



## **FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

### **VARIABLE MESSAGE SIGN SUPPORT STRUCTURES**

#### **HIGHWAY 402**

**SIGN 1 – STATION 11+677, GEOGRAPHIC TOWNSHIP OF DELAWARE, COUNTY OF MIDDLESEX,**

**SIGN 2 – STATION 12+032, GEOGRAPHIC TOWNSHIP OF WARWICK, COUNTY OF LAMBTON,**

**SIGN 3 – STATION 16+722, GEOGRAPHIC TOWNSHIP OF SARNIA, COUNTY OF LAMBTON,**

**SIGN 4 – STATION 20+826, GEOGRAPHIC TOWNSHIP OF ADELAIDE, COUNTY OF MIDDLESEX,**

**ONTARIO**

**G.W.P. 3006-20-00**

**ASSIGNMENT NO. 3017-E-0006**

**WORK ITEM NO. 12**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email:toronto@petomaccallum.com

#### **Distribution:**

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Foundations Section**

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**PML Ref.: 20TF024  
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GEOCRES No.: 40114-195  
Janaury 26, 2021**



**PART A - FOUNDATION INVESTIGATION REPORT**

**for**

**VARIABLE MESSAGE SIGN SUPPORT STRUCTURES  
HIGHWAY 402**

**SIGN 1 – STATION 11+677, GEOGRAPHIC TOWNSHIP OF DELAWARE, COUNTY OF MIDDLESEX,  
SIGN 2 – STATION 12+032, GEOGRAPHIC TOWNSHIP OF WARWICK, COUNTY OF LAMBTON,  
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**PART A – FOUNDATION INVESTIGATION REPORT**

**For**

Variable Message Sign Support Structures

Highway 402

Sarnia to London, Ontario

G.W.P. 3006-20-00, Assignment No. 3017-E-0006, Work Item No. 12

**1. INTRODUCTION**

The Ministry of Transportation Ontario (MTO) has retained WSP Global Inc. (WSP) as the Prime Consultant, to provide design services for the new Variable Message Sign (VMS) support structures to be installed along Highway 402. WSP retained Peto MacCallum Ltd. (PML) on behalf of MTO to provide foundation engineering services. The Terms of Reference and Scope of Work for the Foundation Engineering services are outlined in MTO Assignment No. 3017-E-0006, Work Item No. 12, dated August 5, 2020. The foundation engineering services under this assignment include the following:

**Table 1: Proposed VMS Locations**

SIGN ID	APPROXIMATE STATION <sup>1</sup>	DIRECTION	LOCATION	TOWNSHIP	COUNTY	SITE NO.	WP
1	11+677	Westbound	1.5 km east of Longwoods Road	Delaware	Middlesex County	19X-0734/S0	3015-20-01
2	12+032	Westbound	1.5 km east of Hwy 21 Forest	Warwick	Lambton County	14X-0812/S0	3014-20-01
3	16+722	Eastbound	1.5 km west of Airport Road	Sarnia	Lambton County	14X-0813/S0	3013-20-01
4	20+826	Eastbound	1.5 km west of Centre Road	Adelaide	Middlesex County	19X-0735/S0	3012-20-01

**Note:** 1. Sign support structure locations and stations are in accordance with AutoCAD drawings “Design – Hwy 402 VMS – Sign 1.dwg”, “Design – Hwy 402 VMS – Sign 2.dwg”, “Design – Hwy 402 VMS – Sign 3.dwg”, and “Design – Hwy 402 VMS – Sign 4.dwg” provided to PML by WSP via e-mail dated October 13, 2020.

The foundation investigation work reported herein pertains to the four (4) VMS support structures.

This report summarizes the results of the foundation investigation carried out for the proposed four (4) VMS support structures as outlined in Table 1.

The purpose of the investigation was to explore the subsurface conditions at the proposed locations of the VMS support structures.



## 2. SITE DESCRIPTION

The existing Highway 402 roadway is slightly elevated from the natural topography, and accommodates two (2) lanes of vehicular traffic in each direction (eastbound and westbound). The site is generally a flat area, with the exception of the highway embankments. The study area is surrounded by a mixture of commercial, agricultural and residential developments.

## 3. FIELD INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out on October 7 and 8, 2020. A total of four (4) boreholes were advanced to depths of 8.3 m and 9.8 m below the existing ground surface. The Record of Borehole sheets are provided in Appendix A. The borehole location plans are presented on Drawings DWG-1 to DWG-4. The field investigation work for the proposed VMS support structures was carried out in accordance with MTO Guideline For Foundation Engineering Services; Version 2.0, October 2020.

Table 2 below provides the proposed locations of the sign support structures, drilled borehole locations and borehole termination depths.

**Table 2: Borehole Information**

SIGN No.	BOREHOLE ID	DRILLED DEPTH (m)	LATITUDE	LONGITUDE	COORDINATES (MTM ON-11)	
					NORTHING	EASTING
1	SS-1	8.3	42.894762	-81.404444	4 751 136.0	394 274.1
2	SS-2	8.3	42.991729	-81.978889	4 761 456.6	347 285.9
3	SS-3	9.8	42.990431	-82.333056	4 761 194.2	318 512.2
4	SS-4	8.3	42.992074	-81.656111	4 761 708.7	373 613.2

PML staff visited the site on September 23, 2020 to mark out the borehole locations. The appropriate utility companies cleared the underground services at the borehole locations. Public and private utility authorities were informed and all utility clearance documents were obtained prior to commencement of the drilling work.



PML staff used a portable GPS device to establish the location of boreholes in the field. Subsequently, PML carried out a survey of the as-drilled borehole locations and elevations using a Sokkia SHC5000 Differential GPS system, equipped with a GCX3 (Network RTK rover) GNSS Receiver. The vertical and horizontal accuracy of this equipment are within 0.1 m and 0.5 m, respectively. All elevations (EL.) reported in this report are referenced to MTM NAD 83 Northing and Easting (MTM Zone – ON11) Geodetic datum and expressed in metres.

The equipment used for drilling was owned and operated by PML Field Services Ltd. (PML FS), of Toronto, Ontario. PML FS is a specialist drilling contractor and the drilling operations were carried out under the full-time supervision of a PML field supervisor. Boreholes SS-1 to SS-4 were drilled on October 7 and 8, 2020. The boreholes were advanced using a geoprobe track-mounted drilling rig equipped with 200 mm diameter hollow stem augers.

Refer to Drawings DWG-1 to DWG-4 in Appendix A for borehole location details.

Representative soil samples were recovered from the boreholes at 0.75 m intervals to a depth of 6.0 m and at 1.5 m to the depth of termination, using a conventional 51 mm OD split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. In addition, attempts were made to measure in-situ vane shear strength of clayey soils at depths where SPT values were below 8 blows/300 mm, using an N-size (MTO) vane.

The groundwater conditions at the borehole locations were observed during the drilling operations by visual examination of the soil samples, sampler and drill rods as the samples were retrieved. In addition, water level measurements were taken in the open boreholes upon completion of drilling. Water levels were measured using a Solinst flat tape water level reader.

Upon completion of drilling, the boreholes were backfilled in accordance with the MTO guidelines and Ontario Regulation 903, amended by Ontario Regulation 372.

The recovered soil samples were delivered to PML's laboratory to carry out detailed visual examination and determination of soil index properties.



#### **4. LABORATORY TEST PROCEDURES**

Laboratory tests were conducted on representative SPT soil samples recovered during the field investigation work. Geotechnical testing was conducted at PML's laboratory facility located in Toronto, Ontario. The laboratory testing program (geotechnical and chemical) included the following:

- Natural moisture content testing (32)
- Grain size distribution analysis (8)
- Atterberg limit tests (8)
- Soil chemical (corrosivity) tests (4)

All laboratory tests to determine soil index properties were performed in accordance with the MTO test procedures, which follow the American Society for Testing Materials (ASTM) standards, with the exception of hydrometer tests (LS-702). The results of the grain size distribution analyses are presented in Figures GS-1 to GS-3. The results of the Atterberg limit tests are presented in Figures PC-1 to PC-3. All test results are summarized in the attached Record of Borehole Sheets provided in Appendix A.

#### **5. SITE GEOLOGY AND SUBSURFACE CONDITIONS**

##### **5.1 Site Geology – Sign 1**

The proposed sign is located within the Caradoc Sand Plains and London Annex physiographic region. The Quaternary Geology map published by the Ontario Ministry of Northern Development and Mines (MNDM), indicates that the surface conditions at the site location consist of fluvial deposits; gravel, sand, silt and clay, deposited flood plains. Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the MNDM, the project area consists of Middle Devonian limestone, dolostone and shale of the Hamilton Group rock formation.

##### **5.2 Site Geology – Sign 2**

The proposed sign is located within the Horseshoe Moraines physiographic region. The MNDM Quaternary Geology map indicates that the surface conditions at the site location consist of St. Joseph's Till; silt to silty clay matrix. Based on the MNDM Bedrock Geology map, the project area consists of Upper Devonian shale of the Kettle Point formation.



### **5.3 Site Geology – Sign 3**

The proposed sign is located within the Huron Fringe physiographic region. The MNDM Quaternary Geology map indicates that the surface conditions at the site location consist of lacustrine deposits; sand, gravelly sand and gravel, nearshore and beach deposits. Based on the MNDM Bedrock Geology map, the project area consists of Upper Devonian shale of the Kettle Point formation.

