Foundation Investigation and Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto **- Highway 400 CSP Culvert Replacement (CV-0252-0400-0050)**

GWP: 2044-23-00
Assignment No. 2020-E-0028
MTO Central Region
Latitude: 44.639180; Longitude: -79.654120
Geocres No. 31D12-002

Type of Document:
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CONSOR Engineers LLC

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B	April 30, 2024	pdf	S. Fredericks N. Tamrakar	T.C.KIM	S. Gonsalves	Final Report

Table of Contents

Appendices

Part I: Foundation Investigation Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto **- Highway 400 CSP Culvert Replacement (CV-0252-0400-0050)**

1.0 Introduction

EXP Services Inc. (EXP) was retained by CONSOR Engineers LLC (CONSOR) on behalf of The Ministry of Transportation (MTO) to provide detailed foundation investigation and engineering services and pavement engineering services for the proposed rehabilitation/replacement of 25 Non-Structural Culverts project at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto. The findings, analyses and recommendations related to foundation scope are presented in a Foundation Investigation Design Report created for each culvert location. The work was undertaken under GWP 2044-23-00, Assignment No. 2020-E-0028. The terms of reference (TOR) and the scope of work for the foundation investigation are outlined in Ministry of Transpiration Ontario's (MTO) Request for Proposal, dated February 2022. The scope of this report is specifically limited to the proposed replacement of the Corrugated Steel Pipe (CSP) culvert on Highway 400 (CV-0252-0400-0050).

The general design drawings for the proposed culvert replacement were provided to EXP by CONSOR. The purpose of the investigation was to evaluate the subsurface conditions along the existing culvert, and based on this data, to permit detailed design for the culvert replacement and to examine the suitability of trenchless methods of replacement both at the existing culvert alignment and at a new alignment.

The site-specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing. The field and laboratory work for this structure was performed by EXP. Based on collected geotechnical data, this report provides an assessment of the geotechnical issues, geotechnical design parameters, and geotechnical foundation design recommendations for the proposed structure. Geotechnical-related construction recommendations are also provided.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

2.0 Structure Description

The contract drawing prepared by CONSOR shows the 90% design configuration of the proposed trenchless replacement of the Highway 400 culvert. A summary of the proposed structure is as follows:

- The existing culvert has two segments CSP culverts with a 1150 mm diameter CSP pipe on the west segment and a 1220 mm diameter CSP pipe on the east segment with about a 9-degree skew connection from along its alignment near mid section (located about the median of the Hwy 400). The total length of the existing culvert is about 74.5 m with about 30.7 m and 43.8 m long west and east segments, respectively.
- It is understood that the existing culvert is proposed to be replaced with twin CSP/HDPE culverts of sizes 1400 mm diameter and 800 mm diameter. The 1400 mm diameter culvert with about 400 mm thick substrate and native material will be replaced at the existing inlet and outlet locations while the 800 mm diameter culvert will be installed about 3 diameters (i.e about 4.2 m) south of the existing culvert location or proposed 1400 diameter culvert location. Based on the 90% contract drawing the invert levels of the new 1400 mm diameter culvert is proposed to be 196.86 m and 195.97 m at inlet and outlet locations, respectively. Whereas the invert levels of the 800 mm diameter culvert will be matched the existing culvert levels 196.6 m and 195.7 m at the inlet and outlet, respectively.

- The existing Highway 400 profile grade is planned to remain unchanged. It is understood that trenchless methods will be used to replace the existing culvert.

The 90% contract drawings were included as part of this report is used for initial context to address the nature and scope of the investigation. It is understood that some changes might occur as a result of normal refinement or the findings of the geotechnical report.

3.0 Site Description and Geological Setting

3.1 Site Description

The CSP culvert is located on Highway 400, about 2.7 km southwest of the intersection of Highway 400 with Highway 19 in the Simcoe region, Ontario, in the Ministry of Transportation (MTO) Central Region. Highway 400 generally runs in the north-south direction, however, at the location of Culvert CV-0252-0400-0050, Highway 400 runs in a northeast-southwest direction. At the site, Highway 400 is a four lane roadway with the northbound lane (NBL) and (southbound lane) SBL separated by a boulevard (two lanes each direction). Based on the contract drawings, the NBL and SBL roadway is about 12.9 m and 12.8 m wide from edge of pavement to edge of pavement, respectively. The boulevard between the NBL and SBL is approximately 20.3 m wide from edge of pavement to edge of pavement. In total, the existing roadway with both paved shoulders and median included is about 46.0 m wide along the culvert footprint. The elevation of highway pavement centerline at the site is about 202.0 m for both the NBL and the SBL. The roadway embankment above the existing ground is about 5.5 m on the SBL (inlet) side and 6.3 m on the NBL (outlet) side. The sides of the embankment slope range from approximately 1.3H:1V to 2.7H:1V on the west side and 1.8H:1V to 3.5H:1V on the east side. Selected photographs of the site and existing culvert are presented in Appendix A. The site plan and cross-section profiles for the proposed culvert alignment are shown on the drawings attached in Appendix B.

The general site conditions were assessed during a site reconnaissance on February 6, 2022, and during the field investigation works that took place EXP between February 13 to 15, 2023 and between to April 26 to 27, 2023. At the time of the field investigation, the approximate top of water elevation at the inlet and outlet of the culvert was measured to be about 196.7 m and 195. 8 m, respectively. No riprap to protect against scour or erosion was observed on the outlet/east of the culvert. Vegetation at the site consists predominantly of coniferous trees with some deciduous trees wild bushes and shrubs adjacent to the culvert area. The side slopes of the embankment are lightly vegetated. A chain link fence runs across the outlet/east side of culvert near the culvert opening.

Photographs 1 and 2 (taken by MTO) and Photographs 3 to 11 (taken by EXP between February 2023 and April 2023 in Appendix A show the existing site, culvert, and road conditions. Photographs 1 and 2 show the condition of the inside of the culvert. It can be seen that the culvert barrels are heavily corroded at the bottom, especially at the outlet side. Photographs 3 and 4 shows the condition of the culverts from the outside. The outlet of the culvert is completely corroded through the barrel and is partially compressed where the barrel meets the embankment. Photographs 5 and 6 show the side slopes of the embankment and vegetation beyond the culvert footprint. Photographs 7 to 9 show the typical conditions of the roadway surface around the culvert footprint. The highway surface in general is observed to be in a mildly deteriorated condition with a large portion of the roadway experiencing extensive longitudinal and radial cracking. Photographs 10 and 11 show the drilling of borehole BH400-050-01 and BH400-050-02 respectively.

3.2 Geological Setting

Based on a review of geological maps of Southern Ontario (Chapman and Putnam, 1984), the site is situated within the Simcoe Uplands physiographic region where the predominate landforms are broad, rolling till plains separated by steep-sided flat-floored valleys. The numerous shorelines indicate the area lies on the lake bed of glacial Lake Algonquin.

According to the Ministry of Northern Development and Mines, Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) the surface conditions in the vicinity of the project area typically consists of coarse-textured glaciolacustrine deposits comprised predominantly of sandy silt to silt matrix, commonly rich in clasts, often high in total matrix carbonate content. In addition, Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991), the bedrock geology at the site consists of limestone, dolostone, shale, arkose, and siltstone belonging to the Ottawa Group and Simcoe Group of the Shadow Lake Formation.

4.0 Previous Investigations

There are no available reports of any previously performed geotechnical investigation at this site in the MTO GEOCRES library. The only available data is from the adjacent sites approximately 2.7 km northeast and 1.6 km southwest from the site. The reports are listed below for reference.

- *Geocres No. 31D00-083. "Soils Report for Highway #400 Underpass at Gravel Rd., Near Coldwater River, W.P. 64-60". E.M. Peto Associates Ltd., dated July, 1960.*
- *Geocres No. 31D00-092. "Soils Report for Highway 400 Underpass". E.M. Peto Associates Ltd., dated June, 1960.*

5.0 Investigation Procedures

5.1 Site Investigation and Field Testing

A site-specific investigation was undertaken by EXP between February 13 to 15, 2023 and between to April 26 to 27, 2023, and it included the following:

1. A walkover site assessment was carried out by a Geotechnical Engineer from EXP;
2. Subsequent to the borehole layouts in the field, existing utilities were cleared by public utility companies;
3. Traffic control required to close the driving lanes of Highway 400 during the drilling of on-road boreholes was provided by Barricade Traffic Services.
4. At the time of this report, the program involved the drilling of six (6) boreholes for sampling numbered BH400-050-01 to BH400-050-05. Two (2) boreholes were located at each end of the existing culverts, which were BH400-050-01 and BH400-050-02. Boreholes BH400-050-04 and BH400-050-05 were drilled on the roadway at the NBL and SBL lanes, respectively. Boreholes BH400-050-03A and BH400-050-03B were drilled at the highway median. BH400-050-01 was drilled approximately 1.2 m south and 1.8 m west of the culvert inlet opening, and BH400-050-02 was drilled approximately 2.9 m south and 1.9 m south of the culvert

outlet opening. The locations of the boreholes drilled during this investigation are shown on Drawing 1 in Appendix C. Table 1.1 provides a summary of the boreholes completed by EXP.

5. The roadway/median boreholes drilled during this fieldwork were advanced using a track mounted M5I 5T98-09 (BH400-050-03A/03B), truck mounted B-53 (BH400-050-04) and truck mounted M5T 94 drill rig (BH400-050-05). The offroad boreholes were advanced via manual drilling. The drill rigs were owned and operated by Drilltech drilling Ltd. The machines are equipped with solid stem augers and fitted with capability for Standard Penetration Testing (SPT).

1. Soil samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split barrel (SS-split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance, or the N-value, of the soil which is indicative of the compactness of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils). However, in the case of sampling done by the manually lifting portable hammer (31.7 kg, half weight of conventional hammer weight), the corresponding blow counts were factored by 0.5;

2. The fieldwork was supervised by a member of EXP's engineering staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification;

3. All spoon samples obtained in the Standard Penetration Tests (SPT, ASTM D-1586) were placed in moisture proof bags after field classification. Samples were allocated from the spoon samples for moisture content testing without delay. They were subsequently re-examined under controlled laboratory conditions prior to assigning other laboratory tests;

4. Selected soil samples for chemical analytical testing were sent to the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. The selected soil samples for the analytical testing were placed in a laboratory prepared glass jar, labelled, and stored in a secure cooler.

5. The borehole locations and their ground surface elevations were surveyed by EXP using a Trimble DA2 GNSS receiver with Trimble Catalyst GNSS positioning, having an accuracy of ±0.10 m horizontal and vertical directions. MTM NAD83 Zone 10 coordinates and the geodetic elevation for the boreholes are listed in Table 1.1 below. It can also be found on the Record of Borehole Sheet (Appendix D); and

6. Upon completion of drilling and field testing, the boreholes were backfilled with a mixture of bentonite and auger cuttings. groundwater level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded groundwater levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix D.

7. The borehole decommissioning was in general accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

Table 1.1: Summary of boreholes completed

Borehole No.	Borehole Location	Location (MTM NAD83 Zone 10)		Latitude	Longitude	Borehole Elevation (m)	Borehole Depth (m)
		Northing	Easting				
BH400-050-01	Inlet, off-road	4944363.7	292571.1	44.639176	-79.654148	197.0	8.4
BH400-050-02	Outlet, off-road	4944329.5	292637.1	44.638869	-79.653315	196.5	8.3
BH400-050-03A	Median Boulevard	4944358.7	292608.5	44.639132	-79.653676	200.7	9.1
BH400-050-03B	Median Boulevard	4944357.9	292609.0	44.639124	-79.653670	200.7	10.4
BH400-050-04	NBL, east shoulder	4944342.0	292624.1	44.638982	-79.653480	201.9	12.8
BH400-050-05	SBL, west shoulder	4944363.2	292589.6	44.639172	-79.653915	201.9	13.1

5.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program performed by EXP included the determination of the natural moisture content on all samples and particle size distribution and Atterberg limits (for cohesive soils) for approximately 25% of the collected soil samples. Chemical analyses were also carried out on one soil sample selected by EXP. The samples were tested at the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. All of the laboratory tests were carried out according to MTO and/or ASTM Standards as appropriate. The performed laboratory testing program is listed in Table 1.2.

Table 1.2: List of Laboratory Test Completed by EXP

Borehole No.	Moisture Content	Atterberg Limits	Sieve	Hydrometer	Corrosivity
BH400-050-01	4	1	2	2	1
BH400-050-02	4	1	2	2	---
BH400-050-03A	11	1	3	3	---
BH400-050-03B	2	---	---	---	---
BH400-050-04	15	1	3	3	---
BH400-050-05	15	1	4	3	---

The laboratory test results are provided on the attached borehole log sheets in Appendix D as well as graphically in Appendix E.

6.0 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. Laboratory test results of grain size analyses and Atterberg limit tests are provided in Appendix E. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix D forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix C. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles are inferred from semi-continuous sampling, observations of drilling progress and results of Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

Below the roadway, the subsurface conditions encountered within the investigated depths of the geotechnical investigation indicates the following subsurface sequence: asphalt underlain by sand and gravel to gravelly sand followed by predominantly sand fill with layers of clayey silt fill. The embankment fill is underlain by clayey silt to silty clay.

At the culvert inlet, the encountered subsurface conditions were observed to consist of topsoil over silty sand followed by gravelly sand underlain by clayey silt to silty clay. At the outlet, the encountered subsurface conditions were observed to consist of topsoil over clayey silt followed by silty sand to sandy silt underlain by clayey silt to silty clay.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by EXP. The lab test results available at the time of writing this draft report are included, while the other results will be added in the next submission of this report.

6.1 Subsoils

6.1.1 Asphalt

A pavement structure consisting of asphalt was encountered at the ground surface in boreholes BH400-050-04 and BH400-050-05. The thickness of asphalt ranged from approximately 225 mm to 380 mm.

6.1.2 Topsoil

A topsoil layer was encountered at the ground surface of boreholes BH400-050-01, BH400-050-02, and BH400-050-03A/3B. The thickness of this layer ranged from approximately 100 mm to 250 mm.

6.1.3 Cohesionless Fill: Sand and Gravel to Gravelly Sand(SW-GW)

Cohesionless fill consisting of sand and gravel was encountered below the pavement structure in boreholes BH400-050-04 and BH400-050-05. Additionally, a sand and gravel to gravelly sand fill layer was encountered embedded in the sand fill layer in borehole BH400-050-05. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.3 below:

Table 1.3: Summary of Sand and Gravel to Gravelly Sand Fill Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-04	201.5	201.1	0.4	0.4	Sand and Gravel	---
BH400-050-05	201.7	201.0	0.2	0.7	Sand and Gravel	---
	199.6	198.1	2.3	1.5	Sand and Gravel to Gravelly Sand	44 – 52

The composition of this fill was predominantly comprised of sand and gravel with some silt and trace clay; trace asphalt fragments were observed near the surface of the layers near the pavement structure. The fill was generally brown to grey to black in colour and ranged from dry to wet. The SPT "N" values within this layer ranged from 44 to 52 blows per 300 mm penetration, corresponding to dense to very dense in compactness condition.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests. The test results are as follows:

Moisture Content:

- 2% to 10%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix D.

6.1.4 Cohesionless Fill: Sand(SW)

Cohesionless fill layers consisting of sand were encountered below the clayey silt fill in borehole BH400-050-03A and below the sand and gravel fill in borehole BH400-050-04 and BH400-050-05. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.4 below:

Table 1.4: Summary of Sand Fill Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-03A	199.2	193.6	1.5	5.6	Sand	1 – 15
BH400-050-04	201.1	194.0	0.8	7.1	Sand	2 – 61
BH400-050-05	201.0	199.6	0.9	1.4	Sand	20 – 42
	198.1	196.2	3.8	1.9	Sand	3 – 5
	196.0	194.9	5.9	1.1	Sand	12
	194.3	194.1	7.6	0.2	Sand	---

The composition of this fill was predominantly comprised of sand with trace to some gravel, trace clay, trace rootlets, and occasional clayey seams/layers. An obstruction, possibly/likely a cobble, was encountered within this layer in borehole BH400-050-03A. The fill was generally brown to grey to black in colour and ranged from dry to wet. The SPT "N" values within this layer ranged from 1 to 61 blows per 300 mm penetration, corresponding to very loose to very dense but generally very loose to compact in compactness condition.

