Foundation Investigation and Design Report

Watermain Installation Station 15+825, QEW Widening from West of Mississauga Road to West of Hurontario Street, City of Mississauga Ministry of Transportation, Ontario, GWP 2002-13-00

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Table of Contents

REFERENCES

TABLES

DRAWINGS

APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT
WATERMAIN INSTALLATION AT STATION 15+825
QEW WIDENING FROM WEST OF MISSISSAUGA ROAD TO WEST OF HURONTARIO STREET, CITY OF MISSISSAUGA
MTO, GWP 2002-13-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the watermain installation at Station 15+825 associated with the widening of the Queen Elizabeth Way (QEW) from west of Mississauga Road to west of Hurontario Street in the City of Mississauga, Ontario, as shown on the Key Plan on Drawing 1.

The purpose of the foundation investigation is to explore the subsurface soil, bedrock and groundwater conditions along the alignment of the proposed watermain installation by borehole drilling, bedrock coring, geotechnical laboratory testing and analytical chemistry laboratory testing on selected soil and bedrock samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated July 2016, and the approved Change Request letters, which form part of the Consultant's Assignment Number (2015-E-0033) 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 February 3, 2017.

2.0 SITE DESCRIPTION

The proposed watermain installation at Station 15+825 is located approximately 35 m west of the intersection of Indian Grove Avenue and South Sheridan Way south of the QEW and extends from the grassy area north of the Mississauga Road W - QEW W On-Ramp southwards to just north of South Sheridan Way, located south of the QEW, in the City of Mississauga, Ontario (see Drawing 1). The QEW is oriented in a southwest-northeast direction which at this location and for the purpose of this report, is referred to as west-east orientation.

The QEW consists of three eastbound lanes (to Toronto) and three westbound lanes (to Hamilton), while South Sheridan Way consists of one lane in each direction. Residential areas are located on the south side of South Sheridan Way and a golf course is located north of Mississauga Road. The existing ground surface along the watermain alignment varies from about Elevation 100.6 m at the north end of the watermain alignment, to about Elevation 101.2 m on the pavement surface of the QEW (westbound lanes), to about Elevation 100.5 m at the south end of the alignment.

3.0 INVESTIGATION PROCEDURES

Field work for the foundation investigation was carried out between February 21 to March 10, 2019, during which time a total of four sampled boreholes, designated as Boreholes C1-1, C1-2, C1-3 and C1-4 were advanced along or adjacent to the proposed watermain alignment approximately at the locations shown on Drawing 1. This information was supplemented with Borehole NW4-5 advanced on July 3, 2018 for the proposed Noise Barrier Wall. In addition, use of the water level information obtained from a standpipe piezometer installed in Borehole C2-1 for the proposed sanitary sewer installation at Station 15+850 (located about 25 m east of the proposed watermain) is included in this report.

Field drilling was carried out using a truck-mounted CME 75 drilling rig supplied and operated by Geo-Environmental Drilling Inc., of Halton Hills, Ontario and a track-mounted CME 55 drilling rig and a truck-mounted CME 75 drilling rig supplied and operated by Davis Drilling Ltd., of Milton Ontario. The boreholes were advanced through the overburden using 70 mm, 83 mm and 108 mm inside diameter (I.D.) hollow-stem augers. Soil samples were obtained at 0.60 m, 0.75 m and 1.5 m intervals of depth, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-11)[1]. Samples of the bedrock were obtained using an 'HQ' size rock core barrel and wireline coring techniques in Boreholes C1-1 to C1-4 and NW4-5.

The boreholes were advanced to depths between 7.6 m and 13.1 m below existing ground surface, including coring of bedrock for core lengths of between 3.5 m and 9.7 m, in Boreholes C1-1 to C1-4 and NW4-5.

Groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in Boreholes C2-1 and C1-4 to allow monitoring of the water level at these borehole locations. The installed piezometers consist of a 50 mm diameter PVC pipe, with a slotted screen. The annulus surrounding the piezometer screens was backfilled with a filter sand pack. The section of borehole below the standpipe piezometers 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 cold patch asphalt 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).

Field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil and rock 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 laboratory testing. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. All of the soil laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

Selected rock core samples were submitted to Geomechanica Inc. of Toronto, Ontario for unconfined compression (UC) testing, assessment of Young's modulus and bulk density, CERCHAR abrasivity testing and slake durability testing. Rock core specimens were also submitted to Western University in London, Ontario for a suite of swell testing, which includes free swell, null swell and semi-confined, with accompanying moisture, salt, and calcite content testing; however, due to the long duration of the test, the results are not available for this reporting stage.

Selected bedrock samples were submitted to Maxxam Analytics (Maxxam) of Mississauga, Ontario, which is a Standards Council of Canada (SCC) accredited laboratory, for chemical analysis of a suite of characteristics including Petroleum Hydrocarbons, CCME F1 and BTEX. Additional bedrock core samples were also analyzed by Maxxam 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 on the Record of Borehole / Drillhole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) CSRS CBNV6-2010.0 northing and easting coordinates and the ground surface elevations are

[1] ASTM D1586-11 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the soil.

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

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (Latitude)	Easting (Longitude)		
C1-1	4,823,375.5 (43.550254)	295,216.1 (-79.618614)	100.8	12.7 (including 9.62 m of bedrock core)
C1-2	4,823,347.4 (43.550001)	295,235.2 (-79.618376)	101.1	12.9 (including 8.98 m of bedrock core)
C1-3	4,823,341.6 (43.549949)	295,290.0 (-79.617698)	100.8	13.1 (including 9.74 m of bedrock core)
C1-4	4,823,329.3 (43.549839)	295,310.9 (-79.617440)	100.4	12.8 (including 9.09 m of bedrock core)
NW4-5	4,823,340.0 (43.549927)	295,333.6 (-79.617156)	100.3	7.6 (including 3.51 m of bedrock core)
C2-1	4,823,392.0 (43.550403)	295,230.5 (-79.618436)	101.1	8.0 (including 4.38 m of bedrock core)

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area is located within the Iroquois Plain physiographic region, as delineated in The Physiography of Southern Ontario (Chapman and Putman, 1984)[2]. The glacial Iroquois Plain stretches along the northern shoreline of Lake Ontario, extending from the Niagara Escarpment in the west to the Scarborough Bluffs in the east. The Iroquois Plain soils consist of glaciolacustrine sediments deposited in Lake Iroquois, primarily sand, silt and gravel, with a shallow cover of till remaining over the bedrock. The Georgian Bay Formation bedrock, which underlies the study area, consists mainly of blue-grey shale, containing siltstone, sandstone and limestone interbeds. Outcrops of this formation are commonly found along water courses on the west side of Toronto and in Mississauga, notably in the Humber River, Mimico Creek, Etobicoke Creek and Credit River valleys.

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 samples are presented on the Records of Borehole and Drillhole sheets provided in Appendix A. Photographs of the recovered bedrock core samples are presented on Figures A-1 to A-5, in Appendix A. The results of the in-situ field tests (i.e., SPT “N”-values) 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 in

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

Appendix A 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 also presented in Appendix B. The analytical laboratory test report is included in Appendix C and the test results are summarized in Section 4.2.7.

Stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile on Drawings 2 and 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 2 and 3 is a simplification of the subsurface conditions.

In general, the stratigraphy encountered at the borehole locations typically consists of surficial layers of asphalt / concrete pavement underlain by fill which is underlain by a silty clay/clayey silt deposit or a residual soil deposit. The silty clay / clayey silt and residual soil deposits are underlain by shale bedrock. Detailed descriptions of the subsurface conditions are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit.

4.2.1 Asphalt / Concrete Pavement

An approximately 150 mm thick layer of asphalt pavement was encountered at ground surface in Boreholes C1-2 to C1-4 and NW4-5. A 240 mm and 270 mm thick layer of concrete was encountered underlying the asphalt pavement in Boreholes C1-2 and C1-3, respectively.

4.2.2 Fill

An approximately 0.4 m to 1.1 m thick layer of fill comprised of gravelly sand to sand and gravel, trace to some silt, trace clay and some organics in places was encountered immediately at ground surface in Borehole C1-1 and underlying the asphalt / concrete pavement in Boreholes C1-2 to C1-4 and NW4-5. The surface of the fill layer was encountered between depths of 0 m to 0.4 m below ground surface (between Elevations 100.8 m and 100.1 m).

The Standard Penetration Test (SPT) “N”-values within the fill layer ranges from 10 blows to 34 blows per 0.3 m of penetration, with an “N”-value of 50 blows for 0.1 m of penetration in Borehole C1-4, suggesting generally a compact to dense compactness condition and an inferred obstruction (cobble) in the fill.

The water content measured on four samples of the fill ranges from about 5 per cent to about 22 per cent.

4.2.3 Clayey Silt to Silty Clay

Underlying the fill in Boreholes C1-3, C1-4 and NW4-5, a 0.5 m to 0.8 m thick cohesive deposit consisting of clayey silt to silty clay, trace to some sand, trace to some gravel was encountered at depths of between 0.6 m to 0.9 m below ground surface (between Elevations 99.9 m and 99.6 m). The cohesive deposit in Borehole C1-3 contains some shale fragments.

The SPT “N”-values within the cohesive deposit range from 10 blows to 21 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

Grain size distribution testing was carried out on two selected samples of the cohesive deposit and the results are shown on Figure B-1 in Appendix B. Atterberg limits testing was carried out on two samples of the cohesive deposit and had measured liquid limits of about 40 per cent and 45 per cent, plastic limits between about 21 per cent and 22 per cent, and plasticity indices ranging between about 18 per cent and 24 per cent. These results, which are plotted on a plasticity chart on Figure B-2 in Appendix B, indicate that the cohesive deposit consists of silty clay of medium plasticity.

The water content measured on two samples of the cohesive deposit are between approximately 15 per cent and 20 per cent.

4.2.4 Silty Clay (Residual Soil)

A 1.0 m thick residual soil deposit comprised of silty clay, trace to some sand, trace to some gravel was encountered underlying the fill in Borehole C1-1 at a depth of 0.8 m below ground surface (Elevation 100.0 m). Residual soil is a heterogeneous mix of fully weathered bedrock that is disintegrated into a soil like material that no longer retains the structure of parent bedrock.

A SPT "N"-value of 18 blows per 0.3 m of penetration was recorded within the residual soil deposit and a SPT "N"-value of 40 blows per 0.3 m of penetration was recorded at the inferred completely weathered shale bedrock contact, suggesting a very stiff to hard consistency.

Grain size distribution testing was carried out on one sample of the residual soil deposit and the results are shown on Figure B-3 in Appendix B. Atterberg limits testing was carried out on one sample of the residual soil and had a measured liquid limit of about 36 per cent, a plastic limit of about 22, and a corresponding plastic index of about 14 per cent. The result, which is plotted on a plasticity chart on Figure B-4 in Appendix B, indicates that the residual soil deposit consists of silty clay of medium plasticity. The water content measured on one sample of the residual soil deposit is 10 per cent.

4.2.5 Shale Bedrock

The upper portion of the bedrock was sampled by split-spoon and the bedrock was confirmed by rock coring in Boreholes C1-1 to C1-4 and NW4-5. The length of bedrock sampled by split-spooning and by coring and the depths to and corresponding elevation of the completely to moderately weathered shale bedrock and the depths to and corresponding elevations of, the slightly weathered to fresh shale bedrock are summarized below.

Borehole No.	Completely to Moderately Weathered Bedrock		Length of Bedrock Split-Spoon Sampled (m)	Slightly Weathered to Fresh Bedrock		Length of Bedrock Cored (m)
	Depth (m)	Elevation (m)		Depth (m)	Elevation (m)	
C1-1	1.8 – 3.0	99.0 – 97.8	1.3	3.05 – 12.67	97.75 – 88.13	9.62
C1-2	1.5 – 4.0	99.6 – 97.1	2.5	3.96 – 12.94	97.14 – 88.16	8.98
C1-3	1.4 – 3.2	99.4 - 97.6	1.8	3.2 – 13.09	97.6 – 87.71	9.74
C1-4	1.2 – 4.0	99.2 – 96.4	2.6	4.0 – 12.75	96.4 – 87.65	9.09
NW4-5	1.5 – 3.8	98.8 – 96.5	2.4	3.8 – 7.63	96.5 – 92.70	3.51

Completely to Moderately Weathered Shale

Completely to moderately weathered shale bedrock was inferred at depths ranging from 1.2 m to 1.8 m below ground surface (Elevations 99.6 m to 98.8 m) based on drilling behaviour, observations of drilling cuttings and split-spoon sampling. The thickness of the completely to moderately weathered bedrock is inferred to range from about 1.2 m to 2.8 m.

The SPT “N”-values measured within the completely to moderately weathered shale bedrock range from 26 blows per 0.3 m of penetration to 100 blows for 0.15 m of penetration, suggesting a very stiff to hard consistency and blockages of sampling equipment by fragments of rock.

Grain size distribution testing was carried out on four samples of the inferred completely to moderately weathered shale bedrock obtained by split-spoon sampling and the results are shown on Figure B-5 in Appendix B. The split-spoon samples obtained from within the inferred completely to moderately weathered bedrock do not contain larger fragments of rock due to the sampler size and sampling method. Larger fragments of unweathered shale bedrock may be present in-situ. In addition, the percentage of gravel size particles may include shale fragments that either remained intact after or were broken during sampling and sample preparation. Therefore, the results of the grain size distribution testing may not be representative of the bulk grain size distribution or behaviour of the in-situ or excavated completely to moderately weathered shale bedrock.

Atterberg limits testing was carried out on the finer fractions of four samples of the inferred completely to moderately weathered shale bedrock and measured liquid limits ranging from about 32 per cent to 38 per cent, plastic limits ranging from about 20 per cent to 22 per cent, and plastic indices ranging from about 12 per cent to 16 per cent. These results are plotted on a plasticity chart on Figure B-6 in Appendix B and indicate that the finer fraction of the inferred completely to moderately weathered shale bedrock, when broken down to a soil consists of a clayey silt of low plasticity to a silty clay of medium plasticity.

The water content measured on eleven samples of the inferred completely to moderately weathered shale bedrock range between approximately 5 per cent and 15 per cent.

Moderately Weathered to Fresh Shale

Based on a review of the recovered bedrock core samples, the bedrock consists of shale of the Georgian Bay Formation. In general, the bedrock core samples are described as slightly weathered to fresh, very thinly to thinly laminated to medium bedded, very fine to fine grained, faintly porous, weak, grey, shale, with slightly weathered to fresh, grey, fine grained, laminated to medium bedded, strong to very strong limestone interbeds at varying intervals of depth as presented on the drillhole records. An exception to these generalized conditions was found at Borehole C1-4 where a 0.4 m thick zone of moderately weathered shale that was classified as very weak, based on field description, was encountered at the bedrock surface. The limestone layers within the slightly weathered to fresh shale range in thickness from about 10 mm to 240 mm, with an average thickness of about 40 mm. The rock core samples obtained during the drilling investigation contain less than 5 per cent to up to 35 per cent stronger limestone layers (based on the percentage of limestone in a core run). Details of the bedrock descriptions are presented on the drillhole records and a photograph of the recovered bedrock core samples is presented on Figures A-1 to A-5 in Appendix A. The degree of weathering of the bedrock core samples (i.e., fresh to moderately weathered – W1 to W3), and the strength classification of the intact rock mass based on field identification (i.e., weak – R2) are described in accordance with the International Society for Rock Mechanics (ISRM[3]) standard classification system.

[3] 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.

The Rock Quality Designation (RQD) measured on the core samples ranges from about 70 per cent to 100 per cent, indicating that the slightly weathered to fresh portion of the rock mass consists of fair to excellent quality as per Table 3.10 of CFEM (2006)[4]. The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered range between 96 per cent and 100 per cent and between 82 per cent and 100 per cent, respectively.

Unconfined Compression (UC) testing (ASTM D7012)[5] was carried out on seven selected core samples of the shale bedrock and the uniaxial compressive strength (UCS), bulk density and Young's moduli of the intact samples are summarized below and the details are presented in the Rock Laboratory Test Results report from Geomechanica in Appendix B. The UCS of intact shale rock specimens ranges from 11 MPa to 25 MPa, with an average of about 17.6 MPa, for the slightly weathered to fresh portion of the bedrock formation. Based on the range of laboratory UCS test results, in accordance with Table 3.5 in CFEM (2006)[4], the shale bedrock is classified as weak rock (R2, 5 MPa < UCS < 25 MPa). A single limestone bedrock core sample was also tested with a UCS test result of 210 MPa which is classified as very strong rock (R5, 100 MPa < UCS < 250 MPa); however, the results of one test should not be considered representative of all limestone interbeds.

Borehole No. / Sample No.*	Sample Depth (m)	Sample Elevation (m)	UCS (MPa)	Young's Modulus, E at 2.5 MPa (GPa)	Young's Modulus, E at 50% UCS (GPa)	Density (g/cm^3)	Rock Type
C1-1 / SA-02	5.25 - 5.55	95.55 - 95.25	19.3	1.8	1.0	2.607	Shale
C1-1 / SA-03	6.79 - 7.13	94.01 - 93.67	15.2	1.4	1.0	2.602	Inter-bedded limestone and shale
C1-2 / SA-05	8.13 - 8.32	92.97 - 92.78	19.1	2.1	0.7	2.600	Shale
C1-2 / SA-06	10.86 - 11.07	90.24 - 90.03	25.0	2.4	1.5	2.602	Shale
C1-3 / SA-04	6.54 - 6.75	94.26 - 94.05	210.2	N/A	44.4	2.667	Limestone
C1-4 / SA-02	7.49 - 7.81	92.91 - 92.59	15.9	1.4	1.0	2.603	Shale
C1-4 / SA-03	7.15 - 7.38	93.25 - 93.02	11.0	0.9	0.5	2.585	Shale

NOTE:

* The sample numbers listed above and in the two tables below are related to the samples selected from the rock core and do not correspond to the run number shown on the drillhole sheets.

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

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

The results of the slake durability testing carried out on one selected core sample of the shale bedrock obtained in Borehole C1-4 are presented below and in Appendix B.

Borehole No. / Sample No.	Sample Depth (m)	Sample Elevation (m)	Moisture Content (%)	Slake Durability Index (1st Cycle) I_{d1} (%)	Slake Durability Index (2nd Cycle) I_{d2} (%)
C1-4 / SA-01	6.27 - 6.47	94.13 - 93.93	0.9	80.9	57.1

The results of the CERCHAR abrasivity index (CAI) testing carried out on one selected core sample of the shale bedrock obtained in Borehole C1-2 are presented below and in Appendix B.

Borehole No. / Sample No.	Sample Depth (m)	Sample Elevation (m)	Mean Wear (mm)	CAI	Standard Deviation of CAI	ASTM Classification
C1-2 / SA-02	4.78 - 4.91	96.32 - 96.19	0.025	0.25	0.06	< Very Low

The swelling potential of the shale bedrock was investigated by conducting a suite of swell tests at Western University (K.Y. Lo Inc.) in London, Ontario. The samples were subjected to either free swell (samples with no applied pressure), semi-confined (confining pressure applied to samples in the direction of the sample axis) or null swell conditions (swelling in the direction of the sample axis was fully restricted and the pressure applied to suppress swelling was measured), in either vertical and horizontal orientations (sample axis perpendicular and along the bedding plane respectively), with accompanying moisture, salt, and calcite content testing.

The tests assessing the swell potential are still underway at the time of this report and will be issued to the MTO under a separate cover.

4.2.6 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are presented on the Records of Boreholes in Appendix A. A standpipe piezometer was installed in Borehole C1-4 to monitor the groundwater level at the borehole location. In addition, for the proposed sanitary sewer installation at Station 15+850, located about 25 m east of the proposed watermain, a standpipe piezometer was installed in Borehole C2-1. This information is included below to supplement the groundwater information obtained from Borehole C1-4. 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
C1-1	100.8	Dry	-	February 26, 2019	Dry prior to bedrock coring
C1-2	101.1	Dry	-	February 26, 2019	Dry prior to bedrock coring
C1-3	100.8	Dry	-	March 7, 2019	Dry prior to bedrock coring

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C1-4	100.4	Dry	-	February 21, 2019	Dry prior to bedrock coring
		4.6	95.8	March 19, 2019	Piezometer – sealed into shale bedrock
NW4-5	100.3	Dry	-	July 3, 2018	Dry prior to bedrock coring
C2-1	101.1	Dry	-	February 26, 201926-Feb-19	Dry prior to bedrock coring
		4.7	96.4	March 13, 2019	Piezometer – sealed into shale bedrock
		5.7	95.4	March 21, 2019	

4.2.7 Analytical Testing Results

Selected specimens of the rock core samples collected from Boreholes C1-2 and C1-3 were submitted to Maxxam Analytics (Maxxam), a Standards Council of Canada (SCC) accredited laboratory, of Mississauga, Ontario, for chemical analysis of the following parameters: Petroleum Hydrocarbons, CCME F1 and BTEX.

No evidence of odour or staining was noted during drilling in any of the samples. The Maxxam report is provided in Appendix C. A summary of the parameters analyzed is provided below.

Borehole No. / Sample No.	Sample Depth (m)	Sample Elevation (m)	Analyzed Parameters
C1-2 / SA-01	4.29 - 4.37	96.81 - 96.73	Petroleum Hydrocarbons, CCME F1 and BTEX
C1-3 / SA-03	6.31 - 6.37	94.49 - 94.43	Petroleum Hydrocarbons, CCME F1 and BTEX

Two specimens from the bedrock core samples were submitted for analysis of parameters used to assess the potential corrosivity of the site soil to steel and concrete. The Maxxam report is provided in Appendix C and summarized below.

Borehole No.	Borehole C1-1 Run#3 Specimen at Elev. 94.9 m	Borehole C1-2 Run#2 Specimen at Elev. 95.8 m
pH	8.02	8.19
Resistivity (ohm-cm)	1,700	2,100
Electrical Conductivity (umho/cm)	583	469
Chlorides (ug/g)	37	32
Soluble Sulphates (ug/g)	350	160

5.0 CLOSURE

This report was prepared by Ms. Andrea Begin, E.I.T. of the Mississauga Rock Group, 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., an MTO Foundations Designated Contact and Principal with Golder, conducted a technical and quality control review of the report.

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PART B

FOUNDATION DESIGN REPORT
WATERMAIN INSTALLATION AT STATION 15+825
QEW WIDENING FROM WEST OF MISSISSAUGA ROAD TO WEST OF HURONTARIO STREET, CITY OF MISSISSAUGA
MTO, GWP 2002-13-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation engineering design recommendations for the proposed Region of Peel watermain installation (UTL-1 (WM-1)) at approximately Station 15+825 associated with the widening of the Queen Elizabeth Way (QEW) from west of Mississauga Road to west of Hurontario Street in the City of Mississauga, Ontario (see Key Plan on Drawing 1). These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess alternative / feasible trenchless and open cut installation methods, and to provide the designers with sufficient information to assess the feasible protection system alternatives for the shafts. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

This report addresses geotechnical considerations associated with the installation of the watermain by means of a trenchless and cut-and-cover methods. The proposed alignment for the watermain, including other pertinent features are shown on Drawing 1. Based on the design drawings provided by Morrison Hershfield Limited (MH) on January 8, 2019 and updated drawings provided on March 22, 2019, the proposed watermain construction will consist of the following major elements:

- The new watermain will connect to an existing watermain in a proposed entry shaft in the grassy area between the Mississauga Road and the Mississauga Road E – W QEW On-Ramp at Station 0+060 (north of the QEW).
- From the entry shaft located north of the QEW, the proposed 400 mm diameter PVC pipe will be installed by a trenchless method within an 85.5 m long 1200 mm diameter casing under the QEW and will connect to the proposed exit shaft located on the south side of the QEW at Station 0+155 to 0+160.
- South of the exit shaft at Station 0+160, the proposed watermain will be installed using cut-and-cover methods for a length of 20 m to Station 0+180, where it will connect to the existing 500 mm diameter watermain located on the north side of South Sheridan Way.

Based on the alignment drawing provided by MH, the invert of the proposed approximately 1200 mm diameter casing will be at Elevation 94.6 m and the depth of cover, based on the existing ground surface profile, to the obvert of the casing (at Elevation 95.8 m) will vary from approximately 3.7 m to 5.3 m along the tunnel alignment. The depth of cover used in this report is measured to the obvert of the cut diameter of the tunnel crossing (approximately 1200 mm diameter) to the variable existing ground surface along the alignment, as shown on the latest design drawings provided by MH; however, depending on the final equipment selected for construction, the depth of cover to the top of the trenchless/tunnel cut may be different and should be evaluated again once additional information becomes available regarding the trenchless method and casing size ultimately chosen by the contractor.

The invert of the proposed watermain for the portion installed using cut-and-cover methods will also be at Elevation 94.6 m (between approximately 5.2 m and 5.9 m depth below ground surface). The proposed shaft locations are shown on Drawing 1 and the base of the proposed shafts will be at a depth of about 6.6 m below ground surface (Elevation 94.1 m).

The contractor should be fully responsible for the selection of the trenchless technology which best suits the contract requirements and subsurface conditions. All trenchless work should be carried out in accordance with MTO's Non-Standard Special Provision (NSSP) titled "Pipe Installation by Trenchless Method" dated November 2018, a copy of which is included in Appendix D; and has been modified by recommendations provided in this report. It is assumed that the work will be carried out by an experienced specialist contractor employing only qualified workers skilled in their trade. The work plan should include a provision for grouting around the outside of any temporary or permanent ground support systems should the need arise. It is recommended that the geotechnical aspects of the contractor's work plan for the trenchless undercrossing be reviewed by a qualified geotechnical engineer prior to construction.

In general, when crossing beneath highways, trenchless operations should be carried out continuously (i.e., 24 hours per day) from the start until the installation is complete. Continuous operations assist with minimizing risks of equipment becoming bound in the excavation by time-dependent increases in friction and/or adhesion, uncontrolled ground losses, and other critical problems that may occur while the work area is unattended. Recommendations specific to the methodologies appropriate for this site are provided in the following report sections.

6.1 Anticipated Ground Conditions Along the Proposed Watermain Alignment

Based on the subsurface data, it is anticipated that the proposed tunnel alignment will be located within the slightly weathered to fresh shale bedrock with limestone and siltstone interbeds of the Georgian Bay Formation (herein after referred to as bedrock) with approximately 1.8 m to 2.2 m of slightly weathered bedrock cover above the obvert of the proposed casing elevation and the bedrock (completely to moderately weathered) surface is about 3.4 m to 3.6 m above the obvert of the tunnel. The subsurface soil conditions overlying the bedrock consist of stiff to very stiff clayey silt to silty clay deposit at the borehole advanced near the exit shaft and very stiff to hard silty clay residual soil deposit at the borehole advanced near the entry shaft. All four boreholes advanced along the proposed tunnel alignment were dry upon completion of overburden drilling. The groundwater level measured in the standpipe piezometer installed in Boreholes C1-4 and C2-1 were at depths of about 4.6 m and 5.7 m below ground surface (Elevation 95.8 m and 95.4 m), respectively, which is about coincident with the obvert of the casing of the proposed tunnel.

The behaviour of the anticipated subsurface soil can be classified using Terzaghi's Tunnelman's Ground Classification system as modified by Heuer (1974)[6]. The behaviour of the cohesive deposit is classified as "firm" to "slow ravelling", while the silty clay residual soil deposit is classified as "slow" to "fast ravelling". The cohesive deposit and residual soil deposit would have a stand-up time ranging from a few minutes to several hours depending on the degree of seepage, disturbance and localized grain size distribution. The stand-up time of this material will likely be unpredictable.

[6] Heuer, R.E. *Important Ground Parameters in Soft Ground Tunneling*. Proceedings of a Specialty Conference on Subsurface Explorations for Underground Excavation and Heavy Construction, ASCE, New York, page 41 to 55, 1974.

The measured SPT "N"-values within the completely to moderately weathered shale bedrock range from 27 blows per 0.3 m of penetration to 100 blows for 0.13 m of penetration, suggesting a very stiff to hard consistency. The completely to moderately weathered shale will be partly to completely disintegrated to a soil-like material, with weathered shale inclusions, has been classified as "slow ravelling" within this report and would have a stand-up time in the order of minutes to several hours. The moderately to highly weathered shale will also have intact shale layers and particles of variable sizes. The bedrock also typically contains harder limestone and or siltstone layers that will be much stronger (typically 70 MPa to 210 MPa strength) and more abrasive (moderately to highly abrasive) than the shale layers. The harder layers may cause some difficulties in excavation at the shafts and tunnelling and in maintaining vertical alignments of the tunnel, depending on the tunnelling method and equipment. It is expected that a tunnel face or excavation at the shafts made in the slightly weathered to fresh zone of the bedrock will stand unsupported for several hours and then begin to degrade. The face and crown of the tunnel will begin to ravel, and slab failures are possible (due to delamination along bedding).

