

FINAL REPORT**Foundation Investigation and Design Report**

Trenchless Sanitary Crossing West of Insley Road, QEW Widening from East of Cawthra Road to the East Mall, Cities of Mississauga and Etobicoke, Ministry of Transportation, Ontario, GWP 2102-13-00 & 2432-13-00

Submitted to:

AECOM Canada

30 Leek Crescent
Richmond Hill, Ontario
L4B 4N4

Submitted by:

Golder Associates Ltd.

6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada

+1 905 567 4444

GEOCRES No.: 30M11-313

Latitude 43.589455, Longitude -79.577312

1530382.7000 Rev.0

September 23, 2021



Distribution List

1 pdf copy & 1 hard copy - Ministry of Transportation, Ontario (Central Region)

1 pdf copy & 1 hard copy - Ministry of Transportation, Ontario (Foundations Section)

1 pdf copy - AECOM Canada Ltd.

1 pdf copy - Golder Associates Ltd.

Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS.....	3
4.1 Regional Geology.....	3
4.2 Subsurface Conditions	3
4.2.1 Asphalt	4
4.2.2 Clayey Sand-Silty Sand to Silty Sand to Sand and Gravel (FILL)	4
4.2.3 Silty Sands	4
4.2.4 Clayey Sand – Silty Sand	4
4.2.5 Clayey Silt to Sandy Clayey Silt to Clayey Silt and Sand (TILL)	5
4.2.6 Clayey Silt (RESIDUAL SOIL)	5
4.2.7 Shale Bedrock.....	5
4.3 Groundwater Conditions	8
4.4 Hydraulic Conductivity.....	8
4.5 Analytical Test Results.....	9
5.0 CLOSURE	10

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	12
6.1 General.....	12
6.2 Proposed Structure	12
6.3 Trenchless Technologies	12
6.4 Proposed Sanitary Sewer Alignment and Profile Considerations.....	16
6.5 Anticipated Ground Behaviour	16
6.6 Feasibility of Tunnelling Methods.....	17
6.6.1 Auger Boring with Small Boring Unit.....	17

6.6.2	Micro-Tunneling	18
6.7	Tunneling Risk Assessment and Mitigation	18
6.8	Grouting	19
6.9	Ground Movements.....	19
6.10	Launch and Receiving Pits	20
6.10.1	Open Cut Excavations	20
6.10.2	Groundwater Control.....	21
6.10.3	Trenchless Method Approval Considerations	21
6.11	Final Pipe Design	22
6.12	Construction Considerations.....	22
6.12.1	Temporary Protection Systems	22
6.12.2	Piezometer Decommissioning	24
6.13	Instrumentation and Monitoring	24
6.13.1	General	24
6.13.2	Instruments	25
6.13.3	Monitoring and Reporting Frequency	25
6.13.4	Criteria for Assessment of Roadway Subsidence/Heave	26
7.0	CORROSION ASSESSMENT AND PROTECTION	27
8.0	CLOSURE	27

TABLES

Table 1: Borehole Summary	2
Table 2: Summary of Bedrock	5
Table 3: Summary of Unconfined Compression Testing.....	7
Table 4: Summary of Indirect Tensile Strength Testing	7
Table 5: Summary of Cerchar Abrasivity Testing	7
Table 6: Summary of Point Load Testing	8
Table 7: Ground Water Conditions	8
Table 8: Summary of Estimated Hydraulic Conductivity	9
Table 9: Analytical Test Results	9

Table 10: Summary of Parameter Exceedances.....	10
Table 11: Summary of OHSA Soil Types	20
Table 12: Soil Parameters	23
Table 13: Evaluation of Tunnel Installation Methods.....	29

DRAWINGS

Drawing 1 – Borehole Locations and Soil Strata

Drawing 2 – Settlement Monitoring Point Locations and Installation Details

APPENDICES

APPENDIX A Borehole/Drillhole Records and Bedrock Core Photographs

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

Records of Boreholes/Drillholes CV01-1, CV01-2, 21-2, 21-3, 21-4

Figure A1 Bedrock Core Photograph – Borehole CV01-1
 Figure A2 Bedrock Core Photograph – Borehole CV01-2
 Figure A3 Bedrock Core Photograph – Borehole 21-2
 Figure A4a to A4b Bedrock Core Photograph – Borehole 21-3
 Figure A5a to A5b Bedrock Core Photograph – Borehole 21-4

APPENDIX B Geotechnical Laboratory Test Results

Figure B1 Grain Size Distribution – Clayey Sand-Silty Sand (SC-SM) (FILL)
 Figure B2 Plasticity Chart – Clayey Sand-Silty Sand (SC-SM) (FILL)
 Figure B3 Grain Size Distribution – Silty Sand (SM)
 Figure B4 Grain Size Distribution – Clayey Sand-Silty Sand (SC-SM)
 Figure B5 Plasticity Chart – Clayey Sand-Silty Sand (SC-SM)
 Figure B6 Grain Size Distribution – Sandy Clayey Silt (CL) to Clayey Silt and Sand (CL/SC) (Till)
 Figure B7 Plasticity Chart – Sandy Clayey Silt (CL) to Clayey Silt and Sand (CL/SC) (Till)

Bureau Veritas Laboratories Report No. R6516604
 Bureau Veritas Laboratories Report No. R6534387
 Bureau Veritas Laboratories Report No. R6568677
 Maxxam Analytics Report No. R4252452

Appendix C Geotechnical Laboratory Testing Results – Bedrock

Geomechanica Inc. – Rock Laboratory Testing Results
 Golder Associates Ltd. – Point Load Test on Rock Samples

Appendix D Hydraulic Conductivity Testing Results (Borehole 21-4)

Appendix E Non-Standard Special Provisions

Notice to Contractor – Mixed Face Conditions and Perched Groundwater
 NSSP – Pipe Installation by Trenchless Methods
 NSSP – Working Slab
 NSSP – Removal of Protection Systems
 NSSP – Piezometer Decommissioning

PART A

**FOUNDATION INVESTIGATION REPORT
SANITARY SEWER TRENCHLESS CROSSING WEST OF INSLEY ROAD
QEW WIDENING FROM EAST OF CAWTHRA ROAD TO THE EAST MALL
CITIES OF MISSISSAUGA AND ETOBICOKE
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2102-13-00 & 2432-13-00**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the widening of Queen Elizabeth Way (QEW) from Cawthra Road to the East Mall in the Cities of Mississauga and Etobicoke, Regional Municipality of Peel/City of Toronto, Ontario. This report addresses the results of subsurface explorations and testing carried out for the sanitary sewer replacement under the QEW from North Service Road to South Service Road, west of Insley Road, as shown on Drawing 1. The purpose of the work described in this report was to explore the subsurface soil and bedrock conditions along the alignment of the proposed sanitary sewer crossing by borehole drilling and laboratory testing on selected soil and rock samples. The Terms of Reference (TOR) and the scope of work are outlined in MTO's Request for Proposal, dated January 2016, which forms part of the Consultant's Assignment Number (Number 2015-E-0001) for this project. The scope of work for this sanitary sewer crossing is outlined in Golder's scope change letter dated September 30, 2020. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated June 6, 2016.

2.0 SITE DESCRIPTION

The sanitary sewer replacement crossing is proposed under the QEW from the North Service Road, between Westfield Drive and Insley Road, to the South Service Road, west of Odgen Avenue in the City of Mississauga, Ontario. Residential areas are located to the south and northwest of the QEW right-of-way in the area of the sanitary sewer crossing; a now-abandoned gas station site is located at the north shaft of the crossing. The QEW grade at the site is approximately Elevation 103 m, and the present ground surface on either side of the QEW is at approximately Elevation 103 m.

3.0 INVESTIGATION PROCEDURES

Field work for the proposed sanitary crossing was carried out between September 27, 2016 and February 11, 2021 during which time a total of five sampled boreholes, designated as Boreholes 21-2, 21-3, 21-4, CV01-1 and CV01-2 were advanced along the proposed sanitary sewer alignment. Boreholes 21-2, 21-3 and 21-4 were advanced specifically for this service and the other two boreholes were for a proposed culvert in the general area. The Record of Borehole sheets, Record of Drillhole sheets and the results of the laboratory testing for the boreholes are presented in Appendices A and B, respectively.

The borehole investigation was carried out using a truck-mounted CME 75 and CME 55 drill rig, supplied and operated by Davis Drilling of Milton, Ontario. The boreholes were advanced through the overburden using 108 mm outside diameter (O.D.) solid stem augers and NW casing, or with 150 mm O.D. hollow stem augers and HW casing. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08)¹. Samples of the bedrock were obtained using coring techniques with 'NQ' rock core barrels in Boreholes CV01-1 and CV1-02 and 'HQ' size rock core barrels in Boreholes 21-2, 21-3 and 21-4. The boreholes were advanced to depths ranging between 7.5 m and 13.1 m below existing ground surface, including coring of bedrock for core lengths ranging between 2.9 m and 7.2 m. Photographs of the recovered rock samples are provided in Appendix A.

¹ ASTM D1586-08a – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the soil.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations. Standpipe piezometers were installed in two selected boreholes to permit monitoring of the water level at the site. The installed piezometers consist of a 50 mm diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack at a select depth within the borehole. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to the ground surface with bentonite. Piezometer installation details and water level readings are described on the Record of Borehole sheets included in Appendix A. The borehole in which a standpipe piezometer was not installed was backfilled to ground surface 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. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples.

Selected soil and rock samples were submitted to Bureau Veritas Laboratories (previously known as Maxxam Analytics), a Standards Council of Canada (SCC) accredited laboratory of Mississauga, Ontario for chemical analysis. The results of the chemical analysis are presented in Appendix B.

Unconfined compression (uniaxial) (UC), Young's modulus, Brazilian disc tensile test, point load testing and CERCHER abrasivity testing was carried out on one selected specimen of the bedrock core by Geomechanica Inc. on behalf of Golder. Results of the geotechnical laboratory testing on the rock core samples are included in Appendix C.

Borehole locations and the ground surface elevations at the as-drilled locations were obtained using a GPS Trimble GEO 7X, having an accuracy of 0.1 m in the vertical and 0.1 m in the horizontal directions, or were measured relative to identifiable site features and superimposed on the base plan. The locations given on the Record of Borehole/Drillhole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) CGG2013N northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized in Table 1 below.

Table 1: Borehole Summary

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (Latitude)	Easting (Longitude)		
CV01-1	4,827,716.2 (43.589532)	298,574.2 (-79.577100)	103.3	9.3 (Including 4.6 m of bedrock core)
CV01-2	4,827,685.1 (43.589074)	298,603.1 (-79.576743)	103.0	7.5 (Including 2.9 m of bedrock core)
21-2	4,827,726.5 (43.589455)	298,557.4 (-79.577312)	102.8	13.1 (including 5.4 m of bedrock core)
21-3	4,827,716.5 (43.589365)	298,595.2 (-79.576844)	103.3	11.6 (including 6.3 m of bedrock core)

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (Latitude)	Easting (Longitude)		
21-4	4,827,702.9 (43.589242)	298,617.6 (-79.576566)	102.6	12.4 (including 7.2 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 comprising sands, silts and gravels, with a shallow cover of till remaining over the bedrock. The Georgian Bay Formation, 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, and the results of the geotechnical laboratory tests carried out on selected soil samples, are presented on the borehole and drillhole records provided in Appendix A. Photographs of the recovered bedrock core samples are presented on Figures A1 to A5 in Appendix A. The results of the in-situ field tests (i.e., SPT "N"-values) as presented on the borehole records 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 Appendix A to assist in the interpretation of the Record of Boreholes and Record of Drillholes. The results of the geotechnical laboratory testing on the soil samples are also presented in Appendix B. The analytical laboratory test reports are included in Appendix B and Appendix C and the test results are summarized in Section 4.5.

Stratigraphic boundaries shown on the borehole records and on the stratigraphic profile on Drawing 1 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. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

In general, the subsurface conditions in the area of the proposed sanitary sewer crossing consists of a layer of asphalt underlying a layer of non-cohesive fill. The fill is underlain by a deposit of silty sand to clayey sand-silty sand, which is in turn underlain by a sandy clayey silt to clayey silt and sand till deposit, followed by a clayey silt residual soil deposit. All boreholes are underlain by shale bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

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.)

4.2.1 Asphalt

An approximately 150 mm thick layer of asphalt was encountered at ground surface in Boreholes 21-3, 21-4, CV01-1, and CV01-2.

4.2.2 Clayey Sand-Silty Sand to Silty Sand to Sand and Gravel (FILL)

A 0.2 m to 6.0 m thick layer of primarily non-cohesive fill, consisting of sand and gravel to silty sand to clayey sand-silty sand, was encountered at ground surface in Borehole 21-2 and underlying the asphalt in Boreholes CV01-1, CV01-2, 21-3 and 21-4. The surface of the granular fill was encountered at depths ranging from 0 m to 0.2 m below ground surface (between Elevations 103.1 m and 102.4 m) and extended to depths ranging from 0.4 m to 6.0 m (between Elevations 102.9 m and 96.8 m).

The Standard Penetration Test (SPT) “N”-values measured within the fill ranged from 1 blow to 20 blows per 0.3 m of penetration, indicating a very loose to compact state of compactness.

Grain size distribution testing was carried out on one sample of the granular fill and the results are presented on Figure B1 in Appendix B. Atterberg limits testing was carried out on the fines portion of one sample of the fill and measured a liquid limit of about 22%, a plastic limit of about 16%, corresponding to plastic index of about 6%. The Atterberg limit test results are presented on Figure B2 in Appendix B and indicates that the fines portion of the sample is a clayey silt-silt of low plasticity. The water content measured on samples of the fill ranges from about 13% to 20%.

4.2.3 Silty Sands

A 1.8 m to 2.4 m thick silty sand and sand deposit was encountered underlying the fill in Boreholes CV01-1, CV01-2, 21-3, and 21-4. The top of the silty sand deposit was encountered at depths ranging from 0.4 m to 1.5 m below ground surface (between Elevations 102.9 m and 101.8 m) and the deposit extends to depths ranging from 2.2 m to 3.1 m below ground surface (between Elevations 101.1 m and 99.6 m).

The deposit varies in composition from brown to grey silty sand, containing trace to some gravel. Rootlets were encountered within this deposit in Borehole CV01-2.

The SPT “N”-values measured within the silty sand deposit ranged from 3 blows to 13 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size distribution tests were carried out on three samples of the silty sand deposit and the results are shown on Figure B3 in Appendix B. The water content measured on samples of the silty sand deposit ranges between about 11% and 35%.

4.2.4 Clayey Sand – Silty Sand

A 1.6 m thick clayey sand-silty sand deposit was encountered underlying the fill in Borehole 21-2 at a depth of 6.0 m below ground surface (Elevation 96.8 m). The clayey sand-silty sand extends to a depth of 7.6 m below ground surface (Elevation 95.2 m).

The SPT “N”-value within the clayey sand-silty sand deposit measured 5 blows per 0.3 m of penetration, indicating a loose compactness condition.

Grain size distribution testing was carried out on one sample of the deposit and the results are presented on Figure B4 in Appendix B. Atterberg limits testing was carried out on the fines portion of one sample of the deposit and measured a liquid limit of about 19%, a plastic limit of about 14%, corresponding to plastic index of about 5%. The Atterberg limit test results are presented on Figure B5 in Appendix B and indicates that the fines portion of the

sample is a clayey silt-silt of low plasticity. The water content measured on a sample of clayey sand-silty sand is about 19%.

4.2.5 Clayey Silt to Sandy Clayey Silt to Clayey Silt and Sand (TILL)

A 0.8 m to 1.9 m thick clayey silt to sandy clayey silt to clayey silt and sand till deposit was encountered underlying the silty sand deposit in Boreholes CV01-1, CV01-2, 21-3 and 21-4. The top of the till deposit was encountered at depths ranging from about 2.2 m and 3.1 m below ground surface (between Elevations 101.1 m and 99.6 m) and extends to depths ranging from 3.7 m and 4.8 m below ground surface (between Elevations 99.6 m and 97.8 m). The clayey silt to sandy clayey silt to clayey silt and sand deposit contains trace to some gravel.

The SPT “N”-values measured within the till deposit generally ranged from 17 blows to 28 blows per 0.3 m of penetration, suggesting a very stiff consistency. A SPT “N”-value of 100 blows per 0.25 m was measured in Borehole 21-4, but is not considered representative of the soil consistency due to the bedrock encountered directly below the sample.

Grain size distribution testing was carried out on two samples of the till deposit and the results are presented on Figure B6 in Appendix B. Atterberg limits testing was carried out on four samples of the till deposit, with measured liquid limits ranging from about 25% and 26%, plastic limits ranging from about 15% to 16%, and corresponding plasticity indices ranging from about 10% and 11%. These results, which are plotted on a plasticity chart on Figure B7 in Appendix B, indicate that the till deposit consists of clayey silt of low plasticity. The water contents measured on three samples of the till deposit ranges between about 10% and 17%.

The till deposits in Boreholes CV01-2 and CV1-02 are also noted to be possible residual soils.

4.2.6 Clayey Silt (RESIDUAL SOIL)

A 0.8 m thick deposit of residual soil was encountered underlying the clayey silt and sand till deposit in Borehole 21-3. The top of the residual soil deposit was encountered at a depth of 4.5 m below ground surface (Elevation 98.8 m) and extended to a depth of 5.3 m below ground surface (98.0 m). The residual soil deposit consists of clayey silt containing some sand, with shale and limestone fragments throughout. Residual soil is a heterogenous mix of fully weathered bedrock that is disintegrated into a soil-like material that no longer retains the structure of the parent bedrock.

The SPT “N”-values measured within the residual soil deposit was 85 blows per 0.2 m of penetration, suggesting a hard consistency. The water content measured on one sample of this deposit is about 8%.

4.2.7 Shale Bedrock

The upper portion of the bedrock was sampled by split-spoon and the bedrock was confirmed by rock coring in all boreholes. The depths to bedrock below ground surface, as inferred from augering / split spoon sampling and bedrock coring, and the corresponding bedrock surface elevation are summarized below in Table 2.

Table 2: Summary of Bedrock

Borehole No.	Highly Weathered Bedrock		Length of Bedrock Split-Spoon Sampled/Augered (m)	Moderately Weathered to Fresh Bedrock		Length of Bedrock Cored (m)
	Depth (m)	Elevation (m)		Depth (m)	Elevation (m)	
CV01-1	3.7 – 7.0	99.6 – 96.3	1.0	7.0 – 9.3	96.3 – 94.1	4.5
CV01-2	3.7 – 4.6	99.3 – 98.4	0.9	4.6 – 7.5	98.4 – 95.5	2.9

Borehole No.	Highly Weathered Bedrock		Length of Bedrock Split-Spoon Sampled/Augered (m)	Moderately Weathered to Fresh Bedrock		Length of Bedrock Cored (m)
	Depth (m)	Elevation (m)		Depth (m)	Elevation (m)	
21-2	7.6 – 7.7	95.2 – 95.1	0.1	7.7 – 13.1	95.1 – 89.7	5.4
21-3	5.5 – 5.5	98.0 – 97.8	0.2	5.3 – 11.6	97.8 – 91.7	6.3
21-4	4.7 – 5.2	97.9 – 97.4	0.5	5.2 – 12.4	97.4 – 90.2	7.2

Highly weathered shale bedrock is inferred to be present at depths ranging from 3.7 m to 4.8 m below ground surface (between Elevations 99.6 m and 97.8 m), in Boreholes CV01-1, CV01-2, and 21-4, based on drilling behaviour, observations of drilling cuttings and split-spoon sampling. The thickness of the highly weathered bedrock zone is inferred to be 3.3 m thick in Borehole CV01-1 based on both augering/sampling and coring, 0.9 m thick at Borehole CV01-2 based on the results of augering and split-spoon sampling, and 0.5 m thick in Borehole 21-4 based on the results of augering and split-spoon sampling.

The SPT “N”-values measured within the upper, highly weathered portion of the shale bedrock ranged from 46 blows per 0.3 m of penetration to 100 blows for 0.15 m of penetration, suggesting a hard consistency as well as potential resistance to or blockages of sampling equipment by fragments of rock.

The water content measured on two samples of the inferred highly weathered shale bedrock is approximately 7% and 8%.

Based on a review of the bedrock core samples, the bedrock consists of shale of the Georgian Bay formation. In general, the bedrock samples are described as fresh to highly weathered, thinly to very thinly laminated, fine to very fine grained, non-porous, weak, grey, with very strong to medium strong limestone and interbeds at varying intervals and thicknesses, as presented in the Record of Drillholes in Appendix A, and shown on the photographs of the recovered core samples on Figures A1 to A5 in Appendix A. The degree of weathering of the bedrock samples (i.e. highly weathered to fresh – W4 to W1), and the strength classification of the intact rock mass based on field identification (i.e., very weak to weak – R1 to R2) are described in accordance with the International Society for Rock Mechanics (ISRM³) standard classification system.

The Rock Quality Designation (RQD) measured on the core samples ranges from about 20% to 100%, indicating a rock mass of very poor to excellent quality as per Table 3.10 of CFEM (2006)⁴. The Total Core Recovery (TCR) of samples recovered range between 39% and 100%. The Solid Core Recovery (SCR) of samples recovered generally range from between 81% and 100%, with the exception of samples recovered from Borehole CV01-1 and the first run in Borehole 21-4, in which the SCR ranges between 0% and 25%.

Geotechnical bedrock classification testing carried out by Geomechanica Inc. included unified compression testing, indirect tensile strength and Cerchar Abrasivity. The test results are presented in the *Rock Laboratory Testing Results* report in Appendix C.

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.

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

Unconfined Compression (UC) Tests were carried out on selected samples of the shale bedrock. The uniaxial compressive strength (UCS), bulk density and tangent Young's modulus of the intact samples are summarized below in Table 3.

Table 3: Summary of Unconfined Compression Testing

Borehole No.	Approximate Depth (m)	Sample Elevation (m)	Uniaxial Compressive Strength (UCS) (MPa)	Bulk Density (g/cm ³)	Tangent Young's Modulus (GPa)
21-3	6.48 – 6.70	96.82 – 96.60	6.3	2.621	1.2
21-4	7.44 – 7.58	95.16 – 95.02	23.0	2.632	3.4

In accordance with Table 3.5 of CFEM (2016), the shale bedrock core samples tested may be classified as weak (R2, 5 MPa < UCS < 25 MPa). It is noted that the shale bedrock encountered within the boreholes also includes harder limestone interbeds (i.e. typically medium strong to strong).

The Results of indirect tensile strength (i.e. Brazilian tensile strength) testing carried out on one bedrock core sample recovered from Borehole 21-4 is summarized below in Table 4.

Table 4: Summary of Indirect Tensile Strength Testing

Borehole No.	Approximate Depth (m)	Sample Elevation (m)	Disc No.	Bulk Density P (g/cm ³)	Tensile Strength (MPa)	Failure Type
21-4	8.04 – 8.14	94.56 – 94.46	1	2.608	2.1	Diametric Failure
			2	2.638	3.0	Diametric Failure

The results of Cerchar Abrasivity (ASTM D7625) testing carried out on one shale bedrock core sample recovered from Borehole 21-4 is summarized below in Table 5.

Table 5: Summary of Cerchar Abrasivity Testing

Borehole No.	Approximate Depth (m)	Sample Elevation (m)	Mean Wear (mm)	Cerchar Abrasivity Index (CAI= Mean Wear x10)	ASTM Classification
21-4	6.53 – 6.62	96.07 – 95.98	0.057	0.566	Low

In addition to the laboratory testing by Geomechanica, point load tests (PLTs) were carried out by Golder on selected samples of the bedrock obtained during the field investigation, and the results are summarized below in Table 6.

Table 6: Summary of Point Load Testing

Borehole No.	Approximate Depth (m)	Sample Elevation (m)	Orientation	Axial $I_{s(50mm)}$ (MPa)
21-3	5.70 – 5.79	97.60 – 97.51	Axial	1.491
21-3	6.00 – 6.09	97.30 – 97.21	Axial	1.118
21-4	6.66 – 6.70	95.94 – 95.90	Axial	6.388
21-4	6.70 – 6.75	95.90 – 95.85	Axial	1.705

4.3 Groundwater Conditions

Details of the water levels observed in the boreholes upon completion of drilling are presented on the Record of Boreholes. A total of two standpipe piezometers were installed.

Table 7: Ground Water Conditions

Borehole I.D.	Screened Stratigraphy	Water Level		Date of Measurement
		Depth (m)	Elevation (m)	
21-2	Fill and Clayey Sand/Silty Sand	3.7	99.1	January 11, 2021
		3.3	99.5	February 11, 2021
		3.4	99.4	March 30, 2021
		3.3	99.5	May 13, 2021
21-4	Shale Bedrock	3.2	99.4	February 11, 2021
		2.9	99.7	June 28, 2021

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

4.4 Hydraulic Conductivity

The hydraulic conductivity, k (m/s), test results estimated from the 5-step Lugeon tests at Boreholes 21-2 and 21-4 and an in-situ falling head test within a packer isolated section in the bedrock portion of Borehole 21-4 is presented in Appendix D and summarized in the table below. The 5-step Lugeon tests were analysed using the steady state Theim equation (1906) to estimate the hydraulic conductivity in the immediate area surrounding the borehole wall. The estimated hydraulic conductivity value obtained from the falling head test in Borehole 21-4 was estimated using the Hvorslev (1951) method.

Table 8: Summary of Estimated Hydraulic Conductivity

Borehole Number	Test Date	Test Method	Depth Tested		Hydraulic Conductivity (m/s)
			From (mbgs)	To (mbgs)	
21-2	Jan. 11, 2021	In-situ Packer Testing	8.84	11.89	No flow
			10.67	13.08	No flow
21-4	Feb. 11, 2021	Falling Head Test	6.10	9.14	2E-06
		In-situ Packer Testing	9.14	12.40	1E-07

4.5 Analytical Test Results

One soil sample and two bedrock samples were collected and submitted to Bureau Veritas Laboratories (BV Labs), previously known as Maxxam Analytics, for analysis of parameters used to assess corrosion potential and sulphate attack. A summary of the results is presented in the following Table 9. The detailed Certificates of Analysis are provided in Appendix B.

Table 9: Analytical Test Results

Borehole Number	Sample	Sample Depth (Elevation) (m)	Soil/Rock Type	Parameters				
				Chloride (µg/g)	Sulphate (µg/g)	pH	Conductivity (µmho/cm)	Resistivity (ohm-cm)
21-2	7	4.6 – 5.2 (98.2 – 97.6)	Clayey Sand – Silty Sand	56	<20	7.54	363	2,800
21-4	-	5.2 – 5.3 (97.4 – 97.3)	Shale	110	66	9.04	498	2,000
CV01-1	-	8.7 – 8.8 (94.6 – 94.5)	Shale	260	320	8.14	965	1,000

Analytical laboratory testing was also carried out by BV Labs on two soil samples obtained from within the proposed tunnel horizon to access the environmental quality of the site soils for soil disposal purposes. The samples were submitted for analysis of metals and inorganics under O.Reg. 153/04. The analytical results were compared to the Ontario Ministry of Environment, Conservation, and Parks (MECP) “*Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*”, April 15, 2011, Table 1 Full Depth Background Site Conditions Standards – Soil – Residential/ Parkland/ Instructional/ Industrial/ Commercial/ Community Property Use (Table 1 Standards). The laboratory certificate of analysis is provided in Appendix B and details of the samples submitted and parameter exceedances are summarized below in Table 10.

Table 10: Summary of Parameter Exceedances

Borehole No.	Sample	Soil Description	Sample Depth (Elevation) (m)	Parameter Concentrations Exceeding MECP Table 1
21-2	8	Silty Sand (Fill)	5.3 – 5.9 (97.5 – 96.9)	Sodium Adsorption Ratio (SAR)
21-4	5	Sandy Clayey Silt (Till)	3.8 – 4.4 (98.8 – 98.2)	Sodium Adsorption Ratio (SAR)

The reported concentrations for the parameters analysed are below the values listed on Table 1 Standards, with the following exceptions:

- The measured sodium adsorption ratio (SAR) value of 2.9 is greater than the Table 1 Standard of 2.4 in Borehole 21-2.
- The measured sodium adsorption ratio (SAR) value of 2.6 is greater than the Table 1 Standard of 2.4 in Borehole 21-4.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Katelyn Nero, P.Eng., and Mr. William Cavers, P.Eng., a Senior Geotechnical Engineer and the MTO Foundations Designated Contact for Golder, conducted a technical and quality control review of the report.

Signature Page

Golder Associates Ltd.



Katie Nero, P.Eng.
Geotechnical Engineer



William (Bill) Cavers, P.Eng.
MTO Foundations Designated Contact

KNN/WBC/ml

Golder and the G logo are trademarks of Golder Associates Corporation

[https://golderassociates.sharepoint.com/sites/19542g/1 foundations/9 - reports/19 - contract 2 trenchless crossings/1. insley crossing/3. final/1530382.7000 - final fidr - insley rd trenchless crossing - 23sept2021.docx](https://golderassociates.sharepoint.com/sites/19542g/1%20foundations/9%20-%20reports/19%20-%20contract%202%20trenchless%20crossings/1.%20insley%20crossing/3.%20final/1530382.7000%20-%20final%20fidr%20-%20insley%20rd%20trenchless%20crossing%20-%2023sept2021.docx)

PART B

**FOUNDATION DESIGN REPORT
SANITARY SEWER TRENCHLESS CROSSING WEST OF INSLEY ROAD
QEW WIDENING FROM EAST OF CAWTHRA ROAD TO THE EAST MALL
CITIES OF MISSISSAUGA AND ETOBICOKE
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2102-13-00 & 2432-13-00**

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides detail foundation engineering recommendations for design of the replacement of an existing non-structural sanitary sewer associated with the widening of the Queen Elizabeth Way (QEW) from Cawthra Road to the East Mall, Mississauga/Etobicoke. These recommendations are based on interpretation of the factual data obtained from the boreholes, field testing and laboratory testing, and in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC) and MTO's Pipe Installation by Trenchless Method Special Provision. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible trenchless installation methods for the proposed sanitary sewer replacement.

The Foundation Design 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.

6.2 Proposed Structure

This report addresses potential construction concerns and geotechnical problems associated with the installation of the sanitary sewer by means of a trenchless method. The proposed alignment for the sanitary sewer replacement is shown on Drawing 1. Based on the design drawings provided by AECOM on March 16, 2021, the proposed sanitary sewer construction will consist of the following:

- The sanitary sewer is proposed to be installed by a trenchless method between Sta 0+000 and Sta 0+060, (about 60 m long), from the North Service Road, approximately 45 m west of Insley Road, under the QEW to the South Service Road, approximately 25 m west of Ogden Avenue.
- Based on the design drawings, a 600 mm diameter reinforced concrete pressure pipe (AWWA C302) is proposed for the sanitary sewer. It is understood that consideration is being given to increasing the size of the sewer to a 900 mm diameter pipe.
- The entry shaft located at Sta 0+000 will be about 5.5 m inside diameter and 5.5 m deep and the exit shaft located at Sta 0+060 and will be about 4.5 m inside diameter and 5.0 m deep.

It is understood that it is currently proposed to install this sanitary sewer employing trenchless techniques. 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.

6.3 Trenchless Technologies

The following sections provide more information on the feasibility of trenchless technologies that may be employed at this site.

The Contractor should be responsible for choosing the method and equipment for the crossing installation unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event that alternative methods are considered, the Contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information from the investigations undertaken at this site.

Common trenchless construction methods include horizontal directional drilling, pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling, pilot tube micro-tunneling, tunnel boring machine and tunnel digging machine (i.e., open face shield tunnelling). A brief description of each method is included below.

Further requirements on the various trenchless methods are outlined in the MTO's Pipe Installation by Trenchless Method Special Provision provided in Appendix E.

The following is a general summary of the geotechnical considerations for the design and construction of the particular trenchless methodologies.

1) Pipe Jacking and Horizontal Auger Boring (also referred to as Auger Jack and Bore):

A pipe jacking operation involves pushing an oversized liner pipe (casing) horizontally into the ground by jacking through reaction against a thrust block (i.e., backstop) located within the jacking pit. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The profile needs to be approximately horizontal and there is limited ability to steer the casing during jacking.

The jack and bore method is generally suitable for penetrating cohesive soils (silt and clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). This method is not feasible in flowing ground which can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) sand, silt and/or gravel.

This method is only applicable to installation in the overburden and may not be feasible in bouldery soils (e.g., glacial till) as the presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions.

