



**THURBER** ENGINEERING LTD.



**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
ROSSMERE CREEK CULVERT REPLACEMENT  
HIGHWAY 11, SITE No. 48W-192/C  
HAGEY TOWNSHIP, DISTRICT OF THUNDER BAY  
ONTARIO  
G.W.P. No. 6804-14-00, W.P. No. 6804-14-01  
LATITUDE: 48.635823°, LONGITUDE: -90.185649°**

**GEOCRES Number: 52B-32**

**Report**

to

**HATCH Corporation**

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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Rossmere Creek Culvert on Highway 11, located west of Shebandowan, in Hagey Township, District of Thunder Bay, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert site and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch Corporation (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0012.

**2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 2.9 km west of the intersection of Highway 586 and Highway 11 in Hagey Township, District of Thunder Bay, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and soil Strata Drawings in Appendix D.

Highway 11 runs in a general east-west direction with the culvert perpendicular to the centreline of the highway. The culvert allows Rossmere Creek to flow in a southerly direction and drain into Rossmere Bay, part of Middle Shebandowan Lake.

The Ontario Structural Inspection Manual (Inspection Form) prepared by MTO on December 16 2015 indicates that the existing structure is a 25 m long, three span (1.4 m, 1.4 m, 1.0 m) open

footings, timber structure culvert with an unknown construction date. The grade level of Highway 11 at the existing culvert is at an approximate Elevation of 452.2 m. The culvert invert is at approximately Elevation 449.3 m at the inlet (north end) and 449.2 m at the outlet (south end), and the culvert height is approximately 1.2 m. The existing road grade at the culvert location is approximately Elev. 452.2 m, which indicates approximately 1.8 m of fill above the culvert. The Rossmere water level (ice level) was measured by Thurber at Elevation 450.2 m on March 27, 2017, and was measured by others at 450.0 m in August, 2015.

The lands surrounding Rossmere Creek and the culvert at the site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography is generally of low relief and consists of organic terrain. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist of organic deposits of peat with nearby ground moraine deposits of silty to sand till. Bedrock in the area has been identified as mafic to intermediate metavolcanic bedrock, comprised of basaltic and andesitic flows.

### **3. INVESTIGATION PROCEDURES**

The borehole investigation and field testing program for this project was carried out between March 25 and 27, 2017, and consisted of drilling and sampling seven (7) boreholes, designated as Boreholes 17-15, to 17-21, to depths ranging from 3.7 to 15.3 m below the existing ground surface. Boreholes 17-15 and 17-18 were drilled near the inlet and outlet of the existing culvert, and all other boreholes were drilled through the paved section of Highway 11. Boreholes 17-19 to 17-21 were drilled east of the existing culvert to assess the existence and extents of any frost taper near the culvert.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were derived from cross sections and topographic drawings provided to Thurber by Hatch. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

The boreholes were drilled using a rubber tire buggy mounted drill rig equipped with continuous flight, hollow and solid stem augers. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A Dynamic Cone Penetration Test (DCPT) was carried out at 17-16 and 17-17 adjacent to the original auger hole to cone refusal depth of approximately 15.3 m in

both boreholes.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

A piezometer was installed in Borehole 17-18 and a piezometer reading was taken on March 27, 2017. The piezometer was decommissioned after the water level reading was taken. The boreholes were backfilled in general accordance with Ontario Regulation 903.

Completion details of the boreholes are summarized in Table 3.1.

**Table 3.1 – Borehole Completion Details**

<b>Borehole Number</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
17-15	12.8 / 437.6	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-16	15.3 / 436.9	None installed	Borehole backfilled with bentonite holeplug cuttings and concrete to surface.
17-17	15.3 / 436.8	None installed	Borehole backfilled with bentonite holeplug cuttings and concrete to surface.
17-18	12.8 / 437.4	12.2 / 438	Sand from 12.8 m to 10.7 m, and bentonite holeplug cuttings and concrete to surface.
17-19	3.7 / 448.4	None installed	Borehole backfilled with bentonite holeplug and concrete to surface.
17-20	3.7 / 448.4	None installed	Borehole backfilled with bentonite holeplug and concrete to surface.
17-21	3.7 / 448.4	None installed	Borehole backfilled with bentonite holeplug and concrete to surface.

#### **4. LABORATORY TESTING**

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and/or hydrometer) and plasticity testing (Atterberg Limits) where appropriate. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, two samples of the existing native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

#### **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets included in Appendices A and E. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and should be used for interpretation of site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes below the existing embankment fill typically consist of peat, underlain by silty clay, and deposits of silt and sand. Auger refusal and cone refusal occurred in Boreholes 17-17 and 17-16 beneath the sand deposits on probable bedrock. Descriptions of the individual strata are presented below.

##### **5.1 Asphalt**

The boreholes that were drilled through the paved portion of Highway 11 encountered approximately 75 mm of asphalt at the ground surface (Elev. 452.1 to 452.2).

##### **5.2 Embankment Fill**

Embankment fill was encountered below the asphalt in all boreholes drilled on Highway 11. The embankment fill generally consisted of gravelly sand to sand, with trace to some silt and trace to some gravel and occasional cobbles and boulders in the upper portions of the fill, and sand and

silt in the lower portions of the embankment fill (below 1.5 m depth) in Boreholes 17-16 and 17-17. The embankment fill typically extended to depths of approximately 2.1 m to 3.0 m below existing road surface elevation (Elev 449.1 to Elev 450.0 m).

SPT 'N' values in the fill ranged from 8 to 46 blows for 0.3 m penetration, indicating a loose to dense relative density. A higher blow count of 100 blows for 25 mm was also recorded in Borehole 17-16, which is likely a result of cobbles or boulders within the fill. Measured moisture contents ranged from 2 to 21%.

The results of grain size distribution analyses conducted on samples of the fill are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B1 in Appendix B.

Gravel %	0 to 25
Sand %	60 to 70
Silt and Clay %	10 to 40

### 5.3 Peat

Peat was encountered beneath the embankment fill in all boreholes on Highway 11 and at the ground surface in the boreholes at the inlet and outlet of the existing culvert. The peat is described as black in colour and contains trace to some sand, some roots and rootlets. The peat ranged in thickness from 1.1 m to 1.7 m where fully penetrated. Beneath the road embankment in Boreholes 17-16 and 17-17 the peat extended to depths of approximately 4.1 m to 4.3 m below existing road surface (Elev. 448.1 and Elev 447.8 m), respectively, and at the inlet and outlet in Boreholes 17-15 and 17-18 the peat extended to depths of approximately 1.7 m to 1.4 m below existing ground surface (Elev. 448.7 and Elev. 448.8 m), respectively. In Boreholes 17-19 to 17-21 the peat extended to the maximum depth drilled of 3.7 m below existing road surface (Elev/ 448.4 m).

SPT 'N' values recorded in the peat ranged between 1 to 5 blows for 0.3 m penetration, indicating a very soft to firm consistency. Measured moisture contents in the peat ranged from 104% to 305%.

### 5.4 Silty Clay

A silty clay deposit was encountered beneath the peat in Boreholes 17-15 to 17-18. The silty clay generally contains trace to some sand and is brown in colour. The silty clay deposit was 1.5 to

5.6 m thick and extended to depths of 5.6 m to 7.3 m below existing ground surface (Elev 443.1 to Elev 446.6 m).

SPT 'N' values recorded in the silty clay ranged from 0 to 10 blows for 0.3 m penetration, indicating a very soft to stiff consistency. Measured moisture contents in the silty clay ranged from 31% to 84%.

The results of grain size analyses conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	0 to 20
Silt %	20 to 35
Clay %	45 to 80

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Liquid Limit	41 to 79
Plastic Limit	18 to 27
Plasticity Index	23 to 52

The results of the Atterberg Limits testing indicate that the silty clay has an intermediate to high plasticity with group symbol CI to CH.

## 5.5 Silt

Silt was encountered in Boreholes 17-15 to 17-18 below the silty clay deposit with the exception of Borehole 17-18 where it was encountered below a silty sand deposit. The silt generally contains trace to some sand, trace clay and was grey in colour. The silt was 1.5 to 6.1 m thick and extended to depths of approximately 10.2 m to 11.7 m (Elev 438.7 to Elev. 441.9).

SPT 'N' values recorded in the silt ranged from 6 to 34 blows for 0.3 m penetration, indicating a loose to dense relative density. Measured moisture contents in the silt ranged from 10% to 34%.

The results of grain size analyses conducted on samples of the silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	3 to 5
Silt %	89 to 93
Clay %	4 to 7

## 5.6 Sand to Sand and Silt

Sand to sand and silt was encountered in Boreholes 17-15 to 17-18 generally below the silt deposit and extended to probable bedrock contact in Boreholes 17-16 and 17-17 at depths of approximately 15.3 m (Elev 436.9 to Elev 436.8 m) or to the maximum depth drilled in Boreholes 17-15 and 17-18 of 12.8 m below existing ground surface elevation (Elev. 437.6 to Elev. 437.4 m). The thickness of the deposit ranged from at least 1.1 to 2.6 m in Boreholes 17-15 and 17-18, which were terminated in the deposit, and from 3.6 to 5.1 m where fully penetrated in Boreholes 17-16 and 17-17. The sand to sand and silt generally contains trace to some gravel, trace to some silt, trace clay, and is brown to grey in colour.

SPT 'N' values recorded in the sand to sand and silt ranged from 17 to 60 blows for 0.3 m penetration, indicating a compact to very dense relative density. Measure moisture contents ranged from 6% to 28%.

