

Foundation Investigation Report

*Culvert Replacements, Structure Nos. 34-326/C, 34-331/C and 34-458/C,
Highway 3 and 140, City of Port Colbourne and City of Welland, Ontario
Ministry of Transportation, Ontario, G.W.P. 2374-15-00*

Submitted to:

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Culvert No.	LATITUDE	LONGITUDE
34-326/C	42.980947	-79.204872
34-331/C	42.893553	-79.186572
34-458/C	42.961392	-79.207213



Distribution List

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Table of Contents

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	2
3.1 Previous Investigation	2
3.2 Current Investigation	2
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	5
4.1 Regional Geology	5
4.2 Subsurface Conditions	5
4.2.1 Culvert Site Nos. 34-326/C and 34-458/C	6
4.2.1.1 Asphalt	6
4.2.1.2 Topsoil	6
4.2.1.3 Fill	6
4.2.1.4 Upper Silty Clay to Clay (Crust)	9
4.2.1.5 Lower Clayey Silt to Silty Clay	9
4.2.1.6 Groundwater Conditions	10
4.2.2 Culvert Site No. 34-331/C	11
4.2.2.1 Asphalt	11
4.2.2.2 Topsoil	11
4.2.2.3 Fill	11
4.2.2.4 Clayey Silt	12
4.2.2.5 Sandy Clayey Silt (Till)	12
4.2.2.6 Limestone Bedrock	12
4.2.2.7 Groundwater Conditions	13
4.3 Analytical Testing Results	14
5.0 CLOSURE	15
DRAWINGS	
Drawing 1	Borehole Locations and Soil Strata – Hwy 140, Lyons Creek - Culvert Structure No. 34-326/C
Drawing 2	Borehole Locations and Soil Strata – Hwy 3, West of White Road - Culvert Structure No. 34-331/C
Drawing 3	Borehole Locations and Soil Strata – Hwy 140, North of Hwy 58A - Culvert Structure No. 34-458/C

PHOTOGRAPHS

Photographs 1 & 2 – Culvert Site No. 34-326/C
 Photograph 3 – Culvert Site No. 34-331/C
 Photographs 4 & 5 – Culvert Site No. 34-458/C

APPENDICES

Lists of Symbols and Abbreviations
 Lithological and Geotechnical Rock Description Terminology
 Field Estimation of Rock Hardness
 Rock Weathering Classification

Appendix A – Record of Borehole Sheets and Geotechnical Laboratory Test Results for Culvert Site Nos. 34-326/C and 34-458/C

Record of Boreholes 326-1, 326-2, 326-3, 326-4, 458-1, 458-2, 458-3, and 458-4
Previous Investigation (GEOCRE No. 30L17-030) - Record of Borehole 1

Figure A-1 Grain Size Distribution – Silty Gravelly Sand to Sand and Gravel to Sandy Gravel (Fill)
 Figure A-2 Grain Size Distribution – Gravelly Silty Clay to Silty Clay (Fill)
 Figure A-3 Plasticity Chart – Gravelly Silty Clay to Silty Clay (Fill)
 Figure A-4 Grain Size Distribution – Silty Clay to Clay (Crust) (Culvert Site No. 34-458/C)
 Figure A-5 Plasticity Chart – Silty Clay to Clay (Crust) (Culvert Site No. 34-458/C)
 Figure A-6A Grain Size Distribution – Clayey Silt (Culvert Site No. 34-326/C)
 Figure A-6B Grain Size Distribution – Clayey Silt to Silty Clay (Culvert Site No. 34-458/C)
 Figure 7A Plasticity Chart – Clayey Silt (Culvert Site No. 34-326/C)
 Figure 7B Plasticity Chart – Clayey Silt to Silty Clay (Culvert Site No. 34-458/C)

Appendix B – Record of Borehole, Drillhole and Test Pit Sheets and Geotechnical Laboratory Test Results for Culvert Site No. 34-331/C

Record of Boreholes 331-1 and 331-2

Record of Drillholes 331-1 and 331-2

Record of Test Pit 331-3

Figure B-1 Grain Size Distribution – Gravelly Silty Clay with Sand (Fill)
 Figure B-2 Plasticity Chart – Gravelly Silty Clay with Sand (Fill)
 Figure B-3 Grain Size Distribution – Clayey Silt
 Figure B-4 Plasticity Chart – Clayey Silt
 Figure B-5 Grain Size Distribution – Clayey Silt (Till)
 Figure B-6 Plasticity Chart – Clayey Silt (Till)
 Figure B-7 Bedrock Core Photograph – Drillholes 331-1 and 331-2
 Figure B-8A & B Unconfined Compression Test (UC) of Intact Rock Core Specimens – Borehole 331-1, 4.29 m to 4.48 m
 Figure B-9A & B Unconfined Compression Test (UC) of Intact Rock Core Specimens – Borehole 331-2, 6.02 m to 6.22 m

Appendix C – Analytical Laboratory Test Results (Maxxam Analytics)

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AIA Engineers LLC (AIA) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the rehabilitation / replacement of three culverts as detailed below:

- Culvert Site No. 34-326/C, Highway 140, at Lyons Creek, City of Welland, Ontario
- Culvert Site No. 34-331/C, Highway 3, West of White Road, City of Port Colborne, Ontario
- Culvert Site No. 34-458/C, Highway 140, North of Highway 58A, City of Port Colborne, Ontario

The purpose of this investigation is to explore the subsurface soil, bedrock and groundwater conditions at the culvert sites by borehole drilling / bedrock coring and geotechnical laboratory testing and analytical chemistry laboratory testing on selected soil and bedrock samples.

The Terms of Reference (TOR) and Scope of Work for the foundation investigation are outlined in MTO's Request for Quotation, dated December 2017, which forms part of the Consultant's Assignment Number 2017-E-0068 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated September 2018.

2.0 SITE DESCRIPTION

Existing Culvert Site Nos. 34-326/C and 34-458/C are located along Highway 140 in the City of Welland and the City of Port Colborne, Ontario, respectively and existing Culvert Site No. 34-331/C is located along Highway 3 in Port Colborne, Ontario.

Highway 140 consists of one lane in each direction and is oriented in a north-south direction. Existing Culvert Site Nos. 34-326/C and 34-458/C are generally oriented in an east-west direction. Culvert 34-326/C conveys water from Lyons Creek from a southwest to northeast direction. The existing culvert consists of a 3.3 m wide corrugated steel arch culvert that is approximately 38 m long. At this location, the culvert site is surrounded by farm fields with the exception of the southwest quadrant where a solar farm is located. Culvert Site No. 34-458/C conveys surface water from the west to the east and consists of a 3.75 m wide corrugated steel arch culvert that is approximately 32 m long. At this location, the culvert site has a residential property located to the west of the culvert site and industrial properties are located on the east side of the site. The road surface of Highway 140 at Culvert Site No. 34-326/C is between about 2.9 m and 4.8 m above the toe of the embankment slope and at Culvert Site No. 34-458/C the road surface of Highway 140 is about 1 m above the toe of the embankment slope. Culvert Site No. 34-326/C is shown in Photographs 1 and 2. Culvert Site No. 34-458/C is shown in Photograph 4 and the channel sideslopes are shown in Photograph 5.

Highway 3 is oriented in an east-west direction, and existing Culvert Site No. 34-331/C is generally oriented in a north-south direction and conveys water from north to south. Highway 3 consists of one lane in each direction and residential properties are located surrounding the culvert site. The existing culvert is approximately 20 m long and comprised of three sections; a central (original) 3.5 m diameter, open-footing, reinforced concrete, arch culvert with two end-sections (extensions to the original) that are both 3.5 m wide, open-footing, reinforced concrete, rigid frame

box culverts. No evidence of seepage or sloughing was noted at the existing embankment slopes at Culvert Site No. 34-331/C. Culvert 34-331/C is shown on Photograph 3.

Culvert Site Nos. 34-326/C, 34-331/C and 34-458/C were inspected and the highway embankments in the vicinity of the existing culverts appear to be performing appropriately, from a geotechnical perspective. No settlement or cracking of the culvert is apparent from the field reconnaissance completed as part of the investigation. The nearby embankments are vegetated with grasses and low shrubs, there is no apparent seepage on the face or at the toes of the embankment and there are no signs of sloughing or erosion.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Investigation

From December 4 to 6, 1969, a foundation investigation for the Lyons Creek Culvert (Structure No. 34-326/C) was carried out by the Department of Highways Ontario, during which time a total of six boreholes were drilled. The results of the Department of Highways Ontario investigation are contained in report titled,

- “Foundation Investigation Report for Proposed Multi-Plate Arch Culvert at the Crossing of Hwy. #140 and Lyons Creek, Twp. Of Crowland, County of Welland, District No. 4 (Hamilton), W.J. 69-F-64, W.P. 60-68-04”, dated December 22, 1969 (GEOCRE 30L14-030).

Of the six boreholes advanced Borehole 1 is located in close proximity to inlet of the culvert. While the above noted Department of Highways Ontario report does not reference a coordinate system for the borehole locations, Boreholes 1 from the Borehole Locations and Soil Strata drawing provided in the 1969 report was plotted on Drawing 1 based on common site features and the borehole coordinates were interpreted from the coordinate system superimposed on the plan. The estimated borehole location in MTM NAD 83 Zone 10 Coordinates, geographic coordinates (latitude / longitude), the ground surface elevation in Geodetic Datum, and the drilled depth as presented on or derived from the 1969 borehole record is summarized below.

Borehole No.	Location (MTM NAD 83, Zone 10) ¹		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (Latitude, °)	Easting (Longitude, °)		
1	4,760,174.8 (42.981004)	328,855.7 (-79.205051)	174.8	20.7

1. Coordinates are approximate and have been estimated based on the “Borehole Locations and Soil Strata” drawing provided in GEOCRE 30L14-030.

3.2 Current Investigation

Field work was carried out between January 8 and March 21, 2019, during which time a total of ten boreholes, designated as Boreholes 326-1 to 326-4, 331-1 and 331-2, and 458-1 to 458-4 and one test pit, designated as 331-3 were advanced at the three culvert site locations as shown on Drawings 1, 2, and 3. Test Pit 331-3, was excavated at Culvert Structure No. 34-331/C to assess the topsoil thickness adjacent to the existing culvert.

Field drilling was carried out using a track-mounted CME 75 drilling rig and a truck-mounted CME 55 drilling rig supplied and operated by Geo-Environmental Drilling Inc., of Halton Hills, Ontario, and a track-mounted D50 drilling rig and a Portable Tripod drilling rig with a manual hammer drive system supplied and operated by Walker Drilling Ltd., of Utopia, Ontario. With the exception of Borehole 326-4, the boreholes were advanced through the overburden using 70 mm and 114 mm inner diameter hollow-stem augers. Borehole 326-4 was advanced using 125 mm outer diameter casing with wash boring techniques. Test Pit 331-3 was advanced manually by hand excavation with a shovel. Soil samples were obtained at 0.6 m, 0.75 m and 1.5 m intervals of depth, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer or a manual hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-11)¹. Field vane shear tests were carried out in the cohesive soils for assessment of undrained shear strength (ASTM D2573²) using MTO standard N-size vanes. Samples of the bedrock were obtained using an 'HQ' size core barrel and coring techniques in the boreholes advanced for Culvert Structure No. 34-331/C. The boreholes were advanced to depths between 3.7 m and 17.4 m below existing ground surface, including coring of bedrock for core lengths of between 3.1 m and 3.2 m in Boreholes 331-1 and 331-2. The test pit was advanced to a depth of 0.2 m below existing ground surface.

Groundwater conditions and water levels in the open boreholes were observed during and immediately following drilling operations. A standpipe piezometer was installed in Boreholes 326-1 and 458-4 to allow monitoring of the water level at the borehole locations. The standpipe piezometers consist of a 50 mm diameter PVC pipe with a slotted screen. The annulus surrounding the piezometer screen was backfilled with a filter sand pack. The section of borehole below the standpipe piezometer was backfilled with bentonite to the underside of the sand pack level, and the remainder of the borehole above the sand pack was backfilled with bentonite to near the ground surface and topped with concrete or sand and gravel to match the adjacent ground surface material. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903: Wells (as amended) and Boreholes 326-2, 326-3, 331-1, and 331-2 were topped with cold patch asphalt or sand and gravel to match the adjacent ground surface material.

Field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services including both public and, where applicable, private locates, observed the drilling, sampling and in-situ testing operations, logged the boreholes, and examined the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and geotechnical laboratory testing. All the geotechnical laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits, grain size distribution and organic content) was carried out on selected soil samples. Selected rock core samples were submitted to Golder's Mississauga geotechnical laboratory for unconfined compression (UC) testing.

Six selected soil samples were submitted, under chain-of-custody procedures, to Maxxam Analytics of Mississauga, Ontario (a Standards Council of Canada (SCC) accredited laboratory) for a suite of characteristics that indicate corrosivity potential including pH, resistivity, conductivity, chloride content and sulphate content.

The as-drilled borehole locations and the ground surface elevations were obtained using a GPS (Trimble Geo-7X), having an accuracy of approximately 0.1 m in the vertical and 0.1 m in the horizontal directions. The locations given

¹ ASTM D1586-11 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the soil, ASTM International, West Conshohocken, PA, 2015

² ASTM D2573-15 Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils, ASTM International, West Conshohocken, PA, 2015

on the Record of Borehole / Testpit / Drillhole sheets and shown on Drawings 1 to 3 are positioned relative to MTM NAD 83 (Zone 10) CSRS CBNV6-2010.0 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, geographic coordinates, ground surface elevations and drilled depths are summarized below.

Borehole / Test Pit No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
Culvert Site No. 34-326/C				
326-1	4,760,176.1 (42.981016)	328,858.8 (-79.205013)	175.1	6.7
326-2	4,760,168.5 (42.980947)	328,870.4 (-79.204872)	177.9	17.4
326-3	4,760,190.9 (42.981149)	328,875.1 (-79.204812)	178.0	15.9
326-4	4,760,180.1 (42.981051)	328,885.9 (-79.204681)	175.1	3.7
Culvert Site No. 34-331/C				
331-1	4,750,461.7 (42.893513)	330,386.1 (-79.186731)	179.3	7.5 (including 3.18 m of bedrock core)
331-2	4,750,466.1 (42.893553)	330,399.0 (-79.186572)	179.3	7.5 (including 3.08 m of bedrock core)
331-3 ¹	4,750,469.8 (42.893577)	330,399.7 (-79.186564)	178.9	0.2
Culvert Site No. 34-458/C				
458-1	4,758,013.7 (42.961555)	328,680.5 (-79.207292)	178.7	15.9
458-2	4,757,995.7 (42.961392)	328,686.9 (-79.207213)	179.6	17.4
458-3	4,758,012.8 (42.961546)	328,704.4 (-79.206999)	179.5	17.4
458-4	4,758,016.8 (42.961582)	328,714.7 (-79.206873)	179.3	14.9

1. Test Pit

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area is located within the Haldimand Clay Plain Physiographic Region and partially within either the Clay Plains or Limestone Plains Physiographic Landforms, as delineated in *The Physiography of Southern Ontario*³. Based on mapping by the Ontario Geological Survey (2011)⁴, the bedrock in the vicinity of the structure sites consists of limestone, dolostone and shale of the Salina and Onondaga Formations. The Physiographic Landform and Bedrock Formation at each structure site is summarized below:

Culvert / Bridge Site Number	Physiographic Landform	Bedrock Formation
Culvert No. 34-326/C Highway 140, Welland	Clay Plains	Salina Formation (57c) – shale and argillaceous dolostone
Culvert No. 34-458/C Highway 140, Welland		
Culvert No. 34-331/C Highway 3, Port Colborne	Limestone Plains	Onondaga Formation (59d) – limestone, argillaceous limestone, and minor shale

The Haldimand Clay Plain extends from approximately the Niagara Escarpment south to the shores of Lake Erie and consists of stratified clay and till with areas of sand and lacustrine silt and clay deposits. Generally, bedrock within the Haldimand Clay Plain is less than 15 m below ground surface at the north end near the Niagara Escarpment; south of this the bedrock surface is at depths of up to about 45 m below ground surface, and at the very south near the Lake Erie shore, the bedrock surface varies from about 3 m to 15 m below ground surface.

4.2 Subsurface Conditions

Subsurface soil, bedrock and groundwater conditions as encountered in the boreholes, details of the piezometer installations and water level readings, and the results of the geotechnical laboratory tests carried out on selected soil and bedrock core samples are presented on the Record of Borehole, Drillhole and Test Pit sheets provided in Appendix A for Culvert Site Nos. 34-326/C and 34-458/C, and Appendix B for Culvert Site No. 34-331/C. The subsurface conditions as encountered in the relevant borehole advanced during the previous investigation discussed in Section 3.1, is included in Appendix A, for Culvert 34-326/C. Photographs of the recovered bedrock core samples are presented on Figure B-7, in Appendix B. The results of in-situ field tests (i.e., SPT “N”-values and field vane undrained shear strengths) as presented on the Record of Borehole sheets and in sub-sections of Section 4.2 are uncorrected. Lists on abbreviations and symbols and lithological, geotechnical rock description terminology, field estimation of rock hardness and rock weathering classification are also included following the text of this report to assist in the interpretation of the borehole and drillhole records. The results of the geotechnical laboratory testing on the soil and bedrock samples are presented in Appendix A for Culvert Site Nos. 34-326/C and

³ Chapman, L.J. and Putnam, D.F. 2007. *Physiography of southern Ontario*; Ontario Geological Survey, Miscellaneous Release--Data 228.

⁴ Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release---Data 126-Revision 1.

34-458/C, and Appendix B for Culvert Site No. 34-331/C. The analytical laboratory test report is included in Appendix C and the test results are summarized in Section 4.3.

Stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile on Drawings 1 to 3 are inferred from non-continuous sampling, observations of drilling progress and the results of the Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the borehole and drillhole records governs any interpretation of the site conditions. It should be noted that the interpreted stratigraphy shown on Drawings 1 to 3 is a simplification of the subsurface conditions at each of the culvert replacement sites.

4.2.1 Culvert Site Nos. 34-326/C and 34-458/C

In general, the subsurface conditions at these culvert sites consists of a layer of asphalt or topsoil underlain by fill materials consisting of clayey silt to gravelly silty clay to sand and gravel to gravel. The fill is underlain by a deep deposit of clayey silt to silty clay. A more detailed description of the subsurface conditions encountered in the boreholes from the previous and current investigations are provided in the following sections.

4.2.1.1 Asphalt

An approximately 400 mm thick layer of asphalt pavement was encountered at ground surface in Boreholes 326-2 and 326-3.

4.2.1.2 Topsoil

An approximately 50 mm to 100 mm thick layer of topsoil was encountered at ground surface in Boreholes 326-1, 326-4, and 458-1 and 458-4.

4.2.1.3 Fill

At Culvert Site No. 34-326/C a 1.7 m to 6.9 m thick layer of fill comprised of: sand and gravel, silty clay to clayey silt, and gravel and cobbles was encountered in Boreholes 326-1 to 326-4 underlying the topsoil or asphalt surface layer and in Borehole 1 (from the previous investigation) at the ground surface. Borehole 326-4 was advanced with portable drilling equipment and encountered casing refusal on cobbles at a depth of 3.7 m below ground surface; this borehole was terminated in the fill. An example of a large gravel-sized particle recovered from the cuttings of Borehole 326-4 is shown in Photograph 1 (below).



Photograph 1: Large gravel-sized particle from cuttings of Borehole 326-4

At Culvert Site No. 34-458/C a 0.7 m to 1.5 m thick layer of fill comprised of: silty gravelly sand to sand and gravel was encountered at ground surface in Boreholes 458-2, 458-3 The depth and elevation of the top and bottom of the fill material and the corresponding thickness and soil type are summarized below.

Culvert Site No.	Borehole No.	Top of Layer (below topsoil/pavement surface)		Bottom of Layer		Thickness (m)	Fill Type
		Depth (m)	Elevation (m)	Depth (m)	Elevation (m)		
34-326/C	326-1	0.1	175.0	4.1	171.0	4.0	Sand and Gravel
	326-2	0.4	177.5	0.8	177.1	0.4	Sand and Gravel
		0.8	177.1	1.5	176.4	0.7	Gravelly Silty Clay
		1.5	176.4	3.7	174.2	2.2	Silty Clay
		3.7	174.2	7.2	170.7	3.5	Sandy Gravel
	326-3	0.4	177.6	0.7	177.3	0.3	Sand and Gravel
		0.7	177.3	3.7	174.3	3.0	Silty Clay
		3.7	174.3	7.3	170.7	3.6	Sand and Gravel

Culvert Site No.	Borehole No.	Top of Layer (below topsoil/pavement surface)		Bottom of Layer		Thickness (m)	Fill Type
		Depth (m)	Elevation (m)	Depth (m)	Elevation (m)		
	326-4	0.1	175.0	0.6	174.5	0.5	Clayey Silt
		0.6	174.5	1.4	173.7	0.8	Sandy Gravel
		1.4	173.7	2.2	172.9	0.8	Organic Clayey Silt
		2.2	172.9	3.7*	171.4*	1.5*	Gravel and Cobbles
	1	0.0	174.8	1.7	173.1	1.7	Clayey Silt
34-458/C	458-2	0.0	179.6	0.7	178.9	0.7	Silty Gravelly Sand
	458-3	0.0	179.5	1.5	178.0	1.5	Sand and Gravel

*Borehole terminated within this deposit due to casing refusal on cobbles.