### **5.4 Site Geology – Sign 4**

The proposed sign is located within the Horseshoe Moraines physiographic region. The MNDM Quaternary Geology map indicates that the surface conditions at the site location consist of Rannoch Till; silt to clayey silt matrix. Based on the MNDM Bedrock Geology map, the project area consists of Middle Devonian limestone, dolostone and shale of the Dundee formation.

### **5.5 Subsurface Conditions**

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are provided in the attached Record of Borehole Sheets. The borehole locations are shown in Drawings DWG-1 to DWG-4.

The four sign support structures are located along a stretch of Highway 402 approximately 82.7 km in length. Accordingly, a general stratigraphic description of the subsurface conditions along the entire 82.7 km section of the highway is not provided. For classification and design purposes, the soil encountered at the locations of the four sign support structures can be divided into four (4) distinct zones:

- 1) Sandy Silt (Fill)
- 2) Clayey Silt (Fill)
- 3) Gravelly Sand (Fill)
- 4) Clayey Silt/Silty Clay



Table 3 provides a summary of the subsurface conditions encountered at each borehole location.

**Table 3: Summary of Subsurface Conditions at the Location of Each Borehole**

BOREHOLE	SOIL BOUNDARY DEPTH (m)	SOIL BOUNDARY ELEVATION (m)	SOIL TYPE <sup>1</sup>
SS-1	0.0 to 0.3	230.6 to 230.3	Loose Sandy Silt (Fill)
	0.3 to 8.3	230.3 to 222.3	Very stiff to stiff Clayey Silt SPT-‘N’ values range from 5 to 10 blows (per 0.3 m penetration) In-situ vane shear test results above 120 kPa
SS-2	0.0 to 0.8	218.6 to 217.8	Compact Gravelly Sand (Fill) SPT-‘N’ values recorded was 17 blows
	0.8 to 2.2	217.8 to 216.4	Stiff Clayey Silt (Fill) SPT-‘N’ values recorded were 15 blows and 11 blows
	2.2 to 8.3	216.4 to 210.3	Stiff to very stiff Silty Clay SPT-‘N’ values recorded were between 3 and 16 blows In-situ vane shear test result was above 120 kPa below SPT-‘N’ value of 3 blows
SS-3	0.0 to 2.2	181.0 to 178.8	Stiff to very stiff Clayey Silt (Fill) SPT-‘N’ values recorded were between 3 and 15 blows
SS-3	2.2 to 9.8	178.8 to 171.2	Very stiff to firm Clayey Silt SPT-‘N’ values recorded were between 0 and 11 blows In-situ vane shear test result was above 120 kPa below SPT-‘N’ value of 3 blows in the fill layer In-situ vane shear test result was above 76 kPa below SPT-‘N’ value of 3 blows In-situ vane shear test result was above 47 kPa below SPT-‘N’ value of 0 blows In-situ vane shear test result was above 68 kPa below SPT-‘N’ value of 2 blows



**Table 3: Summary of Subsurface Conditions at the Location of Each Borehole**

BOREHOLE	SOIL BOUNDARY DEPTH (m)	SOIL BOUNDARY ELEVATION (m)	SOIL TYPE <sup>1</sup>
SS-4	0.0 to 0.8	250.2 to 249.4	Compact Gravelly Sand (Fill) SPT-‘N’ values recorded was 16 blows
	0.8 to 8.3	249.4 to 241.9	Very stiff to stiff Clayey Silt to Silty Clay SPT-‘N’ values recorded were between 11 and 15 blows

**Note:** 1. The in-situ field vane tests were conducted within 0.75 m below the SPT. The consistency of the cohesive soils are based on the in-situ field vane tests, where conducted.

#### 5.5.1 Groundwater

Groundwater was not encountered in any of the investigated boreholes during the course of the drilling operations. Upon completion of drilling, groundwater was recorded in Boreholes SS-1 and SS-2 at 4.6 m (EL. 226.0) and 3.1 m (EL. 215.5), respectively, below existing ground surface elevation. Groundwater was not recorded/encountered in the other two Borehole SS-3 and Borehole SS-4 upon completion of drilling.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal changes. The groundwater measurements were observed and measured prior to backfilling the boreholes. Groundwater levels are shown in the Record of Borehole Sheets included in Appendix A.



#### 5.5.2 Soil Corrosivity

Four (4) representative soil samples were delivered to SGS Canada Inc.'s (SGS) laboratory located in Toronto, Ontario for testing to determine corrosivity data. SGS is accredited by Canadian Analytical Laboratory Association (CALA). The corrosivity test report provided by SGS is provided in Appendix A for reference. A summary of the corrosivity test results is presented in Table 4.

**Table 4: Summary of Corrosivity Test Results**

BOREHOLE ID	SAMPLE NO. (DEPTH, m)	CORROSIVITY INDEX	SULPHATE (µg/g)	CHLORIDE (µg/g)	RESISTIVITY (Ohm-cm)	pH
SS-1	5 (4.6 to 5.2)	8	68	2.4	6710	8.57
SS-2	6 (3.8 to 4.4)	4	31	99	4080	8.57
SS-3	5 (3.8 to 4.4)	8	170	13	5010	8.67
SS-4	6 (3.8 to 4.4)	6	460	28	2180	8.39



## 6. CLOSURE

Mr. M. Mohamed carried out the field investigations under the supervision of Mr. N. Rahman, P.Eng., Project Engineer, and Ms. N. Leong-Sem, EIT. PML Field Services of Toronto, Ontario supplied the drilling equipment for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This report was prepared by Ms. N. Leong-Sem, B.Eng., EIT, and Mr. N. Rahman, P.Eng., and reviewed by Mr. G. Uwimana, MEng., P.Eng. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

Natasha Leong-Sem  
EIT  
Geotechnical Services



Nazibur Rahman, P.Eng.  
Project Engineer  
Geotechnical Services



Geoffrey Uwimana, MEng., P.Eng.  
Discipline Head -  
Geotechnical Services



Robert Ng, MBA, PhD, P.Eng.  
MTO Designated Principal Contact



## **APPENDIX A**

Borehole Locations Plan Drawings DWG-1 to DWG-4

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures GS-1 to GS-3

Results of Atterberg Limit Tests – Figures PC-1 to PC-3

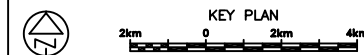
Results of Chemical Tests Provided by SGS Canada Inc.



SHEET



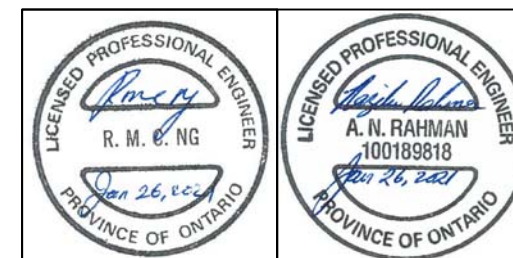
**Peto MacCallum Ltd**  
CONSULTING ENGINEERS



SS-1  
Borehole Location

BH No	ELEVATION	NORTHINGS	EASTINGS
SS-1	230.6	4 751 136.0	394 274.1

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




Reference WSP Ltd. Drawing: Design - Hwy 402 VMS - Sign 1.dwg,  
provided October 13, 2020.