However, this method can be adapted for use in mixed-face conditions and ground with boulders, with the addition of a Small Boring Unit (SBU) cutterhead. The SBU is equipped with mini disc cutters on the cutterhead and is welded to the lead casing to facilitate cutting through mixed ground, ground containing cobbles and boulders and/or bedrock. With the addition of the rotating cutterhead, the SBU also allows for some steering capability.

Jacking and receiving pits are required. The size of the jacking pit is controlled by the equipment size, operator access requirements and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square. The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

2) Pipe Ramming:

Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing with a cutting shoe attached into the ground. The pipe is almost always driven open-ended to thereby direct the soil into the pipe

interior instead of compacting it outside the pipe, reducing the potential for ground loss into the casing during driving. As each casing length is installed, the hammer is removed, the next casing is welded in place and the hammer replaced and restarted. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose.

Entry and receiving pits are also required for pipe ramming but, as there is no need for a thrust block in the entry pit, a smaller pit size is required than in jack and bore installations (which is an advantage for congested urban highways). The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

Pipe ramming is best suited for overburden installations in soft to firm clays and very loose to compact sands above the water table. This method is not considered feasible in mixed face conditions. These methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, although this method can still be obstructed by cobbles and boulders depending on their size and number. Pipe ramming is not-steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced.

Compared to the jack and bore method, the most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

3) Pilot Tube Micro-tunneling:

Pilot Tube Micro-Tunneling (PTMT), also known as guided auger boring, employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and product pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and, since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or micro-tunnelling.

PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator’s skill. The “pilot tube” is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A slanted steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with a casing following behind the reamer, with an auger string inside the casing used to remove cuttings. The product pipes follow the casing to be installed in the ground.

A typical PTMT construction sequence is as follows.

Excavate and prepare the driving and receiving shafts.

- Lower the thrust frame into the driving shaft and set it up. Set up the guidance system including the steering head and target in the driving shaft.

- Install the pilot tube behind the steering head. The boring process proceeds with the rotation and thrust of the pilot tube. Deviations are continuously adjusted through video monitor surveillance of the illuminated target.
- When the steering head reaches the receiving shaft, the reamer and casing with auger inside are connected to the last segment of pilot tube. The reamer and auger enlarge the pilot bore hole by rotating and thrusting the reamer and casing. The steering head and the pilot tubes are then retrieved at the receiving shaft.

4) Micro-tunnelling:

Micro-tunnelling is a method of installing pipes in bores ranging from 0.6 to greater than 3 metres in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remote-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. Availability of this equipment locally is limited.

Micro-tunnelling is a very precise method of tunnelling. The cutter head face and pipe pressures are monitored by externally mounted transducers and this monitoring allows the operator to adjust the bentonite cutting and lubricating slurry pressure to maintain an equilibrium between the external pressures and the slurry injection pressure. Micro-tunnelling also allows for minor alignment corrections by using the manufacturer permitted pipe joints deflections to recover the design alignment. There is relatively little settlement with micro-tunnelling, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive.

This method can be applied to a wide range of ground conditions from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. A micro-tunnel boring machine can also breakup, ingest, and crush rocks, cobbles and boulders up to about 30% of its size. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including mixed face conditions and handling of obstructions such as cobbles and boulders.

5) Horizontal Directional Drilling (HDD):

HDD involves the drilling of a pilot hole using a steerable drill bit on a flexible string of drill rods while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore would be reamed in one or more passes to a larger diameter, and then the pipe would be pulled through the bore (using the drill rods to pull the pipe into place). HDD is typically used for smaller diameter crossings below embankments or rivers and is not suited to gravity pipes (such as sewers). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the product pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment. Bores are typically limited to less than 1.2 m in diameter. Sufficient cover is important to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface.

6) Tunnel Boring Machine (TBM):

TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head horizontally into the ground with successive sections of either an oversized liner pipe or the final product pipe advanced behind the TBM by pipe jacking. The spoil is removed from the tunnel as the TBM is advanced, using augers, conveyor belts or mucking carts. The cutting head is driven and steered by an operator inside the TBM and may be partially open to allow for access to the face. The tunnel profile needs to be approximately horizontal. Jacking and receiving pits

are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in bouldery soils (e.g., glacial till). Excavations through sandy soils below the water table typically require dewatering to maintain face stability when using open faced machines, specialized earth pressure balance or slurry shield TBMs, which pressurize the face of the excavation and improve face stability, or the use of micro-tunnelling.

7) Tunnel Digging Machine (TDM):

TDM tunnelling, also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner (i.e., steel casing) or final pipe would be jacked in sections from the launching shaft. Unlike jack and bore, this method allows personnel to enter the tunnel to allow more control over the operations, such as for removal of obstructions. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual or machine-assisted excavation generally requires a tunnel diameter of about 1.2 m or more.

6.4 Proposed Sanitary Sewer Alignment and Profile Considerations

The base plan mapping provided by AECOM for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of roadway elevation of the QEW in the vicinity of the proposed sanitary sewer crossing is at about Elev. 103.3 m. As outlined above, the proposed crossing is to have invert elevations ranging from Elev. 98.4 m to 98.2 m, and corresponding obvert elevations ranging from Elev. 99.0 m to 98.8 m (for a 600 mm diameter pipe). The minimum cover below the highway surface would therefore be between 4.3 m and 4.5 m (or 4.0 to 4.2 m for a larger 900 mm diameter pipe).

For tunnels under the QEW, MTO generally requires that the minimum overburden cover shall not be less than three tunnel diameters, at any point along the entire length of the tunnel crossing. Based on the profiles provided by AECOM and the estimates provided above, the current crossing alignment meets this requirement with either size of pipe.

Typically, it is recommended that the tunnel invert or obvert be a minimum of 0.5 m above or below (respectively) the interface of the fill materials, native materials and/or bedrock so that the tunnel horizon is not through mixed face conditions. It should be noted that based on the results of the borehole investigation the proposed sanitary sewer crossing will be through a mixed soil / bedrock interface

6.5 Anticipated Ground Behaviour

At the crossing location, the subsurface conditions generally consist of fill, overlying silty sand, glacial till, residual soil and shale bedrock of the Georgian Bay Formation. The groundwater level was most recently measured at the site at a depth of 2.9 m, corresponding to Elevation 99.7 m (approximately 0.9 m above the proposed sanitary obvert elevation). Although the groundwater will fluctuate seasonally, dewatering measures to lower the groundwater level are anticipated to be required to facilitate the excavation of the entry/exit pits.

If auger boring with SBU is chosen, it is recommended that the replacement be conducted during a drier season such as after the spring or prior to the fall season.

The ground conditions along the sanitary sewer alignment within the tunnel vertical limits (i.e., invert and obvert of the drive) are likely to consist of mixed-face soil conditions including granular to cohesive fill, clayey silt and sand to clayey silt till, clayey silt residual soil, and shale bedrock.

Based on the soil descriptions, the embankment fill, glacial till and highly weathered bedrock has been classified according to the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974). This system

is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative “stand-up time” criteria to classify the ground at and above the tunnel face into the following principal categories: hard, firm, slow ravelling, fast ravelling, squeezing, swelling, cohesive-running, running, very soft squeezing, flowing, and boulder.

The granular fill and native silty sand would be classified as running to flowing and the clayey sand-silty sand, native glacial till, residual soil and highly weathered bedrock would be classified as firm to slow ravelling material under the Tunnelman’s Ground Classification System.

6.6 Feasibility of Tunnelling Methods

Based on the available information for this project and the list of methods discussed above, the following methods are not considered suitable or necessary for this crossing and are therefore not considered further in this report.

- Pipe Ramming – This method is not considered feasible in mixed face conditions.
- Pilot Tube Micro-tunneling – This method is not considered feasible in mixed face conditions.
- HDD – Method not suitable for gravity pipes (i.e., sewers) and/or confined sites.
- TBM – Method not suited for small diameter pipes and low cover.
- TDM – Method not suited for small diameter pipes and low cover.

Mixed face conditions are a potential issue wherever the soil-soil or soil-bedrock interface is within the elevation horizon of the proposed bore or where the face conditions are expected to change significantly along the length of the crossing. According to anticipated subsurface conditions (see Drawing 1), a mixed-face condition consisting of mixed interface of varying embankment fill, glacial till and the shale bedrock will be encountered along the vertical limit of tunnel at this site. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel. A mixed face condition is expected to materially affect the selection of trenchless methods.

Given the anticipated mixed face conditions along the bore alignment, groundwater elevation and relatively small sewer diameter, of the methods outlined in Section 6.3, Auger Boring with a SBU or Micro-tunnelling are considered feasible installation options for this site. The feasibility of installing the proposed sanitary sewer using Auger Boring with a SBU or Micro-tunnelling is summarized in Table 13 provided after the text of this report. A summary comparison of the advantages, disadvantages, relative costs, and risks associated with the installation methods is also presented in Table 13.

6.6.1 Auger Boring with Small Boring Unit

To reduce the risk of project delays resulting from encountering bedrock and/or significantly variable soil conditions in the glacial till such as cobbles and boulders, completing the installation by auger boring with a Small Boring Unit (SBU) may be considered.

The use of an SBU would provide some additional steering capability of the bore to maintain the alignment, particularly if obstructions or harder segments of bedrock are encountered. The SBU could progress through the cobbles and boulders without requiring their removal and would also be capable of penetrating bedrock. Typically, different cutterheads would be required for boring through glacial till with boulders and bedrock. At this site, it is anticipated that the highly weathered portion of the shale bedrock that may be encountered within the proposed bore alignment is very weak and would behave similarly to the dense glacial till, but the feasibility of completing the bore with one SBU cutterhead should be left up to the Contractor.

Since auger boring with an SBU creates a partially open face, dewatering and lowering of the groundwater table at the pits and along the bore alignment would be required for construction using this method. Further discussion on groundwater control is provided in Section 6.10.

6.6.2 Micro-Tunneling

Though micro-tunneling is more expensive than auger boring with an SBU, it offers several advantages to deal with mixed face and challenging groundwater conditions. The micro-tunnel boring machine (MTBM) has a rotating cutting head to excavate the ground encountered and can be equipped with a leading crushing cone to crush larger particles or obstructions into smaller sizes for transport back to the jacking shaft through the slurry lines. A MTBM can breakup, ingest, and crush rocks, cobbles, and boulders to about 30% of its size. In this instance for the currently proposed 600 mm diameter pipe, the MTBM should be capable of handling rock, cobbles, and boulders to 180 mm equivalent diameter. A pressurized slurry mixing chamber is present behind the cutter head to maintain face stability. As such, the MTBM is capable of independently counter-balancing earth and hydrostatic pressures as the bore advances. Groundwater pressure can be counter balanced by using pressurized slurry.

Since this method of boring is essentially a steerable, remote-controlled pipe jacking operation controlled from the surface, the necessity for personnel to enter the bore is eliminated and full dewatering of the alignment is not required.

6.7 Tunneling Risk Assessment and Mitigation

As a general guideline, the required cover above the crown of the tunnel/bore should be at least one tunnel/bore diameter relative to the ground surface provided the methodology would not have an unsupported face and ideally two to three diameters should be provided to reduce the risk of displacement. As the overburden cover decreases, the risk of concentrated subsidence or heave increases. Based on the proposed crossing obverts summarized in Section 6.4, the minimum cover below the highway surface would be between 4.3 and 4.5 m, providing a cover-to-diameter ratio of 7.2 for a 600 mm diameter pipe. For a 900 mm diameter pipe, the minimum cover to diameter ratio would be 4.4.

The soil and bedrock conditions observed at the crossing location indicate the bore will encounter mixed face conditions consisting of overburden and interbedded shale and limestone bedrock. The overburden/bedrock interface along the alignment is also indicated to be within 0.3 m of the sanitary sewer interface along much of the alignment and if the selected installation method requires an oversize carrier pipe, there will be greater potential for mixed face conditions along a greater length of the alignment. The installation method proposed by the Contractor will need to be able to advance through overburden and bedrock with a mixed face. A Non-Standard Special Provision (NSSP) should be included in the contract documents to address this issue and a sample version is included in Appendix E. Also, the elevation of the bedrock relative to the tunnel invert in the vicinity of the proposed sewer crossing could present challenges for the cutting faces being prone to alignment challenges.

Further discussion on the potential ground movements is provided in Section 6.9. A plan should be in-place to rapidly repair any distress to the pavement, if needed (and to re-direct traffic, if required).

There is a significant risk that removal of spoil or equipment that is supporting the bore face for dealing with obstructions, if required for the method selected by the Contractor, will result in loss of ground, sinkholes and potentially an immediate hazard to traffic on the highway. Mitigation plans outlining the required dewatering, instrumentation, monitoring and traffic control, that may include closing lanes during such operations, and emergency response plans must be developed prior to initiating the bore.

Before excavation begins at the proposed crossing locations, it is recommended that hand digging or hydro-vacuum methods be used to expose any underground utilities in the vicinity of the proposed crossing, if present, to determine the exact locations and depths. The hydro-vacuum holes must be properly backfilled to prevent preferential pathways for fluid migration.

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, to 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 grouting should be completed no later than 24 hours after the drive completion. This requirement is included in the NSSP for "Pipe Installation by Trenchless Method", see Appendix E.

For any installations at which the displacement monitoring or excavation volume monitoring indicates that pavement displacement 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 sanitary pipe is installed, 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 E.

6.9 Ground Movements

To reduce the risk of ground displacement/subsidence, trenchless installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario, the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters, at least for open-faced tunnelling methods. Lesser cover can be feasible (i.e., as low as 1 diameter) for some methods including micro-tunnelling where a pressurized shield at the front face of the tunnel is used.

The most recent groundwater level was measured at the site at a depth of 2.9 m, corresponding to Elevation 99.7 m, about 1.5 m above the proposed sanitary outlet invert elevation.

Local dewatering at each of the entry and exit pits will be necessary, regardless of tunnelling methodology.

However, since an SBU auger bore proceeds with only a partially supported face, dewatering along the entire alignment would materially reduce the risk of loss of face support in the observed till ground conditions. Also, with the SBU auger bore there is the increased risk of misalignment should the unit skip across the top of the bedrock surface during tunnelling.

Micro-tunnelling would require local dewatering during construction of the entry and exit pits, dewatering of the full alignment would not be necessary.

The potential displacement also depends on the construction practices. To avoid excessive displacement pauses or delays in the tunnelling operation should be minimized.

There is a somewhat lower potential for significant ground displacement with micro-tunnelling versus other trenchless methods as this methodology does not create an unsupported working face, a corresponding reduction in stress in the ground above the tunnel, and the potential for movement of the ground towards the face (such as would often be the case for conventional tunnel construction). The displacements should therefore be more limited in magnitude, provided the gap around the casing created by the overcut is limited in size.

For the ground conditions encountered for this proposed trenchless crossing, there is a significant risk of there being at least some level of impact (i.e., heave or displacement) to the highway surface. It is expected that displacements or heave directly over the tunnel would likely not exceed about 25 mm, provided good construction procedures are followed and obstructions are not encountered which require removal.

It is expected that the bore construction will not result in measurable ground surface displacement beyond a distance on either side of the bore alignment exceeding the bore depth.

6.10 Launch and Receiving Pits

6.10.1 Open Cut Excavations

Excavations for shaft construction are anticipated to extend to depths of approximately 5.5 m (Elevation 97.8 m) and 5.0 m (Elevation 98.0 m) at entry (north) and exit (south) shafts respectively, below finished grade. The shaft founding soils are anticipated to consist of very loose clayey sand-silty sand fill at the entry shaft and very stiff to hard till at the exit shaft. Where loose conditions are encountered, a concrete working slab or granular bedding may be required at the base of the shafts to maintain the integrity of the base during construction, provided adequate groundwater controls are applied. An NSSP for a concrete working slab should be included in the Contract Documents, an example of which is included in Appendix E.

All excavations 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*), OPSS 407 (*Maintenance Hole, Catch Basin, Ditch Inlet and Valve Chamber Installation*) and OPSS.PROV 410 (*Pipe Sewer Installation in Open Cut*). According to OHSA, the soil description, the soil type categorization and corresponding excavation side slopes for the existing fill and native soils to be excavated are provided below. 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.

Table 11: Summary of OHSA Soil Types

Soil Description	Above/Below Groundwater	OHSA Soil Type	Maximum Foundation Excavation Side Slopes
Granular Fill (Very loose to compact)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Silty Sand to Clayey Sand – Silty Sand (Loose to compact)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Clayey Silt to Sandy Clayey Silt to Clayey Silt and Sand (Till) (Very stiff)	Above	Type 2*	1 Horizontal :1 Vertical
	Below	Type 3	1 Horizontal :1 Vertical
Residual Soil (stiff to hard)	Above	Type 2*	1 Horizontal :1 Vertical
	Below	Type 3	1 Horizontal :1 Vertical

*The lower 1.2 m of the excavation may be made vertical in Type 2 soil, if the excavation terminated in this soil type.

Stockpiles of excavated material should be set back from the edge of the excavation by a distance at least equal to the excavation depth. Where sufficient space is not available to stockpile the excavated material at the site, off-site disposal of the excavated material would need to be arranged. Care must also be taken during excavation to ensure that adequate support is provided for any existing structures, roadways and underground services located adjacent to the excavations. Care should be taken to direct surface water runoff away from the open excavations.

6.10.2 Groundwater Control

Temporary excavations for launch (north) and receiving (south) shaft construction are anticipated to extend to Elevation 97.8 m and 98.0 m, respectively. In May 2021, the groundwater level measured in the monitoring wells screened within the overburden and bedrock at the site were about Elevation 99.7 m. As such, excavations for the north and south shafts will extend about 2 m below the measured groundwater level.

Where excavations extend below the groundwater level, advanced dewatering ahead of the excavation is recommended to allow for a more stable and controlled excavation to reduce the risk of an unstable base and/or heaving due to unbalance water pressures. An active groundwater control system using an adequate number and depth of wells outside (or inside) the excavation could be considered. Groundwater levels should be lowered at least 1 m below the base of the shaft excavations to provide a stable excavation and preparation of the base of the shafts in dry conditions. Consideration should be given to installing a relatively watertight protection system and sealing the sides and base of the shaft to create a watertight structure, taking into consideration any buoyancy concerns. Alternatively, the protection system could include provision for some water infiltration to be collected by designated drains / pipes with an adequate number of sumps and pumps (or wells) at the base to keep the shaft dry during trenchless operations.

The tunnel eye seals at the launch (north) and retrieval (south) shafts will need to be designed in collaboration with the temporary shoring designer to ensure that the systems are compatible and groundwater pressures (and any drilling slurry / lubricants used for tunnelling operations) are adequately controlled in these critical areas.

Any surface water inflow and/or natural drainage paths near the shafts / excavations must be diverted away from and/or around the excavation at all times.

6.10.3 Trenchless Method Approval Considerations

For construction, trenchless operations should be carried out in general accordance with MTO's Special Provision titled "*Pipe Installation by Trenchless Methods*", dated February 2021, a copy of which is included in Appendix E, modified as necessary for tunnelling through bedrock or with other specifications as may be approved by the relevant stakeholders. Prior to construction, the contractor should be required to submit the proposed construction and trenchless work plan, dewatering plans, including machine specifications and cutting tools, slurry management plans and equipment, obstruction contingency plans and the monitoring program for review and approval from the MTO, and other relevant stakeholders as may be required. It is further recommended that the geotechnical aspects of the contractor's work plan for the trenchless crossing be reviewed by a qualified geotechnical engineer prior to construction. These plans should identify all hazards and the methods proposed to mitigate interference to the highway corridors, such as ground heave, displacement, obstructions and changes of alignment and grade. The contractor's work plan should also include a provision for lubrication and grouting the annulus of the casing pipe, and a provision for any compensation grouting in any settled / disturbed areas and near / below any temporary or permanent foundation support systems should the need arise.

Performance of the completed trenchless crossing will largely depend on the contractor's construction procedures and techniques. As such, all trenchless works should be carried out by an experienced specialist contractor

employing only qualified workers skilled in their trade, under the direction of an experienced foreman. 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 tunnel by time-dependent increases in friction and/or adhesion, uncontrolled ground losses, and other critical problems that may occur while the work area and equipment are unattended. If forward motion of the casing/pipe is halted at any time other than for pre-planned reasons (e.g., addition of casing/pipe sections, etc.), and prevention of ground disturbance / voids under the highway cannot be assured, consideration may need to be given to abandoning the casing/pipe by filling by pressure-grouting the pipe.

Proper shaft construction is essential for the success of any tunnelling operation. For this reason, it is preferable that construction of shafts be carried out by the trenchless subcontractor and/or in collaboration with the contractor. If the shafts are to be constructed by the general contractor on behalf of the trenchless subcontractor, the shaft design and construction must be compatible with the tunnelling equipment and methods.

6.11 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.

The casing for this tunnel will be installed crossing a knob or ridge in the bedrock and it is considered that the bedrock in that structure will be largely destressed (i.e., will not have in-situ stresses exceeding the existing overburden stress) or the in-situ stresses will be at least well below the suppression pressure required to keep the shale from swelling over previous geologic time and the swelling potential should be negligible.

6.12 Construction Considerations

6.12.1 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, property, underground services or the proposed retaining wall foundations where restriction of lateral movements is required. It must be emphasized that a prefabricated 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 shafts could be constructed using soldier piles and lagging, driven sheet piles or a slide rail system 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. Steel H-piles for soldier piles should be installed in pre-drilled holes. Alternatively, if a watertight shoring system is considered by the contractor, a secant pile shoring system could be used.

As noted above, the use of trench boxes and any system which does not provide continuous support to the excavation walls is not recommended. Design of the shoring will need to consider the limited soil between the excavation floor and the top of the bedrock, which will likely require pinning or socketing of the sheet piles or H-piles.

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 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 walers 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.

Table 12: Soil Parameters

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
Clayey Sand – Silty Sand to Sand and Gravel Fill	19	28	--	0.36	0.53	2.77
Loose to Compact Clayey Sand – Silty Sand to Silty Sand	20	30	--	0.33	0.50	3.00
Very Stiff Clayey Silt to Clayey Silt and Sand (Till)	22	32	100	0.31	0.47	3.25
Very Stiff to Hard Clayey Silt (Residual Soil)	22	32	100	0.31	0.47	3.25

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
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 (2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

If a watertight shoring system is selected or if the backfill materials behind lagging will not allow drainage, the shoring designer will also need to account for hydrostatic pressures.

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 E which addressed the removal or cut-off of the protection system.

6.12.2 Piezometer Decommissioning

A standpipe piezometer was installed in Boreholes 21-2 and 21-4 to permit monitoring of the groundwater level at the site. Ontario Regulation (O.Reg.) 903 amended by O.Reg. 128/03 of the Ontario Water Resources Act requires that monitoring wells are properly abandoned/decommissioned by qualified personnel. It is recommended that the decommissioning of the standpipe piezometers be carried out as part of the construction activities at the site so that water level measurements can be taken immediately prior to and during construction as may be appropriate. The standpipe piezometer in Boreholes 21-2 and 21-4 should then be abandoned under the Construction Contract work; a NSSP for this item is included in Appendix E.

6.13 Instrumentation and Monitoring

6.13.1 General

The displacement monitoring for this project shall be in accordance with MTO's 2021 Pipe Installation by Trenchless Method Special Provision, a copy of which is provide in Appendix E.

That displacement monitoring will serve to:

- Document the effects of the sanitary sewer installation on the overlying roadways, adjacent structures, or services lines/pipes.
- Obtain and provide warning of ground movements that could occur due to the construction methods.
- Allow adjustments to be made to the trenchless construction method such that the settlement limits established are not exceeded, recognizing however that there is typically some delay between the trenchless construction and the full manifestation of the ground surface displacement.

6.13.2 Instruments

A specialist surveying firm should be retained to confirm the set-up and to carry out the displacement monitoring during construction. The equipment and procedures used for displacement monitoring during construction must be capable of surveying the displacement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation. The proposed locations of the displacement points and markers and details of the proposed instrumentation are shown on Drawing 2.

Monitoring of displacement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained. By necessity, a non-intrusive system is recommended for ground surface (i.e., pavement) monitoring points, such as with reflectorless total station monitoring.

Surface displacement 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 and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment.

In-ground displacement monitoring points, consisting of both shallow and deep monitors (1.2 m depth and 1 m above tunnel invert, respectively), shall be installed beyond the traffic lanes and shoulders to monitor displacement and stability of the ground surface between the surface displacement monitoring points and the entry and exit portals.

The Contractor shall install all displacement monitoring points a minimum of two weeks prior to the start of works to permit baseline surveying to be completed. The displacement 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 displacement 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.

6.13.3 Monitoring and Reporting Frequency

Baseline readings:

- Three consecutive readings at least one week prior to commencement of the work. The readings must be carried out on different days, and the average of the three readings will establish the baseline.

Construction readings:

- Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals.
- Two sets of readings per day or shift, if 'review' or 'alert' levels are reached (see below). A minimum time lag between readings shall be 6 hours.

Post-construction readings:

- 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 (i.e, excel spreadsheet) as plots of time versus displacement in comparison to survey data collected prior to commencement of the work. Tabular and graphical plots shall clearly show the review and alert levels, including actual readings and shall provide all readings for the full monitoring duration to that time.

6.13.4 Criteria for Assessment of Roadway Subsidence/Heave

A protocol for assessing the seriousness of any indicated movement is necessary to ensure a timely and appropriate response by the personnel on site. Any significant measured movement could indicate that a response and corrective measure is needed.

The following protocol is therefore recommended.

1) Review Level

If a maximum value of 10 mm relative to the baseline readings is reached for the surface and/or in-ground shallow settlement points, or a maximum value of 15 mm relative to the baseline readings is reached for the in-ground deep settlement monitoring points, 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.

2) Alert Level

If a maximum value of 15 mm relative to the baseline readings is reached for the surface and/or in-ground shallow settlement points, or a maximum value of 25 mm relative to the baseline readings is reached for the in-ground deep settlement monitoring points, 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 displacement 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.

7.0 CORROSION ASSESSMENT AND PROTECTION

Soil and rock corrosivity may affect the concrete pipes, steel pipes and reinforced steel and other concrete elements buried in the soil and 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 soil resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential. The results of analytical tests carried out on one soil sample and two rock samples and are presented in Section 4.5 and on the Certificate of Analysis in Appendix B. The analytical test results were compared to CSA A23.1 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 on the soil and rock samples range from less than 0.002% to 0.032%, which indicates a less than Moderate degree of exposure (i.e., below the class S3 exposure limits) and may be considered negligible according to Table 7.2 of MTO's Gravity Pipe Design Guidelines (2014). Therefore, based on the soil and rock samples tested, when the designer is selecting the exposure class for the concrete structure, the effects of sulphates from within the site soils may not need to be considered.

The pH measured on the soil and rock samples range from about 7.5 to about 9.0. According to the MTO Gravity Pipe Design Guidelines (2014), a pH greater than 8.5 is considered strongly alkaline and is indicative of an increased potential for corrosion. The resistivity measured in the three samples range from 1,000 ohm-cm to 2,800 ohm-cm which indicates that the soil and rock corrosiveness is moderate ($4,500 > R > 2,000$) to severe ($2,000 > R$) as per Table 3.2 of the MTO Gravity Pipe Design Guideline (2014). Based on these results some level of pipe protection will be required depending on pipe material selected. Based on the results of the samples tested and given that the sanitary sewer is located under the roadway and highway and will 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.

These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing, the potential for corrosion and the corrosion susceptibility of materials to be used in construction of the structure foundations in Table 7.1 of the MTO Gravity Pipe Design Guideline (2014) into consideration of the ultimate selection of materials. Ultimately, it is the designer's decision to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 (Durability Requirements) are satisfied.

8.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Katelyn Nero, P.Eng., and Mr. William Cavers, P.Eng., MTO's RAQS recognized specialist for high complexity tunnelling assignments, reviewed the report.

Signature Page

Golder Associates Ltd.



Katie Nero, P.Eng.
Geotechnical Engineer



William (Bill) Cavers, P.Eng.
MTO Foundations Designated Contact

KNN/WBC/ml

Golder and the G logo are trademarks of Golder Associates Corporation

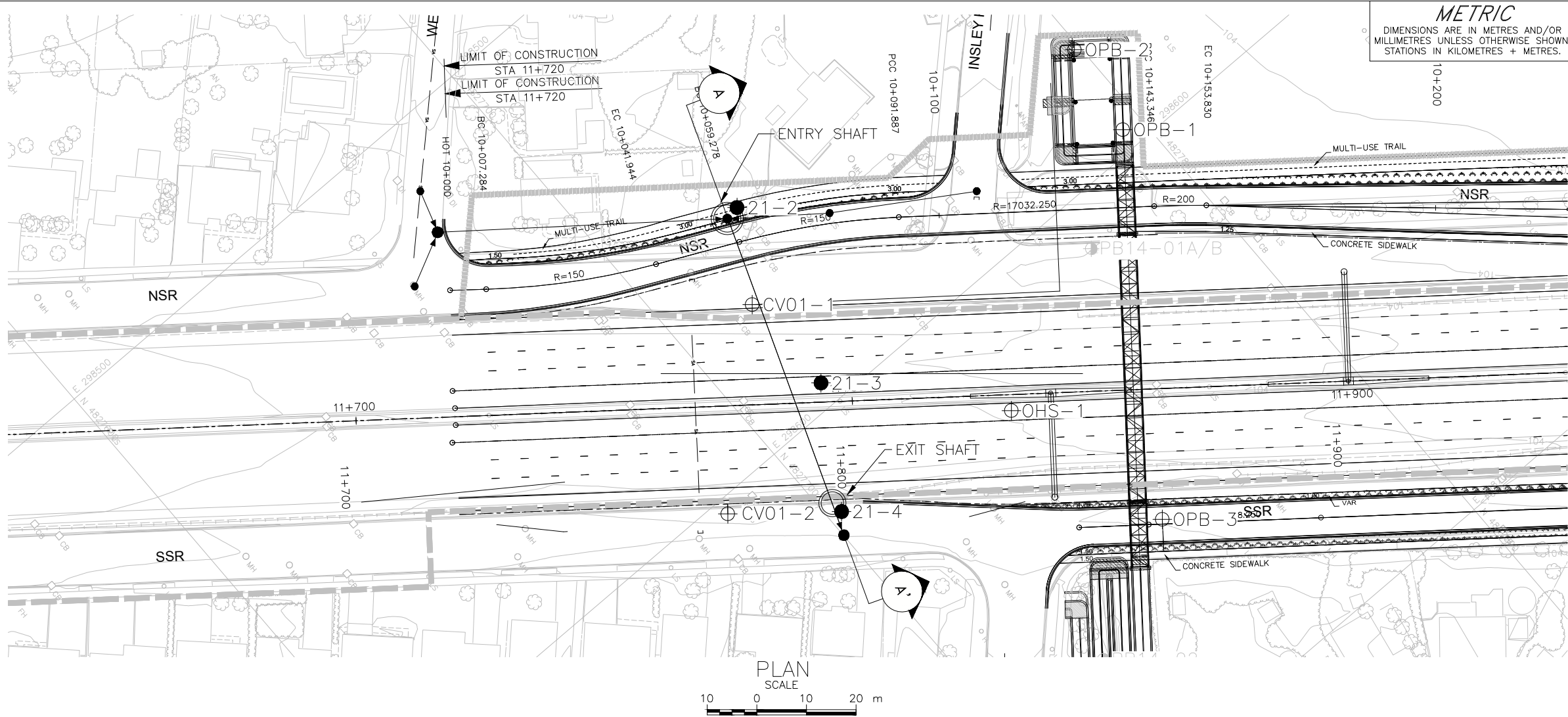
[https://golderassociates.sharepoint.com/sites/19542g/1 foundations/9 - reports/19 - contract 2 trenchless crossings/1. insley crossing/3. final/1530382.7000 - final fidr - insley rd trenchless crossing - 23sept2021.docx](https://golderassociates.sharepoint.com/sites/19542g/1%20foundations/9%20-%20reports/19%20-%20contract%202%20trenchless%20crossings/1.%20insley%20crossing/3.%20final/1530382.7000%20-%20final%20fidr%20-%20insley%20rd%20trenchless%20crossing%20-%2023sept2021.docx)

Table 13: Evaluation of Tunnel Installation Methods

Method	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Auger Boring with SBU	<ul style="list-style-type: none"> Feasible, with dewatering along alignment 	<ul style="list-style-type: none"> Simple construction method. Equipment and skilled construction workforce available. 	<ul style="list-style-type: none"> Significant backstop and jacking/receiving pits are required. Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions that slow installation procedures or if granular soils (particularly below the water table) encountered. Groundwater lowering is required at both the entry/exit pits and along the pipe alignment. Limited ability to steer to correct for line and grade during installation. 	<ul style="list-style-type: none"> Moderate 	<ul style="list-style-type: none"> Large cobbles and/or boulders can impede the auger boring operations where removal of obstructions is not possible. Obstructions can result in deflection of the casing resulting in misalignment of gravity culvert. Potential for loss of ground into casing, particularly if flowing conditions are encountered. Risk of ground surface subsidence increases with decreasing cover.