Laboratory testing performed on selected samples consisted of twenty-five (25) moisture content tests and seven (7) grain size distribution tests. The test results are as follows:

Moisture Content:

- 5% to 63%

Grain Size Distribution:

- 2% to 8% gravel;
- 66% to 83% sand;
- 11% to 26% silt;
- 2% to 6% clay;
- 12% silt and clay;

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The result of the grain size distribution tests are also provided on Figure 1 in Appendix E.

6.1.5 Cohesive Fill: Clayey Silt(CL)/Organic Silty Clay(OI)

Cohesive fill layers consisting of clayey silt were encountered below the topsoil in borehole BH400-050-03A and interbedded in the sand fill layer in borehole BH400-050-05. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.5 below:

Table 1.5: Summary of Clayey Silt Fill Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-03A	200.5	199.2	0.3	1.2	Clayey Silt	8 – 14
BH400-050-05	196.2	196.0	5.7	0.2	Organic Silty Clay	---
	194.9	194.3	7.0	0.6	Clayey Silt	WH[1]

Notes:

1. *WH – split spoon advanced by static weight of hammer (i.e., 0 blows).*

The composition of this fill was predominantly comprised clayey silt with trace sand and trace rootlets. The fill was generally brown to grey and wet. The SPT "N" values within this layer ranged from WH to 14 blows per 300 mm penetration, corresponding to very soft to stiff in consistency. In-situ vane testing with this fill layer measured an undrained shear strength of approximately 60 kPa indicating this material is stiff in consistency. Additionally, a layer of organic clayey silt was encountered, which was comprised of some sand and wood debris. The organic clayey silt was black in color and moist.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests. The test results are as follows:

Moisture Content:

- 12% to 29% (Clayey silt)
- 120% (Organic silty clay)

The results of the moisture content tests are provided on the record of borehole sheets in Appendix D.

6.1.6 Silty Sand to Sandy Silt(SM-ML)

Native silty sand to sandy silt was encountered below the topsoil in borehole BH400-050-01 and below the clayey silt layer in borehole BH400-050-02. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.6 below:

Table 1.6: Summary of Silty Sand to Sandy Silt Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-01	196.9	196.2	0.1	0.7	Silty Sand	2
BH400-050-02	196.2	194.3	0.3	1.9	Silty Sand to Sandy Silt	1 – 4

This layer consisted primarily of silt and sand with trace to some clay, trace gravel, and trace rootlets. The soil was dark brown to dark grey to black in color and wet. The SPT "N" values within this layer ranged from 1 to 4 blows per 300 mm penetration, corresponding to very loose in compactness condition.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests. The test results are as follows:

Moisture Content:

- 24% to 35%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix D.

6.1.7 Gravelly Sand(SW)

Native gravelly sand was encountered below the silty sand layer in borehole BH400-050-01. The approximate elevations of the surface and base of the layer, thickness, description and SPT (N Value) encountered in the borehole are summarized in Table 1.7 below:

Table 1.7: Summary of Gravelly Sand Layer

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-01	196.2	195.5	0.8	0.7	Gravelly Sand	1

This layer consisted primarily of sand and gravel with some silt and trace clay. The soil was grey in color and wet. The SPT "N" value within this layer was 1 blow per 300 mm penetration corresponding to very loose in compactness condition.

Laboratory testing performed on a selected sample consisted of one (1) moisture content test. The test results are as follows:

Moisture Content:

- 34%

The results of the moisture content test are provided on the record of borehole sheets in Appendix D.

6.1.8 Clayey Silt to Silty Clay(CL-CI)

Native cohesive soil was encountered below the gravelly sand layer in borehole BH400-050-01, below the topsoil and below the silty sand to sandy silt layer in borehole BH400-050-02, and below the embankment fill in boreholes BH400-050-03A/3B, BH400-050-04 and BH400-050-05. All boreholes were terminated within this layer. The approximate elevations of the surface and base of this layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.8 below:

Table 1.8: Summary of Clayey Silt to Silty Clay Layer

Borehole	Elevation (m)		Layer Surface Depth (m)	Investigated Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-01	195.5	188.6	1.5	6.9	Clayey Silt to Silty Clay	1 – 2
BH400-050-02	196.4	196.2	0.1	0.2	Clayey Silt	---
	194.3	188.2	2.2	6.1	Clayey Silt to Silty Clay	1 – 4

Borehole	Elevation (m)		Layer Surface Depth (m)	Investigated Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-050-03A	193.6	191.6	7.1	2.0	Clayey Silt	2 – 4
BH400-050-03B	191.6	190.3	9.1	1.3	Clayey Silt	2 – 3
BH400-050-04	194.0	189.1	7.9	4.9	Clayey Silt	1 – 4
BH400-050-05	194.1	188.8	7.8	5.3	Clayey Silt	5 - 6

The composition of this material generally consisted of clay and silt with trace to some sand, trace gravel and occasional silt lenses. The material was generally grey in colour and wet. The SPT "N" values within this layer ranged from 1 to 6 blows per 300 mm penetration, corresponding to very soft to firm in consistency. Additionally, in-situ vane testing with this layer measured an undrained shear strength ranging from approximately 12 kPa to 120 kPa indicating very soft to very stiff, but generally very soft to stiff in consistency. The Atterberg limits test results suggest that this cohesive layer was of low to high plasticity.

Laboratory testing performed on selected samples consisted of fourteen (14) moisture content tests, seven (7) grain size distribution test, and five (5) Atterberg limits tests. The test results are as follows:

Moisture Content:

- 22% to 65%

Grain Size Distribution:

- 0% to 3% gravel;
- 1% to 23% sand;
- 19% to 69% silt;
- 22% to 80% clay;

Atterberg Limits:

- Liquid Limit: 27% to 61%
- Plastic Limit: 13% to 27%
- Plasticity Index: 13% to 34%

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution test and Atterberg limits test are also provided on Figure 2 and Figure 3, respectively, in Appendix E.

6.2 Groundwater and Surface Water Conditions

Groundwater levels were observed upon completion of the boreholes and in piezometers. Groundwater levels measured on completion of boreholes may not be considered stabilized and therefore may not represent the established long-term average groundwater table. A summary of the groundwater levels observed upon completion of the boreholes and in piezometers are summarized in Table 1.9 and are also presented on the record of borehole sheets in Appendix D.

Table 1.9: Summary of Observed Groundwater Levels

Borehole	Ground Surface Elevation (m)	Water Level Depth/ Elevation (m)[1]	Date Measured	Comments
BH400-050-01	197.0	0.6/196.4	February 6, 2024	Taken upon completion of drilling
BH400-050-02	196.5	0.7/195.8	April 26, 2023	Taken upon completion of drilling
BH400-050-03B	200.7	2.8/197.9	Feb. 2, 2024	In piezometer
BH400-050-04	201.9	---	---	Borehole caved at 5.4 m preventing measurement
BH400-050-05	201.9	4.3/197.6	Feb. 15, 2023	Taken upon completion of drilling

Note:

1. *Depths are relative to ground surface*

The measured elevations of the top of creek water at the existing CSP culvert location was Elev. 196.7 m at the inlet (measured on April 26, 2023) and Elev. 195.8 m at the outlet (measured on February 13, 2023).

Groundwater levels would be expected to reflect levels in the adjacent open water and to fluctuate seasonally. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

6.3 Chemical Analysis

One soil sample was selected for chemical analysis during the current investigations performed by EXP. The soil sample collected by EXP was tested at a CALA-certified and accredited laboratory. The results of the corrosion potential chemical analysis testing including sulfide, chloride, sulfate, pH, electrical conductivity, resistivity and redox potential are included in Appendix E and summarized in Table 1.10.

Table 1.10: Summary of chemical analysis results

Borehole ID	Sample	Depth (m)	Chloride (ppm)	Sulphate (ppm)	pH	Electrical Conductivity (umho/cm)	Resistivity (ohm-cm)	Redox Potential (mV)
BH400-050-01	SS3	1.5 – 2.1	<20	35	8.08	181	5500	85

Part II: Foundation Investigation and Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto **- Highway 400 CSP Culvert Replacement (CV-0252-0400-0050)**

7.0 ENGINEERING DISCUSSION & RECOMMENDATIONS

7.1 General

This section of the report provides geotechnical design recommendations for the replacement of the Corrugate Steel Pipe (CSP) culvert on Highway 400 (Culvert ID: CV-0252-0400-0050), located approximately 2.7 km southwest of the intersection of Highway 400 with Highway 19 in the Simcoe region (Latitude: 44.639180; Longitude: -79.654120) in the Ministry of Transportation (MTO) Central Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site performed by EXP between February 13 and February 6, 2024. The compiled factual data is presented in **Part I-Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely to permit designers to evaluate the subsurface conditions along the existing culvert, and based on this data, to provide detailed design for the culvert replacement and to examine the suitability of trenchless methods of replacement. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on the contract drawings provided, the existing culvert has a two segments CSP culverts with a 1150 mm dia CSP pipe on the west segment and a 1220 mm dia CSP pipe on the east segment with about a 9-degree skew connection from along its alignment near mid section (located about the median of the Hwy 400). The west segment and segment are about 30.7 m 43.8 m in length with the total length of the existing culvert is about 74.5 m. The elevation of the highway centerline at the culvert location is approximately Elev. 202.0 m for both the northbound lane (NBL) and southbound lane (SBL). The flow through the culvert is from west to east, following the natural topographic conditions in the vicinity of the site.

The existing culvert is proposed to be replaced with a twin culvert (1400 mm diameter with 400 mm thick substrate and native material and 800 mm diameter) using trenchless installation methods. The 1400 mm diameter culvert will be replaced at the existing culvert location and 800 mm diameter culvert will be installed about 3 diameter (i.e about 4.2 m) south of the existing culvert or proposed 1400 mm diameter culvert. The invert level of the new 1400 mm diameter culvert is proposed to be 196.86 m and 195.97 m at inlet and outlet locations, respectively. Whereas the invert levels of the 800 mm diameter culvert will be matched the existing culvert levels 196.6 m and 195.7 m at the inlet and outlet, respectively. The existing Highway 400 profile grade is planned to remain unchanged at the culvert location.

This part of the report provides comments and recommendations for the geotechnical design and trenchless replacement of the existing culvert. These comments and recommendations are provided in accordance with the latest editions of the Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19), the Canadian Foundation Engineering Manual (CFEM, 2023), MTO Gravity Pipe Design Guidelines (April 2014), Guideline for MTO Foundation Engineering Services Version 03 (April 2022), Appendix: Settlement Monitoring Guidelines – Tunnel from Guidelines for Foundation Engineering – Tunneling Speciality for Corridor Encroachment Permit Application (February 2021), MTO NSSP for Pipe Installation by Trenchless Method (June 2021) and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us in the (MTO) Request for Proposal, dated February 2022. The assessment involved review of options for replacement of the existing culvert via trenchless methods both at the existing culvert alignment and at a new alignment are considered for culvert replacement. The use of temporary shoring systems for sending/receiving pit excavations and protection of the construction site by cofferdams is also addressed.

7.2 Expected Ground Conditions

Based on the geotechnical investigation conducted at the site (as shown in Drawing attached in Appendix C), the subsoils condition below the roadway indicates the following subsurface sequence: asphalt underlain by sand and gravel to gravelly sand followed by predominantly sand fill with layers of clayey silt fill. The embankment fill is underlain by clayey silt to silty clay. At the culvert inlet, the encountered subsurface conditions were observed to consist of topsoil over silty sand followed by gravelly sand underlain by clayey silt to silty clay. At the outlet, the encountered subsurface conditions were observed to consist of topsoil over clayey silt followed by silty sand to sandy silt underlain by clayey silt to silty clay.

Based on groundwater levels measured in the open boreholes and in piezometer, the groundwater level is interpreted to be about Elev. 197.6 m to 197.9 m across the site. At the time of investigation, the top of the creek water was at Elev. 196.7 m at the inlet (measured on April 27, 2023) and Elev. 195.8 m at the outlet (measured on February 13, 2023).

Groundwater levels would be expected to reflect levels in the adjacent open water. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods.

7.2.1 Tunnelman's Ground Classification

The Contract Drawings attached in Appendix B shows that the tunneling horizon of the new culverts are proposed to the invert levels (approximately 196.5 m (1400 mm dia)/196.6 m (800 mm dia) and 195.6 m (1400 mm dia)/195.7 m (800 mm dia) at the inlet and outlet, respectively). Therefore, it is expected that the proposed tunneling excavation will be performed through very loose to compact sand fill. Several thin layers and seams of very soft to firm clayey silt/silty clay were also found interbedded in the sand fill layer and therefore may be encountered within the tunneling excavation. Mixed-face conditions should be anticipated during tunneling. In addition, the tunneling operation is expected to be within the groundwater fluctuation levels. Therefore, it is expected that the tunnel will generally be located within moist to wet cohesionless soils having variety size of grains.

In general, the fill material behavior along the tunnel horizon should be anticipated to vary. However, based on Terzaghi's Tunnelman's Ground Classification System, it is expected that the cohesionless fill will likely behave as "running" material above the groundwater table and as "flowing" below the groundwater table. The cohesive fills and native clayey silt will likely behave as "raveling" above the groundwater table and "squeezing" below the groundwater table. Therefore, tunnel face instability caused by these cohesionless soils would be generally expected, so excavation within unsupported tunnel face should be done in a manner to control potential groundwater seepage and to prevent possible ground loss.

7.3 Tunnel Alignment

Table below provides a summary of the proposed culvert and estimated pipe diameter, approximate overt elevations and the cover thickness at the highway/ median.

Table 2.1: Summary of Site Elements along Tunnel Alignment

Item		Elevation/Thickness (m)	
Proposed Tunnel Dia. (m)		1.4 m	0.8 m
Pavement Elev./ Ground surface Elev.	North Bound Lane	~202.0	~202.0
	South Bound Lane	~202.0	~202.0
	Median	~200.7	~200.7
Obvert	Inlet	~197.9	~197.4
	Outlet	~197	~196.5
Cover	North Bound Lane	~4.1	~4.6
	Median	~3.2	~3.7
	South Bound Lane	~5	~4.5

For tunnels under 400-series highways, MTO typically requires that the minimum overburden cover shall not be less than 1.5 m or generally two tunnel diameters, whichever is greater, at any point along the entire length of the tunnel crossing.

As stated earlier, twin culverts are proposed to be installed using trenchless installation methods at this site. For a twin tunnels typically, a minimum separation of 3 diameters (larger pipe) shall be required. More specific analysis may be necessary if it is required to reduce the separation distance. As stated in the table above, the minimum cover below the Highway 400 surface based on the larger diameter pipe would be between about 3.2 m providing a cover-diameter ratio of about 2.3.

7.4 Trenchless Installation Method

The interior and exterior trenchless replacement method at the existing alignment such as pipe bursting, pipe reaming are considered unsuitable for this project due to presence of bend in the existing alignment. Pipe swallowing (modified pipe ramming method) is also considered unsuitable unless the Contractor has an approach, to jack from both end to an intermediate location to follow the alignment of the existing culvert.

For the trenchless replacement at a new alignment, the installation method such as horizontal directional drilling is considered unsuitable due to proposed culvert diameter equal to or greater than 0.8 m. A jack and bore method of installation is also considered unsuitable for this project unless dewatering at least 1 m below the tunnel invert for full length of the pipe alignment is implanted.

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the existing inlet and outlet locations and at the proposed new alignment are discussed in the following sections:

Trenchless method at the existing alignment:

(i) Pipe eating (modified micro-tunneling)
(ii) Pipe swallowing (modified pipe ramming)

Trenchless method at a new alignment:

(i) Pipe ramming with a hammer head to break obstruction
(ii) Micro-tunneling

The installation of the new culvert should be in accordance with the MTO NSSP for Pipe Installation by Trenchless Method (June 2021) and Guidelines for Foundation Engineering – Tunneling Speciality for Corridor Encroachment Permit Application (February 2021).

