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FOUNDATION INVESTIGATION AND DESIGN REPORT
SITCH CREEK CULVERT REPLACEMENT
TOWNSHIP OF GILLIES, DISTRICT OF THUNDER BAY, ONTARIO
SITE No. 48W-82/C
HIGHWAY 588

ASSIGNMENT NO. 6015-E-0023

GEOCRES Number: 52A-226
W.O.# 2017-11029

Report

to

MINISTRY OF TRANSPORTATION ONTARIO

Lat: 48.294493

Long. -89.703651

Date: August 2, 2017
File: 17840

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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 Sitch Creek Culvert on Highway 588, located in the Township of Gillies, District of Thunder Bay, Ontario.

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

Thurber was retained by the Ministry of Transportation Ontario (MTO) to carry out this foundation investigation under the MTO Retainer Assignment Number 6015-E-0023.

2. SITE DESCRIPTION

The Sitch Creek Culvert site is located on Highway 588, in the Township of Gillies approximately 300 m west of Highway 595, in the District of Thunder Bay, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and Soil Strata drawing in Appendix D.

Highway 588 runs in the general east-west direction, in the vicinity of the culvert. The Sitch Creek is a tributary of the Kaministiquia River and the creek flows from south to north at the culvert site. Local topography is generally of low relief.

The terrain in the culvert area is gently undulating and forested outside of the right-of-way. The existing culvert is a single 4.4 m diameter Corrugated Steel Pipe (CSP) culvert approximately 43 m long. The Structural Inspection Report (SIR) dated January 2014 indicated that the structure is in fair condition apart from deterioration of cut-off wall due to erosion at the outlet of the culvert.

The MTO Site Plan Drawing, E-1078-595-3, indicates that the existing culvert invert is at approximate Elevation 268.2 m at the inlet and Elevation 268.0 m at the outlet. The stream water level was reported to be at about Elevation 268.4 m at the upstream end and about Elevation 267.4 m at the downstream end in June 2014. At the culvert location, the highway embankment grade is at approximately Elevation 278.0 m. The depth of cover over the existing culvert is approximately 5.5 m.

Photographs in Appendix C show the general nature of the site and the existing culvert.

Based on published geological information, the culvert lies within glaciolucstrine plains of clay and clayey deposits underlain by silts and sands in the vicinity of the culvert. Bedrock at the site is identified as granite.

3. INVESTIGATION PROCEDURES

The field investigation and testing program for this project was specified in the Terms of Reference. The field work was carried out on April 8, 9, 29, May 3 and July 5, 2017 during which time seven (7) boreholes designated as Boreholes 17-09 to 17-15 were advanced at the site. Boreholes 17-09 and 17-12 to 17-15 were advanced near the outlet and inlet of the culvert and Boreholes 17-10 and 17-11 were advanced through the highway embankment east and west of the culvert, respectively.

Utility clearances were obtained prior to the start of drilling. A rubber tire buggy mounted drill rig and a track-mounted CME 75 drill rig were used to advance Boreholes 17-09 to 17-11 at the site using hollow stem augers. Boreholes 17-12 to 17-15 were advanced using tripod drilling equipment since access to the inlet and outlet at the base of the steep embankment slope was not possible with a track mounted drilling equipment. An NQ core barrel was used to obtain about 3 m of rock core in Boreholes 17-10 and 17-11.

Since the initial Borehole 17-12 drilled near the inlet met refusal at a shallow depth (2.1 m), three additional boreholes (17-13 to 17-15) were drilled in the vicinity with a tripod equipment to determine the nature of refusal at shallow depth. All three additional boreholes also met refusal at shallow depths ranging between 0.9 m and 2.4 m.

Soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT) procedures as per ASTM

D1586. Where bedrock was cored, rock quality (i.e., TCR, SCR, RQD, weathering and strength index), discontinuity characteristics and classification data was recorded in the field based on visual inspection of the recovered rock cores upon extraction from the core barrel. The bedrock was sequentially photographed and selected samples were transported to our laboratory for strength testing (point load index).

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 and rock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes throughout the drilling operations, and boreholes were backfilled on completion of drilling in general accordance with Ontario Regulation 903, as amended.

