



Foundation Investigation Report

*Temporary Protection System (Site No. 30-118), Willow Creek Bridge
Rehabilitation on Highway 26, Ministry of Transportation, Ontario,
G.W.P. 2204- 14- 00*

Submitted to:

Morrison Hershfield

2440 Don Reid Dr
Ottawa, ON
K1H 1E1

Submitted by:

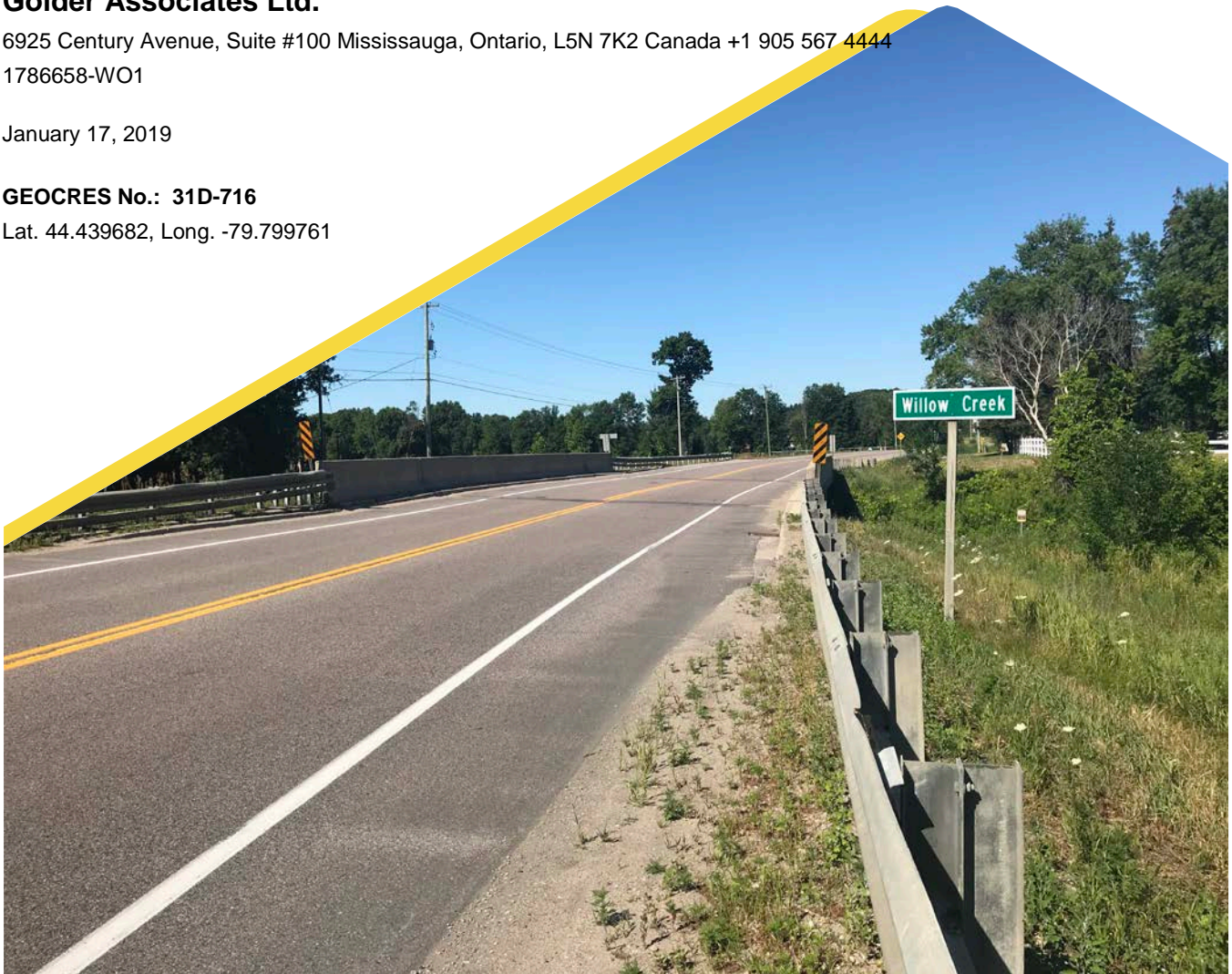
Golder Associates Ltd.

6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada +1 905 567 4444
1786658-WO1

January 17, 2019

GEOCRES No.: 31D-716

Lat. 44.439682, Long. -79.799761



Distribution List

1 eCopy & 1 Copy - Ministry of Transportation, Ontario (Central Region)

1 eCopy & 1 Copy - Ministry of Transportation, Ontario (Foundations)

1 eCopy - Morrison Hershfield

1 eCopy - Golder Associates Ltd.