7.4.1 Trenchless Installation Alternatives

Table 2.2 summarizes advantages and disadvantages for some of the possible alternatives for the culvert installation using trenchless technology. Additionally, Table 2.3 provides a general comparison of technical issues associated with trenchless methods at existing and a new alignment. The following sections provide a discussion for some of the options for proposed trenchless culvert installation.

Table 2.2: Trenchless installation method comparison

Installation Method	Advantages	Disadvantages
Trenchless method at the existing alignment		
Pipe eating (modified micro-tunneling)	• The new pipe may follow the entire old alignment or a limited segment only. Steerable both horizontally and vertically to maintain and allow the culvert to follow the straight-line alignment notwithstanding presence of bends in the existing culvert. • Cutting head can cut the existing pipe and surrounding ground to the required diameter to allow installation of a new pipe. • Handles wide variety of ground conditions. • Suitable for tunnelling underground water table	• The segment of the existing culvert may require pre-grouted to provide a more uniform face condition for excavation and to prevent the loss of excavation fluids. • The surface water flow during the construction has to be conveyed to some other route

Installation Method	Advantages	Disadvantages
Pipe swallowing (modified pipe ramming)	• Minimum groundwater control required along the tunnel if the entire pipe is installed without soil removal. • Minimum equipment outlay, relative simplicity of operation. • The existing pipe itself guards against cavitation.	• Require jacking from both end to intermediate location to follow existing culvert alignment. • Require construction of a manhole at the median area to connect flow, which may not be feasible from a fisheries standpoint. • Since it is a non-steerable system, it will be difficult to control line and grade during installation. Obstructions can cause deflection of casing resulting in misalignment of culvert. • Vibrations could potentially impact the stability of the existing slope and neighbouring structures. • Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining. • Potential for soil heave due to blockage • Requires construction of sending and receiving pits • Groundwater control required at construction of sending/ receiving pits • The surface water flow during the construction has to be conveyed to some other route
Trenchless method at a new alignment		
Pipe Ramming	• Better suited for penetrating through potential obstructions such as cobbles and boulder compared to jack and bore methods. However, nests of cobbles and/or boulders can stop penetration of casing. • Minimum groundwater control required along the tunnel if the entire pipe is installed without soil removal. • Existing culvert could be used for surface water dewatering during construction.	• The length of the proposed culvert might be an issue. Typical drive length for this method is 30 to 60 m. However, up to 100 m drive may be possible by specialists contractor. • Large area requires for ramming pit • Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Since it is a non-steerable system, it will be difficult to control line and grade during installation • Nests of cobbles and boulders can stop penetration of casing requiring hand mining, which may not be feasible for smaller pipe • Potential for soil heave due to blockage • Groundwater control required at construction of sending/ receiving pits

Installation Method	Advantages	Disadvantages
Micro-tunneling	• In general, handles wide variety of ground conditions. • Ability to control excavation face stability. • Typically does not require groundwater lowering except for use of "small boring units" without slurry face pressure and cuttings transport systems. • Minimum surface disruption • High Accuracy • The existing culvert can be used to maintain the surface water flow during the construction	• High construction cost • Excavation and shoring for sending and receiving pits required to achieve starting grade • Requires large area for jacking shaft and support equipment • Dewatering possibly required at sending and receiving pits • Need to take precaution for tunneling, due to presence of organics silty clay/rootlets within the tunnel horizon

Table 2.3: General comparison of technical issues associated with trenchless methods

Typical Limitations	Tunneling Method	
	Pipe Ramming / Pipe Swallowing	**Microtunneling/ Pipe Eating**
Length of drive and diameter	• Generally best suited to short watercourse crossings where risks of ground heave are low • 30 to 60 m drives are typical. However, up to 100 m drive may be possible by specialists contractor • Diameters of 1800 mm are technically feasible with a large hammer; however, the stability and integrity of the soil plug in the lead pipe segment is less certain with larger diameters	• Drive lengths of 300 m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75 m • Micro tunnels up to 1500 mm dia. can be readily constructed in Ontario; 3000 mm dia. may be feasible by specialists
Ability to control line and grade	• Relatively poor • At the existing alignment, existing pipe itself provides some guards but also may obstruct the advancement	• Good • Line and grade control to within ±40 mm is feasible over 300 m drive
Ability to control ground surface displacement	• Poor • Risk of ground heave is moderate to high • If soil plug washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of soil and groundwater conditions • Full and immediate ground support by means of jacking pipe

Typical Limitations	Tunneling Method	
	Pipe Ramming / Pipe Swallowing	Microtunneling/ Pipe Eating
Ability to deal with mixed face ground conditions	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to breakdown cohesive clays
Ability to deal with flowing or unstable face conditions	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment; if the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method
Ability to deal with cobbles, boulders, and other obstructions	• Typically better than Jack & Bore • May require removal of soil plug to remove/breakup boulder which could possibly compromise tunnel stability	• Combination of disk and pick cutters is needed • Person entry not practical • Wood troublesome

7.4.1.1 Discussion of Drilling Methods

The pipe-eating method for installation at the existing inlet and outlet locations and microtunneling method at a new alignment are suitable at this site to follow the proposed straight-line alignment accounting for the existing culvert alignment bend/skew. However, the initial installation cost is anticipated to be higher.

The Pipe ramming method of installation at a new alignment is not a suitable option since the driving length is greater than 60 m unless from a specialized contractor who can drive up to 75 m. Alternatively, it may be feasible if an intermediate jacking pit is considered. Similarly, Pipe ramming/Pipe Swallowing is not a suitable method for installation at the existing inlet and outlet locations if followed proposed straight line alignment. However, if the existing skewed alignment can be maintained, it may be possible to jack to an intermediate location to follow the existing culvert alignment.

A summary of the recommendations based on the various methods is presented in Table 2.4 below. Table 2.5 presents a risk register for installation by trenchless method at this site.

Table 2.4: Summary of Recommendations

Installation Method	Recommendation
Pipe Ramming	Acceptable, if an intermediate jacking pit is considered or if an approach to drive up to 75 m in length is presented
Pipe Swallowing	Acceptable, if an approach to follow the existing skewed alignment to an intermediate location is presented
Microtunneling	Preferred
Pipe-Eating	Preferred

Table 2.5: Risk Register For Installation by Trenchless Method Under Highway 400

Risk Item	Impact	Key Issues and Consequences	Mitigation Measures Recommended	Unmitigated Risk Level	Mitigated Risk Level
1. Ground loss-Settlement of Roadways due to trenchless crossing	• Liability for settlement damage to private property, utilities and/or roadways	• Possible running of soil into excavations or tunnels can lead to ground loss, resulting in settlement of roadway. • Roadway traffic may experience surface depression while driving. • Slower rate of tunneling advancement	• Slurry shield MTBM can balance earth pressures in the shield to a variety of soil and groundwater conditions. • Maintaining a soil plug in the lead pipe segment for methods like pipe swallowing/ pipe ramming. • Lower groundwater level at least 1 m below excavation level • Conduct pre-construction baseline settlement monitoring data along the alignment. • Prepare a comprehensive settlement monitoring program, including an action plan if review and alert level is exceeded.	Likelihood – M Impact - M	Likelihood – L Impact - L
2. Ground loss-Settlement of Roadways due to groundwater inflow greater than anticipated for tunnel drive and at shafts	• Liability for settlement damage to private property, utilities and/or roadways	• Possible flowing of ground into excavations or tunnels can lead to ground loss, resulting in settlement of roadway. • Tunnel or shaft construction encounters local inflow. • Roadway traffic may experience surface depression while driving. • Slower rate of tunneling advancement • More frequent intervention delays and/or delays completion work	• Slurry shield MTBM can balance earth pressures in the shield to a variety of soil and groundwater conditions. • Maintaining a soil plug in the lead pipe segment for methods like pipe swallowing/pipe ramming. • Lower groundwater level at least 1 m below excavation level	Likelihood – M Impact - M	Likelihood – L Impact - L

Risk Item	Impact	Key Issues and Consequences	Mitigation Measures Recommended	Unmitigated Risk Level	Mitigated Risk Level
3. Delay tunnel advancement due to obstructions	• Tunnelling operations may need to be halted to address conditions with associated cost and schedule implications	• Obstructions such as arrays of strong boulders may impact the advancement of tunnel • Delays and/or work stoppage may require • Access to face may be required to remove the obstruction or change the cutter head • Potential for Differing Site Condition (DSC) claims	• Select tunneling methods such as pipe eating/micro tunneling which can handle a wide variety of ground conditions. • Prepare for appropriate tools and methods if encounter any obstruction	Likelihood – M Impact - M	Likelihood – L Impact - L
4. Alignment issue- due to squeezing organic silty clay	• Tunnel vertical alignment may deviate from the planned alignment	• Deviation from the proposed invert levels may create an issue in maintaining flow condition	• Frequent monitoring of alignment during tunnel advancement • Prepare for appropriate tools and methods in case of alignment deviation	Likelihood – M Impact - M	Likelihood – L Impact - L
5. Major equipment failure	• Tunnelling operations may need to be halted to address conditions with associated cost and schedule implications	• Delays and/or work stoppage may require	• Frequent monitoring of equipment operation as well as maintenance frequency	Likelihood – M Impact - L	Likelihood – L Impact - L

The following sections in this report provide general recommendations for trenchless installation of the new culvert at an existing alignment and at a new alignment.

7.4.1.2 Culvert Installation at Existing Culvert

7.4.1.2.1 Pipe Eating

Pipe eating is a modified micro-tunneling system specially adapted for pipe replacement. The method is different than the pipe-bursting operation. The crushed fragments of pipe mixed with soil are vacuumed out, as slurry, through the new pipe and out of the space. A new pipe, of the same or larger nominal size, is simultaneously installed by jacking it behind the micro-tunneling machine. The new pipe may follow the line of the old pipe on the entire length, or may cross the elevation of the old pipe on a limited segment only; this may allow for a straight-line system installation with the remaining section grouted in place. The system is remotely controlled and guided with a surveyed laser line from the drive pit, and prepared to "eat" whatever is in the way, the old pipe or the ground only. The system has a cutting head and a shield section. The cutting head has cutting teeth and rollers that cut the pipe, and cutting arrangements close to the edge of the shield that cut the ground to the required diameter to take the new pipe. The cutting head is cone-shaped, which puts the material of the old pipe into tension and thus reduces the heavy wear of cutting teeth. The shield section carries the cutting head and its hydraulic motor system. The head and shield are launched from a drive pit, where a thrust frame is located. It provides a thrust that is applied on the cutting head through the new pipe to push the head and shield forward through the ground.

A bentonite grout lubricant can be injected behind the cutting face in order to minimize the resistance along the pipe exterior. Pipes may be made of various materials (concrete, steel, fibreglass, etc.). Selected pipe must conform to OPSS requirements for an embankment depth at this site. The launching pit and jacking station should be constructed at the inlet side. A protection system might be required to minimize possible negative impact on the stability of the existing roadway.

7.4.1.2.2 Pipe Swallowing

Pipe swallowing is understood to be the technique based on conventional pipe ramming method using pneumatic percussion to drive steel pipe in a wide variety of soil types. Its advantages over other pipe installation methods include minimum equipment outlay, relative simplicity of operation and suitability for use in sensitive ground conditions without disturbing ground around the pipe or construction or surface features above. As it is driven in place, the pipe itself guards against cavitation, making it a preferred method for installing casing where subsidence is a concern, such as beneath roads and railroad beds. Traffic continues unimpeded by the ramming operations. Pipe ramming can often be used when other means of installation cannot. In some cases, it has been used to save a project when another installation method has failed. The pipe swallowing version of pipe ramming is used to replace a pipe or casing in place with larger diameter casing. The casing is rammed around the existing culvert, which is then removed with the spoil.

7.4.1.3 Culvert Installation at a New Alignment

It is recommended that the new alignment has to be at least 3 pipe diameters offset to the north or south, relative to the existing culvert. During construction, the existing culvert can be used to convey the surface water flow toward the outlet. However, after the construction of new culvert, the abandoned culvert (if any left in place) must be properly decommissioned including its grouting and sealing.

7.4.1.3.1 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 60 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering the length of the proposed culvert (~74.5 m based on the existing culvert length), the pipe ramming method may not be feasible option for the installation of a culvert at this site. However, up to 100 m drive may be possible by specialist contractor. If pipe ramming is a desired option, the tunneling contractor must provide a Work Plan detailing the methodology to control the ram orientation. Potential options include drilling pilot holes or telescoping pipe diameters.

7.4.1.3.2 Micro-tunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the mixed face condition. In order to minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

In general, the major advantage of micro-tunneling method is that its performance is not affected by high groundwater levels, so dewatering is not required if this method is employed. Major disadvantages of micro-tunneling for this project are considered to be the relatively high cost of mobilization and installation, especially given the relatively small tunnel diameter and short tunnel length at the current site.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the sending pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope.

Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of the new culvert.

7.4.2 Sending/Receiving Pits

7.4.2.1 Excavation

The sending and receiving pits for the tunneling equipment are expected to be located at the outlet and inlet of the proposed culvert location, respectively. The bases of the pits are expected to be set at about 0.5 to 1 m depth from invert of the proposed culvert. Excavation for the pit at the existing culvert inlet is expected to be conducted through very loose silty sand, very loose gravelly sand, and very soft clayey silt to silty clay while excavation for the pit at the existing culvert outlet is expected to be conducted through very loose silty sand to sandy silt and soft clayey silt to silty clay. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of soft/loose soils at the toe of the embankment. An example of this NSSP as well as a NSSP for obstructions is provided in Appendix F.

The Contractor should be aware that the slope height, slope inclination, or excavation depths must in no case exceed those specified in local, provincial, or federal safety regulations.

Excavation for the sending/receiving pits shall be performed according to OPSS.PROV 401 and the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). The embankment fill and native soils may be classified as a Type 3 soil above the groundwater table and Type 4 soil below the groundwater table in conformance with the OHSA. In accordance with OHSA regulations, if the excavation contains more than one type of soil, the excavation shall be constructed according to the type with the highest number. Any excavation deeper than 1.2 m should be sloped back to a safe angle of 45 degrees or flatter, according to the Act. Temporary excavation side slopes in Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

In order to limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. Basal instability should be anticipated in excavations since the groundwater level is at or above the base of excavation. Ingress of groundwater and surface water has to be controlled. Technical specifications must ensure that the Contractor submits a groundwater and surface water control plan describing the proposed method for control. In this site the existing culvert could be used to convey the creek water during the construction.

7.4.2.2 Temporary Shoring

Temporary protection systems are anticipated for the construction of the send and receiving pits. Roadway protection systems shall be design in accordance with OPSS.PROV 539 and OPSS.PROV 903 as amended by SP109F57. The complete design, construction, monitoring and removal of the installed protection system should be a responsibility of the Contractor. Due to nature of this application it is expected that much of temporary shoring will be decommissioned in place noting the high cost for removal. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work.

Based on the geotechnical conditions at the site, a shoring system such as steel sheet piling can be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Table 2.6. If a cantilever system is used, an embedded depth of sheet piles should be determined by balancing moments about the pile tip and it could be approximately 2.0 to 2.5 times its exposed height. Alternatively, a system of rakers can be used for support.

An obstruction which was likely a cobble was encountered in BH400-050-03A. Additionally, cobbles and boulders were encountered in the native soils in nearby sites in the region. Therefore, it is recommended that care has to be taken during installation of sheet piles.

The protection system shall be designed for Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the elevations specified. If movement approaches the allowable limit of 25 mm (Performance level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

After construction of the new culvert, the protection system could be removed. In that case the details of the procedures associated with the removal of the protection system indicating: method, sequence of work, and removal limits are required from the Contractor as per OPSS.PROV 539. However, if the protection system is decided to be left in place the top should be removed to at least 1.2 m below the finished grade or ground level or at least 0.6 m below the streambed. All disturbed areas should be restored to an equivalent or better condition than what existed prior to the commencement of construction.

