



FINAL REPORT

**Foundation Investigation
Replacement of Culvert CV-0416-000185
Highway 416
Ottawa, Ontario**

G.W.P. 4113-16-00

W.P. 4045-18-01

Submitted to:

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PART A

Foundation Investigation
Replacement of Culvert CV-0416-000185
Highway 416
Ottawa, Ontario

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detailed design of replacement of a non-structural culvert on Highway 416 and a structural culvert on Highway 417 under Assignment No. 7, of the Eastern Region Retainer Mega 10 (Assignment No. 4017-E-0019).

This report presents the results of the foundation investigation carried out for the replacement of the non-structural Culvert CV-0416-000185. The replacement of the structure is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code, S6-14 (CHBDC).

The scope of work for the foundation engineering services associated with the replacement was outlined in Golder's Change in Scope Memorandum dated May 8, 2019. The investigation program was developed to meet the requirements of Work Item Quote Form for Agreement No. 4016-E-0019, Assignment 7, as well as the structural requirements of Dillon to complete the design. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for the project dated August 2019.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 Site Description

Culvert CV-0416-000185 is located at Station 26+926 under the northbound lanes of Highway 416, approximately 1.0 km north of Ventnor Road near Spencerville, Ontario. The location of the culvert is shown on the Key Plan on Drawings 1 and 2. Site photographs showing the general conditions at the site are presented in Appendix D.

At this location, Highway 416 is a divided highway with two travel lanes in each direction separated by a wide, vegetated median ditch. Steel cable guiderails are present along both side of the highway in the vicinity of the culvert.

Information provided in the Work Order for this assignment indicates that the existing culvert is a structural-plated corrugated steel pipe arch (SPCSPA) culvert with a vertical dimension of 1,850 mm and a horizontal dimension of 2,620 mm at the base of the arch and is 28.3 m long. There are no headwalls at this location. The elevation of the culvert invert ranges from 93.4 to 93.5 m and creek flow through the culvert is from west to east.

The base plan mapping provided by Dillon for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of pavement elevation of Highway 416 in the vicinity of the culvert ranges from 98.6 to 99.0 m and the top of culvert elevation ranges from 95.2 to 95.4 m corresponding to cover over the culvert from the shoulder to the top of the culvert ranging from about 3.2 to 3.8 m. Based on a visual observation at the time of the site investigation, no signs of foundation settlement were observed, and the existing slopes appear to be performing satisfactorily.

The culvert was last inspected in 2013 and identified as a fisheries culvert with the presence of species at risk turtles.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 416 lies within the minor physiographic region known as the Edwardsburg Sand Plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Edwardsburg Sand Plain region is characterized by a slightly undulating sand plain that overlies boulder clay and bedrock. The sand is likely glaciofluvial in origin, probably deposited in the late stages of the Champlain Sea with a few morainic structures remaining.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes that have recently occurred in the WQ zone are the 1935 Témiscaming event, which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event, which had a magnitude of 5.6.

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation

The field work for the 2019 investigation was carried out between July 11 and July 18, 2019 and August 6 and 7 2019, and included advancing six boreholes, numbered 19-7001 to 19-7005 and 19-7015, with three located within the highway platform and one each at the culvert inlet and outlet. Borehole 19-7015 was advanced approximately 1.5 m south of Borehole 19-7005 due to the presence of boulders encountered within the embankment fill at Borehole 19-7005.

Table 1 below further outlines the locations of the boreholes with respect to the existing culvert.

Boreholes 19-7001 and 19-7002 were advanced at the inlet and outlet of the culvert respectively using portable rotary drilling equipment employing a half weight hammer lifted manually and dropped from the Standard Penetration Test (SPT) height. Where a half weight hammer was used, the N values presented on the Record of Boreholes are corrected for the lower energy drive. The highway boreholes were advanced with CME55 truck-mounted drilling equipment. The drilling equipment was supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. (CCC) of Ottawa, Ontario.

Traffic control required to close the driving lanes of Highway 416 while carrying out field operations was provided by Beacon Lite Ltd. of Ottawa, Ontario.

Soil samples in the highway boreholes were obtained at vertical sampling intervals of about 0.76 m, using a 50 mm outer diameter split-spoon sampler in general accordance with the procedure Standard Penetration Test (ASTM D1586). Soil samples from Boreholes 19-7001 and 19-7002, which were advanced with the portable drilling equipment, were obtained in nearly continuous vertical increments of about 0.6 m.

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

Bedrock core samples were obtained in all boreholes, except Borehole 19-7005, using NQ sized diamond drilling equipment at the highway boreholes (Boreholes 19-7003, 19-7004A and 19-7015) and 63 mm outside diameter thin wall coring equipment at the boreholes advanced using a portable drill rig (Boreholes 19-7001 and 19-7002).

The boreholes were backfilled with bentonite within the bedrock, and bentonite mixed with soil cuttings within the overburden. The boreholes were then capped with either asphaltic concrete cold patch or granular material, depending on the surrounding surface cover. The boreholes were backfilled in general accordance with the intent of O.Reg 903, as amended. The site conditions were restored following completion of the field work.

The field work was supervised on a full-time basis by members of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, logged the boreholes and examined and cared for the samples. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg Limits testing were carried out on selected soil samples at Golder's Ottawa laboratory. Unconfined compressive strength testing was carried out on select samples of the dolostone bedrock at Golder's Mississauga laboratory. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths are summarized in Table 1.

Table 1: Summary of Borehole Locations

Borehole	Location	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Depths (m)
		Northing (m)	Easting (m)		
19-7001	Culvert Inlet	4971040.4	379081.6	95.3	8.1
19-7002	Culvert Outlet	4971059.1	379102.1	95.7	8.2
19-7003	Highway 416 North of Culvert	4971065.2	379084.4	98.7	10.9
19-7004A	Highway 416 South of Culvert	4971043.6	379099.6	98.6	11.8
19-7005	Highway 416 South of Culvert	4971027.6	379101.6	99.0	3.6 ¹
19-7015	Highway 416 South of Culvert	4971026.4	379102.4	99.0	12.1

Notes: ¹Borehole terminated at auger refusal within the embankment fill

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ testing from the current investigation are given on the Record of Borehole, and Drillhole sheets presented in Appendix A. The results of the laboratory testing carried out during the investigation are presented on the Record of Borehole sheets as well as on Figures B1 to B7 in Appendix B. The borehole locations and the interpreted stratigraphic profile projected along the highway and along the alignment of the existing culvert and are provided on Drawings 1 and 2, respectively.

Photographs of the core recovered from the underlying bedrock are shown on Figures A1 to A10, provided in Appendix A. The results of basic chemical analysis completed on select soil samples are provided in Appendix C.

The stratigraphic boundaries shown on the borehole sheets and on the interpreted stratigraphic sections from Drawings 1 and 2, are inferred from observations of the drilling progress and noncontinuous sampling and therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

4.2 Site Stratigraphy Overview

At the boreholes, the subsurface conditions generally consist of asphaltic concrete pavement or topsoil, overlying fill materials containing cobbles and boulders, overlying native sand and silt, which in turn overlies clayey silt, overlying glacial till, all underlain by dolostone bedrock. Buried topsoil and peat were encountered below the embankment fill in Boreholes 19-7002, 19-7004A and 19-7015.

A more detailed description of the overburden soil deposits, and bedrock geology conditions encountered during the field investigation is provided in the following sections.

4.3 Highway 416 Embankment

4.3.1 Surface Cover / Surficial Materials

Boreholes 19-7003 to 19-7005 and 19-7015 were advanced through the Highway 416 pavement structure. Asphaltic concrete pavement with thicknesses ranging from 90 to 200 mm was encountered at the surface of the four highway boreholes.

Topsoil with a thickness of 0.2 m was encountered at surface at Boreholes 19-7001 and 19-7002.

4.3.2 Pavement Structure and Embankment Fills

Pavement structure fill consisting predominantly of sand and gravel with varying amounts of silt was encountered below the asphaltic concrete pavement at the highway boreholes. The thickness of the pavement structure fill ranges from 0.3 to 0.6 m. The measured moisture content of a single sample tested was 2 percent. The results of grain size analysis testing carried out a single sample of the pavement structure fill are provided on Figure B1 in Appendix B.

Fill consisting predominantly of sand with varying amounts of silt and gravel was encountered below the pavement structure fill in the highway boreholes. The top of this layer was encountered at elevations ranging from 98.1 to 98.2 m. The thickness of the fill ranges from 3.6 to 4.0 m. Cobbles and boulders were noted in this layer at the highway boreholes. Borehole 19-7005 was terminated at auger refusal within the embankment fill after coring through boulders at a depth of about 2.8 m below the pavement surface.

The SPT N values of the sand fill ranged from 5 to greater than 100 blows per 0.3 m of penetration, but were more typically were 13 to 39, indicating a compact to dense state of packing. The higher blow count (i.e., greater than 100) noted on the Record of Boreholes for the embankment may have been influenced by the presence of cobbles or boulders within the fill, rather than the state of packing of the soil matrix. The measured moisture content of the samples tested ranged from 4 to 7 percent. The results of grain size analysis testing carried out on two samples of this material are provided on Figure B2 in Appendix B.

Silty sand and gravel and gravelly silty sand was encountered underlying the surficial topsoil at the boreholes advanced at the culvert ends. The fill is about 1.7 and 0.9 m in thickness at the inlet and outlet, respectively. The SPT N values ranged from 11 to greater than 100 blows per 0.3 m of penetration but were more typically 11 to 28 indicating a compact state of packing. . The measured moisture content of a single sample tested was 9 percent. The results of grain size analysis testing carried out a single sample of this material are provided on Figure B3 in Appendix B.

4.3.3 Buried Topsoil and Peat

Buried topsoil and peat were encountered below the embankment fill material in Boreholes 19-7002, 19-7004A and 19-7015 at elevations ranging from 94.0 to 94.6 m. The thickness of the buried topsoil and peat at these locations ranges from 0.1 to 0.2 m.

4.3.4 Sand, Sand and Silt to Silty Sand

Sand with varying amounts of silt and gravel was encountered in all boreholes at elevations ranging from 93.4 to 94.5 m. The thickness of the sand layer at these locations ranges from 0.6 to 2.2 m. The SPT N values ranged from 9 to 24 blows per 0.3 m of penetration, indicating a loose to compact state of packing.

The measured moisture content of the samples tested ranged from 24 to 29 percent. The results of grain size analysis testing carried out on three samples of this material are provided on Figure B4 in Appendix B.

4.3.5 Clayey Silt – Silt

Clayey silt – silt was encountered below the sand and silt material in all boreholes at elevations ranging from 92.1 to 92.8 m. The thickness of the clayey layer ranges from 1.2 to 1.8 m. The SPT N values ranged from 4 to 22 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency.

The measured moisture content of the samples tested ranged from 19 to 22 percent. The results of grain size analysis testing carried out on three samples of this material are provided on Figure B5 in Appendix B. The results of Atterberg Limits testing completed on three samples of the clayey silt – silt indicates liquid limits ranging from 19 to 27, plastic limits ranging from 15 to 18, and plasticity indexes ranging from 4 to 10. Atterberg Limits analysis results are illustrated on Figure B6 in Appendix B and indicate a Clayey silt – silt (CL-ML to CL).

4.3.6 Glacial Till

Glacial till was encountered below the clayey silt to silty clay in all boreholes except Borehole 19-7015, where the clayey silt overlies bedrock. The glacial till generally consists of a heterogeneous mixture of cobbles and boulders within a soil matrix of silt, clay or sand, with trace gravel. The thickness of the till layer at the borehole locations ranges from 0.1 to 0.8 m. The SPT N values ranged from 36 to 57 blows per 0.3 m of penetration, indicating a dense to very dense state of packing.