The Contract Documents should contain an NSSP warning the contractor of the expected interbedding of shale and harder limestone layers within the tunnel alignment. An NSSP is provided in Appendix D for inclusion in the Contract Documents.

6.2 Trenchless Pipe Installation Methods – Overview

The contractor will be responsible for choosing the method and equipment for the watermain installation unless specific methods are otherwise prohibited by the contract. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on the suitable trenchless methodologies. It should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A of this report (i.e., Foundation Investigation Report).

Based on the alignment information provided by MH, it is anticipated that the watermain will be installed in bedrock under the QEW using trenchless methods to reduce the potential effects of construction on traffic flow. The following trenchless methods have been considered for this site:

- micro-tunnelling with a micro-tunnel boring machine (MTBM);
- tunnelling with a small boring unit (SBU);
- horizontal directional drilling (HDD); and
- horizontal raise boring.

With any of these options, the selected equipment must be able to excavate through the variable weathering conditions of the shale bedrock, alternating harder layers of bedrock (i.e., strong to very strong limestone interbeds) and variable strength (i.e., very weak to weak) shale bedrock with both of these rock types in layers of variable thickness. The selected method must be able to install the casing pipe as the tunnel advances to reduce the risk of ground losses and settlement around the tunnel excavation. Dewatering will be required at both shaft locations (see Section 6.4.2) as the base of the shafts will extend about 0.5 m below the groundwater surface. As discussed in Section 4.2.6 seasonal fluctuations in the groundwater level should be expected.

6.2.1 Micro-Tunnel Boring Machines (MTBM)

Micro-tunnelling is a method of installing pipes behind a steerable remote controlled shielded micro-tunnel boring machine (MTBM) that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remotely controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling has four main attributes: a remotely controlled, steerable MTBM; a guidance system; pipe jacking to install pipes; and continuous pressure exerted at the excavation face to balance earth and groundwater pressures (ASCE/CI 36-15). Typically, settlement can be controlled with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive. The outer pipe / casing is installed while the bore is being advanced.

The MTBM is used to install a pipe between an entry (launch) shaft and an exit (receiving) shaft in a single pass. The MTBM is launched from the entry shaft and advanced by pushing a casing pipe using hydraulic jacks and a reaction frame that are installed in the entry shaft. The casing pipe is installed in segments by cyclic pipe jacking. Depending on the length of the tunnel drive, intermediate jacking stations (interjacks) are often required to reduce the jacking forces on the main jack while pushing the pipe forward. Interjacks are typically installed approximately every 100 m to 150 m within the outer casing pipe. For longer drives, intermediate jacking shafts could be required depending on the diameter and length of the bore. Tunnel spoil would generally be returned to the entry shaft area using a slurry system. The entry shaft area would require a slurry separation plant and mud pit to separate the solids from the slurry. Both entry and exit shafts are required for micro-tunnelling operations.

Overcut should be minimized by selection of a casing diameter which is similar to that of the shield. If over excavation occurs, the annulus between the outside of the pipe and the ground should be immediately filled with bentonite slurry of an appropriate viscosity. The slurry should be appropriately formulated, using suitable additives, if necessary, for the anticipated ground conditions. A seal will be required to close the annular space between the wall of the entry/exit shaft and the shield and pipes to retain soil behind the temporary shoring and stop backflow of slurry into the shafts.

Properly selected rock cutter discs should be used to cut the bedrock at the face into fragments small enough to pass through the apertures in the cutter head. Other face tools, including rippers and picks, are often broken by the alternating limestone and shale layers. Construction specifications for the installation of the tunnel by the use of a MTBM are given in the NSSP for “Pipe Installation by Trenchless Method” in Appendix D.

6.2.2 Small Boring Unit (SBU)

In the greater Toronto area, some trenchless contractors use small boring units (SBU) and present this system as micro-tunnelling. In general, the SBUs often consist of a rotating cutter head system that is temporarily welded to the lead end of a steel casing. The ground is cut using a variety of face tools (similar to MTBMs described above), but the spoil is transported to the entry shaft using an auger system, much like conventional jack and bore systems. Face openings on the SBUs are typically much smaller than the auger opening on conventional jack and bore systems and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to jack and bore methods. These systems do not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based MTBMs described above. For this reason, micro-tunnelling should not be undertaken using an SBU if there is a risk that saturated or dry granular soils (native or highway and pavement fill materials) or adverse groundwater flow conditions will be encountered. In this case, an SBU fitted with appropriate face tools (as described above for MTBMs) should be capable of completing this work, provided that additional groundwater control and management measures are planned, available and implemented in the event that the highly weathered rock is encountered within the tunnel heading. Similar to the other trenchless methods, entry and exit shafts are required for SBU operations.

6.2.3 Horizontal Directional Drilling (HDD)

Horizontal directional drilling (HDD) uses drilling fluid under pressure and a drilling bit to create the pilot hole which can be reamed to a larger diameter and is typically used for smaller diameter crossings below embankments or rivers, where the installed carrier pipe will be conveying fluid under pressure and therefore is not dependent on gravity drainage. Typically, HDD would require a long entrance / exit bore curvature to achieve the required vertical alignment at the ends of the crossing. For a 400 mm diameter pipe, a reamed diameter on the order of 500 mm to 600 mm may be required. The thickness of cover at this location is marginal with respect to the risk of loss of drilling fluid to the surface (“frac-out”) through fractures in the rock and hydraulic fracturing of the overlying weathered rock/residual soil and cohesive deposits. In this case, HDD is also not generally suitable for installing a steel carrier casing of a diameter contemplated for this project and, typically, steel casings are required for similar highway crossings to reduce the risk of pipeline failures causing losses of ground that could otherwise jeopardize the overlying highway. Therefore, the HDD method has not been considered further herein. If smaller diameter steel casings or elimination of the need for such a casing can be considered, and if HDD appears to be cost-effective given the additional lengths of drilling required to obtain the required horizontal alignment, additional recommendations can be provided at that time.

6.2.4 Horizontal Raise Boring

This method is similar to horizontal directional drilling (HDD) which involves drilling a small hole (i.e., a pilot hole), back reaming the hole to enlarge it, and finally pulling the product pipe through the reamed hole, except this particular method involves drilling and reaming from inside a shaft. This particular method involves the drilling of a pilot hole along the proposed tunnel alignment, typically in the order of 0.2 m to 0.3 m in diameter, and then enlarging the pilot hole to the required size (i.e., final diameter) by one or more reaming passes. Cuttings from the reaming are blown back to the entry shaft using compressed air lines. The selection of the reaming equipment is dependent on the type and strength of the bedrock. Casing pipe is not typically used during back reaming for this method, although it is possible. Alignment control of this method, when passing through horizontally-layered rock of variable strengths, can be significantly problematic.

6.3 Construction Considerations

Trenchless construction methods described in Section 6.2 include various advantages and disadvantages depending on anticipated ground conditions, depth of cover, vertical and horizontal alignment, length of pipe installation, cost and availability of equipment, and carry varying levels of risk of successfully completing the installation. The advantages, disadvantages and relative costs and risks are compared in Table 1, following the text of this report. From a geotechnical perspective the preferred alternative is to use a micro-tunnelling boring machine for the trenchless installation portion of the proposed watermain as it is able to provide appropriate alignment control, ground support, management of cuttings, and pressure to the face of the tunnel in order to minimize groundwater control and ground loss concerns. The methods, construction recommendations and limitations for micro-tunnelling using a MTBM, tunnelling using an SBU, and horizontal raise boring are discussed in the following sections.

6.3.1 Micro-tunnelling Considerations

Micro-tunnelling uses bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. If the slurry pressure at the face is allowed to become too high, hydraulic fracture (typically referred to as “frac-out”) of the ground can occur, allowing bentonite slurry to exit at ground surface. “Frac-out” can then result in a sudden drop in face pressure, creating face instability if tunnelling through non-cohesive soils below the groundwater table. To minimize the risk of “frac-out” slurry micro-tunnelling should not be used for tunnelling construction if the cover is less than 2.5 m. Further, to both properly support ground at the cutting face and along the pipe if an over-cut is used, slurries should have a Marsh funnel viscosity between about 50 and 70 seconds.

It should be noted that while the installation of this watermain is expected to be entirely within the slightly weathered to fresh shale bedrock, there is a potential that more weathered and weaker bedrock may be encountered along the tunnel alignment if there are localized areas where the weathering extends deeper. If variable weathering and strength face conditions are encountered an advantage of using a slurry MTBM is that the slurry pressure applied at the face can help control and minimize any ground losses.

Similar to the other trenchless methods, entry and exit shafts are required for micro-tunnelling operations. The length of the proposed watermain to be installed using trenchless methods is about 85 m, so it is not anticipated that any intermediate shafts or jacking rings will be required to complete the drive. Dewatering or water tight shaft construction will be required at both shaft locations to prevent excessive groundwater seepage. Dewatering recommendations are provided in Section 6.4.2 of this report.

The minimum shaft dimensions for this size of casing pipe installed by micro-tunnelling is approximately 5 m to 6 m diameter for the launch shaft and 4 m to 5 m diameter for the exit shaft.

6.3.2 Small Boring Unit Considerations

A disadvantage of the small boring unit is that it does not have the ability to apply pressure to the face to prevent or minimize ground losses. A small boring unit is best suited to conditions where the tunnel alignment is entirely within the bedrock. As discussed in Section 6.1, the proposed watermain is expected to be excavated entirely within the slightly weathered to fresh shale bedrock; however, there is a potential that for localized areas where more weathered and weaker bedrock may encountered in the upper portion of the tunnel. This may result in the potential for the bedrock in the upper portion of the tunnel having a lower stand-up time and potential ground loss. Although the groundwater level measured in a piezometer installed in Boreholes C1-4 and C2-1 is at about the obvert of the 1200 mm diameter tunnel, the bedrock is expected to yield little groundwater inflow into the tunnel excavation. However, actual groundwater inflows into the tunnel are dependent on parameters such as fracture geometry, frequency, and aperture, and water inflows are typically greater at the weathered rock interface near the top of the bedrock surface. For variable weathering and strength face conditions in bedrock below the groundwater level, small boring units may not be suitable as the weathered rock can ravel into the excavation at the face due to the lack of face pressure, potentially resulting in ground loss below the pavement surface of the highway if the face is left unsupported by other means and subject to saturation.

6.3.3 Horizontal Raise Boring Considerations

Due to the relatively low cover between the ground surface and the obvert of the tunnel (between approximately 3.8 m to 5.2 m), the tunnel must be fully lined as tunnelling progresses in order to minimize the risk of ground losses. The horizontal raise boring method does not lend itself well to this requirement as the casing pipe would have to be pulled back through the hole as it is reamed. Although this method has been previously used on a similar crossing in the Greater Toronto Area, the requirement to advance casing pipe during back reaming has proven to be problematic on previous crossings. As noted above, alignment control in this bedrock formation may also be challenging.

6.4 Entry / Exit Shafts and Cut-and-Cover Method

Open cut construction involves trench excavation and excavation sidewall support, bedding and pipe installation, trench backfilling and pavement restoration (as applicable). The cut-and-cover method offers the best control of horizontal and vertical alignment, reduces the potential for delays resulting from encountering obstructions and provides the least risk of unanticipated damage to the active roadways.

The proposed invert of the watermain is between about 3.8 m and 5.2 m depth below ground surface and depending on construction staging, the watermain could be installed using cut-and-cover methods. However, the major disadvantages with cut-and-cover installation include the requirement for proper construction staging to minimize traffic disruption, the need for large and relatively deep excavations at some locations, dewatering systems where excavation will extend below groundwater levels, and the potential for post-construction settlement of the backfill materials especially in deep trenches. Furthermore, stacked trench box systems for excavation support do not provide for intimate contact with the excavation sidewalls leading to loss of lateral stability and ground movement, and further can be problematic / impractical as temporarily stable unsupported vertical trench sidewalls cannot be maintained due “firm” to “slow ravelling” of the cohesive and residual soil deposits and “slow” ravelling” of the completely to highly weathered shale bedrock .

6.4.1 Open Cut Excavations

Cut-and-cover construction methods are planned to extend from south of the proposed exit shaft at Station 0+160 southward for a length of 20 m to Station 0+180, located in the grassy area between the outside shoulder of the QEW eastbound lanes and the noise barrier wall on the south side of the QEW, where it will connect to the existing 500 mm diameter watermain. Based on the drawings received from MH, the entry and exit shafts are proposed to be constructed at the following locations:

- Entry shaft located at Station 0+060 in the grassy area between the Mississauga Road and the Mississauga Road E – W QEW On-Ramp; and,
- Exit shaft located at Station 0+160, between the outside shoulder of the QEW eastbound lanes and the noise barrier wall on the south side of the QEW.

Given the location of the entry shaft in the grassy area north of the QEW, consideration could be given to excavating the entry shaft in open cut, providing that the performance of the QEW is not impacted. In this regard, consideration could be given to constructing the shaft further to the north; however, Mississauga Road is located north of the grassy area and the shaft would need to be a sufficient distance from Mississauga Road so as not to affect the performance of Mississauga Road. The exit shaft is located adjacent to the outside lane of the QEW eastbound lanes and depending on the time of construction relative to the construction staging, consideration could be given to constructing the exit shaft using open cut excavation methods, providing that the excavation does not impact the live lanes.

Excavations will typically extend through the existing granular (non-cohesive) fill materials, into the clayey silt to silty clay deposit and silty clay residual soil deposits and into the bedrock. All temporary and permanent excavations, including trenches and shafts should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations (OHSA), with local regulations and as outlined in Ontario Provincial Standard Specification (OPSS) 402 (*Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers*), 403 (*Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut),* OPSS 407 (*Maintenance Hole, Catch Basin, Ditch Inlet and Valve Chamber Installation*) and OPSS 441 (*Watermain Installation in Open Cut*). The existing granular fill materials, stiff to very stiff cohesive deposit and residual soil would likely be categorized as Type 3 soils. For preliminary planning purposes, the completely to highly weathered shale should be considered analogous to a soil behaviour that would fall under the general characteristics of Soil Type 2; however, given the variable nature of this material, the soil behaviour type and its relation to excavation support must be examined and judged for each exposure during construction. Temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). However, depending upon the construction procedures adopted by the contractor, actual groundwater seepage conditions, the success of the contractor's groundwater control methods and weather conditions at the time of construction, some flattening and/or blanketing of the slopes may be required. Temporary excavations in the slightly weathered to fresh shale bedrock can be made near vertical; however, the moderately weathered shale bedrock represents a transition between highly weathered and slightly weathered and, depending on the extent of weathering and the duration the excavation remains open, temporary protections system may be required to extend through this material. Excavated material must be stockpiled at a distance away from the excavation equal to or greater than the depth of the open cut excavation through the overburden.

6.4.2 Groundwater Control

Dewatering will be required for the cut-and-cover and the entry and exit shafts, as these excavations are expected to extend approximately 1.7 m below the groundwater level measured at about Elevation 95.8 m within the bedrock. Groundwater control by pumping from filtered sumps placed at the base of the excavation may be sufficient to handle the groundwater inflows from the bedrock into the excavation. Surface water should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade.

Dewatering should be carried out in accordance with OPSS.PROV 517 (*Construction Specification for Dewatering*) and SP517F01 (*Dewatering System*); it is recommended that the requirement for a dewatering design engineer be specified and that an inspection radius of 50 m be used in Table A contained in SP517F01. Construction water takings in excess of 50 m^3/day are regulated by the Ministry of the Environment, Conservation and Parks (MECP). Certain takings of groundwater and stormwater for construction dewatering purposes with a combined total less than 400 m^3/day qualify for self-registration on the MECP's Environmental Activity and Sector Registry (EASR). Registry on the EASR replaces the need to obtain a PTTW for water taking less than 400 m^3/day and a Section 53 approval for discharge of water to the environment. A "Water Taking Plan" and a "Discharge Plan" are required by the MECP if water is taken in accordance with an EASR. In all cases, discharge under the EASR must be in accordance with a Discharge Plan. A Category 3 PTTW would be required for water takings in excess of 400 m^3/day. The construction water taking permit and registration should be prepared adequately in advance of site excavation works so as not to unduly affect the construction schedule.

6.4.3 Temporary Protection Systems

Where the side slopes of cut-and-cover excavations and shafts are required to be steepened to limit the extent of the excavation, then some form of trench support will be required. The shaft excavations could be carried out using a vertically unsupported excavation (using a properly engineered prefabricated support system for personnel protection, certified by an experienced engineer) in open areas which can tolerate lateral movement of the soil deposits; or by a supported excavation (discussed below) if in close proximity to adjacent structures or underground services where restriction of lateral movements is required. It must be emphasized that a prefabricate support system (trench liner box) provides protection for construction personnel but does not provide any lateral support for adjacent excavation walls, underground services or existing structures. It is imperative that underground services and existing structures adjacent to the trench excavations be accurately located prior to construction and adequate support provided where required. Steepened excavations should be left open for as short a duration as possible and completely backfilled at the end of each working day.

The upper portions of the shafts through the soils and completely to highly weathered shale could be constructed using soldier piles and lagging, a slide rail system, or a contiguous reinforced concrete cast-in-place secant pile wall provided that groundwater control systems are fully operational and demonstrated to be effective prior to excavation, including prior to installing lagging or below the edge of the slide rail panels if such a system is adopted. While consideration might be given to driven sheet piles for support of the upper sections of the shafts, adequate embedment through the completely to highly weathered shale bedrock may not be reliably achievable. Steel H-piles for soldier piles should be installed in pre-drilled holes. As noted above, the use of trench boxes and any system which does not provide continuous support to the excavation walls is not recommended. All shaft excavation methods will need to account for the completely to slightly weathered shale bedrock, layered shale and limestone conditions and conventional clam-shell excavators will likely be unsuccessful, even in the soil or soil-like portions of the completely to highly weathered shale.

The temporary excavation support system should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), as amended by SP 105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539 (*Temporary Protection Systems*), as amended by SP 105S09. The design of temporary support systems is the responsibility of the contractor.

For design considerations, the excavation support system design where it passes through the relatively shallow soils and completely to highly weathered bedrock may be based on trapezoid-shaped apparent earth pressure distributions using the design parameters given below as well as applicable groundwater pressures. Where the support to the wall is provided by corner bracing and wales or rakers, the wall design should be based on conventional active and passive earth pressure distributions using the design parameters given below. The internal bracing or raker supports must be designed to accommodate the loads applied from earth pressures, water pressures and surcharge pressures from area, line or point loads as well as the effects of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using conventional passive earth pressure distribution acting over an equivalent width equal to three times the soldier pile socket diameter provided that the soldier piles are separated by more than three times the socket diameter. In the event that circular shaft support systems are planned, the lateral earth pressure coefficients provided below will require modification and Golder should be provided the opportunity to address such designs accordingly.

Soil Type	Unit Weight	Internal Angle of Friction	Undrained Shear Strength	Coefficient of Lateral Earth Pressure		
	(kN/m^3)	(Degrees)	(kPa)	Active, Ka	At Rest, Ko	Passive, Kp
Existing Gravelly Sand (Fill)	19	30	--	0.33	0.50	3.0
Stiff to Very Stiff Clayey Silt to Silty Clay	21	32	75	0.31	0.47	3.25
Completely to highly weathered shale bedrock	22	40	--	0.22	0.36	4.54

Notes:
1) The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients showed need to be corrected accordingly.
2) The total passive resistance below the base of the excavation (i.e., within the shored excavation and / or adjacent to the temporary protection system, may be calculated based on the value of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6:16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

Shaft excavations in the slightly weathered to fresh shale bedrock may be developed with vertical sidewalls, provided that all loosened rock fragments are removed from the excavated rock faces. Over time, the shale will weather and erode when exposed in the shaft walls. The exposed bedrock walls should be supported with temporary rock support such as rock bolts and wire mesh or shotcrete to control ravelling and slaking of the shale due to weathering after excavation and prior to the installation of the final shaft liner. In addition, adverse intersections of discontinuities exposed on the shaft walls might lead to kinematically controlled failures and dislodgements of rock blocks or wedges from the shaft walls. Rock bolts should be used, where required, to support blocks or wedges of rock that might be encountered along the shaft walls due to the expected near-vertical jointing of the rock. The rate of excavation through the bedrock is highly dependent on the method and equipment chosen by the contractor. Consideration could be given to shotcreting the weathered bedrock although due to the small size of the shafts this may not be cost effective.

Depending on the size of the shafts, stress-induced buckling of thin rock layers in the shaft floor should be expected. Consideration should be given to placing shotcrete or concrete over the shaft bottom to control stress induced buckling of the limestone layers in the shale bedrock.

Depending on the time of year, there may be perched water in the fill materials. If groundwater is present it would be necessary to control seepage or include measures to mitigate loss of soil particles through lagging boards if a soldier pile and lagging system is employed. For all shaft excavations with groundwater seepage, the formation of ice on the shaft walls should be expected during the winter months. The accumulation of ice on the walls should be closely monitored and periodic removal will be required to prevent ice from falling into the excavation and endangering workers in the shaft.

Consideration could be given to either partial or full removal of the protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work on the highway. An NSSP is included in Appendix D which addressed the removal or cut-off of the protection system.

6.4.4 Pipe Bedding, Cover and Trench Backfill

The bedding, cover, and backfill for the concrete storm sewer pipe should be compatible with the type and class of pipe, the surrounding subsoil/bedrock conditions and anticipated loading conditions and should be designed in accordance with OPSD 802 (*Rigid Pipe Bedding, Cover, and Backfill*), as presented in OPSD 802.030, 802.031, and 802.033, for construction in Type 2 soil, Type 3 soil, and bedrock, respectively, adopting Class B bedding.

6.4.5 Bedding and Cover

The bedding and cover material should consist of the material as specified in OPSS.PROV 401 (*Trenching, Backfilling, and Compacting*). Clear stone should not be used as bedding or cover material. Bedding shall consist of OPSS.PROV1010 (*Aggregates*) Granular 'A' or OPSS 1359, unshrinkable fill. All bedding and cover material should be placed in loose lifts and uniformly compacted to at least 98 per cent of the material's Standard

Proctor Maximum Dry Density (SPMDD), in accordance with OPSS.PROV 501 *(Compacting),* as amended by SP 105S22.

6.4.6 Backfill

Native site soils or excavated cohesive and non-cohesive fills may be used for trench backfill, provided they are free of topsoil, organic material or other deleterious materials. If water contents of the site soils at the time of construction are too high, or if there is a shortage of suitable in-situ material, then an approved imported material which meets the requirements for OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM) or Granular B" Type I could be used. It should be placed and compacted as indicated above for granular materials and to 95 per cent of the materials SPMDD for native soils/excavated fills. Backfilling operations during cold weather should avoid inclusions of frozen lumps of material, snow and ice, and backfilling with fine grained (i.e. silts and/or clays) materials should not be undertaken.

Settlement of the compacted trench backfill should be anticipated, and the majority of such settlement should take place within about 6 months following the completion of trench backfilling operations. This settlement will be reflected at the ground surface and may be compensated for, where necessary, by placing additional granular material as required. Alternatively, if the asphalt binder course is placed shortly following the completion of trench backfilling operations in these areas, any settlement that may be reflected by subsidence of the surface of the binder asphalt should be compensated for by placing an additional thickness of binder asphalt or by padding.

The design frost depth in the area is estimated to be 1.2 m below ground surface, as interpreted from OPSD 3090.101 (*Frost Penetration Depths for Southern Ontario*). To avoid undue differential movements or settlement of ground surface adjacent to and over the trench, the general backfill materials should match, as practically as possible, to the native or fill material exposed in the trench walls, or granular materials should be used as backfill as it will undergo most of the settlement during construction. Backfill within the zone of frost penetration below the bedrock surface should consist of non-frost susceptible material such as OPSS.PROV 1010 (*Aggregates)* Granular "A" or Granular "B" Type 1.

6.5 Final Pipe Design

The design of the casing pipe will need to consider all load cases, including hydrostatic pressures, static rock loads, seismic loads and the loads from the time-dependent deformation of the shale bedrock. Rock deformation around the tunnel excavation will occur as both an initial elastic relaxation and as a time dependent deformation. Typically, the initial elastic movement will begin to occur immediately upon excavation with all significant displacements occurring within about 2 to 3 tunnel diameters from the face.

The time dependent deformation is composed of two phenomena:

- creep (stress relaxation); and,
- swelling.

Creep starts to occur as soon as the stresses are relaxed around the excavation (i.e., at the time of excavation) and continues over time. The swelling potential is highly variable since it depends on the stress state within the rock mass, groundwater conditions, calcite content and rock composition among other factors. Swelling potential is expressed as the swelling strain (in per cent) that occurs per log cycle of time, in either the vertical (perpendicular to bedding) or horizontal (parallel to bedding) directions.

The swelling potential of the Georgian Bay Formation is stress dependent and has been observed to vary approximately linearly with applied pressure plotted on a logarithmic scale. The pressure at which swelling is totally suppressed is defined as the swelling suppression pressure and the pressure at which free swell of the sample will take place is defined as the threshold pressure. Rock swelling is based on the following assumptions:

- the rock will swell freely at a prescribed rate when unconfined (free swell rate);
- there is a confining pressure above which the rock will not swell (suppressing pressure);
- the swelling strain increases linearly with the logarithm of time; and the strain rate per log time cycle decreases linearly with the logarithm of confinement until it reaches zero at the suppression pressure.

Since there may be little delay between excavation and installation of the casing pipe, the casing, and, potentially, the watermain pipe will need to be designed for loads imparted by the swelling of the shale or a compressible grout would need to be incorporated into the design between the bedrock and the casing pipe or between the casing pipe and the watermain pipe. Pressures on the casing pipe may be somewhat attenuated depending on the dimensions of any overcut and viscosity of slurry that remains between the pipe and rock if an MTBM is used for casing installation. If an SBU system is used for construction, there may be an air gap created by any overcut diameter as compared to the casing pipe diameter. These gaps will close over time and the time-dependent swelling nature of the rock should be considered.

Based on the data from a review of published information, the pipes should be designed for horizontal free swell rates of approximately 0.2% per log cycle of time and vertical free swell rates of approximately 2.0% per log cycle of time, and suppression pressures of approximately 0.8 MPa and 2 MPa in the horizontal and vertical directions, respectively. The lining should be checked for all loading cases including different combinations of the horizontal and vertical swelling which may result in higher bending moments. The final swelling design parameters should be updated once the swell testing results are available.

The design of the watermain will need to be based on a bedrock/pipe interaction analysis taking into consideration the final excavation size, the pipe type (thickness, stiffness, etc.), expected overcut gap filling materials (e.g., viscous bentonite slurry), materials that will be used to fill between the watermain and casing pipe and the rock characteristics (swell rates).

6.6 Existing Utilities

Within the section of the watermain to be installed using trenchless methods the design drawings provided by MH indicate that there are two storm sewer pipes proposed beneath the Mississauga Road E – W QEW On-Ramp having diameters of 825 mm and 1350 mm which are parallel to the QEW and run in an east-west direction. The invert of these two storm sewers are about 2 m above the obvert of the proposed 1200 mm diameter casing. Approximately 6 m east of the proposed watermain there is a 300 mm diameter sanitary sewer installed in a 1200 mm diameter casing and about 2 m further to the east there is an existing 910 mm by 610 mm concrete box storm culvert with an open bottom. Considering that the proposed watermain is anticipated to be tunnelled within the bedrock or potential mixed face conditions of bedrock and residual soil deposit it is considered that the proposed tunnel will have minimal effect on the watermain. Utility monitoring points are recommended to be installed above the top of the storm sewers beneath the Mississauga Road E – W QEW On-Ramp if they are installed prior to tunnelling for the watermain.

6.7 Instrumentation and Monitoring

The trenchless installation horizon is through the bedrock at this site, and as such, significant settlement is not anticipated to occur, provided that appropriate construction methods are utilized during the installation process.

Nonetheless, even with careful workmanship, some post construction settlement may occur as a result of the trenchless installation and instrumentation and monitoring can serve to identify unexpected performance or document that performance was within expectations. Therefore, as per NSSP Pipe Installation by Trenchless Method (March 2018) and MTO's Guidelines for Foundation Engineering-Tunnelling Specialty for Corridor Encroachment Permit Application, dated April 3, 2008, it is recommended that provisions for settlement monitoring should be made in the Contract Documents for monitoring the response of the highway and associated ramps prior to, during and after the watermain installation to:

- document the effects of the watermain installation on the overlying roadways, adjacent structures or services lines/pipes;
- identify adverse movement trends;
- measure the contractor's compliance with the settlement limits specified in the Contract; and,
- provide information to support adaptation of the tunnel installation methods to observed behaviour and ground conditions toward compliance with the settlement limits.