7.4.2.3 Lateral Earth Pressure

Temporary shoring for the excavation of the sending and receiving pits (if any) should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma h + q)$ for braced cut

where,

P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.6 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

Table 2.6: Material types and earth pressure properties

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure At- Rest (K_o)	Unit Weight γ (kN/m^3)
Embankment Fill – Sand (very loose to compact)	28	0.36	2.77	0.53	20
Embankment Fill – Clayey Silt/Organic Silty Clay (very soft to stiff)[1]	26	0.39	2.56	0.56	18
Silty Sand to Sandy Silt to Gravelly Sand (very loose)	27	0.38	2.66	0.55	19
Clayey Silty to Clayey Silt (very soft to firm)[1]	26	0.39	2.56	0.56	18

Notes:

1. *Assumes long term conditions. In short term conditions K_a = K_p = 1*

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design.

The effect of compaction surcharge should be taken into account in the calculations of active and at rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to culvert walls to prevent overstressing.

Bracing for the temporary support system (if any) will be required at a maximum interval of 5 m. For multiple support systems refer to Canadian Foundation Engineering Manual (CFEM, 2023) for apparent earth pressure distributions (CFEM, Section 20.8.1.3, Figure 20.20).

7.4.2.4 Backfilling

It is anticipated that backfilling work will be required at the launching and receiving pits to return site condition to pre-construction grades. These excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted according to OPSS.PROV 501. Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

7.4.3 Ground Movement Monitoring

Following the CMO- Guidelines for Tunnelling, it is recommended that ground movement monitoring be carried out for this site in order to identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Pipe Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of each other, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

7.5 Site Dewatering

7.5.1 Cofferdams

Temporary cofferdams may be required at the location of the sending/receiving pits to envelop the construction site and keep it free of water during replacement if trenchless replacement methods at the same alignment as the existing culvert is selected. Two types of cofferdams, i) sheet pile wall, and ii) rockfill/earth dam/sandbag, could be considered. During construction, creek flow should be maintained through the temporary flow passage system with a culvert in place. Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor.

Based on the geotechnical conditions, suitably designed steel sheet pile walls can be used as cofferdams at this site. Sheet piles perpendicular to the highway at least 3 m into the embankment slopes should be considered to prevent water getting in through the sides. If a cantilever system is used, an embedded depth of sheet piles can be approximately 2.0 to 2.5 times its exposed height. The proposed sheet pile wall should be at least one meter above the designed HWL defined by the Hydraulic Engineer. The required minimum section modulus and embedment pile length should be designed based on the recommended design parameters. Cobbles and/or boulders were not noted to be contained within the native soil deposits; however their presence should be anticipated and care has to be taken during installation of sheet piles. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders at the site. An example of a NSSP for obstructions is provided in Appendix F.

Alternatively, a rockfill/earth cofferdam can be used. The rockfill/earth/sandbag cofferdam will have to be constructed to accommodate all topographic constraints. The size of material suitable for use depends on the erosion potential, stream flow velocity, etc. The rockfill/earth/sandbag cofferdam should be designed with a more impervious water barrier at the outside face to create a more watertight enclosure. Schemes involving 50.8 mm (2") minus crusher run with finer facing material upstream have been successfully used in similar settings. Any required permitting must be determined. The proposed rockfill/earth cofferdam should be at least one meter above the designed high water level (HWL) defined by the Hydraulic Engineer.

As mentioned, which cofferdam system is best suited depends on many technical and economic factors. The advantages and disadvantages of both cofferdam systems are summarized in Table 2.7.

Table 2.7: Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Steel sheet piles	1	▪ Provides more watertight base ▪ Structural elements and seals easier to positively construct ▪ Increased safety with appropriate design ▪ Easily removed ▪ Less seepage ▪ Reusable	▪ More costly ▪ More likely time consuming for installation ▪ May present issues for seepage and/or piping ▪ Larger machines required ▪ May require bracing ▪ May face difficulty driving through soil deposits if cobbles and/or boulders are present ▪ May require strengthening toe of sheet pile	Medium to High	▪ May take longer to install ▪ Environmental permits
Rock fill/ Earth	2	▪ Less costly ▪ Relatively less time consuming for installation ▪ Native material can be usable ▪ Not affected by presence of cobbles and/or boulders	▪ Require more space for installation ▪ Less safe ▪ Subjected to wave erosion ▪ Less watertight ▪ Prone to land shifts, slides and collapse ▪ More likely time consuming to remove	Low to Medium	▪ Less stable and safe. May generate 'mud waves' ▪ May take longer to remove ▪ May require installing clay cut off ▪ More dewatering ▪ Environmental permits

Given the soil conditions, topography of the surrounding terrain, and available space, the use of a suitably designed steel sheet pile system of sufficiently robust cross-section is recommended at the inlet and outlet of the existing culvert (if they are required). The design of these cofferdams, which are temporary retaining structures, is the responsibility of the Contractor. The cofferdam must be designed to withstand the anticipated design loads and to be watertight as practically as possible. The Contractor is also responsible for cofferdam's materials, construction, monitoring and removal.

Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor. Pilling should be in accordance with OPSS.PROV 903. Cantilevered walls should be designed for the earth pressures shown in Table 2.8 and earth pressure diagram shown in the CFEM Figure 20.15. As mentioned before, besides design and construction of the temporary cofferdam system, the Contractor is also responsible for its removal. The temporary cofferdam shall be fully removed, unless it is specified in the Contract Documents that the cofferdam system may be partially left in place. The method and sequence of removal shall be so that there shall be no damage to the new work, existing work, and facility being protected.

For design purposes, the following parameters given in Table 2.8 can be assumed after installation of retaining system.

Table 2.8: Soil parameters and lateral earth pressure coefficient information required for temporary cofferdam design

Unit	Relevant Boreholes	Approx. Elevation (m)	Materials	Unit Weight γ (kN/m³)	GWL/ Creek Water Elevation (m)	Effective Stress Properties			
						Angle of Friction ϕ'(°)	Coefficient of Lateral Earth Pressure		
							K_a	K_p	K_o
Inlet	BH400-050-01	196.9 – 196.2	Silty Sand Very loose	19	197.9 / 196.6 (inlet) 195.7 (outlet)	27	0.38	2.66	0.55
		196.2 – 195.5	Gravelly Sand Very loose	19		27	0.38	2.66	0.55
		195.5 – 188.6	Clayey Silt to Silty Clay[1] Very Soft to Firm	18		26	0.39	2.56	0.56
Outlet	BH400-050-02	196.4 – 196.2	Clayey Silt[1] Soft	18		26	0.39	2.56	0.56
		196.2 – 194.3	Silty Sand to Sandy Silt Very loose	19		27	0.38	2.66	0.55
		194.3 – 188.2	Clayey Silt to Silty Clay[1] Very Soft to Firm	18		26	0.39	2.56	0.56

Notes:

1. *Assumes long term conditions. In short term conditions K_a = K_p = 1*

K_a = active earth pressure coefficient

K_o = coefficient of earth pressure at rest

K_p= passive earth pressure coefficient

7.5.1.1 Piping

Given the groundwater conditions and soils present (pervious materials, sands and silts), piping of the soil is anticipated to be a potential issue at the site due to an unbalanced hydrostatic head causing large upward seepage pressures in the soil at the bottom of the inside cofferdam (if one is required). Piping should be controlled by lowering the water table outside the cofferdam or driving the sheeting to sufficient depth to mitigate against piping. If a rock fill/earth cofferdam is used, piping can be controlled by installing a clay cutoff trench, slurry trench or impervious blanket upstream of the cofferdam.

7.5.2 Groundwater Control

The groundwater level within the embankment fill at the site was encountered at about Elev. 197.9 m based on a monitoring well reading taken February 2, 2024. However, groundwater levels would be expected to reflect levels in the adjacent open water. At the time of the field investigation, the approximate top of water elevation at the inlet and outlet of the culvert was measured to be about 196.7 m (measured April 2023) and 195. 8 m (measured February 2023), respectively. Construction for the replacement of the culvert is recommended during the low water level season.

The soils encountered within potential excavation depths will consist of sand and clayey silt/silty clay fills and both native cohesive (clayey silt) and cohesionless soils (gravelly sand, silty sand, sandy silt). These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled at least 0.5 m below the excavation level to avoid disturbance. Given the conditions at this site, conventional sump pumping may not be effective for deeper excavations below the groundwater table and those conditions will require more positive dewatering systems. Confirmation of control should be verified before general excavation to final levels.

Dewatering may require water taking permits (i.e. Permit to Take Water PTTW). A PTTW is required for any water taking if the volume exceeds 50,000 L/day. The rate and volume required for dewatering will be dependent on the construction methods and staging chosen by the Contractor.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517 and SP 517F01. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions. The method used should not undermine the adjacent embankment and utilities (if any). Alternatively in accordance with SP 517F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

Erosion and sediment control during culvert construction should be as per the MTO Drainage Manual, Volume 2. Silt fences and other sediment control measures should be included to protect the downstream environment from the construction activities.

7.6 Scour/Erosion Protection

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation.

7.7 Corrosion Potential and Cement Type

One (1) soil sample was selected for chemical analyses during this investigation. The testing was completed to determine the potential degradation of the concrete in the presence of soluble sulphates and the potential of corrosion of exposed steel used in foundations and buried infrastructure. The analyses results are summarized in Table 1.10 of this report.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value measured at the site was 8.08 which is within the normal range of soil pH of 5.5 to 8.5 that is not considered to be detrimental to culvert durability (AASHTO, 2000/MTO Gravity Pipe Design Guidelines, April 2014). The chemical data indicates high (R>4500 ohm-cm) resistivity of the tested soil which suggests low potential for corrosion of buried metallic elements as per Table 3.2 of the MTO Gravity Pipe Design Guideline. The measured chloride content was under 20 ppm (µg/g) which also indicates a very low potential for additional corrosion (Molinas and Mommandi, 2009).

These chemical test results may be used to aid in the selection of coatings and corrosion protection systems for buried steel culverts, if selected. If the concrete culvert option is selected, consideration should be given by the designer to designing for a « C » type of exposure class of concrete as defined by CSA A23.1:19 Table 1, since the culvert will be exposed to de-icing salt.

The maximum water-soluble sulphate content of the soils tested is 35 ppm (µg/g), i.e. 0.0035%, and being less than 0.10% (as per CSA A23.1:19, Table 3) does not require sulphate resistant cement. The data supports our local experience.

7.8 Obstructions during Installation of Temporary Protection Systems

Suspected cobbles were noted to be contained within the embankment fill soil deposits at the site during site investigation. Therefore, care has to be taken since the presence of these obstructions may affect the excavation for sending/receiving puts, installation of protection system elements (if any) and installation of the pipe. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders within the overburden soils. An example of NSSP for obstructions is provided in Appendix F.

8.0 CLOSURE

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, EXP will assume no responsibility for the interpretation and use of the recommendations in this report.

A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Daniel Mroz, M.E.Sc., EIT, Stephen Fredericks, M.Eng., P.Eng., and Nimesh Tamrakar, M.Eng., P.Eng. It was reviewed by TaeChul Kim, M.E.Sc., P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Stephen Fredericks, M.Eng., P.Eng.

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9.0 REFERENCES

Canadian Geotechnical Society, 2023. Canadian Foundation Engineering Manual, 5th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.

Ministry of Northern Development and Mines, Map 2556. Quaternary Geology of Ontario, Southern Sheet, 1991

Ministry of Northern Development and Mines Map 2544. Bedrock Geology of Ontario, Southern Sheet, 1991

Ministry of Transportation, May 2007. MTO Gravity Pipe Design Guidelines. Circular Culverts and Storm Sewers.

Ministry of Transportation, October 2022. Guideline for MTO Foundation Engineering Services, Version 03

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS):

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS.MUNI 450 Pipeline and Utility Installation in Soil by Horizontal Directional Drilling

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 903 Construction Specification for Deep Foundations

OPSS.PROV 1205 Material Specification for Clay Seal

Ontario Provincial Standard Drawings (OPSD):

OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets

Special Provisions (SP):

SP 109F57 AMENDMENT TO OPSS 903

SP 517F01 AMENDMENT TO OPSS 517

Ontario Water Resources Act:

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Occupational Health and Safety Act (OHSA):

Ontario Regulation 213/91 Construction Projects

10.0 LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to EXP by its client ("Client"), communications between EXP and the Client, other reports, proposals or documents prepared by EXP for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. EXP is not responsible for use by any party of portions of the Report.

USE OF REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of EXP. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. EXP is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

REPORT FORMAT

Where EXP has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by EXP have utilize specific software and hardware systems. EXP makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are EXP's instruments of professional service and shall not be altered without the written consent of EXP.

Appendix A –
Site Photographs

Photograph 1: Inside of existing CSP culvert at inlet side (taken by MTO)

Photograph 2: Inside of existing CSPA culvert at outlet side (taken by MTO)

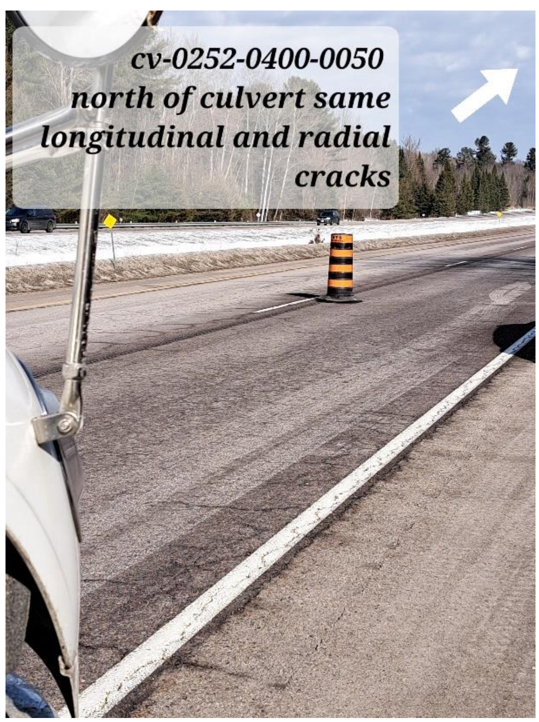

Photograph 3. Condition of culvert at inlet (facing northeast) – February 6, 2024 (taken by EXP)

Photograph 4: Condition of culvert at outlet (facing northeast) – April 26, 2023 (taken by EXP)

Photograph 5. Embankment side slope at inlet/west side of culvert (facing south)– February 6, 2024 (taken by EXP)

Photograph 6. Embankment side slope at outlet/east side of culvert (facing east)– Feb. 13, 2023 (taken by EXP)

Photograph 7. Typical roadway surface condition (facing north)– Feb. 13, 2023 (taken by EXP)



Photograph 8. Typical roadway surface condition, north of culvert (facing north)– Feb. 13, 2023 (taken by EXP)

Photograph 9. Typical shoulder surface condition (facing south)– Feb. 13, 2023 (taken by EXP)

Photograph 10. Drilling of borehole BH400-050-01 (facing nortwest) – February 6, 2024 (taken by EXP)

Photograph 11. Drilling of borehole BH400-050-02 (facing west) – February 6, 2024 (taken by EXP)

Appendix B –
90% Contract Drawings

CV-0252-0400-0050
(HWY 400)

