



FOUNDATION INVESTIGATION AND DESIGN REPORT

PROPOSED HIGH MAST LIGHT POLES TOWN OF NIAGARA-ON-THE-LAKE NIAGARA REGION, ONTARIO

SITE LOCATION (LAT: 43.160074°, LONG: -79.162193°)

MINISTRY OF TRANSPORTATION ONTARIO.

GWP 2423-15-00

GEOCRES NO. 30M3-316

WSP PROJECT NO.: 18M-01021-12

DECEMBER 21, 2019

WSP CANADA INC.
2 INTERNATIONAL BOULEVARD
TORONTO, ON
CANADA, M9W 1A2

T: +1 416 679-9410
WWW.WSP.COM



FOUNDATION INVESTIGATION REPORT

PROPOSED HIGH MAST LIGHT POLES TOWN OF NIAGARA-ON-THE-LAKE, NIAGARA REGION, ONTARIO

SITE LOCATION (LAT: 43.160074°, LONG: -79.162193°)

MINISTRY OF TRANSPORTATION ONTARIO.

GWP 2423-15-00

GEOCRES NO. 30M3-316

WSP PROJECT NO.: 18M-01021-12

DECEMBER 1, 2019

WSP CANADA INC.
2 INTERNATIONAL BOULEVARD
TORONTO, ON
CANADA, M9W 1A2

T: +1 416 679-9410
WWW.WSP.COM

TABLE OF CONTENTS

1	INTRODUCTION	1
2	BACKGROUND INFORMATION	2
2.1	GEOLOGICAL SETTING	2
2.2	PREVIOUS GEOTECHNICAL INFORMATION	2
2.3	SITE DESCRIPTION	2
3	FIELD AND LABORATORY INVESTIGATIONS	3
3.1	FIELD INVESTIGATION	3
3.2	LABORATORY INVESTIGATIONS.....	4
3.3	GROUNDWATER INVESTIGATION	5
4	SUBSURFACE CONDITIONS	6
4.1	GENERAL	6
4.2	OVERVIEW	6
4.3	SUBSURFACE CONDITIONS FOR HM1	7
4.4	SUBSURFACE CONDITIONS FOR HM2	8
4.5	SUBSURFACE CONDITIONS FOR HM3	10
4.6	SUBSURFACE CONDITIONS FOR HM4	12
4.7	SUBSURFACE CONDITIONS FOR HM7	14
4.8	SUBSURFACE CONDITIONS FOR HM8	15
4.9	SUBSURFACE CONDITIONS FOR HM9	16
4.10	GROUNDWATER LEVEL OBSERVATIONS	18
4.11	CORROSIVITY AND WATER-SOLUBLE SULPHATE TESTING OF SOILS.....	20

TABLES

TABLE 3 - 1 PIEZOMETER INSTALLATION DETAILS.....	3
TABLE 3 - 2 PIEZOMETER INSTALLATION DETAILS	5
TABLE 4- 1 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY.....	7
TABLE 4- 2 ATTERBERG LIMIT TEST RESULTS - SILTY CLAY.....	8
TABLE 4- 3 GRAIN SIZE DISTRIBUTION SUMMARY - FILL (SILTY CLAY)	8
TABLE 4- 4 ATTERBERG LIMIT TEST RESULTS - FILL (SILTY CLAY).....	9
TABLE 4- 5 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY TO CLAY.....	9
TABLE 4- 6 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	10
TABLE 4- 7 GRAIN SIZE DISTRIBUTION SUMMARY - FILL (CLAYEY SILT)	10
TABLE 4- 8 ATTERBERG LIMIT TEST RESULTS - FILL (CLAYEY SILT)	11
TABLE 4- 9 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY.....	11
TABLE 4- 10 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	12
TABLE 4- 11 GRAIN SIZE DISTRIBUTION SUMMARY - FILL (SILTY CLAY)	12
TABLE 4- 12 ATTERBERG LIMIT TEST RESULTS - FILL (SILTY CLAY).....	13
TABLE 4- 13 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY TO CLAY.....	13
TABLE 4- 14 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	14
TABLE 4- 15 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY.....	14
TABLE 4- 16 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	15
TABLE 4- 17 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY.....	16
TABLE 4- 18 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	16
TABLE 4- 19 GRAIN SIZE DISTRIBUTION SUMMARY - SILTY CLAY.....	17
TABLE 4- 20 ATTERBERG LIMIT RESULTS - SILTY CLAY.....	17
TABLE 4- 21 GRAIN SIZE DISTRIBUTION SUMMARY - CLAYEY SILT	18
TABLE 4- 22 ATTERBERG LIMIT RESULTS - CLAYEY SILT	18
TABLE 4- 23 SUMMARY OF GROUNDWATER LEVEL OBSERVATIONS	19

DRAWINGS

DRAWING 1 BOREHOLE LOCATION PLAN

DRAWING 2 SUBSURFACE STRATA

APPENDICES

APPENDIX A RECORD OF BOREHOLE SHEETS

APPENDIX B LABORATORY TEST RESULTS

APPENDIX C SITE PHOTOGRAPHS

APPENDIX D CORROSIVITY AND WATER-SOLUBLE SULPHATE
TEST

1 INTRODUCTION

WSP Canada Inc. (WSP) was retained by the Ministry of Transportation, Ontario (MTO) Central Region to conduct a peer review of the preliminary design plan, prepare a Design-Build Ready Package and assist MTO and Niagara Region during the Design Builder Procurement phase of the Queen Elizabeth Way (QEW) / Glendale Avenue interchange improvements project in the Town of Niagara-on-the-Lake, Ontario. This work is carried out under the MTO Central Region Mega 4 Retainer, Assignment No: 2017-E-0018 and forms Work Order No. 12.

As part of the preparation of the Design-Build Ready Package, foundation engineering services were required for the detail design of the following components:

- one 40 m long 2 m high Retaining Wall at Glendale Avenue and York Road Roundabout;
- one 30 m long 7 m high Retaining Wall for the Airport Road Structure;
- three 13 m long and 7 m high Retaining Walls for the Airport Road Structure;
- five Overhead Sign Support (OHS) Structures; and,
- nine High Mast Light (HML) Poles.

This report addresses the foundation investigation carried out in support of the proposed nine High Mast Light (HML) Poles at the QEW/Glendale Avenue Interchange located in the Town of Niagara-On-The-Lake, Ontario. Although nine (9) High Mast Light (HML) Poles were stipulated in the Terms of Reference (TOR), only seven (7) of the proposed HML poles were approved for drilling in our submission to MTO. The reason being that two of the proposed HML poles (HM5 & HM6) were in the exact same locations as two (2) previously existing ones. However, the initial light pole numbering sequence adopted was retained after the two (2) proposed borehole cancellation.

The purpose of the Geotechnical Investigation was to determine the sub-surface conditions and groundwater observations at the site by means of boreholes, field and laboratory tests. Based on the information obtained, the engineering characteristics of the subsurface soils were assessed and site conditions described to develop geotechnical recommendations to address the foundation scope.

Part A of this report presents factual information concerning the subsurface conditions based on all of the subsurface information at hand and is followed by Part B wherein engineering discussion and foundation recommendations are made for the design and construction of the proposed HML foundations.

2 BACKGROUND INFORMATION

2.1 GEOLOGICAL SETTING

The project site is located within the physiographic region of Southern Ontario known as the Iroquois Plain, which lies between Lake Ontario and Niagara Escarpment. The Iroquois Plain was inundated by glacial Lake Iroquois in late Pleistocene times. The Iroquois Plain is flat with little relief and is covered by lacustrine deposits of sands, silt and silty clays overlying glacial clayey silt - Halton (Till). These deposits are underlain by red shale of the Queenston formation of the Upper Ordovician in the region of the project site.

2.2 PREVIOUS GEOTECHNICAL INFORMATION

The following foundation report pertains to the general area of the proposed HML locations.

- Foundation Investigation and Design Report, Airport Road Connection Structure, Niagara-On-The-Lake, GWP 2423-15-00, GEOCRETS NO. 30M3-310, dated May 15, 2019.

According to the report, the soil stratigraphy comprised of a fill material underlain by a silty clay to clay deposit (consisting of a very stiff to hard crust and becoming firm to stiff with depth). This in turn is underlain by deposits of generally hard clayey silt/clayey silt till, and/or dense to very dense sand and silt, overlying shale bedrock.

2.3 SITE DESCRIPTION

The key site plan is shown on **Drawing No. 1**. For the purposes of this report, the Queen Elizabeth Way (QEW) is oriented in the east-west direction with respect to the geographic north while the Glendale Avenue is oriented in the north-south direction. The locations of the proposed HML poles run along/parallel to Queen Elizabeth Way (QEW) between the off-ramps and on-ramps to QEW, i.e. to the east and west of the proposed QEW/Glendale avenue interchange. The topography of the area is generally flat. The indicated project area is well vegetated with trees, shrubs and bushes. There are commercial businesses situated on either side of the interchange. Site photographs showing some of the borehole locations and/or their accesses are shown in **Appendix C**.

3 FIELD AND LABORATORY INVESTIGATIONS

3.1 FIELD INVESTIGATION

Site reconnaissance field visit observations (carried out on June 6, 2019) to assess the nature of the local terrain and access constraints (supplemented by ground information obtained from previous Geocres reports) was carefully considered in planning the field investigation program. This led to the understanding that the site can accommodate the use of conventional drilling gear particularly the track mounted CME 55 type of machine. Some of the borehole locations (such as HM1, HM7 & HM8) permitted the use of a truck mounted M10 type rig.

Field investigation commenced on August 26, 2018 with notification to MTO and ended on September 03, 2019. Generally, traffic protection was not needed for the borehole drilling operation except for borehole HM4 location requiring a crash truck protection for offloading and onloading the rig at the shoulders of the QEW off-ramp during ingress and egress. Borings were achieved by means of solid stem flight augers in all the boreholes.

The fieldwork was carried out under the full-time supervision of WSP technical staff who directed the exploration and sampling operation, logged borehole data in accordance with MTO Soil Classification System and took custody of soil samples retrieved for subsequent laboratory identification and testing. Soil samples were visually classified in the field and later re-evaluated by an engineer in the laboratory. The recovered soil samples were placed in labelled moisture-proof bags and returned to WSP's Galaxy laboratory for further assessment and testing.

Table 3-1 presents the exploratory hole details of the WSP foundation investigation program.

Table 3 - 1 Summary of Exploratory Hole Details

Borehole No.	MTM NAD83 Co-Ordinates: Eastings/ Northings (m)	Ground El. (m)	Explored Depth (m)	Drilling Methodology/Remarks
HM1	E 331899.6 N 4779898.5	114.1	15.9	Truck Mount M10/Solid Stem Auger
HM2	E 331997.6 N 4779835.6	116.4	15.9	Track Mount CME 55/Solid Stem Auger
HM3	E 332082.7 N 4779802.6	119.0	15.5	Track Mount CME 55/Solid Stem Auger
HM4	E 332188.5 N 4779739.2	119.3	15.9	Track Mount CME 55/Solid Stem Auger
HM7	E 332192.1 N 4779671.1	117.0	15.9	Truck Mounted M10/Solid Stem Auger

HM8	E 332024.0 N 4779736.8	115.5	15.9	Truck Mounted M10/Solid Stem Auger
HM9	E 331873.8 N 4779809.7	115.6	15.9	Track Mount CME 55/Solid Stem Auger

Notes:

- 1) Locates done by PVS with participating companies such as Niagara-On-The-Lake Hydro One, Enbridge Gas, Bell Canada and COGECO Cable.
- 2) The spacing and quantity of boreholes generally conform to RFP requirements;
- 3) Type of drilling rig Used: Track Mounted - CME 55 rig (used by Pontil Drilling Services Inc.) and Track Mounted M5T & Truck Mounted M10 rig (used by DrillTech Drilling Ltd.);
- 4) Co-ordinates: based on MTM NAD 83 Zone 10 coordinates; Terminology of directions, e.g., Reference to North is geographic;
- 5) Traffic control to Book 7 by Direct Traffic Management Inc., Hamilton, Ontario;
- 6) Names of Drilling Company: DrillTech Drilling Ltd, Newmarket, Ontario (for drilling boreholes HM1, HM7 & HM8) and Pontil Drilling Services Inc., Mount Albert, Ontario (for drilling boreholes HM2, HM3, HM4 & HM9);
- 7) Drilling Supervision: by WSP staff from Toronto office;
- 8) Borehole Survey by WSP representative using Sokkia Archer Global Positioning System (GPS) unit with a horizontal and vertical accuracy of 0.01 m and 0.05 m respectively.

Samples were retrieved at regular intervals with a 50 mm Outer Diameter (O.D.), split-barrel sampler driven with a hammer weighing 63.5 kg and dropping a vertical distance of 760 mm in accordance with the Standard Penetration Test (ASTM D1586) method. This sampling method recovers samples from the soil strata, and the number of blows required to drive the sampler 300 mm depth into the undisturbed soil (SPT 'N'-values) gives an indication of the compactness condition or consistency of the sampled soil material. The SPT 'N' values are indicated on the Record of Borehole Sheets (Refer to **Appendix A**). The borehole termination criteria are as specified in the Terms of Reference. Pocket penetrometer testing was also carried out on the recovered soil samples.

In-situ shear vane tests (with a MTO 'N' vane) were carried out within the cohesive soils when the consistency of such soils allowed to obtain an indication of the shear strength of the soil. Field vane shear tests were carried-out in accordance with ASTM D2573.

3.2 LABORATORY INVESTIGATIONS

Visual examination and classification were undertaken on the soil samples returned to WSP laboratory. A routine laboratory testing program consisting of natural water content tests, grain size analysis, hydrometer testing and Atterberg Limit Tests was carried out on selected representative soil samples. The grain size distribution curves and the plasticity charts are presented in **Appendix B**. In addition, conductivity / resistivity, pH, sulphate and chloride content testing were carried out on selected samples by a specialist analytical laboratory. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets in **Appendix D**.

3.3 GROUNDWATER INVESTIGATION

Groundwater conditions in the boreholes were observed upon completion of drilling in the open boreholes.

Standpipe piezometers (50 mm) were installed in boreholes HM1, HM7, HM8 and HM9 upon completion to enable long-term groundwater level monitoring. The rest of the boreholes were grouted (decommissioned) using a cement/bentonite mixture as per MTO procedures. As part of the construction, the piezometers need to be decommissioned in accordance with Ontario Regulation 903 (amended to Ontario Regulation 327/07).

Table 3-2 provides information about the piezometers installed for this investigation, including ground surface elevation, depths and the approximate elevations of the screen interval.

Table 3 - 2 Piezometer Installation Details

BH No.	Ground Surface Elevation (m)	Borehole Bottom		Well Screen Interval Depth, m		Well Screen Interval Elevation, m		Remarks
		Depth (m)	Elevation (m)	From	To	From	To	
HM1	141.1	15.9	98.3	6.7	9.8	134.4	131.3	Refer to Drawing 1 for the locations of the HML boreholes.
HM7	117.0	15.9	101.1	6.7	9.8	110.3	107.2	
HM8	115.5	15.9	99.7	6.7	9.8	108.8	105.7	
HM9	115.6	15.9	99.8	12.2	15.9	103.4	99.7	

4 SUBSURFACE CONDITIONS

4.1 GENERAL

The subsurface conditions encountered at the HML pole locations are described in the following sections. The borehole location plan is shown on **Drawing 1**. The soil descriptions are based on visual and tactile observations and complemented by the results of field and laboratory soil test results.

For purposes of soil description, the MTO Soil Classification Manual was generally followed and the secondary components were classified as per CFEM 2006. It should be noted that the subsurface conditions and the topsoil thicknesses encountered might vary in between and beyond the borehole locations and the topsoil thicknesses could vary especially in depressed areas and near watercourses. **Drawing No. 2** shows a fence diagram of the respective boreholes for ease of visualization. All topsoil thicknesses reported should not be relied upon for quantity estimation as they may vary beyond the borehole locations. Unless otherwise stated, all SPT 'N' values quoted are for 300 mm of penetration following the initial seating drive.

Groundwater observations on completion of drilling were recorded. The observed borehole stability conditions upon completion of boreholes are described. All groundwater levels observed in the exploratory holes are subject to seasonal fluctuations and variations due to precipitation events.

An overview of subsurface conditions is described below. All depths quoted are below the existing ground surface.

4.2 OVERVIEW

Fill overlying a native silty clay deposit was predominantly intercepted in all the boreholes (HM1, HM2, HM3, HM4, HM7, HM8 & HM9) which were advanced to approximately 16 m depth (Drawing 2). Cohesive fill thicknesses varying from 1.5 m to 4.6 m were intercepted in all the boreholes. The composition of the fill material is predominately silty clay. A clayey silt fill was intercepted in borehole HM3. In general, the fill had average SPT 'N' blow counts in each borehole ranging from 5 to 22 which typically can be described as a firm to very stiff consistency.

The native stratigraphy (underlying the topsoil and fill deposit) consist mainly of silty clay with proven thicknesses varying from 10.9 m to 14.7 m intercepted in all the boreholes. Underlying this native layer, a clayey silt deposit (700 mm thick) was intercepted in HM9 before the termination depth. An extracted cut sample from a Shelby tube retrieved in BH HM4 at approximate Elev. 105.5 m indicated a varved clay structure indicative of glacio-lacustrine depositional conditions.

