# FINAL REPORT

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**Non-Structural Culvert Replacement, At Sta. 24+527 on Highway 26, East of Meaford, Grey County, ON**

**Agreement No. 3015-E-0017**
**Assignment No. 4**
**GWP 57-00-00**
**Geocres No. 41A-243**

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May 10, 2017

# Ministry of Transportation

## Western Region – Geotechnical Section

**Foundation Investigation and Design Report**
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At STA. 24+527 on Highway 26, East of Meaford, Grey County, ON

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# PART I: FOUNDATION INVESTIGATION REPORT

## 1.1 Introduction

This foundation investigation report presents the results of a geotechnical investigation completed by **exp** Services Inc. (**exp**) for the replacement of an existing non-structural culvert at STA 24+527 on Highway 26, just east of Meaford, Grey County part of the Ministry of Transportation (MTO) West Region. The work was undertaken under Agreement No. 3015-E-0017, Assignment No. 4. The terms of reference (TOR) were as presented in the MTO document entitled “Foundation Engineering Terms of Reference, MTO West Region – Foundations Retainer Assignment, Assignment 4 – Culvert Replacement on Hwy 26” provided via e-mail on January 31, 2017.

The purpose of the investigation is to determine the subsurface conditions along the culvert alignment and to permit detailed design for the culvert replacement including temporary protection systems for culvert replacement. The site specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing.

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

## 1.2 Site Description and Geological Setting

### 1.2.1 Site Description

At the culvert replacement site location, Highway 26 is a two-lane asphalt roadway and is about 7.4 m wide from edge to edge of road lane marks, with approximately 2.7 m wide partially asphalt and partially sand and gravel shoulders on both sides. Based on the observations, the roadway embankment is about 2 m high with side slope of about 3H:1V.

Based on the information provided in the TOR, the existing culvert is a 1.52 m × 0.915 m × 27.0 m concrete non-rigid framed open footing structure. The existing culvert is intended to be replaced with a new 2.4 m x 1.5 m x 27.0 m box culvert along the same alignment. It is also understood that fill from the top of roadway centerline to top of culvert will be 0.3 m thick and about 0.3% slope descending northward. Select photographs of the site and existing culvert are presented in Appendix A. The site plan and cross-section profiles for the proposed culvert alignment are shown on the drawing attached in Appendix B.

The area surrounding the culvert site is generally flat land with farm land on the south side and trees and shrubs covered towards the Georgian trail on the north side. Highway 26 runs in an east-west direction and the water in culvert flows from south to north beneath the highway. At the culvert location, ditches run along the toes of embankment at both inlet and outlet sides. At the time of investigation, the culvert and the vicinity were dry. No obstruction or vegetation were observed along the flow area. However, some sediment deposited inside the culvert was observed, which suggest possible ponding of surface water at outlet side during surface water run off. At the time of this investigation, the bottom of culvert at inlet and outlet were measured at approximate Elevations 224.4 m and 224.5 m, respectively. The elevation of highway at the culvert centerline is approximately Elev. 226.5 m.

At the time of investigation, it is observed that the embankment was in an overall stable configuration with no obvious indications of recent slope movement. However, at the outlet side of culvert, a cut marks and recent backfill was observed (see Photo 8, in Appendix A), that appears to have been temporarily repaired. At the outlet side, wearing and crumbling of concrete of the culvert with exposed rebars were observed. Since, the bottom of culvert was covered with sediment and no foundation was exposed, the condition of existing culvert foundations could not be assessed at the time of investigation. However, the culvert appeared to be in satisfactory condition with no significant damage.

### 1.2.2 Geological Setting

The Map P.2715 (Physiography of Southern Ontario, Third Edition,1984) of the Ministry of Natural Resources indicates that the project area is in a sand plan with beaches and shorecliffs. The Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the surface conditions consist of glaciolacustrine deposits of sand, gravelly sand and gravel nearshore and beach deposits to undifferentiated carbonate and clastic sedimentary rock, exposed at surface or covered by a discontinuous, thin layer of drift. The Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the bedrock formation in the project area consists of queenston formation of shale, limestone, dolostone, siltstone.

## 1.3 Investigation Procedures

### 1.3.1 Site Investigation and Field Testing

The field investigation was performed between March 20, 2017 and March 21, 2017. The field program consisted of drilling four (4) sampled boreholes, numbered BH-1 to BH-4. Since, existing subsurface information at the south end (inlet) of the culvert was available in Geocres (Geocres No. 41A-207, provided by MTO) that includes two boreholes 04A-1 and 04A-2 to a depth of about 4 m and 5 m, respectively, no new boreholes were drilled on the south end of the culvert. Therefore, two (2) boreholes, i.e. BH-1 and BH-2, were strategically located along the rest of the existing culvert alignment to provide subsurface information for the design of the proposed new culvert. In particular, BH-1 was advanced at accessible location near the outlet and BH-2 was advanced within the travelled eastbound lane located about 3.5 m east of the culvert centerline. Two (2) additional boreholes, i.e. BH-3 and BH-4, were strategically located on the embankment to provide subsurface information for the temporary roadway protection. Boreholes BH-3 and BH-4 were advanced in the eastbound and westbound travelled lanes approximately 21.5 m east and west side of the existing culvert, respectively. The borehole locations are shown on Drawing 1 in Appendix B.

All boreholes were advanced using a rubber track mounted CME 55 drill rig equipped with hollow stem augers and standard soil sampling equipment, operated by a specialist drilling contractor, Terrex Drilling Solutions. The off-road borehole BH-1 was advanced to a depth about 12.8 m. The roadway boreholes BH-2 and BH-4 were advanced to depths about 15.4 m and 17.4 m, respectively. BH-4 was advanced 2.4 m below the desired depth of 15 m to investigate ground condition below the obstruction (possible cobbles and boulders) that encountered in BH-2 at 15.4 m below road surface. However, the roadway borehole BH-3, was terminated prematurely at a depth about 12.0 m due to auger teeth breakdown and experiencing difficulty in advancing auger through dense sand and gravel layer.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by **exp** personnel using a temporary benchmark (TBM) set on of top of culvert (southwest corner) at inlet side. The elevation of temporary benchmark (TBM) was assumed 225.7 m based on the CAD drawing provided by MTO. The TBM location is shown on Drawing 1 in Appendix B.

For the drilling program, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ relative density of non-cohesive soils.

Upon completion of the boreholes, ground water level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded ground water levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix C. The boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the *Ontario Water Resources Act)*.

The fieldwork was supervised by an **exp** geotechnical representative who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification.

All recovered soil samples were placed in labelled moisture-proof bags and returned to **exp**'s Brampton laboratory for additional visual, textual, olfactory examination and selective testing.

### 1.3.2 Previous Investigation

The following previous/historical investigation report was provided by client

- Foundation Investigation Report for Proposed Reconstruction of Seventeen (17) Non-Structural Culverts on Township of St. Vincent and Collingwood, Hwy 26 from Meaford to Thornbury; G.W.P. 57-00-00; Agreement # 3006-E-0002; Geocres No. 41A-207; Infrastructure Engineering Group Inc.; April 17, 2009.

Two borehole logs produced based on the investigation conducted by Infrastructure Engineering Group Inc (I.E. Group) in April 2009 at location of this culvert (identified as 04A) are attached in Appendix I of this report. The details of the borehole locations and elevations completed by I.E. Group at the site location are outlined in Table 1.1. The location details of each borehole should be considered an estimate only.

*Table 1.1. Summary of boreholes completed by I.E. Group*

| BH No. | Borehole Locations (Station and Offset from the centreline)[1] | Ground Elevation (m) | Borehole Depth (m) | Borehole Bottom Elevation (m) | Piezometer/ Monitoring Well |
|---|---|---|---|---|---|
| 04A-1 | 2.5 m west of culvert centreline and 5.1 m south of Hwy centreline | 225.68 | 3.96 | 221.72 | None |
| 04A-2 | 2.4 m west of culvert centreline and 6.6 m south of culvert south end (inlet) | 226.4 | 5.03 | 221.37 | None |

*Note: [1] Station and offset measurements are approximate.*

### 1.3.3 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content of all samples and particle size distribution for approximately 25% of the collected soil samples. Atterberg limits tests were carried out on select cohesive soil samples. One corrosivity test was also performed for a selected sample. All of the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate.

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

The corrosivity test was performed by Maxxam Analytics Inc., a CALA-certified and accredited laboratory in Mississauga, Ontario. Details of the chemical testing are discussed below and the lab results are presented in Appendix E.

## 1.4 Subsurface Conditions

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

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

The general stratigraphy encountered within the investigated depths of I.E. Group and current investigations are inline and indicates the following subsurface sequence: an embankment fill consisting of sand and gravel to clayey sandy silt overlying native clayey silt with sand followed by gravelly sand to sand and gravel, underlain by sandy silt followed by clayey silt till.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by I.E. Group and **exp**.

### 1.4.1 Asphalt

Asphalt was encountered at the surface of boreholes advanced on the highway, i.e. BH-2 to BH-4, and thickness of about 0.152 m. Asphalt thicknesses may further vary beyond the borehole locations.

### 1.4.2 Topsoil

Topsoil was encountered at the surface of BH-1 (outlet) and BH 04A-1 (inlet), and ranged in thickness from approximately 0.15 m to 1 m. Topsoil thicknesses may further vary beyond the borehole locations.

### 1.4.3 Fill: Sand and Gravel

Sand and gravel fill was encountered below the asphalt in all boreholes (BH-2, BH-3, BH-4 and BH 04A-2) advanced through the road surface. The sand and gravel fill extended to depths ranging between 0.8 m to 1.5 m below ground surface with elevations ranging between 225.8 m to 225.0 m. The explored thickness of this layer was between 0.6 m to 1.3 m.

The composition of this fill layer is sand and gravel, trace to few silt, trace clay, and trace asphalt inclusions. The material is brown in color, and dry to moist. The SPT "N" values within this layer ranged from 43 to 78 blows per 0.3 m penetration, suggesting dense to very dense relative density.

Laboratory testing performed on selected samples consisted of four (4) moisture content and two (2) grain size distribution tests. The test results are as follows:

Moisture Content: (Performed by **exp**)

- 3.2% to 7.7%

Grain Size Distribution: (Performed by **exp**)

- 32% to 41% gravel;
- 45% to 51% sand; and
- 14% to 17% silt and clay

The results of the moisture content and gain size distribution tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test performed by **exp** are also provided on Figure 1 in Appendix D.

### 1.4.4 Fill: Clayey Sandy Silt to Clayey Silty Sand

Clayey sandy silty to clayey silty sand fill was encountered below the sand and gravel fill in all boreholes advanced through the road surface (BH-2, BH-3, BH-4 and BH 04A-2). The clayey sandy silt to clayey silty sand fill extended to depths ranging between 1.5 m to 2.9 m below ground surface with elevations ranging between 225.1 m to 223.5 m. The explored thickness of this layer was between 0.7 m and 2.15 m.

The composition of this fill layer is sand and silt, some clay and trace to some gravel. The material is brown in color, and moist. The SPT "N" values within this layer ranged from 4 to 32 blows per 0.3 m penetration, suggesting very loose to dense relative density. The results of the Atterberg Limits testing are shown on the plasticity chart on Fig No. C-04A.2 in Appendix I and indicate that the fill of low plasticity.

Laboratory testing performed on selected sample consisted of seven (7) moisture content test, two (2) grain size distribution tests and two (2) Atterberg Limit tests. The test results are as follow:

Moisture Content: (Performed by **exp** and I.E. Group)

- 13.2% to 30%

Grain Size Distribution: (Performed by I.E. Group)

- 15% to 20% gravel;
- 26% to 35% sand;
- 28% to 38% silt; and
- 17% to 21% clay

Atterberg limits (Performed by I.E. Group)

- Liquid Limit: 31% to 32%
- Plastic Limit: 20%
- Plasticity Index: 11% to 12%

The results of the moisture content and gain size distribution tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The results of tests done by I.E. Group are included in Appendix I.

### 1.4.5 Clayey Silt with Sand

Native clayey silt with sand was encountered below the clayey sandy silt to clayey silty sand fill in BH-2 and BH-3. The clayey silt with sand extended to depth of about 3.0 m below the ground surface with elevations ranging between 223.6 m to 223.5 m. The explored thickness of this layer was between 0.7 m and 1.5 m.

The composition of this native layer is silt, some clay, some sand, trace gravel and trace organics. The material is brown to brownish black in color, and moist. The SPT "N" values within this layer ranged from 5 to 11 blows per 0.3 m penetration, suggesting firm to stiff consistency.

Laboratory testing performed on selected sample consisted of three (3) moisture content test and one (1) grain size distribution tests. The test results are as follow:

Moisture Content: (Performed by **exp**)

- 20% to 29%

Grain Size Distribution: (Performed by **exp**)

- 6% gravel;
- 29% sand;
- 43% silt; and
- 22% clay

The results of the moisture content and gain size distribution performed by **exp** are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test performed by **exp** is also provided on Figure 2 in Appendix D.

### 1.4.6 Silty Sand to Sandy Silt

Native silty sand to sandy silt was encountered below the topsoil in off road boreholes (BH-1 and BH 04A-1). The silty sand to sandy silt extended to depths ranging between 2.3 m to 2.44 m below the ground surface with elevations ranging between 223.1 m to 223.24 m. The explored thickness of this layer was between 1.2 m to 2.25 m.

The composition of this layer is silt and sand, few to some clay and trace gravel. The material is brown in color, and moist. The SPT “N” values within this layer ranged from 9 to 15 blows per 0.3 m penetration, suggesting loose to compact relative density. One SPT “N” value of 100 plus blows per 0.3 m penetration was obtained in BH 04A-1. It could be influence of an underlying cobble.

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

Moisture Content: (Performed by **exp** and I.E. Group)

- 7.0% to 32.1%

The results of the moisture content tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The results of tests done by I.E. Group are included in Appendix I.

### 1.4.7 Gravelly Sand to Sand and Gravel

Native gravelly sand to sand and gravel was encountered below the silty sand to sandy silt layer in BH-1 and BH 04A-1, below native clayey silt with sand in BH-2 and BH-3 and below clayey sandy silt to clayey silty sand fill in BH-4 and BH 04A-2. The gravelly sand to sand and gravel extended to depths ranging between 3.96 m to 12 m below the ground surface with elevations ranging between 221.72 m to 214.6 m. The explored thickness of this layer was between 1.5 m to 9 m. Sand and gravel layer also encountered below the clayey silt till in BH-1. It extended to depth of 12.8 m below ground surface with elevation 212.6 m. The explored thickness of this layer was 0.6 m. Boreholes 04A-1, 04A-2, BH-1 and BH--3 were terminated within this layer.

The composition of this layer is sand and gravel, trace to some silt, and trace to few clay. The material is brown to brownish grey in color, and moist to wet. The SPT "N" values within this layer ranged from 9 blows per 0.3 m penetration to 100 blows per 0.125 m penetration, typically 30 to 74 blows per 0.3 m penetration, suggesting dense to very dense relative density.

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

Moisture Content: (Performed by **exp** and I.E. Group)

- 8.5% to 17.5%

Grain Size Distribution: (Performed by **exp** and I.E. Group)

- 24% to 41% gravel;
- 38% to 50% sand;
- 14% to 20% silt; and
- 6% to 8% clay
- or 12% to 27% fines

The results of the moisture content and gain size distribution tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test performed by **exp** is also provided on Figure 3 in Appendix D. The results of tests done by I.E. Group are included in Appendix I.

### 1.4.8 Sandy Silt

Native sandy silt was encountered below the gravelly sand and sand and gravel layer in BH-1, BH-2 and BH-4. The sandy silt layer extended to depths ranging between 10.7 m to 12.2 m below the ground surface with elevations ranging between 214.7 m to 214.4 m. The explored thickness of this layer was about 3.1 m.

The composition of this layer is sand and silt, few to some clay and trace to few gravel. The material is brown to grey in color, and moist to wet. The SPT "N" values within this layer ranged from 27 blows per 0.3 m penetration to 100 blows per 0.125 m penetration, suggesting compact to very dense relative density.

Laboratory testing performed on selected samples consisted of six (6) moisture content and three (3) grain size distribution tests. The test results are as follows:

Moisture Content: (Performed by **exp**)

- 10.3% to 16.8%

Grain Size Distribution: (Performed by **exp**)

- 1% to 7% gravel;
- 22% to 26% sand;
- 55% to 70% silt; and

- 6% to 16% clay

The results of the moisture content and gain size distribution tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test performed by **exp** is also provided on Figure 4 in Appendix D.

### 1.4.9 Till: Clayey Silt

Clayey silt till was encountered below the sandy silt layer in BH-1, BH-2 and BH-4. The clayey silt till extended to depths ranging between 12.2 m to 17.4 m below the ground surface with elevations ranging between 213.2 m to 209.1 m. The explored thickness of this layer was between 1.5 m and 5.2 m. BoreholesBH-2 and BH-4 were terminated in this layer.

The composition of this till layer is clay and silt, trace to some sand, trace gravel and trace shale fragments. The material is grey in color, and moist to dry. The SPT "N" values within this layer ranged from 17 blows per 0.3 m penetration to 100 blows per 0.125 m penetration typically 17 to 30 blows per 0.3 m penetration, suggesting very stiff in consistency. The results of the Atterberg Limts testing are shown on plasticity chart on Figure 6 in Appendix D and indicate that the deposits consist of clayey silt till of low to medium plasticity.

Laboratory testing performed on selected sample consisted of seven (7) moisture content test, three (3) grain size distribution tests and three (3) Atterberg Limit tests. The test results are as follow:

Moisture Content: (Performed by **exp**)

- 11.7% to 18.8%

Grain Size Distribution: (Performed by **exp**)

- 4% gravel;
- 9% to 30% sand;
- 49% to 59% silt; and
- 17% to 28% clay

Atterberg limits (Performed by **exp**)

- Liquid Limit: 20% to 35%
- Plastic Limit: 12% to 20%
- Plasticity Index: 8% to 15%

The results of the moisture content, gain size distribution and Atterberg Limit tests performed by **exp** are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test and Atterberg Limit tests performed by **exp** are also provided on Figure 5 and 6, respectively, in Appendix D.

## 1.5 Groundwater & Surface Water Conditions

Information on groundwater levels at the site was obtained by measuring water levels in the open boreholes after completion of drilling. The groundwater levels encountered in the boreholes are shown on the borehole logs and presented below in Table 1.2.

*Table 1.2. Groundwater data*

| Borehole | Date Completed | Date Measured | Ground Surface Elevation[2] | Depth to Water[3] | Groundwater Elevation |
|---|---|---|---|---|---|
| BH-1 | March 21/17 | March 21/17 | 225.4 | 6.7 | 218.7 |
| BH-2 | March 20/17 | March 20/17 | 226.5 | 7.6 | 218.9 |
| BH-3 | March 20/17 | March 20/17 | 226.6 | 6.1 | 220.5 |
| BH-4 | March 21/17 | March 21/17 | 226.5 | 6.1 | 220.4 |
| Stream WL | - | March 21/17 | - | - | dry |
| BH 04A-1 | July 31/07 | July 3107 | 225.7 | | dry |
| BH 04A-2 | July 31/07 | July 3107 | 226.4 | | dry |

Notes:
1) All units in metres.
2) Elevations surveyed are referenced to a temporary benchmark (TBM) set on (MTO # 92 concrete post, see photograph 10 in Appendix A) approximately 120 m east of the culvert alignment on south of highway. The TBM elevation (216.3 m) is assumed based on the information provided on site plan drawings provided by the MTO.
3) Depths are relative to ground surface.

Note that water levels measured in open boreholes might not be stabilized due to short term observation. However, during borehole investigation wet spoons were observed in the gravelly sand to sand and gravel layer at depths ranging between 3.05 m to 3.9 m below ground surface with elevations ranging between 221.5 m to 223.5 m. At the time of investigation, the culvert was dry.

Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods. Some perched water could exist in the embankment fill as well.

## 1.6 Chemical Analyses

One soil sample was selected for chemical analysis and was sent to Maxxam Analytics Inc., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are presented in Appendix E, and are summarized in Table 1.3, below.

*Table 1.3. Corrosivity chemical analysis*

| Sample Identification | pH (unitless) | Soluble Chloride (ppm) | Soluble Sulphate (ppm) | Resistivity (ohm-cm) | Conductivity (umho/cm) | Redox Potential (mV) | Sulphide (ppm) |
|---|---|---|---|---|---|---|---|
| BH2-SS3 Clayey Sandy Silt Fill | 7.49 | 1700 | <20 | 320 | 3170 | +166 | <0.5 |

# PART II: ENGINEERING DISCUSSION & RECOMMENDATIONS

## 2.1 General

This section of the report provides geotechnical design recommendations for replacement of the existing culvert, located on Highway 26 at STA 24+527, just east of Meaford in Grey County, Ontario, the Ministry of Transportation (MTO) Western Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site performed by **exp** and previous investigation performed by Engineering Group Inc in April 2009. The compiled factual results of these investigations are presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the new culvert and replacement. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on the TOR, the existing culvert is a 1.52 m × 0.91 m × 27 m concrete non-rigid frame open footing structure. It is understood that the existing culvert would be replaced with a new concrete box culvert of dimension 2.4 m x 1.5 m x 27.0 m along the same alignment. It is also understood that fill from the top of roadway centerline to top of culvert will be 0.3 m thick and about 0.3% slope descending northward. For the completeness of this report, the following options are being discussed for the replacement in this report: rigid frame box culvert (precast or cast-in place), rigid frame open footing culvert and corrugated steel pipe culvert.

This part of the report addresses the geotechnical design of the foundation for the new culvert by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-14)*, the *Canadian Foundation Engineering Manual (CFEM)* (2006), *MTO Gravity Pipe Design Guidelines* (May 2007) and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us at January 31, 2017 together with the MTO request email. The assessment involved review of options for replacement of the existing culvert along the same alignment.

## 2.2 Expected Ground Conditions

The following ground conditions along the proposed culvert alignment are evident from two geotechnical investigations:

a) Hwy 26 is a two lane roadway and is about 7.4 m wide from edge to edge of road lane marks, with approximately 2.7 m wide partially asphalt and partially sand and gravel shoulders on both sides. Based on the observations, the roadway embankment is about 2 m high with side slope of about 3H:1V. The current elevation of the crest of the roadway is about 226.5 m.

b) The highway embankment consists of granular fill (0.6 m to 1.3 m thick) and clayey sandy silt fill (0.7 m to 2.15 m thick). Embankment fill is underlain by firm to stiff clayey silt with sand (0.7 m to 1.5 m thick) followed by dense to very dense gravelly sand to sand and gravel (2.1 m to

9.0 m thick, BH 04A-2 (I.E Group) and BH-3 (**exp**) terminated within this layer) followed by compact to very dense sandy silt (~3.1 m thick) and very stiff clayey silt till (3.2 m to 5.2 m thick, BH-2 (**exp**) and BH-4 (**exp**) terminated within this layer).

c) At inlet and outlet sides, a layer of topsoil (~0.15 m (BH-04A-1, I.E Group) to 1 m (BH-1, exp) thick) underlain by loose to compact silty sand to sandy silt (1.2 m to 2.25 m thick) underlain by compact to very dense gravelly sand to sand and gravel (1.5 m to 5.3 m thick, BH 04A-1 (I.E Group) terminated within this layer) followed by compact to very dense sandy silt (3.1 m thick), very stiff clayey silt till (1.5 m thick) and very dense sand and gravel (0.6 m thick) as recorded in BH-1 (exp) which is terminated within the last layer.

d) The foundation soil at the invert of the new culvert is anticipated to be compact sandy silt to silty sand at inlet and outlet locations and compact to very dense gravelly sand to sand and gravel at mid-span of culvert at about Elev. 223.8 m.

e) At the time of investigation, the culvert was dry. Water level measured in open boreholes ranging between 6.1 m to 7.6 m below ground surface with elevations ranging between 218.7 m to 220.5 m. However, during borehole investigation wet spoons were observed at depths ranging between 3.05 m to 3.9 m below ground surface with elevations ranging between 221.5 m to 223.5 m in the gravelly sand to sand and gravel layer. Considering these findings, it is reasonable to assume that the groundwater table at site location is expected to be at approximate elevation 223.5 m, or slightly higher. However, seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods. Some groundwater mounding within the embankment and perched water would be anticipated.

## 2.3 Structure Foundations

As stated before, it is understood that a precast 2.4 m x 1.5 m size box culvert is a preferred option for the replacement of the existing culvert. However, for preliminary design purpose, several other possible options are also discussed below:

- Rigid frame box culvert (precast or cast-in-place);
- Rigid frame open footing culvert supported on shallow foundations; and
- Corrugated steel pipe culvert,

Based on the subsurface information obtained from the site investigations, the native gravelly sand to sand and gravel is considered suitable for support of all replacement options. However, the choice of culvert type will also depend on parameters such as the initial cost, maintenance costs, hydraulic performance, ease of construction, salvageability and local availability of material and equipment.

It is noted that regardless of the option selected, the existing 1.52 m × 0.915 m × 27 m concrete non-rigid frame open footing culvert is to be removed. This will require excavation down to the existing founding elevation for all options. This suggests the need for surface/groundwater control as discussed in Section 2.10 below.

Any loose and/or soft soils encountered below the existing embankment/culvert should be excavated and removed to firm bearing of native soils and the grade restored with engineered fill. If the depth of excavation to remove unstable soils is excessive, using a geotextile fabric, such as Terrafix 270R or equivalent, in conjunction with engineered fill can be considered to assist in providing a stable base for the new culvert. Based on previous experience, typically a minimum thickness of 450 mm of a clear stone (OPSS 1004) over geotextile fabric would establish a stable bearing surface. The fabric should be installed a manner to mitigate the migration of fines from adjacent material.

Based on the subsoil condition, Table 2.1 below compares the possible structure options from a foundations design and constructability perspective with their advantages and disadvantages. Although the foundation soils can provide adequate support for all options listed in the table, the use of a precast rigid frame box culvert is ranked highest for the criteria evaluated.