METRIC

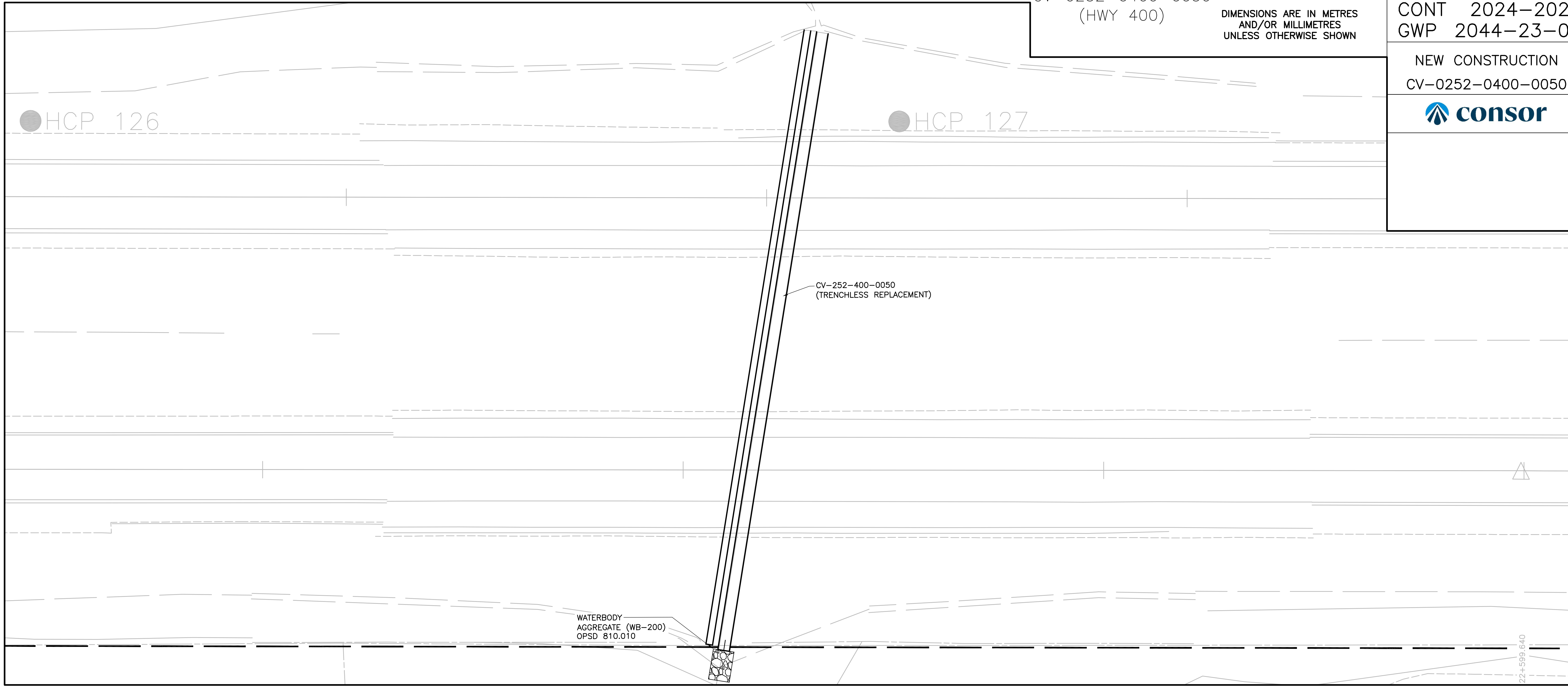
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

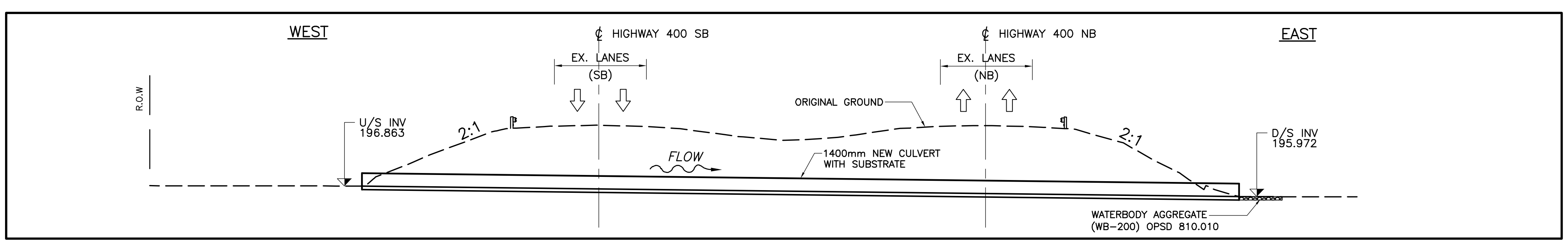
PLATE No
CONT 2024-2025
GWP 2044-23-00

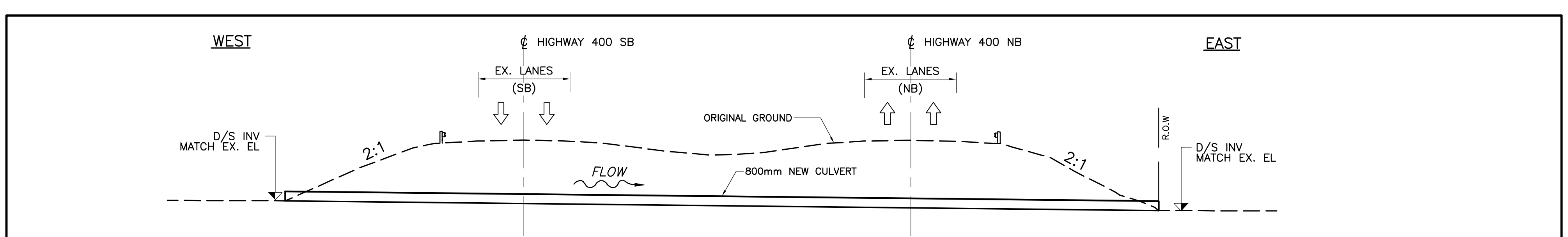
SHEET
##

NEW CONSTRUCTION
CV-0252-0400-0050

consor







LEGEND

- WATERBODY AGGREGATE
- CULVERT REPLACEMENT
- CURB AND GUTTER
- GUIDERAIL
- LIGHT-DUTY SILT FENCE BARRIER
- FLOW DIRECTION
- BOTTOM OF DITCH
- TOE OF SLOPE
- MTO ROW
- FENCE LINE

NOTES:

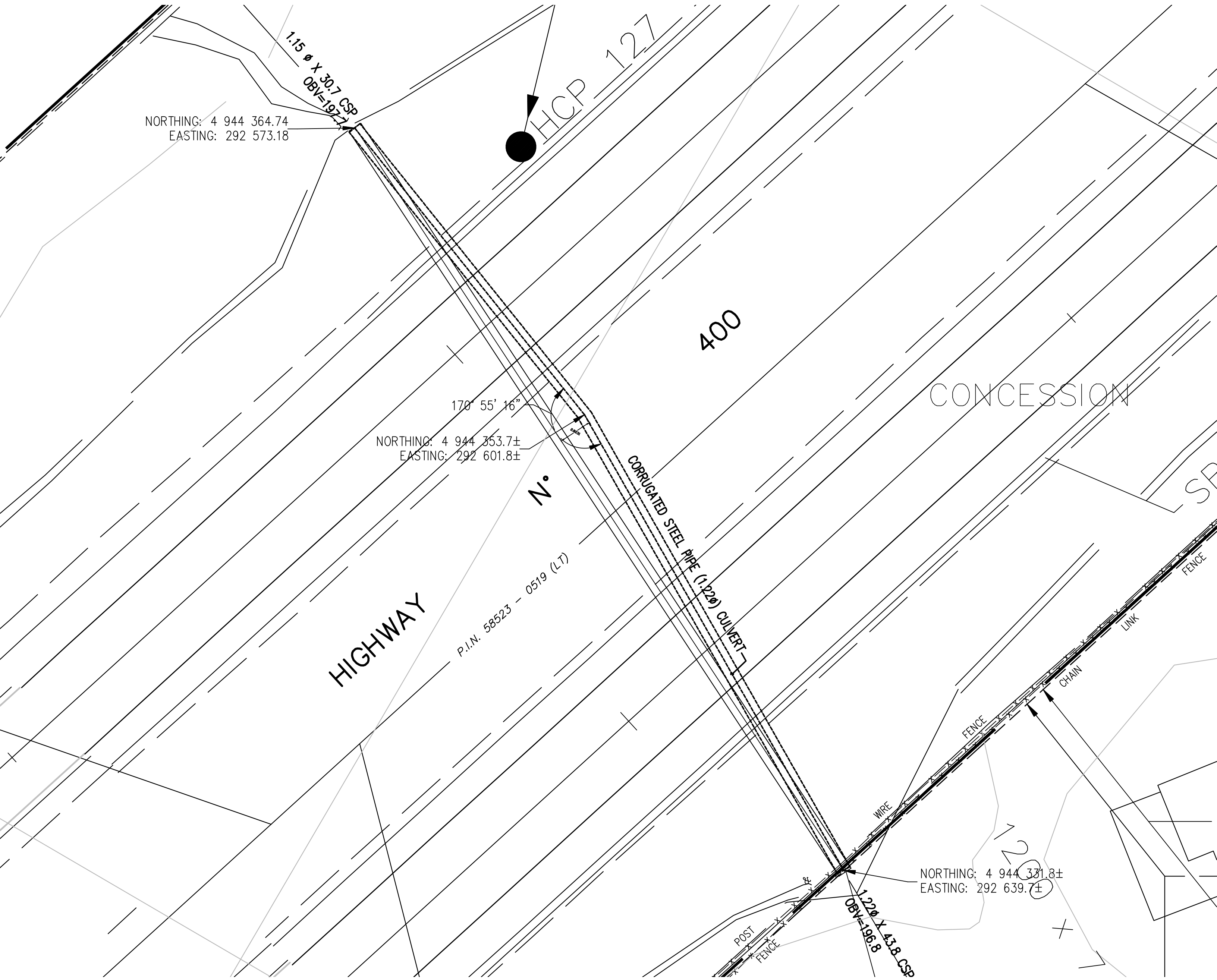
1. 333, 363, 393, DENOTES PAVEMENT MARKING SPACING (ie., 3 m line,3 m gap, 3 m line)
2. Use (1) to Denote PAVEMENT MARKING
3. Use [1] to Denote PAVEMENT MARKING,TEMPORARY
4. Use △ to Denote PAVEMENT MARKING, TEMPORARY- REMOVABLE
5. Use (1) to Denote PAVEMENT MARKING, DURABLE
6. FROST TAPERS are based on OPSD 803.030, 803.031

1	SOLID YELLOW,10cm
2	SOLID DOUBLE YELLOW,10cm
3	363 BROKEN YELLOW,10cm
4	SOLID YELLOW,20cm
5	SOLID WHITE,10cm
6	333 BROKEN WHITE,10cm
7	363 BROKEN WHITE,10cm
8	393 BROKEN WHITE,10cm
9	SOLID WHITE,20cm
10	111 BROKEN WHITE,20cm
11	333 BROKEN WHITE,20cm
12	333 BROKEN WHITE ,30cm
13	SOLID WHITE,30cm
14	SOLID WHITE,45cm
15	SOLID WHITE,60cm
20	SYMBOLS
] [	LIMITS OF MARKINGS

SCALE
5m 0 10m

2016-10
ANSI-D
MINISTRY OF TRANSPORTATION, ONTARIO

CAD FILE LOCATION AND NAME: A:_V-TPD\Projects\CA\Projects\D220768CN_ 25 Culverts\Drafting\Sheets\Highways\Contract Package 1\D220768CN_N02.dwg
MODIFIED: 4/4/2024 11:32:32 AM BY: RMISTRY
DATE PLOTTED: 4/4/2024 11:33:48 AM BY: RMISTRY



1.15 ø X 30.7 CSP
OBV=197.7
NORTHING: 4 944 364.74
EASTING: 292 573.18
HCP 127
400
CONCESSION
170° 55' 16"
NORTHING: 4 944 353.7±
EASTING: 292 601.8±
CORRUGATED STEEL PIPE (1.22ø) CULVERT
N°
HIGHWAY
P.I.N. 58523 - 0519 (LT)
FENCE
LINK
CHAIN
FENCE
WIRE
NORTHING: 4 944 331.8±
EASTING: 292 639.7±
1.22ø X 43.8 CSP
OBV=196.8
POST
FENCE

Appendix C –
Borehole Location Plan and Soil Strata

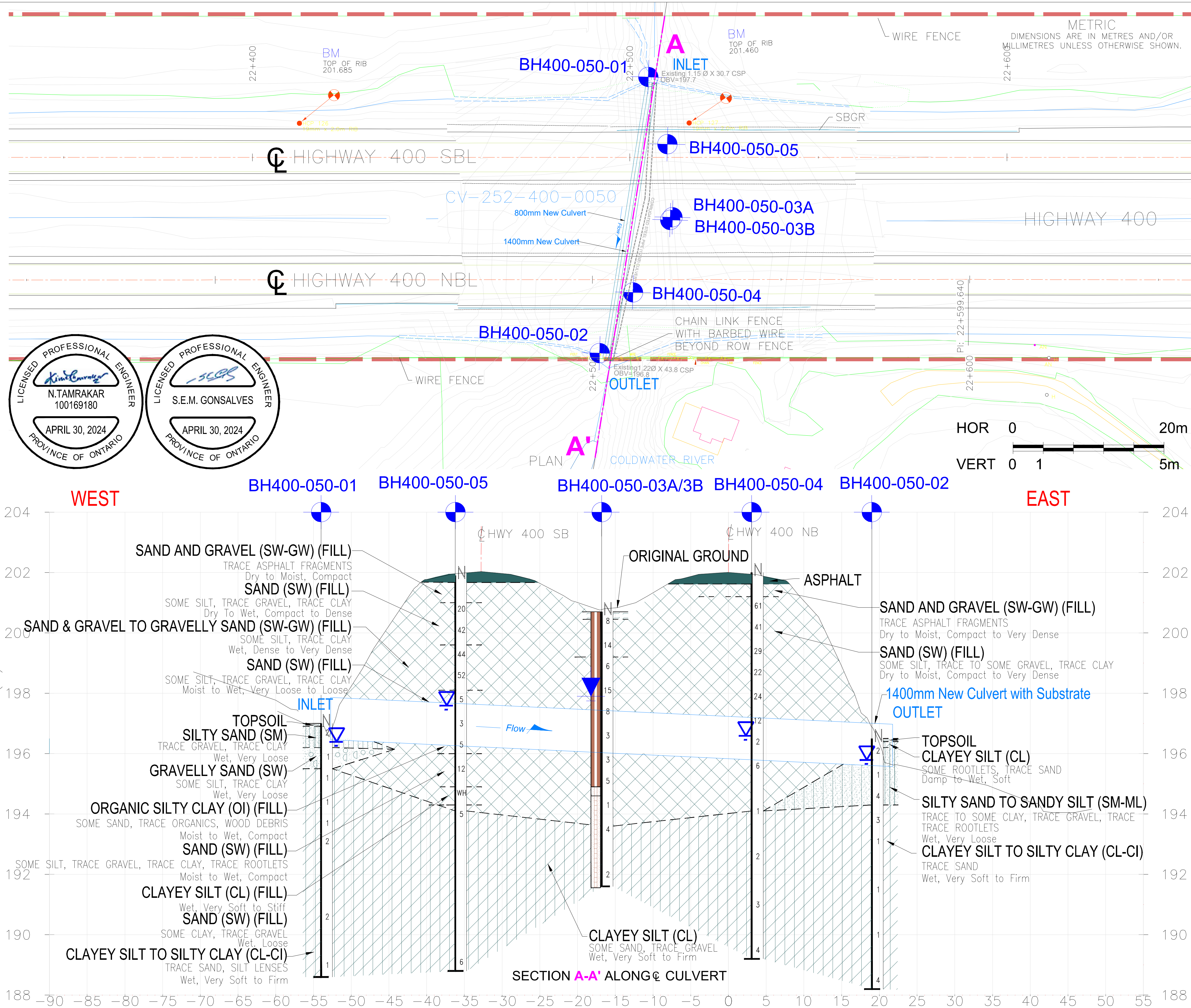
ASSIG No. 2020-E-0028
GWP No. 2111-19-00

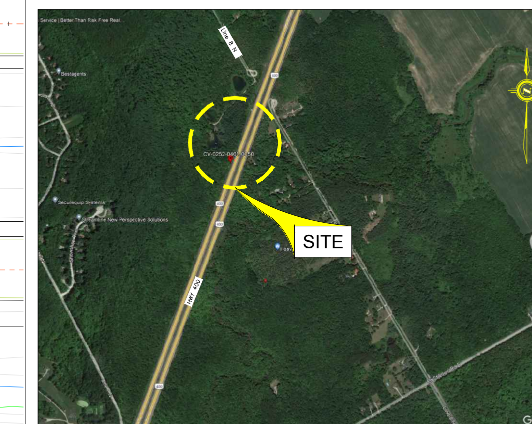
HIGHWAY 400 CULVERT REPLACEMENT,SIMCOE, ON
CV-252-400-0050
Latitude: 44.639180° Longitude: -79.654120°
BOREHOLE LOCATION PLAN & SOIL STRATA

SHEET 1

EXP SERVICES INC.

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





KEY PLAN
N.T.S.

