



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
COBB BAY CREEK CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-190/C
DISTRICT OF KENORA
ONTARIO
G.W.P. No. 6839-14-00
GEOCRES Number: 52J-17**

Latitude 50.020074 ° , Longitude -90.995573 °

Report

to

HATCH Corporation

Date: February 8, 2018
File: 17077



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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 Cobb Bay Creek Culvert on Highway 599, located in the District of Kenora.

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-0030.

2. SITE DESCRIPTION

The site is located on Highway 599, approximately 30.8 km north of the intersection of Highway 599 and Highway 642 in Silver Dollar, 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 599 runs in a general northeast-southwest direction with the culvert generally perpendicular to the centreline of the highway. The culvert allows Cobb Bay Creek to flow in an southerly direction beneath the highway.

The Ontario Structural Inspection Manual (OSIM) prepared by MTO dated November 2, 2015 indicates that the existing structure is a 17 m long, two span open footing, timber structure culvert. Each span is 2.4 m wide. The timber culvert is 1.7 m high. The grade level of Highway 599 at the

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existing culvert is at an approximate Elevation of 425.1 m. The height of the existing fill cover is approximately 0.5 m. The culvert invert is at approximately Elevation 422.9 m at the inlet and 422.8 m at the outlet. The upstream and downstream water levels of Cobb Bay Creek were measured at Elevation 423.51 m and 423.50 m, respectively, in April 2016, as shown on drawings provided by Hatch.

The lands surrounding the Cobb Bay Creek Culvert site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography consists of plains generally of low relief. 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 glaciolacustrine plains of sands and silts overlying shallow knobby and hummocky bedrock of moderate relief. Bedrock geology maps of the area show that the site lies on a border of bedrock comprising of mafic to intermediate metavolcanics rocks and bedrock comprising of felsic to intermediate metavolcanics rocks.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out between July 9 and July 20, 2017 and consisted of drilling and sampling seven (7) boreholes, designated as Boreholes CO17-01 to CO17-05, CO17-07 and CO17-08. Two attempts were made to advance Borehole CO17-07 to an appropriate depth and are designated as CO17-07A and CO17-07B. Boreholes CO17-01 to CO17-03 were drilled along the culvert alignment. Boreholes CO17-01 and CO17-03 were drilled at the inlet and outlet, respectively, and terminated upon refusal at 7.7 m and 9.9 m (Elevation 416.0 and 413.6). Borehole CO17-02 was drilled through the highway embankment. Bedrock was proved by NQ size diamond in Borehole CO17-02. Borehole CO17-02 was advanced 3.4 m into bedrock and terminated at 11.3 m depth (Elevation 413.8).

Due to the site constraints and difficult access to the borehole location, the drilling operations for Borehole CO17-01 were conducted using portable tripod equipment. The tripod equipment allowed us to drill at the proposed borehole location, however it encountered refusal and was not able to advance further. Multiple attempts were made in the area to advance the borehole deeper, but were unsuccessful.

Boreholes CO17-04, CO17-05, CO17-07 and CO17-08 were drilled through the paved section of Highway 599, to the east and west of the existing culvert, at approximately 10.0 m intervals. These boreholes were advanced to assess the existence and extents of any frost taper near the culvert.



Boreholes CO17-04, CO17-07A, CO17-07B, and CO17-08 were terminated at depths ranging from 1.2 m to 3.7 m (Elevations 423.9 to 421.4). Borehole CO17-05 was located approximately 10 m west of the existing culvert centreline, near the alignment of the proposed creek diversion pipe. Bedrock was proved by NQ size diamond in Borehole CO17-05; it was advanced 3.2 m into bedrock and terminated at 11.7 m depth (Elevation 413.4).

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.

All boreholes within Highway 599 were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. Borehole CO17-01 was drilled using the wash boring method on tripod equipment. 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).

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.

All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined. Photos of the rock cores are included in Appendix B.

Groundwater conditions were observed in the open boreholes throughout the drilling operations and upon completion of drilling. Upon completion of drilling operations, 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

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
CO17-01	7.7 / 416.0	Borehole backfilled with bentonite holeplug to surface.
CO17-02	11.3 / 413.8	Borehole backfilled with bentonite holeplug to 6.1 m, gravel from 6.1 m to 0.4 m, cement to 0.05 m, then asphalt patch to surface.
CO17-03	9.9 / 413.6	Borehole backfilled with bentonite holeplug to surface.
CO17-04	3.7 / 421.4	Borehole backfilled with auger cuttings and asphalt patch to surface.
CO17-05	11.7 / 413.4	Borehole backfilled with bentonite holeplug to 6.1 m, gravel from 6.1 m to 0.1 m, then asphalt patch to surface
CO17-07A	1.2 / 423.9	Borehole backfilled with auger cuttings and gravel to 0.2 m, then asphalt cold patch to surface.
CO17-07B	1.5 / 423.6	Borehole backfilled with auger cuttings and gravel to 0.2 m, then asphalt cold patch to surface.
CO17-08	1.5 / 423.6	Borehole backfilled with auger cuttings and gravel to 0.2 m, then asphalt cold patch 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). 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.

Point load tests were carried out on selected samples of intact bedrock upon arrival at the laboratory to assist in evaluation of the compressive strength of the bedrock. Results of point



load tests on the rock core samples are included in Appendix B and on the Record of Borehole sheets in Appendix A.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample 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 Appendix A. 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 below the existing embankment fill typically consist of layers of silt, sandy silt and, sand and silt overlying bedrock. Layers of peat and organic deposits were also encountered immediately underlaying the embankment fill in three boreholes. Descriptions of the individual strata are presented below.

5.1 Asphalt

The boreholes that were drilled through the paved portion of Highway 599 encountered approximately 25 mm of asphalt at the ground surface. The ground surface elevation of the boreholes drilled on the highway platform was 425.1.

5.2 Embankment Fill

Embankment fill consisting of sand and gravel to sand with trace silt and clay, was encountered below the asphalt in all boreholes drilled on Highway 599. The thickness of the embankment fill, where fully penetrated, ranged from 1.5 m to 2.4 m and extended to depths of 1.5 m to 2.4 (Elevations 423.6 to 422.7).



Boreholes CO17-07A, CO17-07B and CO17-08 were terminated within the embankment fill (upon auger refusal) at 1.2 m to 1.5 m depth (Elevations 423.9 to 423.6).

SPT 'N' values in the fill ranged from 7 to 24 blows for 0.3 m of penetration, indicating a loose to compact relative density. Measured moisture contents ranged from 3 to 22 percent.

An SPT 'N' value of 50 blows with no penetration, was measured in Borehole CO17-07B, indicating auger refusal.

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.

Soil Particle	Sand and Gravel Fill (percent)
Gravel	36 to 57
Sand	37 to 56
Silt & Clay	6 to 8

5.3 Peat and Sandy Silt with Organics

Sandy silt with organics was encountered in Boreholes CO17-01 and CO17-03 at the surface. The sandy silt with organics extended to depths of 0.6 m to 1.2 m (Elevations 422.9 to 422.5).

SPT 'N' values in the sandy silt with organics ranged from 2 to 8 blows for 0.3 m penetration, indicating a very loose to loose relative density. The measure moisture content if the sandy silt with organics was 48 percent.

A layer of dark brown, fibrous peat, containing roots and rootlets, trace sand was encountered below the embankment fill in Boreholes CO17-02, CO17-04, and CO17-05 at a depth of 1.5 m to 2.4 m (Elevation 423.6 to 422.7). The peat below the embankment fill was approximately 0.6 m to 1.2 m thick and extended to depths of 2.3 m to 3.0 m (Elevation 422.8 to 422.1).

SPT 'N' values in the peat ranged from 1 to 4 blows for 0.3 m penetration, indicating a very loose to loose state. Measured moisture contents of the peat ranged from 56 percent to 144 percent.



5.4 Silt

Layers of silt, containing trace sand and trace to some clay, were encountered below the peat or sandy silt with organics at depths ranging from 0.6 m to 4.0 m (Elevations 422.9 to 421.1) in Boreholes CO17-01 to CO17-05. Where fully penetrated the silt was 2.4 m to 4.9 m thick and extended to depths of 3.6 m to 8.5 m (Elevations 420.1 to 416.6).

Borehole CO17-04 was terminated within the silt layer at 3.7 m depth (Elevation 421.4).

SPT 'N' values recorded in the silt ranged from 1 to 46 blows for 0.3 m penetration, indicating a very loose to dense consistency. In general, the silt formation was denser at a higher elevation and looser with depth. The loose to very loose conditions were noted within approximate Elevations 420.5 to 417.0, and may have been the result of hydraulic ground disturbance during drilling operations. Measured moisture contents in the silt ranged from 16 percent to 31 percent.

The results of grain size distribution analyses conducted on samples of the silt 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 B2 in Appendix B.

Soil Particle	Silt (percent)
Gravel	0
Sand	0 to 4
Silt	80 to 92
Clay	8 to 20

5.5 Sandy Silt to Sand and Silt

Layers of sandy silt, containing trace clay and gravel, were encountered below the silt formations at depths of 3.6 m and 4.6 m (Elevations 420.1 and 418.9) in Boreholes CO17-01 and CO17-03, respectively. A layer of sand and silt was encountered below the peat layer at a depth of 3.0 m (Elevation 422.1) in Borehole CO17-05.