The results of grain size analyses conducted on samples of the sand to sand and silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Gravel %	0 to 18
Sand %	36 to 84
Silt %	19 to 52
Clay %	4 to 11
Silt and Clay %	2

## 5.7 Auger Refusal on Probable Bedrock

Auger and/or split spoon refusal was encountered on probable bedrock at a depth of 15.3 m (Elev 436.8 to 436.9 m) in Boreholes 17-16 and 17-17.

## 5.8 Groundwater Conditions

Groundwater conditions were observed during drilling and in the open boreholes upon completion, and a piezometer was installed in Borehole 17-18. The groundwater levels measured in the open boreholes and the piezometers are summarised in Table 5.1 below. The piezometer was decommissioned on March 27, 2017.

**Table 5.1 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
17-15	March 27, 2017	0.2	450.2	Open borehole
17-16	March 27, 2017	3.0	449.2	Open borehole
17-17	March 26, 2017	3.0	449.1	Open borehole
17-18	March 27, 2017	0.2	450.0	In piezometer
17-19	March 25, 2017	3.0	449.1	Open borehole
17-20	March 25, 2017	3.0	449.1	Open borehole
17-21	March 25, 2017	3.0	449.1	Open borehole

The creek was frozen at the time of the investigation and the top of ice level was recorded by Thurber at Elev. 450.2 m. The water level in the creek was also recorded by others, as shown on the topographic survey provided by Hatch, and was 450.0 m in August, 2015. The groundwater level should be assumed to reflect the local creek water level.

The above groundwater levels are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

Two samples of the native silty clay from Boreholes 17-16 and 17-17, and a sample of the creek water were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results		
			17-16 SS#5, 4.6 m – 5.2 m	17-17 SS#5, 4.6 m – 5.2 m	Rossmere Creek
			(Silty Clay)	(Silty Clay)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.02	0.014
Chloride	µg/g	mg/L	16	30	24
Sulphate	µg/g	mg/L	150	22	1.1
pH	No unit	No unit	8.98	8.64	6.35
Electrical Conductivity	µS/cm	µS/cm	127	160	115
Resistivity	Ohms.cm	Ohms.cm	7870	6250	8700
Redox Potential	mV	mV	286	210	197

## 7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Amir Fereidouni of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, B.A.Sc. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc. Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta, B.A.Sc., EIT and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for preliminary design of the proposed Rossmere Creek culvert replacement located on Highway 11 in Hagey Township, District of Thunder Bay, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on December 16, 2015. The existing structure is a three span open footing timber culvert. The culvert is approximately 3.8 m wide and 25 m long. The estimated culvert invert is at approximately Elev. 449.3 m at the inlet (north end) and 449.2 m at the outlet (south end). The existing road grade at the culvert location is approximately Elev. 452.2 m, which indicates approximately 1.8 m of fill above the culvert.

Preliminary General Arrangement Drawings and discussions with Hatch/MTO, indicate that the following replacement options are being considered:

## 1. Multiple CSP Pipe Culvert

Multiple circular CSP pipes are being considered to provide increased hydraulic opening. The CSPs are likely to have an approximately 2.7 m diameter each. The invert level of the new pipes (underside of the pipe) are approximately at Elev. 448.6 m and Elev. 448.4 m at the inlet and outlet respectively.

## 2. Single / Twin Precast Concrete Box Culvert

A single cell precast concrete box culvert is another option being considered. The preliminary general arrangement indicated a 4.5 m x 1.8 m box culvert. The proposed invert level (underside of the box) is at approximately Elev. 448.7 m and Elev. 448.5 m at the inlet and outlet respectively. Alternatively, a twin precast concrete box culvert arrangement of two 2.4 m x 1.5 m openings has been considered.

All replacement culvert options will be constructed along a new alignment, 4 m west of the existing culvert alignment. No grade raise is proposed for any of the alternatives. A temporary creek diversion pipe would also be installed during construction, approximately 10 m east of the existing culvert with an invert elevation of approximately Elev. 449.2 m.

## 9. CULVERT DESIGN

### 9.1 Culvert Replacement Options

In general, the subsurface conditions encountered in the boreholes drilled through the highway platform contain embankment fill, typically consisting of sand to sand and silt, underlain by a layer of peat, followed by silty clay, then silt and then sand. The water level in creek was measured at approximately Elev. 450.0 m in the creek and in a piezometer.

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Concrete Pipe, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. From a foundations and constructability perspective, use of the SPCSP, CSP or precast box culverts are both feasible options, based on the following considerations:

- Precast box culvert or pipe culverts would require shallower depth of excavation compared with the open footing culvert;
- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast-in-place open footing culvert, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

An open footing culvert is not recommended at this site since it would involve deeper excavation and more dewatering effort. Hence, recommendations for this option have not been developed.

Recommendations for the design and installation of concrete pipe or SPCSP, and concrete box culverts are presented below.

## **9.2 Foundation Design for Culverts**

The founding soils encountered at the proposed invert level (Elev. 448.7 to Elev. 448.4) generally consist of peat underlain by very soft to firm silty clay. There is approximately 1.2 to 1.4 m of fill above the proposed culvert replacements. Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical capacities, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

### **9.2.1 Corrugated Steel Pipe Culvert**

Replacement of the culvert with multiple SPCSPs or CSPs on the same alignment as the existing culvert, or with an offset alignment 4 m to the west may be considered for this site. Since there is

no grade raise proposed, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

If this alternative is selected, the SPSCPs or CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per Ontario Provincial Standard Drawing (OPSD) OPSD 802.010. All the peat encountered at and below the culvert subgrade must be removed and replaced by compacted granular fill up to the underside of the bedding material within a sheet pile enclosure, as described in Sections 12.1 and 12.2. Based on the preliminary general arrangement drawings, the underside of the bedding material will be at approximately Elev. 448.2 m. Culvert subgrade preparation and placement and compaction of the granular fill replacing the peat must be carried out in the dry, unless rock fill is utilized as described in Section 12.1.2. The granular fill or rock fill below the culvert must be placed on native firm silty clay deposits below the peat. Adequate preparation of the subgrade will be essential for performance of the culvert.

### **9.2.2 Precast Concrete Box Culvert**

Replacement of the culvert with a single-cell or twin-cell precast concrete box culvert on the same alignment or 4 m off-set alignment to the west is considered a viable alternative for this site. Since there is no grade raise proposed, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

Based on preliminary general arrangement drawings, it is anticipated that the base of the box culvert replacement will be at approximately Elev. 448.7 to 448.5 m. It is anticipated that the invert elevation will expose the peat deposits. The peat is underlain by native silty clay deposits.

In order to provide a competent foundation subgrade, the peat deposit must be excavated and replaced with compacted granular fill or rock fill, as described in Section 12.1. The culvert should then be placed on a 300 mm thick layer of bedding material and a levelling course, as discussed in Section 12.2 of this report. Based on the preliminary general arrangement drawings, the underside of the bedding material will be at approximately Elev. 448.2 m.

The following geotechnical capacities could be used for design of a box culvert founded at or below Elev. 448.2 m on the compacted granular fill used to replace the peat:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 100 kPa.

The above values of the geotechnical resistance and reaction were based on the outside box culvert widths of between 4 m and 6 m.

The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per Canadian Highway Bridge Design Code (CHBDC) 2014, Sec. 6.9.

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design should be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

### **9.2.3 Culvert Headwall / Wingwalls**

If headwalls or wingwalls are required, consideration may be given to the use of Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are relatively more tolerant to limited differential settlement.

The borehole information indicates that the founding soils at the inlet/outlet generally consist of peat underlain by very soft to firm silty clay.

#### **9.2.3.1 RSS Walls**

For RSS walls, the contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS mass and, in severe cases, to possible failure of the system. The foundation under the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

All peat encountered along the alignment of the RSS wall must be removed down to native clay. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native silty clay at or below approximate Elevation 448.0 m. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 135 kPa and a geotechnical reaction at SLS of 65 kPa (up to 25 mm of settlement). The engineered fill pad placed under the RSS mass must consist of Ontario Provincial Standard Specification (OPSS) OPSS.PROV 1010 Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.45 for an engineered granular fill subgrade.

Topsoil, peat, organics, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the RSS wall and placement and compaction of the granular fill must be carried out in the dry.

A geotextile filter fabric must be incorporated in the RSS design to prevent loss of fines from granular material behind the wall subject to fluctuating water level. Since the RSS wall will be constructed adjacent to a creek, the wall may be subjected to flooding. The RSS supplier should be made aware that for submerged conditions the RSS strips may need to be longer than the usual 70% of fill height and the strips must be corrosion resistant.

Adequate erosion protection must be provided for the bases of the RSS walls so that they are not undermined by creek flow.

The proprietary RSS system must meet MTO's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary product selected for this site.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 11. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Global stability of the RSS walls should be assessed once the detailed configurations of the walls are known.

### **9.2.3.2 Concrete Retaining Walls**

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the soft to firm silty clay subgrade. All peat encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.3 m at this site) and founded at Elevation 448.0 m or lower. A factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 75 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the wall footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to sliding between precast concrete and the underlying silty clay should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.30.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 10. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Adequate erosion protection must be provided for the bases of the retaining walls so that they are not undermined by creek flow.

### **9.3 Settlement**

Embankment grade raise or widening was not anticipated as part of the culvert replacement. It is recommended that the underlying peat deposit be excavated and replaced with compacted granular or rock fill. Therefore, changes in the loading conditions on the foundation soils consisting of native silty clay are expected to be small. If the peat below the culvert footprint is completely removed and replaced with granular or rock fill, the post construction settlements after culvert construction and embankment reconstruction at this site is estimated to be less than 30 to 40 mm. The settlement may be mitigated by designing an oversized culvert or designing a camber to accommodate the settlement.