The measured moisture content of a single sample tested was 18 percent. The results of grain size analysis testing carried out on two samples of glacial till are provided on Figure B7 in Appendix B. Atterberg Limits test results on a single sample indicate a non-plastic silt till (ML).

4.4 Bedrock

The overburden materials are underlain by dolostone bedrock with shale partings and interbeds.

Bedrock core samples were obtained in all boreholes, except Borehole 19-7005, using a combination of NQ sized diamond drilling equipment at the highway boreholes (Boreholes 19-7003, 19-7004A and 19-7015) and 63 mm outside diameter thin wall coring equipment at the portable boreholes advanced using a portable drill rig (Boreholes 19-7001 and 19-7002)..

Table 2 summarizes the depths and the elevations of the bedrock surface as encountered at the borehole locations.

Table 2: Summary of Bedrock Surface Depths and Elevations

Borehole	Location	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
19-7001	Culvert Inlet	95.3	4.8	90.5
19-7002	Culvert Outlet	95.7	4.9	90.8
19-7003	Highway 416 North of Culvert	98.7	8.0	90.7
19-7004A	Highway 416 South of Culvert	98.6	8.3	90.3
19-7015	Highway 416 South of Culvert	99.0	8.7	90.3

The bedrock encountered was slightly weathered to fresh and medium bedded. Thin shale interbeds were present in the bedrock core. Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 54 to 98 percent, but were more typically 65 to 90 percent, indicating a good to excellent rock quality.

Results of unconfined compressive strength (UCS) testing carried out on three bedrock core samples are presented on Figure B8 provided in Appendix B. The samples tested had UCS values ranging from 55 to 270 MPa, but more typically 137 to 230 percent, indicating a very strong bedrock.

4.5 Groundwater Conditions

The groundwater level was measured in the open boreholes prior to carrying out coring operations and the measured depths to the water levels ranged from 1.9 to 5.3 m below existing grade, corresponding to elevations ranging from 93.2 to 94.0 m.

The groundwater level in the area of the culvert is expected to reflect the creek water level.

The water level in the creek was measured at the time of Golder's field investigation at a depth of 1.3 m below the top of the culvert at the invert; corresponding Elevation 93.9 m.

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

4.6 Steel Corrosion and Sulphate Attack, Chemical Analysis

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized in Table 3.

Table 3: Steel Corrosion and Sulphate Attack, Chemical Analysis

Borehole	Sample	Sample Depth (m)	Sample Type	Chloride (%)	Sulphate (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)
19-7002	SS5	2.7	Silty Sand	0.007	0.02	0.24	7.9	4,120
19-7004A	SS5	3.3	Sand Fill	0.006	<0.01	0.12	8.7	8,700

5.0 CLOSURE

This report was prepared by Mr. Kenton Power, P.Eng. It was reviewed by Mr. Bill Cavers, P.Eng., a Senior Geotechnical Engineer and Associate with Golder. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

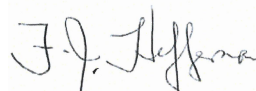
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Kenton C. Power, P.Eng.
Geotechnical Engineer



William Cavers, P.Eng
Associate, Senior Geotechnical Engineer



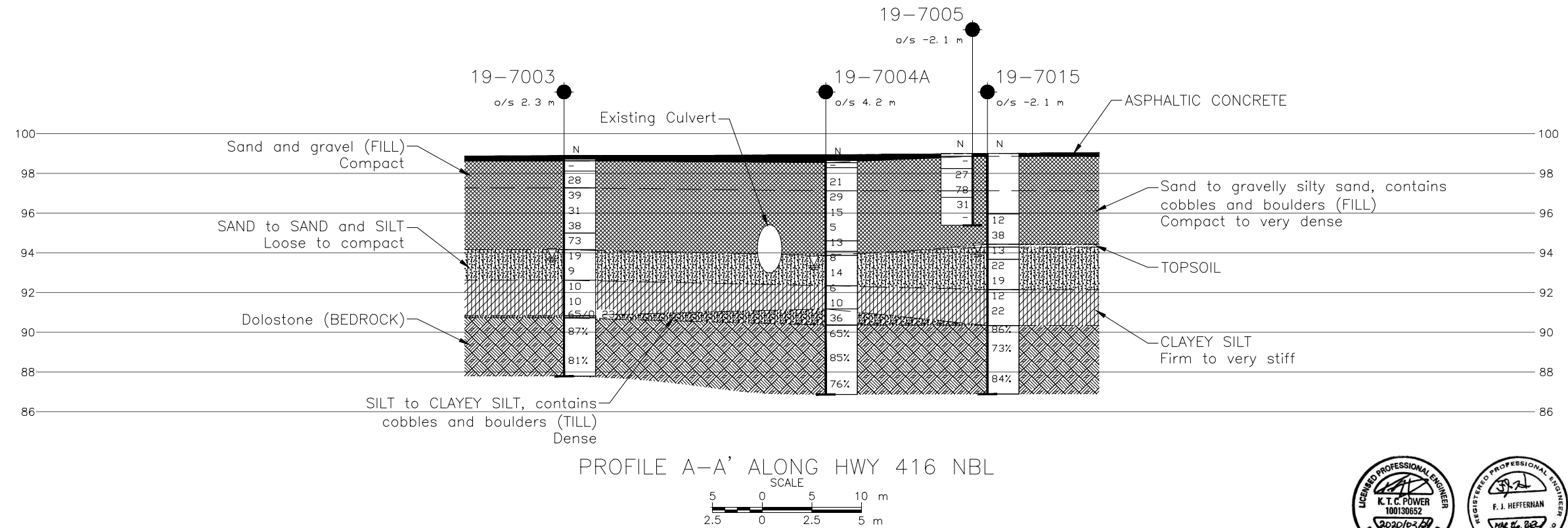
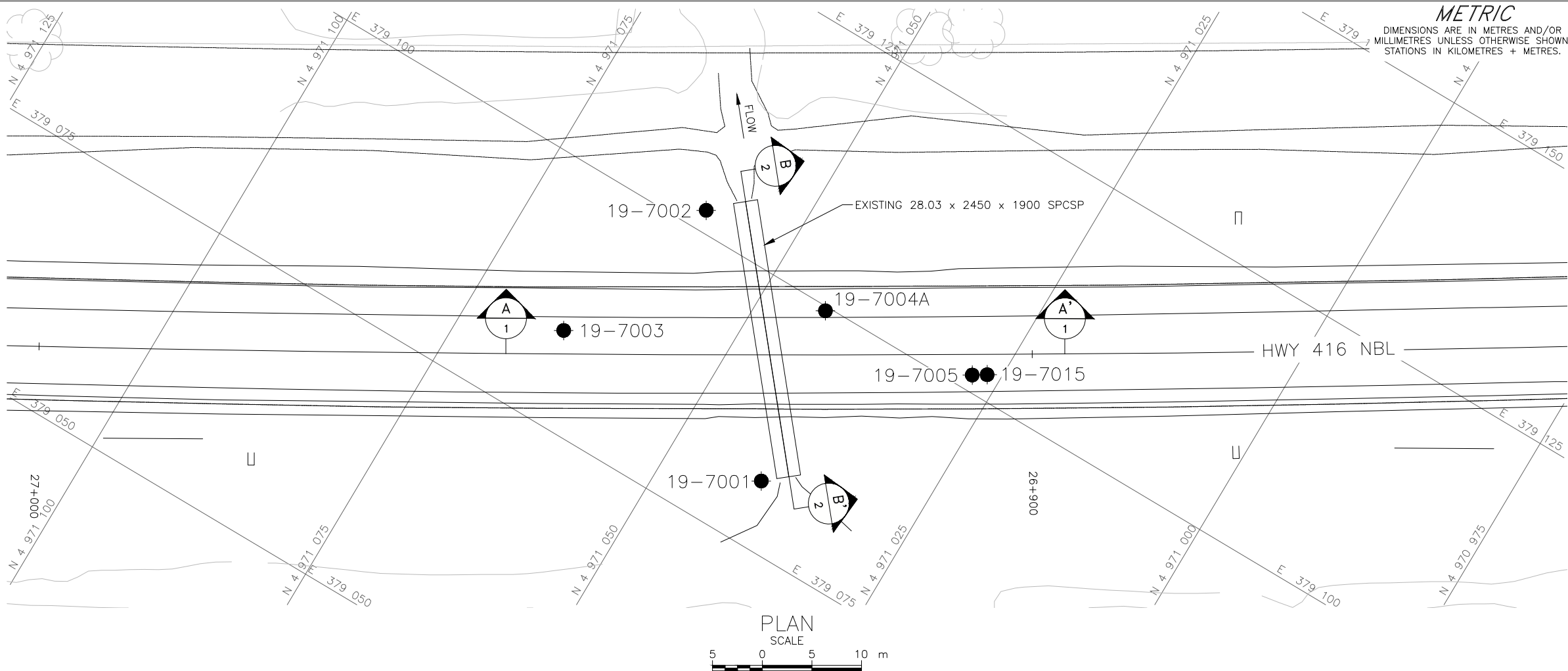
Fintan J. Heffernan, P.Eng.
Designated MTO Foundations Contact



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CONT No.
WP No.4045-18-01

CULVERT CV-0416-000185
REPLACEMENT
HIGHWAY 416
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 44.875536 LONG. -75.559694

KEY PLAN
SCALE
0 1 2 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
19-7001	95.3	4971040.4	379081.6
19-7002	95.7	4971059.1	379102.1
19-7003	98.7	4971065.2	379084.4
19-7004A	98.6	4971043.6	379099.6
19-7005	99.0	4971027.6	379101.6
19-7015	99.0	4971026.4	379102.4