Generally, the measured moisture content for the predominant native deposit ranged from 23% - 41% indicating moist to wet condition. The recorded SPT 'N' Values ranged from 5 to 31 which is indicative of a firm to hard consistency. The SPT 'N' values were observed to generally decrease with depth.

Measured groundwater levels in four boreholes installed with monitoring wells recorded water levels that ranged from El. 111.3 m to 107.4 m.

Overlying the fill deposit was a veneer of topsoil intercepted in every borehole and ranged in thickness from 75 mm to 180 mm.

4.3 SUBSURFACE CONDITIONS FOR HM1

4.3.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 100 mm thickness, a fill comprised of silty clay was intercepted in HM1 with an explored thickness of 1.2 m and a corresponding base elevation of Elev. 112.9 m. Measured moisture contents from two spoon samples average 22% indicative of a moist condition. SPT 'N' values recorded in the range of 10 to 16 indicate the fill to be of stiff to very stiff consistency.

4.3.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM1 with an explored thickness of 14.7 m and a corresponding base elevation of Elev. 98.3 m on termination of the borehole.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-1**.

Table 4- 1 Grain Size Distribution Summary - Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM1/SS6 HM1/SS12 HM1/SS15	0	1-3	33 - 44	54 - 66	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheet

Three (3) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-2**.

Table 4- 2 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM1/SS6 HM1/SS12 HM1/SS15	43 - 48	18 - 20	25 - 28	Shown in Figure B-4, Appendix B Summarized on the relevant Record of Borehole Sheet

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as silty clay of intermediate plasticity (CI).

Measured moisture contents of the spoon samples ranged from 23% to 32% indicative of a moist to wet condition. SPT ‘N’ values recorded in the range of 10 to 13 indicate the deposit to be of stiff consistency.

4.4 SUBSURFACE CONDITIONS FOR HM2

4.4.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 180 mm thickness, a fill comprised of silty clay was intercepted in HM2 with an explored thickness of 3.1 m and a corresponding base elevation of Elev. 113.6 m.

The grain size distributions of selected samples from this material were determined in the laboratory and gave the following grain size distribution shown in **Table 4-3**.

Table 4- 3 Grain Size Distribution Summary – Fill (Silty Clay)

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM2/SS3	0	4	36	60	Shown in Figure B-1, Appendix B Summarized on the relevant Record of Borehole Sheet

One (1) Atterberg limits test was also performed on the above fill and the tests indicated the following index value as shown in **Table 4-4**.

Table 4- 4 Atterberg Limits Test Results – Fill (Silty Clay)

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM2/SS3	48	20	28	Shown in Figure B-2, Appendix B Summarized on the relevant Record of Borehole Sheet

Based on the laboratory test results, the tested sample can be classified (according to MTC & CFEM 2006) as silty clay of intermediate plasticity (CI).

Measured moisture content of the spoon sample was 22% indicative of a moist condition. The recorded SPT ‘N’ value was 18 which indicates the fill to be of stiff consistency.

4.4.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM2 with an explored thickness of 12.8 m and a corresponding base elevation of Elev. 100.8 m on termination of the borehole.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-5**.

Table 4- 5 Grain Size Distribution Summary – Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM2/SS11 HM2/SS14	0	1-2	33	65 - 66	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheet

Two (2) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-6**.

Table 4- 6 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM2/SS11 HM2/SS14	43 - 48	18 - 20	25 - 28	Shown in Figure B-4, Appendix B Summarized on the relevant Record of Borehole Sheet

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as silty clay of intermediate plasticity (CI).

Measured moisture contents of the spoon samples ranged from 28% to 35% indicative of a moist to wet condition. SPT 'N' values recorded in the range 6 to 10 indicate the deposit to be of a firm to stiff consistency.

4.5 SUBSURFACE CONDITIONS FOR HM3

4.5.1 FILL (CLAYEY SILT)

Underlying a veneer of topsoil of 150 mm thickness, a fill comprising of clayey silt was intercepted in HM3 with an explored thickness of 4.4 m and a corresponding base elevation of Elev. 114.4 m.

The grain size distributions of selected samples from this material was determined in the laboratory and gave the following grain size distribution shown in **Table 4-7**.

Table 4- 7 Grain Size Distribution Summary – Fill (Clayey Silt)

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM3/SS3 HM3/SS6	0	7-11	54-56	30-37	Shown in Figure B-1, Appendix B Summarized on the relevant Record of Borehole Sheet

Two (2) Atterberg limits tests were also performed on the fill material and the tests indicated the following index values as shown in **Table 4-8**.

Table 4- 8 Atterberg Limits Test Results – Fill (Clayey Silt)

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM3/SS3 HM3/SS6	31-34	16-19	15	Shown in Figure B-2, Appendix B Summarized on the relevant Record of Borehole Sheet

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as Clayey Silt of low plasticity (CL).

Measured moisture contents of the spoon sample ranged from 27% to 34% indicative of a moist to wet condition. The recorded SPT ‘N’ values ranged from 7 to 16 which indicate the deposit to be of firm to very stiff consistency.

4.5.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM3 with an explored thickness of 10.9 m and a corresponding base elevation of Elev. 103.4 m on termination of the borehole.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-9**.

Table 4- 9 Grain Size Distribution Summary – Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM3/SS10 HM3/SS14	0	1-2	20-30	68 - 79	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheets

Two (2) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-10**.

Table 4- 10 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM3/SS10 HM3/SS14	54 - 66	22 - 23	32 - 43	Shown in Figure B-4, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested samples can be described (according to MTC & CFEM 2006) as silty clay of high plasticity (CH).

Measured moisture contents of the spoon samples ranged from 27% to 34% indicative of a moist to wet condition. SPT ‘N’ values recorded in the range 7 to 16 indicate the deposit to be of firm to very stiff consistency.

4.6 SUBSURFACE CONDITIONS FOR HM4

4.6.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 150 mm thickness, a fill comprising of silty clay was intercepted in HM4 with an explored thickness of 1.9 m and a corresponding base elevation of Elev. 117.2 m.

The grain size distribution of a selected sample from this material was determined in the laboratory and gave the following grain size distribution shown in **Table 4-11**.

Table 4- 11 Grain Size Distribution Summary – Fill (Silty Clay)

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM4/SS3	0	2	40	58	Shown in Figure B-1, Appendix B Summarized on the relevant Record of Borehole Sheet

One (1) Atterberg limits test was also performed on the above fill and the test indicated the following index values as shown in **Table 4-12**.

Table 4- 12 Atterberg Limits Test Results – Fill (Silty Clay)

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM4/SS3	49	22	27	Shown in Figure B-2, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested sample can be classified (according to MTC & CFEM 2006) as Silty Clay of intermediate plasticity (CI).

Measured moisture content of the spoon sample was 21% indicative of a moist condition. The recorded SPT ‘N’ value was 29 which indicates the fill to be of very stiff consistency.

4.6.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM4 with an explored thickness of 13.8 m and a corresponding base elevation of Elev. 103.5 m on termination of the borehole. An extracted cut sample from a Shelby tube retrieved in BH HM4 at approximate Elev. 105.5 m indicated a varved clay structure indicative of glacio-lacustrine depositional conditions.

The grain size distribution of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-13**.

Table 4- 13 Grain Size Distribution Summary – Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM4/SS6 HM4/SS13	0	1-2	31- 43	55 - 68	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheets

Two (2) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-14**.

Table 4- 14 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM4/SS6 HM4/SS13	46 - 48	19 - 20	27 - 28	Shown in Figure B-4, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as a silty clay of intermediate plasticity (CI).

Measured moisture contents of the spoon samples ranged from 23% to 32% indicative of a moist to wet condition. SPT ‘N’ values recorded in the range 5 to 19 indicate the deposit to be of firm to very stiff consistency.

4.7 SUBSURFACE CONDITIONS FOR HM7

4.7.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 130 mm thickness, a fill comprising of silty clay was intercepted in HM7 with an explored thickness of 1.5 m and a corresponding base elevation of Elev. 115.5 m.

4.7.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM7 with an explored thickness of 14.4 m and a corresponding base elevation of Elev. 101.1 m on termination of the borehole.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-15**.

Table 4- 15 Grain Size Distribution Summary – Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM7/SS5 HM7/SS11 HM7/SS13	0	1-9	33	58 - 66	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheets

Three (3) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-16**.

Table 4- 16 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM7/SS5 HM7/SS11 HM7/SS13	45 - 56	19 - 23	26 - 33	Shown in Figure B-4, Appendix B Summarized on the relevant Record of Borehole Sheet

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as a silty clay of intermediate to high plasticity (CI/CH).

Measured moisture contents of the spoon samples ranged from 25% to 41% indicative of a moist to wet conditions. SPT 'N' values recorded in the range 11 to 17 indicate the deposit to be of stiff to very stiff consistency.

4.8 SUBSURFACE CONDITIONS FOR HM8

4.8.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 75 mm thickness, a fill comprising of silty clay was intercepted in HM8 with an explored thickness of 2.1 m and a corresponding base elevation of Elev. 113.4 m.

4.8.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM8 with an explored thickness of 13.8 m and a corresponding base elevation of Elev. 99.7 m on termination of the borehole.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-17**.

Table 4- 17 Grain Size Distribution Summary - Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM8/SS6 HM8/SS12 HM8/SS15	0	2	31-37	61 - 67	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheet

Three (3) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-18**.

Table 4- 18 Atterberg Limits Test Results - Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM8/SS6 HM8/SS12 HM8/SS15	46 - 59	20 - 23	26 - 36	Shown in Figure B-5, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as silty clay of intermediate to high plasticity (CI/CH).

Measured moisture contents of the spoon samples ranged from 27% to 32% indicative of a moist to wet condition. SPT 'N' values recorded in the range 11 to 19 indicate the deposit to be of stiff to very stiff consistency.

4.9 SUBSURFACE CONDITIONS FOR HM9

4.9.1 FILL (SILTY CLAY)

Underlying a veneer of topsoil of 110 mm thickness, a fill comprising of silty clay was intercepted in HM9 with an explored thickness of 1.5 m and a corresponding base elevation of Elev. 114.1 m.

4.9.2 SILTY CLAY

Underlying the fill, a silty clay deposit was intercepted in HM9 with an explored thickness of 13.7 m and a corresponding base elevation of Elev. 100.4 m.

The grain size distributions of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-19**.

Table 4- 19 Grain Size Distribution Summary – Silty Clay

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM9/SS7 HM9/SS11	0	1-2	31-37	62 - 67	Shown in Figure B-3, Appendix B Summarized on the relevant Record of Borehole Sheets

Two (2) Atterberg limits tests were also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-20**.

Table 4- 20 Atterberg Limits Test Results – Silty Clay

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM9/SS7 HM9/SS11	45 - 53	20 - 22	25 - 31	Shown in Figure B-5, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested samples can be classified (according to MTC & CFEM 2006) as a silty clay of intermediate to high plasticity (CI/CH).

Measured moisture contents of the spoon samples ranged from 26% to 30% indicative of a moist to wet condition. SPT 'N' values recorded in the range 11 to 13 indicate the deposit to be of stiff consistency.

4.9.3 CLAYEY SILT

Underlying the silty clay, a clayey silt deposit was intercepted in HM9 with an explored thickness of 0.7 m and a corresponding base elevation of Elev. 99.8 m on termination of the borehole.

The grain size distribution of selected samples from this deposit were determined in the laboratory and gave the following grain size distribution shown in **Table 4-21**.

Table 4- 21 Grain Size Distribution Summary – Clayey Silt

Samples Tested (BH No.)	Size Fraction (%)				Remarks
	Gravel	Sand	Silt	Clay	
HM9/SS15	14	21	41	23	Shown in Figure B-6, Appendix B Summarized on the relevant Record of Borehole Sheets

One (1) Atterberg limits test was also performed on the above native deposit and the tests indicated the following index values as shown in **Table 4-22**.

Table 4- 22 Atterberg Limits Test Results – Clayey Silt

Samples Tested (BH No.)	Atterberg Limits (%)			Remarks
	Liquid Limit	Plastic Limit	Plasticity Index	
HM9/SS15	27	15	12	Shown in Figure B-7, Appendix B Summarized on the relevant Record of Borehole Sheets

Based on the laboratory test results, the tested sample can be classified (according to MTC & CFEM 2006) as a clayey silt of low plasticity (CL).

Measured moisture content of the spoon sample was 24% indicative of a wet condition. SPT ‘N’ value of 11 indicates the deposit to be of stiff consistency.

4.10 GROUNDWATER LEVEL OBSERVATIONS

Upon completion, no groundwater levels were observed in all boreholes. As regard the stability of the boreholes upon completion, no cave-ins were observed.

As earlier mentioned in Section 3.3, 50 mm diameter monitoring wells were installed in four (4) boreholes - HM1, HM7, HM8 & HM9. Groundwater levels in each of the monitoring wells were taken at least a week after completion. It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations in response to major weather events. Findings are summarized in **Table 4-23**.

TABLE 4- 23 Summary of Groundwater Level Observations

BH No.	Existing Ground Elevation	Date of Measurement	Groundwater Level- Depth (m)	Groundwater Level - Elevation (m)	Notes
HM1	114.1	August 27, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
		September 20, 2019	3.10	111.0	
		September 25, 2019	3.9	110.2	
HM2	116.6	August 30, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
HM3	118.8	August 30, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
HM4	119.3	September 03, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
HM7	117.0	August 26, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
		September 25, 2019	5.7	111.3	
HM8		August 28, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in

HM8	115.5	September 19, 2019	8.1	107.4	Solid Stem Auger used No cave-in
HM9	115.6	August 29, 2019 (upon completion)	dry	dry	Solid Stem Auger used No cave-in
		September 19, 2019	6.4	109.2	

4.11 CORROSIVITY AND WATER-SOLUBLE SULPHATE TESTING OF SOILS

Five (5) soil samples (HM1 SS3, HM2 SS5, HM4 SS8, HM7 SS10 & HM9 SS14) were analyzed for corrosivity parameters, including the resistivity of the soil, pH, Electrical Conductivity and sulphide concentration for corrosion protection to the proposed High Mast Lighting Poles. The test results are summarized as follows:

- Resistivity was measured ranging from 422 to 1170 ohm.cm;
- pH was measured that ranged from 7.80 to 8.01;
- Electrical Conductivity was measured at 0.86 to 2.37 mS/cm; and,
- Sulphide concentration was measured at less than 0.05%.

The sulphate (SO₄) resistance of the concrete in contact with the soils was evaluated by performing water-soluble sulphate test on same soil samples taken from selected HML boreholes listed above at depths ranging from 1.5 to 13.7 m below grade. The tests revealed that the sulphate concentration in the tested soil samples ranged from 556 to 2840 µg/g.

SIGNATURES



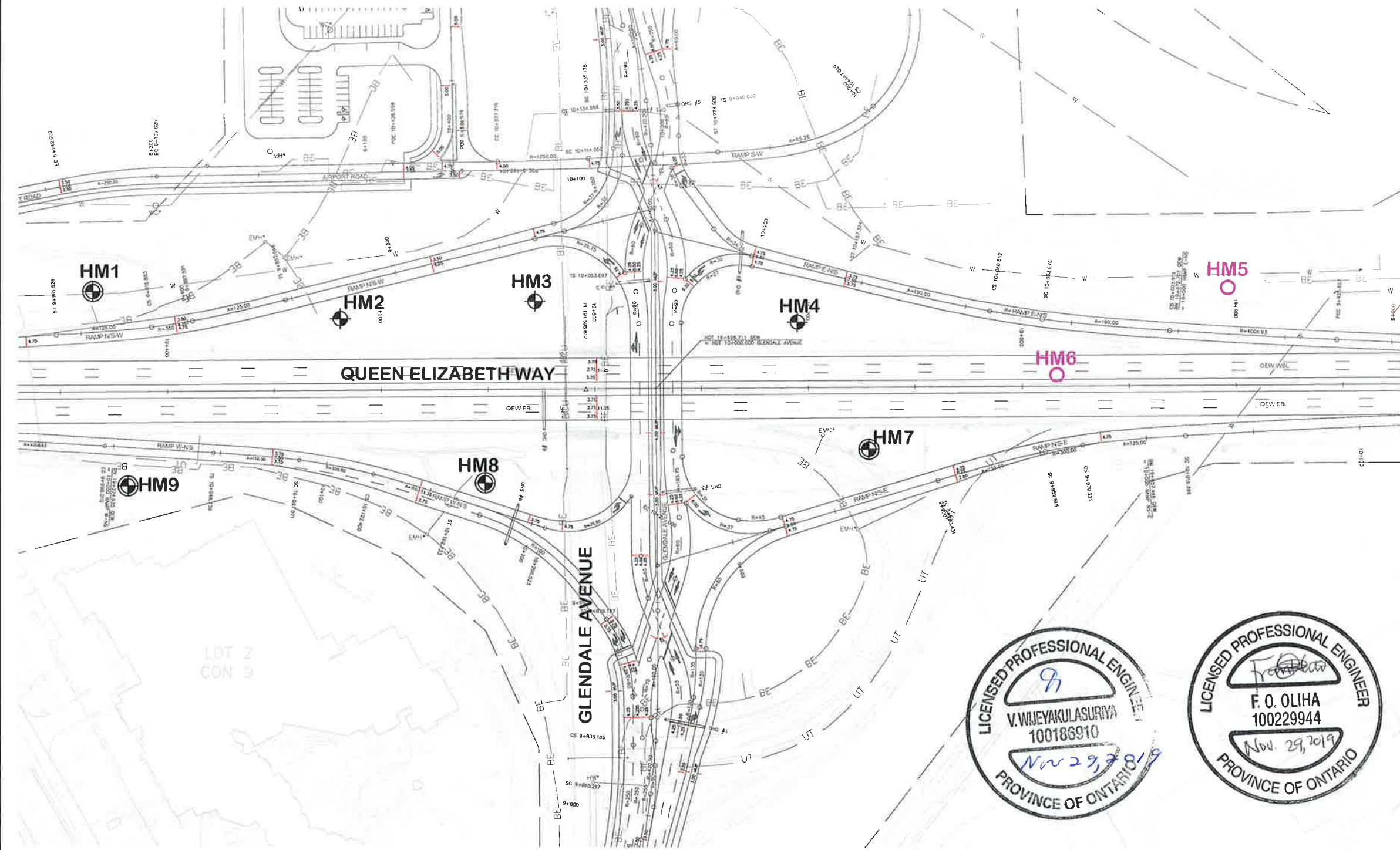
Franklin Oliha, MSc., P.Eng.
Geotechnical Engineer



Vasantha Wijeyakulasuriya, M.Eng., P.Eng.
MTO Designate (Foundations).

