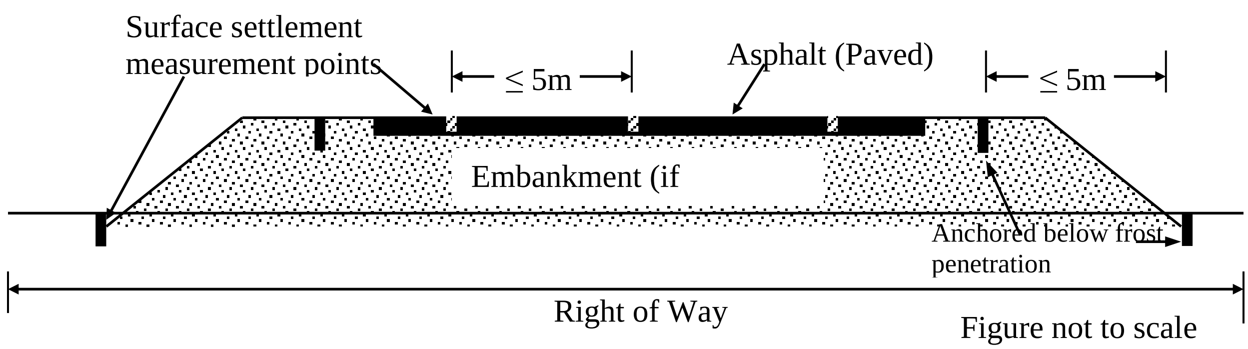

Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.
A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility for Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.