



Foundation Investigation and Design Report

Overhead Sign Support Structures

*Highway 401 Eastbound Collector Lanes, Avenue Road to Warden Avenue,
Toronto, Ontario*

MTO G.W.P. 2130-01-00

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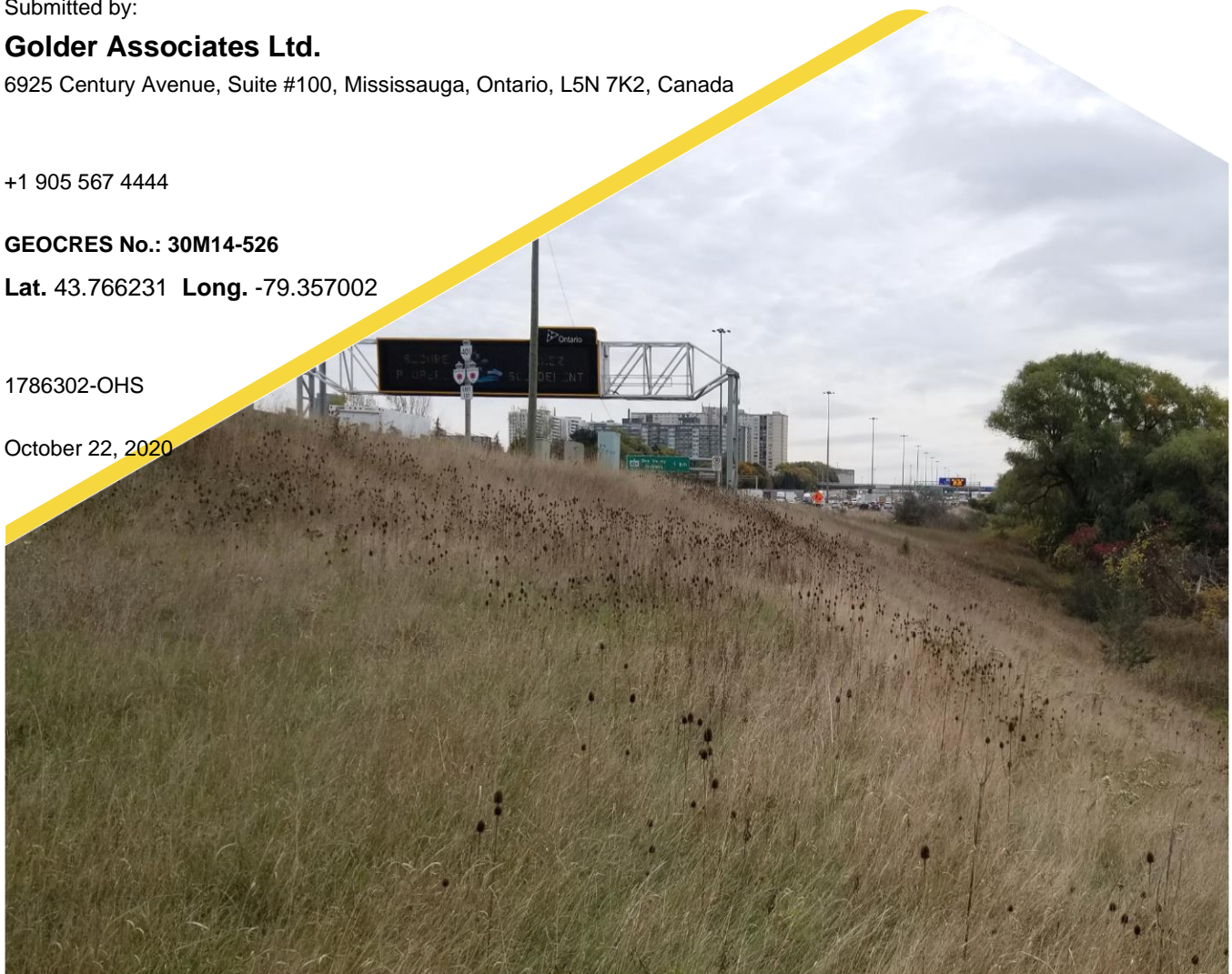
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PART A

FOUNDATION INVESTIGATION REPORT
OVERHEAD SIGN SUPPORT STRUCTURES
HIGHWAY 401 EASTBOUND COLLECTOR LANES FROM AVENUE ROAD
TO WARDEN AVENUE, TORONTO, ONTARIO
MTO GWP 2130-01-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the rehabilitation of the Highway 401 Eastbound Collector lanes between Avenue Road and Warden Avenue (approximately 10 km) in Toronto, Ontario (Assignment No. 2016-E-0089).

This report presents the subsurface conditions at the site of two new overhead sign (OHS) support structures located along the proposed Highway 401 Eastbound Collector (EBC) widening, east and west of the Leslie Street interchange. A total of four boreholes were advanced for three OHS structures originally proposed; however, it understood that one of these signs is no longer required. The results of foundation investigations for other works associated with this assignment are presented in separate reports.

2.0 SITE DESCRIPTION

The highway is on downward gradient from west to east between the two sign support structures, ranging from about Elevation 151 m to Elevation 132 m. The proposed sign support foundation elements are located at either the median between the existing Eastbound Core and Collector lanes, the outside shoulder of the existing Eastbound Collector lanes or the grass-covered area at the toe of embankment slope beyond the outside shoulders. Vegetation at the toe of embankment slope consists of grass, small shrubs, and sparsely spaced trees.

3.0 INVESTIGATION PROCEDURES

The field work for the proposed OHS support structures was carried out between November 4, 2019 and May 20, 2020, at which time a total of four boreholes designated VMS-1, VMS-2, VMS-3 and VMS-4 were advanced.

Due to the existing reinforced concrete composite pavement structure along Highway 401, the coring of the pavement structure was completed by 254 mm outside diameter (O.D.) core bit, supplied and operated by Canadian Cutting and Coring of Brampton, Ontario. Upon completion of the coring of the pavement structure, boreholes were advanced using a CME 75 truck-mounted and CME 55 track-mounted drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Halton Hills, Ontario. The boreholes were advanced using 150 mm and 200 mm O.D. hollow stem augers. Soil samples were generally obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm O.D. split-spoon sampler driven by automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586¹). 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.

Groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended), and the ground surface was restored to near original condition as practical.

The field work was observed by members of Golder's engineering and technical staff, who arranged for the clearance of underground services, observed the drilling, sampling and in-situ testing operations, logged the borehole, and examined and cared for the soil samples. The soil samples were identified in the field, placed in

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

appropriate containers, labelled and transported back to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All the soil laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

The as-drilled borehole locations and the ground surface elevation were measured relative to identifiable site features and superimposed on the base plan. The locations given on the Record of Borehole, and as shown on Drawing 1 are positioned related to MTM NAD 83 (Zone 10) CSRS CGVD28 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole location, geographic coordinates, ground surface elevation and drilled depth is presented below.

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Depth of Borehole (m)
	Northing (Latitude, °)	Easting (Longitude, °)		
VMS-1	4,847,322.4 (43.765792)	315,541.2 (-79.366593)	151.2	11.3
VMS-2	4,847,368.1 (43.766192)	316,280.6 (-79.357409)	132.4	11.3
VMS-3	4,847,332.8 (43.765874)	316,286.6 (-79.357336)	124.7	11.3
VMS-4	4,847,401.2 (43.766485)	316,599.4 (-79.353449)	138.1	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The area surrounding the Highway 401 / Leslie Street interchange is within the physiographic region known as the South Slope, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)² and *Urban Geology of Canadian Cities* (Menzies and Taylor, 1998)³.

The South Slope physiographic region is characterized by a smooth to drumlinized till plain that was formed as a result of glacial action and deposition of till material south of the Oak Ridges Moraine. The South Slope contains a variety of soil deposits that have developed over till and the overburden soils can typically be more than 50 m thick.

²Chapman, 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.

³Menzies, J., and Taylor, E.M., 1998. *Urban Geology of St. Catharines-Niagara Falls, Region Niagara*. In *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White.

The underlying bedrock consists of grey shale of the Georgian Bay Formation interbedded with limestone, siltstone and sandstone. Within and adjacent to the East Don River, interglacial and post-glacial flooding in the valley has produced deposits of glaciolacustrine sands, silts, and silty clay.

4.2 General Overview of Subsurface Conditions

The soil and groundwater conditions as encountered in the boreholes advanced during the foundation investigation is presented on the Record of Borehole sheets in Appendix A and the geotechnical laboratory test results are presented in Appendix B.

The results of in-situ tests (i.e., SPT) as presented in the borehole records and in Section 4.2 are uncorrected. The boundaries between the soil deposits on the borehole records have been inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the subsurface soils encountered consist of surficial layers of topsoil or composite pavement structure, underlain by cohesive and non-cohesive fill. The fill is then underlain by a cohesive deposit consisting of clayey silt to sandy clayey silt-silt which is followed by a deposit of silty sand to sand layer. The silty sand to sand is underlain by a deposit of silty clay to sandy clayey silt, which is in turn underlain by a deposit of silt to sandy silt. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

An approximately 50 mm thick layer of topsoil was encountered at ground surface in Borehole VMS-3.