The SPT “N”-values measured within the granular fill layers range from 5 blows to 38 blows per 0.3 m of penetration, indicating a loose to dense compactness condition. The SPT “N”-values measured within the cohesive fill layers in the boreholes advanced during the current investigation range from 5 blows to 12 blows per 0.3 m of penetration, suggesting a firm to stiff consistency. The SPT “N”-value measured in the fill in Borehole 1 (from the previous investigation) was 49 blows per 0.3 m of penetration; however, this value may not be representative of the deposit as the Record of Borehole 1 indicates that occasional rock fragments were noted, which may have affected the SPT result.

Grain size distribution tests were carried out on five samples from the silty gravelly sand to sand and gravel to sandy gravel fill layers and the results are shown on Figure A-1 Appendix A. The water content measured on eight samples of the granular fill ranges between about 3 per cent and 13 per cent.

Grain size distribution tests were carried out on three samples from the gravelly silty clay to silty clay fill layers and the results are shown on Figure A-2 Appendix A. Atterberg limits tests were carried out on two samples of the gravelly silty clay and silty clay fill and measured liquid limits of about 37 per cent and 44 per cent, plastic limits of about 18 per cent and plastic indices of about 19 per cent and 26 per cent. The results, which are plotted on the plasticity chart on Figure A-3 in Appendix A, indicate that the cohesive fill consists of silty clay of medium plasticity.

The water content measured on four samples of the cohesive fill ranges from about 15 per cent to 22 per cent. One organic content test was completed on a sample of the organic clayey silt fill from Borehole 326-4 and the result is 6.9 per cent.

4.2.1.4 Upper Silty Clay to Clay (Crust)

An upper brown and grey, silty clay to clay, trace sand (crust) was encountered below the fill in Boreholes 458-2 to 458-3 and below the topsoil in Boreholes 458-1 and 458-4 at depths of between about 0.1 m and 1.5 m below ground surface (between Elevations 179.2 m and 178.0 m). The upper silt clay to clay crust extends to depths of between about 3.7 m to 4.4 m below ground surface (between Elevations 175.9 m and 174.3 m). In Borehole 458-1, between a depth of 3.8 m and 4.4 m below ground surface, the clay deposit was varved.

SPT “N”-values within the upper silty clay to clay crust range from 5 blows to 26 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency.

Grain size distribution tests were carried out on six selected samples of the silty clay to clay deposit from the current investigation and the results are shown in Figure A-4 in Appendix A. Atterberg limits testing was carried out on six samples of the silty clay to clay deposit and measured liquid limits ranging from about 47 per cent to 58 per cent, plastic limits ranging from about 21 per cent to 26 per cent, and plasticity indices ranging from about 24 per cent to 34 per cent. These results, which are plotted on a plasticity chart on Figure A-5 in Appendix A, indicate that the upper cohesive deposit consists of silty clay of medium plasticity to clay of high plasticity.

The water content measured on 9 samples of the silty clay to clay deposit ranges between about 22 per cent and 33 per cent.

4.2.1.5 Lower Clayey Silt to Silty Clay

At Culvert Site No. 34-326/C a deposit consisting of clayey silt, trace to some sand, trace to some gravel, was encountered underlying the fill in Boreholes 326-1, 326-2, 326-3, and Borehole 1 from the previous investigation, at depths ranging from 4.1 m to 7.3 m below ground surface (between Elevations 171.0 m and 170.7 m). The surface of the deposit was encountered in Borehole 1 at a depth of 1.7 m below ground surface (Elevation 173.1 m). Organic material, including wood chips, was encountered in Borehole 1 between depths of 1.7 m and 3.0 m below ground surface (between Elevations 173.1 m and 171.8 m) and from a depth of 18.3 m and the end of the borehole, 75 mm thick layers of silt were noted to have been encountered during the previous investigation. Borehole 1 terminated in this clayey silt deposit at a depth of 20.7 m below ground surface (Elevation 154.1 m). Boreholes 326-1, 326-2 and 326-3 were terminated within the clayey silt deposit at depths ranging between 6.7 m and 17.4 m below ground surface (between Elevations 168.4 m and 160.5 m).

At Culvert Site No. 34-458/C a lower deposit consisting of clayey silt to silty clay, trace sand, trace gravel, was encountered underlying the upper silty clay to clay crust in Boreholes 458-1 to 458-4 at depths of between 3.7 m to 4.4 m below ground surface (between Elevations 175.9 m and 174.3 m). All of these boreholes terminated within the clayey silt to silty clay deposit, at depths ranging between 14.9 m and 17.4 m below ground surface (between Elevations 164.4 m and 162.1 m). In Borehole 458-1 at a depth of 14.3 m, sandy silt pockets were noted within the clayey silt deposit. In Borehole 458-3, rootlets were noted at a depth of about 7.9 m below ground surface (Elevation 171.6 m).

SPT “N”-values within the clayey silt to silty clay deposit range from weight of hammer to 21 blows per 0.3 m of penetration. In-situ vane tests carried out within the cohesive deposit measured undrained shear strengths ranging from about 34 kPa to about 61 kPa, with two values greater than 95 kPa, with a calculated sensitivity ranging between about 1.1 and 3.2. The field vane test results together with the SPT “N” values indicate that the clayey silt to silty clay deposit has a firm to very stiff consistency. In Borehole 1 the SPT “N”-values within the clayey silt

deposit below a depth of about 18.3 m below ground surface (Elevation 156.5 m) were 60 blows and 120 blows per 0.3 m of penetration, suggesting a hard consistency below Elevation 156.5 m to the end of the borehole at Elevation 154.1 m.

Grain size distribution tests were carried out on thirteen samples of the clayey silt to silty clay deposit from the current investigation and the results are shown in Figures A-6A (for Culvert Site No. 34-326/C) and A-6B (for Culvert Site No. 34-458/C) in Appendix A. Atterberg limits testing was carried out on thirteen samples of the clayey silt to silty clay deposit and measured liquid limits ranging from about 23 per cent to 37 per cent, plastic limits ranging from about 14 per cent to 20 per cent, and plasticity indices ranging from about 9 per cent to 18 per cent. These results, which are plotted on a plasticity chart on Figures A-7A (for Culvert Site No. 34-326/C) and A-7B (for Culvert Site No. 34-458/C) in Appendix A, indicate that the cohesive deposit consists of clayey silt of low plasticity to silty clay of medium plasticity.

The water content measured on 26 samples of the clayey silt to silty clay to clay deposit ranges between about 16 per cent and 36 per cent.

4.2.1.6 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are presented on the Records of Borehole sheets in Appendix A. A standpipe piezometer was installed in Boreholes 326-1 and 458-4 to monitor the groundwater level at the borehole locations. The water levels measured in the open boreholes and the piezometers are summarized below. It should be noted that the groundwater level in the area is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet periods of the year.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
326-1	175.1	2.0	173.1	January 17, 2019	Upon completion of drilling
		1.2	173.9	March 20, 2019	Within piezometer
		0.9	174.2	April 21, 2019	
		1.2	173.9	May 29, 2019	
326-2	177.9	4.3	173.6	January 16, 2019	Upon completion of drilling
326-3	178.0	4.0	174.0	January 15, 2019	Upon completion of drilling
326-4	175.1	0.0	175.1	March 20 & 21, 2019	Water used during borehole advancement and therefore is not representative of in-situ conditions
1	174.8	1.2	173.6	December 6, 1969	Upon completion of drilling
458-1	178.7	Dry	-	March 20, 2019	
458-2	179.6	Dry	-	January 10, 2019	

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
458-3	179.5	2.8	176.7	Morning of January 9, 2019	Prior to continuing to borehole advancement
		Dry	-	January 9, 2019	Upon completion of drilling
458-4	179.3	13.7	165.6	March 19, 2019	Upon completion of drilling
		12.1	167.2	March 20, 2019	Within piezometer
		8.7	170.6	April 21, 2019	
		8.7	170.6	May 29, 2019	

4.2.2 Culvert Site No. 34-331/C

In general, the subsurface conditions at this culvert site consists of a layer of asphalt or topsoil underlain by fill material consisting of sand and gravel, and gravelly silty clay to sandy clayey silt. The fill is underlain by a clayey silt deposit which is further underlain by a till deposit consisting of sandy clayey silt. Limestone bedrock was encountered underlying the till deposit in both of the boreholes. A more detailed description of the subsurface conditions encountered in the boreholes and the test pit is provided in the following sections.

4.2.2.1 Asphalt

An approximately 150 mm and 130 mm thick layer of asphalt pavement was encountered at ground surface in Boreholes 331-1 and 331-2, respectively.

4.2.2.2 Topsoil

An approximately 100 mm thick layer of topsoil was encountered at ground surface in Test Pit 331-3.

4.2.2.3 Fill

A 0.4 m and 0.9 m thick layer of sand and gravel fill was encountered underlying the asphalt in Boreholes 331-1 and 331-2 at depths of 0.2 m and 0.1 m below ground surface (at Elevations 179.1 and 179.2 m, respectively). A 0.4 m and 0.5 m thick fill layer comprised of sandy clayey silt to clayey silt was encountered underlying the sand and gravel fill layer in Boreholes 331-1 and 331-2, at depths of about 0.6 m and 1.0 m below ground surface (Elevations 178.7 m and 178.3 m, respectively). Test Pit 331-3 encountered fill consisting of gravelly silty clay with sand underlying the topsoil and the test pit terminated in the fill at a depth of 0.2 m below ground surface (Elevation 178.7 m).

A SPT “N”-value of 16 blows per 0.3 m of penetration was recorded in the clayey silt fill layer, and a SPT “N”-value of 12 blows per 0.3 m of penetration was recorded at the transition between the sandy clayey silt fill layer and the underlying clayey silt, suggesting a stiff to very stiff consistency.

Grain size distribution testing was carried out on one sample of the gravelly silty clay with sand fill material from Test Pit 331-3 and the result is presented on Figure B-1 in Appendix B. Atterberg limits testing was carried out on

one sample from the gravelly silty clay with sand fill layer and measured a liquid limit of about 40 per cent, a plastic limit of about 25 per cent, and a plasticity index of about 15 per cent. These results, which are plotted on a plasticity chart on Figure B-2 in Appendix B, indicate that the gravelly clayey silt with sand fill material from Test Pit 331-3 consists of silty clay of medium plasticity.

The water content measured on two samples of the sand and gravel fill ranges between about 5 per cent and 22 per cent. The water content measured on two samples of the sandy clayey silt and gravelly silty clay with sand fill are about 19 per cent and 22 per cent.

4.2.2.4 Clayey Silt

An approximately 3.2 m and 2.2 m thick cohesive deposit comprised of clayey silt, trace sand, trace gravel with silt pockets and sand pockets was encountered underlying the fill in Boreholes 331-1 and 331-2, respectively at depths of 1.0 m and 1.5 m below ground surface (at Elevations 178.3 m and 177.8 m) and extends to depths of 4.2 m and 3.7 m below ground surface (Elevations 175.1 m and 175.6 m).

The SPT “N”-values measured within the clayey silt deposit range from 11 blows to 22 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

Grain size distribution testing was carried out on one sample of the clayey silt deposit and the result is shown on Figure B-3, in Appendix B. Atterberg limits testing was carried out on two samples of the clayey silt deposit and measured liquid limits of about 31 per cent and 32 per cent, plastic limits of about 16 per cent, and plasticity indices of about 15 per cent and 16 per cent. These results, which are plotted on a plasticity chart on Figure B-4 in Appendix B, indicate that the deposit consists of clayey silt of low plasticity.

Water content measured on two samples of the clayey silt deposit are approximately 15 per cent and 16 per cent.

4.2.2.5 Sandy Clayey Silt (Till)

An approximately 0.1 m and 0.7 m thick glacial till deposit comprised of sandy clayey silt, trace gravel was encountered underlying the clayey silt deposit in Boreholes 331-1 and 331-2 respectively at depths of 4.2 m and 3.7 m below ground surface (at Elevations 175.1 m and 175.6 m) and extends to depths of 4.3 m and 4.4 m below ground surface (Elevations 175.0 m and 174.9 m).

A SPT “N”-value of 16 blows per 0.3 m of penetration was recorded in the till deposit, suggesting a very stiff consistency.

Grain size distribution testing was carried out on one sample of the till deposit and the result is shown on Figure B-5, in Appendix B. Atterberg limits testing was carried out on one sample of the cohesive till deposit and measured a liquid limit of about 22 per cent, a plastic limit of about 13 per cent, and a plasticity index of about 9 per cent. The result, which is plotted on a plasticity chart on Figure B-6 in Appendix B, indicates that the cohesive deposit consists of clayey silt of low plasticity.

Water content measured on two samples of the cohesive till deposit are approximately 12 per cent and 13 per cent.

4.2.2.6 Limestone Bedrock

Bedrock was confirmed by bedrock coring in Boreholes 331-1 and 331-2. The depths to bedrock below ground surface and the corresponding bedrock surface elevations are summarized below:

Borehole No.	Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)	Comments
331-1	179.3	4.3	175.0	Bedrock coring for 3.18 m
331-2	179.3	4.4	174.9	Bedrock coring for 3.01 m

Based on a review of the bedrock core samples, the bedrock consists of limestone of the Onondaga Formation. In general, the bedrock core samples are described as fresh, thinly bedded, grey, very fine grained to fine grained, non-porous to faintly porous, strong limestone, as presented on the Record of Drillhole sheets in Appendix B, and as shown on the photographs of the recovered core samples on Figure B-7 in Appendix B. The degree of weathering of the bedrock core samples (i.e., fresh – W1), and the strength classification of the intact rock mass based on field identification (i.e., strong – R4) are described in accordance with the International Society for Rock Mechanics (ISRM⁵) standard classification system.

The Rock Quality Designation (RQD) measured on the core samples ranges from about 84 per cent to 98 per cent, indicating a rock mass of good to excellent quality as per Table 3.10 of CFEM (2006)⁶. The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered range between 99 per cent and 100 per cent and between 91 per cent and 98 per cent, respectively.

Unconfined Compression (UC) testing (ASTM D7012)⁷ was carried out on two selected core samples of the limestone bedrock and the uniaxial compressive strength (UCS) of the intact samples are summarized below and are presented on Figures B-7A, B-7B, B-8A and B-8B in Appendix B. The UCS of the intact limestone rock specimens was 72.4 MPa and 74.5 MPa in Boreholes 331-1 and 331-2, respectively, which is classified as strong rock (R4, 50 MPa < UCS < 100 MPa).

Borehole No.	Sample Depth (m)	Sample Elevation (m)	UCS (MPa)	Bedrock Type
331-1	4.29 – 4.48	175.01 – 174.82	72.4	Limestone
331-2	6.02 – 6.22	173.28 – 173.08	74.5	Limestone

4.2.2.7 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are presented on the Record of Borehole sheets in Appendix B. Boreholes 331-1 and 331-2 were both dry upon completion of soil drilling. It should

⁵ International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

⁶ Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.

⁷ ASTM D7012 – Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

be noted that the groundwater level in the area is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet periods of the year.

4.3 Analytical Testing Results

Six soil samples were submitted for analysis of parameters used to assess the potential corrosivity of the soil to steel and concrete at the three culvert sites. The following summarizes the results of the testing:

Parameter	Culvert Site No. 34-326/C		Culvert Site No. 34-458/C		Culvert Site No. 34-331/C	
	Borehole 326-2 SA#3 Silty Clay Fill	Borehole 326-3 SA#4 Silty Clay Fill	Borehole 458-2 SA#5 Clayey Silt to Silty Clay	Borehole 458-3 SA#6 Clayey Silt to Silty Clay	Borehole 331-1 SA#4 Clayey Silt	Borehole 331-2 SA#5 Sandy Clayey Silt (Till)
pH	7.70	7.73	7.83	7.78	7.82	7.81
Resistivity (ohm-cm)	670	1,000	430	1,300	700	3,200
Electrical Conductivity (umho/cm)	1,490	966	2,340	794	1,420	312
Chlorides (ug/g)	410	76	58	330	710	82
Soluble Sulphates (ug/g)	830	810	3,600	220	120	61

5.0 CLOSURE

This report was prepared by Ms. Katelyn Nero, a geotechnical Engineer-In-Training with Golder and reviewed by Ms. Sandra McGaghran, M.Eng., P.Eng., an Associate and Senior Geotechnical Engineer with Golder. Mr. Paul Dittrich, Ph.D., P.Eng., a Principal with Golder and an MTO Foundations Designated Contact, conducted a technical and quality control review of the report.

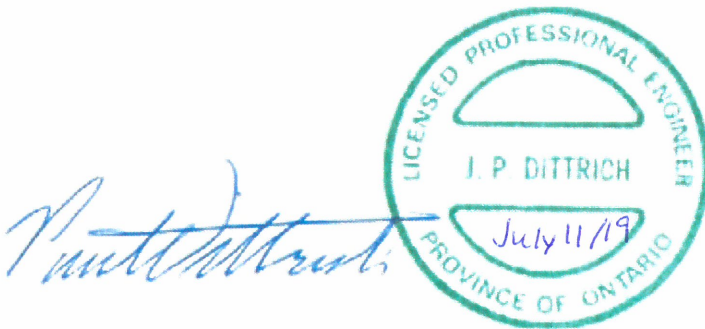
Golder Associates Ltd.

Kater Nero
July 11/19

Katelyn Nero, E.I.T.
Geotechnical Group



Sandra McGaghran, M.Eng., P.Eng.
Associate, Senior Geotechnical Engineer

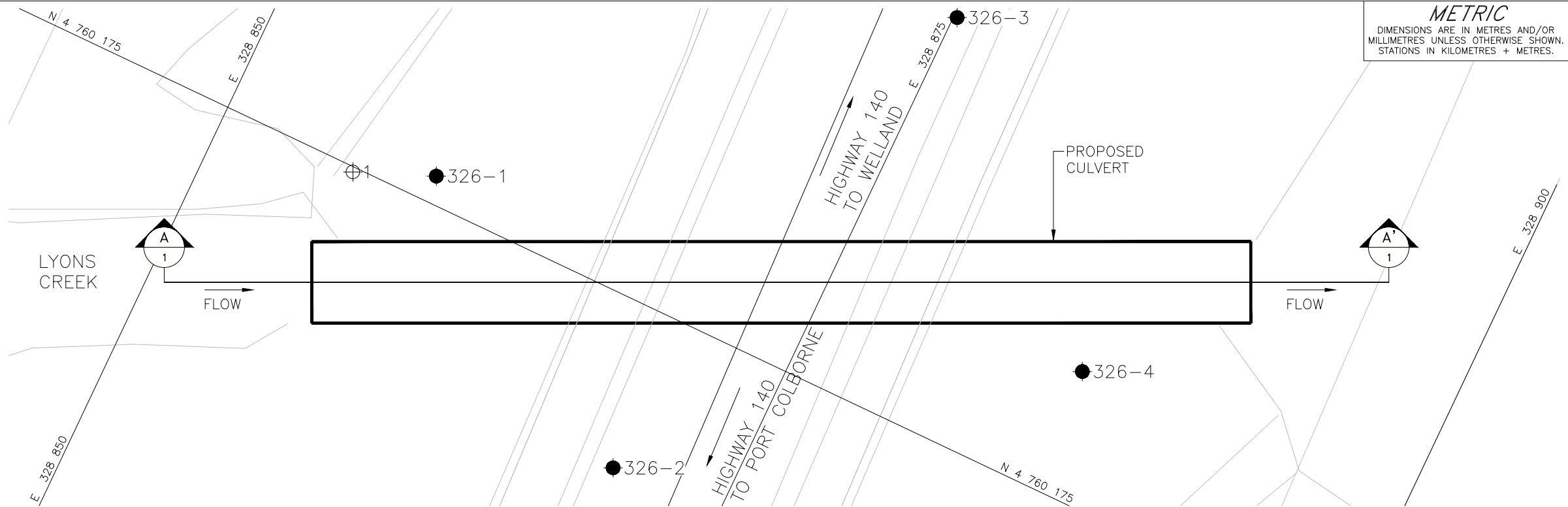


Paul Dittrich, Ph.D., P.Eng.
MTO Foundations Designated Contact, Principal

KN/AJS/SMM/JPD/rb

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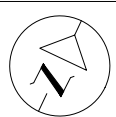
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METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. 1
GWP No. 2374-15-00