The locations of the settlement monitoring points to the installed as part of the settlement monitoring program are shown on Drawing 2; and details and general specifications pertaining to the monitoring points are also presented on the drawing.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume along the QEW and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the surface of the highway must be read remotely and the use of reflectorless precision surveying methods are recommended. A specialist surveying firm should be retained by the Contractor to confirm the set-up and to carry out the settlement monitoring pre-construction baseline, during construction and post construction; their equipment and procedures must be capable of surveying the settlement point elevation with sufficient accuracy and precision to meet a repeatability of ± 2 mm of the actual elevation. In general, the owner should also survey the monitoring points to an equivalent repeatability as an independent confirmation of the baseline and monitoring data at a surveying frequency decided upon by the owner. In addition, in-ground settlement points, consisting of sleeved reinforcing steel, set at just below frost depth or 0.3 m into the top of the completely to moderately weathered shale along the crossing centerline at readily accessible locations (e.g., highway shoulders) should also be installed. The elevation of the top of the bar would be read using conventional precision levelling equipment and this would require lane closure and traffic protection. The in-ground monitoring points provide the best measure of the ground settlement effects of tunnelling, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure. Consideration should also be given to installing utility monitoring points above the two existing storm sewers that extend parallel along the north and south side of the Mississauga Road E – W QEW On-Ramp if they are installed prior to tunnelling for the watermain.

All monitoring points should be read at least three times (on separate days) before the start of the watermain installation to establish a pre-construction baseline. All monitoring points behind the face of the trenchless excavation and those within 10 m of the front of the face should be read every 4 hours over the duration of the tunnel drive. For in-ground settlement points on the QEW the frequency of the readings could be reduced to a reading at the start and end of the permitted closure window. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

The following procedure should be followed if settlement levels of 10 mm (Review Level) and 15 mm (Alert Level) are reached:

- If the Review Level is reached, the contractor should be required to provide a formal plan that states actions that will be implemented to ensure that the Alert Level is not reached.
- If the Alert Level is reached, the contractor should be required to stop all work, make the site secure, and proposed methods for remediating the excess ground displacements and completing the necessary remedial work at the contractor's own cost. In this case, the contractor should also bear all costs associated with delays until the MTO is satisfied that pipe installation can proceed without endangering the travelling public.

Plotting and interpretation of the survey results for the purposes of controlling construction should be by the contractor with interpretation of data for the purposes of monitoring contract compliance by the owner's representative. Surveying data prepared by all parties should be provided to the owner's representative within 24 hours (or sooner) for comparison against settlement tolerances identified in the NSSP. If the Review/Alert Level is exceeded (see Appendix D), the surveying frequency and communication of results should be altered to provide data to the owner every two hours. A settlement monitoring plan is presented in Drawing 2 and is consistent with the requirements in the "Appendix: Settlement Monitoring Guideline – Tunnelling" of MTO's "Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application", and NSSP Pipe Installation by Trenchless Method (March 2018) and should be included in the Contract Documents.

In addition to settlement monitoring, line and grade should be carefully monitored during construction. It is also recommended to measure, to the extent practicable and possible, the volume of ground removed from beneath the paved areas as compared to theoretical cut hole volume on a frequency of at least once per 6 m section of pipe installed. Measuring excavated ground volumes will be difficult because of bulking that occurs when excavating shale and possibly residual soil and the fact that some discharge systems are not readily conducive to such measurements (e.g., microtunnelling using a slurry machine). However, onsite observations of construction operations and measurements of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

6.8 Grouting

All voids between the primary lining and the wall of the excavated tunnel shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. This requirement is included in the NSSP for "Pipe Installation by Trenchless Method", see Appendix D

For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the casing pipe and/or repair of the pavements.

After the permanent watermain pipe is installed within the casing, post installation grouting to fill the annular space between the pipes may be carried out as noted in the NSSP for "Pipe Installation by Trenchless Method", included in Appendix D.

6.9 Analytical Testing for Construction Material

Rock corrosivity may affect the concrete pipes, steel pipes and reinforced steel and other concrete elements buried in the rock. The long-term performance and durability of the structures are directly related to their respective corrosion resistance. Generally, the corrosivity of a structure depends on the rock resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential.

The results of an analytical test on two samples of bedrock core samples from boreholes advanced near the alignment of the proposed watermain are summarized in Section 4.2.7, and the analytical laboratory test reports are presented in Appendix C. The potential for sulphate attack and corrosion are discussed in the following sub-sections. However, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 “Durability Requirements” are followed when designing concrete elements.

6.9.1 Potential for Sulphate Attack

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 *("Additional requirements for concrete subjected to sulphate attack”)* to assess the potential severity of sulphate attack on concrete during its service life. The sulphate concentrations measured in the samples of the bedrock were 0.016 per cent and 0.035 per cent, which is below the exposure class of “S-3” (Moderate - 0.1 – 0.2 per cent; the sulphate concentrations are considered negligible according to the Gravity Pipe Design Guidelines Table 7.2 (MTO, 2014). Therefore, based on the bedrock core samples tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the bedrock may not need to be considered. However, given that the watermain is located under the highway and may be exposed to de-icing salt, consideration should be given by the designer to designing for a “C” type exposure class as defined by CSA A23.1 Table 1.

6.9.2 Potential for Corrosion

Based on the test results from the bedrock core samples the pH ranges from about 8.02 to 8.19 and the resistivity ranges from 1,700 to 2,100 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to the watermain durability. The resistivity is less than 2,000 ohm-cm, which indicates that the bedrock corrosiveness is severe (R < 2,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). All pipes should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.10 Natural Gas

Based on experience at other tunnel projects in southern Ontario, methane and hydrogen sulphide are known to be present in the bedrock, although no indication of the presence of natural gas was observed while the boreholes were advanced. However, natural gas within the Georgian Bay Formation is typically present in localized pockets. Therefore, the absence of natural gas at the borehole locations should not be construed to indicate that there is no risk of the presence of natural gas within the project area. Methane forms an explosive mixture with air and is a potential hazard for excavation and construction work. Changes in groundwater pressure which may be caused by dewatering or seepage into excavations/underground spaces can lead to migration/release of gaseous or dissolved methane. The tunnel should be considered as “potentially gassy”, according to the OSHA Underground Construction (Tunnelling) Regulations (29 CFR Part 1926.800, "Tunnels and Shafts.").

6.11 Spoil Management

This section of the report provides preliminary management considerations for excavated material from the tunnelled and shaft sections, with respect to re-use on-site or disposal off-site during construction. The spoil from the tunnelled section is expected to be comprised only of rock, while the entry and exit shafts will contain both rock and soil spoil. MH is responsible for management of the soil spoil and thus, chemical analysis of soil samples was not carried out by Golder. However, rock samples were submitted for analysis of Petroleum Hydrocarbons, CCME F1 and BTEX due to the possibility of high levels of these constituents which naturally occur in the Georgian Bay Formation.

6.11.1 Geotechnical Considerations

The reuse of the excavated materials is subject to their environmental suitability. The excavated materials from the site will mainly consist shale fragments.

6.11.2 Applicable Regulations and Guidance

Rock quality was evaluated relative to the generic site condition standards for a potable groundwater condition defined by O.Reg. 153/04 and presented in the Ministry of the Environment, Conservation and Parks (MECP) "*Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act*" dated April 15, 2011. Although the application of these standards is intended to apply to naturally occurring soils having particle sizes of less than 2 mm, the standards were considered herein to evaluate the potential for bedrock spoil to contribute to environmental impacts if used as fill material. Comparison to the MECP Table 3 Standards: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition for Industrial, Commercial and Community Property Use for Coarse Textured Soil (MECP 2011 Table 3 Standards) was applied for this purpose. The Table 3 Standards were also applied in order to evaluate whether the rock spoil may be considered environmentally suitable for reuse as backfill material onsite. A Qualified Person (QP) should be retained to advise if more stringent standards are required for the reuse of soil within 30 m of a water body, an area of natural and scientific interest, or in proximity to a water supply well or a residential building.

To assess whether the environmental quality of rock spoil is such that it may be restricted in its potential off-site reuse, the analytical results were compared to the MECP 2011 Table 1 Standards: Full Depth Generic Site Condition Standards in Background Condition for All Property Uses and for all soil textures (MECP 2011 Table 1 Standards). The Table 1 Standards may also be considered to be suitable for application to the scenarios described above in which more stringent standards would need to be considered.

6.11.3 Results of Testing

As described in Section 4.2.7, selected bedrock core samples were obtained from the boreholes and submitted to Maxxam for chemical analysis. A summary of the comparison of the analytical results to the standards listed above is provided below:

Borehole No. / Sample No. (Depth)	Analyzed Parameters	MECP 2011 Table 1 Standards Exceedances	MECP 2011 Table 3 Standards Exceedances
C1-2 / SA-01 (4.29 - 4.37 m)	Petroleum Hydrocarbons, CCME F1 and BTEX	Benzene Exceedance[1]	No Exceedances
C1-3 / SA-03 (6.31 - 6.37 m)	Petroleum Hydrocarbons, CCME F1 and BTEX	Benzene Exceedance[1] and others below detection limit[2]	No Exceedances

Notes:

[1] BH C1-2 / SA-01 and BH C1-3 / SA-03 Benzene exceedance for MECP 2011 Table 1 all land uses and all textured soils (rock).
[2] BH C1-3 / SA-03 Due to dilution, etc., of the sample, the reportable detection limit (RDL) for the following parameters was above the MECP 2011 Table 1 Guideline criteria for all land uses and all textured soils: Ethylbenzene, Total Xylenes, F1 (C6-C10), and F1 (C6-C10) – BTEX. These values were reported as less than the RDL and it is unknown whether they exceed the Table 1 Guideline criteria.

6.11.4 Analytical Considerations

A total of two bedrock samples were submitted for analytical testing, both samples showed results that exceeded the Table 1 Standards, as summarized in Section 6.11.3. Based on the analytical results, the bedrock appears to be environmentally suitable for reuse on-site.

The bedrock spoil exceeds the Table 1 Standards and would therefore not be considered suitable for placement in an environmentally sensitive area.

Any excess material generated during construction activities that are of a similar environmental quality to the tested samples noted in Section 6.11.3, may be reused as backfill provided:

- It is obtained from a location that is not within an area of potential environmental concern, as determined by a Phase I environmental site assessment prepared by a Qualified Person in general accordance with O.Reg. 153/04;
- There is no evidence of potential environmental impact, including staining, discoloration or odours that are potentially associated with petroleum hydrocarbons or other contaminants; and
- It is geotechnically suitable and approved for use as a backfill material by a geotechnical engineer.

Alternatively, any excess material may be removed off-site to a receiving site, such as a property appropriately permitted in accordance with the applicable bylaw of the local municipality or a waste management facility permitted in accordance with Part V of the Environmental Protection Act based on their acceptance. It is advisable to review a potential receiving site's acceptable fill protocol to determine what documentation must be submitted to facilitate acceptance by the receiving site.

Furthermore, movement of soil to a site that has a Record of Site Condition on file with the MECP may require that specific testing protocols are followed and that the materials must satisfy the Standards applicable to the receiving site.

7.0 CLOSURE

This report was prepared by Ms. Sarah Pidgen, P.Eng, a geological engineer with Golder. This report was reviewed by Mr. Mark Telesnicki, P.Eng. a Principal and rock engineer with Golder and reviewed by Ms. Sandra McGaghran, M.Eng., P.Eng. an Associate and senior geotechnical engineer with Golder. Mr. Storer Boone, Ph.D., P.Eng., MTO's RAQS recognized specialist for high complexity tunnelling assignments, reviewed the report.

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REFERENCES

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

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.

Concrete materials and methods of concrete construction / Test methods and standard practices for concrete (CSA A23.1-14/A23.2-14). Canadian Standard Association. (CSA) Group.

Heuer, Ronald E., 1974 "Important Ground Parameters in Soft Ground Tunneling", Proceedings Specialty Conference on Subsurface Explorations for Underground Excavations and Heavy Construction, ASCE, NY.

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.

Ministry of Transportation Ontario. 2014. *Gravity Pipe Design Guideline*. Drainage and Hydrology Design and Contract Standards Office.

Ontario Provincial Standard Drawings:

OPSD 802.030	Rigid Pipe Bedding, Cover and Backfill, Type 1 or 2 Soil – Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation
OPSD 802.033	Rigid Pipe Bedding, Cover and Backfill, Rock Excavation
OPSD 3090.101	Foundation Frost Penetration Depth for Southern Ontario

Ontario Provincial Standard Specifications (OPSS)

OPSS 402	Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403	Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 407	Maintenance Hole, Catch Basin, Ditch Inlet and Valve Chamber Installation
OPSS 441	Watermain Installation in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Special Provision (SP)

SP 517F01	Dewatering Systems

ASTM International:

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

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

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213 Construction Projects (as amended)

TABLE 1 – EVALUATION OF TRENCHLESS CROSSING ALTERNATIVES FOR WATERMAIN INSTALLATION AT STATION 15+825

Installation Method / Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
Micro-tunnelling (MTBM) Feasible	■ Minimal traffic disruption. ■ Slurry machine is able to counterbalance earth and groundwater pressures in a controlled manner, providing continuous face support and eliminating need for dewatering at the tunnel face. ■ Can be steered continuously, providing precise control over line and grade if concrete casing pipe is used. ■ A MTBM generally requires a smaller footprint at the launch shaft compared to a SBU. ■ Tunnel is fully lined as excavation progresses. Concrete casing is installed behind the face during excavation. ■ No man entry required	■ Greater cost for muck handling and disposal. ■ Lack of readily available machines. ■ Relatively expensive – high mobilization costs for short crossings. ■ Slurry processing systems required along with additional working area at shaft / pit locations for some systems. ■ MTBMs do not allow cutter changes during the length of the bore / tunnel.	Most expensive method.	■ Low to moderate risk for trenchless installation provided appropriate equipment and slurry properties are selected and controlled. ■ Greater risk of hydraulic fracturing (frac-out) compared to other methods which do not utilize a slurry machine, but the potential of frac-out depends on slurry viscosity and pressure. ■ Potential schedule delay in obtaining a suitable MTBM.
Small Boring Unit (SBU) Feasible	■ Minimal traffic disruption. ■ Tunnel is fully lined as excavation progresses. Concrete casing is installed behind the face during excavation. ■ No man entry required	■ Limited ability for excavating below the groundwater table; generally requires dewatering at the tunnel face. ■ A relatively large pit / shaft is required to launch the SBU.	Moderately expensive	■ Greater risk of settlement induced damage to nearby infrastructure (including underground utilities) due to dewatering operations, if required.
Horizontal Raise Boring Not preferred	■ Minimal traffic disruption. ■ Relatively short set-up times compared to MTBMs and SBUs. ■ Relatively low investment costs compared to MTBMs and SBUs. ■ Pilot hole can provide information on rock behaviour prior to back reaming operation. ■ No man entry required	■ Less common trenchless method in the GTA compared to micro-tunnelling and tunnelling with SBUs. ■ Lack of readily available machines. ■ Little to no directional control during drilling (not steerable) ■ No lining during pilot hole drilling. Rock must be stable so that the pipe can be installed after/during reaming ■ Groundwater inflows need to be managed	Least expensive method	■ Greater risk of misalignment during back reaming compared to micro-tunnelling and tunnelling with an SBU. ■ Greater risk of settlement induced damage to nearby infrastructure (including underground utilities) due to dewatering operations, if required.

CONT No. 7/30/2019
GWP No. 2002-13-00

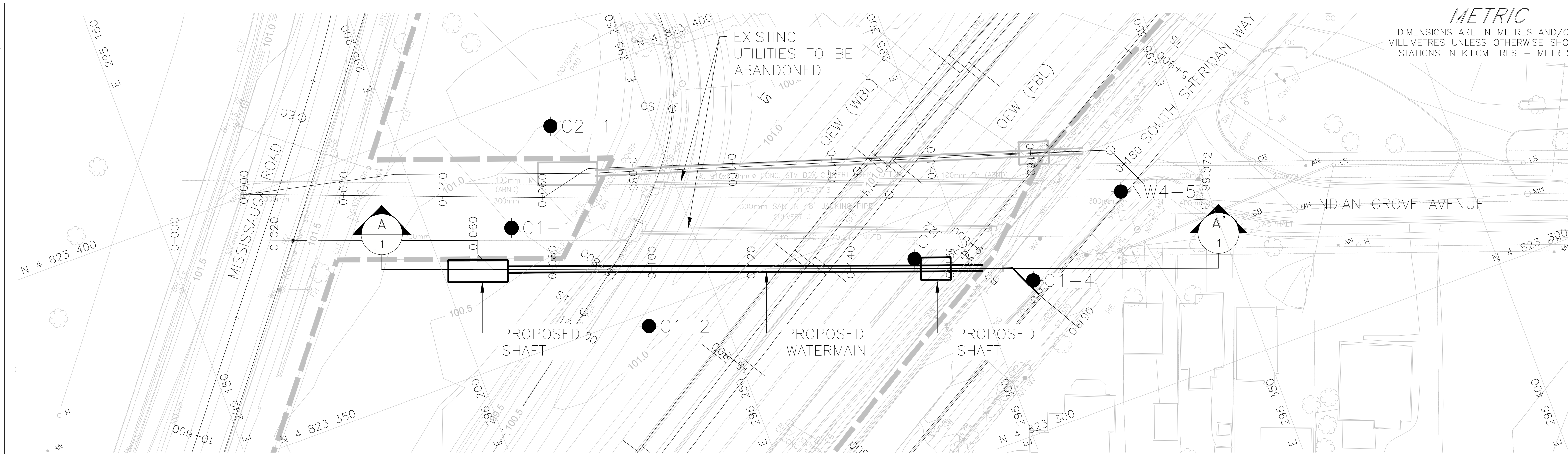
SHEET

QEW WIDENING – MISSISSAUGA RD TO HURONTARIO ST
WATERMAIN INSTALLATION STATION 15+825

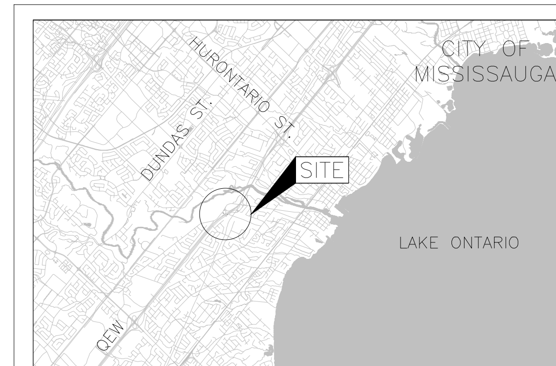
BOREHOLE LOCATIONS PLAN AND SOIL STRATA

GOLDER

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



PLAN
SCALE
10 0 10 20 m



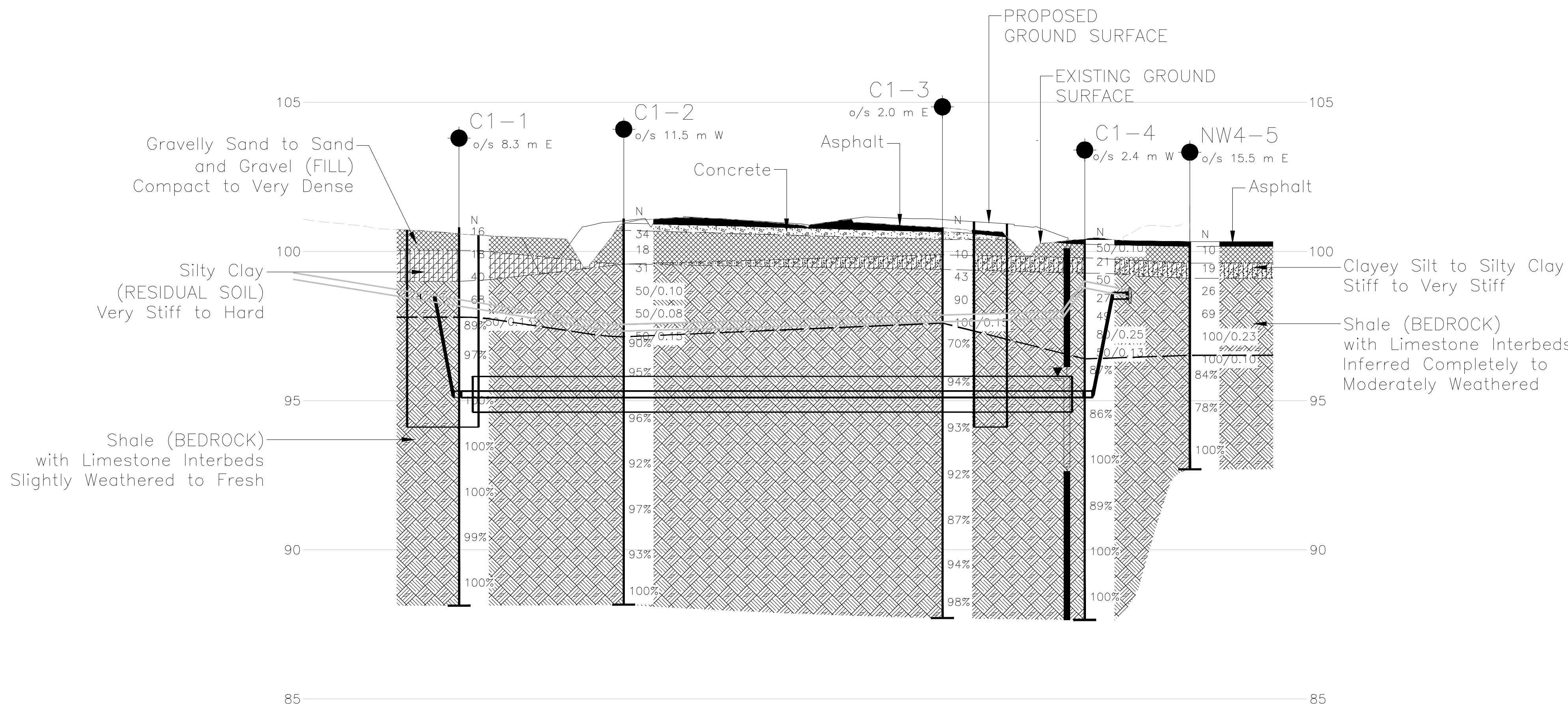
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

●	Borehole – Current Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer MAR 13, 2019
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
C1-1	100.8	4823375.5	295216.1
C1-2	101.1	4823347.4	295235.2
C1-3	100.8	4823341.6	295290.0
C1-4	100.4	4823329.3	295310.9
C2-1	101.1	4823392.0	295230.5
NW4-5	100.3	4823340.0	295333.6



PROFILE A–A' – WATERMAIN – STATION 15+825

VERTICAL SCALE
2 0 2 4 m

HORIZONTAL SCALE
10 0 10 20 m

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 MH, drawing file nos. X11609340Base.dwg, X-Final Merged Util.dwg, X-PROP-UTIL.dwg, Existing Property.dwg, 11609340 – QEW Prop Util-Dickson & Lynchmere – C3D 2017.dwg, 11609340 – QEW Prop Util-IndianGroveAve – C3D 2017.dwg, 11609340 – QEW Prop Util-Stavebank Rd – C3D 2017.dwg, 11609340 – QEW Prop Util-Knareswood Dr – C3D 2017.dwg, and x1160934_Align.dwg, received March 25, 2019.

LICENSED PROFESSIONAL ENGINEER J.P. DITTRICH Jul. 30, 2019 PROVINCE OF ONTARIO

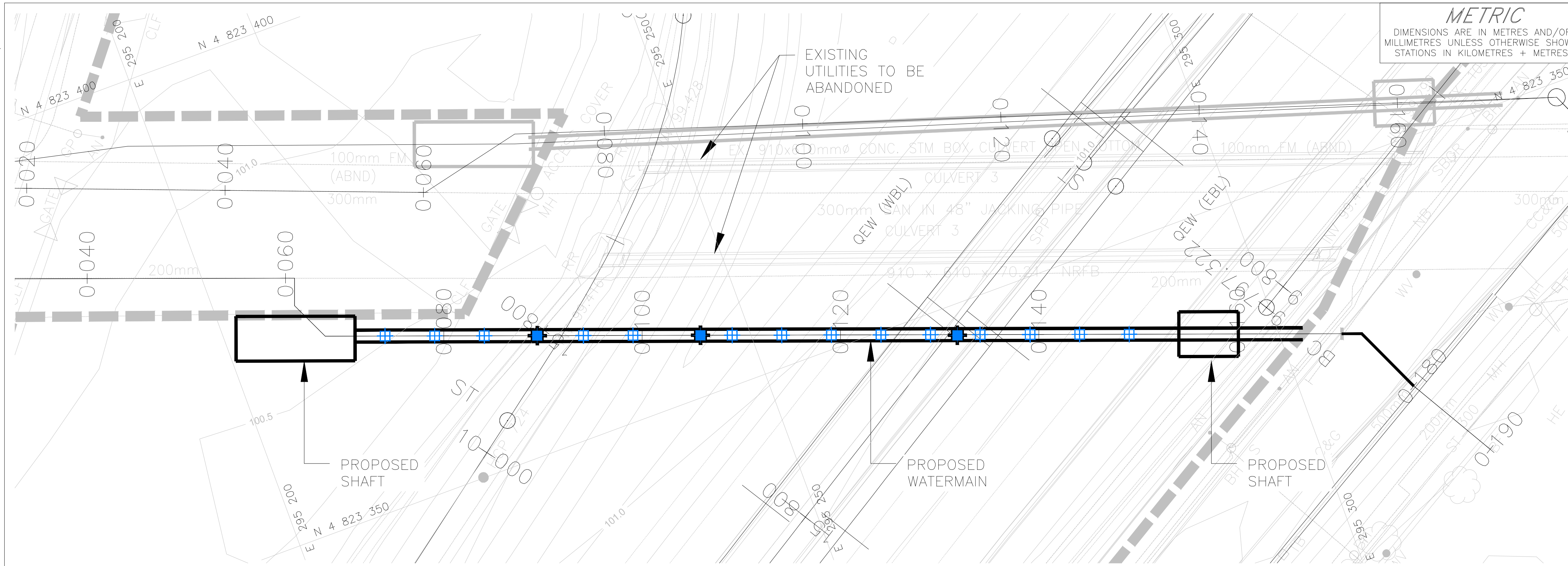
LICENSED PROFESSIONAL ENGINEER S. McGAGHRAN Jul. 30, 2019 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 30M12-447

HWY. QEW	PROJECT NO. 1662333	DIST. CENTRAL
SUBM'D. AB/EJ	CHKD. DM	DATE: 7/30/2019	SITE:
DRAWN: DD	CHKD. SMM	APPD. JPD	DWG. 1

PLOT DATE: July 29, 2019



PLAN
SCALE
5 0 5 10 m

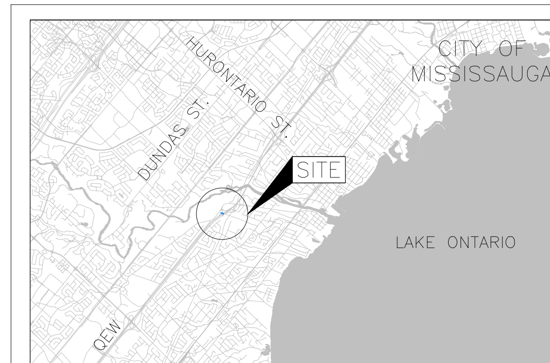
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2002–13–00

SHEET

QEW WIDENING – MISSISSAUGA RD TO HURONTARIO ST
WATERMAIN INSTALLATION STATION 15+825
SETTLEMENT MONITORING INSTALLATION LOCATION AND DETAILS

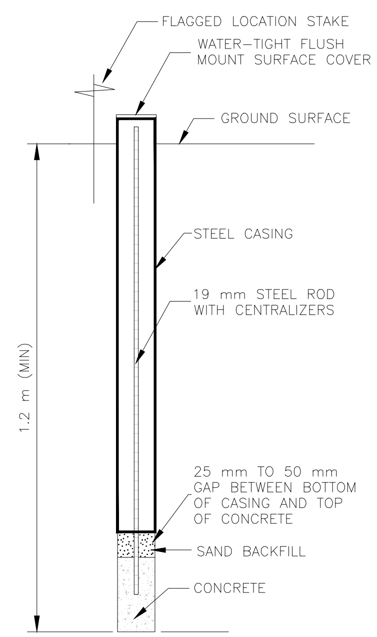
GOLDER



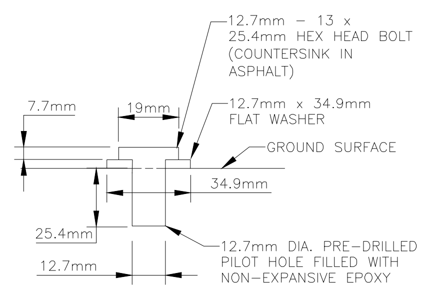
KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Surface Settlement Marker
- Settlement Point



SETTLEMENT POINT (SP)
INSTALLATION DETAIL
NOT TO SCALE



SURFACE SETTLEMENT MARKER
(SSM) INSTALLATION DETAIL
NOT TO SCALE

NOTES

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

REFERENCE

Base plans provided in digital format by MH, drawing file nos. X11609340Base.dwg, X–Final Merged Util.dwg, X–PROP–UTIL.dwg, Existing Property.dwg, 11609340 – QEW Prop Util–Dickson & Lynchmere – C3D 2017.dwg, 11609340 – QEW Prop Util–IndianGroveAve – C3D 2017.dwg, 11609340 – QEW Prop Util–Stavebank Rd – C3D 2017.dwg, 11609340 – QEW Prop Util–Knareswood Dr – C3D 2017.dwg, and x1160934_Align.dwg, received March 25, 2019.