These materials were classified solely based on visual and textural evidence. Testing or organic content for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.2.2 Asphalt and Concrete Pavement Structure

An approximately 90 mm to 150 mm thick layer of asphalt was encountered at the ground surface in Boreholes VMS-1, VMS-2 and VMS-4, which was advanced at Highway 401 grade.

An approximately 240 mm and 178 mm thick layer of reinforced concrete, which forms part of the composite pavement structure, was encountered underlying the asphalt in Boreholes VMS-1 and VMS-2, respectively.

Photographs of the recovered pavement structure can be seen on Figures A1 to A3 in Appendix A.

4.2.3 SAND (SP) and Gravel (FILL)

A 5.3 m thick layer of non-cohesive fill consisting of sand and gravel, trace to some silt, was encountered underlying the composite pavement structure at Borehole VMS-1. The top of the sand and gravel fill was encountered at a depth of 0.3 m below ground surface (Elevation 150.9 m) and extended to a depth of 5.6 m below ground surface (Elevation 145.6 m).

The SPT “N”-values measured within the granular fill ranges from 32 blows per 0.3 m of penetration to 100 blows per 0.2 m of penetration, indicating a compact to very dense state of compactness.

Water content measured on samples of the sand and gravel fill is about 13% and 16%.

Grain size distribution testing was carried out on a sample of the sand and gravel fill, and the results are presented on Figure B1 in Appendix B.

4.2.4 Sandy CLAYEY SILT (CL) to CLAYEY SILT (CL/SC) and Sand (FILL)

A 1.2 m to 6.9 m thick layer of cohesive fill was encountered underlying the sand and gravel fill in Borehole VMS-1, underlying the pavement structure in Boreholes VMS-2 and VMS-4, and underlying the topsoil in Borehole VMS-3. The cohesive fill consists of clayey silt, some sand to sandy to and sand, to sandy clayey silt-silt, trace gravel, containing rootlets and organics. The cohesive fill was encountered at depths ranging from 0.1 m to 5.6 m below ground surface (between Elevations 145.6 m and 124.6 m) and extends to depths ranging from 1.5 m to 8.7 m below ground surface (between Elevations 142.5 m and 123.3 m).

The SPT “N”-values measured within the cohesive fill range from 5 blows to 33 blows per 0.3 m of penetration, suggested a firm to hard consistency.

Grain size distribution testing was carried out on a sample of the sandy clayey silt fill, and the results are presented on Figure B2 in Appendix B.

Atterberg limit testing was carried out on a sample of the cohesive fill and measured a liquid limit of about 22%, a plastic limit of about 12%, corresponding to a plastic index of about 10%. The Atterberg limit test results are presented on Figure B3 in Appendix B and indicates that the fill is a clayey silt of low plasticity. The water content measured on samples of the deposit range from about 9% to 12%.

4.2.5 Sandy SILT (ML) to SILTY SAND (SM)

A 2.6 m thick deposit of sandy silt, some gravel to silty sand was encountered underlying the cohesive fill in Borehole VMS-1 at a depth of 8.7 m below ground surface (Elevation 142.5 m). The deposit extends to a depth of 11.3 m below ground surface (Elevation 139.9 m) prior to borehole termination.

The SPT “N”-values measured within the sandy silt to silty sand deposit are 19 blows and 20 blows per 0.3 m of penetration, indicating a compact state of compactness.

Grain size distribution testing was carried samples of the sandy silt to silty sand deposit, and the results are presented on Figure B4 in Appendix B.

Atterberg limit testing was carried out on one sample of the deposit and measured a liquid limit of about 16%, a plastic limit of about 12%, corresponding to a plastic index of about 4%. The Atterberg limit test results are presented on Figure B5 in Appendix B and indicates that the material is a silt of low plasticity. The water content measured on samples of the deposit are about 8% and 16%.

4.2.6 SILTY CLAY (CI) to Sandy CLAYEY SILT-SILT (CL-ML)

A 4.1 m and 8.7 m thick deposit of silty clay to clayey silt, sandy to and sand, to sandy clayey silt-silt, trace to some gravel, containing fibrous rootlets and organics was encountered underlying the cohesive fill in Boreholes VMS-2 to VMS-4. The deposit was encountered at depths from 1.5 m to 7.2 m below ground surface (between Elevations 136.6 m and 123.3 m) and extended to depths from 5.6 m to 10.2 m below ground surface (between Elevations 127.9 m and 119.1 m). Borehole VMS-2 was terminated within this deposit at an Elevation 121.1 m. An interlayer of silty sand to sand was observed within this deposit in Boreholes VMS-2 and VMS-3 as discussed in Section 4.2.6.1.

The SPT “N”-values measured within the cohesive deposit range from 0 blows (weight of hammer) and 35 blows per 0.3 m of penetration, suggesting a very soft to hard consistency.

Organic content testing was carried out on one sample from Borehole VMS-2 and measured an organic content of about 4%.

Grain size distribution testing was carried samples of the cohesive deposit, and the results are presented on Figure B6 in Appendix B.

Atterberg limit testing was carried out on samples of the deposit and measured liquid limits ranging from about 23% to 36%, plastic limits of about 12% and 21%, and plastic indices of about 7% and 20%. The Atterberg limit test results are presented on Figure B7 in Appendix B and indicates that the deposit is a silty clay of medium plasticity to a clayey silt-silt of low plasticity. The water content measured on nine samples of the deposit are ranging from about 16% to 36%.

4.2.6.1 SILTY SAND (SM) to SAND (SP) – Interlayer

A 0.6 m and 1.5 m thick interlayer of silty sand to sandy silt, trace to some gravel, containing organics, was encountered within the clayey silt to sandy clayey silt-silt deposit in Boreholes VMS-3 and VMS-2, respectively. The silty sand to sand deposit was encountered at depths of 2.2 m and 8.7 m below ground surface (at Elevations 123.7 m and 122.5 m), and extended to depths of 2.8 m and 10.2 m below ground surface (at Elevations 122.2 m and 121.9 m) in Boreholes VMS-3 and VMS-2, respectively.

The SPT “N”-values measured within this deposit are 5 blows and 13 blows per 0.3 m of penetration, suggesting a loose to compact compactness condition.

Water content was measured on a sample of the deposit at about 19%.

Grain size distribution testing was carried a sample of the silty sand deposit, and the results are presented on Figure B8 in Appendix B.

4.2.7 Sandy SILT (ML) to SILTY SAND (SM)

A 1.1 m and 5.7 m thick deposit of sandy silt to silty sand was encountered underlying the clayey silt to silty clay deposit in Boreholes VMS-4 and VMS-3, respectively. The sandy silt to silty sand deposit was encountered at depths of 5.6 m and 10.2 m below ground surface (at Elevations 127.9 m and 119.1 m) in Boreholes VMS-3 and VMS-4, respectively, and extends to a borehole termination depth of 11.3 m below grounds surface (at Elevations 126.8 m and 113.4 m). A silt interlayer was encountered in Borehole VMS-3 from a depth of 9.1 m to 9.3 m below ground surface (between Elevations 115.6 m and 115.4 m).

The SPT “N”-values measured within this deposit ranges from 2 blows to 15 blows per 0.3 m of penetration, indicating a very loose to compact state of compactness.

The water content measured on samples of the deposit are about 15% and 20%.

Grain size distribution testing was carried out on one sample of the deposit, and on a sample of the silt interlayer, and the results are presented on Figure B9 in Appendix B.

4.3 Groundwater Conditions

In general, the soil samples taken in the boreholes ranged from moist to wet. Boreholes VMS-1, VMS-2 and VMS-4 were noted to be dry and open upon completion of drilling. The groundwater was observed at a depth of 1.5 m below ground surface (Elevation 123.2 m) in Borehole VMS-3 upon completion of drilling. However, these conditions and water levels do not represent the stabilized groundwater level at the site.

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

The Foundation Investigation Report was prepared by Ms. Katelyn Nero, E.I.T., and reviewed by Ms. Manisha Ahuja, P.Eng., P.E, a geotechnical engineer with Golder. Mr. Christopher Ng, P.Eng., an Associate and MTO Foundations Designated Contact with Golder conducted an independent technical and quality review of this report.