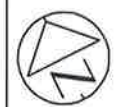


DRAWINGS



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

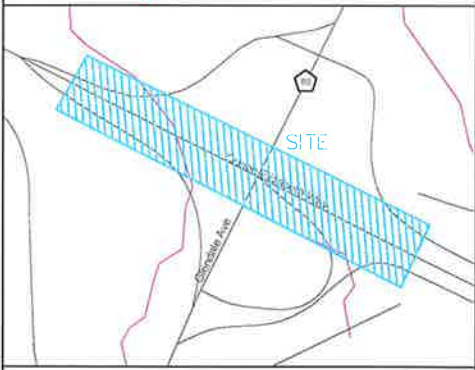
DIST
CONT
WP No: 2423-15-00



QEW/ GLENDALE AVENUE
INTERCHANGE
High Mast Light Poles
BOREHOLE LOCATIONS PLAN

SHEET
S-1

wsp 2 International Blvd, Suite 201
Toronto, Ontario
M9W 1A2

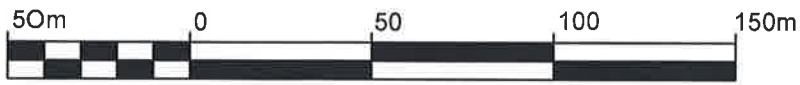


KEY PLAN

LEGEND

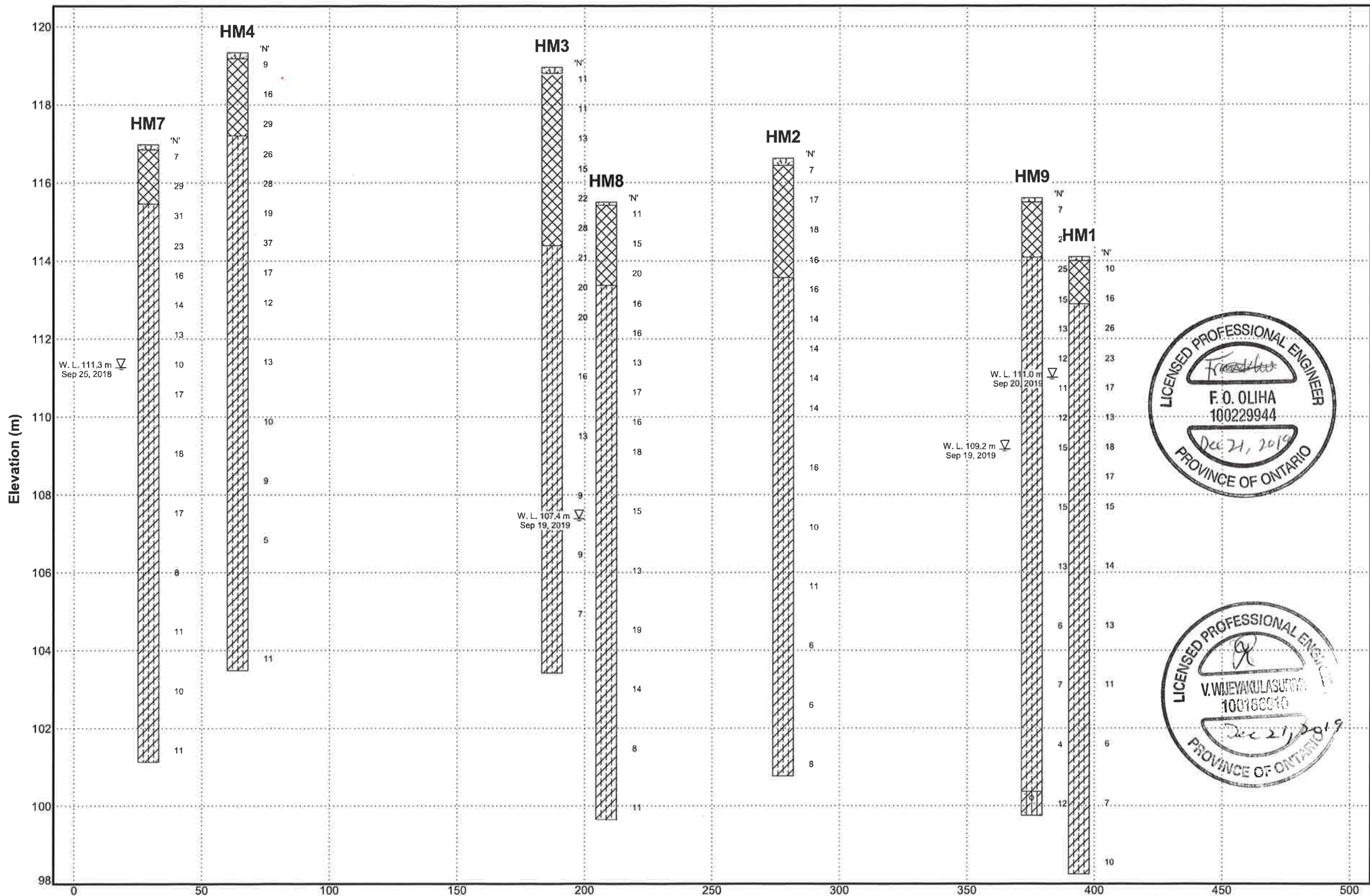
- Borehole - Completed
- Borehole with Monitoring Well - Completed
- Borehole - Proposed and later deleted

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 10 CO-ORDINATES	
		NORTH (m)	EAST (m)
HM1	114.1	4779898.4	331899.5
HM2	116.6	4779835.6	331997.6
HM3	119.0	4779802.5	332082.7
HM4	119.3	4779739.2	332188.5
HM7	117.0	4779671.0	332192.0
HM8	115.5	4779736.8	332024.0
HM9	115.6	4779809.7	331873.7



SITE LOCATION (LAT: 43.160074; LONG: -79.162193)

REVISIONS		DATE		BY		DESCRIPTION	
Oct 11/19		ZMO				Submission for MTO review	
GEOCRES No : 30M3-316							
HWY No	QEW	CHECKED FO	DATE	Oct 11/19	DIST	CENTRAL	
SUBM'D		CHECKED FO	DATE	Oct 11/19	SITE		
DRAWN	ZMO	CHECKED FO	APPROVED	MK	DWG	1	



APPENDIX

A

RECORD OF BOREHOLE SHEETS

METRIC 1 OF 2

[illegible]

18M-01021-12

	1st	2nd	3rd	4th
Measurement				

RECORD OF BOREHOLE No HM1

METRIC 2 OF 2

W.P. 2423-15-00 LOCATION MTM NAD 1983 (Zone 10), E 331899.6, N 4779898.5 ORIGINATED BY FO
DIST HWY QEW BOREHOLE TYPE M10 Truck Mount/Solid Stem Auger (150 mm O.D) COMPILED BY FO
DATUM Geodetic DATE Aug/27/2019 CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT		POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	Wp	W			
Continued	SILTY CLAY: trace sand, brown/red brown to grey, moist to wet, firm to very stiff (continued)													
11	silt seams		12	SS	11							48	25	0 1 33 66
12														
13			13	SS	6							13		
14			14	SS	7									
15			15	SS	10							43		0 2 44 54
98.3														
15.9	END OF BOREHOLE Notes: 1) No Cave-in upon borehole completion 2) No water at the bottom of borehole upon completion 3) Water level in monitoring wells measured as follows: Water Level: Date W.L. Depth (m) Elevation (m) September 20, 2019 3.1 111.0 September 25, 2019 3.9 110.2													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity


○ 3% Strain at Failure

18M-01021-12

METRIC 1 OF 2

[illegible]

18M-01021-12

Measurement 

1st 2nd 3rd 4th

RECORD OF BOREHOLE No HM3

METRIC 2 OF 2

W.P. 2423-15-00 LOCATION MTM NAD 1983 (Zone 10), E 332082.7, N 4779802.6 ORIGINATED BY FO
DIST HWY QEW BOREHOLE TYPE CME55 Track Mount/Solid Stem Auger (150 mm O.D) COMPILED BY FO
DATUM Geodetic DATE Aug/30/2019 CHECKED BY MK

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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						
	Continued														
	SILTY CLAY: trace sand, brown to grey, moist to wet, firm to very stiff (continued)														
11			12	SS	9		108						25		
12							107								
			13	SS	9								100		
13							106								
14			14	SS	7		105						38	0	1 20 79
15							104								
103.4															
15.5	END OF BOREHOLE Notes: 1) No Cave-in upon borehole completion 2) No water at the bottom of borehole upon completion														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 6=3% Strain at Failure

18M-01021-12

RECORD OF BOREHOLE No HM4

METRIC 2 OF 2

W.P. 2423-15-00 LOCATION MTM NAD 1983 (Zone 10), E 332188.5, N 4779739.2 ORIGINATED BY FO
DIST HWY QEW BOREHOLE TYPE CME55 Track Mount/Solid Stem Auger (150 mm O.D) COMPILED BY FO
DATUM Geodetic DATE Sep/03/2019 CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		w _p	w	w _L	WATER CONTENT (%)					
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE									
	Continued							20 40 60 80 100				10 20 30						GR SA SI CL
	SILTY CLAY: trace sand, brown to grey, moist to wet, firm to hard (continued)																	
11			12	SS	9		109									38		
12							108											
13			13	SS	5		107									25		0 1 31 68
14			14	SH			106											Varved clay structure observed
15							105											
103.5			15	SS	11		104											
15.9	END OF BOREHOLE Notes: 1) No Cave-in upon borehole completion 2) No water at the bottom of borehole upon completion																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

18M-01021-12

RECORD OF BOREHOLE No HM8

METRIC 2 OF 2

W.P. 2423-15-00 LOCATION MTM NAD 1983 (Zone 10), E 332024, N 4779736.8 ORIGINATED BY FO
DIST HWY QEW BOREHOLE TYPE M10 Truck Mount/Solid Stem Auger (150 mm O.D) COMPILED BY FO
DATUM Geodetic DATE Aug/28/2019 CHECKED BY MK

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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						
	Continued														
	SILTY CLAY: trace sand, red brown to grey, moist to wet, firm to very stiff (continued)														
11	silt seams		12	SS	19								53	100	0 2 33 65
12															
13			13	SS	14								113		
14			14	SS	8										
15			15	SS	11								46		0 2 37 61
99.7															
15.9	END OF BOREHOLE Notes: 1) No Cave-in upon borehole completion 2) No water at the bottom of borehole upon completion Water Level: Date September 19, 2019 W.L. Depth (m) 8.1 Elevation (m) 107.4														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity


○ 3% Strain at Failure

18M-01021-12

METRIC 1 OF 2

SOIL PROFILE						SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		PCKET PEN.	NATURAL UNIT WT	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W _p	w	W _L	POCKET PEN. (kg)	NATURAL UNIT WT (kN/m³)	GR	SA	SI	CL				
115.6	Ground Surface																				
0.1	TOPSOIL 110 mm FILL: silty clay, trace gravel, trace to some sand, trace rootlets, brown, moist, firm to very stiff		1	SS	7		Concrete/ Casing														
1			2	SS	23		115														
114.1																					
1.5	SILT CLAY: trace sand, greyish brown to grey, moist to wet, firm to very stiff		3	SS	25		114														
2																					
-			4	SS	15		113						163								
3																					
-			5	SS	13		112						125								
4																					
-			6	SS	12		111						88								
5																					
-			7	SS	11		110						75	0	2	31	67				
6							Bentonite hole plug						75								
-																					
7			9	SS	15		W. L. 109.2 m Sep 19, 2019						100								
8																					
9																					
10			10	SS	15		108						125								
11																					
12																					
13																					
14																					
15																					
16																					
17																					
18																					
19																					
20																					
21																					
22																					
23																					
24																					
25																					
26																					
27																					

18M-01021-12

Measurement 

METRIC 2 OF 2

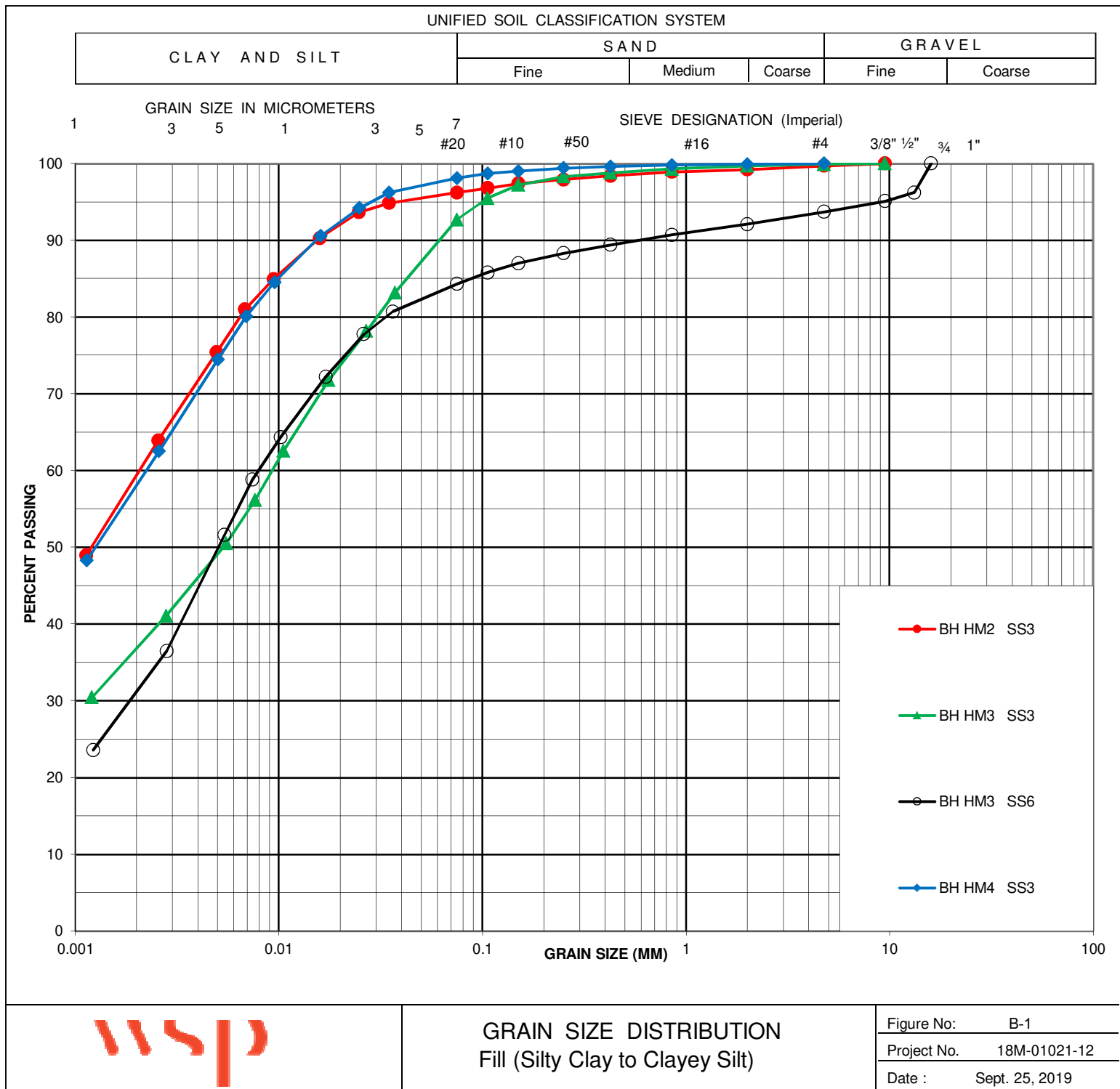
ELEV. DEPTH	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (KPa) NATURAL UNIT WT (KN/m ³) γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
								SHEAR STRENGTH kPa				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
							20 40 60 80 100 20 40 60 80 100					

