

## **Final Foundation Investigation and Design Report**

Highway 24 Resurfacing and  
Replacement of Culvert at  
Station 16+453 (Site No. 17)  
Township of South Dumfries, ON

G.W.P. 3065-11-00

Geocres No. 40P08-239



Prepared for:  
Ministry of Transportation Ontario

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Project No. 165000903

January 2017

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## FOUNDATION INVESTIGATION REPORT

For

G.W.P 3065-11-00

Highway 24 – Replacement of Culvert at Station 16+453

Site No. 17

Township of South Dumfries

## 1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation Ontario (MTO) to undertake the detailed design for resurfacing of Highway 24, Township of South Dumfries, Ontario. The geotechnical investigations are required to support the design of the replacement of six non-structural culverts located on Highway 24 between Highway 5 and Glen Morris Road East. The culvert numbers along with their approximate easting and northing coordinates given in Table 1.1 below.

**Table 1.1: Coordinates of Culverts on Highway 24, Township of South Dumfries, ON (MTM Zone 10)**

| Culvert Station (Site No.) | Easting    | Northing    | Culvert Station (Site No.) | Easting    | Northing    |
|----------------------------|------------|-------------|----------------------------|------------|-------------|
| 15+138 (10)                | 240328.968 | 4790308.382 | 16+453 (17)                | 239955.403 | 4791538.822 |
| 15+738 (12)                | 240146.455 | 4790857.376 | 17+001 (23)                | 239823.628 | 4792085.529 |
| 16+167 (16)                | 240028.947 | 4791272.063 | 17+845 (29)                | 239596.513 | 4792892.253 |

This Foundation Investigation Report has been prepared specifically and solely for the replacement of Culvert No. 17 which is located at Station 16+453.

Project Number: G.W.P. 3065-11-00

Project Location: Highway 24, 572 m south of McLean School Road

The work was carried out under MTO Agreement Number 3013-E-0019 with Stantec Consulting Ltd., the Detailed Design Consultant for this project.

## 2.0 SITE DESCRIPTION AND GEOLOGY

### Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The existing Culvert crosses beneath Highway 24 near Station 16+453, approximately 572 m south of the intersection of Highway 24 and McLean School Road.

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## General Site Description

It is noted that Highway 24 runs approximately north to south at the project location with chainage increasing from south to north. In the vicinity of the culvert, Highway 24 has a two lane rural cross-section with approximately 1 m wide paved shoulder with wood guide rails on both sides.

The culvert allows the water of the watercourses on the east and west sides of the highway to follow under the road. The road embankment has side slopes of approximately 1.5H:1V to 2.5H:1V. The paved surface of the highway is approximately 3.2 to 4.1 m higher than the ditches surface on both sides of the road. The area beyond the water course is covered with brush and trees. Site photos are shown in Appendix A.

## Existing Culvert

The terms of reference indicate the existing culvert type is a Corrugated Steel Pipe (CSP). The culvert has a diameter of 950 mm and a length of 36.71 m. The culvert is covered with approximately 3 m of fill. The approximate alignment of the existing culvert is shown on Drawing No. 1 in Appendix A.

## **3.0 INVESTIGATION PROCEDURES**

### **3.1 REVIEW OF PREVIOUS INVESTIGATION**

A review of the Geocres report for the Alder Creek Culvert Replacement located 5.6 km north of the study area suggests that the surficial geology of the site consists of silty sand with gravel to silty gravel with sand till deposits. Depth of bedrock is anticipated greater than 10 m.

### **3.2 FIELD INVESTIGATION – CULVERT SITE**

A field investigation consisting of three boreholes was carried out at the culvert site. The boreholes were designated BH15-10, BH15-11, and BH15-12 and their locations are shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

Prior to carrying out the investigation, Stantec contacted the public utility authorities to clear the borehole locations of public utilities.

The field drilling program was carried out on June 9 and 24, 2015. One borehole (BH15-11) was advanced with hollow-stem augers using a truck mounted drill rig equipped for soil and bedrock sampling owned and operated by Downing Drilling of Hawkesbury, ON. Two boreholes (BH15-10 and BH15-12) were advanced using portable drilling equipment owned and operated by Sonic Soil Sampling of Concord, ON.

The subsurface stratigraphy encountered in each borehole was recorded in the field by experienced Stantec personnel. In BH15-11, split spoon samples were collected at regularly

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spaced intervals (typically every 760 mm) during the course of Standard Penetration Testing (ASTM D1586). In BH15-10 and BH15-12, Dynamic Cone Penetration Testing (DCPT) was performed using a 70 lb weight; a 50% correction factor has been applied to the DCPT results presented on the borehole records. Samples were collected using a split spoon sample advanced using a Pionjar jackhammer within approximately 1 m of the DCPT location. All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing.

Groundwater readings were carried out in open holes immediately upon completion of drilling. Boreholes were backfilled with auger cuttings mixed with bentonite.

## 3.3 LOCATION AND ELEVATION SURVEY

The borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS. The elevations are accurate to 0.1 m. Table 3.1 summarizes the borehole information.

**Table 3.1: Borehole Summary**

|                                   | Boreholes |         |         |
|-----------------------------------|-----------|---------|---------|
|                                   | BH15-10   | BH15-11 | BH15-12 |
| MTM Zone 10 Coordinates           |           |         |         |
| Northing                          | 4791545   | 4791539 | 4791557 |
| Easting                           | 239972    | 239955  | 239931  |
| Ground Surface Elevation, m       | 291.6     | 295.7   | 292.5   |
| Total Depth Drilled, m            | 6.1       | 9.8     | 6.1     |
| End of Borehole Elevation, m      | 285.5     | 286.0   | 286.4   |
| Depth Augered, m                  | NA        | 9.8     | NA      |
| Depth of DCPT from ground surface | 6.1       | NA      | 6.1     |
| Depth of Sampling                 | 6.1       | 9.8     | 6.1     |
| Number of Soil Samples            | 8         | 13      | 8       |

## 3.4 LABORATORY TESTING

All samples were taken to our Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer. Selected soil samples underwent gradation analysis, Atterberg limits testing and moisture content testing. Two samples were submitted to Parcel Laboratories of Ottawa for analysis of pH, soluble sulphate content, chloride content and resistivity. Laboratory testing summary is shown in the Table below.

**Table 3.2: Laboratory Testing for Culvert Site**

| Laboratory Testing | Moisture Content | Gradation Analysis | Atterberg Limits | Chemical Analysis |
|--------------------|------------------|--------------------|------------------|-------------------|
| Number of Tests    | 36               | 10                 | 8                | 2                 |

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Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by MTO.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided.

In general, the subsurface stratigraphy consisted of a pavement structure over fill underlain by clayey silt over peat underlain by sandy silt to silty sand.

Borehole location plans and stratigraphic section of the soils encountered within the boreholes are provided on Drawing No. 1 in Appendix A.

#### 4.1.1 PAVEMENT

70 mm of asphalt pavement was encountered in BH15-11.

#### 4.1.2 Fill

Fill material was encountered beneath the asphalt pavement in BH15-11 and at the ground surface in BH15-10 and BH15-12. The fill consisted of brown to grey silty sand with/without gravel. Organic material was observed within the fill in borehole BH15-12. Fill material was described as moist to wet. The fill was approximately 1.6 m, 3.8 m, and 1.8 m thick and extended to the elevations of 290.0 m, 291.9 m, and 290.7 m in BH15-10, BH15-11, and BH15-12, respectively.

In this layer, the SPT N-values ranged from 6 to 16 blows per 0.3 m and the DCPT results ranged from 1 to 13. The results suggest a loose to compact state.

Moisture content and grain size distribution tests carried out on representative samples of the fill yielded the following results:

|                   |            |
|-------------------|------------|
| Gravel:           | 11 and 35% |
| Sand:             | 29 and 50% |
| Silt:             | 15 to 41%  |
| Clay:             | 7 to 8%    |
| Moisture Content: | 4 to 19%   |

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Moisture content of the organic fill in BH15-12 ranged from 48 to 97%. The grain size distribution curve for the fill material is provided in Figure No. 1 of Appendix C.

Two Atterberg Limit tests were also performed on the fill samples. The Atterberg Limit tests yielded that the samples are non-plastic. The results are shown in Figure No. 4 of Appendix C.

### 4.1.3 Clayey SILT

Clayey silt layer was encountered beneath the fill in BH15-12. The clayey silt was approximately 1.1 m thick and extended to elevation of 289.6 m in BH15-12. Clayey silt was also encountered interlayered within the sandy silt to silty sand layer between elevations of 288.6 m and 283.1 m in BH15-10.

In this layer, the DCPT results ranged from 5 to 19. The results suggest a firm to very stiff consistency. The clayey silt was described as wet.

Moisture content, Atterberg limits, and grain size distribution tests carried out on a representative sample of the clayey silt yielded the following results:

|                   |           |
|-------------------|-----------|
| Gravel:           | 0%        |
| Sand:             | 4 to 7%   |
| Silt:             | 75 to 79% |
| Clay:             | 17 to 18% |
| Moisture Content: | 22 to 42% |

The grain size distribution curve for the clayey silt is provided in Figure No. 2 of Appendix C.

Two Atterberg Limit tests were also performed on the clayey silt samples. The Atterberg Limit test yielded plasticity index of 8 and 13 and liquid limit of 22 and 32. The results suggest a low to medium plasticity. The results are shown in Figure No. 4 of Appendix C.

### 4.1.4 PEAT

A peat layer was encountered beneath the fill in BH15-10 and beneath the clayey silt in BH15-12. The peat layer was approximately 1.4 m and 1.7 m thick and extended to the elevations of 288.6 m and 287.9 m in BH15-10 and BH15-12 respectively.

The moisture content of the peat layer was 95 % to 360 %. The organic content results tested were 76 and 31% for sample SS3 in BH15-10 and sample SS5 in BH15-12 respectively.

### 4.1.5 Sandy SILT to Silty SAND

Sandy silt to silty sand layer was encountered beneath the peat in BH15-10 and BH15-12 and beneath the fill in BH15-11. The deposit extended to the termination depths of these boreholes. Clayey silt was also encountered interlayered within the layer between elevations of 288.6 m and 283.1 m in BH15-10.

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In this layer, the SPT N-values ranged from 7 to 21 blows per 0.3 m and the DCPT results ranged from 22 to 42. The results suggest a loose to dense state.

Moisture content, Atterberg limits, and grain size distribution tests carried out on representative samples of the sandy silt to silty sand yielded the following results:

|                   |           |
|-------------------|-----------|
| Gravel:           | 4 to 13%  |
| Sand:             | 37 to 63% |
| Silt:             | 29 to 79% |
| Clay:             | 2 to 17%  |
| Moisture Content: | 9 to 37%  |

The grain size distribution curves for the sandy silt to silty sand material are provided in Figure No. 3 of Appendix C.

Four Atterberg Limit tests were also performed on the sandy silt to silty sand samples. The Atterberg Limit tests yielded that three samples were non-plastic and one sample from BH15-10 indicated a plasticity index of 8 and a liquid limit of 22. The results are shown in Figure No. 4 of Appendix C.

## 4.1.6 Groundwater

No water was observed in the culvert at the time of the drilling.

The groundwater levels were inferred in open holes and inferred from the wetness of the sample at the time of drilling. Groundwater levels are provided in the Table below.

**Table 4.1: Inferred and Measured Groundwater levels**

| Borehole No. | Observation/Measurement Date | Groundwater Depth (m) | Ground Surface Elevation(m) | Groundwater Elevation (m) |
|--------------|------------------------------|-----------------------|-----------------------------|---------------------------|
| BH15-10      | June 24, 2015                | 0.0 (inferred)        | 291.6                       | 291.6                     |
| BH15-11      | June 9, 2015                 | 2.3 (inferred)        | 295.7                       | 293.4                     |
| BH15-12      | June 24, 2015                | 0.7 (inferred)        | 292.5                       | 291.8                     |

The groundwater level of 293.4 m inferred in BH15-11 is 1.6 m to 1.8 m higher than the water level inferred in BH15-10 and BH15-12. The water level in BH15-11 is likely not representative of the groundwater level, the groundwater level is likely lower.

Fluctuations in the groundwater due to seasonal variations or in response to a particular precipitation event should be anticipated.

## 5.0 CHEMICAL ANALYSIS

Two soil samples were submitted to Paracel Laboratories in Ottawa, Ontario, for analysis of pH, water soluble sulphate and chloride concentration, and resistivity. The analysis results are provided in Table 5.1.

**Table 5.1: Results of Chemical Analysis**

| Borehole No | Sample No. | Depth (m)    | pH   | Chloride (µg/g) | Sulphate (µg/g) | Resistivity (Ohm-m) |
|-------------|------------|--------------|------|-----------------|-----------------|---------------------|
| BH15-10     | SS2        | 0.76 to 1.51 | 7.12 | 12              | <5              | 63.0                |
| BH15-11     | SS5        | 3.05 to 3.66 | 7.45 | 369             | 73              | 11.2                |

## 6.0 MISCELLANEOUS

The field work was carried out under the supervision of Athir Nader, E.I.T., under the direction of Christopher McGrath, P.Eng.

USL-1 Underground Service Locators Inc. of Ottawa, Ontario, carried out the private and public utility locates for the boreholes.

The CME 75 drilling equipment drilling equipment was supplied and operated by Downing Drilling of Hawkesbury, Ontario on June 9, 2015. Portable drilling equipment was supplied and operated by Sonic Soil Sampling of Concord, Ontario on June 24, 2015.

Elevation and location survey of the borehole locations was carried out by Stantec personnel.

Geotechnical laboratory testing was carried out at Stantec's Ottawa laboratory.

This report was prepared by Athir Nader, and reviewed by Christopher McGrath and Raymond Haché, MTO Designated Principal Contact.

## 7.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

Respectfully Submitted;

STANTEC CONSULTING LTD.



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## FOUNDATION INVESTIGATION REPORT

For

G.W.P 3065-11-00

Site No. 17

Highway 24 – Replacement of Culvert at Station 16+453  
Township of South Dumfries

## 8.0 GENERAL BACKGROUND

### Project Purpose/Justification

Resurfacing of Highway 24, Township of South Dumfries, Ontario is proposed. Foundation investigations were carried out to support the detailed design of the replacement of six culverts located on Highway 24 between Highway 5 and Glen Morris Road East. The results of the foundation investigation and the geotechnical engineering recommendations for the replacement of a Culvert at Station 16+453 are presented in this report.

### Proposed Structures

The terms of reference indicate that the existing culvert type is a corrugated steel pipe (CSP). The existing culvert has a diameter of 950 mm and a length of 36.71 m and it is covered with approximately 3.2 m of fill. The invert elevation of the existing culvert is between elevations of 291.6 m and 292.5 m.

The existing CSP culvert will be replaced with 2.4 m by 1.8 m and 42.3 long pre-cast concrete box culvert. The alignment of the proposed culvert replacement will match the existing culvert alignment. The proposed invert elevations of the culvert at upstream and downstream ends are 292.4 m and 291.5 m respectively.

### Construction Staging & Detours

It is understood that a short term local road detour is not anticipated for the culvert replacement.

The culvert replacement will require roadway protection. Since each half of the culvert will be replaced separately, a single lane could be used with highway traffic being controlled by a continual flagging operation or temporary lights.

## 9.0 ENGINEERING RECOMMENDATIONS

### 9.1 GEOTECHNICAL DESIGN PARAMETERS

The soil conditions at this site generally consist of a pavement structure over fill over clayey silt over peat over sandy silt to silty sand.

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For design purposes, the following soils profile will be used:

**Table 9.1: Geotechnical Model for Culvert**

| Approximate Elevation |       | Soil Type  | Design Properties  |
|-----------------------|-------|--|--|
| From                  | To    |  |  |
| 295.7                 | 291.9 | FILL: silty SAND with/without Gravel<br>Organic Fill in BH15-12      | Total Unit Weight = 20.8 kN/m <sup>3</sup><br>Friction Angle, $\phi = 32^\circ$<br>E' = 10 MPa |
| 291.9                 | 286.0 | Sandy SILT to Silty SAND<br>Loose to Compact<br>Cobbles and Boulders | Total Unit Weight = 21.3 kN/m <sup>3</sup><br>Friction Angle, $\phi = 32^\circ$<br>E' = 10 MPa |

For the purpose of this recommendation report, it is assumed that peat and organic material were removed from beneath the culvert under the roadway and that peat and organic material are only present outside the influence area of the culvert away from the culvert ends. However, these materials may still be present on the sides of the culvert and may affect the shoring and other construction stages.

A design water level elevation of 291.8 m will be considered for the culvert site. The water level is based on the water level observed within the fill in borehole BH15-12.

## 9.2 CULVERT OPTIONS

The current CSP culvert will be replaced by a 2.4 m x 1.8 m pre-cast concrete box culvert. It is understood that retaining walls/head walls will not be required for culvert replacement.

Provided that the peat and organic material are removed from beneath the influence area of the culvert and replaced with a compacted structural fill, the soil conditions at the site should be suitable to support the culvert options; it is probable that the peat and organic material directly below the culvert was removed as part of the initial construction, however, this has not been confirmed. Table 9.2 compares the culvert structure options from a constructability perspective.

**Table 9.2: Comparison of the Replacement Options for Culvert at Station 16+453**

| Option                                       | Advantages   | Disadvantages   | Relative Cost | Risk/Consequences   | Rank |
|--|--|---|---------------|---|------|
| Precast Rigid Frame Box                      | <ul style="list-style-type: none"> <li>Spreads culvert load over a larger footprint</li> <li>Use of precast sections reduces construction period</li> <li>Slightly less unwatering volume</li> </ul> | <ul style="list-style-type: none"> <li>Needs heavy lifting equipment</li> <li>Poorer hydraulic performance</li> </ul>   | Medium        |   | 1    |
| Rigid Frame Open Footing                     |  | <ul style="list-style-type: none"> <li>Slower construction process</li> <li>Greater unwatering volume require</li> <li>Poorer hydraulic performance</li> <li>Concrete not readily available</li> <li>Requires RSS at inlet</li> </ul> | High          | <ul style="list-style-type: none"> <li>Higher risk of unwatering related issues</li> <li>Concrete curing process</li> </ul> | 4    |
| Open Bottom Steel Arch with Concrete Footing | <ul style="list-style-type: none"> <li>Low material and installation cost</li> </ul>   | <ul style="list-style-type: none"> <li>Requires RSS at inlet</li> <li>Concrete not readily available</li> </ul>   | Low to Medium | <ul style="list-style-type: none"> <li>Higher risk of unwatering related issues</li> <li>Concrete curing process</li> </ul> | 3    |
| Corrugated Steel Pipe                        | <ul style="list-style-type: none"> <li>Low material and installation cost</li> </ul>   | <ul style="list-style-type: none"> <li>Maintenance Requirements</li> </ul>  | Low           | <ul style="list-style-type: none"> <li>Corrosion of steel</li> <li>Short design life</li> </ul>                             | 2    |

The comparison indicates the preferred culvert replacement option is precast rigid frame box. Additional recommendations regarding bedding and backfill material is provided in Section 9.8.

### 9.3 FOUNDATION RECOMMENDATIONS

The design recommendations presented in the following sections have been developed in accordance with the requirements and methods described in the Canadian Highway Bridge Design Code (CHBDC, 2006).

#### 9.3.1 Shallow Foundation

This section provides recommendations for the design of spread footings founded on undisturbed soil.

**9.3.1.1 Geotechnical Vertical Resistance**

The geotechnical resistances provided in Table 9.3 may be used in the design, provided the footings are placed on undisturbed soil.

**Table 9.3: Geotechnical Resistance for Shallow Foundation (Spread Footing)**

| Founding Element                   | Founding Elevation (m) | Culvert Dimension (m) | Factored Geotechnical Resistance at ULS <sub>f</sub> (kPa) | Geotechnical Resistance at SLS (kPa) |
|------------------------------------|------------------------|-----------------------|--|--------------------------------------|
| Spread footing on undisturbed soil | ± 291.5                | 2.4 x 42.3            | 500  | 150                                  |

In accordance with Section 6.6.2 of the CHBDC, a resistance factor of 0.5 has been applied in calculating the factored geotechnical resistance at Ultimate Limit State (ULS<sub>f</sub>).

The axial reaction at SLS corresponds to a vertical deflection (settlement) of 25 mm.

**9.3.1.2 Geotechnical Horizontal Resistance (Sliding)**

The unfactored horizontal resistance of spread footings may be calculated using the following unfactored coefficients of friction:

- 0.55 Between OPSS Granular A and concrete
- 0.50 between native soil and concrete

In accordance with Table 6.1 of the CHBDC, a resistance factor against sliding of 0.8 should be applied to obtain the resistance at ULS<sub>f</sub>.

**9.4 TEMPORARY PROTECTION SYSTEMS**

A culvert invert elevation of approximately 291.5 m will require a maximum excavation depth of approximately 4.5 m. If the peat or organic material layer is present under the culvert, the excavation will need to extend deeper. Based on the recommended excavation site slope of 1.5H:1V (Section 9.7) a temporary roadway protection will be required for the culvert replacement. The culvert replacement will necessitate excavation below the groundwater levels and below the peat if present under the culvert. As such, unwatering of the excavation will be required for the culvert replacement, and may also be required during installation of the roadway protection system.

The following table compares the available roadway protection options considered for the culvert replacement:

**Table 9.4: Comparison of Roadway Protection Systems**

| Option   | Advantages   | Disadvantages   | Relative Cost | Risk & Consequences  |
|--|--|---|---------------|--|
| H-Piles with timber lagging; struts/rakers                         | <ul style="list-style-type: none"> <li>Simple installation</li> </ul>  | <ul style="list-style-type: none"> <li>Dewatering more difficult</li> </ul>                             | Low           | <ul style="list-style-type: none"> <li>Lack of ground stability when extending below the peat and water table</li> </ul> |
| Steel sheet pile (SSP); rakers/tieback anchors or internal bracing | <ul style="list-style-type: none"> <li>No unwatering required during roadway protection installation</li> <li>The excavation level is expected to extend to sandy silt to silty sand. A coffered sheet pile approach would allow for a construction area kept dry using conventional unwatering practices</li> </ul> | <ul style="list-style-type: none"> <li>Difficult to drive/install in dense soil with cobbles</li> </ul> | High          | <ul style="list-style-type: none"> <li>Damage or loss of sheet pile walls during driving</li> </ul>                      |

Since the excavation is expected to extend to about elevation 291.0 m and the water level at elevation 291.8 m, the use of a simple soldier pile wall along the centerline of the road is not likely a feasible option, particularly if peat is encountered within the excavation.

The contractor may choose to use coffered sheet piles to control groundwater issues. Assuming the water table to be approximately 0.8 m above the excavation depth it is anticipated that provided the sheet piles are driven to at least 1.0 m below the excavation depth, conventional sump pumping from within the sheet piled excavation would be feasible. Sheet piles would be strutted or driven deeper to provide horizontal stability. Damage of sheet piles during driving is possible due to the presence of cobbles and boulders; several attempts to install sheet piles should be anticipated.

The contractor will ultimately be responsible to develop and implement a roadway protection system meeting the requirements of OPSS 539, including establishing appropriate geotechnical design parameters.

Shoring design should meet the requirements of Performance Level 2 as per OPSS 539 and should consider traffic loading. Performance Level 2 specifies a Maximum Angular Distortion of 1:200 and a Maximum Horizontal Displacement of 25 mm. Pile and raker spacing must be designed not to exceed these limits. Horizontal movement should be monitored throughout the culvert replacement process as described in OPSS 539. The monitoring requirements outlines in OPSS 539 are considered to be appropriate for this project.

## 9.4.1 Lateral Earth Pressures

### 9.4.1.1 Lateral Earth Pressures under Static Conditions

Earth pressures will need to be considered in the design of the temporary roadway protection system.

Computation of earth pressures should be in accordance with Section 6.9 of the CHBDC and the Occupational Health and Safety Act Regulations for Construction Projects. The distribution of earth pressures acting on the protection system could be estimated using the Canadian Foundation Engineering Manual. For retaining walls that are designed to allow rotation, active earth pressure may be used for design. For rigidly tied and unyielding structures, the at-rest earth pressure should be used for design. The unfactored soil parameters provided in Table 9.1 may be used for design of walls and protection systems with a horizontal backfill. The effects of compaction should be accounted for by applying a compaction surcharge as shown in Figure 6.6 of the CHBDC.

Values for  $K_a$ ,  $K_o$ ,  $K_p$ , and  $\gamma$  are provided in Table 9.5 for horizontal backfill.

**Table 9.5: Recommended Non-Seismic Earth Pressure Parameters (Horizontal Backfill)**

| Parameter                                       | OPSS Gran A and Gran B Type II | FILL | Clayey SILT | Sandy SILT to Silty SAND |
|---|--------------------------------|------|-------------|--------------------------|
| Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> ) | 22                             | 20.8 | 19.6        | 21.3                     |
| Effective Friction Angle                        | 35°                            | 32°  | 28°         | 32°                      |
| Coefficient of Earth Pressure at Rest ( $K_o$ ) | 0.43                           | 0.47 | 0.53        | 0.47                     |
| Coefficient of Active Earth Pressure ( $K_a$ )  | 0.27                           | 0.31 | 0.36        | 0.31                     |
| Coefficient of Passive Earth Pressure ( $K_p$ ) | 3.69                           | 3.25 | 2.77        | 3.25                     |

## 9.5 EMBANKMENTS

The roadway profile at the culvert location will not be raised above the existing profile. Some minor embankment widening may be carried out to accommodate construction staging.

### 9.5.1 Embankment Construction

Embankment construction widening should be carried out in conformance with SP 206503 and OPSD 203.020 Embankment Over Swamp.

Embankment slopes should be constructed at no steeper than 2H:1V. The existing slopes should be benched as per OPSD 208.010 if widening is proposed. New fill materials should consist of OPSS Select Subgrade Material (or better) placed in 300 mm thick lifts compacted to at least 95% Standard Proctor Maximum Dry Density.

### **9.5.2 Stability of Slopes**

No sign of embankment instability was observed during the foundation drilling. Stantec is not aware of a history of slope instabilities at the culvert location. The proposed slopes will be reinstated at 2H:1V or gentler.

The proposed slopes are considered stable with respect to deep seated failures with factors of safety of greater than 1.3. Surficial and toe failures could occur if proper erosion control is not provided for the new embankments.

### **9.5.3 Embankment Settlement**

The profile and footprint of the existing embankment is not anticipated to be significantly altered.

Settlement of the underlying soil is anticipated to be less than 25 mm. Self settlement of the new fill material is anticipated to be less than 20 mm and should occur during construction.

## **9.6 EROSION AND SCOUR PROTECTION**

All slopes within 3 m of the culvert inlets and outlets should be surfaced with rip-rap at least 300 mm thick placed on a Class II non-woven filter fabric.

Normal slope vegetation should be established as soon as possible after completion of embankment fills in order to control surficial erosion.

A clay seal should be provided at the inlet of the culvert to prevent seepage through the backfill material. The clay seal should be constructed as follows:

- Clay should meet OPSS 1205 specifications.
- At least 0.6 m thick.
- Extend from 0.3 m above the high water level to the full depth of excavation.
- Seal should not be located beneath the pavement structure.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site.

## **9.7 CONSTRUCTION STAGING**

The culvert replacement is anticipated to involve a staged construction. This will involve the closure of one lane at a time for a short duration using appropriate traffic control. Two options are being evaluated for the construction staging:

Option 1: Support the excavation with temporary roadway protection near the centerline of the highway. Recommendations for temporary roadway protection are provided in Section 9.4.

Option 2: Temporarily lowering the profile of the roadway at the culvert and replacing the culvert without temporary roadway protection. Recommendations for temporary excavation side slope are presented in Section 9.8.

### 9.8 EXCAVATION AND BACKFILLING

Excavation and backfill for the new culvert should be carried out in accordance with:

- OPSS 902
- MTOD 803.021

Bedding and backfill material should be provided for the culvert as per the appropriate OPSD specification. The bedding material should include a 275 mm thick layer of OPSS Granular A consisting of a 75 mm thick uncompacted levelling course over a 200 mm thick compacted layer. Peat and organic soil encountered within the footprint of the bedding layer should be subexcavated and the bedding layer thickness increased accordingly. The backfill material should consist of free-draining, non-frost susceptible granular material such as OPSS Granular A or Granular B Type I. The bedding and backfill material should be placed in 300 mm thick lifts compacted to at least 95% SPMDD.

The groundwater level should be lowered at least 0.5 m below the subgrade level of the culverts to provide a stable base during placement of culvert bedding material.

OPSD 3090.101 indicates that the frost penetration depth at the site is 1.4 m. The frost penetration depth should be used for the design of the culvert frost taper.

Side slopes for open cut excavations (if any) should conform to Occupational Health and Safety Act (OHSA) regulations for Construction Projects. The soils encountered at the site may be classified as Type 3 Soil. The excavation walls should be sloped from its bottom with a slope having a minimum gradient of 1H:1V. Excavation below the water table will require gentler slopes. However, excavations within the peat should be classified as Type 4 soil, walls should be sloped from its bottom with a slope having a minimum gradient of 3H:1V.

### 9.9 UNWATERING

Replacement of the culvert will require excavation below the groundwater level encountered during the investigation. Control of groundwater during construction is required. The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert to provide a stable base during placement of culvert bedding material.

The native soils within the anticipated depth of excavation have a low to moderate hydraulic conductivity, in the order of  $10^{-3}$  to  $10^{-5}$  cm/s. Significant groundwater flow should be anticipated within the organic soil and peat layers. For the case of sheet piles extending to at least 1.0 m below the bottom of excavation, unwatering of the culvert excavation using conventional sump and pump techniques should be adequate.

## 9.10 CEMENT TYPE AND CORROSION PROTECTION

Two soil samples were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in Table 5.1.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate concentration for the samples were less than 5 and 73 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH values were 7.12 to 7.45 which are within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided in Table 5.1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

## 10.0 SPECIFICATIONS

The following specifications are referenced in this report:

**Table 10.1: Specifications Referenced in Report**

| Document      | Title  |
|---------------|--|
| OPSD 3090.101 | Foundation, Frost Depths for Southern Ontario                          |
| OPSS 539      | Construction Specification for Temporary Protection System             |
| OPSS 902      | Construction Specification for Excavation and Backfilling – Structures |
| MTOD 803.021  | Bedding and Backfill for Precast Concrete Box Culvert                  |
| OPSS 1205     | Material Specification for Clay Seal                                   |
| OPSD 203.030  | Embankment Over Swamp Existing Slope Excavated to 1H:1V                |

## **11.0 REFERENCES**

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

CHBDC. 2006. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

# FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

## 12.0 CLOSURE

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

This report was prepared by Athir Nader, and reviewed by Christopher McGrath and Raymond Haché.

Respectfully submitted,

STANTEC CONSULTING LTD.



Christopher McGrath, P.Eng.  
Associate- Senior Geotechnical Engineer

Raymond Haché, M.Sc., P.Eng.  
Designated Principal MTO Foundation Contact

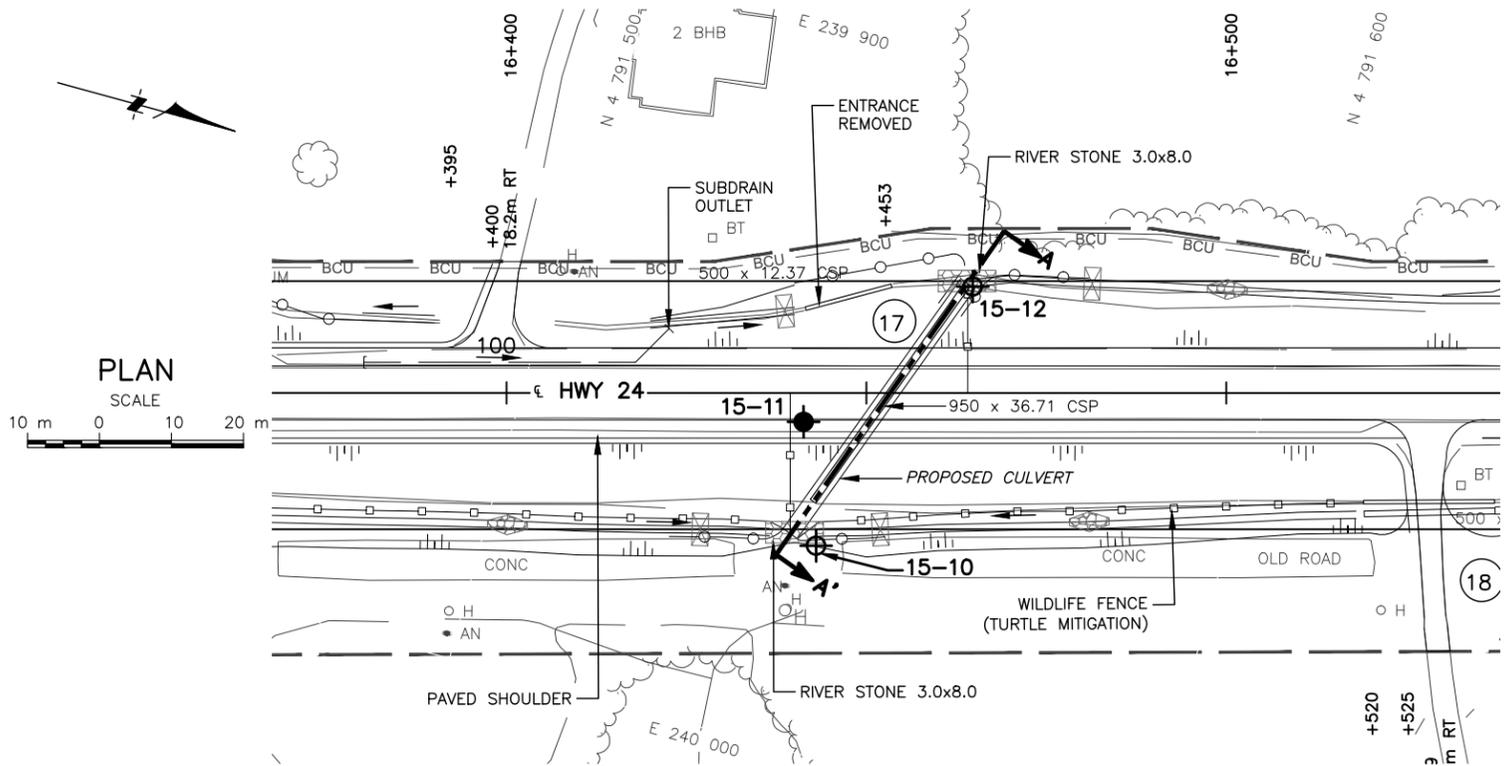


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## **APPENDIX A**

Drawing No. 1 – Borehole Location Plan and Soil Strata Plot

Site Photos

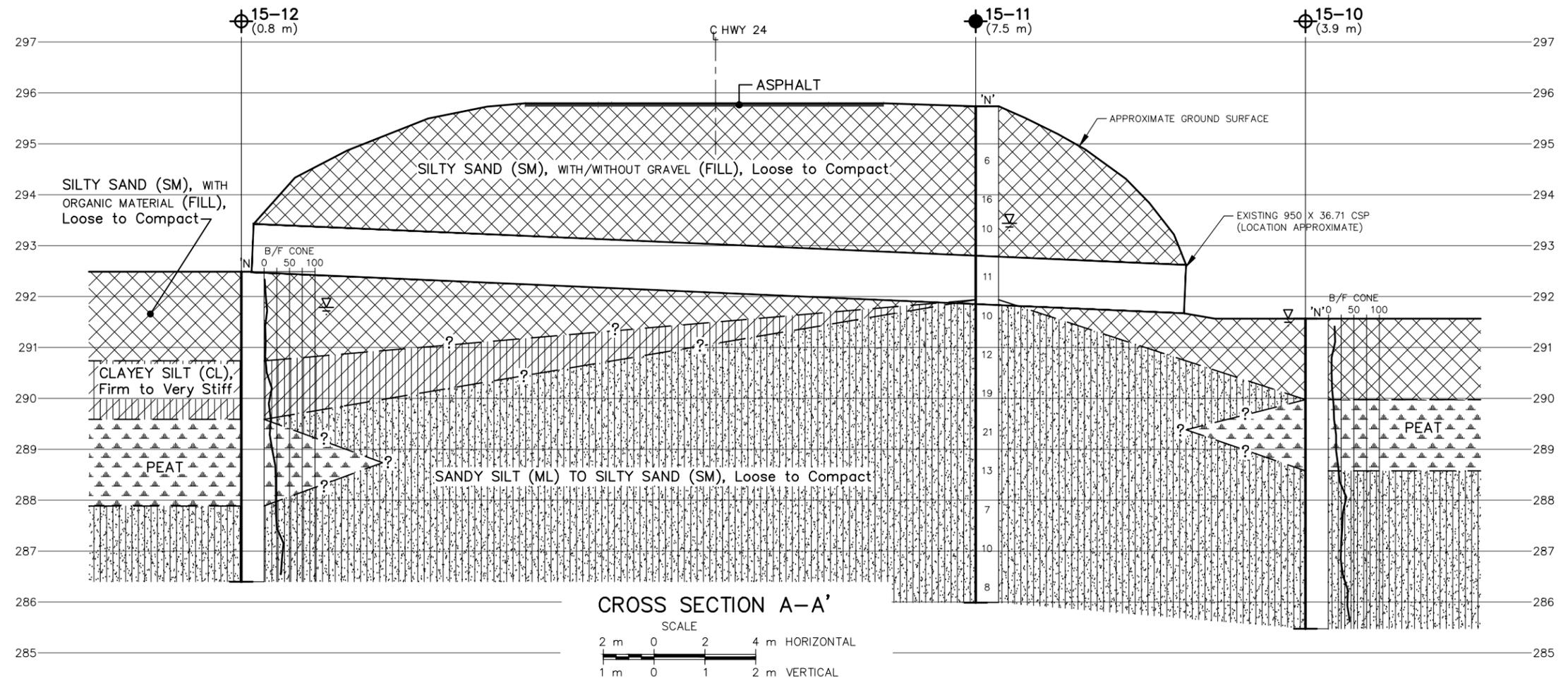
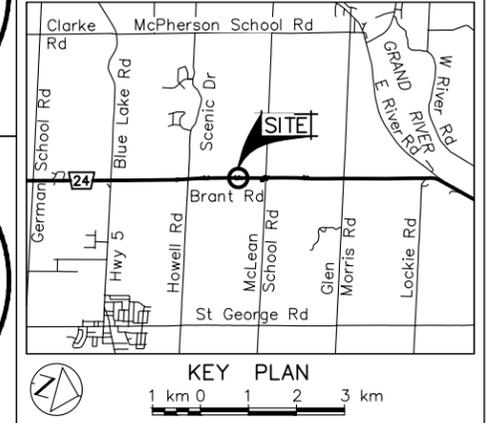


**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

PLATE No  
**CONT**  
**WP 3065-11-00**

HWY 24, TWP OF S DUMFRIES, ON  
CULVERT AT STA 16+453 (SITE 17)  
BOREHOLE LOCATIONS & SOIL STRATA

**SHEET**



**LEGEND**

- Borehole
- ⊕ Dynamic Cone Penetration Test (Cone)
- (x.x m) Offset from Cross Section Line in meters
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- ▽ Inferred WL at time of investigation, June 2015

| No    | ELEVATION | MTM_ZONE 10 NORTH | COORDINATES EAST |
|-------|-----------|-------------------|------------------|
| 15-10 | 291.6     | 4 791 545.0       | 239 971.5        |
| 15-11 | 295.7     | 4 791 538.8       | 239 955.4        |
| 15-12 | 292.5     | 4 971 556.6       | 239 931.1        |

**NOTES**

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

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

| REVISIONS  | DATE | BY    | DESCRIPTION    |
|------------|------|-------|----------------|
| 2017-01-09 | CM   | ADDED | GEOGRES NUMBER |

GEOGRES No 40P08-239

| HWY No | HWY | DIST |
|--------|-----|------|
| 24     |     |      |

| SUBM'D | CHECKED | DATE       | SITE |
|--------|---------|------------|------|
| AN     |         | 2015-12-11 | C17  |

| DRAWN | CHECKED | APPROVED | DWG |
|-------|---------|----------|-----|
| GBB   |         |          | 1   |



Project No.: 165000903

GWP: 3065-11-00

Site Photographs

Project Name: Culvert at Station 16+453, Highway  
24 Pavement Rehabilitation,  
Township of South Dumfries, ON

Date: June 9, 2015



Site Photo No.: 1

Looking north on BH15-11



Site Photo No.: 2

Looking south on BH15-11



Project No.: 165000903

GWP: 3065-11-00

Site Photographs

Project Name: Culvert at Station 16+453, Highway  
24 Pavement Rehabilitation,  
Township of South Dumfries, ON

Date: June 9, 2015



Site Photo No.: 3

Looking southeast toward BH15-10 on BH15-11



Site Photo No.: 4

Looking northwest toward BH15-12 on BH15-11



Project No.: 165000903

GWP: 3065-11-00

Site Photographs

Project Name: Culvert at Station 16+453, Highway  
24 Pavement Rehabilitation,  
Township of South Dumfries, ON

Date: June 24, 2015



Site Photo No.: 5

Looking northwest near BH15-10



Site Photo No.: 6

Looking northeast on BH15-12

## **APPENDIX B**

Symbols and Terms Used on Borehole Records

Borehole Records

## SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

|                |   |
|----------------|---|
| <i>Rootmat</i> | - vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface |
| <i>Topsoil</i> | - mixture of soil and humus capable of supporting vegetative growth   |
| <i>Peat</i>    | - mixture of visible and invisible fragments of decayed organic matter  |
| <i>Till</i>    | - unstratified glacial deposit which may range from clay to boulders  |
| <i>Fill</i>    | - material below the surface identified as placed by humans (excluding buried services)                         |

#### Terminology describing soil structure:

|                   |  |
|-------------------|--|
| <i>Desiccated</i> | - having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc. |
| <i>Fissured</i>   | - having cracks, and hence a blocky structure  |
| <i>Varved</i>     | - composed of regular alternating layers of silt and clay                                    |
| <i>Stratified</i> | - composed of alternating successions of different soil types, e.g. silt and sand            |
| <i>Layer</i>      | - > 75 mm in thickness   |
| <i>Seam</i>       | - 2 mm to 75 mm in thickness   |
| <i>Parting</i>    | - < 2 mm in thickness  |

#### Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

#### Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

|                             |               |
|-----------------------------|---------------|
| <i>Trace, or occasional</i> | Less than 10% |
| <i>Some</i>                 | 10-20%        |
| <i>Frequent</i>             | > 20%         |

#### Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

| Compactness Condition | SPT N-Value |
|-----------------------|-------------|
| <i>Very Loose</i>     | <4          |
| <i>Loose</i>          | 4-10        |
| <i>Compact</i>        | 10-30       |
| <i>Dense</i>          | 30-50       |
| <i>Very Dense</i>     | >50         |

#### Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

| Consistency       | Undrained Shear Strength |           | Approximate SPT N-Value |
|-------------------|--------------------------|-----------|-------------------------|
|                   | kips/sq.ft.              | kPa       |                         |
| <i>Very Soft</i>  | <0.25                    | <12.5     | <2                      |
| <i>Soft</i>       | 0.25 - 0.5               | 12.5 - 25 | 2-4                     |
| <i>Firm</i>       | 0.5 - 1.0                | 25 - 50   | 4-8                     |
| <i>Stiff</i>      | 1.0 - 2.0                | 50 - 100  | 8-15                    |
| <i>Very Stiff</i> | 2.0 - 4.0                | 100 - 200 | 15-30                   |
| <i>Hard</i>       | >4.0                     | >200      | >30                     |

## ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

### Terminology describing rock quality:

| RQD    | Rock Mass Quality        |
|--------|--------------------------|
| 0-25   | <i>Very Poor Quality</i> |
| 25-50  | <i>Poor Quality</i>      |
| 50-75  | <i>Fair Quality</i>      |
| 75-90  | <i>Good Quality</i>      |
| 90-100 | <i>Excellent Quality</i> |

| Alternate (Colloquial) Rock Mass Quality |                                 |
|--|---------------------------------|
| <i>Very Severely Fractured</i>           | <i>Crushed</i>                  |
| <i>Severely Fractured</i>                | <i>Shattered or Very Blocky</i> |
| <i>Fractured</i>                         | <i>Blocky</i>                   |
| <i>Moderately Jointed</i>                | <i>Sound</i>                    |
| <i>Intact</i>                            | <i>Very Sound</i>               |

**RQD (Rock Quality Designation)** denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

**SCR (Solid Core Recovery)** denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

**Fracture Index (FI)** is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

### Terminology describing rock with respect to discontinuity and bedding spacing:

| Spacing (mm) | Discontinuities        | Bedding                 |
|--------------|------------------------|-------------------------|
| >6000        | <i>Extremely Wide</i>  | -                       |
| 2000-6000    | <i>Very Wide</i>       | <i>Very Thick</i>       |
| 600-2000     | <i>Wide</i>            | <i>Thick</i>            |
| 200-600      | <i>Moderate</i>        | <i>Medium</i>           |
| 60-200       | <i>Close</i>           | <i>Thin</i>             |
| 20-60        | <i>Very Close</i>      | <i>Very Thin</i>        |
| <20          | <i>Extremely Close</i> | <i>Laminated</i>        |
| <6           | -                      | <i>Thinly Laminated</i> |

### Terminology describing rock strength:

| Strength Classification | Grade | Unconfined Compressive Strength (MPa) |
|-------------------------|-------|---------------------------------------|
| <i>Extremely Weak</i>   | R0    | <1                                    |
| <i>Very Weak</i>        | R1    | 1 – 5                                 |
| <i>Weak</i>             | R2    | 5 – 25                                |
| <i>Medium Strong</i>    | R3    | 25 – 50                               |
| <i>Strong</i>           | R4    | 50 – 100                              |
| <i>Very Strong</i>      | R5    | 100 – 250                             |
| <i>Extremely Strong</i> | R6    | >250                                  |

### Terminology describing rock weathering:

| Term                 | Symbol | Description  |
|----------------------|--------|--|
| <i>Fresh</i>         | W1     | No visible signs of rock weathering. Slight discoloration along major discontinuities                                    |
| <i>Slightly</i>      | W2     | Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.           |
| <i>Moderately</i>    | W3     | Less than half the rock is decomposed and/or disintegrated into soil.  |
| <i>Highly</i>        | W4     | More than half the rock is decomposed and/or disintegrated into soil.  |
| <i>Completely</i>    | W5     | All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact. |
| <i>Residual Soil</i> | W6     | All the rock converted to soil. Structure and fabric destroyed.  |

## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



## SAMPLE TYPE

|                  |   |
|------------------|---|
| SS               | Split spoon sample (obtained by performing the Standard Penetration Test)     |
| ST               | Shelby tube or thin wall tube   |
| DP               | Direct-Push sample (small diameter tube sampler hydraulically advanced)       |
| PS               | Piston sample   |
| BS               | Bulk sample   |
| HQ, NQ, BQ, etc. | Rock core samples obtained with the use of standard size diamond coring bits. |

## WATER LEVEL MEASUREMENT



measured in standpipe, piezometer, or well



inferred

## RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

## N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

## DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

## OTHER TESTS

|          |  |
|----------|--|
| S        | Sieve analysis   |
| H        | Hydrometer analysis  |
| k        | Laboratory permeability  |
| $\gamma$ | Unit weight  |
| $G_s$    | Specific gravity of soil particles   |
| CD       | Consolidated drained triaxial  |
| CU       | Consolidated undrained triaxial with pore pressure measurements  |
| UU       | Unconsolidated undrained triaxial  |
| DS       | Direct Shear   |
| C        | Consolidation  |
| $Q_u$    | Unconfined compression   |
| $I_p$    | Point Load Index ( $I_p$ on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm) |

|  |   |
|--|---|
|  | Single packer permeability test; test interval from depth shown to bottom of borehole |
|  | Double packer permeability test; test interval as indicated                           |
|  | Falling head permeability test using casing   |
|  | Falling head permeability test using well point or piezometer                         |





# RECORD OF BOREHOLE No BH15-11

1 OF 1

METRIC

W.P. 3065-11-00 LOCATION Hwy 24, Township of South Dumfries, ON N: 4 791 539 E: 239 955 ORIGINATED BY AN  
 DIST South Dumfries HWY 24 BOREHOLE TYPE Hollow Stem Augers - Split spoon Sampler COMPILED BY AN  
 DATUM Geodetic DATE 2015 06 09 - 2015 06 09 CHECKED BY CM

| SOIL PROFILE   |  | SAMPLES    |        |      | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                    |    |     |    | PLASTIC LIMIT<br>W <sub>p</sub> | NATURAL MOISTURE CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub> | UNIT WEIGHT<br>γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |                   |    |    |    |    |    |  |
|----------------|--|------------|--------|------|-------------------------|-----------------|--|--------------------|----|-----|----|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|-------------------|----|----|----|----|----|--|
| ELEV. DEPTH    | DESCRIPTION  | STRAT PLOT | NUMBER | TYPE |                         |                 | "N" VALUES                               | SHEAR STRENGTH kPa |    |     |    |                                 |                               |                                |                  |                                       | WATER CONTENT (%) |    |    |    |    |    |  |
|                |  |            |        |      |                         | 20              | 40                                       | 60                 | 80 | 100 | 20 | 40                              | 60                            | 80                             | 100              | 10                                    | 20                | 30 | GR | SA | SI | CL |  |
| 295.7<br>290.1 | 70 mm ASPHALT<br>Fill: silty SAND (SM) with/without gravel<br><br>Loose to compact<br>Brown to grey, moist to wet<br>-Groundwater observed at a depth of 2.3 m |            | 1      | GS   | -                       |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 2      | SS   | 6                       |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 3      | SS   | 16                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 4      | SS   | 10                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 5      | SS   | 11                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
| 291.9<br>3.8   | Sandy SILT (ML) to silty SAND (SM)<br><br>Loose to compact<br>Brown to grey, wet<br>-Cobbles and boulders encountered between 8.3 m and 9.0 m                  |            | 6      | SS   | 10                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 7      | SS   | 12                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 8      | SS   | 19                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 9      | SS   | 21                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 10     | SS   | 13                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 11     | SS   | 7                       |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 12     | SS   | 10                      |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
|                |  |            | 13     | SS   | 8                       |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |
| 286.0<br>9.8   | End of Borehole  |            |        |      |                         |                 |  |                    |    |     |    |                                 |                               |                                |                  |                                       |                   |    |    |    |    |    |  |

STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO.MOT.GDT 9/11/15

✕<sup>3</sup>, ✕<sub>3</sub>: Numbers refer to Sensitivity ○<sup>3</sup>% STRAIN AT FAILURE



# RECORD OF BOREHOLE No BH15-12

1 OF 1

METRIC

W.P. 3065-11-00 LOCATION Hwy 24, Township of South Dumfries, ON N: 4 791 557 E: 239 931 ORIGINATED BY AN  
 DIST South Dumfries HWY 24 BOREHOLE TYPE Portable Equipment, DCPT - Pionjar Split spoon Sampler COMPILED BY AN  
 DATUM Geodetic DATE 2015 06 24 - 2015 06 24 CHECKED BY CM

| SOIL PROFILE  |   | SAMPLES                 |        |      | GROUND WATER CONDITIONS | ELEVATION SCALE  | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                    | PLASTIC LIMIT<br>W <sub>p</sub> | NATURAL MOISTURE CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub> | UNIT WEIGHT<br>γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |                          |
|---|---|-------------------------|--------|------|-------------------------|------------------|--|--------------------|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|--------------------------|
| ELEV DEPTH  | DESCRIPTION   | STRAT PLOT              | NUMBER | TYPE |                         |                  | "N" VALUES                               | SHEAR STRENGTH kPa |                                 |                               |                                |                  |                                       | WATER CONTENT (%)        |
| 292.5   | FILL: silty SAND (SM) with organic material<br>Loose to compact<br>Black, moist to wet, organic material<br>-Groundwater observed at a depth of 0.7 m | [Cross-hatched pattern] | 1      | SS   | -                       | [DCPT Plot Line] | 20                                       | 40                 | 60                              | 80                            | 100                            | 89               | 25 29 38 8<br>non-plastic             |                          |
| 0.0   |   |                         | 2      | SS   | -                       |                  | 20                                       | 40                 | 60                              | 80                            | 100                            | 97               |                                       |                          |
| 290.7   | Clayey SILT (CL)<br>Firm to very stiff<br>Grey, wet   | [Diagonal lines]        | 3      | SS   | -                       |                  | 291                                      | 20                 | 40                              | 60                            | 80                             | 100              | 48                                    | 0 7 75 18                |
| 1.8   |   |                         | 4      | SS   | -                       |                  | 290                                      | 20                 | 40                              | 60                            | 80                             | 100              | 42                                    |                          |
| 289.6   | PEAT<br>Black, wet  | [Wavy pattern]          | 5      | SS   | -                       |                  | 289                                      | 20                 | 40                              | 60                            | 80                             | 100              | 140                                   |                          |
| 2.9   |   |                         | 6      | SS   | -                       |                  | 289                                      | 20                 | 40                              | 60                            | 80                             | 100              | 148                                   |                          |
| 287.9   |   |                         | 7      | SS   | -                       |                  | 288                                      | 20                 | 40                              | 60                            | 80                             | 100              | 95                                    |                          |
| 286.4   | Sandy SILT (ML) to silty SAND (SM)<br>Loose to compact<br>Grey to brown, wet  | [Dotted pattern]        | 8      | SS   | -                       |                  | 287                                      | 20                 | 40                              | 60                            | 80                             | 100              | 95                                    | 6 63 29 2<br>non-plastic |
| 4.6   |   |                         | 8      | SS   | -                       | 287              | 20                                       | 40                 | 60                              | 80                            | 100                            | 95               |                                       |                          |
| 286.4   | 6.1   | End of Borehole         |        |      |                         |                  |  |                    |                                 |                               |                                |                  |                                       |                          |
| -Split spoon sampler was advanced using a Pionjar jackhammer<br>-DCPT was carried out using a 70 lb weight hammer and 30 in. drop<br>-DCPT values corrected for 50% of the field values |   |                         |        |      |                         |                  |  |                    |                                 |                               |                                |                  |                                       |                          |

STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO.MOT.GDT 9/11/15

✕<sup>3</sup>, ✕<sub>3</sub>: Numbers refer to Sensitivity ○<sup>3</sup>% STRAIN AT FAILURE

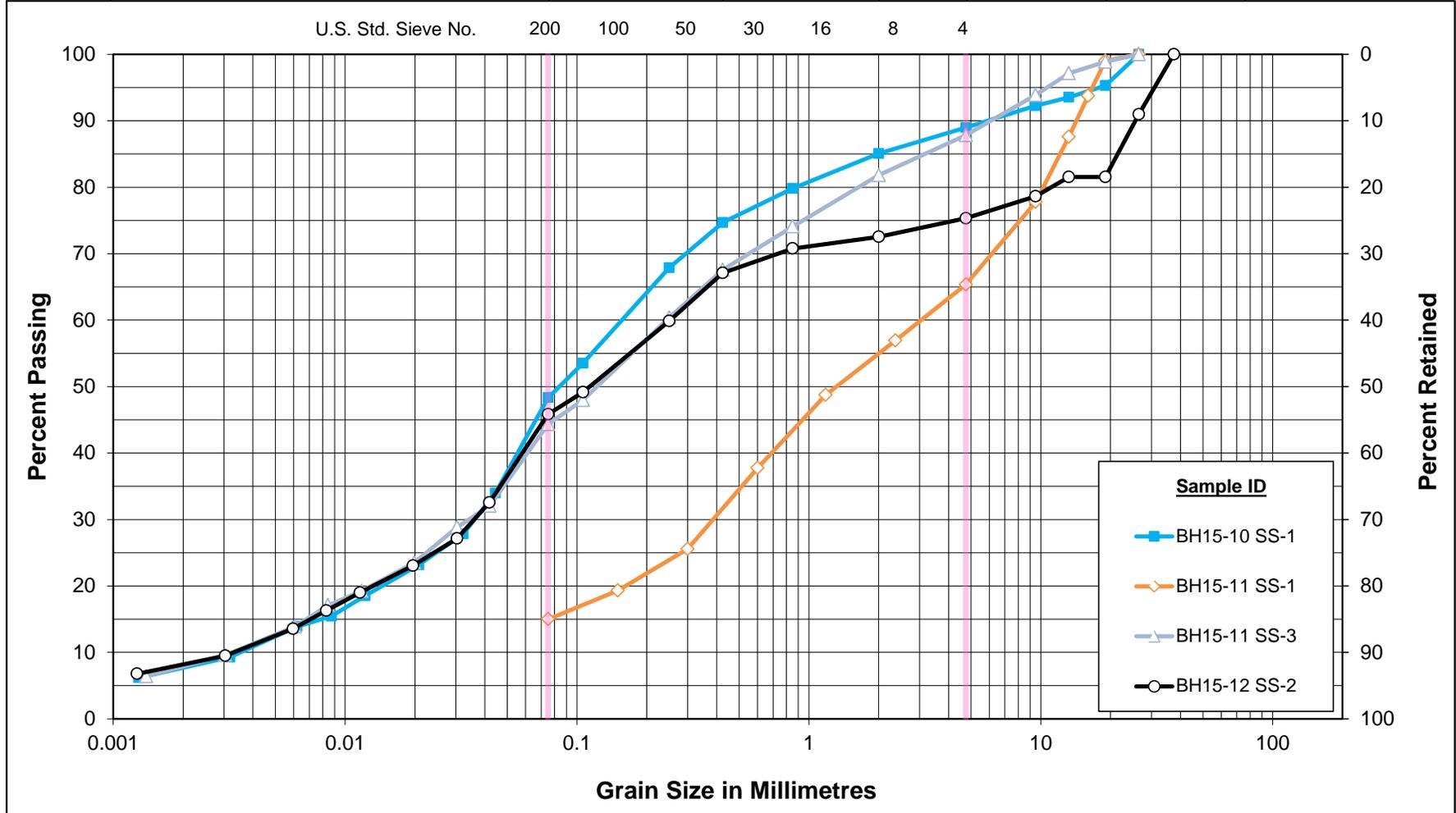
# APPENDIX C

Laboratory Test Results

# Unified Soil Classification System

|             |      |        |        |        |        |
|-------------|------|--------|--------|--------|--------|
|             | SAND |        |        | Gravel |        |
| CLAY & SILT | Fine | Medium | Coarse | Fine   | Coarse |

U.S. Std. Sieve No.      200    100    50    30    16    8    4

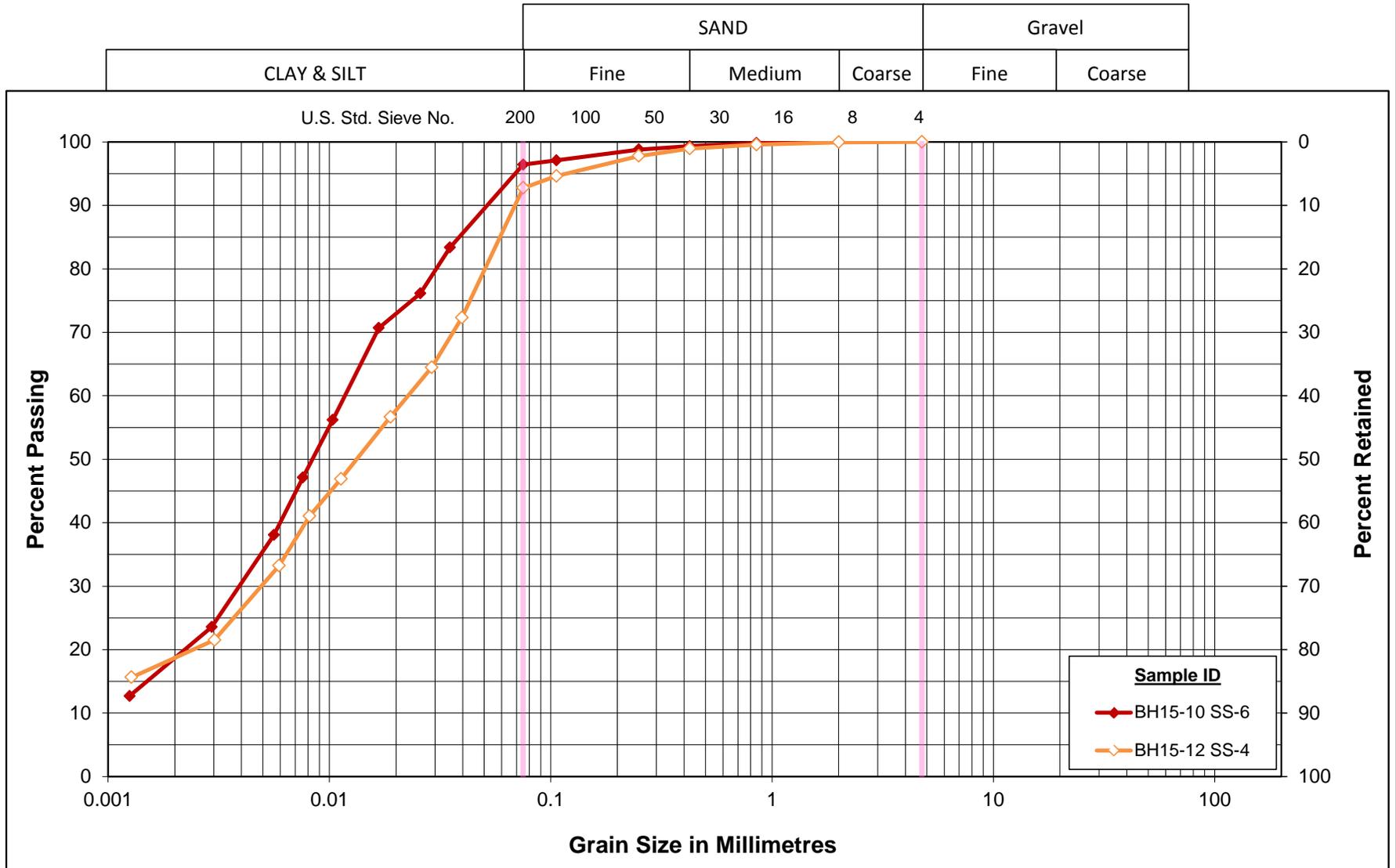


GRAIN SIZE DISTRIBUTION  
FILL: Silty SAND (SM)  
with/without Gravel

Figure No. 1

Project No. 165000903

# Unified Soil Classification System

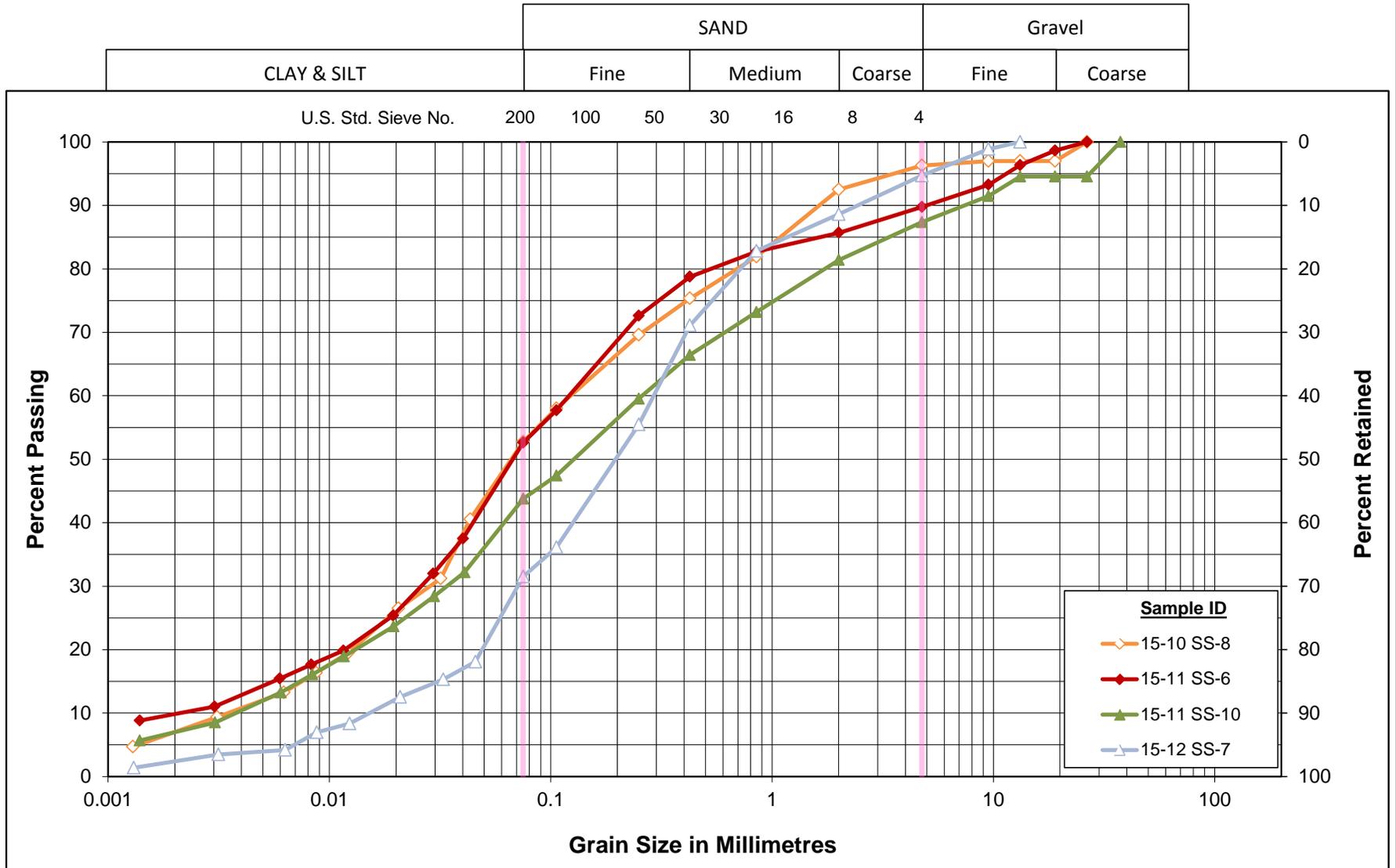


## GRAIN SIZE DISTRIBUTION Clayey SILT (CL)

Figure No. 2

Project No. 165000903

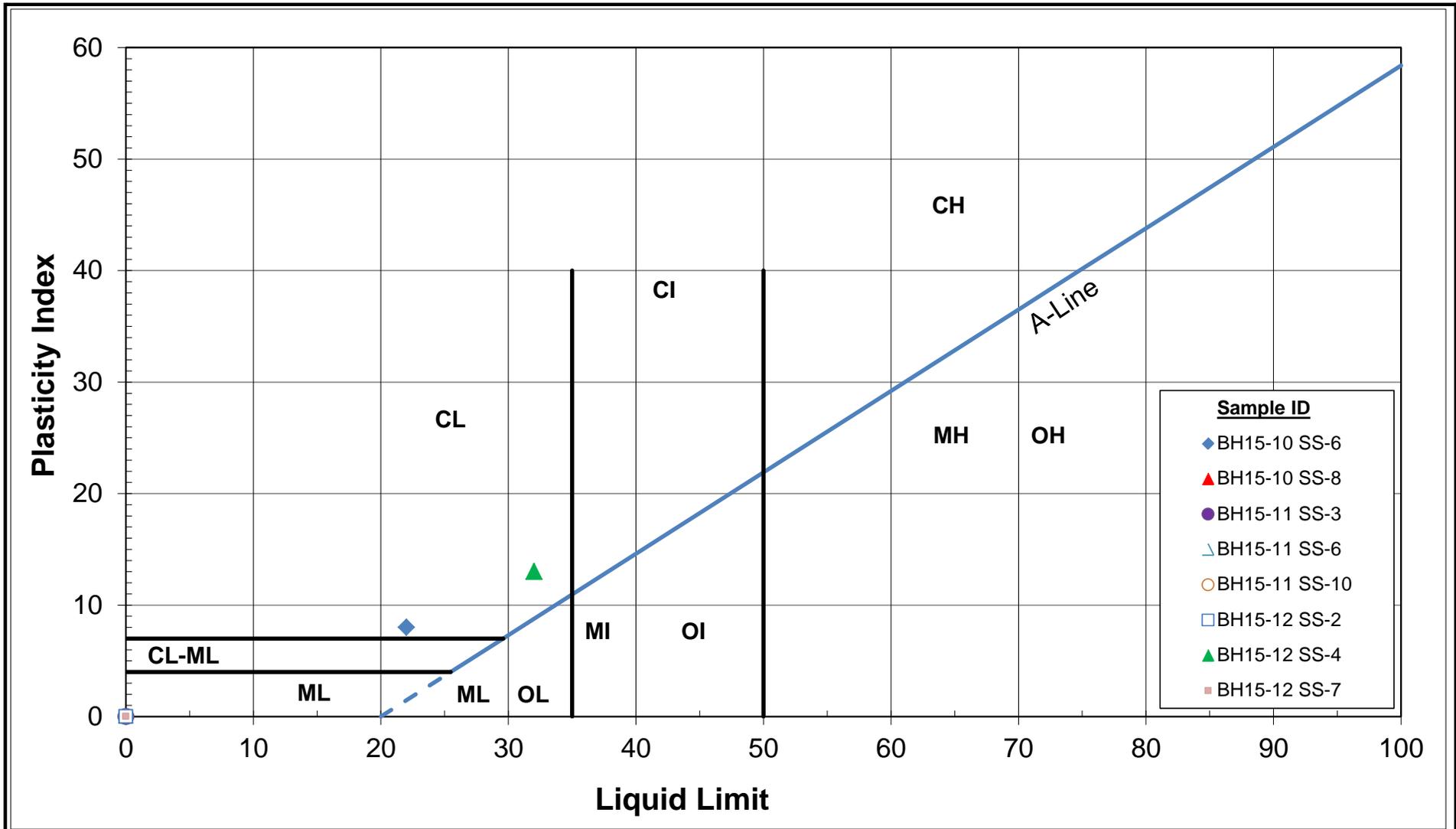
# Unified Soil Classification System



GRAIN SIZE DISTRIBUTION  
Sandy SILT (ML) to Silty SAND (SM)

Figure No. 3

Project No. 165000903



# PLASTICITY CHART

Figure No. 4

Project No. 165000903

## **APPENDIX D**

Notice to Contractor – Presence of Cobbles and Boulders

## **NOTICE TO CONTRACTOR – Cobbles and Boulders**

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### Special Provision

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#### **Cobbles and Boulders within Soil**

Cobbles and boulders were inferred during drilling of the boreholes at several of the culvert replacement locations. Cobbles and boulders were inferred during drilling and the observations are documented in the Foundation Investigations noted below. It recommended that the bidder review the Foundation Investigation Reports and borehole records provided in the Reports with respect to the presence of cobbles and boulders.

Presence of cobbles and boulders are noted in the following Foundation Investigation Report:

- Foundation Investigation and Design Report titled Highway 24 Resurfacing and Replacement of Culvert at Station 16+453 (Site No. 17) Township of South Dumfries, ON (Project No. 165000903)