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PART B

FOUNDATION DESIGN REPORT
OVERHEAD SIGN SUPPORT STRUCTURES
HIGHWAY 401 EASTBOUND COLLECTOR LANES FROM AVENUE ROAD
TO WARDEN AVENUE, TORONTO, ONTARIO
MTO GWP 2130-01-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides geotechnical engineering parameters and foundation design recommendations for the design of foundations of three overhead sign (OHS) support structures; however, subsequent to completing the foundation investigation, MTO has advised that the proposed pole-mounted variable message sign located at Station 26+470 is no longer required. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation within the project limits. The design report with the interpretation and recommendations is intended for the use of the Ministry of Transportation to provide the designers with sufficient information to carry out detail design of the OHS support structure foundations and shall not be used or relied upon for any other purpose or by any other parties, including the constructor or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (i.e. Part A of the report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design on the project, and for which special provisions or operation constraints may be required in the Contract Documents. Contractors must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Design of Sign Support Foundations

It is understood that different types of sign supports are required for the three overhead signs to be constructed for the widening of Highway 401. It is also understood that the right (south) footing of the tri-chord OHS No. 2 has been constructed as part of the previous contract, and that all recommendations within this report are for the left (north) footing at OHS No. 2. The locations of the proposed overhead signs and sign-support structure type at each overhead sign location is summarized below.

Sign Support Designation	Approximate Sign Location	Proposed Sign Support Structure Type
OHS No. 2	Station 25+413 EBC Left (North) Footing	Tri-Chord
OHS No. 3	Station 26+188 EBC	Variable Message Sign
--	Station 26+470 EBC	Pole Mounted Variable Message Sign

Caissons foundations for sign supports should be designed in accordance with the requirements provided in MTO's *Sign Support Manual* (MTO 2019). The *Sign Support Manual* includes standard caisson foundation designs for each sign type as follows:

- **Tri-Chord Overhead Signs:** Tri-Chord Static Sign Supports, Section 4 and Standard Drawings SS118-3, SS118-4 and SS118-5.
- **Overhead Variable Message Signs:** Variable Message Sign Support (VMS), Section 8 and Standard Drawings SS118-6, SS118-7 and SS118-8.

- **Pole Mounted Variable Message Signs:** Variable Message Sign Support (VMS), Section 8 and Standard Drawings SS118-3, SS118-4 and SS118-5.

In the standard caisson foundation design, the caisson is extended at least 5 m below the design frost depth, which for this site is 1.2 m as interpreted from OPSD 3090.101 (*Foundation, Frost Penetration Depth*) resulting in a total caisson length of at least 6.2 m below the final grade. The standard sign foundation designs presented in MTO's *Sign Support Manual* have been developed based on the minimum soil conditions given below.

- **Case 1 (Non-Cohesive Soils):** Sand with a friction angle of 28 degrees surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and sand with a friction angle of 30 degrees surrounding the lower third portion of the caisson below the frost depth.
- **Case 2 (Cohesive Soils):** Soft clay with an undrained shear strength of 25 kPa surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and "soft" clay with an undrained shear strength of 50 kPa surrounding the lower third of the portion of the caisson below the design frost depth.

The standard foundation design provided in MTO's *Sign Support Manual* does not apply to sites where extensive poor fill materials or materials looser or softer than those of Case 1 or Case 2 are present. For such subsurface conditions, a site-specific design is required. Based on the review of the subsurface conditions at the proposed sign locations, the footings for the overhead signs does not require special design considerations and can be carried out using the standard foundation design as outlined in MTO's *Sign Support Manual*.

If the sign area is larger than that permitted under the standard design outlined in MTO's *Sign Support Manual*, a site-specific caisson foundation design can be carried out by the structural designer using the equations provided below to calculate the unfactored passive lateral earth pressure P_p (kPa), distributed along the length of the caisson, based on the idealized stratigraphy and geotechnical parameters given in Table 1 following the text of this report. The geotechnical parameters presented in Table 1 are based on field and laboratory test data as well as accepted correlations (NAVFAC, 1986, Bowles, 1984 and Kulhawy and Mayne, 1990) and the analysis was tempered by engineering judgement based on experience in similar soils.

$$\begin{aligned}
 P_p &= K_p \cdot \gamma \cdot d \quad \text{above the groundwater table, and,} \\
 P_p &= K_p \cdot \gamma \cdot d_w + K_p \cdot \gamma' \cdot (d - d_w) \quad \text{below the groundwater table.}
 \end{aligned}$$

Where

- K_p = passive earth pressure coefficient
- γ = bulk unit weight (kN/m³)
- γ' = effective unit weight below the groundwater level (kN/m³)
- d = depth below the ground surface (m); and
- d_w = depth of groundwater level (m)

Referring to the design parameters in Table 1, at the three OHS locations where the proposed ground surface is higher than the ground surface at the time of investigation, it is assumed that suitable engineered fill will be placed and compacted in accordance with OPSS.PROV 501, and the soil parameters provided for the existing fill can be assumed to extend to the existing grade.

In the design of the sign foundations, the passive resistance within the upper 1.2 m below ground surface should be neglected to account for frost action.

The unfactored lateral resistance should be calculated assuming an equivalent width equal to three times the caisson ultimate diameter. A resistance factor of 0.5 (consistent with a “typical” consequence level and degree of site understanding, per the 2019 *Canadian Highway Bridge Design Code CSA S6:19* (CHBDC, 2019)) should be applied to this unfactored lateral resistance to obtain the factored ultimate lateral geotechnical resistance.

6.3 Construction Considerations

Construction of the footing foundations for the sign support structures should be in accordance with OPSS.PROV 915 (Sign Support Structures).

6.3.1 Control of Soil and Groundwater

Water-bearing non-cohesive soils at this site should be expected to run or flow into the drilled shaft (caisson) hole during or after drilling of the footings/caissons for the OHS. Therefore, appropriate equipment and procedures will be required to minimize ground loss during drilling and concrete placement. This could include the use of temporary caisson liners, and/or the use of bentonite and/or polymer slurry.

7.0 CLOSURE

Foundation Design Report was prepared by Ms. Katelyn Nero, E.I.T., and reviewed by Ms. Manisha Ahuja, P.Eng., P.E., a geotechnical engineer with Golder. Mr. Christopher Ng, P.Eng., as Associate and MTO Foundations Designated Contact with Golder conducted an independent technical and quality review of this report.

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ASTM International:

ATSM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Occupational Health and Safety Act:

Ontario Regulation 903 Wells (as amended)

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 915 Construction Specification for Sign Support Structures

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101 Foundation, Frost Penetration Depths for Southern Ontario

Table 1: Geotechnical Design Parameters for Sign Support Foundations

Borehole No.	Sign Location	Sign Structure	Soil Stratum	Depth ¹ (m)	Elevation ¹ (m)	Design Groundwater Elevation ² (m)	Design Parameters ³				
							S_u (kPa)	ϕ' (°)	γ (kN/m ³)	γ' (kN/m ³)	K_p ⁴
VMS-1	Highway 401 EBC STA. 25+413 (Left Footing)	OHS No. 2	Compact to Very Dense SAND (SM/GM) and Gravel (FILL)	0.3 – 5.6	150.9 – 145.6	138.7	--	36	21	11	3.9
			Very Stiff to Hard CLAYEY SILT (CL/SC) and Sand (FILL)	5.6 – 8.7	145.6 – 142.5		100	28	21	11	2.8
			Compact Sandy SILT (ML) to SILTY SAND (SM)	Below 8.7	Below 142.5		--	32	20	10	3.3
VMS-2 VMS-3	Highway 401 EBC STA. 26+188	OHS No. 3	Firm to Very Stiff Sandy CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (FILL)	0.3 – 9.1	132.1 – 123.3	123.2	100	28	21	11	2.8
			Very Soft to Very Stiff CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML)	9.1 – 13.3	123.3 – 119.1		55	31	21	11	3.1
			Very Loose to Compact Sandy SILT (ML) to SILTY SAND (SM)	Below 13.3	Below 119.1		--	32	20	10	3.3
VMS-4	Highway 401 EBC STA. 26+470	--	Hard CLAYEY SILT (CL) (FILL)	0.2 – 1.5	137.9 – 136.6	126.5	200	28	21	11	2.8
			Soft to Hard SILTY CLAY (CI) to CLAYEY SILT (CL)	1.5 – 10.2	136.6 – 127.9		75	29	21	11	2.9
			Compact Sandy SILT (ML)	Below 10.2	Below 127.9		--	32	20	10	3.3

NOTES:

1. Depths are given related to the borehole ground surface elevation at the existing highway grade; the ground surface elevation at the borehole location(s) should be compared to the ground surface elevation at the actual OHS location, and the depths to various soil stratum adjusted accordingly
2. Groundwater level inferred based on additional boreholes in the vicinity of the OHS locations
3. Design Parameters:
 - S_u = undrained shear strength (kPa)
 - ϕ' = effective friction angle (degrees)
 - γ = bulk unit weight (kN/m³)
 - γ' = effective unit weight below the groundwater level (kN/m³)
 - K_p = passive earth pressure coefficient
4. The total passive resistance may be calculated based on the K_p indicated above but reduced by an approximate factor that considers the allowable wall movement in accordance with Figure C6.27 of the *Canadian Highway Bridge Design Code* (CHBDC, 2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