HIGHWAY 140, LYONS CREEK
CULVERT REHABILITATION
BOREHOLE LOCATIONS AND SOIL
STRATA



KEY PLAN
SCALE
500 0 500 1000 m

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation (GEOCRE 30L14-030)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on APR 21, 2019
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
1	174.8	4760174.8	328855.7
326-1	175.1	4760176.1	328858.8
326-2	177.9	4760168.5	328870.4
326-3	178.0	4760190.9	328875.1
326-4	175.1	4760180.1	328885.9

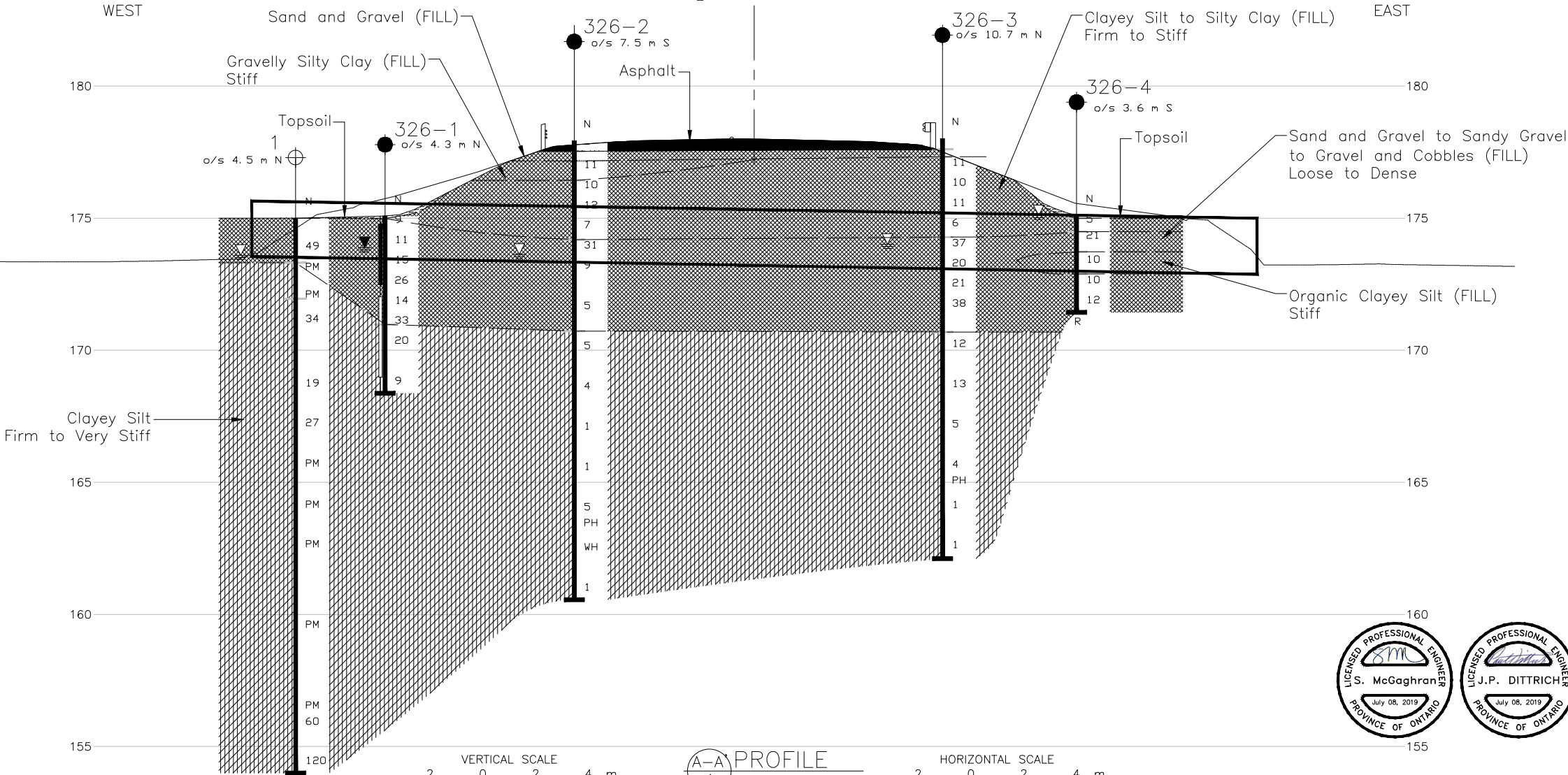
NOTES

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.

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

REFERENCE

Base plans provided in digital format by AIA Engineers, drawing file no. 34-326_C ACAD2010.dwg, received January 2, 2019.
General Arrangement provided in digital format by AIA Engineers, drawing file no. 7010-Hwy140 Lyons-GA.dwg, received April 16, 2019.

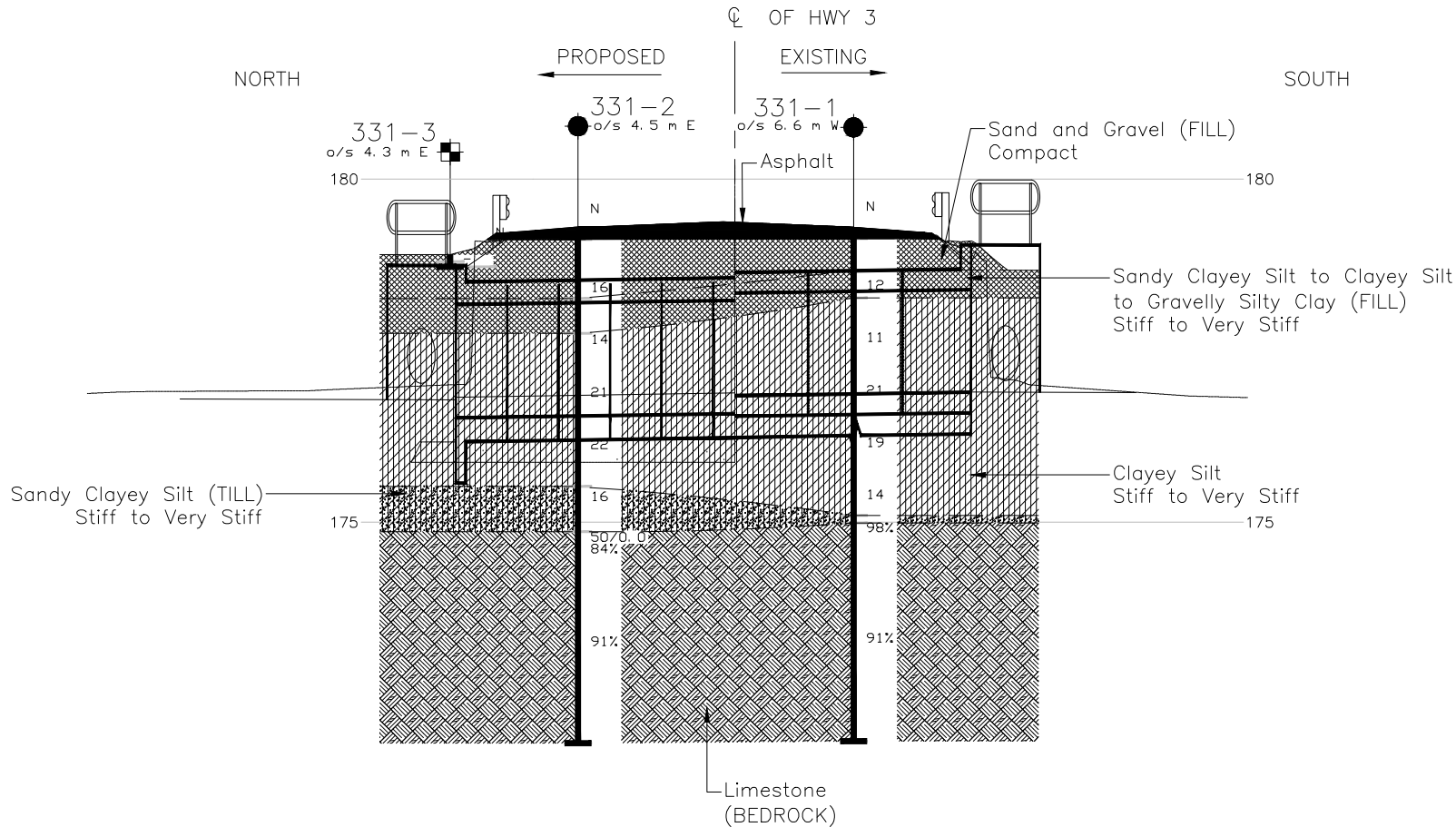
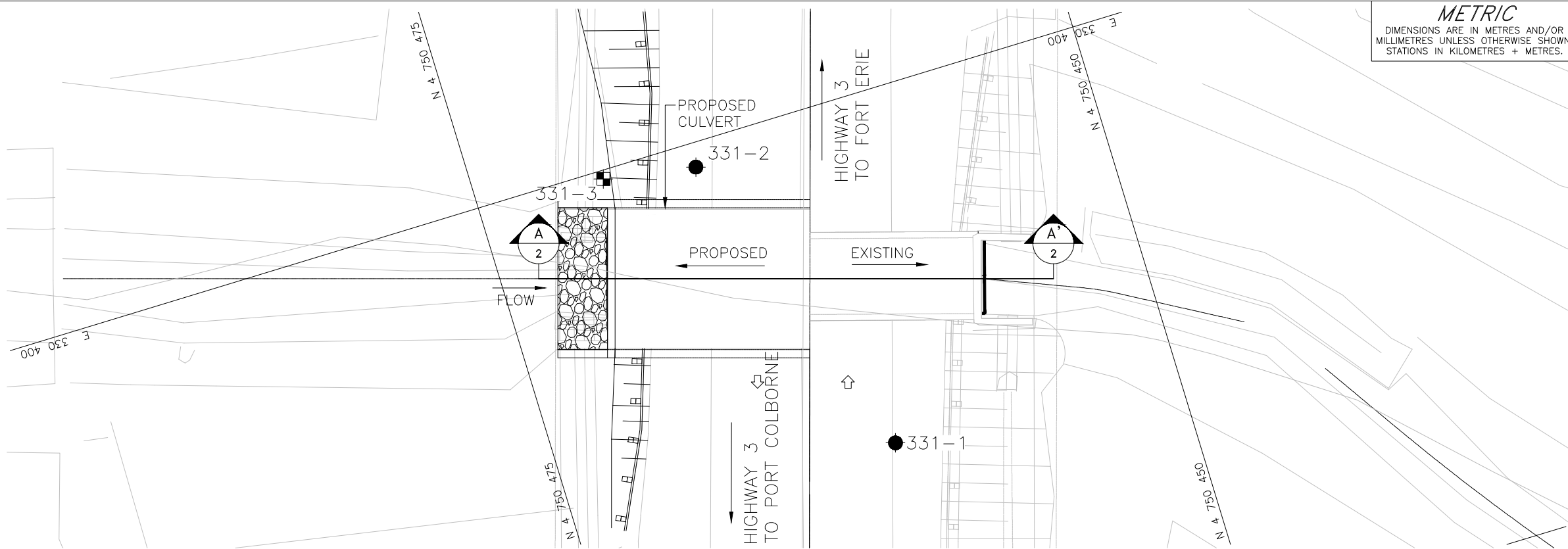


A-A' PROFILE
1

NO.	DATE	BY	REVISION
1	07/08/2019	DD	1

Geocres No. 30L14-62

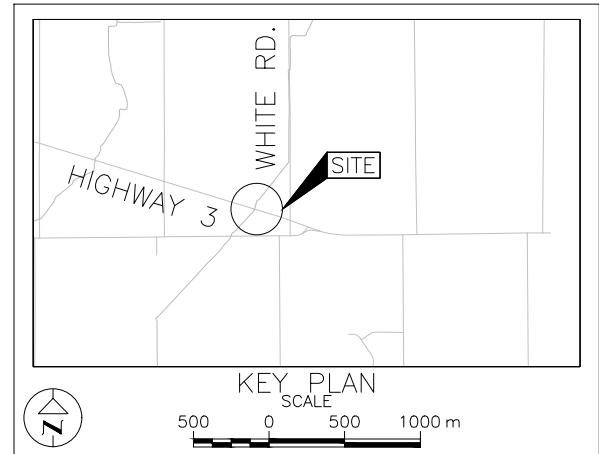
HWY. 140	PROJECT NO. 18105193	DIST. CENTRAL
SUBM'D. ACK	CHKD. AJS	DATE: 07/08/2019
DRAWN: DD	CHKD. SMM	APPD. JPD
		DWG. 1



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

CONT No. 1
GWP No. 2374-15-00

HWY 3, WEST OF WHITE ROAD
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL
STRATA



LEGEND	
	Borehole
	Test Pit
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)

TEST PIT AND BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
331-1	179.3	4750461.7	330386.1
331-2	179.3	4750466.1	330399.0
331-3	178.9	4750469.8	330399.7

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.

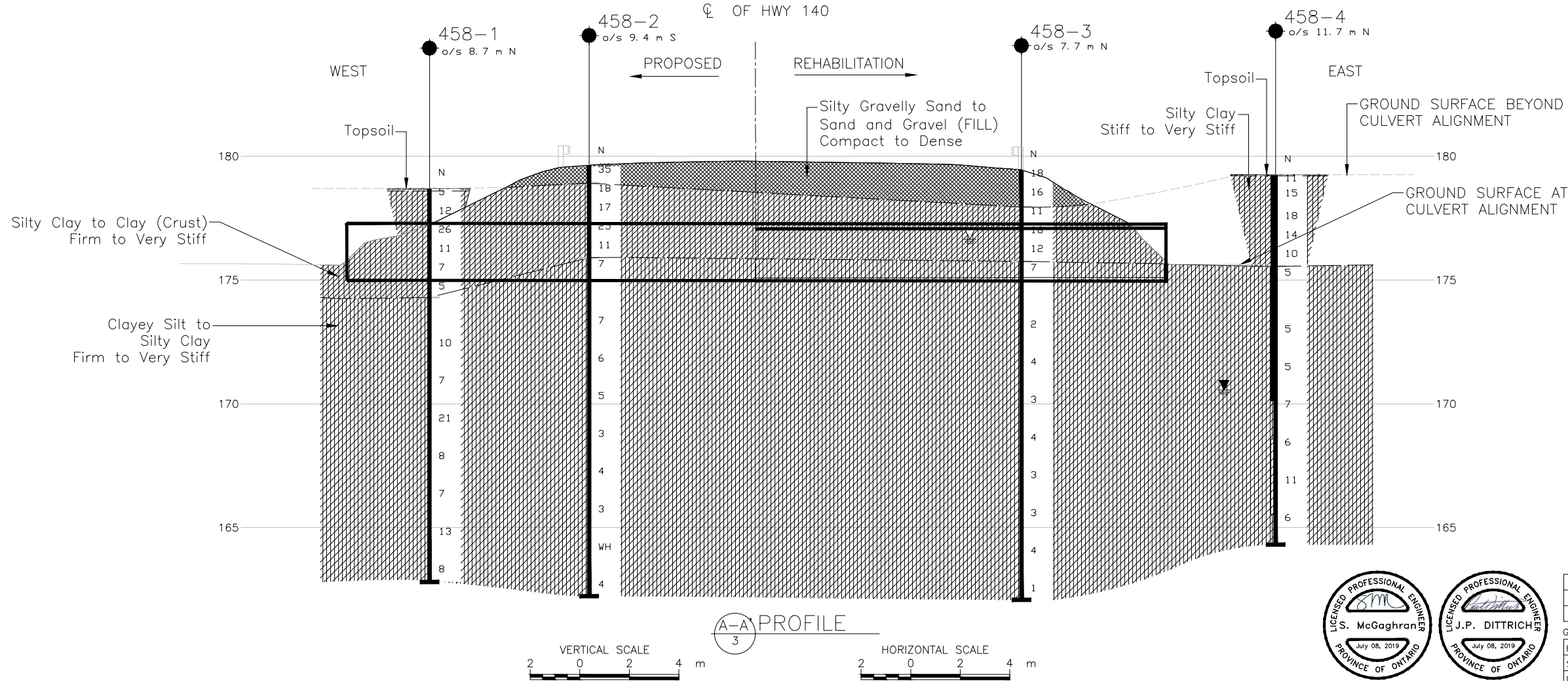
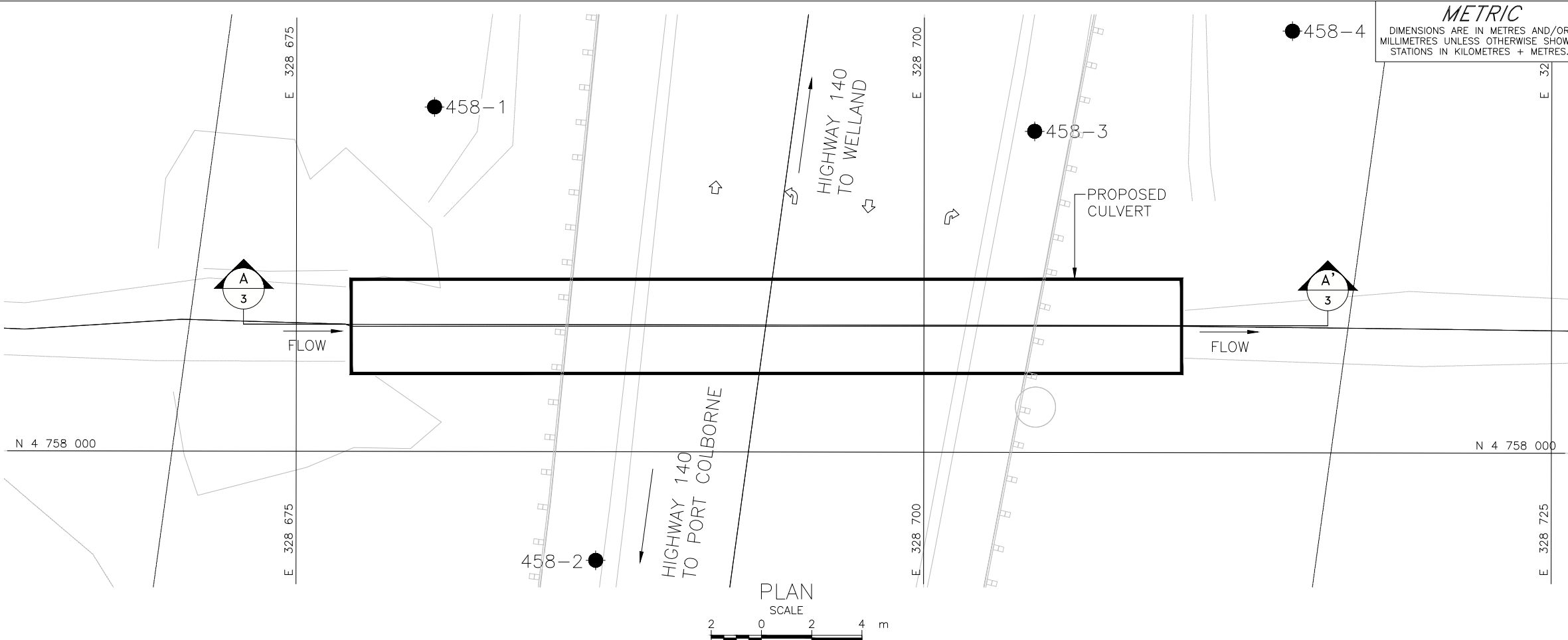
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by AIA Engineers, drawing file no. 34-326_C ACAD2010.dwg, received January 2, 2019.
General Arrangement provided in digital format by AIA Engineers, drawing file no. 7010- site 34-331-Hwy3- West of White Rd-v2.dwg, received June 11, 2019.



NO.	DATE	BY	REVISION
Geocres No. 30L14-62			
HWY. 3	PROJECT NO. 18105193		DIST. CENTRAL
SUBM'D. AJS	CHKD. ACK	DATE: 07/05/2019	SITE: 34-331/C
DRAWN: SW	CHKD. SMM	APPD. JPD	DWG. 2



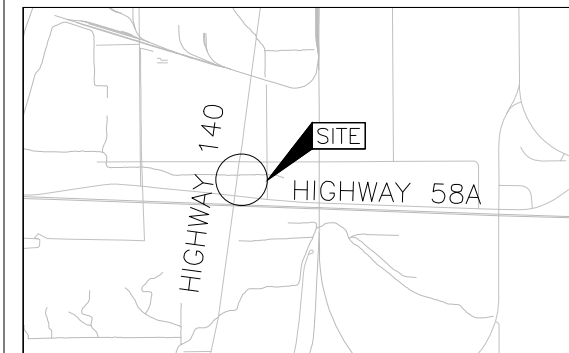
METRIC
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STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2374-15-00



HWY 140, NORTH OF HWY 58A
CULVERT REHABILITATION
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



KEY PLAN
SCALE
500 0 500 1000 m

LEGEND

- Borehole
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on APR 21, 2019
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
458-1	178.7	4758013.7	328680.5
458-2	179.6	4757995.7	328686.9
458-3	179.5	4758012.8	328704.4
458-4	179.3	4758016.8	328714.7

NOTES

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

REFERENCE

Base plans provided in digital format by AIA Engineers, drawing file no. 34-326_C ACAD2010.dwg, received January 2, 2019.
General Arrangement provided in digital format by AIA Engineers, drawing file no.7010- site 34-458- Hwy140 north of hwy 58a-GA.dwg, received June 11, 2019.