NOTES

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

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

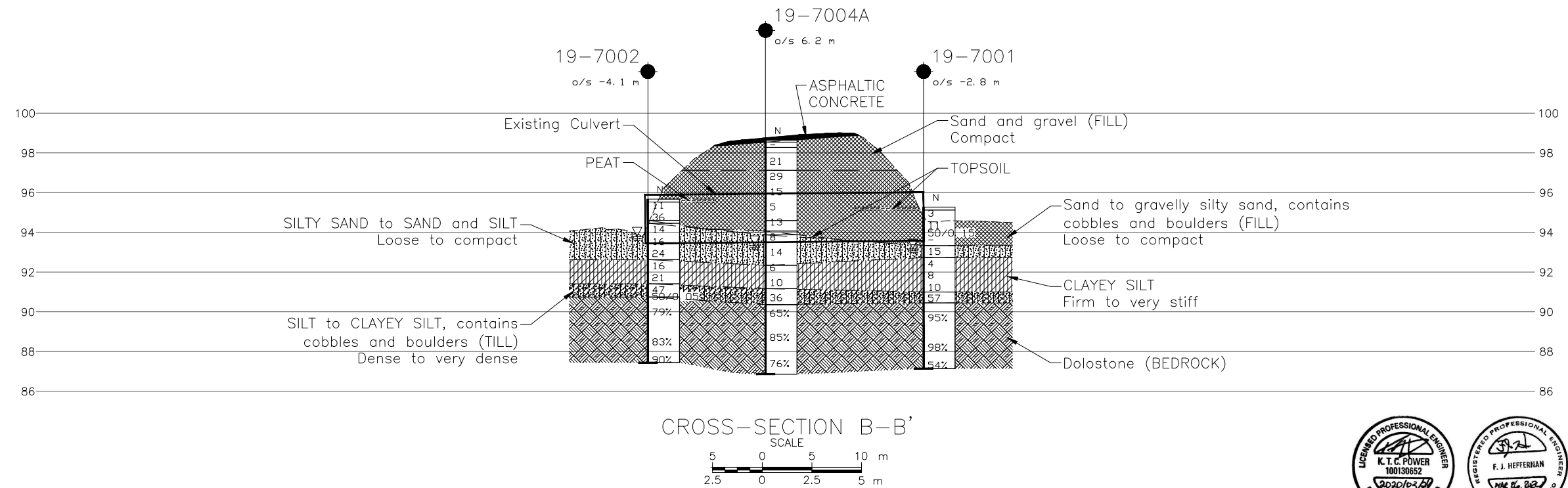
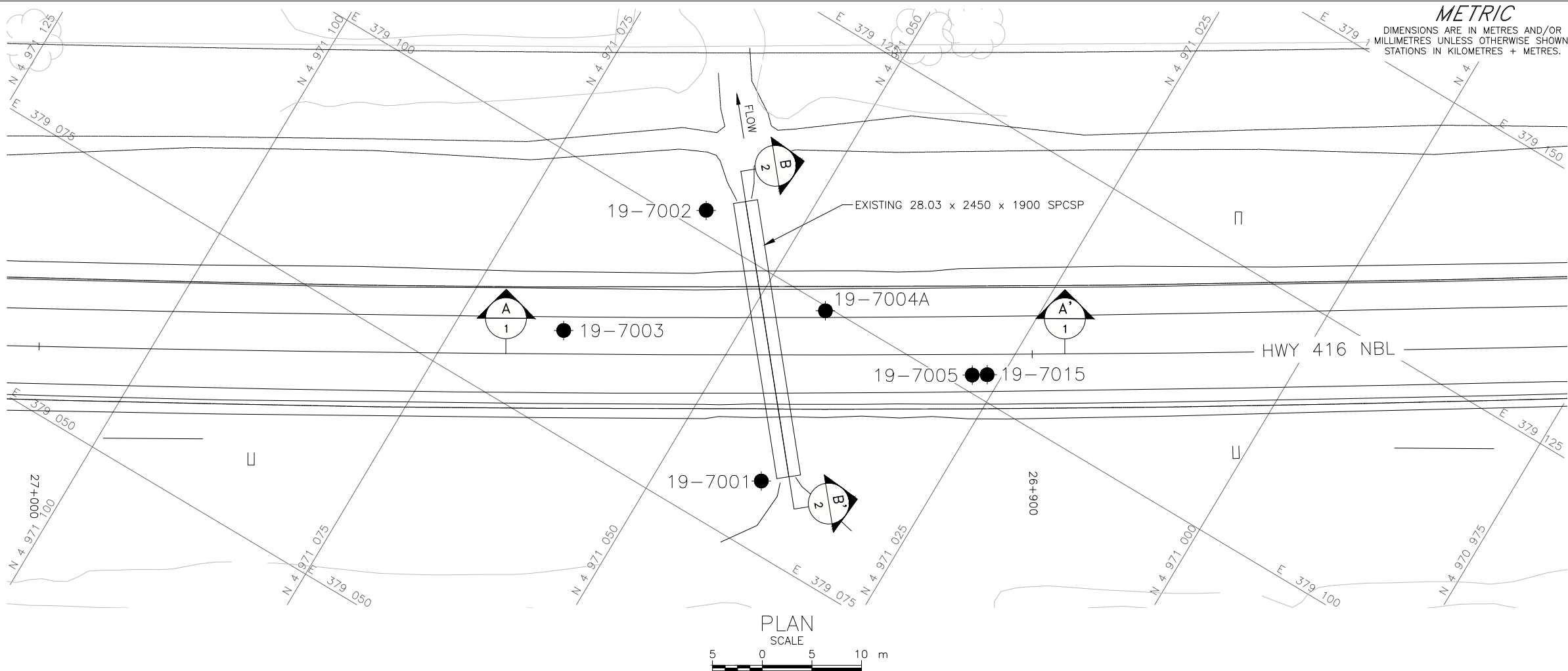
Although not shown it is anticipated that backfill material exists around the culvert.

REFERENCE

Base plans provided in digital format by Dillon Consulting Limited, drawing file no. Hwy 416 Edwardsburgh Culvert 000185.dwg, received JULY 22, 2019.

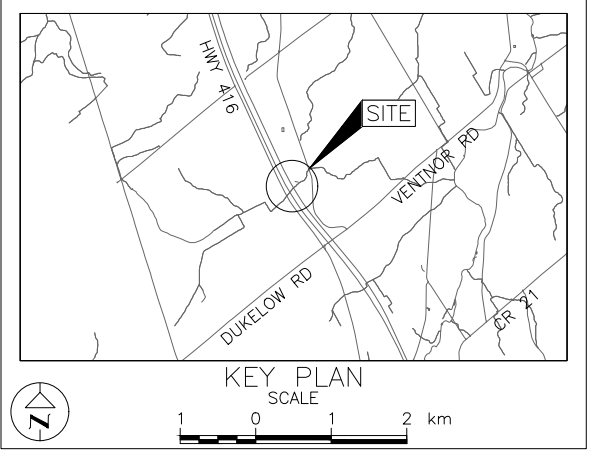
NO.	DATE	BY	REVISION
Geocres No. 31B-096			
HWY. 416		PROJECT NO. 1899802	
SUBM'D. KCP		DATE: 3/30/2020	
DRAWN: JM		SITE: -	
CHKD. FJH		APPD. FJH	
DIST. EASTERN		DWG. 1	





CONT No.
WP No.4045-18-01

CULVERT CV-0416-000185
REPLACEMENT
HIGHWAY 416
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 44.875536 LONG. -75.559694



LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
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Base plans provided in digital format by Dillon Consulting Limited, drawing file no. Hwy 416 Edwardsburgh Culvert 000185.dwg, received JULY 22, 2019.

NO.	DATE	BY	REVISION
Geocres No. 31B-096			
HWY. 416		PROJECT NO. 1899802	
SUBM'D. KCP		CHKD. KCP	DATE: 3/30/2020
DRAWN: JM		CHKD. FJH	APPD. FJH
DIST. EASTERN		SITE: -	
DWG. 2			



APPENDIX A

Record of Borehole

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 19-7001 to 19-7005 and 19-7015

Bedrock Core Photographs, Figures A1 to A10

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

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

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

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

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

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

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

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

SOIL TESTS

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

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

COARSE-GRAINED SOILS

Compactness¹

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

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

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

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

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

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

Field Moisture Condition

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

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

* 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 $= (w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_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 $= \sigma'_p / \sigma'_{vo}$

(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

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

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

Description	Bedding Plane Spacing
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

Description	Spacing
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

Term	Size*
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, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

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	

PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7001		SHEET 1 OF 2		METRIC										
G.W.P.		4045-18-01		LOCATION		N 4971040.4; E 379081.6 NAD 83 MTM ZONE 9 (LAT. 44.875490; LONG. -75.559840)		ORIGINATED BY										
DIST		Eastern HWY 416		BOREHOLE TYPE		Wash Boring, BW Casing, Portable Rotary Drill, AW Casing		COMPILED BY										
DATUM		Geodetic		DATE		August 6, 2019		CHECKED BY										
								KCP										
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										WATER CONTENT (%)
95.3	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL							20	40	60	80	100						
0.2	(SM) Silty sand and gravel, contains cobbles and boulders (FILL) Loose to compact Brown Moist		1	SS	3													
			2	SS	11													
	- Cobbles and boulders from 1.3 m to 1.9 m		3	SS	50/0.15													
			4	RC	-													
93.4	(ML) SANDY SILT Compact Grey Wet		5	SS	15													
92.8	(CL-ML) CLAYEY SILT-SILT, trace sand Stiff to very stiff Grey Wet		6	SS	4													
			7	SS	8													
			8	SS	10													
91.0	(CL) CLAYEY SILT, some gravel, contains cobbles (TILL) Very dense Grey Wet		9	SS	57													
90.5	Dolostone (BEDROCK)		10	RC	-													
4.8	Bedrock cored from depths 4.8 m to 8.1 m For bedrock coring details refer to Record of Drillhole 19-7001		1	RC	REC 100%													
			2	RC	REC 100%													
			3	RC	REC 100%													
87.2	END OF BOREHOLE																	
8.1	NOTES: 1. Manual half-weight hammer used for all split spoon samples. SPT N-values are corrected to approximate expected values that would be obtained using a standard weight hammer. 2. Water level in open borehole at 2.1 m depth below ground surface (Elev. 93.2 m), upon completion of drilling.																	

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PROJECT: 1899802-7000

RECORD OF DRILLHOLE: 19-7001

SHEET 2 OF 2

LOCATION: N 4971040.4 ;E 379081.6

DRILLING DATE: August 6, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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											TOTAL CORE %	SOLID CORE %	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	10 ⁻⁸	10 ⁻⁷	10 ⁻⁶	W1	W2	W3		W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: RI

CHECKED: KCP

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

PROJECT: 1899802-7000

RECORD OF DRILLHOLE: 19-7002

SHEET 2 OF 2

LOCATION: N 4971059.1 ;E 379102.1

DRILLING DATE: August 7, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC

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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: RI

CHECKED: KCP


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PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7003		SHEET 1 OF 3		METRIC										
G.W.P.		4045-18-01		LOCATION		N 4971065.2; E 379084.4 NAD 83 MTM ZONE 9 (LAT. 44.875710; LONG. -75.559800)		ORIGINATED BY JS										
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, HW Casing		COMPILED BY JM										
DATUM		Geodetic		DATE		July 11-12, 2019		CHECKED BY KCP										
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							WATER CONTENT (%)			
98.7	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALTIC CONCRETE																	
0.1	(SM/GM) Silty sand and gravel (FILL) Grey Damp		1	GRAB	-												37 43 (20)	
98.1	(SW) Sand and gravel, some silt, contains cobbles (FILL) Compact Brown Damp		2	SS	28													
0.6																		
97.3	(SP) Sand, some silt (FILL) Dense Brown Moist		3	SS	39													
1.5																		
			4	SS	31												0 90 (10)	
			5	SS	38													
95.0	(SW) Gravelly sand (FILL) Very dense Brown Moist		6	SS	73													
3.7																		
94.1	(SM/ML) SAND and SILT, contains clayey silt seams Compact to loose Grey Wet		7	SS	19													
4.6			8	SS	9													
92.6	(CI) CLAYEY SILT Very stiff Grey Wet		9	SS	10												0 1 76 23	
6.1																		
			10	SS	10													
90.8	SAND and GRAVEL (TILL) Dolostone (BEDROCK)		11	SS	65/0.23													
8.0																		
	Bedrock cored from depths 8.0 m to 10.9 m																	
	For bedrock coring details refer to Record of Drillhole 19-7003		1	RC	REC 100%												RQD = 87%	
			2	RC	REC 100%												RQD = 81%	

Continued Next Page

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

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PROJECT		RECORD OF BOREHOLE No 19-7003				SHEET 2 OF 3		METRIC									
G.W.P. 4045-18-01		LOCATION N 4971065.2; E 379084.4 NAD 83 MTM ZONE 9 (LAT. 44.875710; LONG. -75.559800)				ORIGINATED BY JS											
DIST Eastern HWY 416		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, HW Casing				COMPILED BY JM											
DATUM Geodetic		DATE July 11-12, 2019				CHECKED BY KCP											
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									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
87.8	Dolostone (BEDROCK)		2	RC	REC 100%	88											RQD = 81%
10.9	Bedrock cored from depths 8.0 m to 10.9 m For bedrock coring details refer to Record of Drillhole 19-7003																
	END OF BOREHOLE																
	NOTES: 1. Water level in open borehole at 5.0 m depth below ground surface (Elev. 93.7 m), upon completion of drilling.																