REVISIONS		
DATE	BY	DESCRIPTION

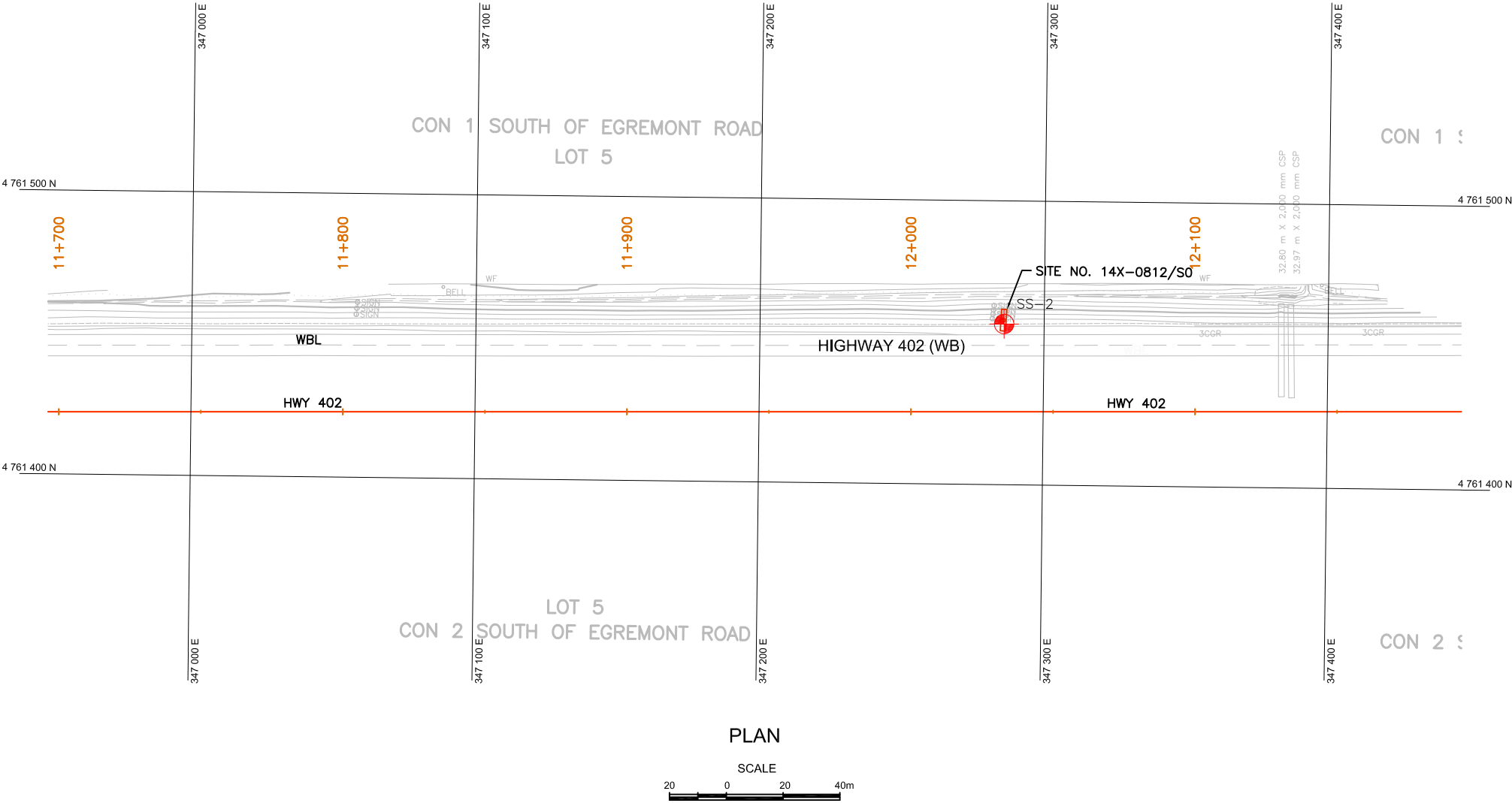
Geocres No. 40114-195

HWY No 402				DIST WEST REGION	
SUBM'D	NL	CHECKED NR	DATE JAN. 26, 2021		SITE 19X-0734/S0
DRAWN	NL	CHECKED	APPROVED RN		DWG DWG-1



LEGEND			
SS-2			
	Borehole Location		
BH No	ELEVATION	NORTHINGS	EASTINGS
SS-2	218.6	4 761 456.6	347 285.9

REVISIONS			
DATE	BY	DESCRIPTION	
Geocres No. 40114-195			
HWY No	402		DIST WEST REGION
SUBM'D	NL	CHECKED NR	DATE JAN. 26, 2021 SITE 14X-0812/S
DRAWN	NL	CHECKED	APPROVED RN DWG DWG-2




- NOTES:
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Reference WSP Ltd. Drawing: Design - Hwy 402 VMS - Sign 2.dwg, provided October 13, 2020.



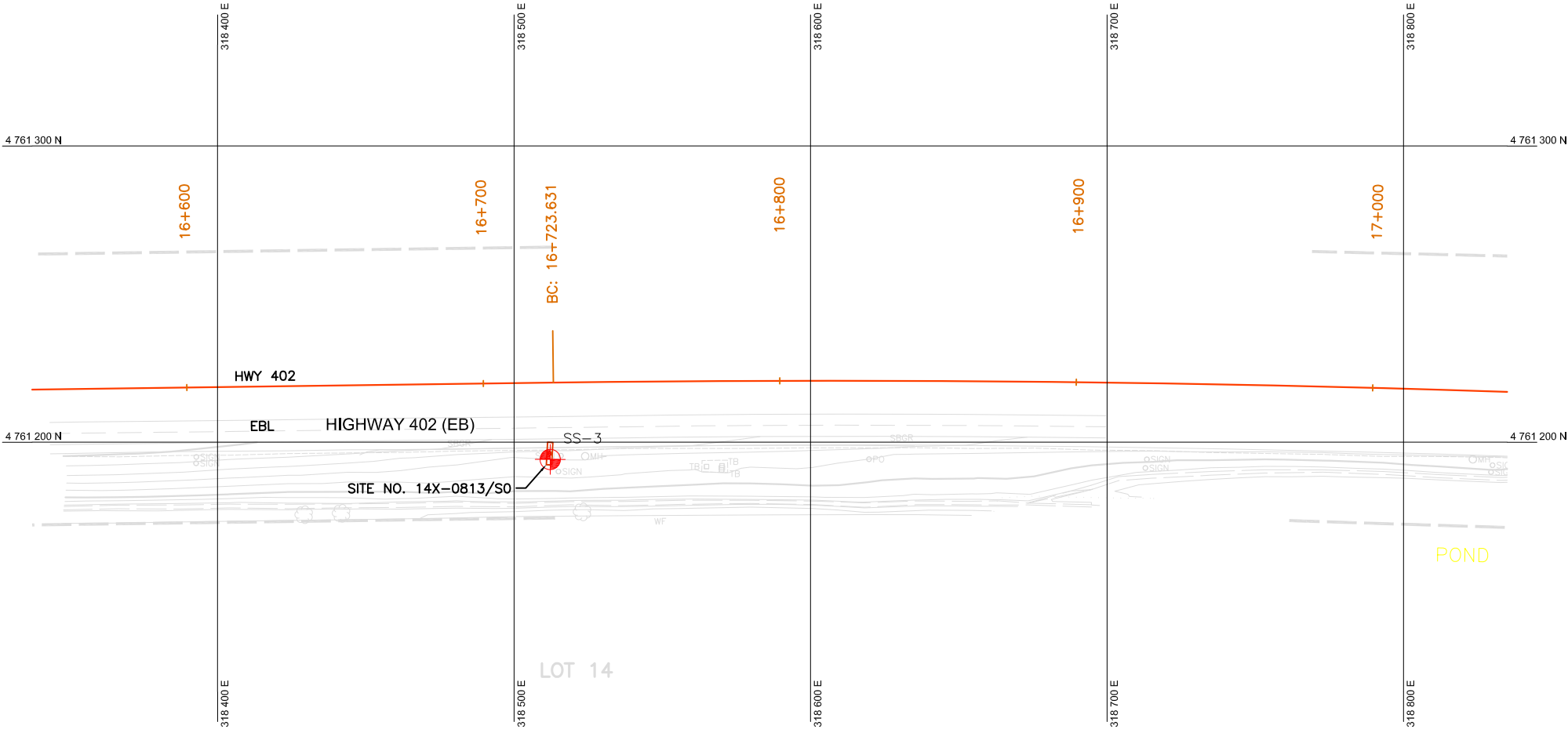
LEGEND

SS-3  
 Borehole Location

BH No	ELEVATION	NORTHINGS	EASTINGS
SS-3	181.0	4 761 194.2	318 512.2

DATE	BY	DESCRIPTION

Geocres No. 40114-195		DIST WEST REGION	
HWY No	402	SUBM'D	NL
CHECKED	NR	DATE	JAN. 26, 2021
APPROVED	RN	DWG	DWG-3

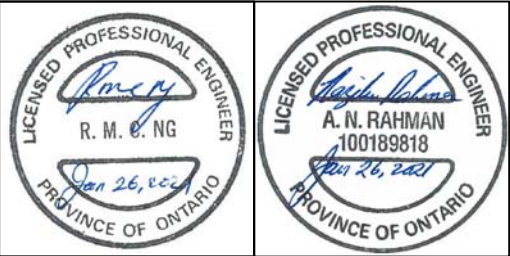


PLAN

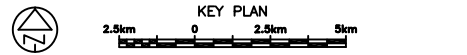


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Reference WSP Ltd. Drawing: Design - Hwy 402 VMS - Sign 3.dwg, provided October 13, 2020.



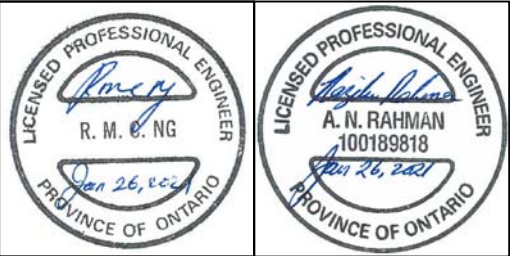
LEGEND

SS-4  
Borehole Location

BH No	ELEVATION	NORTHINGS	EASTINGS
SS-4	250.2	4 761 708.7	373 613.2

NOTES:

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Reference WSP Ltd. Drawing: Design - Hwy 402 VMS - Sign 4.dwg, provided October 13, 2020.