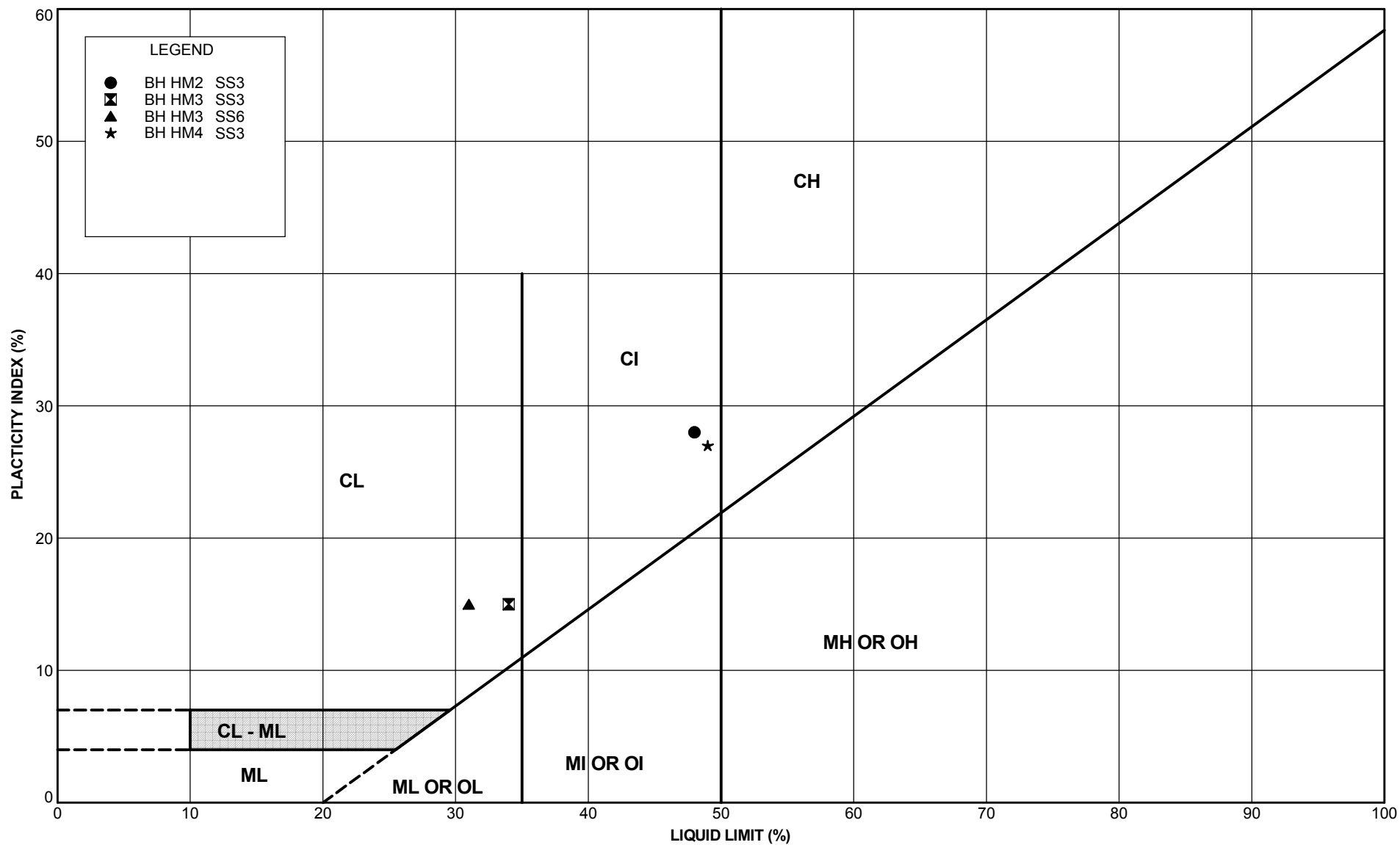
[illegible]