In order to minimize settlement of the peat outside of the replacement culvert footprint, it is recommended that the granular fill or rock fill be placed within a sheet pile enclosure below the culvert. This will allow for a vertical excavation of peat. A sloped excavation in the peat would result in placement of heavier granular fill or rock fill above the remaining peat along the highway alignment, which would cause settlement of the embankment outside of the culvert footprint.

It must be noted that any additional load imposed on the culvert replacement, including fill placed adjacent to the extended culvert barrels, will induce immediate settlement and consolidation settlement of the cohesive soils (soft to stiff silty clay) at this site.

### **9.4 Frost Cover**

The depth of frost penetration at this site is approximately 2.3 m, as per OPSD 3090.100. The base of retaining wall footings, if employed, should be provided with a minimum of 2.3 m of earth cover as protection against frost action. The pipe and box culvert options do not require frost cover/protection.

The frost taper investigation in Boreholes 17-19 to 17-21 indicated the presence of 2.1 to 2.4 m of granular and sand fill overlying peat deposits to at least 30 m east of the centreline of the existing culvert. The majority of the granular fill is not frost susceptible, except for the sand and silt fill below a depth of 1.5 m in Boreholes 17-16 and 17-17 near the existing culvert, which has low frost susceptibility. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment fill and base material above the peat.

The peat soils and native silty clay soils underlying the fill are frost susceptible. As the frost penetration line is below the top of culvert, frost treatment/taper for the culvert should be provided as per OPSD 803.031 for a CSP culvert or OPSD 803.010 for a box culvert. Since the existing

embankment material beyond the excavations for the existing culvert is not frost susceptible, a new frost taper does not appear to be warranted.

## 10. LATERAL EARTH PRESSURES

A triangular distribution of lateral earth pressures acting on the culvert walls may be assumed for design. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	$p_h$	=	horizontal pressure on the wall at depth $h$ (kPa)
	$K$	=	earth pressure coefficient (see table below)
	$\gamma$	=	unit weight of retained soil (see table below)
	$h$	=	depth below top of fill where pressure is computed (m)
	$q$	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 10.1 below.

**Table 10.1 – Lateral Earth Pressure Coefficients (K)**

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

## 11. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the averaged soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site includes a very soft to stiff silty clay overlying compact sand and silt soils. This would correspond to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.040 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 11.1 may be used:

**Table 11.1 – Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ , $\gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I $\phi = 32^\circ$ , $\gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ$ , $\gamma = 20 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.30	0.33	0.36
At Rest ( $K_{OE}$ )**	0.52	0.57	0.60

\* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

\*\* After Woods

In view of the low potential for seismic activity in the area, liquefaction is not considered to be a major concern at this site.

## 12. CULVERT CONSTRUCTION CONSIDERATIONS

### 12.1 Peat Replacement and Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. The borehole information indicates a variable thickness of peat within the culvert footprint area and east of the culvert along the stream diversion pipe alignment. Approximately 1.1 to 1.7 m of peat

was encountered at the culvert location. The base elevation of the peat deposit ranges from 447.8 to 448.8m.

The peat must be subexcavated to expose the native silty clay subgrade. The subexcavation should be carried out within a sheet pile enclosure to allow a vertical excavation, as indicated in Section 9.3. No information was available to confirm whether the existing culvert is founded on footings or timber piles. If timber piles are encountered during the peat removal excavations, they should either be extracted (if short piles) or cut off (if long piles) in order to facilitate removal of the peat. This issue should be evaluated further during the detailed design stage.

The sheet piles should be designed for the case where they are exposed to the bottom of the peat excavation. The removal of peat within the sheet pile enclosure should extend for 1.5 m beyond the width of the replacement culvert and for the entire length of the culvert. The sheet piles should remain in place following project completion and should not be extracted. The excavation should be carried out in accordance with OPSS 209 (Embankments over Swamps and Compressible Soils). The subexcavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 for Granular A or Granular B Type II placed in accordance with OPSS.PROV.206, and compacted as per OPSS.PROV 501, provided that the peat subexcavation and compaction and placement of the replacement granular fill is carried out in the dry as per OPSS 902, as described in Section 12.1.1. If full dewatering is not possible, the peat should be replaced with rock fill as described in Section 12.1.2.

A separation layer consisting of a non-woven geotextile should be placed between the peat replacement materials, such as Granular A, Granular B Type II or rock fill, and the underside of the bedding material. The geotextile should meet the specifications for OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres.

Construction equipment should not be allowed to travel on the prepared subgrade, which has to be protected from disturbance during construction.

### **12.1.1 Peat Removal with Full Dewatering**

Prior to peat excavation, the following dewatering measures must be in place:

- Creek diversion
- Sheet pile cofferdam enclosure
- Pumping from inside the cofferdam using sumps/pumps

The dewatering above must be effective to lower the groundwater level a minimum of 0.5 m below the base of the peat excavation so as not to create basal instability in the native silty clay below the peat. If this full dewatering option is employed, the peat may be removed to the top of native silty clay and replaced with Granular A or Granular B Type II and compacted as per OPSS.PROV 501.

Following peat removal, a separation layer consisting of a non-woven geotextile should be placed between the native clay and the peat replacement materials such as Granular A or Granular B Type II. The geotextile should meet the specifications for OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres.

### **12.1.2 Peat Removal without Full Dewatering**

Given that removal and replacement of peat below the water table is required, and that groundwater flow and seepage of surface water through the embankment fill is expected, backfilling in the wet conditions (below water level) could be considered. When backfilling is conducted in the wet, select rock fill should be used. The recommended gradation of the rock fill is as follows:

<b>Sieve Size</b>	<b>Percent Passing (%)</b>
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15
0.075 mm	0 – 2

Following peat removal, a separation layer consisting of a non-woven geotextile should be placed between the native clay and rock fill. The geotextile should meet the specifications for OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres. The rock fill should be completely wrapped with the geotextile to minimize migration of fines into the rock fill.

Rock fill used to backfill subexcavated areas below the water table may be placed by end dumping. Granular fill must not be used to backfill excavations below the water table. The rock fill placement below the water level should follow OPSS.PROV 209 (Embankments over Swamps and Compressible Soils).

Rock fill placed above the water level should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging. Rock fill above the water level must be compacted as per OPSS.PROV 206. Where granular fill or bedding material is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS 501.

For this backfilling option under water, if the peat is not completely removed or the rock fill traps peat, there is a risk of additional settlement of the culvert.

## **12.2 Culvert Backfill**

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010, 802.014 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 421 for a CSP and OPSS 422 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

## **12.3 Excavation and Groundwater Control**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silts and sands at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits, peat, and silty clay should be classified as Type 4 soils.

Excavation for culvert construction should be carried out in accordance with OPSS 902. Excavations for culvert replacement will be carried out through the existing embankment fill and the underlying peat. The depth to the base of peat may vary significantly along the culvert length.

Excavation for culvert replacement will be carried out below the creek water level indicated at Elev. 450.0 m, and diversion of the creek flow will be required. Given the relatively high permeability of the embankment fill materials, water inflow/seepage into the excavation should be anticipated from the embankment fill. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with the use of sumps/pumps within an enclosure

will be required to maintain relatively dry excavations during the course of staged construction. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native soils. Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517 and SP 517F01 Amendment to OPSS 517.

The design of an effective dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective until the culvert is installed and backfilled. Suggesting wording for an NSSP in this regard is included in Appendix F.

### **13. STREAM DIVERSION PIPE**

A stream diversion pipe consisting of a CSP may be used to facilitate construction of the CSP or box culvert replacement options, as indicated on a Preliminary General Arrangement drawings. The diversion pipe is shown to be located approximately 10 m to the east of the centreline of the existing culvert with the invert at approximate Elev. 449.2 m. Below the invert level, the subgrade will consist of at least 0.8 m of peat, but may extend deeper, as documented in Boreholes 17-19 to 17-21.

The peat should be sub-excavated where encountered, however sub-excavation should not exceed 0.5 m if the peat extends deeper. The peat should then be replaced with a minimum 500 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010, or clear stone if wet. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

The stream diversion pipe could be installed within the temporary open cut excavations, or alternatively within a shored trench. The installation of the diversion pipe in open cut should follow OPSD 802.014 (Flexible Pipe Embedment in Embankment) and OPSS 421 (Pipe Culvert Installation in Open Cut).

### **14. TEMPORARY PROTECTION SYSTEM**

The temporary roadway protection system should be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2.

Interlocking sheet piles could be considered at this site. The soil parameters in Table 14.1 may be used for design of the temporary roadway protection system with horizontal backfill.

Full hydrostatic pressure should be considered assuming a water level equal to the design high water level in the creek.

**Table 14.1 –Soil Parameters for Temporary Protection System Design**

Soil Parameter	Existing Fill	Native Silty Clay	Native Silt to Sand
Angle of Internal Friction ( $\phi$ )	30°	24°	30°
Bulk Unit Weight ( $\gamma$ )	20 kN/m <sup>3</sup>	19 kN/m <sup>3</sup>	20 kN/m <sup>3</sup>
Submerged Unit Weight ( $\gamma_w$ )	10 kN/m <sup>3</sup>	9 kN/m <sup>3</sup>	10 kN/m <sup>3</sup>
Coefficient of Active Earth Pressure ( $K_a$ )	0.33	0.42	0.33
Coefficient of Passive Earth Pressure ( $K_p$ )	3.0	2.4	3.0

The design of the temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

## 15. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined at not steeper than 2H:1V, the restored embankment slopes should remain stable. As discussed in Section 9.3, if all the peat is removed from under the culvert footprint, settlement of the embankment in the order of 30 to 40 mm should be expected under the existing culvert footprint. For underwater peat replacement with rock fill, it may be difficult to completely remove all of the peat. If some peat is left or the rock fill traps some peat, there is a risk of additional settlement of the culvert/embankment.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Alternatively, the existing granular embankment fill may be reused above the culvert, provided it is unfrozen, free of organics, and at a moisture content that it is suitable for compaction.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel must be conducted at this site.