LEGEND

- Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

TOPSOIL, ASPHALT, FILL, GRAVELLY SAND, CLAYEY SILT/ SILTY CLAY, SILTY SAND TO SANDY SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH400-050-01	197.0	4944363.7	292571.1
BH400-050-02	196.5	4944329.5	292637.1
BH400-050-03A	200.7	4944358.7	292608.5
BH400-050-03B	200.7	4944357.9	292609.0
BH400-050-04	201.9	4944342.0	292624.1
BH400-050-05	201.9	4944363.2	292589.6

NOTES

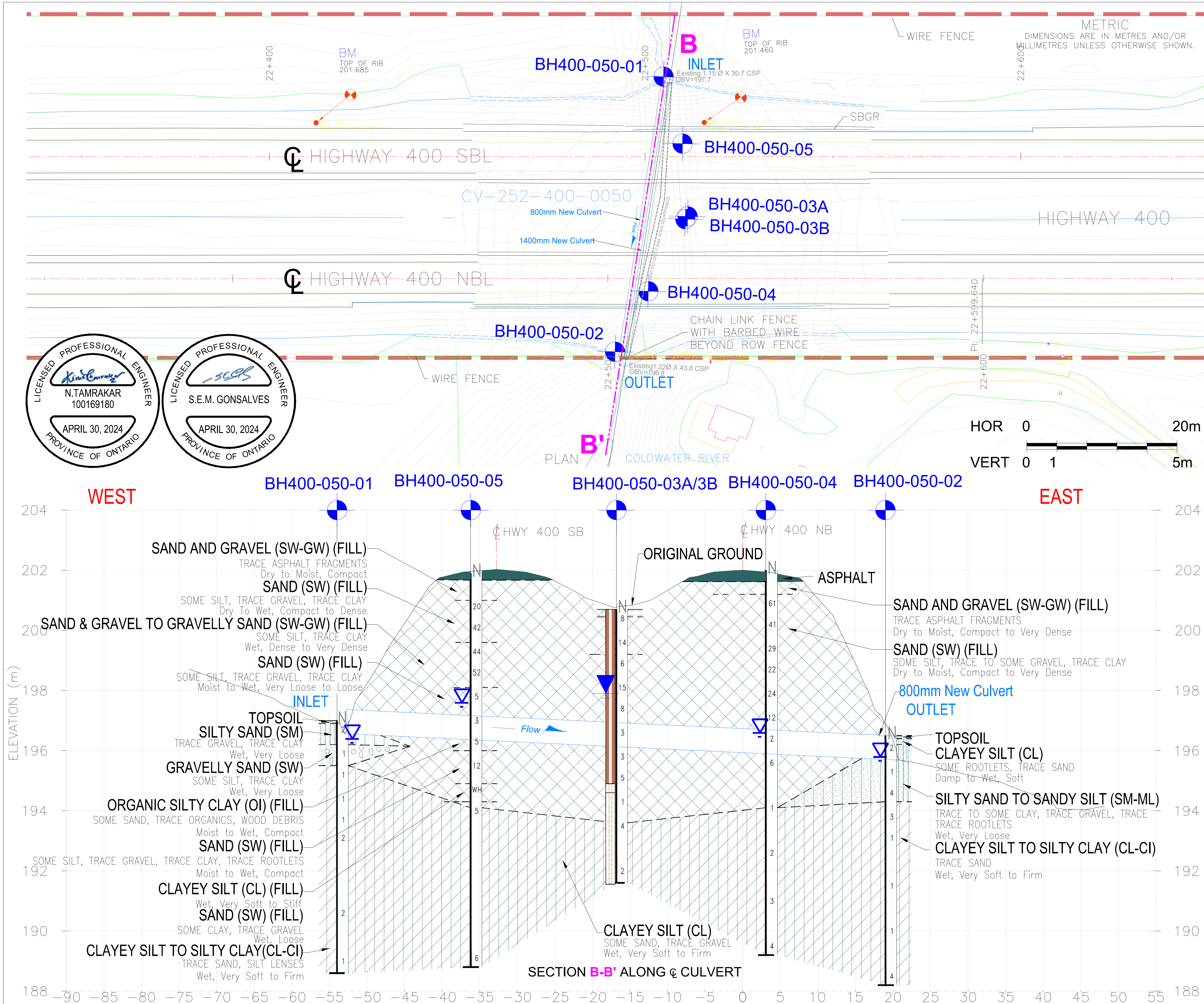
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REVISIONS NO	DATE	BY	DESCRIPTION
			SUBMISSION FOR MTO REVIEW

PROJECT No. ADM-22007871-A0		GEOCRES No. 31D12-002	
SUBM'D SH	CHKD. DM	DATE APRIL 30, 2024	SITE -
DRAWN SH	CHKD. TC	APPRD SG	DWG 01



ASSIG No. 2020-E-0028
GWP No. 2111-19-00

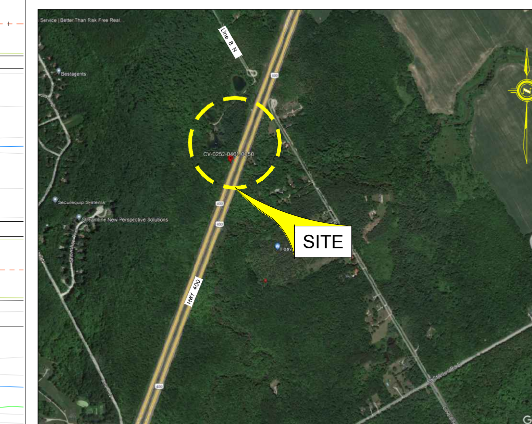
SHEET 2

HIGHWAY 400 CULVERT REPLACEMENT,SIMCOE, ON
CV-252-400-0050
Latitude: 44.639180° Longitude: -79.654120°
BOREHOLE LOCATION PLAN & SOIL STRATA

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

exp.

EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

- Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- ASPHALT
- FILL
- GRAVELLY SAND
- CLAYEY SILT/ SILTY CLAY
- SILTY SAND TO SANDY SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH400-050-01	197.0	4944363.7	292571.1
BH400-050-02	196.5	4944329.5	292637.1
BH400-050-03A	200.7	4944358.7	292608.5
BH400-050-03B	200.7	4944357.9	292609.0
BH400-050-04	201.9	4944342.0	292624.1
BH400-050-05	201.9	4944363.2	292589.6

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.

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REVISIONS NO	DATE	BY	DESCRIPTION
			SUBMISSION FOR MTO REVIEW

PROJECT No. ADM-22007871-A0		GEOCRES No. 31D12-002	
SUBM'D SH	CHKD. DM	DATE APRIL 30, 2024	SITE -
DRAWN SH	CHKD. TC	APPRD SG	DWG 02

Appendix D – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002 0.006 0.02 0.06 0.2 0.6 2.0 6.0 20 60 200

EQUIVALENT GRAIN DIAMETER IN MILLIMETRES

CLAY (PLASTIC) TO	FINE	MEDIUM	CRS.	FINE	COARSE
SILT (NONPLASTIC)	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

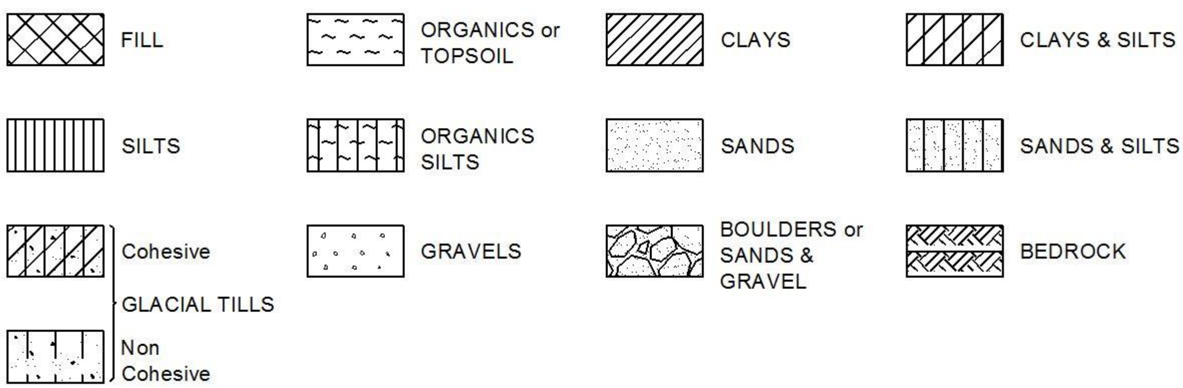
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICALL PROPERIES OF SOIL

m_v	kPa^{-1}	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path
T_V	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_P	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	$-^\circ$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$-^\circ$	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	Density of solid particles
γ_s	kN/m^3	Unit weight of solid particles
ρ_w	kg/m^3	Density of water
γ_w	kN/m^3	Unit weight of water
ρ	kg/m^3	Density of soil
γ	kN/m^3	Unit weight of soil
ρ_d	kg/m^3	Density of dry soil
γ_d	kN/m^3	Unit weight of dry soil
ρ_{sat}	kg/m^3	Density of saturated soil
γ_{sat}	kN/m^3	Unit weight of saturated soil
ρ'	kg/m^3	Density of submerged soil
γ'	kN/m^3	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_P	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_P$
I_C	%	Consistency index = $(W_L - W)/I_P$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m^3/s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m^3	Seepage force

RECORD OF BOREHOLE No BH400-050-01

METRIC

W.P. GWP-2044-23-00	LOCATION CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292571.1E 4944363.7N		ORIGINATED BY OD
DIST Simcoe HWY 400	BOREHOLE TYPE Manual Drilling/SPT/Solid Stem Auger		COMPILED BY DM
DATUM Geodetic	DATE 2023.04.27 - 2023.04.27	LATITUDE 44.639176 LONGITUDE -79.654148	CHECKED BY NT

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
197.0	
196.9 / 0.1	**TOPSOIL**, ~100 mm thick
	SILTY SAND (SM), trace gravel, trace clay, dark brown, wet, very loose
196.2 / 0.8	**GRAVELLY SAND(SW)**, some silt, trace clay, grey, wet, very loose
195.5 / 1.5	**CLAYEY SILT TO SILTY CLAY (CL-CI)**, trace sand, grey, wet, very soft to firm - silt lenses encountered below depth of 4.6 m
188.6 / 8.4	**END OF BOREHOLE** NOTE: 1) Groundwater was encountered at a depth of 0.6 m in open borehole upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	Water content / Shear strength	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
SS1	SPT	2		
SS2	SPT	1		
SS3	SPT	1		
SS4	SPT	1		0 9 69 22
FV1	VANE		+ 1	
SS5	SPT	1		
SS6	SPT	2		
FV2	VANE		+ 2	
SS7	SPT	2		Corrosivity sample 0 2 33 65
FV3	VANE		+ 2	
SS8	SPT	1		
FV4	VANE		+ 3	

Ground water level symbol (▽) at approx. 0.6 m depth.

Elevation scale: 196, 195, 194, 193, 192, 191, 190, 189

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE; ● QUICK TRIAXIAL × P. PENETROMETER: 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH400-050-02

METRIC

W.P.	GWP-2044-23-00	LOCATION	CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292637.1E 4944329.5N	ORIGINATED BY	OD
DIST	Simcoe HWY 400	BOREHOLE TYPE	Manual Drilling/SPT/Solid Stem Auger	COMPILED BY	DM
DATUM	Geodetic	DATE	2023.04.26 - 2023.04.26 LATITUDE 44.638869 LONGITUDE -79.653315	CHECKED BY	NT

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
196.5	
196.5 / 0.0	**TOPSOIL**, ~100 mm thick
196.4 / 0.1	**CLAYEY SILT(CL)**, some rootlets, trace sand, dark brown, damp to wet, soft
196.2 / 0.3	**SILTY SAND TO SANDY SILT (SM-ML)**, trace to some clay, trace gravel, trace rootlets, dark brown to dark grey to black, wet, very loose
194.3 / 2.2	**CLAYEY SILT TO SILTY CLAY (CL-CI)**, trace sand, grey, wet, very soft to firm
188.2 / 8.3	**END OF BOREHOLE**

NOTE:
1) Groundwater was encountered at a depth of 0.7 m in open borehole upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	Field vane shear strength (kPa, approx.) / sensitivity	Water content	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
SS1	SPT	2			
SS2	SPT	1		~27%	
SS3	SPT	4		~30%	
SS4	SPT	3			
FV1	VANE		~12 / 1		
SS5	SPT	1		~40%	0 8 62 30
SS6	SPT	1			
FV2	VANE		~24 / 1		
SS7	SPT	1			
FV3	VANE		~35 / 2		
SS8	SPT	4		~47% (w_P ~27, w_L ~45)	0 1 19 80

GROUND WATER CONDITIONS: water level symbol at approx. elev. 195.8

ELEVATION SCALE: 196, 195, 194, 193, 192, 191, 190, 189

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × P. PENETROMETER — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

EXP Services Inc.
Brampton, Ontario

Foundation Design

RECORD OF BOREHOLE No BH400-050-03A

METRIC

W.P. GWP-2044-23-00 | LOCATION CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292608.5E 4944358.7N | ORIGINATED BY SF

DIST Simcoe HWY 400 | BOREHOLE TYPE Track Mounted M5I 5T98-09/Solid Stem Augers | COMPILED BY DM

DATUM Geodetic | DATE 2023.02.14 - 2023.02.14 | LATITUDE 44.639132 | LONGITUDE -79.653676 | CHECKED BY NT

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
200.7 / 0.0	**TOPSOIL**, ~250 mm thick						
200.5 / 0.3	**CLAYEY SILT (CL) (FILL)**, trace sand, trace rootlets, brown to grey, wet, stiff	SS1	SPT	8			
		SS2	SPT	14	200		
199.2 / 1.5	**SAND (SW) (FILL)**, some silt, trace gravel, trace clay, brown to grey to black, wet, loose to compact - possible cobble encountered at a depth of 2.0 m - trace rootlets encountered between a depth of 3.0 m and 4.4 m - becoming very loose to loose below a depth of 3.8 m	SS3	SPT	6	199		
		SS4	SPT	15	198		
		SS5	SPT	8	197		
		SS6	SPT	3			8 73 17 2
		SS7	SPT	3	196		
		SS8	SPT	5	195		8 71 18 3
		SS9	SPT	1	194		
193.6 / 7.1	**CLAYEY SILT (CL)**, some sand, grey, wet, soft to stiff	SS10	SPT	4			
		FV1	VANE		193	+ 1.3	
		SS11	SPT	2	192		0 10 65 25
191.6 / 9.1	**END OF BOREHOLE**	FV2	VANE			+ 1	

NOTE:
1) Groundwater could not be measured due to snow melt entering borehole during drilling.
2) Borehole abandoned due to filling up with water which prevented advancement of borehole. A companion borehole (BH400-050-03B) was drilled approximately 1.0 m southeast of borehole BH400-050-03A.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × P. PENETROMETER; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; STRAT PLOT; GROUND WATER CONDITIONS

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

RECORD OF BOREHOLE No BH400-050-03B

METRIC

W.P. GWP-2044-23-00	LOCATION CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292609.0E 4944357.9N		ORIGINATED BY SF
DIST Simcoe HWY 400	BOREHOLE TYPE Track Mounted M5I 5T98-09/Solid Stem Augers		COMPILED BY DM
DATUM Geodetic	DATE 2023.02.14 - 2023.02.14	LATITUDE 44.639124 LONGITUDE -79.65367	CHECKED BY NT

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
200.7 / 0.0	- continuation of BH400-050-03A - solid stem augering to a depth of 9.1 m						
191.6 / 9.1	**CLAYEY SILT(CL)**, some sand, grey, wet, soft	SS12	SPT	3			
		SS13	SPT	2			
190.3 / 10.4	**END OF BOREHOLE** NOTE: 1) Monitoring Well Readings Date Depth Elev. Feb 2/2024 2.8 197.9						

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (200, 199, 198, 197, 196, 195, 194, 193, 192, 191); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × P. PENETROMETER 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60.

