



REPORT

**Foundation Investigation and Design
Unnamed Creek Culvert Replacement
0.2 km North of Walkley Road
Highway 417
Ottawa, Ontario
*W.P. No. 4145-10-00***

Submitted to:

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Table of Contents

PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION AND GEOLOGY	1
2.1 General.....	1
2.2 Regional Geology.....	1
3.0 INVESTIGATION PROCEDURES	2
4.0 DESCRIPTION OF SUBSURFACE CONDITIONS	3
4.1 General.....	3
4.2 Topsoil and Fill	3
4.3 Silty Clay to Clay (Weathered Crust)	4
4.4 Silty Clay and Clayey Silt	4
4.5 Gravelly Sand to Silty Sand Till.....	5
4.6 Bedrock	5
4.7 Groundwater Conditions	6
4.8 Corrosion and Sulphate Attack, Chemical Analyses	7
5.0 CLOSURE	7

PART B – FOUNDATION DESIGN

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	8
6.1 General.....	8
6.2 Overview	9
6.3 Culvert Replacement Options	9
6.3.1 Trenchless Technologies	9
6.4 Assessment of Feasible Replacement Methods.....	11
6.4.1 Trenchless Technologies	11
6.4.2 Open Cut Replacement	13
6.5 Recommendations and Considerations for Trenchless Replacement.....	13
6.5.1 Temporary Excavations, Shoring and Temporary Protection for Entrance and Exit Pits	14
6.5.2 Surface Water and Groundwater Control	15
6.5.3 Erosion Protection.....	15
6.6 Recommendations and Considerations for Open-Cut Replacement.....	16

6.6.1	Settlements	16
6.6.2	Culvert Bedding, Backfill and Erosion Protection	16
6.6.3	Excavations, Shoring and Temporary Roadway Protection	17
6.6.4	Surface Water and Groundwater Control	17
6.7	Temporary Water Diversion Systems	17
6.7.1.1	Sand Bags or Glacial Till Cofferdam.....	18
6.7.1.2	Inflatable Water Diversion System.....	18
6.8	Corrosion and Cement, Steel Type.....	18
7.0	CLOSURE	19

TABLES

Table 1: Summary of Borehole Locations and Depths.....	3
Table 2: Summary of Bedrock Depths and Elevations.....	6
Table 3: Summary of Groundwater Conditions	6
Table 4: Summary of Basic Chemical Results	7
Table 5: Summary of Proposed Culvert Dimensions	8
Table 6: Summary of Risk Register Associated with Trenchless Technologies	12
Table 7: Summary of Soil Properties.....	18

DRAWINGS

Drawing 1 - Unnamed Creek Culvert Replacement, Borehole Locations and Soil Strata

APPENDICES

APPENDIX A

Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Bedrock Core Photographs, Figures A1 to A6

APPENDIX B

Laboratory Test Results, Current Investigation

Figure B1 – Grain Size Distribution Test Results – FILL

Figure B2 – Plasticity Chart – Silty Clay (FILL)

Figure B3 – Plasticity Chart – Silty Clay to Clay (WEATHERED CRUST)

Figure B4 – Grain Size Distribution Test Results – Silty Clay to Clayey Silt

Figure B5 – Plasticity Chart – Silty Clay to Clayey Silt

Figure B6 – Grain Size Distribution Test Results – Silty Sand (TILL)

Figure B7 – Plasticity Chart – Silty Sand (TILL)

Figure B8 – Summary of Laboratory Compressive Strength Testing – Unconfined Compression Tests

APPENDIX C

Basic Chemical Analysis – Eurofins Report Number 1818602

APPENDIX D
Site Photographs

APPENDIX E
NON STANDARD SPECIAL PROVISIONS
Pipe Installation by Trenchless Methods
Obstructions
Earth Excavations for Structure with Obstructions

PART A

Foundation Investigation
Proposed Un-named Creek Culvert Replacement
Highway 417
Ottawa, Ontario
W.P. 4145-10-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous bridge and structural culvert rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road as well as the widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to provide foundation design recommendations of the proposed replacement of the existing Unnamed Creek Culvert, North of Walkley Road, in Ottawa, Ontario (W.P. 4145-10-00).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal (RFP), dated May 2016, and subsequent addenda. The scope of work associated with the culvert replacement follows the Scope Change Request 1 for Assignment No. 4016-E-0008, dated August 2, 2018. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project, dated March 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 General

The existing Unnamed Creek Culvert is located underneath the Highway 417 WBLs approximately 0.22 km north of the Walkley Road Overpass in Ottawa, Ontario. At this location, Highway 417 is a divided highway with two EBL travel lanes, and two WBL travel lanes and the S-W Ramp from Walkley Road speed change lane. Both the Highway 417 EBL and WBL, as well as the WBL and speed change lane are separated by a green median area with an approximate width of 25 m and 30 m, respectively.

The existing culvert is a 914 mm diameter, 55 m long corrugated steel pipe. The structure is founded on the underlying silty clay and gravelly sand fill.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 417 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock². The Russell and Prescott Sand Plains are generally characterized by a sand mantle approximately 3 to 5 m thick overlying an extensive deposit of sensitive marine clay deposited within the Champlain Sea basin, underlain by glacial till and shale bedrock.

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

² Belanger, J.R. "Urban Geology of Canada's National Capital Area", in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

This region is underlain by a series of sedimentary rocks, consisting of shales, limestones and siltstones and that are, in turn, underlain at depth by bedrock of Carlsbad Formation.

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

3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the culvert replacement was carried out between September 23 and October 3, 2018. During that time, four boreholes (18-1501 to 18-1504, inclusive) were advanced at the mouth of the culvert replacement and along the proposed locations of culvert expansion. The borehole locations are shown on Drawing 1.

The boreholes were advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on track and truck mounted drill rigs, supplied and operated by George Downing Estate Drilling of Hawkesbury, Ontario. The boreholes were advanced to depths ranging from approximately 7.7 to 10.8 m below the existing ground surface.

Samples of the overburden were obtained at 0.8 m intervals of depth using 50 mm outside diameter split-spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586-11).

Upon reaching refusal to augering in Boreholes 18-1502, 18-1503 and 18-1504, the boreholes were advanced into the bedrock surface to depths of 3.0 to 3.6 m using rotary diamond drilling techniques while retrieving NQ sized core. A water truck was on site to supply the drill rigs with water for advancing the casing in the overburden and for the coring the bedrock. Traffic control required to allow the water truck and support vehicles to park adjacent to the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

One monitoring well was installed in Borehole 18-1503 to monitor the groundwater level at the site. The monitoring well consisted of 30 mm outside diameter PVC tubing with a 1.5 m long screen. The groundwater level in the monitoring well at borehole 18-1503 was measured on October 12, 2018. The monitoring well was subsequently decommissioned on October 12, 2018 by backfilling the monitoring well with bentonite, removing the top section of the monitoring well, and the asphalt patched upon completion, as per MOE Regulation 903.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings. The site conditions were restored following completion of the field work.

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

Two soil samples from Boreholes 18-1501 and 18-1503 were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole elevations were surveyed by Golder using a Trimble R8 GPS unit. The borehole locations, including MTM NAD83 northing and easting coordinates, ground surface elevations referenced to geodetic datum, and drilled depths are summarized in the following table and are shown on Drawing 1.

Table 1: Summary of Borehole Locations and Depths

Borehole Number	Borehole Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
18-1501	Median between Highway 417 EBL and WBL	5029343.0	375769.7	63.8	7.7
18-1502	Median between Highway 417 WBL and S-W On-Ramp	5029328.4	3758114.4	62.3	10.3
18-1503	Highway 417 S-W On-Ramp Embankment	5029348.9	375844.2	65.4	10.8
18-1504	East of Highway 417 S-W On-Ramp	5029361.7	375859.8	62.0	10.5

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The Record of Borehole sheets from the current investigation are presented in Appendix A. The results of the laboratory testing carried out during the current investigation are presented on the Record of Boreholes sheets and on Figures B1 to B8 in Appendix B. The results of basic chemical analysis completed on select soil samples are provided in Appendix C. The borehole locations and the interpreted stratigraphic profile projected along the proposed culvert replacement are shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and noncontinuous- sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the borehole locations consist of topsoil, overlying granular or silty sand fill, silty clay fill, with various amounts of cobbles and organic matter, overlying silty clay to clayey silt, over glacial till and shale bedrock.

A more detailed description of the soil deposits, bedrock and groundwater conditions encountered in the boreholes from the investigation are provided below.

4.2 Topsoil and Fill

A layer of silty sand to sandy silt topsoil was encountered at the ground surface at boreholes 18-1501, 18-1502 and 18-1504 with a thickness of about 200 to 400 mm.

Fill was found at surface of Borehole 18-1503, which was advanced through the shoulder of Highway 417 S-W On-Ramp and underlying the topsoil at Boreholes 18-1501 and 18-1502. At these borehole locations, the fill ranges in thickness from about 0.8 to 2.3 m, and extends to depths ranging from 1.2 to 2.3 m below existing ground surface.

The fill at Borehole 18-1503 varies in composition, consisting of sand and gravel, sand some gravel containing cobbles and boulders, and gravelly sand containing some cobbles. The granular fill at Borehole 18-1502 consists of silty sand containing some organic matter and silty clay/clayey silt with some sand. The fill material at Borehole 18-1501 consists of interlayers of silty clay and sandy gravel.

The measured Standard Penetration Test (SPT) "N" values in the fill material are variable, ranging from 1 to 85 blows per 0.3 m of penetration in the cohesionless fill materials, indicated a very loose to very dense state of packing. The measured SPT "N" values range from 4 to 12 blows per 0.3 m of penetration in the cohesive fill materials, indicating a stiff to very stiff consistency. The measured Standard Penetration Test (SPT) 'N' values may be affected by the presence of cobbles and boulders present in the fill.

The measured water contents of select samples of the cohesionless fill materials ranged from 3 to 32 percent, and the measured water content of one sample of the cohesive fill material was 46 percent. The results of Atterberg Limits testing on one selected sample of the silty clay portions of the fill gave a liquid limit of 45 percent and a plasticity index of 24 percent, indicating a soil of intermediate plasticity and is presented on Figure B2. The results of grain size distribution tests on two selected samples of the fill are presented on Figure B1.

4.3 Silty Clay to Clay (Weathered Crust)

Underlying the fill at Borehole 18-1503, there is a localized deposit of silty clay to clay that has been weathered to a grey-brown crust. The weathered silty clay deposit is about 1.7 m in thickness and extends to about 4.0 m depth below the existing ground surface (Elevation 61.4 m).

Measured SPT "N" values within the weathered silty clay deposit gave values of 7 and 9 blows per 0.3 metres of penetration, indicating a very stiff consistency.

Atterberg limits testing was conducted on one sample of the weathered silty clay and measured a plasticity index of 30 percent and a liquid limit of 52 percent, as shown on Figure B3; these results confirm that this material is a silty clay to clay soil of high plasticity. The measured natural water content of the weathered material ranges from about 27 to 35 percent.

4.4 Silty Clay and Clayey Silt

A deposit of interlayered silty clay and clayey silt containing silty sand seams, was encountered below the topsoil at Borehole 18-1504, and below the fill and/or weathered silty clay, where present, in Boreholes 18-1501, 18-1502 and 18-1503.

The silty clay and clayey silt deposit thickness ranges from about 0.4 to 1.5 m. At these locations, the silty clay to clayey silt extends to about 0.6 to 4.4 m depth below the existing ground surface (at Elevations 60.0 to 61.4 m).

The measured SPT "N" values in the interlayered silty clay and clayey silt range from 4 to 6 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency.

The results of grain size distribution testing on three samples of the silty clay to clayey silt are shown on Figure B4. Atterberg limits testing was conducted on four samples of the silty clay to clayey silt and measured plasticity indices of 10 to 13 percent and liquid limits of 23 to 32 percent, as shown on Figure B5; these results confirm that this material is a silty clay soil of low plasticity. The measured natural water content of the weathered material ranges from about 29 to 37 percent.

4.5 Gravelly Sand to Silty Sand Till

A till deposit was encountered below the fill and silty clay and clayey silt at all of the Borehole locations. The till generally consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of gravelly sand to silty sand, with some clay, and occasional clay/silt seams.

The till deposit was fully penetrated in Boreholes 18-1502, 18-1503 and 18-1504. Where penetrated, the till varies in thickness between about 0.3 and 2.7 m in thickness and was proven to depths of about 3.4 to 6.4 m below ground surface (Elevations 55.0 to 57.7m). The till was not fully penetrated in Borehole 18-1501, but proven to auger refusal to a depth of about 7.7 m below existing ground surface (Elevation 56.1 m).

Measured SPT “N” values within the till range from 12 to greater than 50 blows per 0.3 metres of penetration, indicating a generally compact to very dense relative density. Values greater than 50 are considered to likely reflect cobbles/boulders in the till or refusal on the bedrock surface rather than the relative density of the till.

Atterberg limits testing carried out on the cohesive portion of the glacial till gave (i.e. clay/silt seams) a plasticity index of 6 percent and a liquid limit of 20 percent, indicating the cohesive portion of the till consists of a silty clay to clayey silt of low plasticity.

The results of grain size distribution testing on six samples of the gravelly sand to silty sand till are shown on Figure B6. It should be noted that the samples were retrieved using a 50 mm outside diameter sampler and therefore the samples do not properly reflect the cobble and boulder portions of the deposit.

The measured natural water content of the till ranges from about 3 to 14 to percent.

4.6 Bedrock

Refusal to augering was encountered at Borehole 18-1501 at a depth of 7.7 m below existing ground surface (i.e. Elevation of approximately 56.1 m).

Bedrock was encountered beneath the glacial till in Boreholes 18-1502, 18-1503, and 18-1504 at depths ranging from 6.8 to 7.8 m below the existing ground surface (i.e., Elevations ranging from 55.0 to 57.7 m). The bedrock was cored between 3.0 and 3.5 m using a NQ drill bit and rods.

The following table summarizes the bedrock surface or refusal depths and elevations as encountered at the borehole locations.

Table 2: Summary of Bedrock Depths and Elevations

Borehole Number	Borehole Location with respect to Future/Existing Structure	Existing Ground Surface Elevation (m)	Depth to Bedrock/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
18-1501	Median between Highway 417 EBL and WBL	63.8	7.7 ¹	56.1 ¹
18-1502	Median between Highway 417 WBL and S-W On-Ramp	62.3	6.8	55.5
18-1503	Highway 417 S-W On-Ramp Embankment	65.4	7.8	57.7
18-1504	East of Highway 417 S-W On-Ramp	62.0	7.0	55.0

Note 1: Refusal to auger advancement.