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PROJECT: 1899802-7000

RECORD OF DRILLHOLE: 19-7003

SHEET 3 OF 3

LOCATION: N 4971065.2 ;E 379084.4

DRILLING DATE: July 11-12, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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DEPTH SCALE

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PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7004A		SHEET 1 OF 3		METRIC							
G.W.P.		4045-18-01		LOCATION		N 4971043.6; E 379099.6 NAD 83 MTM ZONE 9 (LAT. 44.875525; LONG. -75.559614)		ORIGINATED BY JS							
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core		COMPILED BY JM							
DATUM		Geodetic		DATE		July 11, 2019		CHECKED BY KCP							
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			SHEAR STRENGTH kPa			WATER CONTENT (%)				
98.6	GROUND SURFACE														
0.0	ASPHALTIC CONCRETE														
98.2	(SW) Gravelly sand (FILL)		1	GRAB	-										
0.4	Grey Damp														
	(SW) Sand and gravel, some fines (FILL)														
	Compact Grey brown Damp		2	SS	21										
97.1															
1.5	(SP) Sand, trace fines (FILL)														
	Compact to loose Brown Moist		3	SS	29										
			4	SS	15										
			5	SS	5										
94.6	(GW) Sandy gravel (FILL)														
4.0	Brown Wet		6	SS	13										
94.0															
93.8	(SM) Silty sand (TOPSOIL)														
4.8	Black Moist to wet		7	SS	8										
	(SM/ML) SAND and SILT, contains rootlets														
	Compact Grey brown Wet		8	SS	14										
92.3	(CL-ML) CLAYEY SILT														
6.3	Very stiff Grey Wet		9	SS	6										
			10	SS	10										
91.1	(ML) SILT, contains clayey silt seams, cobbles and boulders (TILL)														
7.5	Dense Grey Wet		11	SS	36										
90.3	Dolostone (BEDROCK)														
8.3	Bedrock cored from depths 8.3 m to 11.8 m		1	RC	REC 82%										
	For bedrock coring details refer to Record of Drillhole 19-7004A														
			2	RC	REC 100%										

Continued Next Page

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

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PROJECT		RECORD OF BOREHOLE				No 19-7004A		SHEET 2 OF 3		METRIC							
G.W.P. 4045-18-01		LOCATION				N 4971043.6; E 379099.6 NAD 83 MTM ZONE 9 (LAT. 44.875525; LONG. -75.559614)				ORIGINATED BY JS							
DIST Eastern HWY 416		BOREHOLE TYPE				Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core				COMPILED BY JM							
DATUM Geodetic		DATE				July 11, 2019				CHECKED BY KCP							
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									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	Dolostone (BEDROCK)		2	RC	REC 100%												RQD = 85%
	Bedrock cored from depths 8.3 m to 11.8 m For bedrock coring details refer to Record of Drillhole 19-7004A		3	RC	REC 98%												
86.8 11.8	END OF BOREHOLE																
	NOTES: 1. Water level in open borehole at 5.3 m depth below ground surface (Elev. 93.3 m), upon completion of drilling.																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IM\MTOWHY417BRIDGES\02_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT: 1899802-7000

RECORD OF DRILLHOLE: 19-7004A

SHEET 3 OF 3

LOCATION: N 4971043.6 ;E 379099.6

DRILLING DATE: July 11, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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DEPTH SCALE

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**GOLDER**

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PROJECT <u>1899802-7000</u>		RECORD OF BOREHOLE No 19-7005		SHEET 1 OF 1		METRIC	
G.W.P. <u>4045-18-01</u>		LOCATION <u>N 4971027.6; E 379101.6 NAD 83 MTM ZONE 9 (LAT. 44.875382; LONG. -75.559591)</u>		ORIGINATED BY <u>JS</u>			
DIST <u>Eastern</u> HWY <u>416</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>July 12, 2019</u>		CHECKED BY <u>KCP</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					W _P W W _L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)							
99.0	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALTIC CONCRETE																			
0.2	(GW) Silty gravel and sand (FILL) Grey to brown Moist		-	GS	-															
98.2																				
0.8	(SM) Silty sand, some gravel, contains cobbles (FILL) Compact Brown Moist		1	SS	27															
97.1			2	SS	78															
1.9	(SP) Sand (FILL) Brown Moist																			
96.8																				
2.2	(SM) Silty sand, some gravel, contains cobbles and boulders (FILL) Dense Brown, mottled Moist		3	SS	31															
			4	RC	-															
	- Boulder from 2.8 m to 3.6 m																			
95.4																				
3.6	END OF BOREHOLE AUGER REFUSAL																			


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PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7015		SHEET 1 OF 3		METRIC									
G.W.P.		4045-18-01		LOCATION		N 4971026.4; E 379102.4 NAD 83 MTM ZONE 9 (LAT. 44.875370; LONG. -75.559581)		ORIGINATED BY JS									
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core		COMPILED BY JM									
DATUM		Geodetic		DATE		July 18, 2019		CHECKED BY KCP									
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									WATER CONTENT (%)
99.0	GROUND SURFACE							20	40	60	80	100					
0.0	For soil descriptions from 0.0 m to 3.1 m refer to Record of Borehole 19-7005																
96.0																	
3.1	(SM/ML) Gravelly sand and silt, contains cobbles and boulders (FILL) Brown Moist		1	SS	12												27 37 (36)
			2	SS	38												
94.4																	
4.7	(SM) Silty sand (TOPSOIL) Black Moist		3	SS	13												
	(SP) SAND, some silt Grey brown Wet																
93.7																	
5.3	(SM) SILTY SAND, trace gravel Compact Grey Wet		4	SS	22												6 71 (23)
			5	SS	19												
92.1																	
6.9	(CL) CLAYEY SILT Very stiff Grey		6	SS	12												0 2 72 26
			7	SS	22												
90.3																	
8.7	Dolostone (BEDROCK)		1	RC	REC 100%												RQD = 86%
	Bedrock cored from depths 8.7 m to 12.1 m		2	RC	REC 100%												RQD = 73%
	For bedrock coring details refer to Record of Drillhole 19-7015																

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IM\MTOWHY417BRIDGES\02_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT		RECORD OF BOREHOLE No 19-7015				SHEET 2 OF 3		METRIC									
G.W.P. 4045-18-01		LOCATION N 4971026.4; E 379102.4 NAD 83 MTM ZONE 9 (LAT. 44.875370; LONG. -75.559581)				ORIGINATED BY JS											
DIST Eastern HWY 416		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core				COMPILED BY JM											
DATUM Geodetic		DATE July 18, 2019				CHECKED BY KCP											
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									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
	Dolostone (BEDROCK)		2	RC	REC 100%												RQD = 73%
	Bedrock cored from depths 8.7 m to 12.1 m For bedrock coring details refer to Record of Drillhole 19-7015		3	RC	REC 97%												RQD = 84%
86.9 12.1	END OF BOREHOLE																
	NOTES: 1. Water level in open borehole at 5.0 m depth below ground surface (Elev. 94.0 m), upon completion of drilling.																

PROJECT: 1899802-7000

RECORD OF DRILLHOLE: 19-7015

SHEET 3 OF 3

LOCATION: N 4971026.4 ;E 379102.4

DRILLING DATE: July 18, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC

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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³	W1		W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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DEPTH SCALE

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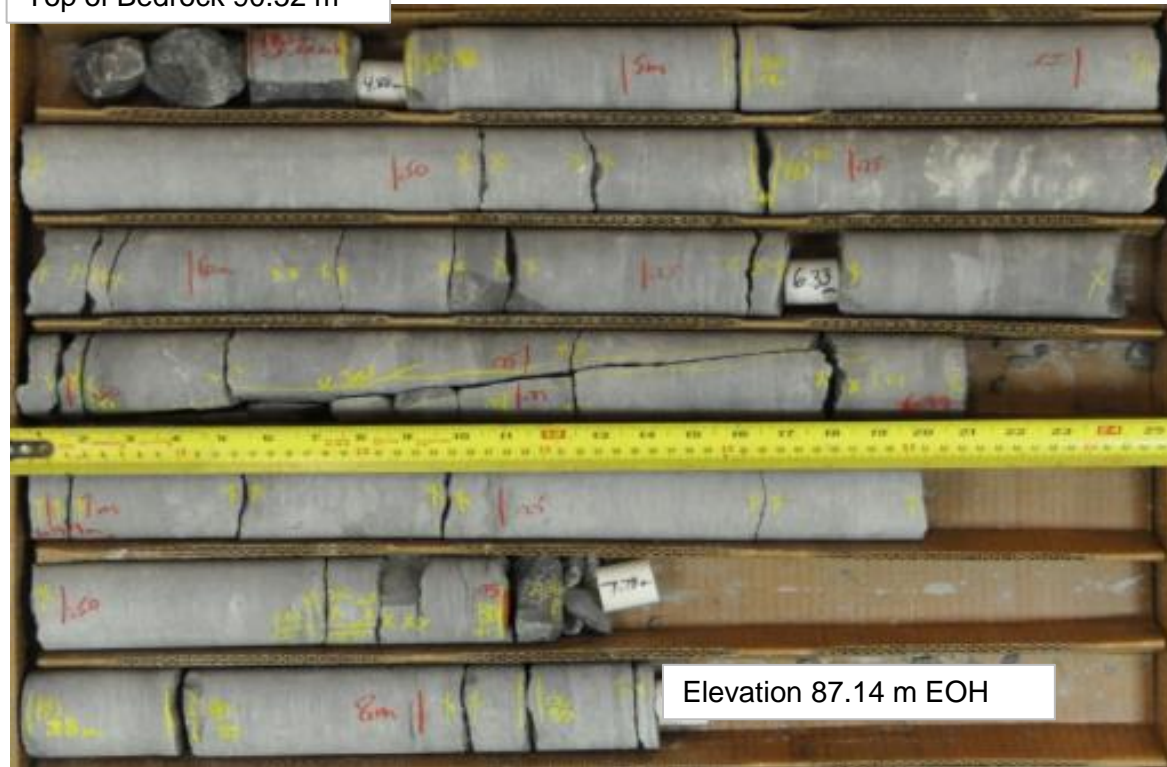
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BH 19-7001 (Dry)
Core Box 1 and 2 of 2