*Table 2.1 Evaluation of foundation alternatives*

| Options | Rank | Advantages | Disadvantages | Relative Costs | Risks/ Consequences |
|---|---|---|---|---|---|
| Precast rigid frame box culvert | 1 | ▪ Straightforward construction<br>▪ Reduced construction period, consequently traffic management and water control period<br>▪ Reduced excavation depth | ▪ If floor is thin and poorly reinforced, it may heave and crack<br>▪ During high flows, the concrete floor can be undermined<br>▪ Requires bedding material | ▪ Low | ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil<br>▪ Risk of leaking from joints if not properly installed |
| Cast-in-place rigid frame box culvert | 3 | ▪ Suitable if site is not conductive to heavy equipment for installation of precast sections<br>▪ Reduced excavation depth | ▪ Slower construction process<br>▪ If floor is thin and poorly reinforced, it may heave and crack<br>▪ During high flows, the concrete floor can be undermined<br>▪ Requires concrete curing | ▪ Low to medium | ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil<br>▪ Risk of disturbance of base during construction |
| Rigid frame open footing concrete culvert | 4 | ▪ Wider span may be considered if required | ▪ Deeper excavation or below water excavation may required<br>▪ More extensive dewatering system may required | ▪ Likely more expensive than Option 1 | ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil<br>▪ Risk of delay in construction if |

| Options | Rank | Advantages | Disadvantages | Relative Costs | Risks/ Consequences |
|---|---|---|---|---|---|
| | | | ▪ May require placement of lean concrete | | excavation required below water in more permeable zones<br>▪ Higher risk of scour |
| Corrugated steel pipe culvert | 2 | ▪ Straightforward construction<br>▪ Reduced construction period, consequently traffic management and water control period<br>▪ Reduced excavation depth | ▪ Requires bedding material<br>▪ Limited design life<br>▪ Potential for corrosion | ▪ Low to medium | ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil<br>▪ Risk of structure segment loss due to corrosion |

### 2.3.1 Shallow Foundations

#### 2.3.1.1. Geotechnical Resistance

Based on the subsurface stratigraphy encountered at this site and the assumed invert elevation of the new culvert, the recommended founding depths and geotechnical resistances for a structure founded on undisturbed competent natural soils are tabulated below.

*Table 2.2 Recommended spread footing design parameters*

| Culvert Type | Founding Elevation (m) | Assumed Footing Size (m) | Founding Soil Type | Factored Geotechnical Resistance at ULS (kPa) | Geotechnical Reaction at SLS** (kPa) |
|---|---|---|---|---|---|
| Rigid frame box culvert and CSP pipe culvert | ~223.8 or below | 3.0 m | Minimum 300 mm compacted granular material (Granular A or Granular B Type II) over native compact silty sand to sandy silt or compact to dense gravelly sand to sand and gravel | 300 | 200 |
| Rigid frame open footing concrete culvert and retaining (wing) wall | ~223.0* | 1.0 | Native compact to dense gravelly sand to sand and gravel | 450 | 300 |

*Notes:*
**Below the frost line*
*** for maximum settlement of 25 mm*

It is presumed that if any underlying organic fibers and any other soft or very loose materials are to be replaced with clean and compactable soil such as Granular A or Granular B Type II. Given that no (or minimal) grade raise is planned, the anticipated maximum total settlements for the new proposed culvert are not expected to exceed 25 mm for construction done in accordance with these design parameters and assuming good construction practice including sound base preparation.

#### 2.3.1.2. Resistance to Lateral Loads

Resistance to lateral forces/ sliding should be calculated in accordance with Section 6.10.5 of the CHBDC, using the following parameters:

*Table 2.3 Recommended parameters for calculation of unfactored horizontal resistance*

| Interface and loading conditions | Parameters |
|---|---|
| Between Granular A and pre-cast concrete | Coefficient of friction (tan $\delta$)=0.5 |
| Between cast-in-place concrete and native gravelly sand to sand and gravel | Coefficient of friction (tan $\delta$)=0.6 |

The listed values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

#### 2.3.1.3. Frost Protection

The frost depth in the culvert is estimated to be approximately 1.4 m in accordance with OPSD 3090.101. During construction of any temporary and permanent support system using shallow foundations should be provided a minimum 1.4 m of soil cover or equivalent frost protection should be provided using thermal insulation. This frost protection requirement applies to the rigid frame open footing culvert option. Frost protection is not required for the box culvert.

If the frost penetration line is at or above top of the culvert the backfill and cover for these culverts should be as per OPSD 803.010. Where less than 1.4 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.010 for the concrete culverts with spans less than or equal to 3.0 m.

## 2.4 Lateral Earth Pressure

Culvert walls and temporary shoring should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

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

where

$P$ = earth pressure intensity at depth h, kPa

$K$ = earth pressure coefficient

$\gamma$ = unit weight of retained soil, kN/m$^3$

q = surcharge near wall, kPa

h = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.4 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. This would normally be the case for concrete box culverts.

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

For multiple support systems refer to *Canadian Foundation Engineering Manual* (CFEM) for apparent earth pressure distributions (CFEM, Section 26.10.3, Figure 26.8)

*Table 2.4 Material types and earth pressure properties*

| Material | Unfactored Friction Angle φ’ | Coefficient of Active Earth Pressure ($K_a$) | Coefficient of Passive Earth Pressure ($K_p$) | Coefficient of Earth Pressure At-Rest ($K_o$) | Unit Weight γ kN/m$^3$) |
|---|---|---|---|---|---|
| Sand and Gravel Fill | 32 | 0.31 | 3.25 | 0.47 | 21 |
| Clayey Sandy Silt Fill (loose to dense) | 29 | 0.35 | 2.88 | 0.52 | 19 |
| Clayey Silt with Sand (firm to stiff) | 29 | 0.35 | 2.88 | 0.52 | 19 |
| Gravelly Sand to Sand and Gravel (loose to very dense) | 32 | 0.31 | 3.25 | 0.47 | 20 |
| Sandy Silt (compact to v. dense) | 30 | 0.33 | 3 | 0.50 | 20 |
| Clayey Silt Till (v. stiff to hard) | 30 | 0.33 | 3 | 0.50 | 20 |

## 2.5 Seismic and Liquefaction Potential Consideration

Seismic characterization of the site must be compliant with the Canadian Highway Bridge Design Code CHBDC (CAN/CSA-S6-14). The potential for seismic loading must be considered for design in accordance with Section 4.4 of the CHDBC with respect to soil conditions encountered at the site. Table 4.1 in CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on soil average properties in top 30 m. The borehole information shows the presence of native compact soil and bedrock. Based on these soil characteristics, the site class for this site is estimated to be Class “D” according to Table 4.1.

From the Natural Resources Canada website, 2015 NBCC seismic hazard values are obtained using the site location coordinates (44°17'13.8"N, 80°50.55'2"W) and the damped reference spectral accelerations for the project site are Sa(0.2)=0.041g, Sa(0.5)=0.032g, Sa(1.0)=0.019g, Sa(2.0)=0.0091g and the reference peak ground acceleration (PGA) is 0.022g (g=acceleration due to gravity -9.81 m/s$^2$). These values are associated with an earthquake having 10 percent probability of exceedance in a 50-year period.

Based on soils and groundwater condition encountered at the site, no liquefaction is expected due to the ground motion from an earthquake having 10% probability of exceedance in a 50-year period.

## 2.6 Construction Alternatives

For the proposed culvert replacement, the following methods were considered as possible alternatives for the new culvert installation at this site:

1. Half-and-half construction using roadway protection to allow excavation as maintaining signalized one lane of traffic on the existing embankment during construction. The following two options of excavation and replacement using the half-and-half approach were considered:
   A. Construction using roadway protection and unsupported excavation of cut sides
   B. Construction using roadway protection and braced cut sides
2. Full road closure followed by open cut/unsupported excavation to replace culvert;
3. Construct temporary detour embankments at the site followed by open cut/unsupported excavation to expose and replace culvert

All methods considered utilize a cut and cover approach for culvert replacement which allows complete removal of the existing culvert, but it requires disruption of traffic. In contrast, a trenchless approach for culvert replacement does not require disruption of traffic. However, considering the size and nature of the existing culvert and topography of the surrounding terrain, tunneling for trenchless replacement of this culvert was not considered as an applicable option. The other trenchless methods such as pipe bursting, pipe splitting, pipe swallowing and interior replacement methods were also not considered as applicable in this project, since the type of the precast culvert is an unsuitable candidate for these techniques. For all approaches, provision must be made to maintain surface water flow to the outlet.

The following Table 2.5 summarize advantages and disadvantages of considered construction alternatives. The table also shows assessed risk/consequences and relative costs of the considered methods. Schematic diagrams of considered alternatives are attached in Appendix H.

*Table 2.5 Construction alternatives for culvert replacement (see schematic sketches in Appendix H)*

| **Installation Method** | **Advantages** | **Disadvantages** | **Relative Cost** | **Ranking** |
|---|---|---|---|---|
| OPTION 1.A<br><br>Half-and-half Construction with Roadway Protection and Unsupported Cut Sides (Figure H1.A, Appendix H) | • Traffic flow maintained at the site during construction<br>• Short mobilization time<br>• Straight forward construction and construction procedures | • Traffic interruption<br>• Roadway protection of up to 3.5 m high required to maintain one lane of traffic<br>• High cost of roadway protection system<br>• Large amount of soil to be excavated than braced cut<br>• Need to temporarily control the flow of water<br>• Risk of cost overrun and inability to finish job: low to moderate | Relatively more expensive than full road closure due to high costs of roadway protection system | 1 |
| OPTION 1.B<br><br>Half-and- half Construction with Braced or Anchored Cut Sides<br><br>(Figure H1.B, Appendix H ) | • One or possibly two lanes of traffic flow maintained on existing road (e.g. steel decking, but costly)<br>• Global stability of excavation enhanced by narrow geometry<br>• Less traffic interruption than with unsupported cut sides approach<br>• Temporary decking could be usable over braced cut to allow for excavation of both halves prior to diverting stream and backfilling<br>• Cost savings due to limited excavation and backfill | • Traffic interruption<br>• Roadway protection of up to 3.5 m high required to maintain one lane of traffic if steel decking is not possible<br>• High cost of roadway protection system and/or decking<br>• Require side shoring and bracing<br>• Bracing (e.g. struts) may interfere with excavation<br>• Excavation of material and placement of bracing required in limited space<br>• Need to decommission the shoring system<br>• Need to temporarily control flow of water<br>• Risk of cost overrun and instability to finish job: low to moderate | More expensive than full road closure and other open cut sides approach due to high costs for shoring system and temporary decking (if feasible) to maintain continuous flow of traffic | 2 |

| Installation Method | Advantages | Disadvantages | Relative Cost | Ranking |
|---|---|---|---|---|
| OPTION 2<br><br>Full Road Closure using Existing Local Roadways and Open Cut Unsupported Excavation (Figure H2, Appendix H) | • Existing culvert will completely remove and replaced with new culvert<br>• No construction of detour roads or roadway protection required<br>• No excavation support required<br>• Install entire new culvert at once<br>• Straightforward construction<br>• Short mobilization time<br>• Low capital investment; cost saving in time and materials required for construction | • Traffic interruption<br>• Long detour around site using other existing roads required<br>• Large amount of soil to be excavated<br>• Erosion control of temporary cuts required<br>• Need to temporarily control flow of water<br>• Potential claims to compensate vehicle occupants and local business for delays or time lost due to detour routes<br>• Risk of cost overrun and inability to finish job: low | Relatively less expensive than other methods due to cost savings in time and materials required for construction, but potential claims to compensate vehicle occupants and local business for delays or time lost due to detour routes | 3 |
| OPTION 3<br><br>Build Temporary Detour and Open Cut Unsupported Excavation<br><br>(Figure H3, Appendix H) | • Traffic flow maintained at the site during construction<br>• Simple detour roads can be constructed<br>• Existing culvert will completely remove and replaced with new culvert<br>• No excavation support required<br>• Install entire new culvert at once | • Construction of detour embankments required at one side of highway<br>• Possible extra cost to purchase of private property<br>• Increased time for construction of detour<br>• Large amount of soil to be excavated<br>• Erosion control of temporary cuts required<br>• Need to temporarily control existing creek water<br>• Risk of cost overrun and inability to finish job: low to moderate<br>• Possible extra cost to purchase of private property | More expensive than full road closure due to high costs to build local detours | 4 |

Based on the above list of advantages and disadvantages of the possible construction methods, we recommend the following ranking of the considered options:

1. OPTION 1.A: Half-and-half construction with roadway protection and unsupported cut sides (Figure H1.A, Appendix H)

2. OPTION 1.B: Half-and-half construction with braced or anchored cut sides (Figure H1.B, Appendix H)

3. OPTION 2: Full road closure using existing local roadways and open cut unsupported excavation (Figure H2, Appendix H)

4. OPTION 3: Build temporary detour and open cut unsupported excavation (Figure H3, Appendix H)

The following sections discuss these options in more details.

### 2.6.1 Half-and-Half Construction (Options 1)

The half-and-half construction method could be utilized to maintain the flow of the traffic on Hwy 26 (see Figures H1.A, and H1.B, Appendix H). In this method, one lane of the existing highway will be used to maintain the local traffic while the other half of the existing highway will be excavated and the half of the existing culvert will be exposed. Then the excavated portion of the existing culvert will be removed and replaced with a new culvert, followed by rebuilding of that half of the embankment to grade. Upon completion of the new embankment, the traffic will be moved onto the new fill and the process will be repeated to complete the construction and culvert replacement.

The temporary excavation required to remove half of the existing embankment would be up to 3.5 m deep. Therefore, temporary shoring such as a soldier pile and lagging system will be required as a roadway protection system to allow staging excavation/construction. It will be the Contractors responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor is to follow OPSS 902, regarding excavations for structures, and OPSS.PROV 539, regarding temporary protection systems. Recommendations for a temporary roadway protection are given in Section 2.7. Using the half-and-half construction approach, two methods of culvert replacement were considered for this site suitable as discussed below:

A. Construction using roadway protection and unsupported excavation of cut sides
B. Construction using roadway protection and braced or anchored cut sides

Option 1.A could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment. Option 1.B will disrupt less of the embankment but would cost more, i.e. about 1.8 times of Option 1.A. Excavation and backfilling operations will also be more challenging with Option 1.B. Both options require decommissioning of shoring system upon completion of the work.

#### 2.6.1.1 Option 1.A: Half-and-Half Construction with Roadway Protection and Unsupported Cut Sides

This method provides roadway protection parallel to the highway between two lanes, and allows to divert traffic to the one side and undertake open cut with sloping sides at the other side (see Figure H1.A, Appendix H). The roadway protection can take the form of reversible shoring such as a solder pile and lagging with rakers or anchors for horizontal support. Where the cut extends below prevailing groundwater a suitable control/system is required. Once one lane is completed the supports can be reversed and the other lane constructed in similar fashion. The shoring system would likely be decommissioned in place. Temporary surface water flow control must be developed by contractor.

Option 1.A could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment than Option 1.B since it needs to excavate a large amount of soil.

#### 2.6.1.2 Option 1.B: Half-and-Half Construction with Braced or Anchored Cut Sides

This method provides braced or anchored cut shoring system perpendicular to the highway for face protection and to allow culvert construction (see Figure H1.B., Appendix H). Excavation in this case would have to accommodate the necessary cross-bracing such as struts. With this option, consideration would have been given to how the new culvert sections will be installed given the relatively narrow work area and potential for obstructions form the lateral bracing using struts. Installation of tiebacks could be the solution. Temporary decking could possibly be used over the supported cut to allow for excavation of both halves prior to diverting stream and backfilling. However decking would be costly. As well as Option 1.A, decommissioning of the shoring system and temporary surface water flow control must be performed/developed by contractor.

Option 1.B will disrupt less of the embankment than Option 1.A but would cost more, i.e. about 1.8 times of Option 1.A, due to the cost of shoring system. Excavation and backfilling operations will also be more challenging with Option 1.B. Both options require decommissioning of shoring system upon completion of the work.

### 2.6.2 Detour Options (Options 2 and 3)

Both detour options, the option with full closure of Hwy 26 and long detours around the area using existing local roadways (see Figure H2, Appendix H), and the option with the detour embankment construction at the site to maintain the local flow of traffic during the replacement (see Figure H3, Appendix H), allow for open cut, unsupported excavation to facilitate the replacement of the existing culvert. A major benefit of these options is that the existing culvert will be completely removed once and replaced the new culvert. The other advantages are that neither excavation support nor roadway protection is required with these options. The major disadvantages of both options are traffic interruption, large amounts of excavated soils and need for temporary construction unwatering and dewatering systems (i.e. cofferdams, and sumps and pumps, etc.) to prevent existing surface water and groundwater flow into the construction area which is the responsibility of the contractor.

The detour construction alternative would involve construction of a temporary on-site embankment at the one side of the existing embankment depending on the available space and suitable terrain. Compacted engineered fill for construction of the temporary detour road is recommended. Prior to construction of the temporary detour embankment, the site will need to be cleared and grubbed of any existing bushes and vegetation. All surficial topsoil (if exists), organics and softened or loosened soil should be stripped form below the proposed temporary detour road embankment. All subgrade soils should be proof-rolled prior to fill placement and embankment fill should be placed in accordance with OPSS. PROV 206 (dated November 2014).

### 2.6.3 Excavations

All excavations at this site must be conducted in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). All fills (i.e. sand and gravel fill and clayey sandy silt fill) and native silty sand to sandy silt and clayey silt with sand may be classified as a Type 3 soil above the groundwater table in conformance with the OHSA. The sandy soils below the groundwater table may be classified as a Type 4 soil. It is expected that most of excavations will be above the groundwater levels except those at the invert level. To avoid disturbance of the founding subgrade and to allow placement of backfill in dry conditions, groundwater must be controlled to below the proposed invert excavation levels prior to digging to final levels. As mentioned before, the ingress of surface water must be controlled using a suitable system as well.

Temporary excavation side slopes for Type 3 soil should not exceed 1H:1V in accordance with OHSA. Temporary excavation side slopes for Type 4 soils should not exceed 3H:1V where applicable. There is a potential for sloughing to occur if the trench remains open for an extended period of time (i.e. > 24 hours) or during a rainfall event. In addition, some localized surficial sloughing may be experienced in areas of perched groundwater seepage (i.e. within the embankment fill).

## 2.7 Temporary Roadway Protection

Temporary roadway protection is anticipated to be a part of the half-and-half construction approach that will be required to maintain on-site traffic during the construction. It is recommended that roadway protection system be in accordance with OPSS.PROV 539. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539. The complete design, construction, monitoring and removal of the installed protection system should be a responsibility of the contractor. Due to nature of this application it is expected that much of temporary shoring will be decommissioned in place noting the high cost for removal. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work.

At this site a shoring system, such as soldier piles and timber lagging may be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Section 2.4. The actual depth of embedment should be determined by balancing moments about the pile tip. For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided that the center-to-center spacing of the soldier piles does not exceed 2.5 m. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours.

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

## 2.8 Culvert Bedding

OPSDs 802.010, 802.031, 802.032 and 803.010 which are included in Appendix G provide the bedding, embedment, cover and backfill standards for the different culvert material. According to these standards the culvert bedding should consist of Granular A (OPSS.PROV. 1010) with thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. The bedding material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted accordance with OPSS 501 before a subsequent layer is placed in accordance with OPSS. PROV 401. Bedding on each side of the culvert (i.e. CSP pipe) shall be completed simultaneously. At no time, shall the levels on each side differ more than the 200 mm uncompacted layers.

Prior to placing any fill material, the exposed native subgrade should be inspected according to OPSS 902. A non-woven geotextile separator is to be placed between the approved subgrade and the compacted fill to assist in material placement and maintain the integrity of the founding soil along the entire length of the culvert. The geotextile separator is to be a Class II non-woven material with an equivalent opening size of 75-150 µm.

For the site area, a frost penetration depth of approximately 1.4 m can occur in open, unheated areas without snow cover. At the culvert inlet and outlet, and beneath the proposed culvert, mostly the native soils consist of clayey silt/sandy silt. This material has medium to high frost susceptibility based upon the MTO Frost Classification guideline of percent particles between 5 to 75 µm. Therefore, non-frost susceptible materials such as sand and gravel need to be provided to the limit of frost penetration beneath the inlet and outlet of the culvert. However, considering that cold air blowing through the culvert during the winter season will freeze soil next to the culvert, a minimum 500 mm thick layer of non-susceptible material should be considered to be placed as a bedding along the entire culvert length.

## 2.9 Culvert Backfill

The selection and placing of the backfill and cover should be in accordance with OPSS 902, OPSS.PROV 421, OPSS 422 and OPSD 803.010 for concrete and pipe culverts. The backfill should consist of free-draining, non-frost susceptible granular materials confirming to OPSS.PROV 1010.

For fills immediately below any roadway, it is recommended that Granular A or B materials be used. Where necessary, proper tapering as per standards should be provided. Below a depth of about 1.4 m from any finished road grade, approved compactable fill, such as select subgrade materials (OPSS.PROV 1010) or imported fill can be used.

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS 501.

The use of heavy compaction equipment should be avoided immediately adjacent and above the culvert, as per MTO practice. The minimum height of fill cover above the crown of the culvert before power operated tractors or rolling equipment shall be 900 mm, unless otherwise noted by the structural engineer. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the structure, to avoid lateral displacement of the structure.

Where less than 1.4 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.010, 803.030 and 803.031.

Backfilling behind any retaining (wing) walls should consist of granular materials in accordance with the MTO standards. Free draining backfill materials and perforated drains (as per Figure C6.20a of the CHBDC), suitably outleted etc. should be provided in order to prevent hydrostatic pressure build-up.

## 2.10 Groundwater and Surface Water Control

The soils encountered below the groundwater table and within potential excavation depths consist of native gravelly sand to sand and gravel. The groundwater level needs to be controlled to at least 0.5 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the culvert bedding material placement of granular backfill in the dry. In general, pumping using properly filtered sumps, and/or filtered drains placed along the base of the excavation should provide sufficient groundwater control during foundation works.

Provided that the existing culvert is to remain in use during construction of the new culvert, the majority of the upstream flow of the existing culvert can be diverted around the construction area. For the control of the water flow in the creek might require a cofferdam. If the existing culvert is to be removed prior to completion of the new culvert, a system of sumps and pumps will be required to divert the surface water up and over the existing embankment.

Dewatering requirements behind the cofferdams to keep the construction site dry will be impacted by water levels in the stream at the time of construction activities. Dewatering shall be carried out in accordance with OPSS 517 and OPSS 518. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions for prior approval of the MTO. The method used should not undermine the existing road embankment or adjacent side slopes. In this connection, the provision of toe protection at side slopes during drawdown may be required to minimize sloughing and undercutting during dewatering.

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

## 2.11 Embankment Design

### 2.11.1 Embankment Stability

A preliminary slope stability analysis was performed to assess the global stability of the existing embankment and to check that a minimum Factor of Safety of 1.3 will be achieved for the new embankment at the location of the proposed culvert. Given the embankment height and side slope geometry, slope stability is not considered an issue. This analysis is provided for completeness. The static slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments of existing slopes under static conditions were performed on the cross-section perpendicular to the highway at the proposed culvert location. Stability assessment for temporary condition for open cut unsupported excavation was also performed on the cross-section parallel to the highway. The cross-section of the existing embankment with the approximate slopes of 3H:1V was developed based on the cross-sections provided by MTO. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Based on the borehole information, the subsoils encountered at the work area consist of embankment fill, underlain by clayey silt with sand followed by gravelly sand to sand and gravel, sandy silt and clayey silt till deposits. Therefore, an effective stress analysis for a long term and total stress for short term assessment of the embankment slope was performed taking into consideration the subsoil conditions encountered beneath the existing embankment.

The SLOPE/W graphical printout, for analysis performed is included in Appendix F. Since the geometry and soil stratigraphy at the north and south side slopes are similar, the result of the slope analysis performed for the south side slope, is only presented.

Tabulated below in Table 2.6 are the soil parameters used for the slope stability analysis. The soil parameters were generally estimated based on the results of field and laboratory investigation.

*Table 2.6 Soil properties used in slope stability analysis*

| Soil Type | Short-term Conditions | | | Long-term Conditions | | |
|---|---|---|---|---|---|---|
| | ϕ (degrees) | c (kPa) | γ (kN/m³) | ϕ' (degrees) | c' (kPa) | γ' (kN/m³) |
| Sand and Gravel Fill | 32 | 0 | 21 | 32 | 0 | 21 |
| Clayey Sandy Silt Fill | 29 | 0 | 19 | 29 | 0 | 19 |
| Sandy Silt | 30 | 0 | 20 | 30 | 0 | 20 |
| Clayey Silt with Sand | 0 | 50 | 19 | 29 | 0 | 19 |
| Silty Sand | 28 | 0 | 19 | 28 | 0 | 19 |
| Gravelly Sand to Sand and Gravel | 32 | 0 | 20 | 32 | 0 | 20 |

The results of slope stability analyses for the 3H:1V west side slope of the existing embankment using drained (long term stability) soil parameters are presented graphically in Figure 1 in Appendix F. A minimum Factor of Safety is more than 1.3, indicating that the existing embankment is stable. The slope stability analyses performed for the new embankment constructed of engineered fill show that the embankment is stable if the side slope of 2H:1V are designed (Figure 2 in Appendix F).

### 2.11.2 Embankment Settlement

It is not planned to change significantly the existing embankment grade at the culvert location. Therefore, there should be negligible additional settlements under the existing embankment. However, a settlement of about 25 mm should be allowed for due to rebound during the construction.

## 2.12 Inlet and Outlet

### 2.12.1 Erosion Protection

Erosion/scour protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions for preliminary guidance considering native material anticipated. In general, rip-rap protection should be provided where the culvert discharges into the open creek. The rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow the OPSD 810.010, which is included in Appendix G of this report. The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends.

Where the embankment side slopes have been scarred and/or excavated (beyond rip-rap limit) to facilitate the existing culvert replacement, the scarred and/or reinstated embankment side slopes are to be vegetated with sodding, seeding or planting as necessary depending on the flow rate and volume. Should seeding be utilized, a 100 mm thick layer of topsoil should be placed along with a degradable erosion blanket to help minimize erosion until the vegetation begins to grow.

### 2.12.2 Stream Bed Rip-Rap

The stream bed rip-rap thickness is to be at least twice the median particle size, and/or 300 mm thick as a minimum as outlined by OPSD 810.010 included in Appendix G of this report.

### 2.12.3 Seepage Cut-off Requirements

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet, outlet side has a high potential for migration with high seepage gradients. For the culvert replacement and new culvert installation, methods to avoid piping/undermining/scouring of material resulting from seepage along the culvert must be considered and implemented. To prevent surface water from flowing beneath the culvert (potentially causing undermining/scouring) or around the culvert (seeping through embankment fill) these flows should be restricted. For culverts the following are typical methods: (i) clay seal, (ii) steel or wooden sheet pile cutoff at the upstream end of culvert, (iii) cut-off wall incorporated in the apron slab (if one is used) of the culvert, (iv) cut-off trench constructed with geotextile, and (v) rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. Only the clay seal and cut-off trench will be addressed since the sheet pile cut-off will require the understanding of the hydraulics of the stream.

#### 2.12.3.1 Clay Seal

Where readily available a clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment (OPSD 802.095, Appendix G). OPSS. PROV 1205 specifies that material used for clay seals shall be natural clay, clay mixture (1 part Bentonite powder and 3.5 parts Granular “A”) or a geosynthetic clay liner (GCL). The coefficient of permeability shall not exceed $1 \times 10^{-6}$ cm/s.

The following outlines the installation procedures and minimum material requirement of the clay seal:

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than 0.73 x (Liquid Limit – 20%).