Based on the bedrock surface elevations obtained where bedrock was proven, it is likely that the refusal to augering was encountered at the surface of the bedrock in Borehole 18-1501.

The bedrock encountered in these boreholes consist of weathered to fresh, thinly to medium bedded, grey, fine grained porous shale with laminations of limestone. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from approximately 26 to 100 percent, but more generally between 40 to 90 percent indicating a poor to excellent quality rock.

Results of unconfined compressive strength testing carried out on one bedrock core specimen from Borehole 18-1504 is presented on Figure B8. The results gave 43 MPa and indicate a medium strong bedrock.

4.7 Groundwater Conditions

A monitoring well was installed in Borehole 18-1503 to monitor the groundwater level at the site. The water level was measured in the monitoring well on October 12, 2018, about 3 weeks after installation, and are summarized in the following table.

Table 3: Summary of Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Screened Interval Material	Water Level Depth (mbgs)	Water Level Elevation (m)	Date of Reading
18-1503	65.43	Glacial Till	2.7	62.7	Oct. 12, 2018

Open water levels during drilling procedures were recorded and ranged from Elevations 56.0 to 61.4 m.

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

4.8 Corrosion and Sulphate Attack, Chemical Analyses

Two samples of soil from boreholes 18-1501 and 18-1503 were submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of this testing are provided in Appendix C and are summarized below.

Table 4: Summary of Basic Chemical Results

Borehole / Sample No.	Sample Depth (m)	Sample Type	Chloride (%)	pH	Electrical Conductivity (mS/cm)	Resistivity (ohm-cm)	Sulphate (ug/g)
18-1501/ 3	1.5 – 2.1	Soil	0.035	7.79	1.09	917	420
18-1503/ 3	2.3 - 2.9	Soil	0.053	7.97	1.28	781	130

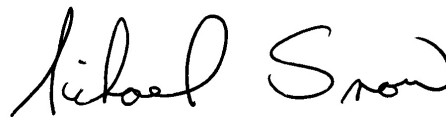
5.0 CLOSURE

This report was prepared by Ms. Kim MacDonald, E.I.T., and reviewed by Mr. Michael Snow P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Fintan Heffernan, P.Eng., a Senior Consultant with Golder and the Designated MTO Foundations Contact, conducted an independent quality control review of this report.

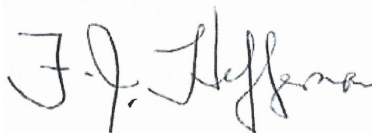
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PART B

Foundation Design
Proposed Unnamed Creek Culvert Replacement
0.2 km North of Walkley Road
Highway 417
Ottawa, Ontario
W.P. 4145-10-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the replacement of the Unnamed Creek Culvert located 0.2 km North of Walkley Road beneath Highway 417 Westbound Lanes (WBL) in Ottawa, Ontario as part of W.P., 4045-10-00. Based on discussions with WSP, it is understood that the both trenchless technologies and open cut construction methods of the proposed replacement are being considered at this point.

The foundation investigation report, discussion, and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

The following details summarize our understanding and the options for replacement that are being evaluated:

- Replacement of the existing culvert underneath Highway 417 WBL, aligned on Profile A-A on Drawing 1:
 - The existing culvert is 0.91 m in diameter, and approximately 55 m in length;
 - The replacement pipe will be installed with either trenchless or open-cut technologies;
 - The replacement pipe will match length and diameter sizes to the existing and will be installed along an alignment parallel to the existing culvert; and,
 - The replacement pipe will have invert levels at elevations 62.5 and 62.3 m, at the inlet and outlet, respectively.
- Installation of a new culvert located directly east of the existing, beneath the Highway 417 S-W On Ramp from Walkley Rd, aligned on Profile B-B on Drawing 1:
 - The new culvert will be 0.91 m in diameter, and measure approximately 57 to 60 m in length;
 - The new culvert will be installed using either trenchless or open-cut technologies; and,
 - The new culvert will have invert levels at elevations 62.4 and 61.8 m, at the inlet and outlet, respectively.

This is summarized in the table below:

Table 5: Summary of Proposed Culvert Dimensions

Property	Culvert	
	Highway 417 WBL (Profile A-A)	Highway 417 S-W On-Ramp (Profile B-B)
Length (m)	55	57 to 60
Existing Culvert Diameter (m)	0.91	N/A
Proposed Culvert Diameter (m)	0.91	0.91
Bore Diameter (m)	1.2	1.2

Property	Culvert	
	Highway 417 WBL (Profile A-A)	Highway 417 S-W On-Ramp (Profile B-B)
Culvert Upstream Elevation (m)	62.5	62.4
Culvert Downstream Elevation (m)	62.3	61.8
Depth of Cover to Obvert (m)	1.6	2.0 to 2.6

The discussion and recommendations for both culvert replacement options (i.e. replacement of the HWY 417 WBL culvert, and the HWY 417 S-W On-Ramp culvert) using either open cut and trenchless installations are presented below in this report. These guidelines are applicable to both culvert locations and are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigation at the site.

6.2 Overview

The following sections of this report provide replacement options and recommendations for both the Unnamed Creek Culvert replacement pipe and new culvert underneath Highway 417 WBL and Highway 417 S-W On-Ramp, respectively, using trenchless and/or open cut methods, as well as the design of temporary water diversion systems. The existing culvert is a 0.91 metre diameter corrugated steel pipe (CSP) with a span of approximately 55 m in length. The existing culvert inverts are at approximate Elevations 62.3 and 62.5 m, founded on the silty clay and sandy gravel fill. The flow in the culvert is from east to west. The date of construction of the culvert is circa 1974.

The existing pavement grades at the existing culvert location are at an approximate Elevation of 65.4 m. At the location of the culvert, HWY 417 is a divided highway and has two travel lanes and a speed change lane in the WBL direction. The shoulders are fully paved to 3 m width on the outside and to 1 m width at the median side. The existing embankments at the WBL culvert location are approximately 3 m in height and have a slope of approximately 6H:1V (horizontal : vertical) in the median and approximately 4H:1V on the WBL outside embankment. The existing pavement grade at the Highway 417 S-W On-Ramp is at an approximate Elevation of 65.6 m. The embankment slopes are generally in good condition, no erosion was noted during the field program.

It is understood that the culvert pipe will be 0.91 m in diameter at both the replacement culvert and new diversion culvert locations and the replacement culvert will be installed at invert Elevations of 62.5 m and 62.3 m and the new culvert under the Highway 417 S-W On-Ramp will be installed at invert Elevations of 62.4 and 61.8 m. The sections below (Section 6.3, 6.4 and 6.5) provide more information on the feasibility of trenchless technologies and open cut replacements at this site.

6.3 Culvert Replacement Options

6.3.1 Trenchless Technologies

Based on the information provided by WSP, it is understood that trenchless methods may be an option for the replacement of the Unnamed Creek Culvert under Highway 417 WBL and the new Unnamed Creek culvert under Highway 417 S-W On-Ramp. The Contractor should be responsible for choosing the method and equipment for the trenchless crossing installations, unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of

ground behaviour on some possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information from the investigations.

The non-standard special provision (NSSP) provided in Appendix E is provided to implement potential trenchless options.

A brief discussion of which trenchless methods is considered feasible for this culvert replacement is included in Section 6.4.1. The relatively limited amount of ground cover for a 0.9 m diameter culvert pipe, and corresponding 1.2 metre diameter steel carrier pipe where needed, through highway roadway fills makes this a challenging crossing. For the proposed service installations for this project, a number of construction methods may be considered: horizontal directional drilling, pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling, pilot tube micro-tunneling, tunnel boring machine (TBM) and tunnel digging machine (TDM - i.e., open face shield tunnelling). In brief, these construction methods involve the following:

- **Horizontal Directional Drilling (HDD):** HDD involves the drilling of a pilot hole using a steerable drill bit on a flexible string of drill rods while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore would be reamed in one or more passes to a larger diameter, and then the steel or HDPE pipe would be pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the product pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment. Bores are typically limited to less than 1,200 millimetres in diameter.
- **Pipe Jacking and Horizontal Auger Boring:** A pipe jacking operation involves pushing an oversized steel liner pipe (casing) horizontally into the ground by jacking. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The profile needs to be approximately horizontal. Jacking and receiving pits are required. There can be limited ability to steer the casing during jacking. This method is only applicable to construction in the overburden, and may not be feasible in bouldery soils (e.g., glacial till) or in flowing ground. The alignment accuracy for this method can be improved using an initial "pilot tube".
- **Pipe Ramming:** Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven 'open' to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Ability to steer is limited. The alignment accuracy for this method can be improved using an initial "pilot tube".
- **Micro-tunnelling:** Micro-tunnelling is a method of installing concrete pipes in bores ranging from 0.6 to 1.5 metres in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling equipment is generally more suited to drilling in overburden. Availability of this equipment locally is limited.

- **Pilot Tube Micro tunneling:** PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and product pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and, since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or microtunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator's skill. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.
- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head horizontally into the ground with successive sections of an oversized steel liner pipe or a concrete product pipe advanced behind the TBM by pipe jacking. The spoil is removed from the tunnel as the TBM is advanced, using augers, conveyor belts or mucking carts. The cutting head is driven and steered by an operator inside the TBM and may be partially open to allow for access to the face. The tunnel profile needs to be approximately horizontal. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in bouldery soils (e.g., glacial till). Excavations through sandy soils below the water table typically require dewatering to maintain face stability when using open faced machines, specialized earth pressure balance or slurry shield TBMs, which pressurize the face of the excavation and improve face stability, or the use of microtunnelling.
- **Tunnel Digging Machine (TDM):** TDM tunnelling, also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner (i.e., steel casing) or final concrete pipe would be jacked in sections from the launching shaft. Unlike jack and bore, this method allows personnel to enter the tunnel to allow more control over the operations, such as for removal of obstructions. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual or machine-assisted excavation generally requires a tunnel diameter of approximately 1.2 m or more.

6.4 Assessment of Feasible Replacement Methods

The following presents the feasibility of using trenchless and open cut replacement methods, advantages, disadvantages and geotechnical concerns.

6.4.1 Trenchless Technologies

Based on the borehole data along HWY 417 westbound lanes at existing culvert location (i.e. boreholes 18-1501 and 18-1502) and at the diversion pipe along Highway 417 S-W On Ramp from Walkley Rd (i.e. boreholes 18-1503 and 18-1504), the ground conditions along the pipe replacement within the tunnel vertical limits (i.e., invert and obvert of the casing) are likely to consist of cohesive and granular fill and or silty clay and clayey silt. Anticipated thickness of cover over a tunnel bore are expected to be approximately 1.5 to 1.7 m under the paved roadways, or less if a steel casing liner is required.

As such, Pipe Jacking, Pipe Ramming, HDD, TBM, TDM and PTMT methods are all applicable methods. However, Pipe Jacking and/or Pipe Ramming are the two recommended trenchless technologies as it would be the most economically feasible options in the anticipated ground conditions over short distances.

The following geotechnical issues/risks associated with these trenchless construction methods should be considered and evaluated, and are summarized in the table below:

- Mixed face conditions are a potential issue wherever the soil-soil (or soil-rock) interface is within the elevation horizon of the proposed bore or where the face conditions are expected to change significantly along the length of the crossing.
 - According to anticipated subsurface conditions (see Drawing 1), a mixed-face condition consisting of fill and silty clay will be encountered along the vertical limit of the Highway 417 S-W On-Ramp at this site but are not expected to materially affect the selection of trenchless methods.
 - At the pipe installation at the culvert located on Highway 417 S-W On-Ramp, the presence of cobbles and boulders within the fill (BH 18-1503), which could cause the tunnel bore to be misaligned and/or cause cobbles/boulders to “jack” up to surface. Due to the proposed elevation of the new culvert at this location (Elevation 62.4 to 63.7 m) the anticipated risk of misalignment/boulder “jacking” is considered medium to minimal, as the cobbles and boulders were predominately present above the proposed tunnel bore elevation of 63.7 m.
- As a general guideline, the required cover above the crown of the tunnel/bore for trenchless installation should be at least one tunnel/bore diameter (and preferably two diameters) relative to the ground surface (which is the case for this planned work). Lesser amounts of cover could jeopardize the stability of the working face (depending on the method) or lead to excessive ground movements.
- Similarly, the separation between bores, should multiple smaller diameter pipes be proposed, should be at least one, preferably two, tunnel diameters in both the vertical and horizontal directions. The objectives of having this separation are: to avoid providing too narrow of a ‘pillar’ of soil between two adjacent trenchless crossings which could be unstable/overstressed under the weight of overlying soil and bedrock; and, to avoid the bore possibly intersecting other existing services or foundations during drilling, should there be ‘drift’ from the intended alignment.
- Oversize casings should be installed for subsequent installation of the services. Selection of casing size should consider the potential for mis-alignment over the tunnel length due to ground conditions (i.e., mixed face condition), access to the tunnel face (if potentially necessary), proposed tunneling methodology (i.e., steerable or non-steerable) and the length of the tunnel drive.

Table 6: Summary of Risk Register Associated with Trenchless Technologies

Risks	Trenchless Method	Risk (L/M/H)	Mitigation	Mitigated Risk (L/M/H)
Loss of alignment due to cobbles/boulders	1)Pipe Jacking	L to M*	-Limited	L to M*
	2)Pipe Ramming	M to H*	-Limited	M to H*
	3)HDD	H	-Multiply Number of Reams	M
	4)TBM	L	-N/A	L
	5)TDM		-N/A	L
	6)PTMT		-N/A	L

Risks	Trenchless Method	Risk (L/M/H)	Mitigation	Mitigated Risk (L/M/H)
Instability of working face, loss of crown cover, excessive ground movements	1)Pipe Jacking	H	-Keep auger head back from face	M
	2)Pipe Ramming	L	-N/A	L
	3)HDD	L	-N/A	N/A
	4)TBM	M	-Use head with reduced openings, monitor advances and soil volume removal	L
	5)TDM	H	-Use partial face shield	M
	6)PTMT	H	-Keep auger face back from face	M
Daylight into roadway, high fluid pressures (face-out)	1)Pipe Jacking	N/A	-N/A	N/A
	2)Pipe Ramming	N/A	-N/A	N/A
	3)HDD	H	-Reduce fluid pressures	M
	4)TBM	L	-N/A	L
	5)TDM	N/A	-N/A	N/A
	6)PTMT	N/A	-N/A	N/A

Note: *Applicable to culvert on Highway 417 S-W On-Ramp

6.4.2 Open Cut Replacement

Based on discussions with WSP, it is understood that the feasibility to install the new and replacement culvert pipes within the embankment fill and/or silty clay overburden, using open excavation construction methods is being considered.