## **16. SCOUR AND EROSION PROTECTION**

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures considering hydrologic and hydraulic factors should be carried out by specialists experienced in this field and in accordance with OPSS 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection will be required over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A concrete cut-off wall and a clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should be provided at the inlet and should extend laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

## **17. CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the native soil and creek water from the current investigation indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested.
- The potential for soil or surface water corrosion on metal is considered to be mild.
- Appropriate protection measures commensurate with the above are recommended if metal structural elements are used.

## **18. CONSTRUCTION CONCERNS**

Potential construction concerns include, but are not necessarily limited to:

- Peat excavation will be required. The Contractor should be prepared to have appropriate equipment for peat removal.
- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix F.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

## **19. DETAILED DESIGN INVESTIGATION**

For detailed design of the culvert, the following additional investigation is recommended:

- No additional investigation required through the existing embankment along the culvert alignment. Existing borehole information is sufficient for detailed design.
- Additional boreholes are recommended along the alignment of the proposed temporary diversion pipe, if the pipe is to be installed using trenchless methods. 3 boreholes should be advanced, including 1 near each end of the pipe and 1 through the embankment, in order to assess the presence of any obstructions that may impede a trenchless installation. The boreholes should be drilled to depths of 3 times the pipe diameter below the proposed invert level. If bedrock is encountered, it should be cored for a minimum depth of 3 m below the pipe invert. No boreholes are required if the temporary diversion pipe will be installed in an open trench.
- Based on the MTO's typical Minimum Investigation Requirements, it is recommended that 2 boreholes be drilled at each proposed cofferdam location. Depending on the cofferdam locations, Boreholes 17-15 and 17-18 may be used, and should be supplemented by 1 additional borehole at each cofferdam. The boreholes should be advanced to minimum depths of 10 m, and if bedrock is encountered, it should be cored for a minimum depth of

3 m. If the cofferdams are too far away from the inlet and outlet, then 2 boreholes should be drilled at each location instead.

- A review of MTO archival drawings should be conducted to check the existing foundation type and assess whether the foundations may obstruct the peat excavation below the culvert.

## 20. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, EIT, and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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## **Appendix A**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer


### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level

$C_{pen}$  Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT              Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION





MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No 17-15

1 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 618.3 E 291 128.0 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)									
								○ UNCONFINED      + FIELD VANE												
						● QUICK TRIAXIAL      × LAB VANE														
450.4	GROUND SURFACE							20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>					
0.0	<b>PEAT</b> , trace roots and rootlets Very Soft Dark Brown Wet		1	GS			450													163
			1	SS	1			449												
448.7																				
1.7	Silty <b>CLAY</b> , some sand Very Soft to Stiff Brown Wet (CI)		2	SS	1			448							○					
			3	SS	4			447							○					
			4	SS	3			446												
			5	SS	10			445												
			6	SS	0			444												84
443.1								443												
7.3	<b>SILT</b> , trace sand and clay Loose Grey Wet		7	SS	10			442							○					
			8	SS	9		441							○						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-15

2 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 618.3 E 291 128.0 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20 40 60 80 100									20 40 60			
Continued From Previous Page																				
							440													
			9	SS	6															
							439													
438.7																				
11.7	<b>SAND</b> and <b>SILT</b> , trace clay, trace gravel Very Dense Grey Wet																			
			10	SS	60		438									8 36 52 4				
437.6																				
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 0.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-16

1 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 606.7 E 291 118.7 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
452.2	GROUND SURFACE							20 40 60 80 100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
0.0 0.1	ASPHALT: (75mm)							20 40 60 80 100	WATER CONTENT (%)			
	SAND, some silt, trace gravel, occasional cobbles and boulders Compact Brown Moist (FILL)		1	GS					○ UNCONFINED	+ FIELD VANE		
			1	SS	100/				● QUICK TRIAXIAL	× LAB VANE		
			2	GS	0.025							
450.7												
1.5	SAND and SILT, trace clay Compact Brown Moist (FILL)		2	SS	14							
			3	SS	11							
449.2												
3.0	PEAT, trace sand, roots and rootlets Soft Dark Brown Wet		4	SS	4							
448.1												
4.1	Silty CLAY, trace sand Very Soft Brown Wet		5	SS	2							
446.6												
5.6	SILT, trace sand and clay Loose to Compact Grey Wet		6	SS	7							
			7	SS	11							
			8	SS	10							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-16

2 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 606.7 E 291 118.7 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		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 (%)			
	Continued From Previous Page							20 40 60 80 100	20 40 60	W <sub>P</sub> W W <sub>L</sub>		GR SA SI CL	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	Becoming dense		9	SS	34		442						
							441						
440.5							440						
11.7	SAND, some gravel, trace silt Dense to Compact Grey Wet		10	SS	36		439						
							438						
			11	SS	27		437						
436.9			12	SS	100								
15.3	END OF BOREHOLE AT 15.3m ON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE.  DYNAMIC CONE PENETRATION TEST CONDUCTED ADJACENT TO BOREHOLE.				0.025								

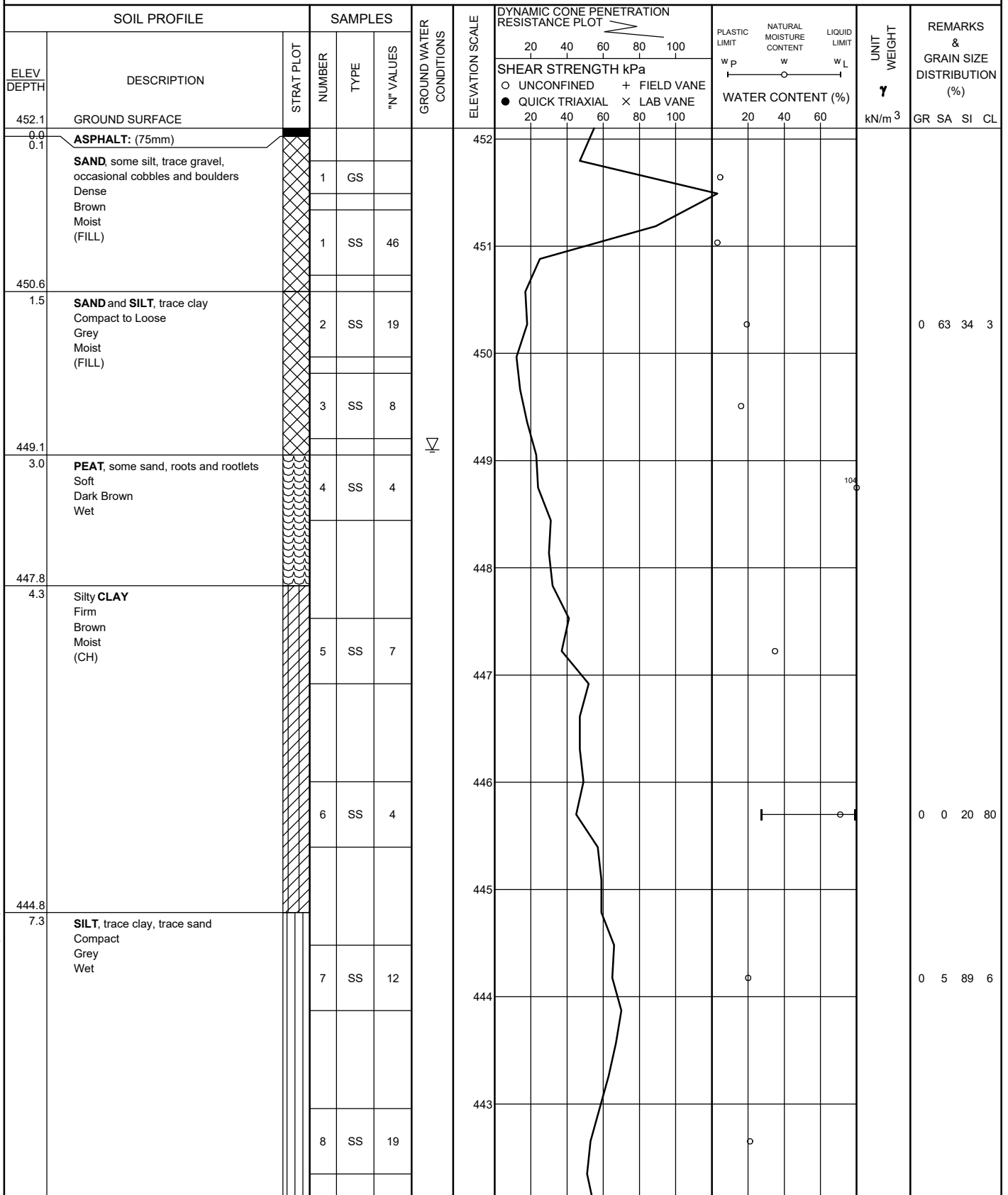
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-17

1 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 602.7 E 291 128.2 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.26 CHECKED BY CZ



Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-17

2 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 602.7 E 291 128.2 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.26 CHECKED BY CZ