The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided by the MTO. The coordinate system MTM NAD 83, Zone 14 was used for the boreholes. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D. The borehole coordinates, ground surface elevations, drilled depths and the completion details are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Coordinates (MTM NAD 83, Zone 14)		Ground Surface Elevation (m)	Borehole Depth (m)	Completion Details
	Northing (m)	Easting (m)			
17-09	5,350,696.3	326,810.1	272.4	9.8	Bentonite holeplug to 3.0 m, cuttings to ground surface.
17-10	5,350,677.0	326,800.7	278.2	19.5	Bentonite holeplug to 2.4 m, cuttings to 0.9 m then asphalt cold patch to ground surface.
17-11	5,350,676.0	326,790.8	277.7	19.2	Bentonite holeplug and cuttings to 0.6 m, cement to 0.1 m, then asphalt cold patch to ground surface.
17-12	5,350,651.6	326,798.9	269.6	2.1	Bentonite holeplug to ground surface.
17-13	5,350,647.3	326,797.4	268.7	0.9	Bentonite holeplug to ground surface.
17-14	5,350,647.3	326,797.1	268.7	0.9	Bentonite holeplug to ground surface.
17-15	5,350,646.3	326,798.5	268.8	2.4	Bentonite holeplug to ground surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected soil samples were also subjected to grain size distribution analyses (sieve, hydrometer, and/or Atterberg limits). Selected bedrock core specimen were also subjected to point load strength index test. The results of the laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the native soil near the invert level, 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. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the "Borehole Locations and Soil Strata" drawing included in Appendix D. 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 must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising of sand beneath the roadway and silty clay near the outlet of the culvert. The fill is overlying a deposit of native firm to stiff silty clay to clay and/or compact gravelly sand to sand which are in turn underlain by a layer of compact silt to silty sand over bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 17-10 and 17-11 were drilled through the existing asphalt pavement on Highway 588. The asphalt was 25 mm thick at both borehole locations. The thickness of asphalt may vary along the highway.

5.2 Fill

Embankment fill was encountered below the asphalt in Boreholes 17-10 and 17-11, and at the ground surface in Borehole 17-09 east of the culvert oulet. The fill in Borehole 17-09 generally consisted of silty clay, and the fill in Boreholes 17-10 and 17-11 generally consisted of sand.

5.2.1 Silty Clay Fill

The silty clay fill in Borehole 17-09 extended to a depth of approximately 4.6 m (Elevation 267.8 m). The silty clay fill typically contained some sand and trace gravel, and was brown in colour. Rock fragments were observed in one of the samples taken from the silty clay.

SPT 'N' values within the silty clay fill ranged from 4 to 18 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. The measured moisture content of the cohesive fill ranged from 26% to 38%.

The results of grain size analyses conducted on a selected sample of the silty clay fill are presented on the Record of Borehole sheets included in Appendix A, and on Figure B1 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	2
Sand	15
Silt	40
Clay	43

The results of Atterberg Limits tests conducted on a sample of the silty clay fill are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B2 in Appendix B. The results are summarized as follows:

Measured Limit	Percentage (%)
Liquid Limit	43
Plastic Limit	23

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

5.2.2 Sand Fill

Sand fill in Boreholes 17-10 and 17-11 extended to depths of approximately 8.8 m and 8.7 m (Elevations 269.3 m and 269.0 m), respectively. The sand fill generally contains trace to some gravel and fines, and is brown in colour.

SPT ‘N’ values in the sand fill ranged between 8 and 50 blows for 0.3 m penetration, indicating a loose to very dense relative density, predominantly compact. Measured moisture content of the sand fill samples ranged from 3% to 8%.

The results of grain size analyses conducted on samples of the sand fill are presented on the Record of Borehole sheets included in Appendix A, and on Figure B3 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	14 to 18
Sand	64 to 67
Silt and Clay	16 and 19

5.3 Silty Clay

A layer of silty clay was encountered in Boreholes 17-09 and 17-10 below the fill, in Borehole 17-12 at the ground surface and in Borehole 17-15 within the silty sand layer. The silty clay layer was extended to depths of 7.2 m and 12.3 m (Elevations 265.3 m and 265.9 m) in Boreholes 17-09 and 17-10 and to a depth of about 1.5 m (Elevation 268.0 m) in Borehole 17-12 and to a depth of 2.1 m (Elevation 266.6 m) in Borehole 17-15. The layer generally contained trace to some sand and was brown to grey in colour.

SPT ‘N’ values in the deposit ranged from 3 to 9 blows per 0.3 m of penetration, indicating a soft to stiff consistency. A higher SPT-N value of 60 blows per 0.13 m of penetration was recorded in Borehole 17-12 due to split spoon sampler bouncing on possible cobbles. In situ vane testing was conducted in the silty clay deposit and measured undrained shear strengths that are greater than 100 kPa indicating a very stiff consistency. Moisture contents in the silty clay layer ranged from 23% to 44%.