Boreholes CO17-01 and CO17-03 were terminated within the sandy silt on auger refusal at depths of 7.7 m and 9.9 m (Elevation 416.0 and 413.6), respectively. The sand and silt layer in Borehole CO17-05 was approximately 1.0 m thick and extended to a depth of 4.0 m (Elevation 421.1).



SPT 'N' values recorded in the sandy silt to sand and silt ranged from 6 to 21 blows for 0.3 m penetration, indicating a loose to compact relative density. Measured moisture contents in the sandy silt to sand and silt ranged from 9 percent to 25 percent.

The results of grain size distribution analyses conducted on samples of the sandy silt to sand and silt 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 B3 in Appendix B.

Soil Particle	Sandy Silt/ Sand and Silt (percent)
Gravel	0 to 7
Sand	21 to 36
Silt	58 to 73
Clay	4 to 6

5.6 Bedrock

The soils described above are underlain by basalt bedrock. The bedrock was grey to black with steeply dipping white cemented joints. Occasional mechanical breaks were noted throughout the bedrock cores. The bedrock is generally described as slightly weathered. Bedrock was proved by coring in Boreholes CO17-02 and CO17-05. Table 5.1 summarizes depths and elevations to the top of bedrock and refusal.

Table 5.1 - Depths and Elevations of Top of Bedrock

Borehole	Top of Bedrock		Comment
	Depth (m)	Elevation (m)	
CO17-01	7.7	416.0	Auger refusal
CO17-02	7.9	417.2 ⁽¹⁾	Bedrock
CO17-03	9.9	413.6	Auger refusal
CO17-05	8.5	416.6 ⁽¹⁾	Bedrock

⁽¹⁾ Proved by coring



Total Core Recovery (TCR) in the bedrock ranged from 100% with Solid Core Recovery (SCR) ranging from 81% to 98%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 71% to 88%, indicating fair to good rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to 4.

Average unconfined compressive strengths (UCS) of the rock ranged between 138 MPa and 219 MPa, indicating the rock is very strong. An UCS of the rock measured in Run 3 of Borehole CO-17-02 was 27.0 MPa, indicating a medium strong rock. These estimated rock strength values are interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results and photographs of bedrock cores are presented in Appendix B.

5.7 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels measured in the open boreholes are summarized in the Table 5.2.

Table 5.2 - Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
CO17-01	July 9, 2017	0.5	423.2	Open borehole
CO17-02	July 20, 2017	1.9	423.2	Open borehole
CO17-03	July 9, 2017	0.5	423.0	Open borehole
CO17-04	July 19, 2017	Dry	-	Open borehole
CO17-05	July 19, 2017	3.4	421.7	Open borehole
CO17-07A	July 20, 2017	Dry	-	Open borehole
CO17-07B	July 20, 2017	Dry	-	Open borehole
CO17-08	July 20, 2017	Dry	-	Open borehole

The upstream and downstream water levels of Cobb Bay Creek were measured at Elevation 423.51 m and 423.50 m, respectively, in April 2016, as shown on drawings provided by Hatch.

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

A sample of the native silt from Borehole CO17-03, and a sample of the creek water obtained at the culvert inlet, taken from the inlet area, were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown 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	
			CO17-03 SS 4 Depth 1.8 m	Cobb Bay Creek
			(Soil Sample)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	1.2	1.7
Sulphate	µg/g	mg/L	46	0.6
pH	No unit	No unit	8.65	7.70
Electrical Conductivity	µS/cm	µS/cm	83	78
Resistivity	Ohms.cm	Ohms.cm	12000	12800
Redox Potential	mV	mV	295	301

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 Stephen Hillier 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, EIT and Ms. R. Palomeque Reyna,



The report was reviewed by Mr. Jason Lee, P.Eng and 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 design of the proposed Cobb Bay culvert replacement located on Highway 599, approximately 30.8 km north of the intersection of Highway 599 and Highway 642 in Silver Dollar, 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 dated November 2, 2015. The existing structure is a two-span open footing timber culvert. Each span is 2.4 m wide, resulting in a 4.8-m wide culvert. The length of the culvert is 17.0 m. The estimated culvert invert level is at approximately Elevations 422.9 m at the inlet and 422.8 m at the outlet. The existing road grade at the culvert location is at about Elevation 425.1 m, which indicates approximately 0.6 m of fill above the culvert.

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General Arrangement (GA) Drawing and discussions with Hatch/MTO, indicate that the following replacement option is being considered:

1. Multiple CSP Pipe Culvert

Two circular CSP pipes are being considered to provide increased hydraulic opening. The CSPs are likely to be approximately 2.7-m in diameter. The proposed founding level (base of granular bedding) of the CSP pipes is near Elevation 421.0 to 421.1. The length of the pipes is 21.4 m.

The alignment of the replacement culvert will remain largely the same as for the existing culvert. Grade raise is not anticipated at the culvert location.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary roadway protection system and a temporary stream diversion pipe (CSP). A temporary stream diversion pipe, approximately 10.0 m west of the existing culvert centreline, with an invert elevation of approximately 422.6 (as indicated on the GA drawing), would be installed during construction.

The discussions and recommendations presented in this report are based on information provided by Hatch and on the factual data obtained during the course of the current investigation.

9. CULVERT DESIGN

9.1 Culvert Replacement Options

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
- Precast Concrete Slabs Supported on Sheet Pile Abutments (Sheet pile culvert)



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, precast box culvert or sheet pile culvert are 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;
- The sheet pile culvert minimizes any disturbance or environmental impact on the creek bed. The design also minimizes use of cast-in-place concrete which increases the cost of construction;

An open footing culvert is not recommended at this site since it would involve deeper excavation and more dewatering effort. In addition, the soils at this site have relatively low geotechnical resistance and are prone to settlement. Hence, recommendations for this option have not been developed.

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

9.2 Foundation Design for Culverts

In general, the subsurface conditions encountered in the boreholes drilled through Highway 599 platform consists of compact to loose sand/sand and gravel fill (approximately 1.2 m to 2.4 m thick), over a deposit of peat, over layers of native very loose to dense silt and sandy silt. The above soils are underlain by bedrock. Topsoil/organics were encountered surficially in the boreholes drilled at the inlet and outlet. A layer of peat (0.6 m to 1.2 m thick) was contacted at the base of the embankment fill in three boreholes drilled through the highway embankment. The water level at the Cobb Bay culvert was measured at Elevations 423.51 and 423.50, in the inlet and outlet, respectively, in April 2016, as indicated in drawings provided by Hatch.



The founding soils encountered at the proposed founding elevation 421.1 (base of bedding) generally consist of very loose to compact silt.

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 existing culvert with multiple SPCSPs or CSPs on the same alignment as the existing culvert may be considered for this site. Grade raise is not anticipated at this site, therefore, settlement of the underlying soils is not expected.

If this alternative is selected, the SPCSPs 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. The underside of the bedding layer should be placed at or below Elevation 421.1, which corresponds to native very loose to compact silt. Geotextile should be placed between the founding soils and the granular layer of bedding material.

Any remaining peat, organics, loose/soft or deleterious material should be removed from final subgrade level and replaced with compacted granular material. Culvert subgrade preparation and placement and compaction of the granular bedding must be carried out in the dry. Adequate preparation of the subgrade will be essential for performance of the culvert.

9.2.2 Precast Concrete Box Culvert

Replacement of the existing culvert with precast concrete box culvert on the same alignment is considered a viable alternative for this site. Grade raise is not anticipated at this site, therefore, settlement of the underlying soils is not expected.

Based on available information, it is anticipated that the founding levels (base of bedding) of the culvert will be near Elevation 421.1.

The founding elevations will expose native very loose to compact silt.

Any exposed peat deposit within the culvert footprint must be subexcavated and removed. In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material



conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A. Geotextile should be placed between the founding soils and the granular layer of bedding material. Subgrade preparation should also be conducted as indicated in Section 11.1.

Assessment of the geotechnical capacities for the design of a box culvert founded at or below Elevation 421.1 on the native loose to compact silt, indicates a Factored Geotechnical Resistance at ULS of 150 kPa and a Geotechnical Resistance at SLS (up to 25 mm settlement) of 100 kPa. We understand that these values are lower than the estimated bearing pressure that will be applied by the replacement culvert.

Discussions with the designers indicate that higher geotechnical capacities are required: Factored Geotechnical Resistance at ULS of 230 kPa and a Geotechnical Resistance at SLS of 150 kPa. These higher bearing pressures would induce a higher settlement of 40 mm and the culvert must be designed to accommodate the larger settlements.

Alternatively, to achieve the required higher bearing capacities for the box culvert at this site, one option would be to subexcavate the existing loose silt and replace it with a compacted granular pad under the footprint of the culvert. The engineered pad must be at least 500 mm beyond the limits of the culvert footprint. For a Factored Geotechnical Resistance at ULS of 230 kPa and a Geotechnical Resistance at SLS of 150 kPa, the following pad thickness and associated settlements are presented below:

<u>Granular Pad Thickness (m)</u>	<u>Settlement (mm)</u>
1.0	38
1.5	32
2.0	28

The above values of the geotechnical resistance and reaction were based on a box culvert width of about 6.0 m.