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

RECORD OF BOREHOLE No BH400-050-04

METRIC

W.P. GWP-2044-23-00	LOCATION CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292624.1E 4944342.0N		ORIGINATED BY SF
DIST Simcoe HWY 400	BOREHOLE TYPE B-53 Explorer Truck Drill/Solid Stem Auger		COMPILED BY DM
DATUM Geodetic	DATE 2023.02.13 - 2023.02.13	LATITUDE 44.638982 LONGITUDE -79.65348	CHECKED BY NT

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
201.9 / 0.0	**ASPHALT**, 380 mm thick							
201.5 / 0.4	**SAND AND GRAVEL (SW-GW) (FILL)**, trace asphalt fragments, brown, dry to moist	AS1	AUGER					
201.1 / 0.8	**SAND (SW) (FILL)**, trace to some gravel, trace clay, brown, moist, compact to very dense	SS2	SPT	61	201			
		SS3	SPT	41	200			
		SS4	SPT	29	199			4 83 11 2
		SS5	SPT	22				
		SS6	SPT	24	198			
		SS7	SPT	12	197			
	- becoming very loose to loose below a depth of 5.3 m	SS8	SPT	2	196			
	- becoming grey below a depth of 6.1 m	SS9	SPT	6	195			2 66 26 6
194.0 / 7.9	**CLAYEY SILT (CL)**, some sand, trace gravel, grey, wet, very soft to firm	SS10	SPT	1	194			
		FV1	VANE		193	+ 1.5		
		SS11	SPT	2				
		FV2	VANE		192	+ 1		
		SS12	SPT	3	191			3 14 48 35
		FV3	VANE		190	+ 1		
		SS13	VANE	4				
189.1 / 12.8	**END OF BOREHOLE**							

NOTE:
1) Groundwater could not be measured due to borehole caving at a depth of 5.4 m.

+3, ×3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH400-050-05

METRIC

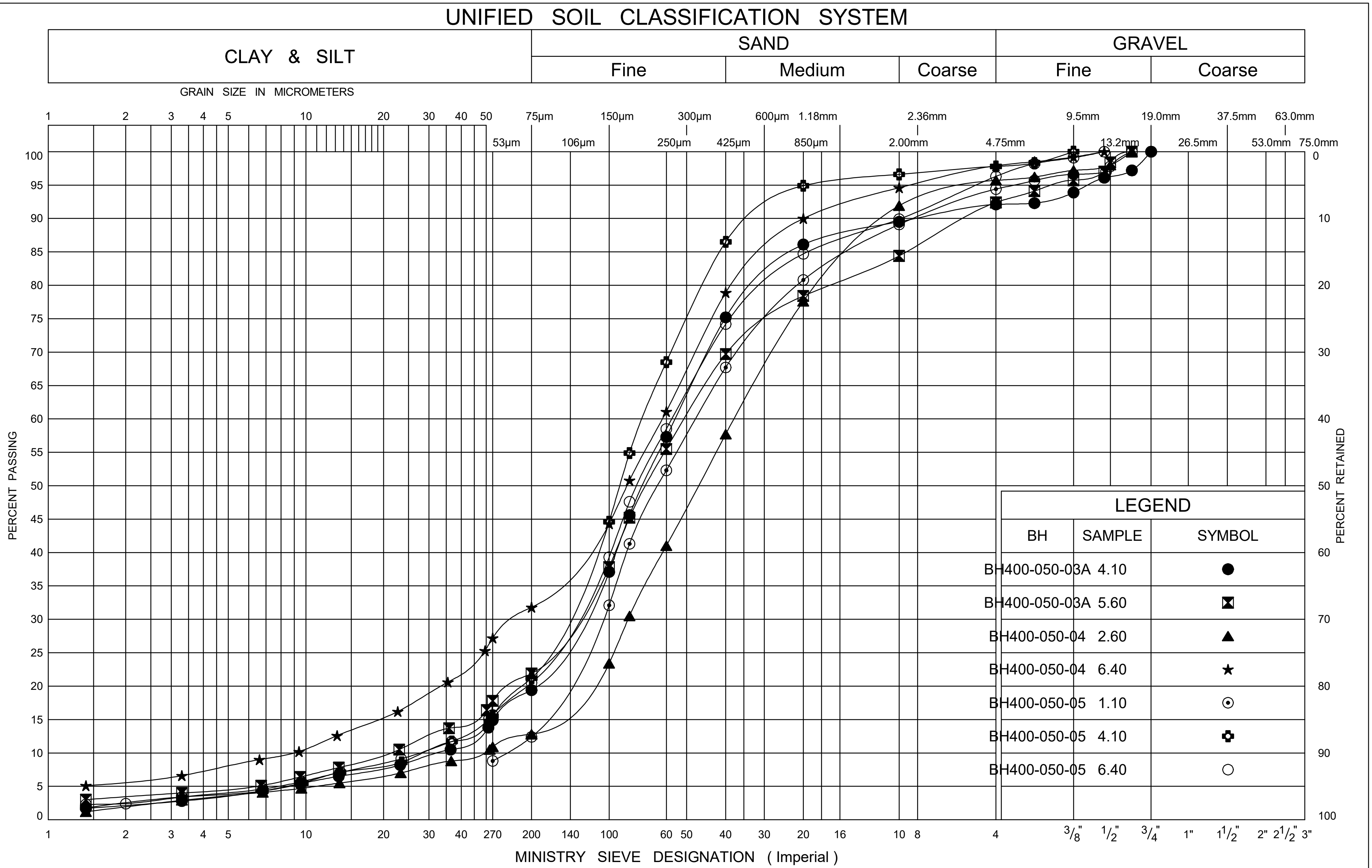
W.P. GWP-2044-23-00	LOCATION CV-0252-0400-0050, Simcoe County, ON, MTM ON-10 292589.6E 4944363.2N		ORIGINATED BY SF
DIST Simcoe HWY 400	BOREHOLE TYPE Truck Mounted M5T 94/Solid Stem Augers		COMPILED BY DM
DATUM Geodetic	DATE 2023.02.15 - 2023.02.15	LATITUDE 44.639172 LONGITUDE -79.653915	CHECKED BY NT

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	SHEAR STRENGTH / WATER CONTENT NOTES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
201.9 / 0.0	**ASPHALT**, 225 mm thick						
201.7 / 0.2	**SAND AND GRAVEL(SW-GW) (FILL)**, trace asphalt fragments, grey to black, dry to moist, compact	AS1	AUGER				
201.0 / 0.9	**SAND (SW) (FILL)**, some silt, trace gravel, trace clay, grey to brown, dry to wet, compact to dense	SS2	SPT	20			6 82 (12)
		SS3	SPT	42			
199.6 / 2.3	**SAND AND GRAVEL TO GRAVELLY SAND (SW-GW) (FILL)**, some silt, trace clay, grey to brown, wet, dense to very dense	SS4	SPT	44			
	- becoming dry below a depth of 3.2 m	SS5	SPT	52			
198.1 / 3.8	**SAND(SW) (FILL)**, some silt, trace gravel, trace clay, moist to wet, very loose to loose	SS6	SPT	5	▽		2 77 19 2
		SS7	SPT	3			
		SS8	SPT	5		120.3	
196.2 / 5.7	**ORGANIC SILTY CLAY(OI) (FILL)**, some sand, trace organics, wood debris, black, moist, firm						
196.0 / 5.9	**SAND(SW) (FILL)**, some silt, trace gravel, trace clay, trace rootlets, brown to black, moist to wet, compact	SS9	SPT	12			4 76 18 2
194.9 / 7.0	**CLAYEY SILT(CL) (FILL)**, brown to grey, wet, very soft to stiff	SS10	SPT	WH			
		FV1	VANE			+ 1.7	
194.3 / 7.6	**SAND(SW) (FILL)**, some clay, trace gravel, grey, wet, loose						
194.1 / 7.8	**CLAYEY SILT(CL)**, trace sand, trace gravel, wet, firm	SS11	SPT	5			
		ST12	SH				
		FV2	VANE			3.3	
		ST13	SH				
		FV3	VANE			+ 1.3	
		FV4	VANE			+ 4	
		SS14	SPT	6			3 23 34 40
188.8 / 13.1	**END OF BOREHOLE** NOTE: 1) Groundwater was encountered at a depth of 4.3 m in open borehole upon completion of drilling.						

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (201–189); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × P. PENETROMETER 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Appendix E –
Laboratory Data



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

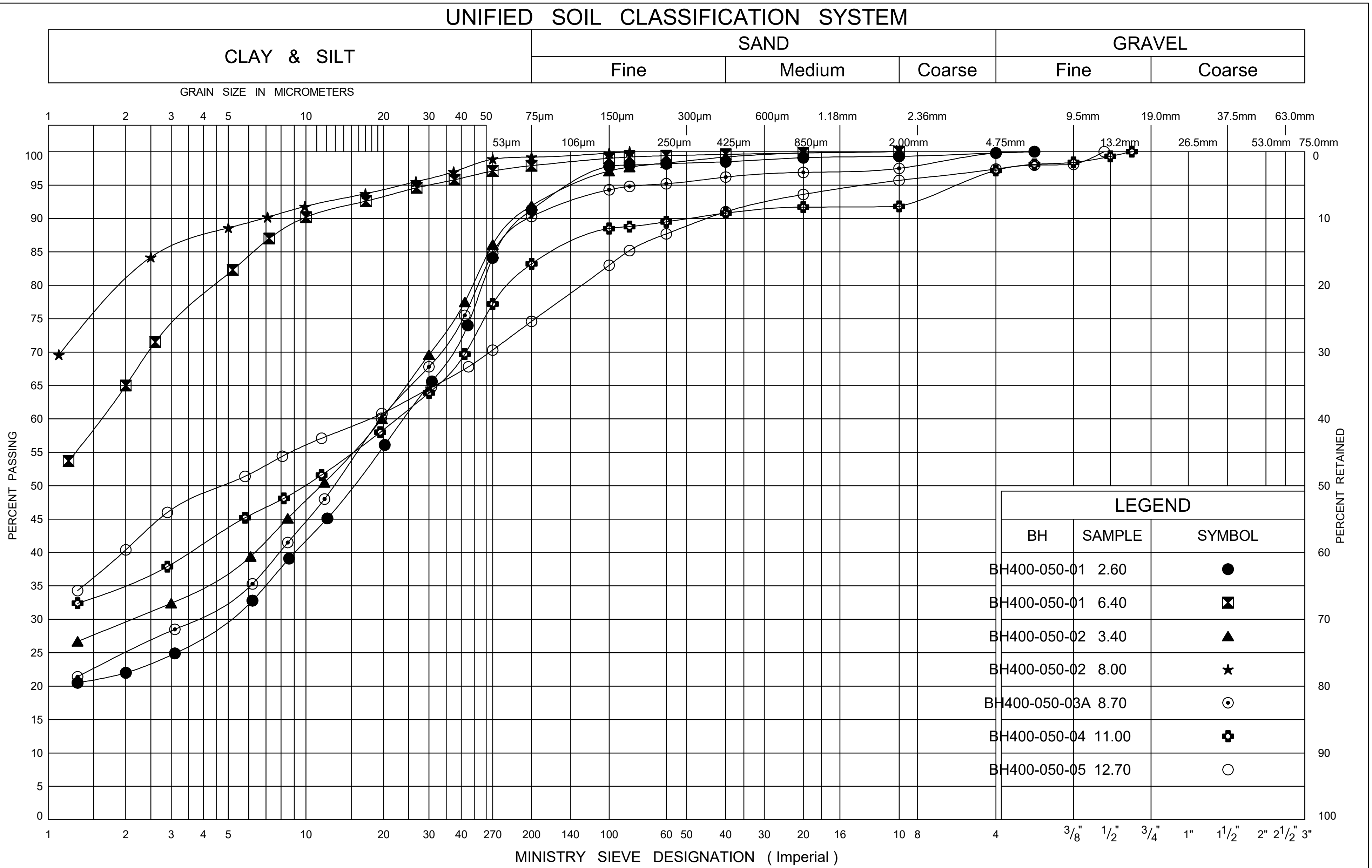
Sand(SW) (FILL)

FIG No 1

GWP 2111-19-00

Culvert ID CV-0252-0400-0050

ONTARIO MOT GRAIN SIZE CV-0252-0400-0050.GPJ ONTARIO MOT.GDT 8/16/23



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

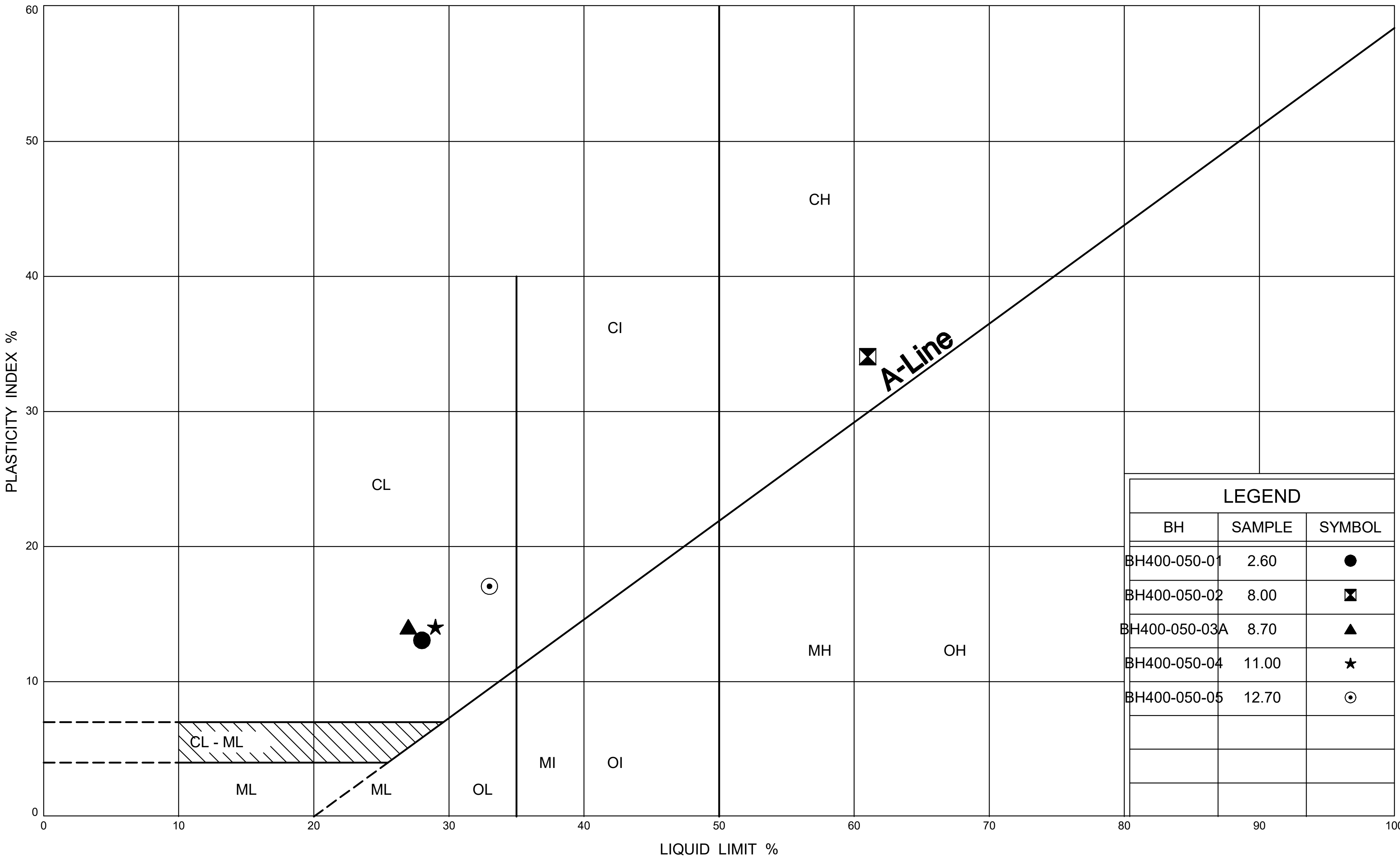
Clayey Silt to Silty Clay(CL-CI)

FIG No 2

GWP 2111-19-00

Culvert ID CV-0252-0400-0050

ONTARIO MOT GRAIN SIZE CV-0252-0400-0050.GPJ ONTARIO MOT.GDT 8/16/23



BH	SAMPLE	SYMBOL
BH400-050-01	2.60	●
BH400-050-02	8.00	⧗
BH400-050-03A	8.70	▲
BH400-050-04	11.00	★
BH400-050-05	12.70	⊙

Ministry of Transportation
Ontario

PLASTICITY CHART

Clayey Silt to Silty Clay(CL-CI)

FIG No 3
GWP 2111-19-00
Culvert ID CV-0252-0400-0050

BUREAU VERITAS

Your Project #: ADM-22000797-A0
Site Location: HWY 401 FROM VICTORIA TO NELSON AVE, ON
Your C.O.C. #: 903374-11-01

Attention: Nimesh Tamrakar

exp Services Inc
Brampton Branch
1595 Clark Blvd
Brampton, ON
CANADA L6T 4V1

Report Date: 2023/05/04
Report #: R7615044
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3C0241
Received: 2023/04/28, 11:47

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (20:1 extract)	2	2023/05/03	2023/05/03	CAM SOP-00463	MOE E3013 m
Conductivity	2	2023/05/03	2023/05/03	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	2	N/A	2023/05/03	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	2	N/A	2023/05/03	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	2	2023/05/03	2023/05/03	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	2	2023/05/02	2023/05/02	CAM SOP-00421	SM 2580 B
Resistivity of Soil	2	2023/04/28	2023/05/04	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	2023/05/03	2023/05/03	CAM SOP-00464	MOE E3013 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.
(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE , Calgary, AB, T2E 6P8
(2) Offsite analysis requires that subcontracted moisture be reported.