Table of Contents

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
3.1 Previous Investigation	1
3.2 Current Investigation	2
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 Subsurface Conditions	3
4.2.1 Asphalt Pavement	4
4.2.2 Gravelly Sand (Fill)	4
4.2.3 Silty Sand to Silty Sand and Gravel	4
4.2.4 Clayey Silt to Clay	4
4.2.5 Silty Sand	5
4.3 Groundwater Conditions	5
5.0 CLOSURE	6

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

APPENDICES

APPENDIX A - Previous Investigation (GEOCRE 31D-168)

Record of Boreholes 2 and 4

APPENDIX B - Record of Borehole Sheets

Lists of Symbols and Abbreviations

Record of Boreholes WC1 and WC2

APPENDIX C - Geotechnical Laboratory Test Results

Figure C-1 Grain Size Distribution – Gravelly Sand (Fill)

Figure C-2 Grain Size Distribution – Silty Sand to Sand

Figure C-3 Grain Size Distribution – Clayey Silt to Clay

Figure C-4 Plasticity Chart – Clayey Silt to Clay

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for temporary protection systems associated with the rehabilitation of the Willow Creek Bridge on Highway 26 east of Minesing (near Midhurst), Ontario. The location of the site is shown on the Key Plan in Drawing 1.

The Terms of Reference (TOR) for the foundation engineering services are outlined in MTO's Request for Proposals (RFP) for Assignment No. 2017-E-0016/0017, dated September 2017. Golder's proposal for the foundation engineering services associated with the rehabilitation work is contained in MH's proposal for Work Order No. 1. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated June, 2018. The General Arrangement (GA) Drawing, dated June 2018, for the existing bridge was provided by MH.

The purpose of this investigation is to establish the subsurface soil conditions at the existing bridge site in the areas of proposed temporary protection systems, by borehole drilling, in situ testing and laboratory testing on selected soil samples.

2.0 SITE DESCRIPTION

The Willow Creek Bridge carries eastbound and westbound traffic on Highway 26 over Willow Creek and is located in the Township of Springwater in the Simcoe County, Ontario. The existing Willow Creek Bridge was constructed in 1974 and is a single span, rectangular voided slab structure with a span length of about 20 m and a width of about 11 m. The bridge is founded on piles with the pile caps at about Elevation 187.1 m.

In general, the topography in the area of the bridge consists of relatively flat terrain, including sparsely and densely treed areas. Land use in the area is generally residential and agricultural.

The natural ground surface at the site is between about Elevations 189 m and 190 m. The road grade of Highway 26 at the site is about Elevation 190 m, gradually rising to the east beyond the structure site. Residential and agricultural areas are present in all quadrants of the structure site.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Investigation

The results of a previous geotechnical investigation carried out at the site in 1970 for the existing Willow Creek bridge was obtained from the MTO GEOCRE library, and is summarized in a report prepared for the Department of Highways – Ontario, by the Foundation Section, Materials and Testing Office of the Department of Highways - Ontario (Department of Highways – Ontario, 1970) titled:

- "Foundation Investigation Report for the Proposed New Willow Creek Bridge on Highway #26, 3.1 Miles West of Midhurst Corners, District No. 5 (Owen Sound), W.P. 139-66-00", dated April 1970, GEOCRE No. 31D-168.

During the 1970 investigation, a total of two sampled boreholes (Boreholes 2 and 4,) were advanced in the footprint of the Willow Creek Bridge abutments, the approximate locations shown on Drawing 1. The record of borehole sheets, including the summarized results of geotechnical laboratory tests and groundwater conditions are presented in Appendix A.

The borehole locations positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations referenced to Geodetic datum, and borehole depths are summarized below.

Borehole Number	MTM NAD83 Northing (m) (Latitude, °)	MTM NAD83 Easting (m) (Longitude, °)	Ground Surface Elevation (m)	Borehole Depth (m)
2	4,922,228.5 (44.439680)	280,948.8 (-79.799628)	188.2	30.9
4	4,922,233.6 (44.439725)	280,928.1 (-79.799889)	189.6	20.3

3.2 Current Investigation

The field work for the current investigation was carried out on August 7 and 15, 2018 during which time a total of two boreholes (designated as Boreholes WC1 and WC2) were advanced on the approach embankments near the existing bridge abutments at the locations shown on Drawing 1. The boreholes were advanced to depths of 12.8 m below ground surface and a Dynamic Cone Penetration Testing (DCPT) was carried out from the bottom of Borehole WC2 to a depth of 26.4 m. Traffic control in accordance with MTO Ontario Traffic Manual Book 7 was provided by Alliance Traffic Control Inc. for the fieldwork carried out at this location.

The investigation was carried out using a truck-mounted Diedrich D90 drill rig, supplied and operated by Walker Drilling of Utopia, Ontario. The boreholes were advanced through the overburden using 210 mm outside diameter (O.D.) hollow-stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)¹. The split-spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573)² using MTO Standard 'N' size vanes.

The groundwater conditions were noted in the boreholes upon removal of the hollow stem augers upon completion of drilling. Boreholes were backfilled with bentonite to near ground surface, in accordance with Ontario Regulation 903, Wells (as amended), and the roadway surface was restored to near original condition as practical using cold-patch asphalt.

The field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga laboratory where the samples underwent further visual examination. Geotechnical laboratory testing (water content, grain size distribution, and Atterberg limits) was carried out on selected soil samples, to MTO and/or ASTM Standards, as appropriate.

The borehole locations are provided on the Record of Boreholes in Appendix B and shown on Drawing 1. The locations are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface

¹ ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soil

² ASTM D2573 – Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

elevations are referenced to Geodetic datum. The borehole locations, including geographic coordinates, ground surface elevations and borehole depths are summarized below.