No geotechnical concerns for construction using open cut replacement methods of the culvert as the proposed invert elevations are above the bedrock surface and anticipated to be within the fill and silty clay overburden, as indicated by the borehole logs. Excavation work may encounter cobbles/boulders in the fill.

From a geotechnical standpoint, open-cut methods is the preferred method of replacement/ new installation of both culverts over trenchless technologies given the limited amount of soil cover. However, open-cut methods require lane closures and restrictions to traffic and/or detour staging would be required.

Frost tapers should conform to OPSD 205 and 803 series and are detailed in Section 6.6.2 below.

6.5 Recommendations and Considerations for Trenchless Replacement

Pipe installation by trenchless methods, if retained, should follow guidelines and specifications detailed as per the non special provision, which is provided in Appendix E.

There is a relatively low potential for significant settlement with a pipe ramming trenchless installation since the soil is typically not removed from within the casing/pipe until it has been fully advanced to the exit pit. This methodology does not, therefore, create an unsupported working face, a corresponding reduction in stress in the ground above the tunnel, and the potential for movement of the ground towards the face (such as would often be the case for a conventional tunnel construction). The settlements should therefore be limited in magnitude, provided the gap around the casing created by the overcut is limited in size. The risks of settlement using pipe jacking and auger bore are considered moderate due to the presence of an unsupported bore and less than 2 bore diameters of soil cover. The risk of settlement due to jacking and auger bore are most likely within tolerable limits, however, cannot be predicted at this time.

For the ground conditions at this site, it is expected that settlements directly over the tunnel should not exceed approximately 5-10 mm, provided good construction procedures are followed.

As required by Section 7.07 of the Pipe Installation by Trenchless Method NSSP (see Appendix E) for this project, and in accordance with MTO's "Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application", a settlement monitoring program will need to be implemented, if a trenchless approach is retained. That settlement monitoring and will serve to:

- Document the effects of tunnelling;
- Obtain prior warning of ground movements that could occur due to the construction methods; and,
- Allow adjustments to be made to the trenchless construction method such that the settlement limits established are not exceeded, recognizing however that there is typically some delay between the trenchless construction and the full manifestation of the ground surface settlements.

6.5.1 Temporary Excavations, Shoring and Temporary Protection for Entrance and Exit Pits

Shallow excavations are anticipated for the entrance and exit pits, which will be constructed in areas adjacent to the inlet and outlet of the new culvert alignment. The excavations will therefore only be up to approximately 2.5 m deep.

It is understood that the entrance pit floor will be covered with a concrete mud slab and then on top of clear stone to support the steel rails that will guide the trenchless equipment. Given the wet ground conditions at this site, it is considered that these measures will be necessary, in order to provide a trafficable excavation floor.

The pits will be excavated through the embankment fill and into the underlying stiff to very stiff native silty clay to clay. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The existing fill above the water table and silty clay would be classified as Type 3 soil based on the OHSA. Accordingly, excavations should be made with side slopes no steeper than 1H:1V. Any fill which extends below the water table would be classified as Type 4 soil based on OSHA, and excavations in these materials should be sloped no steeper than 3H:1V. If 3H:1V open cut excavation side slopes cannot be accommodated, then a temporary protection system (i.e., temporary excavation shoring) will be required, or the surficial fills could first be dewatered.

For the pits, it is envisioned that temporary protection systems will be required adjacent to the embankments/active highway lanes. This support system shall be designed and constructed by the contractor in accordance with the Ontario Provincial Standard Specification OPSS.PROV 539. The lateral movement of the temporary shoring system shall meet Performance Level 2 as specified in OPSS.PROV 539.

A conventional shoring system for these conditions could consist of soldier piling and lagging or interlocking steel sheet piling supported against lateral movement using walers, tie backs and/or internal struts/braces. Interlocking steel sheet piling would aid in groundwater control. The design of that system is the responsibility of the contractor. The shoring system may also need to resist forces generated from trenchless operations.

It is understood that an underground MTO electrical cable crossing is located along the Highway 417 WB right shoulder (east end of the existing culvert). It is recommended that the excavations for the construction of the exit pit would be carried out no closer than approximately 7 to 10 m from the fibre-optic cable.

6.5.2 Surface Water and Groundwater Control

The water level in the monitoring well at 18-1503 was measured at approximately an Elevation of 62.7 m on October 12, 2018 at the proposed new Highway 417 S-W On-Ramp culvert location, and open water levels during drilling procedures recorded open hole water levels ranging from Elevations 56.0 to 61.4 m during the current investigations. It is anticipated that the groundwater table may be encountered above the base of the excavations at the entrance and exit pits. There may be additional seepage from the nearby creek channel.

It is understood that interlocking steel sheet piling is likely to be driven between the creek and the pit to limit the groundwater seepage. It is further understood that the entrance pit floor will be covered with a concrete mud slab.

The actual rate of groundwater seepage is not anticipated to be excessive, given the relatively low hydraulic conductivity of the native clayey soils. Covering of the excavation floor with a concrete slab will help to reduce the flows. Higher inflows could occur from the surficial sandy fills. Given the above measures, pumping from sumps in the excavations would probably be adequate to handle the inflow to the pits.

Some additional groundwater inflow to the pits could, however, occur if the excavations expose/intercept the sandy backfill to the existing culvert. Similarly, the risk of settlement above the bore would be increased due to flow from the saturated sandy fills, if these materials are intercepted by the crown of the bore; in at least some of the boreholes, the sandy fill materials are likely backfill soils to the frost tapers beside the culvert.

Consideration should therefore be given to carrying out some pre-drainage of the sandy embankment fill, to at least partially lower the groundwater level in advance of excavations and boring, by pumping from two or more sumps excavated in the adjacent ground (i.e., into the embankment fill at the inlet and outlet locations of the existing culvert). One to two weeks of pre-pumping, in advance of excavation, may be sufficient to provide some lowering of the groundwater level along the alignment.

Due to the stiffness of the upper silty clay at the Highway 417 S-W On-Ramp, the effects of de-watering on the silty clay will not result in material settlements.

A Permit-To-Take-Water (PTTW) is required from the Ministry of the Environment, Conservation and Parks (MECP) if a volume of water (groundwater water and surface water) greater than 400,000 litres per day is pumped from the excavations. If the volume of water to be pumped will be less than 400,000 litres per day, but more than 50,000 litres per day, the water taking will not require a PTTW, but will need to be registered in the Environmental Activity and Sector Registry (EASR) as a prescribed activity. Depending on the size of the excavations, the number of excavations that are open at one time, and the time of year that the excavating takes place, pumping of volumes greater than 50,000 litres per day (but less than 400,000 litres per day) may occur, and EASR registration may be required.

6.5.3 Erosion Protection

Since the casing will be driven directly into the embankment, there will be no new granular bedding or cover material which might be vulnerable to forming a preferential seepage conduit along/around the culvert. There is therefore no particular requirement to provide a cut-off (such as a clay seal) at the inlet.

The need for (and design of) erosion protection at the culvert inlet and outlet (including the slopes and sides of the channel) will depend on the anticipated hydrologic/hydraulic conditions. Typically, rip-rap protection should be provided over these areas. The rip-rap layer should cover all surfaces on the embankment slopes against which creek water is likely to be in contact. If needed, rip-rap treatment should be consistent with the Ontario Provincial Standard Drawing OPSD 810.010.

6.6 Recommendations and Considerations for Open-Cut Replacement

6.6.1 Settlements

It is understood that no grade raise is currently proposed for Highway 417 as part of the culvert replacement. Minor widenings of less than 2 m in width at the shoulders of both the east and west embankment slopes are proposed temporarily to help facilitate construction staging and to a lesser extent for the final embankment geometry. As such, settlements for the new culverts are not considered material to their performance.

6.6.2 Culvert Bedding, Backfill and Erosion Protection

As previously noted, a new flexible culvert (CSP) is being considered for the culvert replacement and the new culvert will be founded between Elevations 62.5 to 62.3 and 62.4 to 61.8 m, respectively, within the existing embankment fill and native silty clay.

Since the pipe culvert will be installed within the embankment fill, which contains potential for cobbles and boulders, the pipe embedment should be in accordance with OPSD 802.014 (*Flexible Pipe Embedment in Embankment, Original Ground: Earth or Rock*). An NSSP for excavations with obstructions is provided in Appendix E. Due to the presence potential cobbles and boulders and limited soil cover, open-cut replacement is the preferred replacement option for the culverts along both alignment. It is expected that the cobbles and boulders should not hinder the progression of the excavation. The pipe embedment material should consist of OPSS.PROV 1010 Granular A fully encapsulated in non-woven geotextile. The granular material placed in the haunch area should be compacted to at least 95 percent of the material's Standard Proctor Dry Density using suitable vibratory equipment prior to placing and compacting the remainder of the embedment material.

For a pipe culvert replacement, the bedding levelling pad and backfill requirements should be in accordance with OPSS.PROV 421 (*Construction Specification for Pipe Culvert Installation in Open Cut*). The bedding and cover should be placed in maximum 200 mm thick lifts and should be compacted to at least 95 percent of the standard Proctor dry density. The backfill should be placed in maximum 300 mm thick lifts and should be compacted to at least 95 percent of the standard Proctor dry density. The backfill should extend vertically up to at least 1.5 m above the pipe to match existing grade. The fill depth during placement should be maintained equal on both sides of the culvert, with one side not exceeding the other by more than 200 mm in height. To limit compaction induced stresses in the culvert, heavy equipment should not be allowed within 1 m of the culvert during compaction of the backfill.

Based on the results of the investigations, the existing embankment fill consists of silty sand to sand mixed and silty clay. Gravel, cobbles and boulders were encountered within the fill in Borehole18-1503. Results of the grain size distribution on two samples obtained from the embankment fill indicate a fines content of 46 and 64 percent. In accordance with the *MTO Pavement Design Manual*, the fill is classified to have a moderate susceptibility of frost heave and therefore frost tapers are considered necessary for the new culvert, which is being installed within the existing embankment fill.

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth at the site is 1.8 m below the existing ground surface.

This depth should be utilized when designing frost tapers in accordance with OPSD 205 and OPSD 803 series.

The culvert replacement should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 22 kN/m³.

Considering the culvert will be constructed within embankment fill, which is relatively permeable, a clay seal or concrete cut-off wall is not required at the upstream and downstream ends of the culvert replacement.

If the flow velocities are sufficiently high, a provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSS 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*), with the rip-rap placed up to the outlet invert level, in combination with the cut-off measures noted above.

6.6.3 Excavations, Shoring and Temporary Roadway Protection

Temporary excavations for the culvert replacement will be made through the existing pavement structure and embankment fill. No unusual problems are anticipated with trenching in the overburden materials using conventional hydraulic excavating equipment, although cobble and boulder removal could be required within the embankment fill. Boulders or rock slabs larger than 0.3 m in diameter should be removed from the excavation side slopes for worker safety and should not be used as backfill.

The embankment fill above the groundwater level would generally be classified as a Type 3 soil in accordance with the Occupational Health and Safety Act of Ontario (OHSA) and Regulations for Construction Projects. As such, excavations in these soils may be made with side slopes at 1H:1V.

If 1H:1V open cut excavation side slopes cannot be accommodated, then temporary roadway protection (i.e., excavation shoring) will be required. Where shoring is required, the support system shall be designed and constructed in accordance with SP105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP105S19.

6.6.4 Surface Water and Groundwater Control

The water level in the monitoring well at 18-1503 was measured at approximately an Elevation of 62.7 m on October 12, 2018 at the proposed new culvert location, and open water levels during drilling procedures recorded open hole water levels ranging from Elevations 56.0 to 61.4 m during the current investigations. It is anticipated that the groundwater table will likely not be encountered above the base of the excavations at the entrance and exit pits. There may be additional seepage or flooding from the nearby creek channel.

Groundwater and surface water control should follow guidelines as per Section 6.5.2.

6.7 Temporary Water Diversion Systems

Control of the creek flow, surface water and groundwater will be necessary for the rehabilitation of the culvert, to allow construction to be carried out in dry conditions.

Depending on the creek flow, surface water flow conditions and the groundwater levels at the time of construction, water flow could be bypassed through either the existing culvert or through the newly installed diversion pipe by diverting the flow toward or pumping from behind a temporary water diversion system. Temporary water diversion systems for these works shall consist of either sand bags or glacial till cofferdam advanced to an appropriate depth to control the surface water and groundwater inflow from the creek. Alternatively, an inflatable water diversion system could be used. However, the selection and design of temporary unwatering/dewatering system is the responsibility of the contractor and shall be carried out in accordance with Ontario Provincial Standard Specification (OPSS), PROV 517 (*Dewatering*) with amendments as per Special Provision (SP) 517F01. Given the groundwater and soil conditions at this site, dewatering is expected to be of low complexity and it is therefore not a requirement to carry out a preconstruction survey or to require a dewatering design engineer for the dewatering system as per Table A of SP 517F01 (*Dewatering System*).

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth at the site is 1.8 m below the existing ground surface.

6.7.1.1 Sand Bags or Glacial Till Cofferdam

The water diversion system could consist of a temporary sand bag or glacial till embankment. The temporary embankment should have a thickness of 1 m, and should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet/outlet opening, and a minimum vertical height equivalent to the maximum 100 year water level including treatment of the adjacent side slopes. Alternatively, clay blankets may be constructed, extending upstream/downstream to a distance equal to three times the culvert height. Normally, a clay blanket would extend along the adjacent embankment side slopes to a height of two times the culvert height or the high water level, whichever is higher; however, at this site where the cover over the culvert is relatively thin, it is recommended that a clay blanket, if adopted, extend to the top of the embankment side slope.

Where a clay blanket is used, the clay core should be covered with an approximately 1.0 m thick layer of OPSS.PROV 1010 (*Aggregates*) Granular B Type II to reduce the potential for erosion of the embankment side slopes.

6.7.1.2 Inflatable Water Diversion System

Consideration could also be given to the use of an inflatable water diversion system. These systems typically consist of vinyl coated polyester water-inflated bladders with internal baffle systems. Various barrier heights are available, with a standard maximum height of about 2.5 m. However, the height of barrier should typically maintain a minimum of at least 25 percent of freeboard above the static water level. Inflatable systems also rely on surface friction in order to stabilize when exposed to uneven water pressure. An anchoring system at the creek bank may also be required depending on the water flow in the creek at the time of construction. The below design parameters can be used for the design of an inflatable water diversion system; however it should be noted that these types of systems are proprietary to individual suppliers and may require additional investigation and/or input for design.