Method	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Micro-Tunneling	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Unsupported face condition not created Ability to steer allowing greater certainty about final profile and alignment. Better suited for tunneling in mixed face conditions Better suited for penetrating through potential obstructions such as cobbles, boulders and bedrock than jack and bore methods. Does not require groundwater lowering along the pipe alignment. Relatively small working area required compared to other methods. 	<ul style="list-style-type: none"> Limited of availability of machines though availability has increased in recent years Relatively expensive compared to other methods. Requires skilled construction workforce 	<ul style="list-style-type: none"> Higher than auger bore methods 	<ul style="list-style-type: none"> Hydraulic fracture (frac-out) could occur at sites where relatively shallow overburden cover exists. Time delay in sourcing a machine.
Pipe Ramming	<ul style="list-style-type: none"> Not feasible 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A
Horizontal Directional Drilling	<ul style="list-style-type: none"> Not feasible 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A
Tunnel Boring Machine	<ul style="list-style-type: none"> Not feasible 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A
Tunnel Digging Machine	<ul style="list-style-type: none"> Not feasible 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A

DRAWINGS

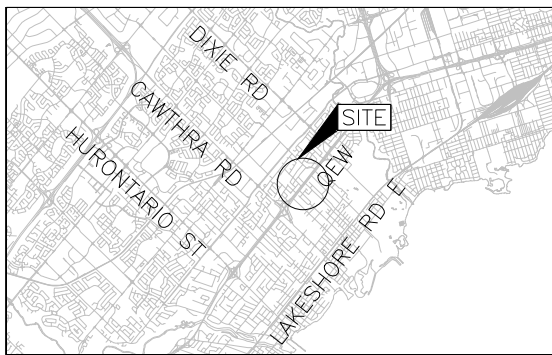


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP NoWQ102-13-00 & 2432-13-00



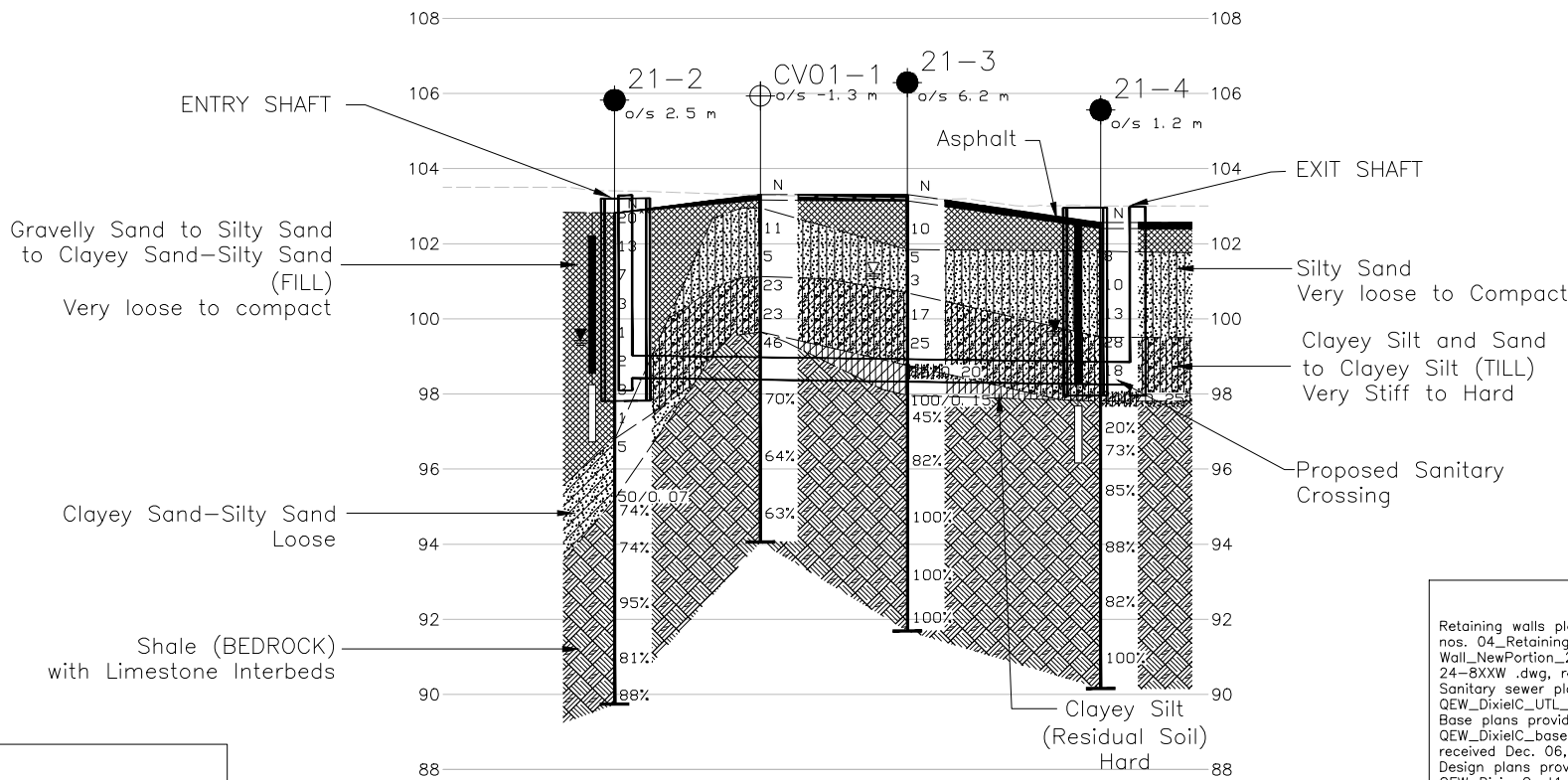
QEW – EAST OF CAWTHRA RD. TO THE EAST MALL
TRENCHLESS SANITARY CROSSING WEST OF INSLEY RD
**BOREHOLE LOCATIONS AND SOIL
STRATA**



KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- ⊕ Borehole – Previous Golder Investigation
- Borehole – Previous Investigation (2014) (Geocres No.30M11-253)
- 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
- ≡ WL upon completion of drilling



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.

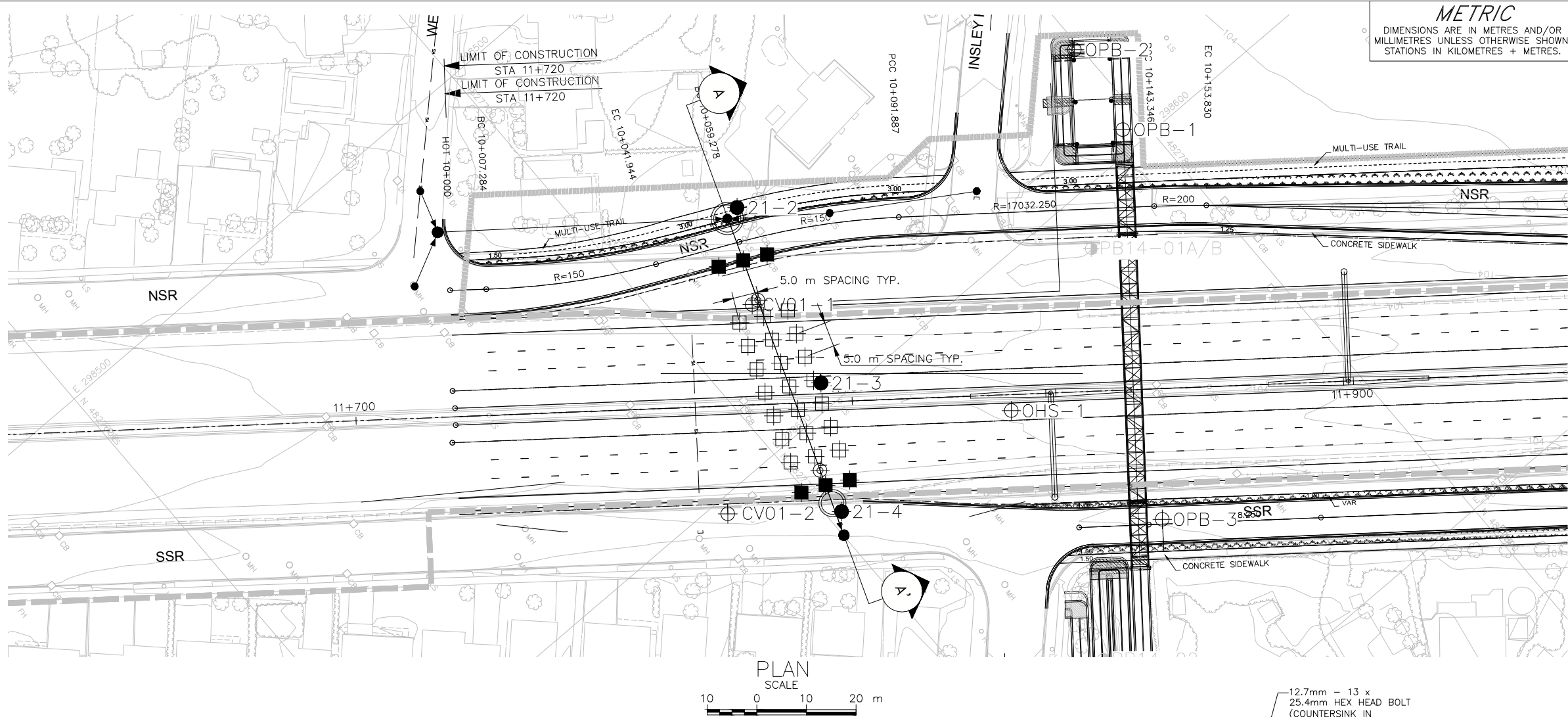
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Retaining walls plans provided in digital format by AECOM, drawing file nos. 04_Retaining Wall_New_24-887W.dwg and 07_Retaining Wall_NewPortion_24-888W.dwg, received January 18, 2018, R.Wall New 24-8XXW.dwg, received April 19, 2018.
Sanitary sewer plan provided in digital format by AECOM, drawing file no. QEW_DixielC_UTL_PROP_SANITARY.dwg, received March 16, 2021.
Base plans provided in digital format by AECOM, drawing file nos. QEW_DixielC_base.dwg and QEW_DixielC_plan.dwg, dated July 20, 2016, received Dec. 06, 2016.
Design plans provided in digital format by AECOM, drawing file nos. QEW_Dixie_Cont1_plan.dwg and QEW_Dixie_Cont2_plan.dwg, received July 21, 2017.
Existing ground contours provided in digital format by AECOM, drawing file no. QEW_DixielC_Contours3D.dwg, received Nov. 08, 2016, contour interval 0.5 m.
Sanitary sewer profile provided in digital format by AECOM, drawing file no. WS_19_CONT2.dgn, received April 9, 2021.
Key plan base data – MNR LIO, obtained 2015.



NO.	DATE	BY	REVISION
Geocres No. 30M11-313			Lat.43.589455, Long. -79.577312
HWY. QEW		PROJECT NO. 1530382	DIST. CENTRAL
SUBM'D. KN	CHKD. KN	DATE: 09/21/2021	SITE: .
DRAWN: DD/SA	CHKD. WC	APPD. WC	DWG. 1

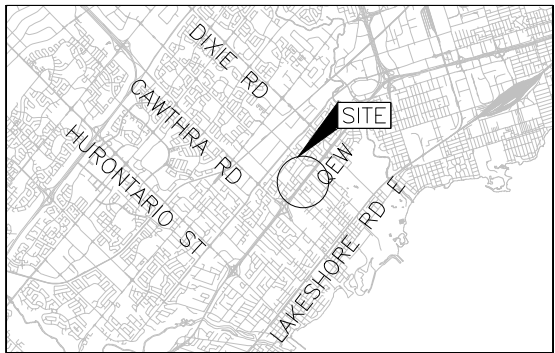


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP NoWQ102-13-00 & 2432-13-00



QEW – EAST OF CAWTHRA RD. TO THE EAST MALL
TRENCHLESS SANITARY CROSSING WEST OF INSLEY RD
SETTLEMENT MONITORING POINT
LOCATIONS AND INSTALLATION DETAILS

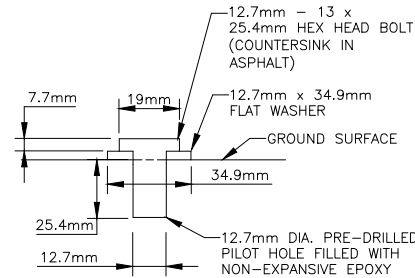


KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- ⊕ Borehole – Previous Golder Investigation
- Borehole – Previous Investigation (2014) (Geocres No.30M11-253)
- ⊕ Surface Monitoring Point
- In-Ground Shallow Settlement Monitoring Station
- ⊕ In-Ground Deep Settlement Monitoring Station

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
PB14-02	103.3	4827723.6	298674.4
PB14-01A/B	103.8	4827775.4	298610.0
OPB-3	103.5	4827751.0	298660.7
OPB-2	103.2	4827798.8	298577.3
OPB-1	103.1	4827795.8	298595.9
OHS-1	103.5	4827742.0	298624.3
CV01-2	103.0	4827685.1	298603.1
CV01-1	103.3	4827716.2	298574.2
21-4	102.6	4827702.9	298617.6
21-3	103.3	4827716.5	298595.2
21-2	102.8	4827726.5	298557.4



SURFACE SETTLEMENT MARKER (SSM) INSTALLATION DETAIL

N.T.S.

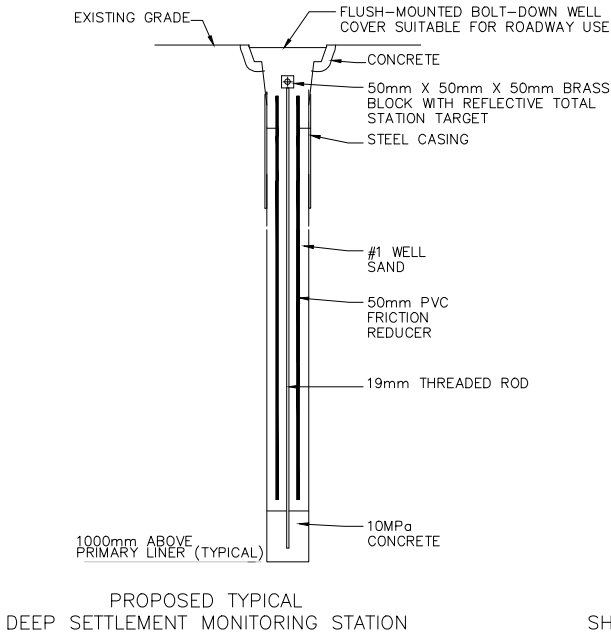
NOTES

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.

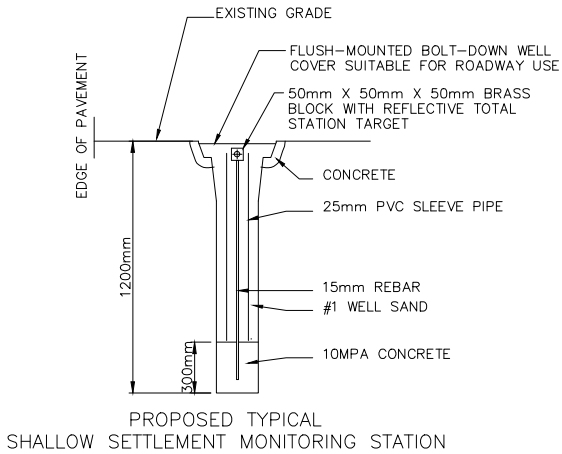
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Retaining walls plans provided in digital format by AECOM, drawing file nos. 04_Retaining Wall_New24-887W.dwg and 07_Retaining Wall_NewPortion24-888W.dwg, received January 18, 2018, R.Wall New 24-8XXW.dwg, received April 19, 2018.
Sanitary sewer plan provided in digital format by AECOM, drawing file no. QEW_DixielC_UTL_PROP_SANITARY.dwg, received March 16, 2021.
Base plans provided in digital format by AECOM, drawing file nos. QEW_DixielC_base.dwg and QEW_DixielC_plan.dwg, dated July 20, 2016, received Dec. 06, 2016.
Design plans provided in digital format by AECOM, drawing file nos. QEW_Dixie_Cont1_plan.dwg and QEW_Dixie_Cont2_plan.dwg, received July 21, 2017.
Existing ground contours provided in digital format by AECOM, drawing file no. QEW_DixielC_Contours3D.dwg, received Nov. 08, 2016, contour interval 0.5 m.
Sanitary sewer profile provided in digital format by AECOM, drawing file no. WS_19_CONT2.dgn, received April 9, 2021.
Key plan base data – MNR LIO, obtained 2015.



PROPOSED TYPICAL
DEEP SETTLEMENT MONITORING STATION



PROPOSED TYPICAL
SHALLOW SETTLEMENT MONITORING STATION

DEEP AND SHALLOW MONITORING STATIONS TYPICAL INSTALLATION DETAILS

N.T.S.

APPENDIX A

**Borehole/Drillhole Records and
Bedrock Core Photographs**

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

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

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

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

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

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

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

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

SOIL TESTS

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

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

COARSE-GRAINED SOILS

Compactness¹

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

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

FINE-GRAINED SOILS

Consistency

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

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

Field Moisture Condition

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

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

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

II. STRESS AND STRAIN

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

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING CLASSIFICATION

Fresh (W1): no visible sign of rock material weathering.

Slightly Weathered (W2): discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

Moderately Weathered (W3): less than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Highly Weathered (W4): more than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Completely Weathered (W5): 100% of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

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.

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250

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.

PROJECT		1530382		RECORD OF BOREHOLE No CV01-1		SHEET 1 OF 2		METRIC													
G.W.P.		2102-13-00; 2432-13-00		LOCATION		N 4827716.2; E 298574.2 MTM NAD 83 ZONE 10 (LAT. 43.589532; LONG. -79.577100)		ORIGINATED BY													
DIST		Central HWY QEW		BOREHOLE TYPE		CME 75, 108 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY													
DATUM		Geodetic		DATE		September 27, 2016		CHECKED BY													
SMM																					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION	SCALE	20	40	60	80	100	W _p	W	W _L	γ	GR	SA	SI	CL
103.3	0.0	GROUND SURFACE																			
		ASPHALT (150 mm)																			
102.9	0.4	Sand and gravel (FILL) Brown Moist					103														
		Silty SAND, trace gravel, trace to some clay Loose to compact Brown Moist		1	SS	11															
							102														
				2	SS	5															
101.1	2.2	CLAYEY SILT, some sand, trace to some gravel, containing shale fragments (TILL / Possible RESIDUAL SOIL) Very stiff to hard Grey Moist		3	SS	23	101														
				4	SS	23	100														
99.6	3.7	Inferred highly weathered, grey, extremely weak SHALE (BEDROCK) (Georgian Bay Formation)		5	SS	46	99														
98.6	4.7	Highly weathered to a depth of 7.00 m to moderately weathered below a depth of 7.00 m																			
		Bedrock cored from depths of 4.7 m to 9.3 m.		1	RC	REC 94%	98														RQD = 70%
		For bedrock coring details refer to Record of Drillhole CV01-1.																			
				2	RC	REC 90%	97														RQD = 64%
				3	RC	REC 100%	96														RQD = 63%
							95														
94.1	9.3	END OF BOREHOLE																			

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTQEW-DIXIE\02_DATA\INTQEW-DIXIE.GPJ GAL-GTA.GDT 5/19/21

PROJECT <u>1530382</u>		RECORD OF BOREHOLE No CV01-1				SHEET 2 OF 2		METRIC								
G.W.P. <u>2102-13-00; 2432-13-00</u>		LOCATION <u>N 4827716.2; E 298574.2 MTM NAD 83 ZONE 10 (LAT. 43.589532; LONG. -79.577100)</u>				ORIGINATED BY <u>PKS</u>										
DIST <u>Central</u> HWY <u>QEW</u>		BOREHOLE TYPE <u>CME 75, 108 mm O.D. Continuous Flight Solid Stem Augers</u>				COMPILED BY <u>ACK</u>										
DATUM <u>Geodetic</u>		DATE <u>September 27, 2016</u>				CHECKED BY <u>SMM</u>										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W		
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					10 20 30 WATER CONTENT (%)				
	NOTE: 1. Open borehole dry upon completion of drilling prior to rock coring.															

SHEET 1 OF 1

DATUM: Geodetic

DRILL RIG: CME 75 (Truck Mounted)

DRILLING CONTRACTOR: Davis Drilling Ltd.

[illegible]

PROJECT 1530382		RECORD OF BOREHOLE No CV01-2				SHEET 1 OF 1		METRIC						
G.W.P. 2102-13-00; 2432-13-00		LOCATION N 4827685.1; E 298603.1 MTM NAD 83 ZONE 10 (LAT. 43.589074; LONG. -79.576743)				ORIGINATED BY PKS								
DIST Central HWY QEW		BOREHOLE TYPE CME 75, 108 mm O.D. Continuous Flight Solid Stem Augers				COMPILED BY ACK								
DATUM Geodetic		DATE September 27, 2016				CHECKED BY SMM								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
103.0	GROUND SURFACE													
0.0	ASPHALT (150 mm)													
0.2	Sand and gravel (FILL) Moist													
102.5														
0.5	SAND, some silt, trace to some gravel, containing rootlets Loose Brown to grey		1	SS	8									14 64 18 4
	-Grey below a depth of 1.5 m		2	SS	4									
	- Moist to wet below a depth of 2.1 m		3	SS	7									
100.1														
2.9	CLAYEY SILT, some sand, trace gravel, some shale and limestone pieces (TILL / Possible RESIDUAL SOIL) Very stiff to hard Grey Moist		4	SS	27									
99.3														
3.7	Inferred highly weathered, grey, extremely weak SHALE (BEDROCK) (Georgian Bay Formation)		5	SS	100/0.15									
98.4														
4.6	Moderately weathered													
	Bedrock cored from depths of 4.6 m to 7.5 m. For bedrock coring details refer to Record of Drillhole CV01-2.		1	RC	REC 97%									RQD = 47%
			2	RC	REC 91%									RQD = 59%
95.5														
7.5	END OF BOREHOLE													
	NOTE: 1. Open borehole dry upon completion of drilling prior to rock coring.													

GTA-MTO 001 S:\CLIENTS\MTQEQW-DIXIE\02_DATA\GINTQEQW-DIXIE.GPJ GAL-GTA.GDT 5/19/21

[illegible]

FEATURES LEGEND



BROKEN CORE



CLAY SEAM



LIMESTONE



LOST CORE

DEPTH SCALE

1 : 50



GOLDER

LOGGED: PKS

CHECKED: CEC/AB


PROJECT 1530382		RECORD OF BOREHOLE No 21-2		SHEET 1 OF 2	METRIC
G.W.P. 2102-13-00; 2432-13-00		LOCATION N 4827726.5; E 298557.4 MTM NAD 83 ZONE 10 (LAT. 43.589455; LONG. -79.577312)		ORIGINATED BY LM	
DIST Central HWY QEW		BOREHOLE TYPE CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)		COMPILED BY SK	
DATUM Geodetic		DATE January 11, 2021		CHECKED BY KN	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
102.8	GROUND SURFACE													
0.0	Gravelly SAND (SP), trace silt (FILL) Compact Brown Dry		1	SS	20									
102.1														
0.7	SILTY SAND (SM), some gravel (FILL) Compact to loose Brown Moist		2	SS	13									
			3	SS	7									
100.6														
2.2	CLAYEY SAND - SILTY SAND (SC-SM), some gravel, contains shale fragments (FILL) Very loose Grey Wet		4	SS	3									
			5	SS	1									
			6	SS	2									
			7	SS	3									
97.5														
5.3	SILTY SAND (SM), brick fragments from 5.3 m to 5.9 m (FILL) Very loose Black/brown Wet		8	SS	1									
96.8														
6.0	CLAYEY SAND - SILTY SAND (SC-SM), trace gravel Loose Grey Wet		9	SS	5									
95.2														
7.6	SHALE (BEDROCK) Grey		10	SS	50/0.07									
	Bedrock cored from depths of 7.7 m to 13.1 m (between Elev. 95.1 m and 89.7 m). For bedrock coring details refer to Record of Drillhole BH21-2.		1	RC	REC 100%									RQD = 74%
			2	RC	REC 100%									RQD = 74%
			3	RC	REC 100%									RQD = 95%

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTQEQW-DIXIE\02_DATA\INTQEQW-DIXIE.GPJ GAL-GTA.GDT 5/19/21

PROJECT		RECORD OF BOREHOLE No 21-2				SHEET 2 OF 2		METRIC																					
G.W.P. 2102-13-00; 2432-13-00		LOCATION N 4827726.5; E 298557.4 MTM NAD 83 ZONE 10 (LAT. 43.589455; LONG. -79.577312)				ORIGINATED BY LM																							
DIST Central HWY QEW		BOREHOLE TYPE CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)				COMPILED BY SK																							
DATUM Geodetic		DATE January 11, 2021				CHECKED BY KN																							
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)													
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)																
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100	W _p	W	W _L															
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED																						
							20	40	60	80	100	10	20	30															
89.7	SHALE (BEDROCK) Grey		3	RC	REC 100%												RQD = 95%												
	Bedrock cored from depths of 7.7 m to 13.1 m (between Elev. 95.1 m and 89.7 m). For bedrock coring details refer to Record of Drillhole BH21-2.		4	RC	REC 100%												RQD = 81%												
			5	RC	REC 88%												RQD = 88%												
13.1	END OF BOREHOLE																												
	NOTES: 1. Water level measured at a depth of 3.7 m below ground surface (Elev. 99.1 m) upon completion of drilling. 2. Groundwater level measurements in piezometer: <table border="1" style="display: inline-table; margin-left: 20px;"> <thead> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev. (m)</th> </tr> </thead> <tbody> <tr> <td>11-02-21</td> <td>3.3</td> <td>99.5</td> </tr> <tr> <td>30-03-21</td> <td>3.4</td> <td>99.4</td> </tr> <tr> <td>13-05-21</td> <td>3.3</td> <td>99.5</td> </tr> </tbody> </table>	Date	Depth (m)	Elev. (m)	11-02-21	3.3	99.5	30-03-21	3.4	99.4	13-05-21	3.3	99.5																
Date	Depth (m)	Elev. (m)																											
11-02-21	3.3	99.5																											
30-03-21	3.4	99.4																											
13-05-21	3.3	99.5																											

GTA-MTO 001 S:\CLIENTS\MTQEW-DIXIE\02_DATA\INTQEW-DIXIE.GPJ GAL-GTA.GDT 5/19/21

PROJECT: 1530382

RECORD OF DRILLHOLE: 21-2

SHEET 1 OF 1

LOCATION: N 4827726.5 ;E 298557.4

DRILLING DATE: January 11, 2021

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mounted

DRILLING CONTRACTOR: Davis Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	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.																		FEATURES	R0/R1 ZONES	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
						RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA				ROCK STRENGTH INDEX			WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
						TOTAL CORE %	SOLID CORE %			B Angle	DIP w/L CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	R4	R3	R2	R1	W1	W2	W3	W4	W5				W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
						80 60 20	80 60 20																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
8	HQ3 Core Rotary drilling	Continued from Record of Borehole BH21-2		95.12																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					

FEATURES LEGEND



BROKEN CORE



CLAY SEAM



LIMESTONE



LOST CORE

DEPTH SCALE

1 : 50

LOGGED: LM


CHECKED:

PROJECT		RECORD OF BOREHOLE No 21-3		SHEET 1 OF 2		METRIC											
G.W.P. 2102-13-00; 2432-13-00		LOCATION N 4827716.5; E 298595.2 MTM NAD 83 ZONE 10 (LAT. 43.589365; LONG. -79.576844)		ORIGINATED BY LM													
DIST Central HWY QEW		BOREHOLE TYPE CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)		COMPILED BY SK													
DATUM Geodetic		DATE January 13, 2021		CHECKED BY KN													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	γ	GR	SA	SI	CL
103.3	GROUND SURFACE																
0.0	ASPHALT (150 mm)																
0.2	SILTY SAND (SM), trace gravel, trace organics (FILL) Compact Dark brown Moist		1	SS	10		103										
101.9							102										
1.5	SILTY SAND (SM), trace gravel Very loose to loose Brown to grey Moist to wet		2	SS	5												
	- Wet below a depth of 2.3 m		3A	SS	3		101										
100.7			3B														
2.6	CLAYEY SILT and SAND (CL/SC), trace gravel (TILL) Soft to very stiff Grey Wet		4	SS	17		100										
			5	SS	25		99										
98.8																	
4.5	CLAYEY SILT (CL), some gravel, shale fragments (RESIDUAL SOIL) Hard Grey Wet		6	SS	85/0.20		98										
98.0																	
5.3	SHALE (BEDROCK) Grey		7	SS	100/0.15		97										
	Bedrock cored from depths of 5.5 m to 11.6 m (between Elev. 97.8 m and 91.7 m). For bedrock coring details refer to Record of Drillhole BH21-3.		1	RC	REC 100%												RQD = 45%
			2	RC	REC 100%												RQD = 82%
			3	RC	REC 100%												RQD = 100%
			4	RC	REC 100%												RQD = 100%

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTQEQW-DIXIE\02_DATA\INTQEQW-DIXIE.GPJ GAL-GTA-GDT 5/19/21


PROJECT 1530382		RECORD OF BOREHOLE No 21-3				SHEET 2 OF 2		METRIC								
G.W.P. 2102-13-00; 2432-13-00		LOCATION N 4827716.5; E 298595.2 MTM NAD 83 ZONE 10 (LAT. 43.589365; LONG. -79.576844)				ORIGINATED BY LM										
DIST Central HWY QEWS		BOREHOLE TYPE CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)				COMPILED BY SK										
DATUM Geodetic		DATE January 13, 2021				CHECKED BY KN										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100					
	SHALE (BEDROCK) Grey		4	RC	REC 100%	93										
	Bedrock cored from depths of 5.5 m to 11.6 m (between Elev. 97.8 m and 91.7 m). For bedrock coring details refer to Record of Drillhole BH21-3.		5	RC	REC 100%	92										
91.7 11.6	END OF BOREHOLE NOTE: 1. Water level measured at a depth of 2.1 m below ground surface (Elev. 101.2 m) prior to rock coring.															

GTA-MTO 001 S:\CLIENTS\MTQ\QEW-DIXIE02_DATA\GINTQEW-DIXIE.GPJ GAL-GTA.GDT 5/19/21

SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: Davis Drilling Ltd.