Bureau Veritas 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.bvna.com

Your Project #: ADM-22000797-A0
Site Location: HWY 401 FROM VICTORIA TO NELSON AVE, ON
Your C.O.C. #: 903374-11-01

Attention: Nimesh Tamrakar

exp Services Inc
Brampton Branch
1595 Clark Blvd
Brampton, ON
CANADA L6T 4V1

Report Date: 2023/05/04
Report #: R7615044
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3C0241
Received: 2023/04/28, 11:47

(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to:
Patricia Legette, Project Manager
Email: Patricia.Legette@bureauveritas.com
Phone# (905)817-5799
==

SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		VRE196			VRE196			VRE197		
Sampling Date		2023/04/27 12:00			2023/04/27 12:00			2023/04/27 12:00		
COC Number		903374-11-01			903374-11-01			903374-11-01		
	UNITS	**BH400-050-01-SS3**	**RDL**	**QC Batch**	**BH400-050-01-SS3 Lab-Dup**	**RDL**	**QC Batch**	**BH400-0501-01-SS3**	**RDL**	**QC Batch**
Calculated Parameters										
Resistivity	ohm-cm	5500		8635096				6700		8635096
CONVENTIONALS										
Redox Potential	mV	85	N/A	8640030				170	N/A	8640030
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	8642980				<20	20	8642980
Conductivity	umho/cm	181	2	8642849	182	2	8642849	148	2	8642849
Available (CaCl2) pH	pH	8.08		8643146				8.37		8643146
Soluble (20:1) Sulphate (SO4)	ug/g	35	20	8642987				45	20	8642987
Sulphide	mg/kg	21.9 (1)	0.5	8647012				68 (1)	5	8647012

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable
(1) Sample contained greater than 10% headspace at time of extraction.

Bureau Veritas Job #: C3C0241
Report Date: 2023/05/04

exp Services Inc
Client Project #: ADM-22000797-A0
Site Location: HWY 401 FROM VICTORIA TO NELSON AVE, ON
Sampler Initials: IB

RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		VRE196	VRE197		
Sampling Date		2023/04/27 12:00	2023/04/27 12:00		
COC Number		903374-11-01	903374-11-01		
	UNITS	**BH400-050-01-SS3**	**BH400-0501-01-SS3**	**RDL**	**QC Batch**
Physical Testing					
Moisture-Subcontracted	%	28	21	0.30	8647043

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Bureau Veritas Job #: C3C0241
Report Date: 2023/05/04

exp Services Inc
Client Project #: ADM-22000797-A0
Site Location: HWY 401 FROM VICTORIA TO NELSON AVE, ON
Sampler Initials: IB

TEST SUMMARY

Bureau Veritas ID: VRE196
Sample ID: BH400-050-01-SS3
Matrix: Soil

Collected: 2023/04/27
Shipped:
Received: 2023/04/28

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8642980	2023/05/03	2023/05/03	Massarat Jan
Conductivity	AT	8642849	2023/05/03	2023/05/03	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8647043	N/A	2023/05/03	Ashley Henderson
Sulphide in Soil	SPEC	8647012	N/A	2023/05/03	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8643146	2023/05/03	2023/05/03	Surinder Rai
Redox Potential	COND	8640030	2023/05/02	2023/05/02	Gurparteek KAUR
Resistivity of Soil		8635096	2023/05/04	2023/05/04	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8642987	2023/05/03	2023/05/03	Massarat Jan

Bureau Veritas ID: VRE196 Dup
Sample ID: BH400-050-01-SS3
Matrix: Soil

Collected: 2023/04/27
Shipped:
Received: 2023/04/28

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	8642849	2023/05/03	2023/05/03	Gurparteek KAUR

Bureau Veritas ID: VRE197
Sample ID: BH400-0501-01-SS3
Matrix: Soil

Collected: 2023/04/27
Shipped:
Received: 2023/04/28

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8642980	2023/05/03	2023/05/03	Massarat Jan
Conductivity	AT	8642849	2023/05/03	2023/05/03	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8647043	N/A	2023/05/03	Ashley Henderson
Sulphide in Soil	SPEC	8647012	N/A	2023/05/03	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8643146	2023/05/03	2023/05/03	Surinder Rai
Redox Potential	COND	8640030	2023/05/02	2023/05/02	Gurparteek KAUR
Resistivity of Soil		8635096	2023/05/04	2023/05/04	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8642987	2023/05/03	2023/05/03	Massarat Jan

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GENERAL COMMENTS

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

Package 1	-1.0°C

Results relate only to the items tested.

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QUALITY ASSURANCE REPORT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8640030	Redox Potential	2023/05/02			102	95 - 105			3.3	35
8642849	Conductivity	2023/05/03			99	90 - 110	<2	umho/cm	0.39	10
8642980	Soluble (20:1) Chloride (Cl-)	2023/05/03	112	70 - 130	91	70 - 130	<20	ug/g	NC	35
8642987	Soluble (20:1) Sulphate (SO4)	2023/05/03	NC	70 - 130	94	70 - 130	<20	ug/g	13	35
8643146	Available (CaCl2) pH	2023/05/03			100	97 - 103			1.6	N/A
8647012	Sulphide	2023/05/03	305 (1)	75 - 125	97	75 - 125	<0.5	mg/kg	NC	30
8647043	Moisture-Subcontracted	2023/05/03					<0.30	%		

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).

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Cristina Carriere, Senior Scientific Specialist

Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

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

CHAIN OF CUSTODY RECORD

Page of

28-Apr-23 11:47
Patricia Legette
C3C0241
RUK ENV-1105

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:	
Company Name:	#17488 exp Services Inc	Company Name:		Quotation #:	C20328
Attention:	Accounts Payable	Attention:	Nimesh Tamrakar	P.O. #:	
Address:	1595 Clark Blvd, Brampton ON L6T 4V1	Address:		Project:	ADM-22000797-A0
				Project Name:	
Tel:	(905) 793-9800 Fax: (905) 793-0641	Tel:	(905) 796-3200 Ext: 3026 Fax:	Site #:	
Email:	AP@exp.com; Karen.Burke@exp.com	Email:	Nimesh.Tamrakar@exp.com	Sampled By:	

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS 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)? ____

ANALYSIS REQUESTED (PLEASE BE SPECIFIC): Field Filtered (please circle): Metals / Hg / Cr VI; corrosivity suite

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

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

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

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered	Corrosivity suite	# of Bottles	Comments
1		BH 400-050-01-SS3	APR 27/23	12:00			✓		
2		BH-400-0501-01SS3	APR 27/23	12:00			✓		
3									
4									
5									
6									
7									
8									
9									
10									

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
Ivon Barup	APR 28/23	12:00	[signature]	2023/04/28	1147	

Laboratory Use Only

Time Sensitive	Temperature (°C) on Recei	Custody Seal	Yes	No
	11-11-1	Present		✓
		Intact		✓

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BUREAU VERITAS'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVNA.COM/ENVIRONMENTAL-LABORATORIES/RESOURCES/COC-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.BVNA.COM/ENVIRONMENTAL-LABORATORIES/RESOURCES/CHAIN-CUSTODY-FORMS-COCS.

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

White: Bureau Veritas Yellow: Client

Bureau Veritas Canada (2019) Inc.

Your Project #: Campobello job# C3C0241

Attention: Patricia Legette

BUREAU VERITAS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2023/05/04
Report #: R3331578
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C329984
Received: 2023/05/02, 11:00

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Moisture	2	N/A	2023/05/03	AB SOP-00002	CCME PHC-CWS m
Sulphide	2	2023/05/02	2023/05/03	AB SOP-00080	EPA9030B/SM4500S2-DF

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.

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

Bureau Veritas Calgary: 2021 - 41st Avenue N.E. T2E 6P2 Telephone (403) 291-3077 Fax (403) 291-9468

Your Project #: Campobello job# C3C0241

Attention: Patricia Legette

BUREAU VERITAS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2023/05/04
Report #: R3331578
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C329984
Received: 2023/05/02, 11:00

Encryption Key

Please direct all questions regarding this Certificate of Analysis to:
Customer Solutions, Western Canada Customer Experience Team
Email: customersolutionswest@bvlabs.com
Phone# (403) 291-3077
==
This report has been generated and distributed using a secure automated process.
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RESULTS OF CHEMICAL ANALYSES OF SOIL

Bureau Veritas ID		BPO906		BPO908		
Sampling Date		2023/04/27 12:00		2023/04/27 12:00		
	UNITS	**BH400-050-01-SS3**	**RDL**	**BH400-0501-01-SS3**	**RDL**	**QC Batch**
Misc. Inorganics						
Sulphide	mg/kg	21.9 (1)	0.5	68 (1)	5	A949891

RDL = Reportable Detection Limit

(1) Sample contained greater than 10% headspace at time of extraction.

PHYSICAL TESTING (SOIL)

Bureau Veritas ID		BPO906	BPO908		
Sampling Date		2023/04/27 12:00	2023/04/27 12:00		
	UNITS	BH400-050-01-SS3	BH400-0501-01-SS3	RDL	QC Batch
Physical Properties					
Moisture	%	28	21	0.30	A950729
RDL = Reportable Detection Limit					

TEST SUMMARY

Bureau Veritas ID: BPO906
Sample ID: BH400-050-01-SS3
Matrix: Soil

Collected: 2023/04/27
Shipped:
Received: 2023/05/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL	A950729	N/A	2023/05/03	Ashley Henderson
Sulphide	SPEC	A949891	2023/05/02	2023/05/03	Princess Nicole Hernaez

Bureau Veritas ID: BPO908
Sample ID: BH400-0501-01-SS3
Matrix: Soil

Collected: 2023/04/27
Shipped:
Received: 2023/05/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL	A950729	N/A	2023/05/03	Ashley Henderson
Sulphide	SPEC	A949891	2023/05/02	2023/05/03	Princess Nicole Hernaez

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GENERAL COMMENTS

Results relate only to the items tested.

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Bureau Veritas Job #: C329984
Report Date: 2023/05/04

QUALITY ASSURANCE REPORT

BUREAU VERITAS
Client Project #: Campobello job# C3C0241
Sampler Initials: IB

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
A949891	Sulphide	2023/05/03	305 (1)	75 - 125	97	75 - 125	<0.5	mg/kg	NC	30
A950729	Moisture	2023/05/03					<0.30	%	4.1	20

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

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

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

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

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

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

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VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

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Appendix F – NSSPs

NSSP FOR OBSTRUCTIONS

Scope of Work

The Contractor shall be alerted to the potential presence of cobbles and boulders in the fill soils encountered in few boreholes advanced at the site. Therefore, appropriate equipment and procedures will be required for open cut excavation and installation of roadway protection systems and temporary dewatering/unwatering systems.

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.

NSSP FOR PIT CONSTRUCTION IN SOFT/LOOSE SOILS AT TOE OF EMBANKMENT

Scope of Work

The Contractor shall be alerted to the presence of loose/soft soils encountered at the toe of the embankment on both sides. Therefore, appropriate equipment and procedures will be required for the construction of the sending and receiving pits so that the embankment is not destabilized during excavation.

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.

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
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) 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 m^3 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 m^3 or greater.

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

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a 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.

A directional drilling method of installation shall not be used at this site. Jack and Bore method of installation shall not be used at this site unless dewatering at least 1 m below the tunnel invert for the full length of the pipe alignment is implanted. The pipe ramming method of installation shall not be used unless specific details of equipment and methods to drive a casing at least 75 m in length crossing Highway 400 are demonstrated.

Pipe crushing methods such as Pipe reaming and pipe bursting methods shall not be used at this site. The pipe swallowing method of installation shall not be used unless specific details of equipment and methods of installation to follow existing skewed alignment and bend to an intermediate location are demonstrated.

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 dosage 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

Pipe Ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The Pipe Ramming hammer(s) shall be capable of driving the pipe casing of at least 75 m in length from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

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 pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

6.03 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling (HDD) equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.

b) Have drill rod that is suitable for both the drill and the product pipe installation.

c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.

d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.

e) Contain a guidance system to accurately guide boring operations.

f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.

g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

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

a) rock or boulder breaking and removal;
b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
c) jacking systems;
d) alignment control systems;

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

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting Microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils 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.

6.06 Pipe Swallowing

The pipe swallowing method of installation is a technique based on the conventional pipe ramming method using pneumatic percussion to drive steel pipe. The pipe-swallowing version of pipe ramming is used to replace a pipe or casing in place with a larger diameter casing. The casing is rammed around the existing culvert, which is then removed with the spoil.

Pipe Ramming equipment to swallow the existing pipe along its alignment and bend shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The Pipe Ramming hammer(s) shall be capable of driving the pipe casing from the entry pits (inlet and outlet ends) to the exit pit (intermediate pit) through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

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 pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

6.07 Pipe Eating Equipment

Pipe Eating is a modified micro-tunneling system specially adapted for pipe replacement. The crushed fragments of pipe mixed with soil are vacuumed out, as slurry, through the new pipe and out of the space. A new pipe, of the same or larger nominal size, is simultaneously installed by jacking it behind the micro-tunneling machine. The new pipe may follow the line of the old pipe on the entire length or may cross the elevation of the old pipe on a limited segment only.

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 crushing the existing pipe and 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. The interior volume of the existing pipe shall be pre-grouted to provide a more uniform face condition for excavation and to prevent the loss of excavation fluids.

In addition to the above Refer to Section 6.05 for equipment details.

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.

Intermediate shafts shall be considered as required to advance the pipe at the existing alignment and the new alignment.

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. 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 possibility of encountering potential cobbles and boulders in the fill and till layers should be anticipated.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions 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.

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

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe and the required length. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.
- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.03.01 Pipe Swallowing (Technique based on Pipe Ramming) Installation

For the Pipe swallowing method of installation, the following requirements apply:

- Only smooth-walled steel pipe larger than the existing pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe and interfering with the existing pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials and existing pipe from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.
- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For Horizontal Directional Drilling (HDD), the Contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated Working Areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall, at all times and for the entire length of the installation alignment, be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates, and pressures.

7.04.04 Drilling Fluid Losses to Surface ("Frac-Out")

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully Reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and Reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to ensure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls 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.

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

7.05.02 Tunnelling Method

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

7.05.03 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Pipe Eating

Excavation of existing pipe, 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 interior volume of the existing pipe should be pre- grouted to provide a more uniform face condition for excavation and to prevent the loss of excavation fluids.

7.06.03 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.

7.06.04 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

A Settlement monitoring plan shall be prepared by the Contractor or trenchless subcontractor showing the location of all Surface and In-Ground Monitoring Points along the trenchless installation at the Culvert location.

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 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.

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 three time 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, 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, 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.