NO.	DATE	BY	REVISION
Geocres No. 30L14-62			
HWY. 140	PROJECT NO. 18105193		DIST. CENTRAL
SUBM'D. AJS	CHKD. ACK	DATE: 07/08/2019	SITE: 34-458/C
DRAWN: SW	CHKD. SMM	APPD. JPD	DWG. 3



Culvert Site No. 34-326/C inlet, looking west



Culvert Site No. 34-326/C, inlet and embankment, looking south



Culvert Site No. 34-331/C outlet, looking east



Culvert Site No. 34-458/C outlet, looking west



South of Culvert Site No. 34-458/C, looking east at the channel sideslopes east of outlet

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1
2

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

FIELD ESTIMATION OF ROCK HARDNESS

Grade	Description	Field Identification	Approx. Range of UCS (MPa)
R0	Extremely Weak Rock	Indented by thumbnail	0.25 - 1
R1	Very Weak Rock	Material can be peeled or shaped with a knife. Crumbles under firm blows from geological hammer.	1 - 5
R2	Weak Rock	Knife cuts material but too hard to shape into triaxial specimens or material can be peeled with a knife with difficulty. Shallow (<5mm) indentations made by firm blows from pick of a geological hammer.	5 - 25
R3	Moderately Strong Rock	Cannot be peeled or scraped with a knife. Hand held specimens can be fractured with single firm blow of geological hammer.	25 - 50
R4	Strong Rock	Hand held specimen requires more than one blow of geological hammer to fracture.	50 - 100
R5	Very Strong Rock	Hand held specimen requires many blows of geological hammer to fracture.	100 - 250
R6	Extremely Strong Rock	Specimen can only be chipped under repeated hammer blows, rings when hit.	> 250

Notes:

1. Hand held specimens should have height approximately 2 times the diameter.
2. Materials having a uniaxial compressive strength of less than approximately 0.5 MPa and cohesionless materials should be classified using soil classification systems.
3. Rocks with a uniaxial compressive strength below 25 MPa (i.e. below R2) are likely to yield highly ambiguous results under point load testing.

Reference:

Brown, 1981. "Suggested Methods for Rock Characterization Testing and Monitoring", International Society for Rock Mechanics.

Hoek, E., Kaiser, P.K., Bawden, W.F., 1995. "Support of Underground Excavations in Hard Rock", Balkema, Rotterdam.

ROCK WEATHERING CLASSIFICATION

Term	Symbol	Description	Discoloration Extent	Fracture Condition	Surface Characteristics
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	Throughout	N/A	Resembles soil
Completely weathered	W5	100% of rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	Throughout	Filled with alteration minerals	Resembles soil
Highly weathered	W4	More than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	Throughout	Filled with alteration minerals	Friable and possibly pitted
Moderately weathered	W3	Less than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. Visible texture of the host rock still preserved. Surface planes are weathered (oxidized or carbonate filling) even when breaking the "intact rock".	>20% of fracture spacing on both sides of fracture	Discoloured, may contain thick filling	Partial to complete discoloration, not friable except poorly cemented rocks
Slightly weathered	W2	Discoloration indicates weathering of rock material on discontinuity surfaces (usually oxidized). Less than 5% of rock mass altered.	<20% of fracture spacing on both sides of fracture	Discoloured, may contain thin filling	Partial discoloration
Fresh	W1	No visible sign of rock material weathering.	None	Closed or discoloured	Unchanged

Reference:

Brown, 1981. "Suggested Methods for Rock Characterization Testing and Monitoring", International Society for Rock Mechanics.

APPENDIX A

**Record of Borehole Sheets and
Geotechnical Laboratory Results for
Culvert Site Nos. 34 326/C and 34-
458/C**

PROJECT		18105193		RECORD OF BOREHOLE No 326-1		SHEET 1 OF 1		METRIC											
G.W.P.		2374-15-00		LOCATION		N 4760176.1; E 328858.8 MTM NAD 83 ZONE 10 (LAT. 42.981016; LONG. -79.205013)		ORIGINATED BY TP											
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 114 mm I.D. Hollow Stem Augers		COMPILED BY SE											
DATUM		Geodetic		DATE		January 17, 2019		CHECKED BY AJS											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL	
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	10 20 30	kN/m ³					
175.1	0.0	GROUND SURFACE						175											
	0.1	TOPSOIL (90 mm)		1	SS	9		175											
		Sand and gravel, trace to some silt, trace clay (FILL)		2	SS	11		174										53	33 12 2
		Loose to dense		3	SS	15		173											
		Brown, grey below a depth of 1.5 m		4	SS	26		172											
		Wet		5	SS	14		171										59	32 7 2
171.0	4.1	CLAYEY SILT, trace to some sand, trace gravel		6A	SS	33		171											
		Stiff to very stiff		6B				170										2	10 57 31
		Brown		7	SS	20		169											
		Moist		8	SS	9													
168.4	6.7	END OF BOREHOLE																	
		NOTES:																	
		1. Water level measured at a depth of about 2.0 m below ground surface (Elev. 173.1 m) upon completion of drilling.																	
		2. Water level in piezometer:																	
		Date Depth (m) Elev. (m)																	
		3/20/2019 1.2 m 173.9 m																	
		4/21/2019 0.9 m 174.2 m																	
		5/29/2019 1.2 m 173.9 m																	

PROJECT		18105193		RECORD OF BOREHOLE No 326-2		SHEET 1 OF 2		METRIC						
G.W.P.		2374-15-00		LOCATION		N 4760168.5; E 328870.4 MTM NAD 83 ZONE 10 (LAT. 42.980947; LONG. -79.204872)		ORIGINATED BY TP						
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 114 mm I.D. Hollow Stem Augers		COMPILED BY SE						
DATUM		Geodetic		DATE		January 16, 2019		CHECKED BY AJS						
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						
177.9	GROUND SURFACE													
0.0	ASPHALT (400 mm)		1	AS	-									
177.5	Sand and gravel (FILL)													
177.1			2	SS	11									
0.8	Gravelly silty clay, some sand (FILL)													
176.4	Stiff Brown Moist													
1.5	Silty clay, trace sand (FILL)		3	SS	10									
	Firm to stiff Brown Moist													
			4	SS	12									
			5	SS	7									
174.2														
3.7	Sandy gravel, trace silt (FILL)		6	SS	31									
	Loose to dense Grey Wet													
			7	SS	9									
			8	SS	5									
170.7														
7.2	CLAYEY SILT, trace to some sand, trace gravel		9	SS	5									
	Firm to stiff Brown Wet													
			10	SS	4									
			11	SS	1									
			12	SS	1									
			13	SS	5									
			14	TO	PH									

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

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PROJECT <u>18105193</u>		RECORD OF BOREHOLE No 326-2		SHEET 2 OF 2		METRIC	
G.W.P. <u>2374-15-00</u>		LOCATION <u>N 4760168.5; E 328870.4 MTM NAD 83 ZONE 10 (LAT. 42.980947; LONG. -79.204872)</u>		ORIGINATED BY <u>TP</u>			
DIST <u>Central</u> HWY <u>140</u>		BOREHOLE TYPE <u>Power Auger, 114 mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>SE</u>			
DATUM <u>Geodetic</u>		DATE <u>January 16, 2019</u>		CHECKED BY <u>AJS</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	w _p	w	w _L					
--- CONTINUED FROM PREVIOUS PAGE ---							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED													



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PROJECT		18105193		RECORD OF BOREHOLE No 326-3		SHEET 1 OF 2		METRIC					
G.W.P.		2374-15-00		LOCATION		N 4760190.9; E 328875.1 MTM NAD 83 ZONE 10 (LAT. 42.981149; LONG. -79.204812)		ORIGINATED BY KN					
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 114 mm I.D. Hollow Stem Augers		COMPILED BY SE					
DATUM		Geodetic		DATE		January 15 and 16, 2019		CHECKED BY AJS					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
178.0	GROUND SURFACE												
0.0	ASPHALT (400 mm)												
177.6													
177.3	Sand and gravel (FILL)												
0.7	Silty clay, trace gravel, trace sand, trace silt pockets. trace organics at 3.1 m (FILL) Firm to stiff Brown Moist		1	SS	11								
			2	SS	10								
			3	SS	11								
			4	SS	6								
174.3													
3.7	Sand and gravel, trace to some silt, trace clay (FILL) Compact to dense Grey Wet		5	SS	37								
			6	SS	20								
			7	SS	21								
			8	SS	38								
170.7													
7.3	CLAYEY SILT trace to some gravel, trace to some sand Firm to stiff Brown Moist to wet		9	SS	12								
			10	SS	13								
			11	SS	5								
			12	SS	4								
			13	TO	PH								
			14	SS	1								

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PROJECT		18105193		RECORD OF BOREHOLE No 326-3		SHEET 2 OF 2		METRIC							
G.W.P.		2374-15-00		LOCATION		N 4760190.9; E 328875.1 MTM NAD 83 ZONE 10 (LAT. 42.981149; LONG. -79.204812)		ORIGINATED BY							
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 114 mm I.D. Hollow Stem Augers		COMPILED BY							
DATUM		Geodetic		DATE		January 15 and 16, 2019		CHECKED BY							
AJS															
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100		W _p	W	W _L	γ	GR SA SI CL	
--- CONTINUED FROM PREVIOUS PAGE ---															
162.1	CLAYEY SILT trace to some gravel, trace to some sand Firm to stiff Brown Moist to wet		15	SS	1										
15.9	END OF BOREHOLE NOTE: 1. Water level measured at a depth of 4.0 m below ground surface (Elev. 174.0 m) upon completion of drilling on January 15, 2019														


PROJECT		18105193		RECORD OF BOREHOLE No 326-4		SHEET 1 OF 1		METRIC							
G.W.P.		2374-15-00		LOCATION		N 4760180.1; E 328885.9 MTM NAD 83 ZONE 10 (LAT. 42.981051; LONG. -79.204681)		ORIGINATED BY							
DIST		Central HWY 140		BOREHOLE TYPE		Portable Tripod, 150 mm O.D. casing with wash boring		COMPILED BY							
DATUM		Geodetic		DATE		March 20 and 21, 2019		CHECKED BY							
AJS															
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
175.1	0.0	GROUND SURFACE													
174.5	0.6	TOPSOIL (100 mm) Clayey silt, trace sand, trace gravel, trace to some organics (FILL) Firm Brown Moist		1	SS	5									
173.7	1.4	Sandy gravel, trace to some silt, trace clay (FILL) Compact Grey Moist		2	SS	21									
172.9	2.2	Organic clayey silt, some gravel, trace to some sand, trace to some organics (FILL) Stiff Brown Wet		3	SS	10									
171.4	3.7	Gravel and cobbles (FILL) Compact Grey Wet		4	SS	10									
		END OF BOREHOLE CASING REFUSAL ON COBBLES		5	SS	12									
NOTES: 1. Borehole sampled to a depth of 1.5 m (Elev. 173.6 m) below ground surface at original Borehole 326-4 location. Casing refusal was encountered at a depth of 1.5 m (Elev. 173.6 m). 2. Additional borehole advancement attempt was made 0.3 m north of original Borehole 326-4 location. Borehole sampled from 1.5 m to 3.7 m (Elev. 171.4 m) below ground surface and samples are included in this Record of Borehole. Casing refusal was encountered at a depth of 3.7 m (Elev. 171.3 m). 3. Additional borehole advancement attempt were made 0.6 m north of the original Borehole 326-4 location. Casing refusal encountered at a depth of 3.1 m (Elev. 172.0 m) below ground surface. 4. Three additional borehole advancement attempts were made 2.6 m, 2.9 m, and 3.2 m south of the original Borehole 326-4 location. Casing refusal encountered at depths of 0.8 m and 0.9 m (Elev. 173.9 m and 174.0 m) below ground surface. 5. Water level at top of casing upon completion of drilling; however, water added during advance of casing and therefore the water level is not reflective of in-situ conditions.															

PROJECT		18105193		RECORD OF BOREHOLE No 458-1		SHEET 1 OF 2		METRIC					
G.W.P.		2374-15-00		LOCATION		N 4758013.7; E 328680.5 MTM NAD 83 ZONE 10 (LAT. 42.961555; LONG. -79.207292)		ORIGINATED BY					
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 200 mm O.D. Hollow Stem Augers		COMPILED BY					
DATUM		Geodetic		DATE		March 19 and 20, 2019		CHECKED BY					
AJS													
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
178.7	GROUND SURFACE												
0.1	TOPSOIL (50 mm)												
	SILTY CLAY to CLAY, trace sand, trace gravel		1	SS	5								
	Firm to very stiff		2	SS	12								
	Brown		3	SS	26								
	Moist to wet		4	SS	11								
			5	SS	7								
	- Varved at a depth of 3.8 m to 4.4 m		6	SS	5								
174.3	CLAYEY SILT, trace sand												
4.4	Firm to very stiff												
	Brown		7	SS	10								
	Moist to wet		8	SS	7								
			9	SS	21								
			10	SS	8								
			11	SS	7								
			12	SS	13								
	- Sandy silt pockets at a depth of 14.3 m												

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PROJECT		RECORD OF BOREHOLE No 458-1				SHEET 2 OF 2		METRIC				
18105193		G.W.P. 2374-15-00		LOCATION N 4758013.7; E 328680.5 MTM NAD 83 ZONE 10 (LAT. 42.961555; LONG. -79.207292)		ORIGINATED BY KN						
DIST Central HWY 140		BOREHOLE TYPE Power Auger, 200 mm O.D. Hollow Stem Augers		COMPILED BY EN								
DATUM Geodetic		DATE March 19 and 20, 2019		CHECKED BY AJS								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---											
162.8	CLAYEY SILT, trace sand Firm to very stiff Brown Moist to wet		13	SS	8		163					
15.9	END OF BOREHOLE NOTE: 1. Borehole open and dry upon completion of soil drilling.											



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

PROJECT		RECORD OF BOREHOLE No 458-2				SHEET 2 OF 2		METRIC									
18105193		G.W.P. 2374-15-00		LOCATION N 4757995.7; E 328686.9 MTM NAD 83 ZONE 10 (LAT. 42.961392; LONG. -79.207213)		ORIGINATED BY KN											
DIST Central HWY 140		BOREHOLE TYPE Power Auger, 70 mm I.D. Hollow Stem Augers		COMPILED BY SE													
DATUM Geodetic		DATE January 10, 2019		CHECKED BY AJS													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100	W _p	W	W _L			
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED										
							20	40	60	80	100	10	20	30			
162.2	CLAYEY SILT to SILTY CLAY trace sand, trace gravel Stiff to very stiff Brown, mottled grey Moist to wet at a depth below 13.7 m		13	SS	WH												
163																	
17.4	END OF BOREHOLE		14	SS	4												
	NOTE: 1. Borehole dry and open to a depth of 14.6 m below ground surface (Elev. 165.0 m) upon completion of drilling and removal of augers.																




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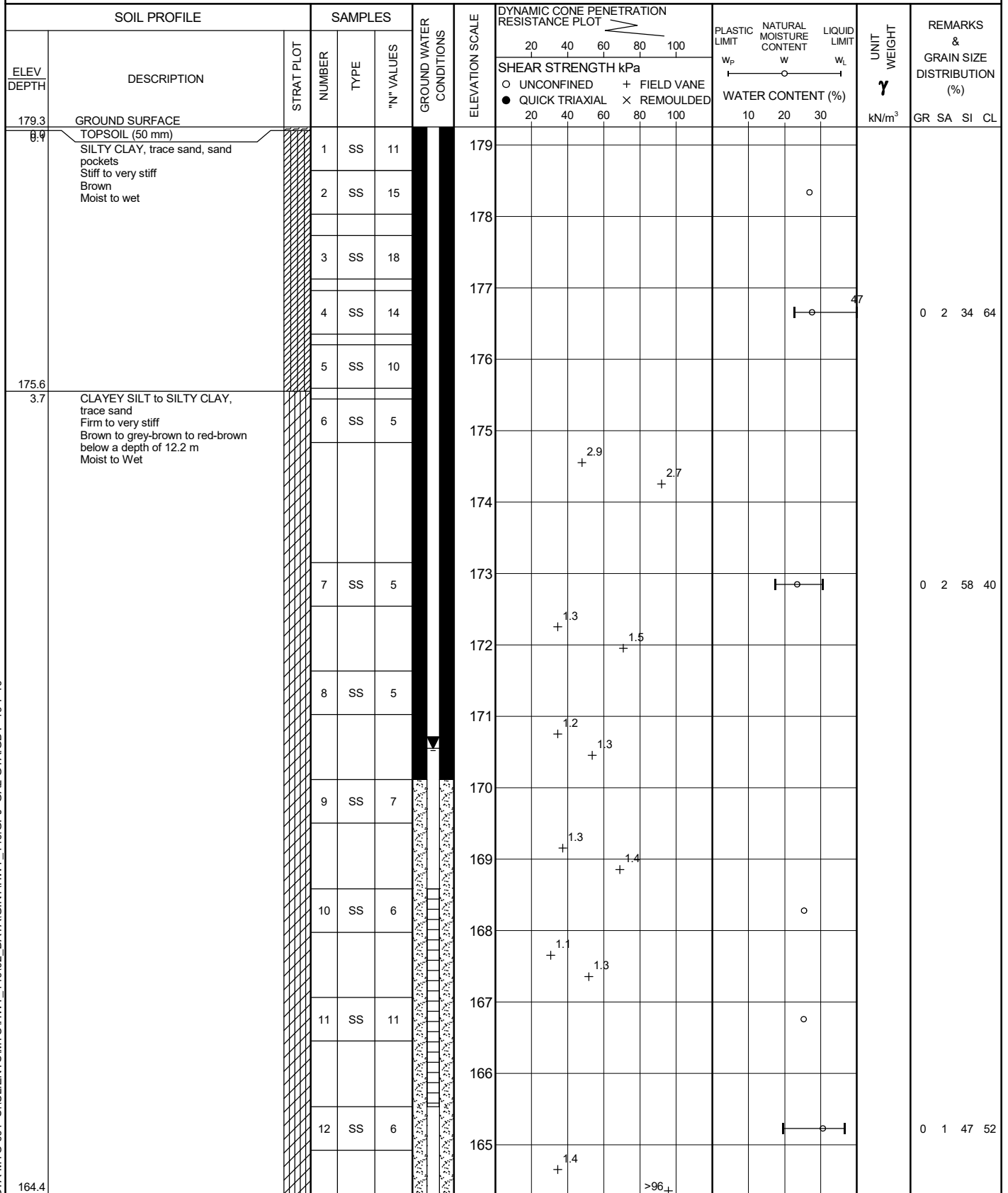
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>18105193</u>		RECORD OF BOREHOLE No 458-3		SHEET 2 OF 2		METRIC	
G.W.P. <u>2374-15-00</u>		LOCATION <u>N 4758012.8; E 328704.4 MTM NAD 83 ZONE 10 (LAT. 42.961546; LONG. -79.206999)</u>		ORIGINATED BY <u>KN</u>			
DIST <u>Central</u> HWY <u>140</u>		BOREHOLE TYPE <u>Power Auger, 70 mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>SE</u>			
DATUM <u>Geodetic</u>		DATE <u>January 8 and 9, 2019</u>		CHECKED BY <u>AJS</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								20 40 60 80 100	20 40 60 80 100						10 20 30	
--- CONTINUED FROM PREVIOUS PAGE ---																
162.1	CLAYEY SILT, trace sand, rootlets at a depth of 7.9 m Stiff Brown Moist to wet		13	SS	4		164									
							163									
			14	SS	1											
17.4	END OF BOREHOLE															
NOTE: 1. Water level at a depth of 2.8 m below ground surface (Elev. 176.7 m) on the morning of January 9, 2019. 2. Borehole dry and open to a depth of 5.5 m below ground surface (Elev. 174.0) upon completion of drilling and removal of augers.																