Table 7: Summary of Soil Properties

Soil Type	Internal Angle of Friction (ϕ , degrees)	Unit Weight (γ , kN/m ³)	Coefficients of Earth Pressure		
			Active, K_a	At-Rest, K_o	Passive, K_p
Embankment Fill	28	20	0.36	0.53	2.8
Till	30	22	0.33	0.50	3.0

6.8 Corrosion and Cement, Steel Type

Two soil samples from Boreholes 18-1501 and 18-1503 were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The results of the testing are attached in Appendix C.

The results indicate a low to moderate potential for concrete degradation due to the presence of sulphates, and that concrete made with Type MS Portland cement should be used for substructures.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH was 7.79 and 7.97 which is within what is considered the normal range for soil pH of 5.5 to 9.0. There is a high potential for corrosion of exposed ferrous metals due to the resistivity of the soil. The test results provided in Section 4.8 and attached in Appendix C can be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

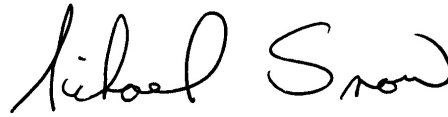
7.0 CLOSURE

This report was prepared by Ms. Kim MacDonald, E.I.T., and was reviewed by Mr. Michael Snow, P.Eng. provided technical input and Mr. Fintan Heffernan, P.Eng., Designated MTO Foundations Contact, conducted an independent quality control review of this report.

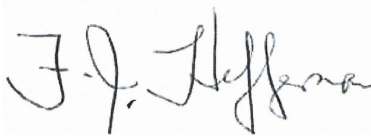
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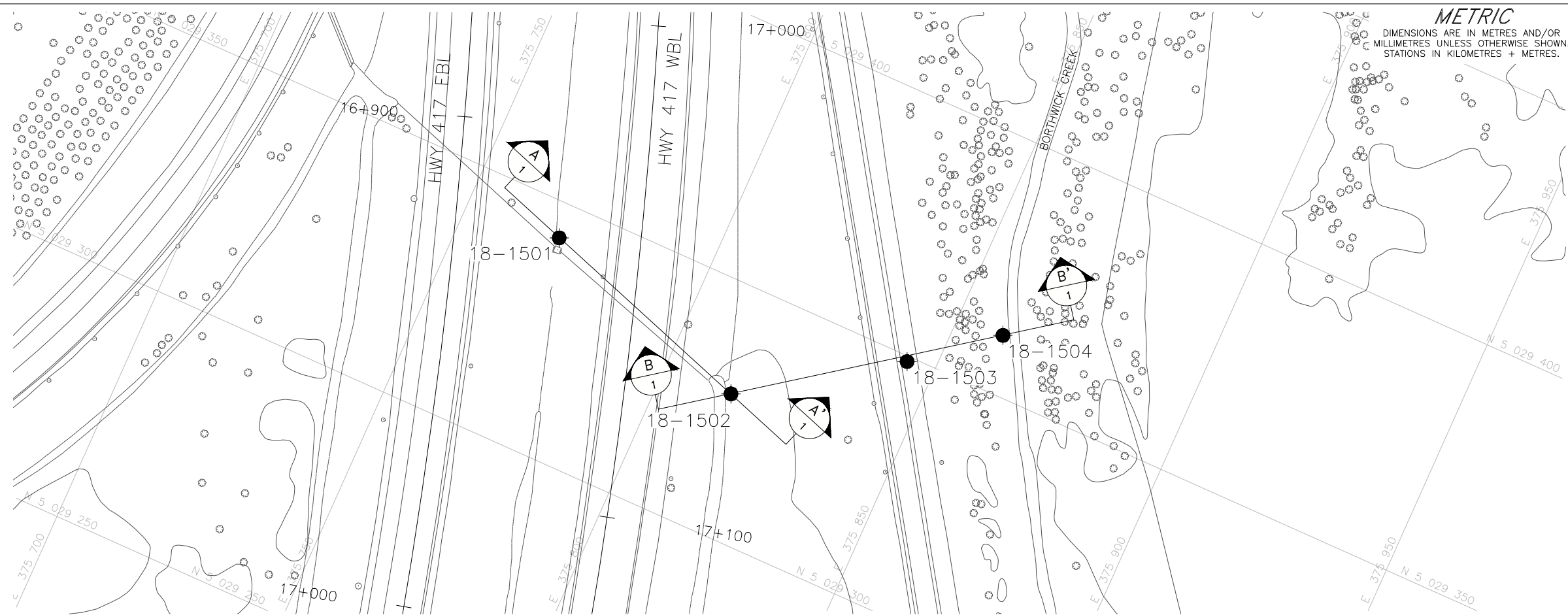
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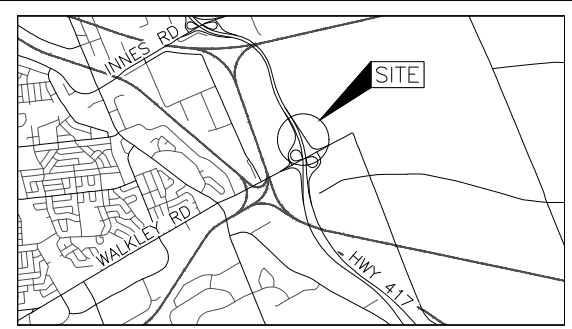


METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 4145-10-00

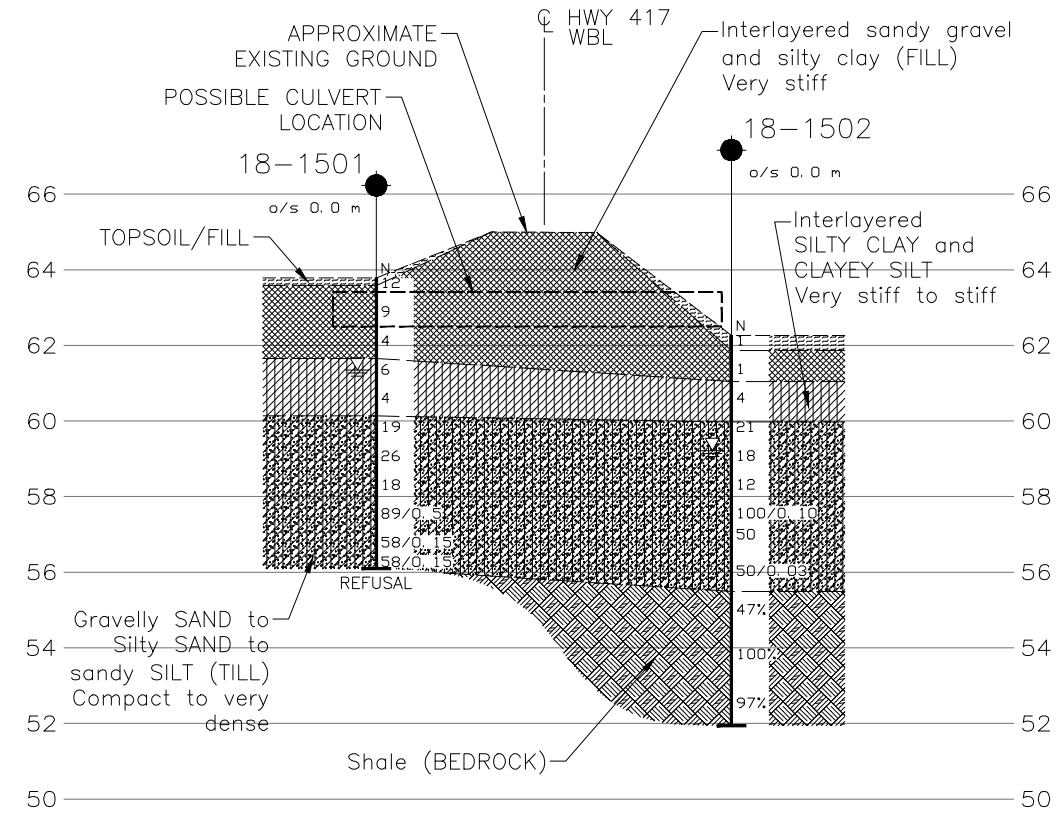
UNNAMED CREEK CULVERT REPLACEMENT HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.400448 LONG. -75.592834

SHEET

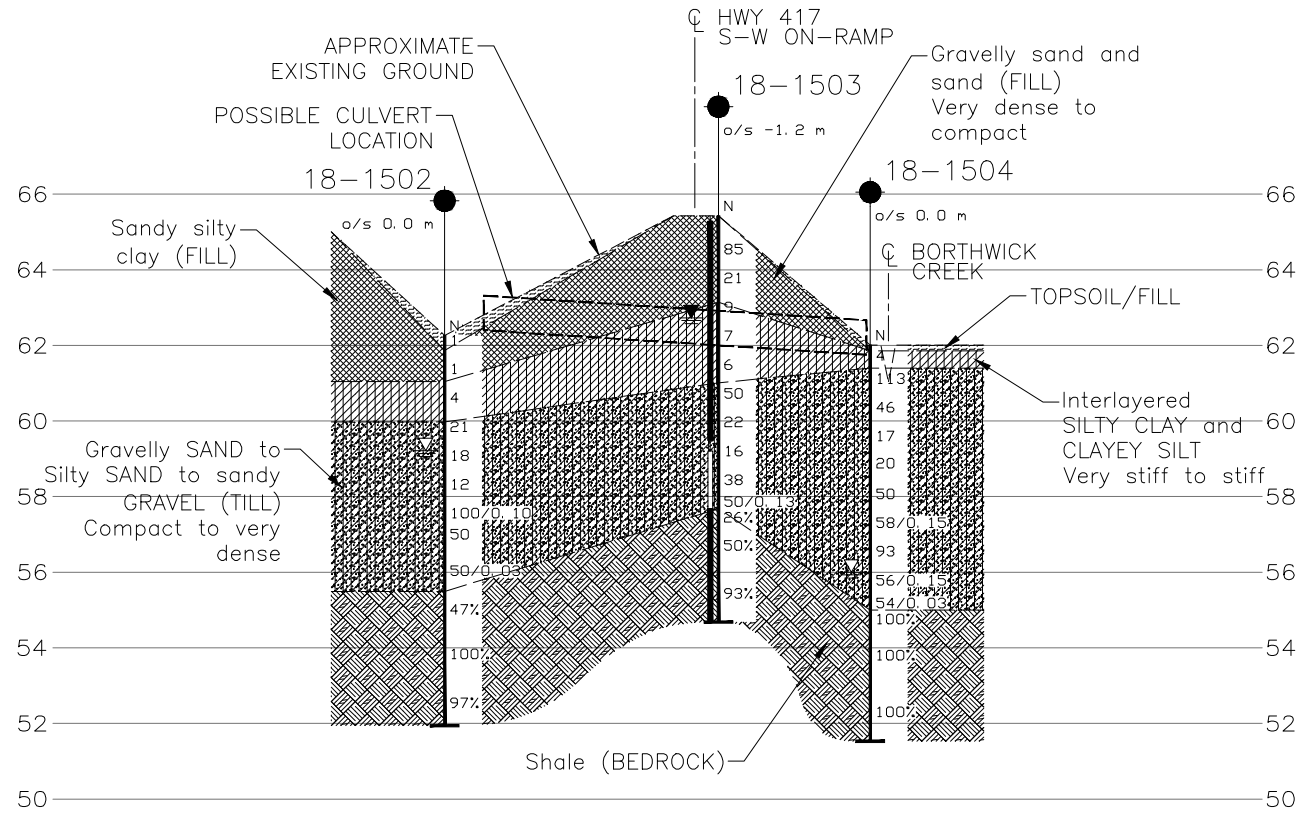


KEY PLAN
SCALE 1 0 1 2 km

- LEGEND**
- Borehole - Current Investigation
 - ⊥ Seal
 - ⊥ Piezometer
 - N Standard Penetration Test Value
 - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
 - 100% Rock Quality Designation (RQD)
 - ⊥ WL in piezometer, measured on October 12, 2018
 - ⊥ WL upon completion of drilling



PROFILE A-A'
SCALE 10 0 10 20 m



PROFILE B-B'
SCALE 10 0 10 20 m

BOREHOLE CO-ORDINATES NAD83 (CSRS) MTM ZONE 9

No.	ELEVATION	NORTHING	EASTING
18-1501	63.8	5029343.0	375769.7
18-1502	62.3	5029328.4	375814.4
18-1503	65.4	5029348.9	375844.2
18-1504	62.0	5029361.7	375859.8

NOTES

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

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

REFERENCE

Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

NO.	DATE	BY	REVISION

Geocres No. 31G5-297

HWY. 417	PROJECT NO. 1662565	DIST. EASTERN
SUBM'D. KM	CHKD. KM	DATE: 3/28/2019
DRAWN: JM	CHKD. MSS	APPD. FUJ
		DWG. 1



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 PLOTNAME: C:\Users\jheffernan\OneDrive\Documents\1662565_10_00\1662565_10_00.dwg

APPENDIX A

Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-1501 to 18-1504

Bedrock Core Photographs, Figures A1 to A6

LIST OF SYMBOLS

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

I.	GENERAL	(a)	Index Properties (continued)
π	3.1416	w	water content
$\ln x$,	natural logarithm of x	w_l or LL	liquid limit
\log_{10}	x or log x, logarithm of x to base 10	w_p or PL	plastic limit
g	acceleration due to gravity	I_p or PI	plasticity index = $(w_l - w_p)$
t	time	w_s	shrinkage limit
FoS	factor of safety	I_L	liquidity index = $(w - w_p) / I_p$
		IC	consistency index = $(w_l - w) / I_p$
		e_{max}	void ratio in loosest state
		e_{min}	void ratio in densest state
		I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)
II.	STRESS AND STRAIN	(b)	Hydraulic Properties
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
σ	total stress	(c)	Consolidation (one-dimensional)
σ'	effective stress ($\sigma' = \sigma - u$)	C	compression index (normally consolidated range)
σ'_{vo}	initial effective overburden stress	C_r	recompression index (over-consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)	C_s	swelling index
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3) / 3$	C_α	secondary compression index
τ	shear stress	m_v	coefficient of volume change
u	porewater pressure	C_v	coefficient of consolidation (vertical direction)
E	modulus of deformation	C_h	coefficient of consolidation (horizontal direction)
G	shear modulus of deformation	T_v	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
III.	SOIL PROPERTIES	σ'_p	pre-consolidation stress
(a)	Index Properties	OCR	over-consolidation ratio = σ'_p / σ'_{vo}
$\rho(\gamma)$	bulk density (bulk unit weight)*	(d)	Shear Strength
$\rho_d(\gamma_d)$	dry density (dry unit weight)	τ_p, τ_r	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	ϕ'	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	δ	angle of interface friction
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	μ	coefficient of friction = $\tan \delta$
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)	c'	effective cohesion
e	void ratio	c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3) / 2$
S	degree of saturation	p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
		q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
		q_u	compressive strength $(\sigma_1 - \sigma_3)$
		S_t	sensitivity

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

Notes: 1
2

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 10	Trace	Trace sand
10 to 20	Some	Some sand
20 to 35	(ey) or (y)	Sandy
over 35	And	Sand and Gravel

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1501	SHEET 1 OF 1	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029343.0; E 375769.7 NAD 83 MTM ZONE 9 (LAT. 45.400436; LONG. -75.593479)</u>	ORIGINATED BY <u>DG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>September 24, 2018</u>	CHECKED BY <u>KM</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)						
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL	
63.8	GROUND SURFACE																						
0.0	(SM) Silty sand, contains organic matter (TOPSOIL)																						
63.6	Brown Moist		1	SS	12																		
0.2	(CI/GP) Interlayered silty clay and sandy gravel (FILL)																						
	Grey-brown Moist		2	SS	9																		
63																							
62.3	(CI) Sandy silty clay, trace organic matter (FILL)																						
1.5	Very stiff Moist		3	SS	4																		
61.7	(CL/ML) Interlayered SILTY CLAY and CLAYEY SILT, contains silt seams																						
2.1	Very stiff Grey Wet		4	SS	6																		
61																							
60.2	(ML) sandy CLAYEY SIL very stiff to hard																						
3.7	Grey-brown Wet		5	SS	4																		
60																							
60.2			6	SS	19																		
60																							
59			7	SS	26																		
59																							
58			8	SS	18																		
58																							
57			9	SS	89/0.5																		
57																							
57			10	SS	58/0.15																		
57																							
56.1	END OF BOREHOLE AUGER REFUSAL		11	SS	58/0.15																		
7.7	NOTES: 1. Water level in open borehole at 2.4 m (Elev. 61.4 m), measured during drilling.																						