LICENSED PROFESSIONAL ENGINEER S.J.BOONE 90559733 Jul. 30, 2019 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER S. McGaghran Jul. 30, 2019 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 30M12–447

HWY. QEW	PROJECT NO. 1662333		DIST. CENTRAL
SUBM'D. AB/EJ	CHKD. DM	DATE: 7/30/2019	SITE:
DRAWN: DD	CHKD. SMM	APPD. SJB	DWG. 2

PLOT DATE: July 29, 2019
FILENAME: S:\Clients\MTO\QEW-Credit_River\99_PROJ\1662333_MH_P&F\40_PROD\0020_WM_Relocation_Crossing_1\1662333-0020-BG-0002.dwg

APPENDIX A

Records of Borehole and Drillhole Sheets and Bedrock Core Photographs

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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 $\tau = c' + \sigma' \tan \phi'$
2 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, 60º 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 cm^2 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 Condition	N 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	c_u, s_u 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

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, 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 90º 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.

GOLDER

Foundation Design

RECORD OF BOREHOLE No C1-1

SHEET 1 OF 1

METRIC

PROJECT 1662333

G.W.P. 2002-13-00

LOCATION N 4823375.5; E 295216.1 MTM NAD ZONE 10 (LAT. 43.550254; LONG. -79.618614)

ORIGINATED BY EJ

DIST Central HWY QEW

BOREHOLE TYPE CME 55, 83 mm I.D. Hollow Stem Augers, HQ Casing

COMPILED BY SE

DATUM Geodetic

DATE February 26, 2019

CHECKED BY SEMP/SMM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.8	GROUND SURFACE					
0.0	Gravelly sand, trace to some silt, trace clay (FILL) Compact Brown Moist	1	SS	16		
100.0 / 0.8	SILTY CLAY, trace to some sand, trace to some gravel, trace organics (RESIDUAL SOIL) Very stiff to hard Brown-grey with oxidation staining Moist	2	SS	18	100	
		3A / 3B	SS	40	99	6 9 55 30
99.0 / 1.8	Inferred completely to moderately weathered, brown to grey, extremely weak to very weak SHALE (Georgian Bay Formation)	4	SS	68	98	
97.8 / 3.0	SHALE (BEDROCK) Grey Slightly weathered to fresh Bedrock cored from a depth of 3.0 m to 12.7 m. For bedrock coring details, refer to Record of Drillhole C1-1.	5	SS	50/0.13		
		1	RC	REC 96%		RQD = 89%
		2	RC	REC 100%	97	RQD = 97%
		3	RC	REC 100%	96, 95	RQD = 100%
		4	RC	REC 100%	94, 93	RQD = 100%
		5	RC	REC 100%	92	RQD = 100%
		6	RC	REC 100%	91, 90	RQD = 99%
		7	RC	REC 100%	89	RQD = 100%
88.1 / 12.7	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling prior to rock coring.					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

LOCATION: N 4823375.5 ;E 295216.1

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 27, 2019

DRILL RIG: CME 55 Track

DRILLING CONTRACTOR: Davis Drilling Ltd.

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20) | R.Q.D. % 80 60 40 20 | FRACT. INDEX PER 0.25 m 5 10 15 20 | DISCONTINUITY DATA (B Angle 0 90 180 270; DIP w.r.t. CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jr; Ja) | ROCK STRENGTH INDEX R4 R3 R2 R1 | WEATH-ERING INDEX W1 W2 W3 W4 W5 W6 | FEATURES | R0/R1 ZONES | NOTES WATER LEVELS INSTRUMENTATION

Continued from Record of Borehole C1-1 — 97.75

3.05 — Slightly weathered to fresh, very thinly to thinly laminated, grey, fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds

Depth scale (m)	Run No.	Type and Surface Description	Jr	Ja	Notes
	1	BD,PL,SM	1	1	
	2	BD,PL,SM	1	8	
	2	IN,CL, 5 mm	1.5	3	
4	2	BD,PL,RO PC			
5	3	CO,PL,SM	1	1	UCS = 19.3 MPa
6	3	CO,UN,SM	2	1	
7	4				UCS = 15.2 MPa
8	5	CO,UN,SM	2	1	
	5	BD,UN,SM SA	2	2	
9					
10	6	CO,UN,SM	2	1	
11	6	CO,UN,SM CC,CL	2	4	
	7	BD,UN,SM	2	1	
12					

CONTINUED NEXT PAGE

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-1

LOCATION: N 4823375.5 ;E 295216.1

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 27, 2019

DRILL RIG: CME 55 Track

DRILLING CONTRACTOR: Davis Drilling Ltd.

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25 m	B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	ROCK STRENGTH INDEX	WEATHERING INDEX	FEATURES	R0/R1 ZONES	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---																	
		Slightly weathered to fresh, very thinly to thinly laminated, grey, fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds		88.13 12.67	7							CO,UN,SM	2	1					
		END OF DRILLHOLE																	
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: EJ

CHECKED: AC

RECORD OF BOREHOLE No C1-2

SHEET 1 OF 1 — **METRIC**

PROJECT 1662333
G.W.P. 2002-13-00
LOCATION N 4823347.4; E 295235.2 MTM NAD ZONE 10 (LAT. 43.550001; LONG. -79.618376)
ORIGINATED BY AB
DIST Central HWY QEW
BOREHOLE TYPE CME 75, 70 mm I.D. Hollow Stem Augers, HQ Casing
COMPILED BY SE
DATUM Geodetic
DATE February 26, 2019
CHECKED BY AC

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.1	GROUND SURFACE				101		
0.0	ASPHALT (150 mm)						
	CONCRETE (240 mm)						
0.4	Gravelly sand to sand and gravel, some silt, some organics, trace clay (FILL) Compact to dense Brown to dark grey Moist	1	SS	34			
99.6		2	SS	18	100	w ≈ 8	
1.5	Inferred completely to moderately weathered, brown to grey, extremely weak to very weak SHALE (Georgian Bay Formation)	3	SS	31		w ≈ 15; wP ≈ 22, wL ≈ 37	10 8 51 31
		4	SS	50/0.10	99		
		5	SS	50/0.08	98	w ≈ 5	35 21 34 10
97.1		6	SS	50/0.15			
4.0	SHALE (BEDROCK) Grey Slightly weathered to fresh. Bedrock cored from a depth of 4.0 m to 12.9 m. For bedrock coring details, refer to Record of Drillhole C1-2.	1	RC	REC 100%	97		RQD = 90%
		2	RC	REC 100%	96		RQD = 95%
		3	RC	REC 100%	95, 94		RQD = 96%
		4	RC	REC 100%	93		RQD = 92%
		5	RC	REC 100%	92, 91		RQD = 97%
		6	RC	REC 100%	90		RQD = 93%
88.2		7	RC	REC 100%	89		RQD = 100%
12.9	END OF BOREHOLE						

NOTE:

1. Borehole dry upon completion of drilling prior to rock coring.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m^3; GROUND WATER CONDITIONS; STRAT PLOT.

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

RECORD OF DRILLHOLE: C1-2

PROJECT: 1662333
LOCATION: N 4823347.4 ;E 295235.2
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 6, 2019
DRILL RIG: CME 75 Truck
DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Continued from Record of Borehole C1-2

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	TYPE AND SURFACE DESCRIPTION	Jr	Ja	NOTES WATER LEVELS INSTRUMENTATION
		97.14					
4	Slightly weathered to fresh, thinly bedded, grey, very fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds	3.96	1				
			2	CO,UN,RO CC,CL	3	4	
5				BD,UN,SM PC,CL	2	4	
6			3	BD,UN,SM SA	2	2	
				CO,UN,RO SA	3	2	
				CO,PL,RO SA	1.5	2	
7				BD,UN,RO SA	3	2	
			4	BD,PL,SM	1	6	
				IN,CL, 5 mm	1	2	
				BD,PL,SM SA	1.5	2	
8				BD,PL,RO SA			UCS = 19.1 MPa
				BD,PL,RO SA	1.5	2	
				CO,IR,RO SA	3	2	
9			5	CO,IR,SM SA	2	2	
				CO,IR,RO SA	3	2	
				BD,CU,SM SA	2	2	
10				BD,PL,RO PC,CL	1.5	4	
				CO,PL,RO CC,CL	1.5	4	
			6	CO,IR,RO PC,CL	3	4	
11							UCS = 25.0 MPa
				CO,IR,RO SA	3	2	
12				CO,CU,SM SA	2	2	
				CO,ST,RO SA	3	2	
		88.16	7	BD,CU,RO SA	3	2	

CONTINUED NEXT PAGE

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE
1 : 50

LOGGED: AB
CHECKED: AC

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-2

SHEET 2 OF 2

LOCATION: N 4823347.4 ;E 295235.2

DRILLING DATE: March 6, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75 Truck

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.25 m (5 10 15 20)	DISCONTINUITY DATA B Angle (0 90 180 270)	DIP w.r.t. CORE AXIS (0 30 60 90)	TYPE AND SURFACE DESCRIPTION	Jr	Ja	ROCK STRENGTH INDEX (R4 R3 R2 R1)	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	FEATURES	R0/R1 ZONES	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---																	
13		END OF BOREHOLE		12.94															
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: AB

CHECKED: AC

GOLDER

Foundation Design

RECORD OF BOREHOLE No C1-3

SHEET 1 OF 1 **METRIC**

PROJECT 1662333

G.W.P. 2002-13-00

LOCATION N 4823341.6; E 295290.0 MTM NAD ZONE 10 (LAT. 43.549949; LONG. -79.617698)

ORIGINATED BY AB

DIST Central HWY QEW

BOREHOLE TYPE CME 75, 108 mm I.D. Hollow Stem Augers, HQ Casing

COMPILED BY ACM

DATUM Geodetic

DATE March 7, 2019

CHECKED BY AC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.8	GROUND SURFACE					
0.0	ASPHALT (140 mm)					
	CONCRETE (270 mm)					
0.4	Gravelly sand, some silt (FILL) Compact Brown Moist					
99.9 / 0.9	SILTY CLAY, some sand, some shale fragments, trace to some gravel Stiff Mottled grey to brown with oxidation staining Moist	1A / 1B	SS	10	w_L = 45	9 13 39 39
99.4 / 1.4	Inferred completely to moderately weathered, brown to grey, extremely weak to weak SHALE (Georgian Bay Formation)	2	SS	43		
		3	SS	90		
		4	SS	100/0.15		
97.6 / 3.2	SHALE (BEDROCK) Grey Slightly weathered to fresh Bedrock cored from a depth of 3.4 m to 13.1 m. For bedrock coring details, refer to Record of Drillhole C1-3.	1	RC	REC 96%		RQD = 70%
		2	RC	REC 100%		RQD = 94%
		3	RC	REC 100%		RQD = 93%
		4	RC	REC 100%		RQD = 92%
		5	RC	REC 100%		RQD = 87%
		6	RC	REC 100%		RQD = 94%
		7	RC	REC 100%		RQD = 98%
87.7 / 13.1	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling prior to rock coring.					

Elevation scale: 100, 99, 98, 97, 96, 95, 94, 93, 92, 91, 90, 89, 88

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-3

LOCATION: N 4823341.6 ;E 295290.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 10, 2019

DRILL RIG: CME 75 Truck

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate

BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage

PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular

PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | RECOVERY (TOTAL CORE %, SOLID CORE %; 80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25 m (5 10 15 20) | DISCONTINUITY DATA: B Angle (0 90 180 270), DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jr, Ja | ROCK STRENGTH INDEX (R4 R3 R2 R1) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | FEATURES | R0/R1 ZONES | NOTES WATER LEVELS INSTRUMENTATION

Continued from Record of Borehole C1-3

ELEV. / DEPTH (m)	DESCRIPTION
97.45 / 3.35	Slightly weathered to fresh, thinly bedded, grey, very fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12

RUN No.	TYPE AND SURFACE DESCRIPTION	Jr	Ja
1	BD,PL,RO	1.5	1
1	CO,IR,RO CC,CL, 1 mm	3	4
1	BD,PL,SM PC,CL	1	3
1	BD,PL,SM	1	1
1	BD,PL,SM PC,CL	1	3
1	BD,PL,RO PC,CL	1.5	3
2	BD,IR,RO CC,CL, 5 mm	3	4
2	BD,PL,SM PC,CL	1	3
2	CO,IR,RO	3	1
2	CO,IR,RO	3	1
2	BD,PL,SM PL,CL	1	3
3	BD,CU,SM	2	3
3	PC,CL	3	4
3	CO,IR,RO CC,CL, 2 mm	3	15
3	CO,IR,RO CC,CL, 7 mm	3	1
3	BD,CU,RO CO,IR,RO	3	1
3	BD,PL,SM	1	1
4	BD,CU,SM	2	1
4	BD,IR,SM	2	1
4	BD,PL,SM	1	1
4	CO,IR,RO PC,CL	1	3
5	BD,PL,SM	1	1
5	CO,CU,RO	3	1
5	CO,IR,RO	3	1
5	BD,PL,SM CC,CL, 1 mm	1	3
6	BD,PL,SM	1	1
6	CO,IR,RO	3	1
7	BD,PL,RO	1.5	3
7	PC,CL	1	1

R0/R1 ZONES: R1, R1 (near 3.5 m); RO (near 5.4 m); RO (near 8.4 m); R1 (near 10.1 m)

NOTES: UCS = 210.2 MPa

CONTINUED NEXT PAGE

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE 1 : 50

GOLDER

LOGGED: AB

CHECKED: AC

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-3

LOCATION: N 4823341.6 ;E 295290.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 10, 2019

DRILL RIG: CME 75 Truck

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	ROCK STRENGTH INDEX	WEATHERING INDEX	FEATURES	R0/R1 ZONES	NOTES WATER LEVELS INSTRUMENTATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---																	
13		Slightly weathered to fresh, thinly bedded, grey, very fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds		87.71 13.09	7							BD,PL,SM CO,PL,RO BD,IR,RO CC,CL, 10 mm	1.5 1.5	1 15					
		END OF DRILLHOLE																	

Depth scale marks: 14, 15, 16, 17, 18, 19, 20, 21

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE

1 : 50

LOGGED: AB

CHECKED: AC

GOLDER

Foundation Design

RECORD OF BOREHOLE No C1-4

SHEET 1 OF 1

METRIC

PROJECT 1662333

G.W.P. 2002-13-00

LOCATION N 4823329.3; E 295310.9 MTM NAD ZONE 10 (LAT. 43.549839; LONG. -79.617440)

ORIGINATED BY EJ

DIST Central HWY QEW

BOREHOLE TYPE CME 75, 83 mm I.D. Hollow Stem Augers, HQ Casing

COMPILED BY KN

DATUM Geodetic

DATE February 21, 2019

CHECKED BY SEMP/SMM

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL
100.4	GROUND SURFACE				
0.0	ASPHALT (150 mm)				
0.2	Gravelly sand, trace silt (FILL) Very dense Brown to dark brown Moist	1	SS	50/0.10	
99.8 0.6	CLAYEY SILT, some sand Very stiff Light brown Dry to moist	2	SS	21	
99.2 1.2	Inferred completely to moderately weathered, brown to grey, extremely weak to very weak SHALE (Georgian Bay Formation)	3	SS	50	33 23 27 17
		4	SS	27	
		5	SS	49	35 10 36 19
		6	SS	80/0.25	
96.7 3.7	SHALE (BEDROCK) Grey Moderately weathered to 4.0 m depth to slightly weathered to fresh below 4.0 m depth Bedrock cored from a depth of 3.7 m to 12.8 m. For bedrock coring details, refer to Record of Drillhole C1-4.	7	SS	50/0.13	
		1	RC	REC 100%	RQD = 87%
		2	RC	REC 100%	RQD = 86%
		3	RC	REC 100%	RQD = 100%
		4	RC	REC 100%	RQD = 89%
		5	RC	REC 100%	RQD = 100%
		6	RC	REC 100%	RQD = 100%
87.7 12.8	END OF BOREHOLE				

NOTE:

1. Open Borehole dry upon completion of drilling prior to bedrock coring.

2. Water level measured at 4.6 m depth below ground surface (Elev. 95.8 m) in piezometer on March 19, 2019.

Elevation scale: 100, 99, 98, 97, 96, 95, 94, 93, 92, 91, 90, 89, 88

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-4

SHEET 1 OF 2

LOCATION: N 4823329.3 ;E 295310.9

DRILLING DATE: February 21, 2019

DATUM: Geodetic

DRILL RIG: CME 75 Truck

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Davis Drilling

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25 m | DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja) | ROCK STRENGTH INDEX (R4 R3 R2 R1) | WEATHERING INDEX (W1–W6) | FEATURES | R0/R1 ZONES | NOTES WATER LEVELS INSTRUMENTATION

Continued from Record of Borehole C1-4 — 96.74

3.66 — Moderately weathered from 3.66 m to 4.00 m depth, to fresh below 4.00 m depth, very thinly laminated to thinly laminated, grey, fine grained, faintly porous, very weak from 3.66 m to 4.00 m depth, to weak below 4.00 m depth SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds

Runs: 1, 2, 3, 4, 5, 6

Type and Surface Description	Jr	Ja
CO,PL,SM	1	1
CO,IR,SM	2	1
BD,IR,SM	2	1
JN,CU,SM	2	1
JN,IR,SM	2	4
CC,CL, 1 mm	1	1
BD,PL,SM	2	1
BD,UN,SM	2	1
BD,UN,SM	2	4
JN,IR,SM	2	1
CC,CL, 1 mm		
CO,UN,SM		
CO,UN,SM	2	1
BD,UN,SM	2	1
BD,UN,SM	1	8
IN,CL, 5 mm		
BD,PL,SM	1	15
IN,CL, 30 mm	1.5	3
JN,PL,RO		
PC,CA, 1 mm	1	1
BD,PL,SM		
BD,UN,SM	2	1
BD,PL,SM	1	1
BD,PL,SM	1	1

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12

Notes / Instrumentation: Bentonite; Sand; Screen; UCS = 11.00 MPa; Sand; UCS = 15.9 MPa; Bentonite

CONTINUED NEXT PAGE

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE 1 : 50

GOLDER

LOGGED: EJ

CHECKED: AC

GTA-RCK 054 S:\CLIENTS\MTO\QEW-CREDIT_RIVER\02_DATA\GINT\QEW-CREDIT_RIVER.GPJ GAL-MISS.GDT 07/29/19

PROJECT: 1662333

RECORD OF DRILLHOLE: C1-4

LOCATION: N 4823329.3 ;E 295310.9

DRILLING DATE: February 21, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75 Truck

DRILLING CONTRACTOR: Davis Drilling

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	ROCK STRENGTH INDEX	WEATHERING INDEX	FEATURES	R0/R1 ZONES	NOTES WATER LEVELS INSTRUMENTATION
		--- CONTINUED FROM PREVIOUS PAGE ---																	
		END OF DRILLHOLE		87.65 12.75															

Depth scale: 13, 14, 15, 16, 17, 18, 19, 20, 21

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: EJ

CHECKED: AC

GOLDER

Foundation Design

RECORD OF BOREHOLE No C2-1

SHEET 1 OF 1

METRIC

PROJECT 1662333

G.W.P. 2002-13-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4823392.0; E 295230.5 MTM NAD ZONE 10 (LAT. 43.550403; LONG. -79.618436)

BOREHOLE TYPE CME 55, 83 mm I.D. Hollow Stem Augers, HQ Casing

DATE February 26, 2019

ORIGINATED BY EJ

COMPILED BY SE

CHECKED BY SEMP/SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.1	GROUND SURFACE				
0.0	Clayey silt, trace to some sand, some organics (FILL) Stiff Brown Wet	1	SS	10	
100.5 0.6	Sand and gravel, trace to some silt, trace clay (FILL) Compact Brown Moist -Styrofoam encountered at 0.6 m	2	SS	19	32 55 10 3
99.9 1.2	Inferred completely to moderately weathered, brown to grey, extremely weak to weak SHALE (Georgian Bay Formation)	3	SS	30	
		4	SS	88/0.25	
		5	SS	98/0.28	25 7 46 22
		6	SS	50/0.13	
97.4 3.7	SHALE (BEDROCK) Grey Slightly weathered to fresh Bedrock cored from a depth of 3.7 m to 8.0 m. For bedrock coring details, refer to Record of Drillhole C2-1.	7	SS	50/0.13	
		1	RC	REC 100%	RQD = 83%
		2	RC	REC 100%	RQD = 98%
		3	RC	REC 100%	RQD = 100%
93.1 8.0	END OF BOREHOLE				

NOTES:

1. Borehole dry upon completion of soil drilling prior to rock coring.

2. Water level measured at 2.5 m depth below ground surface (Elev. 98.6 m) after piezometer installation.

3. Water level measured at 4.7 m depth below ground surface (Elev. 96.4 m) in piezometer on March 13, 2019.

4. Water level measured at 5.7 m depth below ground surface (Elev. 95.4 m) on March 21, 2019.

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (101, 100, 99, 98, 97, 96, 95, 94); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 1662333

RECORD OF DRILLHOLE: C2-1

SHEET 1 OF 1

LOCATION: N 4823392.0 ;E 295230.5

DRILLING DATE: February 25, 2019

DATUM: Geodetic

DRILL RIG: CME 55 Track

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Davis Drilling Ltd.

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate, BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage, PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular, PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	NOTES WATER LEVELS INSTRUMENTATION
	Continued from Record of Borehole C2-1	97.44					
4	Slightly weathered to fresh, very thinly to thinly laminated, grey, fine grained, faintly porous, weak, SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds	3.66	1	BD,UN,SM	2	1	Bentonite
				BD,UN,SM	2	1	UCS = 17.1 MPa
5				BD,UN,SM	2	1	Sand
			2				UCS = 20.2 MPa
6				BD,UN,SM	2	1	Screen
7			3				
8		93.06 8.04					Sand
	END OF DRILLHOLE						

Depth scale: 9, 10, 11, 12

FEATURES LEGEND

BROKEN CORE | CLAY SEAM | LIMESTONE | LOST CORE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: EJ

CHECKED: AC

GOLDER

Foundation Design

RECORD OF BOREHOLE No NW4-5

SHEET 1 OF 1

METRIC

PROJECT 1662333	LOCATION N 4823340.0; E 295333.6 MTM NAD 83 ZONE 10 (LAT. 43.549927; LONG. -79.617156)	ORIGINATED BY CC	
G.W.P. 2002-13-00	BOREHOLE TYPE CME 75, 150 mm O.D., Solid Stem Augers	COMPILED BY SE	
DIST Central HWY QEW	DATE July 3, 2018	CHECKED BY SMM	
DATUM Geodetic			

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.3	GROUND SURFACE						
0.0	ASPHALT (150 mm)						
0.2	Sand and gravel, some silt (FILL) Compact Brown, mottled red, mottled grey Moist	1A / 1B	SS	10	100		
99.6 / 0.7	SILTY CLAY, some gravel, trace to some sand Very stiff Brown to grey Moist	2	SS	19	99		18 6 46 30
98.8 / 1.5	Inferred highly to moderately weathered, brown to grey, extremely weak to weak SHALE (Georgian Bay Formation)	3	SS	26			
		4	SS	69	98		
		5	SS	100/0.23	97		
96.5 / 3.8	SHALE (BEDROCK) Grey Slightly weathered to fresh. Bedrock cored from a depth of 4.1 m to 7.6 m. For bedrock coring details, refer to Record of Drillhole NW4-5.	6	SS	100/0.10	96		
		1	RC	REC 100%			RQD = 84%
		2	RC	REC 100%	95		RQD = 78%
		3	RC	REC 100%	94, 93		RQD = 100%
92.7 / 7.6	END OF BOREHOLE						

NOTE:

1. Open borehole dry upon completion of drilling.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

RECORD OF DRILLHOLE: NW4-5

PROJECT: 1662333

SHEET 1 OF 1

LOCATION: N 4823340.0 ;E 295333.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: July 3, 2018

DRILL RIG: CME 75

DRILLING CONTRACTOR: Davis Drilling

DATUM: Geodetic

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	FEATURES	R0/R1 ZONES
		Continued from Borehole NW4-5	96.21						
	HQ Core	Slightly weathered to fresh, thinly laminated to medium bedded, grey, very fine to fine grained, faintly porous, weak SHALE (Georgian Bay Formation) with slightly weathered to fresh, grey, fine grained, strong to very strong LIMESTONE interbeds	4.12	1	BD,PL,SM SO	1	1		R1
					BD,UN,SM SO	2	1		
5				2	BD,PL,SM SO	1	1		
					BD,PL,SM SO	1	1		
					BD,PL,SM SO	1	1		
					BD,PL,SM Sa	1	2		
					BD,PL,RO PC	1.5	3		
					BD,UN,SM SO	2	1		
6					BD,PL,SM SO	1	1		
					BD,PL,SM SO	1	1		
				3	BD,CU,SM SO	2	1		
7					BD,PL,SM SO	1	1		
					BD,CU,SM SO	2	1		
			92.70 / 7.63		BD,PL,SM SO	1	1		
		END OF DRILLHOLE							
8									
9									
10									
11									
12									
13									

Other column headings: SYMBOLIC LOG; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25 m; B Angle; DIP w.r.t. CORE AXIS; ROCK STRENGTH INDEX (R4 R3 R2 R1); WEATHERING INDEX (W1 W2 W3 W4 W5 W6); NOTES WATER LEVELS INSTRUMENTATION

FEATURES LEGEND

BROKEN CORE CLAY SEAM LIMESTONE LOST CORE

DEPTH SCALE 1 : 50

GOLDER

LOGGED: CC

CHECKED: AB

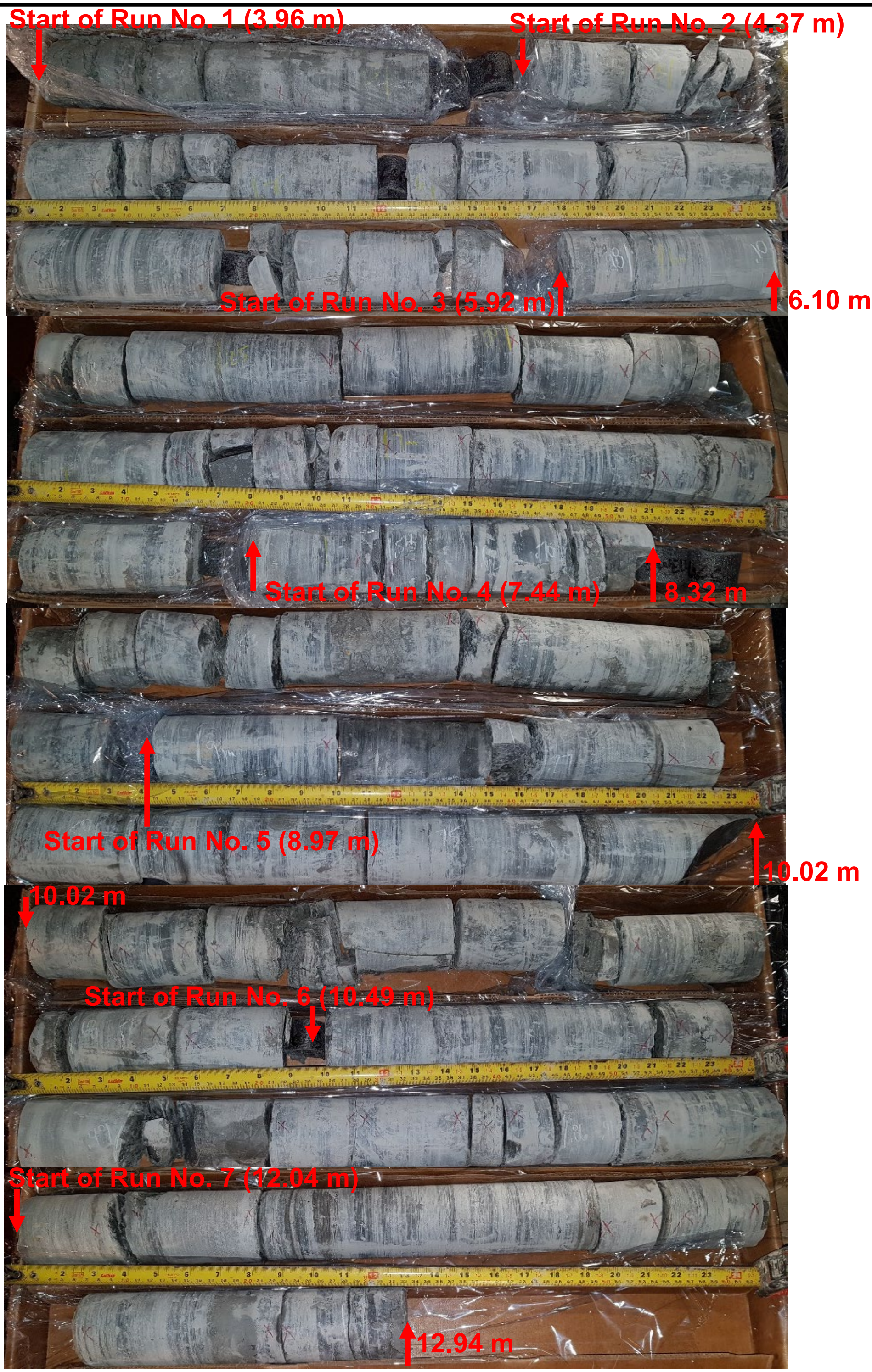
0 m | 0.25 m | 0.5 m | 0.75 m | 1.0 m | 1.25 m | 1.5 m