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

PROJECT 18105193		RECORD OF BOREHOLE No 458-4		SHEET 1 OF 2		METRIC	
G.W.P. 2374-15-00		LOCATION N 4758016.8; E 328714.7 MTM NAD 83 ZONE 10 (LAT. 42.961582; LONG. -79.206873)		ORIGINATED BY KN			
DIST Central HWY 140		BOREHOLE TYPE Power Auger, 200 mm O.D. Hollow Stem Augers		COMPILED BY EN			
DATUM Geodetic		DATE March 18 and 19, 2019		CHECKED BY AJS			



Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTOWHY_140\02_DATA\GINT\HWY_140.GPJ GAL-GTA.GDT 19-7-10

PROJECT <u>18105193</u>		RECORD OF BOREHOLE No 458-4				SHEET 2 OF 2		METRIC	
G.W.P. <u>2374-15-00</u>		LOCATION <u>N 4758016.8; E 328714.7 MTM NAD 83 ZONE 10 (LAT. 42.961582; LONG. -79.206873)</u>				ORIGINATED BY <u>KN</u>			
DIST <u>Central</u> HWY <u>140</u>		BOREHOLE TYPE <u>Power Auger, 200 mm O.D. Hollow Stem Augers</u>				COMPILED BY <u>EN</u>			
DATUM <u>Geodetic</u>		DATE <u>March 18 and 19, 2019</u>				CHECKED BY <u>AJS</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)												
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W			W _L											
14.9	END OF BOREHOLE NOTES: 1. Water level measured at a depth of about 13.7 m below ground surface (Elev. 165.6 m) upon completion of drilling. 2. Water level in piezometer: <table style="margin-left: 20px;"> <tr> <td>Date</td> <td>Depth (m)</td> <td>Elev. (m)</td> </tr> <tr> <td>3/20/2019</td> <td>12.1 m</td> <td>167.2 m</td> </tr> <tr> <td>4/21/2019</td> <td>8.7 m</td> <td>170.6 m</td> </tr> <tr> <td>5/29/2019</td> <td>8.7 m</td> <td>170.6 m</td> </tr> </table>	Date	Depth (m)	Elev. (m)	3/20/2019	12.1 m	167.2 m	4/21/2019	8.7 m	170.6 m	5/29/2019	8.7 m	170.6 m															
Date	Depth (m)	Elev. (m)																										
3/20/2019	12.1 m	167.2 m																										
4/21/2019	8.7 m	170.6 m																										
5/29/2019	8.7 m	170.6 m																										
	--- CONTINUED FROM PREVIOUS PAGE ---																											

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 69-F-64

LOCATION 342+23 51' Lt.

ORIGINATED BY BTD

W.P. 60-68-CL

BORING DATE December 4, 5 and 6, 1969

COMPILED BY BTD

DATUM Geodetic

BOREHOLE TYPE Washboring -NX Casing, Dynamic Cone Penetration Test

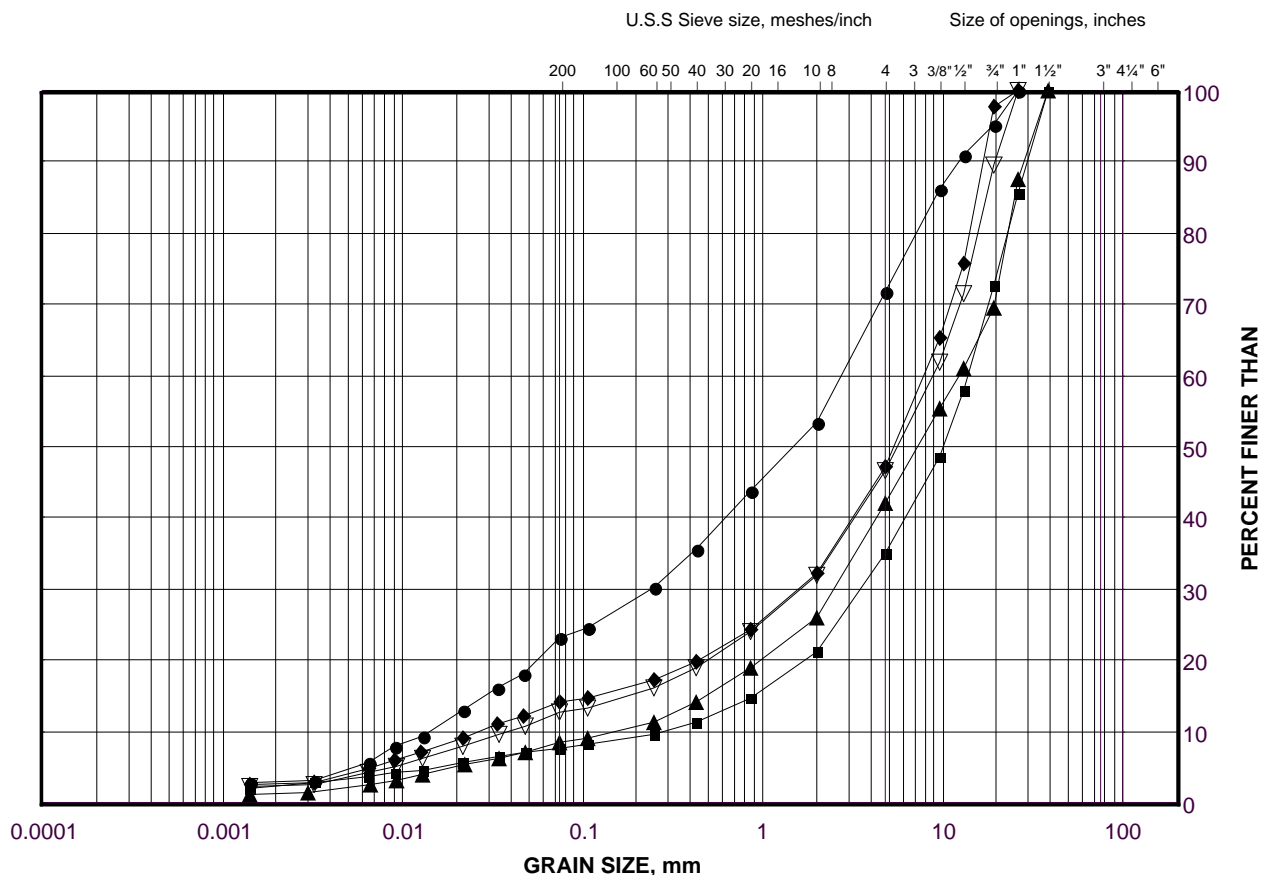
CHECKED BY

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.					WATER CONTENT %				
							20 40 60 80 100					w_p — w — w_L				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE									
573.5	Ground Level					400	800	1200	1600	2000	20	40	60			
0.0	Clayey Silt, trace of sand and gravel, occ. rock fragments (FILL) (Grey Brown) HARD		1	SS	49	570									569.5	
568.0																
5.5	Clayey silt, with related org. matt, wood chips etc. FIRM		2	TW	PM										W.L. in	
563.5			3	TW	PM										Open BH	
10.0	Silty Clay to Clayey Silt														Dec. 6/69	
	trace of sand and gravel (occasional partings and seam of silt up to 1/4" thick) (Mottled Brown to Reddish Brown)		4	SS	34	560										
	Hard to Firm		5	SS	19	550										
			6	SS	27											
			7	TW	PM	540										
			8	TW	PM											
			9	TW	PM	530										
			10	TW	PM	520										
513.5			11	TW	PM											
60.0	(Layers of silt up to 3" thick)		12	SS	60	510										
505.5	Hard		13	SS	120											
68.0	End of Borehole					500										

GRAIN SIZE DISTRIBUTION

Silty Gravelly Sand to Sandy Gravel (FILL)

FIGURE A-1



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

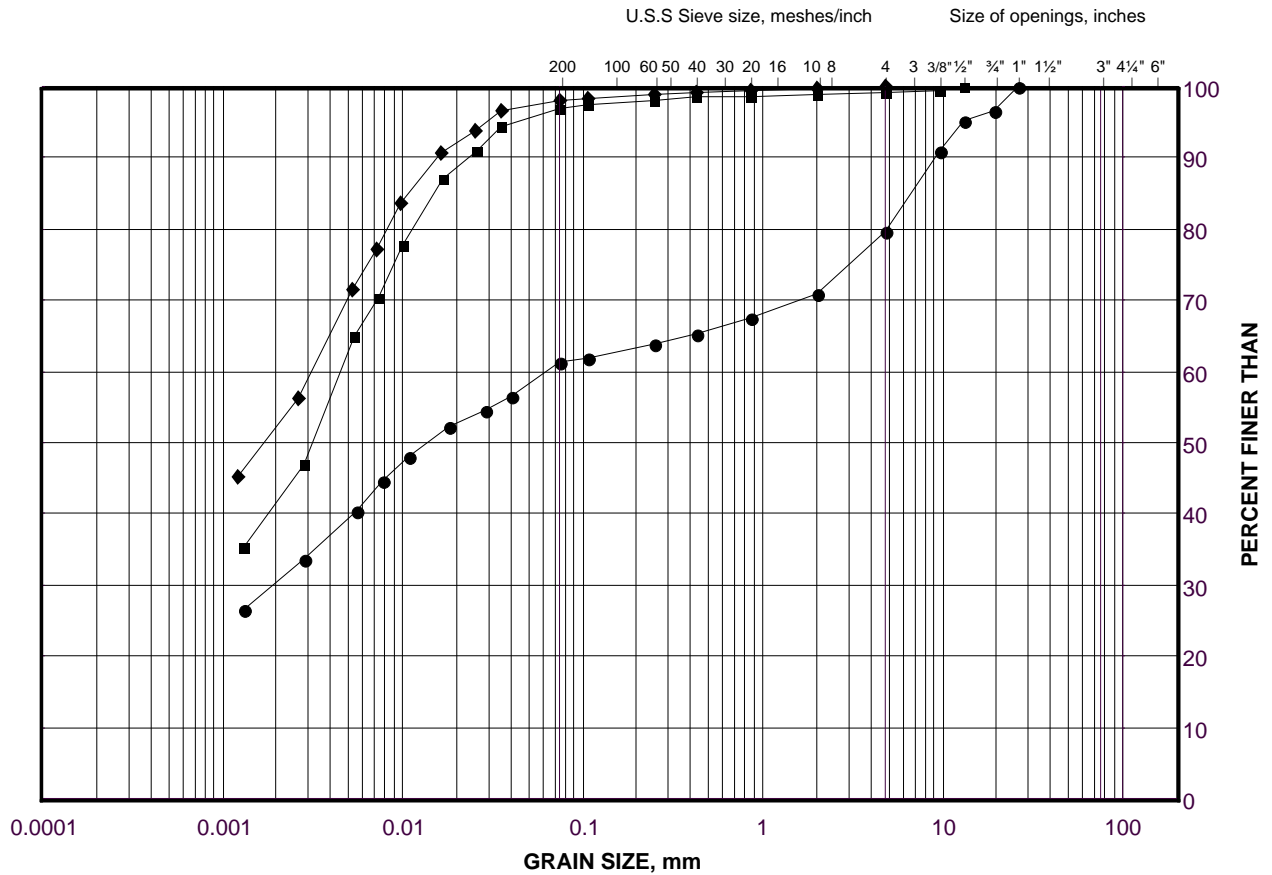
LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	458-2	1	179.3
■	326-4	2	174.2
◆	326-1	2	174.0
▲	326-1	5	171.7
▽	326-3	6	173.1

GRAIN SIZE DISTRIBUTION

Gravelly Silty Clay to Silty Clay (FILL)

FIGURE A-2



LEGEND

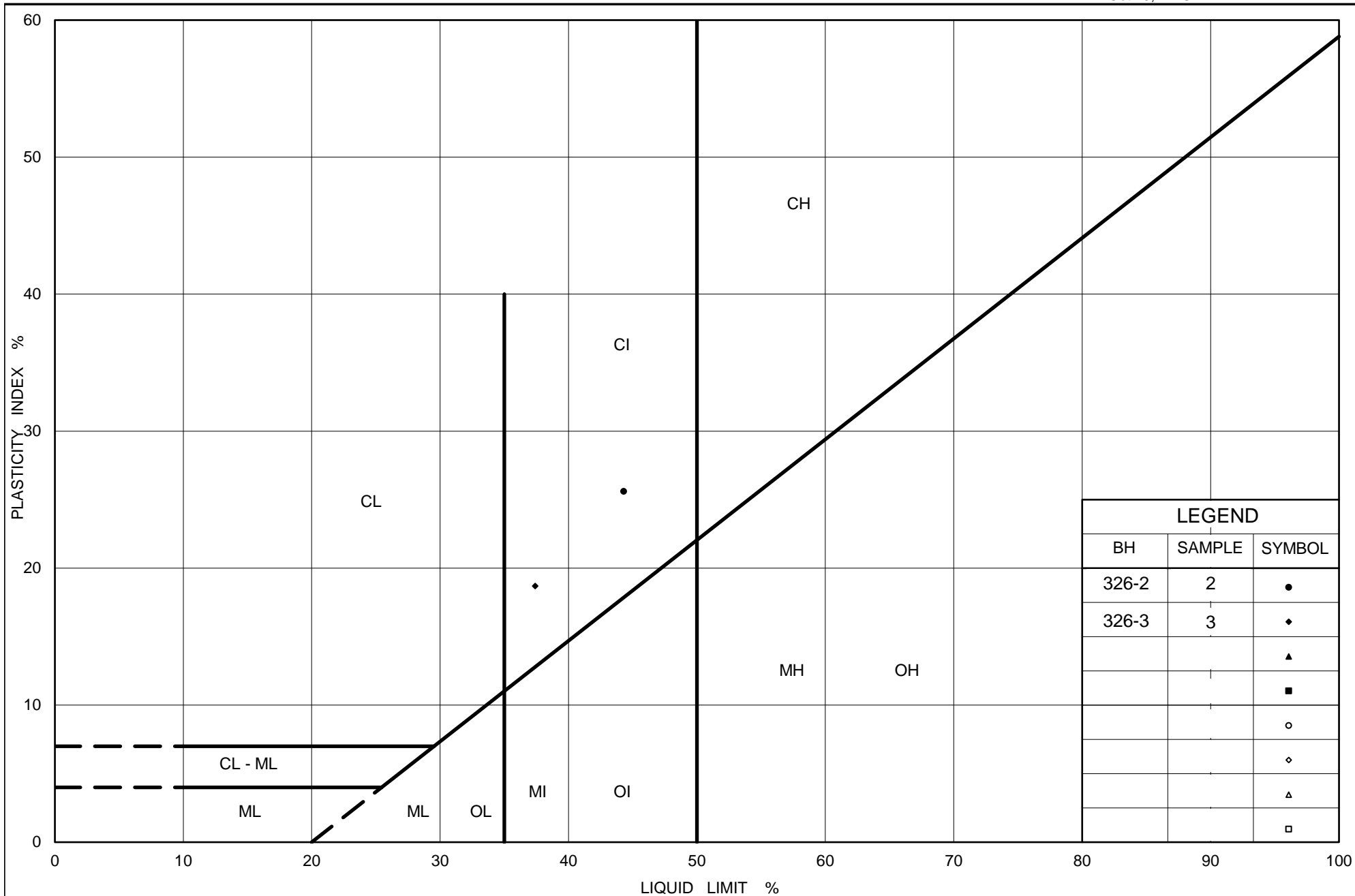
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	326-2	2	176.8
■	326-3	3	175.5
◆	326-2	4	175.3

Project Number: 18105193

Checked By: SMM

Golder Associates

Date: 02-May-19



Ministry of Transportation

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PLASTICITY CHART Gravelly Silty Clay to Silty Clay (FILL)

Figure No. A-3

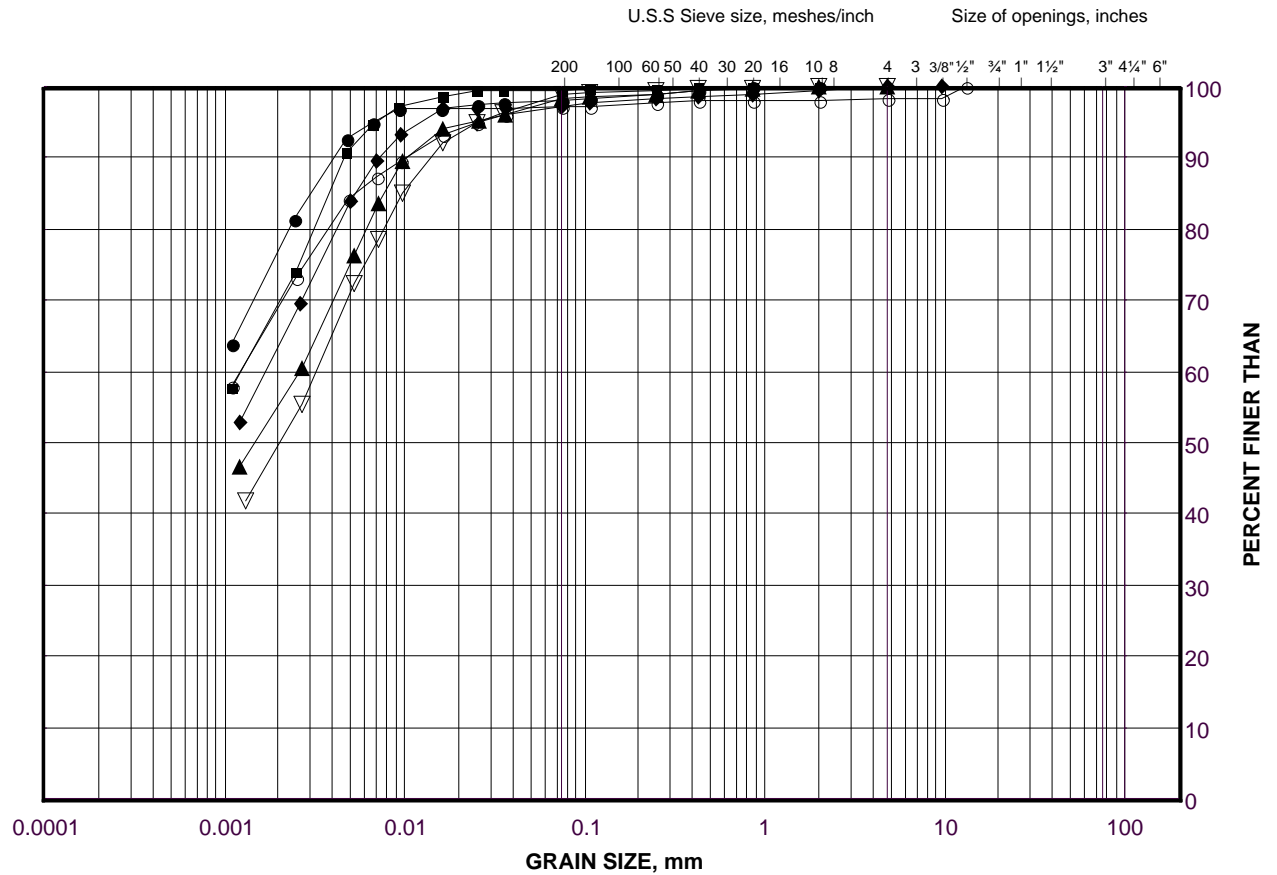
Project No. 18105193

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Silty Clay to Clay (Crust)
(Culvert Site No. 34-458/C)

FIGURE A-4



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

LEGEND

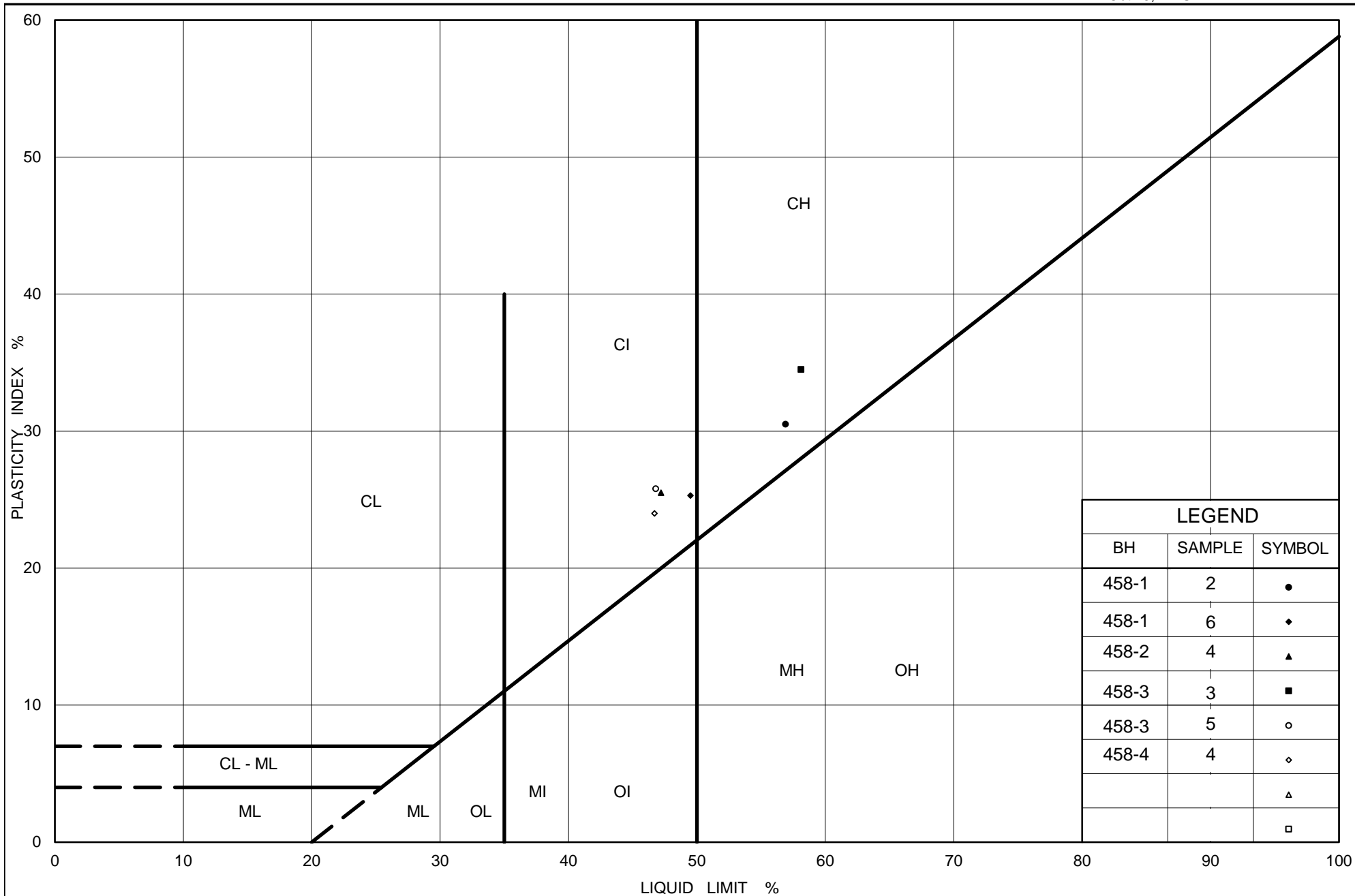
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	458-1	2	177.7
■	458-3	3	177.6
◆	458-4	4	176.7
▲	458-2	4	177.0
▽	458-3	5	176.1
○	458-1	6	174.6