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

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1502	SHEET 1 OF 3	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029328.4; E 375814.4 NAD 83 MTM ZONE 9 (LAT. 45.400300; LONG. -75.592911)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>October 2-3, 2018</u>	CHECKED BY <u>KM</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)				
							20	40	60	80	100						GR	SA	SI	CL		
62.3	GROUND SURFACE																					
0.0	(SM) Silty sand, contains organic matter (rootlets) (TOPSOIL)																					
61.9	Very loose Dark brown Moist		1	SS	1		62															
0.4	(SM) Silty clayey sand, trace gravel, contains organic matter (rootlets) (FILL)																					
61.1	Very loose Grey-brown Wet		2	SS	1		61											4	49	27	20	
1.2	(CL/ML) Interlayered SILTY CLAY to CLAYEY SILT, some sand, contains silt seams																					
60.0	Very stiff to stiff Grey Moist		3	SS	4		60											0	3	61	36	
2.3	(GM/SM) Sandy GRAVEL to Silty SAND, contains cobbles and shale fragments (TILL)																					
	Compact to very dense Grey Wet		4	SS	21		59															
			5	SS	18		58															
			6	SS	12		57															
			7	SS	100/0.10		56															
			8	SS	50		55															
			9	SS	50/0.03		54															
55.5	Shale (BEDROCK)						53															
6.8	Bedrock cored from depths 6.8 m to 10.3 m		1	RC	REC 85%		55														RQD = 47%	
	For bedrock coring details refer to Record of Drillhole 18-1502		2	RC	REC 100%		54															RQD = 100%
			3	RC	REC 100%		53															RQD = 97%

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

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1502	SHEET 2 OF 3	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029328.4; E 375814.4 NAD 83 MTM ZONE 9 (LAT. 45.400300; LONG. -75.592911)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>October 2-3, 2018</u>	CHECKED BY <u>KM</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L
52.0	--- CONTINUED FROM PREVIOUS PAGE ---	[Hatched Box]	3	RC	REC 100%												
10.3	END OF BOREHOLE NOTES: 1. Water level in open borehole at 3.1 m (Elev. 59.2 m), measured during drilling.																

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+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1503	SHEET 1 OF 3	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029348.9; E 375844.2 NAD 83 MTM ZONE 9 (LAT. 45.400482; LONG. -75.592526)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>September 23-24, 2018</u>	CHECKED BY <u>KM</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
65.4	GROUND SURFACE													
0.0	(SW/GW) Sand and gravel (FILL) Brown Moist													
64.9														
0.6	(SP) Sand, some gravel, contains cobbles and boulders (FILL) Very dense Brown													
64.4			1	SS	85									
1.1	(SP) Gravelly sand, contains cobbles (FILL) Compact Brown Moist		2	SS	21									
63.1														
2.3	(CI/CH) SILTY CLAY to CLAY, contains sand seams Very stiff Grey-brown (WEATHERED CRUST) Moist		3	SS	9									
			4	SS	7									
61.4														
4.0	(CL/ML) Interbedded SILTY CLAY and CLAYEY SILT, contains silt and sand layers Very stiff to stiff Grey Moist		5	SS	6								0	9 69 22
61.0														
4.4	(SM) Silty SAND, some gravel, trace clay, contains cobbles (TILL) Very compact to dense Grey Moist		6	SS	50									
			7	SS	22									
57.7														
7.8	Shale (BEDROCK), with limestone interbeds (CARLSBAD FORMATION) Bedrock cored from depths of 7.8 m to 10.8 m For bedrock coring details refer to Record of Drillhole 18-1503		10	SS	50/0.13									
			1	RC	REC 67%									RQD = 26%
			2	RC	REC 91%									RQD = 50%
			3	RC	REC 100%									RQD = 93%

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

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1503	SHEET 2 OF 3	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029348.9; E 375844.2 NAD 83 MTM ZONE 9 (LAT. 45.400482; LONG. -75.592526)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>September 23-24, 2018</u>	CHECKED BY <u>KM</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80					
	--- CONTINUED FROM PREVIOUS PAGE ---															
54.7			3	RC	REC 100%											RQD = 93%
10.8	END OF BOREHOLE NOTES: 1. Water level in well screen at a depth of 2.7 m below ground surface (Elev. 62.7 m), measured on October 12, 2018.															

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

PROJECT 1662565-1150 **RECORD OF BOREHOLE No 18-1504** SHEET 1 OF 3 **METRIC**
G.W.P. 4145-10-00 **LOCATION** N 5029361.7; E 375859.8 NAD 83 MTM ZONE 9 (LAT. 45.400595; LONG. -75.592326) **ORIGINATED BY** DJG
DIST Eastern **HWY** 417 **BOREHOLE TYPE** Power Auger, 200 mm Diam. (Hollow Stem) **COMPILED BY** ZS
DATUM Geodetic **DATE** September 26, 2018 **CHECKED BY** KM


SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)						
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL	
62.0	GROUND SURFACE																						
0.0	(SM) Silty sand, contains organic matter (rootlets) (TOPSOIL) Brown																						
0.2	(CL) SILTY CLAY, contains silt seams Very stiff to stiff Grey-brown Wet		1	SS	4																		
61.4	(SP/SM/GP) Gravelly SAND to Silty SAND to sandy GRAVEL, contains cobbles, boulders and shale fragments (TILL) Compact to very dense Grey-brown Moist		2	SS	113																		42 43 13 2
0.6			3	SS	46																		
			4	SS	17																		19 46 30 4
			5	SS	20																		
			6	SS	50																		
			7	SS	58/0.15																		
			8	SS	93																		36 32 27 5
			9	SS	56/0.15																		
			10	SS	54/0.03																		
55.0	Shale (BEDROCK)																						
7.0	Bedrock cored from depths 7.0 m to 10.5 m For bedrock coring details refer to Record of Drillhole 18-1504		1	RC	REC 100%																		RQD = 100%
			2	RC	REC 100%																		RQD = 100%
			3	RC	REC 100%																		RQD = 100%

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 28/3/19 ZS

Continued Next Page

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

PROJECT <u>1662565-1150</u>	RECORD OF BOREHOLE No 18-1504	SHEET 2 OF 3	METRIC
G.W.P. <u>4145-10-00</u>	LOCATION <u>N 5029361.7; E 375859.8 NAD 83 MTM ZONE 9 (LAT. 45.400595; LONG. -75.592326)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>September 26, 2018</u>	CHECKED BY <u>KM</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L	25
51.5 10.5	END OF BOREHOLE NOTES: 1. Water level in open borehole at 6.0 m (Elev. 56.0 m), measured during drilling.		3	RC	REC 100%													RQD = 100%

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 28/3/19 ZS

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

BH 18-1502 (Dry)
Cored Length of 6.77 to 10.32 metres
Core Box 1 and 2 of 2

6.77 m Top of Bedrock



10.32 m End of Borehole



Geotechnical Investigation
Un-Named Culvert North Of Walkley, Highway 417
Ottawa, Ontario

Project No.	1662565
Drawn:	KM
Date:	22/10/2018
Checked:	
Review:	

Figure A1

BH 18-1502 (Wet)
Cored Length of 6.77 to 10.32 metres
Core Box 1 and 2 of 2

6.77 m Top of Bedrock



10.32 m End of Borehole

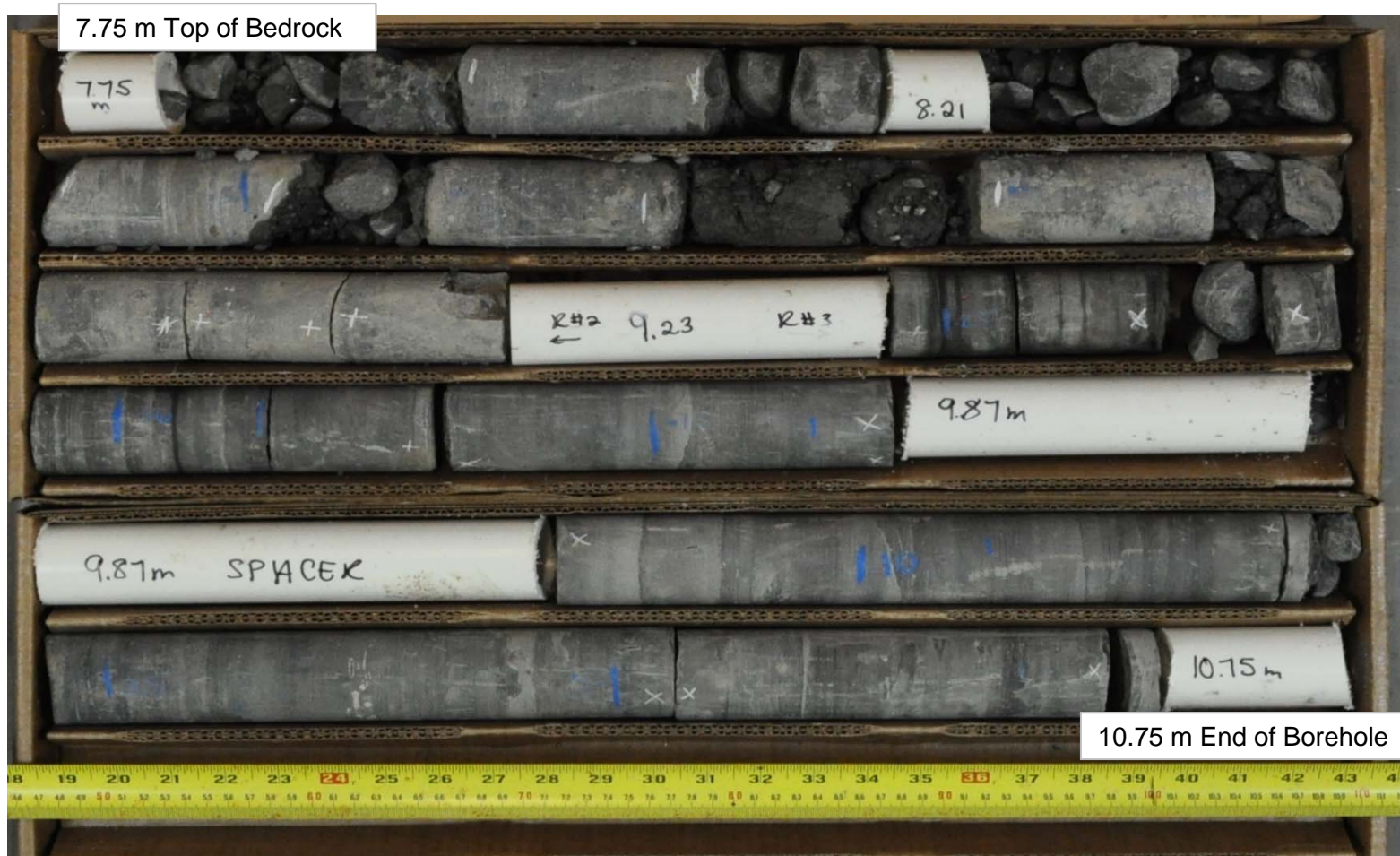


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Figure A2

BH 18-1503 (Dry)
Cored Length of 7.75 to 10.75 metres
Core Box 1 and 2 of 2



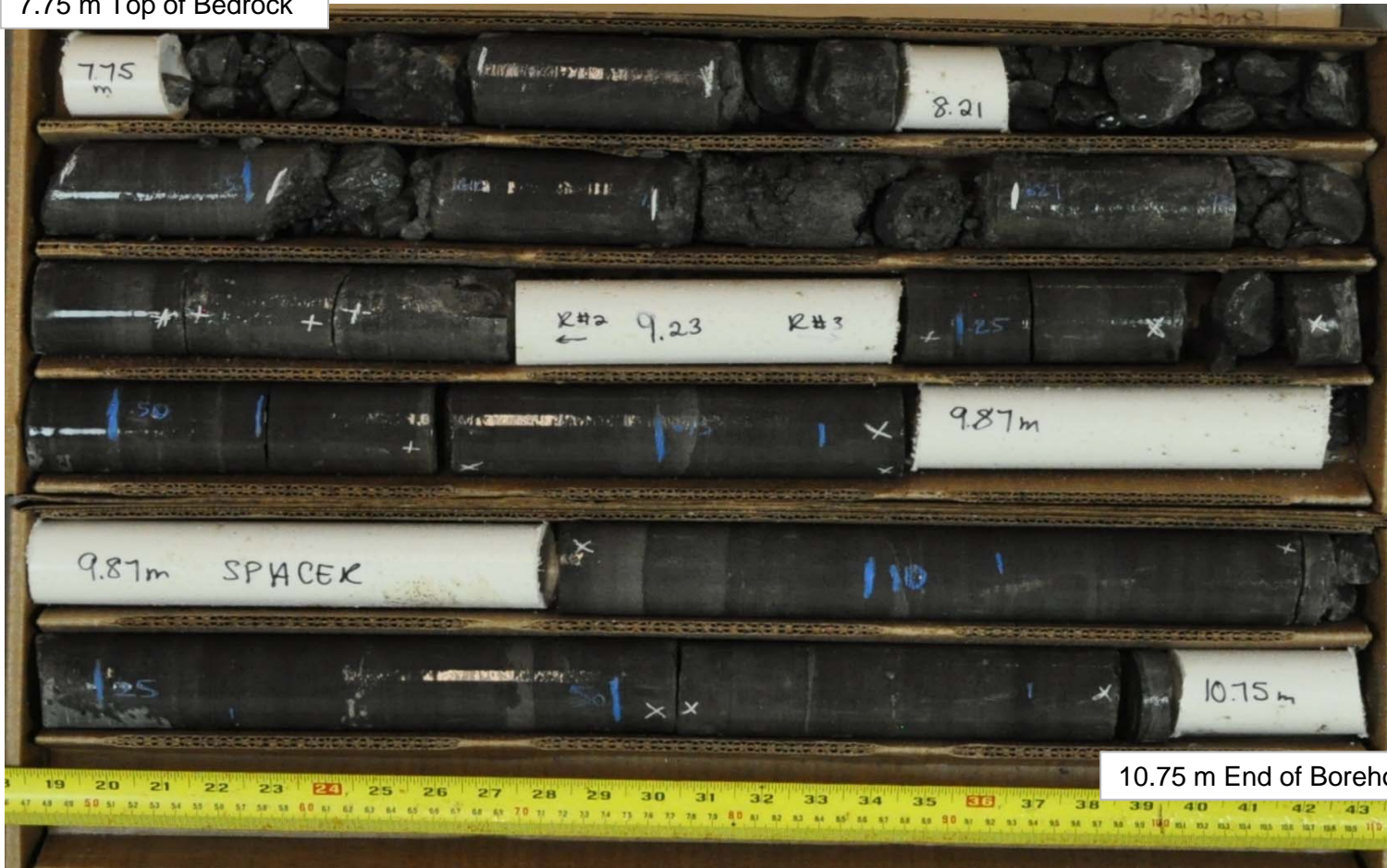
Geotechnical Investigation
Un-Named Culvert North Of Walkley, Highway 417
Ottawa, Ontario