DATE	BY	DESCRIPTION

Geocres No. 40114-195		DIST WEST REGION	
HWY No	402	SUBM'D	NL
CHECKED	NR	DATE	JAN. 26, 2021
APPROVED	RN	DWG	DWG-4

## 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 SS-1

1 OF 1

METRIC

G.W.P. 3006-20-00 LOCATION Coords: 4 751 136.0 N; 394 274.1 E ORIGINATED BY M.M.  
DIST West Region HWY 402 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.  
DATUM Geodetic DATE 2020.10.07 LATITUDE 42.894762 LONGITUDE -81.404444 CHECKED BY N.R.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
230.6	Ground Surface															
0.0	SANDY SILT															
230.3	Loose, Brown, Moist (FILL)		1	SS	5											
0.3	CLAYEY SILT															
	Very stiff to stiff, Grey, Moist		2	SS	8											
			VANE													
			3	SS	7											
			VANE													
			4	SS	9											
		5	SS	10												
		6	SS	8												
		VANE														

## METRIC

[illegible]

RECORD OF BOREHOLE No SS-3

1 OF 1

METRIC

G.W.P. 3006-20-00 LOCATION Coords: 4 761 194.2 N; 318 512.2 E ORIGINATED BY M.M.  
DIST West Region HWY 402 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.  
DATUM Geodetic DATE 2020.10.08 LATITUDE 42.990431 LONGITUDE -82.333056 CHECKED BY N.R.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)									
								20	40	60	80	100						20	40	60	
181.0	Ground Surface																				
0.0	CLAYEY SILT, some sand to sandy, trace gravel		1	SS	9																
	Stiff to very stiff, Brown, Moist to wet (FILL)																				
			2	SS	15																
			3	SS	3																
178.8	CLAYEY SILT, some sand, trace gravel			VANE																	
2.2	Very stiff to stiff, Brown, Moist																				
			4	SS	11																
	grey		5	SS	3																
				VANE																	
	firm		6	SS	0																
				VANE																	
			7	SS	2																
				VANE																	
			8	SS	8																
171.2	End of borehole																				
9.8																					
NOTES: 1. Groundwater level was not encountered in the borehole during or upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.																					

ONTARIO MTO 20TF024.GPJ ONTARIO MTO.GDT 20-11-18

# RECORD OF BOREHOLE No SS-4

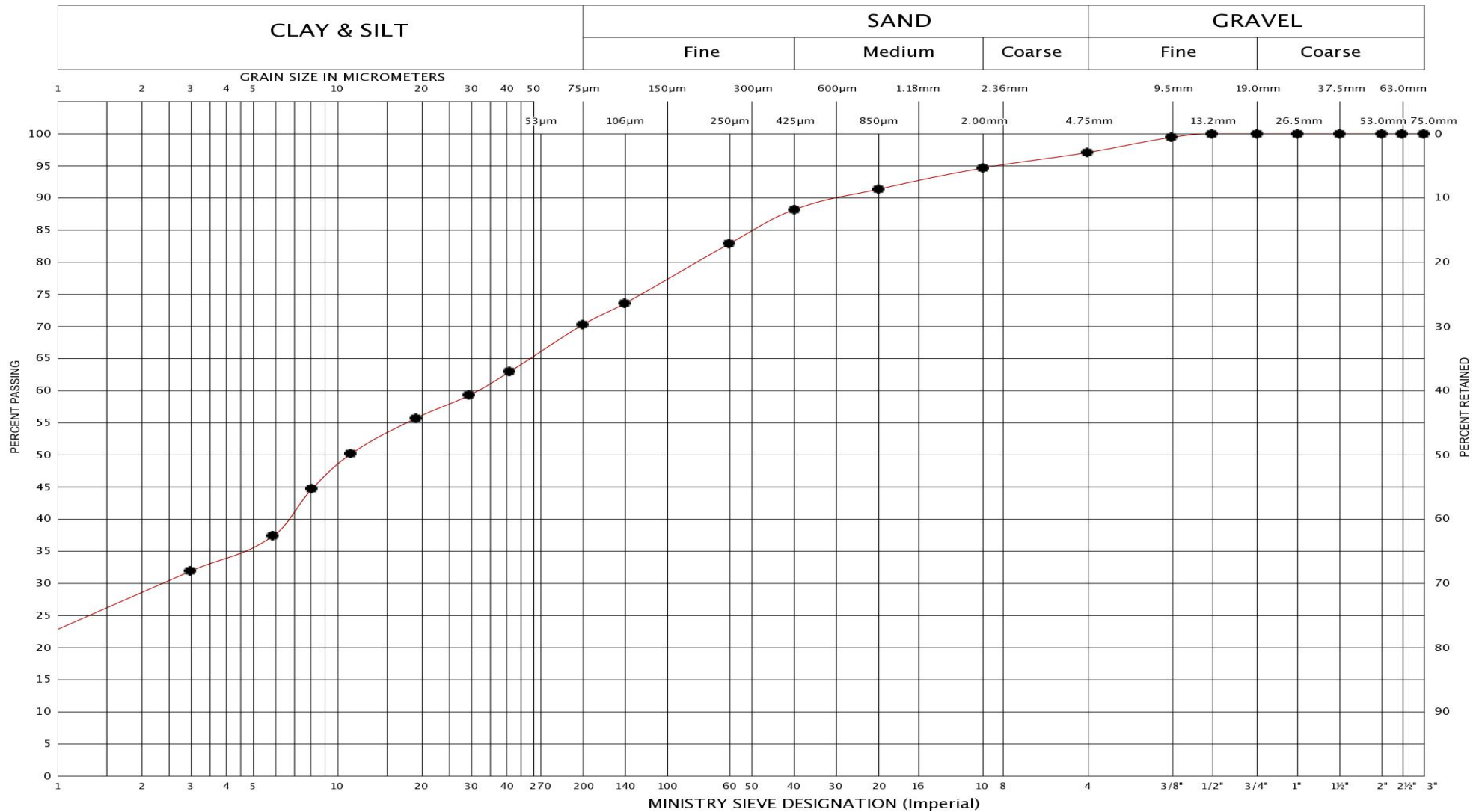
1 OF 1

METRIC

G.W.P. 3006-20-00 LOCATION Coords: 4 761 708.7 N; 373 613.2 E ORIGINATED BY M.M.  
 DIST West Region HWY 402 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.  
 DATUM Geodetic DATE 2020.10.08 LATITUDE 42.992074 LONGITUDE -81.656111 CHECKED BY N.R.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
250.2	Ground Surface							20	40	60	80	100					
0.0	GRAVELLY SAND		1	SS	16		250										
	Compact, Grey, Moist (FILL)																
249.4	SILTY CLAY to CLAYEY SILT, trace sand		2	SS	15		249										
0.8	Very stiff to stiff, Brown, Moist		3	SS	14												
			4	SS	12		248										
			5	SS	13		247										
			6	SS	11		246										
			7	SS	11		245										
			8	SS	11												
			9	SS	12		244										
			10	SS	11		243										
241.9	End of borehole						242										
8.3	NOTES: 1. Groundwater level was not encountered in the borehole during or upon completion of drilling.  2. No cave-in was noted in the borehole upon extraction of hollow stem augers.																

# UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	SS-3
	SAMPLE	3
	SYMBOL	•



## GRAIN SIZE DISTRIBUTION

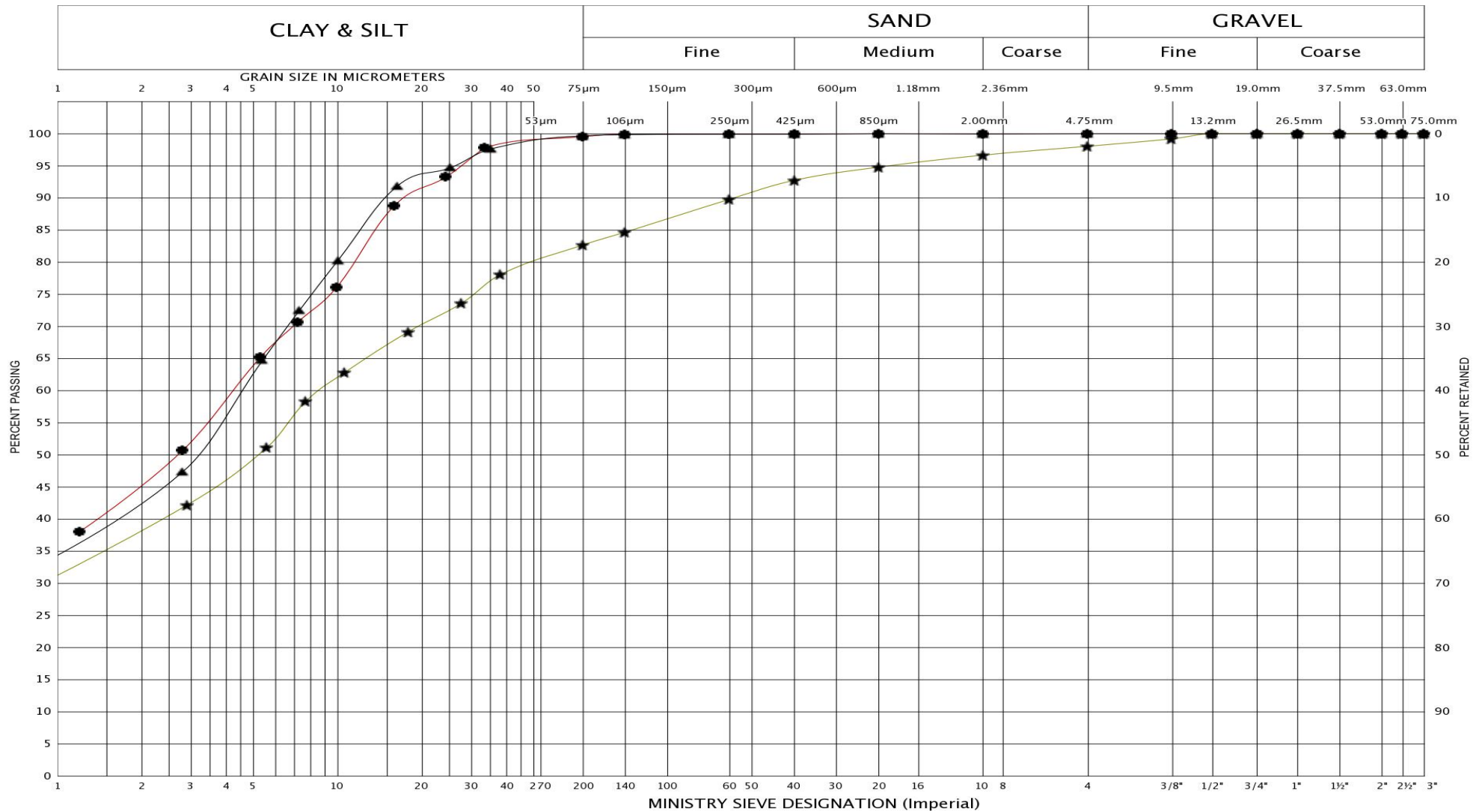
Sandy CLAYEY SILT, trace gravel (FILL)