Borehole Number	Location	MTM NAD83 Northing (Latitude, °)	MTM NAD83 Easting (Longitude, °)	Ground Surface Elevation (m)	Borehole (DCPT) Depth (m)
WC1	West Side	4,922,224.4 (44.439642)	280,922.3 (-79.799961)	190.7	12.8
WC2	East Side	4,922,238.5 (44.439770)	280,954.2 (-79.799560)	190.3	12.8 (26.4)

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area is located within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putman, 1984)³. The Simcoe Lowlands region borders Lake Simcoe and extends to the south eastern shores of Georgian Bay. Within the Simcoe Lowlands, the site is located in the Minesing Flats within the Nottawasaga Basin and is characterized by broad flats and soils of deltaic and lacustrine origin from what was once Lake Algonquin. The surficial soils in the Minesing Flats are typically comprised of calcareous clay, some marl, and sands. More recent alluvial deposits of gravel, sand silt, and/or clay are present in the creek valleys.

4.2 Subsurface Conditions

Subsurface soil and groundwater conditions as encountered in the boreholes are presented on the borehole records in Appendix B and shown on the stratigraphic profile on Drawing 1. Method of Soil Classification, Abbreviations and Terms Used on Records of Boreholes and Test Pits and List of Symbols sheets are provided in Appendix B to assist in the interpretation of the borehole records. The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and on the test results sheets in Appendix C.

The results of in situ field tests (i.e., SPT “N”-values and field vane tests) as presented on the borehole records and in Section 4.2 are uncorrected. The boundaries between the strata shown on the borehole records and stratigraphic profile have been inferred from drilling observations and non-continuous sampling. Therefore, these boundaries represent transitions between soil types rather than exact planes of geological change. The interpreted stratigraphic profile along the structure, as shown on Drawing 1, is a simplification of the subsurface conditions. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the subsurface conditions consist of asphalt and granular fill, underlain by a deposit of silty sand to sand, in turn underlain by a clayey silt to clay deposit and a deposit of silty sand.

³ Chapman, L.J. and Putman, D.F., 1984, *The Physiography of Southern Ontario*, Ontario Geological Society, Special Volume 2, Third Edition. Accompanied by Map p. 2715, Scale 1:600,000.)

4.2.1 Asphalt Pavement

An approximately 200 mm and 305 mm thick layer of asphalt (pavement) was encountered at ground surface in Boreholes WC1 and WC2, respectively.

4.2.2 Gravelly Sand (Fill)

A 0.6 m and 1.2 m thick layer of granular fill was encountered underlying the asphalt in Boreholes WC1 and WC2, respectively. This fill extends to depths of 0.8 m and 1.5 m below ground surface (Elevations 189.9 m and 188.8 m), in boreholes WC1 and WC2, respectively, and consists of gravelly sand, trace to some silt, trace clay.

The SPT “N”-values measured within the non-cohesive fill range from 31 blows to 84 blows per 0.3 m of penetration, indicating a dense to very dense state of compactness.

The water content measured on two samples of the fill is about 2 per cent and 3 per cent.

Grain size distribution testing was carried out on a sample of the fill from the 2018 investigation and the result is presented on Figure C-1 in Appendix C.

4.2.3 Silty Sand to Silty Sand and Gravel

A 1.4 m to 7.9 m thick deposit of silty sand to sand to silty sand and gravel, trace clay was encountered underlying the fill in Boreholes WC1 and WC2 and from ground surface in Boreholes 2 and 4. In Boreholes WC1 and WC2, the silty sand to sand deposit was encountered at depths of 0.8 m and 1.5 m below ground surface (Elevations 189.9 m and 188.8 m, respectively) and extends to depths of 2.2 m and 5.6 m below ground surface, while in Boreholes 2 and 4, the non-cohesive deposit extends to depths of 1.6 m and 7.9 m below ground surface (Elevations 188.0 m and 180.3 m), respectively.

The SPT “N”-values measured within the silty sand to silty sand and gravel deposit range from 4 blows to 31 blows per 0.3 m of penetration, indicating a very loose to dense state of compactness.

The water content measured on samples of this deposit ranges from about 8 per cent to 19 per cent.

Grain size distribution testing was carried out on one sample from Borehole 2 of the 1970 investigation and two samples of the non-cohesive deposit from the 2018 investigation and the results are presented on the borehole records and on Figure C-2 in Appendix C for the current investigation.

4.2.4 Clayey Silt to Clay

A 7.2 m to 14.5 m thick deposit comprised of clayey silt to clay, trace to some sand was encountered underlying the silty sand to sand deposit in all boreholes. The cohesive deposit was encountered at depths ranging from 1.7 m to 7.9 m below ground surface (Elevations 188.5 m to 180.3 m) and extends to depths ranging from 12.8 m to 16.5 m below ground surface (Elevations 177.9 m to 171.7 m). Boreholes WC1 and WC2 were terminated within this deposit at a depth of 12.8 m below ground surface (Elevations 177.9 m and 177.5 m).