Project No.	1662565
Drawn:	KM
Date:	22/10/2018
Checked:	
Review:	

Figure A3

BH 18-1503 (Wet)
Cored Length of 7.75 to 10.75 metres
Core Box 1 and 2 of 2

7.75 m Top of Bedrock



10.75 m End of Borehole

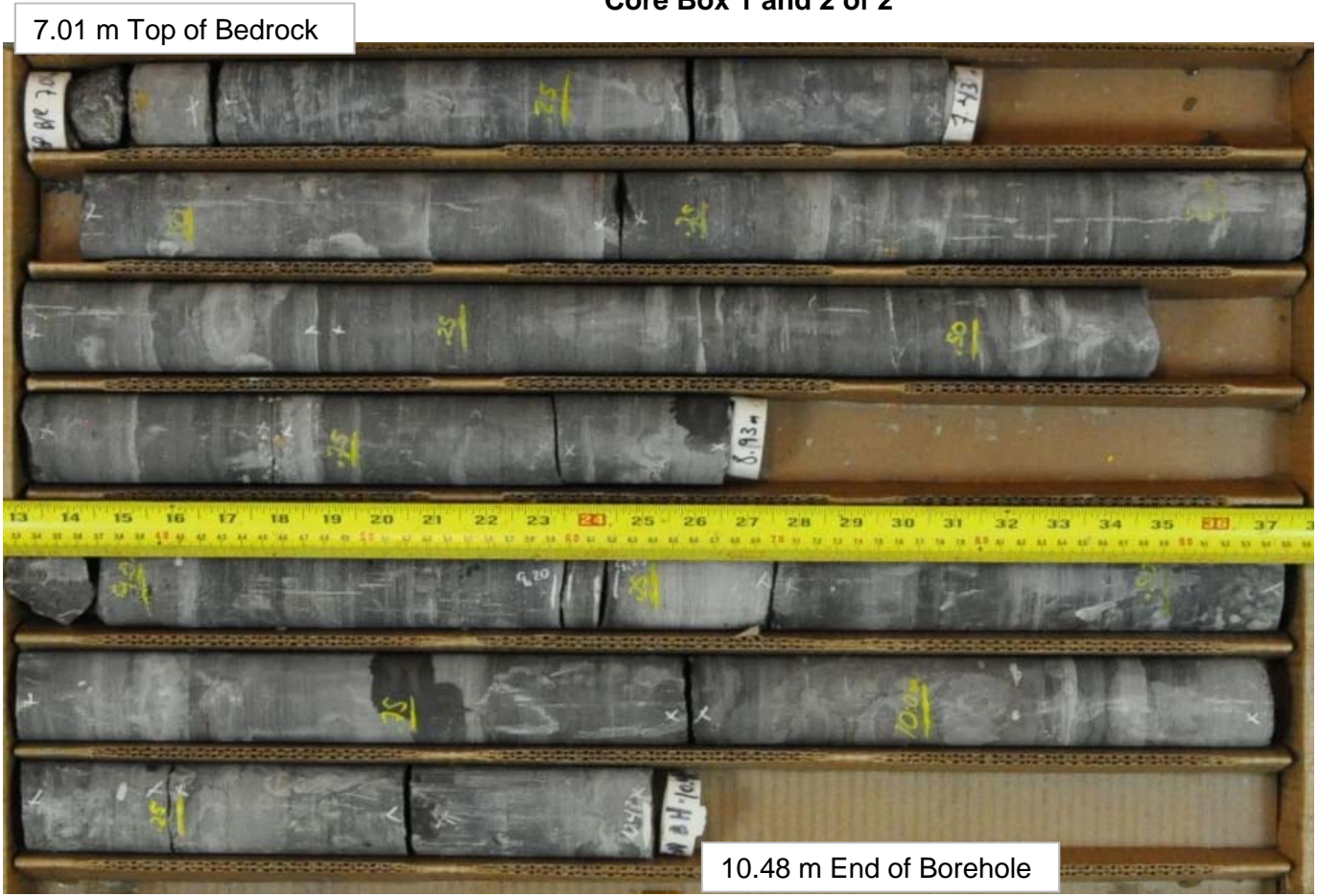


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Figure A4

BH 18-1504 (Dry)
Cored Length of 7.01 to 10.48 metres
Core Box 1 and 2 of 2



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Figure A5

BH 18-1504 (Wet)
Cored Length of 7.01 to 10.48 metres
Core Box 1 and 2 of 2

7.01 m Top of Bedrock



10.48 m End of Borehole



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Ottawa, Ontario

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Date:	22/10/2018
Checked:	
Review:	

Figure A6

APPENDIX B

Laboratory Test Results, Current Investigation

Figure B1 – Grain Size Distribution Test Results – FILL

Figure B2 – Plasticity Chart – Silty Clay (FILL)

Figure B3 – Plasticity Chart – Silty Clay to Clay (WEATHERED CRUST)

Figure B4 – Grain Size Distribution Test Results – Silty Clay to Clayey Silt

Figure B5 – Plasticity Chart – Silty Clay to Clayey Silt

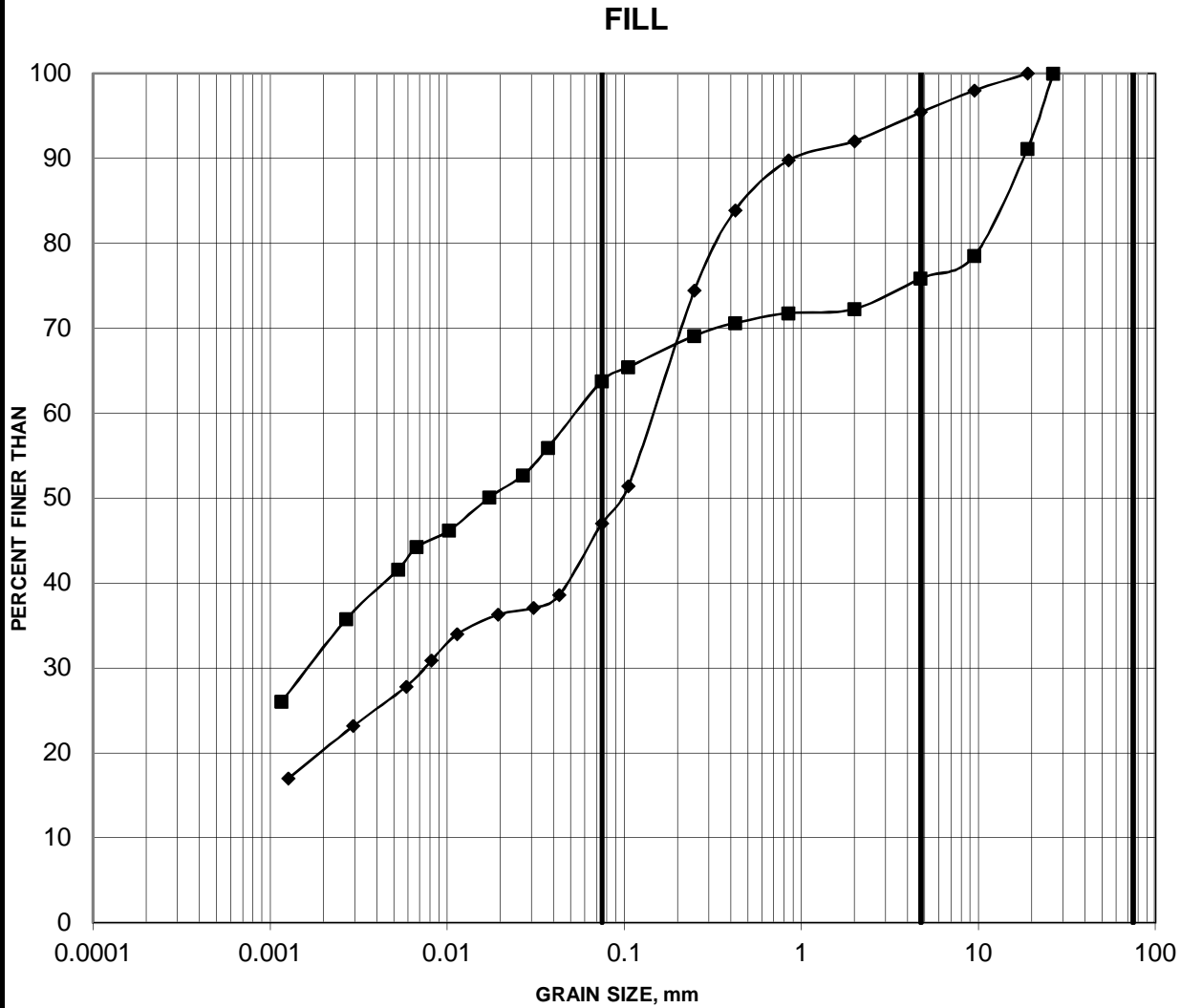
Figure B6 – Grain Size Distribution Test Results – Silty Sand (TILL)

Figure B7 – Plasticity Chart – Silty Sand (TILL)

Figure B8 – Summary of Laboratory Compressive Strength Testing – Unconfined Compression Tests