The granular pad must be constructed with Granular A or B Type and compacted in thin lifts to 100% of SPMDD. A geotextile layer should be used between the native silt and the granular pad. The pad construction must be done in the dry that is under fully dewatered condition.

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 and 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 Steel Sheet Pile Walls

Consideration was given to supporting the culvert on steel sheet piles driven to bedrock or to refusal.

The depths and elevations where bedrock and/or refusal were contacted, are presented in Table 9.1.



Table 9.1 – Depths and Elevations to Bedrock or Refusal

Borehole location relative to culvert	Borehole	Depth to refusal or bedrock (m)	Elevation to refusal or bedrock (m)	Comment
Inlet	CO17-01	7.7	416.0	Refusal depth encountered by tripod equipment. Possible bedrock.
Roadway	CO17-02	7.9	417.2	Refusal on bedrock. Bedrock proved by coring.
Outlet	CO17-03	9.9	413.6	Refusal depth encountered by tripod equipment. Possible bedrock.
Roadway	CO17-05	8.5	416.6	Refusal on bedrock. Bedrock proved by coring.

Vertical, factored geotechnical resistance at Ultimate Limit States (ULS_r) for a sheet pile section driven to refusal or to bedrock is presented in Table 9.2.

Table 9.2– Recommended Axial Resistances of Steel Sheet Piles

Sheet Pile Section	Factored ULS Resistance per meter width (kN/m)
SKZ-22	1,250

The geotechnical reaction at SLS will not govern design of sheet piles on bedrock.

Sheet piles should be provided with sheet pile tip protector to minimize any tip damage.

Vertical design loads on the sheet pile walls were provided by Hatch, and are as follows:

- 270 kN/m (SLS)
- 195 kN/m (ULS)

Steel sheet pile installation should be in accordance with OPSS 903.



Sheet piles should be driven to bedrock or refusal to the elevations noted in Table 9.1. An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

9.2.3.1 Sheet Pile Lateral Resistance

Design for lateral resistance of the sheet piles may be carried out using the earth pressure coefficients (K_a = active, K_o = at rest, K_p = passive) and soil unit weights provided in Table 9.3 below and Table 10.1 in Section 10.

The interaction between the sheet pile wall and the adjacent soil may be analysed using a soil-spring model and a coefficient of horizontal subgrade reaction, k_s . For cohesive soils, the value of k_s may be assumed to be constant with depth. In cohesionless soils, the horizontal subgrade reaction per linear meter varies with depth and can be calculated as follows:

$$k_s = n_h z \quad (\text{kN/m}^3)$$

where z = depth of embedment of pile in metres

n_h = coefficient related to soil density, see table below (kN/m^3)

For soil-spring analysis, the spring constant, K_s , may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3) and L is the length (m) of the pile segment or element used in the analysis.

Table 9.3 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m^3)	n_h (kN/m^3)	K_a	K_o	K_p	S_u (kPa)
	Top	Bottom						
Sand Fill	425.1	422.7	21	1,500*	0.33	0.50	1.3*	-
Peat	422.7	422.1	2	500	0.41	0.58	2.4	-
Silt/Sandy Silt	422.1	416.0	9	1,200	0.35	0.52	2.9	-

Note: * Top of fill at the existing culvert; top of sheet pile may vary. K_p accounts for 2H:1V fill slope.

** Sheet pile tip elevations may vary at sheet pile locations.



9.2.3.2 Construction Considerations for Sheet Piles

In general, backfill to the sheet pile walls should be in accordance with OPSS 902 and should consist of Granular A, Granular B Type II or Granular B Type III material. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

Even though cobbles and boulders were not encountered within the embankment fill at the borehole locations, they may be encountered during driving the sheet piles through other areas of the existing embankment fill. Any rock fill/erosion protection materials if present at the culvert site, as well as any visible obstructions along the sides of the culvert should be removed prior to driving the sheet piles.

The sheet pile alignment should be strategically located to avoid encountering the existing culvert.

Use of tip protection is recommended for the sheet piles at this site.

In light of the very loose to compact silt/sandy silt, vibratory methods should not be used at this site to install the sheet piles.

Design of the permanent sheet pile culvert should consider environmental factors such as road salts, presence of organic deposits or fluctuating creek water level that may cause corrosion and reduce the service life of the structure.

The native soils in front of the sheet piles must be protected from scour and erosion so that the sheet piles do not lose lateral support.

Consideration should be given to placement of biaxial geogrid above the sheet pile structure to mitigate potential settlement that may develop in the approach fills. The biaxial geogrid should extend a minimum of 10.0 m beyond the sheet pile abutment and should be placed longitudinally as a single uninterrupted run of geogrid with no transverse joints/overlaps.

9.2.3.3 Downdrag

Downdrag on the sheet piles is not considered to be an issue at this site, since no highway grade raise is proposed.

9.2.4 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 somewhat more tolerant to limited differential settlement.

The borehole information indicates that the founding soils at the inlet and outlet generally consist of loose to compact silt.

9.2.4.1 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.

Any peat, loose, soft, organic or deleterious soils encountered along the alignment of the RSS wall, must be removed down to native silt. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native silt layer at or below approximate Elevation 422.5 or lower. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement). The engineered fill pad placed under the RSS mass must consist of 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.

Peat, topsoil, 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 scour and 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 RSS walls 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.

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

9.2.4.2 Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on compact sand/sand and gravel subgrade. All topsoil, organics or soft soils encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.5 m at this site) and founded at Elevations



421.0 or lower. A factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for 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 sand, and sand and gravel should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35.

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

Grade raise or embankment widening are not anticipated at this site, therefore, settlement of the underlying soils is not expected.

It must be noted that any additional load imposed on the new culvert, including fill placed adjacent to the extended culvert barrels and embankment widening, will induce immediate settlement of the cohesionless foundation soils at this site.

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.6 m, as per OPSD 3090.100. The base of any retaining wall footings, if employed, should be provided with a minimum of 2.6 m of earth cover as protection against frost action. The pipe and box culvert foundations do not require frost cover/protection.

The frost taper investigation indicated the presence of 1.5 m to 2.4 m of sand fill and sand and gravel fill overlying native silt and sandy silt to approximately 20 m north and south of the centreline of the existing culvert. A layer of peat was contacted at the base of the fill in three boreholes, the thickness of the peat ranged from 0.6 m to 1.2 m. The majority of the granular fill is not frost susceptible. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment fill and base material.



The peat underlying the fill is frost susceptible; as recommended earlier, the peat should be excavated if encountered within the culvert excavation. The silt and sandy silt soils underlying the fill are moderate to high frost susceptible. As the frost penetration line is below the top of culvert, frost treatment/taper for the culvert would normally be provided as per OPSD 803.031. It is understood that for this site the limits of the frost taper governed by the criteria of $20(k - d)$, where k is the depth of frost treatment and d is the depth of roadbed granular.

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)
	γ	=	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.

11. CULVERT CONSTRUCTION CONSIDERATIONS

It is understood that construction staging will be required to maintain one lane of traffic.

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, an effective dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert and headwall subgrade preparation and foundation preparation must be carried out in the dry.

11.1 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. Approximately 0.6 to 1.2 m of peat was encountered in the boreholes drilled at this site. The elevation of the top of the peat layer ranges from Elevations 423.6 to 422.7. The base elevation of the peat deposit ranges from 422.1 to 422.8. It should be noted that if the new culvert is longer than the existing culvert and extends beyond the existing inlet and outlet, peat may be encountered in this extension area which must be removed.

After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, peat, topsoil, loose river bed deposits, disturbed soils and any deleterious materials within the replacement culvert and headwall footprint at the subgrade level must be removed and replaced with well compacted granular materials.



In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction and all subgrade preparation and placement and compaction of granular material must be carried out in the dry.

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

11.2 Culvert Bedding and Backfill

A minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the CSP or box culvert and compacted in accordance with OPSS 501 in the dry. The culvert subgrade preparation, placement and compaction of granular bedding should be carried out in the dry. However, if the dewatering efforts are not fully effective and if the culvert is to be constructed in the remaining wet condition, coarse 53 mm clear stone wrapped in geotextile should be used as backfill in the wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may then be placed and compacted in the dry. The clear stone backfill may be fully enclosed in geotextile. Geotextile should be placed between the founding soils and the granular layer of bedding material for separation purpose.

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 802.014, and as per the requirements of the CHBDC.

Backfilling for the culvert should be in accordance with OPSS 501, OPSS 902, and as per the CHBDC requirements. 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.

11.3 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 sandy silt and silt at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits, and peat 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, peat and native silt layers.

Excavation for culvert replacement will be carried out below the creek water level indicated at Elevation 423.5 in the GA drawing. In order to construct a pipe or a box culvert in the dry, diversion of the lake/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. A combination of cofferdam enclosures and creek/water course diversion along with the use of sumps/pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. The use of interlocking and watertight, steel sheet pile cofferdam is a feasible option for this site. 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 silts.

Installation of a temporary cofferdam is planned at the inlet and outlet of the culvert. Boreholes were not drilled at the proposed cofferdam location, and the closest boreholes to the cofferdam locations are Boreholes CO17-01 and CO17-03. Record of Boreholes Sheets of these boreholes are included in Appendix B.

Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517, SP 517F01 Amendment to OPSS 517, November 216 (issued July 2017), and OPSS. PROV 902.

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.



12. STREAM DIVERSION PIPE

A stream diversion pipe consisting of a CSP may be used to facilitate construction of the CSP culvert or concrete box culvert replacement options, as indicated on a Preliminary General Arrangement drawing provided by Hatch. The diversion pipe is shown to be located approximately 10.0 m to the west of the centreline of the existing culvert with the invert at approximate Elevation 422.6 as per GA drawing. Based on information from Borehole CO17-05, peat was encountered at the proposed founding level of the diversion pipe.

The peat soils should be sub-excavated where encountered, and the pipe should be founded on the native silt below the peat. The pipe 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, 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.

13. 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 or a soldier pile and lagging wall could be considered at this site. The soil parameters in Table 13.1 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 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silt/Silty Sand
Angle of Internal Friction (ϕ)	30°	29°
Bulk Unit Weight (γ)	20 kN/m ³	20 kN/m ³
Submerged Unit Weight (γ_w)	10 kN/m ³	10 kN/m ³
Coefficient of Active Earth Pressure (K_a)	0.33	0.35
Coefficient of Passive Earth Pressure (K_p)	3.0	2.9

Given the presence of the sensitive sand/silt deposits vibratory methods must not be used at this site to install or extract the sheet piles and H-piles (if used). A NSSP to this effect is provided in Appendix F.

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.

14. EMBANKMENT WIDENING AND RESTORATION

Provided that the embankment is reconstructed with side slopes inclined at not steeper than 2H:1V, the restored embankment slopes should remain stable.

It is anticipated that there will be no grade raise or embankment widening at this site for the culvert replacement.

Grade raise is not anticipated at this site; therefore, settlement of the underlying soils is not expected. However, if embankment widening is proposed, the settlement under the widening must be assessed.



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. Where new embankment fill is placed against existing embankment slopes or on sloping ground surface steeper than 3H : 1V, the existing fill slope must be benched in accordance with OPSD 208.010.

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

15. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site includes compact granular fill underlain by a layer of peat underlain by loose to compact silt and sandy silt. 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 0.054 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 15.1 may be used:

Table 15.1 – 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})*	0.29	0.33	0.36
At Rest (K_{OE})**	0.50	0.54	0.57

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

** After Woods

The site is underlain by layers of loose to compact silt and sandy silt. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.



Localized liquefaction during a seismic event may result in local toe failure or minor embankment settlement, but this is expected to be readily repairable.

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 OPSD 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.

RSS walls and concrete headwalls and concrete headwalls must be protected for scour and erosion.

A concrete cut-off wall or 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 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 selection of class of concrete should consider the effects of the road de-icing salts.
- The potential for soil or surface water corrosion on metal is considered to be very mild to mild.
- Appropriate protection measures commensurate with the above are recommended if metal structural elements are used. The protection measures should consider the effects of road de-icing salts.



18. CONSTRUCTION CONCERNS

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

- Peat excavation will be required within the culvert footprint. The Contractor should be prepared to have appropriate equipment for peat removal.
- An effective 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.
- 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 (e.g., 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. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng., and Mr. Jason Lee, 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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Client: Hatch Corporation

File No.: 17077

E file: H:\17000-17999\17077 MTO Detail Design of Six Structures on Hwy 599 6016-E-0030\Reports & Memos\Cobb Bay Culvert\FINAL\Hwy 599 Cobb Creek- FIDR Final.docx

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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 ⁽¹⁾ '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

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


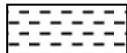



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (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			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No CO17-01

1 OF 1

METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 543 003.8 E 233 456.8 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.09 - 2017.07.09 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
423.7	GROUND SURFACE														
0.0	Sandy SILT , with organics, rootlets Very Loose to Loose Dark Brown Moist		1	SS	2		423								
422.5			2	SS	6										
1.2	SILT , trace to some sand, trace clay Dense to Loose Grey Wet		3	SS	46		422								
			4	SS	12									0 4 87 9	
			5	SS	8		421								
420.1								420							
3.6	Sandy SILT , trace clay Loose Grey Wet		6	SS	8									0 21 73 6	
							419								
			7	SS	9		418								
							417								
416.0															
7.7	END OF BOREHOLE AT 7.7m UPON AUGER REFUSAL WATER LEVEL AT 0.5m FROM SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

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RECORD OF BOREHOLE No CO17-02

1 OF 2

METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 993.7 E 233 460.3 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.20 - 2017.07.20 CHECKED BY RPR

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	20 40 60			
425.1	GROUND SURFACE												
0.8	ASPHALT: (25mm)		1	GS			425						
424.5	SAND and GRAVEL , trace silt Brown Moist (FILL)												
0.6	SAND , some gravel Compact to Loose Brown Moist (FILL)		2	SS	13		424						
			3	SS	7		423						
422.7	PEAT , trace sand, fibrous Very Loose Dark Brown Wet		4	SS	1		422						
422.1	SILT , trace to some clay Compact to Very Loose Grey Wet		5	SS	12		421						
3.0	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 420.5m to 418.0m		6	SS	1		420						
			7	SS	1		419						
							418						
417.2	BEDROCK BASALT , highly weathered, grey to white bands, occasional mechanical breaks		8	SS	30/ 0.050		417						
7.9			1	RUN			416						
			2	RUN									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CO17-02 2 OF 2 METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 993.7 E 233 460.3 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.20 - 2017.07.20 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page							20	40	60	80	100					
413.8	BEDROCK BASALT, slightly weathered, grey to white bands, occasional mechanical breaks		3	RUN			415									1	RUN #3 TCR=100% SCR=98% RQD=88% UCS=150MPa (Average)
							414									0	
11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 1.9m BELOW SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 6.1m, GRAVEL TO 0.4m, CONCRETE TO 0.05m THEN ASPHALT TO SURFACE.																

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RECORD OF BOREHOLE No CO17-03

1 OF 2

METRIC



GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 976.8 E 233 457.2 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Tripod/ Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.09 - 2017.07.09 CHECKED BY RPR

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _P	W	W _L					
423.5	GROUND SURFACE																			
0.0	Sandy SILT , with organics, occasional rootlets, occasional wood fragments		1	SS	8		423													
422.9	Compact Dark Brown		2	SS	35		422													
0.6	SILT , trace to some clay, occasional sand seams		3	SS	35		421													
			4	SS	33		420													
			5	SS	19		419													
418.9							418													
4.6	Sandy SILT , trace clay and gravel		6	SS	6		417													
	Loose to Compact						416													
	Grey		7	SS	21		415													
	Wet						414													
			8	SS	16															
							</													

Continued Next Page

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

METRIC

ELEV. DEPTH	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
	Continued From Previous Page						SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60		kN/m ³	GR SA SI CL	

[illegible]

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+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No CO17-04

1 OF 1

METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 975.5 E 233 436.1 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.19 - 2017.07.19 CHECKED BY RPR

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL
425.1	GROUND SURFACE																		
0.0 424.8	ASPHALT: (25mm)		1	GS			425							○					
0.3	SAND and GRAVEL , trace silt (FILL)																		
	SAND , trace to some gravel, trace silt Brown Moist (FILL)		2	GS			424							○					
423.6																			
1.5	PEAT , fibrous, organics, some wood pieces Dark Brown Wet		3	GS			423										○		
422.8																			
2.3	SILT , trace clay, Compact Grey Wet		4	GS										○					
																			
							422												
			4	SS	11									○				0 0 91 9	
421.4																			
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS AND COLD MIX ASPHALT TO SURFACE.																		

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METRIC

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE "N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	w _p w w _L	WATER CONTENT (%)			
425.1	GROUND SURFACE											
0.8	ASPHALT: (25mm)											
	SAND and GRAVEL, trace silt Brown Moist (FILL)		1	GS								
423.9												
1.2	SAND, trace to some silt Compact Grey Moist (FILL)		2	SS	16							
423.3												
1.8	PEAT, organics, occasional roots and rootlets, fibrous Very Loose Dark Brown Wet		3	SS	2							
			4	SS	4							
422.1												
3.0	SAND and SILT, trace clay Loose Grey Wet		5	SS	8							
421.1												
4.0	SILT, trace sand, trace clay, Very Loose Grey Wet											
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 420.5m to 417.0m		6	SS	3							
			7	SS	1							
			8	SS	1							
416.6												
8.5	BEDROCK BASALT, slightly weathered, grey to black with white bands, cemented joints		1	RUN								

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No CO17-05

2 OF 2


METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 979.3 E 233 444.1 ORIGINATED BY STH
HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2017.07.19 - 2017.07.19 CHECKED BY RPR

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
	Continued From Previous Page							20 40 60 80 100								
								○ UNCONFINED + FIELD VANE								
								● QUICK TRIAXIAL × LAB VANE								

RECORD OF BOREHOLE No CO17-07A 1 OF 1 METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 997.2 E 233 467.5 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.20 - 2017.07.20 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	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						PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L				
425.1	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (25mm) SAND and GRAVEL, trace silt, trace clay Brown Moist (FILL)		1	GS			425											
			2	GS			424											57 37 6 (SI+CL)
423.9																		
1.2	END OF BOREHOLE AT 1.2m UPON AUGER REFUSAL, BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS AND GRAVEL TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																	