[illegible] BROKEN CORE CLAY SEAM

LIMESTONE

■ LOST CORE

DEPTH SCALE

1 : 50

LOGGED: LM

CHECKED:


GTA-RCK 054 S:\CLIENTS\IMTO\QEW-DIXIE\02 DATA\GIN\QEW-DIXIE.GPJ GAL-MISS.GDT 5/19/21

PROJECT		1530382		RECORD OF BOREHOLE No 21-4		SHEET 1 OF 2		METRIC				
G.W.P.		2102-13-00; 2432-13-00		LOCATION		N 4827702.9; E 298617.6 MTM NAD 83 ZONE 10 (LAT. 43.589242; LONG. -79.576566)		ORIGINATED BY				
DIST		Central HWY QEW		BOREHOLE TYPE		CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)		COMPILED BY				
DATUM		Geodetic		DATE		February 10 and 11, 2021		CHECKED BY				
KN												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100	20 40 60 80 100	W _p W W _L		
102.6	GROUND SURFACE											
0.0	ASPHALT (150 mm)											
0.2	SAND (SP) and GRAVEL (FILL)											
101.8												
0.8	SILTY SAND (SM), trace gravel Loose to compact Brown to grey below a depth of 1.5 m Dry to wet		1	SS	8							4 60 24 12
			2	SS	10							
	- Wet below a depth of 2.3 m		3	SS	13							
99.6												
3.1	Sandy CLAYEY SILT (CL), some gravel (TILL) Very stiff to hard Grey Moist		4	SS	28							15 30 38 17
			5	SS	18							
97.9			6A	SS	100/0.23							
4.7	Inferred highly weathered, grey SHALE		6B									
97.4												
5.2	SHALE (BEDROCK) Gray		1	RC	REC 39%							RQD = 20%
	Bedrock cored from depths of 5.2 m to 12.4 m (between Elev. 97.4 m and 90.2 m).		2	RC	REC 100%							RQD = 73%
	For bedrock coring details refer to Record of Drillhole BH21-4.		3	RC	REC 100%							RQD = 85%
			4	RC	REC 100%							RQD = 88%
			5	RC	REC 100%							RQD = 82%

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTQ\QEW-DIXIE\02_DATAGINT\QEW-DIXIE.GPJ GAL-GTA.GDT 7/6/21


PROJECT		2102-13-00; 2432-13-00		LOCATION		N 4827702.9; E 298617.6 MTM NAD 83 ZONE 10 (LAT. 43.589242; LONG. -79.576566)		SHEET 2 OF 2		METRIC							
G.W.P.		2102-13-00; 2432-13-00		BOREHOLE TYPE		CME 55, 150 mm O.D. Hollow Stem Augers (Auto Hammer)		ORIGINATED BY		LM							
DIST		Central HWY QEW		COMPILED BY		AK		DATE		February 10 and 11, 2021							
DATUM		Geodetic		CHECKED BY		KN											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
90.2	SHALE (BEDROCK) Gray Bedrock cored from depths of 5.2 m to 12.4 m (between Elev. 97.4 m and 90.2 m). For bedrock coring details refer to Record of Drillhole BH21-4.		5	RC	REC 100%												RQD = 82%
			6	RC	REC 100%												RQD = 100%
12.4	END OF BOREHOLE NOTES: 1. Groundwater level measured at a depth of approximately 3.2 m below ground surface (Elev. 99.4 m) prior to rock coring. 2. Groundwater level measurements in piezometer: Date Depth (m) Elev. (m) 11-02-21 3.2 99.4 28-06-21 2.9 99.7																

GTA-MTO 001 S:\CLIENTS\MTQ\QEW-DIXIE02_DATAGINT\QEW-DIXIE.GPJ GAL-GTA.GDT 7/6/21

SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: Davis Drilling Ltd.

[illegible] BROKEN CORE CLAY SEAM

LIMESTONE

LOST CORE

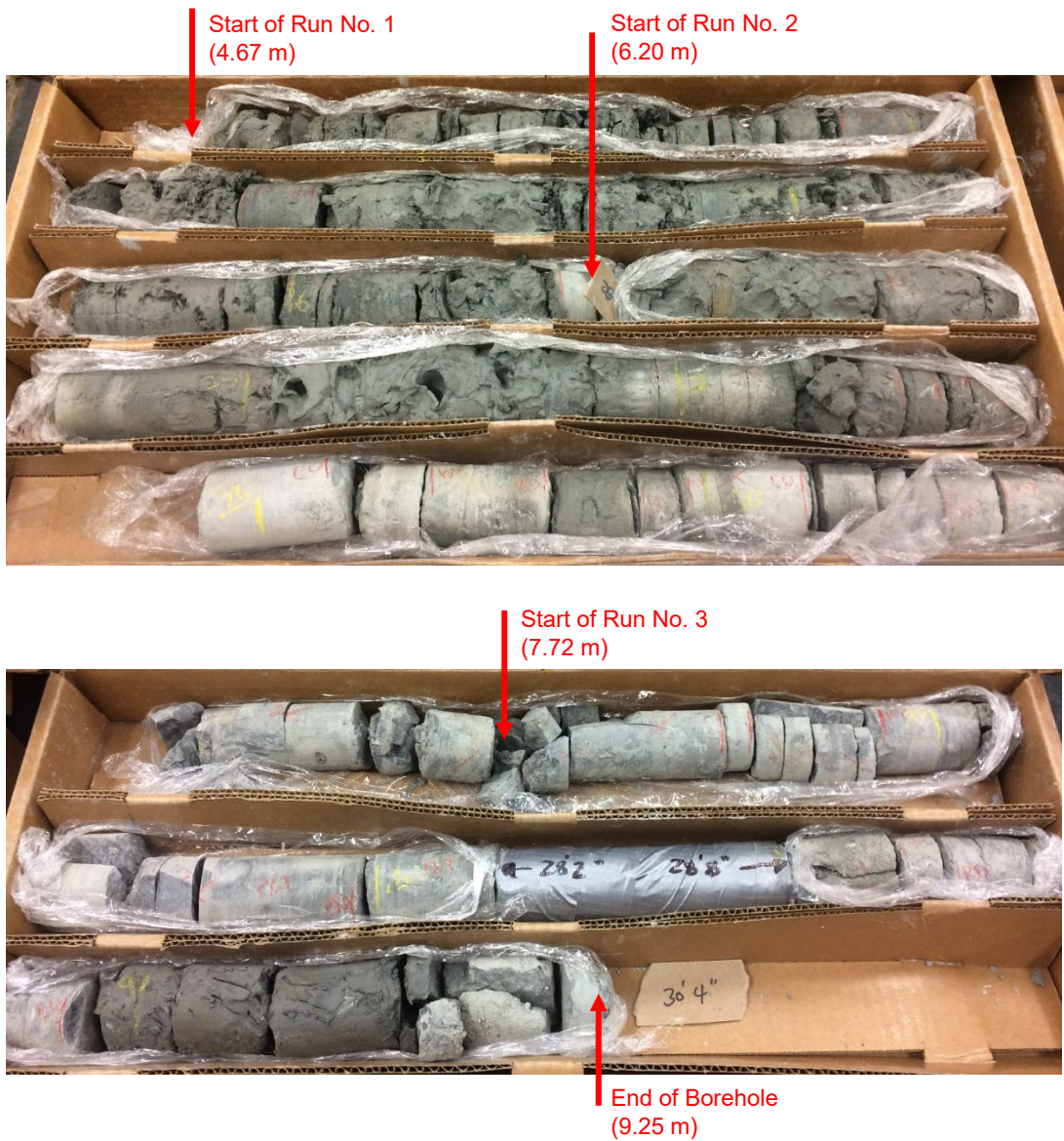
DEPTH SCALE

1 : 50

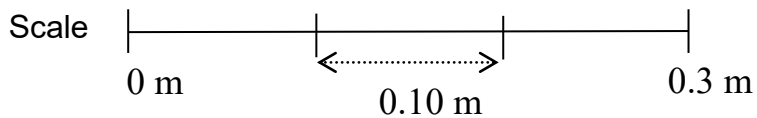



LOGGED: AK

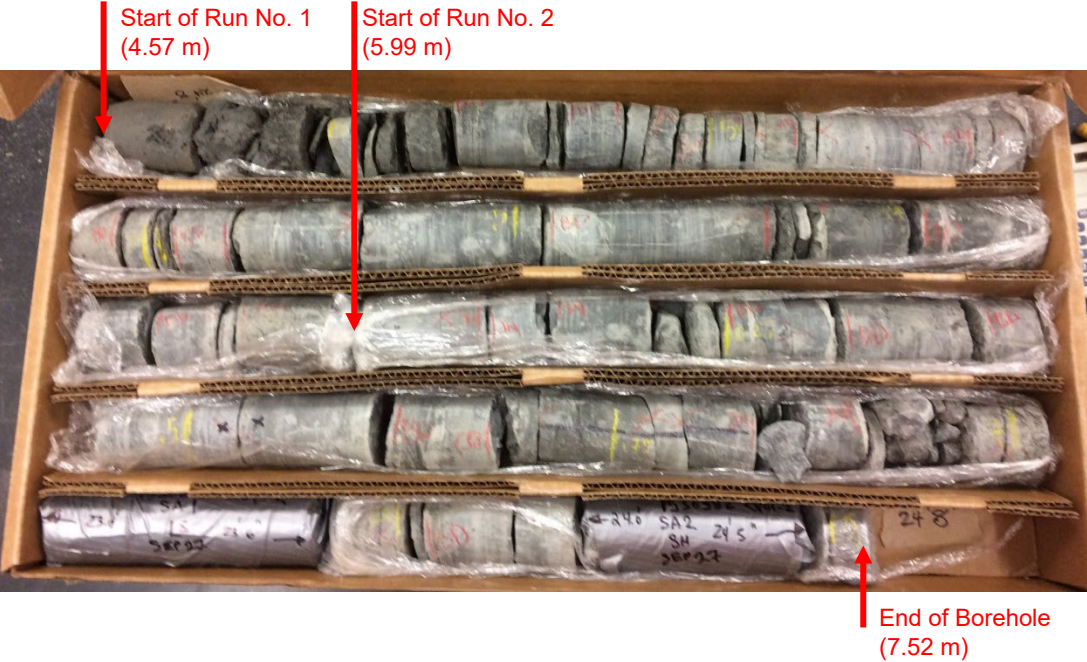
CHECKED:



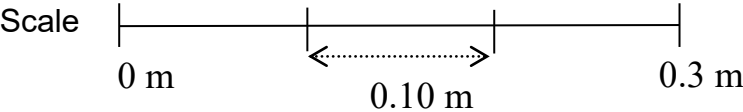
Borehole CV01-1: Bedrock cored between depths of about 4.67 m to 9.25 m



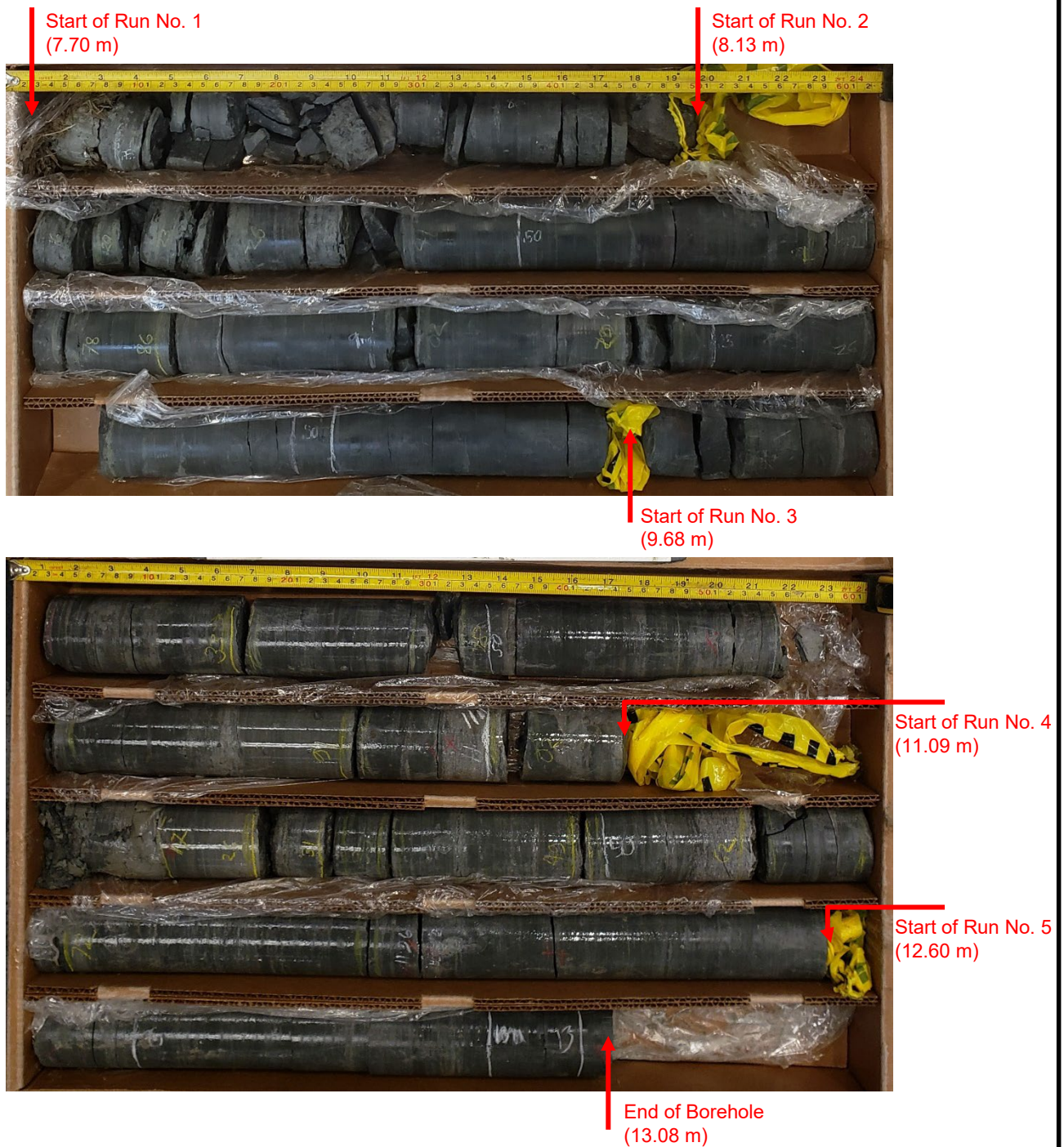
PROJECT					
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario					
TITLE					
BEDROCK CORE PHOTOGRAPHS BOREHOLE CV01-1					
	PROJECT No. 1530382.7000			FILE No. ----	
	DESIGN	KN	20210322	SCALE	NTS
	CADD	--	--	FIGURE A1	
	CHECK	WC			
	REVIEW	WC			



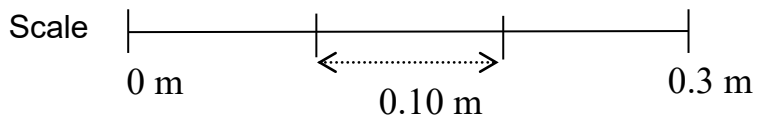
Borehole CV01-2: Bedrock cored between depths of about 4.57 m to 7.52 m




PROJECT						
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario						
TITLE						
BEDROCK CORE PHOTOGRAPHS BOREHOLE CV01-2						
	PROJECT No. 1530382.7000			FILE No. ----		
	DESIGN	KN	20210322	SCALE	NTS	VER. 1.
	CADD	--	--	FIGURE A2		
	CHECK	WC				
	REVIEW	WC				

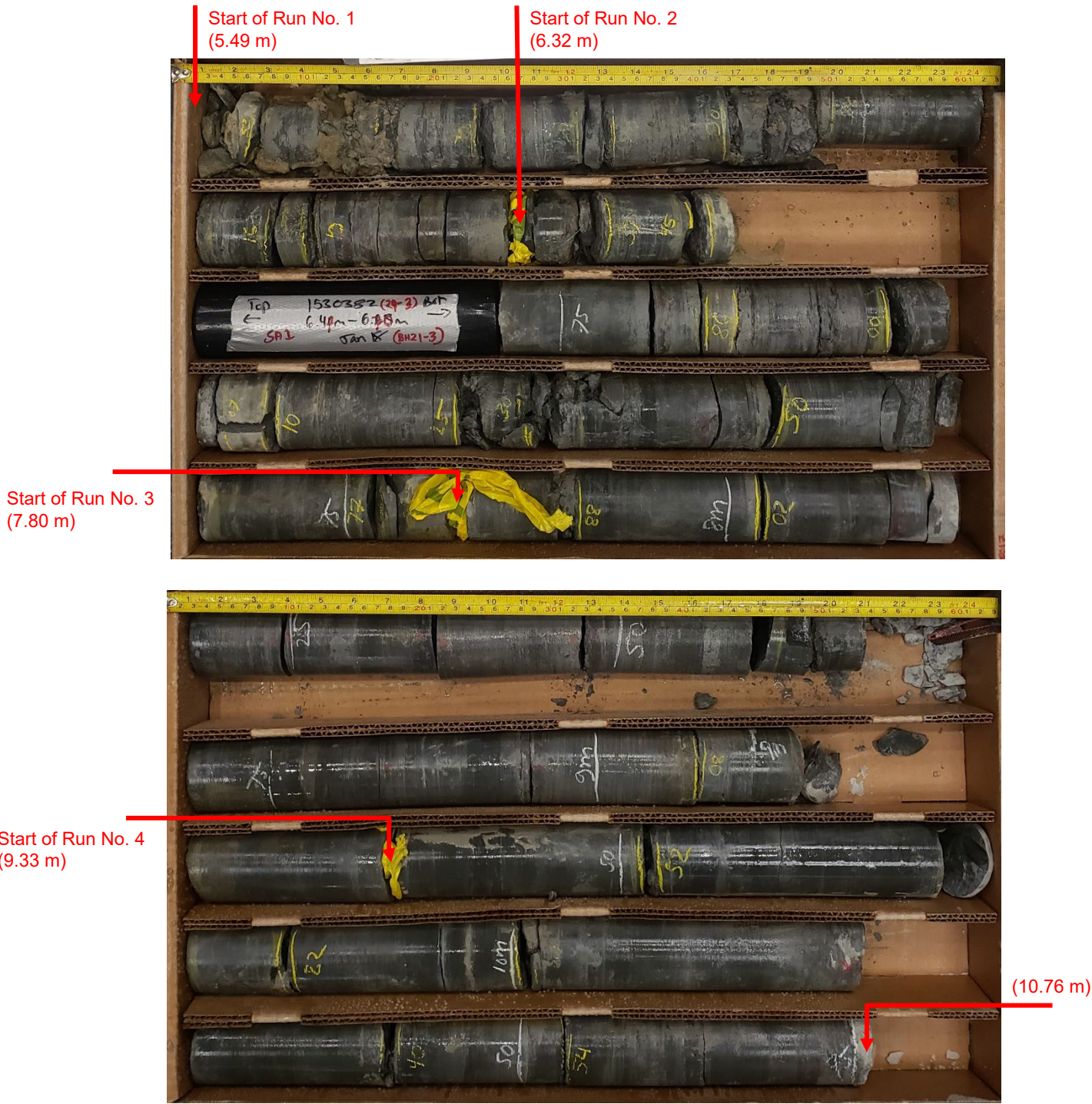


Borehole 21-2: Bedrock cored between depths of about 7.70 m to 13.08 m

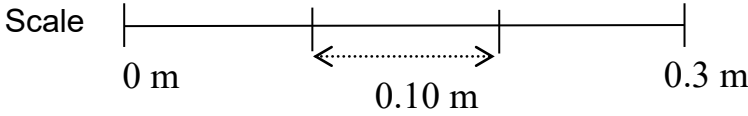


PROJECT					
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario					
TITLE					
BEDROCK CORE PHOTOGRAPHS BOREHOLE 21-2					
	PROJECT No. 1530382.7000			FILE No. ----	
	DESIGN	KN	20210322	SCALE	NTS
	CADD	--	--	FIGURE A3	
	CHECK	WC			
	REVIEW	WC			

REVISION DATE: 2021.0322 BY: KN/ER Project: 1530382.7000



Borehole 21-3: Bedrock cored between depths of about 5.49 m to 10.76 m (continued)




PROJECT

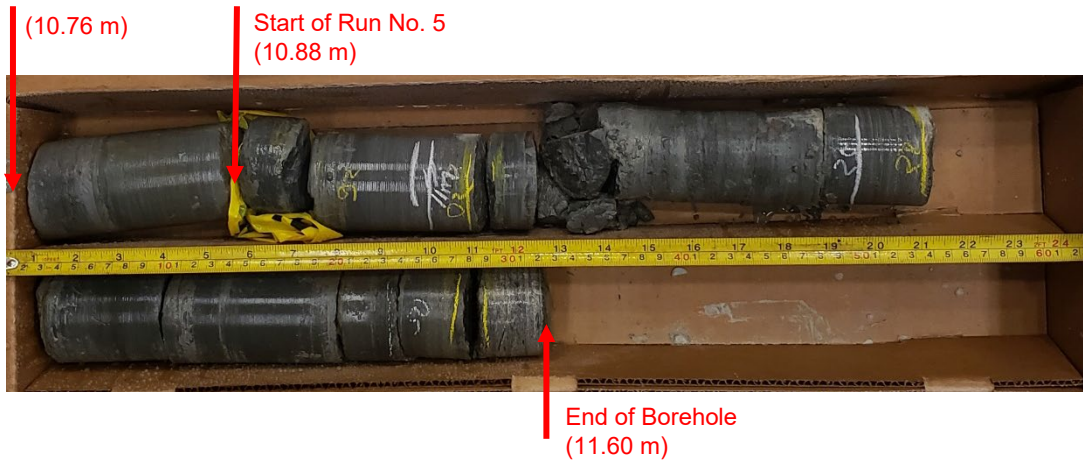
QEW Widening from East Cawthra Road to the East Mall
Sanitary Sewer Trenchless Crossing at Insley Road
Mississauga, Ontario

TITLE

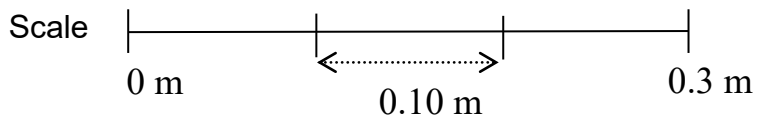
BEDROCK CORE PHOTOGRAPHS
BOREHOLE 21-3


GOLDER

PROJECT No. 1530382.7000			FILE No. ----		
DESIGN	KN	20210322	SCALE	NTS	VER. 1.
CADD	--	--	FIGURE A4 a		
CHECK	WC				
REVIEW	WC				



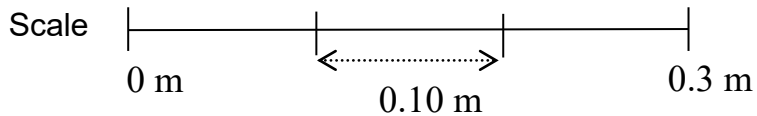
Borehole 21-3: Bedrock cored between depths of about 10.76 m to 11.60 m



PROJECT						
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario						
TITLE						
BEDROCK CORE PHOTOGRAPHS BOREHOLE 21-3						
	PROJECT No. 1530382.7000			FILE No. ----		
	DESIGN	KN	20210322	SCALE	NTS	VER. 1.
	CADD	--	--	FIGURE A4 b		
	CHECK	WC				
	REVIEW	WC				



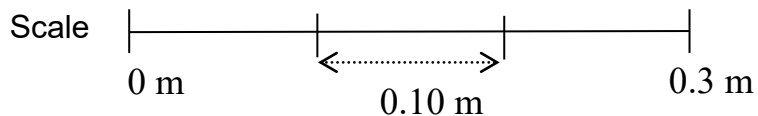
Borehole 21-4: Bedrock cored between depths of about 5.18 m to 10.77 m (continued)




PROJECT					
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario					
TITLE					
BEDROCK CORE PHOTOGRAPHS BOREHOLE 21-4					
	PROJECT No. 1530382.7000			FILE No. ----	
	DESIGN	KN	20210322	SCALE	NTS
	CADD	--	--	FIGURE A5 a	
	CHECK	WC			
	REVIEW	WC			



Borehole 21-4: Bedrock cored between depths of about 10.77 m to 12.40 m



PROJECT					
QEW Widening from East Cawthra Road to the East Mall Sanitary Sewer Trenchless Crossing at Insley Road Mississauga, Ontario					
TITLE					
BEDROCK CORE PHOTOGRAPHS BOREHOLE 21-4					
 GOLDER	PROJECT No. 1530382.7000			FILE No. ----	
	DESIGN	KN	20210322	SCALE	NTS
	CADD	--	--	FIGURE A5 b	
	CHECK	WC			
	REVIEW	WC			

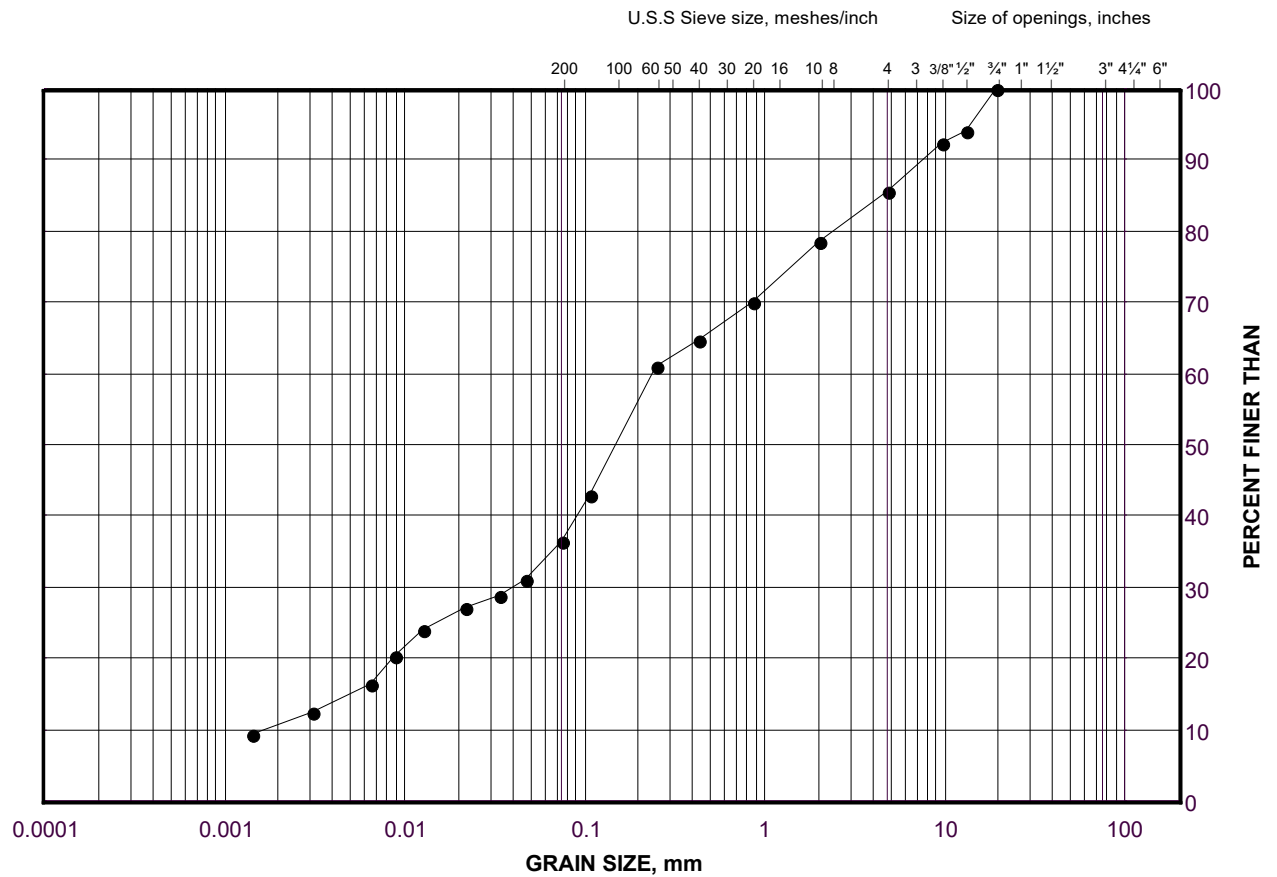
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

CLAYEY SAND-SILTY SAND (SC-SM) (FILL)

FIGURE B1



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

LEGEND

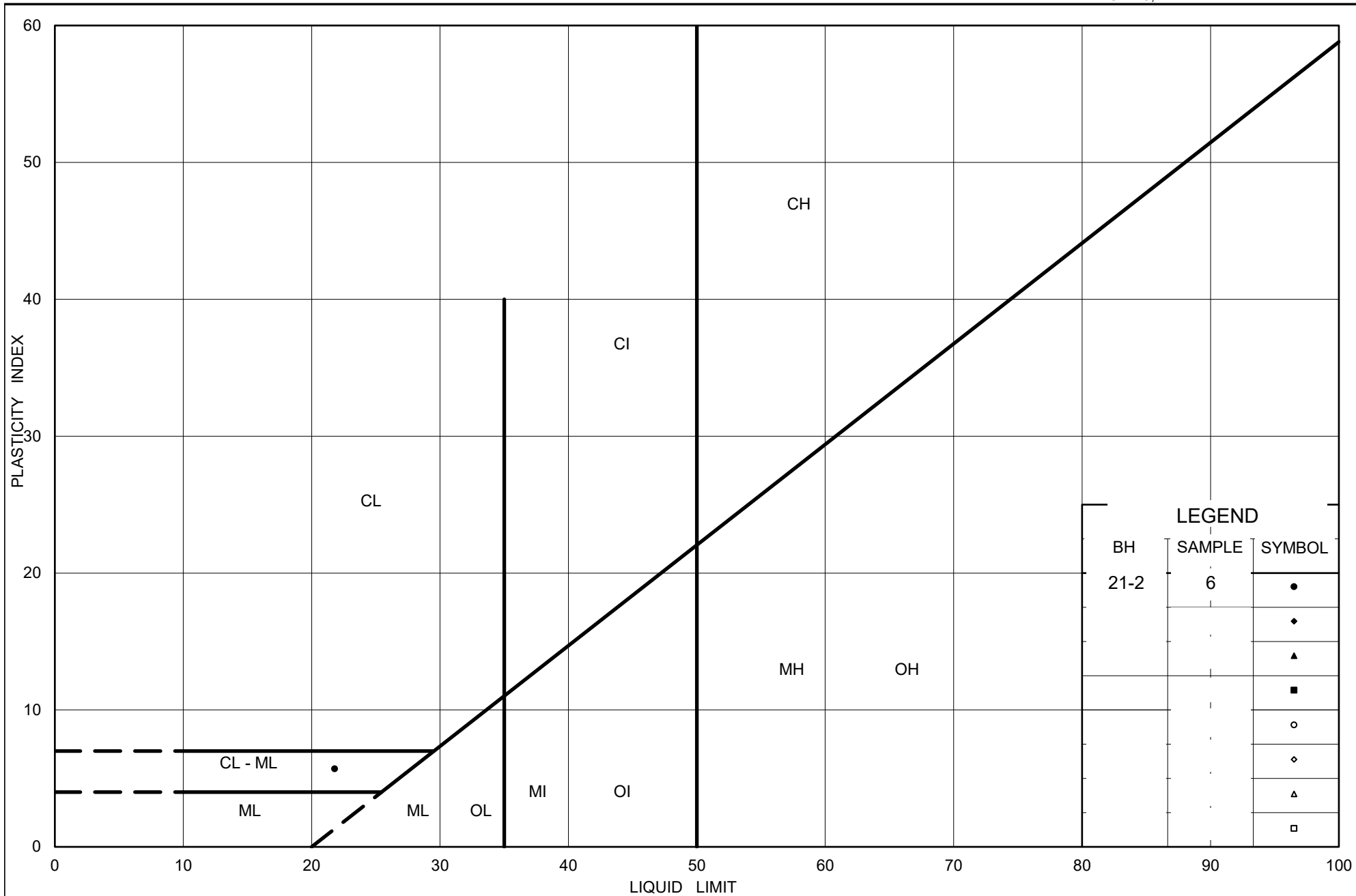
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	21-2	6	98.7

Project Number: 1530382

Checked By: KNN

Golder Associates

Date: 22-Mar-21



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SAND-SILTY SAND (SC-SM) (FILL)