FIG No.: GS-1

HWY : 402

GWP 3006-20-00

# UNIFIED SOIL CLASSIFICATION SYSTEM



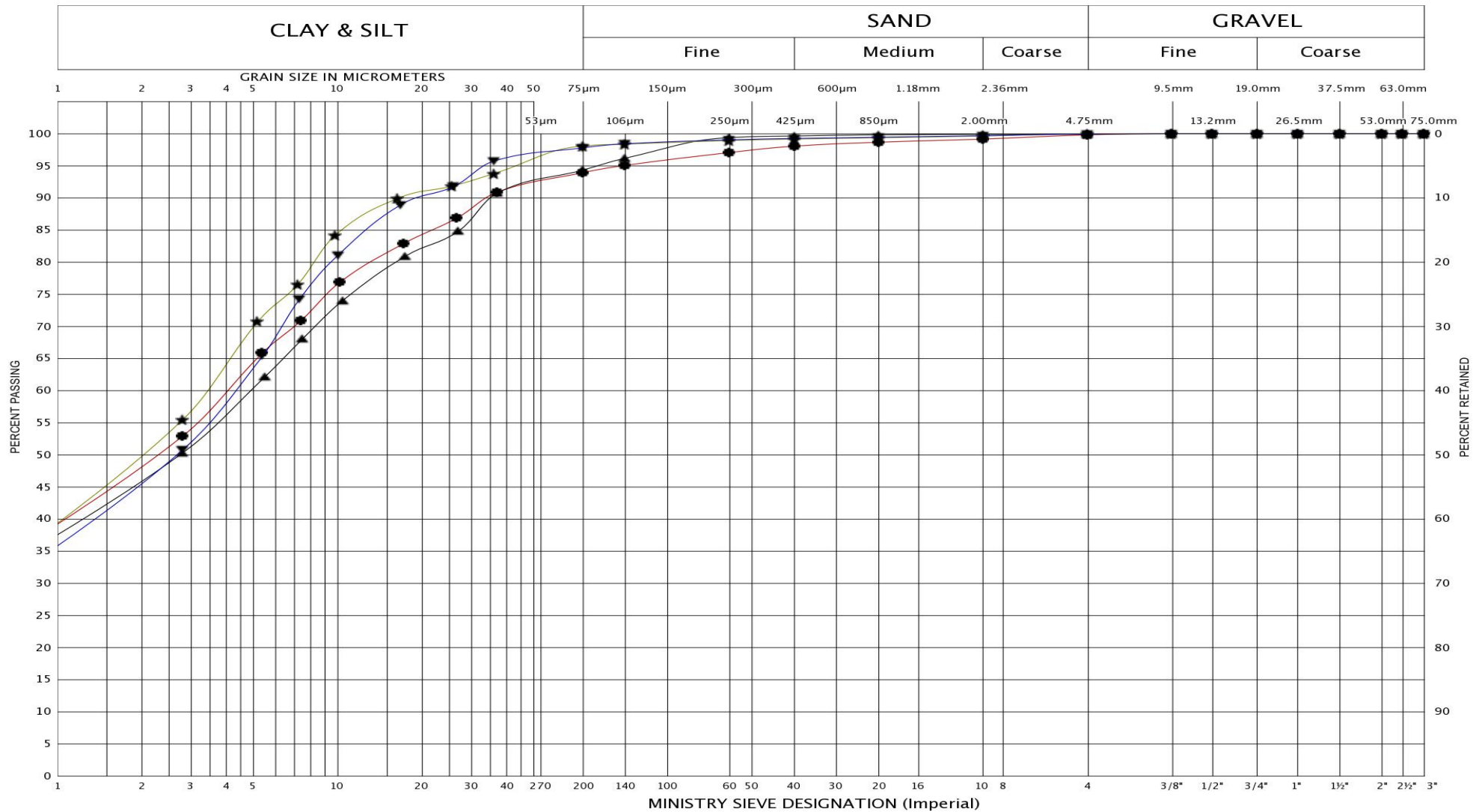
LEGEND	BH	SS-1	SS-1	SS-3
	SAMPLE	4	6	7
	SYMBOL	●	▲	★



**GRAIN SIZE DISTRIBUTION**  
CLAYEY SILT, trace/some sand, trace gravel

FIG No.: GS-2  
HWY : 402  
GWP 3006-20-00

# UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	SS-2	SS-2	SS-4	SS-4
	SAMPLE	5	7	4	9
	SYMBOL	●	▲	★	▼



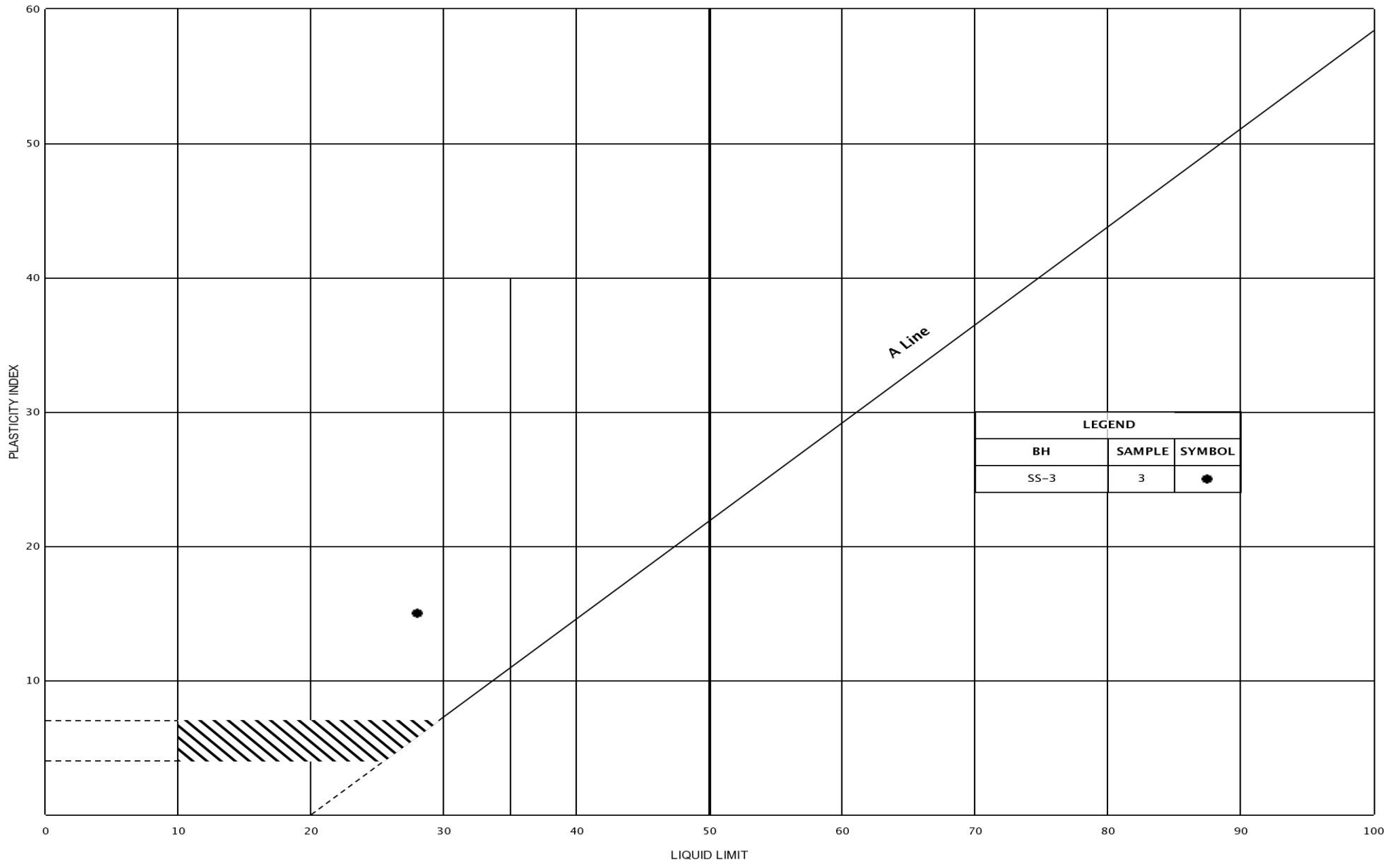
## GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.: GS-3