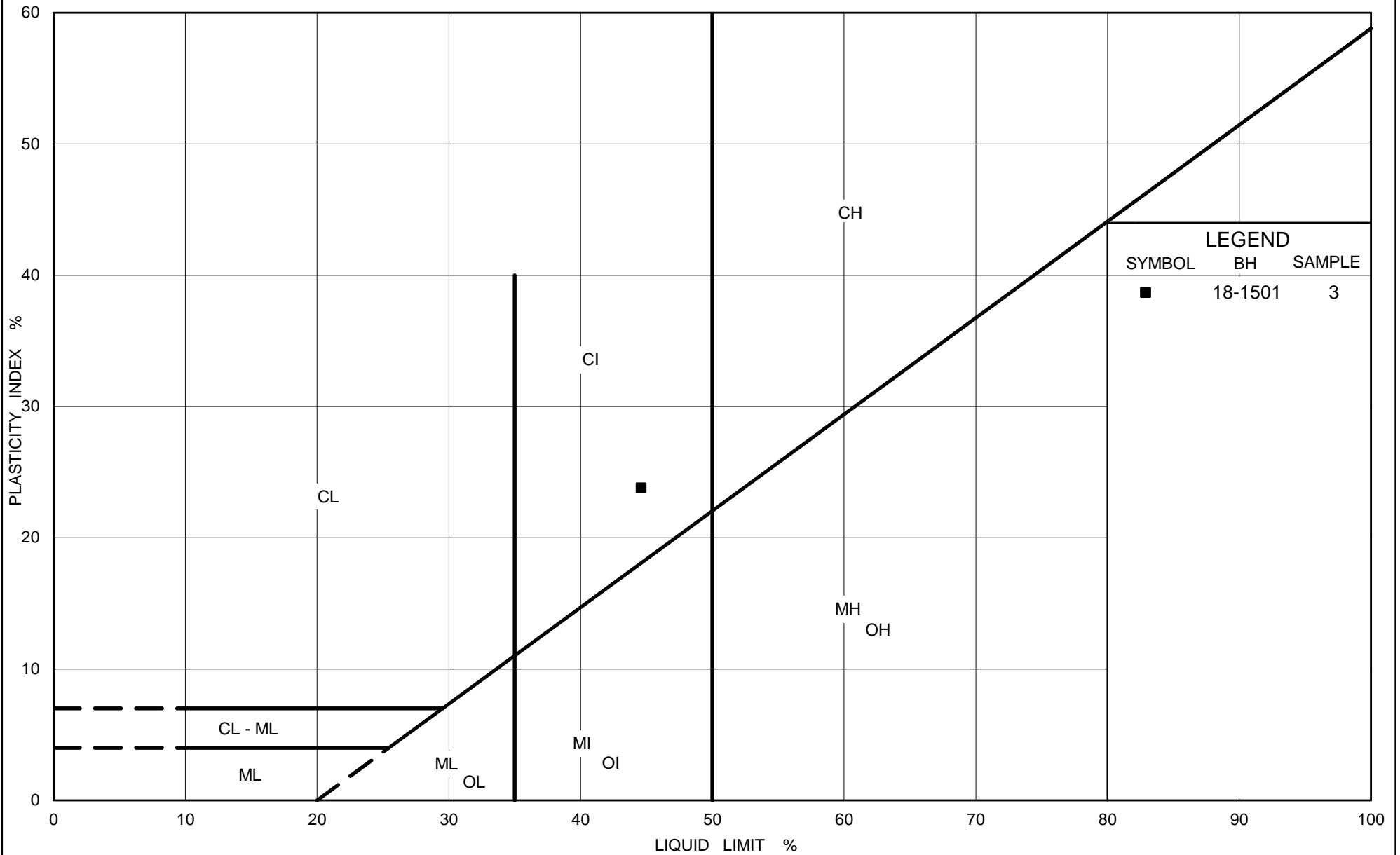
GRAIN SIZE DISTRIBUTION

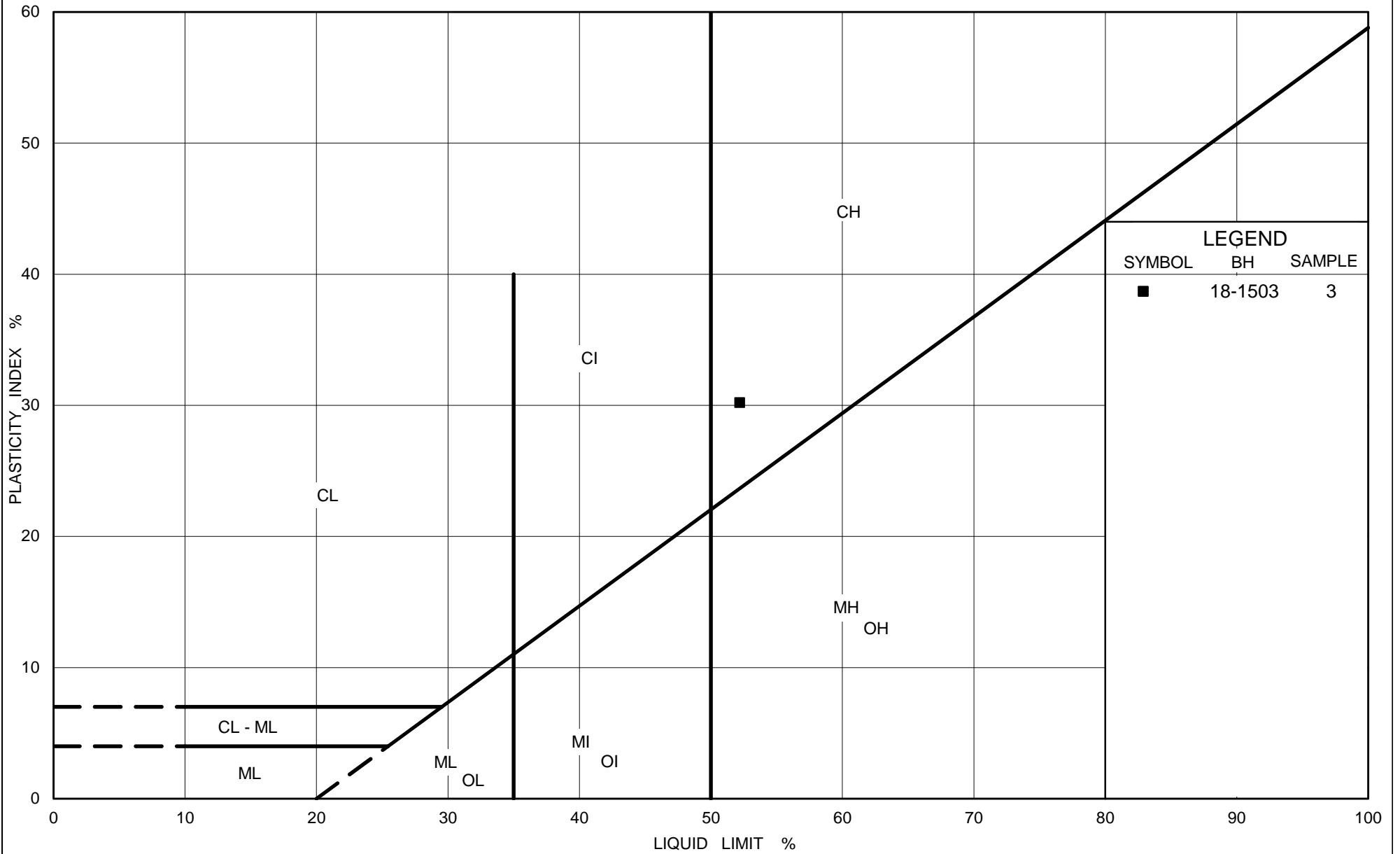
FIGURE B1



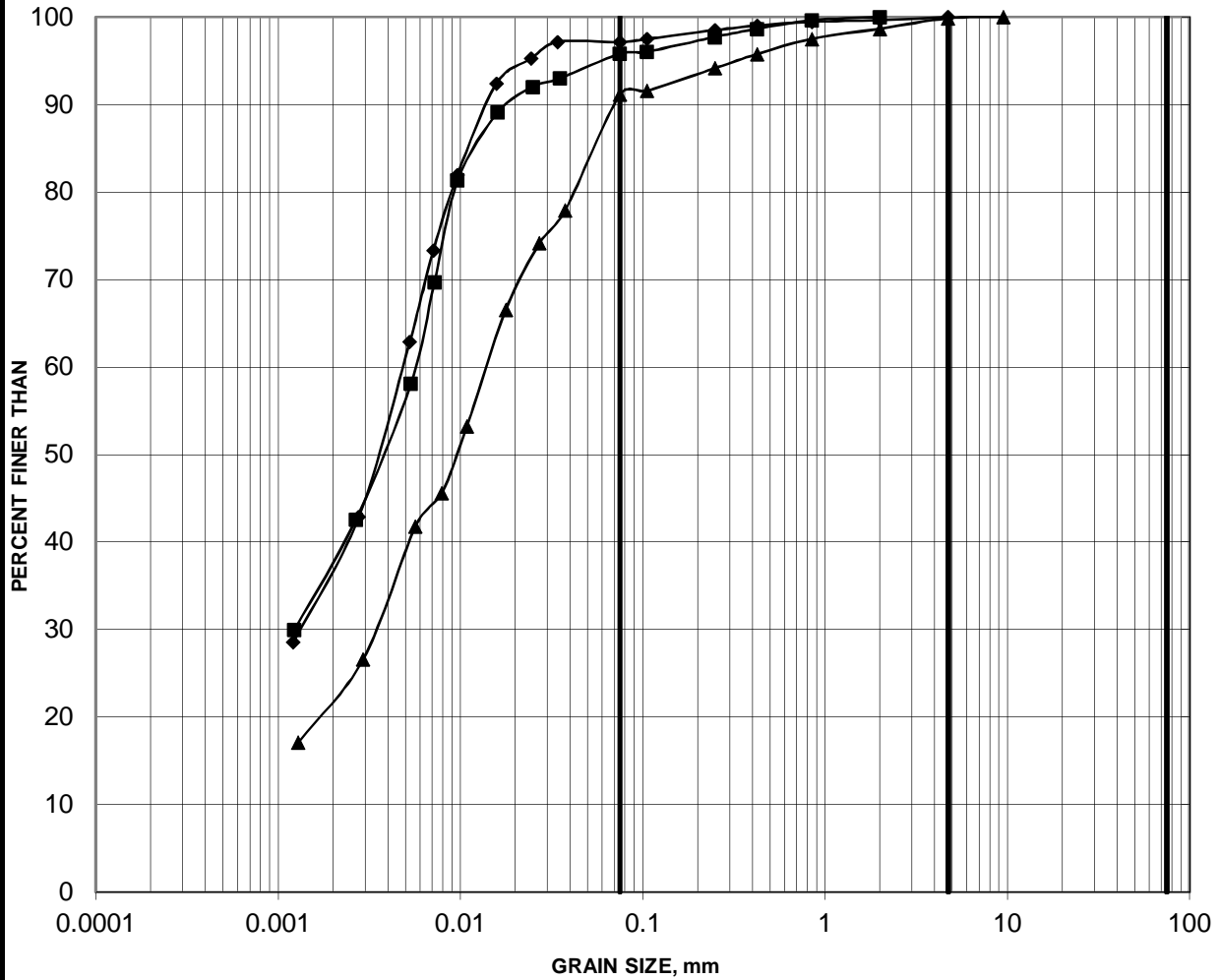
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
—■— 18-1501	1B	0.20-0.61
—◆— 18-1502	2A	0.76-1.22



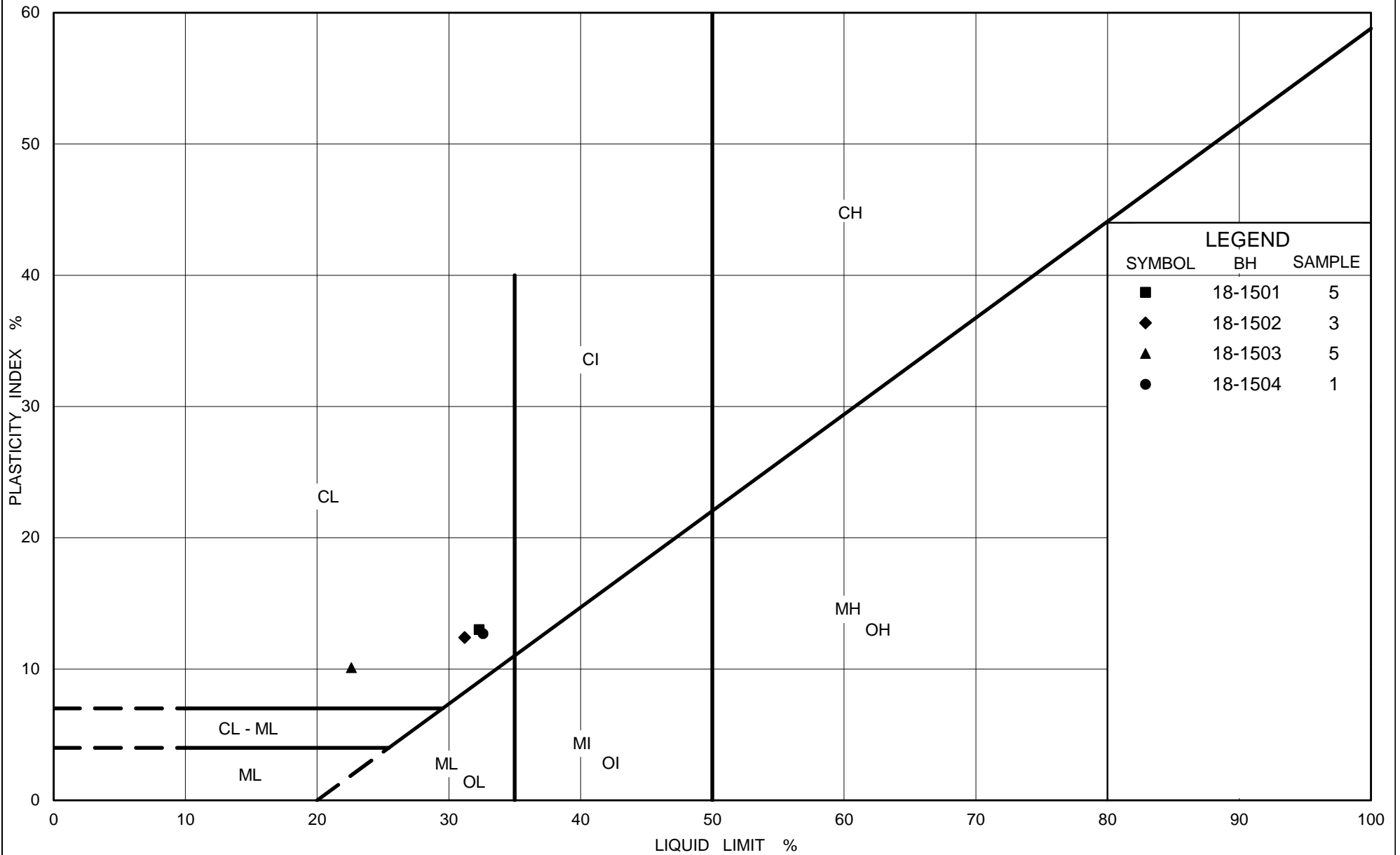


SILTY CLAY TO CLAYEY SILT



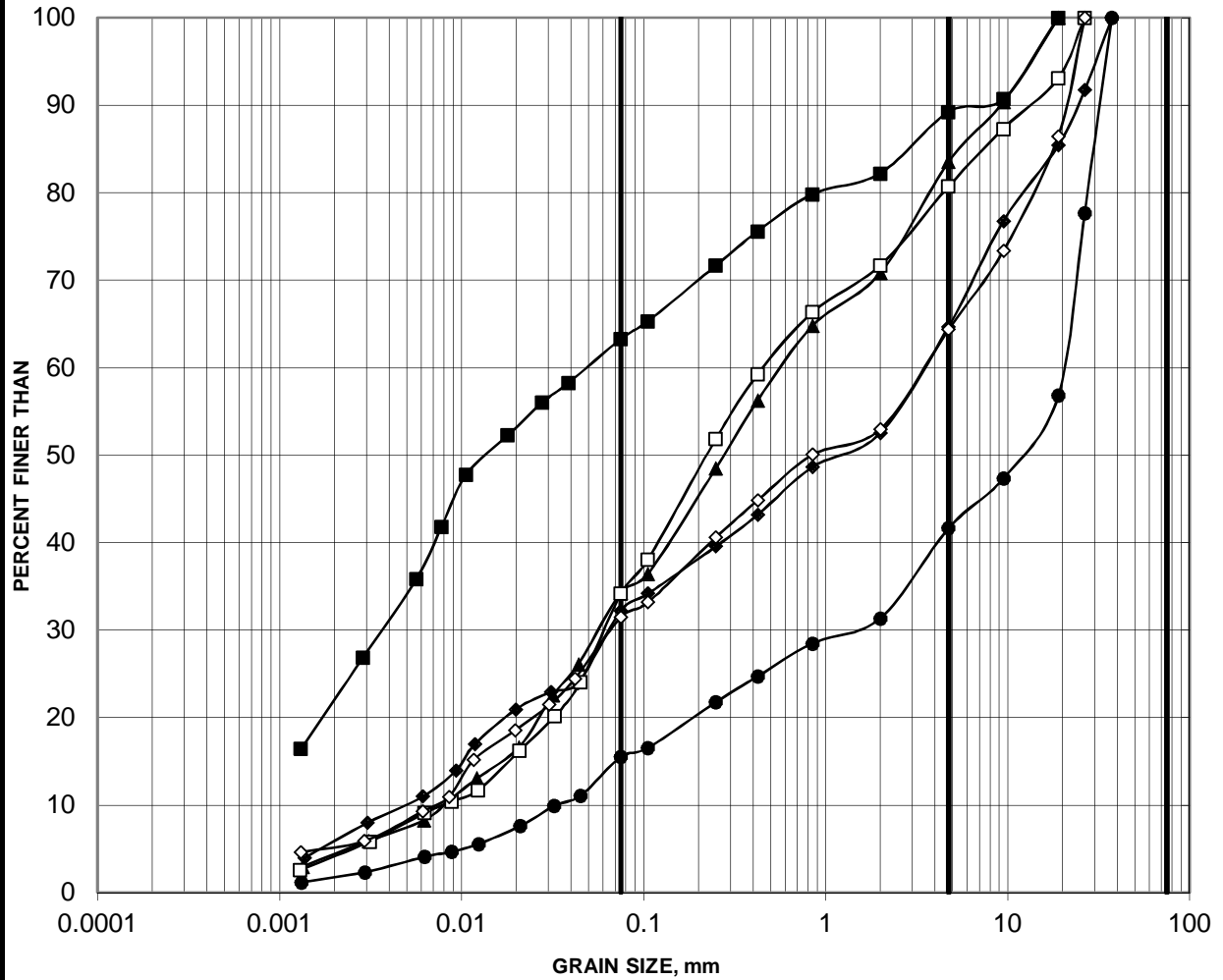
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
■ 18-1501	5	3.05-3.66
◆ 18-1502	3	1.52-2.13
▲ 18-1503	5	3.81-4.42