Figure No. B2

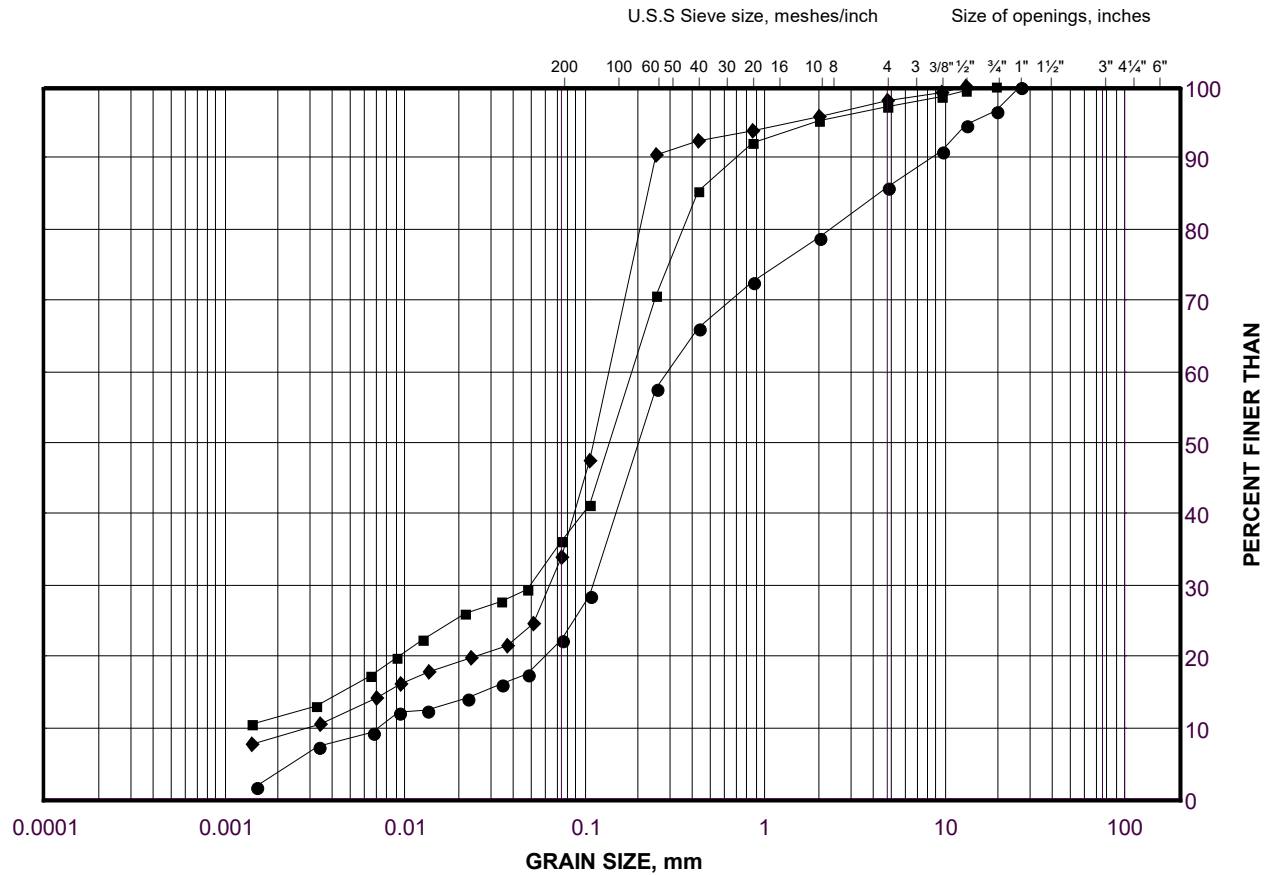
Project No. 1530382 (7000)

Checked By: KNN

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM)

FIGURE B3



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

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
●	CV 01-2	1	101.9
■	21-4	1	101.5
◆	CV 01-1	2	101.5

Project Number: 1530382

Checked By: KNN

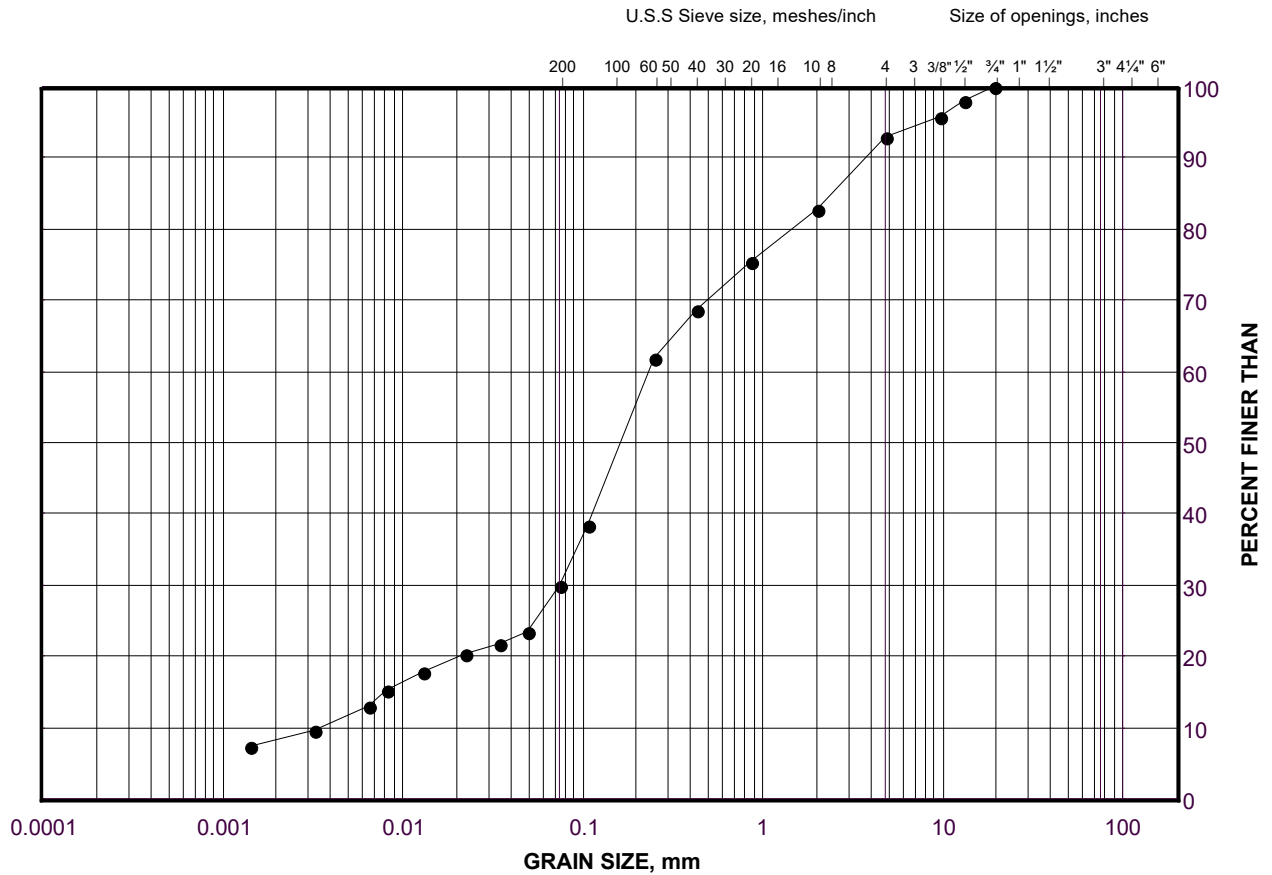
Golder Associates

Date: 24-Mar-21

GRAIN SIZE DISTRIBUTION

CLAYEY SAND-SILTY SAND (SC-SM)

FIGURE B4



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

LEGEND

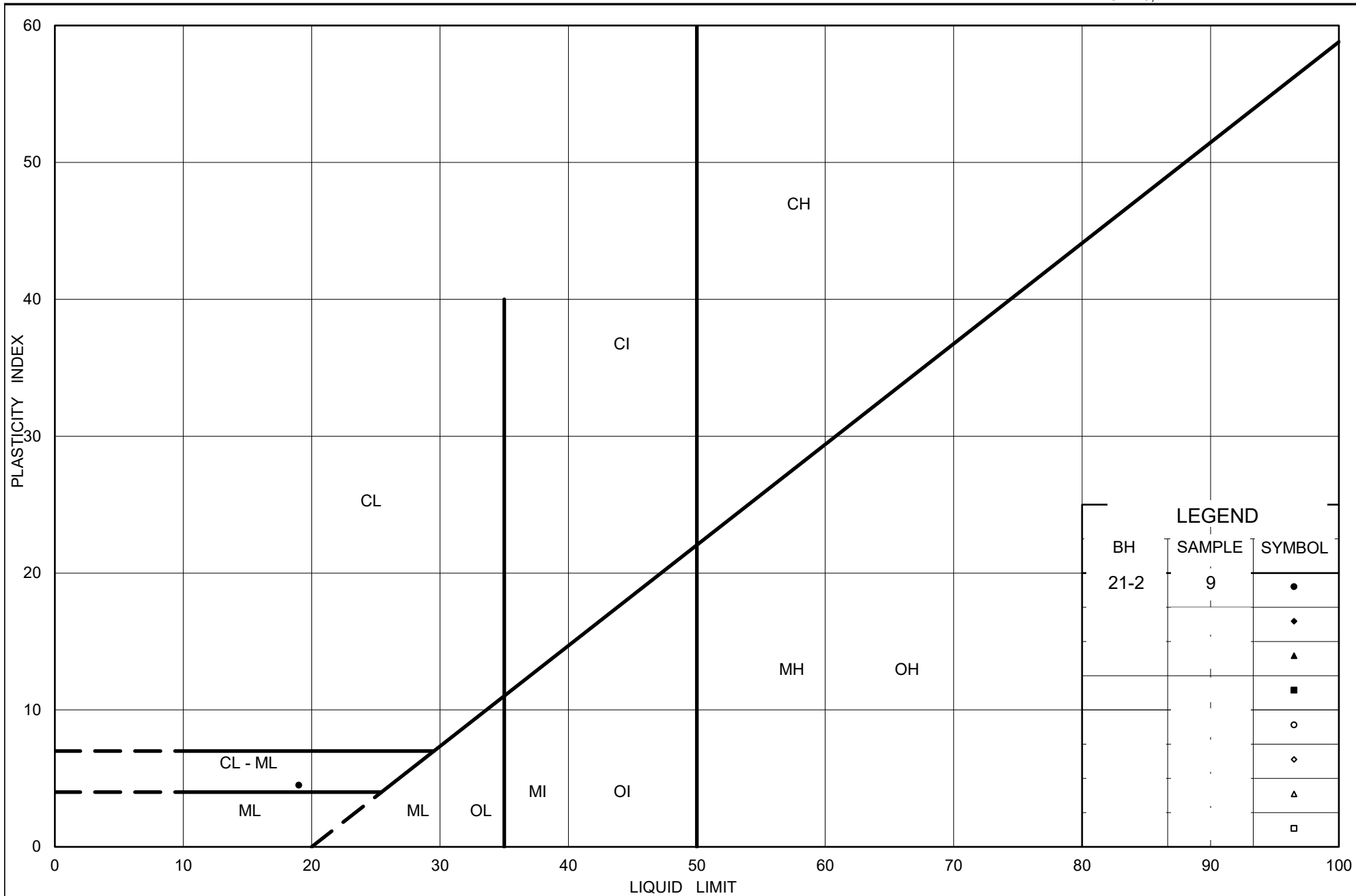
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	21-2	9	96.4

Project Number: 1530382

Checked By: KNN

Golder Associates

Date: 22-Mar-21



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SAND-SILTY SAND (SC-SM)

Figure No. B5

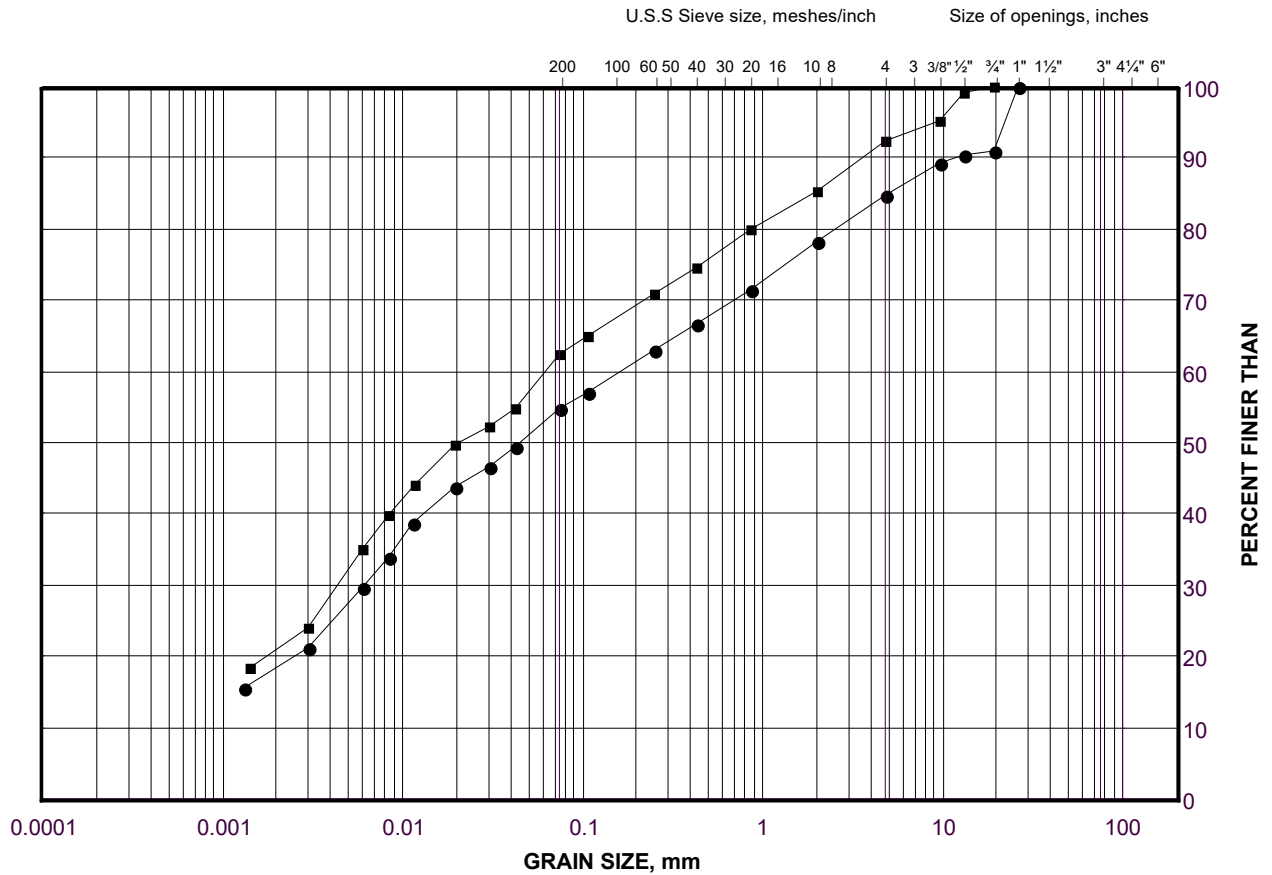
Project No. 1530382 (7000)

Checked By: KNN

GRAIN SIZE DISTRIBUTION

Sandy CLAYEY SILT (CL) to CLAYEY SILT and SAND (Till) (CL/SC)

FIGURE B6



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

LEGEND

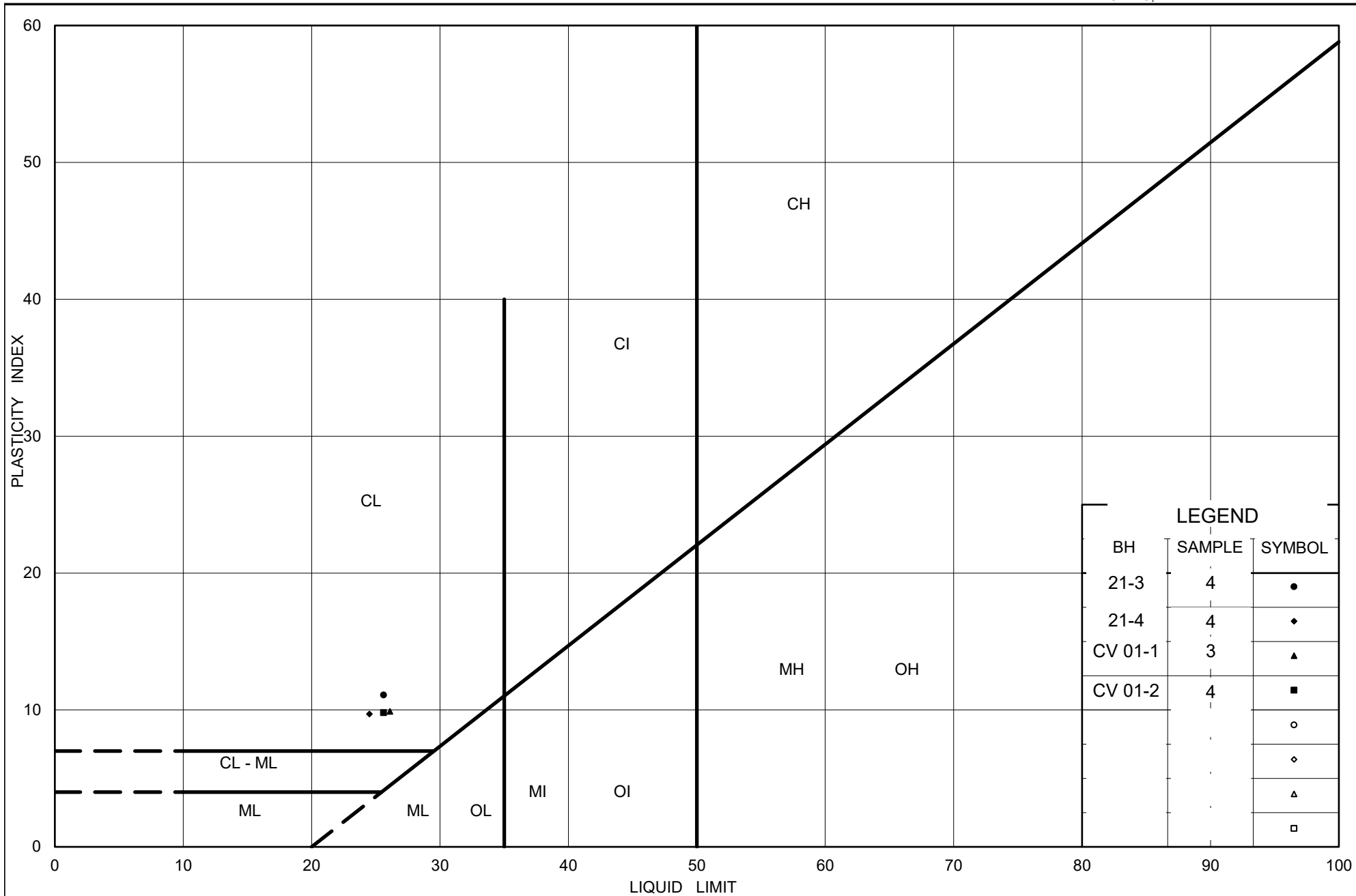
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	21-4	4	99.2
■	21-3	4	99.9

Project Number: 1530382

Checked By: KNN

Golder Associates

Date: 03-May-21



Ministry of Transportation

Ontario

PLASTICITY CHART

Sandy CLAYEY SILT (CL) to CLAYEY SILT and SAND (Till)
(CL/SC)

Figure No. B7

Project No. 1530382 (7000)

Checked By: KNN



Your Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Your C.O.C. #: 657051-08-01

Attention: Katelyn Nero

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

Report Date: 2021/02/12
Report #: R6516604
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C131632

Received: 2021/02/04, 16:47

Sample Matrix: Soil
Samples Received: 4

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Hot Water Extractable Boron	2	2021/02/08	2021/02/08	CAM SOP-00408	R153 Ana. Prot. 2011
Chloride (20:1 extract)	2	2021/02/09	2021/02/10	CAM SOP-00463	SM 23 4500-Cl E m
Free (WAD) Cyanide	2	2021/02/08	2021/02/09	CAM SOP-00457	OMOE E3015 m
Conductivity	2	2021/02/09	2021/02/09	CAM SOP-00414	OMOE E3530 v1 m
Conductivity	2	2021/02/09	2021/02/09	CAM SOP-00414	OMOE E3530 v1 m
Hexavalent Chromium in Soil by IC (1)	2	2021/02/08	2021/02/09	CAM SOP-00436	EPA 3060/7199 m
Strong Acid Leachable Metals by ICPMS	2	2021/02/08	2021/02/08	CAM SOP-00447	EPA 6020B m
Moisture	2	N/A	2021/02/05	CAM SOP-00445	Carter 2nd ed 51.2 m
pH CaCl ₂ EXTRACT	4	2021/02/09	2021/02/09	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2021/02/04	2021/02/09	CAM SOP-00414	SM 23 2510 m
Sodium Adsorption Ratio (SAR)	2	N/A	2021/02/09	CAM SOP-00102	EPA 6010C
Sulphate (20:1 Extract)	2	2021/02/09	2021/02/10	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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 Bureau Veritas, results relate to the supplied samples tested.



Your Project #: 1530382 (7000)
Site Location: OEWD/DIXIE
Your C.O.C. #: 657051-08-01

Attention: Katelyn Nero

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

Report Date: 2021/02/12
Report #: R6516604
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C131632

Received: 2021/02/04, 16:47

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) Soils are reported on a dry weight basis unless otherwise specified.

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: emese.gitej@bureauveritas.com

Phone# (905)817-5829

=====

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



BUREAU
VERITAS

BV Labs Job #: C131632
Report Date: 2021/02/12

Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM

SOIL CORROSIVITY PACKAGE (SOIL)

BV Labs ID		OTU460		OTU463			OTU463		
Sampling Date		2021/01/11		2021/02/02			2021/02/02		
COC Number		657051-08-01		657051-08-01			657051-08-01		
	UNITS	21-2_SA7	QC Batch	21-37_SA4	RDL	QC Batch	21-37_SA4 Lab-Dup	RDL	QC Batch
Calculated Parameters									
Resistivity	ohm-cm	2800	7185326	1400		7185326			
Inorganics									
Soluble (20:1) Chloride (Cl-)	ug/g	56	7191591	350	20	7191591			
Conductivity	umho/cm	363	7191480	705	2	7192297	702	2	7192297
Available (CaCl2) pH	pH	7.54	7191436	7.74		7191436	7.76		7191436
Soluble (20:1) Sulphate (SO4)	ug/g	<20	7191597	47	20	7191597			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate									

BUREAU
VERITASBV Labs Job #: C131632
Report Date: 2021/02/12Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM**O.REG 153 METALS & INORGANICS PKG (SOIL)**

BV Labs ID		OTU461			OTU461			OTU462		
Sampling Date		2021/01/11			2021/01/11			2021/01/12		
COC Number		657051-08-01			657051-08-01			657051-08-01		
	UNITS	21-2_SA8	RDL	QC Batch	21-2_SA8 Lab-Dup	RDL	QC Batch	21-8_SA9	RDL	QC Batch

Calculated Parameters										
Sodium Adsorption Ratio	N/A	2.9		7186111				2.0		7186111
Inorganics										
Conductivity	mS/cm	0.51	0.002	7191836				0.39	0.002	7191836
Moisture	%	19	1.0	7187631				21	1.0	7187631
Available (CaCl ₂) pH	pH	7.47		7191436				7.67		7191436
WAD Cyanide (Free)	ug/g	0.02	0.01	7189884				<0.01	0.01	7189884
Chromium (VI)	ug/g	<0.18	0.18	7189477				<0.18	0.18	7189477
Metals										
Hot Water Ext. Boron (B)	ug/g	1.4	0.050	7189614	1.3	0.050	7189614	0.75	0.050	7189614
Acid Extractable Antimony (Sb)	ug/g	<0.20	0.20	7189411				<0.20	0.20	7189411
Acid Extractable Arsenic (As)	ug/g	3.8	1.0	7189411				3.4	1.0	7189411
Acid Extractable Barium (Ba)	ug/g	41	0.50	7189411				91	0.50	7189411
Acid Extractable Beryllium (Be)	ug/g	0.30	0.20	7189411				0.57	0.20	7189411
Acid Extractable Boron (B)	ug/g	5.5	5.0	7189411				10	5.0	7189411
Acid Extractable Cadmium (Cd)	ug/g	0.12	0.10	7189411				<0.10	0.10	7189411
Acid Extractable Chromium (Cr)	ug/g	11	1.0	7189411				19	1.0	7189411
Acid Extractable Cobalt (Co)	ug/g	4.2	0.10	7189411				9.7	0.10	7189411
Acid Extractable Copper (Cu)	ug/g	9.5	0.50	7189411				21	0.50	7189411
Acid Extractable Lead (Pb)	ug/g	9.3	1.0	7189411				7.3	1.0	7189411
Acid Extractable Molybdenum (Mo)	ug/g	<0.50	0.50	7189411				<0.50	0.50	7189411
Acid Extractable Nickel (Ni)	ug/g	8.7	0.50	7189411				21	0.50	7189411
Acid Extractable Selenium (Se)	ug/g	<0.50	0.50	7189411				<0.50	0.50	7189411
Acid Extractable Silver (Ag)	ug/g	<0.20	0.20	7189411				<0.20	0.20	7189411
Acid Extractable Thallium (Tl)	ug/g	0.062	0.050	7189411				0.12	0.050	7189411
Acid Extractable Uranium (U)	ug/g	0.49	0.050	7189411				0.61	0.050	7189411
Acid Extractable Vanadium (V)	ug/g	21	5.0	7189411				28	5.0	7189411
Acid Extractable Zinc (Zn)	ug/g	33	5.0	7189411				49	5.0	7189411
Acid Extractable Mercury (Hg)	ug/g	<0.050	0.050	7189411				<0.050	0.050	7189411
RDL = Reportable Detection Limit										
QC Batch = Quality Control Batch										
Lab-Dup = Laboratory Initiated Duplicate										

BUREAU
VERITASBV Labs Job #: C131632
Report Date: 2021/02/12Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM

TEST SUMMARY

BV Labs ID: OTU460
Sample ID: 21-2_SA7
Matrix: SoilCollected: 2021/01/11
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7191591	2021/02/09	2021/02/10	Deonarine Ramnarine
Conductivity	AT	7191480	2021/02/09	2021/02/09	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7191436	2021/02/09	2021/02/09	Neil Dassanayake
Resistivity of Soil		7185326	2021/02/09	2021/02/09	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7191597	2021/02/09	2021/02/10	Deonarine Ramnarine

BV Labs ID: OTU461
Sample ID: 21-2_SA8
Matrix: SoilCollected: 2021/01/11
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Hot Water Extractable Boron	ICP	7189614	2021/02/08	2021/02/08	Archana Patel
Free (WAD) Cyanide	TECH	7189884	2021/02/08	2021/02/09	Gnana Thomas
Conductivity	AT	7191836	2021/02/09	2021/02/09	Tarunpreet Kaur
Hexavalent Chromium in Soil by IC	IC/SPEC	7189477	2021/02/08	2021/02/09	Violeta Porcila
Strong Acid Leachable Metals by ICPMS	ICP/MS	7189411	2021/02/08	2021/02/08	Daniel Teclu
Moisture	BAL	7187631	N/A	2021/02/05	Min Yang
pH CaCl2 EXTRACT	AT	7191436	2021/02/09	2021/02/09	Neil Dassanayake
Sodium Adsorption Ratio (SAR)	CALC/MET	7186111	N/A	2021/02/09	Automated Statchk

BV Labs ID: OTU461 Dup
Sample ID: 21-2_SA8
Matrix: SoilCollected: 2021/01/11
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Hot Water Extractable Boron	ICP	7189614	2021/02/08	2021/02/08	Archana Patel

BV Labs ID: OTU462
Sample ID: 21-8_SA9
Matrix: SoilCollected: 2021/01/12
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Hot Water Extractable Boron	ICP	7189614	2021/02/08	2021/02/08	Archana Patel
Free (WAD) Cyanide	TECH	7189884	2021/02/08	2021/02/09	Gnana Thomas
Conductivity	AT	7191836	2021/02/09	2021/02/09	Tarunpreet Kaur
Hexavalent Chromium in Soil by IC	IC/SPEC	7189477	2021/02/08	2021/02/09	Violeta Porcila
Strong Acid Leachable Metals by ICPMS	ICP/MS	7189411	2021/02/08	2021/02/08	Daniel Teclu
Moisture	BAL	7187631	N/A	2021/02/05	Min Yang
pH CaCl2 EXTRACT	AT	7191436	2021/02/09	2021/02/09	Neil Dassanayake
Sodium Adsorption Ratio (SAR)	CALC/MET	7186111	N/A	2021/02/09	Automated Statchk



BUREAU
VERITAS

BV Labs Job #: C131632
Report Date: 2021/02/12

Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM

TEST SUMMARY

BV Labs ID: OTU463
Sample ID: 21-37_SA4
Matrix: Soil

Collected: 2021/02/02
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7191591	2021/02/09	2021/02/10	Deonarine Ramnarine
Conductivity	AT	7192297	2021/02/09	2021/02/09	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7191436	2021/02/09	2021/02/09	Neil Dassanayake
Resistivity of Soil		7185326	2021/02/09	2021/02/09	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7191597	2021/02/09	2021/02/10	Deonarine Ramnarine

BV Labs ID: OTU463 Dup
Sample ID: 21-37_SA4
Matrix: Soil

Collected: 2021/02/02
Shipped:
Received: 2021/02/04

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	7192297	2021/02/09	2021/02/09	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7191436	2021/02/09	2021/02/09	Neil Dassanayake



BUREAU
VERITAS

BV Labs Job #: C131632
Report Date: 2021/02/12

Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM

GENERAL COMMENTS

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

Package 1	5.0°C
-----------	-------

Sample OTU461 [21-2_SA8] : Cyanide analysis: Sample received and analyzed past the recommended hold time.

Sample OTU462 [21-8_SA9] : Cyanide analysis: Sample received and analyzed past the recommended hold time.

Results relate only to the items tested.

BUREAU
VERITAS

BV Labs Job #: C131632

Report Date: 2021/02/12

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1530382 (7000)

Site Location: OEW/DIXIE

Sampler Initials: LM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7187631	Moisture	2021/02/05							5.9	20
7189411	Acid Extractable Antimony (Sb)	2021/02/08	91	75 - 125	96	80 - 120	<0.20	ug/g	NC	30
7189411	Acid Extractable Arsenic (As)	2021/02/08	92	75 - 125	97	80 - 120	<1.0	ug/g	NC	30
7189411	Acid Extractable Barium (Ba)	2021/02/08	93	75 - 125	97	80 - 120	<0.50	ug/g	3.7	30
7189411	Acid Extractable Beryllium (Be)	2021/02/08	94	75 - 125	95	80 - 120	<0.20	ug/g	NC	30
7189411	Acid Extractable Boron (B)	2021/02/08	91	75 - 125	91	80 - 120	<5.0	ug/g	NC	30
7189411	Acid Extractable Cadmium (Cd)	2021/02/08	93	75 - 125	97	80 - 120	<0.10	ug/g	NC	30
7189411	Acid Extractable Chromium (Cr)	2021/02/08	89	75 - 125	94	80 - 120	<1.0	ug/g	1.0	30
7189411	Acid Extractable Cobalt (Co)	2021/02/08	92	75 - 125	97	80 - 120	<0.10	ug/g	0.038	30
7189411	Acid Extractable Copper (Cu)	2021/02/08	92	75 - 125	97	80 - 120	<0.50	ug/g	0.23	30
7189411	Acid Extractable Lead (Pb)	2021/02/08	85	75 - 125	96	80 - 120	<1.0	ug/g	NC	30
7189411	Acid Extractable Mercury (Hg)	2021/02/08	79	75 - 125	88	80 - 120	<0.050	ug/g		
7189411	Acid Extractable Molybdenum (Mo)	2021/02/08	92	75 - 125	94	80 - 120	<0.50	ug/g	NC	30
7189411	Acid Extractable Nickel (Ni)	2021/02/08	93	75 - 125	100	80 - 120	<0.50	ug/g	4.9	30
7189411	Acid Extractable Selenium (Se)	2021/02/08	96	75 - 125	100	80 - 120	<0.50	ug/g	NC	30
7189411	Acid Extractable Silver (Ag)	2021/02/08	94	75 - 125	97	80 - 120	<0.20	ug/g	NC	30
7189411	Acid Extractable Thallium (Tl)	2021/02/08	85	75 - 125	96	80 - 120	<0.050	ug/g	NC	30
7189411	Acid Extractable Uranium (U)	2021/02/08	81	75 - 125	92	80 - 120	<0.050	ug/g	3.7	30
7189411	Acid Extractable Vanadium (V)	2021/02/08	90	75 - 125	95	80 - 120	<5.0	ug/g	0.82	30
7189411	Acid Extractable Zinc (Zn)	2021/02/08	93	75 - 125	98	80 - 120	<5.0	ug/g	5.3	30
7189477	Chromium (VI)	2021/02/09	70	70 - 130	97	80 - 120	<0.18	ug/g	NC	35
7189614	Hot Water Ext. Boron (B)	2021/02/08	96	75 - 125	109	75 - 125	<0.050	ug/g	6.9	40
7189884	WAD Cyanide (Free)	2021/02/09	80	75 - 125	97	80 - 120	<0.01	ug/g	NC	35
7191436	Available (CaCl2) pH	2021/02/09			100	97 - 103			0.25	N/A
7191480	Conductivity	2021/02/09			103	90 - 110	<2	umho/cm	3.2	10
7191591	Soluble (20:1) Chloride (Cl-)	2021/02/10	NC	70 - 130	102	70 - 130	<20	ug/g	14	35
7191597	Soluble (20:1) Sulphate (SO4)	2021/02/10	NC	70 - 130	108	70 - 130	<20	ug/g	3.5	35
7191836	Conductivity	2021/02/09			104	90 - 110	<0.002	mS/cm	1.0	10



BUREAU
VERITAS

BV Labs Job #: C131632

Report Date: 2021/02/12

QUALITY ASSURANCE REPORT(CONT'D)

Golder Associates Ltd

Client Project #: 1530382 (7000)

Site Location: OEW/DIXIE

Sampler Initials: LM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7192297	Conductivity	2021/02/09			104	90 - 110	<2	umho/cm	0.43	10
<p>N/A = Not Applicable</p> <p>Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.</p> <p>Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.</p> <p>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.</p> <p>Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.</p> <p>NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)</p> <p>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).</p>										



BUREAU
VERITAS

BV Labs Job #: C131632
Report Date: 2021/02/12

Golder Associates Ltd
Client Project #: 1530382 (7000)
Site Location: OEW/DIXIE
Sampler Initials: LM

VALIDATION SIGNATURE PAGE

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

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

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Page 1 of 1

Maxxam Analytics International Corporation o/a Maxxam Analytics



Your Project #: 1530382
Site Location: QEW / DIXIE
Your C.O.C. #: 808525-01-01

Attention: Katelyn Nero

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

Report Date: 2021/02/26
Report #: R6534387
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C147255

Received: 2021/02/22, 17:38

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Hot Water Extractable Boron	1	2021/02/24	2021/02/24	CAM SOP-00408	R153 Ana. Prot. 2011
Hot Water Extractable Boron	1	2021/02/25	2021/02/25	CAM SOP-00408	R153 Ana. Prot. 2011
Chloride (20:1 extract)	1	2021/02/24	2021/02/24	CAM SOP-00463	SM 23 4500-Cl E m
Free (WAD) Cyanide	2	2021/02/24	2021/02/25	CAM SOP-00457	OMOE E3015 m
Conductivity	1	2021/02/25	2021/02/25	CAM SOP-00414	OMOE E3530 v1 m
Conductivity	2	2021/02/25	2021/02/25	CAM SOP-00414	OMOE E3530 v1 m
Hexavalent Chromium in Soil by IC (1)	2	2021/02/24	2021/02/25	CAM SOP-00436	EPA 3060/7199 m
Strong Acid Leachable Metals by ICPMS	2	2021/02/24	2021/02/24	CAM SOP-00447	EPA 6020B m
Moisture	2	N/A	2021/02/23	CAM SOP-00445	Carter 2nd ed 51.2 m
pH CaCl ₂ EXTRACT	3	2021/02/24	2021/02/24	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2021/02/22	2021/02/25	CAM SOP-00414	SM 23 2510 m
Sodium Adsorption Ratio (SAR)	2	N/A	2021/02/26	CAM SOP-00102	EPA 6010C
Sulphate (20:1 Extract)	1	2021/02/24	2021/02/25	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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.