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RECORD OF BOREHOLE No CO17-07B 1 OF 1 METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 542 998.0 E 233 468.3 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.20 - 2017.07.20 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
425.1	GROUND SURFACE																
0.0	ASPHALT: (25mm)																
	SAND and GRAVEL, trace silt, trace clay, occasional cobbles Brown Moist (FILL)																
423.6			1	SS	50/												
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL, BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS AND GRAVEL TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.				0.0												

RECORD OF BOREHOLE No CO17-08 1 OF 1 METRIC

GWP# 6839-14-00 LOCATION Cobb Bay Creek Culvert, MTM NAD 83 Zone 15 N 5 543 001.9 E 233 474.9 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.20 - 2017.07.20 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
425.1	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (25mm)		1	GS			425													
	SAND and GRAVEL , trace silt, occasional cobbles Compact Brown Moist (FILL)						424													
423.6			2	SS	24															
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL, BOREHOLE OPEN AND DRY UPON COMPLETION.. BOREHOLE BACKFILLED WITH AUGER CUTTINGS AND GRAVEL TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																			



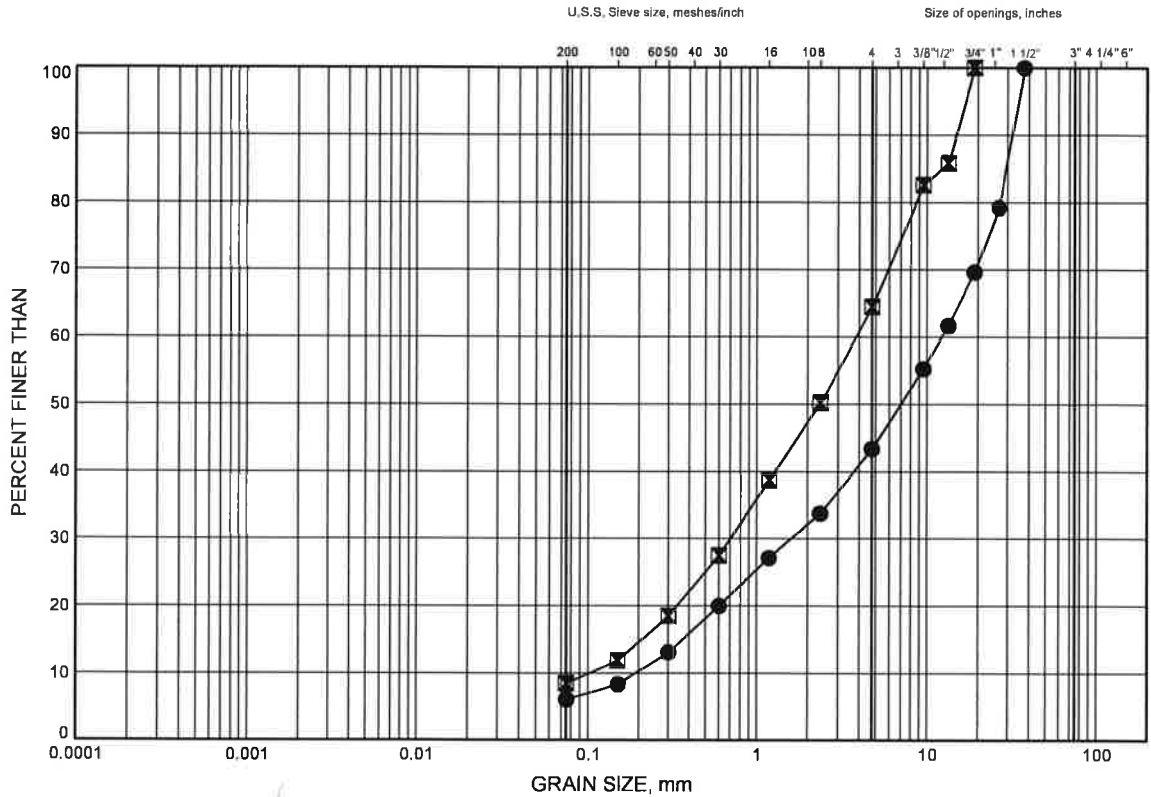
Appendix B

Geotechnical and Analytical Laboratory Test Results And Rock Core Photos

Cobb Bay Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND and GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CO17-07A	0.9	424.2
⊠	CO17-08	0.3	424.8

Date October 2017

GWP# 6839-14-00

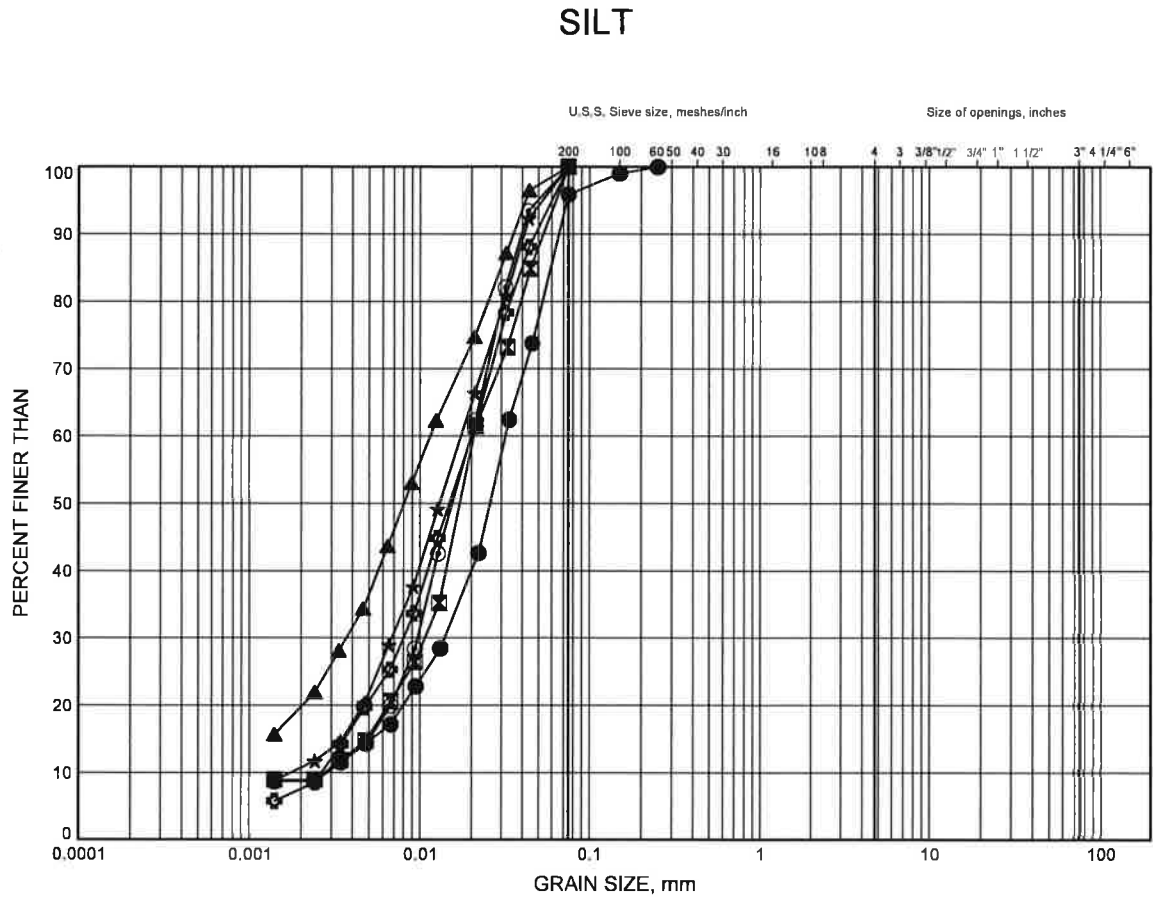


Prep'd AN

Chkd. RPR

Cobb Bay 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)
●	CO17-01	2.1	421.6
⊠	CO17-02	3.4	421.7
▲	CO17-02	6.4	418.7
★	CO17-03	1.5	422.0
⊙	CO17-04	3.4	421.7
⊕	CO17-05	7.9	417.2