DRAWINGS

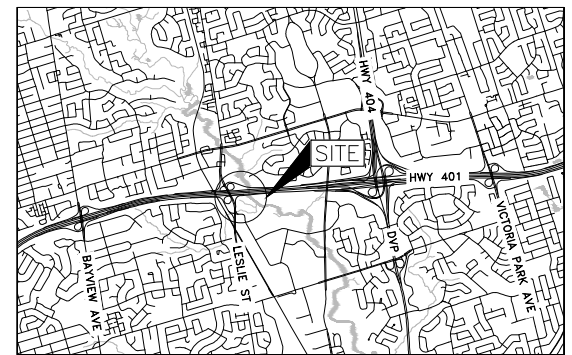
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2130-01-00



HIGHWAY 401
OVERHEAD SIGN SUPPORT STRUCTURES
BOREHOLE LOCATIONS

SHEET



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
(MTO GEOCRES No. 30M14-463)
- ⊕ Cone Penetration Test (CPT) – Current Investigation
- Borehole – Golder Other Investigation
- ⊕ Cone Penetration Test (CPT)
– Golder Other Investigation
- Borehole – Previous Investigation Other Report

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 10)

No.	ELEVATION	NORTHING	EASTING
VMS-1	151.2	4847322.4	315541.2
VMS-2	132.4	4847368.1	316280.6
VMS-3	124.7	4847332.8	316286.6
VMS-4	138.1	4847401.2	316599.4

NOTES

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.

REFERENCE

Base and design plans provided in digital format by AECOM, drawing file no. 401_EBC_Avenue-Warden_base.dwg, received MMM DD, YYYY and 401_EBC_Avenue-Warden_plan.dwg, received October 21, 2020. EB Collector general arrangement plan provided by AECOM, drawing file no. S13 GENERAL ARRANGEMENT.dwg, received March 24, 2020. Proposed and existing ground profiles provided in digital format by AECOM, drawing file no. xs_Leslie Ramp N-E.dwg, received March 6, 2019.



PLAN
SCALE
20 0 20 40 m

APPENDIX A

RECORD OF BOREHOLES

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An 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 (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); 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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, 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
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

- Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
- SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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 $= (w_L - w_P)$
NP	non-plastic
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
$C_{a(e)}$	secondary compression index
C_a	rate of secondary compression
$C_{a(e)}$	modified 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 $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c'	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
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 or 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 $\gamma = \rho \cdot g$ (i.e., mass density multiplied by
acceleration due to gravity)

Notes: 1
2

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

PROJECT		1786302		RECORD OF BOREHOLE No VMS-1		SHEET 1 OF 1		METRIC								
G.W.P.		2130-01-00		LOCATION		N 4847322.4; E 315541.2 MTM NAD 83 ZONE 10 (LAT. 43.765792; LONG. -79.366593)		ORIGINATED BY KN								
DIST		Central HWY 401		BOREHOLE TYPE		Power Augers; 200 mm O.D. Hollow Stem Augers		COMPILED BY JIL								
DATUM		Geodetic		DATE		November 4, 2019		CHECKED BY RM								
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								
151.2	GROUND SURFACE															
0.0	ASPHALT (88 mm)															
0.3	CONCRETE with REBAR (240 mm)															
	SAND (SM/GM), and gravel (FILL) Dense to very dense Brown to grey Moist		1	SS	100/0.20											
			2	SS	54											
			3	SS	42											
			4	SS	32											
			5	SS	63											
			6	SS	35											
145.6	CLAYEY SILT (CL/SC), and sand, trace gravel, containing organics (FILL) Very stiff to hard Brown to grey Moist		7	SS	33											
			8	SS	17											
142.5	Sandy SILT (ML), some gravel Compact Brown Moist		9	SS	19											
			10	SS	20											
141.0	SILTY SAND (SM), containing organics Compact Brown Moist															
139.9	END OF BOREHOLE															
11.3	NOTE: 1. Borehole open and dry upon completion of drilling.															

PROJECT		1786302		RECORD OF BOREHOLE No VMS-2		SHEET 1 OF 1		METRIC								
G.W.P.		2130-01-00		LOCATION		N 4847368.1; E 316280.6 MTM NAD 83 ZONE 10 (LAT. 43.766192; LONG. -79.357409)		ORIGINATED BY SE								
DIST		Central HWY 401		BOREHOLE TYPE		Power Augers; 150 mm O.D. Hollow Stem Augers		COMPILED BY DH								
DATUM		Geodetic		DATE		January 21, 2020		CHECKED BY KN								
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								
132.4	GROUND SURFACE															
0.0	ASPHALT (127 mm)															
0.3	CONCRETE with REBAR (178 mm)															
	Sandy CLAYEY SILT (CL), trace to some gravel (FILL) Stiff to very stiff Brown Moist		1	SS	27											
			2	SS	16											
			3	SS	14											
			4	SS	18											
			5	SS	18											
			6	SS	16											
			7	SS	15											
125.2	CLAYEY SILT (CL), containing fibrous rootlets and organics Very stiff Dark grey Moist		8	SS	15											
123.7	SILTY SAND (SM), trace gravel, containing layers of organic clayey silt Compact Grey Wet		9A 9B	SS	13											
122.2	CLAYEY SILT (CL) Stiff Grey Moist		10	SS	11											
121.1	END OF BOREHOLE															
11.3	NOTE: 1. Borehole open and dry upon completion of drilling.															


GTA-MTO 001 S:\CLIENTS\MTOWHY_401_LESLIE_STREET\GPJ GAL-GTA.GDT 10/19/20

PROJECT		1786302		RECORD OF BOREHOLE No VMS-3		SHEET 1 OF 1		METRIC								
G.W.P.		2130-01-00		LOCATION		N 4847332.8; E 316286.6 MTM NAD 83 ZONE 10 (LAT. 43.765874; LONG. -79.357336)		ORIGINATED BY KN								
DIST		Central HWY 401		BOREHOLE TYPE		Power Auger, 150 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY SK								
DATUM		Geodetic		DATE		May 20, 2020		CHECKED BY KN								
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								
124.7	GROUND SURFACE															
8.9	TOPSOIL (50 mm)															
	Sandy CLAYEY SILT-SILT (CL-ML), trace gravel, containing rootlets (FILL)		1	SS	5											
	Firm Brown Moist		2	SS	7											
123.3	CLAYEY SILT-SILT (CL-ML/SC) and sand															
1.5	Red-brown Soft Moist		3	SS	2											0 37 54 9
122.5	SAND (SP), some gravel															
2.2	Loose Grey Wet		4A	SS	5											
121.9	Sandy CLAYEY SILT (CL), trace gravel															
2.8	Very soft Wet		4B													
			5	SS	WH											
			6	SS	1											7 25 42 27
			7	SS	WH											
119.1	Sandy SILT (ML) to SILTY SAND (SM), containing sand seams															
5.6	Very loose to compact Grey Wet		8	SS	2											
			9	SS	5											
115.6	SILT (ML), trace sand															
9.3	Compact Grey Moist		10A	SS	15											0 6 84 10
	Sandy SILT (ML) to SILTY SAND (SM), containing sand seams															
	Very loose to compact Grey Wet															
			11	SS	7											
113.4	END OF BOREHOLE															
11.3	NOTES:															
	1. Borehole cave to 5.5 m below ground surface (Elev. 119.2 m) upon removal of augers.															
	2. Water level at 1.5 m below ground surface (Elev. 123.2 m) upon completion of borehole.															




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




PROJECT		Highway 401 EB Collectors Avenue to Warden, North York, Toronto, Ontario			
TITLE		PAVEMENT CORE PHOTOGRAPH BOREHOLE VMS-1 0 mm to 330 mm			
	PROJECT No. 1786302		FILE No. ----		
	DESIGN	KNN	20200304	SCALE	NTS
	CADD	--	--	FIGURE A1	
	CHECK	--	--		
	REVIEW	CN	20201008		



PROJECT		Highway 401 EB Collectors Avenue to Warden, North York, Toronto, Ontario			
TITLE		PAVEMENT CORE PHOTOGRAPH BOREHOLE VMS-2 0 mm to 290 mm			
 GOLDER	PROJECT No. 1786302		FILE No. ----		
	DESIGN	KNN	20200304	SCALE	NTS
	CADD	--	--	FIGURE A2	
	CHECK	--	--		
	REVIEW	CN	20201008		
				VER. 1.	