The results of grain size analyses conducted on two samples of the silty clay are presented on the Record of Borehole sheets included in Appendix A, and on Figure B4 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	4 and 20
Silt	45 and 58
Clay	22 and 51

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

Measured Limit	Percentage (%)
Liquid Limit	35 and 53
Plastic Limit	23 and 25

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

5.4 Gravelly Sand to Sand

A 3.0 m thick layer of gravelly sand to sand, trace gravel was encountered below the fill at a depth of about 8.7 m (Elevation 269.0 m) in Borehole 17-11 and extended to a depth of about 11.7 m (Elevation 265.9 m). A very dense silty sand layer was also encountered below the silty clay in Borehole 17-12 The silty sand was also encountered in Boreholes 17-13 to 17-15 at the ground surface. Boreholes 17-12 to 17-15 were terminated at depths ranging between 0.9 m to 2.1 m in the gravelly sand to sand. The gravelly sand to sand contained trace fines, and was brown in colour and wet.

SPT ‘N’ values in the deposit were 10 and 18 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture content in the deposit were 13% and 22%.

The results of a grain size analyses conducted on a sample of the gravelly sand is presented on the Record of Borehole sheets included in Appendix A, and on Figure B6 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	27
Sand	70
Silt and Clay	3

5.5 Silt to Silty Sand

A deposit of silt to silty sand was encountered below the silty clay and/or gravelly sand to sand in Boreholes 17-09 to 17-11 and extended to depths ranging from 9.8 m to 16.2 m (Elevations 261.5 m and 262.7 m). Borehole 17-09 was terminated in the silt layer due to auger refusal on inferred bedrock at a depth of 9.8 m.

SPT ‘N’ values in the silt to silty sand ranged from 10 to 21 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture contents in the deposit ranged from 8% to 29%.

The results of grain size analyses conducted on samples of the silt to silty sand are presented on the Record of Borehole sheets included in Appendix A, and on Figure B7 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 10
Sand	14 to 47
Silt	32 to 81
Clay	5 to 12

The results of Atterberg Limits tests conducted on the fine grained portion of a selected sample of the silty sand is provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B8 of Appendix B. The results are summarized as follows:

Measured Limit	Percentage (%)
Liquid Limit	20
Plastic Limit	14

The results of the Atterberg Limits testing indicate that the fine portion of the silty sand is clayey silt of low plasticity (CL-ML).

5.6 Cobbles/Fractured Bedrock

Cobbles/fractured bedrock was encountered below the silty sand and just above the bedrock in Boreholes 17-10 and 17-11 at depths of 15.8 m and 16.2 m (Elevations 262.3 m and 261.5 m), respectively. The cobbles/fractured bedrock layer was approximately 0.3 m to 0.6 m thick.

5.7 Bedrock

Bedrock was encountered in Boreholes 17-10 and 17-11 at depths of about 16.4 m and 16.5 m (Elevations 261.7 m and 261.2 m), respectively. Auger refusal on probable bedrock was noted in Borehole 17-09 at a depth of 9.8 m (Elevation 262.7 m). Boreholes 17-12 to 17-15 also met refusal on cobbles and boulders, or probable bedrock at depth ranging between 0.9 m and 2.1 m. (Elevations 266.3 m to 267.8 m).

The bedrock was proven in Boreholes 17-10 and 17-11 by coring approximately 3 m in both boreholes. The bedrock is generally described as grey granite, greenish grey to grey in colour with some igneous intrusions. Total Core Recovery (TCR) in the bedrock ranged from 88% to 100% with Solid Core Recovery (SCR) ranging from 78% to 94%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 77% to 88%, indicating good rock quality. The interpreted average UCS values for each core run of the bedrock ranged between 106 MPa and 297 MPa based on correlations with the PLT, indicating the bedrock at the site is very strong to extremely strong.