Your Project #: 1530382
Site Location: QEW / DIXIE
Your C.O.C. #: 808525-01-01

Attention: Katelyn Nero

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

Report Date: 2021/02/26
Report #: R6534387
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C147255

Received: 2021/02/22, 17:38

Results relate to samples tested. When sampling is not conducted by Bureau Veritas, 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) Soils are reported on a dry weight basis unless otherwise specified.

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: emese.gitej@bureauveritas.com

Phone# (905)817-5829

=====

This report has been generated and distributed using a secure automated process.

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



BUREAU
VERITAS

BV Labs Job #: C147255
Report Date: 2021/02/26

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW / DIXIE
Sampler Initials: LM

SOIL CORROSIVITY PACKAGE (SOIL)

BV Labs ID		OXC964			OXC964		
Sampling Date		2021/02/17			2021/02/17		
COC Number		808525-01-01			808525-01-01		
	UNITS	21-11-SA6	RDL	QC Batch	21-11-SA6 Lab-Dup	RDL	QC Batch
Calculated Parameters							
Resistivity	ohm-cm	820		7212116			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	710	20	7215342			
Conductivity	umho/cm	1230	2	7217633			
Available (CaCl2) pH	pH	7.79		7215151			
Soluble (20:1) Sulphate (SO4)	ug/g	84	20	7215361	77	20	7215361
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							

BUREAU
VERITASBV Labs Job #: C147255
Report Date: 2021/02/26Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW / DIXIE
Sampler Initials: LM**O.REG 153 METALS & INORGANICS PKG (SOIL)**

BV Labs ID		OXC963		OXC965		
Sampling Date		2021/02/10		2021/02/17		
COC Number		808525-01-01		808525-01-01		
	UNITS	21-4-SA5	QC Batch	21-11-SA3	RDL	QC Batch
Calculated Parameters						
Sodium Adsorption Ratio	N/A	2.6	7211706	11		7211706
Inorganics						
Conductivity	mS/cm	0.63	7217591	1.6	0.002	7217591
Moisture	%	10	7212928	18	1.0	7212928
Available (CaCl ₂) pH	pH	7.83	7215151	7.66		7215151
WAD Cyanide (Free)	ug/g	<0.01	7216332	<0.01	0.01	7216332
Chromium (VI)	ug/g	<0.18	7215680	<0.18	0.18	7215680
Metals						
Hot Water Ext. Boron (B)	ug/g	1.2	7214745	0.20	0.050	7217233
Acid Extractable Antimony (Sb)	ug/g	<0.20	7215032	<0.20	0.20	7215032
Acid Extractable Arsenic (As)	ug/g	5.4	7215032	<1.0	1.0	7215032
Acid Extractable Barium (Ba)	ug/g	41	7215032	12	0.50	7215032
Acid Extractable Beryllium (Be)	ug/g	0.84	7215032	<0.20	0.20	7215032
Acid Extractable Boron (B)	ug/g	15	7215032	<5.0	5.0	7215032
Acid Extractable Cadmium (Cd)	ug/g	<0.10	7215032	<0.10	0.10	7215032
Acid Extractable Chromium (Cr)	ug/g	23	7215032	10	1.0	7215032
Acid Extractable Cobalt (Co)	ug/g	14	7215032	2.7	0.10	7215032
Acid Extractable Copper (Cu)	ug/g	27	7215032	4.1	0.50	7215032
Acid Extractable Lead (Pb)	ug/g	7.7	7215032	3.2	1.0	7215032
Acid Extractable Molybdenum (Mo)	ug/g	<0.50	7215032	<0.50	0.50	7215032
Acid Extractable Nickel (Ni)	ug/g	31	7215032	4.9	0.50	7215032
Acid Extractable Selenium (Se)	ug/g	<0.50	7215032	<0.50	0.50	7215032
Acid Extractable Silver (Ag)	ug/g	<0.20	7215032	<0.20	0.20	7215032
Acid Extractable Thallium (Tl)	ug/g	0.098	7215032	<0.050	0.050	7215032
Acid Extractable Uranium (U)	ug/g	0.49	7215032	0.47	0.050	7215032
Acid Extractable Vanadium (V)	ug/g	29	7215032	28	5.0	7215032
Acid Extractable Zinc (Zn)	ug/g	68	7215032	13	5.0	7215032
Acid Extractable Mercury (Hg)	ug/g	<0.050	7215032	<0.050	0.050	7215032
RDL = Reportable Detection Limit						
QC Batch = Quality Control Batch						



BUREAU
VERITAS

BV Labs Job #: C147255
Report Date: 2021/02/26

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW / DIXIE
Sampler Initials: LM

TEST SUMMARY

BV Labs ID: OXC963
Sample ID: 21-4-SA5
Matrix: Soil

Collected: 2021/02/10
Shipped:
Received: 2021/02/22

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Hot Water Extractable Boron	ICP	7214745	2021/02/24	2021/02/24	Meghaben Patel
Free (WAD) Cyanide	TECH	7216332	2021/02/24	2021/02/25	Louise Harding
Conductivity	AT	7217591	2021/02/25	2021/02/25	Tarunpreet Kaur
Hexavalent Chromium in Soil by IC	IC/SPEC	7215680	2021/02/24	2021/02/25	Violeta Porcila
Strong Acid Leachable Metals by ICPMS	ICP/MS	7215032	2021/02/24	2021/02/24	Viviana Canzonieri
Moisture	BAL	7212928	N/A	2021/02/23	Mithunaa Sasitheepan
pH CaCl2 EXTRACT	AT	7215151	2021/02/24	2021/02/24	Neil Dassanayake
Sodium Adsorption Ratio (SAR)	CALC/MET	7211706	N/A	2021/02/26	Automated Statchk

BV Labs ID: OXC964
Sample ID: 21-11-SA6
Matrix: Soil

Collected: 2021/02/17
Shipped:
Received: 2021/02/22

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7215342	2021/02/24	2021/02/24	Alina Dobreanu
Conductivity	AT	7217633	2021/02/25	2021/02/25	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7215151	2021/02/24	2021/02/24	Neil Dassanayake
Resistivity of Soil		7212116	2021/02/25	2021/02/25	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7215361	2021/02/24	2021/02/25	Avneet Kour Sudan

BV Labs ID: OXC964 Dup
Sample ID: 21-11-SA6
Matrix: Soil

Collected: 2021/02/17
Shipped:
Received: 2021/02/22

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	7215361	2021/02/24	2021/02/25	Avneet Kour Sudan

BV Labs ID: OXC965
Sample ID: 21-11-SA3
Matrix: Soil

Collected: 2021/02/17
Shipped:
Received: 2021/02/22

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Hot Water Extractable Boron	ICP	7217233	2021/02/25	2021/02/25	Medhat Nasr
Free (WAD) Cyanide	TECH	7216332	2021/02/24	2021/02/25	Louise Harding
Conductivity	AT	7217591	2021/02/25	2021/02/25	Tarunpreet Kaur
Hexavalent Chromium in Soil by IC	IC/SPEC	7215680	2021/02/24	2021/02/25	Violeta Porcila
Strong Acid Leachable Metals by ICPMS	ICP/MS	7215032	2021/02/24	2021/02/24	Viviana Canzonieri
Moisture	BAL	7212928	N/A	2021/02/23	Mithunaa Sasitheepan
pH CaCl2 EXTRACT	AT	7215151	2021/02/24	2021/02/24	Neil Dassanayake
Sodium Adsorption Ratio (SAR)	CALC/MET	7211706	N/A	2021/02/26	Automated Statchk



BUREAU
VERITAS

BV Labs Job #: C147255
Report Date: 2021/02/26

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW / DIXIE
Sampler Initials: LM

GENERAL COMMENTS

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

Package 1	5.3°C
-----------	-------

Results relate only to the items tested.

BUREAU
VERITAS

BV Labs Job #: C147255

Report Date: 2021/02/26

QUALITY ASSURANCE REPORT

Golder Associates Ltd

Client Project #: 1530382

Site Location: QEW / DIXIE

Sampler Initials: LM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7212928	Moisture	2021/02/23							2.8	20
7214745	Hot Water Ext. Boron (B)	2021/02/24	93	75 - 125	95	75 - 125	<0.050	ug/g	NC	40
7215032	Acid Extractable Antimony (Sb)	2021/02/24	98	75 - 125	103	80 - 120	<0.20	ug/g		
7215032	Acid Extractable Arsenic (As)	2021/02/24	NC	75 - 125	99	80 - 120	<1.0	ug/g	7.1	30
7215032	Acid Extractable Barium (Ba)	2021/02/24	91	75 - 125	98	80 - 120	<0.50	ug/g		
7215032	Acid Extractable Beryllium (Be)	2021/02/24	101	75 - 125	102	80 - 120	<0.20	ug/g		
7215032	Acid Extractable Boron (B)	2021/02/24	98	75 - 125	101	80 - 120	<5.0	ug/g		
7215032	Acid Extractable Cadmium (Cd)	2021/02/24	98	75 - 125	102	80 - 120	<0.10	ug/g		
7215032	Acid Extractable Chromium (Cr)	2021/02/24	94	75 - 125	96	80 - 120	<1.0	ug/g		
7215032	Acid Extractable Cobalt (Co)	2021/02/24	97	75 - 125	99	80 - 120	<0.10	ug/g		
7215032	Acid Extractable Copper (Cu)	2021/02/24	93	75 - 125	99	80 - 120	<0.50	ug/g		
7215032	Acid Extractable Lead (Pb)	2021/02/24	93	75 - 125	101	80 - 120	<1.0	ug/g		
7215032	Acid Extractable Mercury (Hg)	2021/02/24	84	75 - 125	94	80 - 120	<0.050	ug/g		
7215032	Acid Extractable Molybdenum (Mo)	2021/02/24	94	75 - 125	97	80 - 120	<0.50	ug/g		
7215032	Acid Extractable Nickel (Ni)	2021/02/24	96	75 - 125	99	80 - 120	<0.50	ug/g		
7215032	Acid Extractable Selenium (Se)	2021/02/24	98	75 - 125	103	80 - 120	<0.50	ug/g		
7215032	Acid Extractable Silver (Ag)	2021/02/24	98	75 - 125	104	80 - 120	<0.20	ug/g		
7215032	Acid Extractable Thallium (Tl)	2021/02/24	94	75 - 125	100	80 - 120	<0.050	ug/g		
7215032	Acid Extractable Uranium (U)	2021/02/24	95	75 - 125	100	80 - 120	<0.050	ug/g	4.0	30
7215032	Acid Extractable Vanadium (V)	2021/02/24	93	75 - 125	96	80 - 120	<5.0	ug/g		
7215032	Acid Extractable Zinc (Zn)	2021/02/24	98	75 - 125	101	80 - 120	<5.0	ug/g		
7215151	Available (CaCl ₂) pH	2021/02/24			100	97 - 103			0.32	N/A
7215342	Soluble (20:1) Chloride (Cl ⁻)	2021/02/24	NC	70 - 130	105	70 - 130	<20	ug/g	6.5	35
7215361	Soluble (20:1) Sulphate (SO ₄)	2021/02/25	NC	70 - 130	106	70 - 130	<20	ug/g	8.6	35
7215680	Chromium (VI)	2021/02/25	85	70 - 130	94	80 - 120	<0.18	ug/g	NC	35
7216332	WAD Cyanide (Free)	2021/02/25	93	75 - 125	96	80 - 120	<0.01	ug/g	NC	35
7217233	Hot Water Ext. Boron (B)	2021/02/25	106	75 - 125	100	75 - 125	<0.050	ug/g	3.0	40
7217591	Conductivity	2021/02/25			101	90 - 110	<0.002	mS/cm	1.5	10



BUREAU
VERITAS

BV Labs Job #: C147255

Report Date: 2021/02/26

QUALITY ASSURANCE REPORT(CONT'D)

Golder Associates Ltd

Client Project #: 1530382

Site Location: QEW / DIXIE

Sampler Initials: LM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7217633	Conductivity	2021/02/25			103	90 - 110	<2	umho/cm	1.2	10
<p>N/A = Not Applicable</p> <p>Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.</p> <p>Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.</p> <p>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.</p> <p>Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.</p> <p>NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)</p> <p>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).</p>										



BUREAU
VERITAS

BV Labs Job #: C147255
Report Date: 2021/02/26

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW / DIXIE
Sampler Initials: LM

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

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



Bureau Veritas Laboratories
6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel: (905) 817-5700 Toll-free 800-563-6266 Fax: (905) 817-5777 www.bvlab.com

22-Feb-21 17:38

Page of

Ema Gitej

C147255

ily:

Bottle Order #:

808525

Project Manager:

Ema Gitej

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: CanadaAccountsPayableInvoices@golder.com

REPORT TO:
Company Name: GOLDER ASSOCIATES
Attention: Sandra McGaghren, Katelyn Nero
Address: 6925 Century Ave, Suite 100
MISSISSAUGA ON L5N 7K2
Tel: 905 567 4444 Fax: knero@golder.com
Email: smcaghren@golder.com

PROJECT INFORMATION:
Quotation #: B80683
P.O. #:
Project: 1530382 MAF ENV-678
Project Name: CREW/DIXIE
Site #: LM/ACK
Sampled By:

MAF

ENV-678

COC #:

C#808525-01-01

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

Regulation 153 (2011)
☐ Table 1 ☐ Res/Park ☐ Medium/Fine
☐ Table 2 ☐ Ind/Comm ☐ Coarse
☐ Table 3 ☐ Agri/Other ☐ For RSC
☐ Table
Other Regulations
☐ CCME ☐ Sanitary Sewer Bylaw
☐ Reg 558 ☐ Storm Sewer Bylaw
☐ MISA Municipality
☐ PWQO ☐ Reg 406 Table
☐ Other
Special Instructions

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

Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix
1	21-4-SAS	2021/02/12	PM	SOIL
2	21-4-SAS	2021/02/12	PM	SOIL
3	21-4-SAS	2021/02/12	PM	SOIL
4				
5	21-11-SAG	2021/02/17	PM	SOIL
6	21-11-SAG	2021/02/17	PM	SOIL
7				
8				
9				
10				

Field Filtered (please circle):
Metals / Hg / Cr / VI

O Reg 558 TCLP Inorganics Package

O Reg 153 Metals & Inorganics Pkg

Soil Corrosivity Package (short list)

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

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 #)

of Bottles

Comments

* RELINQUISHED BY: (Signature/Print)

Date: (YY/MM/DD)

Time

RECEIVED BY: (Signature/Print)

Date: (YY/MM/DD)

Time

jars used and not submitted

Laboratory Use Only

Time Sensitive

Temperature (°C) on Recei

Custody Seal

Present

Intact

Yes

No

White: BV Labs Yellow: Client

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BV LABS' 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.BVLABS.COM/TERMS-AND-CONDITIONS.

* 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 WWW.BVLABS.COM/RESOURCES/CHAIN-OF-CUSTODY-FORMS.

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

Bureau Veritas Canada (2019) Inc.



Your Project #: 1530382
Site Location: QEW DIXIE
Your C.O.C. #: 808525-02-01

Attention: Katelyn Nero

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

Report Date: 2021/03/25
Report #: R6568677
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C173818

Received: 2021/03/19, 14:00

Sample Matrix: Rock
Samples Received: 2

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	2	2021/03/24	2021/03/24	CAM SOP-00463	SM 23 4500-Cl E m
Conductivity	2	2021/03/24	2021/03/24	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	2	2021/03/23	2021/03/23	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2021/03/19	2021/03/24	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	2021/03/24	2021/03/24	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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 Bureau Veritas, 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 #: 1530382
Site Location: QEW DIXIE
Your C.O.C. #: 808525-02-01

Attention: Katelyn Nero

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

Report Date: 2021/03/25
Report #: R6568677
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C173818
Received: 2021/03/19, 14:00

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: emese.gitej@bureauveritas.com
Phone# (905)817-5829

=====

This report has been generated and distributed using a secure automated process.

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



BUREAU
VERITAS

BV Labs Job #: C173818
Report Date: 2021/03/25

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW DIXIE
Sampler Initials: LM

SOIL CORROSIVITY PACKAGE (ROCK)

BV Labs ID		PCT995	PCT996		
Sampling Date		2021/01/15	2021/02/11		
COC Number		808525-02-01	808525-02-01		
	UNITS	21-34-6.08 TO 6.16	21-4-5.18 TO 5.28	RDL	QC Batch
Calculated Parameters					
Resistivity	ohm-cm	3400	2000		7258172
Inorganics					
Soluble (20:1) Chloride (Cl-)	ug/g	<20	110	20	7264059
Conductivity	umho/cm	295	498	2	7264243
Available (CaCl2) pH	pH	8.62	9.04		7261447
Soluble (20:1) Sulphate (SO4)	ug/g	46	66	20	7264104
RDL = Reportable Detection Limit					
QC Batch = Quality Control Batch					



BUREAU
VERITAS

BV Labs Job #: C173818
Report Date: 2021/03/25

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW DIXIE
Sampler Initials: LM

TEST SUMMARY

BV Labs ID: PCT995
Sample ID: 21-34-6.08 TO 6.16
Matrix: Rock

Collected: 2021/01/15
Shipped:
Received: 2021/03/19

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7264059	2021/03/24	2021/03/24	Avneet Kour Sudan
Conductivity	AT	7264243	2021/03/24	2021/03/24	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7261447	2021/03/23	2021/03/23	Surinder Rai
Resistivity of Soil		7258172	2021/03/24	2021/03/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7264104	2021/03/24	2021/03/24	Avneet Kour Sudan

BV Labs ID: PCT996
Sample ID: 21-4-5.18TO 5.28
Matrix: Rock

Collected: 2021/02/11
Shipped:
Received: 2021/03/19

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7264059	2021/03/24	2021/03/24	Avneet Kour Sudan
Conductivity	AT	7264243	2021/03/24	2021/03/24	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7261447	2021/03/23	2021/03/23	Surinder Rai
Resistivity of Soil		7258172	2021/03/24	2021/03/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7264104	2021/03/24	2021/03/24	Avneet Kour Sudan



BUREAU
VERITAS

BV Labs Job #: C173818
Report Date: 2021/03/25

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW DIXIE
Sampler Initials: LM

GENERAL COMMENTS

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

Package 1	3.0°C
-----------	-------

Results relate only to the items tested.



BUREAU
VERITAS

BV Labs Job #: C173818

Report Date: 2021/03/25

QUALITY ASSURANCE REPORT

Golder Associates Ltd

Client Project #: 1530382

Site Location: QEW DIXIE

Sampler Initials: LM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7261447	Available (CaCl ₂) pH	2021/03/23			100	97 - 103			0.10	N/A
7264059	Soluble (20:1) Chloride (Cl ⁻)	2021/03/24	NC	70 - 130	98	70 - 130	<20	ug/g	13	35
7264104	Soluble (20:1) Sulphate (SO ₄)	2021/03/24	118	70 - 130	104	70 - 130	<20	ug/g	NC	35
7264243	Conductivity	2021/03/24			103	90 - 110	<2	umho/cm	4.0	10

N/A = Not Applicable

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

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

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

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

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

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



BUREAU
VERITAS

BV Labs Job #: C173818
Report Date: 2021/03/25

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW DIXIE
Sampler Initials: LM

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

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Your Project #: 1530382
Site Location: QEW-CAWTHRA
Your C.O.C. #: 70344

Attention: Alysha Kobylinski

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

Report Date: 2016/11/19
Report #: R4252452
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B605411

Received: 2016/11/10, 17:14

Sample Matrix: SOLID
Samples Received: 5

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride (20:1 extract)	5	N/A	2016/11/16	CAM SOP-00463	EPA 325.2 m
Conductivity	5	N/A	2016/11/16	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	5	2016/11/16	2016/11/16	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	5	2016/11/10	2016/11/17	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	5	N/A	2016/11/16	CAM SOP-00464	EPA 375.4 m

Remarks:

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

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

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.

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.

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 #: 1530382
Site Location: QEW-CAWTHRA
Your C.O.C. #: 70344

Attention: Alysha Kobylinski

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

Report Date: 2016/11/19
Report #: R4252452
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6O5411
Received: 2016/11/10, 17:14

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.

RESULTS OF ANALYSES OF SOLID

Maxxam ID		DKV715	DKV715		DKV716		
Sampling Date		2016/11/03	2016/11/03		2016/11/10		
COC Number		70344	70344		70344		
	UNITS	RW3-3-4.33M-4.43M	RW3-3-4.33M-4.43M Lab-Dup	QC Batch	OHS-4-SA4-2.29M-2.59M	RDL	QC Batch

Calculated Parameters							
Resistivity	ohm-cm	2000		4745989	850		4745989
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g	<20		4748291	500	20	4748291
Conductivity	umho/cm	499		4749169	1180	2	4749169
Available (CaCl ₂) pH	pH	8.18		4750330	7.92		4750333
Soluble (20:1) Sulphate (SO ₄)	ug/g	250	230	4748348	270	20	4748348
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							

Maxxam ID		DKV716		DKV717	DKV718		
Sampling Date		2016/11/10		2016/11/10	2016/11/03		
COC Number		70344		70344	70344		
	UNITS	OHS-4-SA4-2.29M-2.59M Lab-Dup	QC Batch	OHS-5-SA5-3.81M-4.42M	CV01-01-8.74M-8.80M	RDL	QC Batch

Calculated Parameters							
Resistivity	ohm-cm		4745989	1400	1000		4745989
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g		4748291	40	260	20	4748291
Conductivity	umho/cm		4749169	720	965	2	4749169
Available (CaCl ₂) pH	pH	7.90	4750333	7.86	8.14		4750330
Soluble (20:1) Sulphate (SO ₄)	ug/g		4748348	560	320	20	4748348
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							

Maxxam Job #: B605411
Report Date: 2016/11/19

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW-CAWTHRA
Sampler Initials: AJ

RESULTS OF ANALYSES OF SOLID

Maxxam ID		DKV719		
Sampling Date		2016/11/03		
COC Number		70344		
	UNITS	CV02/3-1-5.27M-5.32M	RDL	QC Batch
Calculated Parameters				
Resistivity	ohm-cm	1500		4745989
Inorganics				
Soluble (20:1) Chloride (Cl)	ug/g	100	20	4748291
Conductivity	umho/cm	682	2	4749169
Available (CaCl2) pH	pH	8.01		4750330
Soluble (20:1) Sulphate (SO4)	ug/g	250	20	4748348
RDL = Reportable Detection Limit				
QC Batch = Quality Control Batch				

TEST SUMMARY

Maxxam ID: DKV715
Sample ID: RW3-3-4.33M-4.43M
Matrix: SOLID

Collected: 2016/11/03
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4748291	N/A	2016/11/16	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750330	2016/11/16	2016/11/16	Neil Dassanayake
Resistivity of Soil		4745989	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

Maxxam ID: DKV715 Dup
Sample ID: RW3-3-4.33M-4.43M
Matrix: SOLID

Collected: 2016/11/03
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

Maxxam ID: DKV716
Sample ID: OHS-4-SA4-2.29M-2.59M
Matrix: SOLID

Collected: 2016/11/10
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4748291	N/A	2016/11/16	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750333	2016/11/16	2016/11/16	Neil Dassanayake
Resistivity of Soil		4745989	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

Maxxam ID: DKV716 Dup
Sample ID: OHS-4-SA4-2.29M-2.59M
Matrix: SOLID

Collected: 2016/11/10
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	4750333	2016/11/16	2016/11/16	Neil Dassanayake

Maxxam ID: DKV717
Sample ID: OHS-5-SA5-3.81M-4.42M
Matrix: SOLID

Collected: 2016/11/10
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4748291	N/A	2016/11/16	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750330	2016/11/16	2016/11/16	Neil Dassanayake
Resistivity of Soil		4745989	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

Maxxam Job #: B605411
Report Date: 2016/11/19

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW-CAWTHRA
Sampler Initials: AJ

TEST SUMMARY

Maxxam ID: DKV718
Sample ID: CV01-01-8.74M-8.80M
Matrix: SOLID

Collected: 2016/11/03
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4748291	N/A	2016/11/16	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750330	2016/11/16	2016/11/16	Neil Dassanayake
Resistivity of Soil		4745989	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

Maxxam ID: DKV719
Sample ID: CV02/3-1-5.27M-5.32M
Matrix: SOLID

Collected: 2016/11/03
Shipped:
Received: 2016/11/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4748291	N/A	2016/11/16	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750330	2016/11/16	2016/11/16	Neil Dassanayake
Resistivity of Soil		4745989	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4748348	N/A	2016/11/16	Deonarine Ramnarine

GENERAL COMMENTS

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

Package 1	14.0°C
-----------	--------

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1530382
Site Location: QEW-CAWTHRA
Sampler Initials: AJ

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4748291	Soluble (20:1) Chloride (Cl)	2016/11/16	NC	70 - 130	108	70 - 130	<20	ug/g	0.49	35
4748348	Soluble (20:1) Sulphate (SO4)	2016/11/16	NC	70 - 130	107	70 - 130	<20	ug/g	9.4	35
4749169	Conductivity	2016/11/16			99	90 - 110	<2	umho/cm	0.93	10
4750330	Available (CaCl2) pH	2016/11/16			99	97 - 103			0.28	N/A
4750333	Available (CaCl2) pH	2016/11/16			99	97 - 103			0.26	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.

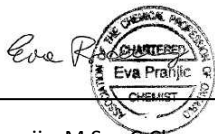
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

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

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).


VALIDATION SIGNATURE PAGE

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



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

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.

INVOICE INFORMATION				REPORT INFORMATION (if differs from invoice)				PROJECT INFORMATION				MAXXAM JOB NUMBER																																							
Company Name: <u>Golder Associates</u>				Company Name: _____				Quotation #: _____				00																																							
Contact Name: <u>Alysha Kobylinski</u>				Contact Name: _____				P.O. #: _____																																											
Address: <u>6925 CENTURY AVE, SUITE 100</u>				Address: _____				Project #: <u>1530382</u>																																											
City: <u>MISSISSAUGA, ON</u>				City: _____				Site Location: <u>QEW - CAWTHRA</u>																																											
Phone: <u>647-618-1364</u> Fax: <u>905-567-6561</u>				Phone: _____ Fax: _____				Site #: _____																																											
Email: <u>Alysha_Kobylinski@golder.com</u>				Email: _____				Sampled By: _____																																											
<p>***Note: For MOE Regulated Drinking Water samples, please use the Drinking Water CoC.***</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th colspan="4">Regulation 153 (2011)</th> <th colspan="4">Other Regulations</th> </tr> <tr> <td>Table 1</td> <td>Res/Park</td> <td>Med/Fine</td> <td>CCME</td> <td>Table 2</td> <td>Ind/Comm</td> <td>Coarse</td> <td>Reg. 558</td> </tr> <tr> <td>Table 3</td> <td>Agri/Other</td> <td>For RSC</td> <td>MISA</td> <td>Table 4</td> <td>For RSC</td> <td>Yes</td> <td>PWQO</td> </tr> <tr> <td></td> <td></td> <td>No</td> <td>Other (specify):</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>												Regulation 153 (2011)				Other Regulations				Table 1	Res/Park	Med/Fine	CCME	Table 2	Ind/Comm	Coarse	Reg. 558	Table 3	Agri/Other	For RSC	MISA	Table 4	For RSC	Yes	PWQO			No	Other (specify):					ANALYSIS REQUESTED (Please be specific)				TURNAROUND TIME (TAT) REQUIRED			
Regulation 153 (2011)				Other Regulations																																															
Table 1	Res/Park	Med/Fine	CCME	Table 2	Ind/Comm	Coarse	Reg. 558																																												
Table 3	Agri/Other	For RSC	MISA	Table 4	For RSC	Yes	PWQO																																												
		No	Other (specify):																																																
CORROSIVITY PACKAGE								PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS.																																											
								Regular (Standard) TAT: <input checked="" type="checkbox"/> (5-7 working days for most tests)																																											
								Rush TAT: <input type="checkbox"/> (Samples must be received by 3pm to guarantee your TAT)																																											
								Rush Confirmation #: PN _____																																											
								Date Req'd: _____																																											
								TATs for certain tests are > 5 days. Please contact your Project Manager for details.																																											
								COMMENTS / TAT COMMENTS																																											
								<p>10-Nov-16 17:14</p> <p>Ema Gitej</p>  <p>B605411</p> <p>KP7 ENV-803</p>																																											
*RELINQUISHED BY (Signature/Print)				Date (YYYY/MM/DD)				Time				*RECEIVED BY (Signature/Print)				Date (YYYY/MM/DD)				Time				#JARS USED AND NOT SUBMITTED				Laboratory Use Only																							
Amela Jewison				2016/11/10				17:10				[Signature]				2016/11/10				17:14								<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>Custody Seal</td> <td>Yes</td> <td>No</td> <td rowspan="3">Temperature (°C) on Receipt</td> </tr> <tr> <td>Present</td> <td></td> <td></td> </tr> <tr> <td>Intact</td> <td></td> <td></td> </tr> </table>				Custody Seal	Yes	No	Temperature (°C) on Receipt	Present			Intact												
Custody Seal	Yes	No	Temperature (°C) on Receipt																																																
Present																																																			
Intact																																																			

***MANDATORY SECTIONS IN GREY MUST BE FILLED OUT. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.**

COC-1004 (10/11) - ENV. ENG.