Top of Bedrock 90.52 m



Elevation 87.14 m EOH



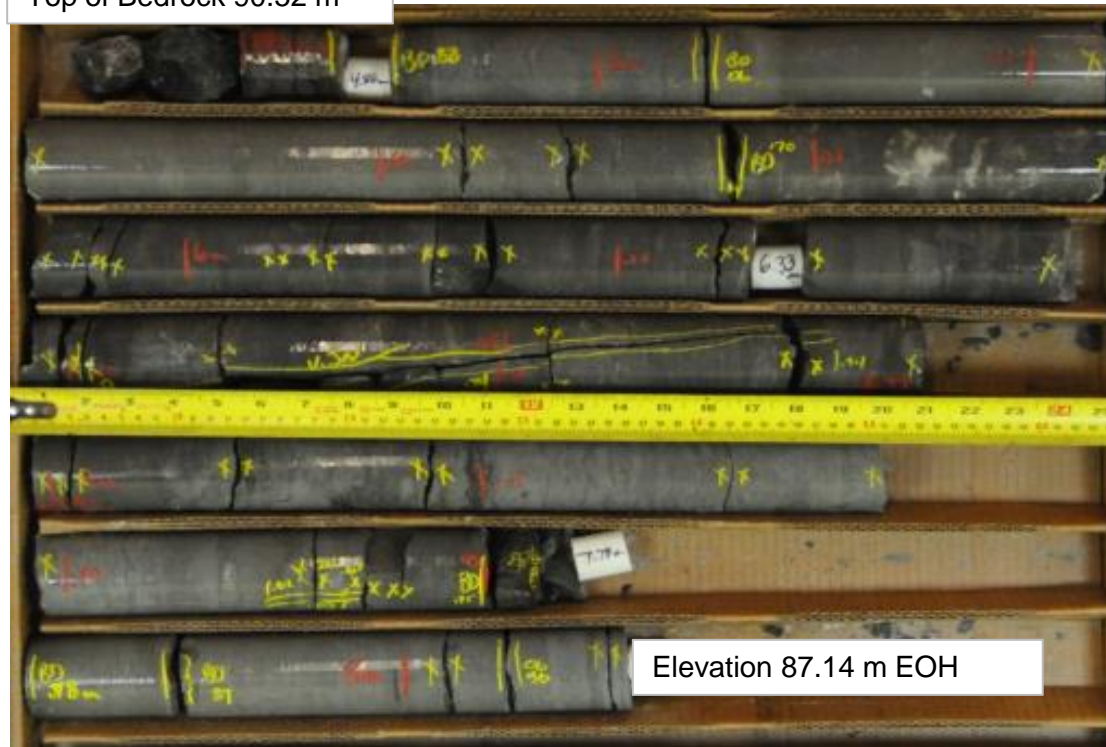
Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A1

BH 19-7001 (wet)
Core Box 1 and 2 of 2

Top of Bedrock 90.52 m



Elevation 87.14 m EOH



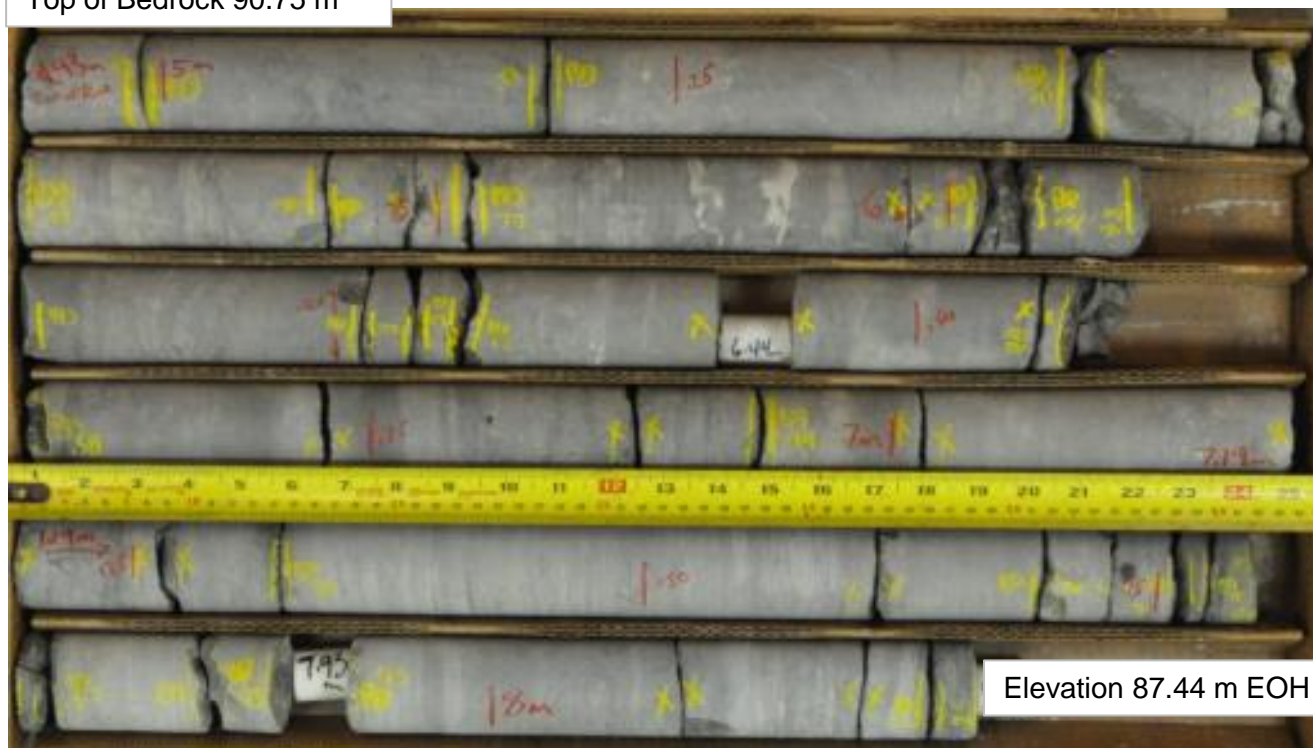
Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
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Review:	FJH

Figure A2

BH 19-7002 (Dry)
Core Box 1 of 1

Top of Bedrock 90.75 m



Elevation 87.44 m EOH



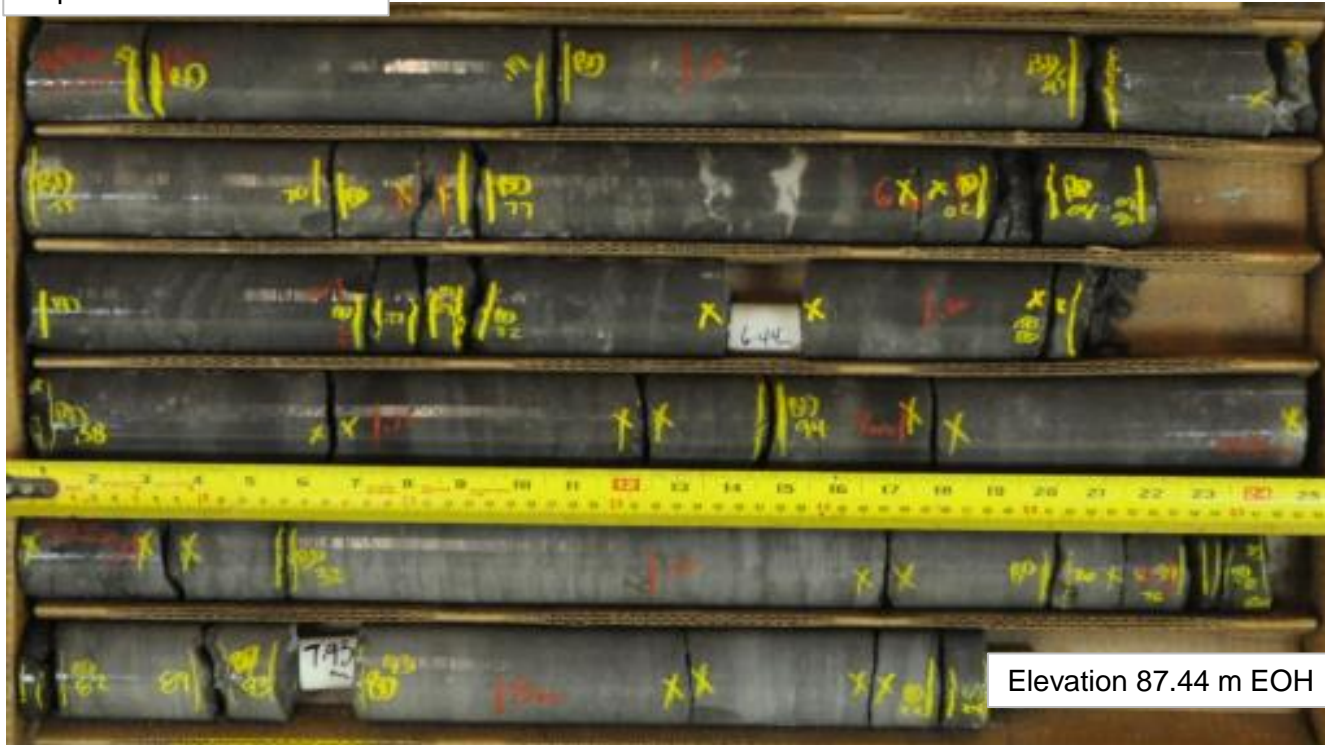
Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A3

BH 19-7002 (wet)
Core Box 1 to 2 of 2

Top of Bedrock 90.75 m



Elevation 87.44 m EOH



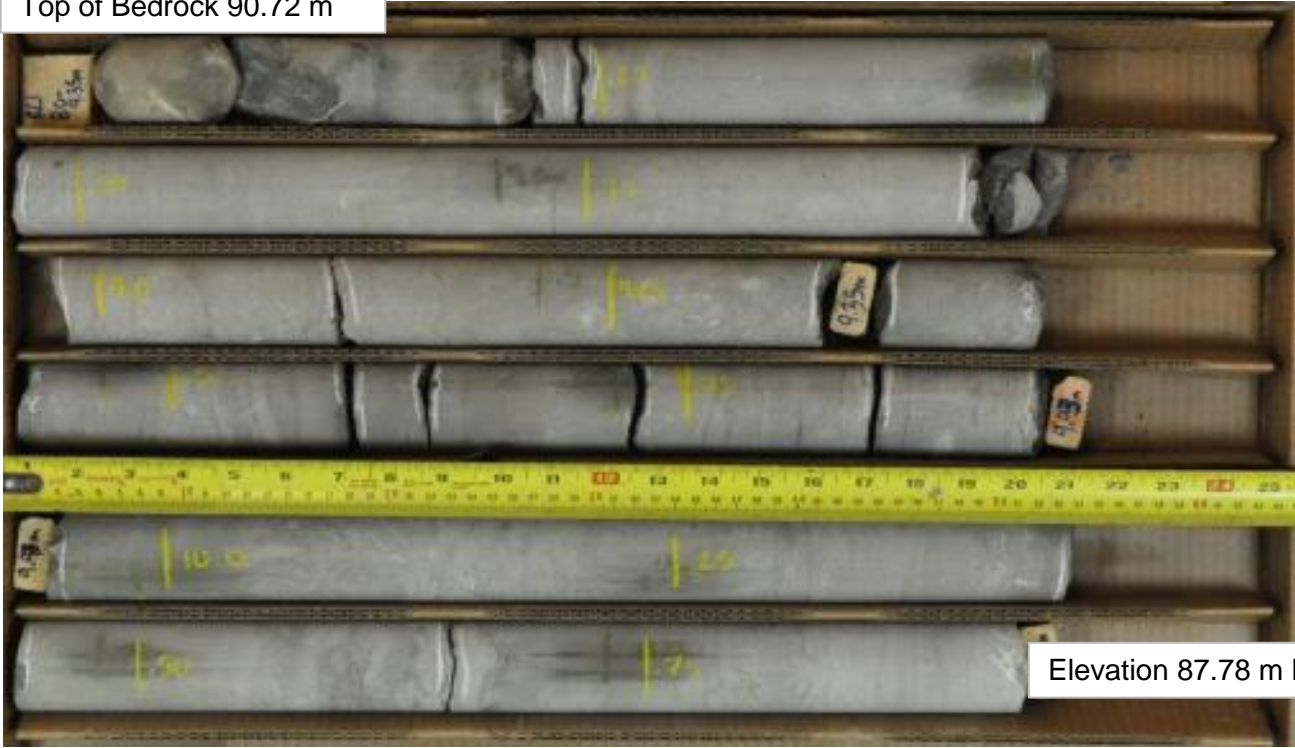
Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
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Review:	FJH

Figure A4

BH 19-7003 (Dry)
Core Box 1 of 1

Top of Bedrock 90.72 m



Elevation 87.78 m EOH



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
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Review:	FJH