The SPT “N”-values measured within this cohesive deposit range from 0 blows (weight of rods or hammer) to 5 blows per 0.3 m of penetration, with SPT “N”-values greater than 0 blows for 0.3 m of penetration measured within the upper approximately 2 m of the cohesive deposit in Boreholes WC1 and Borehole 4. In situ field vane tests carried out during the 2018 investigation measured undrained shear strengths generally ranges from about 4 kPa to 29 kPa with one measurement of greater than 96 kPa within the upper 2 m of the deposit. The field vane test results indicate that the clayey silt to clay deposit has a very soft to firm consistency, and stiff consistency indicated by the SPT “N”-values, within the upper approximately 2 m zone.

The water content measured on samples of the cohesive deposit range between about 25 per cent and 58 per cent.

Grain size distribution testing was carried out on three samples of the clayey silt to clay deposit from the 2018 investigation and the results are presented on Figure C-3 in Appendix C.

Atterberg limit testing was carried out on eleven samples of the cohesive deposit from the 1970 investigation, and five samples from the 2018 investigation and measured liquid limits ranging from about 23 to 52 per cent, plastic limits ranging from 12 to 21 per cent, and plasticity indices ranging from 11 to 32 per cent. The Atterberg limit test results are presented on the borehole records and on Figure C-4 and indicate the cohesive deposit ranges from clayey silt of low plasticity to clay of high plasticity. An Atterberg limits test on a partial sample of the cohesive deposit from Borehole 4 measured a liquid limit of about 21 per cent, a plastic limit of about 18 per cent and a corresponding plasticity index of about 3 per cent, indicating that lenses of the deposit may be classified as silt of slight plasticity.

4.2.5 Silty Sand

A non-cohesive deposit described as silty sand at least 14.5 m and 4.1 m thick was encountered underlying the clayey silt to clay in Boreholes 2 and 4, respectively. Based on the composition as described on the record of borehole sheets, the deposit consists of sand some silt, trace gravel, to silt and sand. The silty sand deposit was encountered at depths of 16.5 m and 16.2 m below ground surface (corresponding to Elevations 171.7 m and 173.5 m) and extends to depths of at least 30.9 m and 20.3 m below ground surface (corresponding to Elevations 157.2 m and 169.3 m), in Boreholes 2 and 4, respectively. Both boreholes were terminated within this deposit.

The SPT “N”-values measured within silty sand deposit range from 15 blows to 203 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness.

4.3 Groundwater Conditions

The groundwater level observed in Boreholes WC1 and WC2 upon completion of drilling is at 9.2 m and 10.8 m below existing highway grade, corresponding to Elevations 181.5 m and 179.5 m, respectively. It should be noted that the groundwater level observed in open boreholes may not represent long term, stabilized groundwater level at this site. During the 1970 investigation, artesian groundwater conditions were noted in the silty sand deposit underlying the clayey silt to silty clay to clay deposit in Boreholes 2 and 4, with groundwater levels estimated to be about at Elevations 189.1 m (0.9 m above ground surface) and 190.3 m (0.7 m above ground surface), in the respective boreholes. It should be noted that the groundwater level is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet periods of the year.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Alysha Kobylinski, B.A.Sc., and was reviewed Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and Associate with Golder. Mr. Jorge M.A. Costa, P.Eng., Golder's MTO Foundation Designated Contact for this project and Senior Consultant, conducted an independent technical and quality control review of this report.

Golder Associates Ltd.

Alysha Kobylinski

Alysha Kobylinski, B.A.Sc.
Geotechnical Engineering Analyst



Christopher Ng, P.Eng.
Associate, Senior Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

AK/CNg/JMAC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

<https://golderassociates.sharepoint.com/sites/21998g/deliverables/wo1-willow-creek-bridge/fdns/final-fidr/1786658-wo1-rpt-willow-creek-tps-final-fir-2019jan17.docx>

REFERENCES

Chapman, L.J. and Putnam, D.F. 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

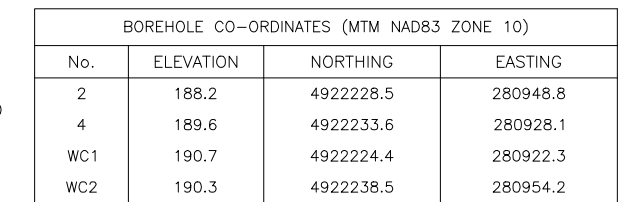
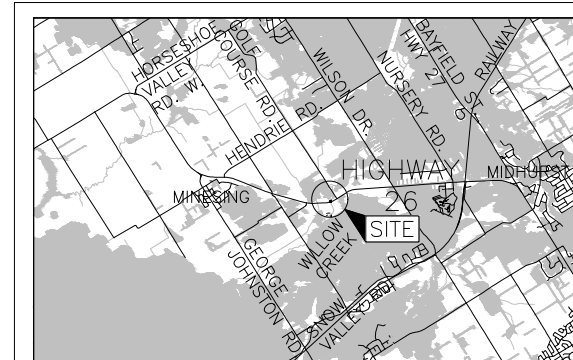
Department of Highways Ontario. 1970. *Foundation Investigation Report for the Proposed New Willow Creek Bridge on Highway #26, 3.1 Miles West of Midhurst Corners, District No. 5 (Owen Sound), W.J. 70-F-9, W.P. 139-66-00*. Department of Highways Ontario – Foundation Section, Ontario.