REVISION DATE: 20200826 BY: KN Project: 1786302



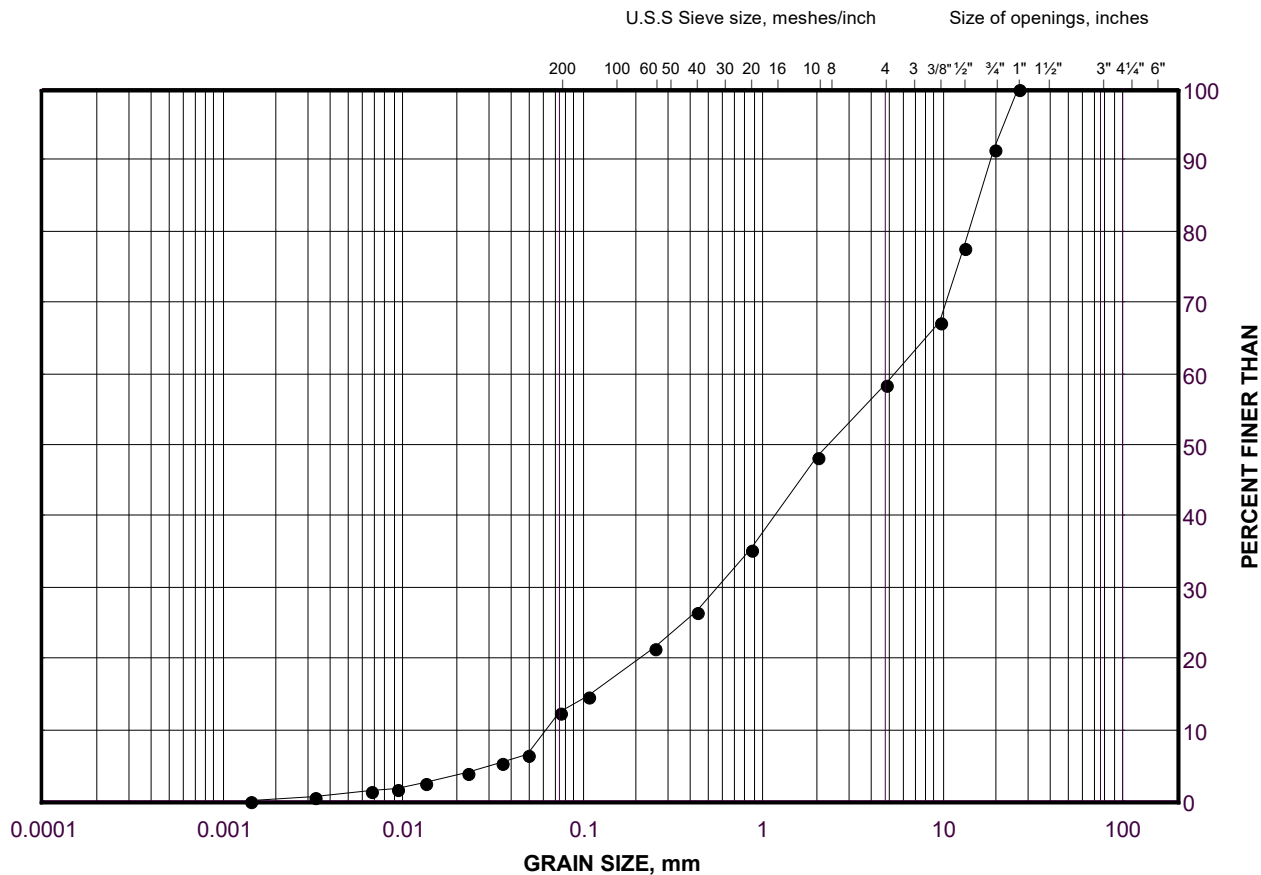
PROJECT		Highway 401 EB Collectors Avenue to Warden, North York, Toronto, Ontario				
TITLE		PAVEMENT CORE PHOTOGRAPH BOREHOLE VMS-4 0 mm to 152 mm				
	PROJECT No. 1786302			FILE No. ----		
	DESIGN	KNN	20200304	SCALE	NTS	VER. 1.
	CADD	--	--	FIGURE A3		
	CHECK	--	--			
	REVIEW	CN	20201008			

APPENDIX B

GEOTECHNICAL LABORATORY TEST RESULTS

GRAIN SIZE DISTRIBUTION
SAND (SM/GM) and Gravel (FILL)

FIGURE B1



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

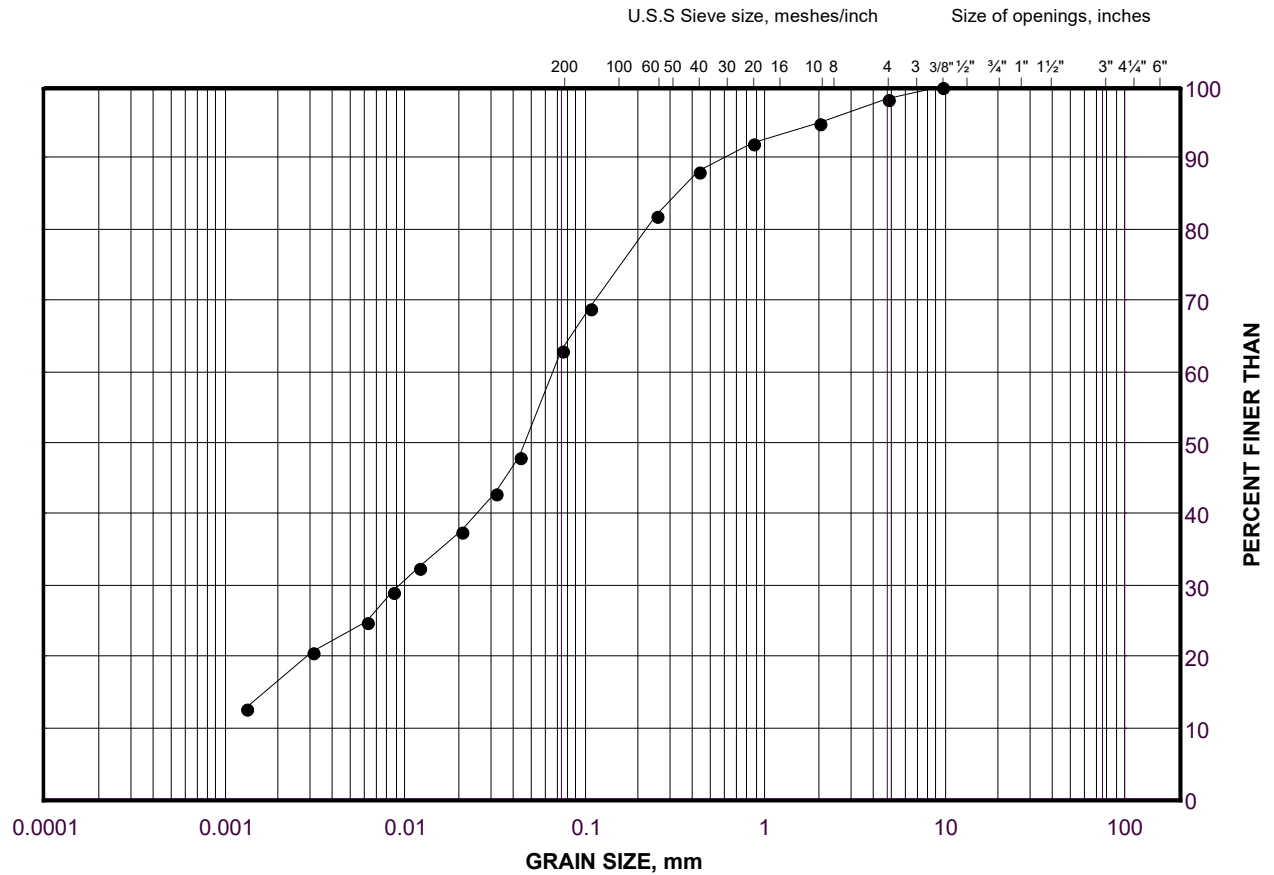
LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	VMS-1	3	148.6

GRAIN SIZE DISTRIBUTION

Sandy CLAYEY SILT (CL) (FILL)