Figure A5

BH 19-7003 (Wet)
Core Box 1 and 2 of 2



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A6

BH 19-7004A (Dry)
Core Box 1 and 2 of 2



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A7

BH 19-7004A (wet)
Core Box 1 and 2 of 2

Top of Bedrock 90.36 m



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
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Review:	FJH

Figure A8

BH 19-7015 (Dry)
Core Box 1 and 2 of 2

Top of Bedrock 90.33 m



Elevation 86.88 m EOH



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A9

BH 19-7015 (Wet)
Core Box 1 and 2 of 2

Top of Bedrock 90.33 m



Elevation 86.88 m EOH



Geotechnical Investigation
Replacement of Culvert CV-0416-000185
Highway 416, Ottawa, Ontario

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

Figure A10

APPENDIX B

Laboratory Test Results, Current Investigation

Figure B1 – Grain Size Distribution Test Results – Sand and Gravel (Fill)

Figure B2 – Grain Size Distribution Test Results – Sand to Sand and Gravel (Fill)

Figure B3 – Grain Size Distribution Test Results - Silty Sand and Gravel (Fill)

Figure B4 – Grain Size Distribution Test Results – Sand and Silt to Silty Sand

Figure B5 – Grain Size Distribution Test Results – Clayey Silt – Silt

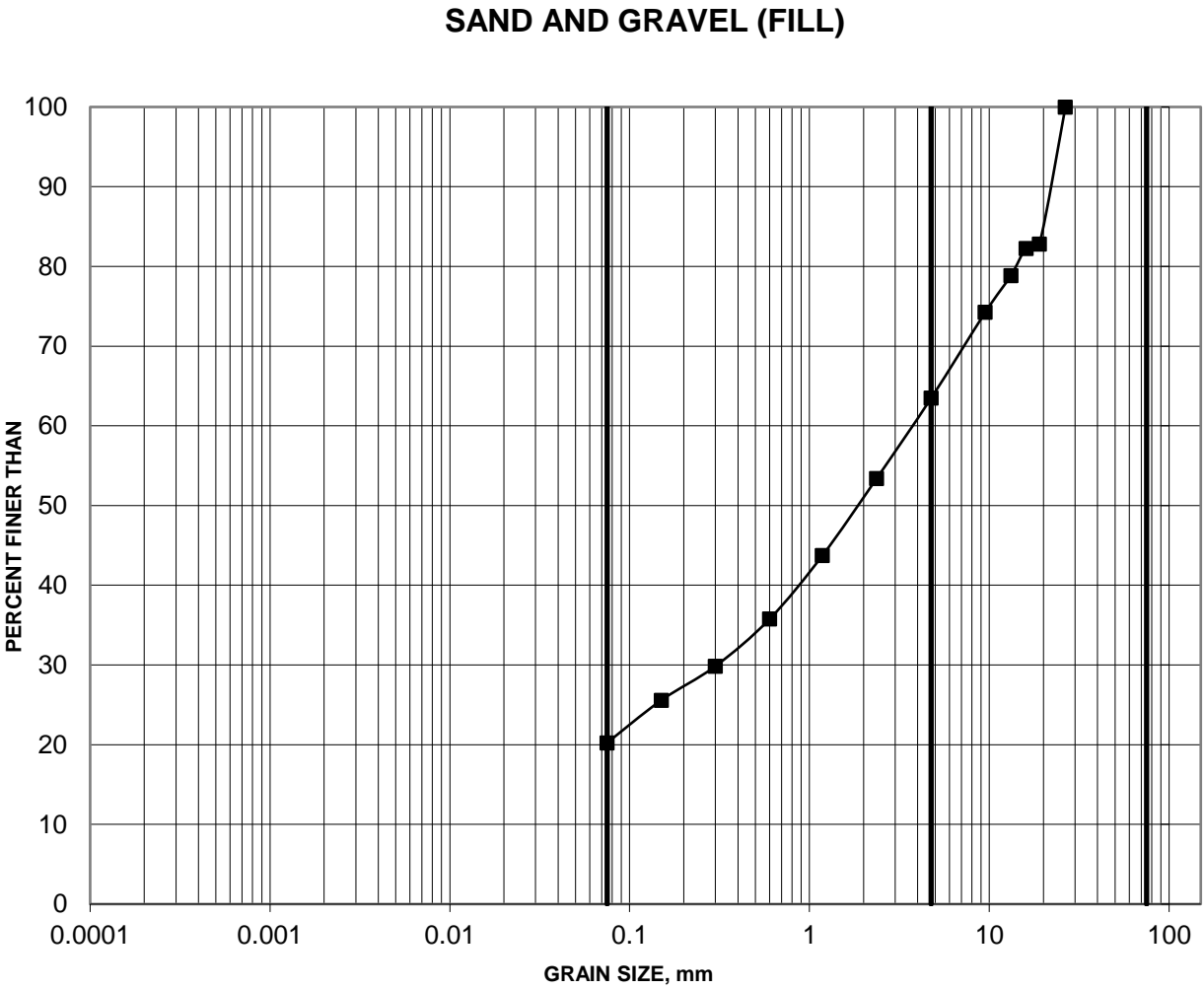
Figure B6 – Plasticity Chart – Clayey Silt – Silt

Figure B7 – Grain Size Distribution Test Results – Silt (Till)

Figure B8 – Summary of Laboratory Compressive Strength Unconfined
Compression Test

GRAIN SIZE DISTRIBUTION

FIGURE B1



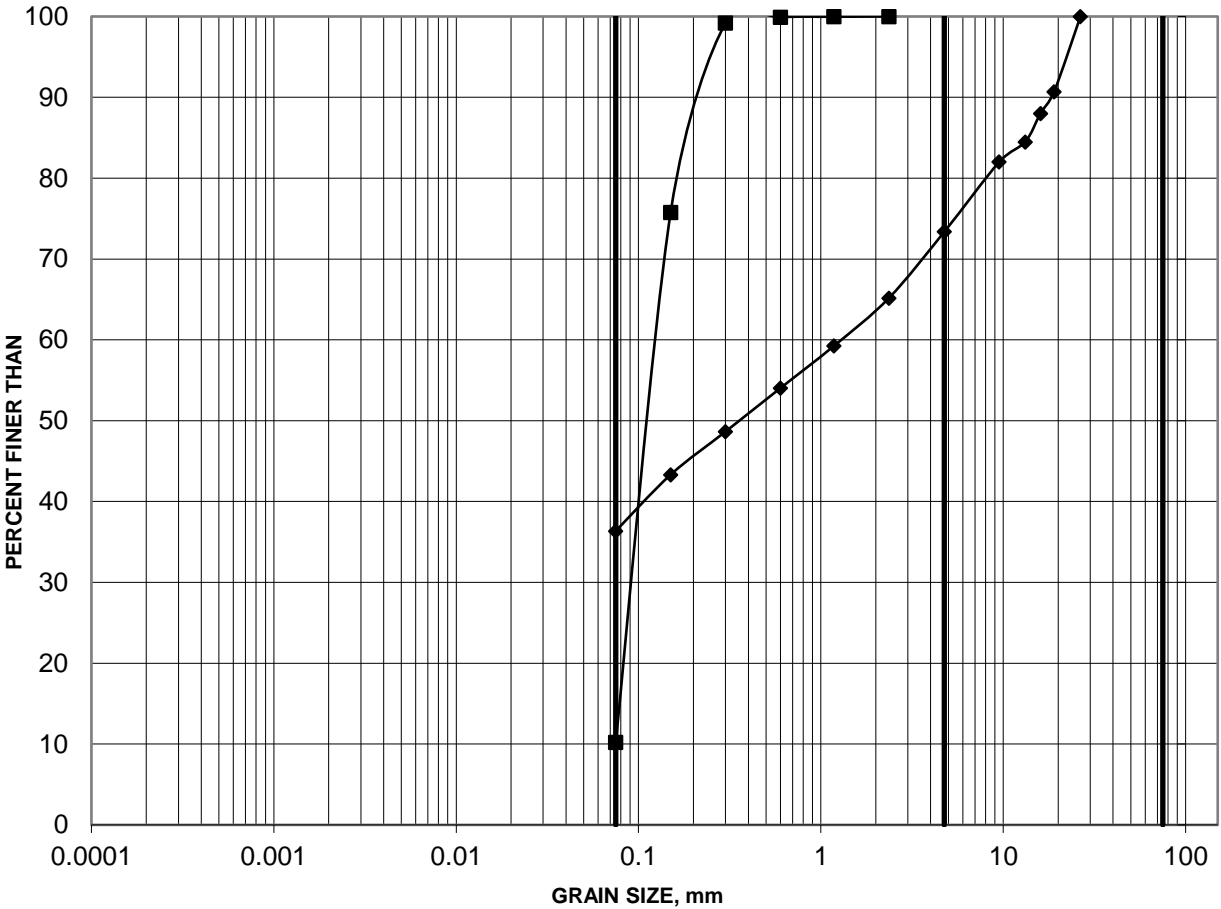
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

	Borehole	Sample	Depth (m)
■	19-7003	1	0.33-1.67

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND TO SAND AND GRAVEL (FILL)



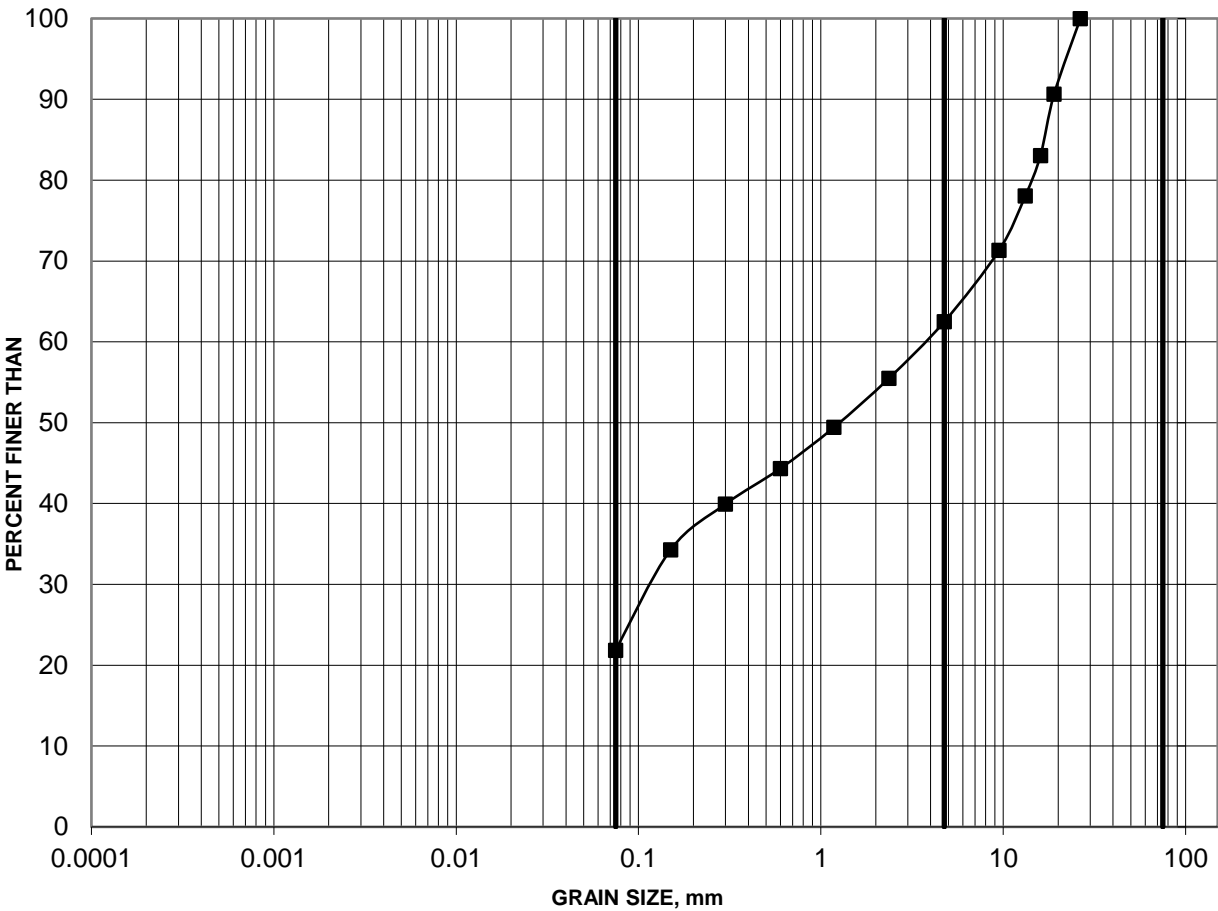
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
19-7003	4	2.29-2.90
19-7015	1	3.05-3.66