Maxxam Analytics International Corporation o/a Maxxam Analytics

White: Maxxam

Yellow: M... Pink: Client

APPENDIX C

Geotechnical Laboratory Testing Results – Bedrock

April 8, 2021

Ms. Katie Nero
Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario
Canada L5N 7K2

Re: UCS, BD, CERCHAR, and Slake testing (Golder Project No. 1530382-7000)

Dear Ms. Nero

On March 19th, 2021, a total of seventeen (17) HQ-sized rock core samples were received by Geomechanica Inc. via drop-off by Golder personnel. These samples were identified as being from project 1530382-7000. From these samples, six (6) UCS, three (3) BD, five (5) CERCHAR Abrasivity, and three (3) Slake Durability were prepared and tested.

Details regarding the steps of specimen preparation and testing are presented in the accompanying laboratory report and summary spreadsheets.

Sincerely,



Bryan Tatone Ph.D., P. Eng.

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

Rock Laboratory Testing Results

A report submitted to:

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

Prepared by:

Bryan Tatone, PhD, PEng
Omid Mahabadi, PhD, PEng
Geomechanica Inc.
#900-390 Bay St.
Toronto ON
M5H 2Y2 Canada
Tel: +1-647-478-9767
lab@geomechanica.com

April 8, 2021

Project number: 1530382-7000

Abstract

This document summarizes the results of rock laboratory testing, including 6 Uniaxial Compression Strength (UCS) tests, 3 Brazilian Disc (BD) tensile strength tests, 5 CERCHAR Abrasivity tests, and 3 Slake Durability tests. The results for each test type presented in separate sub-sections herein.

In this document:

1	Uniaxial Compressive Strength Tests	1
2	Brazilian Disc Tests	4
3	CERCHAR Abrasivity Tests	6
4	Slake Durability	10
	Appendices	12
A	UCS specimen sheets	12
B	BD specimen sheets	19

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 (Figure 1). The preparation and testing procedure for each specimen included the following:

1. Unwrapping 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 the core sample to obtain cylindrical specimens with an appropriate length (length:diameter = 2:1) and nearly parallel end faces.
3. Diamond grinding of the specimen to obtain flat (within ± 0.025 mm) and parallel end faces (within 0.25°).
4. Placing the 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 and axial deformation to determine the peak strength (UCS) and tangent Young's modulus.



Figure 1: Forney loading frame setup for UCS testing.

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 D4543-19. The side straightness criteria, as checked with a feeler gauge, and the minimum length:diameter criteria were met for all specimens unless noted otherwise in Table 1. Testing of the specimens followed ASTM D7012-14 with the following note:

- Testing included measurement of the UCS and elastic modulus, but not the Poisson's ratio. This represents a hybrid between Methods C and D of ASTM D7012-14.

1.2 Results

The results of UCS testing are summarized in Table 1. The corresponding stress-strain curves for the uniaxial compression tests are presented in Figure 2. The Young's modulus is the tangent modulus calculated as the slope of the best-fit line through 600 data points defining the stress-strain curve. Typically the modulus is defined at 50% of the UCS strength. However, due to prevalent non-linear stress-strain behaviour, custom stress ranges (where specimens deformed linearly) were selected for moduli determination. These stress ranges are provided in the summary spreadsheet that accompanies this report. Please note that additional specimen details and measurements are provided in the summary spreadsheet that accompanies this report.

Table 1: Summary of Uniaxial Compression test results.

Sample	Depth (m)	Bulk density ρ (g/cm ³)	UCS (MPa)	Young's modulus E (GPa)	Lithology	Failure description
21-34-7.82to7.95m	7.82 - 7.95	2.620	19.1	2.5	Siltstone, Limestone and Shale	1
21-35-7.4to7.56m	7.40 - 7.56	2.585	7.3	0.4	Shale and Siltstone	2, 3, 4
21-37-7.08to7.3m	7.08 - 7.30	2.627	20.1	2.0	Siltstone, Limestone, and Shale	5, 3
21-36-9.92to10.07m	9.92 - 10.07	2.541	8.5	0.6	Siltstone, Limestone, and Shale	1, 3, 6
21-3-6.47to6.7m	6.47 - 6.70	2.621	6.3	1.2	Siltstone and Shale	1
21-4-7.44to7.58m	7.44 - 7.58	2.632	23.0	3.4	Siltstone, Limestone, and Shale	5

¹ Axial splitting failure

² Inclined shear failure

³ Specimen emitted saline pore water upon loading

⁴ Failure partly along pre-existing structure

⁵ Partial hourglass failure

⁶ Failure localized in softer shale layer

1.3 Specimen photographs

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

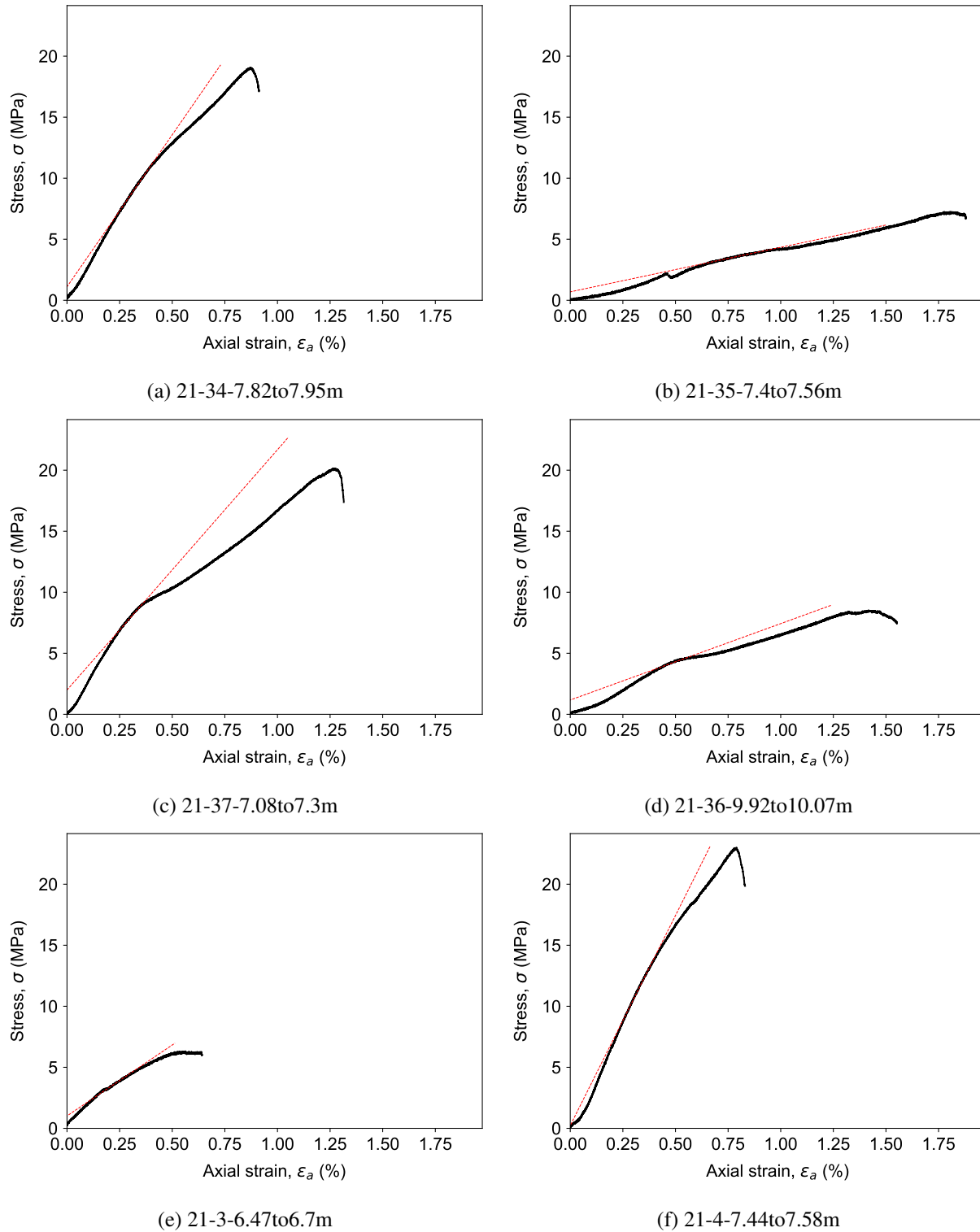


Figure 2: Measured stress-strain curves.

2 Brazilian Disc Tests

2.1 Overview

This section summarizes the results of Brazilian disc testing. The tests were performed using a 12 ton Carver hydraulic loading frame coupled to a SPX hydraulic pump fitted with a pressure-compensated flow control valve (Figure 3). A consistent displacement rate of approximately 0.175 mm/min was employed for all tests. The specimen preparation and testing procedure 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 and possible damage during subsequent specimen preparation.
2. Diamond cutting of core samples to obtain disc specimens with nearly flat (within 0.5 mm) and parallel (within 0.5° end faces and a thickness approximately equal to the core radius. From each core sample as many discs as possible (given the available core sample length) were prepared and tested.
3. Diametric loading of disc specimens to rupture using a hydraulic loading frame equipped with fixed flat loading platens. The applied force and diametric displacement were continuously measured to calculate the indirect tensile strength. Note that a strip of tape and cardboard was placed on the specimens at the platen contact points to act as a cushion to distribute the applied load over the thickness of the sample.

The above Brazilian disc testing procedure adhered to ASTM D3967-16.

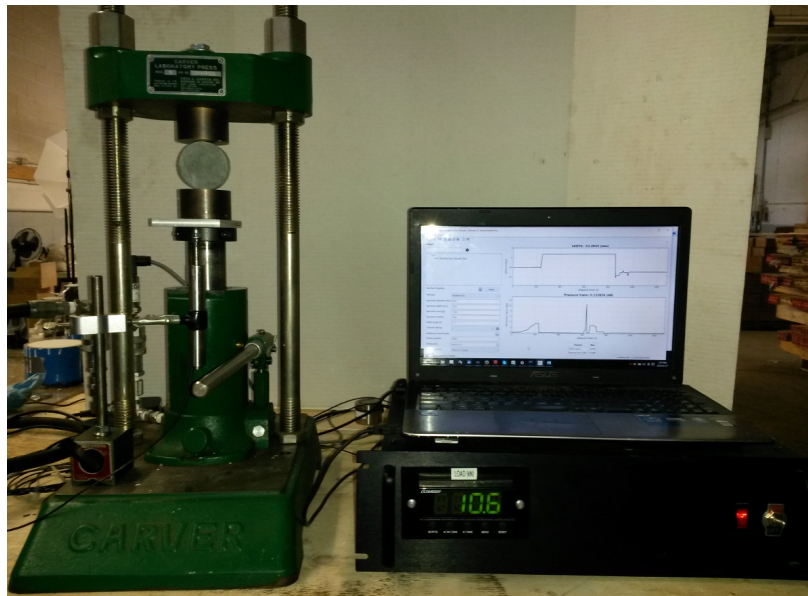


Figure 3: Brazilian disc testing setup.

2.2 Results

A summary of the Brazilian disc testing results are provided in Table 2. Additional details and measurements for the test specimens are included in the accompanying summary spreadsheet. The indirect tensile strength, σ_t , was calculated, as:

$$\sigma_t = \frac{2P}{\pi Dt} \quad (1)$$

where P is the peak diametric load; D is the specimen diameter; and t is the specimen thickness.

It must be noted that some Brazilian disc specimen did not fail via diametric splitting. Some failed via a combination of diametric splitting and fissility delamination, while others simply failed at the platen contact points or by fissility delamination alone. The failure mode of each disc is noted in the last column of the summary table.

Table 2: Summary of Brazilian Disc test results.

Borehole	Sample	Disc	Depth (m)	Bulk density ρ (g/cm ³)	Tensile strength (MPa)	Lithology	Failure description
21-34	21-34-7.29to7.4m	1	7.29 - 7.40	2.578	2.7	Siltstone and Limestone	1
		2		2.602	2.4	Siltstone and Limestone	1
				Average	2.5		
				Standard deviation	0.1		
21-37	21-37-8.42to8.56m	1	8.42 - 8.56	2.609	5.0	Limestone and Siltstone	2, 3
		2		2.609	1.7	Siltstone	4
		3		2.580	3.0	Siltstone and Limestone	1
		4		2.611	3.3	Limestone	4, 3
				Average	3.3		
				Standard deviation	1.2		
21-4	21-4-8.04to8.14m	1	8.04 - 8.14	2.608	2.1	Siltstone and Limestone	1
		2		2.638	3.0	Siltstone and Limestone	1
				Average	2.5		
				Standard deviation	0.4		

¹ Diametric failure

² Partial diametric failure

³ Failure along pre-existing structure

⁴ Non-diametric failure

2.3 Specimen photographs

Photographs of the specimens prior to and after testing are presented in the Appendix of this report.

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 4a. The tips of the styluses were sharpened to a conical angle of 90° using the setup shown in Figure 4b. The styluses used to perform the tests are shown in Figure 4c-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 for each sample, which followed ASTM D7625-10, proceeded as follows:

1. The tips of the five styluses were sharpened using the grinding apparatus (Figure 4b).
2. The styluses were 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 consisted of pieces HQ core with fresh fracture surface perpendicular to the core axis.
4. The specimen was secured in the cross-slide vise of the testing apparatus and the stylus carefully lowered on to the surface of the rock.
5. A scratch measuring 10 mm in length was created over a duration of 10 seconds. This process was repeated with all five styluses on undisturbed parts of the specimen surface (e.g., Figure 5a).
6. Lastly, the worn tips were re-examined under the microscope. From three scaled photos (120° apart), the wear flat, d , was measured (e.g., Figure 5c).

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 5b-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. Further specimen and testing details are included in the summary spreadsheet that accompanies this report.

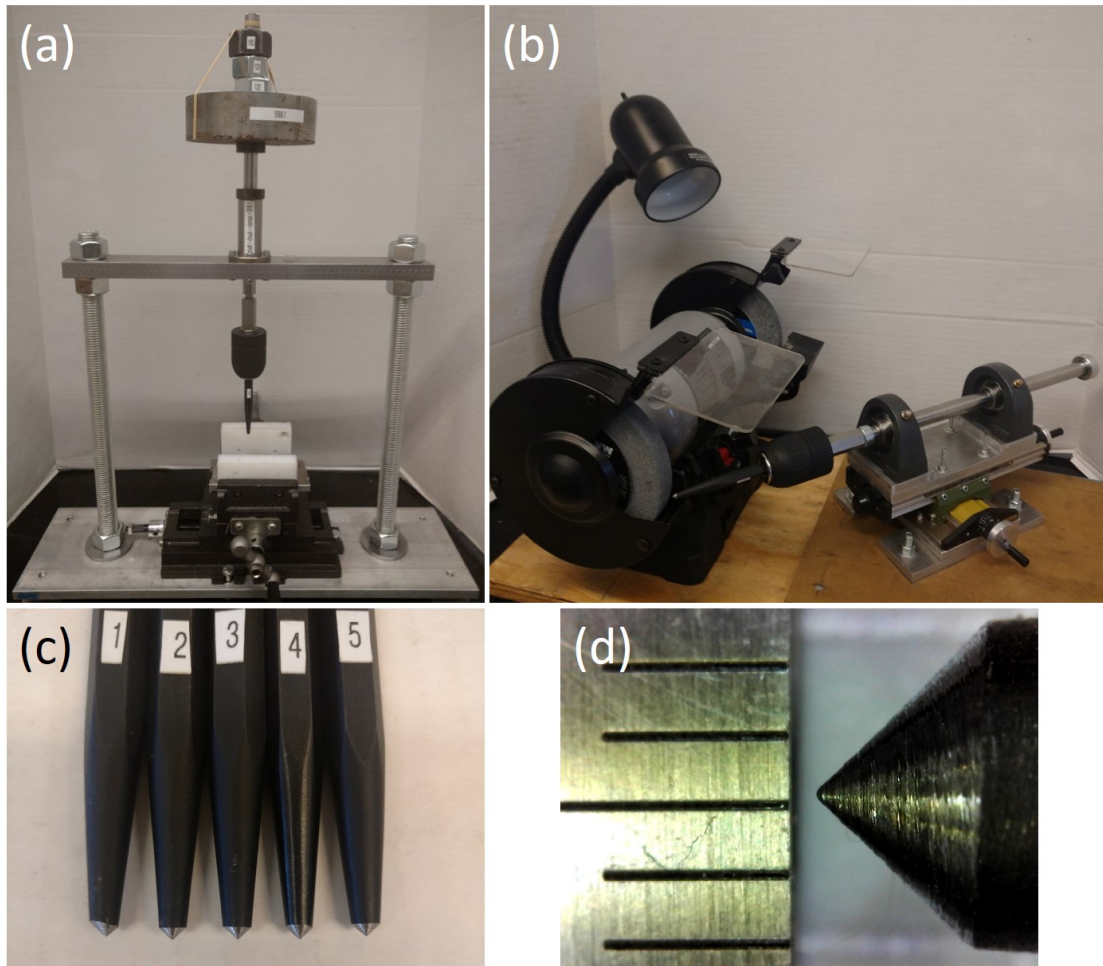


Figure 4: Photos showing (a) the CERCHAR apparatus, (b) tip sharpening setup, (c) the five styluses used to perform the test and (d) a microscope image of one of the stylus tips.

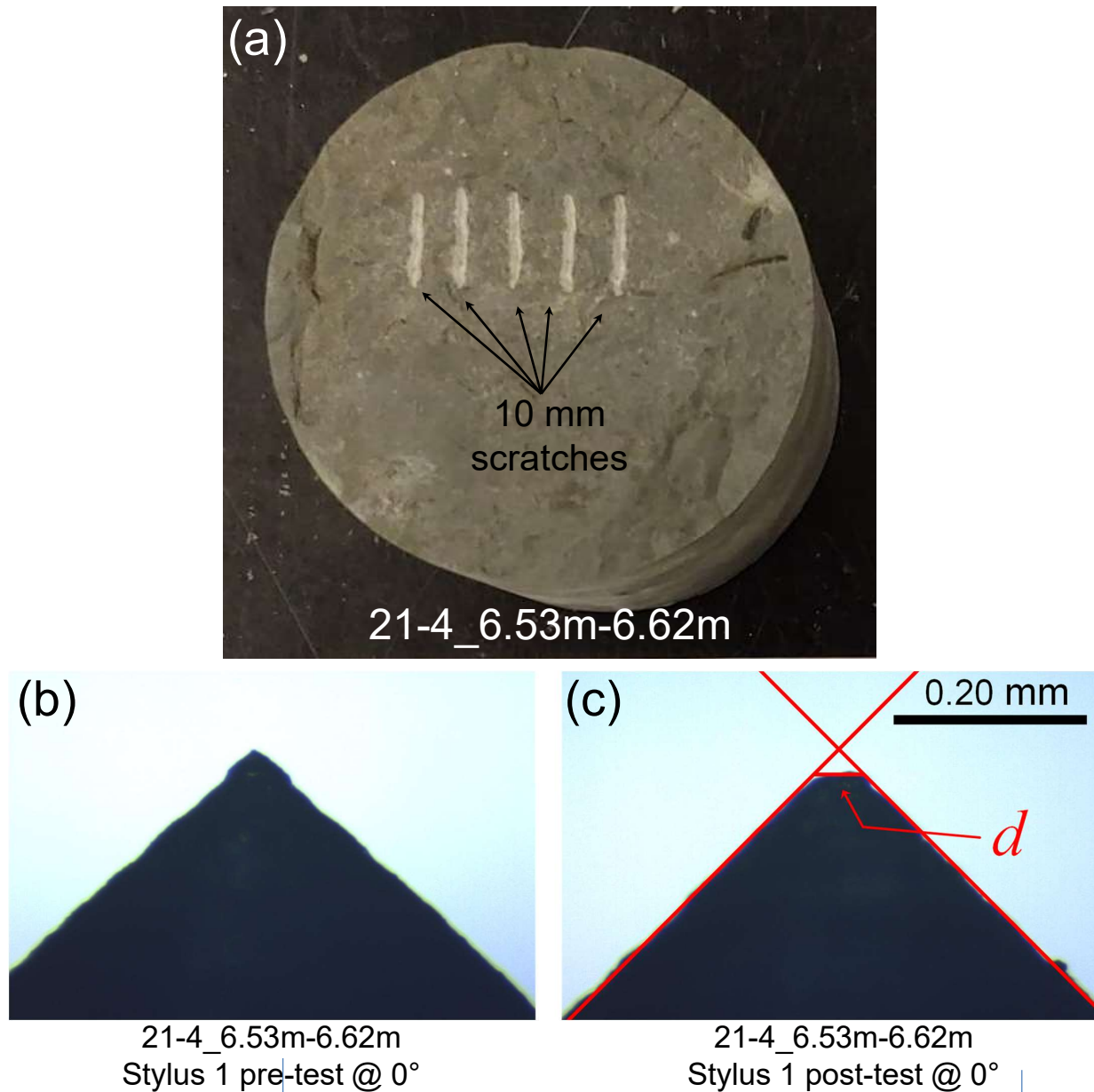


Figure 5: (a) Photograph showing an example of the five 10 mm scratches on a select test specimen; (b) microscope image of select stylus prior to testing at the noted position; and (c) microscope image of the same stylus at the same position following testing with the wear flat, d , denoted.

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	Lithology	ASTM Classification
21-4-6.53m-6.62m	6.53 - 6.62	0.056	0.066	0.053	0.034	0.073	0.057	0.566	Siltstone	Low
21-34-6.38m-6.48m	6.38 - 6.48	0.036	0.028	0.032	0.024	0.030	0.030	0.299	Shale	< Very Low
21-35-7.63m-7.90m	7.63 - 7.90	0.028	0.026	0.026	0.034	0.028	0.028	0.282	Shale	< Very Low
21-36-8.97m-9.09m	8.97 - 9.09	0.050	0.047	0.033	0.043	0.041	0.043	0.430	Shale	Very Low
21-37-7.30m-7.45m	7.30 - 7.45	0.032	0.028	0.028	0.059	0.039	0.037	0.373	Shale	Very Low

4 Slake Durability

4.1 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 and/or filing 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.

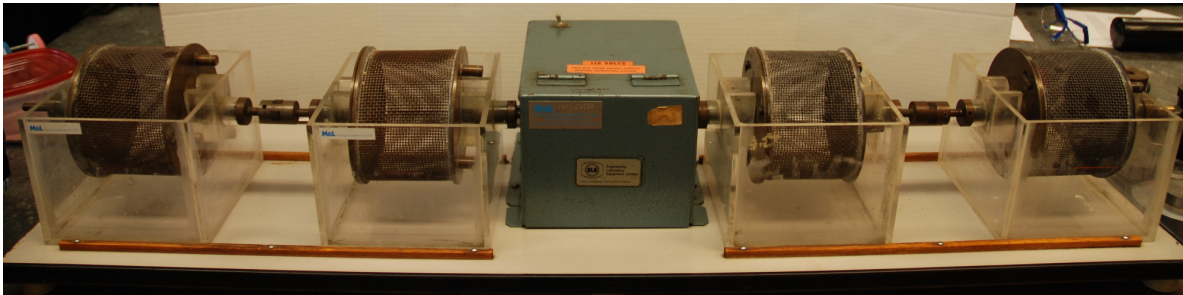


Figure 6: Test setup showing the slake durability apparatus.

4.2 Results

The results of the tests are summarized in Table 4. Additional measurements and sample descriptions are provided the summary spreadsheet that accompanies this report. The slake durability index after one and two cycles was calculated as follows, respectively:

$$I_{d1} = \frac{B - D}{A - D} \times 100\% \quad (2)$$

$$I_{d2} = \frac{C - D}{A - D} \times 100\% \quad (3)$$

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 4: 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
21-34-8.53to8.79	8.53 - 7.79	2.54	2439.01	2388.61	2303.35	1895.48	90.73	75.04	Shale & Limestone
21-35-6.39to6.62	6.39 - 6.62	3.46	2357.54	2295.54	2223.12	1857.24	87.61	73.13	Shale & Limestone
21-37-7.62to7.83	7.62 - 7.83	3.54	2282.26	2225.27	2149.97	1847.18	86.90	69.59	Shale

4.3 Specimen Photographs

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

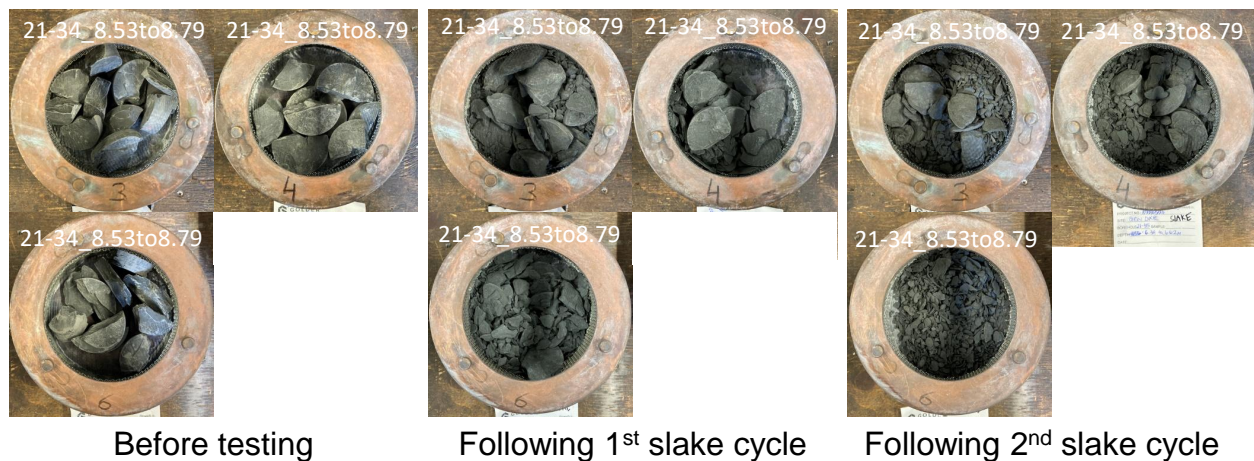




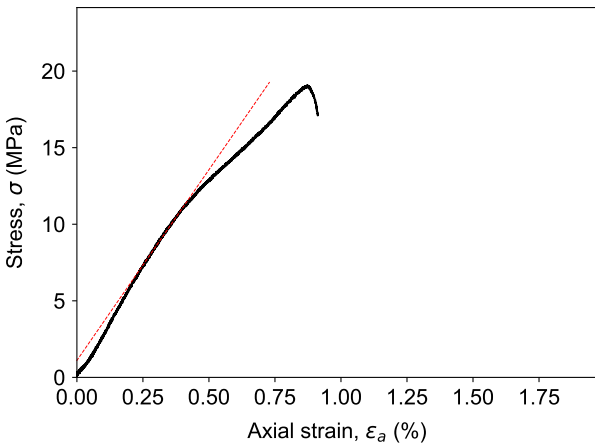
Figure 7: Photographs of slake durability specimens before and after testing.

Appendices



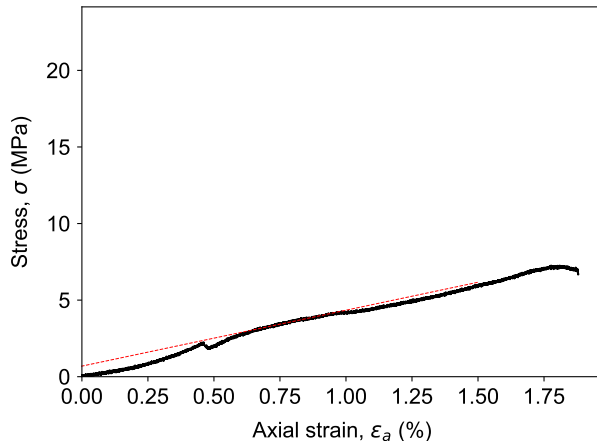
A UCS specimen sheets

- 21-34-7.82to7.95m
- 21-35-7.4to7.56m
- 21-37-7.08to7.3m
- 21-36-9.92to10.07m
- 21-3-6.47to6.7m
- 21-4-7.44to7.58m



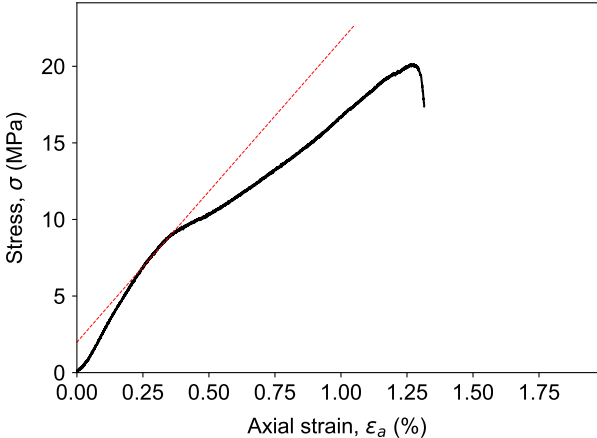
Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000														
Sample	21-34-7.82to7.95m	Depth	7.82 - 7.95														
<div>Specimen parameters</div> <table><tr><td>Diameter (mm) ^a</td><td>59.76</td></tr><tr><td>Length (mm) ^a</td><td>121.00</td></tr><tr><td>Bulk density ρ (g/cm³)</td><td>2.620</td></tr><tr><td>UCS (MPa)</td><td>19.1</td></tr><tr><td>Young's modulus E (GPa) ^b</td><td>2.5</td></tr><tr><td>Lithology</td><td>Siltstone, Limestone and Shale</td></tr><tr><td>Failure description ^c</td><td>1</td></tr></table>		Diameter (mm) ^a	59.76	Length (mm) ^a	121.00	Bulk density ρ (g/cm ³)	2.620	UCS (MPa)	19.1	Young's modulus E (GPa) ^b	2.5	Lithology	Siltstone, Limestone and Shale	Failure description ^c	1	<div>Prior to testing</div> 	<div>After testing</div> 
Diameter (mm) ^a	59.76																
Length (mm) ^a	121.00																
Bulk density ρ (g/cm ³)	2.620																
UCS (MPa)	19.1																
Young's modulus E (GPa) ^b	2.5																
Lithology	Siltstone, Limestone and Shale																
Failure description ^c	1																
<div><div><div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div><div>^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.</div><div>^c Failure description: ¹ Axial splitting failure;</div></div><div></div></div>																	
Remarks:																	
Remarks: Displacement Rate: 0.15mm/min																	
Performed by	PL/SL	Date	2021-03-30														



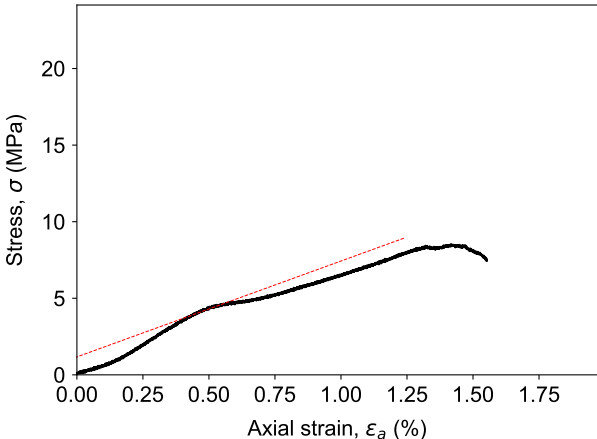
Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000														
Sample	21-35-7.4to7.56m	Depth	7.40 - 7.56														
<div>Specimen parameters</div> <table><tr><td>Diameter (mm) ^a</td><td>59.97</td></tr><tr><td>Length (mm) ^a</td><td>126.74</td></tr><tr><td>Bulk density ρ (g/cm³)</td><td>2.585</td></tr><tr><td>UCS (MPa)</td><td>7.3</td></tr><tr><td>Young's modulus E (GPa) ^b</td><td>0.4</td></tr><tr><td>Lithology</td><td>Shale and Siltstone</td></tr><tr><td>Failure description ^c</td><td>2, 3, 4</td></tr></table>		Diameter (mm) ^a	59.97	Length (mm) ^a	126.74	Bulk density ρ (g/cm ³)	2.585	UCS (MPa)	7.3	Young's modulus E (GPa) ^b	0.4	Lithology	Shale and Siltstone	Failure description ^c	2, 3, 4	<div>Prior to testing</div> 	<div>After testing</div> 
Diameter (mm) ^a	59.97																
Length (mm) ^a	126.74																
Bulk density ρ (g/cm ³)	2.585																
UCS (MPa)	7.3																
Young's modulus E (GPa) ^b	0.4																
Lithology	Shale and Siltstone																
Failure description ^c	2, 3, 4																
<div><div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div><div>^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.</div><div>^c Failure description: ² Inclined shear failure; ³ Specimen emitted saline pore water upon loading; ⁴ Failure partly along pre-existing structure;</div></div>																	
<div></div>																	
Remarks:																	
Performed by	PL/SL	Date	2021-03-30														