FIGURE B2



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

LEGEND

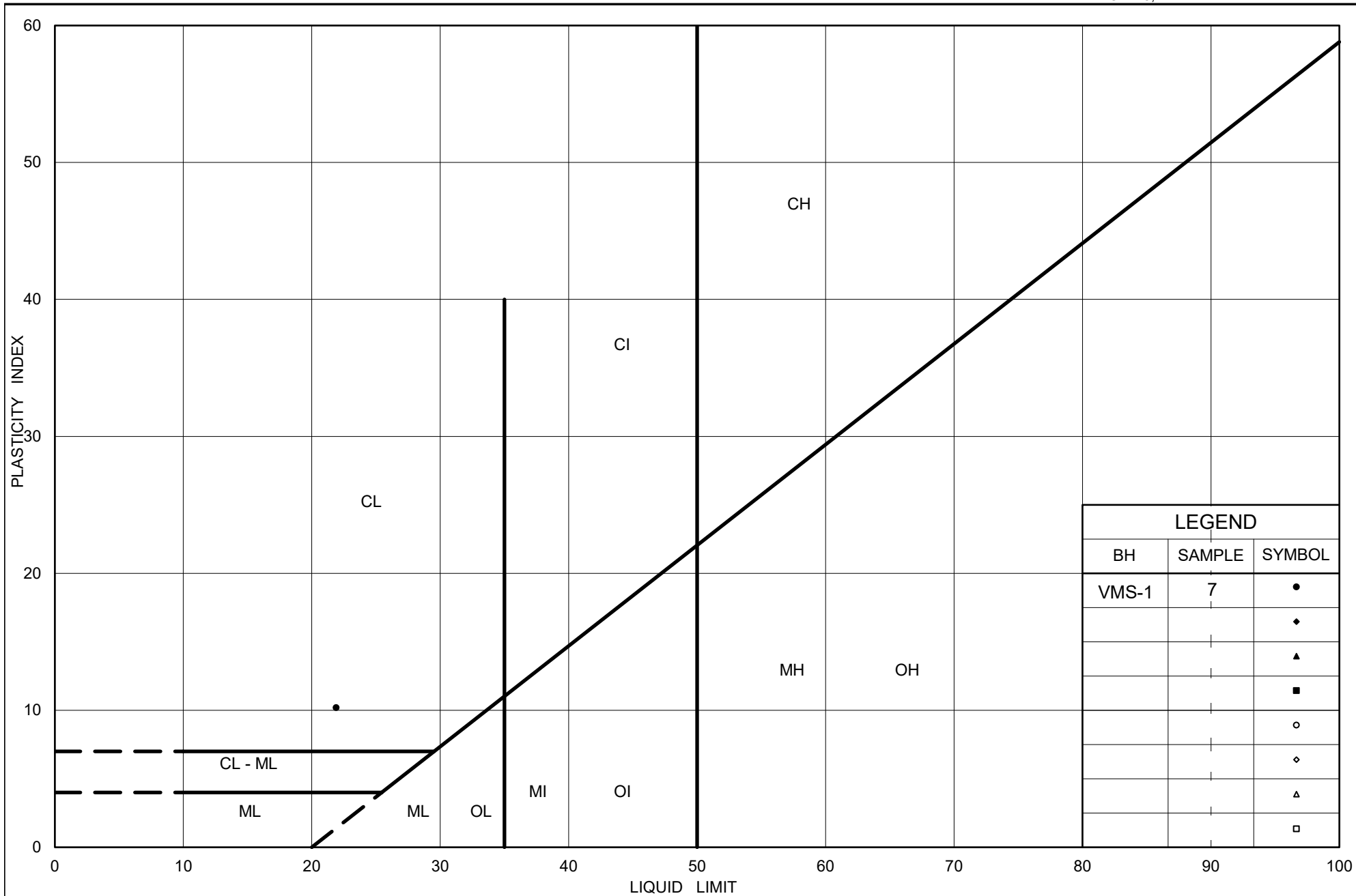
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	VMS-2	3	129.8

Project Number: 1786302

Checked By: CN

Golder Associates

Date: 25-Aug-20



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PLASTICITY CHART CLAYEY SILT (CL/SC) and Sand (FILL)

Figure No. B3

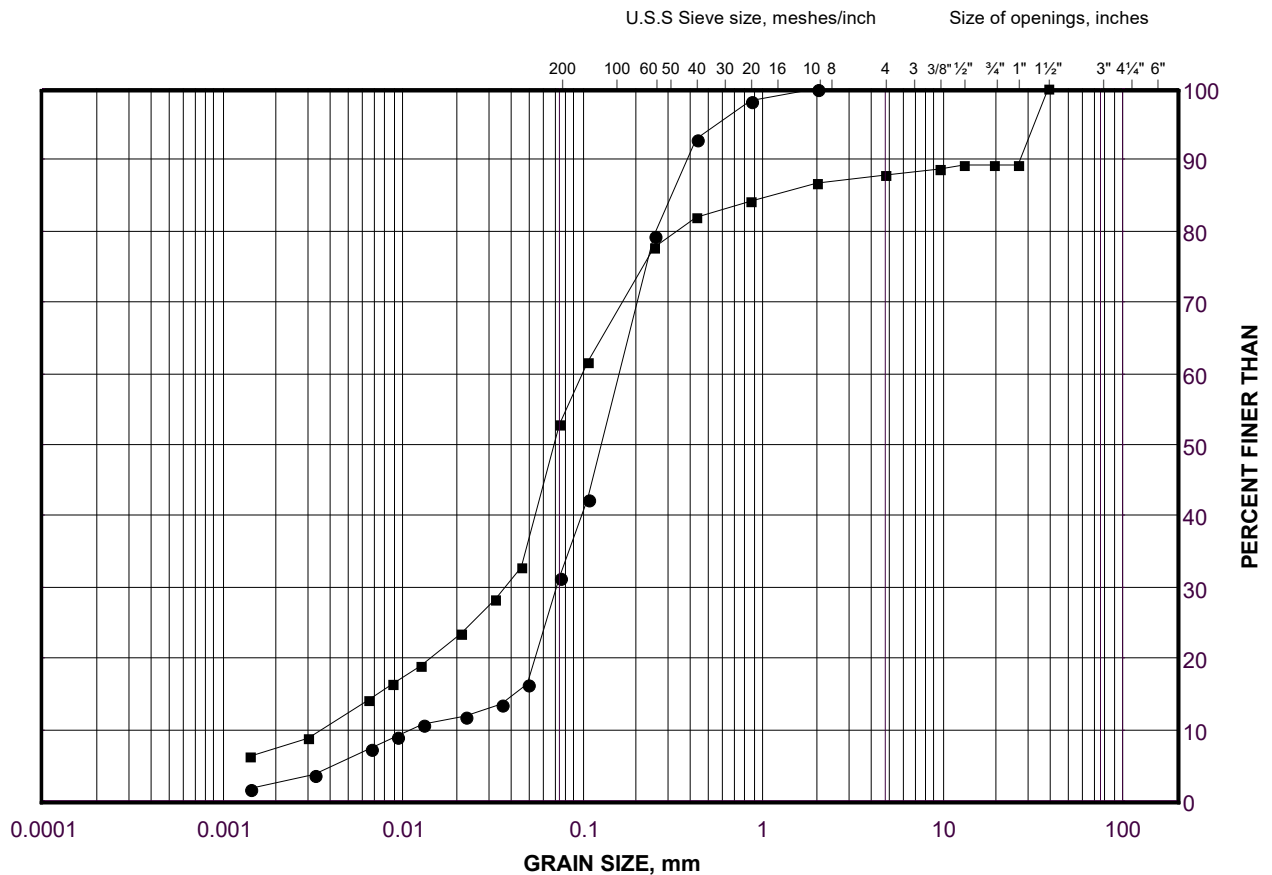
Project No. 1786302

Checked By: CN

GRAIN SIZE DISTRIBUTION

Sandy SILT (ML) to SILTY SAND (SM)

FIGURE B4



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

LEGEND

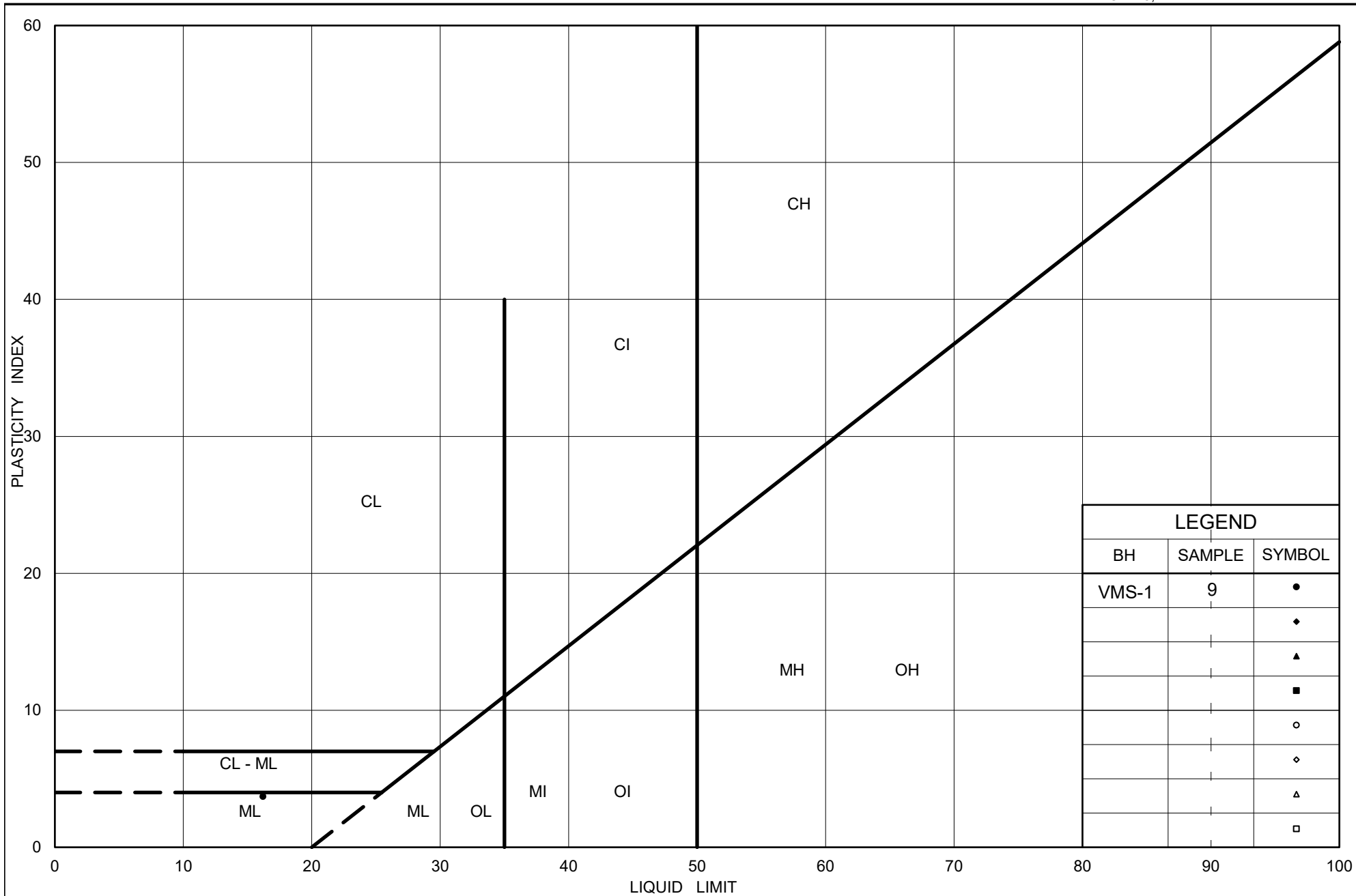
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	VMS-1	10	140.2
■	VMS-1	9	141.8