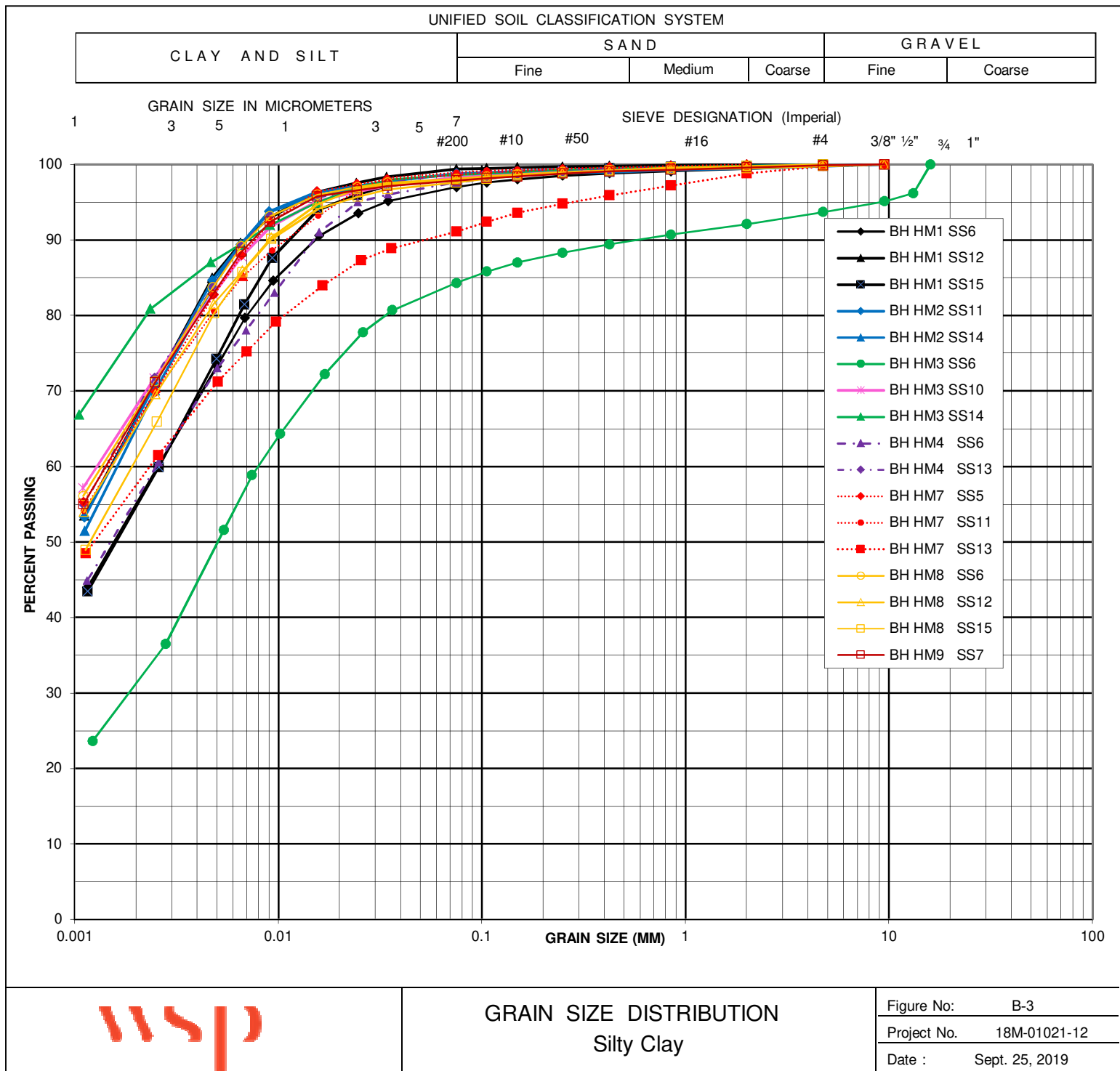
APPENDIX

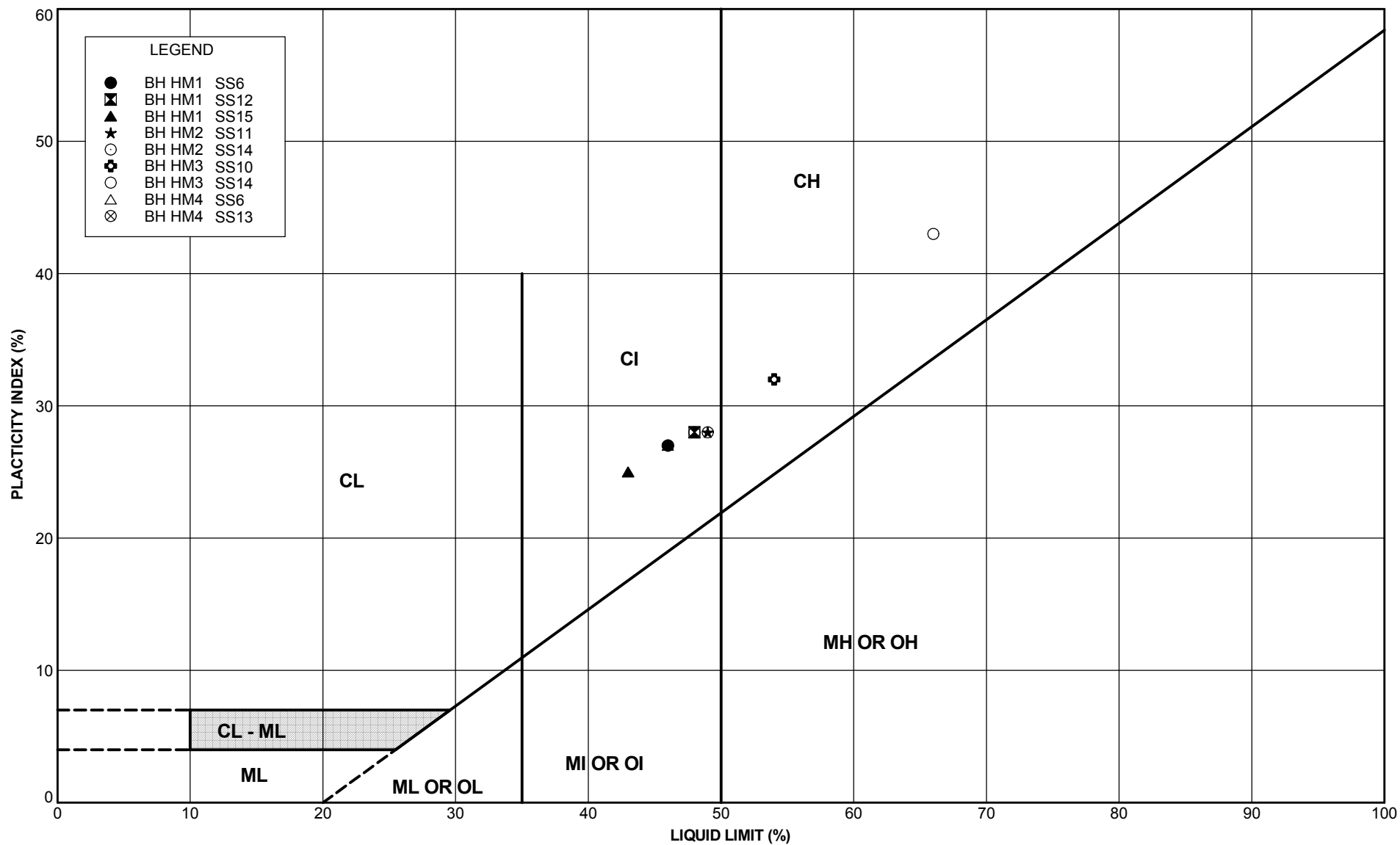
B

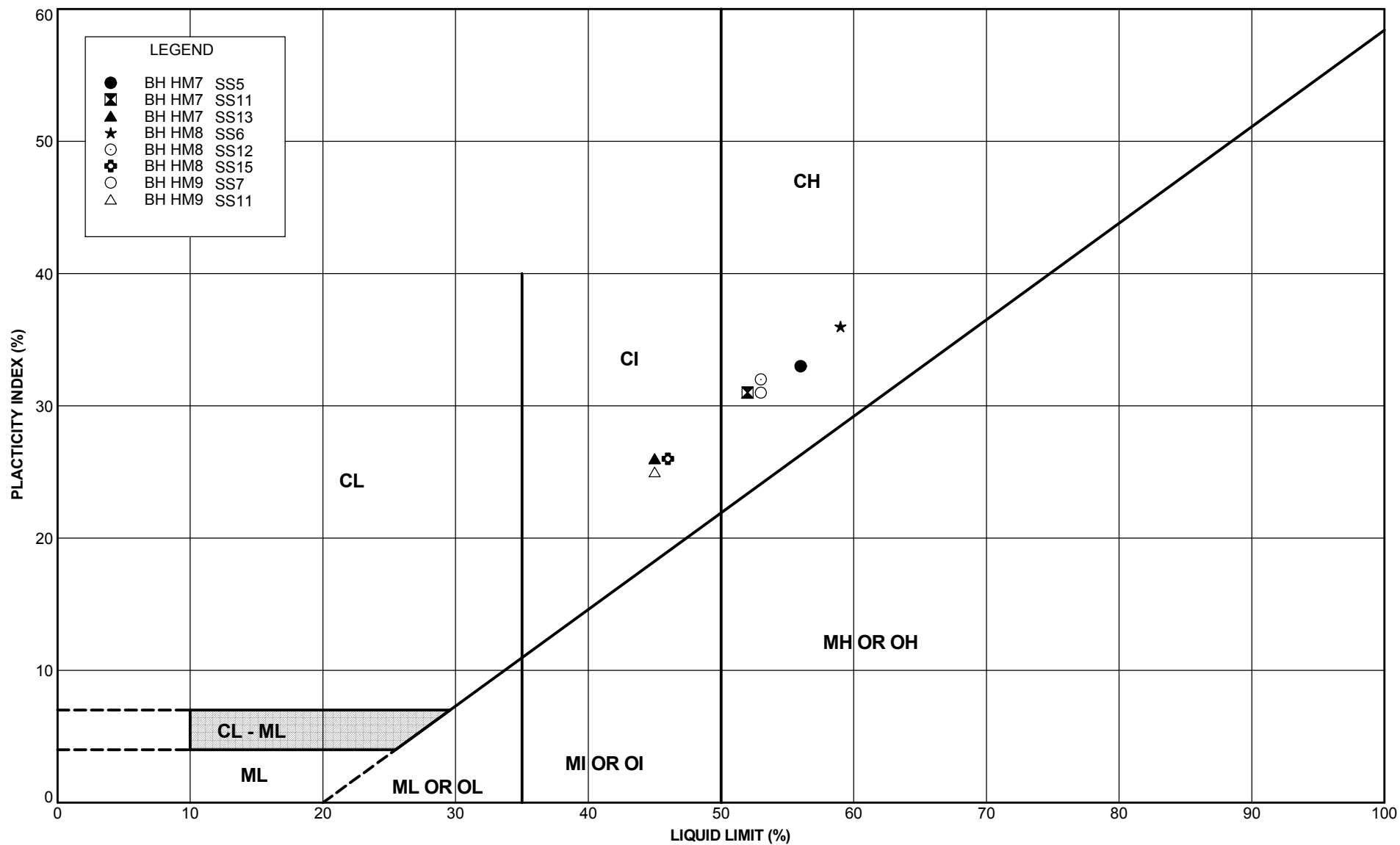
LABORATORY TEST RESULTS

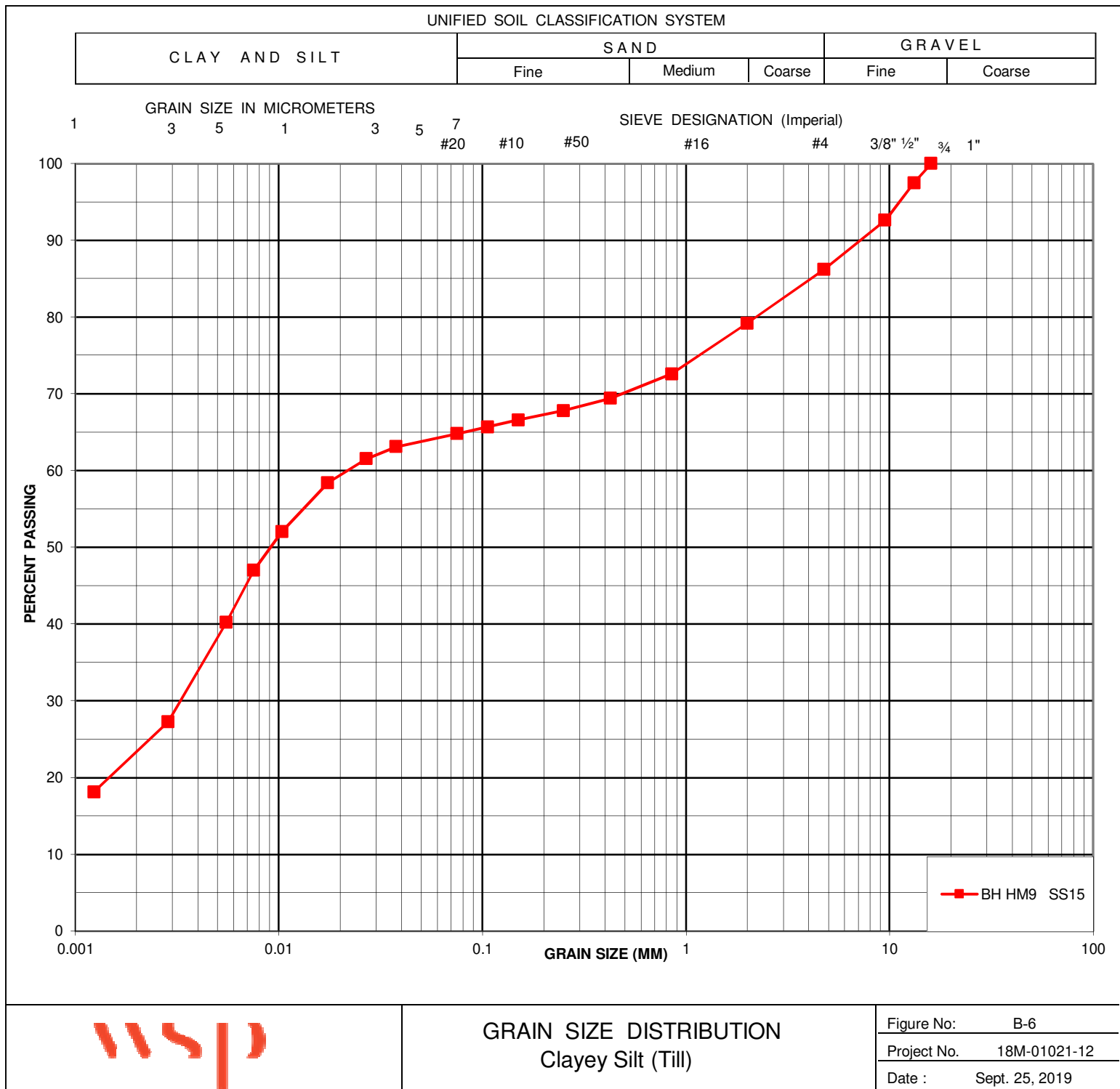












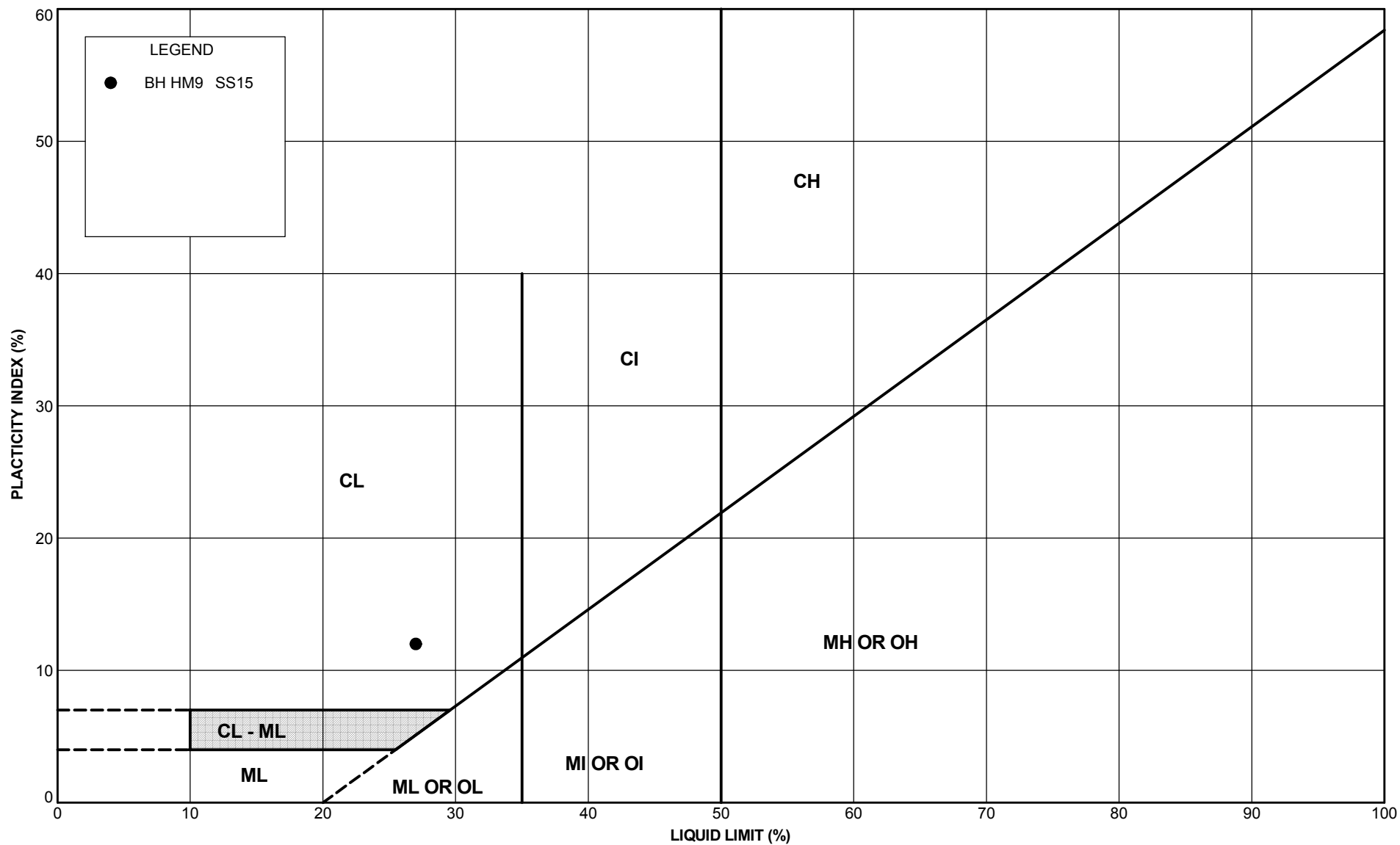
GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

Figure No: B-6

Project No. 18M-01021-12

Date : Sept. 25, 2019



APPENDIX



C

SITE PHOTOGRAPHS

Project: High Mast Lighting Poles

Assignment No. 2017 – E – 0018

SITE VISIT PHOTOGRAPHS



Photo 2-1 Looking towards west: Entrance to HM1 Location (June 2019)



Photo 2-2 Looking Northeast : Entrance to HM4 location (June 2019)



Photo 2-3 Looking towards East: Location of HM7 just after exit 38B (September 2019)

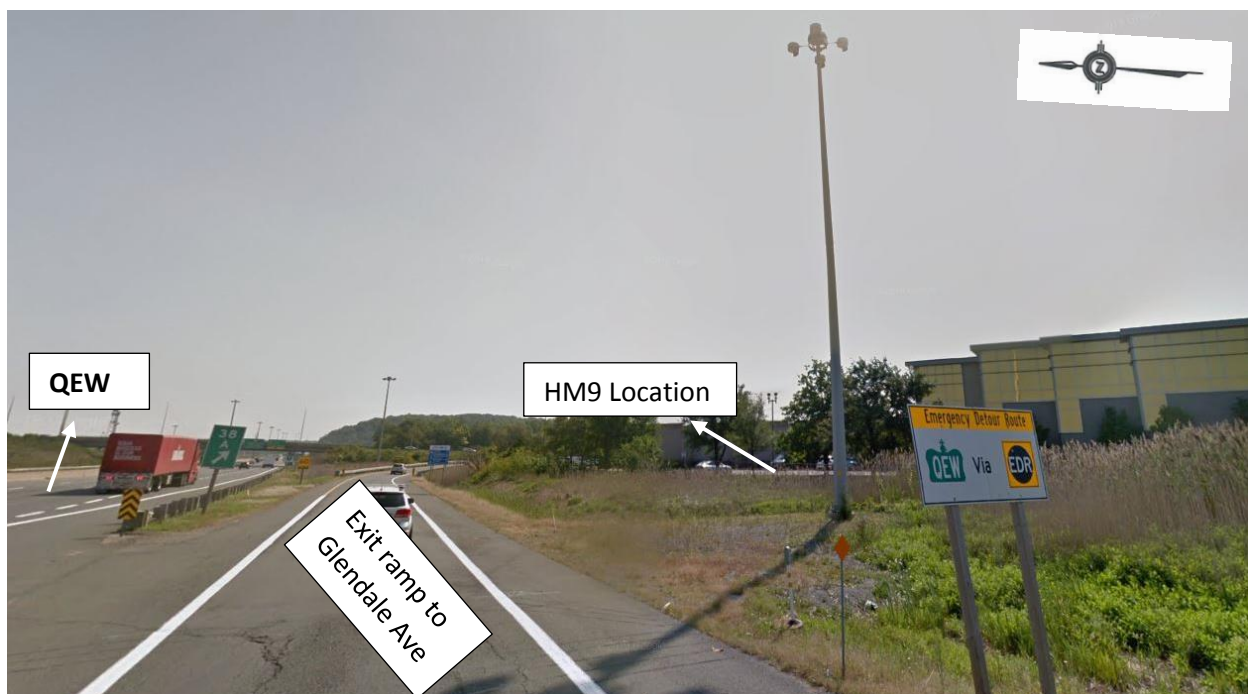


Photo 2-4 Looking towards East: HM9 Location at Exit 38A (June 2019)

APPENDIX

D

CORROSIVITY AND WATER SOLUBLE SULPHATE SOIL
TEST

**CLIENT NAME: WSP CANADA INC.
51 CONSTELLATION COURT
TORONTO, ON M9W1K4
(416) 798-0065**

ATTENTION TO: Mike Wilson

PROJECT: 18M-01021-12

AGAT WORK ORDER: 19T515391

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

DATE REPORTED: Sep 17, 2019

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



Certificate of Analysis

AGAT WORK ORDER: 19T515391

PROJECT: 18M-01021-12

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: WSP CANADA INC.

SAMPLING SITE: QEW and Glendale Ave., Niagara-on-the-Lake, ON

ATTENTION TO: Mike Wilson

SAMPLED BY: CS/JG

Corrosivity Package

DATE RECEIVED: 2019-09-09

DATE REPORTED: 2019-09-17

		SAMPLE DESCRIPTION: HM1 SS3				HM2 SS5		HM4 SS8		HM7 SS10	
		SAMPLE TYPE: Soil				Soil		Soil		Soil	
		DATE SAMPLED: 2019-08-27				2019-08-30		2019-09-03		2019-08-26	
Parameter	Unit	G / S	RDL	510255	RDL	510271	RDL	510272	RDL	510273	
Chloride (2:1)	µg/g		4	359	8	50	4	72	4	23	
Sulphate (2:1)	µg/g		4	869	8	2840	4	1370	8	2010	
pH (2:1)	pH Units		NA	7.83	NA	7.83	NA	7.85	NA	7.80	
Electrical Conductivity (2:1)	mS/cm		0.005	1.54	0.005	2.37	0.005	1.45	0.005	1.88	
Resistivity (2:1) (Calculated)	ohm.cm		1	649	1	422	1	690	1	532	
Redox Potential 1	mV		NA	288	NA	252	NA	215	NA	226	
Redox Potential 2	mV		NA	289	NA	252	NA	241	NA	229	
Redox Potential 3	mV		NA	288	NA	252	NA	216	NA	226	

		SAMPLE DESCRIPTION: HM9 SS14			
		SAMPLE TYPE: Soil			
		DATE SAMPLED: 2019-08-29			
Parameter	Unit	G / S	RDL	510274	
Chloride (2:1)	µg/g		4	73	
Sulphate (2:1)	µg/g		4	556	
pH (2:1)	pH Units		NA	8.01	
Electrical Conductivity (2:1)	mS/cm		0.005	0.857	
Resistivity (2:1) (Calculated)	ohm.cm		1	1170	
Redox Potential 1	mV		NA	105	
Redox Potential 2	mV		NA	108	
Redox Potential 3	mV		NA	109	

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

510255-510274 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.

Elevated RDL indicates the degree of sample dilution prior to the analysis in order to keep analytes within the calibration range of the instrument and to reduce matrix interference.

PI note: Redox Potential is not an accredited parameter.

Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Divine Basily

Quality Assurance

CLIENT NAME: WSP CANADA INC.

AGAT WORK ORDER: 19T515391

PROJECT: 18M-01021-12

ATTENTION TO: Mike Wilson

SAMPLING SITE: QEW and Glendale Ave., Niagara-on-the-Lake, ON

SAMPLED BY: CS/JG

Soil Analysis

RPT Date: Sep 17, 2019			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

Corrosivity Package

Chloride (2:1)	516908		4	4	NA	< 2	95%	80%	120%	101%	80%	120%	99%	70%	130%
Sulphate (2:1)	516908		19	21	10.0%	< 2	95%	80%	120%	102%	80%	120%	99%	70%	130%
pH (2:1)	510255	510255	7.83	7.80	0.4%	NA	100%	90%	110%						
Electrical Conductivity (2:1)	518156		0.554	0.586	5.6%	< 0.005	102%	90%	110%						
Redox Potential 1	1					NA	101%	90%	110%						

Comments: NA signifies Not Applicable.

Duplicate Qualifier: 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.

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Certified By:




Method Summary

CLIENT NAME: WSP CANADA INC.

AGAT WORK ORDER: 19T515391

PROJECT: 18M-01021-12

ATTENTION TO: Mike Wilson

SAMPLING SITE: QEW and Glendale Ave., Niagara-on-the-Lake, ON

SAMPLED BY: CS/JG

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water consumed by humans)

Report Information:

Company: WSP
Contact: Mike Wilson
Address: 2 International Blvd
Etobicoke ON
Phone: _____ Fax: _____
Reports to be sent to:
1. Email: _____
2. Email: _____

Regulatory Requirements:

(Please check all applicable boxes)

☐ Regulation 153/04

Table Indicate One

☐ Ind/Com
☐ Res/Park
☐ Agriculture

Soil Texture (Check One)

☐ Coarse
☐ Fine

☐ Sewer Use

☐ Sanitary

☐ Storm

Region

Indicate One

☐ MISA

☐ Regulation 558

☐ CCME

☐ Prov. Water Quality
Objectives (PWQO)

☐ Other

Indicate One

Is this submission for a
Record of Site Condition?

☐ Yes

☒ No

Report Guideline on
Certificate of Analysis

☒ Yes

☐ No

Project Information:

Project: 18M-01021-12
Site Location: QEW and Glendale Ave. Niagara-on-the-Lake
Sampled By: CS/JG ON
AGAT Quote #: _____ PO: _____

Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes ☒ No ☐

Company: _____
Contact: _____
Address: _____
Email: _____

Sample Matrix Legend

B Biota
GW Ground Water
O Oil
P Paint
S Soil
SD Sediment
SW Surface Water

Field Filtered - Metals, Hg, CrVI

O. Reg 153

Metals and Inorganics
☐ All Metals ☐ 153 Metals (excl. Hydrides)
☐ Hydride Metals ☐ 153 Metals (incl. Hydrides)

ORPs: ☐ B-HWS ☐ Cl ☐ CN
☐ Cr⁶⁺ ☐ EC ☐ FOC ☐ Hg
☐ pH ☐ SAR

Full Metals Scan

Regulation/Custom Metals

Nutrients: ☐ TP ☐ NH₃ ☐ TKN
☐ NO₃ ☐ NO₂ ☐ NO₃+NO₂

Volatiles: ☐ VOC ☐ BTEX ☐ THM

PHCs F1 - F4

ABNs

PAHs

PCBs: ☐ Total ☐ Aroclors

Organochlorine Pesticides

TCLP: ☐ M&I ☐ VOCs ☐ ABNs ☐ B(a)P ☐ PCBs

Sewer Use

Corrosivity

Potentially Hazardous or High Concentration (Y/N)

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Y / N	Metals and Inorganics	ORPs	Nutrients	Volatiles	PHCs F1 - F4	ABNs	PAHs	PCBs	Organochlorine Pesticides	TCLP	Sewer Use	Corrosivity	Potentially Hazardous or High Concentration (Y/N)
HM1 SS3	Aug 27/19	AM	1	S															
HM2 SS5	Aug 30/19		1																
HM4 SS8	Sept 3/19		1																
HM7 SS10	Aug 26/19		1																
HM9 SS14	Aug 29/19		1																

Samples Relinquished By (Print Name and Sign): <u>John Gavin</u>	Date: <u>Sept 9/19</u>	Time: <u>2:28 PM</u>	Samples Received By (Print Name and Sign): <u>Sharmila</u>	Date: <u>Sept 9/19</u>	Time: <u>2:28 pm</u>	Page <u>1</u> of <u>1</u>
Samples Relinquished By (Print Name and Sign):	Date:	Time:	Samples Received By (Print Name and Sign):	Date:	Time:	
Samples Relinquished By (Print Name and Sign):	Date:	Time:	Samples Received By (Print Name and Sign):	Date:	Time:	Nº: T 093275

**CLIENT NAME: WSP CANADA INC.
51 CONSTELLATION COURT
TORONTO, ON M9W1K4
(416) 798-0065**

ATTENTION TO: Mike Wilson

PROJECT: 19T515391

AGAT WORK ORDER: 19T518350

SOLID ANALYSIS REVIEWED BY: Sherin Moussa, Senior Technician

DATE REPORTED: Sep 17, 2019

PAGES (INCLUDING COVER): 5

Should you require any information regarding this analysis please contact your client services representative at (905) 501-9998

***NOTES**

All samples are stored at no charge for 90 days. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 19T518350

PROJECT: 19T515391

5623 McADAM ROAD
MISSISSAUGA, ONTARIO
CANADA L4Z 1N9
TEL (905)501-9998
FAX (905)501-0589
<http://www.agatlabs.com>

CLIENT NAME: WSP CANADA INC.