HWY : 402

GWP 3006-20-00



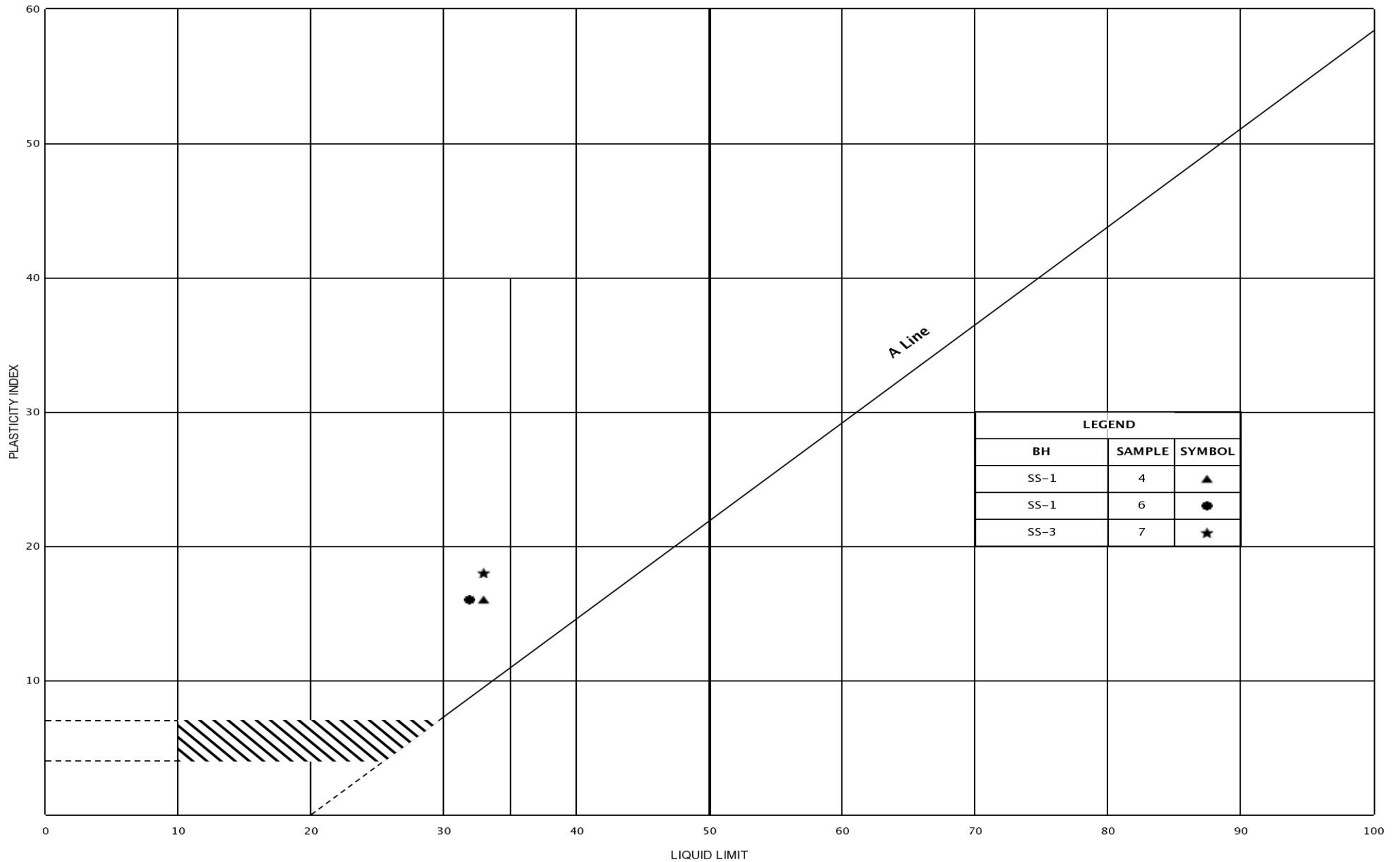
### PLASTICITY CHART

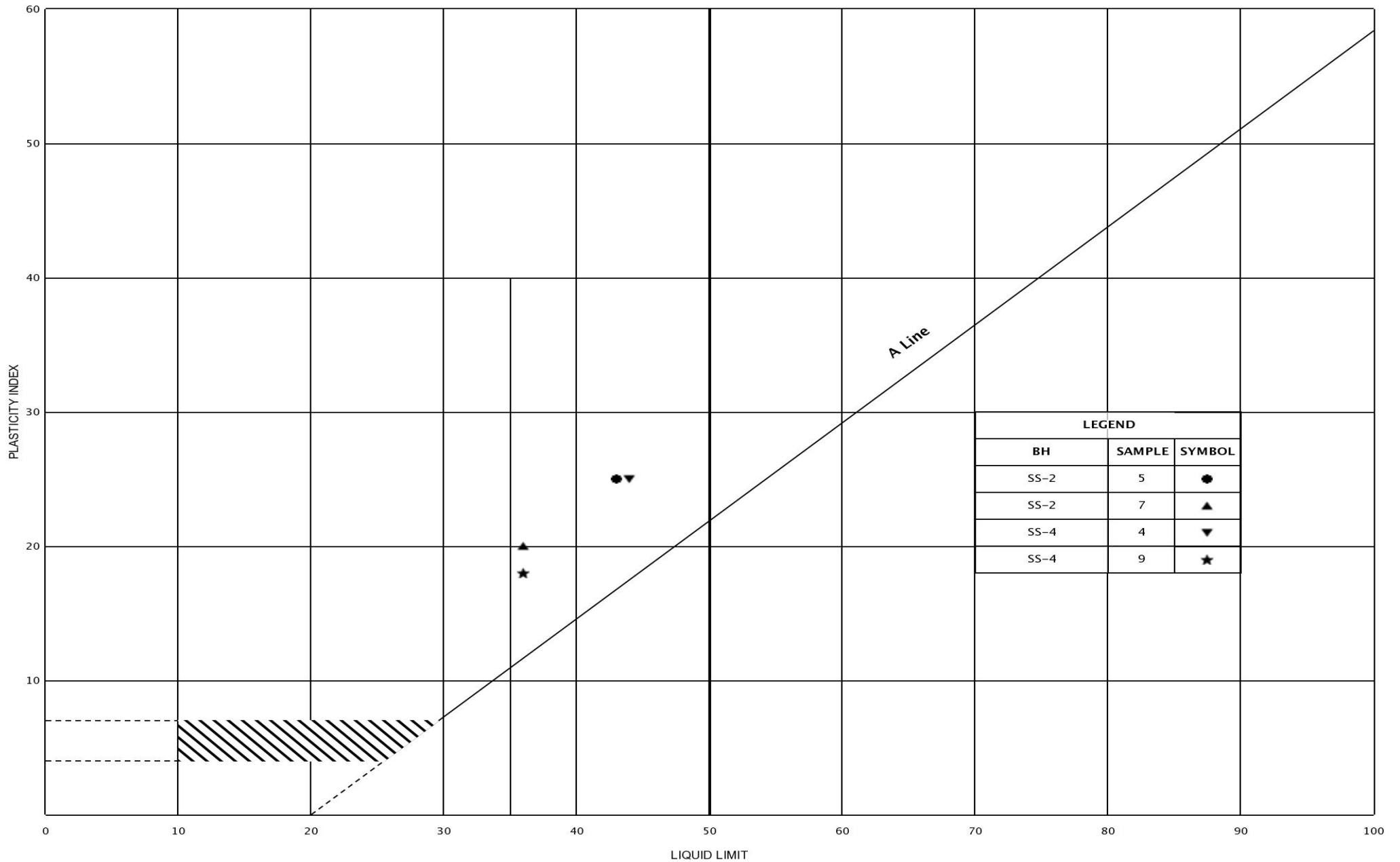
Sandy CLAYEY SILT, trace gravel (FILL)

FIG No.: PC-1

HWY.: 402

Assg No. 3006-20-00







## FINAL REPORT

CA14841-OCT20 R1

20TF024

Prepared for

**Peto MacCallum Ltd**

## First Page

### CLIENT DETAILS

Client Peto MacCallum Ltd

Address 165 Cartwright Ave  
Toronto, ON  
M6A 1V5, Canada

Contact Nazibur Rahman

Telephone 416-785-5110

Facsimile 416-785-5120

Email nrahman@petomacallum.com

Project 20TF024

Order Number

Samples Soil (4)

### LABORATORY DETAILS

Project Specialist Jill Campbell, B.Sc.,GISAS

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 2165

Facsimile 705-652-6365

Email jill.campbell@sgs.com

SGS Reference CA14841-OCT20

Received 10/21/2020

Approved 10/27/2020

Report Number CA14841-OCT20 R1

Date Reported 10/27/2020

### COMMENTS

Temperature of Sample upon Receipt: 7 degrees C

Cooling Agent Present:Yes

Custody Seal Present:Yes

Chain of Custody Number:017325

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

### SIGNATORIES

Jill Campbell, B.Sc.,GISAS







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# FINAL REPORT

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**Client:** Peto MacCallum Ltd

**Project:** 20TF024

**Project Manager:** Nazibur Rahman

**Samplers:** Omar Noor

## PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	6	7	8
Sample Name	Sign 1 Sample 5, 15'-17'	Sign 2 Sample 6, 12.5'-14.5'	Sign 3 Sample 5, 12.5'-14.5'	Sign 4 Sample 6, 12.5'-14.5'
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	19/10/2020	19/10/2020	19/10/2020	19/10/2020