0 ft | 1 ft | 2 ft | 3 ft | 4 ft | 5 ft

Scale

PROJECT	**MTO Assignment 2015-E-0033 Watermain Installation Station 15+825 Mississauga Road to Hurontario Street**					
TITLE	**Bedrock Core Photograph Borehole C1-1 (3.05 m to 12.67 m)**					
GOLDER	PROJECT No. 1662333			FILE No. ----		
	DRAFT	JMP	20190326	SCALE	AS SHOWN	VER. 1.
	CADD	--		**FIGURE A-1**		
	CHECK	SMM	20190329			
	REVIEW	JMAC	201903--			

REVISION DATE: March 26, 2019 BY: JMP Project: 1662333



0 m 0.25 m 0.5 m
0 ft 1 ft 2 ft
Scale

PROJECT	**MTO Assignment 2015-E-0033 Watermain Installation Station 15+825 Mississauga Road to Hurontario Street**
TITLE	**Bedrock Core Photograph Borehole C1-2 (3.96 m to 12.94 m)**

GOLDER

PROJECT No. 1662333			FILE No. ----		
DRAFT	JMP	20190326	SCALE	AS SHOWN	VER. 1.
CADD	--		**FIGURE A-2**		
CHECK	SMM	20190329			
REVIEW	JMAC	201903--			

REVISION DATE: March 26, 2019 BY: JMP Project: 1662333

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

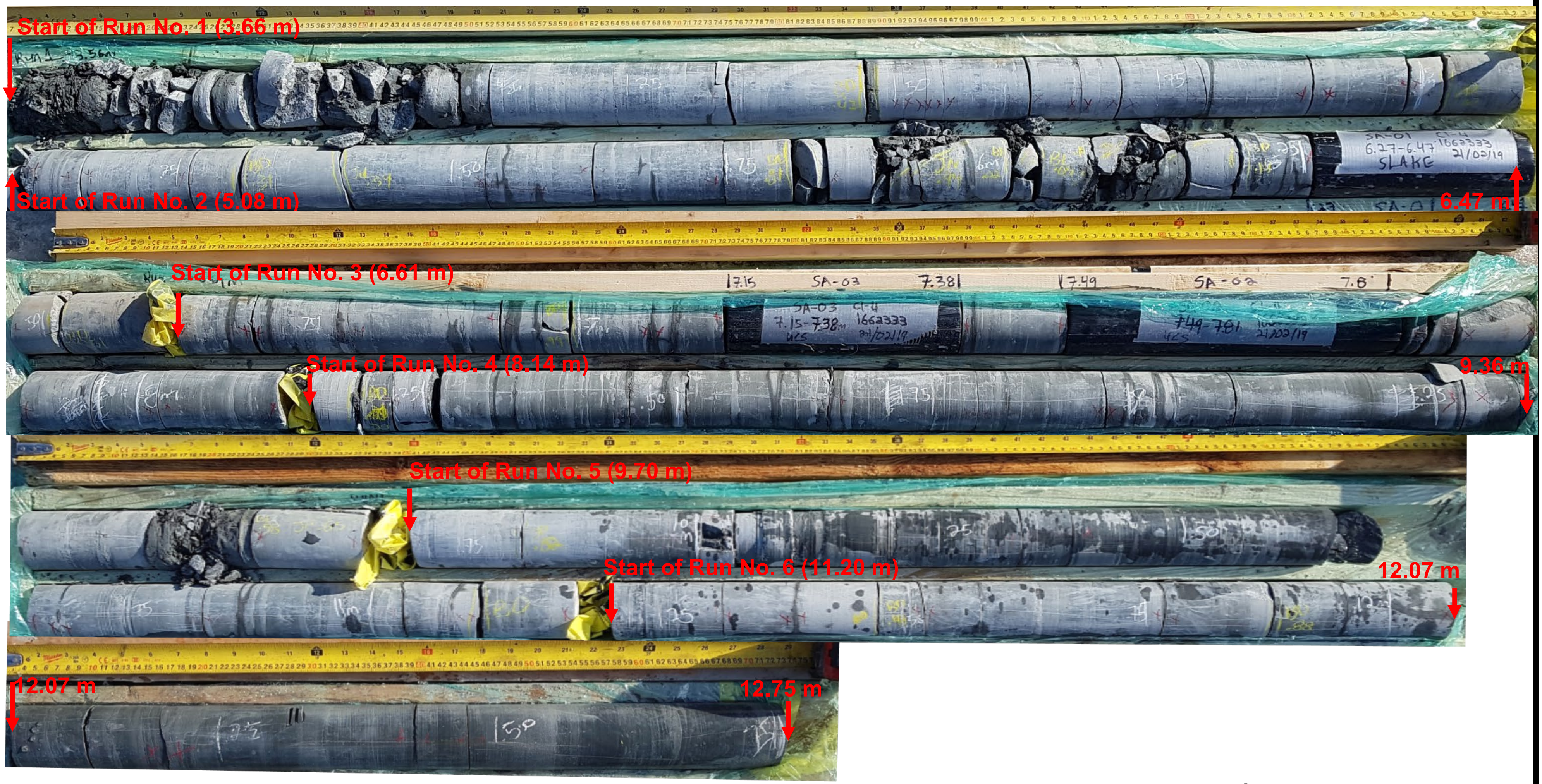
Scale

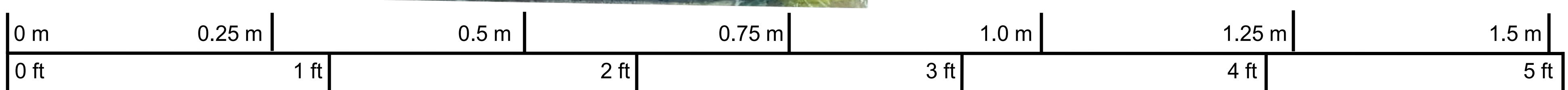
PROJECT	**MTO Assignment 2015-E-0033 Watermain Installation Station 15+825 Mississauga Road to Hurontario Street**
TITLE	**Bedrock Core Photograph Borehole C1-3 (3.35 m to 13.09 m)**

GOLDER

PROJECT No. 1662333			FILE No. ----		
DRAFT	JMP	20190326	SCALE	AS SHOWN	VER. 1.
CADD	--		**FIGURE A-3**		
CHECK	SMM	20190329			
REVIEW	JMAC	201903--			

REVISION DATE: March 26, 2019 BY: JMP Project: 1662333





Scale

PROJECT	**MTO Assignment 2015-E-0033** **Watermain Installation Station 15+825** **Mississauga Road to Hurontario Street**
TITLE	**Bedrock Core Photograph** **Borehole C1-4 (3.66 m to 12.75 m)**

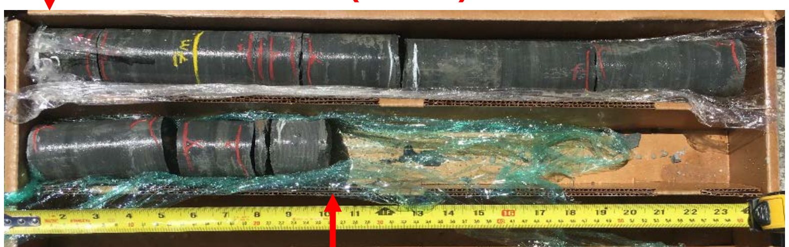
GOLDER	PROJECT No. 1662333			FILE No. ----	
	DRAFT	JMP	20190326	SCALE AS SHOWN	VER. 1.
	CADD	--		**FIGURE A-4**	
	CHECK	SMM	20190329		
	REVIEW	JMAC	201903--		

REVISION DATE: March 26, 2019 BY: JMP Project: 1662333

Start of Run No. 1 (4.12 m)

Start of Run No. 2 (4.80 m)

Start of Run No. 3 (6.33 m)



7.63 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 Assignment 2015-E-0033
Sanitary Sewer Installation Station 15+850
Mississauga Road and Hurontario Street

TITLE

Bedrock Core Photograph
Borehole NW4-5 (4.12 m to 7.63 m)

GOLDER

PROJECT No. 1662333			FILE No. ----		
DRAFT	SE	20180821	SCALE	AS SHOWN	VER. 1.
CADD	--				
CHECK	SMM	20190329	**FIGURE A-4**		
REVIEW	JMAC	201903XX			

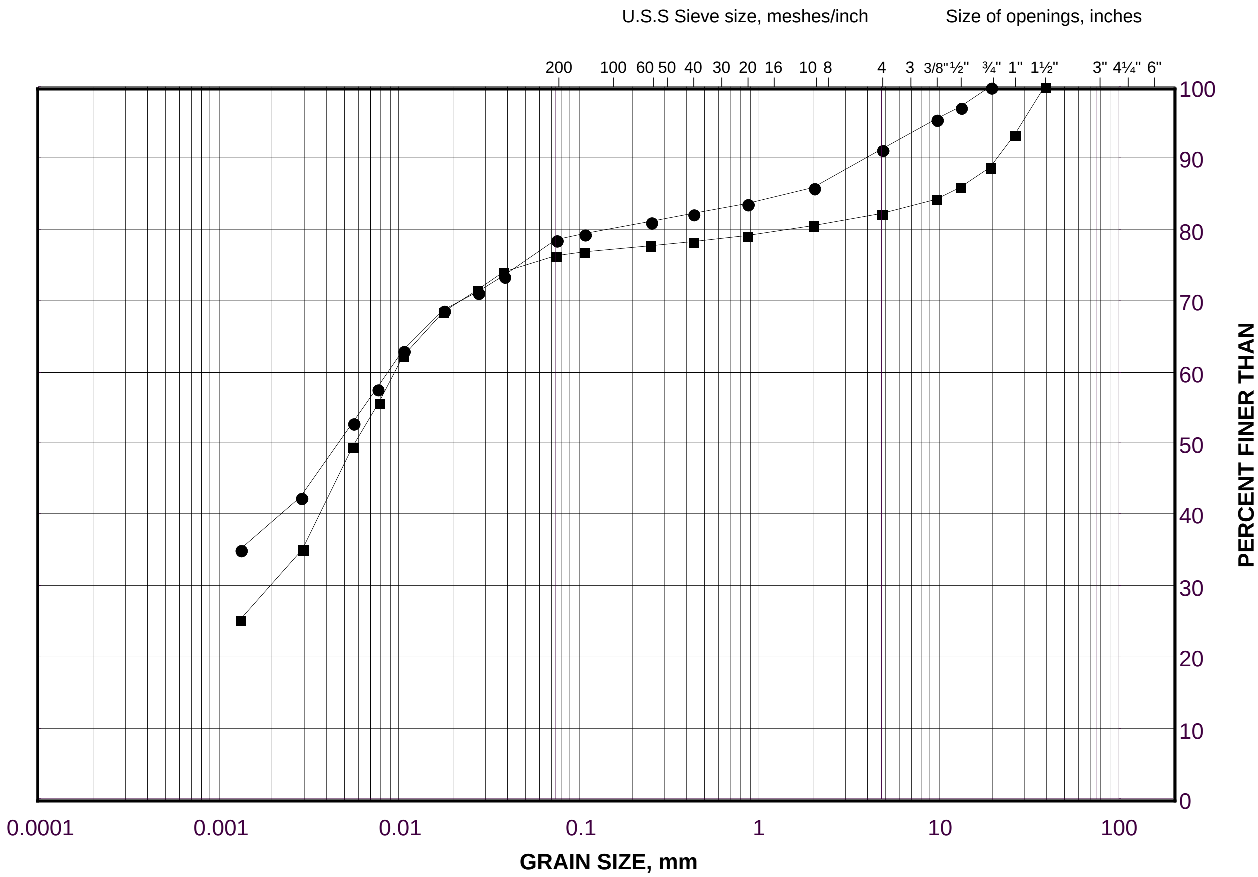
REVISION DATE: August 21, 2018 BY: SE Project: 1662333

APPENDIX B

Geotechnical Laboratory Test Results (incl. Geomechanica Test Results on Rock)

GRAIN SIZE DISTRIBUTION
Silty Clay

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)
●	C1-3	1B	99.8
■	NW4-5	2	99.3

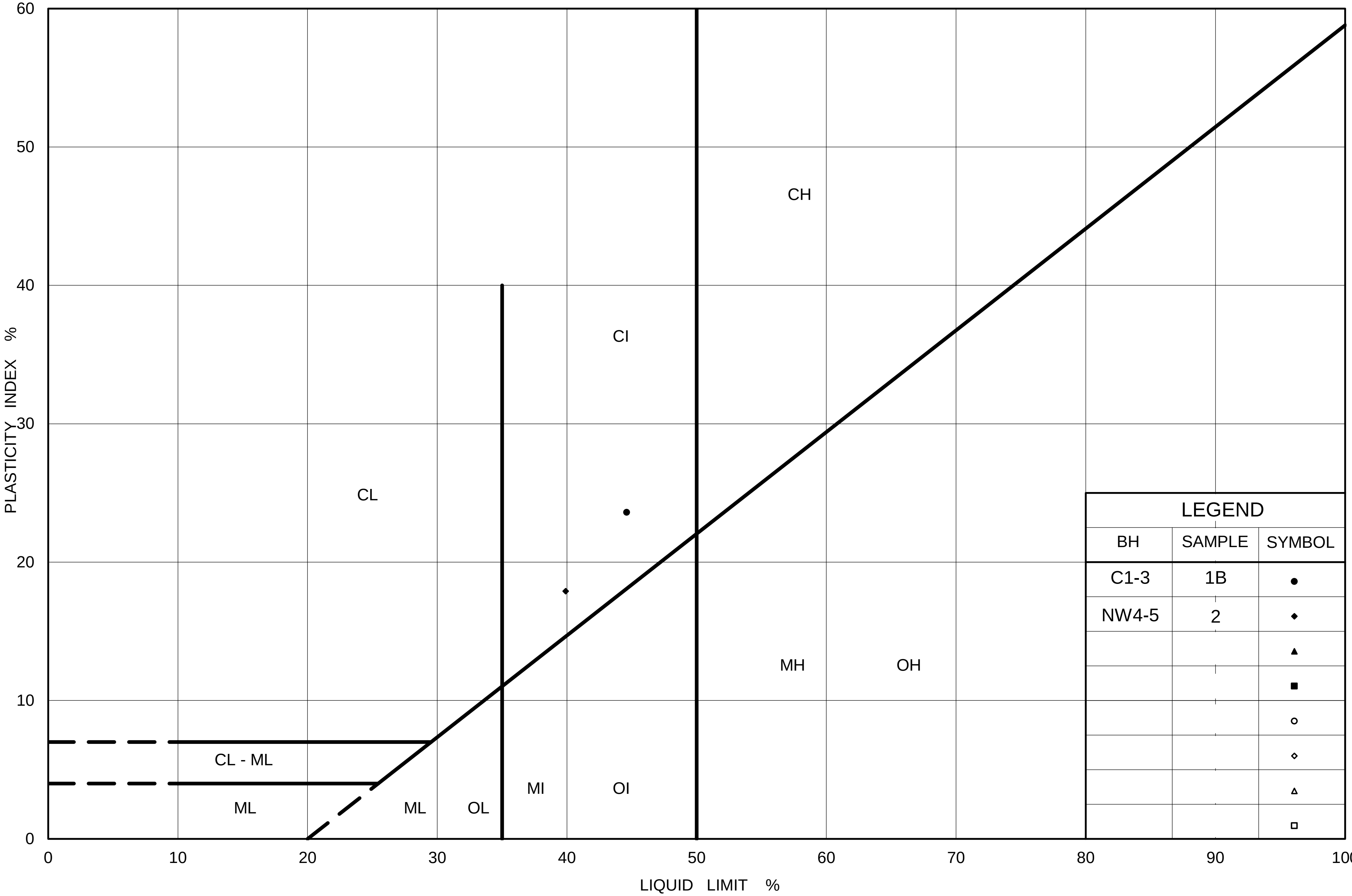
Project Number: 1662333

Checked By: SMM

Golder Associates

Date: 18-Apr-19

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay

Figure No. B-2

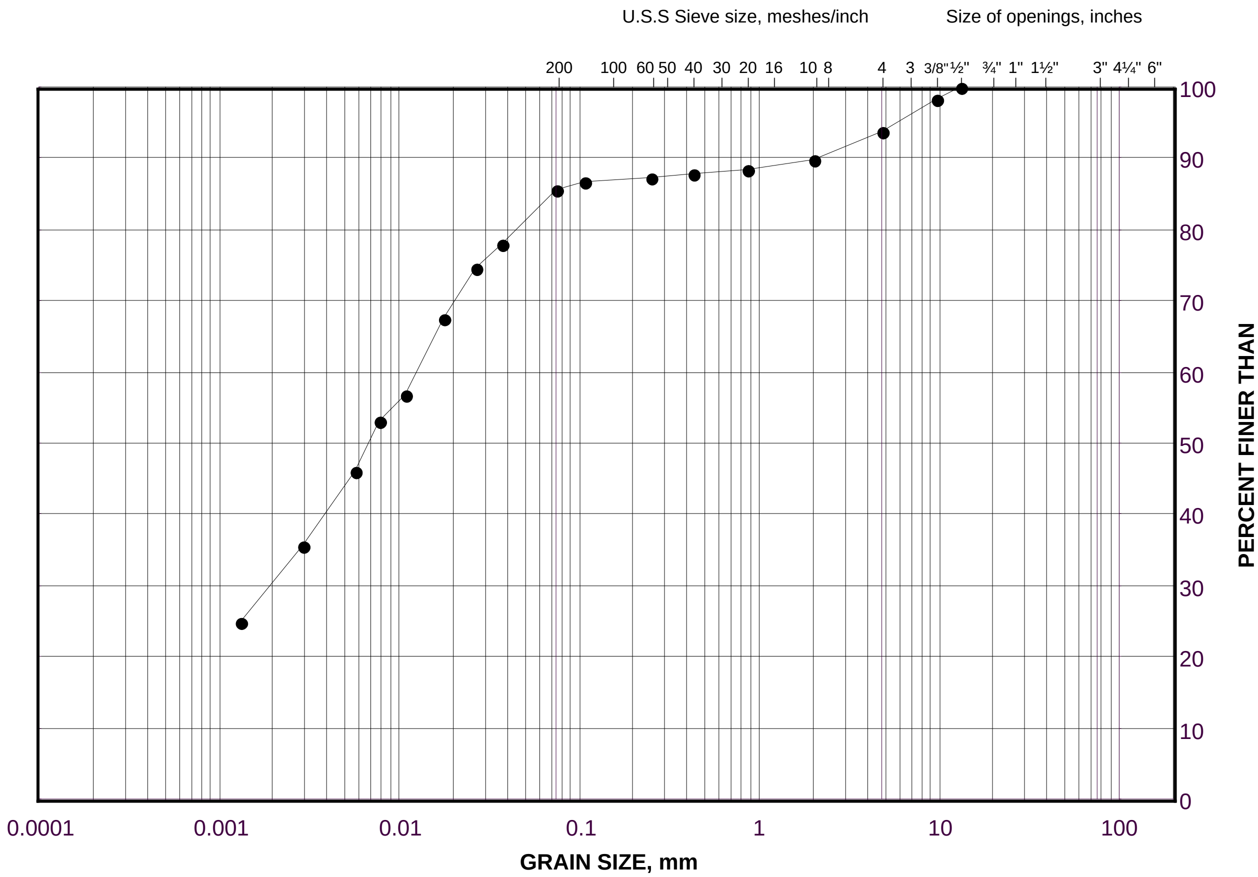
Project No. 1662333

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Silty Clay (Residual Soil)

FIGURE B-3



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C1-1	3A	99.1

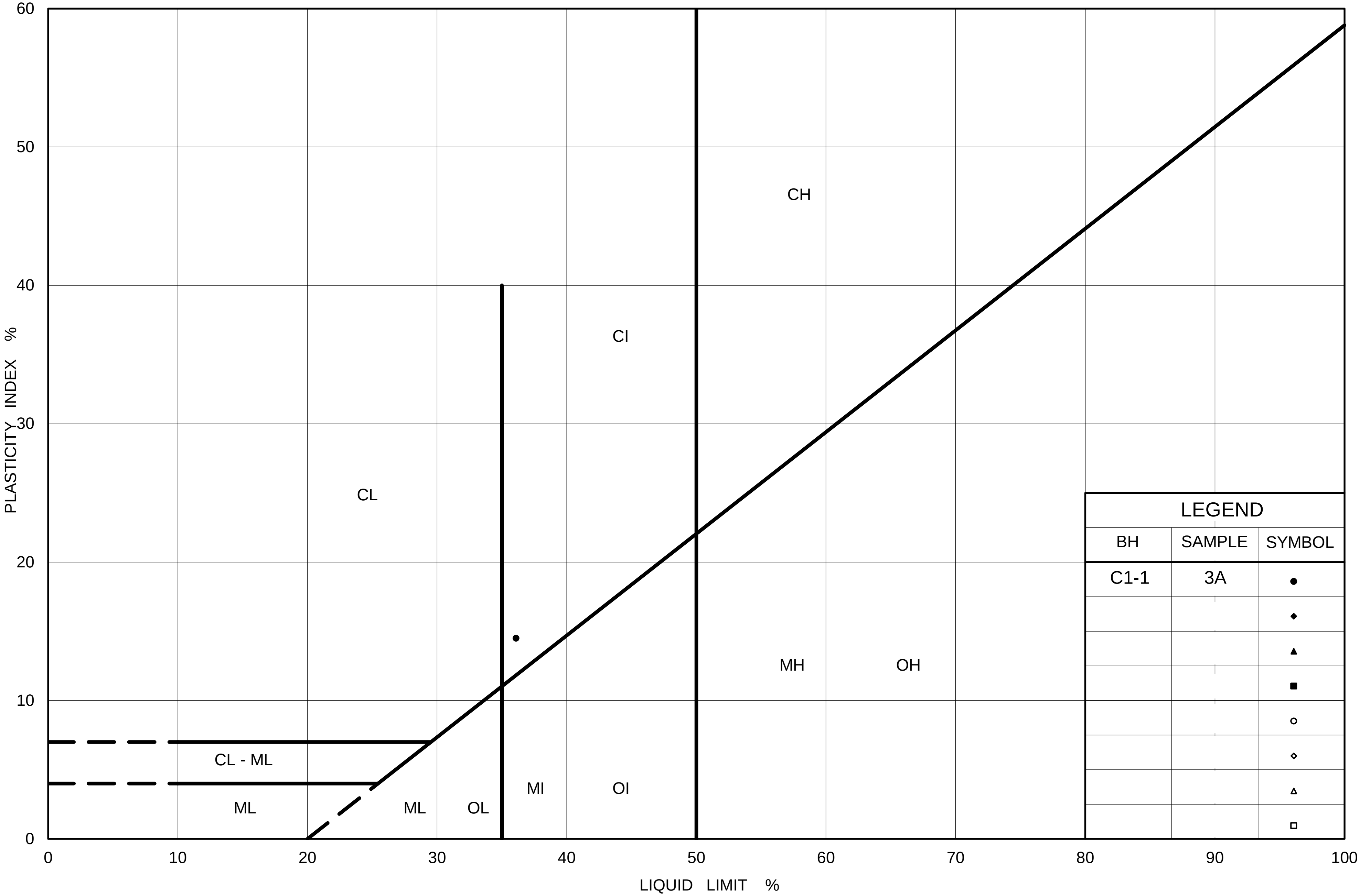
Project Number: 1662333

Checked By: SMM

Golder Associates

Date: 18-Apr-19

Oct 75, FF-S-21



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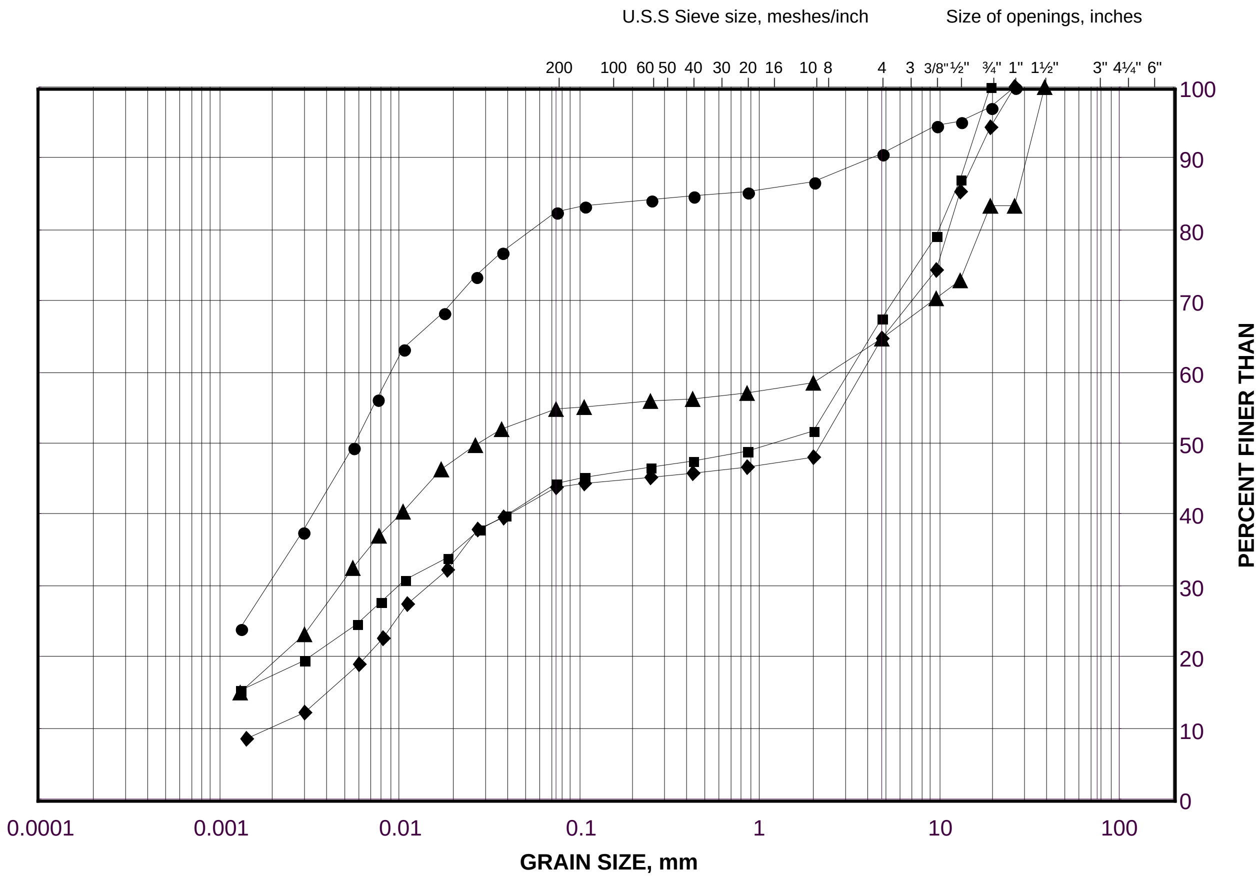
PLASTICITY CHART
Silty Clay (Residual Soil)