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY SAND AND GRAVEL (FILL)



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

Borehole	Sample	Depth (m)
■ 19-7001	2	0.61-1.22

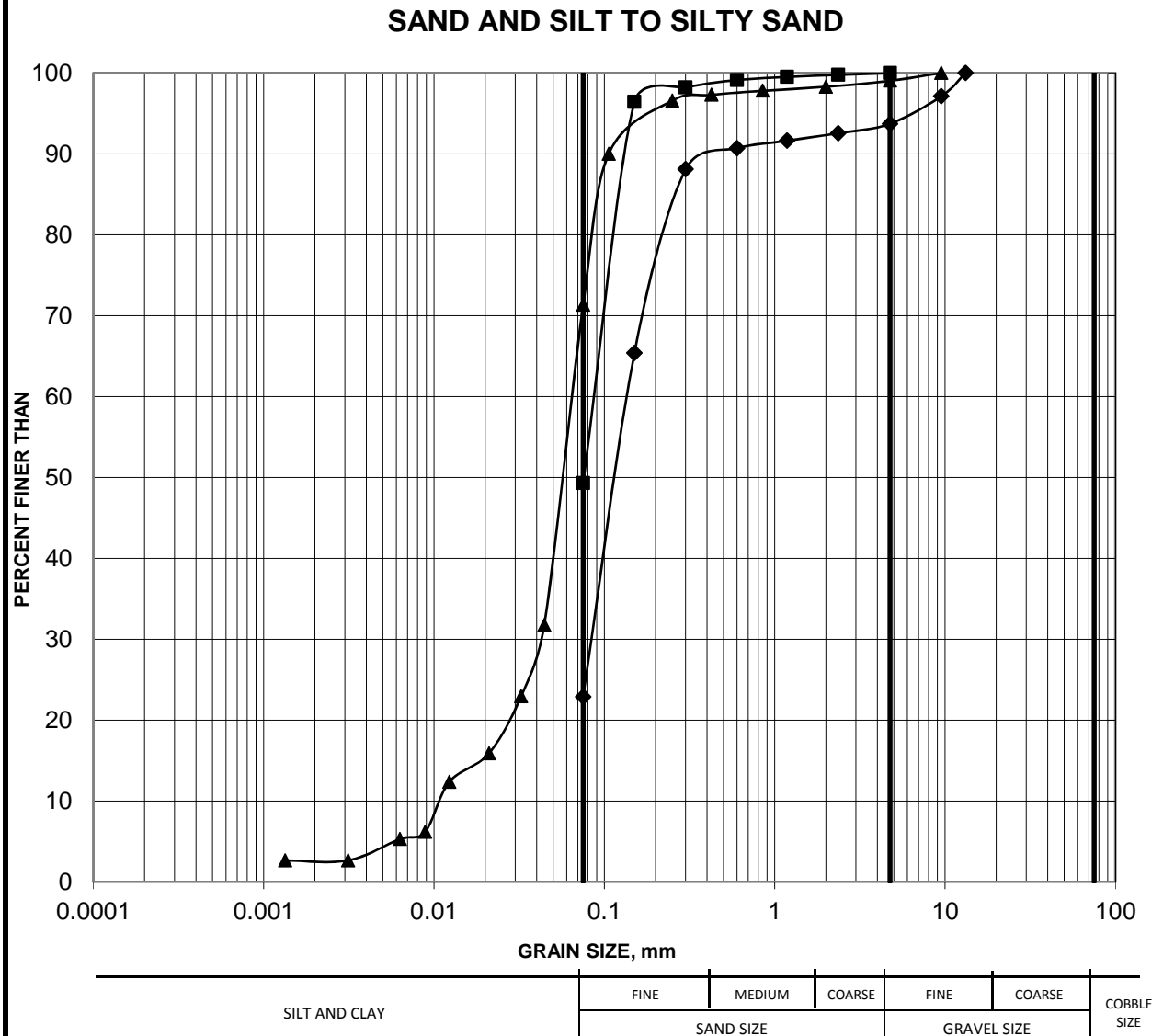
Project: 1899802/7000

Golder Associates

Created by: KCP
Checked by: MI

GRAIN SIZE DISTRIBUTION

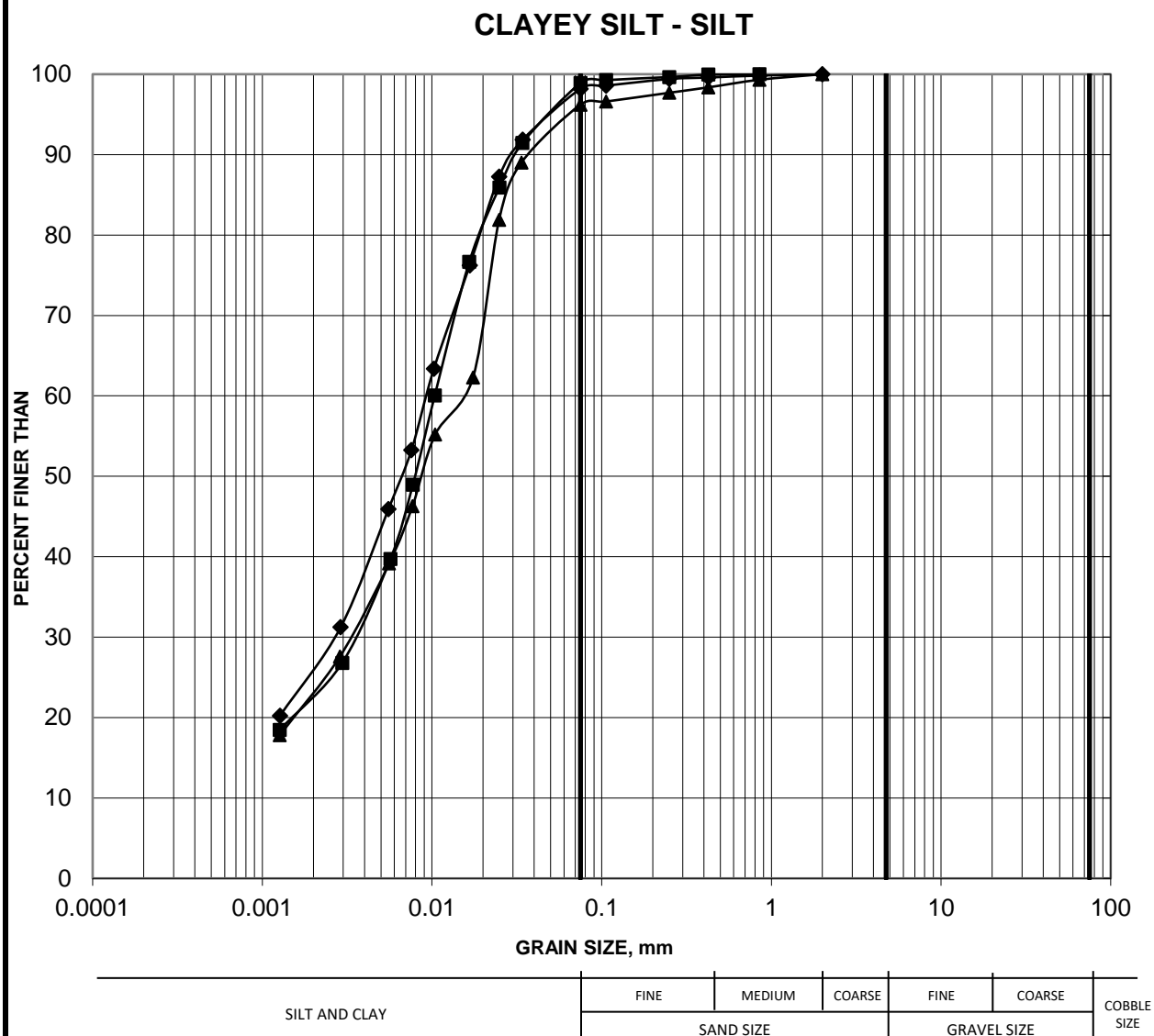
FIGURE B4



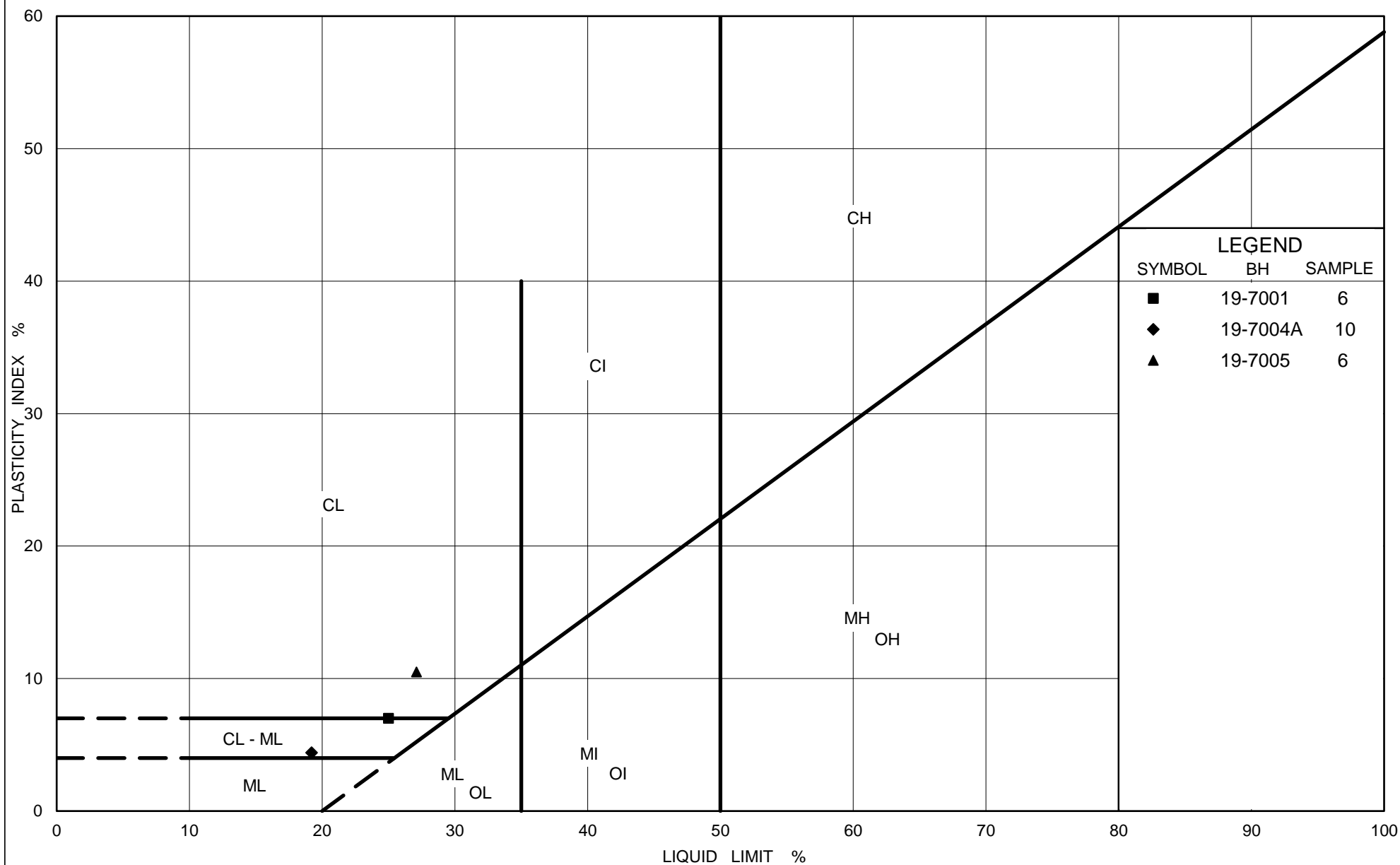
Borehole	Sample	Depth (m)
▲ 19-7001	5	1.92-2.53
■ 19-7004A	8	5.33-5.94
◆ 19-7015	4	5.33-5.94