5.8 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 Table 5.1.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
17-09	May 3, 2017	5.0	267.4	Open borehole
17-10	April 9, 2017	Not measured		Water added to the borehole for coring
17-11	April 8, 2017	Not measured		Water added to the borehole for coring
17-12	April 29, 2017	0.0	269.6	Water at surface
17-13	July 5, 2017	0.3	268.4	Open Borehole
17-14	July 5, 2017	Not measured		-
17-15	July 5, 2017	0.2	268.6	Open Borehole

The groundwater level should be assumed to reflect the local creek water level. Water level measurements in the creek were reported on the MTO Site Plan Drawing, E-872-588-3, at Elevation 268.4 m at the inlet and 267.4 m at the outlet on June 5, 2014. The above groundwater levels are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native soils from Borehole 17-09, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			17-09, SS#9, 6.1 m – 6.7 m (Silty Clay)	Sitch Creek (Creek Water)
Sulphide	%	mg/L	0.67	<0.006
Chloride	µg/g	mg/L	16	3.0
Sulphate	µg/g	mg/L	54	3.0
pH	No unit	No unit	8.73	7.25

Parameter	Units (Soil)	Units (Water)	Test Results	
			17-09, SS#9, 6.1 m – 6.7 m	Sitch Creek
			(Silty Clay)	(Creek Water)
Electrical Conductivity	µS/cm	µS/cm	76	90
Resistivity	Ohms.cm	Ohms.cm	13,200	11,100
Redox Potential	mV	mV	139	303

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7. MISCELLANEOUS

Thurber obtained the borehole northing and easting coordinates and ground surface elevations from measurements taken in the field and relative to the topographic plans provided by the MTO.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Amir Fereidouni and Ms. Eckie Siu 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 Mr. Mehdi Mostakhdemi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for the proposed Sitch Creek Culvert replacement on Highway 588 about 300 m west of Highway 595, located in the Township of Gillies, District of Thunder Bay, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build 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 factual 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 Structural Inspection Report (SIR) dated January 2014. The SIR indicated that the structure is in fair condition apart from deterioration of the outlet cut off wall which was undermined as a result of erosion at the outlet of the culvert. The SIR also indicated that signs of foundation settlement of the culvert were not noticed at the time of the inspection (July 10, 2013).

The existing structures is a Corrugated Steel Pipe (CSP) culvert with a total length of about 43 m and a diameter of about 4.4 m. The Bridge Site Plan prepared by the Geomatics Section of the MTO's Engineering Office indicates that the culvert invert Elevation at the inlet is about 268.2 m, and the invert Elevation at the outlet is about 268.0 m. The finished highway grade is indicated at about Elevation 278.0 m, which results in approximately 5.5 m of fill above the culvert.

It is anticipated that the replacement culvert will be constructed at the same location as the existing culvert. It is also anticipated that the highway grades will remain un-changed at the site, except for possible embankment fill placement if the culvert barrels are extended. A Structural Design Report (SDR) and/or General Arrangement (GA) drawings which typically indicate the preferred replacement option and its dimensions as well as the location of the diversion pipe, if any, were not available at the time of preparation of this report.

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

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill consisting of sand and silty clay overlying a deposit of firm to stiff silty clay and/or compact gravelly sand to sand which are in turn underlain by a compact silt to silty sand over granitic bedrock. The water level in the stream was measured at about Elevations 268.4 m and 267.4 m at the upstream and downstream ends of the culvert, respectively, in June 2014.

8.1 Culvert Design Alternatives

This section presents discussions on available types of replacement culvert and foundation alternatives, and provides foundation design recommendations.

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

- Concrete box (closed) culverts composed of pre-cast segments;
- Concrete pipe or Corrugated steel pipe (CSP); and
- CSP Arch or Concrete, open footing culverts.

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 CSP or pre-cast box culverts are both feasible options, based on the following considerations:

- Pre-cast box culvert or pipe culverts would require reduced depth of excavation (and consequently reduced spoil disposal volume) compared to the open footing culvert;

- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast in place open footing culverts, resulting in shorter durations for dewatering and construction;
- A segmental box (or pipe) structure are more tolerant of some limited differential settlement along the culvert axis if the highway embankment is widened in the future; and
- Due to the relatively high frost penetration depth at the project site (i.e., 2.2 m), open footing culverts would require deeper excavations and consequently more robust temporary shoring and/or groundwater control compared to the other two alternatives.

The open footing culvert option is not recommended at this site due to relatively low geotechnical resistances of the foundation soil and the risk of post construction settlement. This option has not been developed further in the report. Recommendations for the design and installation of CSP and concrete box culverts as well the trenchless installation of the new pipe are presented below.