Figure No. B-4	
Project No. 1662333	
Checked By: SMM	

GRAIN SIZE DISTRIBUTION Inferred Completely to Moderately Weathered Shale (Bedrock)	FIGURE B-5



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

LEGEND

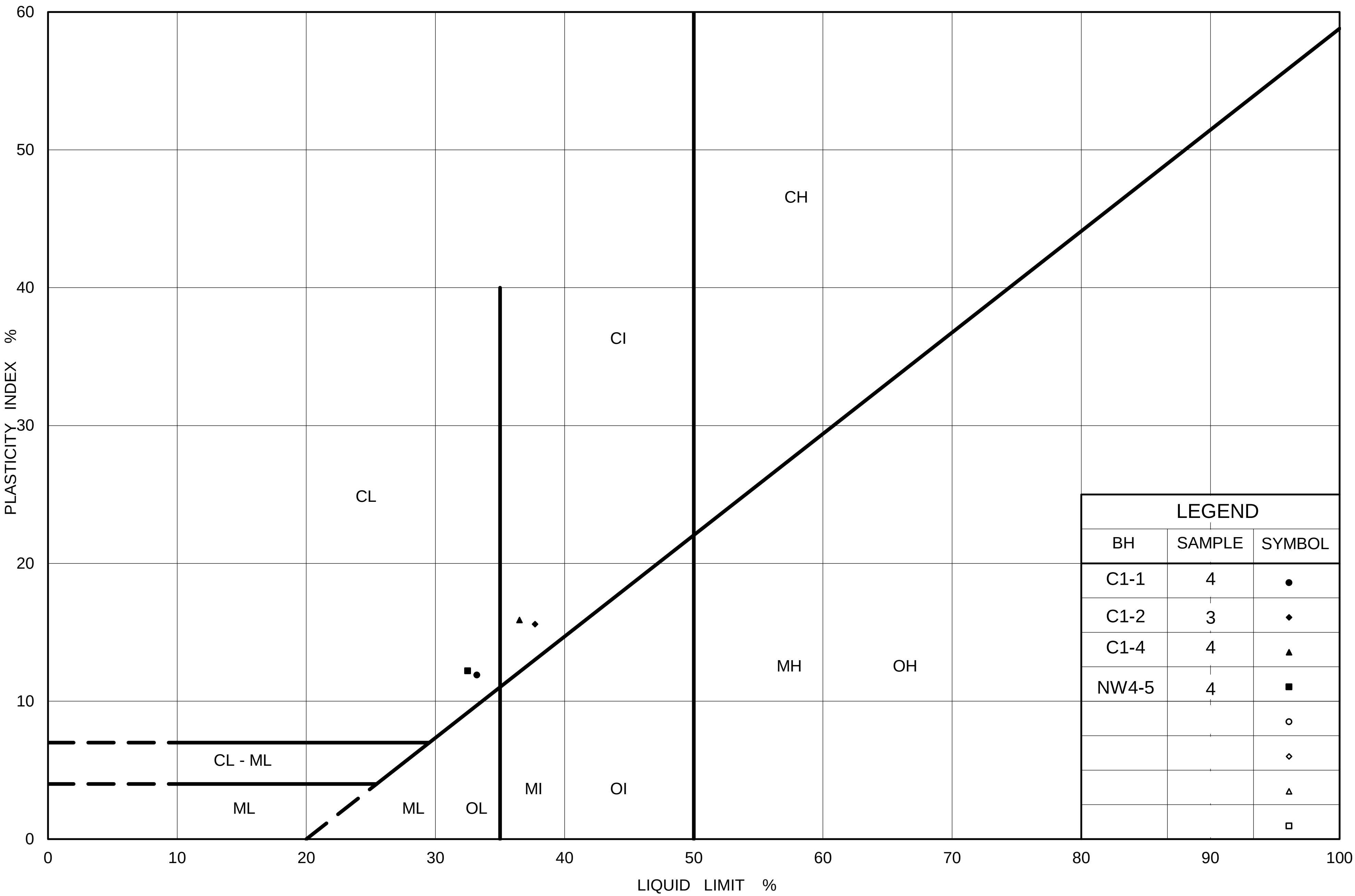
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C1-2	3	99.2
■	C1-4	3	98.9
◆	C1-2	5	97.7
▲	C1-4	5	97.7

NOTES:

1. The samples of inferred completely to moderately weathered bedrock were obtained by split-spoon sampling, and as such, the particle size(s) are effected by the sampling method and are limited to the size of the sampler. Larger fragments of shale bedrock may be present in-situ.
2. The percentage of gravel size particles may include shale fragments that either remained intact after or were broken during sampling and sample preparation. Therefore, the results of the grain size distribution testing may not be representative of the bulk grain size distribution or behavior of the in-situ or excavated completely to moderately weathered shale bedrock.

Project Number: 1662333

Checked By: SMM **Golder Associates** Date: 18-Apr-19



Ministry of Transportation

Ontario

PLASTICITY CHART

Inferred Completely to Moderately Weathered Shale (Bedrock)

Figure No. B-6

Project No. 1662333

Checked By: SMM

Geomechanica Inc.
Suite 900 – 390 Bay St.
Toronto Ontario
Canada M5H 2Y2

March 15, 2019

Mr. David Marmor
Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario
Canada L5N 7K2

Re: UCS, Slake, and CERCHAR testing
(Golder Project No. 1662333)

Dear Mr. Marmor:

On March 8, 2019 and March 12, 2019 eighteen (18) and two (2) HQ-sized core samples were received by Geomechanica Inc. via drop-off by Golder personnel, respectively. These samples were identified as being from boreholes drilled as part of Golder project 1662333. A total of 14 uniaxial compressive strength (UCS) tests, 2 slake durability tests, and 4 CERCHAR tests were performed using these samples.

Details regarding the steps of specimen preparation and testing along with the test results and specimen photographs before and after testing are presented in the accompanying laboratory report.

Sincerely,

Bryan Tatone Ph.D., P. Eng.

Geomechanica Inc.
Tel: (647) 478-9767
Email: bryan.tatone@geomechanica.com

GEOMECHANICA

Rock Laboratory Testing Results

A report submitted to:

David Marmor
Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario
Canada L5N 7K2

Prepared by:

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Tel: +1-647-478-9767
lab@geomechanica.com

March 15, 2019
Project number: 1662333

Abstract

This document summarizes the results of rock laboratory testing, including the results of Uniaxial Compressive Strength (UCS), Slake durability, and CERCHAR abrasivity testing. The results of each test type are presented in separate sub-sections herein.

In this document:

1 Uniaxial Compressive Strength Tests

1.1 Overview

This section summarizes the results of uniaxial compressive strength (UCS) testing of HQ3-sized specimens. The testing was performed in Geomechanica's rock testing laboratory using a 150 ton (1.3 MN) Forney loading frame equipped with pressure-compensated control valve to maintain an axial displacement rate of approximately 0.150 mm/min and 0.100 mm/min for shale and limestone specimens, respectively (Figure 1). The preparation and testing of each specimen included the following:

1. Unwrapping of the core sample, inspecting it for damage, and re-wrapping it in electrical tape to minimize exposure to moisture during subsequent specimen preparation.
2. Diamond cutting of core sample to obtain cylindrical specimens with an appropriate length (length:diameter = 2:1) and nearly parallel end faces.
3. Diamond grinding of specimen to obtain flat (within ± 0.025 mm) and parallel end faces (within 0.25°).
4. Placing specimen into the loading frame, applying a 1 kN axial load, and removing the electrical tape.
5. Axially loading the specimens to rupture while continuously recording axial force, axial deformation, radial deformation (for select samples) to determine the peak strength (UCS), tangent Young's modulus, and Poisson's ratio (for select samples).

Using a precision V-block mounted on the magnetic chuck of the surface grinder, test specimens met the end flatness, end parallelism, and perpendicularity criteria set out in ASTM D4543-08. The side straightness criteria, as checked with a 0.5 mm feeler gauge, was met for all samples and the minimum length:diameter criteria was met for all specimens unless noted otherwise in Table 3. Testing of the specimens followed ASTM D7012-14 with the following exceptions:

- Rather than a spherical seat diameter equal to 1 to 2 times the specimen diameter, the setup used here employed a 25.4 mm diameter high precision ball bearing and seat. Despite the smaller diameter, this seat could move freely to accommodate small angular rotations in any direction, as needed, and therefore did not appreciably influence the results.
- Some tests included measurement of the UCS and tangent Young's (elastic) modulus, but not the Poisson's ratio. This represents a hybrid between Methods C and D of ASTM D7012-14.

Figure 1: Forney loading frame setup for uniaxial compression testing.

1.2 Quantifying Poisson's ratio

To quantify the Poisson's ratio, the radial strain during UCS testing was recorded using a specially designed sensor consisting of a radial spring and non-contact displacement transducer (Figure 2). This sensor was calibrated by axially loading an aluminum cylinder with known elastic modulus and Poisson's ratio and having the same dimensions as the test specimens. By doing so, the output of the non-contact displacement transducer could be calibrated directly to the radial strain of the cylinder. Poisson's ratio was measured over the same range of stresses as the tangent Young's modulus.

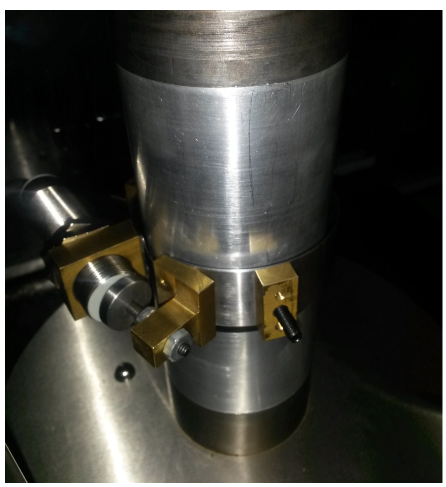


Figure 2: Radial strain sensor comprised of a radial spring and non-contact displacement transducer positioned on the aluminum calibration cylinder.

1.3 Results

The results of UCS testing are summarized in Table 1. The corresponding stress-strain curves are presented in Figures 3 - 5. Please note that additional details and measurements for each test specimen are included in the summary spreadsheet that accompanies this report. The Young's modulus, E, is the tangent modulus, calculated as the slope of the best-fit line through ± 300 axial strain data points and the Poisson's ratio, ν, is defined as the ratio of the slope of the best-fit line through ± 300 radial strain data points divided by the Young's modulus. For this project, the moduli have been defined at stress levels corresponding to both 50% of the UCS strength and at a stress level of 2.5 MPa (for shale samples only). Definition of the moduli at 50% of the UCS is the conventional approach, however the shale samples tested display non-linear behaviour at this stress level. Therefore, the moduli have also been defined at an alternative stress level where the stress-strain response displays a more linear response.

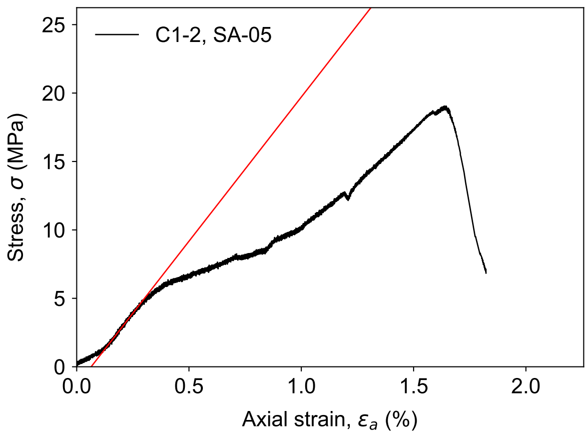
Table 1: Summary of Uniaxial Compression test results.

Sample	Depth (m)	Bulk density ρ (g/cm^3)	UCS (MPa)	Young's modulus E @ 2.5 MPa (GPa)	Poisson's ratio ν @ 2.5 MPa	Young's modulus E @ 50% UCS (GPa)	Poisson's ratio ν @ 50% UCS	Lithology	Failure description
C1-2, SA-05	8.13 - 8.32	2.600	19.1	2.1	-	0.7	-	Shale	1, 2
C1-2, SA-06	10.86 - 11.07	2.602	25.0	2.4	-	1.5	-	Shale	3, 2
C1-4, SA-02	7.49 - 7.81	2.603	15.9	1.4	-	1.0	-	Shale	3, 2
C3-3, SA-02	6.18 - 6.38	2.598	16.6	1.7	-	0.8	-	Shale	4, 5
C1-1, SA-02	5.25 - 5.55	2.607	19.3	1.8	0.54	1.0	0.06	Shale	1, 5
C1-1, SA-03	6.79 - 7.13	2.602	15.2	1.4	0.12	1.0	0.15	Inter-bedded limestone & shale	1, 2
C1-4, SA-03	7.15 - 7.38	2.585	11.0	0.9	0.19	0.5	0.13	Shale	6, 1, 2
C2-1, SA-01	4.60 - 4.85	2.591	17.1	1.5	0.19	0.8	0.05	Shale	3, 5
C2-1, SA-02	4.99 - 5.40	2.589	20.2	1.8	0.18	1.0	0.05	Shale	1, 3, 5
C2-2, SA-01	4.52 - 4.7	2.592	13.3	1.1	0.11	0.8	0.18	Shale	1, 5
C3-4, SA-01	3.09 - 3.41	2.601	17.6	1.9	0.13	0.8	0.14	Shale	1, 5
C3-4, SA-02	3.41 - 3.77	2.594	17.3	2.0	0.20	0.8	0.02	Shale	4, 5
C2-3, SA-05	8.29 - 8.49	2.602	23.2	1.9	0.27	1.4	0.06	Shale	4, 2
C1-3, SA-04	6.54 - 6.75	2.667	210.2	N/A	N/A	44.4	0.25	Limestone	7

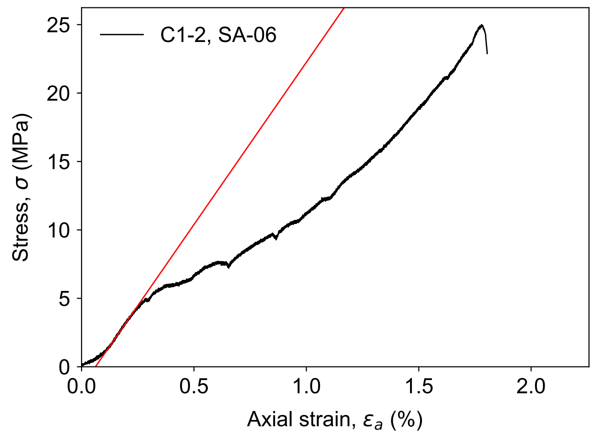
[1] Axial splitting failure
[2] Specimen emitted saline pore water upon loading
[3] Partial hourglass failure
[4] Inclined shear band failure
[5] Specimen emitted pore water upon loading
[6] Localized crushing
[7] Hourglass failure

1.4 Specimen photographs

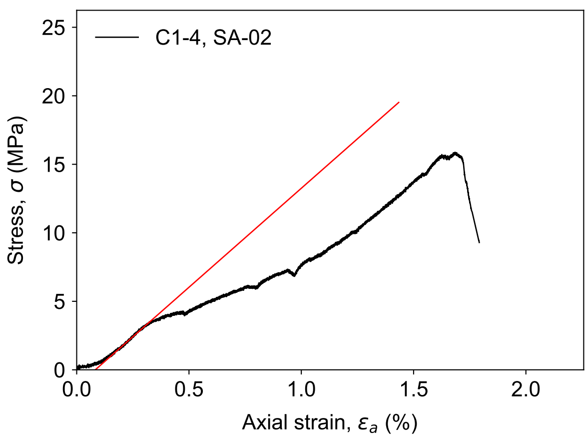
Photographs of the UCS specimens before and after testing are presented in the Appendix of this report.



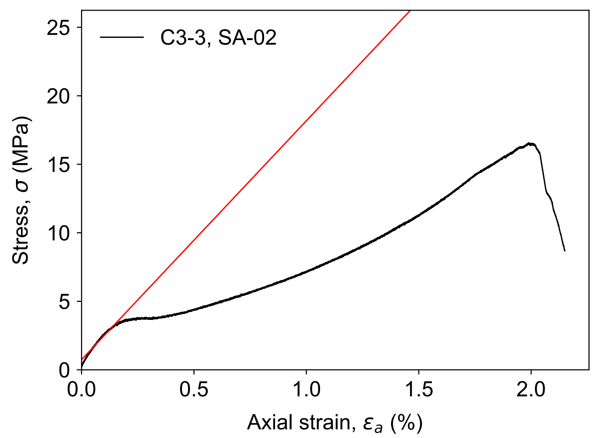
(a) C1-2-SA-05



(b) C1-2-SA-06

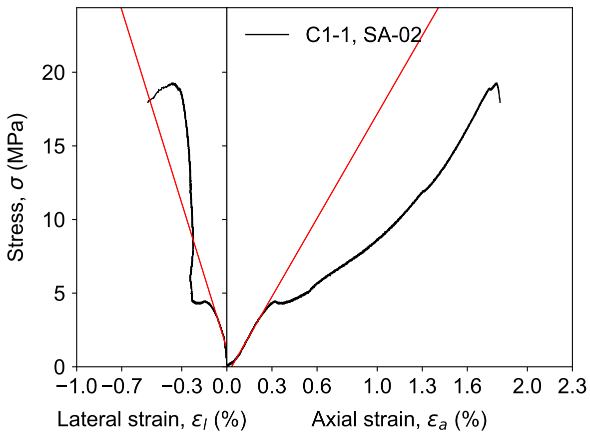


(c) C1-4-SA-02

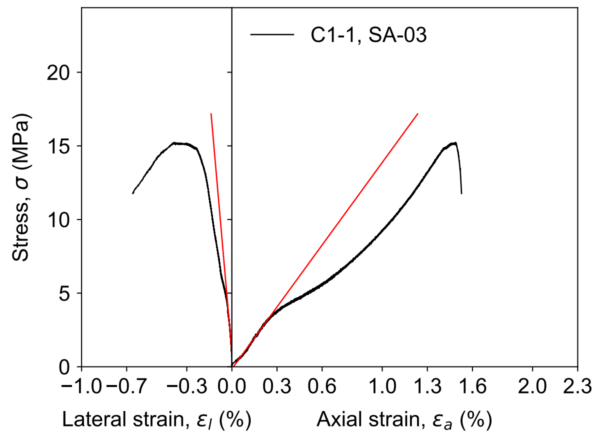


(d) C3-3-SA-02

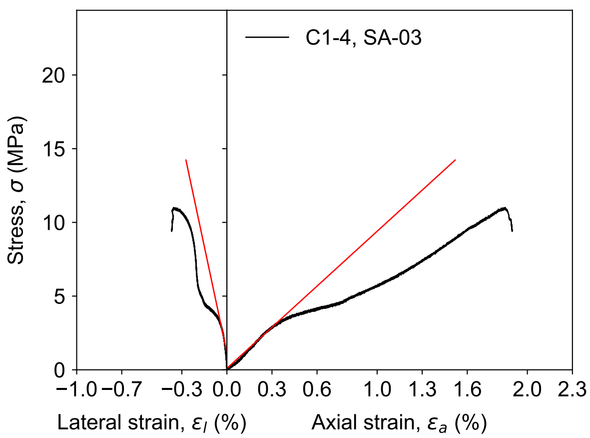
Figure 3: Measured stress-strain curves for specimens without radial strain measurement.



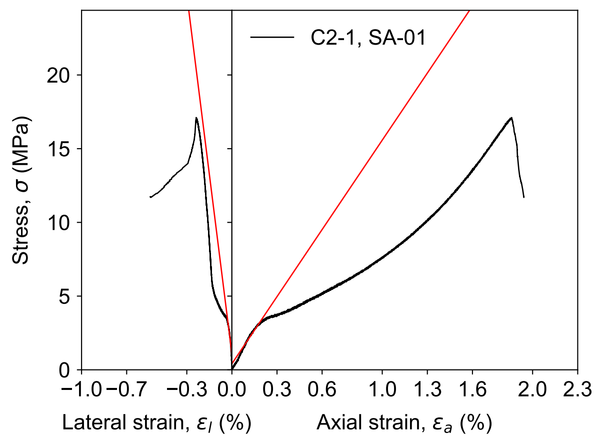
(a) C1-1-SA-02



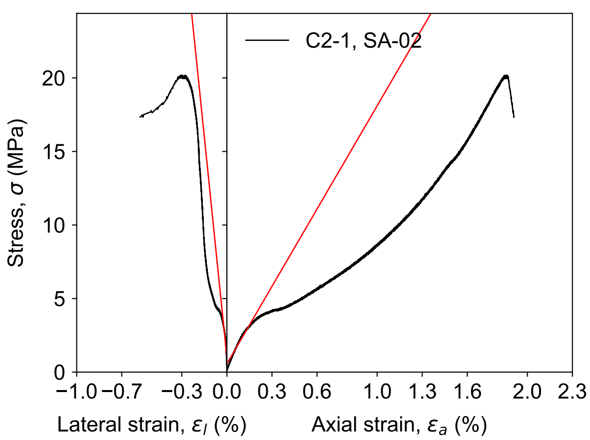
(b) C1-1-SA-03



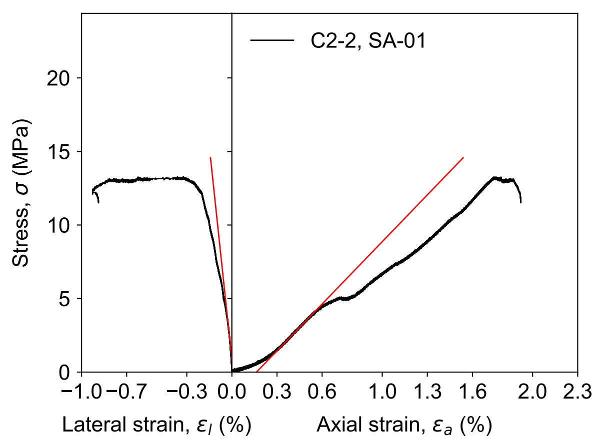
(c) C1-4-SA-03



(d) C2-1-SA-01

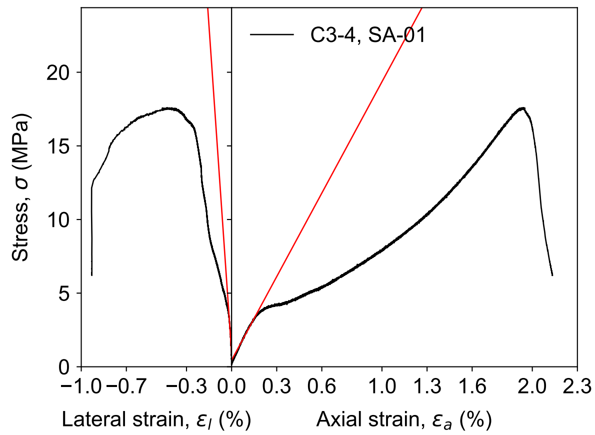


(e) C2-1-SA-02

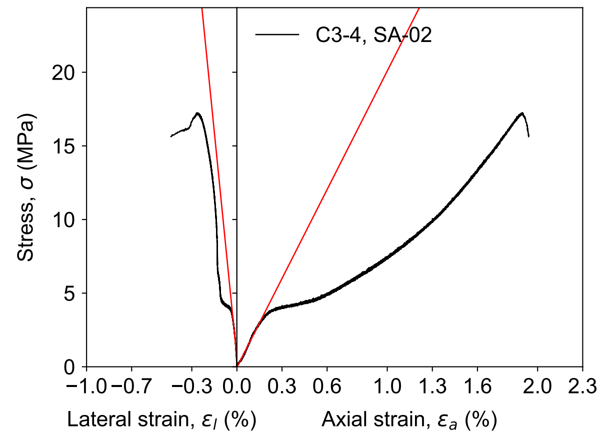


(f) C2-2-SA-01

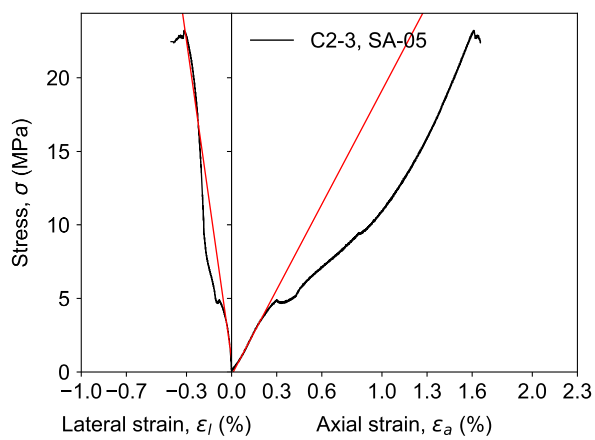
Figure 4: Measured stress-strain curves for specimens with axial and radial strain measurements.



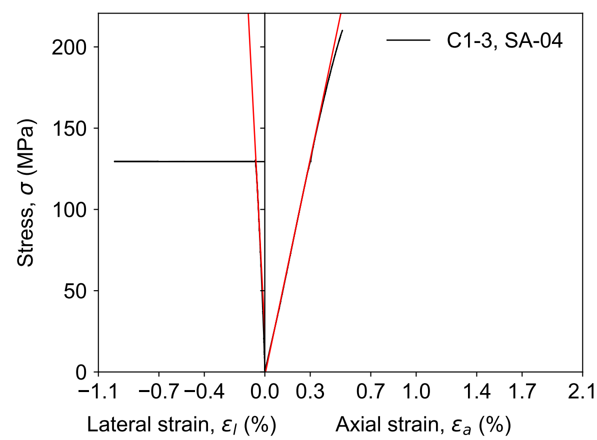
(a) C3-4-SA-01



(b) C3-4-SA-02



(c) C2-3-SA-05



(d) C1-3-SA-04 (limestone)

Figure 5: Measured stress-strain curves for specimens with axial and radial strain measurements (continued).

2 Slake Durability

2.1 Overview

This section summarizes the results of slake durability testing. The tests were performed using an M&L Testing Equipment Slake Durability apparatus capable of simultaneously performing four slake durability tests (Figure 6). The test was conducted using the following procedure:

1. The core was broken using a hammer and point load testing apparatus into 40-60 g lumps. The sharp edges of the lumps were removed by lightly hammering the edges.
2. Approximately 10 lumps weighing 450-550 g were inserted into the drum and dried in the oven at 110 °C until reaching a constant mass.
3. The drum was removed from the oven and allowed to cool to room temperature, weighed, and subsequently rotated in room temperature distilled water at 20 revolutions per minute for 10 minutes.
4. The drum was returned to the oven to dry for approximately one day and weighed again.
5. Steps 3 and 4 were then repeated for a second cycle.
6. The drum was thoroughly cleaned, dried, and weighed.

The above slake durability testing procedure adhered to ASTM D4644-16.

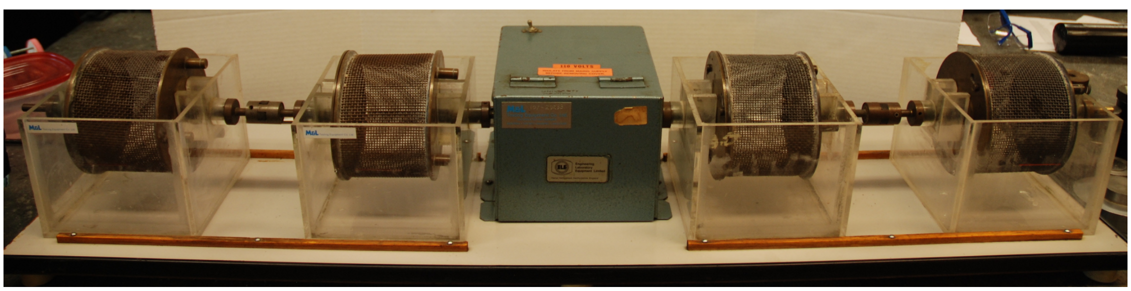


Figure 6: Test setup showing the slake durability apparatus.

2.2 Results

The results of the tests are summarized in Table 2. Additional measurements and sample descriptions are provided in the summary spreadsheet that accompanies this report. The slake durability index after one and two cycles was calculated as follows, respectively:

$$I_{d1} = \frac{B - D}{A - D} \times 100\% \quad (1)$$

$$I_{d2} = \frac{C - D}{A - D} \times 100\% \quad (2)$$

where A is the mass of the specimen and drum before the first test cycle, B is the mass of the specimen and drum after oven drying the first cycle, C is the mass of the specimen and drum after oven drying the second cycle and D is the mass of the drum.

Table 2: Summary of slake durability testing results.