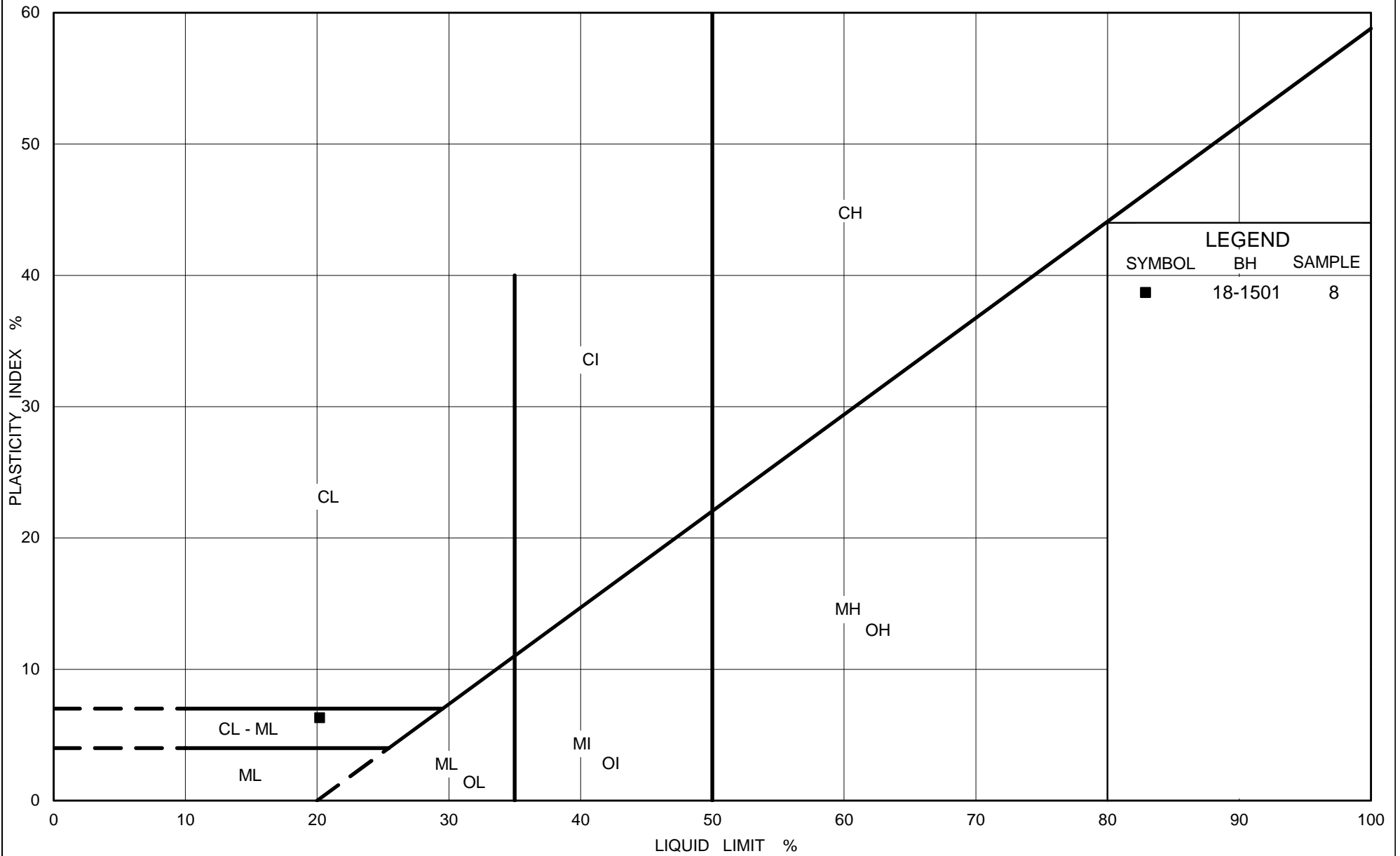
LEGEND		
SYMBOL	BH	SAMPLE
■	18-1501	5
◆	18-1502	3
▲	18-1503	5
●	18-1504	1

SILTY SAND TO GRAVELLY SAND (TILL)



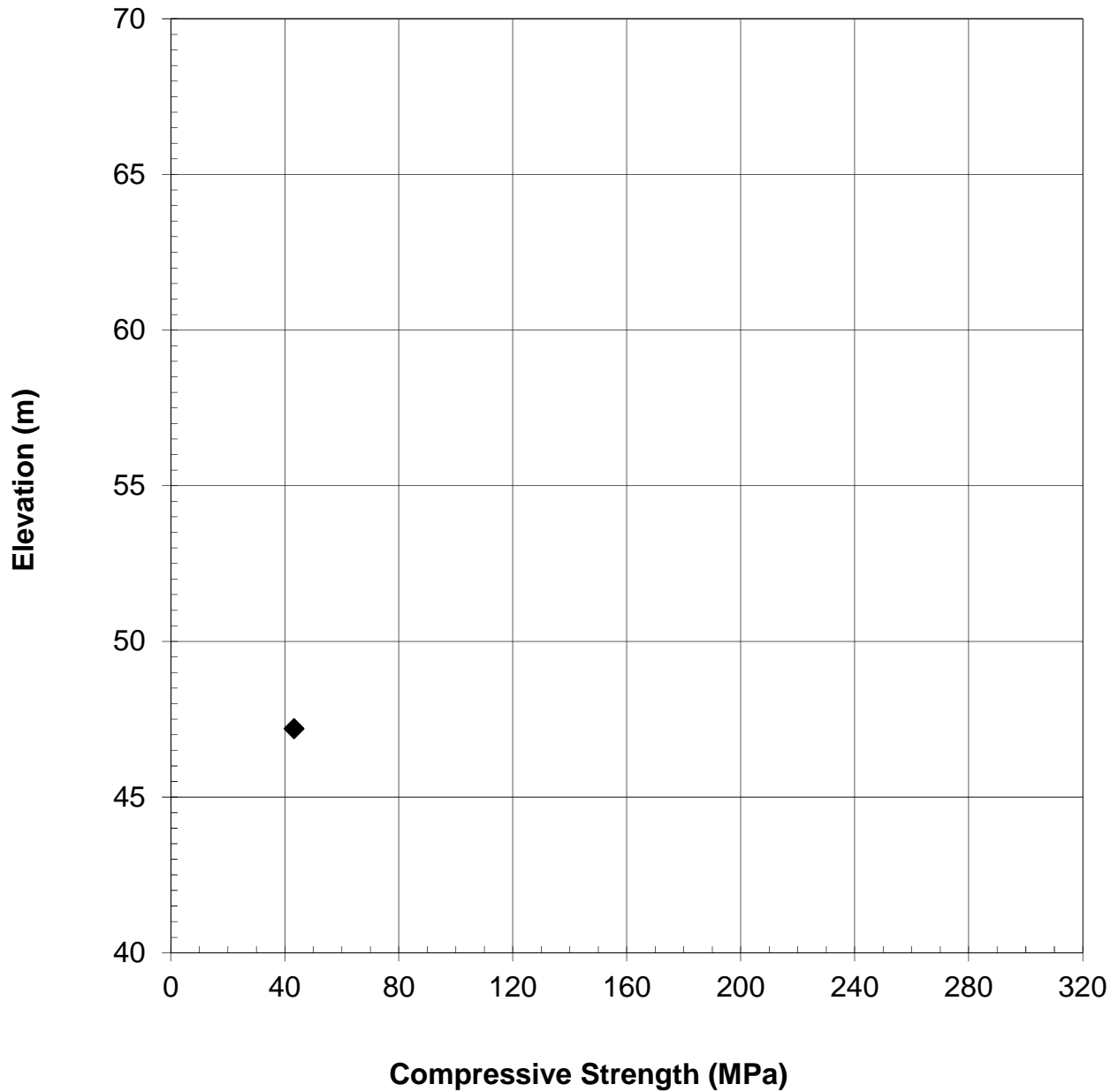
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
■	18-1501	8
◆	18-1502	6
▲	18-1503	9
●	18-1504	2
□	18-1504	4
◇	18-1504	8



**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH
UNCONFINED COMPRESSION TESTS**

FIGURE B8



◆ 18-1504

APPENDIX C

Basic Chemical Analysis – Eurofins Report Number 1818602

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
 1931 Robertson Road
 Ottawa, ON
 K2H 5B7
 Attention: Mr. Gabrielle Marcotte
 PO#:
 Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1818602
 Date Submitted: 2018-10-11
 Date Reported: 2018-10-23
 Project: 1662565 Phase 1150
 COC #: 836515

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1392818 Soil 2018-09-24 18-1501 sa3	1392819 Soil 2018-09-23 18-1503 sa3
Anions	Cl	0.002	%			0.035	0.053
General Chemistry	Electrical Conductivity	0.05	mS/cm			1.09	1.28
	pH	2.00				7.79	7.97
	Resistivity	1	ohm-cm			917	781
Subcontract	SO4	20	ug/g			420	130

Guideline =

* = Guideline Exceedence

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

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

APPENDIX D

Site Photograph (Provided by WSP)



Photograph 1: Unnamed Creek Culvert (WBL), North inlet, looking south (provided by WSP).

CLIENT
WSP CANADA GROUP LIMITED

PROJECT
UNNAMED CREEK CULVERT
HIGHWAY 417, OTTAWA, ONTARIO

CONSULTANT



YYYY-MM-DD	2019/03/19
PREPARED	KM
DESIGN	--
REVIEW	MSS
APPROVED	FJH

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.
1662565

Phase
1150

Rev.
1

Figure
D1

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI/A

APPENDIX E

Non-Standard Special Provisions (NSSPs)

Pipe Installation by Trenchless Methods

Obstructions

Earth Excavations for Structure with Obstructions

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0	SCOPE
2.0	REFERENCES
3.0	DEFINITIONS
4.0	DESIGN AND SUBMISSION REQUIREMENTS
5.0	MATERIALS
6.0	EQUIPMENT
7.0	CONSTRUCTION
8.0	QUALITY ASSURANCE- Not Used
9.0	MEASUREMENT FOR PAYMENT
10.0	BASIS OF PAYMENT
1.0	SCOPE

This specification covers the requirements for the installation of pipe by a selected trenchless method.

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

CSA Standards

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

American Society for Testing and Materials (ASTM) International Standards

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

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

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

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

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

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

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

Trenchless Installation means an underground method of constructing a passage open at both ends that

involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

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

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

DESIGNER FILL IN* - Any method that is not suitable shall be specified.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

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

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

DESIGNER FILL IN** – Specify minimum requirements commensurate with complexity.

4.02.01.02 Trenchless Contractor

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

DESIGNER FILL IN *** – Specify minimum requirements commensurate with complexity.

4.02.01.03 Design Engineer

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

DESIGNER FILL IN **** – Specify minimum requirements commensurate with complexity.

4.02.01.04 Design Checking Engineer

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

DESIGNER FILL IN ***** – Specify minimum requirements commensurate with complexity.

4.02.02 Working Drawings

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

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

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

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

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

- a) Plans and Details:
 - i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
 - ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
 - iii. A list of personnel, including backup personnel, and their qualifications and experience.
 - iv. A safety plan including the company safety manual and emergency procedures.
 - v. The work area layout.
 - vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.

- vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
- ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

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

c) Materials:

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

- type, source, and physical and chemical properties of bentonite, polymer or other additives;
- source of water;
- method of mixing;
- the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

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

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

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

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

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

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

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

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

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

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 HDPE Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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 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 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 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. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face

- pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
- ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
 - vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
 - viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

7. CONSTRUCTION

7.01 General

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

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 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 should be anticipated in 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 shall be expected to be routine and will not be considered cause for obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

DESIGNER FILL IN – Subsurface Condition Baseline Reporting

7.01.14 Management of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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 water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavated volume (e.g.,

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the 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 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 water tight, 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, 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

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 work 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

7.04.06.0 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 insure 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 OSHA requirements for the entire length of the tunnel installed as tunneling progresses.

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

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

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

and revise as necessary to ensure the safe continuation of the work.

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.

- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

DESIGNER FILL IN - The Instrumentation and Monitoring program shall be project specific.

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

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

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

7.07.02 In-Ground Monitoring Points

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

7.07.03 Installation, Replacement and Abandonment

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

7.07.03 Monitoring and Reporting Frequency

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

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

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

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

7.07.03 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

DESIGNER FILL IN – Review and Alert Levels

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

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The

Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
- i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan.
 - iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

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

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

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

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

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

Notes to Designer

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

Designer Fill Ins

Design and Submission Requirements

*4.01 Design Requirements

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

4.02 Qualifications

**4.02.01.01 Project Superintendent

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

***4.02.01.02 Tunnelling/Trenchless Contractor

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

****4.02.01.03 Design Engineer

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

*****4.02.01.04 Design Checking Engineer

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

*****7.01.11 Removal of Cobbles and Boulders

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

*****7.07 Instrumentation and Monitoring

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

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

Criteria selection shall be project specific as recommended in the FIDR

WARRANT: Always with this specification

OBSTRUCTIONS – Item No.

Special Provision

The fill soils at this site are comprised of gravelly sand or sand and are known to contain cobbles and boulders. Appropriate equipment and construction procedures will be required to penetrate or remove obstructions, such as cobbles and boulders, to permit installation of trenchless and of temporary protection 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.

END OF SECTION

EARTH EXCAVATION FOR STRUCTURE – Item No.

Special Provision

Amendment to OPSS 902, November 2010

Excavating Through Obstructions – Structures

902.07 CONSTRUCTION

Section 902.07 of OPSS 902 shall be amended by the addition of the following:

The Contactor is alerted to the potential presence of cobbles and boulders within the fill. Consideration of the presence of these obstructions shall be made in the selection of appropriate equipment and procedures for excavations and temporary protection 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.

END OF SECTION



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