Date October 2017

GWP# 6839-14-00



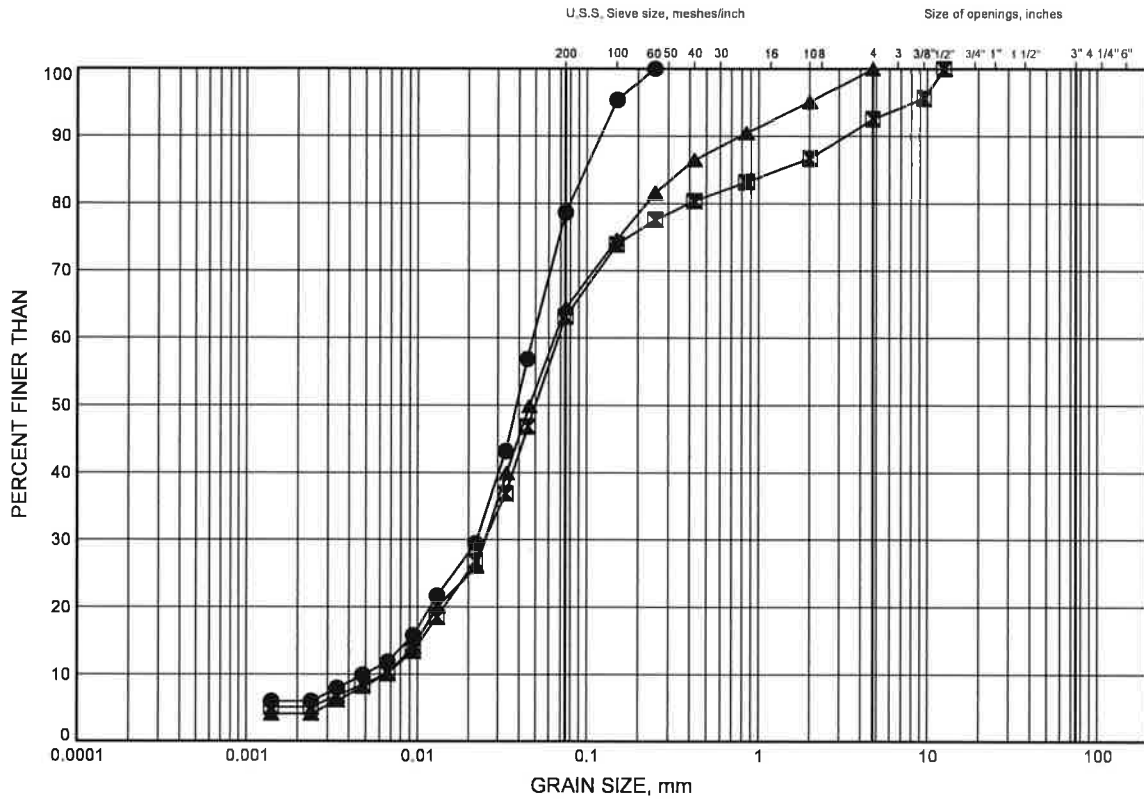
Prep'd AN

Chkd. RPR

Cobb Bay Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CO17-01	4.0	419.7
⊠	CO17-03	7.9	415.6
▲	CO17-05	3.4	421.7

Date October 2017

GWP# 6839-14-00



Prep'd AN

Chkd. RPR



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
 Client: HATCH
 Project Name: Cobb Bay Creek
 Core Size: NQ BH No : CO17-05

Date Drilled: 19-Jul-17
 Date Tested: 23-Aug-17
 Tester: ISP
 Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	8.8	A	18.3	47.0	56.3	5.5	131.9	Basalt	Very Strong
2	1	9.0	D	22.1	47.0	154.7	9.2	221.0	Basalt	Very Strong
3	1	9.1	A	6.0	47.0	55.2	1.8	43.7	Basalt	Medium Strong
4	1	9.4	D	15.5	47.0	154.7	6.5	155.7	Basalt	Very Strong
5	1	9.6	A	14.3	47.0	53.7	4.5	106.8	Basalt	Very Strong
6	1	9.9	D	16.6	47.0	154.7	6.9	165.9	Basalt	Very Strong
7	2	10.2	A	10.4	47.0	55.3	3.2	76.3	Basalt	Strong
8	2	10.6	D	14.2	47.0	154.7	5.9	142.4	Basalt	Very Strong
9	2	10.9	A	10.6	47.0	55.5	3.2	77.7	Basalt	Strong
10	2	11.3	D	31.0	47.0	154.7	12.9	310.5	Basalt	Extremely Strong
11	2	11.6	A	14.8	47.0	56.0	4.5	107.6	Basalt	Very Strong
12										
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35										

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
- Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
 Client: HATCH
 Project Name: Cobb Bay Creek
 Core Size: NQ BH No : CO17-02

Date Drilled: 20-Jul-17
 Date Tested: 23-Aug-17
 Tester: ISP
 Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	8.1	D	12.5	47.0	154.7	5.2	125.6	Basalt	Very Strong
2	1	8.4	A	39.5	47.0	54.2	12.2	293.5	Basalt	Extremely Strong
3	1	8.6	D	15.4	47.0	154.7	6.4	154.7	Basalt	Very Strong
4	2	9.0	A	41.0	47.0	56.0	12.4	297.6	Basalt	Extremely Strong
5	2	9.1	D	24.4	47.0	154.7	10.2	244.8	Basalt	Very Strong
6	2	9.4	A	37.5	47.0	51.8	12.0	289.2	Basalt	Extremely Strong
7	2	9.5	D	17.5	47.0	154.7	7.3	175.3	Basalt	Very Strong
8	2	10.1	A	10.5	47.0	56.2	3.2	76.1	Basalt	Strong
9	2	10.4	D	22.8	47.0	154.7	9.5	228.2	Basalt	Very Strong
10	3	10.7	A	33.6	47.0	54.1	10.4	250.3	Basalt	Extremely Strong
11	3	10.9	D	19.8	47.0	154.7	8.3	198.5	Basalt	Very Strong
12	3	11.2	A	3.6	47.0	54.1	1.1	27.0	Basalt	Medium Strong
13										
14										
15										
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34										
35										

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
- Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.



0 m

50 m

100 m

150 m

Core Photo 1: Borehole CO17-02 Run 1 to Run 3 (7.9 m to 11.3 m)



0 m

50 m

100 m

150 m

Core Photo 2: Borehole CO17-05 Run 1 to Run 2 (8.5 m to 11.7 m)



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077
Thurber Engineering Ltd.
CA15302-AUG17
Corrosivity (Soil)

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada,
K0L 2H0

Sample ID	Unit	PR17-02 SS7	KE 17-03 SS5	ME 17-03 SS3	TU 17-02 SPT5	CO 17-03 SS4	AG 147-02 SS4
Sample Date/Time		30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17
Moisture	%	15.6	7.0	7.7	22.2	15.6	21.0
pH	no unit	8.25	6.40	8.27	8.14	8.65	8.33
Corrosivity Index	none	4.5	1.0	1.0	1.0	4.0	1.0
Soil Redox Potential	mV	325	338	303	301	295	290
Sulphide	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Chloride	mg/L	6.9	240	2.4	25	1.2	150
Sulphate	mg/L	26	10	10	1.2	46	6.1
Conductivity	uS/cm	49	269	35	81	83	213
Resistivity (calculated)	ohms.cm	20300	3720	28700	12400	12000	4690

Corrosivity Scale according to AWWA C-105.

An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077 Hwy 599
Thurber Engineering Ltd.
CA15314-JUN17
Corrosivity (Solution)

Sample ID	Unit	RL	Tug Creek	Pratt Creek	Mile Creek	Cobb Bay	Kekwanzik Lake	Agimak River
			10-Jun-17 12:10	10-Jun-17 12:30	10-Jun-17 10:40	10-Jun-17 11:20	10-Jun-17 12:45	10-Jun-17 13:10
Sample Date/Time								
Temperature Upon Receipt	°C		10.0	10.0	10.0	10.0	10.0	10.0
Soil Redox Potential	mV		334	272	352	301	312	345
Sulphide	mg/L	0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
pH	no unit	0.05	7.78	7.81	7.62	7.70	7.38	7.26
Chloride	mg/L	0.04	2.1	2.9	2.7	1.7	8.8	7.8
Sulphate	mg/L	0.04	0.3	1.2	0.8	0.6	2.0	1.9
Conductivity	µS/cm	2	100	78	63	78	67	56
Resistivity (calculated)	ohms.cm		9990	12700	15800	12800	15000	17700

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

Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

Data reported represents the sample submitted to SGS. Reproduction of this analytical report in full or in part is prohibited without prior written approval. Please refer to SGS General Conditions of Services located at http://www.sgs.com/terms_and_conditions_service.htm. (Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.



Appendix C

Selected Site Photographs



Photo 1: South side of Highway 599 at Cobb Bay Creek Culvert looking west



Photo 2: North side of Highway 599 at Cobb Bay Creek Culvert looking west



Photo 3: Highway 599 at Cobb Bay Creek Culvert looking east



Photo 4: Cobb Bay Creek Culvert outlet



Photo 5: Cobb Bay Creek Culvert inlet



Appendix D

Borehole Locations and Soil Strata Drawings

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

CONT No 2018-6002
WP No 6840-14-01

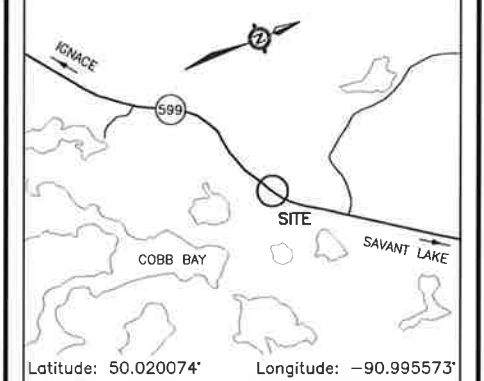
HIGHWAY 599
COBB BAY CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
24

HATCH








THURBER ENGINEERING LTD.