Sample	Depth (m)	Moisture content (%)	Pre-First Cycle, A (g)	Post-First Cycle, B (g)	Post-Second Cycle, C (g)	Mass of Drum, D (g)	Slake Durability Index , (1st Cycle) I_{d1} (%)	Slake Durability Index (2nd Cycle), I_{d2} (%)	Lithology
C1-4, SA-01	6.27 - 6.47	0.90	2378.84	2286.94	2172.12	1897.46	80.9	57.1	Grey shale
C3-1, SA-01	4.50 - 4.69	0.82	2424.48	2365.03	2304.42	1952.74	87.4	74.5	Grey shale

2.3 Specimen Photographs

Photographs of the specimens before testing and after testing are shown in Figure 7.

Figure 7: Photographs of slake durability specimens before and after testing.

3 CERCHAR Abrasivity Tests

3.1 Overview

This section summarizes the results of CERCHAR abrasivity testing. The tests were performed using a Type-2 CERCHAR apparatus as shown in Figure 8a. The tips of the styluses were sharpened to a conical angle of 90° using the setup shown in Figure 8b. The styluses used to perform the tests are shown in Figure 8c-d (Rockwell hardness 55±1). A static force of 70 N was applied on top of the stylus by using a combination of weights. Details of the testing procedure are as follows:

1. The tips of the five styluses are sharpened using the grinding apparatus (Figure 8b).
2. The styluses are placed under a microscope (60x magnification) and three scaled photos (120° apart) are captured before the test is conducted to ensure the 90° point has been properly formed.
3. The test specimens are obtained by breaking core samples to expose a fresh fracture surface perpendicular to the core axis.
4. The specimen is secured in the cross-slide vise of the testing apparatus and the stylus is carefully lowered on to the surface of the rock.
5. A scratch measuring 10 mm in length is performed over a duration of 10 seconds. This process is repeated with all five styluses on undisturbed parts of the fracture surface (e.g., Figure 9a).
6. Lastly, the worn tips are re-examined under the microscope. From three scaled photos (120° apart), the wear flat, *d*, is measured (e.g., Figure 9c).

The length or the diameter of the wear flat, *d*, was measured from scaled microscope images using the image processing software Fiji (e.g., Figure 9b-c). The mean wear of the tip is calculated by taking the average *d* of all tests. The CERCHAR-Abrasivity-Index (CAI) of the sample is subsequently calculated by taking the mean wear and multiplying it by 10.

3.2 Results

The results of the CERCHAR abrasivity tests are summarized in Table 3. Additional measurements and sample descriptions are provided in the summary spreadsheet that accompanies this report.

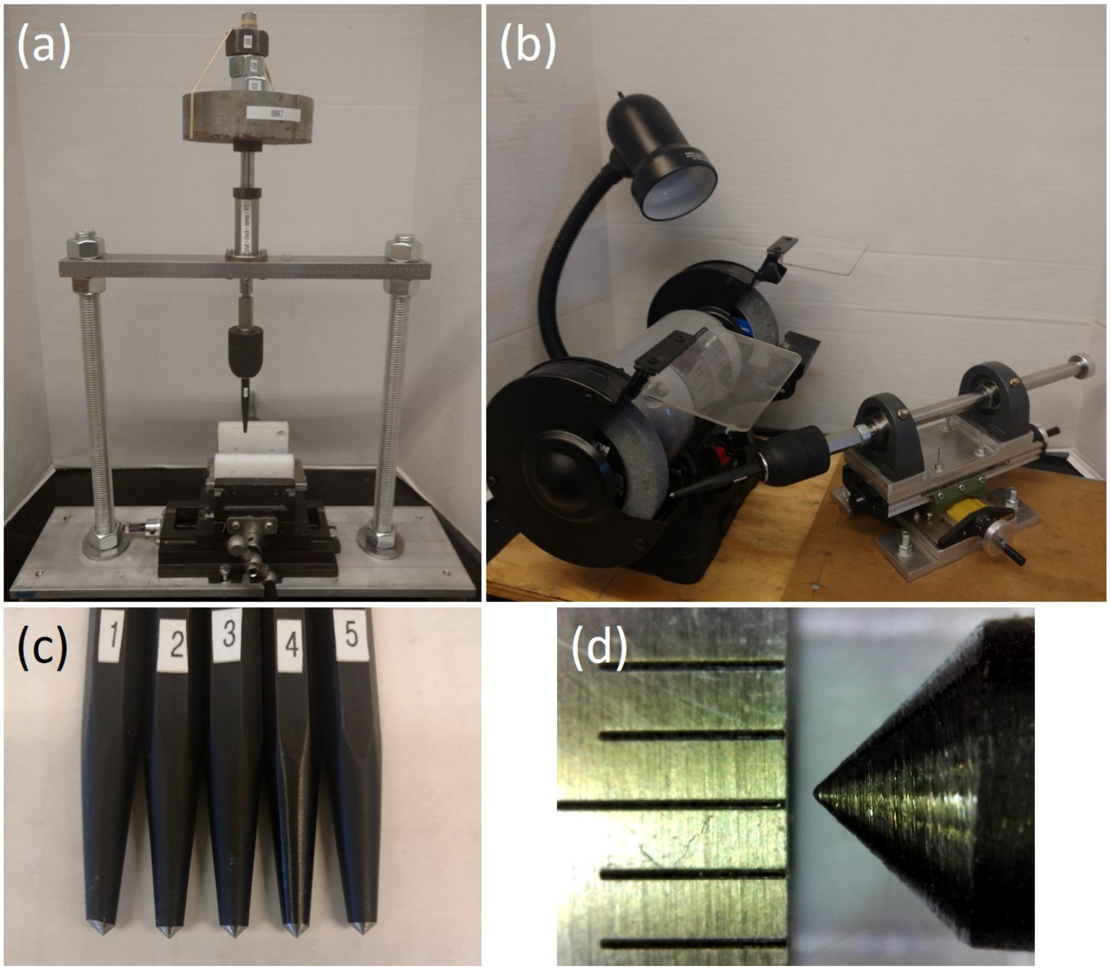


Figure 8: Photos showing (a) the CERCHAR apparatus, (b) tip sharpening setup, (c) the five styluses used to perform the test and (d) a microscope image of one of the stylus tips.

Table 3: Summary of CERCHAR abrasivity test results.

Sample	Depth (m)	Test 1 Mean (mm)	Test 2 Mean (mm)	Test 3 Mean (mm)	Test 4 Mean (mm)	Test 5 Mean (mm)	Mean Wear (mm)	CAI	Standard Deviation of CAI	ASTM Classification
C1-2, SA-02	4.78 - 4.91	0.019	0.022	0.035	0.024	0.026	0.025	0.25	0.06	$<$ Very Low
C2-2, SA-02	7.20 - 7.29	0.026	0.015	0.033	0.045	0.015	0.027	0.27	0.12	$<$ Very Low
C3-2, SA-03	7.55 - 7.68	0.027	0.042	0.008	0.022	0.015	0.023	0.23	0.13	$<$ Very Low
C3-3, SA-04	7.03 - 7.18	0.015	0.025	0.060	0.032	0.033	0.033	0.33	0.17	$<$ Very Low

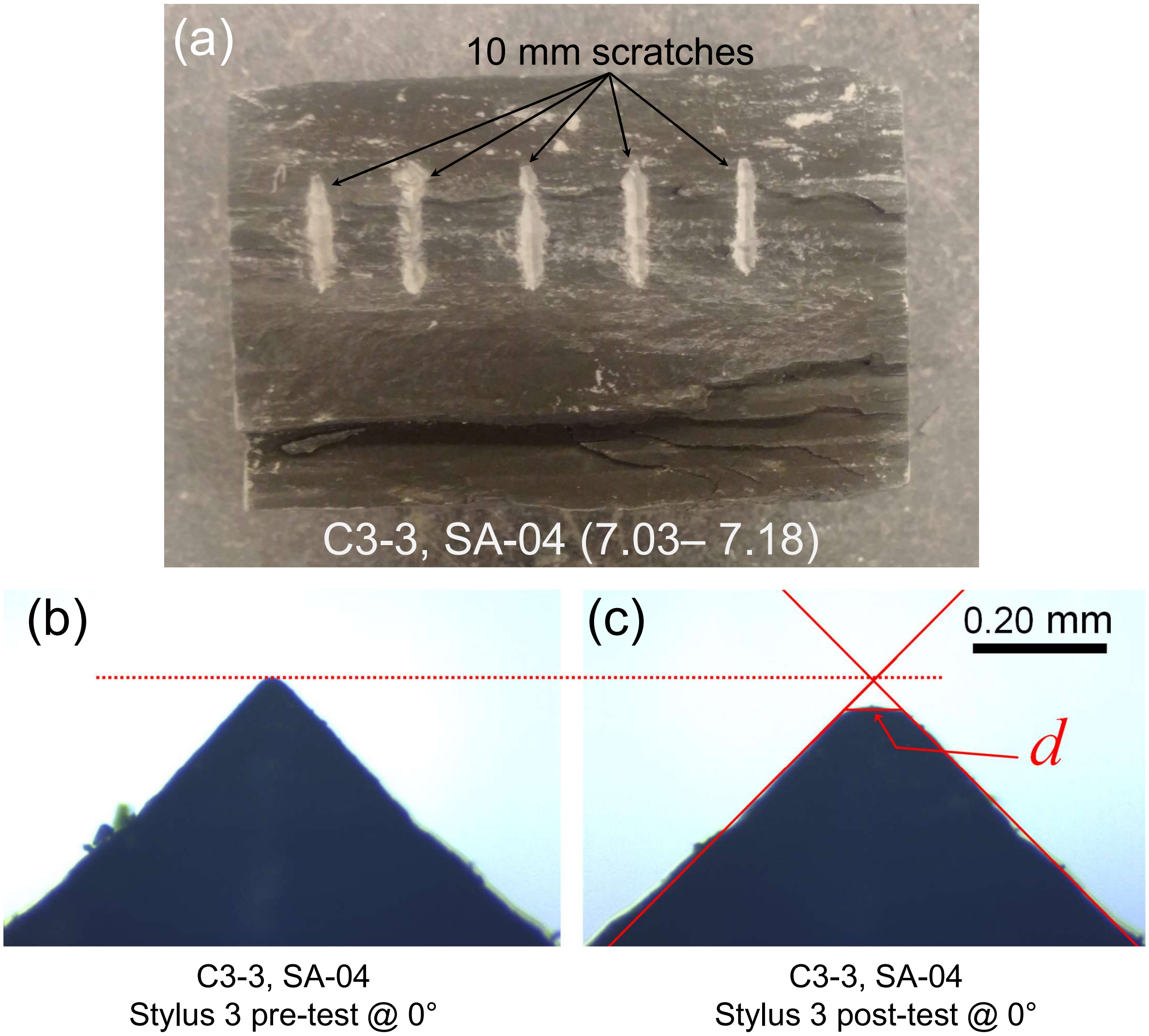


Figure 9: (a) Photograph showing an example of the five 10 mm scratches on a test specimen (b) microscope image of select stylus prior to testing at the noted position; and (c) microscope image of the same stylus at the same position following testing with the wear flat, d, denoted.

Appendices

A UCS specimen sheets

Tests without radial strain measurement

- C1-2, SA-05
- C1-2, SA-06
- C1-4, SA-02
- C3-3, SA-02

Tests with radial strain measurement

- C1-1, SA-02
- C1-1, SA-03
- C1-4, SA-03
- C2-1, SA-01
- C2-1, SA-02
- C2-2, SA-01
- C3-4, SA-01
- C3-4, SA-02
- C2-3, SA-05
- C1-3, SA-04

Uniaxial Compression Test

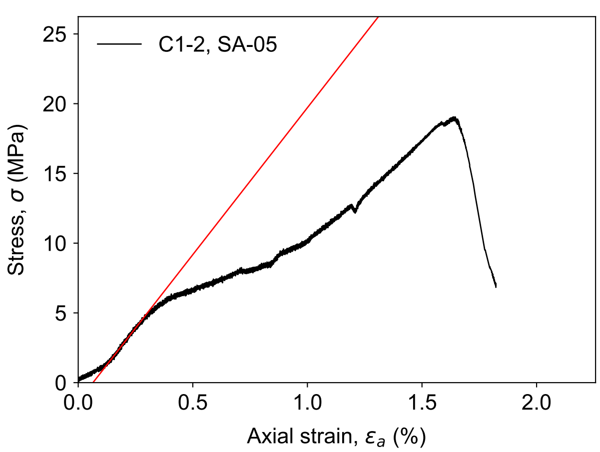
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-2, SA-05	**Depth**	8.13 - 8.32

Specimen parameters	
Diameter (mm) [a]	62.26
Length (mm) [a]	121.79
Bulk density ρ (g/cm^3)	2.600
UCS (MPa)	19.1
Young's modulus E (GPa) [b]	2.1
Lithology	Shale
Failure description [c]	1, 2

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 13.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [2] Specimen emitted saline pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

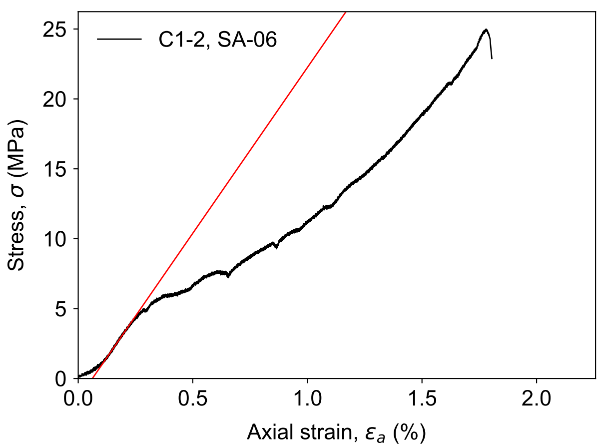
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-2, SA-06	**Depth**	10.86 - 11.07

Specimen parameters	
Diameter (mm) [a]	62.25
Length (mm) [a]	122.19
Bulk density ρ (g/cm^3)	2.602
UCS (MPa)	25.0
Young's modulus E (GPa) [b]	2.4
Lithology	Shale
Failure description [c]	3, 2

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 10.0% of the peak strength.
[c] Failure description: [3] Partial hourglass failure; [2] Specimen emitted saline pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

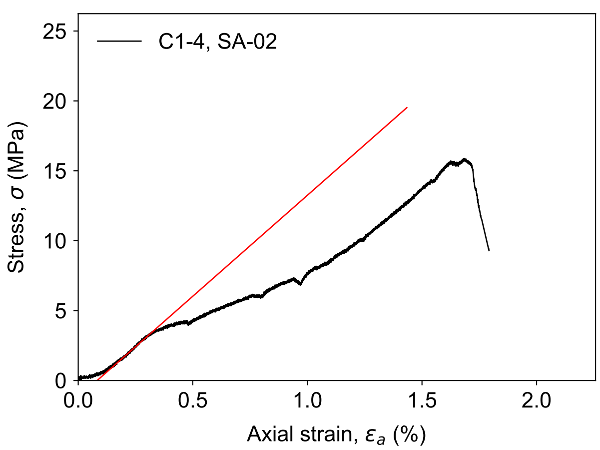
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-4, SA-02	**Depth**	7.49 - 7.81

Specimen parameters	
Diameter (mm) [a]	60.80
Length (mm) [a]	122.21
Bulk density ρ (g/cm^3)	2.603
UCS (MPa)	15.9
Young's modulus E (GPa) [b]	1.4
Lithology	Shale
Failure description [c]	3, 2

Prior to testing

After testing

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through $\pm$300 data points on either side of the point representing 16.0% of the peak strength.
[c] Failure description: [3] Partial hourglass failure; [2] Specimen emitted saline pore water upon loading;



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

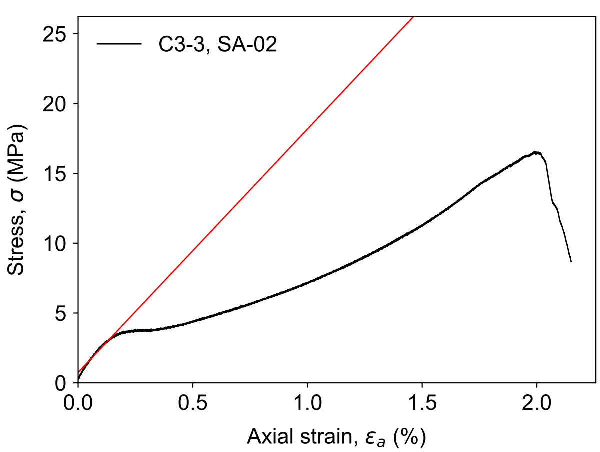
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C3-3, SA-02	**Depth**	6.18 - 6.38

Specimen parameters	
Diameter (mm) [a]	63.02
Length (mm) [a]	121.86
Bulk density ρ (g/cm^3)	2.598
UCS (MPa)	16.6
Young's modulus E (GPa) [b]	1.7
Lithology	Shale
Failure description [c]	4, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 15.0% of the peak strength.
[c] Failure description: [4] Inclined shear band failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

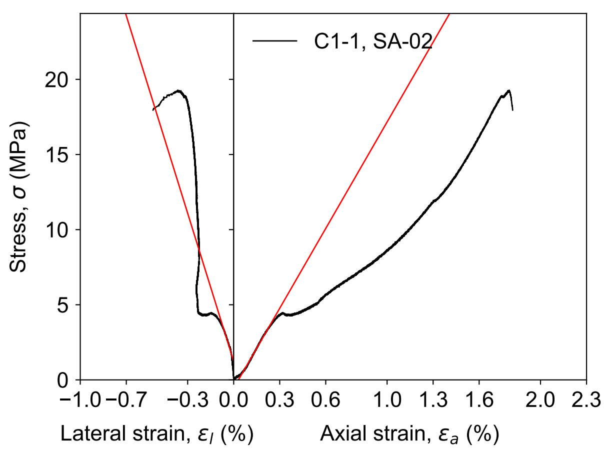
Client	Golder Associates Ltd.	Project	1662333
Sample	C1-1, SA-02	Depth	5.25 - 5.55

Specimen parameters	
Diameter (mm) [a]	60.67
Length (mm) [a]	123.08
Bulk density ρ (g/cm^3)	2.607
UCS (MPa)	19.3
Young's modulus E (GPa) [b]	1.8
Poisson's ratio ν (-) [b]	0.54
Lithology	Shale
Failure description [c]	1, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 13.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	Date	2019-03-11

Uniaxial Compression Test

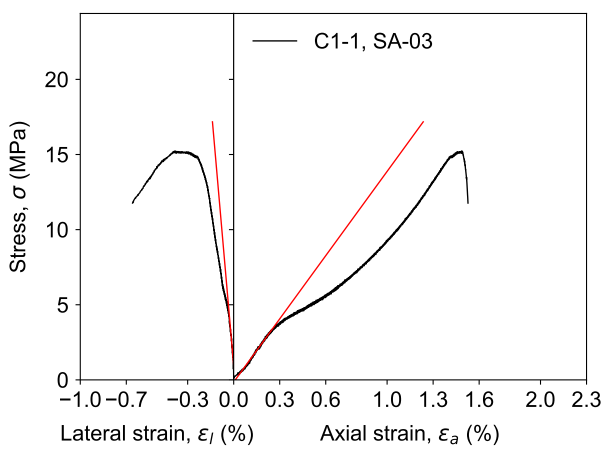
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-1, SA-03	**Depth**	6.79 - 7.13

Specimen parameters	
Diameter (mm) [a]	60.70
Length (mm) [a]	119.52
Bulk density ρ (g/cm^3)	2.602
UCS (MPa)	15.2
Young's modulus E (GPa) [b]	1.4
Poisson's ratio ν (-) [b]	0.12
Lithology	Inter-bedded limestone and s
Failure description [c]	1, 2

Prior to testing

After testing

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 16.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [2] Specimen emitted saline pore water upon loading;



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

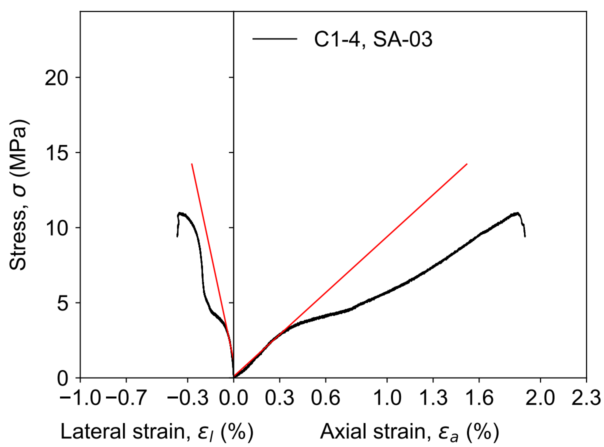
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-4, SA-03	**Depth**	7.15 - 7.38

Specimen parameters	
Diameter (mm) [a]	60.80
Length (mm) [a]	122.48
Bulk density ρ (g/cm^3)	2.585
UCS (MPa)	11.0
Young's modulus E (GPa) [b]	0.9
Poisson's ratio ν (-) [b]	0.19
Lithology	Shale
Failure description [c]	6, 1, 2

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 23.0% of the peak strength.
[c] Failure description: [6] Localized crushing; [1] Axial splitting failure; [2] Specimen emitted saline pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

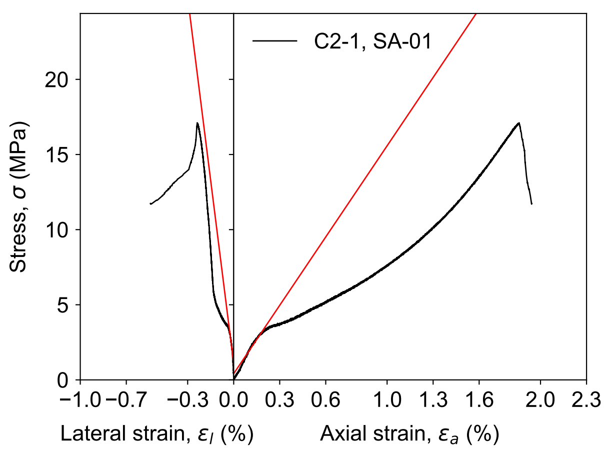
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C2-1, SA-01	**Depth**	4.60 - 4.85

Specimen parameters	
Diameter (mm) [a]	60.65
Length (mm) [a]	122.77
Bulk density ρ (g/cm^3)	2.591
UCS (MPa)	17.1
Young's modulus E (GPa) [b]	1.5
Poisson's ratio ν (-) [b]	0.19
Lithology	Shale
Failure description [c]	3, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 15.0% of the peak strength.
[c] Failure description: [3] Partial hourglass failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-11

Uniaxial Compression Test

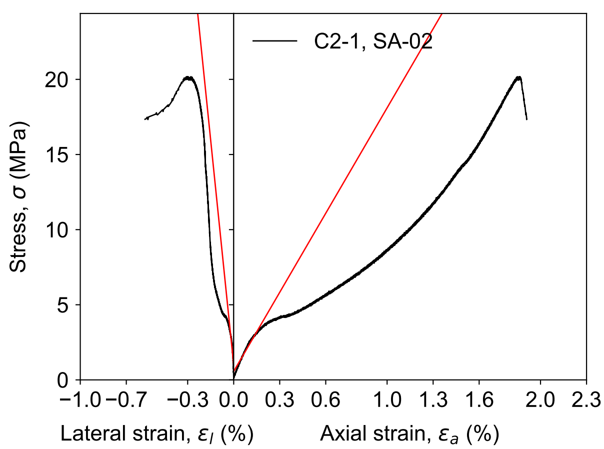
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C2-1, SA-02	**Depth**	4.99 - 5.40

Specimen parameters	
Diameter (mm) [a]	60.73
Length (mm) [a]	122.55
Bulk density ρ (g/cm^3)	2.589
UCS (MPa)	20.2
Young's modulus E (GPa) [b]	1.8
Poisson's ratio ν (-) [b]	0.18
Lithology	Shale
Failure description [c]	1, 3, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 12.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [3] Partial hourglass failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-12

Uniaxial Compression Test

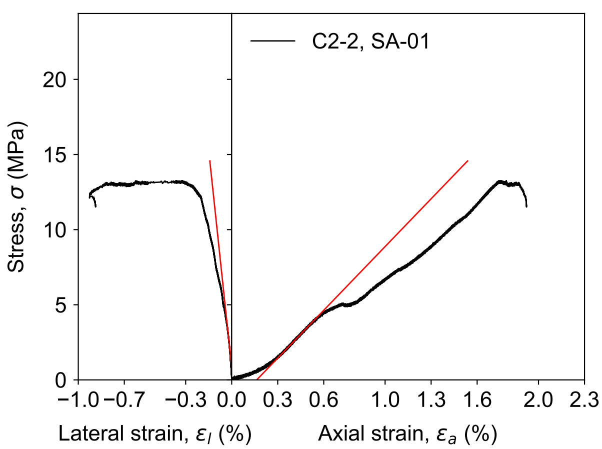
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C2-2, SA-01	**Depth**	4.52 - 4.7

Specimen parameters	
Diameter (mm) [a]	61.78
Length (mm) [a]	122.04
Bulk density ρ (g/cm^3)	2.592
UCS (MPa)	13.3
Young's modulus E (GPa) [b]	1.1
Poisson's ratio ν (-) [b]	0.11
Lithology	Shale
Failure description [c]	1, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 19.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-12

Uniaxial Compression Test

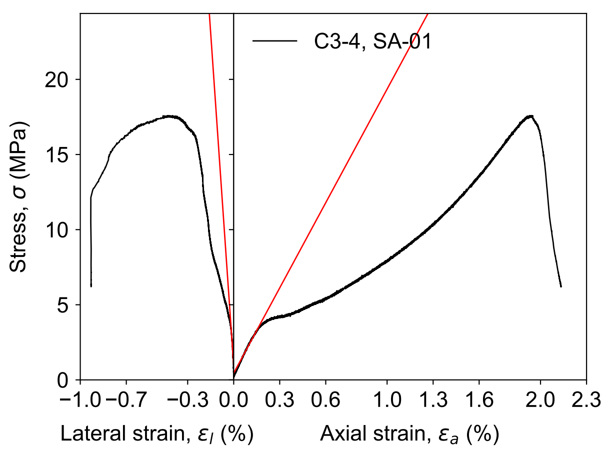
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C3-4, SA-01	**Depth**	3.09 - 3.41

Specimen parameters	
Diameter (mm) [a]	60.65
Length (mm) [a]	121.72
Bulk density ρ (g/cm^3)	2.601
UCS (MPa)	17.6
Young's modulus E (GPa) [b]	1.9
Poisson's ratio ν (-) [b]	0.13
Lithology	Shale
Failure description [c]	1, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 14.0% of the peak strength.
[c] Failure description: [1] Axial splitting failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-13

Uniaxial Compression Test

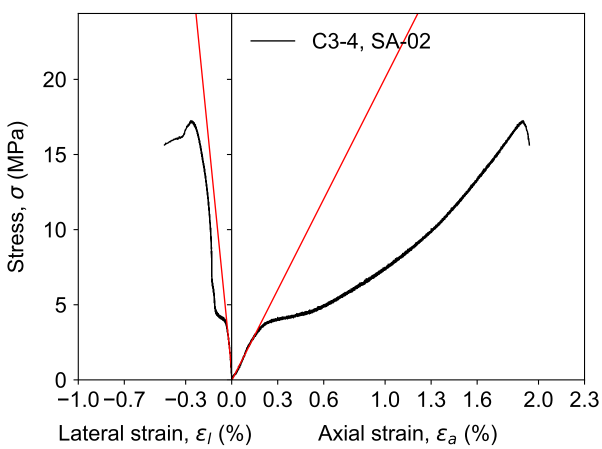
Client	Golder Associates Ltd.	Project	1662333
Sample	C3-4, SA-02	Depth	3.41 - 3.77

Specimen parameters	
Diameter (mm) [a]	60.76
Length (mm) [a]	122.84
Bulk density ρ (g/cm^3)	2.594
UCS (MPa)	17.3
Young's modulus E (GPa) [b]	2.0
Poisson's ratio ν (-) [b]	0.20
Lithology	Shale
Failure description [c]	4, 5

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through $\pm$300 data points on either side of the point representing 14.0% of the peak strength.
[c] Failure description: [4] Inclined shear band failure; [5] Specimen emitted pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	Date	2019-03-13

Uniaxial Compression Test

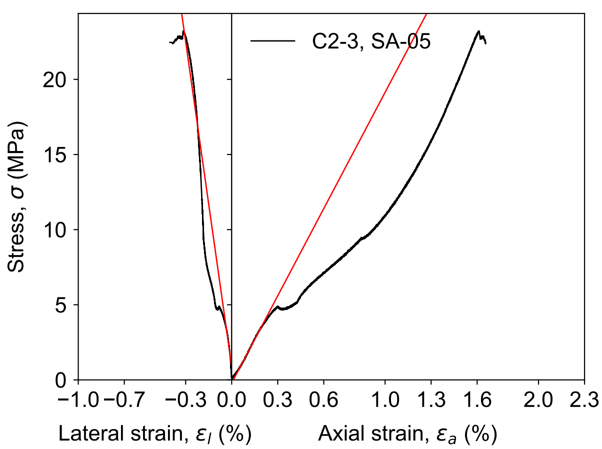
Client	Golder Associates Ltd.	**Project**	1662333
Sample	C2-3, SA-05	**Depth**	8.29 - 8.49

Specimen parameters	
Diameter (mm) [a]	62.29
Length (mm) [a]	124.74
Bulk density ρ (g/cm^3)	2.602
UCS (MPa)	23.2
Young's modulus E (GPa) [b]	1.9
Poisson's ratio ν (-) [b]	0.27
Lithology	Shale
Failure description [c]	4, 2

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 11.0% of the peak strength.
[c] Failure description: [4] Inclined shear band failure; [2] Specimen emitted saline pore water upon loading;

Prior to testing

After testing



Remarks:

Performed by	BSAT	**Date**	2019-03-13

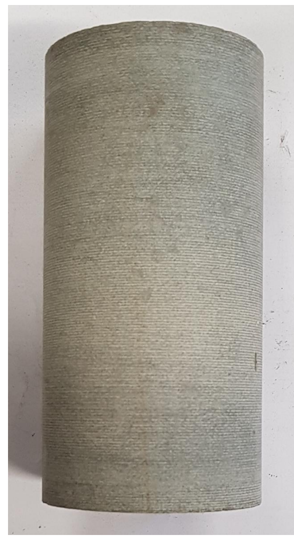
Uniaxial Compression Test

Client	Golder Associates Ltd.	**Project**	1662333
Sample	C1-3, SA-04	**Depth**	6.54 - 6.75

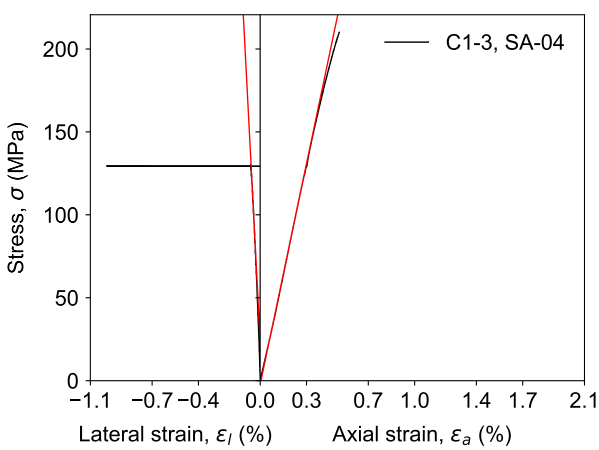
Specimen parameters	
Diameter (mm) [a]	62.34
Length (mm) [a]	125.90
Bulk density ρ (g/cm^3)	2.667
UCS (MPa)	210.2
Young's modulus E (GPa) [b]	44.4
Poisson's ratio ν (-) [b]	0.25
Lithology	Limestone
Failure description [c]	7

[a] Additional specimen measurement/details provides in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 50.0% of the peak strength.
[c] Failure description: [7] Hourglass failure;

Prior to testing



After testing



Remarks: Removed radial strain sensor prior to rupture to avoid possible damage.