ATTENTION TO: Mike Wilson

(201-042) Sulfide

DATE SAMPLED: Sep 15, 2019

DATE RECEIVED: Sep 16, 2019

DATE REPORTED: Sep 17, 2019

SAMPLE TYPE: Other

Analyte:	Sulfide
Unit:	%
RDL:	0.05

Sample ID (AGAT ID)

HM1 SS3 (530199)	<0.05
HM2 SS5 (530200)	<0.05
HM4 SS8 (530201)	<0.05
HM7 SS10 (530202)	<0.05
HM9 SS14 (530203)	0.21

Comments: RDL - Reported Detection Limit

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Sherin Hoossaf



AGAT Laboratories

Quality Assurance - Replicate

AGAT WORK ORDER: 19T518350

PROJECT: 19T515391

5623 McADAM ROAD
MISSISSAUGA, ONTARIO
CANADA L4Z 1N9
TEL (905)501-9998
FAX (905)501-0589
<http://www.agatlabs.com>

CLIENT NAME: WSP CANADA INC.

ATTENTION TO: Mike Wilson

(201-042) Sulfide

Parameter	REPLICATE #1				REPLICATE #2											
	Sample ID	Original	Replicate	RPD	Sample ID	Original	Replicate	RPD								
S	530199	0.062	0.067	7.8%	530203	0.239	0.242	1.2%								
Sulfate	530199	0.05	0.05	0.0%	530203	0.03	0.03	0.0%								
Sulfide	530199	< 0.05	<0.05	0.0%	530203	0.21	0.21	0.0%								



AGAT Laboratories

Quality Assurance - Certified Reference materials

AGAT WORK ORDER: 19T518350

PROJECT: 19T515391

5623 McADAM ROAD
MISSISSAUGA, ONTARIO
CANADA L4Z 1N9
TEL (905)501-9998
FAX (905)501-0589
<http://www.agatlabs.com>

CLIENT NAME: WSP CANADA INC.

ATTENTION TO: Mike Wilson

(201-042) Sulfide

Parameter	CRM #1				CRM #2											
	Expect	Actual	Recovery	Limits	Expect	Actual	Recovery	Limits								
S	0.8	0.82	102%	90% - 110%	0.8	0.8	100%	90% - 110%								
Sulfate	0.01	0.01	100%	90% - 110%	0.01	0.01	100%	90% - 110%								
Sulfide	0.8	0.81	101%	90% - 110%	0.8	0.79	98%	90% - 110%								

Method Summary

CLIENT NAME: WSP CANADA INC.

AGAT WORK ORDER: 19T518350

PROJECT: 19T515391

ATTENTION TO: Mike Wilson

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Solid Analysis			
Sulfide	MIN-200-12037		LECO



FOUNDATION DESIGN REPORT PROPOSED HIGH MAST LIGHT POLES, TOWN OF NIAGARA-ON-THE-LAKE, NIAGARA REGION, ONTARIO

SITE LOCATION (LAT: 43.160074°, LONG: -79.162193°)

MINISTRY OF TRANSPORTATION ONTARIO

C.W.P 2423-15-00

GEOCRES NO. 30M3-316

WSP PROJECT NO.: 18M-01021-12

DECEMBER 21, 2019

WSP CANADA INC.
2 INTERNATIONAL BOULEVARD
TORONTO, ON
CANADA, M9W 1A2

T: +1 416 679-9410
WWW.WSP.COM

TABLE OF CONTENTS

5	DISCUSSION AND RECOMMENDATIONS	21
5.1	GENERAL	21
5.2	GROUND CHARACTERISATION	21
5.2.1	OVERVIEW OF SUB-SURFACE CONDITIONS	21
5.2.2	SHEAR STRENGTH CHARACTERISATION	21
5.2.3	GROUND MOTION PARAMETERS	23
5.2.4	FROST DEPTH AND FROST SUSCEPTIBILITY	23
5.2.5	CONSEQUENCE AND SITE UNDERSTANDING CLASSIFICATION	23
5.3	FOUNDATION RECOMMENDATIONS	23
5.3.1	GENERAL	23
5.3.2	FOUNDATIONS	24
5.4	CONSTRUCTION CONSIDERATIONS	25
5.4.1	SITE PREPARATION	25
5.4.2	EXCAVATIONS	25
5.4.3	GROUNDWATER CONTROL	26
5.4.4	CONSTRUCTION OF CAISSONS	26
5.5	POTENTIAL FOR SULPHATE ATTACK/CORROSION ON CAISSONS	26

TABLES

TABLE 5-1 UNDRAINED SHEAR STRENGTH MODELS FOR HML LOCATIONS (UNFACTORED).....	22
TABLE 5-2 GEOTECHNICAL RESISTANCES – AXIAL LOADING.....	25

LIST OF FIGURES

FIG. 1. SPT 'N' Value Vs Elevation
FIG. 2a. SPT 'N' Value Vs Elevation (Native)
FIG. 2b. Pocket Penetrometer Based Undrained Shear Vs Elevation
FIG. 3. Undrained Shear Strength, $Su_{(FV)}$ Vs SPT 'N' Values
FIG. 4. Characteristic SPT 'N' Profile for Indicative Analysis
FIG. 5. HML Lateral Loading Analysis

APPENDICES

APPENDIX E LIST OF SSPs, OPSS AND OPSD
APPENDIX F LIMITATIONS OF REPORT

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

This section of the report provides recommendations for the foundation aspects for the proposed seven HML poles on the north side of QEW on either side of the QEW/the proposed Glendale Avenue Underpass Interchange (See Drawing No. 1). The recommendations are based on our understanding of the project and on the interpretation of factual data compiled from both field and laboratory investigations carried out by WSP.

The discussions and recommendations presented in this report are intended to assist the designers with sufficient information that would enable them to proceed with the design of the HML pole foundations.

Construction comments made herein are based on geotechnical considerations only and should not be relied upon without further independent assessment and qualification in the selection of means and methods for construction.

In what follows, Canadian Highway Bridge Design Code (CHBDC, 2014: CSA S6-14) will be referred to as **CHBDC (2014)**, the Commentary on CSA S6-14, Canadian Highway Bridge Design Code will be referred to as **CHBDC (2014) Commentary** and the MTO Guidelines for the Design of High Mast Pole Foundations (4th edition, 2004) will be referred to as **MTO HMPF (2004)**.

5.2 GROUND CHARACTERISATION

5.2.1 OVERVIEW OF SUB-SURFACE CONDITIONS

The stratigraphy at the site generally consists of a cohesive fill underlying a veneer of topsoil with thickness ranging from 1.5 m to 4.6 m. The fill was generally found to be of firm to very stiff consistency. Underlying the fill was found a silty clay deposit with explored thickness ranging from 10.9 m to 14.7 m. The consistency of the deposit based on SPT 'N' values, undrained shear strengths from the field vane and pocket penetrometer generally ranged from firm to very stiff. An extracted cut sample from a Shelby tube retrieved in BH HM4 at approximate Elev. 105.5 m indicated a varved clay structure indicative of glacio-lacustrine depositional conditions. BH HM 9 was advanced below the silty clay layer into a clayey silt (Till) layer on termination. The explored depth of the boreholes was approximately 16 m. The SPT 'N' values were observed to generally decrease with depth.

The intercepted ground conditions are in general agreement with the findings of the previous Golder investigation for the Airport Road Connection Structure mentioned in Section 2.2.

Groundwater level observations were carried out in four boreholes. The design groundwater level can be taken as at Elev. 112.3 m, i.e. 1 m higher than the highest water level observed (i.e. in BH HM 7).

5.2.2 SHEAR STRENGTH CHARACTERISATION

In order to develop an undrained shear strength profile for purposes of foundation design, the observed SPT 'N' blow counts were plotted against elevation for all the HML boreholes and is shown in Fig. 1. This plot shows that

- The SPT 'N' values in the fill show significant scatter
- The SPT 'N' values within the native deposit show less scatter and a decreasing trend of N values with decreasing elevation, i.e. with depth

During the field investigation, pocket penetrometer penetration tests were also carried out on the retrieved spoon samples. Although pocket penetrometer based undrained shear strength assessments are not considered accurate, for purposes of identifying trends in undrained shear strength they can be expected to play a useful role. Within the native deposit, Figure 2(a) shows the trend of SPT 'N' values with elevation and Fig.2(b) shows the trend of deduced undrained shear strengths with elevation. The horizontal scale of Fig.2(a) has a range from 0 to 30, i.e. up to the maximum SPT 'N' value for very stiff soils as per the consistency tabulation for fine-grained soils. In a similar vein, the horizontal scale for Fig.2(b) has a range from 0 to 200 kPa, the upper strength limit for very stiff cohesive soils. Both Figs 2(a) and 2(b) show a decrease of undrained shear strength with depth. The larger scatter in Fig.2(b) is due to the crude nature of assessment of undrained shear strength when deduced with a pocket penetrometer.

Figure 3 shows the Field Vane based undrained shear strengths with averaged SPT 'N' values corresponding to the elevations where field vane shear strength measurements have been made. The outlier points shown in green have been excluded from the deduction of a relationship between undrained shear strength and SPT 'N' values. Based on site specific undrained shear strength and SPT 'N' values, a lower-bound undrained shear strength envelope is estimated that gives the following empirical relationship:

$$S_u = 8N \text{ (kPa)} - \text{Equation (1)}$$

Based on the above site specific empirical characterization between undrained shear strength and SPT N, i.e. Eqn. (1), the geotechnical strength models at the individual HML locations are given in Table 5-1.

Table 5-1 Undrained Shear Strength Models for HML Locations (unfactored)

HML Pole Location	Fill (below frost depth) Unit Weight: 20kN/m ³			Native Deposits								
				Very Stiff Clay Unit Weight: 20kN/m ³			Stiff Clay Unit Weight: 20kN/m ³			Firm Clay Unit Weight: 20kN/m ³		
	Depth (m)	Elev.	S _u (kPa)	Depth (m)	Elev.	S _u (kPa)	Depth (m)	Elev.	S _u (kPa)	Depth (m)	Elev.	S _u (kPa)
HML 1				1.2 – 6.6	112.9 – 107.5	150	6.6 – 11.3	107.5 – 102.8	100	11.3 – 15.9	102.8 – 98.3	50
HML 2	1.2 – 3.1	115.4 – 113.6	70				3.1 – 11.3	113.6 – 105.3	100	11.3 – 15.9	105.3 – 100.8	50
HML 3	1.2 – 4.6	117.8 – 114.4	80	4.6 – 8.2	114.4 – 110.8	150	8.2 – 15.5	110.8 – 103.4	75			
HML 4	1.2 – 2.1	118.1 – 117.2	100	2.1 – 5.8	117.2 – 113.5	200	5.3 – 11.3	113.5 – 108.0	85	11.3 – 15.9	108.0 – 103.5	50
HML 7	1.2 -1.5	115.8 - 115.5	100	1.5 – 9.2	115.5 – 107.9	140	9.7 -15.9	107.2 – 101.1	80			
HML 8	1.2 – 2.1	114.3 – 113.4	70	2.1 – 8.2	113.4 – 107.3	125	8.2 – 15.9	107.3 – 99.7	100			
HML 9	1.2 – 1.5	114.4 - 114.1	90	1.5 – 2.8	114.1 – 112.7	160	2.8 – 9.7	112.7 – 105.5	100	9.7 – 15.2	105.5 - 100.4	50

The undrained shear strength within the first 1.2 m (i.e. frost depth) below built-ground surface should be neglected for undrained shear strength/passive resistance purposes.

5.2.3 GROUND MOTION PARAMETERS

Based on the borehole information and our review of the general subsurface conditions in the area, the subject site for the proposed HML pole foundations can be classified as ‘Site Class D’ for seismic site response according to Table 4.1.8.4.A of **National Building Code (NBC) 2015** and Table 4.1 of the CHBDC (2014).

The Peak Ground Acceleration (PGA) and spectral acceleration $S_a(T)$ values for $T = 0.2, 0.5, 1.0, 2.0, 5.0$ and 10.0 for the Town of Niagara-On-The-Fall was obtained from the Natural Resources Canada (NRC) website on September 9, 2019 (<http://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php>). NRC reports seismic parameters for each region in Canada for the 2% in 50-year probability of exceedance, for Site Class C conditions. The PGA and $S_a(T)$ parameters for the above T values for site Class C for the subject region are 0.207g and 0.321, 0.157, 0.072, 0.032, 0.0076 and 0.0030, respectively.

Since the seismic site class classification at the project site is Site Class D, the regional value for PGA reported for Site Class C need to be modified to reflect Site Class D. This subject site adjustment was carried out in accordance with Section 4.4.3.3 Table 4.8 of the CHBDC (2014). As per Section 4.4.3.3 of the CHBDC (2014), Table 4.8, the site adjusted PGA value (for Site Class D) is 0.241g for a 2% in 50-year probability of exceedance (2,475 return period).

For the calculation of the design spectral acceleration, $S(T)$, associated with the governing structural vibration mode of the HML structures (a structural dynamic consideration), a value of 0.1656 for PGA_{ref} can be used along with the Seismic Site Class to be used in Cl. 4.4.3.4 of CHBDC (2014).

5.2.4 FROST DEPTH AND FROST SUSCEPTIBILITY

The minimum earth cover required for a structure subjected to frost action at the project site is 1.2 m in accordance with Ontario Provincial Standard Drawing (**OPSD 3090.101**) (Foundation, Frost Penetration Depths for Southern Ontario). Based on Fig. B1, the frost susceptibility of the near surface soils within the first 2 m can be classified as predominantly of Low frost susceptible nature.

5.2.5 CONSEQUENCE AND SITE UNDERSTANDING CLASSIFICATION

The proposed HML pole foundations are classified as having a “Low Consequence Level” associated with exceeding limit states design, as per Section 6.5 and C6.16.2.1 of the CHBDC (2014) and its Commentary.

Based on the level of foundation investigations completed at the proposed HML pole locations in comparison to the degree of site understanding outline in Section 6.5 of CHBDC (2014), a “Typical Degree of Site and Prediction Model Understanding” is considered appropriate for the proposed pole foundations.

Values for the corresponding consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the CHBDC (2014) have been used for the appropriate aspects of the foundation design.

5.3 FOUNDATION RECOMMENDATIONS

5.3.1 GENERAL

HML foundations are typically founded on short caisson foundations unless this is not possible due to shallow bedrock which is not the ground conditions intercepted at the subject site as discussed. SLS conditions typically dictate pole foundation design

(CHBDC (2014) Commentary, Section C6.16). Vertical loading effects are not considered significant for HMPFs compared to horizontal loading effects.

SLS limit on pole rotation is considered the governing SLS criterion (a rotation not exceeding 0.005 radians) and pole rotation is acknowledged as the more reliable criterion than pile head deflection, as per MTO HMPF (2004), page 2.

Based on the above considerations the following LRFD resistance factors are applicable (based on Table 6.2 of CHBDC (2014)):

$$\Psi = 1.15$$

ULS : Lateral, $\phi_{gu} = 0.5$; Compression, $\phi_{gu} = 0.4$

SLS : Lateral, $\phi_{gs} = 0.8$

5.3.2 FOUNDATIONS

Based on the borehole findings, the subsurface geology at the proposed HML locations are typically cohesive fill underlain by native cohesive deposits, of firm or better consistency down to about 16 m of explored depth. The typical type of foundation of HML structures is caissons and based on HMPF (2004), the length of the caissons is unlikely to be more than 12 m for 45 m high poles (the tallest category of HML poles (1.52 m diameter) discussed in the MTO document) under less competent ground conditions than as intercepted on site.

GEOTECHNICAL CONSIDERATIONS – LATERAL LOADING

Geotechnical considerations (pertaining to lateral capacity and lateral deformations) are addressed in the following with respect to lateral loading of high mast light pole foundations as relevant to the intercepted ground conditions, i.e. cohesive soils:

- Lateral capacity of piles: the estimated undrained strength S_u (for cohesive soils) address pile lateral capacity issues
- Lateral deformation of piles: the coefficient of horizontal subgrade reaction, k_s (via S_u for cohesive soils) provide the input for lateral deformation analyses

The geotechnical lateral resistance is greatly affected by the soil properties close to the ground level (about 10 pile diameters, Ref: Piling Engineering, Fleming, et. al.).

As the sub-soils within the depth range of the proposed caissons are primarily cohesive, the coefficient of horizontal subgrade reaction can be estimated from:

$$k_s = 67 S_u / d$$

where S_u = undrained shear strength (individual HML site specific S_u values are given in Table 5.1) and d is the caisson diameter.

Note: The design water level is assumed at Elev. 112.3 m for lateral pile resistance considerations; neglect lateral resistance within the frost depth, i.e. the upper 1.2 m.

According to MTO HMPF (2004), Table 12.2.1, for a pole height of 45 m (the maximum pole height in the Table) and for the higher wind loading considered ($475 < q_{50} < 595$ (Pa)), the required length of a caisson is indicated to be less than 12 m for firm to better cohesive soil consistency conditions. Table 11.1 shows that for a pole height of 45 m, the caisson diameter is given as 1.52 m. Section 11.1 indicates for the stipulated pole height of 45 m and for a wind loading condition of $q_{50} = 595$ Pa, the SLS horizontal loading is less than 50 kN and the bending moment, BM is less than 2000 kNm.

For an indicative analysis of the effects of lateral loading (using Rocscience, RSPile (2018)), the above geometry and loading parameters were applied on the geotechnical model shown in Fig. 4. Figure 4 shows Fig.1 curves along with a lower-bound design SPT 'N' profile that defines the characteristic SPT 'N' profile. Using Eqn. (1), this SPT 'N' profile has been converted to an undrained shear strength envelope and used in the indicative analysis.