DISTRICT OF KENORA
UNSURVEYED TERRITORY

KEYPLAN

LEGEND

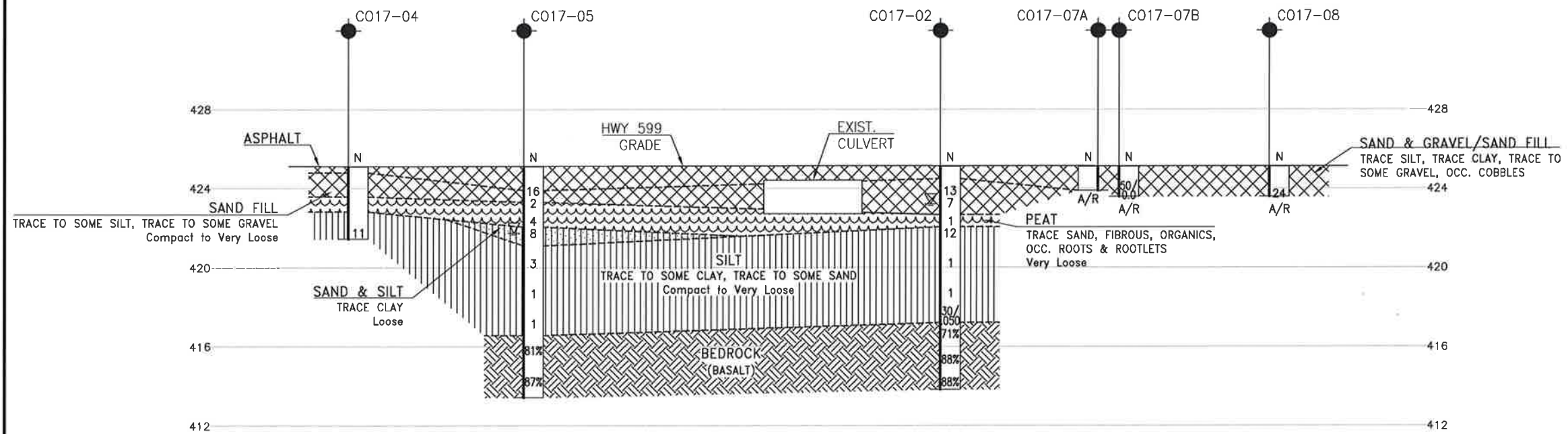
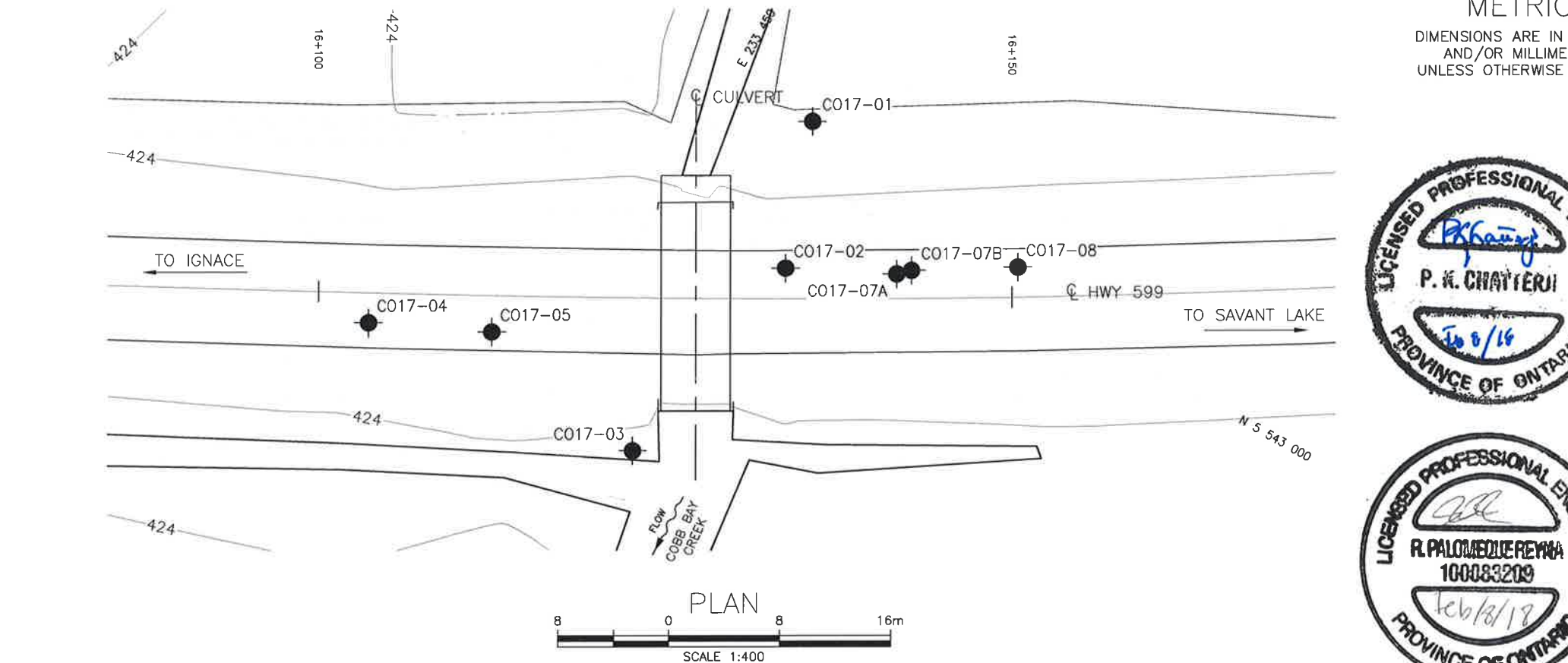
	Borehole
	Cone and Borehole
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger/Casing/DCPT Refusal

NO	ELEVATION	NORTHING	EASTING
C017-01	423.7	5 543 003.8	233 456.8
C017-02	425.1	5 542 993.7	233 460.3
C017-03	423.5	5 542 976.8	233 457.2
C017-04	425.1	5 542 975.5	233 436.1
C017-05	425.1	5 542 979.3	233 444.1
C017-07A	425.1	5 542 997.2	233 467.5
C017-07B	425.1	5 542 998.0	233 468.3
C017-08	425.1	5 543 001.9	233 474.9

-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.