8.2 Foundation Design for Culvert Replacement

Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical resistances, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

8.2.1 Corrugated Steel Pipe Culvert

Replacement of the culvert with CSPs on the same alignment is feasible from foundation design and constructability perspectives. In order to accommodate the hydraulic requirements, multiple pipes may be required. The underside of the bedding layer should be placed at about Elevation 268.0 m, which corresponds to the native firm to stiff silty clay and/or compact gravelly sand subgrade. Excavation for placement of the pipe bedding below about Elevation 267.8 m may encounter probable bedrock or a layer of cobbles and boulders near the culvert inlet.

If the CSP option is selected, it 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 as per OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation and placement and compaction of the bedding materials must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction. Any soft or loose soil encountered at the final subgrade elevation should be sub-excavated and backfilled with compacted granular fill to provide a uniformly competent subgrade condition. The depth of sub-excavation should be decided by the QVE during construction based on visual inspection.

A modulus of subgrade reaction of about 15 MN/m^3 may be used for design of the pipe culvert placed on the firm to stiff silty clay subgrade at the site.

8.2.2 Concrete Box Culvert

Replacement of the existing CSP culvert with a concrete box culvert on the same alignment is a feasible option for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading from the replacement culvert.

In order to provide a uniform foundation subgrade, 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 box culvert, similar to as shown on OPSD 803.010. 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 prepared surface for support of the box units should have a 75 mm minimum thickness top levelling course consisting of un-compacted Granular A as per OPSS 422. The bedding and the prepared subgrade should be protected from disturbance during construction, therefore, construction equipment should not travel on the prepared subgrade or the bedding. Any soft or loose soil encountered at the final subgrade elevation should be sub-excavated and backfilled with compacted granular fill to provide a uniformly competent subgrade condition. The depth of sub-excavation should be decided by the QVE during construction based on visual inspection.

The underside of the culvert bedding should be placed at or below Elevation 268.0 m, which corresponds to the firm to stiff silty clay to clay and/or compact gravelly sand subgrade. Excavation for placement of the culvert bedding below about Elevation 267.8 m may encounter probable bedrock or a layer of cobbles and boulders near the culvert inlet.The following axial geotechnical resistances may be used for design of a box culvert of 5 m to 6 m wide with the culvert founded at the elevations outlined above:

- Factored Geotechnical Resistance at Ultimate Limit State (ULS) of 300 kPa
- Factored Geotechnical Resistance at Serviceability Limit State (SLS) of 200 kPa for a settlement of 25 mm.

The consequence factor of 1 was utilized in estimating the above resistances adopting a "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, in accordance with Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC) 2014.

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 applicable for vertical, concentric loads only. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with Clause 6.10.3 and Clause 6.10.4 of the CHBDC 2014.

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II should be calculated assuming an ultimate (un-factored) coefficient of friction of 0.45. A resistance factor of 0.8 should be applied for the calculation of the factored sliding resistance in accordance with Table 6.2 of CHBDC 2014 based on a "typical" degree of understanding.

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.

8.2.3 Culvert Headwalls

If headwalls are designed and constructed at the inlet and outlet of the replacement culvert, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to a limited amount of differential settlement.

The borehole information indicates that the founding conditions at the wall locations generally consist of native firm to stiff silty clay or compact gravelly sand.

8.2.4 RSS Walls

RSS walls are considered to be a suitable option provided differential settlements are within tolerable limits and adequate factor of safety against global instability is achieved. The performance of an RSS wall when settlement occurs depends primarily on the characteristics of its front facing system. A typical precast panel facing can typically tolerate up to 1 per cent differential settlement and up to 30-40 mm of total settlement.

To provide an acceptable foundation performance, the RSS walls should be placed on a 0.5 m thick engineered (granular) pad to deal with circumstances such as variable subsurface conditions and provide a consistent founding materials under the facing. The pad should extend to 300 mm beyond the outside edge of the facing and then downward at 1 horizontal to 1 vertical (1H:1V) side slope to the native soil. The engineered fill must consist of OPSS PROV 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 RSS walls should meet the geometry, performance and appearance criteria as outlined in the MTO's RSS Design Guidelines, 2008. RSS walls should be designed and constructed similar to MTO requirements which are provided in MTO Special Provision SP 599S22 (Retained Soil Systems) and SP 599S23 (Retained Soil System – Facing Elements).

The performance of a RSS wall 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 and, in severe cases, to possible failure (global instability) of the system. The entire block of reinforced earth must be designed against various modes of failure including bearing, sliding, overturning as well as internal stability.

An RSS wall founded on the native firm silty clay or compact silty sand to sand at about Elevation 267.8 m may be designed using a factored geotechnical resistance at ULS of 200 kPa and a factored geotechnical resistance at SLS of 150 kPa (for 25 mm of settlement).