- The clay seal is to be place in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

If the GCL is used as a clay seal its material specifications containing the physical, mechanical and hydraulic properties shall be obtained from the manufacture. It is estimated that an approximately 12 mm thick GCL should be installed a minimum 1.0 m along the side of the culvert.

#### 2.12.3.2 Cut-Off Trench

A cut-off trench can be used at both the upstream and downstream ends of the culvert and can be incorporated when the rip-rap apron at both ends of the culvert are being installed. In general, a trench is dug across the stream alignment to well beyond the walls of the culvert and a geomembrane liner is laid on the side of the trench keyed into the culvert at the top and on the base of the trench. The trench is then backfilled with graded rip-rap.

## 2.13 Corrosion Protection

One soil sample was selected for chemical analyses and was sent to Maxxam Analytics Inc., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are summarized in Section 1.6 of this report and detailed results are included in Appendix E.

The chemical data indicates very low resistivity of the tested soil (<2000 ohm-cm), which indicates a severe potential for corrosion of buried metallic elements, particularly pipes and appurtenances (MTO Gravity Pipe Design Guidelines, Page 25). Therefore, some level of pipe protection requires, depending upon the pipe material type. The maximum chloride content reported is 1700 ppm (μg/g) which indicates a high potential for additional corrosion.

The maximum water soluble sulphate content of the soils tested is < 20 ppm (μg/g), i.e. <0.02% and being less than 0.10%, does not indicate the potential to corrode normal Portland cement concrete.

## 2.14 Obstructions

Gravelly sand to sand and gravel layers were noted to be underneath fill or clayey silt layer. These potential obstructions may impact excavations and/or elements of temporary protection systems. A Non-Standard Special Provision (NSSP) for the potential issues associated with the excavation through obstructions should be included with the contract documents and sample has been provided in Appendix J of this report.

# PART III: CLOSURE

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

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

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

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

This Foundation Investigation and Design Report has been prepared by Nimesh Tamrakar, M.Eng, EIT., and Silvana Micic, Ph.D., P.Eng. It was reviewed by TaeChul Kim, P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Nimesh Tamrakar.

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# PART IV: LIMITATIONS AND USE OF REPORT

## BASIS OF REPORT

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

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

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

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

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

## RELIANCE ON INFORMATION PROVIDED

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

**STANDARD OF CARE**

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

**COMPLETE REPORT**

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

**USE OF REPORT**

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

**REPORT FORMAT**

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

# Appendix A – Site Photographs


Photo 1: Hwy 26 looking west from the culvert location


Photo 2: Hwy 26 looking east from the culvert location

Photo 3: Looking north (outlet side) from culvert alignment

Photo 4: : Looking south (inlet side) from culvert alignment

Photo 5: South side slope and ditch looking west

Photo 6:  North side slope and ditch looking west

Photo 7: Deterioration of wingwall on outlet side

Photo 8: Recent cut and backfill mark on outlet side of the culvert

# Appendix B – Drawings

Agreement No. 3015-E-0017
Assignment No. 4
WP - 57-00-00

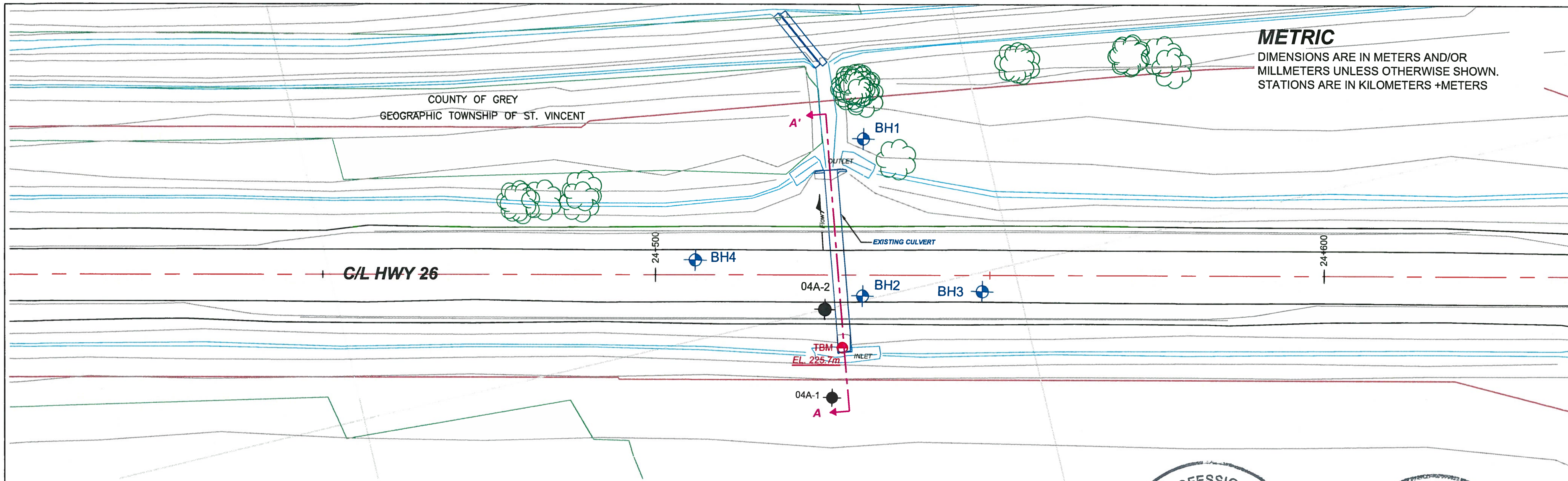
**CULVERT REPLACEMENT, HWY 26**
**THORNBURY TO MEAFORD**
**BOREHOLE LOCATION PLAN AND SOIL STRATA**

SHEET

exp Services Inc.

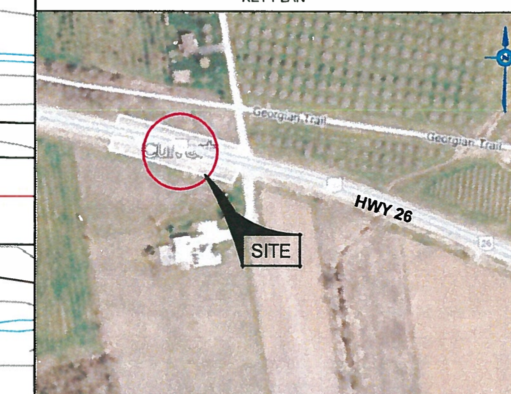
# METRIC

DIMENSIONS ARE IN METERS AND/OR MILLMETERS UNLESS OTHERWISE SHOWN.
STATIONS ARE IN KILOMETERS +METERS




## PLAN

KEY PLAN

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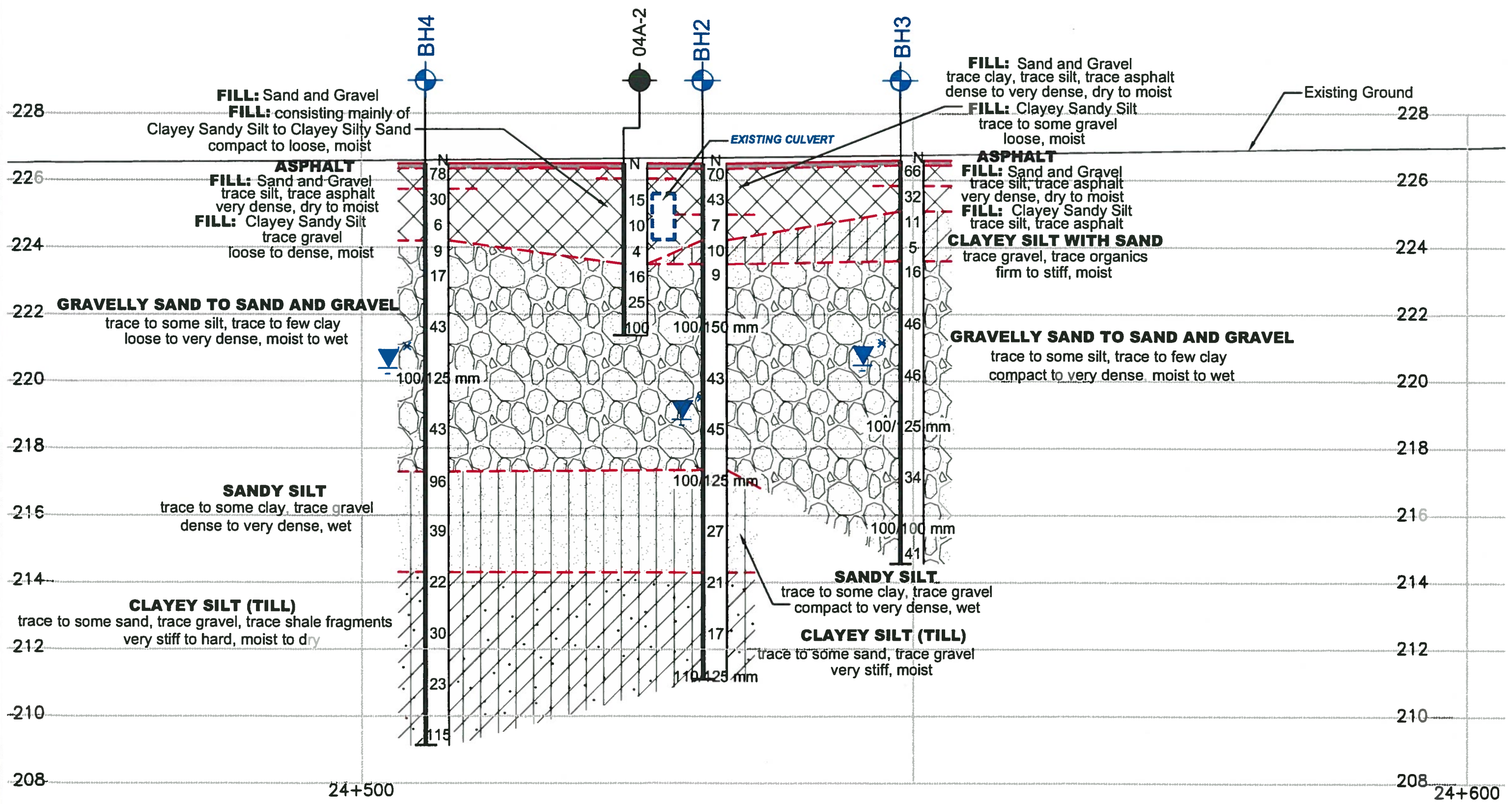
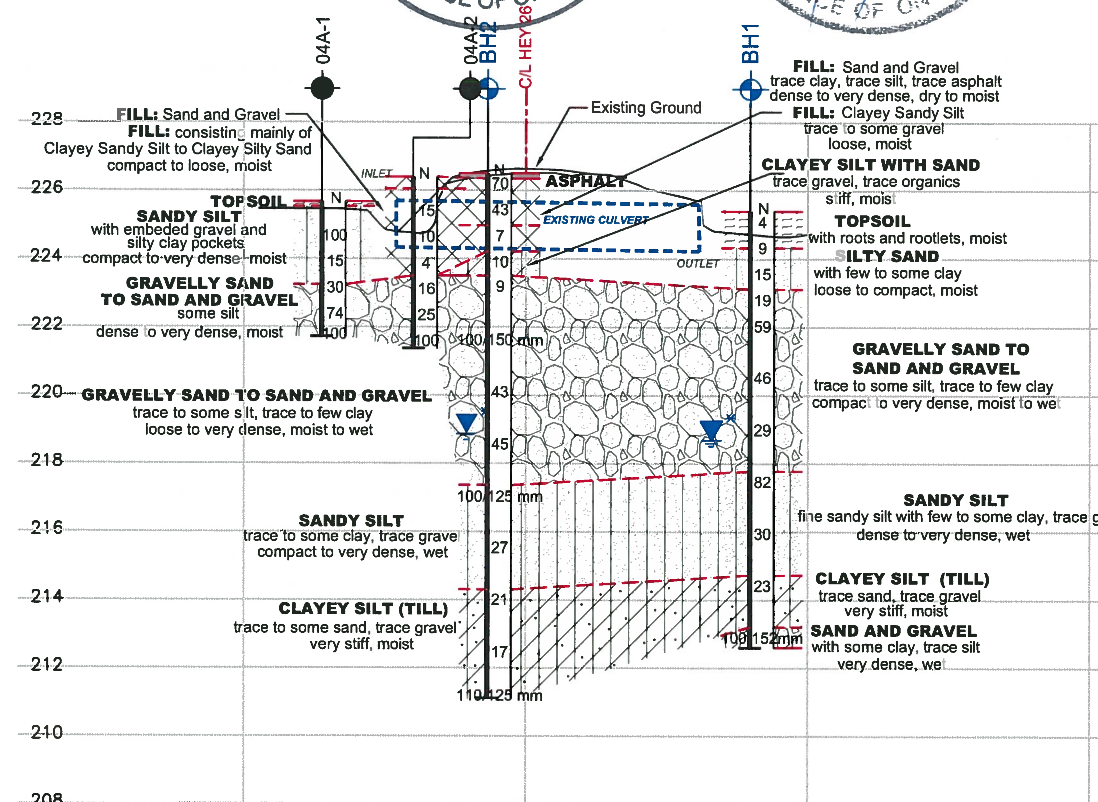



## PROFILE ALONG C/L HWY 26




## SECTION A-A'

**LEGEND**

| | |
|---|---|
| ⊕ | New Borehole |
| N | Standard Penetration Test (Blows/0.3 m) |
| ▽ | Water Level Upon Completion of Drilling |
| ● | Previous Borehole by I.E. Group |
| ● | Temporary Bench Mark (EL. 225.7m ) |

**SOIL STRATA SYMBOLS**

ASPHALT
FILL
CLAYEY SILT WITH SAND
CLAYEY SILT TILL
SANDY SILT/ SILTY SAND
CLAYEY SILT WITH SAND

| BH No. | APPROX. ELEV. | MTM CO-ORDINATES | |
|---|---|---|---|
| | | NORTH | EAST |
| BH1 | 225.4 | 4939523.3 | 220082.4 |
| BH2 | 226.5 | 4939500.6 | 220076.9 |
| BH3 | 226.6 | 4939497.1 | 220094.5 |
| BH4 | 226.5 | 4939511.6 | 220053.8 |
| 04A-1 | 225.7 | 4939487.0 | 220069.0 |
| 04A-2 | 226.4 | 4939500.0 | 220071.0 |

**NOTE**

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

SCALE
HOR 0 5 15 m
VERT 0 5

| | | |
|---|---|---|
| 08/05/2017 | - | SUBMISSION FOR MTO REVIEW |
| DATE | BY | DESCRIPTION |
| | | GEOCRES NO. 41A-243 |
| | | PROJECT NO. ADM-00235197-D0 |
| SUBM'D SM | CHECKED SM | DATE 08/05/2017 |
| DRAWN SH | CHECKED SG | APPROVED SG DWG. 1 |

# Appendix C –
# Borehole Logs

# Explanation of Terms Used on Borehole Records

## SOIL DESCRIPTION

Terminology describing common soil genesis:

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

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

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

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

Terminology describing soil structure:

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

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

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

*Fissured:* material breaks along plane of fracture.

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

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

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

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

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

*Homogeneous:* same color and appearance throughout.

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

*Uniformly Graded:* predominantly on grain size.

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

ISSMFE SOIL CLASSIFICATION

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

0.002 0.006 0.02 0.06 0.2 0.6 2.0 6.0 20 60 200

EQUIVALENT GRAIN DIAMETER IN MILLIMETRES

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

UNIFIED SOIL CLASSIFICATION

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

| | Criteria |
|---|---|
| Trace | Particles are present but estimated to be less than 5% |
| Few | 5≤Pp≤10% |
| Little | 15≤Pp≤25% |
| Some | 30≤Pp≤45% |
| Mostly | 50≤Pp≤100% |

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

Table b: Apparent Density of Cohesionless Soil

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

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

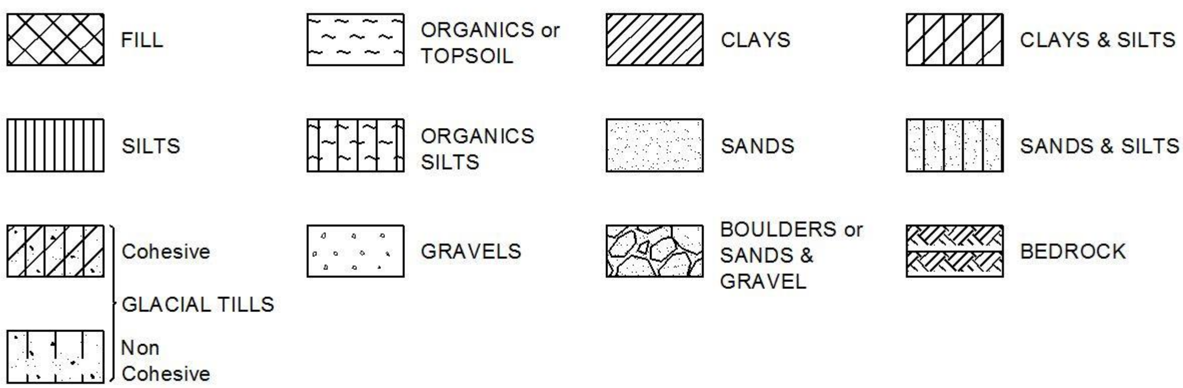
Table c: Consistency of Cohesive Soil

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

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

## STRATA PLOT

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




## WATER LEVEL MEASUREMENT

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

| | | |
|---|---|---|
| $u_w$ | kPa | Pore water pressure |
| $r_u$ | 1 | Pore pressure ratio |
| $\sigma$ | kPa | Total normal stress |
| $\sigma'$ | kPa | Effective normal stress |
| $\tau$ | kPa | Shear stress |
| $\sigma_1, \sigma_2, \sigma_3$ | kPa | Principal stresses |
| $\varepsilon$ | % | Linear strain |
| $\varepsilon_1, \varepsilon_2, \varepsilon_3$ | % | Principal strains |
| E | kPa | Modulus of linear deformation |
| G | kPa | Modulus of shear deformation |
| $\mu$ | 1 | Coefficient of friction |

### MECHANICALL PROPERIES OF SOIL

| | | |
|---|---|---|
| $m_v$ | kPa$^{-1}$ | Coefficient of volume change |
| $c_c$ | 1 | Compression index |
| $c_s$ | 1 | Swelling index |
| $c_r$ | 1 | Recompression index |
| $c_v$ | m$^2$/s | Coefficient of consolidation |
| H | m | Drainage path |
| $T_V$ | 1 | Time factor |
| U | % | Degree of consolidation |
| $\sigma'_{v0}$ | kPa | Effective overburden pressure |
| $\sigma'_P$ | kPa | Preconsolidation pressure |
| $\tau_f$ | kPa | Shear strength |
| $c'$ | kPa | Effective cohesion intercept |
| $\phi'$ | $-°$ | Effective angle of internal friction |
| $c_u$ | kPa | Apparent cohesion intercept |
| $\phi_u$ | $-°$ | Apparent angle of internal friction |
| $\tau_R$ | kPa | Residual shear strength |
| $\tau_r$ | kPa | Remoulded shear strength |
| $S_t$ | 1 | Sensitivity = $c_u/\tau_r$ |

### PHYSICAL PROPERTIES OF SOIL

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

# RECORD OF BOREHOLE No BH-1



**METRIC**

| | | | |
|---|---|---|---|
| W.P. | | LOCATION: Hwy 26, Meaford, MTM ON10 N, E | ORIGINATED BY: NT |
| DIST: Grey County HWY 26 | | BOREHOLE TYPE: CME-55/ Continuous Flight Hollow Stem Auger | COMPILED BY: NT |
| DATUM: TBM (225.7 m) | DATE: 2017.03.21 - 2017.03.21 | LATITUDE: 44.590658 LONGITUDE: -80.566996 | CHECKED BY: SM |

| ELEV / DEPTH (m) | SOIL PROFILE – DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 225.4 | Ground Surface | | | | | |
| 0.0 | **TOPSOIL:** brown, black, moist with roots and rootlets | 1 | SS | 4 | | |
| | | 2 | SS | 9 | | |
| 224.3 / 1.1 | **SILTY SAND:** with few to some clay, brown, moist, loose to compact | 3 | SS | 15 | | |
| 223.1 / 2.3 | **GRAVELLY SAND TO SAND AND GRAVEL:** trace to some silt, trace to few clay, brown to brownish grey, moist to wet, compact to very dense | 4 | SS | 19 | | 33 50 (17) |
| | | 5 | SS | 59 | | No Sample Recovery |
| | | | | | | Wet Spoon @ 3.9 m |
| | | 6 | SS | 46 | | |
| | | 7 | SS | 29 | ∇ (approx. El. 218.8) | |
| 217.8 / 7.6 | **SANDY SILT:** fine sandy silt with few to some clay, trace gravel, brownish grey to grey, wet, dense to very dense | 8 | SS | 82 | | |
| | | 9 | SS | 30 | | 1 23 70 6 |
| 214.7 / 10.7 | **TILL: CLAYEY SILT:** trace sand, trace gravel, grey, moist, very stiff | 10 | SS | 23 | | |

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³. Elevation scale 225 to 214.

Continued Next Page

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

# RECORD OF BOREHOLE No BH-1 2 OF 2 METRIC

W.P. ______ LOCATION Hwy 26, Meaford, MTM ON10 N, E ORIGINATED BY NT
DIST Grey County HWY 26 BOREHOLE TYPE CME-55/ Continuous Flight Hollow Stem Auger COMPILED BY NT
DATUM TBM (225.7 m) DATE 2017.03.21 - 2017.03.21 LATITUDE 44.590658 LONGITUDE -80.566996 CHECKED BY SM

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT w / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 20 40 60 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 213.2 | | | | | | | | | | | |
| 12.2 | **SAND AND GRAVEL:** with some clay, trace silt, grey, wet, very dense | | 11 | SS | 100/ 152mm | | 213 | | ○ | | 40 38 (22) |
| 212.6 / 12.8 | **End of Borehole at 12.8 m depth.**<br><br>Notes:<br>1. This log is to be read with the subject report and project numbers as presented above.<br>2. Groundwater level was measured at 6.7 m below ground surface upon completion of drilling.<br>3. Borehole open upto 7.62 m below ground surface | | | | | | | | | | |

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

# RECORD OF BOREHOLE No BH-2



**METRIC**

W.P. ______ LOCATION Hwy 26, Meaford, MTM ON10 N, E ORIGINATED BY NT

DIST Grey County HWY 26 BOREHOLE TYPE CME-55/ Continuous Flight Hollow Stem Auger COMPILED BY NT

DATUM TBM (225.7 m) DATE 2017.03.20 - 2017.03.20 LATITUDE 44.5905279088889 LONGITUDE -80.5670612725 CHECKED BY SM

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 226.5 | Road Surface | | | | | |
| 226.4 / 0.0 | **ASPHALT:** (~152 mm thick) | | | | | |
| 0.2 | **FILL: SAND AND GRAVEL:** trace clay, trace silt, trace asphalt, brown, dry to moist, dense to very dense | 1 | SS | 70 | | |
| | | 2 | SS | 43 | | 32 51 (17) |
| 225.0 / 1.5 | **FILL: CLAYEY SANDY SILT:** trace to some gravel, brown, moist, loose | 3 | SS | 7 | | |
| 224.2 / 2.3 | **CLAYEY SILT WITH SAND:** trace gravel, trace organics, brown, moist, stiff | 4 | SS | 10 | | |
| 223.5 / 3.0 | **GRAVELLY SAND TO SAND AND GRAVEL:** trace to some silt, trace to few clay, brown to greyish brown, moist to wet, loose to very dense | 5 | SS | 9 | | wet spoon @ 3.05 m |
| | | 6 | SS | 100/ 150 mm | | |
| | | 7 | SS | 43 | | 38 50 (12) |
| | | | | | ▽ (approx. 219.0) | |
| | | 8 | SS | 45 | | |
| 217.4 / 9.1 | **SANDY SILT:** trace to some clay, trace gravel, grey, wet, compact to very dense | 9 | SS | 100/ 125 mm | | |
| | | 10 | SS | 27 | | 6 26 59 9 |

Elevation scale: 226, 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

Exp Services Inc.
Brampton, Ontario



# RECORD OF BOREHOLE No BH-2



**METRIC**

W.P. ______ LOCATION Hwy 26, Meaford, MTM ON10 N, E ORIGINATED BY NT

DIST Grey County HWY 26 BOREHOLE TYPE CME-55/ Continuous Flight Hollow Stem Auger COMPILED BY NT

DATUM TBM (225.7 m) DATE 2017.03.20 - 2017.03.20 LATITUDE 44.5905279088889 LONGITUDE -80.5670612725 CHECKED BY SM

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | W (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 214.3 | | | | | | | | | | | |
| 12.2 | **TILL: CLAYEY SILT:** trace to some sand, trace gravel, grey, moist, very stiff | 11 | SS | 21 | | 214 | | 4 | 30 | 49 | 17 |
| | | | | | | 213 | | | | | |
| | | 12 | SS | 17 | | | | | | | |
| | | | | | | 212 | | | | | |
| 211.1 | | 13 | SS | 110/ 125 mm | | | | | | | |
| 15.4 | **End of Borehole at 15.4 m depth.** | | | | | | | | | | |

Notes:
1. This log is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured at 7.62 m below ground surface upon completion of drilling.
3. Borehole open upto 9.14 m below ground surface

Legend: SOIL PROFILE; SAMPLES; STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

# RECORD OF BOREHOLE No BH-3



**METRIC**

W.P. ______ LOCATION Hwy 26, Meaford, MTM ON10 N, E ORIGINATED BY NT

DIST Grey County HWY 26 BOREHOLE TYPE CME-55/ Continuous Flight Hollow Stem Auger COMPILED BY NT

DATUM TBM (225.7 m) DATE 2017.03.20 - 2017.03.20 LATITUDE 44.5906241719444 LONGITUDE -80.5673539713889 CHECKED BY SM

| ELEV DEPTH | SOIL PROFILE DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 226.6 | Road Surface | | | | | |
| 226.6 / 0.0 | **ASPHALT:** (~152 mm thick) | | | | | |
| 0.2 | **FILL: SAND AND GRAVEL:** trace silt, trace asphalt, brown, dry to moist, very dense | 1 | SS | 66 | | 41 45 (14) |
| 225.8 / 0.8 | **FILL: CLAYEY SANDY SILT:** trace to some gravel, brown, moist, dense | 2 | SS | 32 | | |
| 225.1 / 1.5 | **CLAYEY SILT WITH SAND:** trace gravel, trace organics, brown to brownish black, moist, firm to stiff | 3 | SS | 11 | | |
| | | 4 | SS | 5 | | 6 29 43 22 |
| 223.6 / 3.0 | **GRAVELLY SAND TO SAND AND GRAVEL:** trace to some silt, trace to few clay, brown to grey, moist to wet, compact to very dense | 5 | SS | 16 | | Wet Spoon @ 3.35 m |
| | | 6 | SS | 46 | | 38 50 (12) |
| | | | | | ∇ (approx. elev. 220.5) | |
| | | 7 | SS | 46 | | |
| | - Auger grinding, encountered cobbles in tip | 8 | SS | 100/ 125 mm | | |
| | | 9 | SS | 34 | | |
| | | 10 | SS | 100/ 100 mm | | |
| | | 11 | SS | 41 | | 35 38 (27) |

Chart columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); ELEVATION SCALE 226 – 215; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$, WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³.

Continued Next Page

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

# RECORD OF BOREHOLE No BH-3



**METRIC**

| | | | |
|---|---|---|---|
| W.P. | | LOCATION | Hwy 26, Meaford, MTM ON10 N, E |
| DIST | Grey County HWY 26 | BOREHOLE TYPE | CME-55/ Continuous Flight Hollow Stem Auger |
| DATUM | TBM (225.7 m) | DATE | 2017.03.20 - 2017.03.20 |
| LATITUDE | 44.5906241719444 | LONGITUDE | -80.567353971 |
| ORIGINATED BY | NT | COMPILED BY | NT |
| CHECKED BY | SM | | |

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 20 40 60 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 214.6<br>12.0 | **End of Borehole**<br>**Borehole terminated @ 12.04 m due to auger teeth broken and difficult in passing dense sand and gravel layer.**<br><br>**Notes:**<br>**1. This log is to be read with the subject report and project numbers as presented above.**<br>**2. Groundwater level was measured at 6.1 m below ground surface upon completion of drilling.**<br>**3. Borehole open upto 9.14 m below ground surface** | | | | | | | | | | |

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

# RECORD OF BOREHOLE No BH-4

 **METRIC**

W.P. ______ LOCATION Hwy 26, Meaford, MTM ON10 N, E ORIGINATED BY NT
DIST Grey County HWY 26 BOREHOLE TYPE CME-55/ Continuous Flight Hollow Stem Auger COMPILED BY NT
DATUM TBM (225.7 m) DATE 2017.03.21 - 2017.03.21 LATITUDE 44.5905218155556 LONGITUDE -80.5671354694444 CHECKED BY SM

| ELEV / DEPTH (m) | SOIL PROFILE – DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 226.5 | Road Surface | | | | | |
| 226.4 / 0.0 | **ASPHALT:** (~152 mm thick) | | | | | |
| 0.2 | **FILL: SAND AND GRAVEL:** trace silt, trace asphalt, brown, dry to moist, very dense | 1 | SS | 78 | | |
| 225.7 / 0.8 | **FILL: CLAYEY SANDY SILT:** trace gravel, brown, moist, loose to dense | 2 | SS | 30 | | |
| | | 3 | SS | 6 | | |
| 224.2 / 2.3 | **GRAVELLY SAND TO SAND AND GRAVEL:** trace to some silt, trace to few clay, brown to grey, moist to wet, loose to very dense | 4 | SS | 9 | | 37 40 (23) |
| | | 5 | SS | 17 | | Wet Spoon @ 3.65 m |
| | | 6 | SS | 43 | | |
| | -No recovery, possible cobbles | 7 | SS | 100/ 125 mm | ▽ (approx. 220.5) | |
| | | 8 | SS | 43 | | |
| 217.4 / 9.1 | **SANDY SILT:** trace to some clay, trace gravel, brown to grey, wet, dense to very dense | 9 | SS | 96 | | |
| | | 10 | SS | 39 | | 7 22 55 16 |

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $W_L$; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³
ELEVATION SCALE: 226, 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215

Continued Next Page

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

# RECORD OF BOREHOLE No BH-4

 **METRIC**

| | | | |
|---|---|---|---|
| W.P. | | LOCATION | Hwy 26, Meaford, MTM ON10 N, E |
| ORIGINATED BY | NT | | |
| DIST | Grey County HWY 26 | BOREHOLE TYPE | CME-55/ Continuous Flight Hollow Stem Auger |
| COMPILED BY | NT | | |
| DATUM | TBM (225.7 m) | DATE | 2017.03.21 - 2017.03.21 |
| LATITUDE | 44.5905218155556 | LONGITUDE | -80.5671354694444 |
| CHECKED BY | SM | | |

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 214.3 / 12.2 | **TILL: CLAYEY SILT:** trace to some sand, trace gravel, trace shale fragments, grey, moist to dry, very stiff to hard | 11 | SS | 22 | 214 | |
| | | | | | 213 | |
| | | 12 | SS | 30 | | 4 9 59 28 |
| | | | | | 212 | |
| | - some shale fragments | 13 | SS | 23 | 211 | |
| | | | | | 210 | |
| | - some shale fragments | 14 | SS | 115 | | 4 12 57 28 |
| 209.1 / 17.4 | **End of Borehole at 17.37 m depth.** | | | | | |

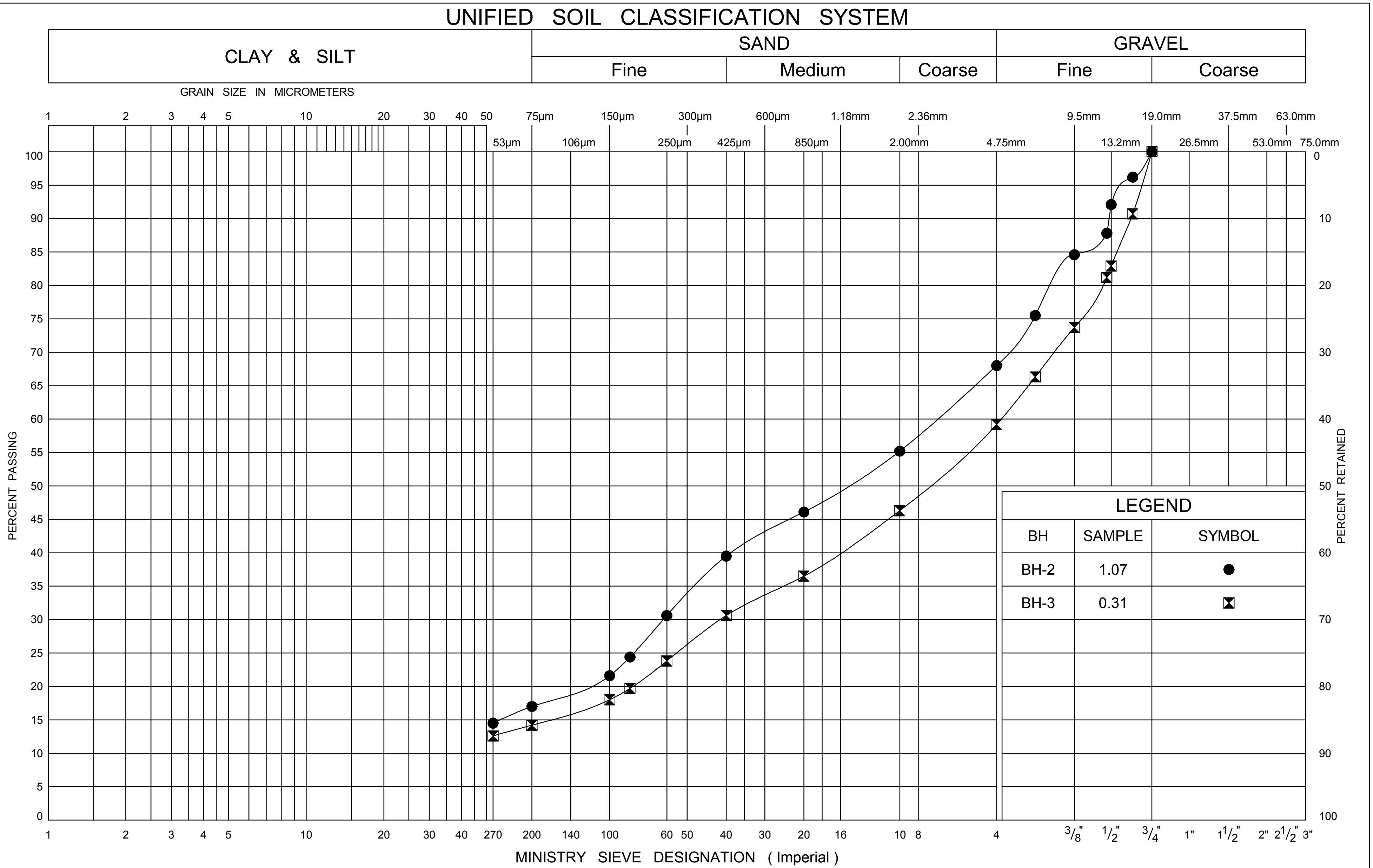
Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$, WATER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

Notes:
1. This log is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured at 6.1 m below ground surface upon completion of drilling.
3. Borehole open upto 7.62 m below ground surface

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

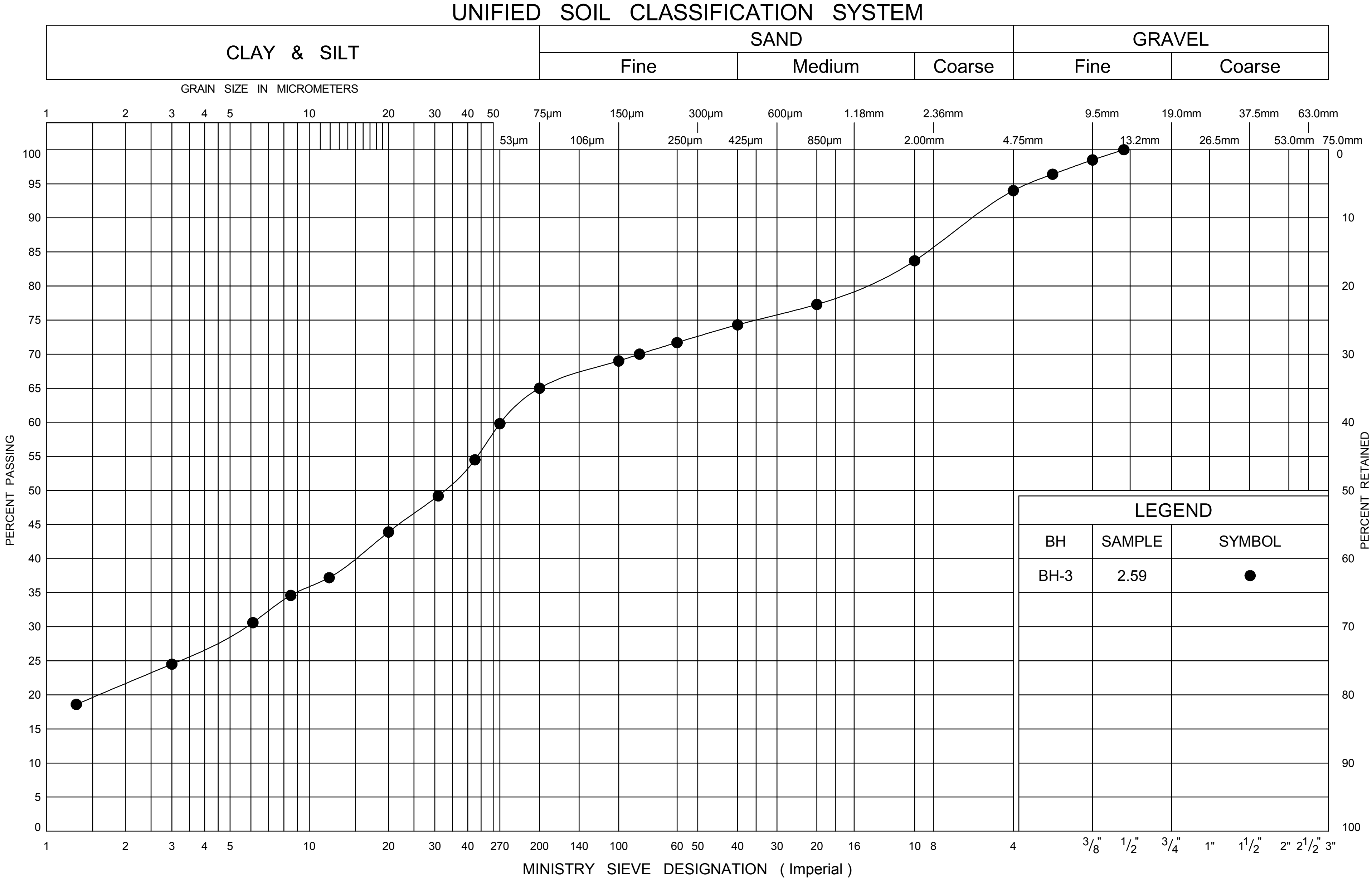
# Appendix D –
# Laboratory Data

78 12 M




| Ministry of Transportation Ontario | GRAIN SIZE DISTRIBUTION | FIG No 1 |
|---|---|---|
| | | W P |
| | | 3015-E-0017, Assignment 4 |

78 12 M




## LEGEND

| BH | SAMPLE | SYMBOL |
|---|---|---|
| BH-3 | 2.59 | ● |

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# GRAIN SIZE DISTRIBUTION

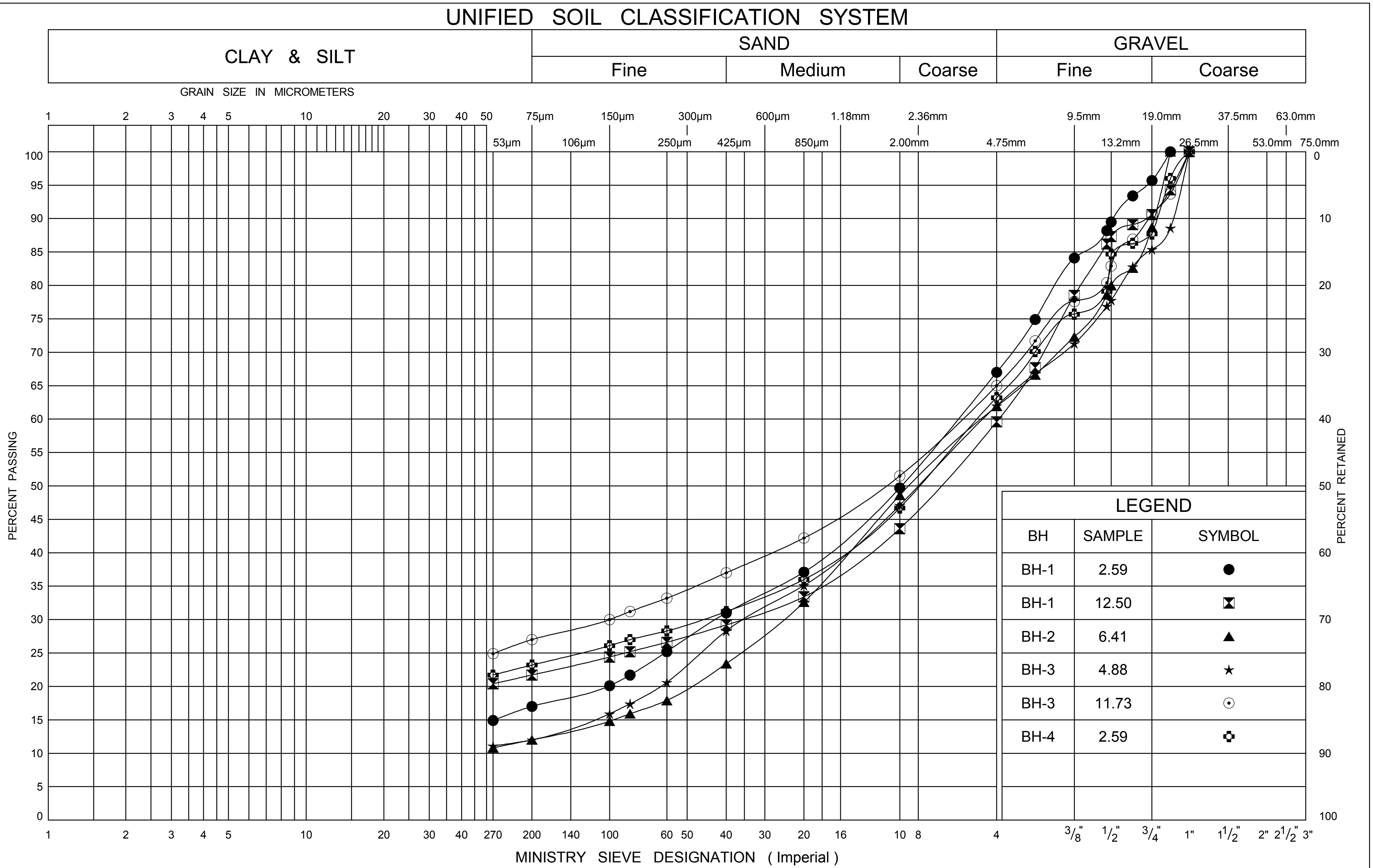
FIG No 2

W P

3015-E-0017, Assignment 4

ONTARIO MOT GRAIN SIZE ADM-00235197-D0 - HWY 26 CULVERT.GPJ ONTARIO MOT.GDT 3/29/17

78 12 M

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# GRAIN SIZE DISTRIBUTION

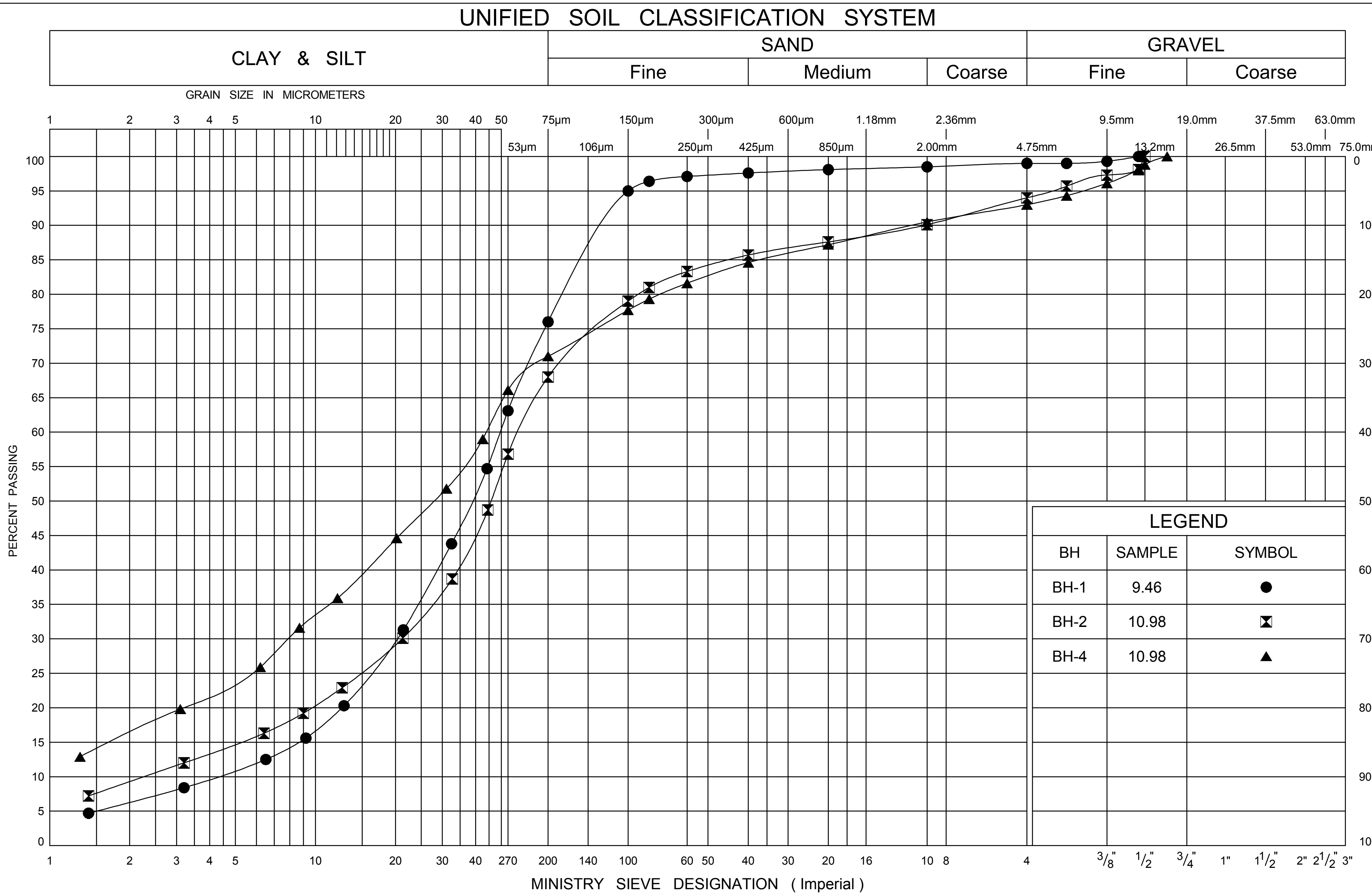
FIG No 3

W P

3015-E-0017, Assignment 4

ONTARIO MOT GRAIN SIZE ADM-00235197-D0 - HWY 26 CULVERT.GPJ ONTARIO MOT.GDT 3/29/17

78 12 M




| BH | SAMPLE | SYMBOL |
|---|---|---|
| BH-1 | 9.46 | ● |
| BH-2 | 10.98 | ⧗ |
| BH-4 | 10.98 | ▲ |

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# GRAIN SIZE DISTRIBUTION

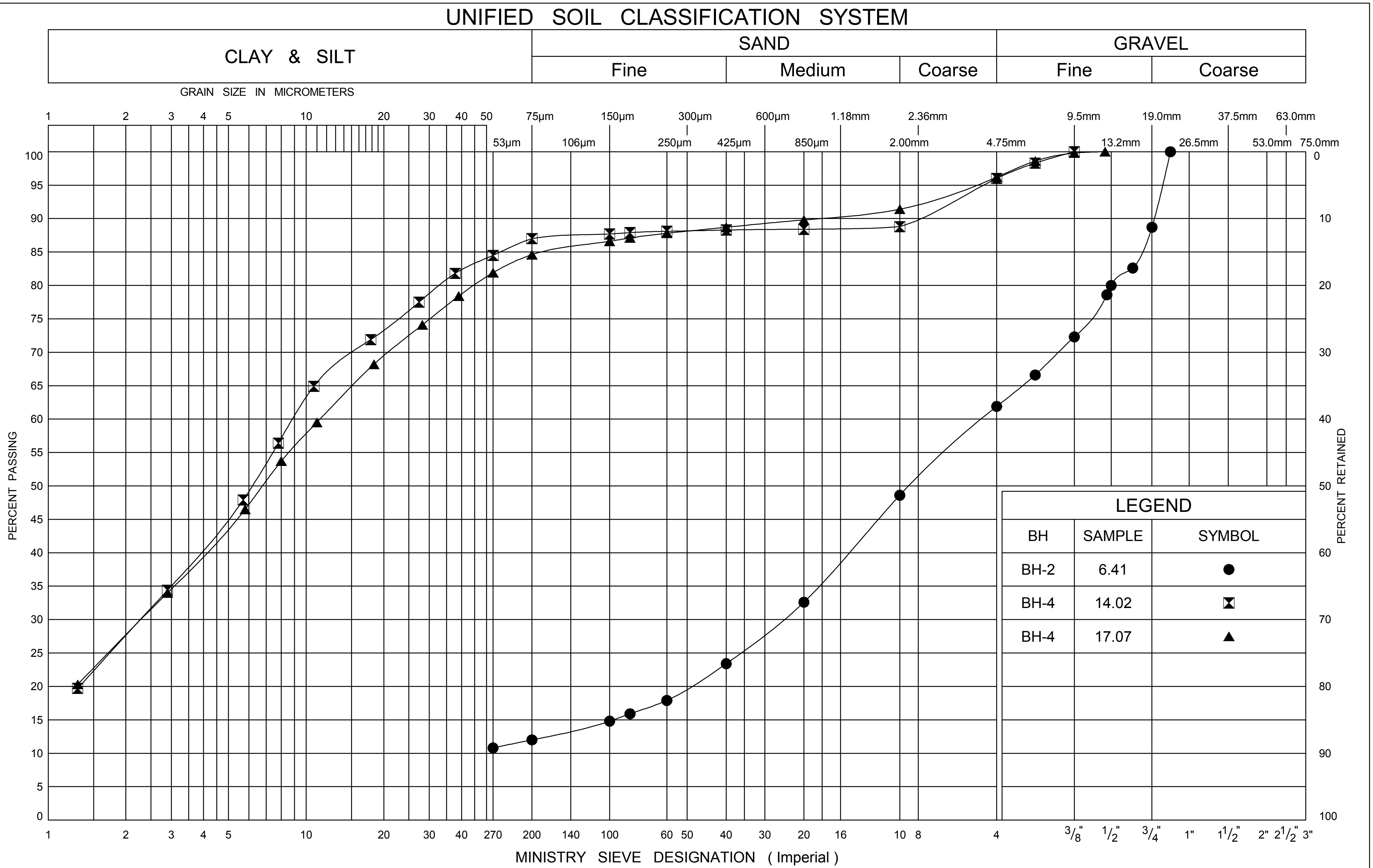
FIG No 4

W P

3015-E-0017, Assignment 4

ONTARIO MOT GRAIN SIZE ADM-00235197-D0 - HWY 26 CULVERT.GPJ ONTARIO MOT.GDT 3/29/17

78 12 M

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# GRAIN SIZE DISTRIBUTION

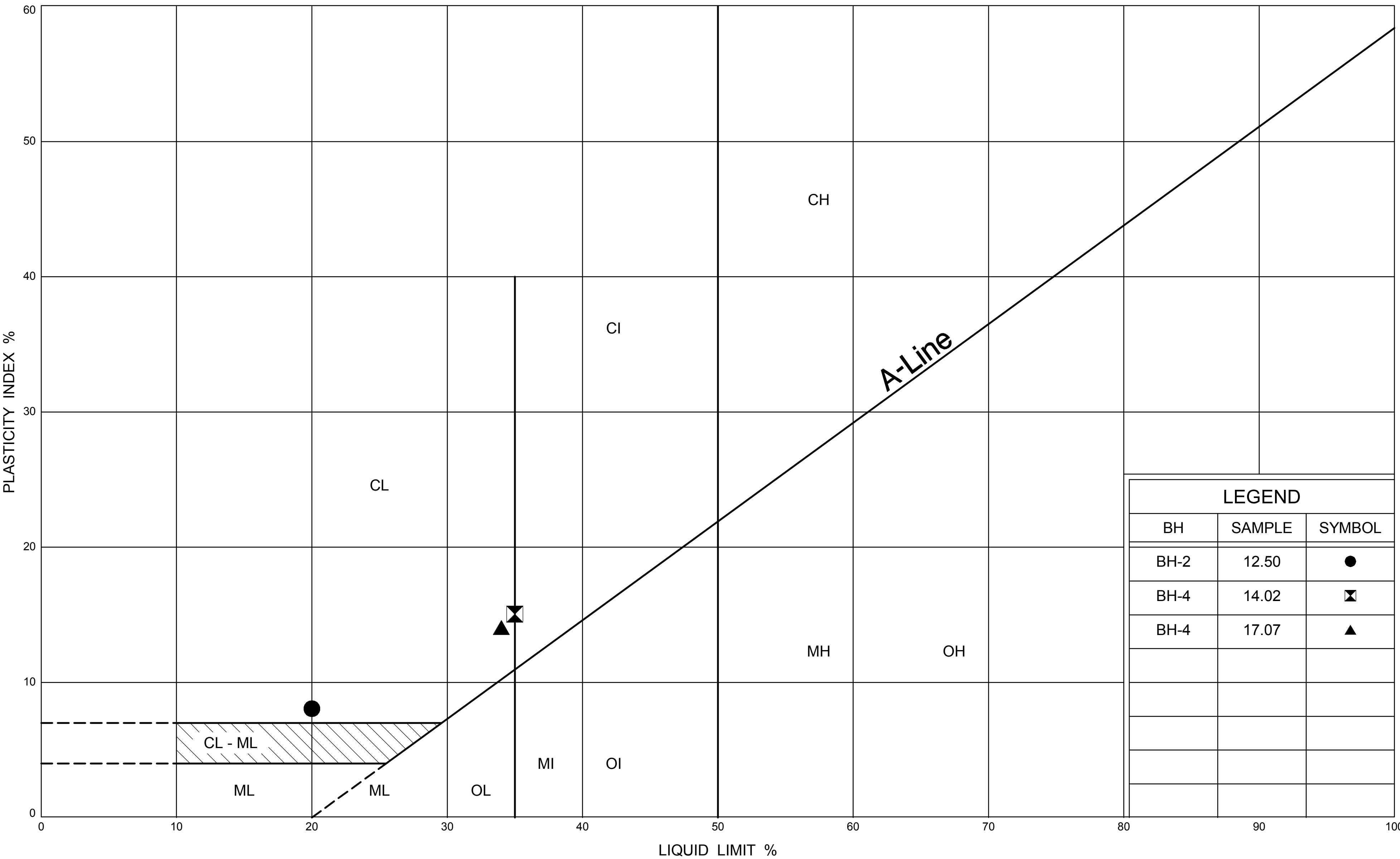
FIG No 5

W P

3015-E-0017, Assignment 4

ONTARIO MOT GRAIN SIZE ADM-00235197-D0 - HWY 26 CULVERT.GPJ ONTARIO MOT.GDT 3/29/17

Oct 75, FF - S - 21




| LEGEND | | |
|---|---|---|
| BH | SAMPLE | SYMBOL |
| BH-2 | 12.50 | ● |
| BH-4 | 14.02 | ⧗ |
| BH-4 | 17.07 | ▲ |

ONTARIO MOT PLASTICITY CHART ADM-00235197-D0 - HWY 26 CULVERT.GPJ ONTARIO MOT.GDT 3/29/17

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Ontario

# PLASTICITY CHART

FIG No 6

W P

3015-E-0017, Assignment 4

# Appendix E – Chemical Analyses

Your P.O. #: BRM-GEO
Your Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your C.O.C. #: 74957

**Attention:Nimesh Tamrakar**

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

**Report Date: 2017/03/29**
Report #: R4406390
Version: 1 - Final

# CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B757064**
**Received: 2017/03/22, 12:07**

Sample Matrix: Soil
# Samples Received: 1

| Analyses | Quantity | Date Extracted | Date Analyzed | Laboratory Method | Reference |
|---|---|---|---|---|---|
| Chloride (20:1 extract) | 1 | N/A | 2017/03/27 | CAM SOP-00463 | EPA 325.2 m |
| Conductivity | 1 | N/A | 2017/03/28 | CAM SOP-00414 | OMOE E3530 v1 m |
| pH CaCl2 EXTRACT | 1 | 2017/03/27 | 2017/03/27 | CAM SOP-00413 | EPA 9045 D m |
| Resistivity of Soil | 1 | 2017/03/22 | 2017/03/28 | CAM SOP-00414 | SM 22 2510 m |
| Sulphate (20:1 Extract) | 1 | N/A | 2017/03/27 | CAM SOP-00464 | EPA 375.4 m |
| Oxidation-Reduction Potential (1, 2) | 1 | 2017/03/23 | 2017/03/27 | SLA SOP-00101 | In house |

**Remarks:**

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

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

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Maxxam Sladeview Petrochemical
(2) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.


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

Your P.O. #: BRM-GEO
Your Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your C.O.C. #: 74957

**Attention:Nimesh Tamrakar**

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

**Report Date: 2017/03/29**
Report #: R4406390
Version: 1 - Final

# CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B757064**
**Received: 2017/03/22, 12:07**

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Deepthi Shaji, Project Manager
Email: dshaji@maxxam.ca
Phone# (905)817-5700 Ext:5807
====================================================================
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B757064
Report Date: 2017/03/29

exp Services Inc
Client Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your P.O. #: BRM-GEO
Sampler Initials: NI

## SOIL CORROSIVITY PACKAGE (SOIL)

| Maxxam ID | | ECC331 | ECC331 | | |
|---|---|---|---|---|---|
| Sampling Date | | 2017/03/22 09:30 | 2017/03/22 09:30 | | |
| COC Number | | 74957 | 74957 | | |
| | **UNITS** | **BH2-SS3** | **BH2-SS3 Lab-Dup** | **RDL** | **QC Batch** |
| **Calculated Parameters** | | | | | |
| Resistivity | ohm-cm | 320 | | | 4909607 |
| **Inorganics** | | | | | |
| Soluble (20:1) Chloride (Cl) | ug/g | 1700 | | 80 | 4912955 |
| Conductivity | umho/cm | 3170 | 3160 | 2 | 4915103 |
| Available (CaCl2) pH | pH | 7.49 | | | 4912618 |
| Soluble (20:1) Sulphate (SO4) | ug/g | <20 | <20 | 20 | 4912948 |
| **Subcontracted Analysis** | | | | | |
| Oxidation-Reduction Potential | mV | +166 | +166 | | 4911744 |

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate



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Maxxam Job #: B757064
Report Date: 2017/03/29

exp Services Inc
Client Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your P.O. #: BRM-GEO
Sampler Initials: NI

## TEST SUMMARY

**Maxxam ID:** ECC331
**Sample ID:** BH2-SS3
**Matrix:** Soil

**Collected:** 2017/03/22
**Shipped:**
**Received:** 2017/03/22

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|---|---|---|---|---|---|
| Chloride (20:1 extract) | KONE/EC | 4912955 | N/A | 2017/03/27 | Deonarine Ramnarine |
| Conductivity | AT | 4915103 | N/A | 2017/03/28 | Neil Dassanayake |
| pH CaCl2 EXTRACT | AT | 4912618 | 2017/03/27 | 2017/03/27 | Tahir Anwar |
| Resistivity of Soil | | 4909607 | 2017/03/28 | 2017/03/28 | Automated Statchk |
| Sulphate (20:1 Extract) | KONE/EC | 4912948 | N/A | 2017/03/27 | Deonarine Ramnarine |
| Oxidation-Reduction Potential | PH | 4911744 | 2017/03/23 | 2017/03/27 | Grace Sison |

**Maxxam ID:** ECC331 Dup
**Sample ID:** BH2-SS3
**Matrix:** Soil

**Collected:** 2017/03/22
**Shipped:**
**Received:** 2017/03/22

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|---|---|---|---|---|---|
| Conductivity | AT | 4915103 | N/A | 2017/03/28 | Neil Dassanayake |
| Sulphate (20:1 Extract) | KONE/EC | 4912948 | N/A | 2017/03/27 | Deonarine Ramnarine |
| Oxidation-Reduction Potential | PH | 4911744 | 2017/03/23 | | Grace Sison |



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Maxxam Job #: B757064
Report Date: 2017/03/29

exp Services Inc
Client Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your P.O. #: BRM-GEO
Sampler Initials: NI

## GENERAL COMMENTS

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

| | |
|---|---|
| Package 1 | -2.3°C |

**Results relate only to the items tested.**

Maxxam Job #: B757064
Report Date: 2017/03/29

## QUALITY ASSURANCE REPORT

exp Services Inc
Client Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your P.O. #: BRM-GEO
Sampler Initials: NI

| | | | Matrix Spike | | SPIKED BLANK | | Method Blank | | RPD | | QC Standard | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QC Batch | Parameter | Date | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits | % Recovery | QC Limits |
| 4911744 | Oxidation-Reduction Potential | | | | | | +139 | mV | 0 | 20 | +243 | 238 - 248 |
| 4912618 | Available (CaCl2) pH | 2017/03/27 | | | 97 | 97 - 103 | | | 0.10 | N/A | | |
| 4912948 | Soluble (20:1) Sulphate (SO4) | 2017/03/27 | 121 | 70 - 130 | 113 | 70 - 130 | <20 | ug/g | NC | 35 | | |
| 4912955 | Soluble (20:1) Chloride (Cl) | 2017/03/27 | 120 | 70 - 130 | 103 | 70 - 130 | <20 | ug/g | NC | 35 | | |
| 4915103 | Conductivity | 2017/03/28 | | | 99 | 90 - 110 | <2 | umho/cm | 0.32 | 10 | | |

N/A = Not Applicable

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

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

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

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

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

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



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Maxxam Job #: B757064
Report Date: 2017/03/29

exp Services Inc
Client Project #: ADM-00235197-D0
Site Location: HWY 26, MEAFORD
Your P.O. #: BRM-GEO
Sampler Initials: NI

## VALIDATION SIGNATURE PAGE

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

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

Grace Sison, B.Sc., C.Chem, Senior Project Manager - Petroleum Division

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



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Your Project #: MB757064
Site Location: ADM 00235197-DO
Your C.O.C. #: B757064-M058-01-01

**Attention:SUB CONTRACTOR**

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

**Report Date: 2017/03/28**
Report #: R2362918
Version: 1 - Final

# CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B721661**
**Received: 2017/03/24, 09:00**

Sample Matrix: Soil
# Samples Received: 1

| Analyses | Quantity | Date Extracted | Date Analyzed | Laboratory Method | Analytical Method |
|---|---|---|---|---|---|
| Moisture | 1 | 2017/03/27 | 2017/03/28 | BBY8SOP-00017 | BCMOE BCLM Dec2000 m |
| Sulphide in Soil | 1 | 2017/03/27 | 2017/03/27 | BBY6SOP-00006 | SM 22 4500 S2- D m |

**Remarks:**

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

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Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Your Project #: MB757064
Site Location: ADM 00235197-DO
Your C.O.C. #: B757064-M058-01-01

**Attention:SUB CONTRACTOR**

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

**Report Date: 2017/03/28**
Report #: R2362918
Version: 1 - Final

# CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B721661**
**Received: 2017/03/24, 09:00**

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Amandeep Nagra, Account Specialist
Email: ANagra@maxxam.ca
Phone# (604)639-2602
====================================================================
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Maxxam Job #: B721661
Report Date: 2017/03/28

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

## RESULTS OF CHEMICAL ANALYSES OF SOIL

| **Maxxam ID** | | QT8048 | QT8048 | | |
|---|---|---|---|---|---|
| **Sampling Date** | | 2017/03/22 09:30 | 2017/03/22 09:30 | | |
| **COC Number** | | B757064-M058-01-01 | B757064-M058-01-01 | | |
| | **UNITS** | **BH2-SS3 (ECC331)** | **BH2-SS3 (ECC331) Lab-Dup** | **RDL** | **QC Batch** |
| **MISCELLANEOUS** | | | | | |
| Sulphide | ug/g | 0.94 (1) | 1.03 | 0.50 | 8588152 |

RDL = Reportable Detection Limit

Lab-Dup = Laboratory Initiated Duplicate

(1) Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.



Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B721661
Report Date: 2017/03/28

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

## PHYSICAL TESTING (SOIL)

| **Maxxam ID** | | QT8048 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2017/03/22 09:30 | | |
| **COC Number** | | B757064-M058-01-01 | | |
| | **UNITS** | **BH2-SS3 (ECC331)** | **RDL** | **QC Batch** |
| **Physical Properties** | | | | |
| Moisture | % | 14 | 0.30 | 8588204 |
| RDL = Reportable Detection Limit | | | | |


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Maxxam Job #: B721661
Report Date: 2017/03/28

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

## TEST SUMMARY

**Maxxam ID:** QT8048
**Sample ID:** BH2-SS3 (ECC331)
**Matrix:** Soil

**Collected:** 2017/03/22
**Shipped:**
**Received:** 2017/03/24

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|---|---|---|---|---|---|
| Moisture | BAL/BAL | 8588204 | 2017/03/27 | 2017/03/28 | Rommel Goda |
| Sulphide in Soil | SPEC/COL | 8588152 | 2017/03/27 | 2017/03/27 | Jamie Sun |

**Maxxam ID:** QT8048 Dup
**Sample ID:** BH2-SS3 (ECC331)
**Matrix:** Soil

**Collected:** 2017/03/22
**Shipped:**
**Received:** 2017/03/24

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|---|---|---|---|---|---|
| Sulphide in Soil | SPEC/COL | 8588152 | 2017/03/27 | 2017/03/27 | Jamie Sun |



Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B721661
Report Date: 2017/03/28

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

## GENERAL COMMENTS

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

| | |
|---|---|
| Package 1 | 1.7°C |

**Results relate only to the items tested.**



Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B721661
Report Date: 2017/03/28

## QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

| | | | Matrix Spike | | Spiked Blank | | Method Blank | | RPD | |
|---|---|---|---|---|---|---|---|---|---|---|
| QC Batch | Parameter | Date | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits |
| 8588152 | Sulphide | 2017/03/27 | 26 (1,2) | 75 - 125 | 112 | 75 - 125 | <0.50 | ug/g | 9.2 (3) | 30 |

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

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

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

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

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

(2) Matrix Spike Parent ID [QT8048-01]

(3) Duplicate Parent ID [QT8048-01]

Maxxam Job #: B721661
Report Date: 2017/03/28

MAXXAM ANALYTICS
Client Project #: MB757064
Site Location: ADM 00235197-DO
Sampler Initials: NI

## VALIDATION SIGNATURE PAGE

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

Andy Lu, Ph.D., P.Chem., Scientific Specialist

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Maxxam
A Bureau Veritas Group Company

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/2

# CHAIN OF CUSTODY RECORD 74957

Page ____ of ____

| Invoice Information | | Report Information (if differs from invoice) | | Project Information (where applicable) | |
|---|---|---|---|---|---|
| Company Name: | EXP services Inc. | Company Name: | EXP services Inc. | Quotation #: | |
| Contact Name: | Nimesh Tamrakar | Contact Name: | Nimesh Tamrakar | P.O. #/ AFE#: | GEO |
| Address: | 56 Queen St. E Suite#301 Brampton | Address: | | Project #: | ADM-00235197-DO |
| | | | | Site Location: | HWY 26, Meaford |
| Phone: | 905-796-3200 Fax: | Phone: | Fax: | Site #: | |
| Email: | nimesh.tamrakar@exp.com | Email: | | Sampled By: | Nimesh |

**Turnaround Time (TAT) Required**

- [ ] Regular TAT (5-7 days) Most analyses

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Rush TAT (Surcharges will be applied)
- [ ] 1 Day
- [ ] 2 Days
- [ ] 3-4 Days

Date Required:

Rush Confirmation #:

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

**Regulation 153**

- [ ] Table 1 - [ ] Res/Park - [ ] Med/ Fine
- [ ] Table 2 - [ ] Ind/Comm - [ ] Coarse
- [ ] Table 3 - [ ] Agri/ Other
- [ ] Table ____

FOR RSC (PLEASE CIRCLE) Y / N

**Other Regulations**

- [ ] CCME - [ ] Sanitary Sewer Bylaw
- [ ] MISA - [ ] Storm Sewer Bylaw
- [ ] PWQO Region
- [ ] Other (Specify)
- [ ] REG 558 (MIN. 3 DAY TAT REQUIRED)

Include Criteria on Certificate of Analysis: Y / N

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

**Analysis Requested** (REFER TO BACK OF COC)

| | SAMPLE IDENTIFICATION | DATE SAMPLED (YYYY/MM/DD) | TIME SAMPLED (HH:MM) | MATRIX | # OF CONTAINERS SUBMITTED | FIELD FILTERED (CIRCLE) Metals / Hg / CrVI | BTEX/ PHC F1 | PHCs F2 - F4 | VOCs | REG 153 METALS & INORGANICS | REG 153 ICPMS METALS | REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B) | corrosivity + sulphate | | | | | | | HOLD- DO NOT ANALYZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BH2-SS3 | 2017/03/22 | 9:30 | Soil | 2 | | | | | | | | ✓ | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | |

22-Mar-17 12:07
Deepthi Shaji
B757064
GK1 ENV-900

**LABORATORY USE ONLY**

| CUSTODY SEAL Y / N | | COOLER TEMPERATURES |
|---|---|---|
| Present | Intact | |
| N | N | -1, -4, -2 |

COOLING MEDIA PRESENT: (Y) / N

COMMENTS

| RELINQUISHED BY: (Signature/Print) | DATE: (YYYY/MM/DD) | TIME: (HH:MM) | RECEIVED BY: (Signature/Print) | DATE: (YYYY/MM/DD) | TIME: (HH:MM) |
|---|---|---|---|---|---|
| Nimesh Tamrakar | 2017/03/22 | 10:00 | PARAMJEET SINGH | 2017/03/22 | 12:07 |
| | | | | | |

MAXXAM JOB #

COC-1004 (10/14) - ENV. ENG.

White: Maxxam – Yellow: Client

# Appendix F –
# Slope Stability Analysis

Non-Structural Culvert Replacement on Hwy 26
East of Meaford, Grey Country
South Embankment (Inlet)
Drained Static Condtion

Name: Sand and Gravel Fill Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion': 0 kPa Phi': 32 °
Name: Clayey Sandy Silt Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 29 °
Name: Clayey Silt with Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 28 °
Name: Silty Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 28 °
Name: Gravelly Sand to Sand and Gravel Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 32 °
Name: Sandy Silt Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 30 °

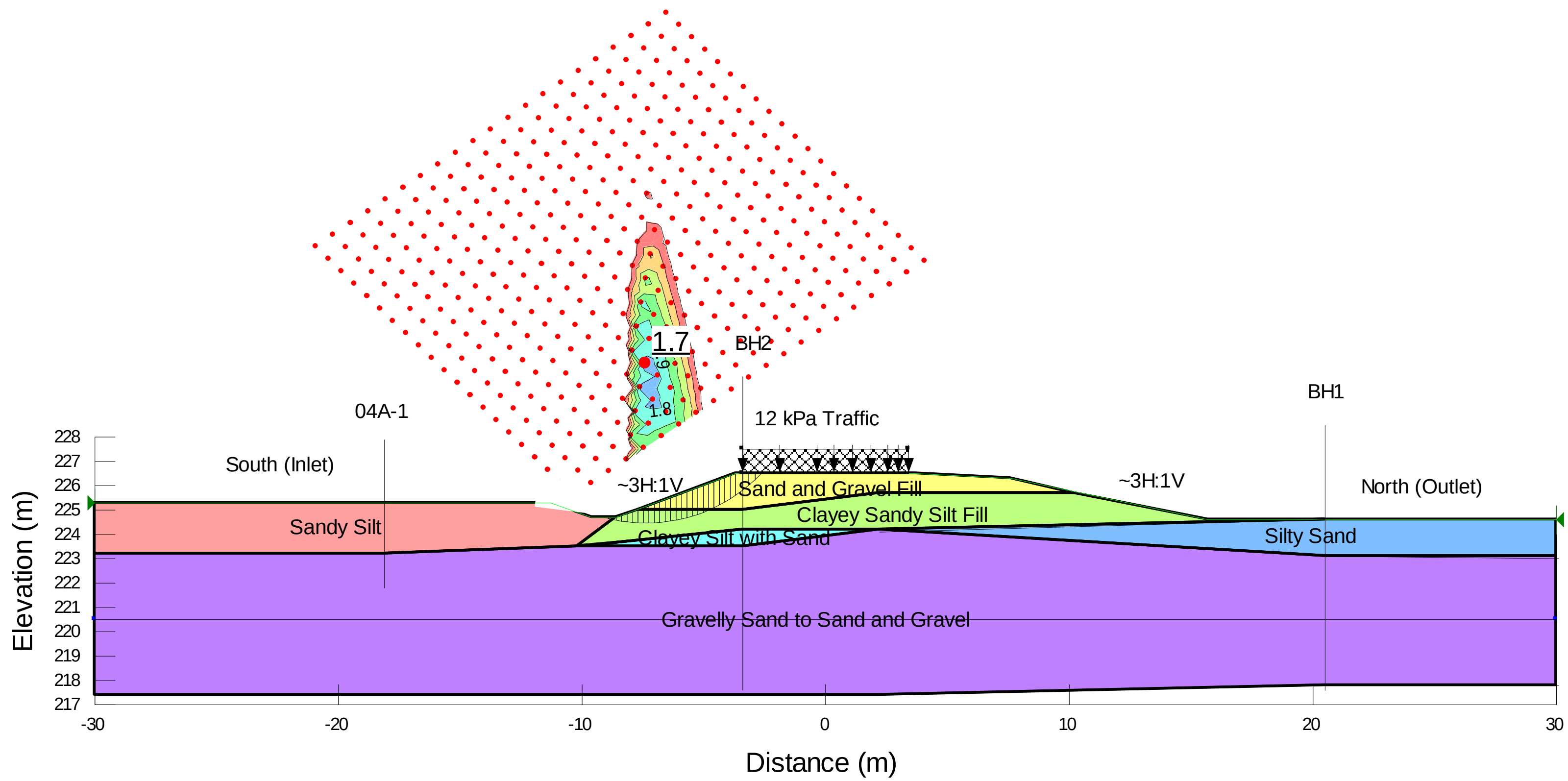



Figure 1: Slope stability analysis for existing embankment – drained static conditions

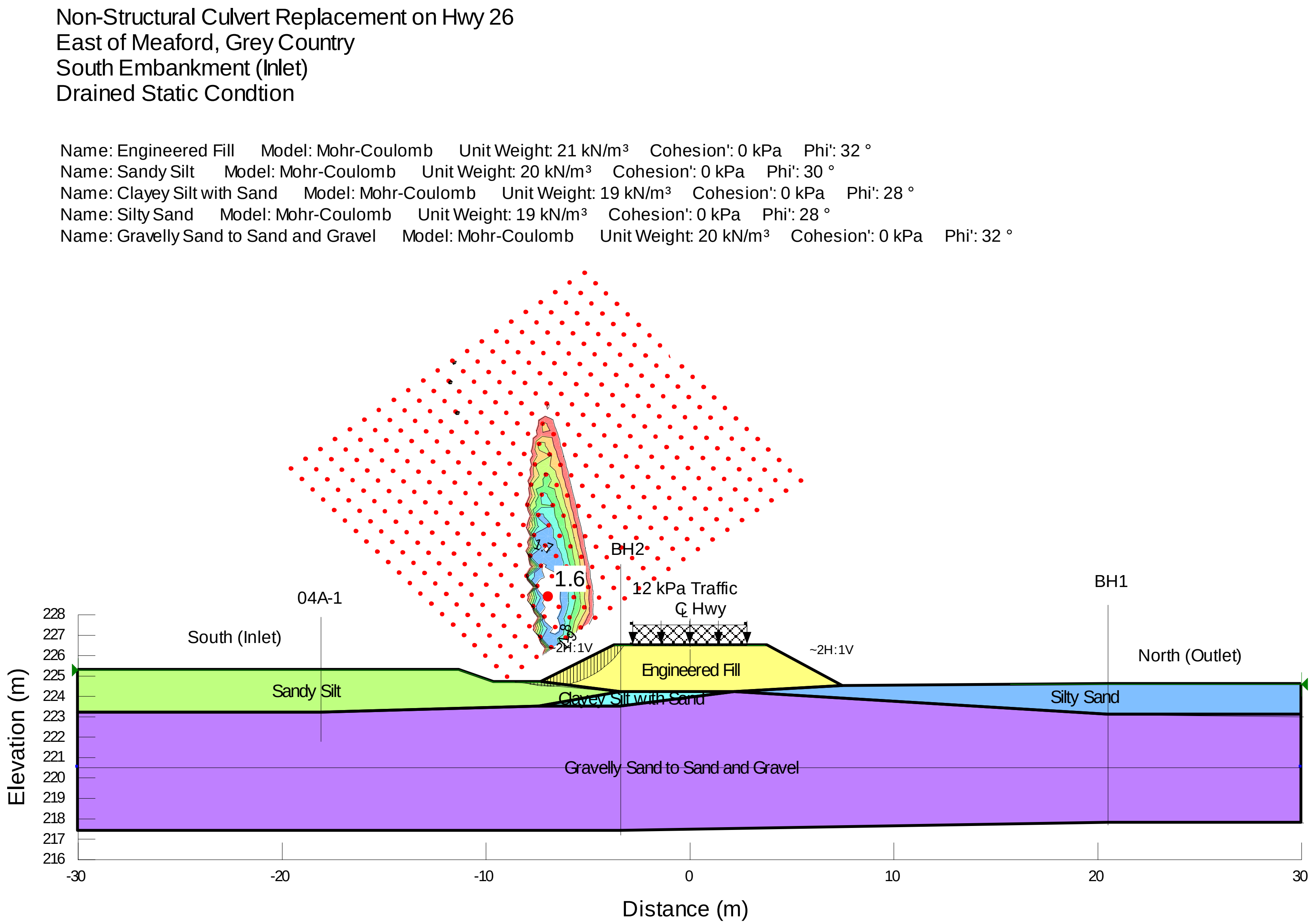
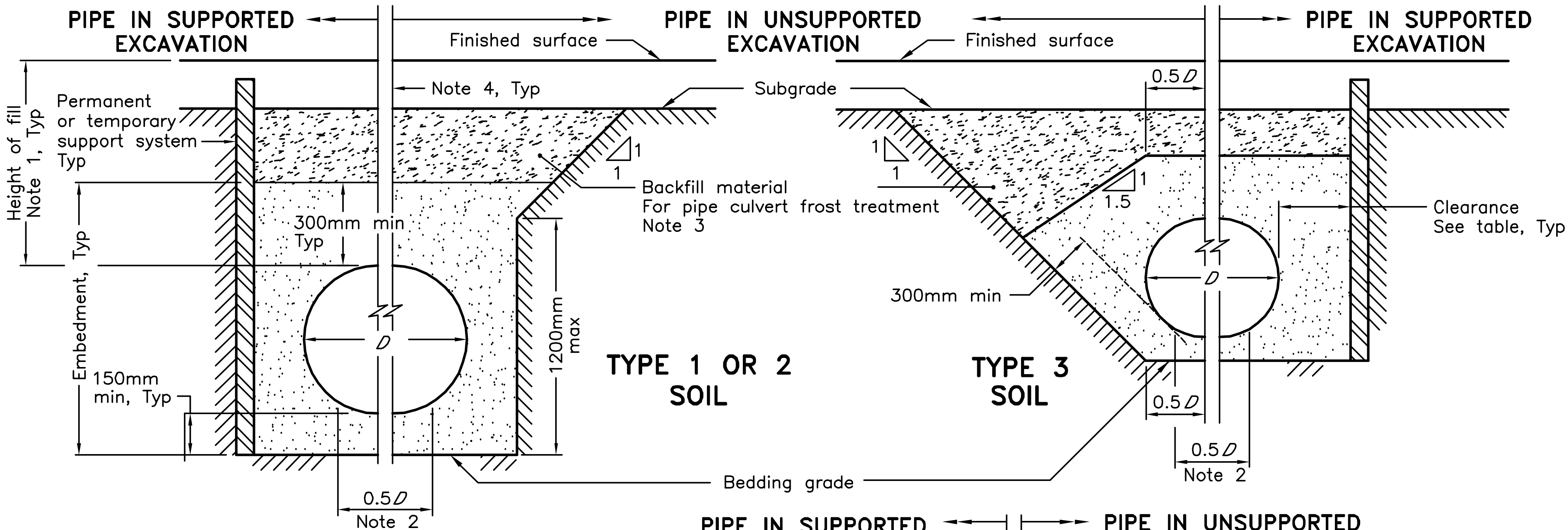
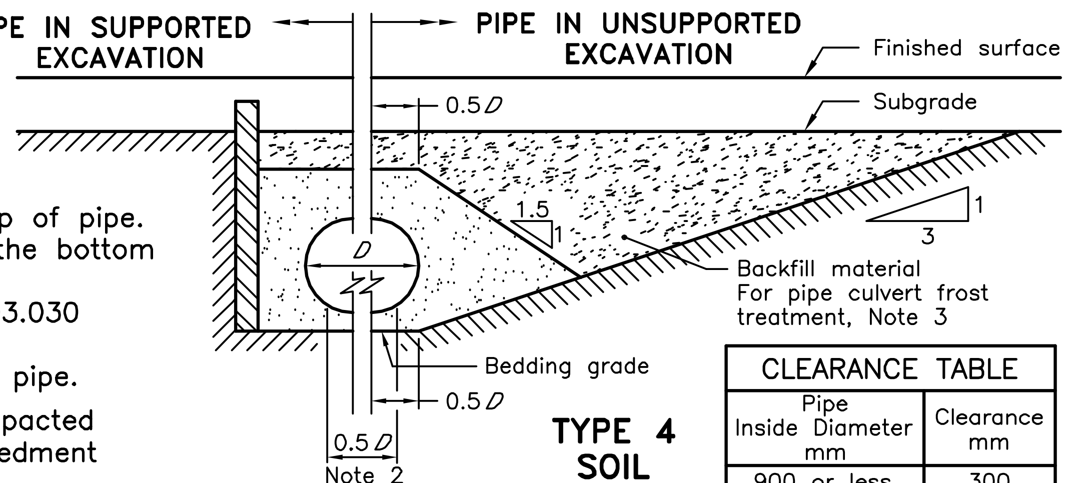



Figure 2: Slope stability analysis for embankment after culvert replacement with 2H:1V slope – drained static conditions

# Appendix G –
# Ontario Provincial Standard Drawings




LEGEND:

*D* – Inside diameter

NOTES:

1 Height of fill is measured from the finished surface to top of pipe.
2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
3 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
4 Condition of excavation is symmetrical about centreline of pipe.

A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.

B Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

C All dimensions are in metres unless otherwise shown.

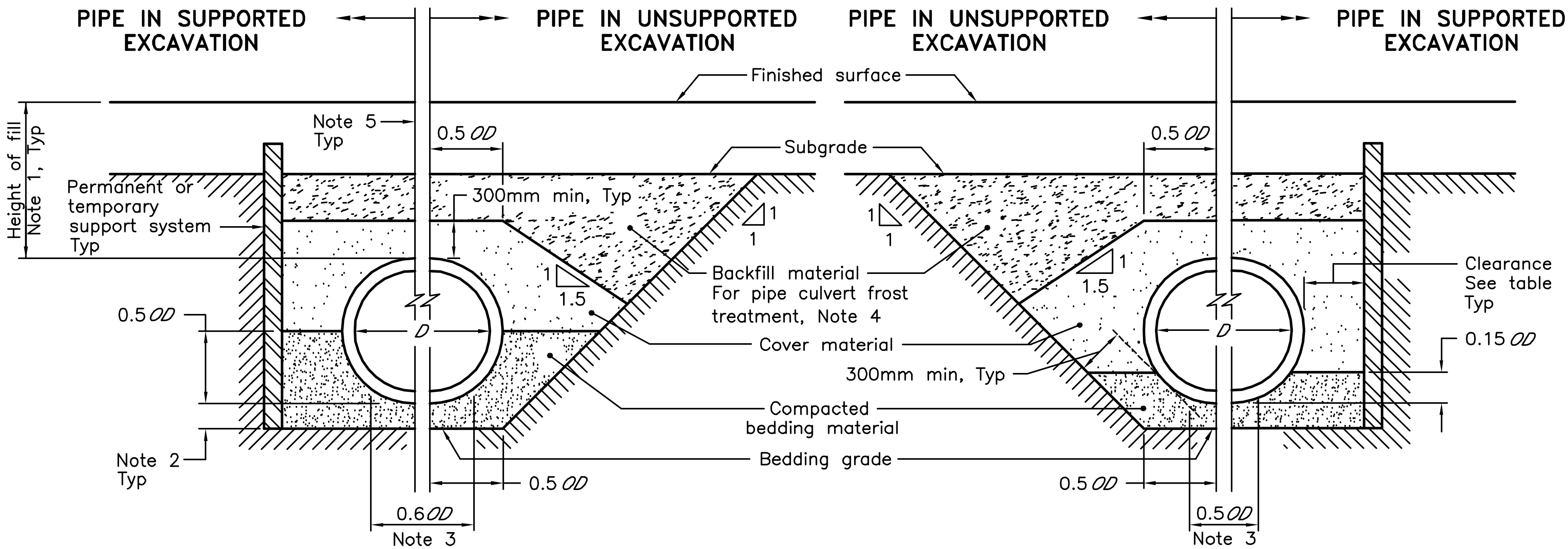
CLEARANCE TABLE

| Pipe Inside Diameter mm | Clearance mm |
|---|---|
| 900 or less | 300 |
| Over 900 | 500 |

ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 2

# FLEXIBLE PIPE EMBEDMENT AND BACKFILL EARTH EXCAVATION

OPSD 802.010




**CLASS B BEDDING** **CLASS C BEDDING**

NOTES:

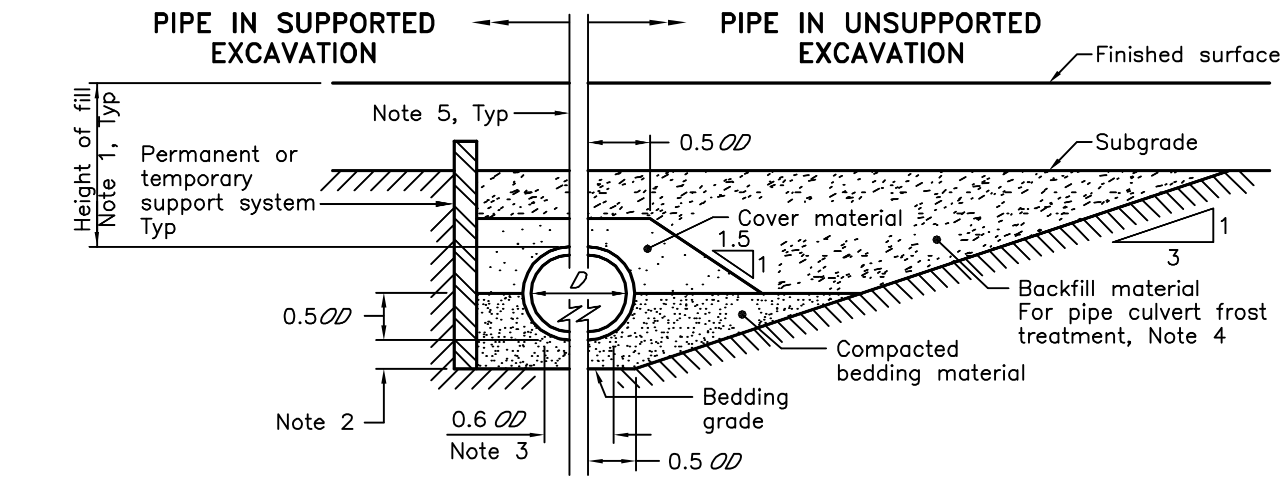
1 Height of fill is measured from the finished surface to top of pipe.
2 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.
3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
5 Condition of excavation is symmetrical about centreline of pipe.
A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
B All dimensions are in metres unless otherwise shown.

LEGEND:

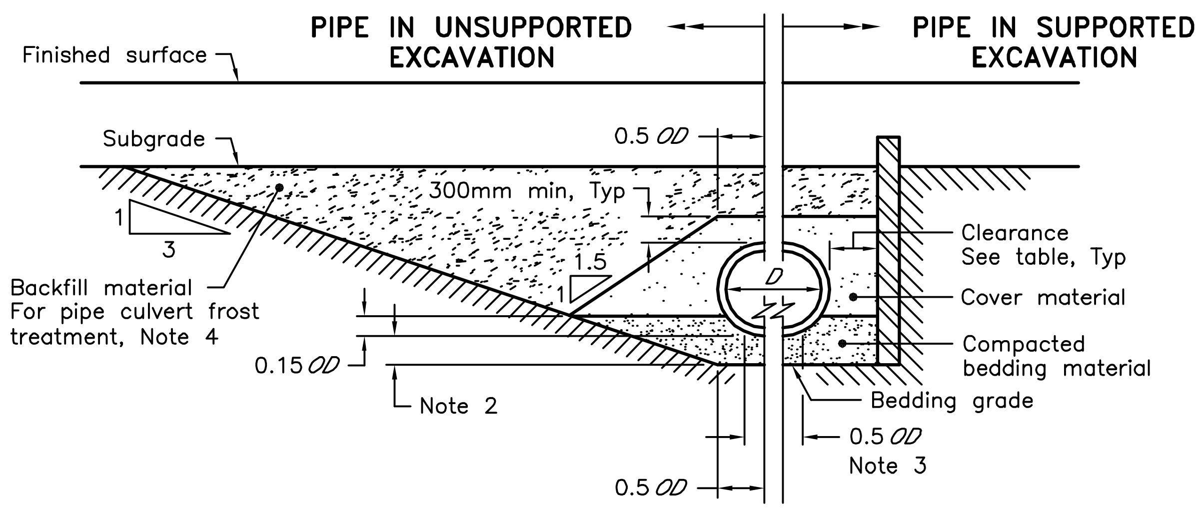
*D* – Inside diameter
*OD* – Outside diameter

| CLEARANCE TABLE | |
|---|---|
| Pipe Inside Diameter mm | Clearance mm |
| 900 or less | 300 |
| Over 900 | 500 |

| ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 2 |
|---|---|---|
| RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 3 SOIL – EARTH EXCAVATION | OPSD 802.031 | |




## CLASS B BEDDING




## CLASS C BEDDING

| CLEARANCE TABLE | |
|---|---|
| Pipe Inside Diameter mm | Clearance mm |
| 900 or less | 300 |
| Over 900 | 500 |

**LEGEND:**

*D* – Inside diameter

*OD* – Outside diameter

**NOTES:**

1 Height of fill is measured from the finished surface to top of pipe.

2 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.

3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.

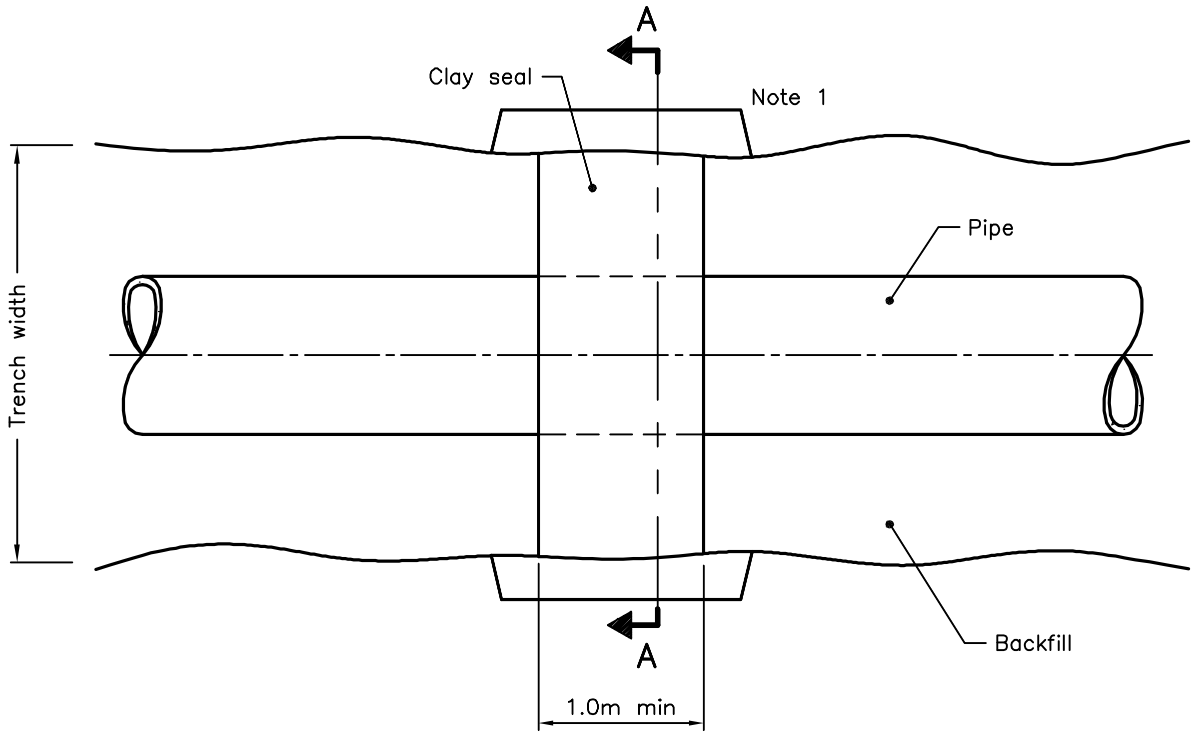
4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.

5 Condition of excavation is symmetrical about centreline of pipe.

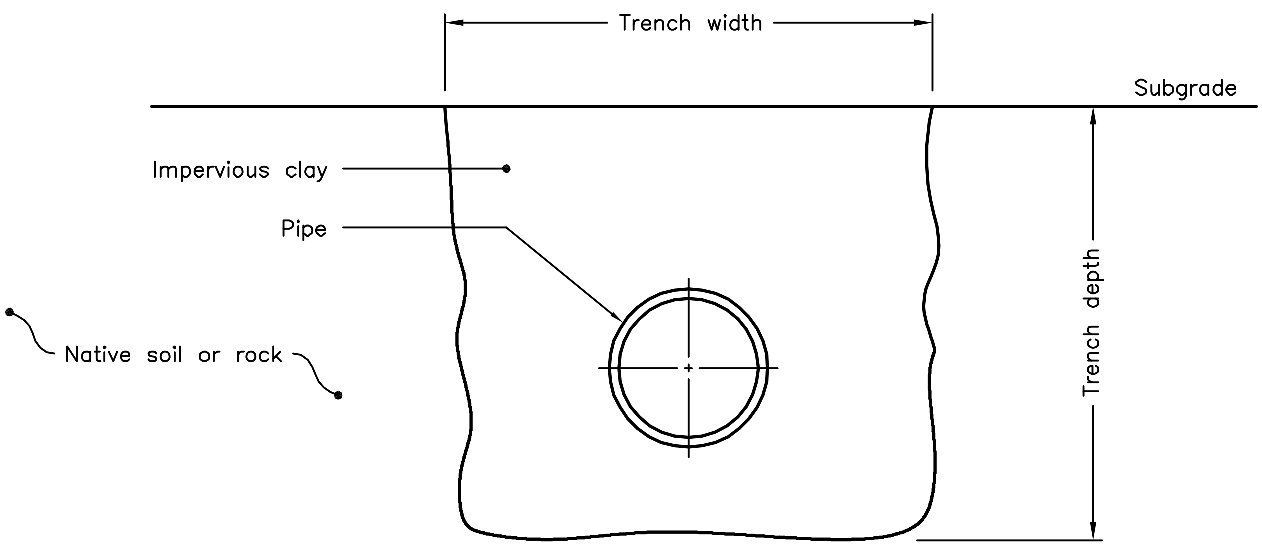
A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

B All dimensions are in metres unless otherwise shown.

| ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 2 |
|---|---|---|
| RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 4 SOIL – EARTH EXCAVATION | OPSD 802.032 | |




**PLAN**




**SECTION A–A**

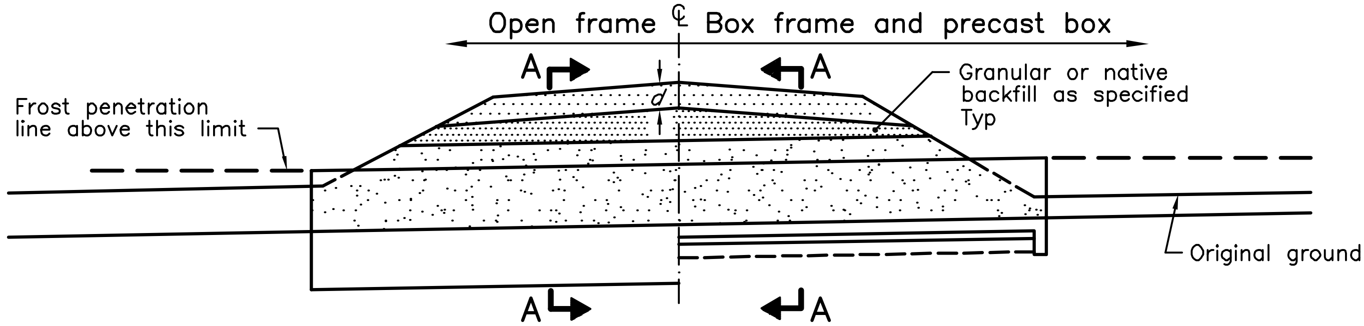
NOTES:

1. Key into undisturbed trench soil.

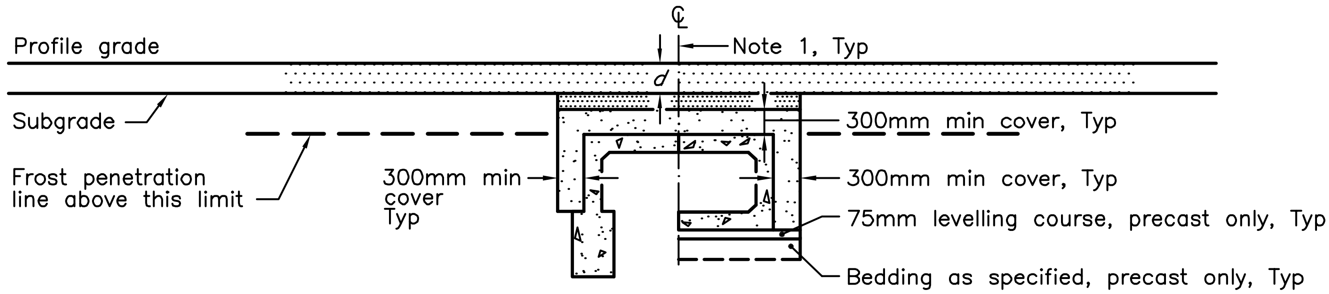
A Clay seal shall extend from bottom of trench excavation to the subgrade.
B Clay seal shall be located so that no pipe joints are within the clay seal material.
C All dimensions are in metres unless otherwise shown.

| ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2011 | Rev 1 |
|---|---|---|
| **CLAY SEAL FOR PIPE TRENCHES** | OPSD 802.095 | |

## FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT

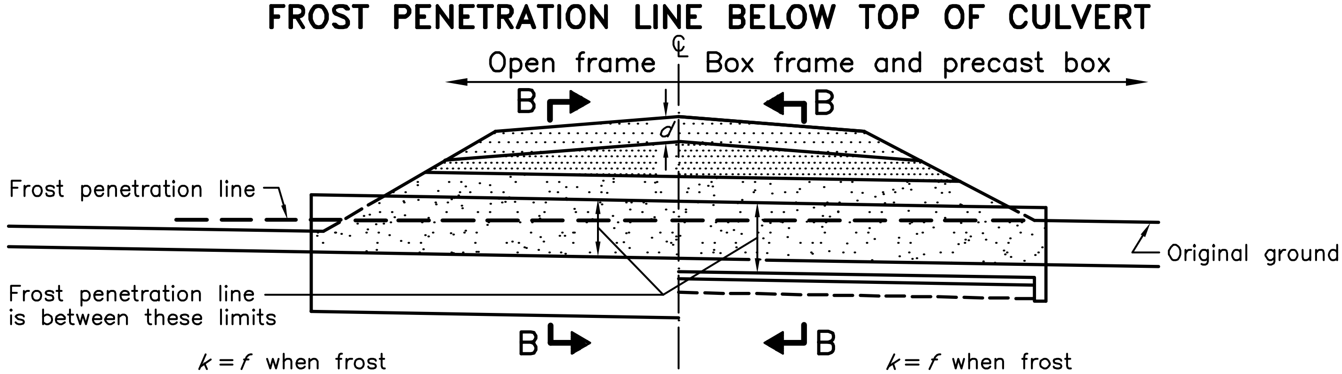



**LONGITUDINAL SECTION**

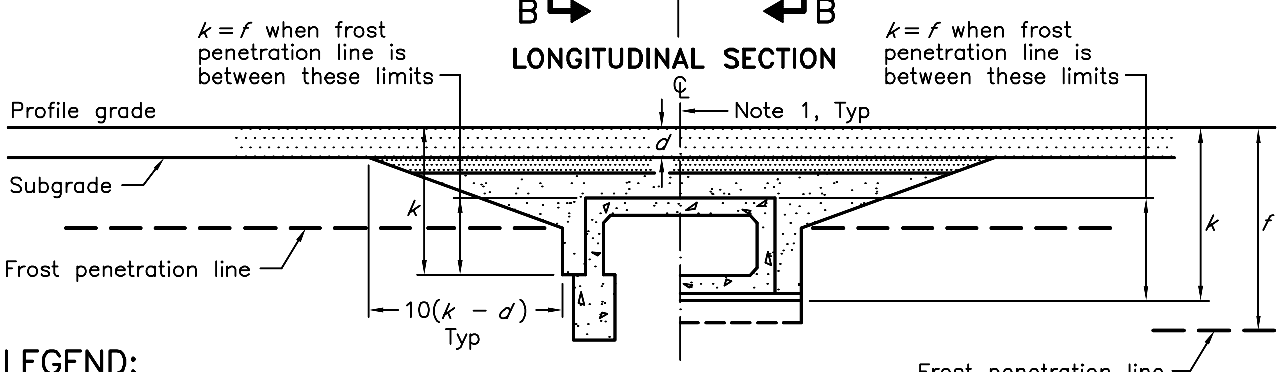



**SECTION A–A**

## FROST PENETRATION LINE BELOW TOP OF CULVERT




**LONGITUDINAL SECTION**




**SECTION B–B**

## LEGEND:

$d$ = depth of roadbed granular
$k$ = depth of frost treatment below profile grade
$f$ = depth of frost penetration below profile grade

## NOTES:

1 Condition of frost treatment symmetrical about centreline of culvert.

A Bedding, levelling, and cover material shall be granular as specified.

B The depth of roadbed granular shall be 600mm minimum.

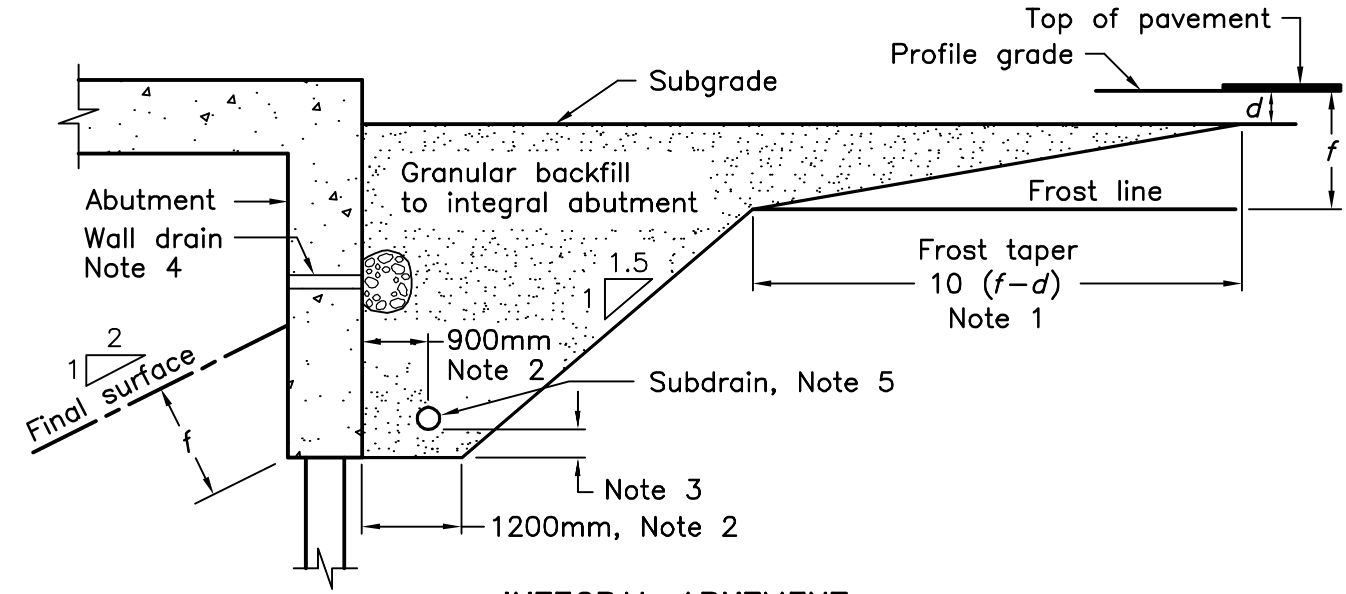
C The maximum depth of frost treatment shall be bottom of box frame or top of footing.

D All dimensions are in millimetres unless otherwise shown.

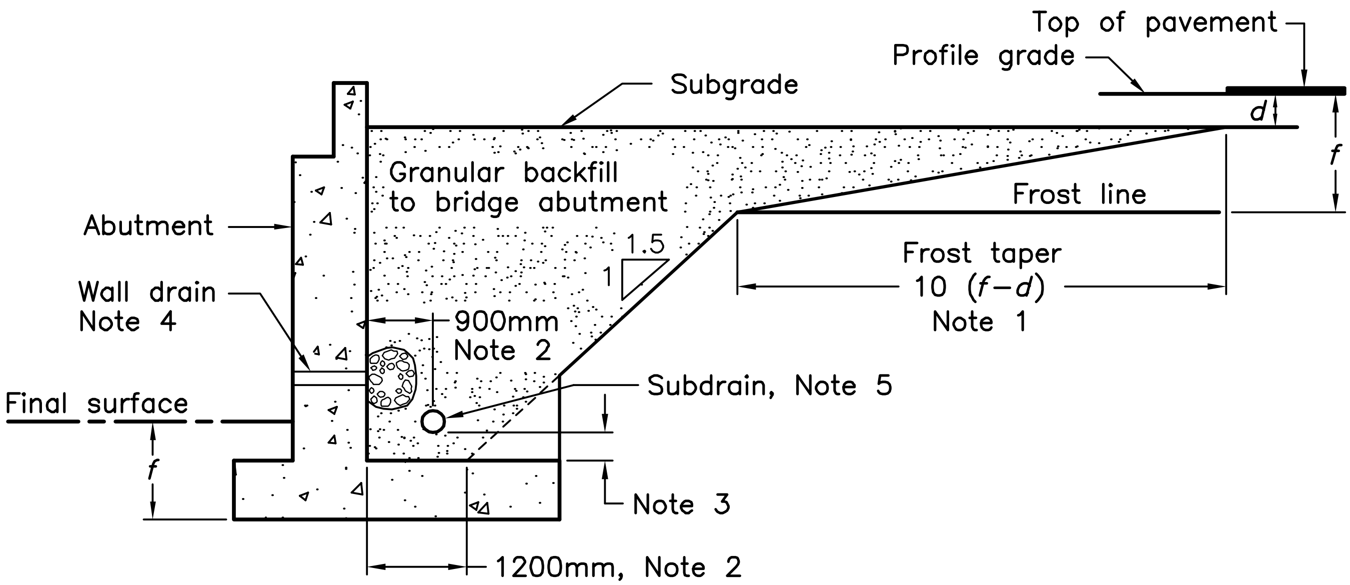
ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 2

# BACKFILL AND COVER FOR CONCRETE CULVERTS WITH SPANS LESS THAN OR EQUAL TO 3.0M

**OPSD 803.010**




**INTEGRAL ABUTMENT**




**ABUTMENT**

NOTES:

1 $d$ = depth of combined base and subbase courses
  $f$ = frost penetration depth as specified

2 Dimensions perpendicular to back face of abutment.

3 Height to be consistent with positive drainage of subdrain as specified.

4 Where specified, wall drains shall be installed according to OPSD 3190.100.

5 150mm dia perforated pipe subdrain wrapped with geotextile.

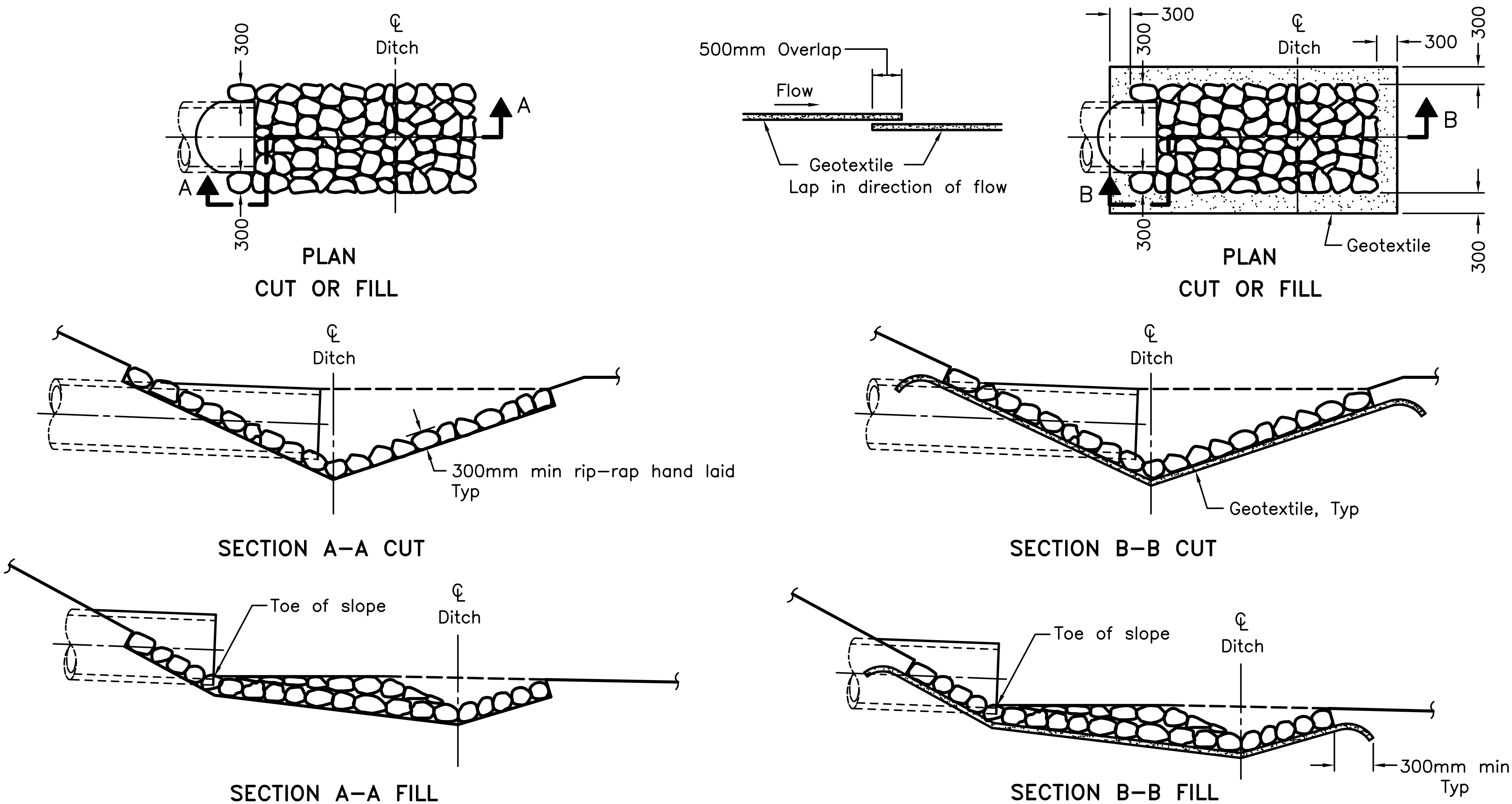
A Lateral limits of granular backfill to bridge abutment to be inside face to inside face of retaining wall or wingwall. Frost taper shall extend the full width of the backfill unless interrupted by the retaining wall or wingwall.

B Sections shown are parallel to centreline of roadway.

C Subdrain shall be installed with a 2% gradient behind wall.

D All dimensions are in millimetres unless otherwise shown.

| ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 1 |
|---|---|---|
| WALLS<br>ABUTMENT, BACKFILL<br>MINIMUM GRANULAR REQUIREMENT | OPSD 3101.150 | |




**TYPE A – WITHOUT GEOTEXTILE**

**TYPE B – WITH GEOTEXTILE**

NOTES:

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2001 | Rev 0

# RIP–RAP TREATMENT

FOR SEWER AND CULVERT OUTLETS

**OPSD – 810.010**

If rock fill is used as a backfill material, consideration should be given to the possible deterioration of the rockfill with time, which could result in the reduction or even the total loss of free-draining properties and, hence, increased frost susceptibility.

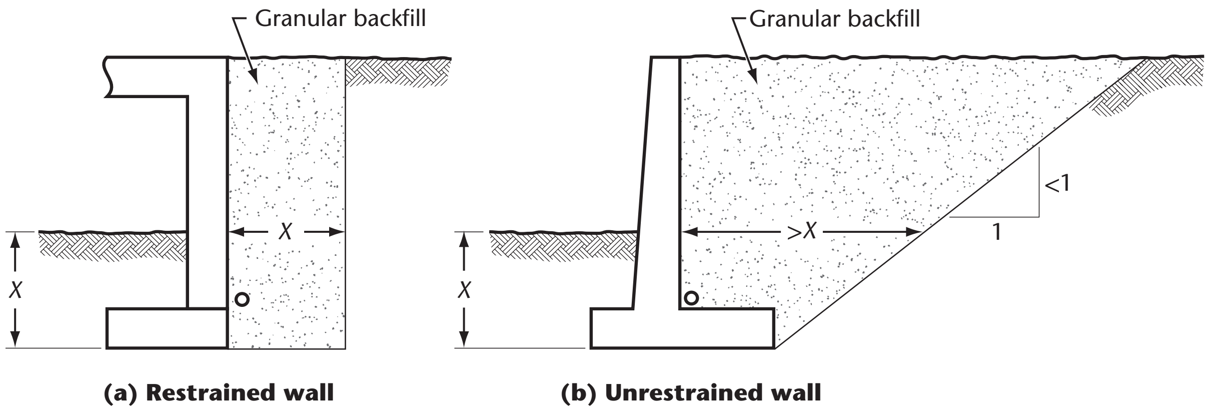



**Figure C6.20**
**Backfill for frost protection**
(See Clause C6.9.1.)

## C6.9.2 Lateral pressures

### C6.9.2.1 General

Earth pressure acting on a structure depends on the relative movement of the structure, the backfill, the type of soil adjacent to the backfill, and the soil below the footing or supporting piles. Appropriate geotechnical parameters should be chosen for the calculation of lateral pressures based on recognized geotechnical theories as specified in Clause 6.9.2.2 for the backfill behind the wall. Geotechnical parameters frequently used in allowable stress design methods are applicable in limit states design pressure calculation. Where the possibility exists, hydrostatic pressure needs to be considered, e.g., in situations where walls are partially submerged or where non-free-draining backfill is used.

Clause 6.9.2.1 includes the specification of four lateral pressure conditions for design. The first two cases apply to unrestrained structures, with Item (a) applying to the sizing of the base or pile arrangement with respect to external stability, and Item (b) to the sizing of the structural sections with respect to internal stability. Such sections could be of structural concrete, structural steel, or a proprietary product.

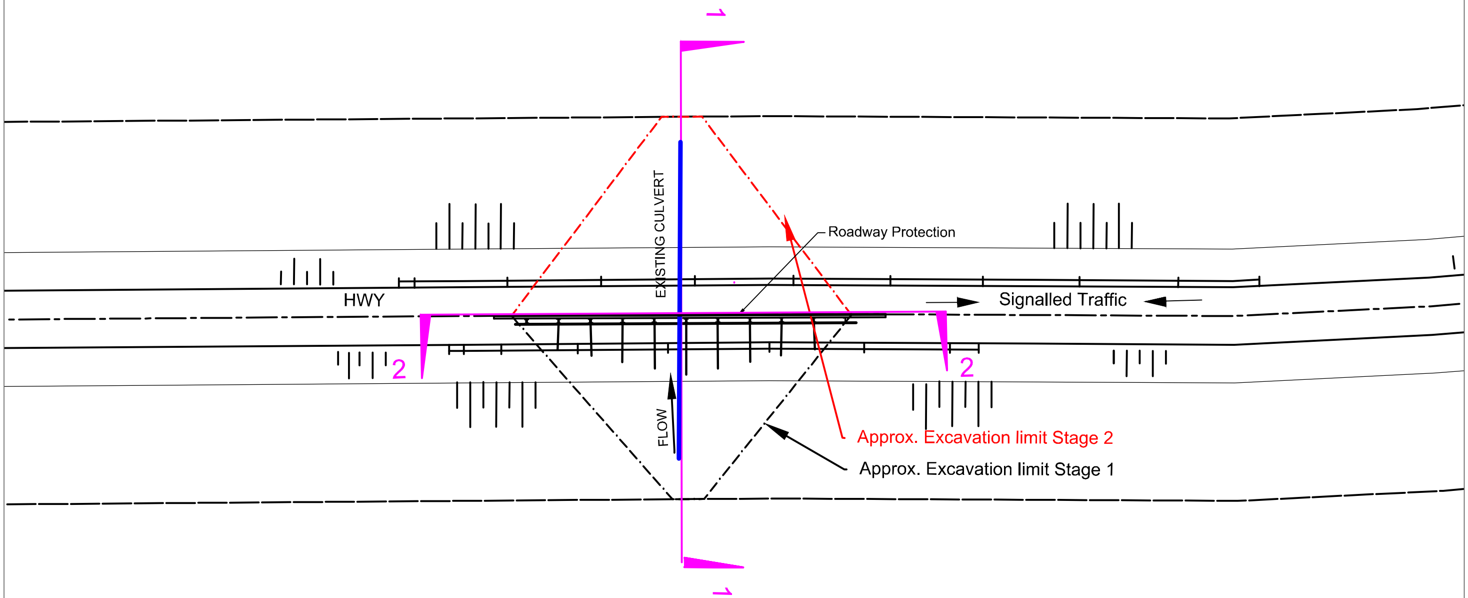
An unrestrained structure is one in which active pressure is mobilized in the backfill due to movement in the supporting structure. This movement corresponds to a rotation of approximately 0.002 about the base of a vertical wall, a horizontal translation of 0.001 times the height of the wall, or a combination of these movements. The lateral pressure applied to the wall for the condition described is an active pressure.

The supporting material will generally be more robust than what is assumed by the Geotechnical Engineer for factored conditions in design. Hence, following installation of the backfill, movement sufficient to cause active condition will generally not have taken place. Horizontal or rotational movement of the base will occur during the installation of each lift of the backfill. Wall deflection during each application and compaction of the backfill will add to the existing deformations. For such a post placement of the fill condition, Item (b) applies, the forces acting on the retaining structure being a function of the compacting equipment and the flexural stiffness of the wall. The residual horizontal pressures due to compaction are largest at the top of the wall, and this is reflected in Clause 6.9.3.

# Appendix H –
# Schematic Sketches for Construction Alternatives

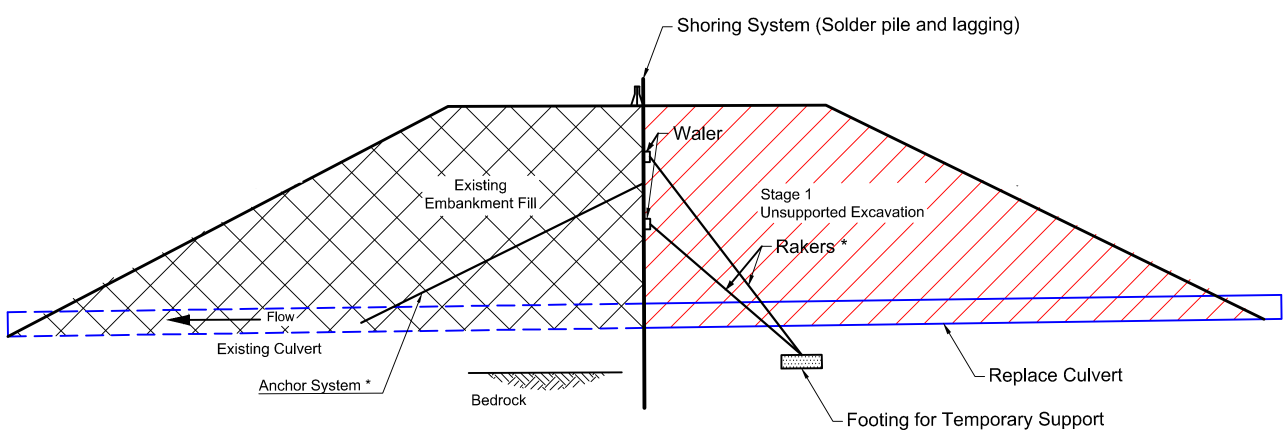
# FIGURE H.1.A: HALF AND HALF CONSTRUCTION WITH UNSUPPORTED CUT SIDES (OPTION 1.A)

## SCHEMATIC DIAGRAMS (NTS)



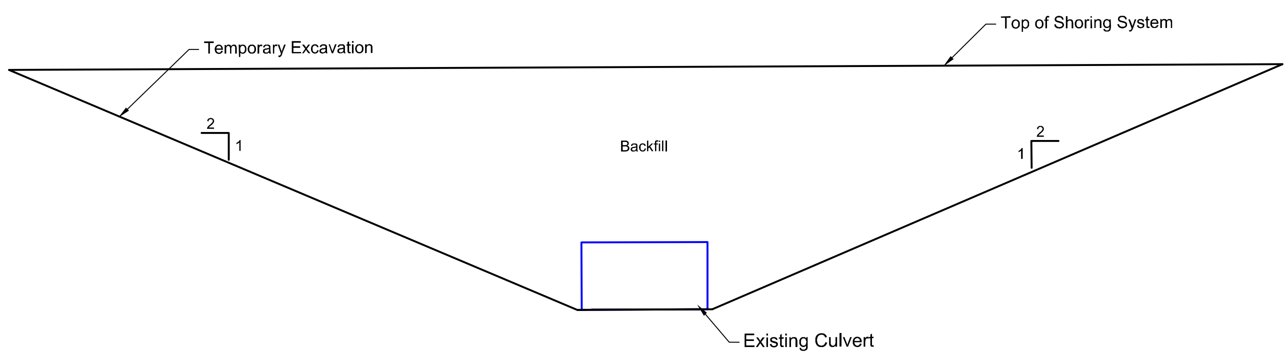

**PLAN**

Half and Half Construction, Shoring system with either rakers or anchor system - Unsupported Excavation




* Rakers or Anchor System

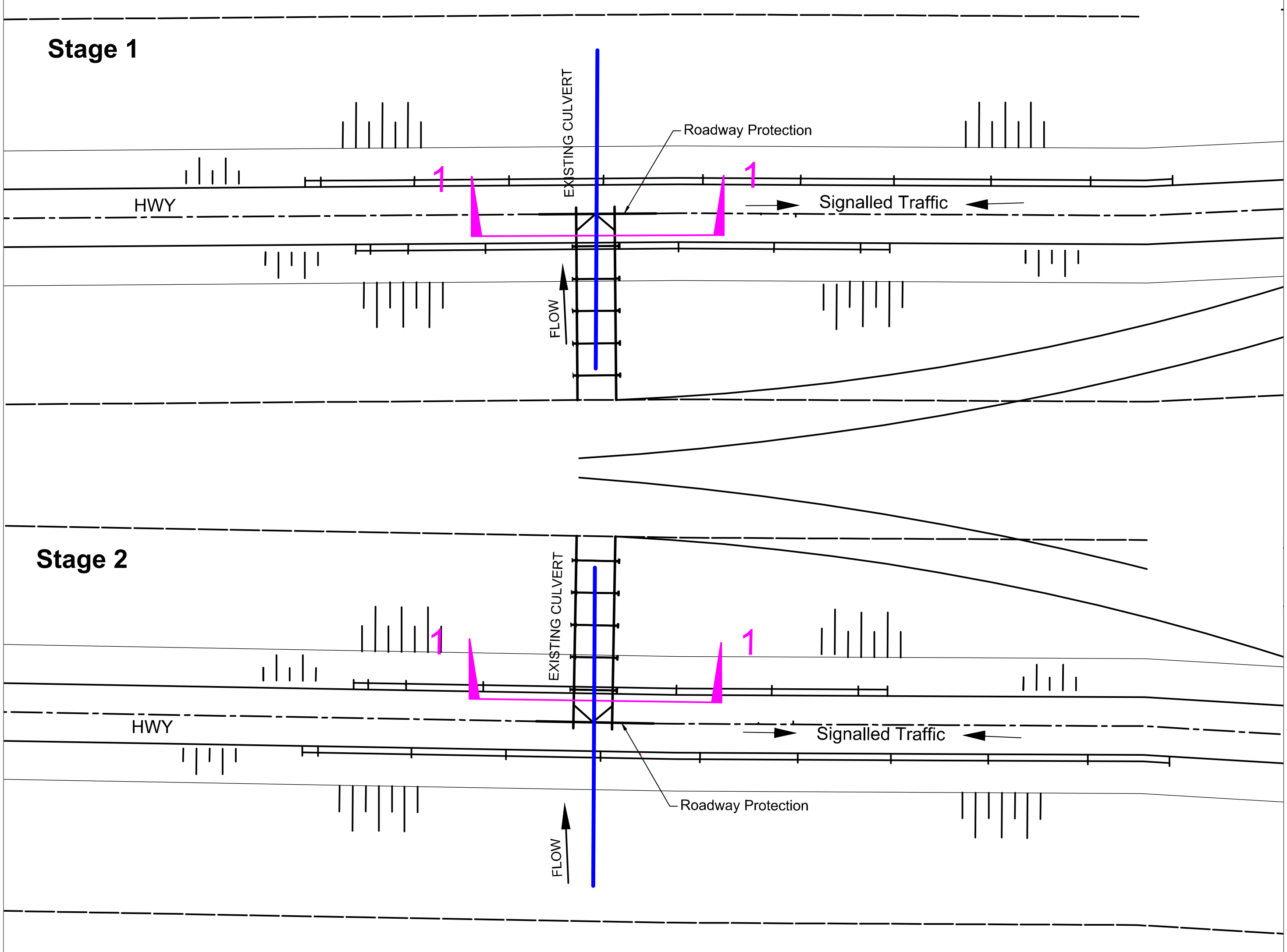
**SECTION 1-1**




**SECTION 2-2**

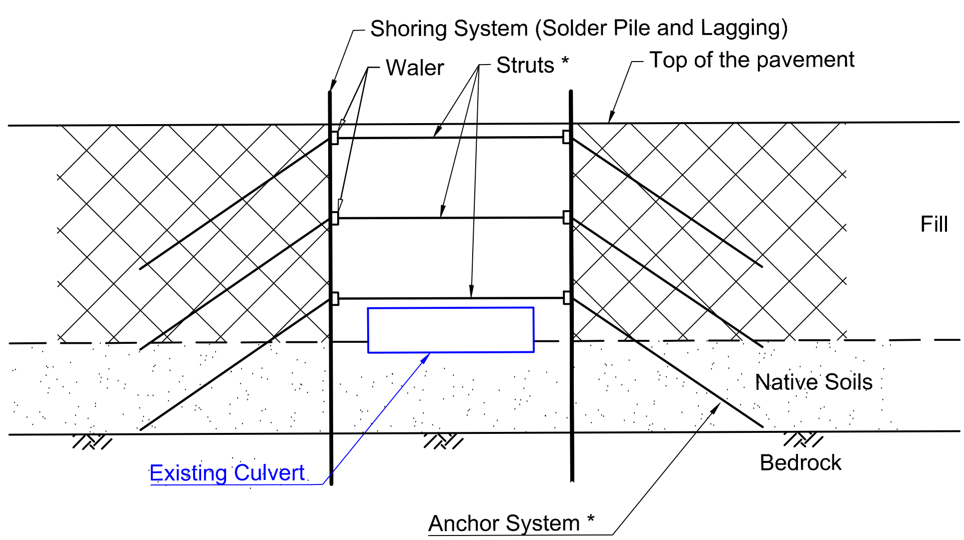
# FIGURE H.1.B: HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES OR ANCHOR SYSTEM (OPTION 1.B)

## SCHEMATIC DIAGRAMS (NTS)




**PLAN**

Half and Half Construction, Shoring System - Braced Cut Struts or Anchor System

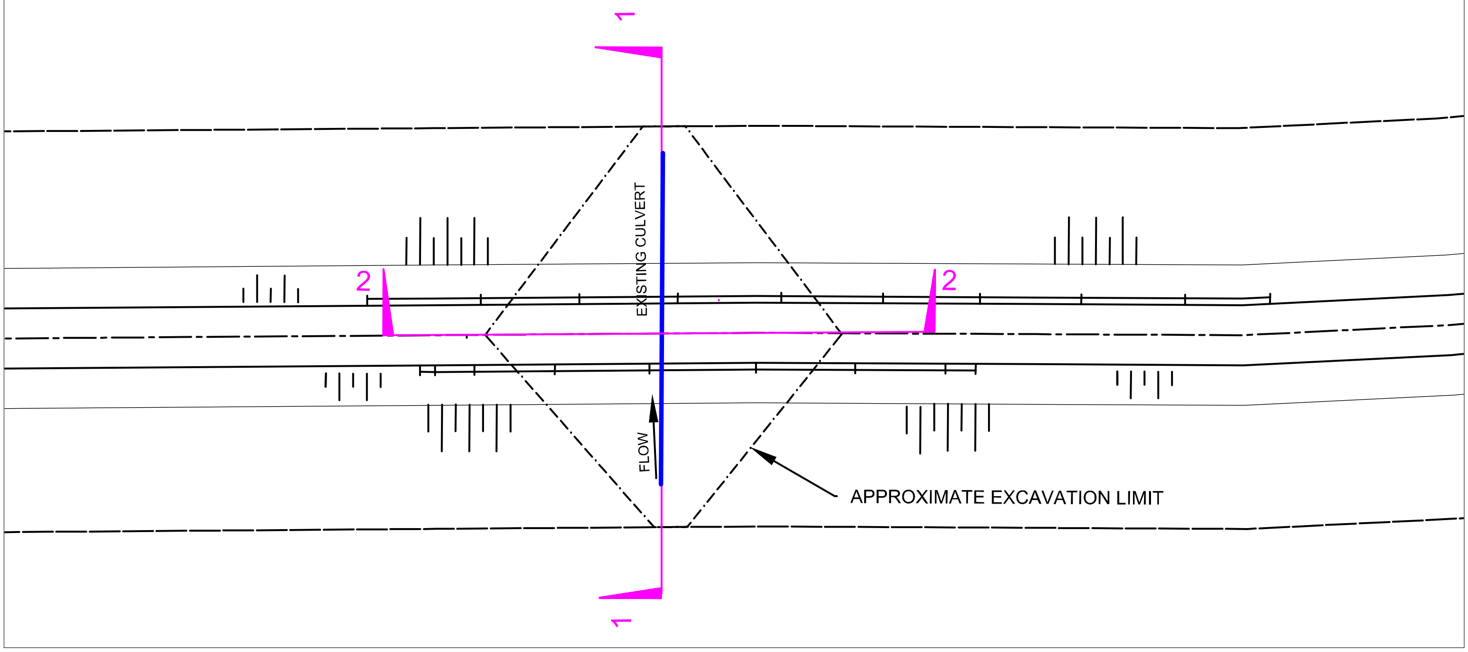



* Struts or Anchor System

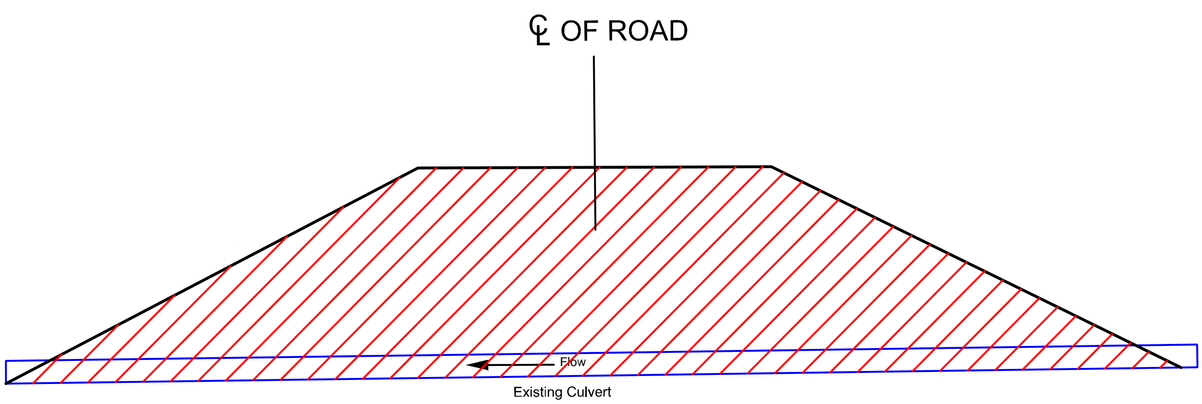
**SECTION 1-1**

## FIGURE H.2: FULL ROAD CLOSURE USING EXISTING ROADWAYS AND OPEN CUT UNSUPORTED EXCAVATION (OPTION 2)

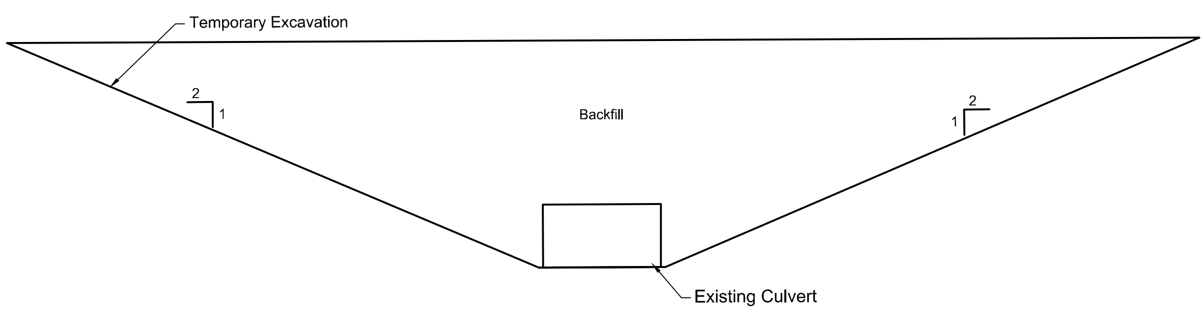
**SCHEMATIC DIAGRAMS (NTS)**




**PLAN**



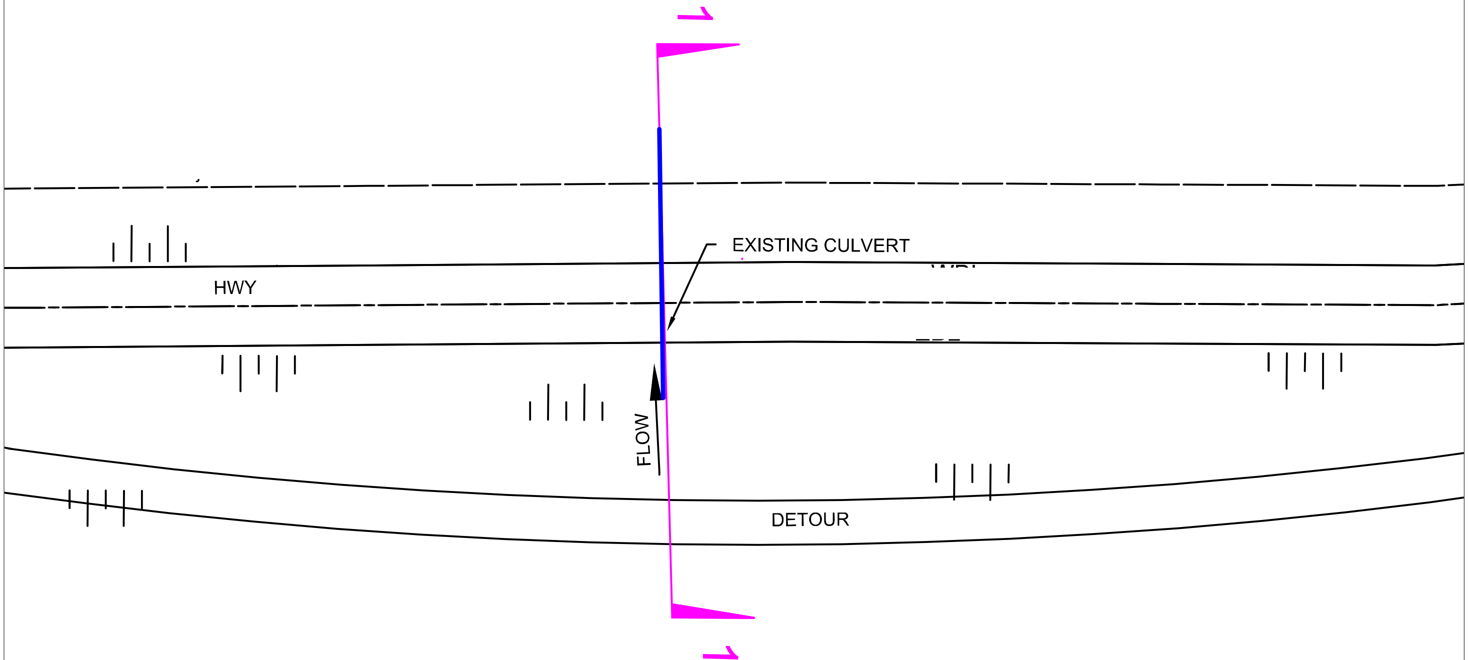

**SECTION 1-1**




**SECTION 2-2**

# FIGURE H.3: TEMPORARY LOCAL DETOUR AND OPEN CUT UNSUPPORTED EXCAVATION (OPTION 3)

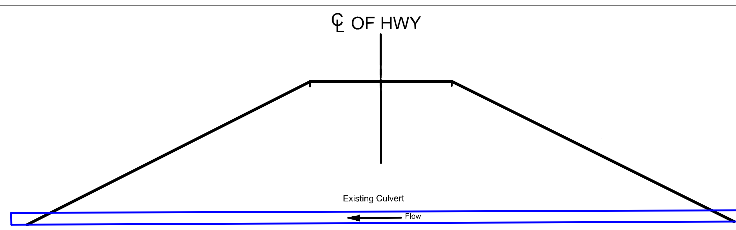
**SCHEMATIC DIAGRAMS (NTS)**



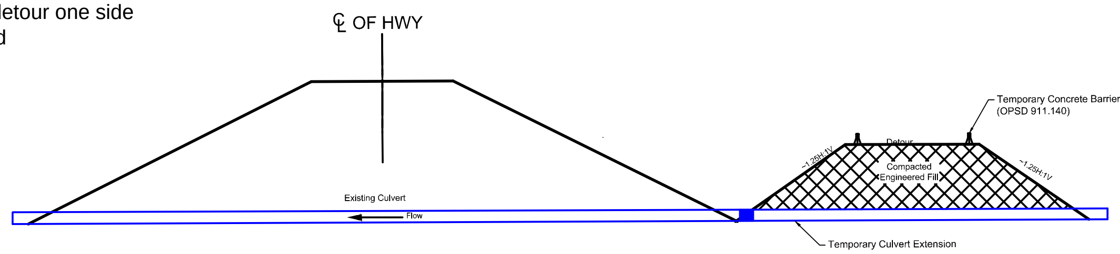

**PLAN**

**RECOMMENDED STAGES**

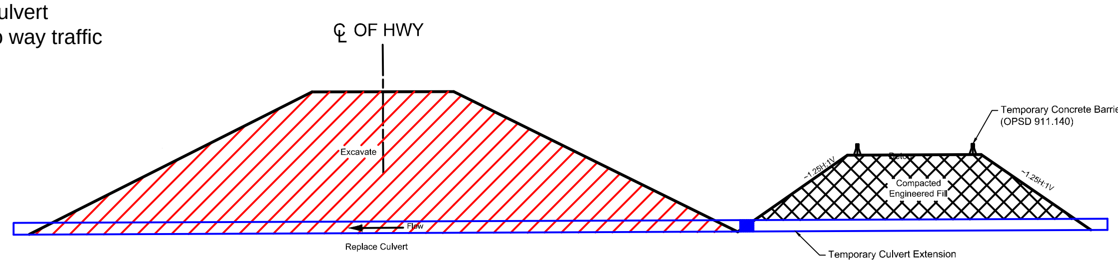
1.0 Stage 1 - Current condition



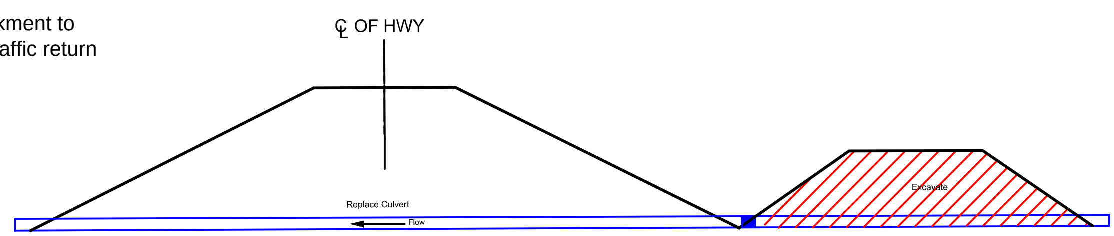

2.0 Stage 2 - Build temporary detour one side
Two-way traffic on existing road




3.0 Stage 3 - Excavation and culvert construction on other side; Two way traffic shiftted to detour




4.0 Stage 4 - Build the embankment to existing alignment; Two-way traffic return




**SECTION 1-1**

# Appendix I –
# Borehole Logs and Tests Results (I.E. Group)

Ministry of Transportation Ontario

Foundation Design

# RECORD OF BOREHOLE No 04A-1



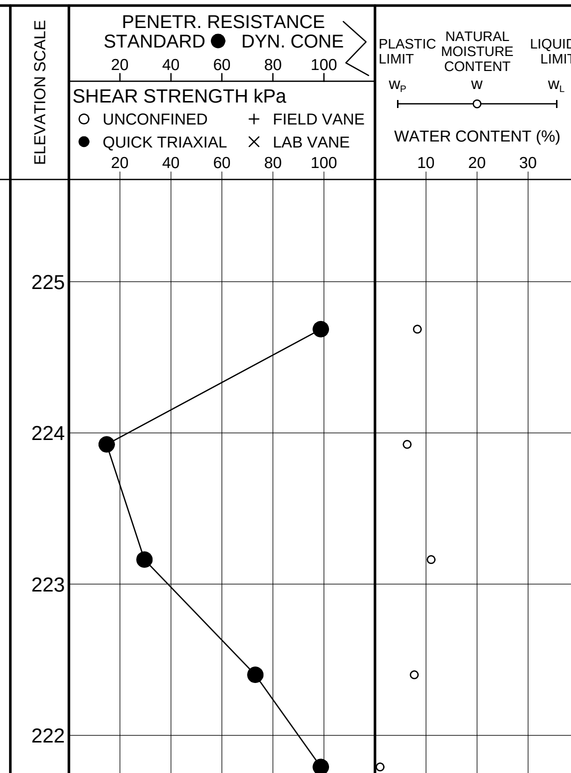
**METRIC**

W.P. GWP 57-00-00  LOCATION HWY 26, Thornbury to Meaford  Northing - 4939487, Easting - 220069  ORIGINATED BY JL

DIST Owen Sound  HWY 26  BOREHOLE TYPE S/S Augering, 110 mm dia.  COMPILED BY JL

DATUM Geodetic  DATE 07.31.07 - 07.31.07  CHECKED BY EC

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 225.68 | Ground | | | | | |
| 0.00 | 150 mm TOPSOIL. | | | | | |
| | Sandy SILT, ML<br>Brown, moist, compact to very dense, with embedded gravel and silty clay pockets. | 1 | SPT | 100+ | | hit cobble @ 1.1m. |
| | | 2 | SPT | 15 | | |
| 223.24 / 2.44 | Gravelley SAND TO SAND & GRAVEL, SW-GW<br>Brown, moist, dense to very dense, some silt. | 3 | SPT | 30 | | 41 39 14 6 (20) |
| | | 4 | SPT | 74 | | 24 49 20 8 (27) |
| 221.72 | | 5 | SPT | 100+ | | |
| 3.96 | End of borehole. | | | | | Borehole dry and open @ completion. |




UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity

O 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

JOE MTO 07-6-IEG1.GPJ ONTARIO MOT.GDT 04/12/09

Ministry of Transportation Ontario

Foundation Design

# RECORD OF BOREHOLE No 04A-2



**METRIC**

W.P. GWP 57-00-00 LOCATION HWY 26, Thornbury to Meaford Northing - 4939500, Easting - 220071 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia. COMPILED BY JL

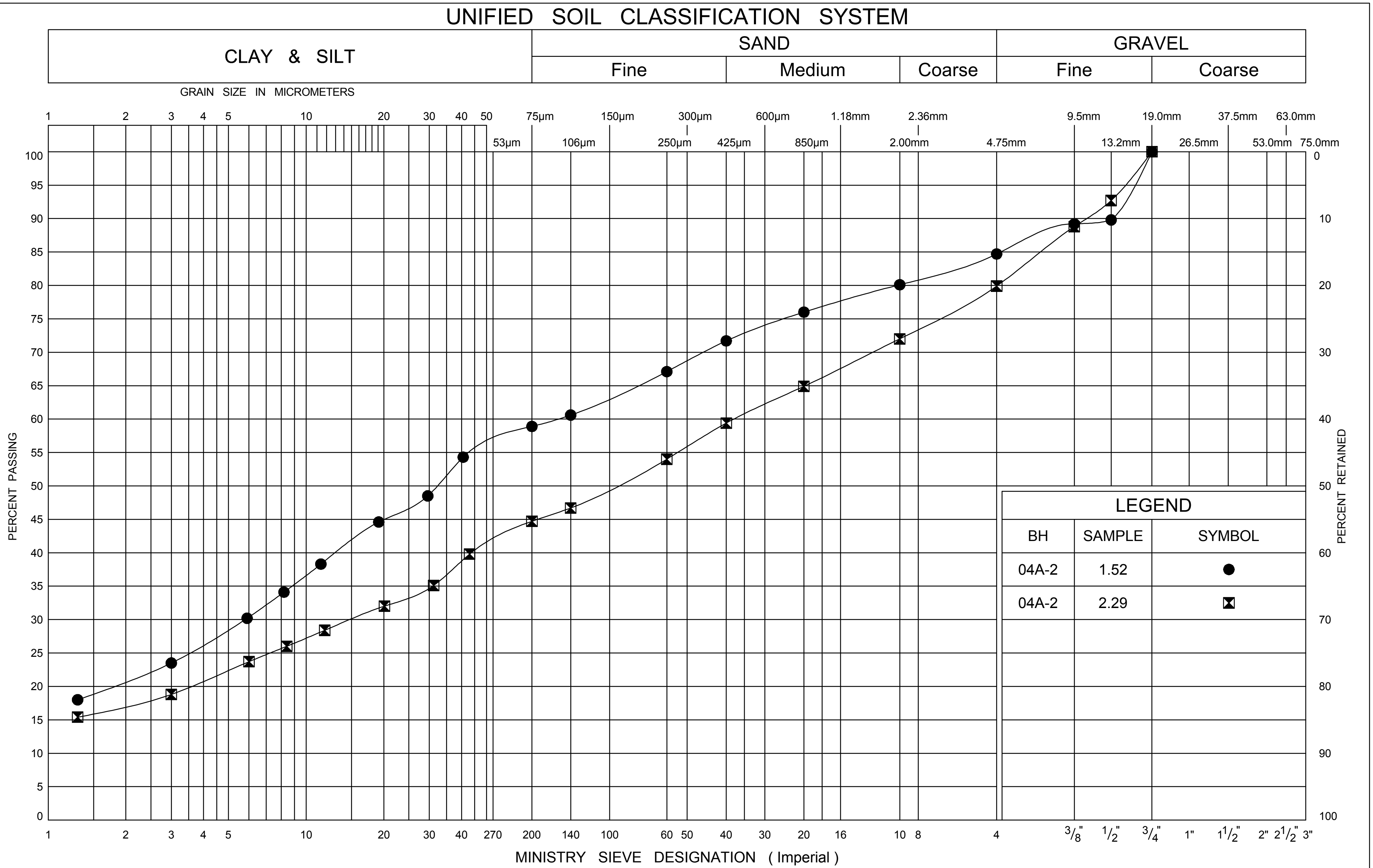
DATUM Geodetic DATE 07.31.07 - 07.31.07 CHECKED BY EC

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | W (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 226.40 | Ground | | | | | |
| 0.00 | 350 mm sand and gravel FILL. | | | | | |
| | FILL<br>Brown, moist, compact to loose, consisting mainly of clayey sandy silt to clayey silty sand. | 1 | SPT | 15 | | |
| | | 2 | SPT | 10 | | 15 26 38 21 (59) |
| | | 3 | SPT | 4 | | 20 35 28 17 (45) |
| 223.50<br>2.90 | GRAVELLY SAND TO SAND & GRAVEL, SW-GW<br>Brown, moist, compact to very dense, some silt. | 4 | SPT | 16 | | |
| | | 5 | SPT | 25 | | |
| | | 6 | SPT | 100+ | | |
| 221.37<br>5.03 | End of borehole. | | | | | Borehole dry and open @ completion. |

Chart headings: PENETR. RESISTANCE STANDARD ● DYN. CONE (20, 40, 60, 80, 100); SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 226, 225, 224, 223, 222.

+³, ×³: Numbers refer to Sensitivity ○¹⁵⁰ UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

78 12 M




| BH | SAMPLE | SYMBOL |
|---|---|---|
| 04A-2 | 1.52 | ● |
| 04A-2 | 2.29 | ⊠ |

Ministry of Transportation
Ontario

# GRAIN SIZE DISTRIBUTION

## FILL

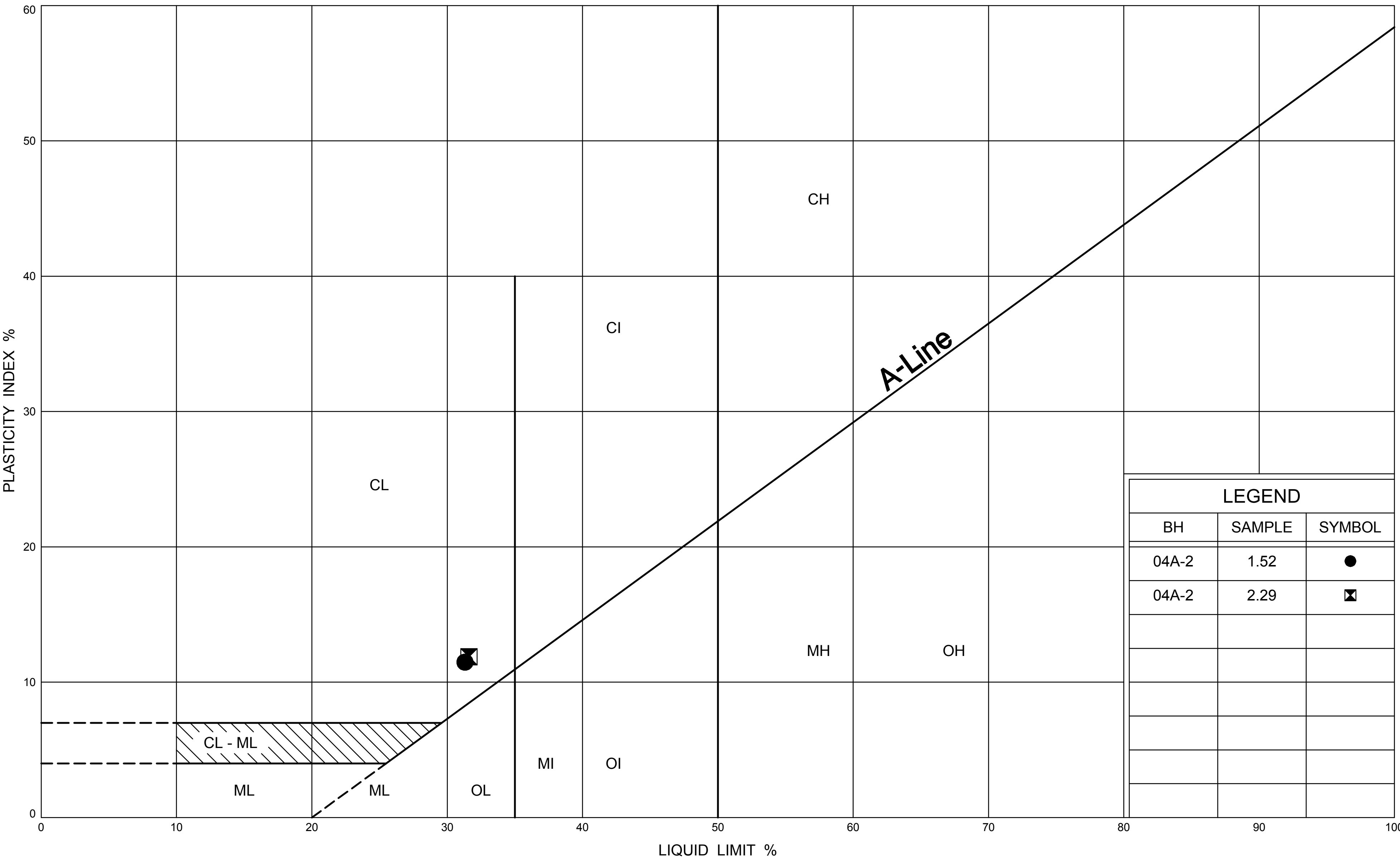
FIG No C- 04A.1

GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT GRAIN SIZE SMALL CULVERTS 07-6-IEG1.GPJ ONTARIO MOT.GDT 04/12/09

Oct 75, FF - S - 21




| LEGEND | | |
|---|---|---|
| BH | SAMPLE | SYMBOL |
| 04A-2 | 1.52 | ● |
| 04A-2 | 2.29 | ⧗ |

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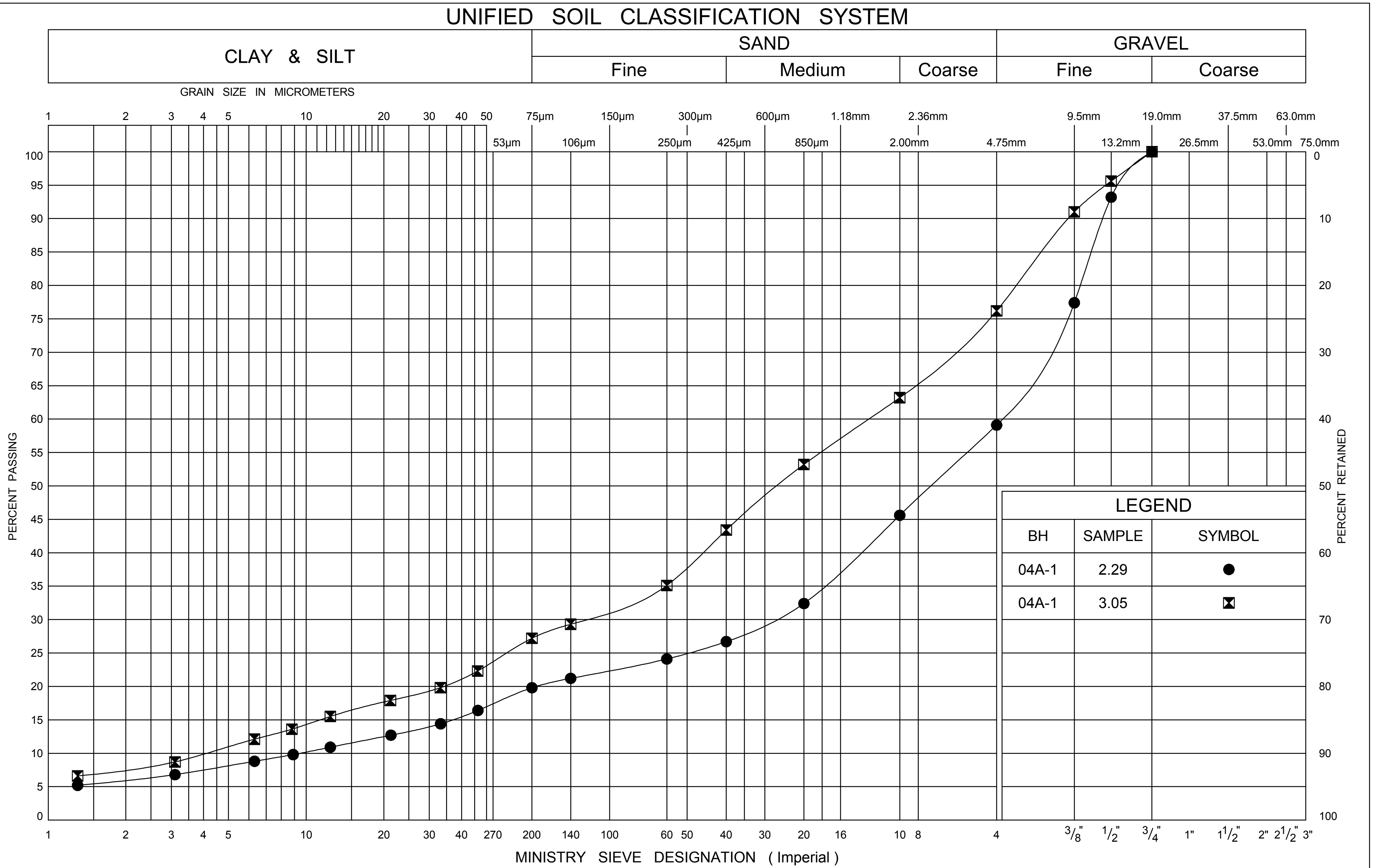
# PLASTICITY CHART
## FILL

FIG No C- 04A.2

GWP 57-00-00

HWY 26, Thornbury to Meaford

78 12 M

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# GRAIN SIZE DISTRIBUTION

## GRAVELLY SAND TO SAND AND GRAVEL, SW-GW

FIG No C- 04A.3

GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT GRAIN SIZE SMALL CULVERTS 07-6-IEG1.GPJ ONTARIO MOT.GDT 04/12/09

# Appendix J – NSSPs

## NSSP FOR GRAVELLY SAND TO SAND AND GRAVEL OBSTRUCTIONS

### Scope of Work

The Contractor should be aware that the embankment at the site consists of granular fill or clayey silt underlain by generally dense to very dense gravelly sand to sand and gravel materials which may impact excavations and/or elements of temporary protection systems. Appropriate equipment and procedures will be required to penetrate the material when encountered during excavation or when advancing elements of the 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.