Parameter	Units	RL		Result	Result	Result	Result
<b>Corrosivity Index</b>							
Corrosivity Index	none	1		8	4	8	6
Soil Redox Potential	mV	-		132	187	154	134
Sulphide (Na2CO3)	%	0.04		0.08	< 0.04	0.12	0.15
pH	pH Units	0.05		8.57	8.57	8.67	8.39
Resistivity (calculated)	ohms.cm	-9999		6710	4080	5010	2180

## PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6	7	8
Sample Name	Sign 1 Sample 5, 15'-17'	Sign 2 Sample 6, 12.5'-14.5'	Sign 3 Sample 5, 12.5'-14.5'	Sign 4 Sample 6, 12.5'-14.5'
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	19/10/2020	19/10/2020	19/10/2020	19/10/2020

Parameter	Units	RL		Result	Result	Result	Result
<b>General Chemistry</b>							
Conductivity	uS/cm	2		149	245	200	458

## PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6	7	8
Sample Name	Sign 1 Sample 5, 15'-17'	Sign 2 Sample 6, 12.5'-14.5'	Sign 3 Sample 5, 12.5'-14.5'	Sign 4 Sample 6, 12.5'-14.5'
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	19/10/2020	19/10/2020	19/10/2020	19/10/2020

Parameter	Units	RL		Result	Result	Result	Result
<b>Metals and Inorganics</b>							
Moisture Content	%	0.1		19.5	14.8	16.4	17.4



FINAL REPORT

CA14841-OCT20 R1

Client: Peto MacCallum Ltd

Project: 20TF024

Project Manager: Nazibur Rahman

Samplers: Omar Noor

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6	7	8
Sample Name	Sign 1 Sample 5, 15'-17'	Sign 2 Sample 6, 12.5'-14.5'	Sign 3 Sample 5, 12.5'-14.5'	Sign 4 Sample 6, 12.5'-14.5'
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	19/10/2020	19/10/2020	19/10/2020	19/10/2020

Parameter	Units	RL		Result	Result	Result	Result
Metals and Inorganics (continued)							
Sulphate	µg/g	0.4		68	31	170	460

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6	7	8
Sample Name	Sign 1 Sample 5, 15'-17'	Sign 2 Sample 6, 12.5'-14.5'	Sign 3 Sample 5, 12.5'-14.5'	Sign 4 Sample 6, 12.5'-14.5'
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	19/10/2020	19/10/2020	19/10/2020	19/10/2020

Parameter	Units	RL		Result	Result	Result	Result
Other (ORP)							
Chloride	µg/g	0.4		2.4	99	13	28



FINAL REPORT

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QC SUMMARY

Anions by IC  
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0467-OCT20	µg/g	0.4	<0.4	12	20	94	80	120	98	75	125
Sulphate	DIO0467-OCT20	µg/g	0.4	<0.4	7	20	94	80	120	110	75	125

Carbon/Sulphur  
Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide (Na2CO3)	ECS0033-OCT20	%	0.04	< 0.04	ND	20	117	80	120			

Conductivity  
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0421-OCT20	uS/cm	2	< 2	0	20	100	90	110	NA		



FINAL REPORT

CA14841-OCT20 R1

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-1ENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0421-OCT20	pH Units	0.05	NA	0		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

## LEGEND

## FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

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-- End of Analytical Report --



**PART B – FOUNDATION DESIGN REPORT**

**for**

**VARIABLE MESSAGE SIGN SUPPORT STRUCTURES  
HIGHWAY 402**

**SIGN 1 – STATION 11+677, GEOGRAPHIC TOWNSHIP OF DELAWARE, COUNTY OF MIDDLESEX,  
SIGN 2 – STATION 12+032, GEOGRAPHIC TOWNSHIP OF WARWICK, COUNTY OF LAMBTON,  
SIGN 3 – STATION 16+722, GEOGRAPHIC TOWNSHIP OF SARNIA, COUNTY OF LAMBTON,  
SIGN 4 – STATION 20+826, GEOGRAPHIC TOWNSHIP OF ADELAIDE, COUNTY OF MIDDLESEX,  
ONTARIO**

**G.W.P. 3006-20-00**

**ASSIGNMENT NO. 3017-E-0006**

**WORK ITEM NO. 07**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email:toronto@petomaccallum.com

Distribution:

Electronic Copy: WSP for Distribution to MTO  
Project Manager and  
Foundations Section

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January 26, 2021



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Appendix B - List of Standard Specifications Relevant to Report

**PART B – FOUNDATION DESIGN REPORT**

**For**

Variable Message Sign Support Structures  
Highway 402

Sarnia to London, Ontario

G.W.P. 3006-20-00, Assignment No. 3017-E-0006, Work Item No. 12

**7. INTRODUCTION**

This foundation investigation and design report with the interpretation and recommendations are intended for the use of WSP on behalf of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the contractor. Where comments are made on construction, they are provided only to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the factual information provided in Part A of the report, as it may affect equipment selection, proposed construction methods, and scheduling.

**8. PROJECT DESCRIPTION**

**8.1 General**

This report provides foundation design recommendations based on interpretation of the geotechnical data presented in the factual report (Part A). This section of the report provides foundation recommendations for the design of four (4) proposed variable message sign (VMS) support structures to be installed along Highway 402 from Sarnia to London, Ontario, as outlined in Table 5.

**Table 5: Proposed VMS Locations**

SIGN ID	APPROXIMATE STATION <sup>1</sup>	DIRECTION	LOCATION	TOWNSHIP	COUNTY	SITE NO.	WP
1	11+677	Westbound	1.5 km east of Longwoods Road	Delaware	Middlesex County	19X-0734/S0	3015-20-01
2	12+032	Westbound	1.5 km east of Hwy 21 Forest	Warwick	Lambton County	14X-0812/S0	3014-20-01
3	16+722	Eastbound	1.5 km west of Airport Road	Sarnia	Lambton County	14X-0813/S0	3013-20-01
4	20+826	Eastbound	1.5 km west of Centre Road	Adelaide	Middlesex County	19X-0735/S0	3012-20-01

**Note:** 1. Sign support structure locations and stations are in accordance with AutoCAD drawings "Design – Hwy 402 VMS – Sign 1.dwg", "Design – Hwy 402 VMS – Sign 2.dwg", "Design – Hwy 402 VMS – Sign 3.dwg", and "Design – Hwy 402 VMS – Sign 4.dwg" provided to PML by WSP via e-mail dated October 13, 2020.

The discussions and recommendations presented in this report are based on the information provided by WSP and the factual data obtained during the geotechnical investigation carried out by PML.



## 8.2 Design of Sign Support Structure Foundations

### 8.2.1 Standard VMS Support Structure

Design of standard VMS support structure foundations should be in accordance with MTO *Sign Support Manual*, dated February 2019. The standard design for VMS support structure foundation presented in the *Sign Support Manual (February 2019)* was developed based on the following assumed minimum cohesive soil strength parameters below the depth of frost penetration:

**Cohesive soils:** “Soft” clay with an undrained shear strength,  $s_u$ , of 25 kPa, and “firm” clay with an undrained shear strength,  $s_u$ , of 50 kPa.

Table 6 presents design parameters based on the subsoil conditions encountered.

**Table 6: Geotechnical Design Parameters for Standard VMS Support Structures**

SIGN No. <sup>1</sup>	BOREHOLE ID	ELEVATION (m)		SOIL TYPE	DESIGN PARAMETERS		
		FROM <sup>1</sup>	TO		BULK UNIT WEIGHT (KN/m <sup>3</sup> )	SHEAR STRENGTH (KPa)	INTERNAL FRICTION ANGLE (degrees)
1	SS-1	229.4	222.3	Very Stiff to Stiff Clayey Silt	19	50	0
2	SS-2	217.4	216.4	Clayey Silt (Fill)	18	25	0
		216.4	210.3	Stiff to Very Stiff Silty Clay	19	50	
3	SS-3	179.8	178.8	Clayey Silt (Fill)	18	25	0
		178.8	171.2	Very Stiff to Firm Clayey Silt	19	50	
4	SS-4	249.0	241.9	Very Stiff to Stiff Clayey Silt to Silty Clay	19	50	0

**Note:** 1. Refer to Table 5 for the details of the proposed sign locations. The ‘FROM’ elevation excludes the 1.2 m frost depth below the existing ground surface.

Based on the existing subsurface information, the soil conditions at the locations of SS-1 to SS-4 are expected to have equal to or higher undrained shear strength/internal friction angle values than the design parameters assumed in the *Sign Support Manual (February 2019)*. The standard foundation design is considered applicable for standard VMS support structures.



Based on OPSD 3090.101, the anticipated frost depth is 1.2 m. Passive resistance within the frost depth are neglected and soil parameters within the upper 1.2 m are not provided in Table 6.

## 8.2.2 Non-Standard VMS Support Structures

For proposed VMS support structures that do not meet the requirements for standard design in accordance with MTO *Sign Support Manual (February 2019)*, lateral resistance of the foundation may be computed using the equations provided below for cohesive soils and the soil parameters recommended in Table 7.