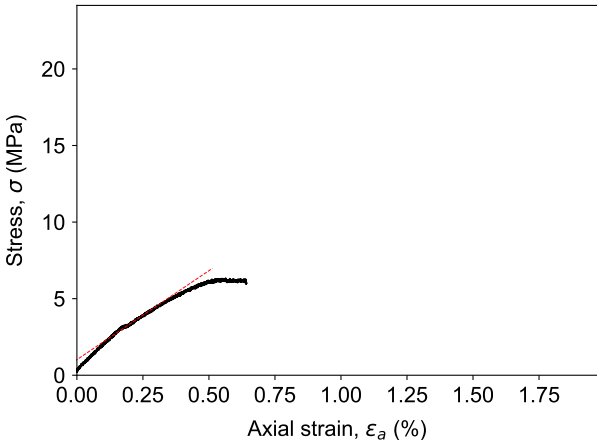
Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000
Sample	21-37-7.08to7.3m	Depth	7.08 - 7.30
Specimen parameters		Prior to testing	After testing
Diameter (mm) ^a	59.90		
Length (mm) ^a	126.69		
Bulk density ρ (g/cm ³)	2.627		
UCS (MPa)	20.1		
Young's modulus E (GPa) ^b	2.0		
Lithology	Siltstone, Limestone, and Shale		
Failure description ^c	5, 3		
^a Additional specimen measurement/details provided 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 40.0% of the peak strength.			
^c Failure description: ⁵ Partial hourglass failure; ³ Specimen emitted saline pore water upon loading;			
			
Remarks:			
Performed by	PL/SL	Date	2021-03-30



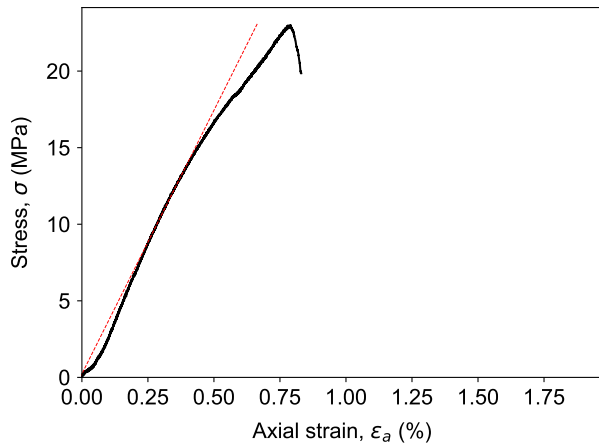
Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000														
Sample	21-36-9.92to10.07m	Depth	9.92 - 10.07														
<div>Specimen parameters</div> <table><tr><td>Diameter (mm) ^a</td><td>59.99</td></tr><tr><td>Length (mm) ^a</td><td>120.65</td></tr><tr><td>Bulk density ρ (g/cm³)</td><td>2.541</td></tr><tr><td>UCS (MPa)</td><td>8.5</td></tr><tr><td>Young's modulus E (GPa) ^b</td><td>0.6</td></tr><tr><td>Lithology</td><td>Siltstone, Limestone, and Shale</td></tr><tr><td>Failure description ^c</td><td>1, 3, 6</td></tr></table>		Diameter (mm) ^a	59.99	Length (mm) ^a	120.65	Bulk density ρ (g/cm ³)	2.541	UCS (MPa)	8.5	Young's modulus E (GPa) ^b	0.6	Lithology	Siltstone, Limestone, and Shale	Failure description ^c	1, 3, 6	<div>Prior to testing</div> 	<div>After testing</div> 
Diameter (mm) ^a	59.99																
Length (mm) ^a	120.65																
Bulk density ρ (g/cm ³)	2.541																
UCS (MPa)	8.5																
Young's modulus E (GPa) ^b	0.6																
Lithology	Siltstone, Limestone, and Shale																
Failure description ^c	1, 3, 6																
<div>^a Additional specimen measurement/details provided 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: ¹ Axial splitting failure; ³ Specimen emitted saline pore water upon loading; ⁶ Failure localized in softer shale layer;</div>																	
<div></div>																	
Remarks:																	
Performed by	PL/SL	Date	2021-03-30														

Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000														
Sample	21-3-6.47to6.7m	Depth	6.47 - 6.70														
<div>Specimen parameters</div> <table><tr><td>Diameter (mm) ^a</td><td>59.81</td></tr><tr><td>Length (mm) ^a</td><td>126.69</td></tr><tr><td>Bulk density ρ (g/cm³)</td><td>2.621</td></tr><tr><td>UCS (MPa)</td><td>6.3</td></tr><tr><td>Young's modulus E (GPa) ^b</td><td>1.2</td></tr><tr><td>Lithology</td><td>Siltstone and Shale</td></tr><tr><td>Failure description ^c</td><td>1</td></tr></table>		Diameter (mm) ^a	59.81	Length (mm) ^a	126.69	Bulk density ρ (g/cm ³)	2.621	UCS (MPa)	6.3	Young's modulus E (GPa) ^b	1.2	Lithology	Siltstone and Shale	Failure description ^c	1	<div>Prior to testing</div> 	<div>After testing</div> 
Diameter (mm) ^a	59.81																
Length (mm) ^a	126.69																
Bulk density ρ (g/cm ³)	2.621																
UCS (MPa)	6.3																
Young's modulus E (GPa) ^b	1.2																
Lithology	Siltstone and Shale																
Failure description ^c	1																
<div><div><div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div><div>^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.</div><div>^c Failure description: ¹ Axial splitting failure;</div></div><div></div></div>																	
Remarks:																	
Performed by	PL/SL	Date	2021-03-30														

Uniaxial Compression Test

Client	Golder Associates Ltd.	Project	1530382-7000														
Sample	21-4-7.44to7.58m	Depth	7.44 - 7.58														
<div>Specimen parameters</div> <table><tr><td>Diameter (mm) ^a</td><td>60.05</td></tr><tr><td>Length (mm) ^a</td><td>126.77</td></tr><tr><td>Bulk density ρ (g/cm³)</td><td>2.632</td></tr><tr><td>UCS (MPa)</td><td>23.0</td></tr><tr><td>Young's modulus E (GPa) ^b</td><td>3.4</td></tr><tr><td>Lithology</td><td>Siltstone, Limestone, and Shale</td></tr><tr><td>Failure description ^c</td><td>5</td></tr></table>		Diameter (mm) ^a	60.05	Length (mm) ^a	126.77	Bulk density ρ (g/cm ³)	2.632	UCS (MPa)	23.0	Young's modulus E (GPa) ^b	3.4	Lithology	Siltstone, Limestone, and Shale	Failure description ^c	5	<div>Prior to testing</div> 	<div>After testing</div> 
Diameter (mm) ^a	60.05																
Length (mm) ^a	126.77																
Bulk density ρ (g/cm ³)	2.632																
UCS (MPa)	23.0																
Young's modulus E (GPa) ^b	3.4																
Lithology	Siltstone, Limestone, and Shale																
Failure description ^c	5																
<div><div><div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div><div>^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.</div><div>^c Failure description: ⁵ Partial hourglass failure;</div></div><div></div></div>																	
Remarks:																	
Performed by	PL/SL	Date	2021-03-30														

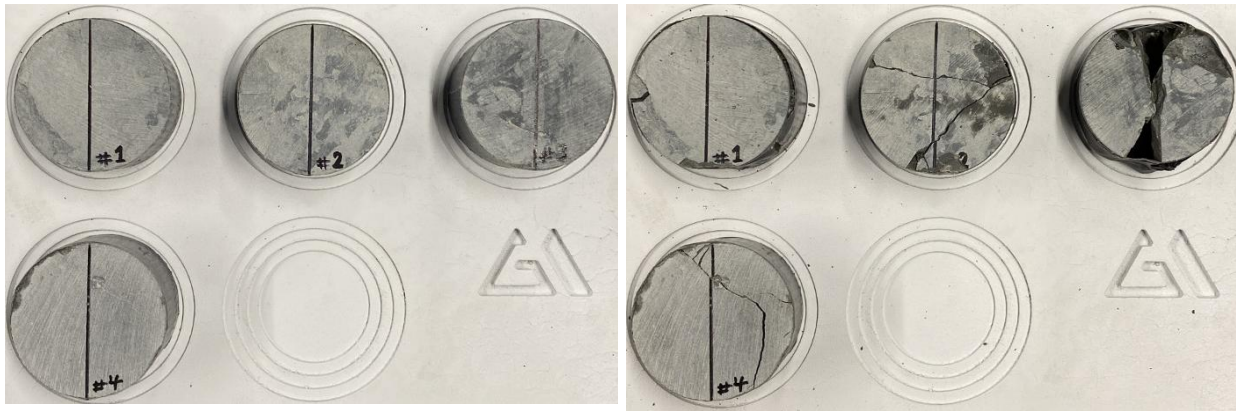
B BD specimen sheets

- 21-34-21-34-7.29to7.4m
- 21-37-21-37-8.42to8.56m
- 21-4-21-4-8.04to8.14m

Brazilian Disc Test

Client	Golder Associates Ltd.	Project	1530382-7000																		
Sample	21-34-21-34-7.29to7.4m	Depth	7.29 - 7.40																		
<div>Specimen parameters</div> <table><tr><td>Disc</td><td>1</td><td>2</td></tr><tr><td>Thickness (mm) ^a</td><td>33.41</td><td>33.60</td></tr><tr><td>Diameter (mm) ^a</td><td>59.98</td><td>59.98</td></tr><tr><td>Tensile strength (MPa)</td><td>2.7</td><td>2.4</td></tr><tr><td>Lithology</td><td colspan="2">Siltstone and Limestone</td></tr><tr><td>Failure description ^b</td><td>1</td><td>1</td></tr></table>				Disc	1	2	Thickness (mm) ^a	33.41	33.60	Diameter (mm) ^a	59.98	59.98	Tensile strength (MPa)	2.7	2.4	Lithology	Siltstone and Limestone		Failure description ^b	1	1
Disc	1	2																			
Thickness (mm) ^a	33.41	33.60																			
Diameter (mm) ^a	59.98	59.98																			
Tensile strength (MPa)	2.7	2.4																			
Lithology	Siltstone and Limestone																				
Failure description ^b	1	1																			
<div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div> <div>^b Failure description: ¹ Diametric failure;</div>																					
<div>Average tensile strength (MPa) 2.6</div>																					
<div><div>Prior to testing</div><div>After testing</div></div>																					
<div>Performed by PL/SL</div> <div>Date 2021-03-20</div>																					

Brazilian Disc Test

Client	Golder Associates Ltd.		Project	1530382-7000
Sample	21-37-21-37-8.42to8.56m		Depth	8.42 - 8.56
Specimen parameters				
Disc	1	2	3	4
Thickness (mm) ^a	33.32	33.18	33.72	33.42
Diameter (mm) ^a	59.88	59.83	59.78	59.92
Tensile strength (MPa)	5.0	1.7	3.0	3.3
Lithology	Limestone and Siltstone	Siltstone	Siltstone and Limestone	Limestone
Failure description ^b	2, 3	4	1	4, 3
^a Additional specimen measurement/details provided in accompanying summary spreadsheet. ^b Failure description: ² Partial diametric failure; ³ Failure along pre-existing structure; ⁴ Non-diametric failure; ¹ Diametric failure;				
Average tensile strength (MPa) 3.2				
<div><div>Prior to testing</div><div>After testing</div></div> <div></div>				
Performed by	PL/SL		Date	2021-03-20

Brazilian Disc Test

Client	Golder Associates Ltd.	Project	1530382-7000																		
Sample	21-4-21-4-8.04to8.14m	Depth	8.04 - 8.14																		
<div>Specimen parameters</div> <table><tr><td>Disc</td><td>1</td><td>2</td></tr><tr><td>Thickness (mm) ^a</td><td>33.29</td><td>32.80</td></tr><tr><td>Diameter (mm) ^a</td><td>60.21</td><td>60.09</td></tr><tr><td>Tensile strength (MPa)</td><td>2.1</td><td>3.0</td></tr><tr><td>Lithology</td><td colspan="2">Siltstone and Limestone</td></tr><tr><td>Failure description ^b</td><td>1</td><td>1</td></tr></table>				Disc	1	2	Thickness (mm) ^a	33.29	32.80	Diameter (mm) ^a	60.21	60.09	Tensile strength (MPa)	2.1	3.0	Lithology	Siltstone and Limestone		Failure description ^b	1	1
Disc	1	2																			
Thickness (mm) ^a	33.29	32.80																			
Diameter (mm) ^a	60.21	60.09																			
Tensile strength (MPa)	2.1	3.0																			
Lithology	Siltstone and Limestone																				
Failure description ^b	1	1																			
<div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div> <div>^b Failure description: ¹ Diametric failure;</div>																					
<div>Average tensile strength (MPa) 2.6</div>																					
<div><div>Prior to testing</div><div>After testing</div></div>																					
<div>Performed by PL/SLDate2021-03-20</div>																					

POINT LOAD TEST ON ROCK SAMPLES

ASTM D5731

PROJECT NO. 1530382 (7000)
 TITLE AECOM/2015-E-0001/QEW Cawthra
 DATE March 23, 2021

Borehole Number	Sample Number	Sample Depth (m)	Test Type	Core Length (mm)	Core ⁽²⁾ Diameter (mm)	Equivalent Diameter (mm)	Ram Pressure (kPa)	Load (P) (kN)	Is Axial (MPa)	Is Diametral (MPa)	Is (50mm) (MPa)	Approx. ⁽¹⁾ UCS (MPa)
21-3	-	5.70-5.79	A	21.40	59.21	40.17	2,800.00	2.65	1.645	-	1.491	31
21-3	-	6.00-6.09	A	22.66	59.75	41.52	2,210.00	2.10	1.215	-	1.118	23
21-4	-	6.66-6.70	A	21.94	60.15	40.99	12,380.00	11.74	6.985	-	6.388	134
21-4	-	6.70-6.75	A	26.08	60.17	44.70	3,780.00	3.58	1.794	-	1.705	36
21-34	-	6.78-6.85	A	21.35	59.04	40.06	4,710.00	4.47	2.782	-	2.518	53
21-34	-	6.22-6.28	A	29.83	60.32	47.86	4,820.00	4.57	1.995	-	1.956	45
21-35	-	6.12-6.17	A	22.64	59.05	41.26	4,850.00	4.60	2.701	-	2.477	52
21-35	-	5.58-5.64	A	22.37	60.17	41.40	10,020.00	9.50	5.543	-	5.091	107
21-36	-	6.41-6.44	A	24.49	60.16	43.31	1,460.00	1.38	0.738	-	0.692	15
21-36	-	7.24-7.27	A	23.53	60.09	42.43	10,850.00	10.29	5.714	-	5.307	111
21-37	-	6.86-6.92	A	22.81	60.17	41.80	3,790.00	3.59	2.056	-	1.897	40
21-37	-	7.00-7.05	A	29.22	60.01	47.25	4,950.00	4.69	2.102	-	2.049	47

⁽¹⁾ $Is_{50} \times C$ from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.

⁽²⁾ Actual distance between point load cones at time of failure.

Checked By:



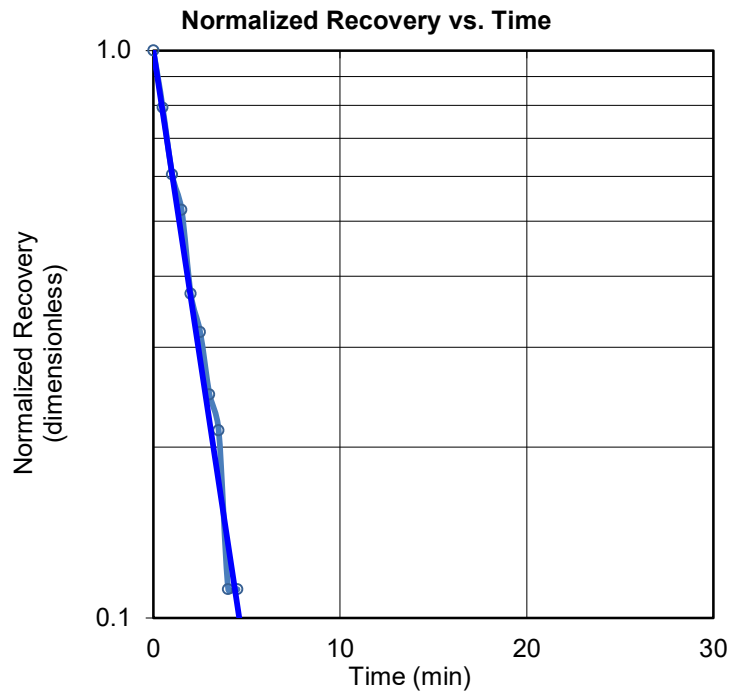
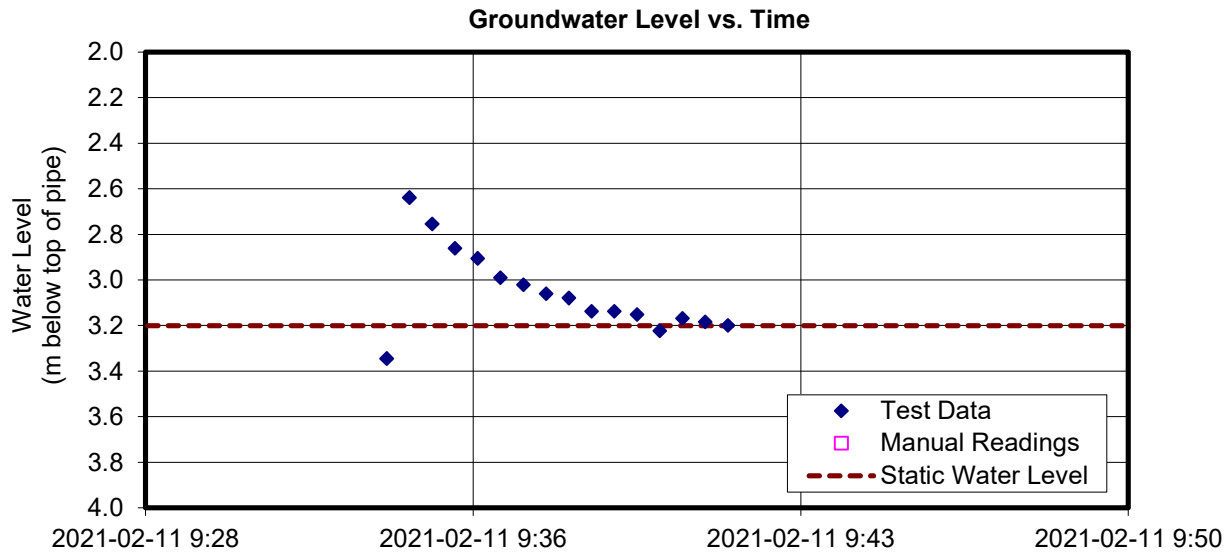
Golder Associates

APPENDIX D

Hydraulic Conductivity Testing Results (Borehole 21-4)

In-Situ Hydraulic Conductivity Test Report

Borehole 21-4 FHT



Screened Interval (below top of pipe)

6.1 m to 9.14 m

Formation Screened

Shale

Static Water Level (below top of pipe)

3.2 m

Test Interval (L) = 3.04 m

Well Radius (r) = 0.025 m

Hole Radius (R) = 0.048 m

Points Used for Match Line

$h_1/H_0 = 1.0$

$t_1 = 0$ min

$h_2/H_0 = 0.1$

$t_2 = 4.6$ min

Hvorslev Analysis

$$\text{Hydraulic Conductivity (K)} = \frac{-(r^2) \cdot \ln(L/R)}{2 \cdot L} \cdot \frac{\ln(h_2/H_0) - \ln(h_1/H_0)}{t_2 - t_1} = 2\text{E-6 m/s}$$

DATE: June 2, 2021

PROJECT: 1530382 (7000)



GOLDER
MEMBER OF WSP

ANALYSIS: LB

CHECK: JG

Borehole 21-4 CHT-Test 2

Interval Information

Borehole Radius [R] (m)	Interval Information		
	Top (m)	Bottom (m)	Length (m)
0.048	9.14	12.40	3.26

Steady State Equation:

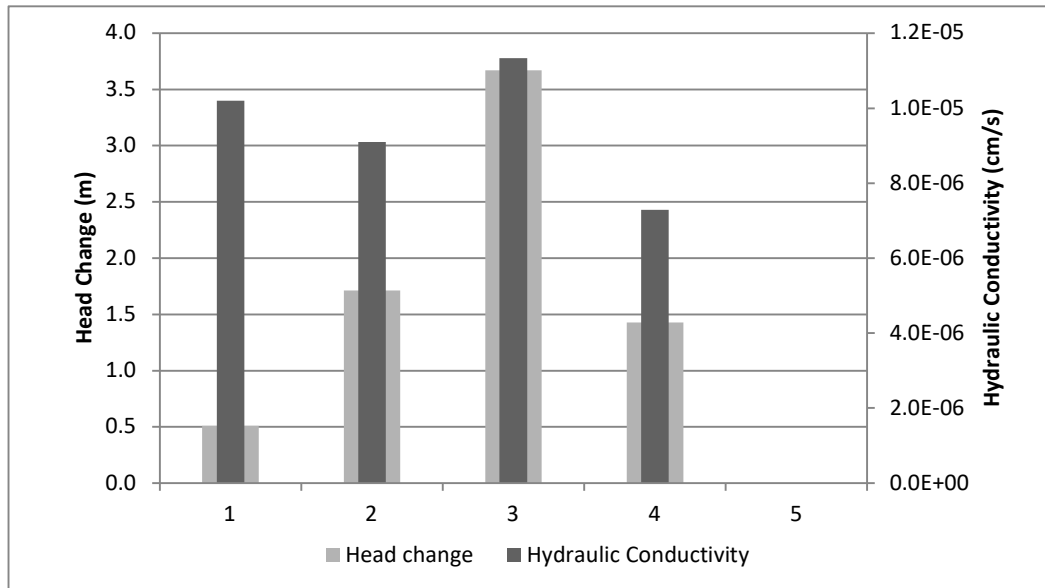
$$K = \frac{Q \cdot \ln(L/D) + \sqrt{1 + (L/D)^2}}{2(P_i)LP}$$
 (Thiem 1906)

Steps	Hydraulic Conductivity cm/s
1	1E-05
2	9E-06
3	1E-05
4	7E-06
5	-

Test Information

Test Data		
1	Flow Rate (Q) =	2E-02 L/min
	Pressure (P) =	5 kPa
2	Flow Rate (Q) =	5E-02 L/min
	Pressure (P) =	17 kPa
3	Flow Rate (Q) =	1E-01 L/min
	Pressure (P) =	36 kPa
4	Flow Rate (Q) =	3E-02 L/min
	Pressure (P) =	14 kPa
5	Flow Rate (Q) =	- L/min
	Pressure (P) =	- kPa

Pressure and Hydraulic Conductivity



Constant Head Packer Test

QEW Cawthra

Mississauga, Ontario

Project No.	1530382 (7000)
Date:	2021-06-04
Calcs By:	LB
Review:	JG

APPENDIX E

Non-Standard Special Provisions

TRENCHLESS SEWER INSTALLATION - Item No.

Notice to Contractor

The Contractor shall construct a trenchless sanitary sewer crossing the QEW in the west of Insley Road in conformance with the design and at the locations indicated in the Contract Documents.

The Contractor is advised that variable subsurface conditions may be encountered at the trenchless crossing locations. For bidding purposes, the Contractor shall assume the following:

- For trenchless installations in the vicinity of the trenchless crossing west of Insley Road, it shall be assumed that portions of the crossing will be constructed in very loose to compact gravelly sand to clayey sand-silty sand fill, very stiff to hard clayey silt and sand to clayey silt till, hard clayey silt residual soil, and shale bedrock; these shall be assumed to form mixed face conditions, as well as to vary in depth and extent along the length of the trenchless installation. The groundwater conditions in the closest boreholes to each section shall be assumed, as shown in the Foundation Investigation Reports; the Contractor shall also assume that perched groundwater conditions may be present, depending on precipitation events around the time of construction.

Additional geotechnical information in the vicinity of the trenchless crossings can be found in the Foundation Investigation Reports for the Noise Barrier Walls.

BASIS OF PAYMENT

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

**CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY
TRENCHLESS METHOD**

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
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 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
B182.8 Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings

B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
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 Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

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.

Boulder Number Ratio (BNR) means the number of individual boulders per m³ of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

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.

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.

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.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

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 microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

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

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

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 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 m³ 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 tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

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.

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.

TBM means a tunnel boring machine.

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

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.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling 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 trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with 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.

Given the anticipated soil and groundwater conditions along the bore alignment, Auger Boring with a Small Boring Unit (SBU) or Micro-tunnelling are considered feasible installation options for this site.

Trenchless installation methods that are not considered suitable at this site include pipe ramming, pilot tube micro-tunneling, HDD, TBM, and Tunnel Digging Machine (TDM).

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change 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 (5) years experience on projects with similar scope and complexity.

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

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

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 traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. 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.
- ix. 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.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.
 - Deviation from required alignment and grade.

- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

- i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing 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.
- iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.
- v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

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 (EPB), Slurry Pressure Balance (SPB).
- 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 dosages rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (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. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- 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 tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

- i. 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, Slurry Pressure Balance (SPB) and Earth Pressure Balance (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.); and
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

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 High Density Polyethylene 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 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 and be wetted with only sufficient water to make the mixture plastic.

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with 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 shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems.

6.02 Pipe Ramming

N/A

6.03 Horizontal Directional Drilling

N/A

6.04 Tunnelling

N/

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 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 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.
 - ii. 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.
 - iii. 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.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. 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.
 - viii. 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.
 - ix. 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 – The Contractor shall provide a 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.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. 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 % 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.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting the 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 Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

- a) Site Surveying (see Clause 4.02)
- b) Excavation for pits including dewatering of excavations
- c) Jacking / Ramming / Directional Drilling of Casing / Liner
- d) Installation of the Product
- e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

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 Working 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 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or proposed works 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 recommendations for transporting, unloading, storing, and handling of materials 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 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 within the soil deposits at the site (i.e. till, residual soil and weathered and highly fractured bedrock). Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

The Boulder Volume Ratio (BVR), within glacial till soils in the area typically ranges between 0.15% and 0.3% of the extracted volume. Typically, the size distribution of boulders is such that between 5 and 10 boulders of varying sizes are found for every cumulative cubic metre of boulder rock. The number of boulders per cubic metre of cumulative boulder volume encountered is the Boulder Number Ratio (BNR).

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions are expected within the trenchless alignment as identified in the Contract Documents.

Specifically, it is to be expected that weathered, fractured and intact rock will be encountered along a portion of the tunnel (as indicated in the Foundation Investigation Report) and the selected method must be capable of advancing through all of these rock materials.

Accordingly, the Contractor shall address methods for advancement of the tunnel and removal of obstructions, if required, in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal, if needed.

7.01.13 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.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be watertight 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 watertight, expandable, and stable grout.

7.03 Pipe Ramming Installation

N/A

7.04 Horizontal Directional Drilling Installation

N/A

7.05 Tunnelling Installation

N/A

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

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

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.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points 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.

7.07.03 In-Ground Settlement Monitoring Points

In-Ground Shallow Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

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.

In-Ground Deep Settlement Monitoring Points

In-ground deep settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals.

In-ground settlement monitoring points shall be a 19 mm rebar encased in a 50-70 mm, steel casing, set to a depth of 1.0 m above the tunnel invert. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) 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.

7.07.05 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.

7.07.06 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 the 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 for the surface and/or in-ground shallow settlement points, or a maximum value of 15 mm relative to the baseline readings is reached for the in-ground deep settlement monitoring points, 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 Contract Administrator 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 for the surface and/or in-ground shallow settlement points, or a maximum value of 25 mm relative to the baseline readings is reached for the in-ground deep settlement monitoring points, 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 complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.

- iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. 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 Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline 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.

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe 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 removal of boulders exceeding the Boulder Volume Ratio (BVR) and the Boulder Number Ratio (BNR), as outlined in Section 7.01.11, shall be by Time and Material.

No payment shall be made for removal of weathered, fractured or intact shale bedrock.

***** Designer Fill-in, See Notes to Designer

NOTES TO DESIGNER:

WARRANT: Always with this specification.

WORKING SLAB - Item No.

Special Provision

1.0 SCOPE

This Special Provision covers the requirements for the supply and placement of a concrete working slab under structure foundations.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 902 Excavating and Backfilling - Structures

3.0 DEFINITIONS - Not Used

4.0 DESIGN AND SUBMISSION REQUIREMENTS - Not Used

5.0 MATERIALS

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 Excavation

Excavation for the working slab shall be according to OPSS 902.

7.02 Protection of Founding Soil

Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

7.03 Protection of Founding Bedrock

The surface of the footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed. The working slab shall be placed on the exposed cleaned sound founding rock surface as specified in the Contract Documents.

Thickness of the mass concrete pad shall depend on the slope and irregularities in the exposed founding rock surface. A nominal thickness and a footprint plan view area has been specified on the Contract Documents

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 **QUALITY ASSURANCE - Not Used**

9.0 **MEASUREMENT FOR PAYMENT - Not Used**

10.0 **BASIS OF PAYMENT**

10.01 **Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

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

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.

WELL DECOMMISSIONING - Item No.

Special Provision

1.0 SCOPE

This specification covers the requirements for the decommissioning of wells/piezometers identified in Table 1 below, for which the registered owner is the Ministry of Transportation, Ontario.

Table 1 – Well/Piezometer Information

Well/Piezometer Identification	Location (Northing / Easting)	PVC Pipe and Screen Diameter / Borehole Diameter	Depth (Below Ground Surface) to Tip of Screen / Borehole Depth
21-2	(4,827,726.5/ 298,557.4)	50 mm / 200 mm	6.1 m / 13.1 m
21-4	(4,827,702.9/ 298,617.6)	50 mm / 200 mm	6.4 m / 12.4 m

2.0 REFERENCES

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

Ontario Water Resources Act, R.S.O. 1990; Regulation 903

3.0 DEFINITIONS – Not Used

4.0 DESIGN AND SUBMISSION REQUIREMENTS – Not Used

5.0 MATERIALS – Not Used

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

Each well must be decommissioned/abandoned (sealed) by a licensed well contractor in accordance with regulations of the Ontario Water Resources Act (O.Reg. 903). The Contractor shall obtain said information from the Ministry of Environment, Conservation and Parks and bear liability for compliance to the regulation. As a minimum, the existing casing shall be removed to a depth of 2.0 m below the original ground surface and the remaining well casing backfilled in accordance with regulations.

As part of the abandonment process, in accordance with regulations of the Ontario Water Resources Act (O.Reg. 903), if the well has a well tag, it must be removed and returned to the MECP Director within 30 days after its removal. If the well has a well tag attached to the well casing or near the well, the well tag must be removed at the beginning of the plugging operation and safeguarded throughout the process. The well tag must be returned within 30 days after completion of abandonment and removing the tag. The well tag must be

returned to Wells Help Desk, Environmental Monitoring and Reporting Branch Ministry of the Environment, Conservation and Parks, 125 Resources Road, Toronto, Ontario, M9P 3V6 (1-888-396-9355).

Licensed well contractors shall forward the water well record (abandonment report), with an accompanying transmittal letter to the Ministry of Environment, Conservation and Parks. A copy of the above record and letter shall be sent to the Contract Administrator. This shall be provided to the Contract Administrator before payment of the abandoned wells is approved.

The Contractor must; obtain a blank well record form from the Ministry of the Environment, Conservation and Parks. On completion of the abandonment of a well, the Contractor must:

- Within 14 days after the date on which the well construction equipment is removed from the site, deliver a copy of the well record to the owner of the land on which the well is situated; and
- Within 30 days after the date on which the well construction equipment is removed from the site, forward a copy of the well record and any well tag that was removed from the well, to the Ministry of Environment, Conservation and Parks.

7.01 Removal and Disposal

Any effluent pumped during well decommissioning shall be managed in accordance with the requirements of O.Reg 347. Further, all material resulting from the abandonment of the wells shall become property of the Contractor and shall be disposed of in accordance with OPSS 180.

8.0 QUALITY ASSURANCE - Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement for the above tender item shall be for each well decommissioned.

10.0 BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour, Equipment and Materials required to do the work.



golder.com