GRAIN SIZE DISTRIBUTION

FIGURE B5



Borehole	Sample	Depth (m)
▲ 19-7001	6	2.53-3.14
■ 19-7003	9	6.10-6.71
◆ 19-7015	6	6.86-7.47



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SILT - SILT

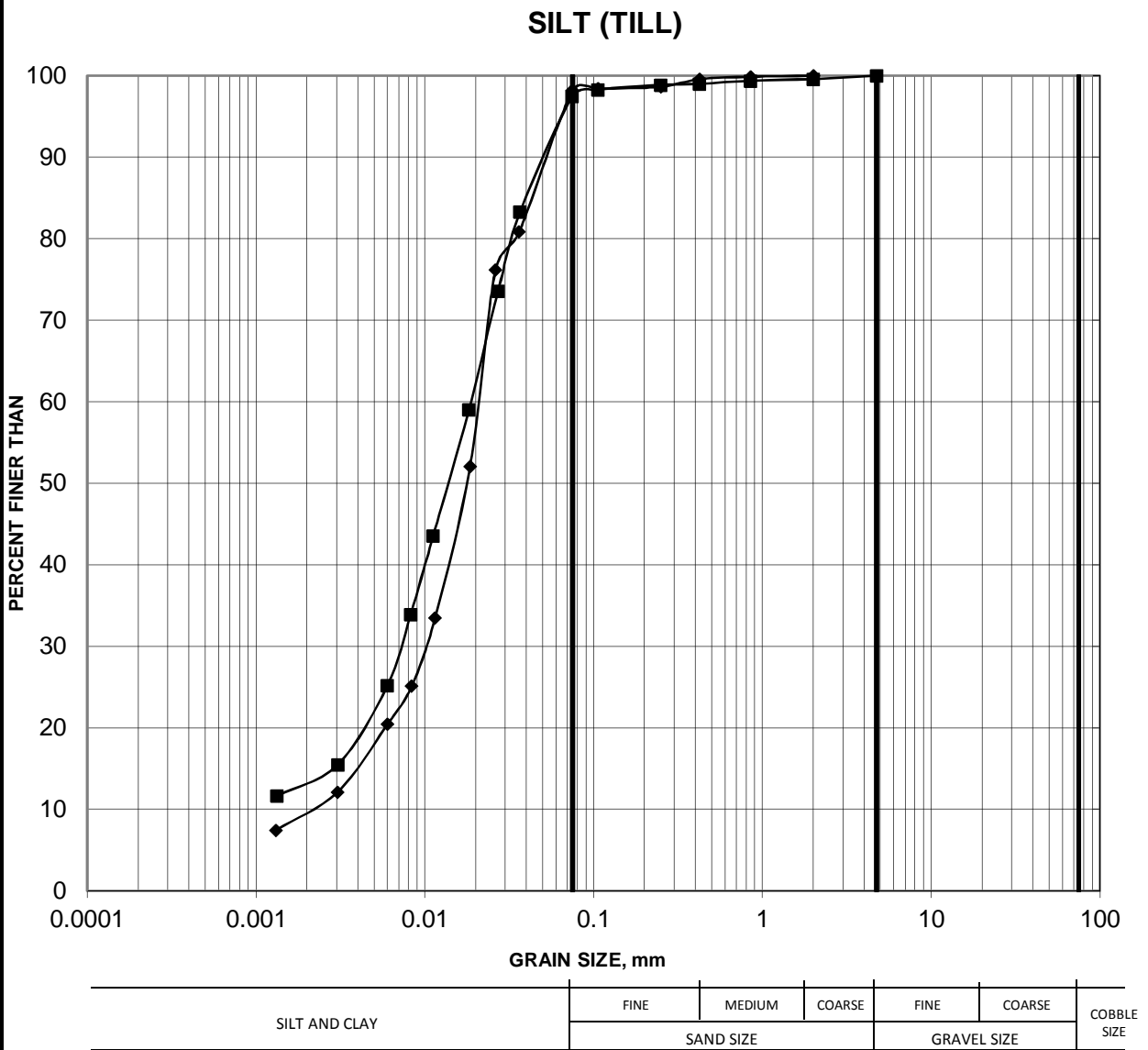
FIG No. B6

Project No. 1899802/7000

Compiled By : KCP Checked By : MI

GRAIN SIZE DISTRIBUTION

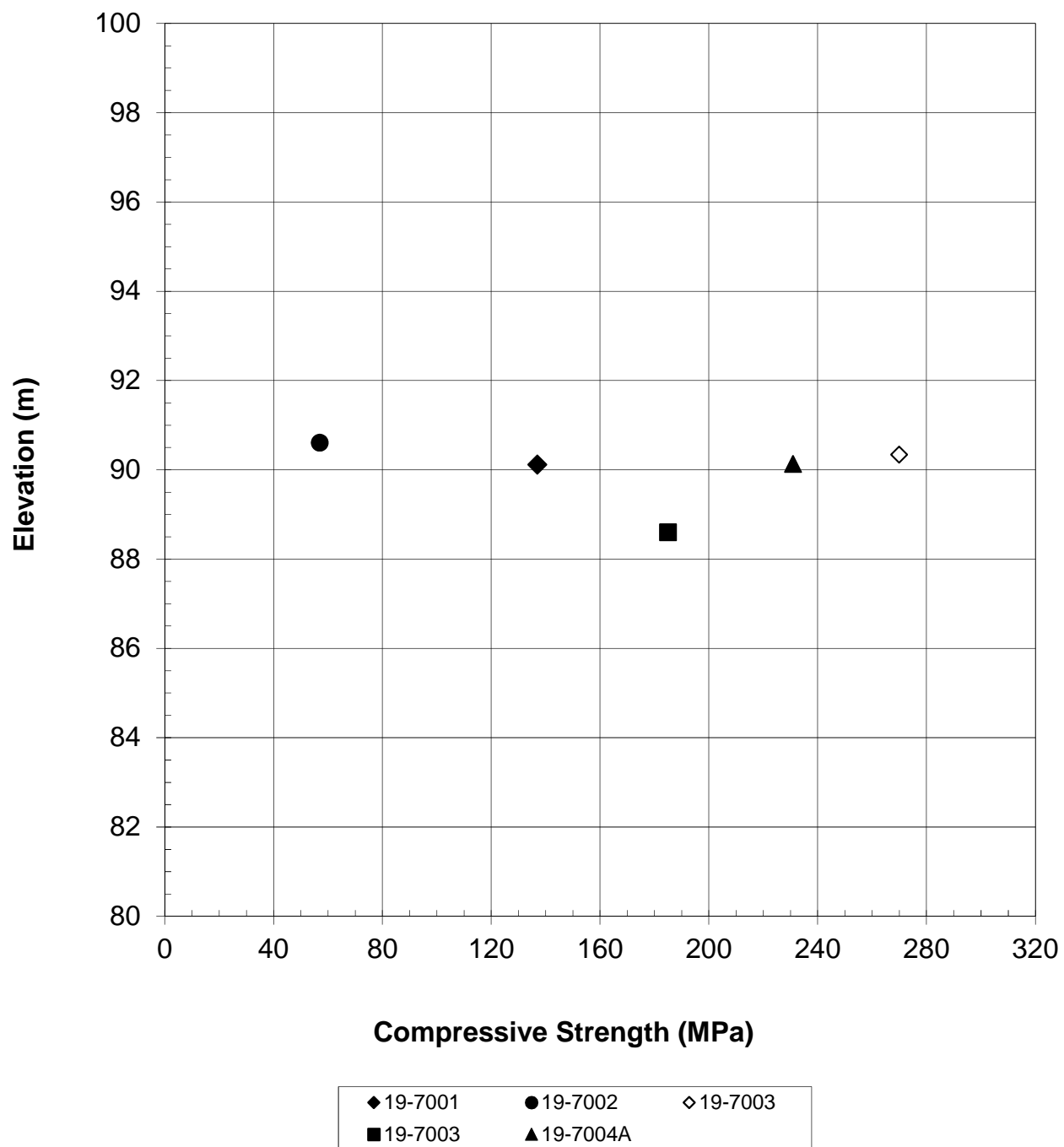
FIGURE B7



Borehole	Sample	Depth (m)
19-7002	8	4.27-4.88
19-7004A	11	7.62-8.23

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH UNCONFINED COMPRESSION TESTS

FIGURE B8



APPENDIX C

Results of Chemical Analysis

Eurofins Environment Testing Report No. 1913683 and 1915176



Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario

Attention: Kenton Power

PO#:

Invoice to: Golder Associates Ltd

Report Number: 1913683
Date Submitted: 2019-07-31
Date Reported: 2019-08-08
Project: 1899802/7000
COC #: 847133

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1444568 Soil 2019-07-11 19-7004 sa5	1444569 Soil 2019-07-15 19-7006B sa5	1444570 Soil 2019-07-16 19-7009 sa3
Group	Analyte	MRL	Units	Guideline				
Anions	Cl	0.002	%			0.006	0.067	0.006
	SO4	0.01	%			<0.01	<0.01	<0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm			0.12	0.64	0.16
	pH	2.00				8.66	8.06	8.56
	Resistivity	1	ohm-cm			8700	1570	6130

Guideline =

* = Guideline Exceedence

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range



Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
K2L 4G1
Attention: Kenton Power
PO#:
Invoice to: Golder Associates Ltd

Report Number: 1915176
Date Submitted: 2019-08-21
Date Reported: 2019-08-29
Project: 1899802 pH 7000
COC #: 847895

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.
Group	Analyte	MRL	Units	Guideline	1448940 Soil 2019-08-07 19-7002 SS 5
Anions	Cl	0.002	%		0.007
	SO4	0.01	%		0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.24
	pH	2.00			7.98
	Resistivity	1	ohm-cm		4120

Guideline =

* = Guideline Exceedence

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX D

Site Photographs



Photograph 1: Highway 416 platform looking north at culvert crossing; 2019-06-26



Photograph 2: Looking west upstream from culvert inlet towards Highway 416 southbound; 2019-06-26



Photograph 3: Looking east downstream from culvert outlet; 2019-06-18



Photograph 4: Looking north along west embankment / ditchline; 2019-06-26



Photograph 5: Looking north along east embankment / ditchline; 2019-06-26



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