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								
							20	40	60	80	100					
441.9	Continued From Previous Page															
10.2	SAND, some silt, some gravel, trace clay Compact Grey Wet		9	SS	17											
			10	SS	29											18 58 19 5
			11	SS	20											
436.8	END OF BOREHOLE AT 15.3m ON SPLIT SPOON REFUSAL ON PROBABLE BEDROCK. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE.  DYNAMIC CONE PENETRATION TEST CONDUCTED ADJACENT TO BOREHOLE.		12	SS	100/0.025											
15.3																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-18

1 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 592.6 E 291 119.4 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.25 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
450.2	GROUND SURFACE						20	40	60	80	100								
0.0	<b>PEAT</b> , some roots and rootlets, trace sand Very Soft Dark Brown Wet		1	GS															
			1	SS	1														
448.8																			
1.4	Silty <b>CLAY</b> , trace sand Very Soft to Firm Brown Wet (CH)		2	SS	1														
			3	SS	1														
			4	SS	6														
			5	SS	4														
444.1																			
6.1	Silty <b>SAND</b> , some clay Compact Brown Wet		6	SS	18														
			7	SS	24														
441.5																			
8.7	<b>SILT</b> , trace sand, trace clay Compact Grey Wet		8	SS	16														

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-18

2 OF 2

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 592.6 E 291 119.4 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.25 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  NATURAL MOISTURE CONTENT  LIQUID LIMIT	UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>		
Continued From Previous Page								20	40	60	80	100	20	40	60		
440.0							440										
10.2	Silty <b>SAND</b> , trace gravel Compact Grey Wet		9	SS	17		439							o			
							438										
437.4			10	SS	17												
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL IN OPEN BOREHOLE AT 0.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.  Well installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS DATE      DEPTH(m)    ELEV.(m) 2017.03.27    0.2      450.0 Decommissioned																

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/3/17

# RECORD OF BOREHOLE No 17-19

1 OF 1

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 605.8 E 291 136.1 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2107.03.25 - 2017.03.25 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL		
452.1	GROUND SURFACE											
0.0 0.1	ASPHALT: (75mm)						452					
	Gravelly SAND, some silt Brown Moist (FILL)		1	GS			451					25 65 10 (SI+CL)
450.0							450					
2.1	PEAT, some sand, trace roots and rootlets Soft Dark Brown Wet		2	GS			449				232	
448.4			1	SS	3						235	
3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CONCRETE TO SURFACE.											

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-20

1 OF 1

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 605.5 E 291 146.1 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.25 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × LAB VANE				WATER CONTENT (%) w <sub>P</sub> w   w <sub>L</sub>							
452.1	GROUND SURFACE							20	40	60	80	100							
0.0 0.1	<b>ASPHALT:</b> (75mm)						452												
	<b>SAND</b> , some silt, trace gravel Brown Moist (FILL)		1	GS															7   70   23 (SI+CL)
							451												
450.0							450												
2.1	<b>PEAT</b> , some sand, trace roots and rootlets Soft Dark Brown Wet		2	GS															
							449												
448.4			1	SS	3														
3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CONCRETE TO SURFACE.																		

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-21

1 OF 1

METRIC

W.P. 6804-14-01 LOCATION Rossmere Creek Culvert, MTM NAD 83 Zone 15 N 5 388 605.1 E 291 156.1 ORIGINATED BY AHF  
 HWY 11/17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.03.25 - 2017.03.25 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE			WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>				
452.1	GROUND SURFACE							20	40	60	80	100			
0.0 0.1	<b>ASPHALT:</b> (75mm)						452								
	<b>SAND</b> , some silt, some gravel Brown Moist (FILL)		1	GS											15   68   17 (SI+CL)
							451								
							450							85	
449.7	<b>PEAT</b> , some roots and rootlets, trace sand Dark Brown Wet		2	GS											
2.4	Firm						449							208	
			1	SS	5										
448.4	END OF BOREHOLE AT 3.7m. WATER LEVEL IN OPEN BOREHOLE AT APPROX. 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CONCRETE TO SURFACE.														
3.7															

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

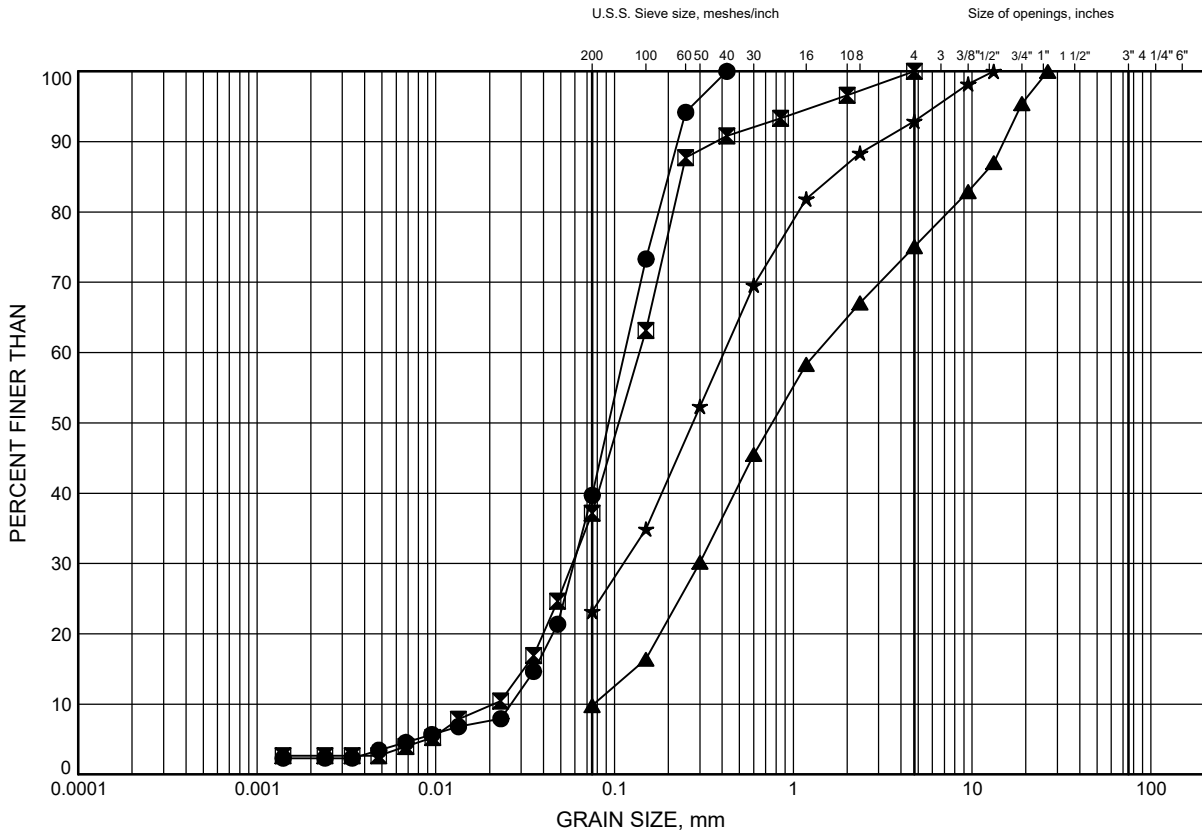
## **Appendix B**

### **Geotechnical and Analytical Laboratory Test Results**

# Rossmere Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

## Embankment FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-16	2.6	449.6
⊠	17-17	1.8	450.3
▲	17-19	0.5	451.6
★	17-20	0.5	451.6