Performed by	BSAT	**Date**	2019-03-14

APPENDIX C

Analytical Laboratory Test Results (Maxxam Analytics)

Maxxam
A Bureau Veritas Group Company

Your C.O.C. #: 705774-01-01

Attention: David Marmor

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

Report Date: 2019/03/15
Report #: R5630057
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B963042
Received: 2019/03/11, 17:34

Sample Matrix: ROCK
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Petroleum Hydro. CCME F1 & BTEX in Soil (1)	3	N/A	2019/03/13	CAM SOP-00315	CCME PHC-CWS m
Moisture	3	N/A	2019/03/12	CAM SOP-00445	Carter 2nd ed 51.2 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.
(1) No lab extraction date is given for F1BTEX & VOC samples that are field preserved with methanol. Extraction date is the date sampled unless otherwise stated.

Your C.O.C. #: 705774-01-01

Attention: David Marmor

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

Report Date: 2019/03/15
Report #: R5630057
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B963042
Received: 2019/03/11, 17:34

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.

Maxxam Job #: B963042
Report Date: 2019/03/15

Golder Associates Ltd
Sampler Initials: AM

RESULTS OF ANALYSES OF ROCK

Maxxam ID		JEB073	JEB074	JEB075		
Sampling Date		2019/03/07 14:00	2019/03/09	2019/03/09 14:55		
COC Number		705774-01-01	705774-01-01	705774-01-01		
	UNITS	**BHC1-2**	**BHC1-3**	**BHC2-3**	**RDL**	**QC Batch**
Inorganics						
Moisture	%	3.8	4.8	4.2	1.0	6013966

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

PETROLEUM HYDROCARBONS (CCME)

Maxxam ID		JEB073		JEB074		JEB075		
Sampling Date		2019/03/07 14:00		2019/03/09		2019/03/09 14:55		
COC Number		705774-01-01		705774-01-01		705774-01-01		
	UNITS	BHC1-2	RDL	BHC1-3	RDL	BHC2-3	RDL	QC Batch
BTEX & F1 Hydrocarbons								
Benzene	ug/g	0.15	0.020	0.11	0.060	0.18	0.020	6016584
Toluene	ug/g	0.030	0.020	<0.060	0.060	<0.020	0.020	6016584
Ethylbenzene	ug/g	<0.020	0.020	<0.060	0.060	<0.020	0.020	6016584
o-Xylene	ug/g	<0.020	0.020	<0.060	0.060	<0.020	0.020	6016584
p+m-Xylene	ug/g	<0.040	0.040	<0.12	0.12	<0.040	0.040	6016584
Total Xylenes	ug/g	<0.040	0.040	<0.12	0.12	<0.040	0.040	6016584
F1 (C6-C10)	ug/g	<10	10	<30	30	<10	10	6016584
F1 (C6-C10) - BTEX	ug/g	<10	10	<30	30	<10	10	6016584
Surrogate Recovery (%)								
1,4-Difluorobenzene	%	101		101		100		6016584
4-Bromofluorobenzene	%	105		103		103		6016584
D10-Ethylbenzene	%	105		123		107		6016584
D4-1,2-Dichloroethane	%	91		90		91		6016584

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B963042
Report Date: 2019/03/15

Golder Associates Ltd
Sampler Initials: AM

TEST SUMMARY

Maxxam ID: JEB073
Sample ID: BHC1-2
Matrix: ROCK

Collected: 2019/03/07
Shipped:
Received: 2019/03/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Petroleum Hydro. CCME F1 & BTEX in Soil	HSGC/MSFD	6016584	N/A	2019/03/13	Joe Paino
Moisture	BAL	6013966	N/A	2019/03/12	Min Yang

Maxxam ID: JEB074
Sample ID: BHC1-3
Matrix: ROCK

Collected: 2019/03/09
Shipped:
Received: 2019/03/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Petroleum Hydro. CCME F1 & BTEX in Soil	HSGC/MSFD	6016584	N/A	2019/03/13	Joe Paino
Moisture	BAL	6013966	N/A	2019/03/12	Min Yang

Maxxam ID: JEB075
Sample ID: BHC2-3
Matrix: ROCK

Collected: 2019/03/09
Shipped:
Received: 2019/03/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Petroleum Hydro. CCME F1 & BTEX in Soil	HSGC/MSFD	6016584	N/A	2019/03/13	Joe Paino
Moisture	BAL	6013966	N/A	2019/03/12	Min Yang

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GENERAL COMMENTS

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

Package 1	3.3°C

Sample JEB074 [BHC1-3] : F1/BTEX Analysis: Detection limits were adjusted for sample weight.

Results relate only to the items tested.

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Maxxam Job #: B963042
Report Date: 2019/03/15

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Sampler Initials: AM

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6016584	1,4-Difluorobenzene	2019/03/13	99	60 - 140	99	60 - 140	101	%		
6016584	4-Bromofluorobenzene	2019/03/13	104	60 - 140	105	60 - 140	103	%		
6016584	D10-Ethylbenzene	2019/03/13	98	60 - 140	98	60 - 140	95	%		
6016584	D4-1,2-Dichloroethane	2019/03/13	91	60 - 140	93	60 - 140	93	%		
6013966	Moisture	2019/03/12							5.5	20
6016584	Benzene	2019/03/13	74	60 - 140	87	60 - 140	<0.020	ug/g	0.62	50
6016584	Ethylbenzene	2019/03/13	76	60 - 140	97	60 - 140	<0.020	ug/g	0.81	50
6016584	F1 (C6-C10) - BTEX	2019/03/13					<10	ug/g	NC	30
6016584	F1 (C6-C10)	2019/03/13	127	60 - 140	109	80 - 120	<10	ug/g	NC	30
6016584	o-Xylene	2019/03/13	81	60 - 140	94	60 - 140	<0.020	ug/g	2.4	50
6016584	p+m-Xylene	2019/03/13	78	60 - 140	104	60 - 140	<0.040	ug/g	0.43	50
6016584	Toluene	2019/03/13	83	60 - 140	95	60 - 140	<0.020	ug/g	8.5	50
6016584	Total Xylenes	2019/03/13					<0.040	ug/g	0.47	50

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.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

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).

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VALIDATION SIGNATURE PAGE

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

Anastassia Hamanov, Scientific Specialist

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.

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CHAIN OF CUSTODY RECORD

Page 1 of 1

INVOICE TO:	REPORT TO:	PROJECT INFORMATION:	Laboratory Use Only:
Company Name: #1326 Golder Associates Ltd	Company Name:	Quotation #: B80683	Maxxam Job #:
Attention: Accounts Payable	Attention: David Marmor	P.O. #:	Bottle Order #: 705774
Address: 6925 Century Ave Suite 100 Mississauga ON L5N 7K2	Address:	Project:	COC #: C#705774-01-01
Tel: (905) 567-4444 Fax: (905) 567-6561	Tel: Fax:	Project Name:	Project Manager: Ema Gitej
Email: AP_CustomerService@golder.com	Email: David_Marmor@golder.com	Site #: Sampled By:	

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011): Table 1 / Table 2 / Table 3 / Table ___ ; Res/Park / Ind/Comm / Agri/Other ; Medium/Fine / Coarse / For RSC

Other Regulations: CCME / Reg 558 / MISA / PWQO / Other ___ ; Sanitary Sewer Bylaw / Storm Sewer Bylaw / Municipality ___

Special Instructions:

Include Criteria on Certificate of Analysis (Y/N)? ___

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

#	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle): Metals / Hg / Cr VI	Petroleum Hydro. CCME F1 & BTEX	# of Bottles	Comments
1	BHC1-2		2019/03/07	02:00	Rock		X	3	
2	BHC1-3		2019/03/09	AM	Rock		X	3	
3	BHC2-3		2019/03/09	02:55	Rock		X	3	
4	↳ a little bit of methanol spilled before sample taken								
5									
6									
7									
8									
9									
10									

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects

Regular (Standard) TAT: ☒
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ___ Time Required: ___
Rush Confirmation Number: ___ *(call lab for #)*

11-Mar-19 17:34
Ema Gitej
B963042
THP ENV-1335

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Time Sensitive	Temperature (°C) on Recei	Custody Seal	Yes	No
Alex MacMillan	19/03/11	17:33	Ronald Walman	2019/03/11	1734			3 / 4 / 3	Present		X
									Intact		X

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxa Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

Your Project #: 1662333
Your C.O.C. #: 709061-01-01

Attention: David Marmor

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

Report Date: 2019/03/26
Report #: R5644475
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B974455
Received: 2019/03/21, 16:07

Sample Matrix: Rock
Samples Received: 10

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	10	2019/03/25	2019/03/26	CAM SOP-00463	EPA 325.2 m
Conductivity	10	2019/03/25	2019/03/25	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	10	2019/03/25	2019/03/25	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	10	2019/03/22	2019/03/26	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	10	2019/03/25	2019/03/26	CAM SOP-00464	EPA 375.4 m

Remarks:

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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 #: 1662333
Your C.O.C. #: 709061-01-01

Attention: David Marmor

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

Report Date: 2019/03/26
Report #: R5644475
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B974455
Received: 2019/03/21, 16:07

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
==
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Maxxam Job #: B974455
Report Date: 2019/03/26

Golder Associates Ltd
Client Project #: 1662333
Sampler Initials: JP

RESULTS OF ANALYSES OF ROCK

Maxxam ID		JGK384	JGK385	JGK386	JGK387	JGK388	JGK389		
Sampling Date		2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30		
COC Number		709061-01-01	709061-01-01	709061-01-01	709061-01-01	709061-01-01	709061-01-01		
	UNITS	**1662333 C1-2**	**1662333 C1-1**	**1662333 C2-2**	**1662333 C2-3**	**1662333 C3-3**	**1662333 C3-1**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity	ohm-cm	2100	1700	2500	2600	3800	3700		6032288
Inorganics									
Soluble (20:1) Chloride (Cl-)	ug/g	32	37	<20	71	<20	<20	20	6035188
Conductivity	umho/cm	469	583	407	391	266	274	2	6035037
Available (CaCl2) pH	pH	8.19	8.02	8.08	8.14	8.19	8.19		6035215
Soluble (20:1) Sulphate (SO4)	ug/g	160	350	190	72	51	35	20	6035189

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam ID		JGK390	JGK391	JGK392	JGK393		
Sampling Date		2019/03/20 04:30	2019/03/20 04:30	2019/03/20 04:30	2019/03/20 04:30		
COC Number		709061-01-01	709061-01-01	709061-01-01	709061-01-01		
	UNITS	**1662333 C4-2**	**1662333 C4-3**	**1662333 C5-2**	**1662333 C5-1**	**RDL**	**QC Batch**
Calculated Parameters							
Resistivity	ohm-cm	1500	1000	1700	3100		6032288
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	250	410	240	<20	20	6035188
Conductivity	umho/cm	670	991	578	323	2	6035037
Available (CaCl2) pH	pH	7.77	7.77	7.85	7.78		6035215
Soluble (20:1) Sulphate (SO4)	ug/g	130	190	130	220	20	6035189

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

TEST SUMMARY

Maxxam ID: JGK384
Sample ID: 1662333 C1-2
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK385
Sample ID: 1662333 C1-1
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK386
Sample ID: 1662333 C2-2
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK387
Sample ID: 1662333 C2-3
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK388
Sample ID: 1662333 C3-3
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B974455
Report Date: 2019/03/26

Golder Associates Ltd
Client Project #: 1662333
Sampler Initials: JP

TEST SUMMARY

Maxxam ID: JGK388
Sample ID: 1662333 C3-3
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK389
Sample ID: 1662333 C3-1
Matrix: Rock

Collected: 2019/03/21
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK390
Sample ID: 1662333 C4-2
Matrix: Rock

Collected: 2019/03/20
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK391
Sample ID: 1662333 C4-3
Matrix: Rock

Collected: 2019/03/20
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam ID: JGK392
Sample ID: 1662333 C5-2
Matrix: Rock

Collected: 2019/03/20
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

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A Bureau Veritas Group Company

Maxxam Job #: B974455
Report Date: 2019/03/26

Golder Associates Ltd
Client Project #: 1662333
Sampler Initials: JP

TEST SUMMARY

Maxxam ID: JGK393
Sample ID: 1662333 C5-1
Matrix: Rock

Collected: 2019/03/20
Shipped:
Received: 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

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GENERAL COMMENTS

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

Package 1	-2.0°C

Results relate only to the items tested.

Maxxam Job #: B974455
Report Date: 2019/03/26

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1662333
Sampler Initials: JP

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6035037	Conductivity	2019/03/25			102	90 - 110	<2	umho/cm	0.40	10
6035188	Soluble (20:1) Chloride (Cl-)	2019/03/26	108	70 - 130	103	70 - 130	<20	ug/g	NC	35
6035189	Soluble (20:1) Sulphate (SO4)	2019/03/26	115	70 - 130	109	70 - 130	<20	ug/g	3.8	35
6035215	Available (CaCl2) pH	2019/03/25			100	97 - 103			0.39	N/A

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 (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).

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Maxxam Job #: B974455
Report Date: 2019/03/26

Golder Associates Ltd
Client Project #: 1662333
Sampler Initials: JP

VALIDATION SIGNATURE PAGE

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

Anastassia Hamanov, Scientific Specialist

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.

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CHAIN OF CUSTODY RECORD

Page of

INVOICE TO:
Company Name: #1326 Golder Associates Ltd
Attention: Accounts Payable
Address: 6925 Century Ave Suite 100
Mississauga ON L5N 7K2
Tel: (905) 567-4444 Fax: (905) 567-6561
Email: AP_CustomerService@golder.com

REPORT TO:
Company Name:
Attention: David Marmor
Address:
Tel: Fax:
Email: David_Marmor@golder.com

PROJECT INFORMATION:
Quotation #: B80683
P.O. #:
Project: 1662333
Project Name:
Site #:
Sampled By:

Laboratory Use Only:
Maxxam Job #:
Bottle Order #: 709061
COC #: C#709061-01-01
Project Manager: Ema Gitej

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011): Table 1, Table 2, Table 3, Table ___; Res/Park, Ind/Comm, Agri/Other; Medium/Fine, Coarse, For RSC

Other Regulations: CCME, Reg 558, MISA, PWQO, Other; Sanitary Sewer Bylaw, Storm Sewer Bylaw, Municipality

Special Instructions

Include Criteria on Certificate of Analysis (Y/N)? ______

ANALYSIS REQUESTED (PLEASE BE SPECIFIC): Field Filtered (please circle): Metals / Hg / Cr VI; Corrosivity pkg (Cl, SO4, pH, EC/Resistivity)

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects
Regular (Standard) TAT: ☑
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.
Job Specific Rush TAT (if applies to entire submission)
Date Required: ______ Time Required: ______
Rush Confirmation Number: ______ *(call lab for #)*

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered	Corrosivity pkg	# of Bottles	Comments
1		1662333 C1-2	21/3/2019	1:30	Rock		X		
2		1662333 C1-1	21/3/2019	1:30	Rock		X		
3		1662333 C2-2	21/3/2019	1:30	Rock		X		
4		1662333 C2-3	21/3/2019	1:30	Rock		X		
5		1662333 C3-3	21/3/2019	1:30	Rock		X		
6		1662333 C3-1	20/3/2019	1:30	Rock		X		
7		1662333 C4-2	20/3/2019	4:30	Soil		X		
8		1662333 C4-3	20/3/2019	4:30	Soil		X		
9		1662333 C5-2	20/3/2019	4:30	Soil		X		
10		1662333 C5-1	20/3/2019	4:30	Soil		X		

21-Mar-19 16:07
Ema Gitej
B974455
URE ENV-1222

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
JANE PETER (Jane)	2019/03/21	3:00pm		2019/03/21	16:07	

Laboratory Use Only
Time Sensitive | Temperature (°C) on Recei: 3/-2/-1 | Custody Seal Present: Yes ✓ | Intact: ✓

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX D

Non-Standard Special Provisions and Notice to Contractor

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the requirements for the installation of watermain at Station 15+825 and Station 17+035 and sanitary sewer at Station 15+825, Station 16+560 and Station 17+460 crossing the Queen Elizabeth Way (QEW) between west of Mississauga Road and west of Hurontario Street by a selected trenchless method.

2.0 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401 Trenching, Backfilling, and Compacting

OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers

OPSS 403	Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404	Support Systems
OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

CSA Standards

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials (ASTM) International Standards

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories

3.0 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer means the Engineer retained by the Contractor who produces the design and working drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario, shall not be an employee of the Contractor and shall be independent from the Design Engineer.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a "digger" type shield with a hydraulic excavator arm or "road-header" rock cutting machine to remove materials from inside the shield and liner pipe.

Horizontal Directional Drilling (HDD) means horizontal directional boring or guided boring.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or "Frac Out" means a condition where the drilling fluid's pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine") or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits and ducts.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m^3 or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a TBM or MTBM through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnel boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of installation for each location within the terms of this specification.

The installation method selected for each pipe crossing shall be designed for the subsurface conditions as reported in the Contract Documents.

The detailed design of the installation method selected to carry out the work as specified in the Contract Documents shall be completed.

Pipe ramming, horizontal directional drilling and Auger Jack and Bore methods are prohibited for use on these trenchless crossings.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, Trenchless contractor, Design Engineer, and Design Checking Engineer shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five years' experience on projects with similar scope and complexity.

During construction, the project superintendent shall not change without written permission from the Contract Administrator. A proposal for a change in the project superintendent shall be submitted at least one week prior to the actual change in project superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.04 Design Checking Engineer

The Design Checking Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two weeks prior to the commencement of the work. All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

The working drawings shall be submitted to the Contract Administrator under cover with a Request to Proceed.

The Contractor shall not proceed with the work until a Notice to Proceed has been received from the Contract Administrator

A copy of the Working Drawings shall be kept at the site during construction.

Information and details shown on the Working Drawings shall include, but not be limited to:

a) Plans and Details:

   i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
   ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
   iii. A list of personnel, including backup personnel, and their qualifications and experience.
   iv. A safety plan including the company safety manual and emergency procedures.
   v. The work area layout.
   vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
   vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
   viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
   ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
   x. Excavated materials disposal plan.

xi. Locations of protection systems.

b) Designs

i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, etc.),
ii. Design assumption and material data when materials other than those specified are proposed for use.
iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance, Slurry Pressure Balance
iii. Manufacturer data sheets for drilling systems.
iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and EPB TBM and MTBM operations.
v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
vi. Compressive strength of concrete pipe products.
vii. Pipe class for all steel pipe products.
viii. Steel for Permanent Casings
    - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
    - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
    - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory

ix. The Contractor shall submit the following to the Contract Administrator two weeks prior to construction:

    - type, source, and physical and chemical properties of bentonite, polymer or other additives;
    - source of water;
    - method of mixing;
    - the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;

- details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

i. The access shaft or entry/exit pit details, as applicable.
ii. Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

i. Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.
ii. Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
iii. Equipment and methods for removal of cobbles and boulders;
iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, SPB and EPB pressures;
v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;
viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

i. Maintaining the alignment of the installation;
ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
iii. Jacking forces on pipes, linings and cutting tools;
iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
v. Grout injection pressures and volumes;

vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Quality Control Certificate sealed and signed by the Design and Design Checking Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Quality Control Certificate shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

The Contractor shall submit a Request to Proceed to the Contract Administrator upon completion of each of the milestones.

The Contractor shall not proceed to the subsequent operation until a Notice to Proceed has been received from the Contract Administrator

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design and Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the working drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 HDPE Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer’s recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer’s instructions and ASTM D2657, the manufacturer’s instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

Selection of drilling fluid type shall be based on the soils and bedrock encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer’s recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
b) lubricate installation of primary liners as required;
c) transport spoil through pipe systems;

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 wetted with only sufficient water to make the mixture plastic

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Auger Jack and Bore methods are prohibited for use on these crossings.

6.02 Pipe Ramming

Pipe ramming methods are prohibited for use on these crossings

6.03 Horizontal Directional Drilling

6.03.01 General

Horizontal Directional Drilling methods are prohibited for use on these crossings.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of tunnelling equipment included in the submission shall be provided for:

a) rock or boulder breaking and removal;

b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;

c) jacking systems;

d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils and bedrock that will be encountered.

The Contractor shall employ microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil and bedrock ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:

i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
iv. The system shall monitor and continuously balance the soil/bedrock and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:

i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

a) Has the main jacks mounted in a jacking frame located in the launch shaft.
b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.

d) The main jack station may be complemented with the use of intermediate jacking stations as required.
e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.
Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected in the soil deposits at the site. The Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and shall set aside materials claimed as boulders for quantification in the presence of the Contract Administrator. Quantities of boulders expected at this site for the basis of bidding and adjustments to the price, if any, are provided within the Contract Documents.

7.01.14 Management of Excess Material

Management of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

Auger Jack and Bore methods are prohibited for these crossings,

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

Pipe ramming methods are prohibited for these crossings.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

Horizontal Direction Drilling methods are prohibited for these crossings.

7. 05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill and bedrock shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the Casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the Casing and the wall of the excavation shall be filled with grout that is compatible with the Casing.

The Casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the Casing.

The Casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline. For trenchless crossings at Station 17+035 and Station 17+460 surface settlement points shall be installed as arrays of three points at intervals of 5 m or less along the tunnel alignment centreline of the highway crossing and centred on the tunnel alignment. Arrays are not required for trenchless crossings at Station 15+825, Station 15+850 and Station 16+650. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.02 In-Ground Monitoring Points

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.03 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor’s operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.03 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and
c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.03 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

   i. The cause of the settlement has been identified.
   ii. The Contractor submits a corrective/preventive plan.
   iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
   iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the pipe installed inside the pipe liner shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders exceeding Boulder Volume Rations (BVR) and Boulder Number Ration (BNR) shall be by Time and Material.

Notes to Designer

A Foundation Engineering Specialist shall be retained by the Contract Administrator to assist the CA in ensuring that the Design and Submission Requirements are met and to ensure quality management of the work. Terms of Reference for the Foundation Engineering Specialist shall be provided by the Foundations Office and finalized in collaboration with the Regional Operations.

Designer Fill Ins

Design and Submission Requirements

*4.01 Design Requirements

Any method that is not suitable shall be specified. Restrictions on tunnelling methodologies shall be specified

4.02 Qualifications

******4.02.01.01 Project Superintendent

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

***4.02.01.02 Tunnelling/Trenchless Contractor

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

****4.02.01.03 Design Engineer

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

*****4.02.01.04 Design Checking Engineer

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

******7.01.11 Removal of Cobbles and Boulders

Subsurface Condition Baseline Reporting that includes Boulder Volume Ration (BVR), Boulder Number Ration (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

******7.07 Instrumentation and Monitoring

The Instrumentation and Monitoring program shall be project specific as recommended in the FIDR.

*******7.08 Criteria for Assessment of Roadway Subsidence/Heave

Criteria selection shall be project specific as recommended in the FIDR

WARRANT: Always with this specification

PROTECTION SYSTEM – Item No.

Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finished grade or ground level.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work and facility being protected.

All disturbed areas shall be restored to an equivalent or better condition than existing prior to the commencement of construction.

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01	July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO’s website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

IDF Curve Location	Latitude: 43.554167	Longitude: -79.612500

Temporary Flow Passage Systems

Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m^3/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Credit River Bridge	2	120.0	223.0	291.0	369.0	Yes
Stavebank Creek	2	0.7	1.1	1.6	2.0	No
Kenollie Creek	2	3.1	4.7	5.4	10.0	No

Dewatering Systems

Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)	Design Engineer Requirements (Note 1)
Credit River Bridge	50	Yes

Note:

1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. “N/A” indicates a preconstruction survey is not required.

<u>NOTICE TO CONTRACTOR</u> – Subsurface Obstructions

Special Provision

The Contactor shall be alerted to the potential presence of cobbles, boulders and limestone and shale fragments in the fill and native soils, glacially derived soils and residual soils, as encountered in various boreholes advance at the various structure locations associated with the QEW widening from Mississauga Road to Hurontario Street. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for advancing caissons, excavations for shallow foundations, stormwater management pond, overhead sign supports, high mast light pole foundations, noise barrier walls, culverts, and installation of any temporary protection systems that may be required.

The Contactor is hereby notified that in some areas of the site, and in particular in the general vicinity of the east pier for the QEW Credit River Bridge WB, rip-rap and other cobble and boulder size obstructions are present at and below ground surface. These obstructions may impede or prevent excavation, grading, construction of access roads and/or crane pads and lay-down areas, and the installation of some types of protection systems/cofferdams.

The Contractor is hereby notified that in some areas of the site, and in particular in the general vicinity of the front and side slopes adjacent to the west abutment for the QEW Credit River Bridge WB, soil/rock anchor obstructions are present at and below the ground surface. These obstructions may impede or prevent excavation, grading, and construction of the abutment and/or the Multi-Use Trail and are to be removed where encountered above the elevation of the existing upper access road only. No soil/rock anchors are to be removed below the elevation of the existing upper access road.

The Contractor is hereby notified that between the west abutment of the existing QEW Credit River Bridge and the west abutment of the existing multi-use path (beneath the existing QEW Credit River Bridge) soil/rock anchor obstructions are present at and below the ground surface. These obstructions may impede or prevent the advancement of the drilled shafts for the west abutment of the East-West Active Transportation bridge. If they are encountered the Contract Administrator is to be notified immediately and this may require adjustments to the drilled shaft layout.

The presence of the above-noted near surface conditions shall be considered by the Contractor in the selection of appropriate equipment and procedures for various activities, including but not limited to excavation, grading, installation of the foundations and installation of cofferdams/protection systems.

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