Project Number: 18105193

Checked By: SMM

Golder Associates

Date: 08-May-19



Ministry of Transportation

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PLASTICITY CHART
Silty Clay to Clay (Crust)
(Culvert Site No. 34-458/C)

Figure No. A-5

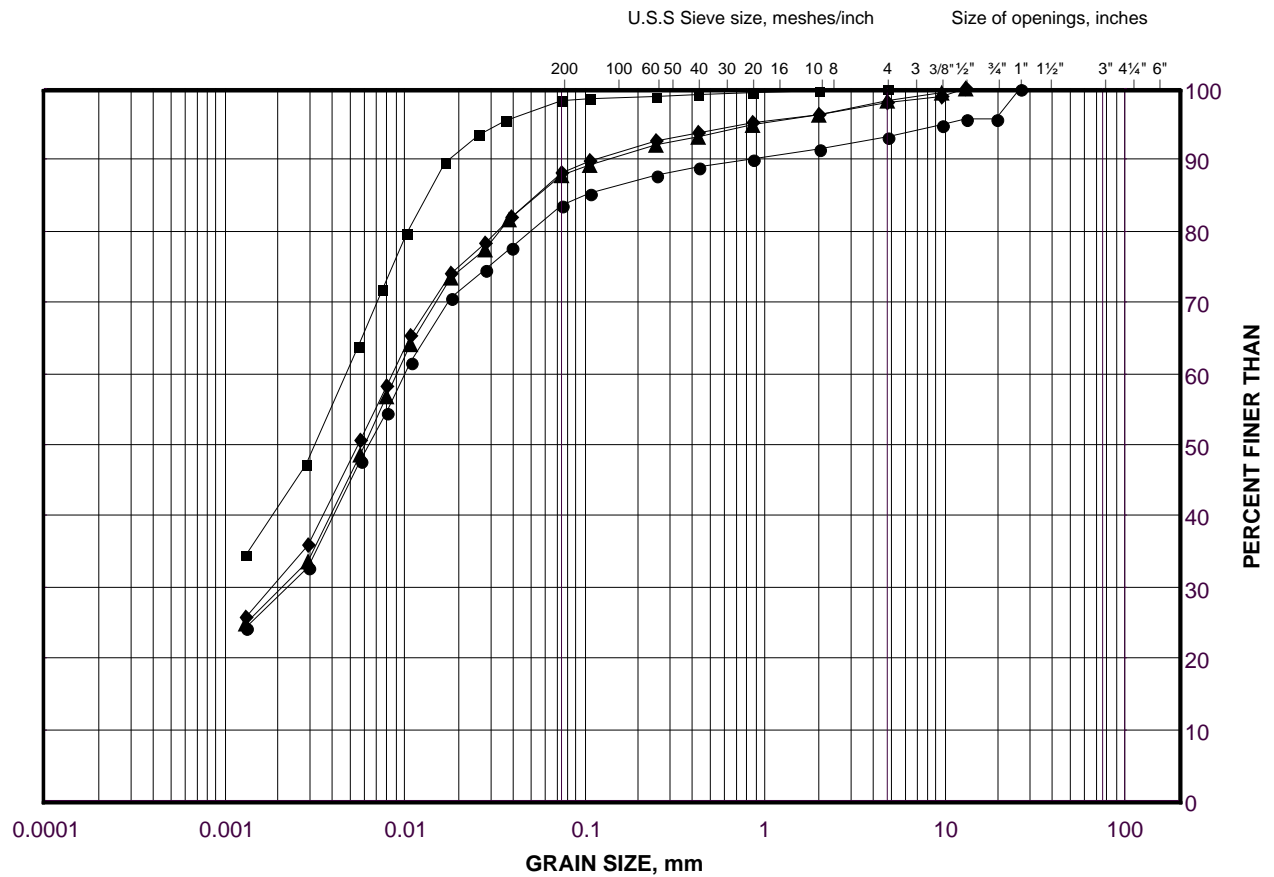
Project No. 18105193

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt
(Culvert Site No. 34-326/C)

FIGURE A-6A



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	326-3	10	168.6
■	326-3	12	165.5
◆	326-1	7	170.2
▲	326-2	9	170.0

Project Number: 18105193

Checked By: SMM

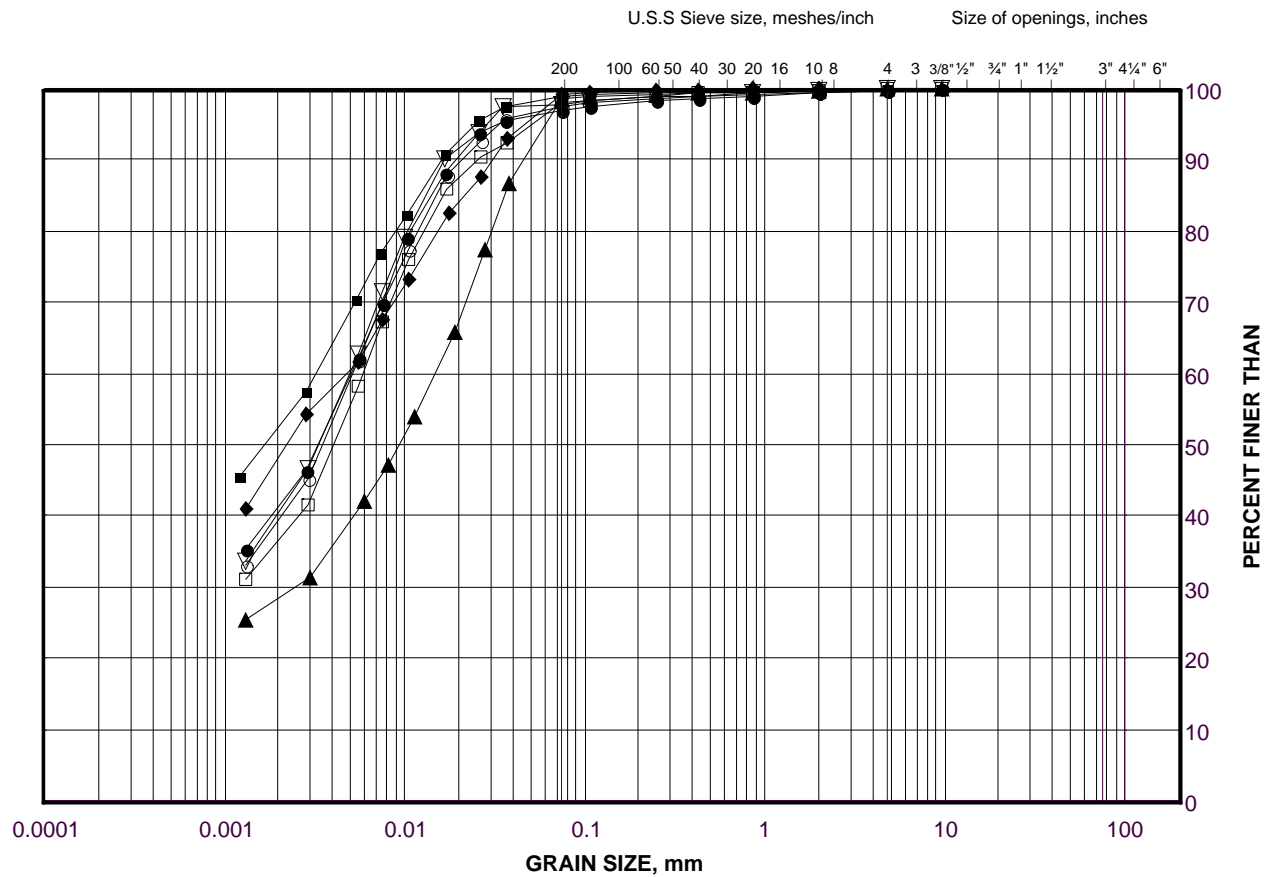
Golder Associates

Date: 08-May-19

GRAIN SIZE DISTRIBUTION

Clayey Silt to Silty Clay
(Culvert Site No. 34-458/C)

FIGURE A-6B



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

LEGEND

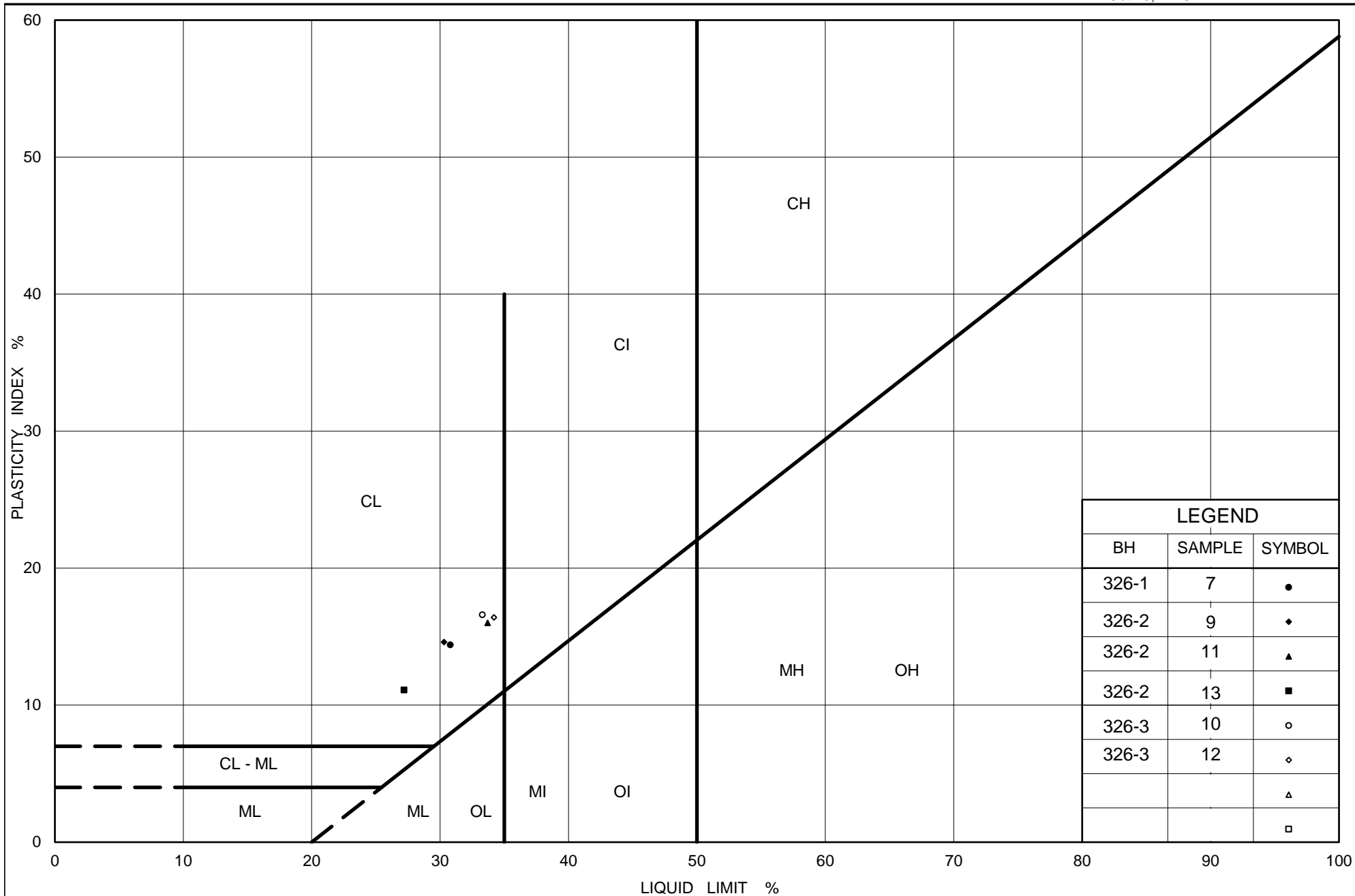
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	458-1	11	166.2
■	458-4	12	165.2
◆	458-2	12	165.6
▲	458-3	12	165.4
▽	458-4	7	172.9
○	458-1	8	170.8
□	458-2	8	171.7

Project Number: 18105193

Checked By: SMM

Golder Associates

Date: 08-May-19



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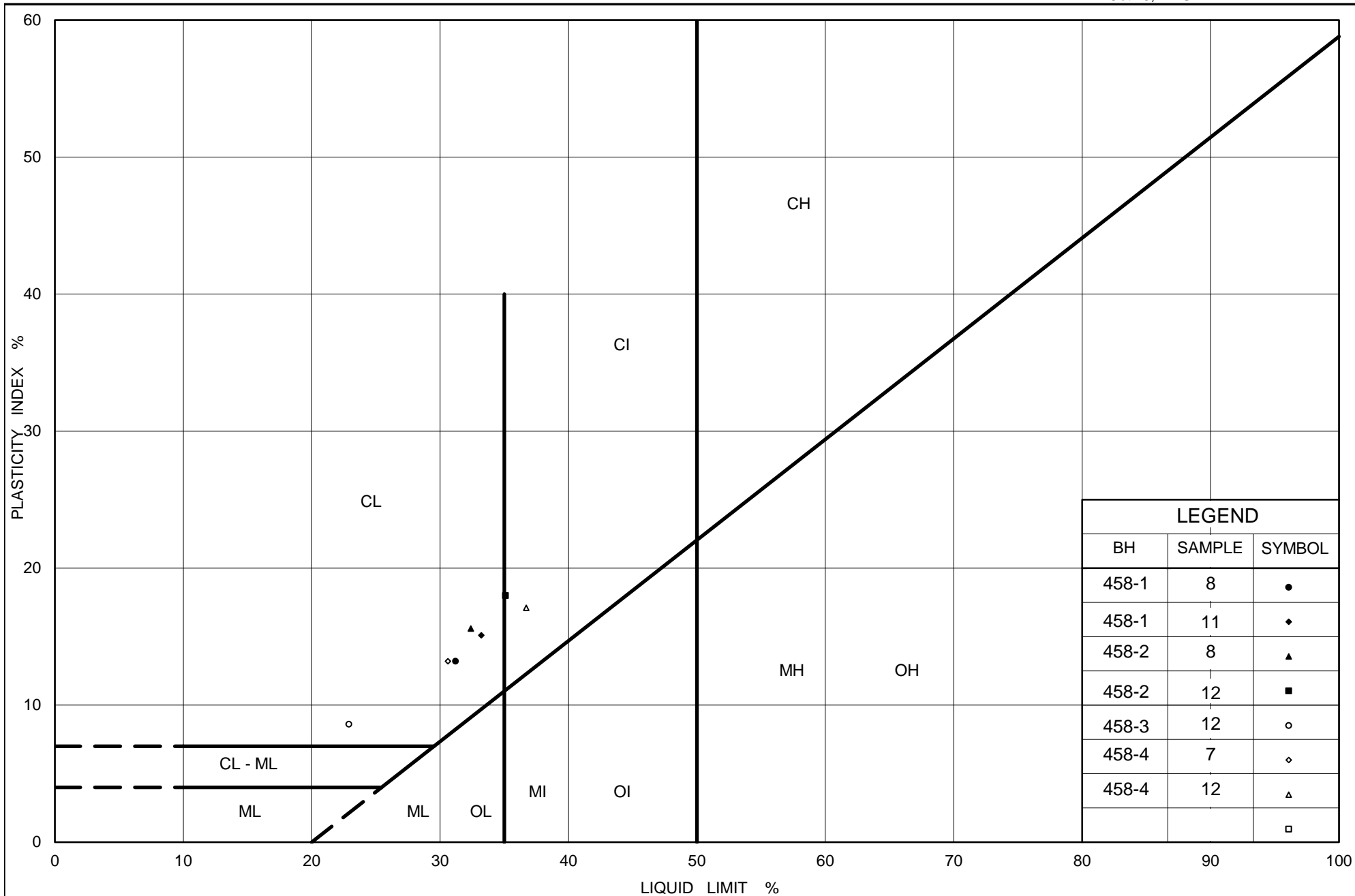
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PLASTICITY CHART Clayey Silt (Culvert Site No. 34-326/C)

Figure No. A-7A

Project No. 18105193

Checked By: SMM



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PLASTICITY CHART Clayey Silt to Silty Clay (Culvert Site No. 34-458/C)

Figure No. A-7B

Project No. 18105193

Checked By: SMM

APPENDIX B

Record of Borehole, Drillhole and
Test Pit Sheets and Geotechnical
Laboratory Results for
Culvert Site No. 34-331/C

PROJECT		18105193		RECORD OF BOREHOLE No 331-1		SHEET 1 OF 1		METRIC											
G.W.P.		2374-15-00		LOCATION		N 4750461.7; E 330386.1 MTM NAD 83 ZONE 10 (LAT. 42.893513; LONG. -79.186731)		ORIGINATED BY KN											
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 70 mm I.D. Hollow Stem Augers		COMPILED BY SE											
DATUM		Geodetic		DATE		January 11 and 14, 2019		CHECKED BY AJS											
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			20	40						60	80	100	20	40
179.3	GROUND SURFACE																		
0.0	ASPHALT (150 mm)																		
0.2	Sand and gravel (FILL)																		
178.7																			
178.3	Sandy clayey silt, trace to some gravel, trace rootlets (FILL)		1A	SS	12														
1.0	Stiff Brown Moist		1B																
	CLAYEY SILT, trace sand, trace gravel, trace silt pockets, trace sand pockets		2	SS	11														
	Stiff to very stiff Brown Moist																		
			3	SS	21														
			4	SS	19														
175.1			5A	SS	14														
			5B																
4.3	Sandy CLAYEY SILT, trace gravel, (TILL)																		
	Stiff Brown Moist																		
	LIMESTONE (BEDROCK) Grey		1	RC	REC 100%														
	Bedrock cored from a depth of 4.3 m to 7.5 m																		
	For bedrock coring details, refer to Record of Drillhole 331-1.																		
			2	RC	REC 99%														
171.8																			
7.5	END OF BOREHOLE																		
	NOTE:																		
	1. Bedrock cored on January 14, 2019, from a drillhole advanced approximately 1 m east of the borehole location.																		
	2. Borehole dry upon completion of soil drilling.																		

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PROJECT: 18105193

RECORD OF DRILLHOLE: 331-1

SHEET 1 OF 1

LOCATION: N 4750461.70 ;E 330386.08

DRILLING DATE: January 14, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 Truck

DRILLING CONTRACTOR: Geo-Environmental

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY												FEATURES	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA				WEATH- ERING INDEX		Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jzon	W1	W2																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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		Continued from Record of Borehole 331-1		175.03																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

DEPTH SCALE

1 : 50



LOGGED: KN

CHECKED: SE

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PROJECT		18105193		RECORD OF BOREHOLE No 331-2		SHEET 1 OF 1		METRIC					
G.W.P.		2374-15-00		LOCATION		N 4750466.1; E 330399.0 MTM NAD 83 ZONE 10 (LAT. 42.893553; LONG. -79.186572)		ORIGINATED BY KN					
DIST		Central HWY 140		BOREHOLE TYPE		Power Auger, 70 mm I.D. Hollow Stem Augers		COMPILED BY SE					
DATUM		Geodetic		DATE		January 11 and 14, 2019		CHECKED BY AJS					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
179.3	GROUND SURFACE												
0.0	ASPHALT (130 mm)												
0.1	Sand and gravel (FILL) Compact Grey Moist		1A	SS	16								
178.3	Clayey silt, some sand, some gravel (FILL) Very stiff Brown-black Moist		1B										
1.0													
177.8	CLAYEY SILT, trace sand, trace gravel Stiff to very stiff Brown, mottled grey Moist		2	SS	14								
1.5													
			3	SS	21								
			4	SS	22								
175.6													
3.7	Sandy CLAYEY SILT, trace gravel (TILL) Very stiff Brown Moist		5	SS	16								
174.9													
4.4	LIMESTONE (BEDROCK) Grey		6	SS	50/0.0								
	Bedrock cored from a depth of 4.4 m to 7.5 m For bedrock coring details, refer to Record of Drillhole 331-2.		1	RC	REC 100%								RQD = 84%
			2	RC	REC 99%								RQD = 91%
171.8	END OF BOREHOLE												
7.5	NOTE: 1. Augers grinding and split-spoon refusal at 4.4 m depth. 2. Bedrock cored on January 14, 2019, from a drillhole advanced approximately 0.3 m south west of the borehole location. 3. Borehole dry upon completion of soil drilling.												