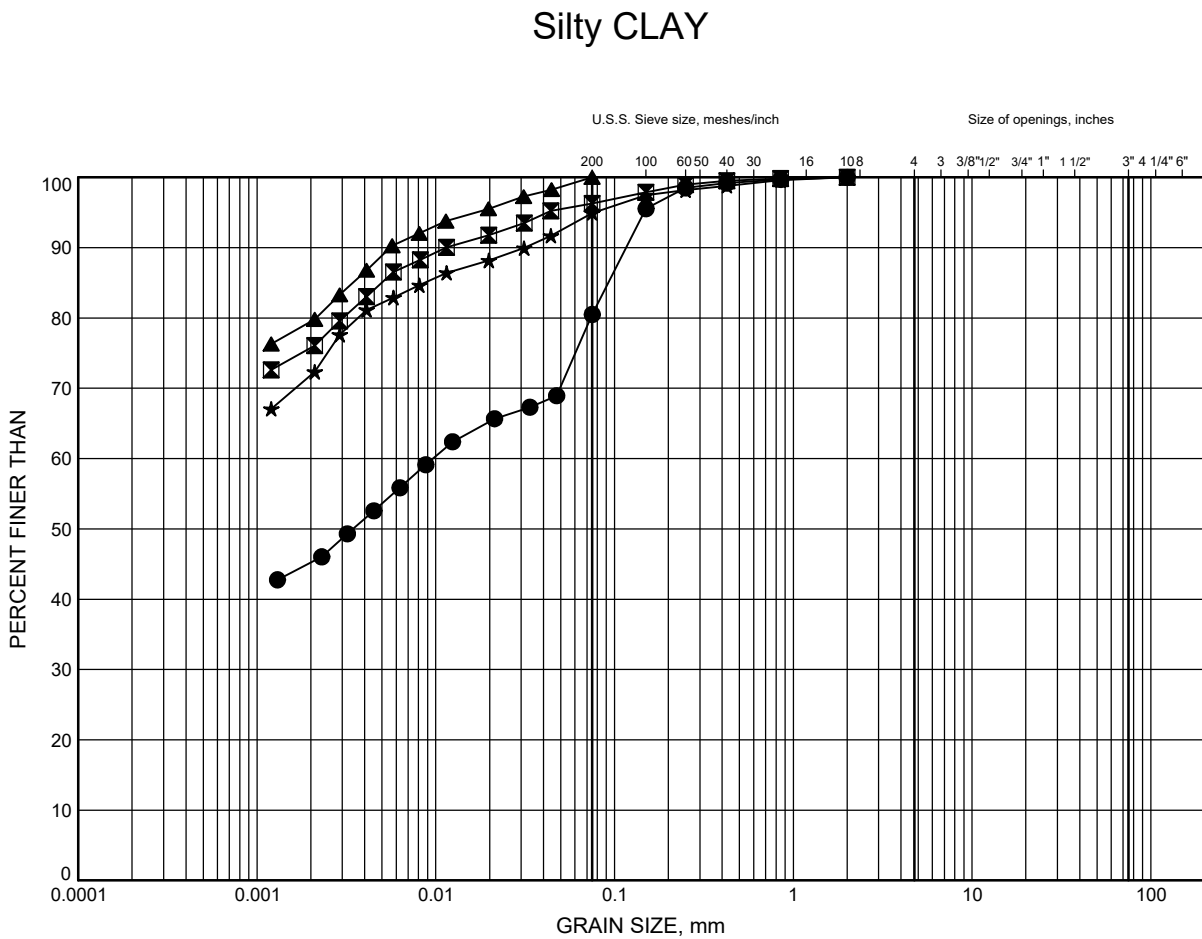
Date May 2017  
W.P. 6804-14-01



Prep'd AN  
Chkd. CZ

# Rossmere Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-15	2.6	447.8
⊠	17-16	4.9	447.3
▲	17-17	6.4	445.7
★	17-18	3.4	446.8

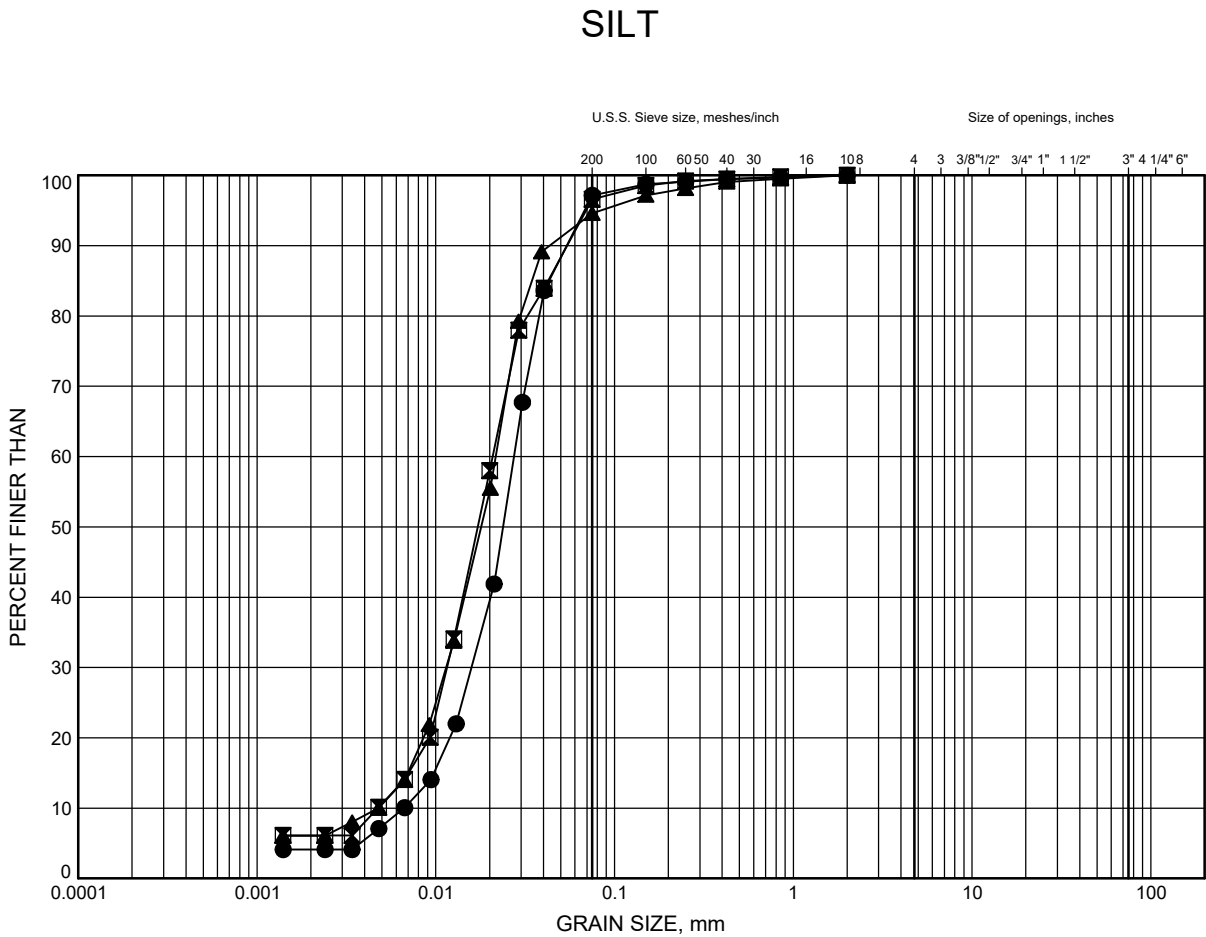
Date May 2017  
W.P. 6804-14-01



Prep'd AN  
Chkd. CZ

# Rossmere Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-15	7.9	442.5
⊠	17-16	9.4	442.8
▲	17-17	7.9	444.2

Date May 2017  
W.P. 6804-14-01

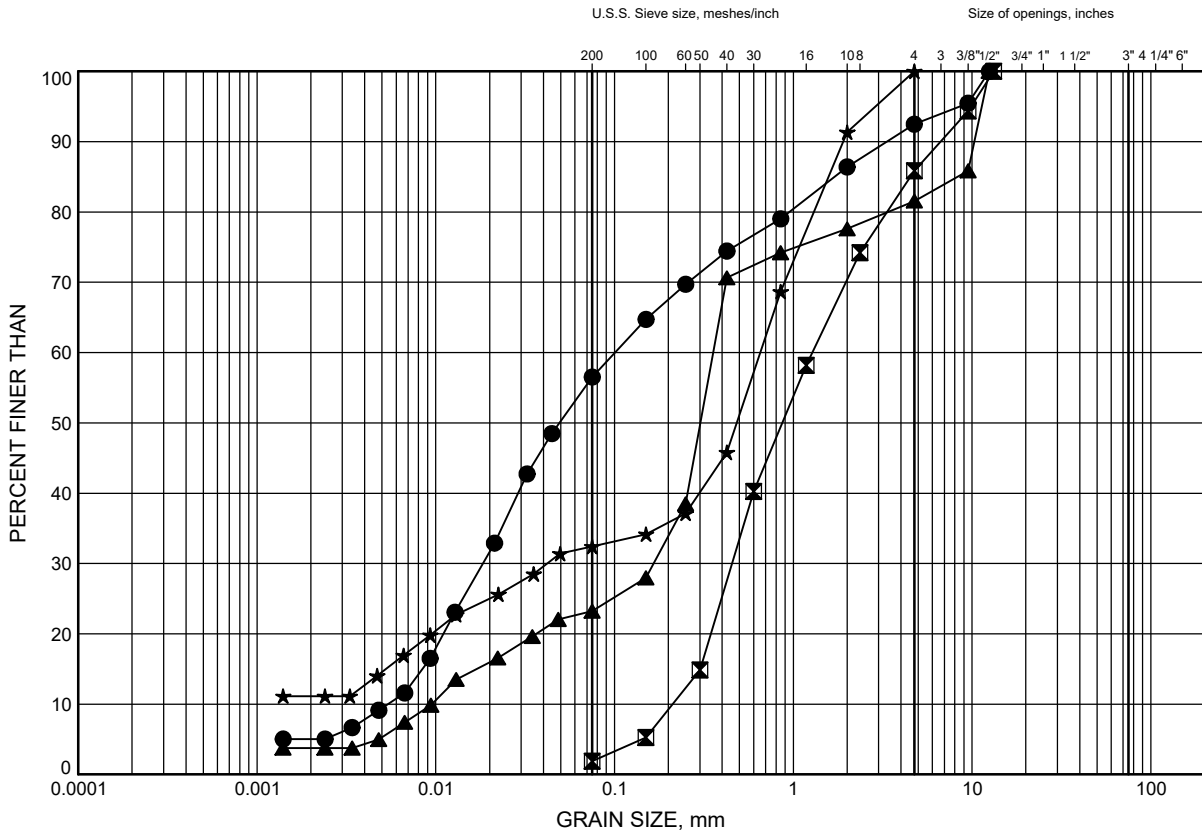


Prep'd AN  
Chkd. CZ

# Rossmere Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4

## SAND to SAND and SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-15	12.5	437.9
⊠	17-16	12.5	439.7
▲	17-17	12.5	439.6
★	17-18	7.9	442.3