American Standard for Testing and Materials:

ASTM D1586	Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soil
ASTM D2573	Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

Ontario Water Resources Act:

Ontario Regulation 903 Wells (As Amended)



This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

Base plans and bridge in profile provided in digital format by Morrison Hershfield, drawing file no. E78261.dwg, received Aug. 8, 2018.
General arrangement plan and profile provided in digital format by Morrison Hershfield, drawing file no. 1171166-01 GENERAL ARRANGEMENT 1.dwg, received Sept. 24, 2018 and placed approximately.

-	-	-	-	-
NO.	DATE	BY	REVISION	
Geocres No. 31D-716				
HWY. 26		PROJECT NO. 1786658		DIST. CENTRAL
SUBM'D. MCK		CHKD. AK	DATE: 1/15/2019	SITE: 30-118
DRAWN: MR		CHKD. CN	APPD. JMAG	DWG. 1

APPENDIX A

**Previous Investigation
(GEOCRES 31D-168)**

JOB 70-F-9 LOCATION Sta. 154 + 05 18' Lt. of E ORIGINATED BY DM
W.P. 139-66-00 BORING DATE February 5 - 9, 1970 COMPILED BY AKB
DATUM Geodetic BOREHOLE TYPE Washboring, NX Casing CHECKED BY AKB

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ P.C.F.	REMARKS			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		BLOWS / FOOT					SHEAR STRENGTH P.S.F.					WATER CONTENT %		
							20 40 60 80 100					200 400 600 800 1000					w_p — w — w_L		
							20 40 60 80 100					200 400 600 800 1000					20 40 60		
							20 40 60 80 100					200 400 600 800 1000					20 40 60		
617.4	Ground Level															620.4 Art. Head (estimated)			
0.0	Silty sand with gravel, roots and decayed organics.		1	SS	2	610							○			11 72 13 4			
	Very loose		2	SS	9								○						
	Brown		3	SS	1	600							○						
591.4			4	SS	0	590													
26.0	Sensitive		5	SS	0								○						
	Silty clay to clayey silt, thin seams of silt					580													
	Very soft to soft		6	TW	FM		○	○					○		115				
	Grey		7	TW	FM	570	○						○		117				
563.4			8	TW	FM								○						
54.0	Silty fine sand					560										560 Art. encountered			
	Very dense		9	SS	51	550							○						
	Grey		10	SS	151								○			1 86 (13)			
			11	SS	136	540							○						
			12	SS	147								○						
			13	SS	141	530							○			0 81 (19)			
			14	SS	85								○						
			15	SS	80	520							○						
515.9			16	SS	72								○			0 59 (41)			
101.5	End of Borehole																		

JOB 70-F-9
W.P. 139-66-00
DATUM Geodetic

LOCATION Sta. 164 + 65 18' Rte. of 8
BORING DATE February 12-13, 1970
BOREHOLE TYPE Washboring, NX Casing

ORIGINATED BY DM
COMPILED BY AKB
CHECKED BY *AKB*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS / FOOT		20	40	60	80	100	w_p	w	w_L		
622.2	Ground Level															
0.0	Silty sand with gravel					620										
616.7			1	SS	5											
5.5	Sensitive clay becoming silty		2	SS	5	610										
	clay with pockets of silt		3	TW	FM											
			4	TW	FM	600										
	Very soft to soft		5	TW	FM	590										
	Grey		6	TW	FM	580										
569.2			7	TW	FM	570										
53.0	Silty fine sand.		7A	SS	16											
	Compact to very dense		8	SS	36											
555.7			9	SS	203											
66.5	End of Borehole															

APPENDIX B

Record of Borehole Sheets

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_c	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_{α}	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness	N
Condition	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 1786658		RECORD OF BOREHOLE No WC1		SHEET 1 OF 1		METRIC												
G.W.P. 2204-14-00		LOCATION N 4922224.4; E 280922.3 MTM NAD ZONE 10 (LAT. 44.439642; LONG. -79.799961)		ORIGINATED BY SK														
DIST Central HWY 26		BOREHOLE TYPE 210 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY AK														
DATUM Geodetic		DATE August 15, 2018		CHECKED BY CN														
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)					
190.7	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L 20 40 60			GR SA SI CL		
0.0	ASPHALT (200 mm)																	
0.2	Gravelly sand, some silt (FILL)		1	SS	69		190											
189.9	Very dense Brown Moist																	
0.8	SAND, trace to some silt, trace gravel, trace clay, trace wood fragments, some shells		2	SS	14		189									0 87 10 3		
	Loose to compact Brown Moist		3	SS	4													
188.5	CLAYEY SILT, trace to some sand		4	SS	1		188											
2.2	Stiff Brown Moist		5	SS	5											0 7 57 36		
186.6	SILTY CLAY						187											
4.1	Very soft to firm Grey Moist to wet		6	SS	WH		186											
							185											
			7	SS	WH		184											
							183											
			8	SS	WR		182											
							181									0 0 45 55		
			9	SS	WH		180											
			10	SS	WR		179											
			11	SS	WH		178											
177.9	END OF BOREHOLE																	
12.8	NOTE:																	
	1. Water level measured in open borehole at a depth of 9.2 m below ground surface (Elev. 181.5 m) upon completion of drilling.																	