As shown in Fig. 5, the above caisson geometry and loading (MTO HMPF (2004)), based on the ground model in Fig. 4, would result in a caisson head rotation of about 0.002 radians (MTO HMPF (2004) rotation limit is 0.005 radians) and satisfies all the LRFD ULS/SLS requirements for lateral loading of deep foundations.

As borehole drilling was undertaken at site specific HML locations and there is no proposed widening of the QEW to the north, the HML pole foundations would not be subjected to slope effects under lateral loading.

GEOTECHNICAL CONSIDERATIONS – AXIAL LOADING

The recommended factored ultimate geotechnical resistance and factored serviceability geotechnical resistance of a 1.52 m diameter, 12 m long caisson embedded 8 m in the upper clay ($S_u = 100$ kPa; with the shaft resistance within the top 1.2 m neglected) and 4 m into the lower clay ($S_u = 55$ kPa) are as follows:

Table 5-2 Geotechnical Resistances – Axial Loading

Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa) [for 25 mm Settlement]
980	700

*Based on the geotechnical model shown in Fig. 4. Geotechnical resistance of the top 1.2 m neglected.

Construction considerations are discussed in Section 5.4.

5.4 CONSTRUCTION CONSIDERATIONS

5.4.1 SITE PREPARATION

It is recommended that all topsoil, organics loosened/softened and deleterious materials should be stripped from the proposed pole locations and backfilled the area in accordance with **OPSS 902** (Excavating and Backfilling Structures).

5.4.2 EXCAVATIONS

All excavations should be carried out in accordance with the **Occupational Health and Safety Act (OHSA), O. Reg. 213/91**. Where space permits, and appropriate groundwater control measures are in place, temporary open cut excavations may be undertaken subject to the following specifications.

In accordance with OHSA and based on the geotechnical understanding of the site conditions, the sub-soils intercepted can be classified as follows:

- Silty Clay/ Fill Material above water table Type 3
- Silty Clay below water table Type 4

The above slopes are for short-term open excavations only and should be visually monitored especially when people are working inside.

Excavations in the native soils should be possible using heavy equipment such as a hydraulic excavator and cobbles and boulders within the fill and native deposits should be anticipated.

Requirements for shoring are not anticipated for the construction of HML foundations consisting of caissons. Additional geotechnical engineering input will be required if any proposed temporary excavation were to abut an existing embankment.

5.4.3 GROUNDWATER CONTROL

Given the varved nature of some of the native silty clay deposits reported by Golder and observed by WSP in the only Shelby tube retrieved from the HML series, i.e. in HM 4, Sample 14 and the groundwater level observations reported in Table 4-23 of the FIR, inflows into the caisson bores should be minimal but cannot be ruled out (in view of the varved clay structure). Therefore, use of temporary liners may be required. Preparedness for bailing/pumping out any groundwater inflow can be anticipated.

The control of groundwater during construction should be undertaken as per **OPSS.PROV 517** (Construction Specification for Dewatering), amended by **SP 517F01**.

5.4.4 CONSTRUCTION OF CAISSONS

In addition to the possible requirement for the use of temporary liners discussed in Section 5.4.3, it is necessary to ensure that concrete is placed within four hours following the caisson bore excavations, cleaning and inspection to minimize the potential for softening of the bore walls/bases comprising intermediate to high plasticity cohesive soils. Construction should be compliant with **OPSS.Prov 903** - Construction Specifications for Deep foundations, amended by **SP 109F57**.

5.5 POTENTIAL FOR SULPHATE ATTACK/CORROSION ON CAISSONS

Laboratory testing carried out on five samples of soil was reported in Section 4.11 of the FIR.

The Canadian Standards Association (**CAN/CSA-A23.1-04**) recognizes four categories of potential sulphate attack of buried concrete based on percent sulphate in soil. From 0 to 0.10 percent the potential is negligible, from 0.10 to 0.20 percent the potential is mild but positive, from 0.20 to 0.50 percent the potential is considerable and 0.50 percent and greater the potential is severe. Based on the above, given the tested soil samples indicated sulphate percentages ranging from 0.06% to 0.28%, the vulnerability to sulphate attack on buried concrete is considered to be from negligible to considerable. This should be factored into the design considerations in the structural design/concrete specifications of the caissons.

Based on **MTO Gravity Pipe Design Guideline (April 2014)**, subgrade soil corrosiveness is categorized to four (4) groups in accordance with Table 3.2 of the MTO guideline. The soil resistivity for the sample tested at this site indicated resistivity ranging from 422 to 1170 ohm-cm, which would categorize the subject soils as severe. Due to the corrosiveness condition of the soils, protection measures such as adequate concrete cover should be provided for steel reinforcement within the caissons.

CLOSURE

The "Limitations of Report" as presented in **Appendix F** are an integral part of this report.

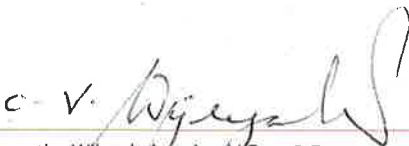
SIGNATURES

We trust that the information contained in this foundation investigation report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

WSP Canada Inc.



Franklin Oliha, MSc., P.Eng.
Geotechnical Engineer



Vasantha Wijeyakulasuriya, M.Eng., P.Eng.
MTO Designate (Foundations)



REFERENCES

Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6-14. 2014. CSA Special Publication, S6.1 14. Canadian Standard Association.

National Building Code (NBC) 2015, NRC.

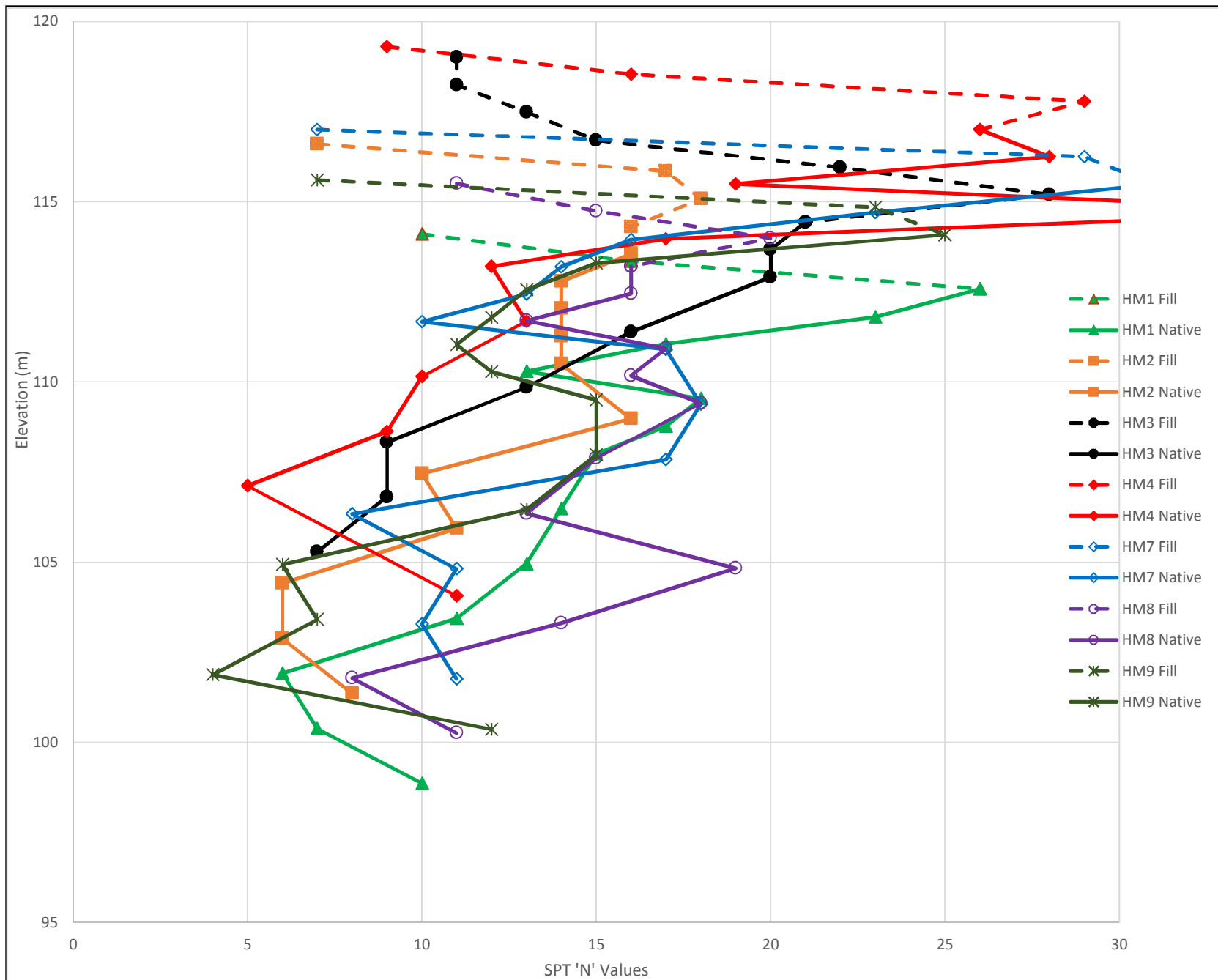
Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.

MTO Guidelines for the Design of High Mast Pole Foundations (4th edition, 2004)

MTO Gravity Pipe Design Guideline, (April 2014)

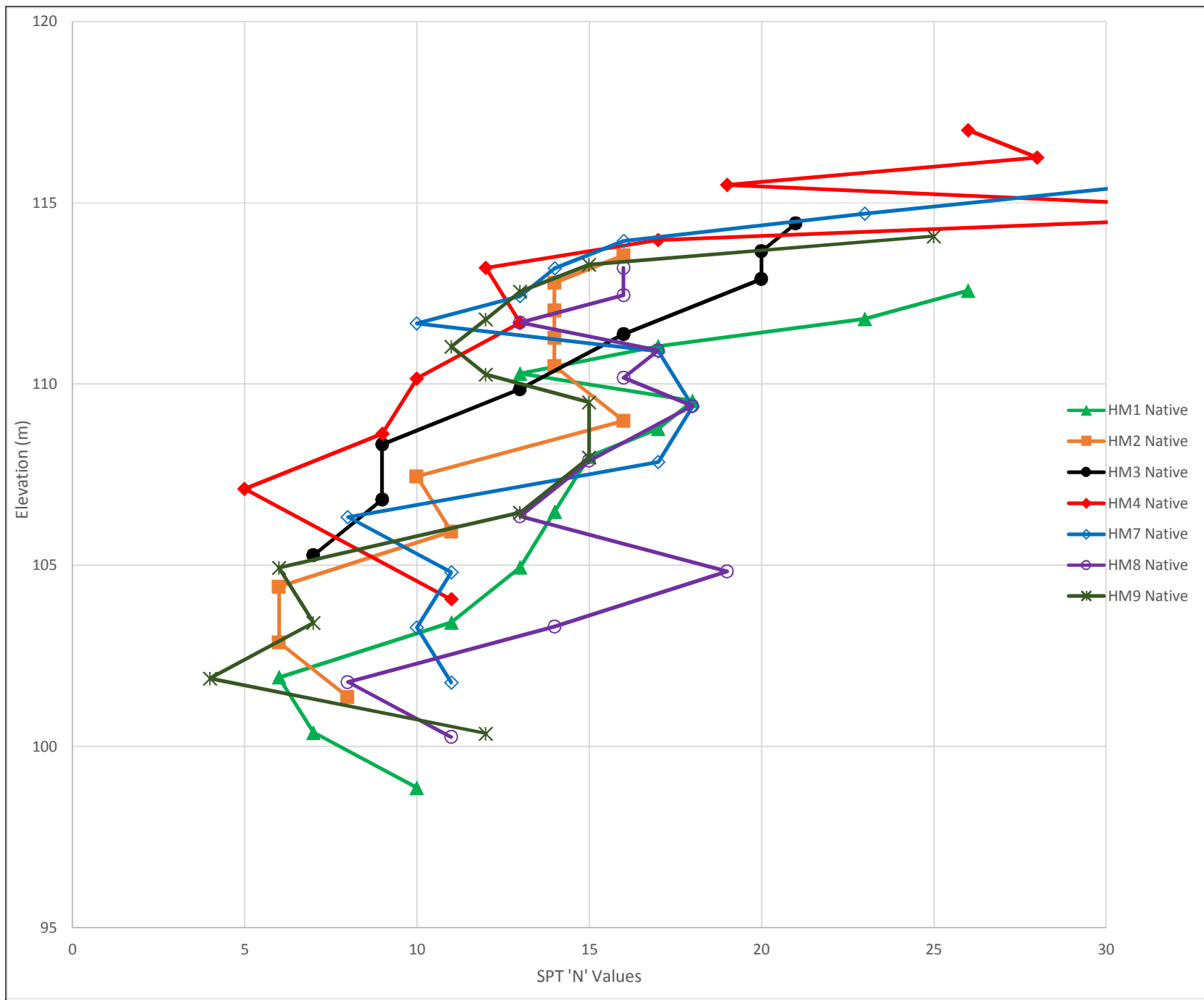
CAC/CSA A23.1-14/A23.2-14 Concrete Materials and Method of Concrete Construction

LIST OF FIGURES



SPT 'N' Value Vs Elevation
HML

Figure No.	1
Project No.	18M-01021-12
Date :	Oct-29-2019



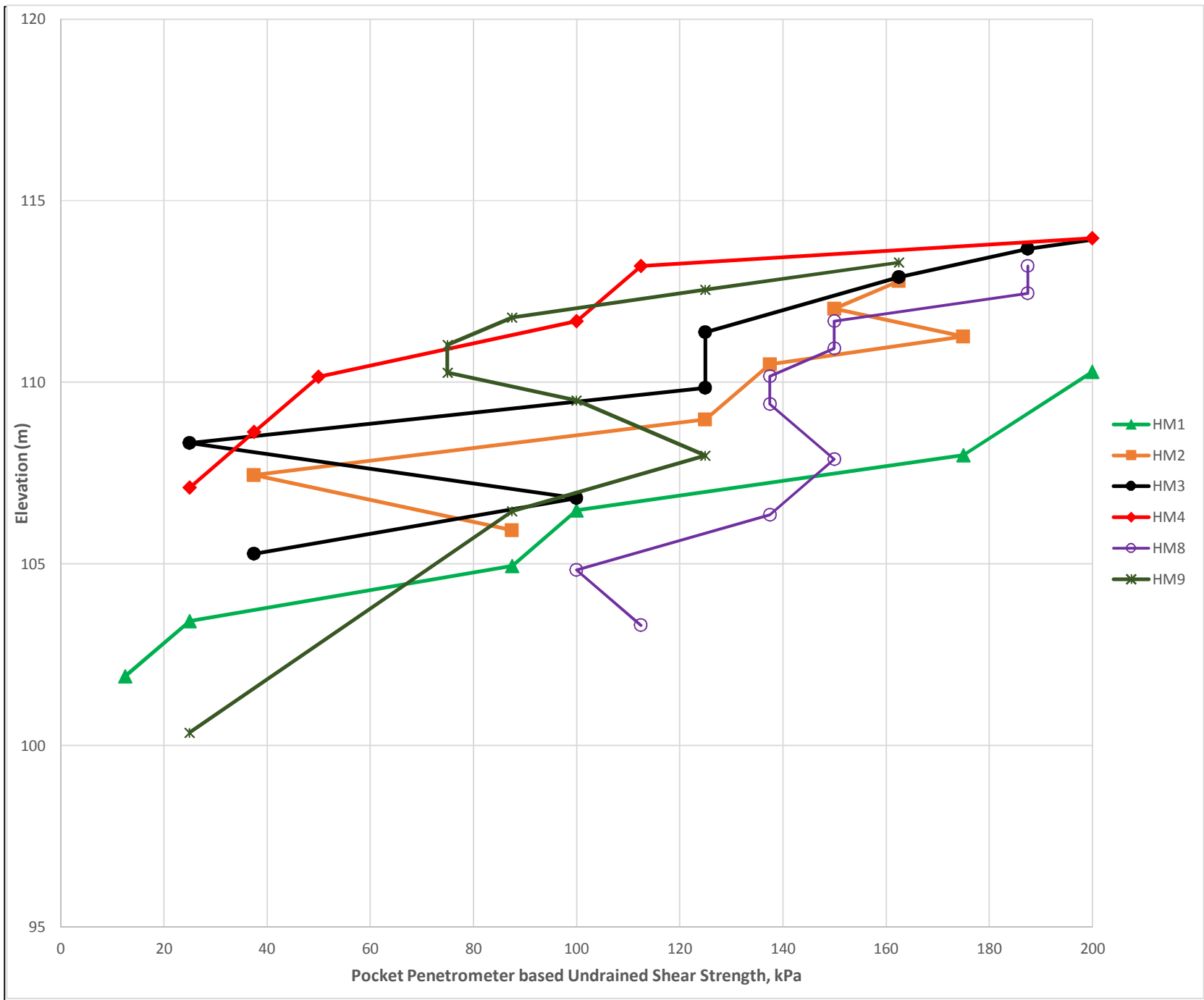
SPT 'N' Value Vs Elevation (m)