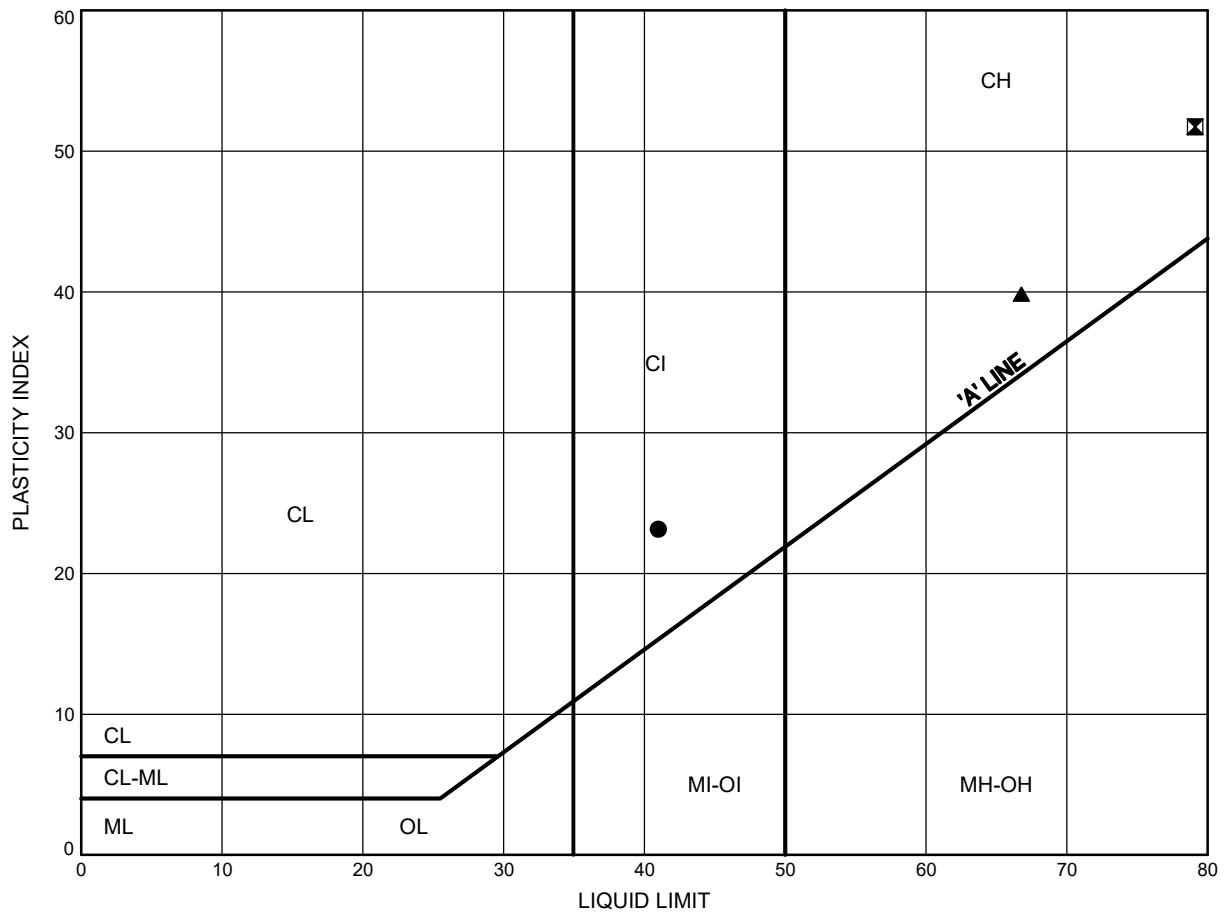
Date May 2017  
W.P. 6804-14-01



Prep'd AN  
Chkd. CZ

Rossmere Creek Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B5



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-15	2.6	447.8
⊠	17-17	6.4	445.7
▲	17-18	3.4	446.8

Date May 2017  
W.P. 6804-14-01



Prep'd AN  
Chkd. CZ



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

## Thurber Engineering Ltd

Attn : Cory Zanatta

2010 Winston Park Dr  
Oakville, ON  
L6H 5R7,

Phone: 905-829-8666 x 240

Fax:

**Project :** 15593

08-May-2017

**Date Rec. :** 02 May 2017

**LR Report:** CA14060-MAY17

**Reference:** 15593 Cory Zanatta

**Copy:** #1

# CERTIFICATE OF ANALYSIS

## Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	9: 17-16 SS5	10: 17-17 SS5
Sample Date & Time					26-Mar-17	26-Mar-17
Temperature Upon Receipt [°C]	---	---	---	---	6.0	6.0
Corrosivity Index [none]	08-May-17	14:35	08-May-17	14:35	5.0	5.0
Soil Redox Potential [mV]	03-May-17	16:33	04-May-17	14:12	286	210
Sulphide [%]	05-May-17	13:47	05-May-17	15:54	< 0.02	< 0.02
% Moisture (wet wt) [%]	04-May-17	13:57	04-May-17	14:37	31.6	30.3
pH [no unit]	03-May-17	15:41	05-May-17	09:17	8.98	8.64
Chloride [µg/g]	05-May-17	17:42	08-May-17	14:40	16	30
Sulphate [µg/g]	05-May-17	17:42	08-May-17	14:40	150	22
Conductivity [uS/cm]	03-May-17	15:41	05-May-17	09:17	127	160
Resistivity (calculated) [Ohms.cm]	03-May-17	15:41	08-May-17	14:21	7870	6250

Temperature of Sample upon Receipt: 12 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.



**SGS Canada Inc.**

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Lakefield - Ontario - K0L 2H0

Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 15593

**LR Report :** CA14060-MAY17

### Method Descriptions

Parameter	SGS Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013
pH	ME-CA-[ENV]EWL-LAK-AN-001

*Deanna Edwards, B.Sc, C.Chem*

*Project Specialist*

*Environmental Services, Analytical*



**SGS Canada Inc.**

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Lakefield - Ontario - KOL 2H0

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**Project :** 15593

**LR Report :** CA14060-MAY17

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0108-MAY17												
Chloride	0.4	µg/g	<0.4		3	20	101	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		2	20	97	80	120	87	75	125
Carbon/Sulphur - QCBatchID: ECS0006-MAY17												
Sulphide	0.02	%	<0.02		ND	20	113	80	120			
Conductivity - QCBatchID: EWL0047-MAY17												
Conductivity	2	uS/cm	< 2		2	10	93	90	110	NA		
pH - QCBatchID: EWL0047-MAY17												
pH	0.05	no unit	NA		0		100			NA		



**SGS Canada Inc.**

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Lakefield - Ontario - K0L 2H0  
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## Thurber Engineering Ltd

Attn : Cory Zanatta

2010 Winston Park Dr  
Oakville, ON  
L6H 5R7,

Phone: 905-829-8666 x 240

Fax:

**Project :** 17840/17792

02-June-2017

**Date Rec. :** 10 May 2017

**LR Report:** CA14294-MAY17

**Reference:** 17840/17792 Cory Zanatta

**Copy:** #2

# CERTIFICATE OF ANALYSIS

## Final Report - Reissue

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Rossmere Creek
Sample Date & Time						25-Apr-17
Temperature Upon Receipt [°C]	---	---	--	--	---	9.0
pH [no unit]	11-May-17	10:30	15-May-17	10:54	0.05	6.35
Conductivity [µS/cm]	11-May-17	10:41	15-May-17	10:51	2	115
Resistivity (calculated) [ohms.cm]	---	---	---	---	---	8700
Redox Potential [mV]	11-May-17	13:57	15-May-17	10:32	---	197
Chloride [mg/L]	15-May-17	18:20	16-May-17	13:24	0.04	24
Sulphate [mg/L]	15-May-17	18:20	16-May-17	13:24	0.04	1.1
Sulphide [mg/L]	11-May-17	12:10	12-May-17	16:01	0.006	0.014



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Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 17840/17792

**LR Report :** CA14294-MAY17

Temperature of Sample upon Receipt: 9 degrees C

Cooling Agent Present: yes

Custody Seal Present: no

*Deanna Edwards, B.Sc, C.Chem*

*Project Specialist*

*Environmental Services, Analytical*



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Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 17840/17792

**LR Report :** CA14294-MAY17

### Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500



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**Project :** 17840/17792

**LR Report :** CA14294-MAY17

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD		LCS / Spike Blank			Matrix Spike / Reference Material		
					Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)		
							Low	High		Low	High	
Anions by IC - QCBatchID: DIO0256-MAY17												
Chloride	0.04	mg/L	<0.04		2	20	97	80	120	100	75	125
Sulphate	0.04	mg/L	<0.04		0	20	96	80	120	89	75	125
Anions by IC - QCBatchID: DIO0269-MAY17												
Chloride	0.04	mg/L	<0.04		0	20	100	80	120	119	75	125
Sulphate	0.04	mg/L	<0.04		0	20	97	80	120	102	75	125
Conductivity - QCBatchID: EWL0183-MAY17												
Conductivity	2	µS/cm	< 2		0	10	99	90	110	NA		
pH - QCBatchID: EWL0182-MAY17												
pH	0.05	no unit	NA		1		100			NA		
Redox Potential - QCBatchID: EWL0192-MAY17												
Redox Potential	no	mV	NA		0	20	103	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0095-MAY17												
Sulphide	0.006	mg/L	<0.006		ND	20	80	80	120	NV	75	125
Sulphide by SFA - QCBatchID: SKA0105-MAY17												
Sulphide	0.006	mg/L	0.009		ND	20	96	80	120	125	75	125