Project Number: 1786302

Checked By: CN

Golder Associates

Date: 25-Aug-20



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PLASTICITY CHART Sandy SILT (ML)

Figure No. B5

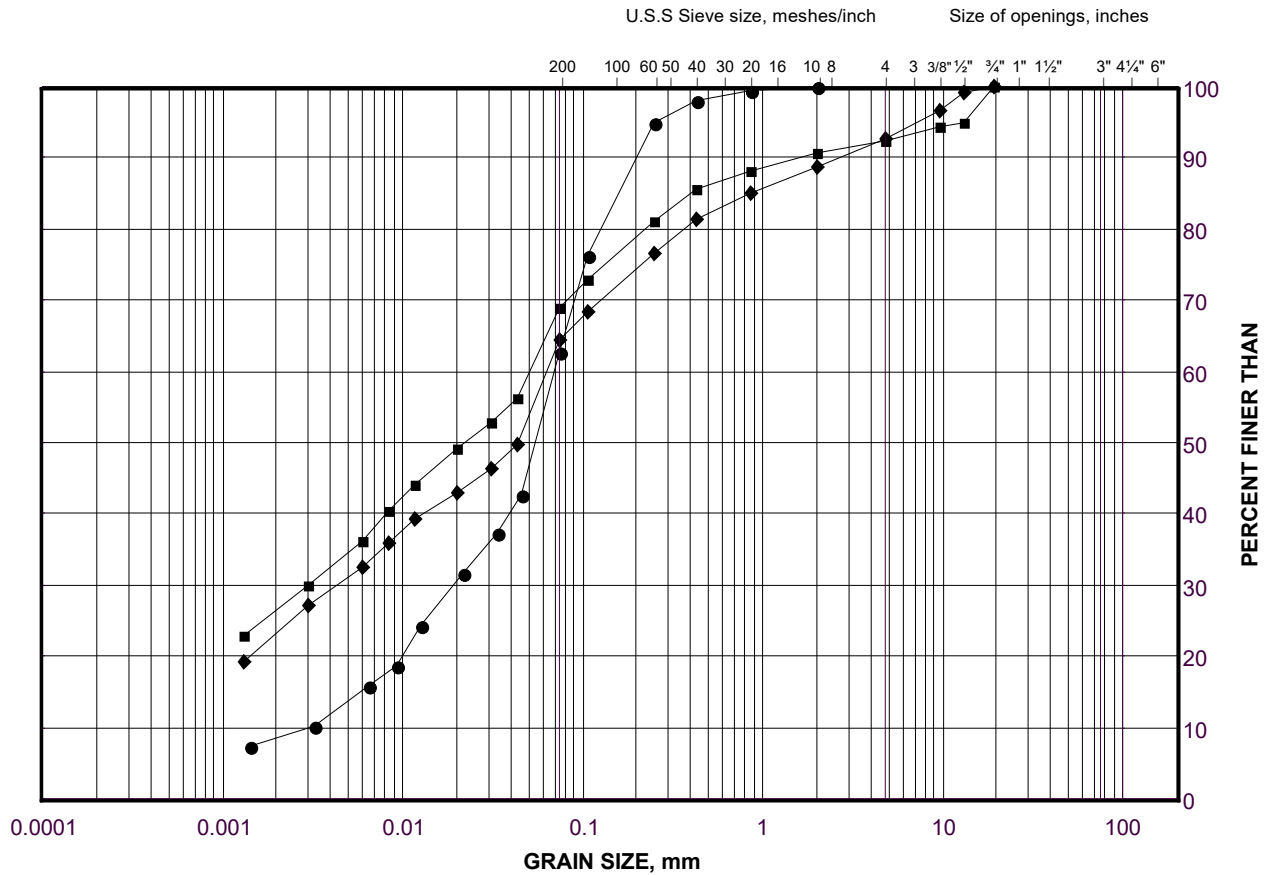
Project No. 1786302

Checked By: CN

GRAIN SIZE DISTRIBUTION

Sandy CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML/SC) and Sand

FIGURE B6



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

LEGEND

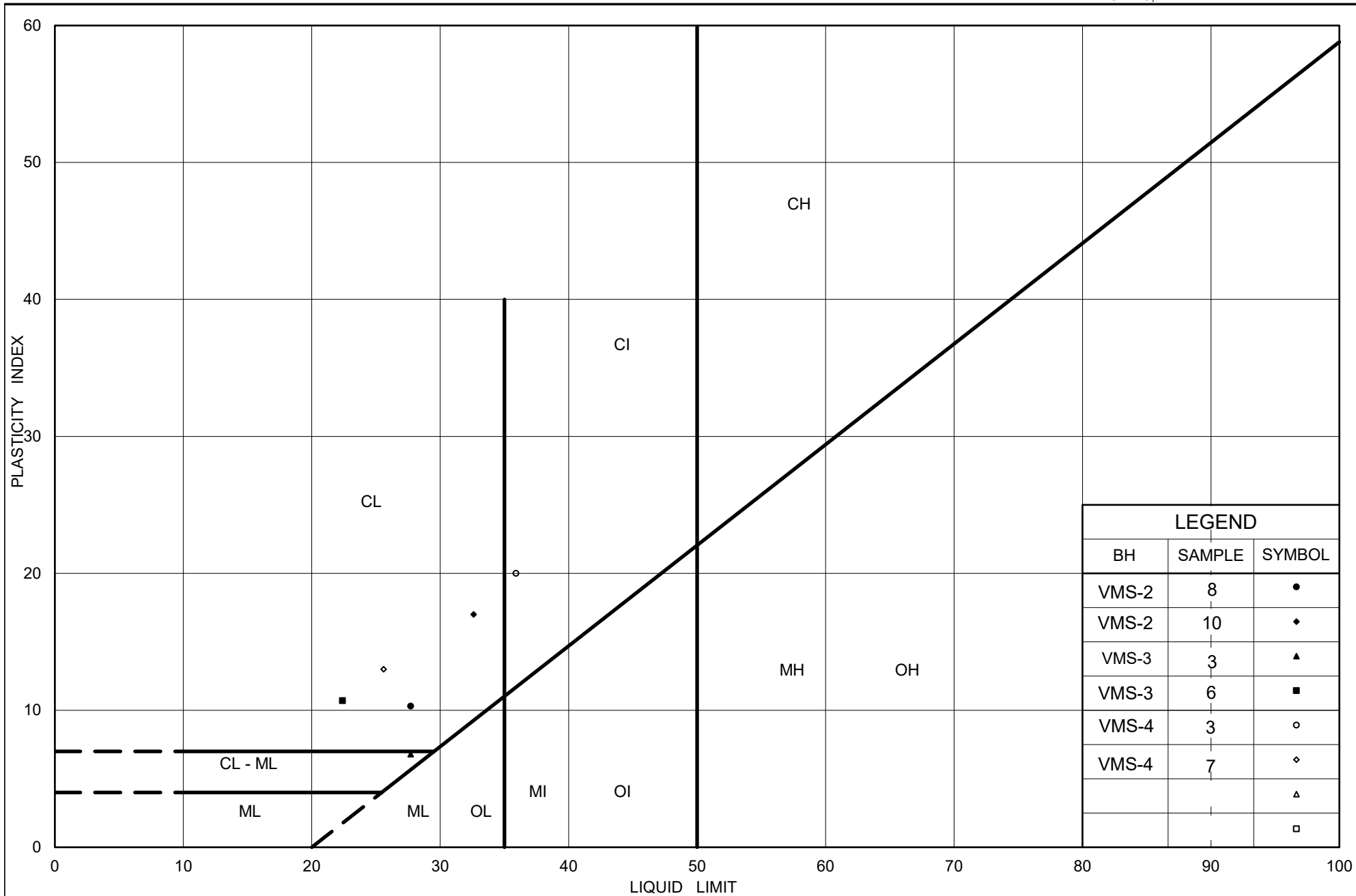
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	VMS-3	3	122.88
■	VMS-3	6	120.59
◆	VMS-4	7	131.70