HML

Figure No. 2a

Project No. 18M-01021-12

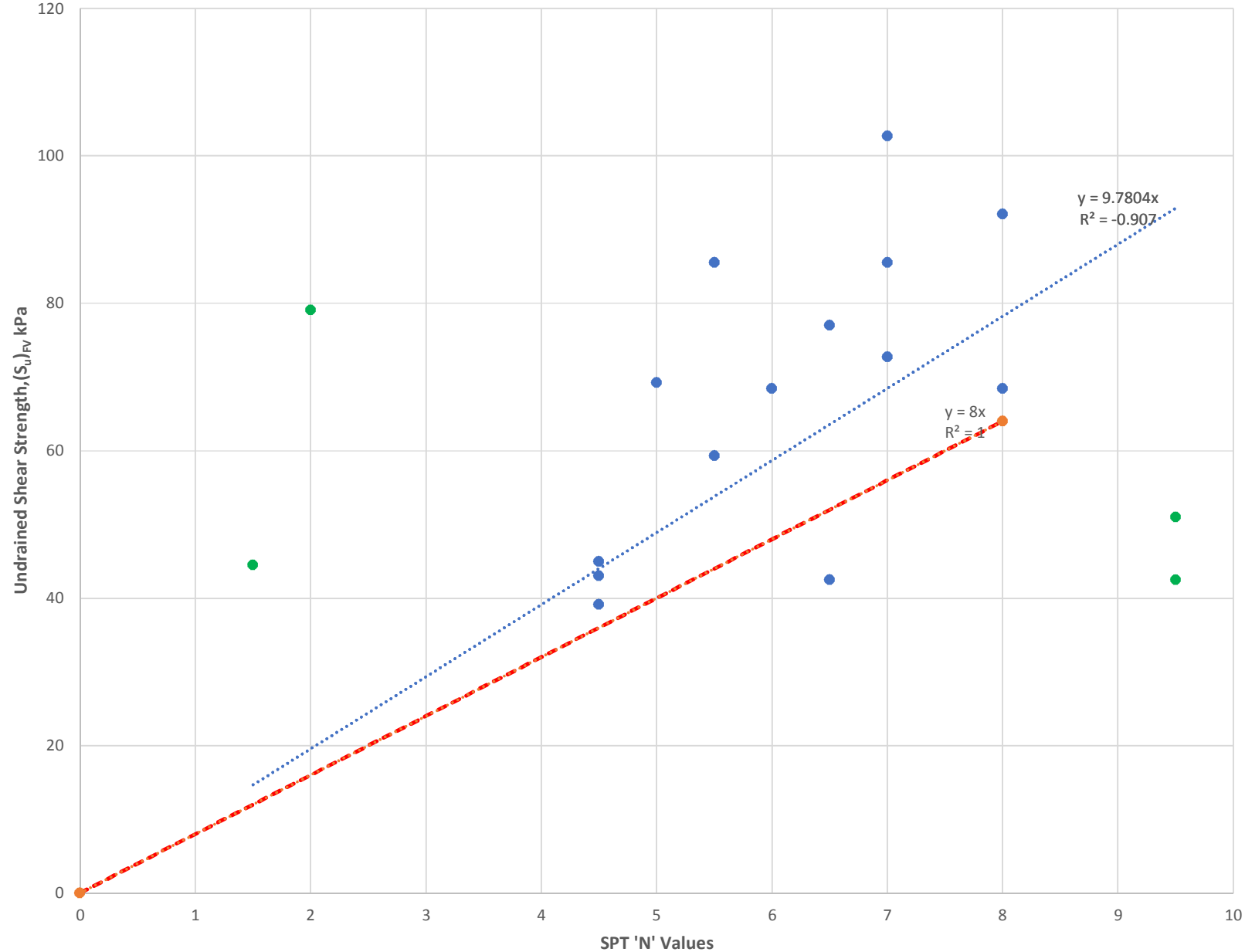
Date : Oct-29-2019



Pocket Penetrometer based Undrained Shear Strength Vs
Elevation (m)
HML

Figure No.	2b
Project No.	18M-01021-12
Date :	Oct-29-2019

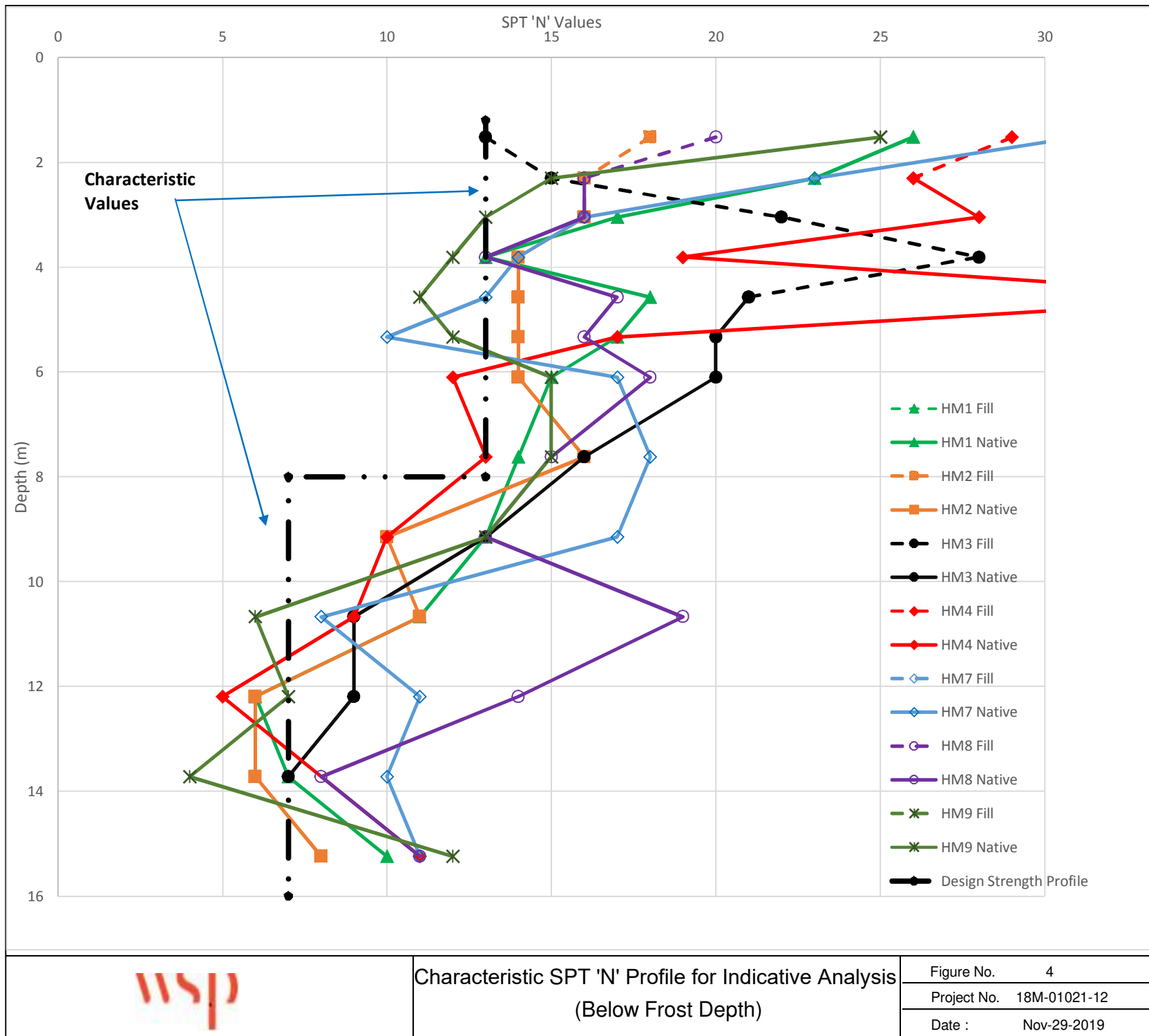
Undrained Shear Strength, $(S_u)_{FV}$ vs SPT 'N' Values



Undrained Shear Strength, $S_u(FV)$ vs SPT 'N' Values

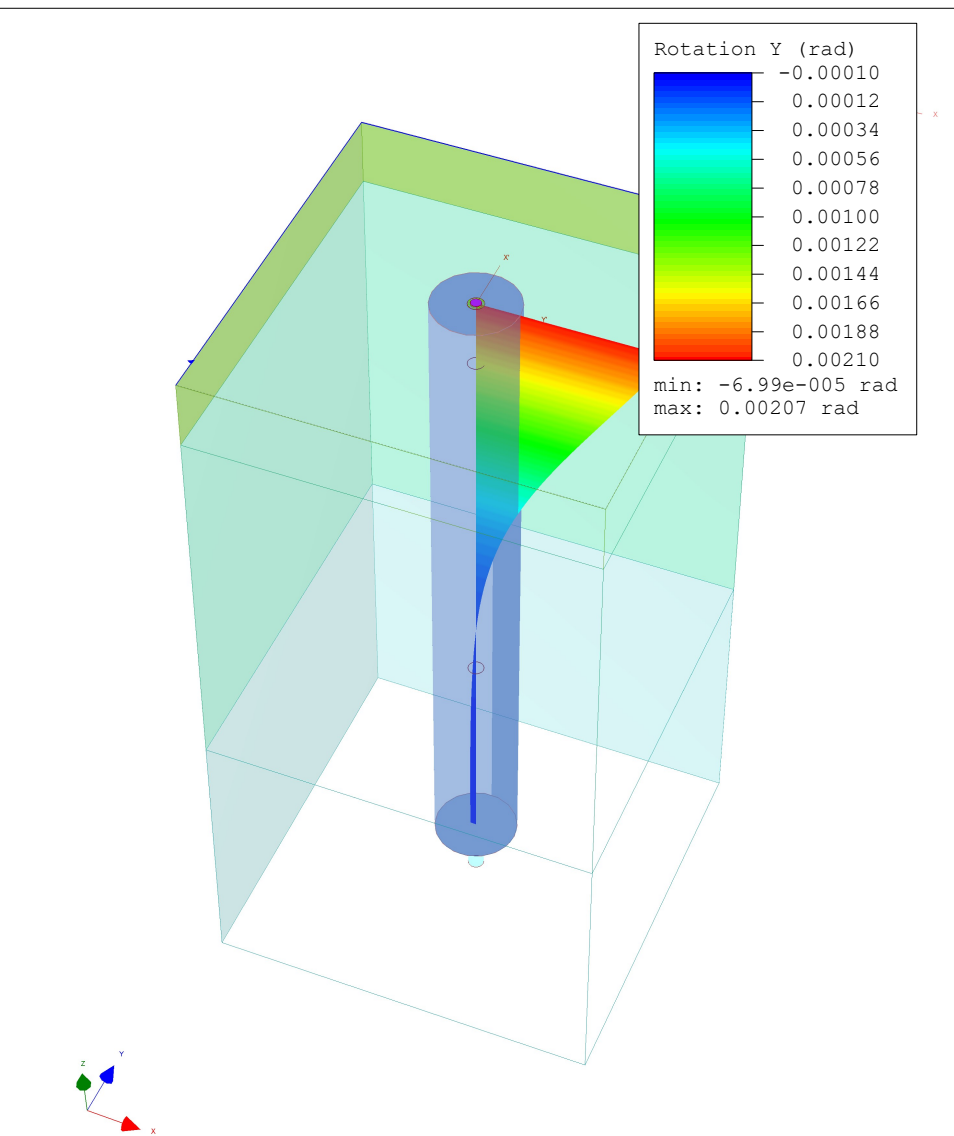
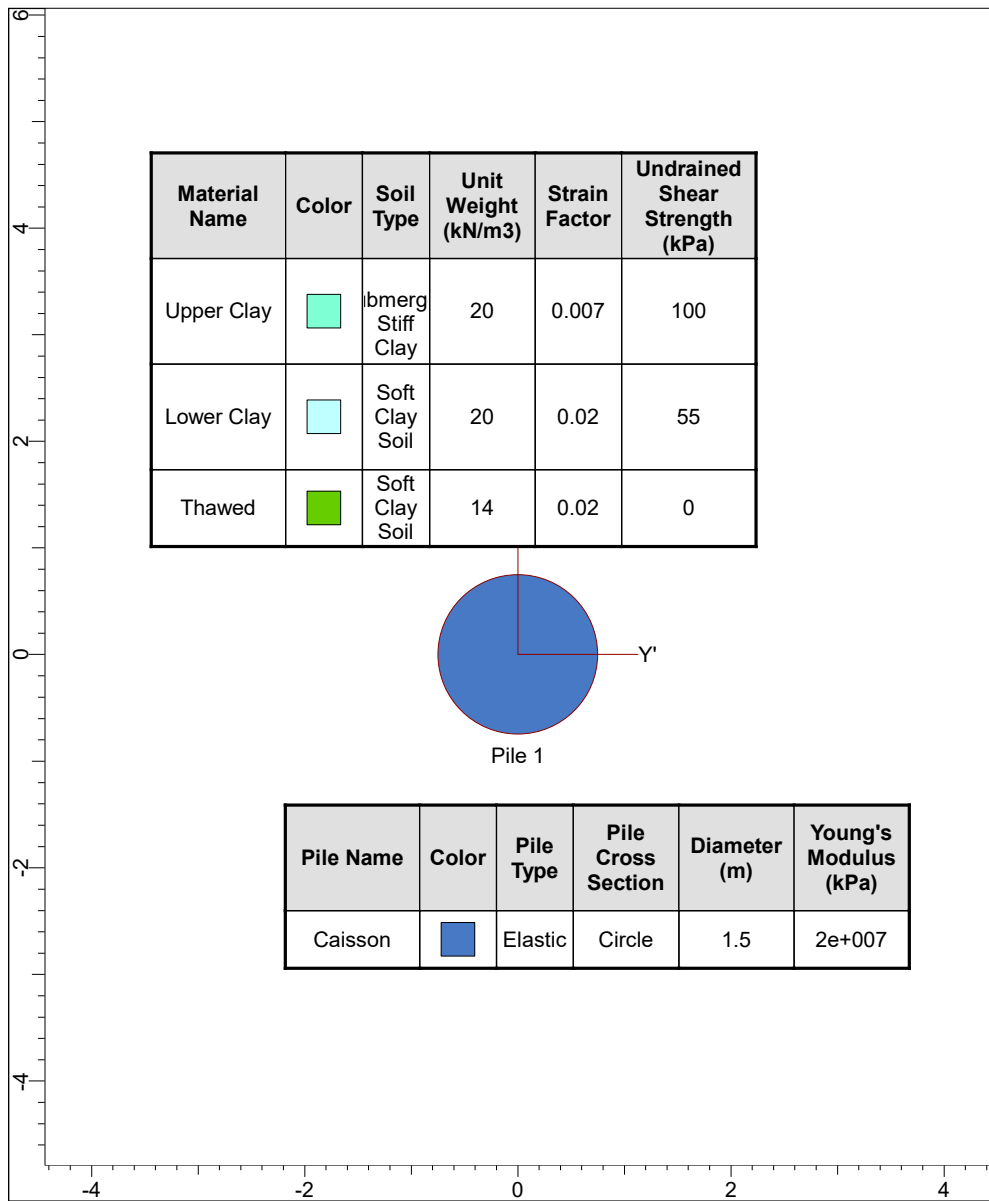
HML

Figure No.	3
Project No.	18M-01021-12
Date :	Oct-29-2019



Characteristic SPT 'N' Profile for Indicative Analysis
(Below Frost Depth)

Figure No.	4
Project No.	18M-01021-12
Date :	Nov-29-2019



APPENDIX

E

LIST OF SSPs, OPSS AND OPSD

List of SSPs, OPSSs, and OPSDs referenced in the Report

OPSD	3090.101	FOUNDATION FROST PENETRATION DEPTHS FOR SOUTHERN ONTARIO
OPSD	3190.100	WALLS RETAINING AND ABUTMENT WALL DRAIN
OPSD	3190.101	FOUNDATION FROST PENETRATION DEPTHS FOR SOUTHERN ONTARIO
OPSD	3121.150	WALLS RETAINING, BACKFILL - MINIMUM GRANULAR REQUIREMENT
OPSS.PROV	501	CONSTRUCTION SPECIFICATION FOR COMPACTING
OPSS.PROV	512	CONSTRUCTION SPECIFICATION FOR INSTALLATION OF GABIONS
OPSS.PROV	517	CONSTRUCTION SPECIFICATION FOR DEWATERING OF PIPELINE
OPSS.PROV	539	CONSTRUCTION SPECIFICATION FOR TEMPORARY PROTECTION
OPSS.PROV	902	CONSTRUCTION SPECIFICATION FOR EXCAVATING AND BACKFILLING STRUCTURES
OPSS.PROV	903	CONSTRUCTION SPECIFICATION FOR DEEP FOUNDATIONS
OPSS.PROV	1010	MATERIAL SPECIFICATION FOR AGGREGATES – BASE, SUBBASE, SELECT SUBGRADE AND BACKFILL MATERIAL
OPSS.PROV	1860	MATERIAL SPECIFICATION FOR GEOTEXTILES
SSP	109S12	AMENDMENT TO OPSS 902
SP	517F01	AMENDMENT TO OPSS.PROV 517
SP	109F57	AMENDMENT TO OPSS.PROV 903

APPENDIX



F

LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to WSP Canada Inc. at the time of preparation. Unless otherwise agreed in writing by WSP Canada Inc., it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP Canada Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.