GTA-MTO 001 S:\CLIENTS\MTOWHY_26_WILLOW_CREEK\02_DATA\GINT\HWY26_WILLOWCREEK.GPJ GAL-GTA.GDT 01/17/19

PROJECT		1786658		RECORD OF BOREHOLE No WC2		SHEET 1 OF 2		METRIC						
G.W.P.		2204-14-00		LOCATION		N 4922238.5; E 280954.2 MTM NAD ZONE 10 (LAT. 44.439770; LONG. -79.799560)		ORIGINATED BY SK/JS						
DIST		Central HWY 26		BOREHOLE TYPE		210 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY AK						
DATUM		Geodetic		DATE		August 7, 2018		CHECKED BY CN						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
190.3	GROUND SURFACE							20 40 60 80 100	20 40 60					
190.0	ASPHALT (305 mm)							20 40 60 80 100	20 40 60					
0.3	Gravelly sand, trace silt, trace clay (FILL) Dense to very dense Brown Moist		1	SS	84									
188.8			2	SS	31									21 72 5 2
1.5	Silty SAND to SAND, trace to some silt, some gravel, trace clay, containing trace organics Loose to dense Brown to grey Moist to wet		3	SS	31									
			4	SS	12									
	- Grey below a depth of 2.8 m (Elev. 187.5 m)		5	SS	21									0 71 25 4
			6	SS	9									
184.7	CLAYEY SILT to CLAY, trace to some sand Very soft to firm Grey Wet		7	SS	WH									0 4 23 73
5.6			8	SS	WH									
	- 50 mm sand seam at a depth of 7.7 m (Elev. 182.6 m)		9	SS	WR									
			10	SS	WR									
			11	SS	WR									
177.5	End of Borehole Dynamic Cone Penetration Test (DCPT)													
12.8														
175.3														

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTOWHY_26_WILLOW_CREEK\02_DATA\GINT\HWY26_WILLOWCREEK.GPJ GAL-GTA.GDT 01/17/19

PROJECT		1786658		RECORD OF BOREHOLE No WC2				SHEET 2 OF 2		METRIC			
G.W.P.		2204-14-00		LOCATION				N 4922238.5; E 280954.2 MTM NAD ZONE 10 (LAT. 44.439770; LONG. -79.799560)		ORIGINATED BY			
DIST		Central HWY 26		BOREHOLE TYPE				210 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY			
DATUM		Geodetic		DATE				August 7, 2018		CHECKED BY			
										CN			
SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60	W _p W W _L	GR SA SI CL		
--- CONTINUED FROM PREVIOUS PAGE ---													
15.0	Dynamic Cone Penetration Test (DCPT)						175						
							174						
							173						
							172						
							171						
							170						
							169						
							168						
							167						
							166						
							165						
163.9	END OF DCPT Refusal to Further Penetration (100 Blows / 0.18 m)						164						
26.4	NOTE: 1. Water level measured in open borehole at a depth of 10.8 m below ground surface (Elev. 179.5 m) upon completion of drilling.												