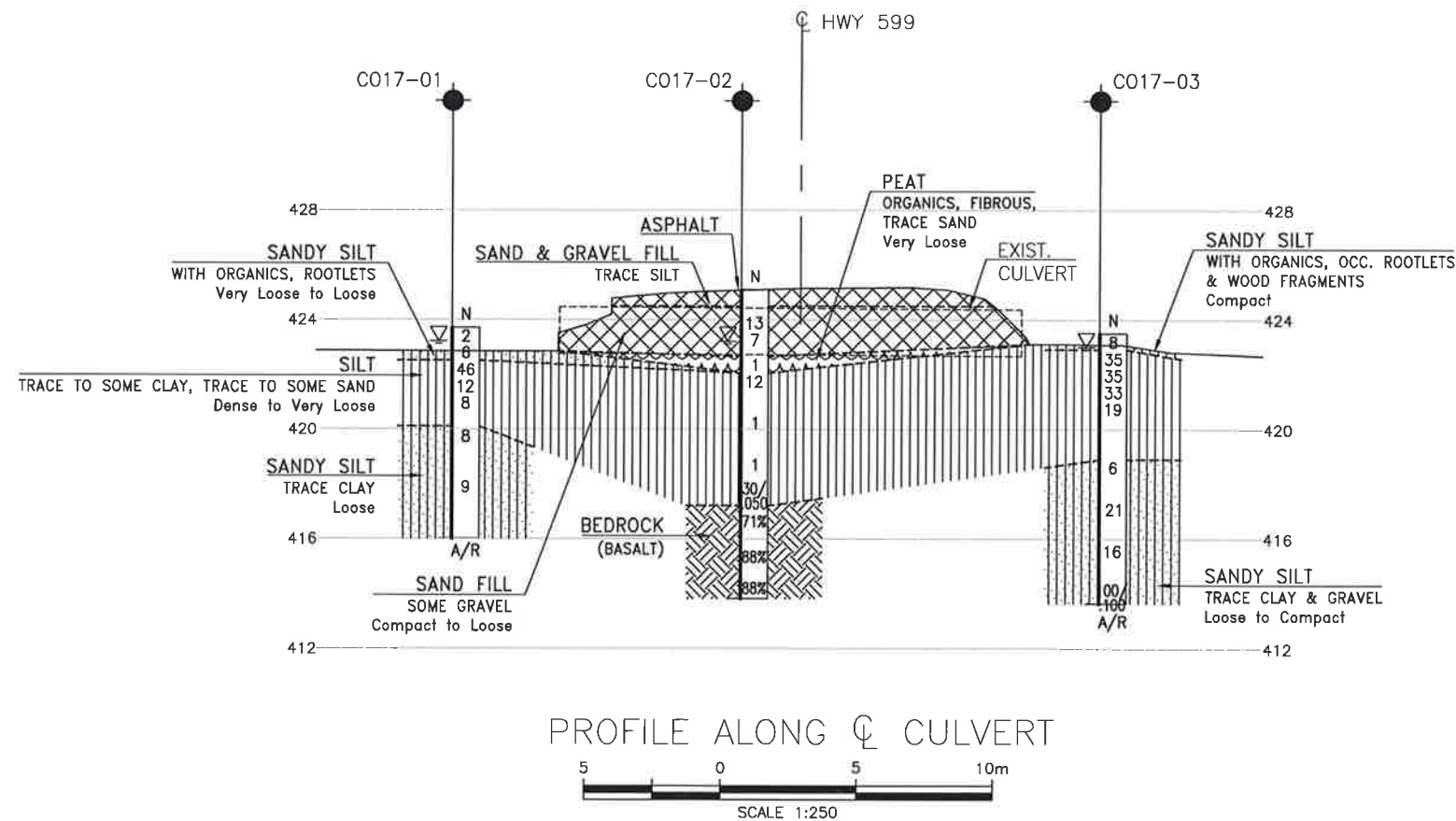
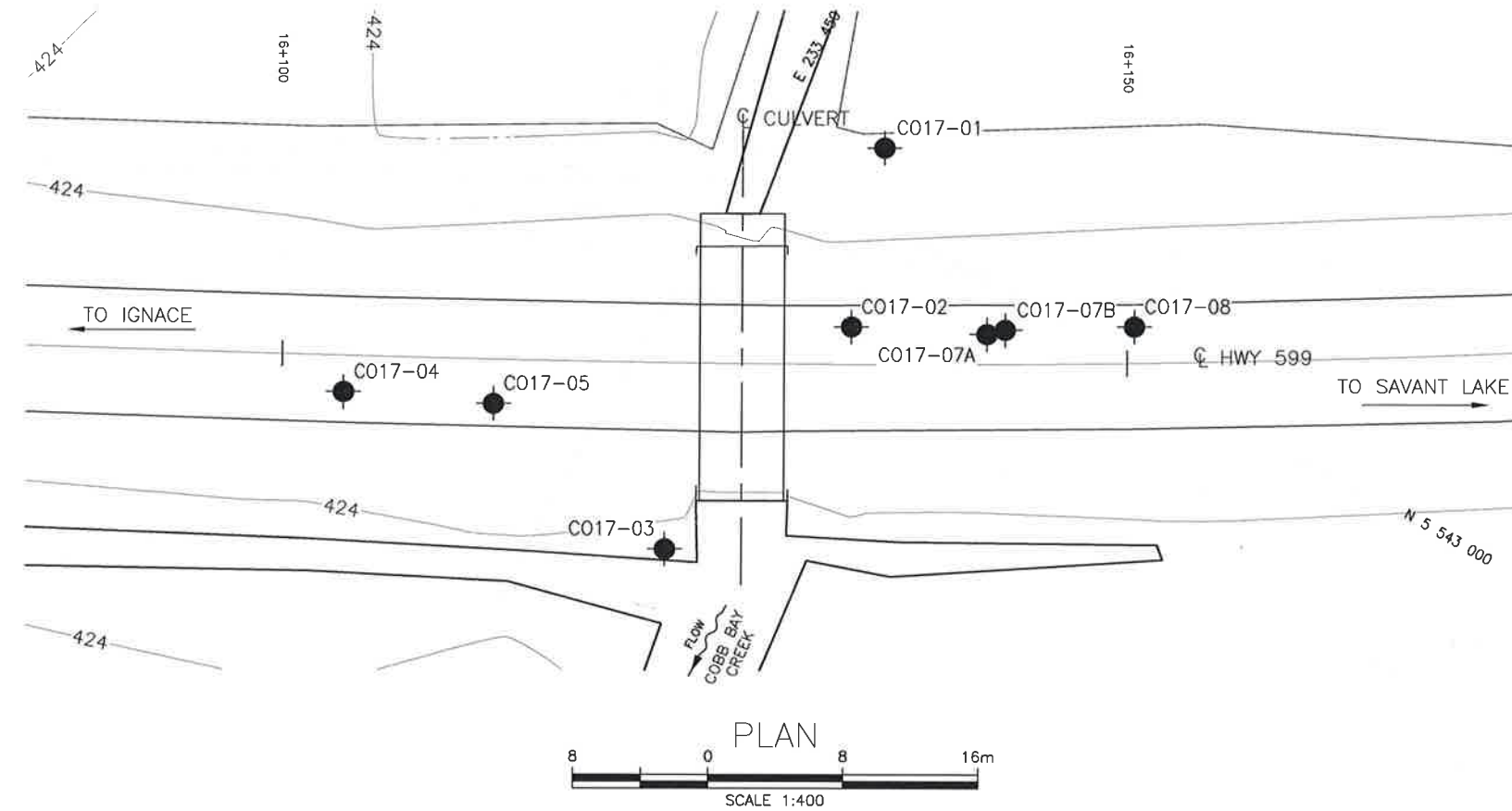
GEOCREs No. 52J-17



PROFILE ALONG \odot HWY 599

[illegible]

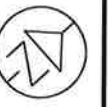
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METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No 2018-6002
WP No 6840-14-01

HIGHWAY 599
COBB BAY CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

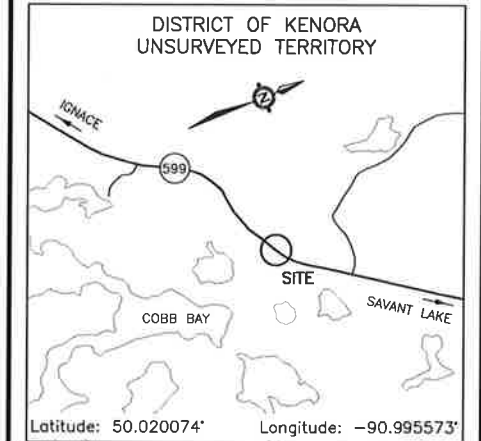


SHEET
25

HATCH



THURBER ENGINEERING LTD.



Latitude: 50.020074° Longitude: -90.995573°

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		
W	Water Level		
↑	Head Artesian Water		
—	Piezometer		
90%	Rock Quality Designation (RQD)		
A/R	Auger/Casing/DCPT Refusal		

NO	ELEVATION	NORTHING	EASTING
C017-01	423.7	5 543 003.8	233 456.8
C017-02	425.1	5 542 993.7	233 460.3
C017-03	423.5	5 542 976.8	233 457.2
C017-04	425.1	5 542 975.5	233 436.1
C017-05	425.1	5 542 979.3	233 444.1
C017-07A	425.1	5 542 997.2	233 467.5
C017-07B	425.1	5 542 998.0	233 468.3
C017-08	425.1	5 543 001.9	233 474.9

- 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.
 - Coordinate system is MTM NAD 83 Zone 15.

GEOCREs No. 52J-17



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK JPL	CODE
DRAWN	AN	CHK RPR	SITE 48W-190C/STRUCT
			LOAD
			DATE
			JAN 2018
			DWG 3



Appendix E

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert	Driven Sheet Piles Driven to Refusal or to Bedrock
<u>Advantages:</u> i. Ease of construction. ii. CSP's can accommodate small differential settlement along culvert axis iii. Steel pipes are likely to be more cost effective than concrete box or open footing culverts.	<u>Advantages:</u> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Segmental option can accommodate limited amount of potential differential settlement along culvert axis. iii. Less requirement for soil geotechnical resistances as loading is spread over a larger width. iv. Can accommodate differential settlement.	<u>Advantages:</u> i. Conventional construction. ii. Generally less costly than deep foundation elements. iii. Eliminates bedding requirement. iv. May have less environmental issues such as those involving spawning fish species.	<u>Advantages:</u> i. Minimizes potential for disturbance of streambed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of sheet piles could continue in freezing weather. v. Potentially minimizes volume of excavation.
<u>Disadvantages:</u> i. Multiple pipes may be needed to meet hydraulic requirements. ii. CSP cannot be rehabilitated as concrete culverts. iii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iv. Dewatering is required. v. Requires subexcavation of soft or organic material from streambed if encountered.	<u>Disadvantages:</u> i. More expensive than a CSP culvert and sheet pile system. ii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iii. Dewatering is required. iv. Requires subexcavation of soft or organic material from streambed if encountered. v. Requires complete excavation of river bed.	<u>Disadvantages:</u> i. Low available geotechnical resistance in native soils. ii. Requires deeper excavation below the groundwater level. Excavation to base of existing roadway embankment is required for footing construction. iii. High groundwater levels Dewatering will be required. Potential longer dewatering requirements. iv. Potential disturbance of river during excavation. v. Cannot tolerate differential settlement. vi. Shallow foundations close to water would be at risk due to scour, erosion and undermining problems.	<u>Disadvantages:</u> i. Less conventional construction.
RECOMMENDED	RECOMMENDED	NOT RECOMMENDED	FEASIBLE



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 501 | Construction specification for compacting |
| - OPSS.PROV 511 | Construction specification for rip-rap, rock protection, and granular sheeting |
| - OPSS.PROV 517 | Construction specification for dewatering |
| - SP 517F01 | Amendment to OPSS 517 |
| - OPSS PROV 539 | Construction specification for temporary protection systems |
| - OPSS PROV 804 | Construction specification for seed and cover |
| - OPSS PROV 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 |
| - OPSD 802.014 | Flexible pipe embedment in embankment. original ground: earth or rock |
| - 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 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 roadway protection (sheet piles) 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.

4. NSSP On Use of Vibratory Equipment

The use of vibratory equipment for the installation and removal of temporary or permanent sheet piles and/or H-piles is prohibited at this site.