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SHEET 1 OF 1


DATUM: Geodetic

DRILLING CONTRACTOR: Geo- Environmental

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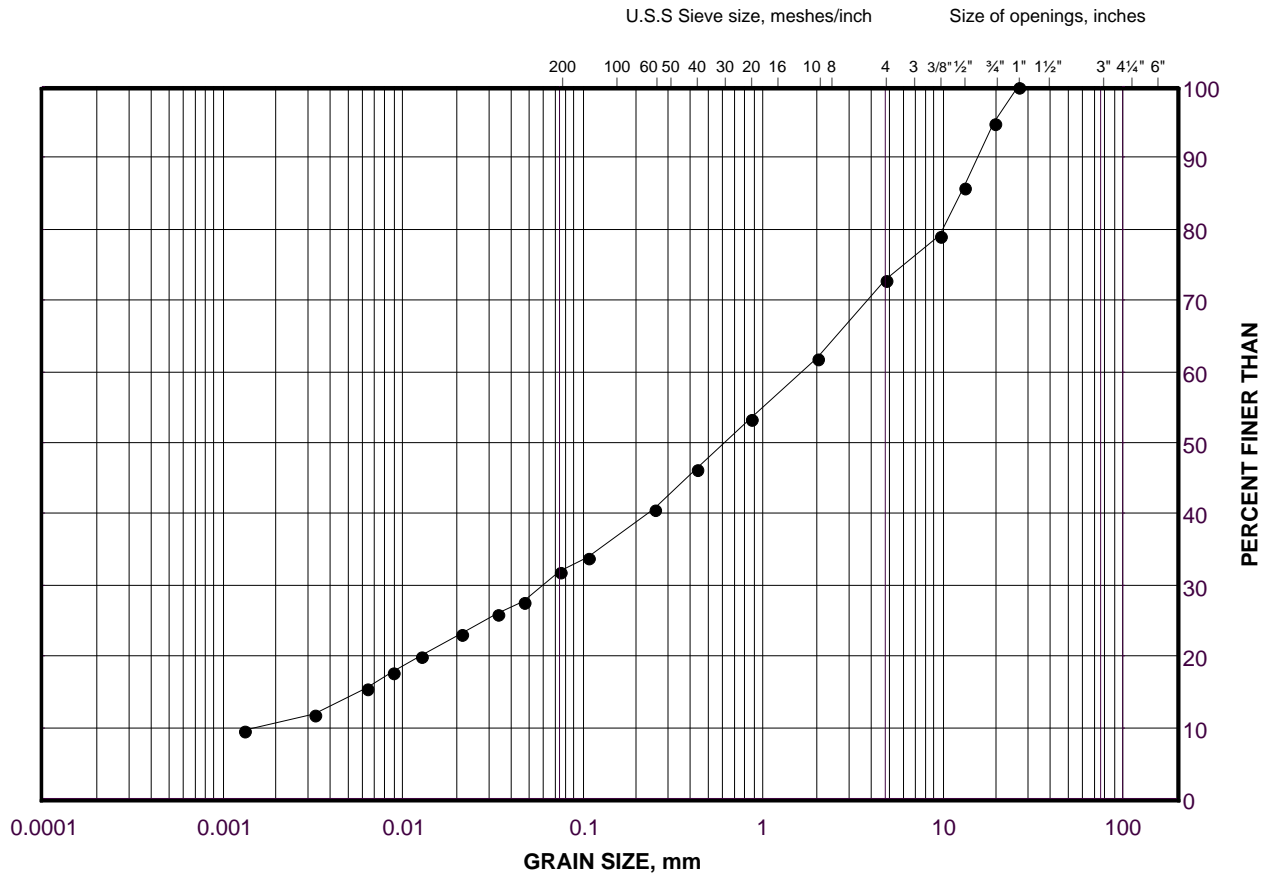
PROJECT <u>18105193</u>		RECORD OF BOREHOLE No 331-3		SHEET 1 OF 1		METRIC										
G.W.P. <u>2374-15-00</u>		LOCATION <u>N 4750469.8; E 330399.7 MTM NAD 83 ZONE 10 (LAT. 42.893577; LONG. -79.186564)</u>		ORIGINATED BY <u>KN</u>												
DIST <u>Central</u> HWY <u>140</u>		BOREHOLE TYPE <u>TEST PIT Manually Advanced</u>		COMPILED BY <u>EN</u>												
DATUM <u>Geodetic</u>		DATE <u>March 21, 2019</u>		CHECKED BY <u>AJS</u>												
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
178.9	GROUND SURFACE															
0.0	TOPSOIL (100 mm)		1	-	-											GR SA SI CL 28 40 21 11
0.2	Gravelly silty clay with sand, trace organics, cobbles (FILL) Brown Moist END OF TEST PIT															

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GRAIN SIZE DISTRIBUTION

Gravelly Silty Clay with Sand (FILL)

FIGURE B-1



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

LEGEND

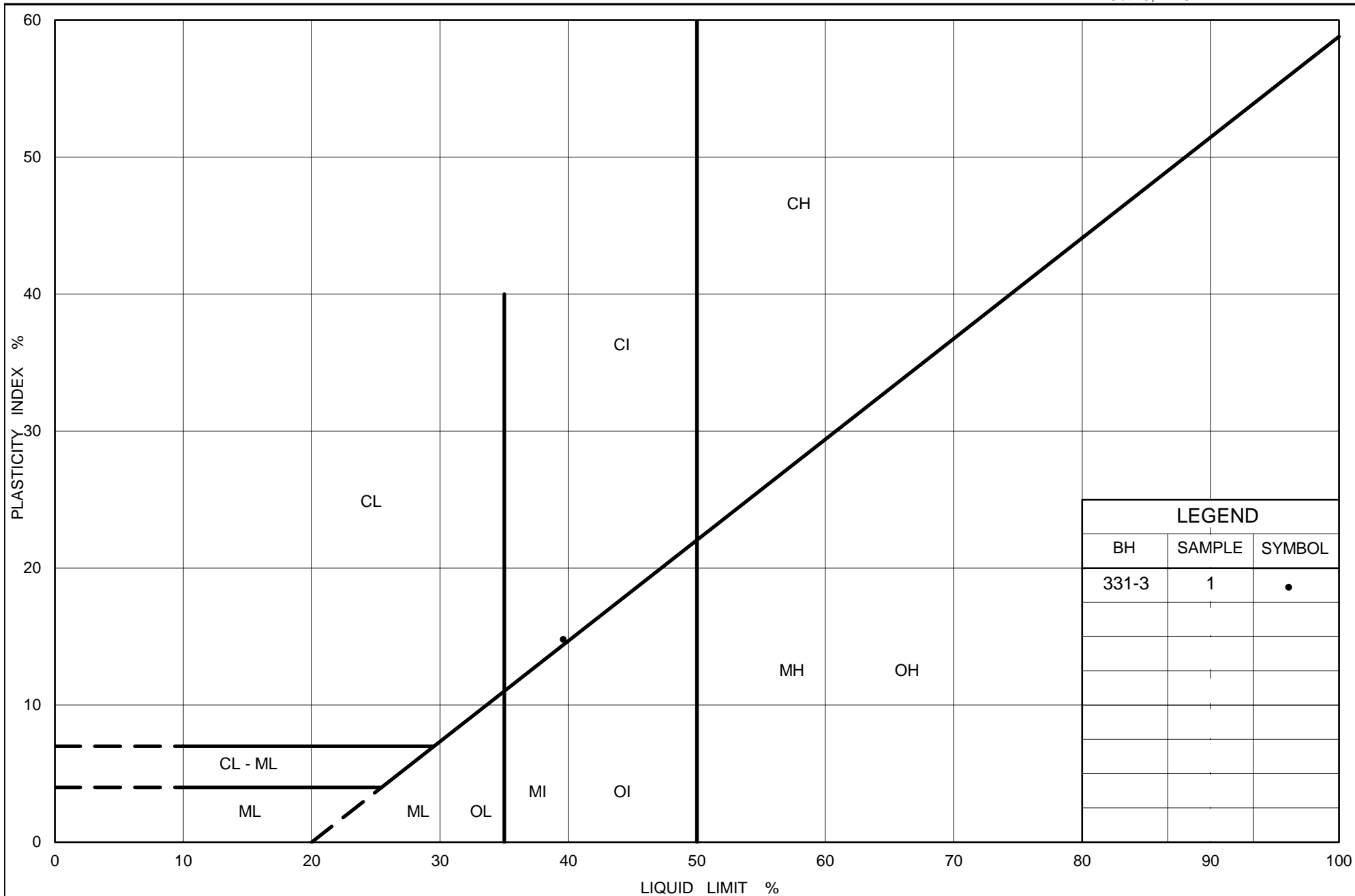
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	331-3	1	178.8

Project Number: 18105193

Checked By: SMM

Golder Associates

Date: 02-May-19



Ministry of Transportation

Ontario

PLASTICITY CHART Gravelly Silty Clay with Sand (FILL)

Figure No. B-2

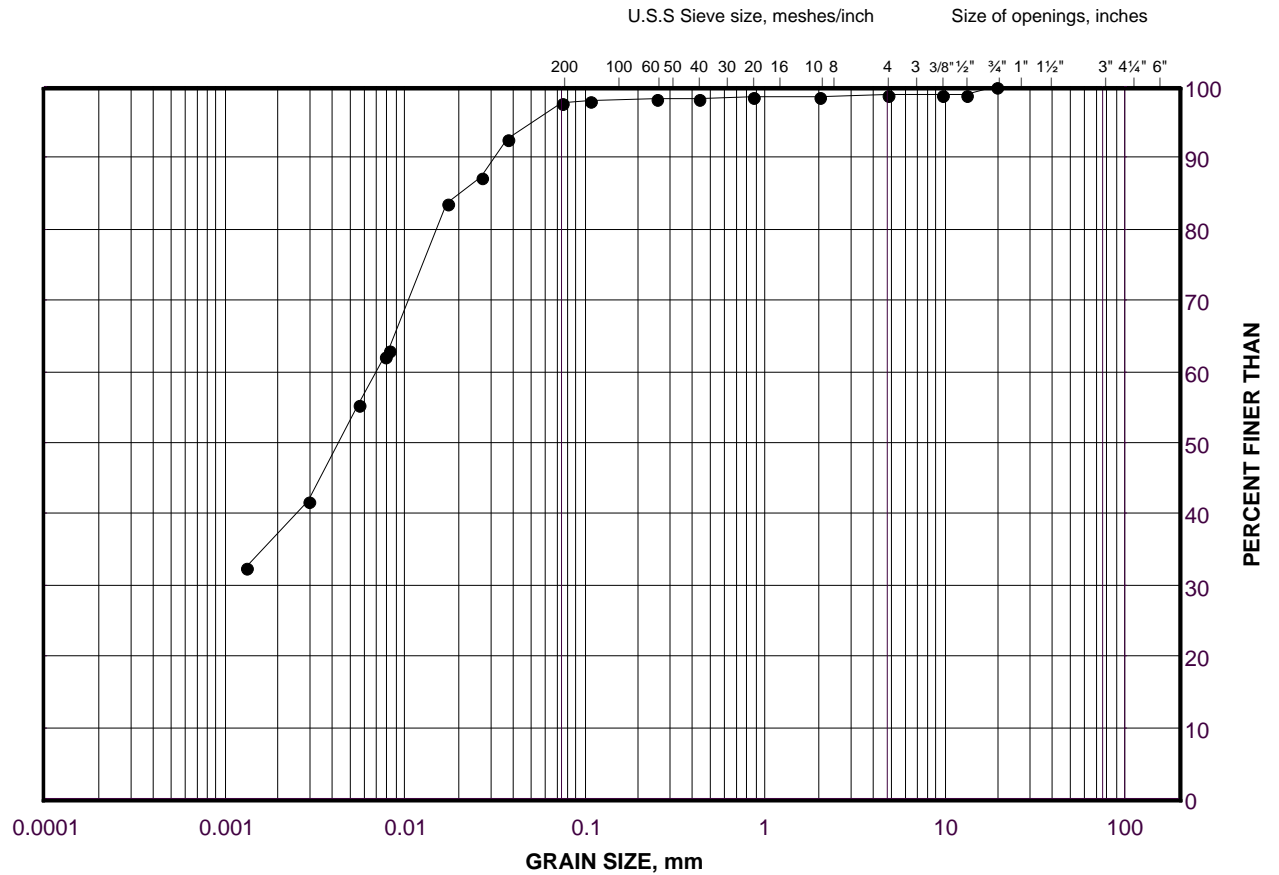
Project No. 18105193

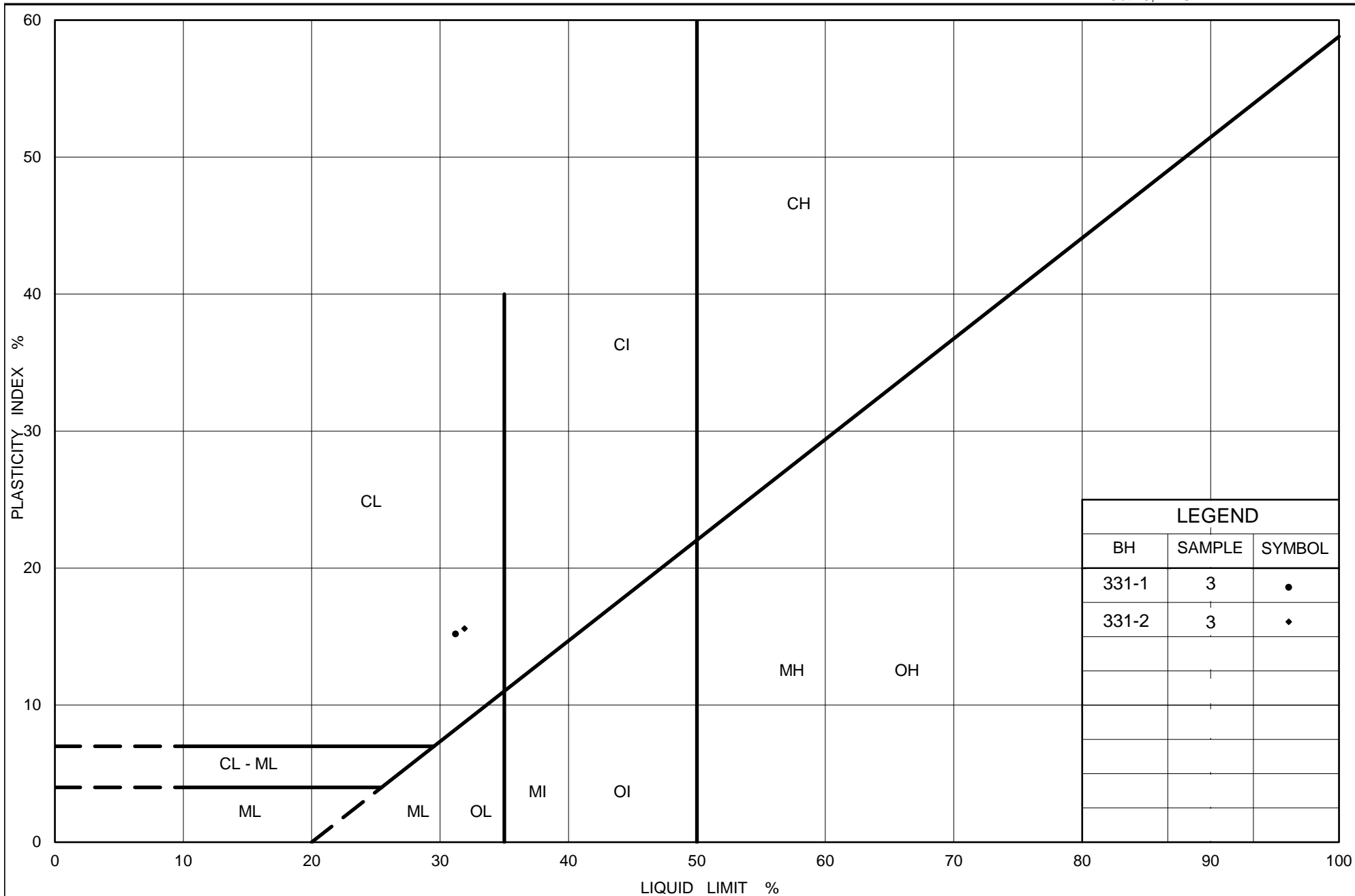
Checked By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE B-3





Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt

Figure No. B-4

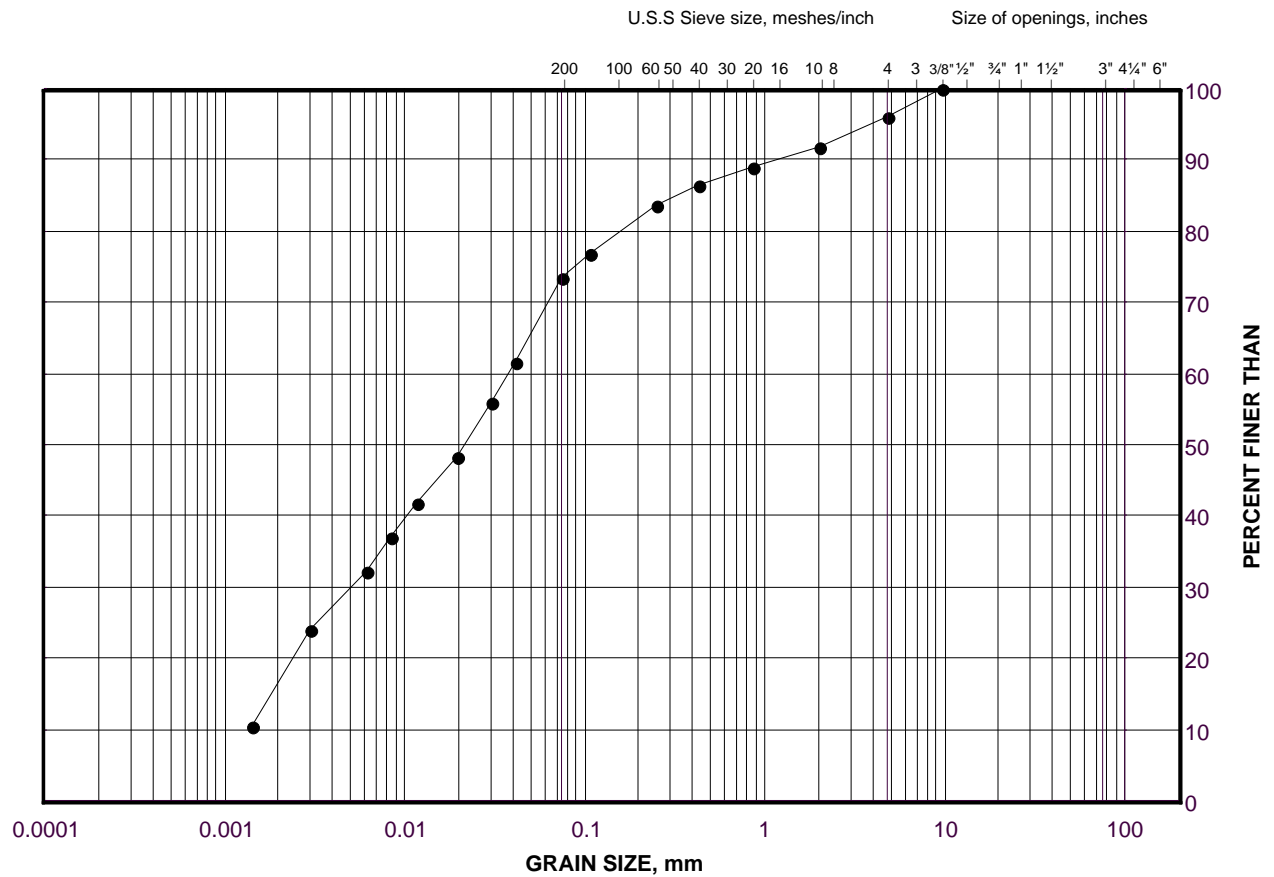
Project No. 18105193

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt (TILL)