## **Appendix C**

### **Selected Site Photographs**



**Photo 1: View looking east along the south embankment of Highway 11**



**Photo 2: View looking west along Highway 11**



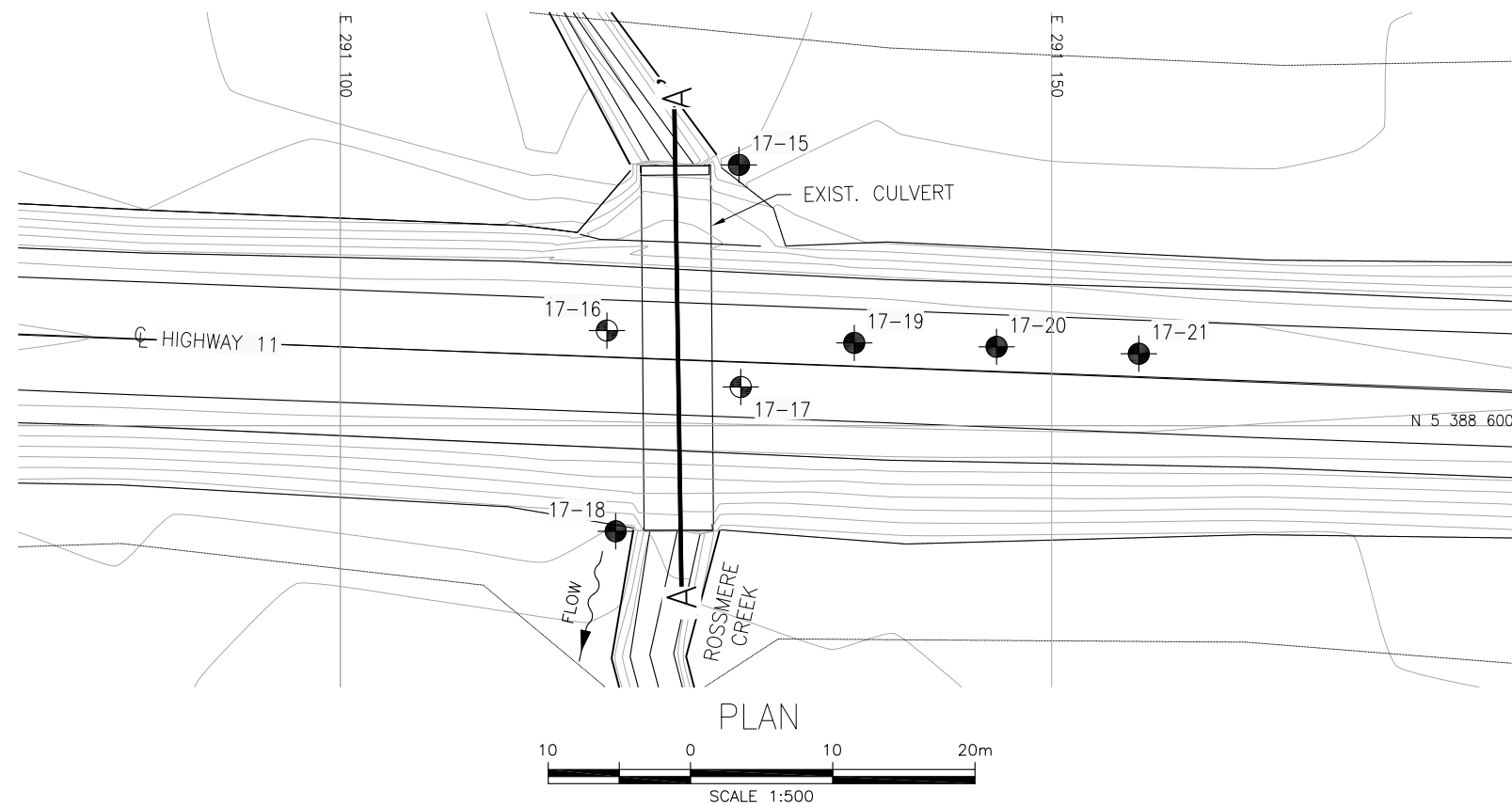
**Photo 3: South Side of Rossmere Creek Culvert**



**Photo 4: North Side of Rossmere Creek Culvert**

## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**



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



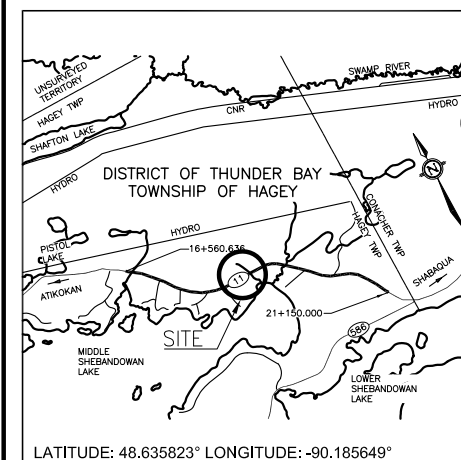
CONT No 6016-E-0012  
WP No 6804-14-01

SHEET

# HATCH








**THURBER** ENGINEERING LTD.



LATITUDE: 48.635823° LONGITUDE: -90.185649°

## KEYPLAN

## LEGEND

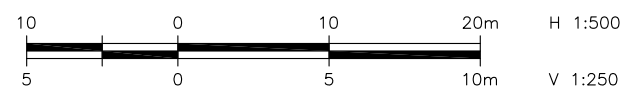
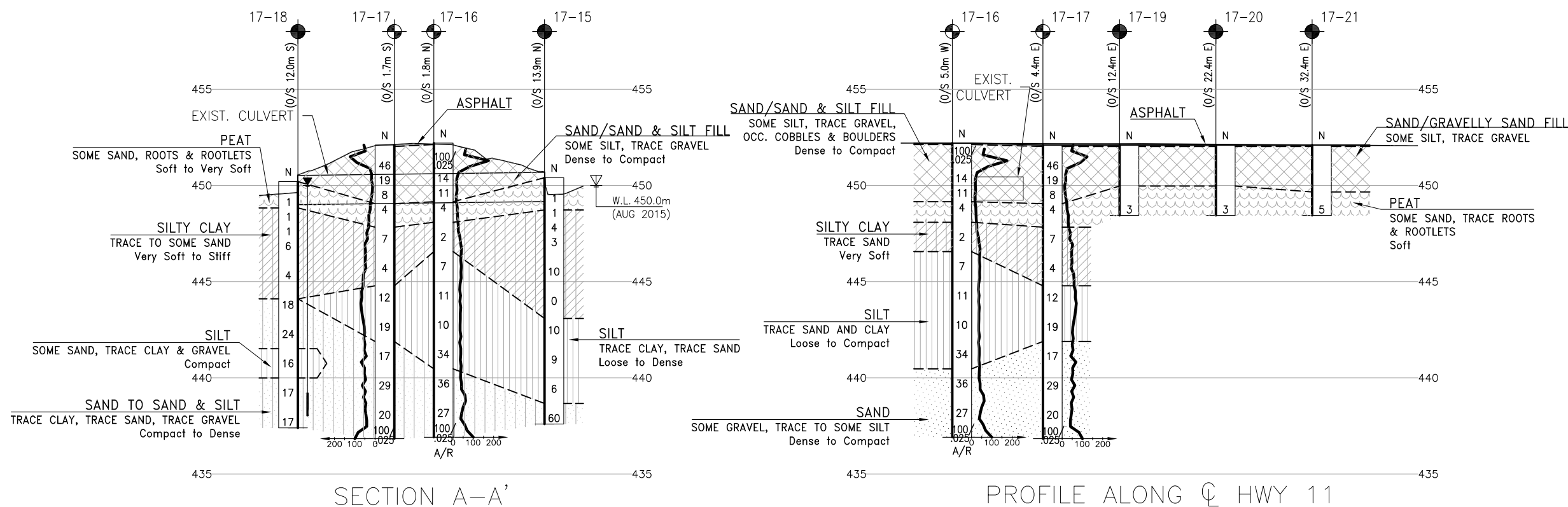
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-15	450.4	5 388 618.3	291 128.0
17-16	452.2	5 388 606.7	291 118.7
17-17	452.1	5 388 602.7	291 128.2
17-18	450.2	5 388 592.6	291 119.4
17-19	452.1	5 388 605.8	291 136.1
17-20	452.1	5 388 605.5	291 146.1
17-21	452.1	5 388 605.1	291 156.1

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 15

**GEOCRES No. 52B-32**



REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	CZ	CHK	MEF	CODE	LOAD		DATE	OCT 2017	
DRAWN	AN	CHK	CZ	SITE 48W-192/C	STRUCT	DWG 1			

## **Appendix E**

### **Foundation Comparison**

### COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. CSP's can accommodate small differential settlement along culvert axis</li> <li>iii. Steel pipes are likely to be more cost effective than concrete box or open footing culverts.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used.</li> <li>ii. Segmental option can accommodate limited amount of potential differential settlement along culvert axis.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Conventional construction.</li> <li>ii. May have less environmental issues such as those involving spawning fish species.</li> </ul>
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Multiple pipes may be needed to meet hydraulic requirements.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. More expensive than a CSP culvert.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Requires deeper excavation and potentially longer dewatering requirements.</li> <li>ii. Requires higher soil geotechnical resistances to support strip footings.</li> <li>iii. Cannot tolerate differential settlement.</li> </ul>
<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>

## **Appendix F**

### **List of Specifications and Suggested Wording for NSSP**

## **1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS.PROV 421 (Construction Specification for Pipe Culvert Installation in Open Cut)
- OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation)
- SP 517F01 Amendment to OPSS 517 (Design Storm Return Period and Preconstruction Survey Distance)
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSS PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment, Original Ground: Earth or Rock)

- OPSD 803.010 (Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m)
- OPSD 803.031 (Frost Treatment – Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade)
- OPSD 810.010 (General Rip-Rap Layout for Sewer and Culvert Outlets)
- OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario)

## **2. Suggested Wording for NSSP on Dewatering**

Effective dewatering shall be designed and provided by the Contractor during culvert excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.

## **3. Suggested Wording for NSSP on Obstructions**

Excavations and installation of cofferdams and roadway protection systems may encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Vibrating equipment is not permitted for installation of sheet piles.