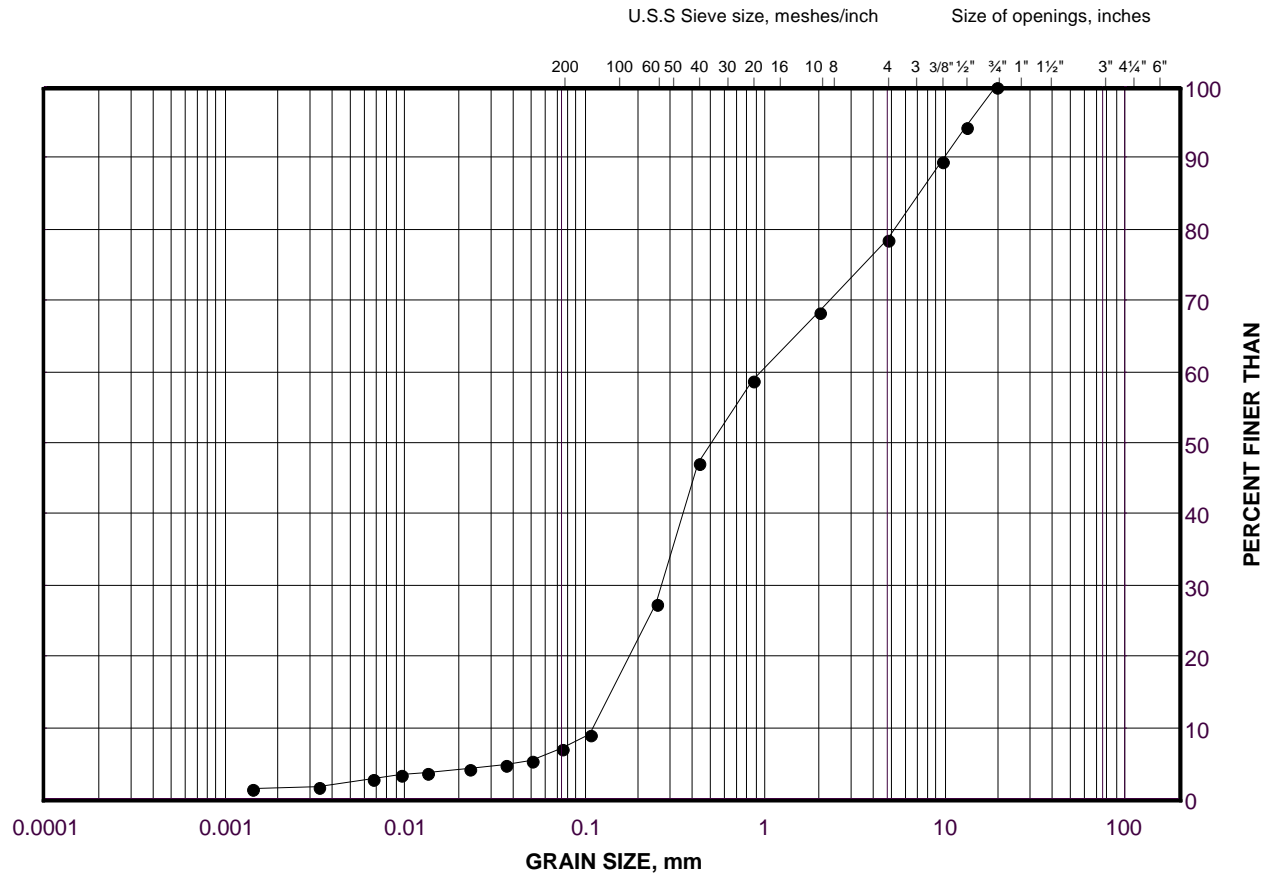
APPENDIX C

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Gravelly Sand (Fill)

FIGURE C-1



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	WC 2	2	189.1

Project Number: 1786658

Checked By: AK

Golder Associates

Date: 14-Sep-18

Silty Sand to Sand

U.S.S Sieve size, meshes/inch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	Percent Finer Than (%) - Square Markers	Percent Finer Than (%) - Circular Markers
0.0075	5	5
0.015	7	5
0.03	10	5
0.06	15	10
0.12	30	25
0.25	90	85
0.425	100	95
0.85	100	100
1.75	100	100
3.5	100	100
7.0	100	100
14.0	100	100
28.0	100	100
56.0	100	100
112.0	100	100
224.0	100	100

SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

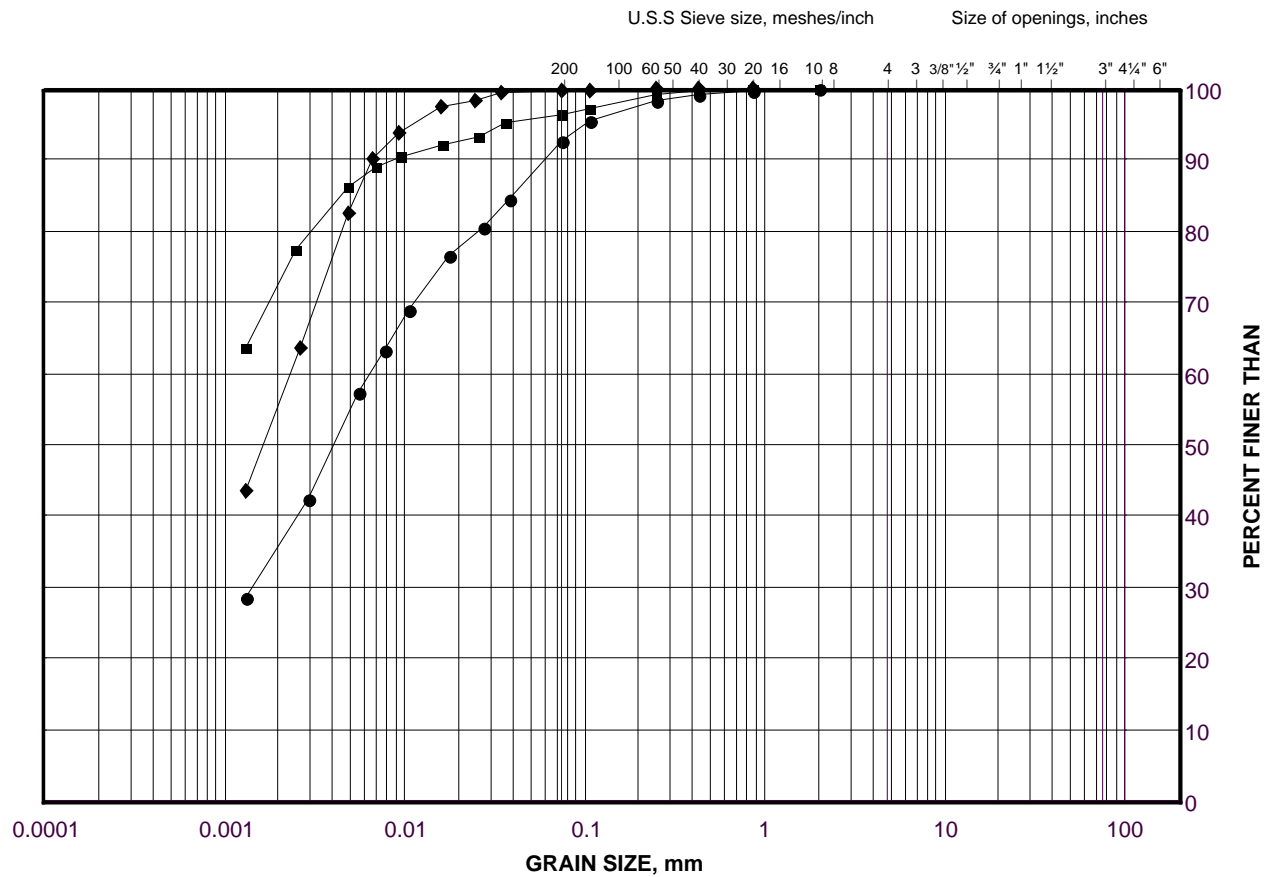
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	WC 1	3	189.5
■	WC 2	5	186.9

Date: 14-Sep-18

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clay

FIGURE C-3



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

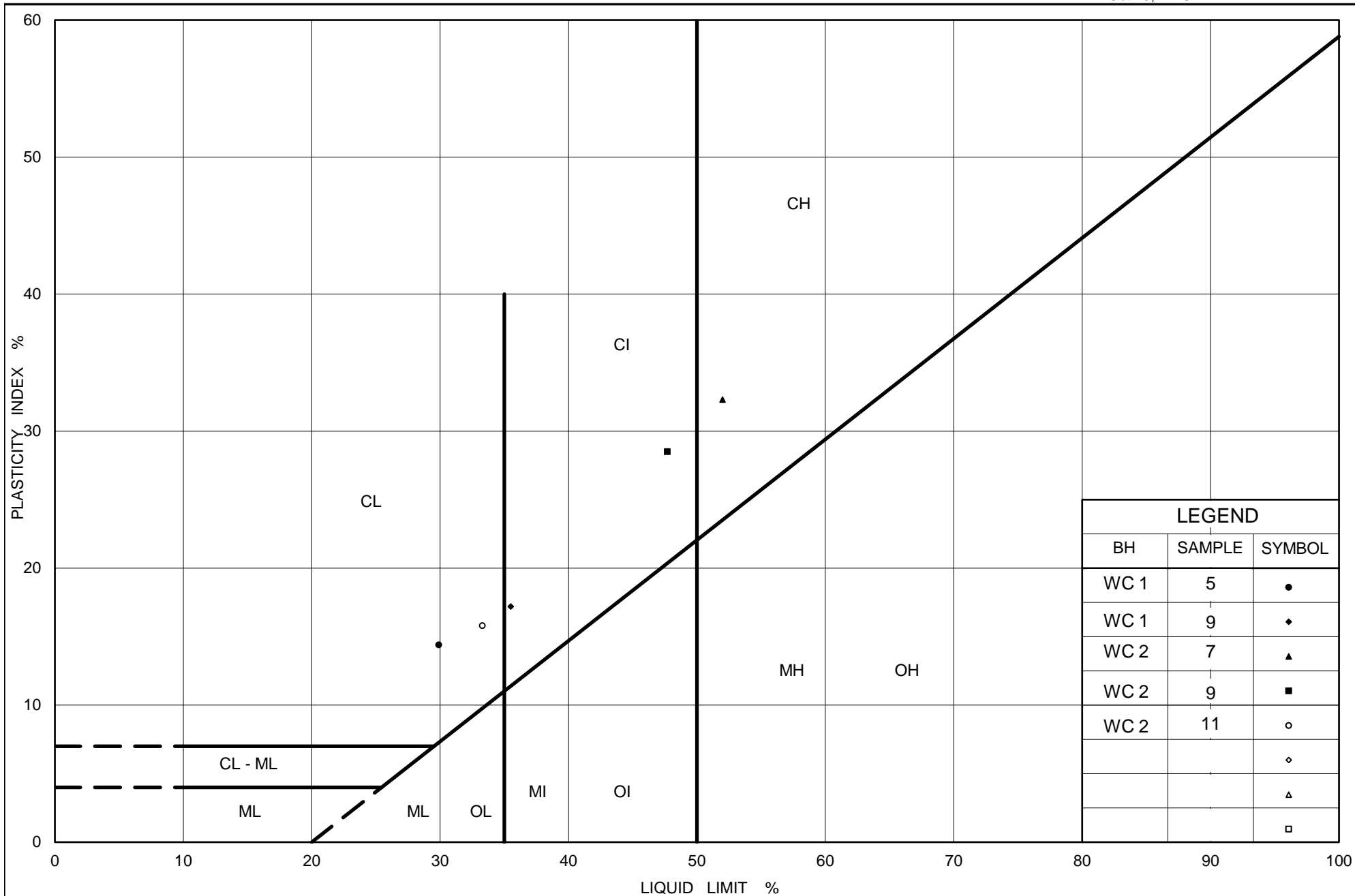
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	WC 1	5	188.9
■	WC 2	7	183.9
◆	WC 1	9	181.3

Project Number: 1786658

Checked By: AK

Golder Associates

Date: 19-Sep-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Clay

Figure No. C-4

Project No. 1786658

Checked By: AK



golder.com