### a) Cohesive Soils (Davison, 1970)

$$k_s = 67 \tau_u / d \text{ (kPa/m or kN/m}^3\text{)}$$

where  $\tau_u$  = Undrained shear strength (kPa)  
 $d$  = diameter or width (meter, m)

### b) $P_{ult} = 0.5 \times 9S_u$ (kPa)

where  $0.5$  = Geotechnical resistance factor for ultimate limit state (CHBDC 2019)  
 $S_u$  = Undrained shear strength (kPa)

**Table 7: Geotechnical Design Parameters for Non-Standard VMS Support Structures**

SIGN No. <sup>1</sup>	BOREHOLE ID	ELEVATION (m)		SOIL TYPE	DESIGN PARAMETERS		
		FROM	TO		BULK UNIT WEIGHT (KN/m <sup>3</sup> )	UNDRAINED SHEAR STRENGTH (kPa)	INTERNAL FRICTION ANGLE (degrees)
1	SS-1	229.4	222.3	Very Stiff to Stiff Clayey Silt	19	80	0
2	SS-2	217.4	216.4	Clayey Silt (Fill)	18	15	0
		216.4	210.3	Stiff to Very Still Silty Clay	19	80	0
3	SS-3	179.8	178.8	Clayey Silt (Fill)	18	15	0
		178.8	176.0	Very Stiff to Stiff Clayey Silt	19	75	0
		176.0	171.2	Firm to Stiff Clayey Silt	19	50	0
4	SS-4	249.0	241.9	Very Stiff to Stiff Clayey Silt	19	80	0

**Note:** 1. Refer to Table 5 for the details of the proposed sign locations.



Based on OPSD 3090.101, the anticipated frost depth is 1.2 m. Passive resistance within the frost depth are neglected and soil parameters within the upper 1.2 m are not provided in Table 7.

The caisson design discussed above is applicable for installations in relatively level ground. If the VMS support structures are to be placed in the proximity of a slope, a detail design may be necessary, resulting in extended embedment length and/or increased pole diameter. The lateral resistance within the embankment fill will be reduced based on the proximity to the crest of the slope, and the inclination of the slope. In these cases, the reduction to the lateral resistance may be referenced to Mezazigh and Levacher<sup>1</sup>. Based on the cross sectional drawings at the proposed VMS structure locations provided by WSP, via email dated November 9, 2020, it is considered that reduction to the lateral resistance is not required. However, the final design should be selected by the Designer.

If the VMS post foundation, for both standard and non-standard, is located on shallow slope that is part of a drainage ditch, the top of the foundation may be located at or below the bottom of the drainage ditch. The appropriate final location may be selected by the Designer.

### 8.2.3 Caisson Capacity

It is understood that the proposed VMS support structures Sign Nos. 1, 2 and 4 may be supported on 1.2 m diameter caisson and the proposed VMS support structure Sign No. 3 may be supported on 1.5 m diameter caisson. The embedment lengths may be 6.0 m to 7.0 m below the frost depth. Table 8 summarizes the factored axial resistances at ULS and SLS for 6.0 m, 6.5 m and 7.0 m embedment depths for 1.2 m and 1.5 m diameter caissons.

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<sup>1</sup> Mezazigh, S and Levacher, D. 1988. CGJ Vol 35.



**Table 8: Factored Geotechnical Resistances**

SIGN No. <sup>1</sup>	EMBEDMENT DEPTH (m) EXCLUDING 1.2 m FROST DEPTH	CAISSON BOTTOM ELEVATION <sup>1</sup> (m)	SOIL TYPE AT BOTTOM ELEVATION	FACTORED RESISTANCES			
				1.2 m Diameter Caisson		1.5 m Diameter Caisson	
				ULS (kN)	SLS (kN)	ULS (kN)	SLS (kN)
1	6.0	223.4	Very Stiff Clayey Silt	400	270	565	375
	6.5	222.9		410	280	585	390
	7.0	222.4	Stiff Clayey Silt	430	290	600	400
2	6.0	211.4	Very Stiff Silty Clay	390	260	550	365
	6.5	210.9		400	270	570	380
	7.0	210.4		420	280	590	390
3	6.0	173.8	Firm Clayey Silt	310	210	430	285
	6.5	173.3		330	220	450	300
	7.0	172.8	Stiff Clayey Silt	340	230	470	315
4	6.0	243.0	Stiff Silty Clay	400	270	565	375
	6.5	242.5		410	280	585	390
	7.0	242.0	Stiff Clayey Silt	430	290	600	400

**Note:**

1. To determine the caisson bottom elevation, the frost depth was considered in addition to the embedment depth.
2. At the VMS locations, it is understood that the existing soil will be extracted prior to installing caissons. The self-weight of the soil has to be considered. The total resistance is factored resistance at SLS + (weight of the soil removed, or total overburden stress removed at foundation level,  $q_{ob}$ ),  $q_{ob}$  is not factored (or load factor = 1).

It is estimated that settlement of individual caissons (SLS condition) may be less than or equal to 25 mm for the factored axial resistance at Serviceability Limit State (SLS) provided in Table 8.

### 8.3 Seismic Considerations

The Spectral and Peak Ground Accelerations ( $S_a$  (0.2), PGA and  $PGA_{ref}$ ) for the proposed VMS locations are provided in Table 9.



**Table 9: Seismic Hazard Values**

SIGN ID	TOWNSHIP	COUNTY	SITE NO.	WP	Sa(0.2) <sup>1</sup>	PGA <sup>1</sup>	PGA <sub>REF</sub> <sup>1</sup>
1	Delaware	Middlesex County	19X-0734/S0	3015-20-01	0.107	0.064	0.0512
2	Warwick	Lambton County	14X-0812/S0	3014-20-01	0.091	0.053	0.0424
3	Sarnia	Lambton County	14X-0813/S0	3013-20-01	0.085	0.049	0.0392
4	Adelaide	Middlesex County	19X-0735/S0	3012-20-01	0.097	0.057	0.0456

**Note:** 1. 2015 National Building Code Interpolated Seismic Hazard Values (earthquakescanada.ca). PGA<sub>ref</sub> in accordance with CHBDC (2019) 4.4.3.3..

The soils at the proposed sites for seismic design purposes is classified as 'Type C' for Sign ID's 1, 2 and 4 and as 'Type D' for Sign ID 3 in accordance with Clause 4.4.3.2 of CHBDC, 2019.

#### **8.4 Construction Considerations**

Appropriate equipment and procedures should be employed to minimize ground loss during drilling and concrete placement. This may include the use of temporary liners, and/or the use of drilling mud.

Upon completion of drilling, groundwater was recorded in Boreholes SS-1 and SS-2 at 4.6 m (EL. 226.0) and 3.1 m (EL. 215.5), respectively, below existing ground surface elevation. Groundwater was not recorded/encountered in the other two Boreholes (SS-3 and SS-4) upon completion of drilling. Conventional sump pumping techniques may be able to handle groundwater seepage. It is considered that tremie concreting of the caisson at the proposed VMS structure locations is feasible. The Contractor should select the installation procedure based on the groundwater and subsurface soil conditions.

Cobbles and/or boulders were not encountered in the four (4) boreholes drilled along Highway 402. Nevertheless, appropriate equipment and procedures may be required to penetrate these obstructions, if encountered, for the installation of caisson.



## **8.5 Soil Corrosivity**

A total of four (4) samples from the clayey silt to silty clay deposit were tested for soil corrosivity and potential exposure of concrete to sulphate attack. A summary of the results of chemical analyses are provided in Section 5.2.2 of Part A of this report. The sulphate concentration varied from 68 µg/g to 460 µg/g (0.0068% to 0.046%) in four (4) samples. Compared to the values suggested in Canadian Standard A23.1-19, the effect of soil on buried concrete is considered negligible.

The chloride contents of the samples ranged from as low as 2.4 µg/g to 99 µg/g (0.00024% to 0.0099%). Generally, the concentration value in excess of 250 ppm (0.025%) leads to corrosive environment for buried metals or reinforcing steel. The potential for corrosive environment based on chloride content is assessed to be low.

Electrical resistivity less than 2000 ohm-cm generally leads to corrosive environment for steel elements in contact with soil. The resistivity values of the four (4) samples from boreholes SS-1 to SS-4 varied from 2180 ohm-cm to 6710 ohm-cm, suggesting a low corrosive environment exist at these sites for steel elements.



## 9. CLOSURE

This report was prepared by Ms. N. Leong-Sem, B.Eng., EIT, and Mr. N. Rahman, P.Eng., and reviewed by Mr. G. Uwimana, MEng., P.Eng. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

Natasha Leong-Sem  
EIT  
Geotechnical Services



Geoffrey Uwimana, MEng., P.Eng.  
Discipline Head  
Geotechnical Services

NL/NR/GU/RN:nl-nr-nk



Nazibur Rahman, P.Eng.  
Project Engineer  
Geotechnical Services



Robert Ng, MBA, PhD, P.Eng.  
MTO Designated Principal Contact



## **APPENDIX B**

### List of Standard Specifications Relevant to Report



## LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 902	Construction Specification for Excavating and Backfilling- Structures
OPSS.PROV 903	Construction Specification For Deep Foundations
OPSS.PROV 915	Construction Specification For Sign Support Structures
SP 109F57	Amendment to OPSS 903, April 2016
SP 109S26	Amendment to OPSS 915, November 2014
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario