

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

Highway 24 Resurfacing and  
Replacement of Culvert at  
Station 15+738 (Site No. 12)  
Township of South Dumfries, ON

G.W.P. 3065-11-00

Geocres No. 40P08-241



Prepared for:  
Ministry of Transportation Ontario

Prepared by:  
Stantec Consulting Ltd.  
400 – 1331 Clyde Avenue  
Ottawa, ON K2C 3G4

Project No. 165000903

January 2017

## Table of Contents

<b>1.0</b>	<b>INTRODUCTION .....</b>	<b>1</b>
<b>2.0</b>	<b>SITE DESCRIPTION AND GEOLOGY .....</b>	<b>1</b>
<b>3.0</b>	<b>INVESTIGATION PROCEDURES .....</b>	<b>2</b>
3.1	REVIEW OF PREVIOUS INVESTIGATION.....	2
3.2	FIELD INVESTIGATION – CULVERT SITE.....	2
3.3	LOCATION AND ELEVATION SURVEY .....	3
3.4	LABORATORY TESTING .....	3
<b>4.0</b>	<b>SUBSURFACE CONDITIONS .....</b>	<b>4</b>
4.1	SUBSURFACE PROFILE .....	4
4.1.1	PAVEMENT .....	4
4.1.2	TOPSOIL .....	4
4.1.3	Fill.....	4
4.1.4	Clayey SILT to Sandy Clayey SILT .....	4
4.1.5	PEAT .....	5
4.1.6	Sandy SILT.....	5
4.1.7	Groundwater.....	6
<b>5.0</b>	<b>CHEMICAL ANALYSIS.....</b>	<b>6</b>
<b>6.0</b>	<b>MISCELLANEOUS .....</b>	<b>7</b>
<b>7.0</b>	<b>CLOSURE.....</b>	<b>8</b>
<b>8.0</b>	<b>GENERAL BACKGROUND.....</b>	<b>9</b>
<b>9.0</b>	<b>ENGINEERING RECOMMENDATIONS .....</b>	<b>9</b>
9.1	GEOTECHNICAL DESIGN PARAMETERS .....	9
9.2	CULVERT OPTIONS.....	10
9.3	FOUNDATION RECOMMENDATIONS .....	11
9.3.1	Shallow Foundation.....	11
9.4	TEMPORARY PROTECTION SYSTEMS .....	12
9.4.1	Lateral Earth Pressures.....	13
9.5	EMBANKMENTS .....	14
9.5.1	Embankment Construction .....	14
9.5.2	Stability of Slopes .....	14
9.5.3	Embankment Settlement.....	15
9.6	EROSION AND SCOUR PROTECTION .....	15
9.7	CONSTRUCTION STAGING .....	15
9.8	EXCAVATION AND BACKFILLING .....	15
9.9	UNWATERING.....	16
9.10	CEMENT TYPE AND CORROSION PROTECTION .....	16

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

<b>10.0</b>	<b>SPECIFICATIONS.....</b>	<b>17</b>
<b>11.0</b>	<b>REFERENCES.....</b>	<b>17</b>
<b>12.0</b>	<b>CLOSURE.....</b>	<b>18</b>

### LIST OF TABLES

Table 1.1: Coordinates of Culverts on Highway 24, Township of South Dumfries, ON (MTM Zone 10) .....	1
Table 3.1: Borehole Summary .....	3
Table 3.2: Laboratory Testing for Culvert Site.....	3
Table 4.1: Inferred and Measured Groundwater levels .....	6
Table 5.1: Results of Chemical Analysis .....	6
Table 9.1: Geotechnical Model for Culvert .....	10
Table 9.2: Comparison of the Replacement Options for Culvert at Station 15+738.....	10
Table 9.3: Geotechnical Resistance for Shallow Foundation (Spread Footing) .....	11
Table 9.4: Comparison of Roadway Protection Systems .....	12
Table 9.5: Recommended Non-Seismic Earth Pressure Parameters (Horizontal Backfill) .....	14
Table 9.6: Recommended Non-Seismic Earth Pressure Parameters (2H:1V Backfill) .....	14
Table 10.1: Specifications Referenced in Report .....	17

### LIST OF APPENDICES

<b>APPENDIX A</b>	Drawing No. 1 – Borehole Location Plan and Soil Strata Plot Site Photos
<b>APPENDIX B</b>	Symbols and Terms Used on Borehole Records Borehole Records
<b>APPENDIX C</b>	Laboratory Test Results

# FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

## FOUNDATION INVESTIGATION REPORT

For

G.W.P 3065-11-00

Highway 24 – Replacement of Culvert at Station 15+738

Site No. 12

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. 12 which is located at Station 15+738.

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

Project Location: Highway 24, 335 m north of Scenic Drive/Howell 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 15+738, approximately 0.34 km north of the intersection of Highway 24 and Scenic Drive/Howell Road.

## 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 of the highway.

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 1H:1V to 2H:1V. The paved surface of the highway is approximately 3.5 to 3.6 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 910 mm and a length of 30.21 m. The culvert is covered with approximately 2.6 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 5.9 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 for this assignment. The boreholes were designated BH15-4, BH15-5, and BH15-6 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 23, 2015. One borehole (BH15-5) 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 (BH15-4 and BH15-6) 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 BH15-5, split spoon samples were collected at regularly spaced intervals (typically every 760 mm) during the course of Standard Penetration Testing

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

(ASTM D1586). At boreholes BH15-4 and BH15-6, 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		
	BH15-4	BH15-5	BH15-6
MTM Zone 10 Coordinates			
Northing	4790862	4790857	4790858
Easting	240157	240146	240125
Ground Surface Elevation, m	296.0	299.6	295.9
Total Depth Drilled, m	6.1	9.8	6.1
End of Borehole Elevation, m	289.9	289.8	289.8
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	32	10	6	2

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 and fill or topsoil over clayey silt to sandy clayey silt underlain by peat over sandy silt.

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**

60 mm of asphalt pavement was encountered in BH15-5.

#### **4.1.2 TOPSOIL**

150 mm to 250 mm of organic topsoil was encountered in BH15-4 and BH15-6.

#### **4.1.3 Fill**

Fill material was encountered beneath the asphalt pavement in BH15-5. The fill consisted of brown poorly graded gravelly sand overlying brown sandy silt. The fill was approximately 3.8 m thick and extended to the elevation of 295.7 m.

In this layer, the SPT N-values ranged from 10 to 40 blows per 0.3 m suggesting a loose to dense consistency. Fill material was described as moist to wet.

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

Gravel:	12%
Sand:	36%
Silt:	40%
Clay:	12%
Moisture Content:	4 to 16%

The grain size distribution curve for the fill material is provided in Figure No. 1 of Appendix C.

#### **4.1.4 Clayey SILT to Sandy Clayey SILT**

A clayey silt to sandy clayey silt layer was encountered beneath the topsoil in BH15-4 and BH15-6 and beneath the fill in BH15-15. The clayey silt to sandy clayey silt was approximately 1.1 m, 1.5

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

m, and 2.1 m thick and extended to elevation of 294.5 m, 294.2 m, and 293.6 m in BH15-4, BH15-5, and BH15-6, respectively.

In this layer, the SPT N-values ranged from 9 to 10 blows per 0.3 m and the DCPT results ranged from 2 to 31. The results suggest a stiff consistency. The clayey silt to sandy clayey silt was described as moist to wet.

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

Gravel:	1%
Sand:	13 to 34%
Silt:	55 to 58%
Clay:	10 to 28%
Moisture Content:	13 to 31%

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

Two Atterberg Limit tests were also performed on the clayey silt to sandy clayey silt samples. The Atterberg Limit test yielded plasticity index of 5 and 17 and liquid limit of 22 and 34. The results suggest a low plasticity. The results are shown in Figure No. 4 of Appendix C.

### 4.1.5 PEAT

A peat layer was encountered beneath the clayey silt to sandy clayey silt in BH15-4. The peat layer was approximately 0.15 m thick and extended to the elevation of 294.4 m.

The moisture content tests on two samples of the peat layer were 86.2 % and 166.5 %.

### 4.1.6 Sandy SILT

A sandy silt layer was encountered beneath the peat in BH15-4 and beneath the clayey silt to sandy clayey silt in BH15-5 and BH15-6. The deposit extended to the termination depths of these boreholes. Within borehole BH15-6 a layer of silty sand with gravel was observed interbedded in the silt deposit.

In this layer, the SPT N-values ranged from 4 to 30 blows per 0.3 m and the DCPT results ranged from 3 to 45. The results suggest a loose to compact state of compactness.

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

Gravel:	1 to 29%
Sand:	22 to 43%
Silt:	25 to 65%
Clay:	3 to 13%
Moisture Content:	8 to 22%

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

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

Four Atterberg Limit tests were also performed on the sandy silt to silty sand with gravel samples. The Atterberg Limit tests yielded plasticity index between 3 and 4 and liquid limit between 16 and 17 and that one sample was non-plastic. The results are shown in Figure No. 4 of Appendix C.

### 4.1.7 Groundwater

The groundwater levels were inferred from samples moisture states 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)
BH15-4	June 23, 2015	1.6 (inferred)	296.0	294.4
BH15-5	June 9, 2015	Dry	299.6	NA
BH15-6	June 23, 2015	2.3 (inferred)	295.9	293.6

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)
BH15-4	SS2	0.7 to 1.5	6.50	638	35	8.12
BH15-5	SS3	1.5 to 2.1	7.65	698	52	8.03

## **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 23, 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.

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

### 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.



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



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



\\cd1218-f02\work\_group2\01224\active\other\_pc\_projects\165000903\reports\culvert 12\rpt\_fldr\_final\_culvert\_12\_201701.docx

# FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

## FOUNDATION INVESTIGATION REPORT

For

G.W.P 3065-11-00

Site No. 12

Highway 24 – Replacement of Culvert at Station 15+738

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 15+738 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 910 mm and a length of 30.21 m and is covered with approximately 2.6 m of fill. The invert elevation of the existing culvert is between elevations of 295.9 m and 296.2 m.

The existing CSP culvert will be replaced with 2.4 m by 1.8 m and 33.5 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 296.2 m and 296.0 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 and fill or topsoil over clayey silt to sandy clayey silt underlain by peat over sandy silt.

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

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		
299.6	295.7	FILL: poorly graded gravelly sand to sandy silt Loose to dense	Total Unit Weight = 20.0 kN/m <sup>3</sup> Friction Angle, $\phi = 32^\circ$ E' = 10 MPa
295.7	293.6	Clayey SILT to sandy clayey SILT Stiff	Total Unit Weight = 19.0 kN/m <sup>3</sup> Undrained Shear Strength = 50 kPa Friction Angle, $\phi = 28^\circ$ (drained) E' = 7 MPa
293.6	289.8	Sandy SILT Loose to Compact	Total Unit Weight = 19.8 kN/m <sup>3</sup> Friction Angle, $\phi = 32^\circ$ E' = 10 MPa

A design water level elevation of 296.2 m will be considered for the culvert site. This water level reflects the minimum possible water flow in the culvert. It is assumed that peat was removed from beneath the culvert during the construction of the original culvert to be replaced. Stantec should be contacted if found otherwise during the construction of the new culvert.

## 9.2 CULVERT OPTIONS

It is understood that 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.

The soil conditions at the site should be suitable to support the culvert options. Table 9.2 compares the culvert structure options from a constructability perspective.

**Table 9.2: Comparison of the Replacement Options for Culvert at Station 15+738**

Option	Advantages	Disadvantages	Relative Cost	Risk/Consequences	Rank
Precast Rigid Frame Box	<ul style="list-style-type: none"><li>• Low bearing pressure on the firm clayey silt</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>• Higher bearing pressure on the firm silty clay</li><li>• Slower construction process</li><li>• Greater unwatering volume require</li><li>• Poorer hydraulic performance</li></ul>	High	<ul style="list-style-type: none"><li>• Higher risk of unwatering related issues</li><li>• Concrete curing process</li></ul>	4

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

Option	Advantages	Disadvantages	Relative Cost	Risk/Consequences	Rank
		<ul style="list-style-type: none"><li>Concrete not readily available</li><li>Requires RSS at inlet</li></ul>			
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 that the preferred culvert replacement option is a 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>r</sub> (kPa)	Geotechnical Resistance at SLS (kPa)
Spread footing on undisturbed soil	± 296.0	2.4 x 33.5	250	125

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>r</sub>).

The axial reaction at SLS corresponds to a vertical deflection (settlement) of 25 mm. The above SLS value considers that the underlying soils have been compressed by the existing embankment.

### 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
- 0.45 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  $ULS_f$ .

## 9.4 TEMPORARY PROTECTION SYSTEMS

A culvert invert elevation of approximately 296.0 m will require a maximum excavation depth of approximately 4.1 m. 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 roadway protection or the culvert replacement will necessitate excavation below the groundwater levels. 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>Possible lack of ground stability when extending below the 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 the sandy clayey silt to silty clay soil. 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. Cobbles and boulders were not encountered in boreholes, the risk of obstructions during driving is low.</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 295.5 m, and the water level at elevation 296.2 m, the use of a simple soldier pile wall along the centerline of the road is not likely a feasible option. The bottom of the clayey silt to sandy clayey silt layer is as high as elevation 294.2 m. It should be noted that the clayey silt to sandy clayey silt layer would behave as an aquitard relative to the underlying sandy silt layer and that sub-artesian conditions will

develop during the excavation period where the water level in the piezometer head in the deeper layer may be 1 m or more above the excavation depth.

The contractor may choose to use coffered sheet piles to control groundwater issues. Assuming the water table to be approximately 0.5 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.

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.

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

Values for  $K_a$ ,  $K_o$ ,  $K_p$ , and  $\gamma$  are provided in Tables 9.5 and 9.6 for horizontal and 2H:1V backfill.

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

Parameter	OPSS Gran A and Gran B Type II	FILL	Clayey SILT to Sandy Clayey SILT	Sandy SILT
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	22	20	19.0	19.8
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

**Table 9.6: Recommended Non-Seismic Earth Pressure Parameters (2H:1V Backfill)**

Parameter	OPSS Gran A and Gran B Type II	FILL	Clayey SILT to Sandy Clayey SILT	Sandy SILT
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	22	20	19.0	19.8
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 ( $K_a$ )	0.39	0.47	0.62	0.47

## 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 should be carried out in conformance with SP 206503.

Embankment slopes should be constructed at no steeper than 2H:1V. The existing slopes should be benched as per OPSS 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 25 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. 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.

### 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  $10^{-5}$  to  $10^{-7}$  cm/s. 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 samples of the native soils 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 concentrations for the samples were 35 µg/g and 52 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.

## FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

January 2017

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH values were 6.50 and 7.65 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

## 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.

## **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

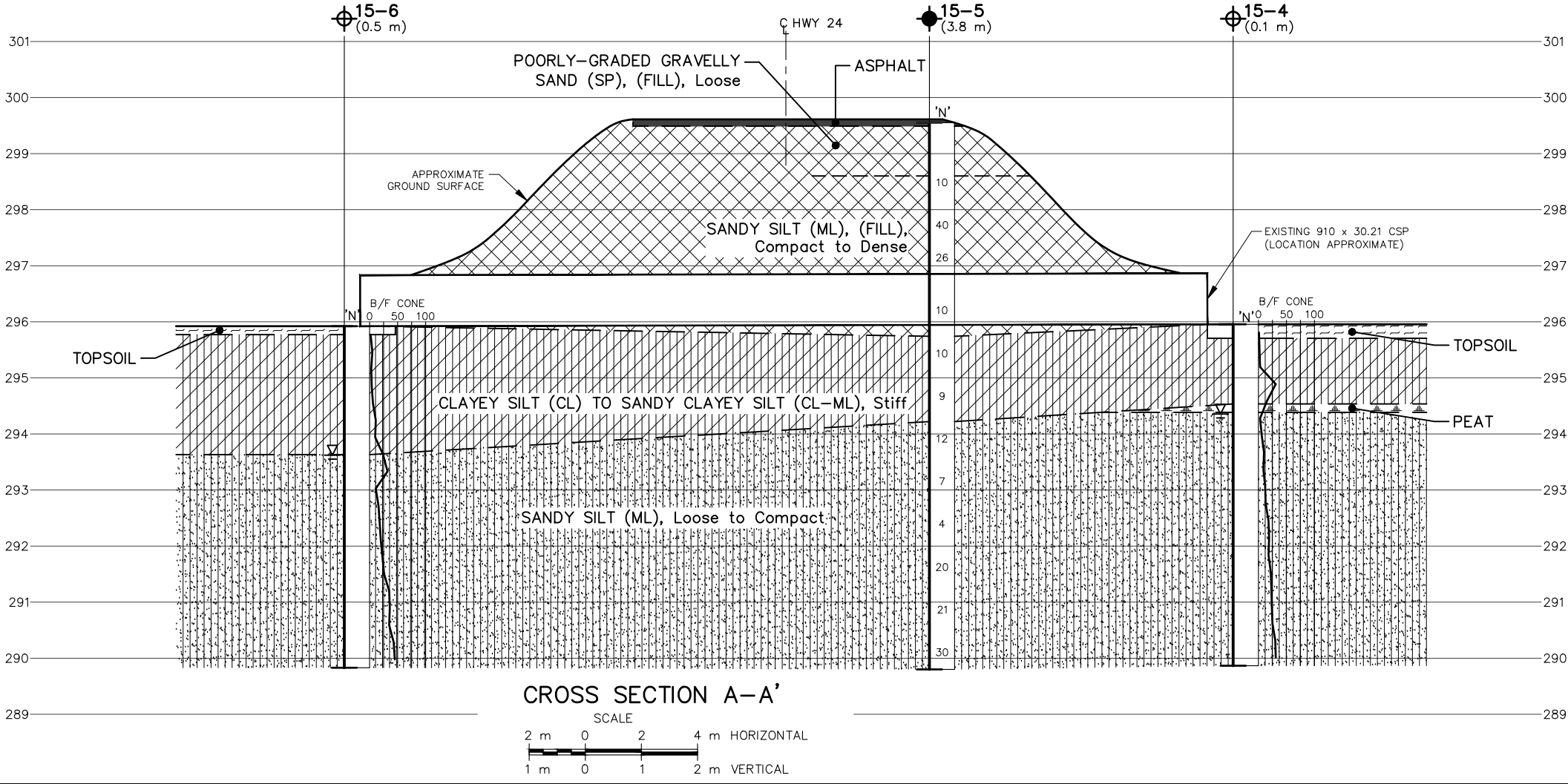
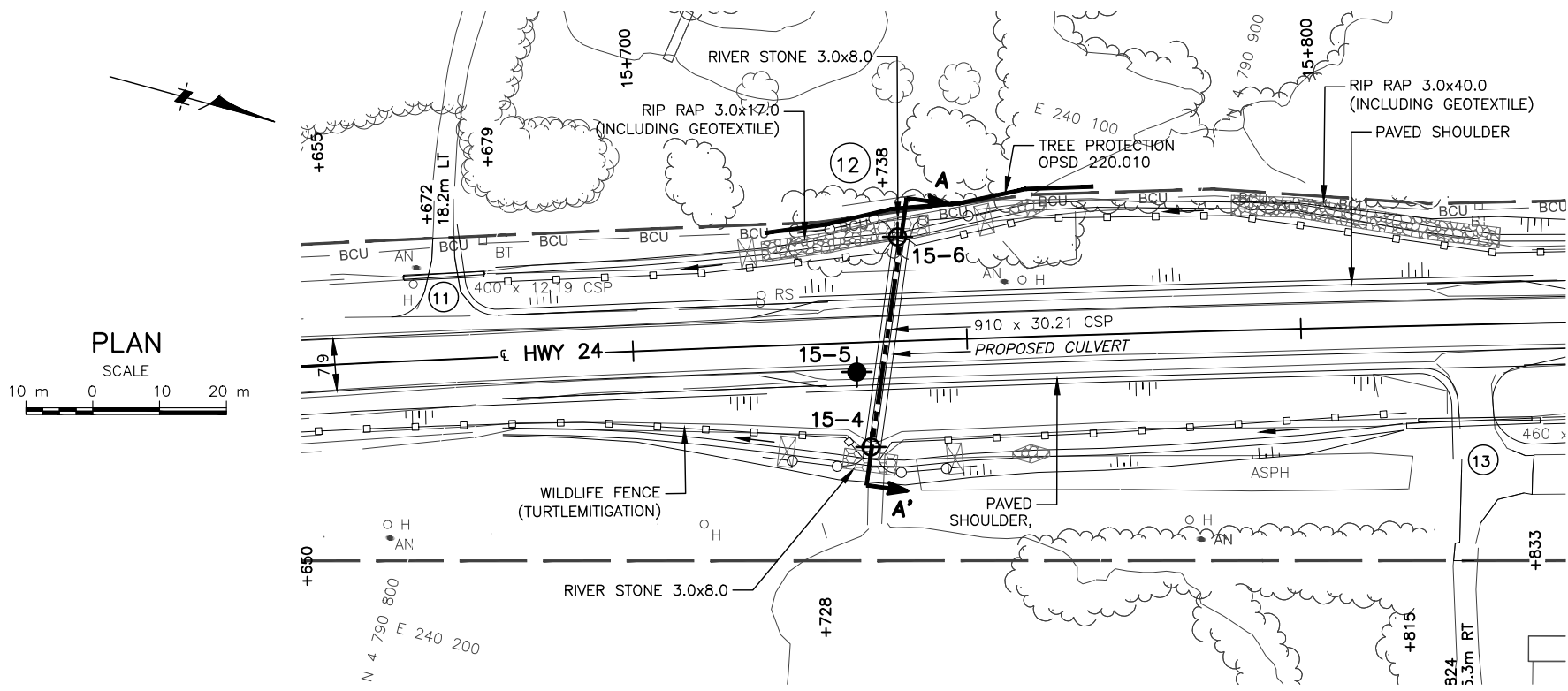
Raymond Haché, M.Sc., P.Eng.  
Designated Principal MTO Foundation Contact

\\cd1218-f02\work\_group2\01224\active\other\_pc\_projects\165000903\reports\culvert 12\rpt\_fidr\_final\_culvert\_12\_201701.docx

## **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

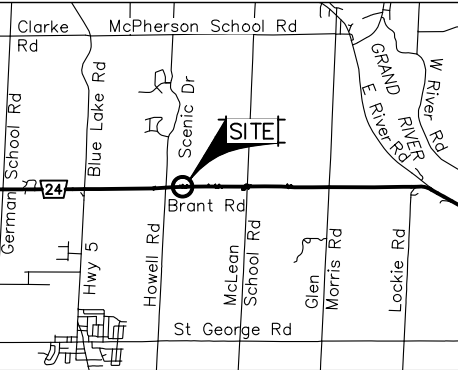


PLATE No  
**CONT**  
**WP** 3065-11-00

HWY 24, TWP OF S DUMFRIES, ON  
CULVERT AT STA 15+738 (SITE 12)  
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
15-4	296.0	4 790 862.4	240 156.7
15-5	299.6	4 790 857.4	240 146.4
15-6	295.9	4 790 857.9	240 125.4

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 GEOCRES NUMBER	

GEOCRES No 40P08-241

HWY No	HWY	24	DIST	
SUBM'D	AN	CHECKED	DATE	2015-10-09
DRAWN	GBB	CHECKED	APPROVED	
			SITE	C12
			DWG	1



Project No.: 165000903

GWP: 3065-11-00

Site Photographs

Project Name: Culvert 12, Highway 24 Pavement Rehabilitation, Township of South Dumfries, ON

Date: June 9, 2015




Site Photo No.: 1


Looking north on BH15-5



Site Photo No.: 2

Looking south on BH15-5

	Project No.: 165000903	GWP: 3065-11-00	Site Photographs
	Project Name: Culvert 12, Highway 24 Pavement Rehabilitation, Township of South Dumfries, ON		Date: June 9, 2015
			
Site Photo No.: 3	Looking east toward BH15-4 on BH15-5		
			
Site Photo No.: 4	Looking west toward BH15-6 on BH15-5		

	Project No.: 165000903	GWP: 3065-11-00	Site Photographs
	Project Name: Culvert 12, Highway 24 Pavement Rehabilitation, Township of South Dumfries, ON		Date: June 23, 2015



Site Photo No.: 5

Looking north on BH15-4



Site Photo No.: 6

Looking south-east on BH15-6

## **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:

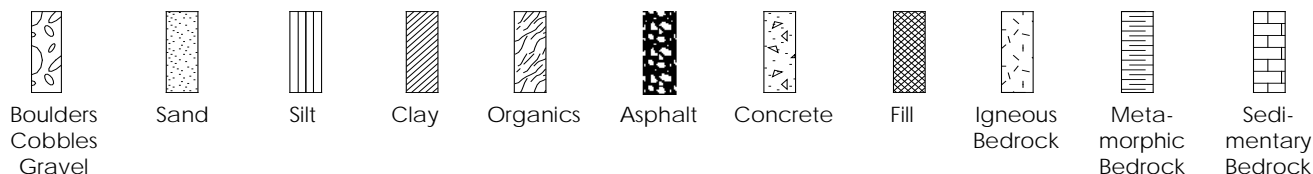
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
<i>Extremely Weak</i>	R0	<1
<i>Very Weak</i>	R1	1 – 5
<i>Weak</i>	R2	5 – 25
<i>Medium Strong</i>	R3	25 – 50
<i>Strong</i>	R4	50 – 100
<i>Very Strong</i>	R5	100 – 250
<i>Extremely Strong</i>	R6	>250

### 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

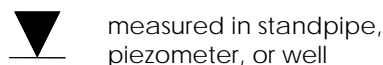
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



## 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 BH15-4

1 OF 1

METRIC

W.P. 3065-11-00 LOCATION Hwy 24, Township of South Dumfries, ON N: 4 790 862 E: 240 157 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 23 - 2015 06 23 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
296.0	250 mm TOPSOIL																
0.0 295.7	Clayey SILT (CL) to sandy clayey SILT (CL-ML)		1	SS	-		295							167 86	6 34 51 9		
0.3	Stiff  Brown to grey, moist		2	SS	-		295										
294.5	-sand seams																
294.4	PEAT																
1.6	Black, wet Sandy SILT (ML) to silty SAND (SM) with gravel		3	SS	-		294										
	Loose to compact		4	SS	-		293										
	Grey, wet		5	SS	-		292										
	-Groundwater observed at a depth of 1.6 m		6	SS	-		291										
			7	SS	-	290											
			8	SS	-												
289.9	End of Borehole																
6.1	-Split spoon sampler was advanced using a Pionjar jackhammer -DCPT was carried out using a 70 lb weight hammer and 30 in. drop -DCPT values corrected for 50% of the field values																

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

STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO MOT.GDT 10/14/15



## RECORD OF BOREHOLE No BH15-5

1 OF 1

METRIC

W.P. 3065-11-00 LOCATION Hwy 24, Township of South Dumfries, ON N: 4 790 857 E: 240 146 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 W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		× FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
299.6	60 mm ASPHALT						20	40	60	80	100						GR	SA	SI	CL
298.6	Fill: poorly graded gravelly SAND (SP)		1	GS	-															
298.6	Loose																			
298.6	Brown, moist		2	SS	10															
1.0	FILL: sandy SILT (ML)																			
	Compact to dense																			
	Brown, moist to wet		3	SS	40															
			4	SS	26															
			5	SS	10															
295.7	Clayey SILT (CL) to sandy clayey SILT (CL-ML)		6	SS	10															
3.8	Stiff																			
	Grey to dark grey, moist		7	SS	9															
294.2	Sandy SILT (ML)		8	SS	12															
5.3	Loose to compact																			
	Grey, moist to wet		9	SS	7															
			10	SS	4															
			11	SS	20															
			12	SS	21															
			13	SS	30															
289.8	End of Borehole																			
9.8																				

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO.MOT.GDT 10/14/15



## RECORD OF BOREHOLE No BH15-6

1 OF 1

METRIC

W.P. 3065-11-00 LOCATION Hwy 24, Township of South Dumfries, ON N: 4 790 858 E: 240 125 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 23 - 2015 06 23 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		WATER CONTENT (%)			
295.9	150 mm TOPSOIL							20 40 60 80 100									
295.6	Clayey SILT (CL) to Sandy clayey SILT (CL-ML)		1	SS	-			20 40 60 80 100	○ UNCONFINED	✕ FIELD VANE		10 20 30				1 34 55 10	
0.2	Stiff		2	SS	-												
	Brown, moist		3	SS	-												
293.6	Sandy SILT (ML)	4	SS	-													
2.3	Loose to compact	5	SS	-													
	Brown to grey, wet	6	SS	-													
	-Groundwater observed at a depth of 2.3 m	7	SS	-													
	-silty SAND (SM) with gravel layer observed between elevation 293 m to 292 m	8	SS	-													
289.8	End of Borehole																
6.1	-Split spoon sampler was advanced using a Pionjar jackhammer -DCPT was carried out using a 70 lb weight hammer and 30 in. drop -DCPT values corrected for 50% of the field values																

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

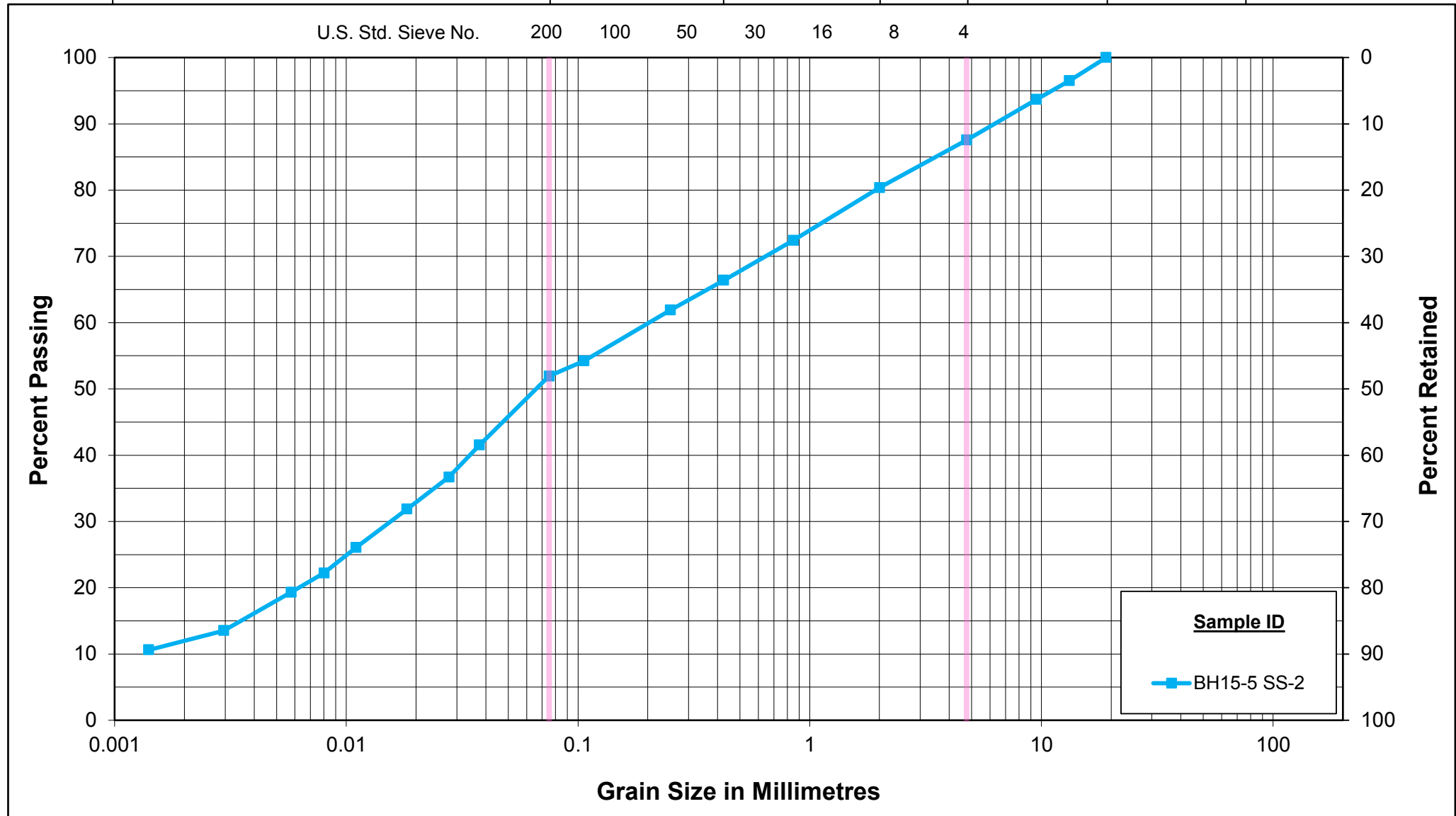
STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO MOT.GDT 10/14/15

## **APPENDIX C**

### Laboratory Test Results

# Unified Soil Classification System

CLAY & SILT			SAND			Gravel	
			Fine	Medium	Coarse	Fine	Coarse

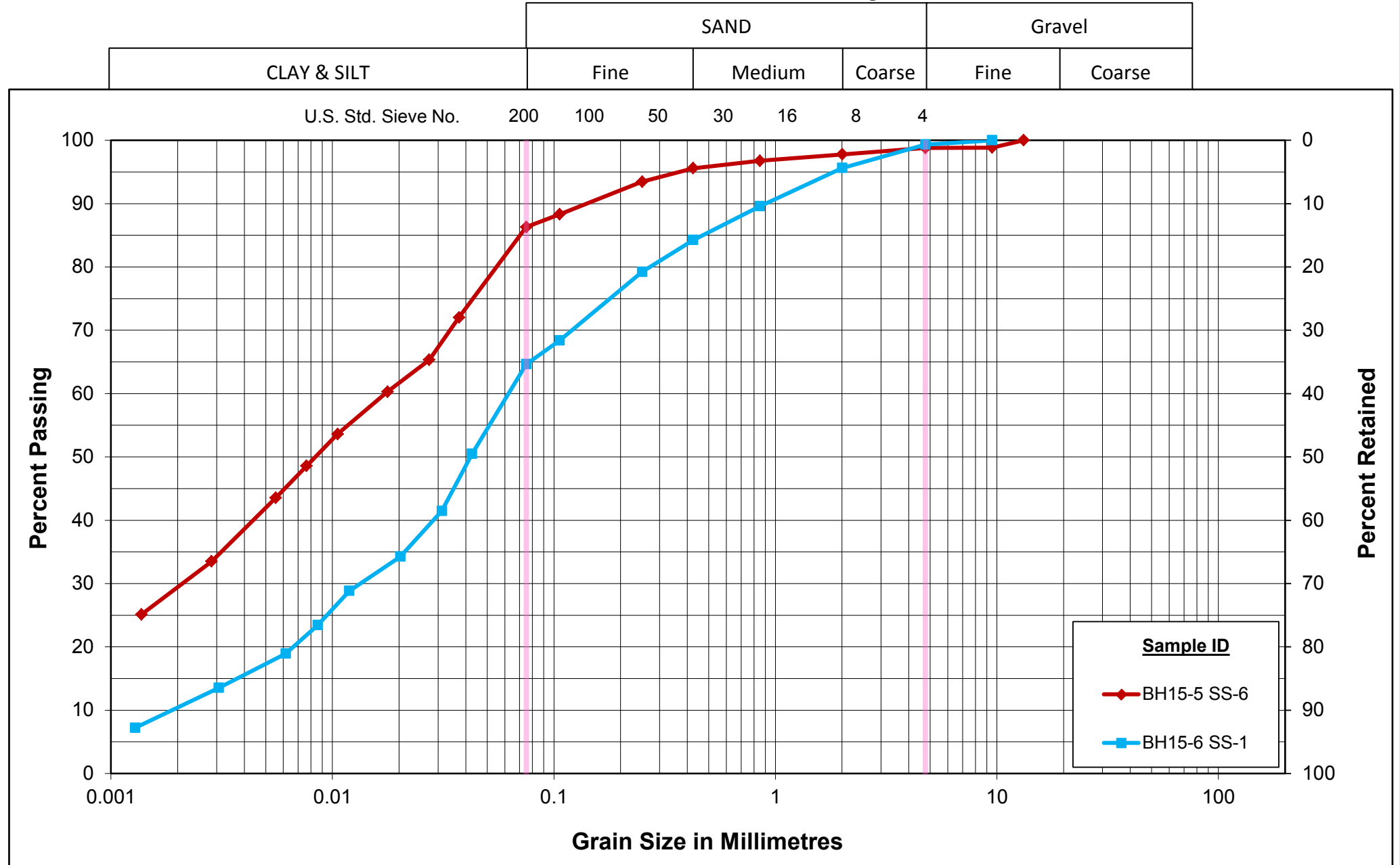


GRAIN SIZE DISTRIBUTION  
FILL: sandy SILT (ML)

Figure No. 1

Project No. 165000903

# Unified Soil Classification System



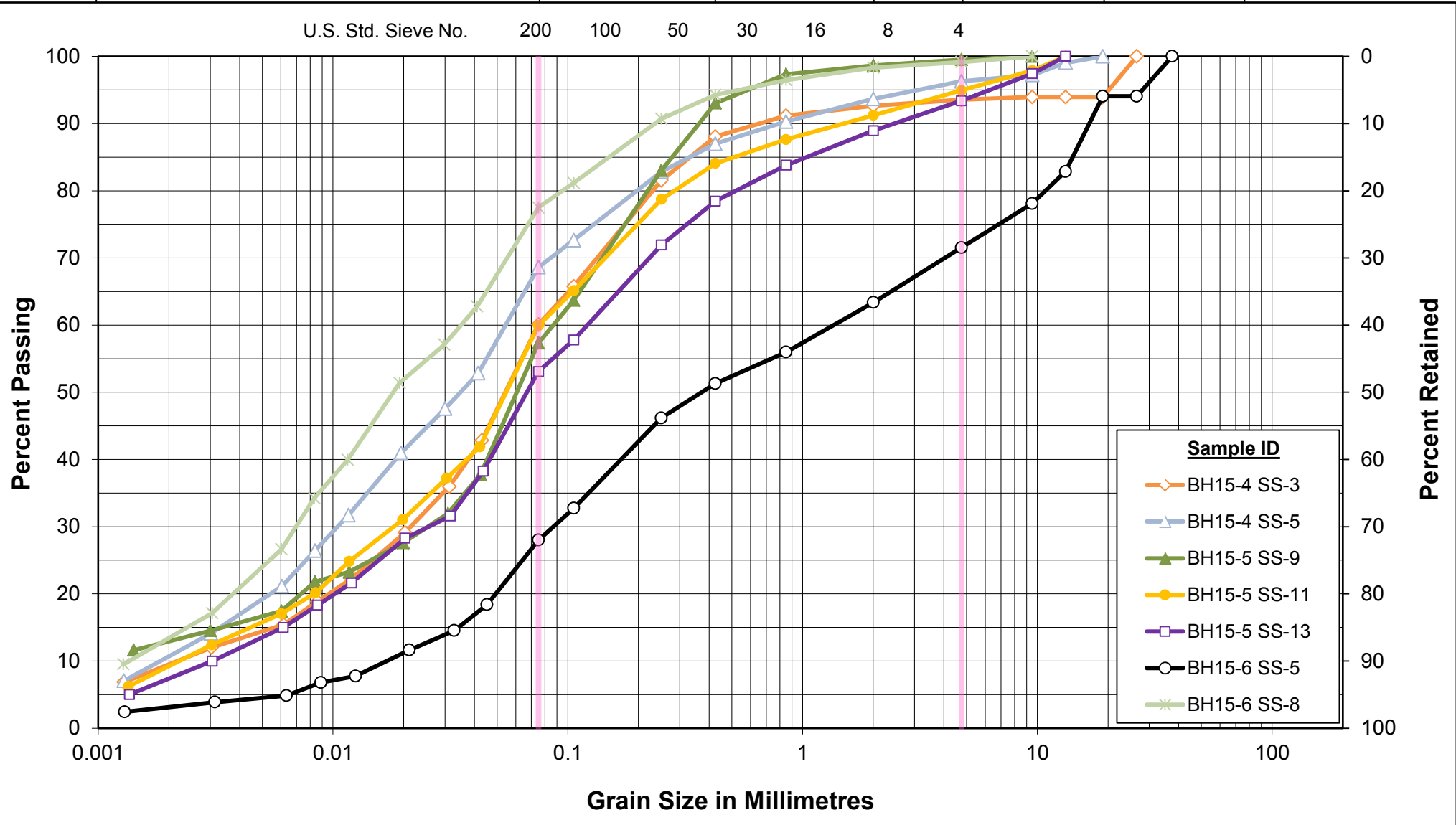
GRAIN SIZE DISTRIBUTION  
Clayey SILT (CL)  
to Sandy Clayey SILT (CL-ML)

Figure No. 2

Project No. 165000903

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



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

Figure No. 3

Project No. 165000903