Project Number: 1786302

Checked By: CN

Golder Associates

Date: 08-Sep-20



Ministry of Transportation

Ontario

PLASTICITY CHART SILTY CLAY (CI) to CLAYEY SILT-SILT (CL-ML/SC) and Sand

Figure No. B7

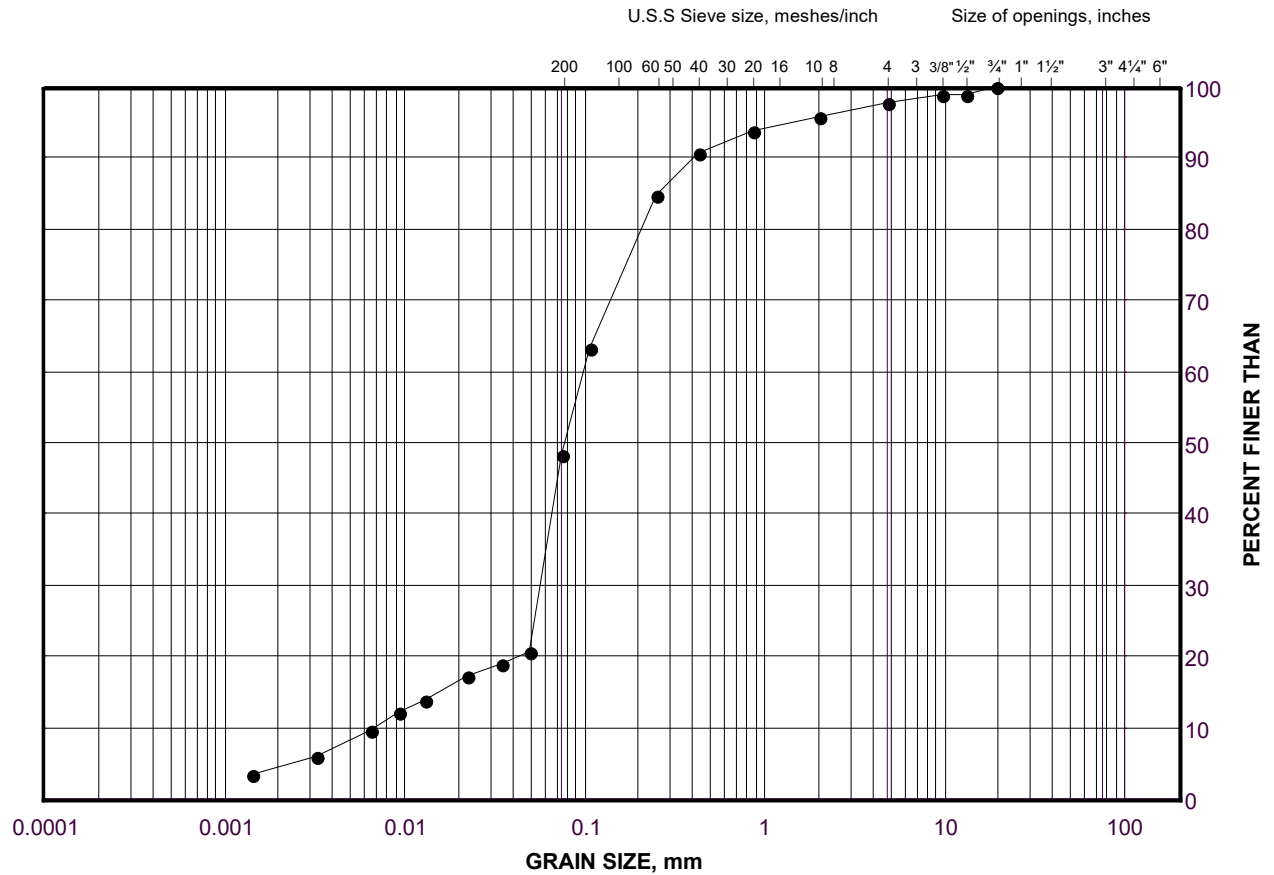
Project No. 1786302

Checked By: CN

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM)

FIGURE B8



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	VMS-2	9A	122.7

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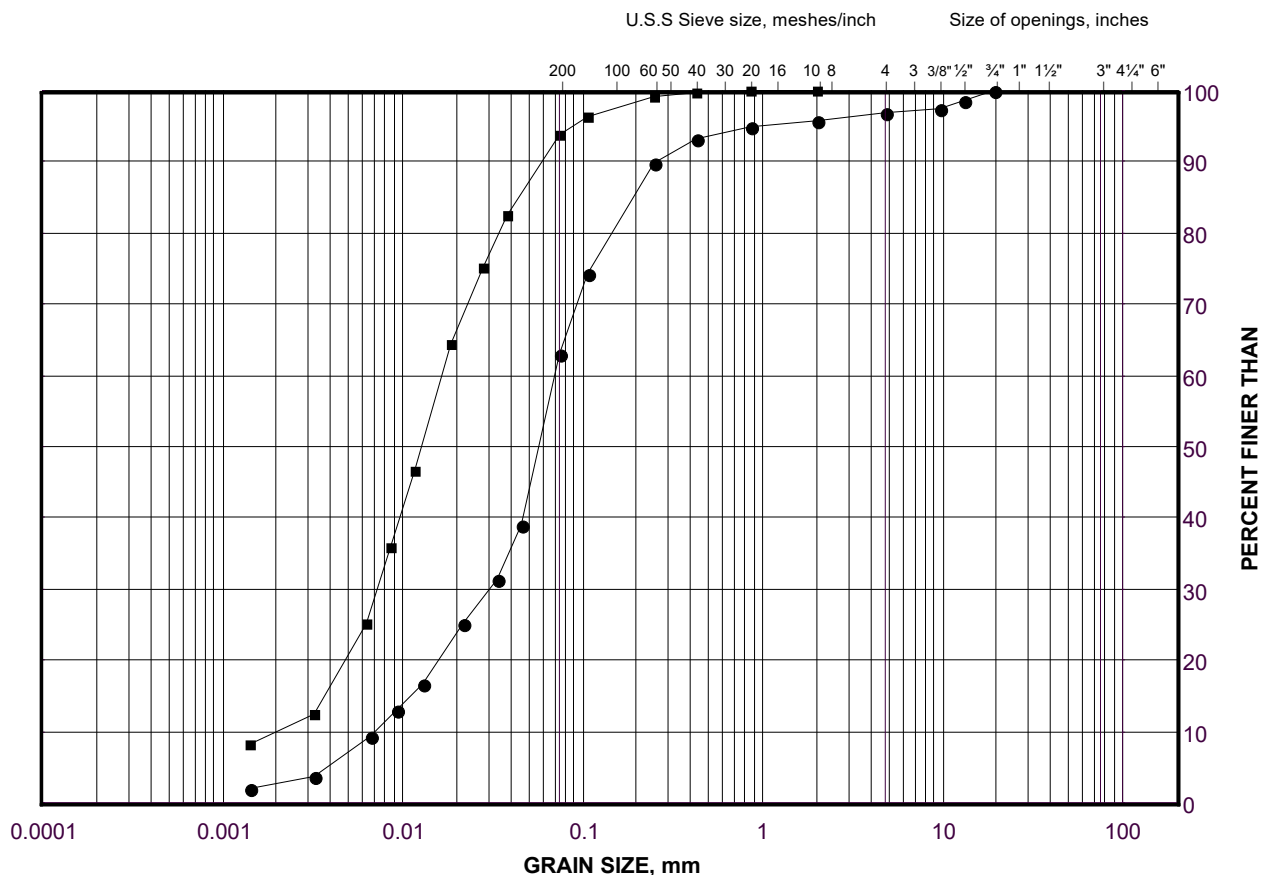
Golder Associates

Date: 26-Aug-20

GRAIN SIZE DISTRIBUTION

SILT (ML) Sandy SILT (ML)

FIGURE B9



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	VMS-4	10	127.1
■	VMS-3	10A	115.5

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