FIGURE B-5



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

LEGEND

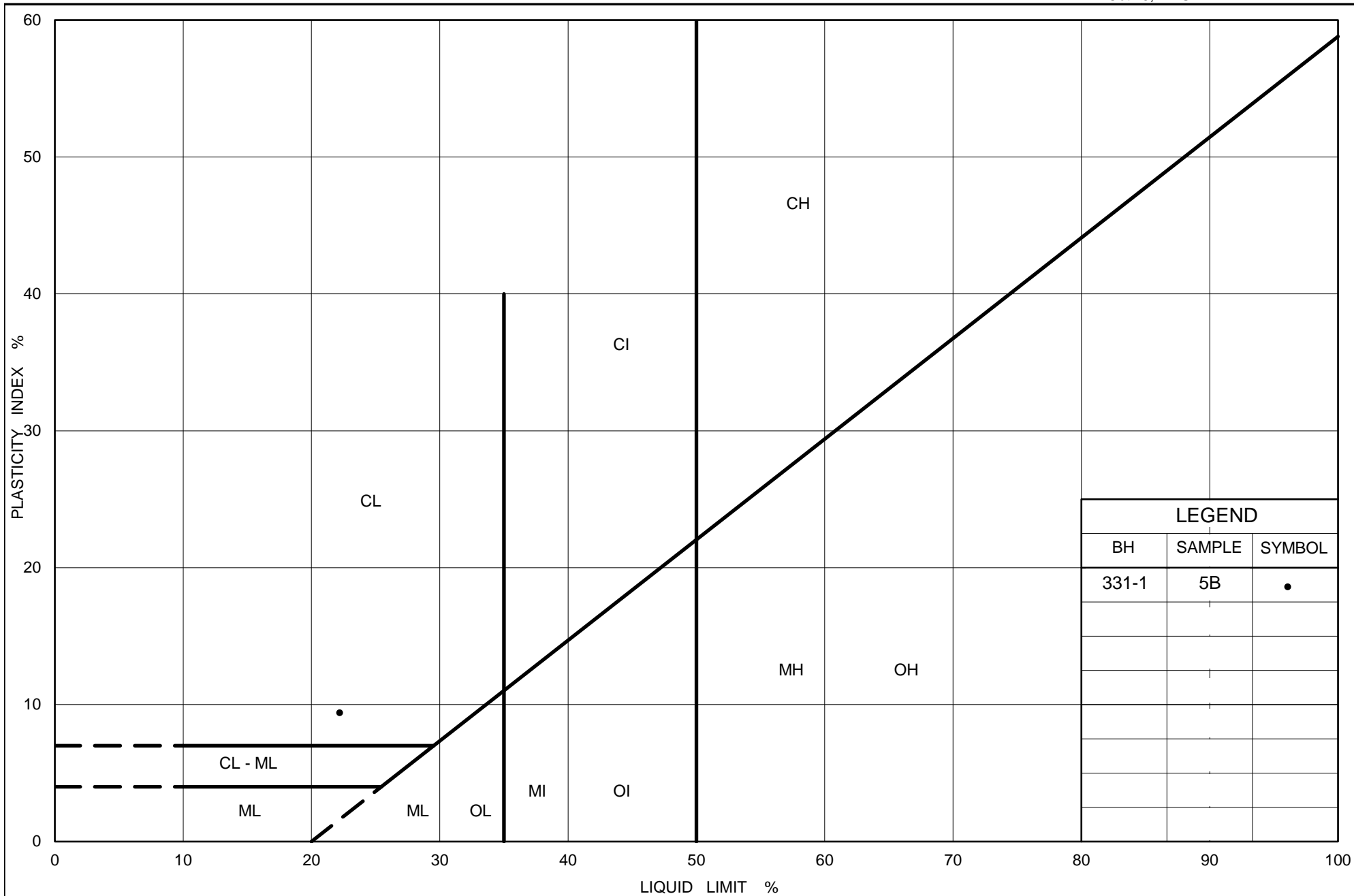
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	331-1	5B	175.2

Project Number: 18105193

Checked By: SMM

Golder Associates

Date: 02-May-19



Ministry of Transportation

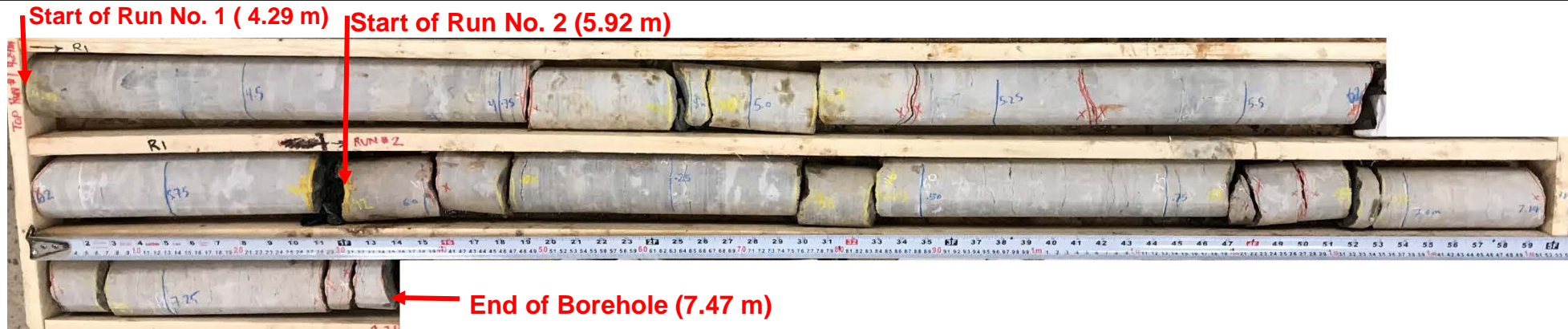
Ontario

PLASTICITY CHART Clayey Silt (TILL)

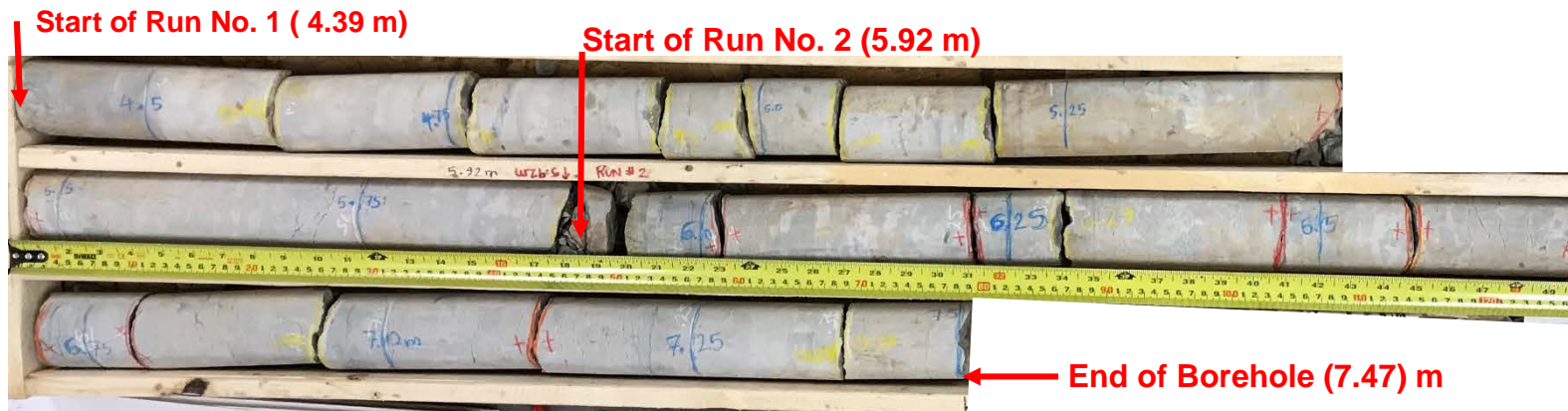
Figure No. B-6

Project No. 18105193

Checked By: SMM




Borehole 331-1: 4.29 m to 7.47 m



Borehole 331-2: 4.39 m to 7.47 m

0 m	0.25 m	0.5 m	0.75 m	1.0 m	1.25 m	1.5 m
0 ft	1 ft	2 ft	3 ft	4 ft	5 ft	

Scale

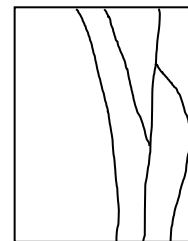
PROJECT		MTO G.W.P. 2374-15-00 Culvert Replacements At Highway 3, 140, Niagara Region			
TITLE		Bedrock Core Photographs Drillholes 331-1 and 331-2			
 GOLDER		PROJECT No. 18105193		FILE No. ----	
		DRAFT	KN	20190415	SCALE AS SHOWN
		CADD	--	--	VER. 1.
		CHECK	SMM		FIGURE B-7
		REVIEW			

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS ASTM D7012

SAMPLE IDENTIFICATION			
PROJECT NUMBER	18105193	SAMPLE NUMBER	UCS 1
PROJECT NAME	AIA /2017-E-0068 hwy 3 58 140 Niaga	SAMPLE DEPTH, m	4.29-4.48
BOREHOLE NUMBER	331-1	DATE:	2019-02-04

TEST CONDITIONS			
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.30

SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	14.63	WATER CONTENT, (specimen) %	0.20
SAMPLE DIAMETER, cm	6.35	UNIT WEIGHT, kN/m ³	26.81
SAMPLE AREA, cm ²	31.66	DRY UNIT WT., kN/m ³	26.76
SAMPLE VOLUME, cm ³	463.08	SPECIFIC GRAVITY	-
WET WEIGHT, g	1266.50	VOID RATIO	-
DRY WEIGHT, g	1263.97		

VISUAL INSPECTION
FAILURE SKETCH


TEST RESULTS			
STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	72.4

REMARKS:

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012

FIGURE B-8B



BEFORE COMPRESSION



AFTER COMPRESSION

Date Feb. 7, 2019
Project 18105193

Golder Associates

Drawn Frank
Chkd. MM

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS ASTM D7012

SAMPLE IDENTIFICATION			
PROJECT NUMBER	18105193	SAMPLE NUMBER	UCS 2
PROJECT NAME	AIA /2017-E-0068 hwy 3 58 140 Niaga	SAMPLE DEPTH, m	6.02-6.22
BOREHOLE NUMBER	331-2	DATE:	2019-02-04

TEST CONDITIONS			
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.26

SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	14.31	WATER CONTENT, (specimen) %	0.10
SAMPLE DIAMETER, cm	6.35	UNIT WEIGHT, kN/m ³	27.37
SAMPLE AREA, cm ²	31.63	DRY UNIT WT., kN/m ³	27.34
SAMPLE VOLUME, cm ³	452.71	SPECIFIC GRAVITY	-
WET WEIGHT, g	1264.01	VOID RATIO	-
DRY WEIGHT, g	1262.75		

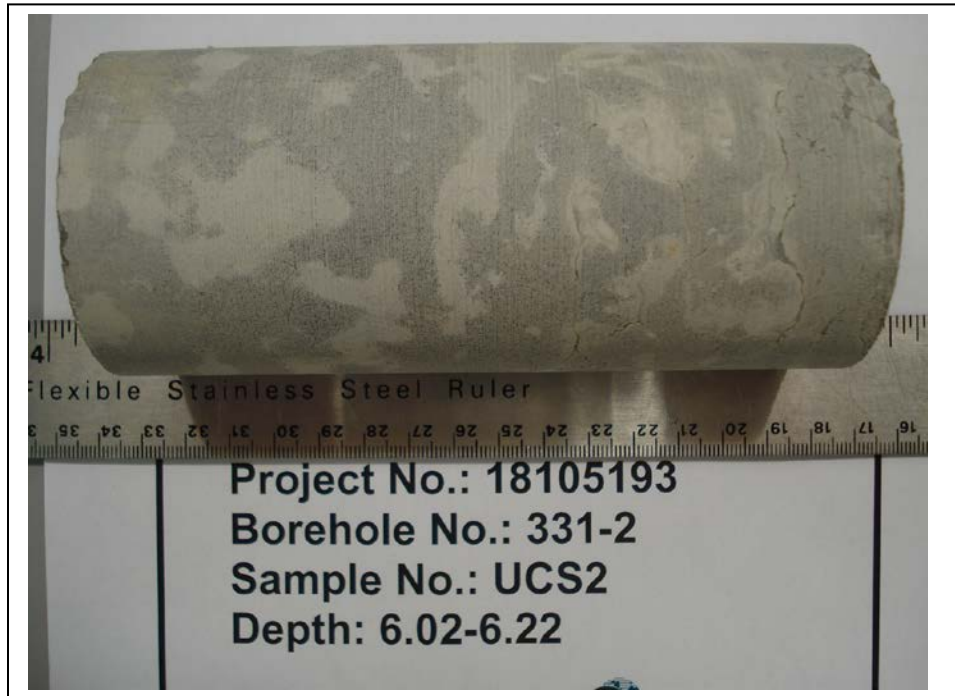
VISUAL INSPECTION
FAILURE SKETCH


TEST RESULTS			
STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	74.5

REMARKS:

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012

FIGURE B-9B



BEFORE COMPRESSION



AFTER COMPRESSION

Date Feb. 7, 2019
Project 18105193

Golder Associates

Drawn Frank
Chkd. MM

APPENDIX C

**Analytical Laboratory Test Results
(Maxxam Analytics)**

Your Project #: 18105193
Site Location: HWY 3, 58, 140 NIAGARA
Your C.O.C. #: 122132

Attention: Alex Szot

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2019/02/05
Report #: R5583500
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B924885

Received: 2019/01/29, 12:40

Sample Matrix: Soil
Samples Received: 6

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	6	N/A	2019/02/04	CAM SOP-00463	EPA 325.2 m
Conductivity	6	N/A	2019/02/01	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	6	2019/02/01	2019/02/01	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	6	2019/01/29	2019/02/01	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	6	N/A	2019/02/04	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing. Maxxam is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested. When sampling is not conducted by Maxxam, results relate to the supplied samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Your Project #: 18105193
Site Location: HWY 3, 58, 140 NIAGARA
Your C.O.C. #: 122132

Attention: Alex Szot

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2019/02/05
Report #: R5583500
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B924885

Received: 2019/01/29, 12:40

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		IWC430		IWC431		IWC432	IWC433		IWC434		
Sampling Date		2019/01/08		2019/01/15		2019/01/11	2019/01/11		2019/01/10		
COC Number		122132		122132		122132	122132		122132		
	UNITS	458-3 SS6	RDL	326-3 SS4	RDL	331-2 SS5	331-1 SS4	RDL	458-2 SS5	RDL	QC Batch

Calculated Parameters											
Resistivity	ohm-cm	1300		1000		3200	700		430		5950491
Inorganics											
Soluble (20:1) Chloride (Cl-)	ug/g	330	20	76	20	82	710	20	58	20	5956167
Conductivity	umho/cm	794	2	966	2	312	1420	2	2340	2	5955891
Available (CaCl2) pH	pH	7.78		7.73		7.81	7.82		7.83		5956055
Soluble (20:1) Sulphate (SO4)	ug/g	220	20	810	40	61	120	20	3600	100	5956190
RDL = Reportable Detection Limit											
QC Batch = Quality Control Batch											

Maxxam ID		IWC434			IWC436		
Sampling Date		2019/01/10			2019/01/16		
COC Number		122132			122132		
	UNITS	458-2 SS5	RDL	QC Batch	326-2 SS3	RDL	QC Batch

Calculated Parameters							
Resistivity	ohm-cm				670		5950491
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g				410	20	5956167
Conductivity	umho/cm	2290	2	5955891	1490	2	5955891
Available (CaCl2) pH	pH				7.70		5956055
Soluble (20:1) Sulphate (SO4)	ug/g				830	40	5956190
RDL = Reportable Detection Limit							
QC Batch = Quality Control Batch							
Lab-Dup = Laboratory Initiated Duplicate							

TEST SUMMARY

Maxxam ID: IWC430
Sample ID: 458-3 SS6
Matrix: Soil

Collected: 2019/01/08
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

Maxxam ID: IWC431
Sample ID: 326-3 SS4
Matrix: Soil

Collected: 2019/01/15
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

Maxxam ID: IWC432
Sample ID: 331-2 SS5
Matrix: Soil

Collected: 2019/01/11
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

Maxxam ID: IWC433
Sample ID: 331-1 SS4
Matrix: Soil

Collected: 2019/01/11
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

Maxxam ID: IWC434
Sample ID: 458-2 SS5
Matrix: Soil

Collected: 2019/01/10
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva

Maxxam Job #: B924885
Report Date: 2019/02/05

Golder Associates Ltd
Client Project #: 18105193
Site Location: HWY 3, 58, 140 NIAGARA
Sampler Initials: KN

TEST SUMMARY

Maxxam ID: IWC434
Sample ID: 458-2 SS5
Matrix: Soil

Collected: 2019/01/10
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

Maxxam ID: IWC434 Dup
Sample ID: 458-2 SS5
Matrix: Soil

Collected: 2019/01/10
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva

Maxxam ID: IWC436
Sample ID: 326-2 SS3
Matrix: Soil

Collected: 2019/01/16
Shipped:
Received: 2019/01/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5956167	N/A	2019/02/04	Deonarine Ramnarine
Conductivity	AT	5955891	N/A	2019/02/01	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	5956055	2019/02/01	2019/02/01	Gnana Thomas
Resistivity of Soil		5950491	2019/02/01	2019/02/01	Ewa Pranjic
Sulphate (20:1 Extract)	KONE/EC	5956190	N/A	2019/02/04	Alina Dobreanu

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	7.7°C
-----------	-------

Sample 326-1 SS3 has not been analyzed as per client request.

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 18105193
Site Location: HWY 3, 58, 140 NIAGARA
Sampler Initials: KN

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5955891	Conductivity	2019/02/01			103	90 - 110	<2	umho/cm	2.2	10
5956055	Available (CaCl2) pH	2019/02/01			100	97 - 103			1.7	N/A
5956167	Soluble (20:1) Chloride (Cl-)	2019/02/04	108	70 - 130	101	70 - 130	<20	ug/g	NC	35
5956190	Soluble (20:1) Sulphate (SO4)	2019/02/04	NC	70 - 130	99	70 - 130	<20	ug/g	2.4	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

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

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.


Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Ewa Pranjić, M.Sc., C.Chem, Scientific Specialist

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Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <u>Goldier Associates</u>		Company Name: <u> </u>		Quotation #: <u> </u>		<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses	
Contact Name: <u>Alex Szot</u>		Contact Name: <u> </u>		P.O. #/ AFER: <u> </u>		PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Address: <u>6925 Century Ave, Suite 100, Mississauga, ON</u>		Address: <u> </u>		Project #: <u>18105193</u>		Rush TAT (Surcharges will be applied)	
Phone: <u>905 567 4444</u> Fax: <u> </u>		Phone: <u> </u> Fax: <u> </u>		Site Location: <u>Hwy 3, 58, 140 Niagara</u>		<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Email: <u>Alex.Szot@goldier.com</u>		Email: <u> </u>		Site #: <u> </u>		Date Required: <u> </u>	
Sampled By: <u>K. Nero</u>		Sampled By: <u> </u>		Sampled By: <u> </u>		Rush Confirmation #: <u> </u>	
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY							
Regulation 153		Other Regulations		Analysis Requested		LABORATORY USE ONLY	
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other <input type="checkbox"/> Table <u> </u> FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQIO <input type="checkbox"/> Region <input type="checkbox"/> Other (Specify) <u> </u> <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)		FIELD FILTERED (CIRCLE) Metals / Hg / CrVI BTEX / PCF1 PCF2, 3, 4 VOCs REG 153 METALS & INORGANICS REG 153 ICMS METALS REG 153 METALS (Pb, Cr, Hg, PCFMS Metals, Hg, B) Corrosivity Package (PH) Sulphate Chloride Resistivity (conductivity)		CUSTODY SEAL Y / N Present Intact N N 8/8/7 COOLING MEDIA PRESENT: Y / <u>N</u> COMMENTS	
Include Criteria on Certificate of Analysis: Y / N							
SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM							
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	LABORATORY USE ONLY
1	458-3 SS6	2019/01/09	AM	Soil	1	1 ml	1 x 250 mL jar
2	326-3 SS4	2019/01/15	AM	Soil	1	1 ml	1 x 250 mL jar
3	331-2 SS5	2019/01/11	AM	Soil	1	1 ml	1 x 250 mL jar
4	331-1 SS4	2019/01/11	AM	Soil	1	1 ml	1 x 250 mL jar
5	458-2 SS5	2019/01/10	AM	Soil	1	1 ml	1 x 25 mL jar
6	326-1 SS3	2019/01/17	AM	Soil	1	1 ml	1 x 25 mL jar
7	326-2 SS3	2019/01/16	AM	Soil	1	1 ml	1 x 25 mL jar
8							
9							
10							
RELINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)
<u>Ema Gitej</u>		2019/01/29	12:30	<u>Dipika Singh</u>		2019/01/29	12:40

29-Jan-19 12:40

Ema Gitej

B924885

CA2

ENV-1405

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golder.com