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

Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.4 for an engineered granular fill subgrade.

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 the granular material behind the wall subject to fluctuating water levels. If the wall is subjected to flooding, the strip lengths may have to be larger than the typical 0.7 times the height of the RSS wall. The RSS supplier/designer of should be alerted of this.

The RSS wall will be founded on native silt/silty sand soil which has a high potential for erosion. Therefore, adequate erosion protection must be provided in front of the base of the RSS wall to prevent the foundation soil erosion and undermining of the wall.

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

8.2.5 Foundation for Concrete Walls

Concrete headwalls may be supported on spread footings founded on firm to stiff silty clay or compact silty sand subgrade. Any topsoil/organics or soft soil must be removed from the foundation subgrade and replaced with granular fill compacted as per OPSS 501. The walls should be provided with sufficient frost cover (minimum 2.2 m) and founded at Elevation 267.8 m. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 150 kPa (for 25 mm of settlement) may be used for design. A 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account according to the CHBDC 2014 Clauses 6.10.3 and 6.10.4.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying granular pad should be evaluated in accordance with the CHBDC 2014 assuming an ultimate coefficient of friction of 0.4 for the granular pad.

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

The concrete wall will be founded on native silt/silty sand soil which has a high potential for erosion. Adequate rock erosion protection must be provided in front of the base of the wall to prevent the foundation soil erosion and undermining of the wall.

8.2.6 Frost Protection

The depth of frost penetration at this site is approximately 2.2 m as per Ontario Provincial Standard Drawing (OPSD) 3090.100 (Foundation Frost Depths for Northern Ontario). Concrete headwall footings, if employed, should be provided with a minimum of 2.2 m of earth cover as protection against frost action. The frost cover requirement does not apply for a CSP or box culvert due to their depth of burial and higher tolerance for differential settlement/heave. The obvert of the existing culvert is below the frost penetration depth at the site. Therefore, the new culvert will not require a frost taper if its obvert is founded at the same elevation as the existing culvert obvert or below.

8.2.7 Subgrade Preparation and Protection

Performance of the replacement culvert and any headwalls will depend on the preparation of the subgrade. 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, topsoil, 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 excavation and backfilling should be carried out in accordance with OPSS 902. The subgrade preparation, placement and compaction of granular material must be carried out in the dry.

Where fine grained soils (silt and clay) are exposed at the foundation subgrade level, they will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that construction equipment be not allowed to travel on the bedding or the prepared subgrade which has to be protected from disturbance during construction.

A separation layer consisting of a non-woven geotextile should be placed between the subgrade and the underside of the bedding material. The geotextile should meet the specifications for OPSS 1860 Class II, and have a Fabric Opening Size (FOS) not greater than 150 micrometres.

8.2.8 Settlement

It is anticipated that the proposed replacement will not result in highway grade raise or re-location of the culverts. Therefore, minimal post construction settlement is expected at this site. It must be noted that any additional load imposed on the culvert replacement, including fill placed adjacent to the extended culvert barrels, will induce immediate settlement and minor long term settlement at this site.

8.3 Construction Considerations

Where construction staging is required to maintain one lane of traffic, the following items should be considered in the planning and execution of the staged construction sequencing:

- Diversion of the creek will be required for construction. In addition, a suitable dewatering program will be required to facilitate the construction of 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.

9. 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 the native silty clay to clay at this site are classified as Type 3 soils. The gravelly sand to sand and any other alluvial soil below the /groundwater table should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902.

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native silty clay and/or the gravelly sand to sand. Obstructions such as cobbles or debris might be encountered within the fill. Suggested wording for an NSSP on potential obstructions in the fill is included in Appendix F.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. Seepage should be anticipated from the embankment fill. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction.

The dewatering system on site should conform to OPSS 518 (Construction Specifications for Control of Water from Dewatering Operation). 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. Additional assessment should be made to determine if a Permit to Take Water (PTTW) is required.

Stockpile of excavated materials and heavy construction equipment should be kept at least the same horizontal distance from the edge of excavation as the depth of the excavation to prevent local instabilities.

10. TRENCHLESS INSTALLATION

The highway embankment height at this site is about 9.0 m. In light of this significant embankment height and the need for a large open excavation, the installation of the replacement culvert and any diversion pipe may be considered using trenchless techniques. For the conventional open cut and backfill installation of the diversion pipe, temporary shoring may be required to install the diversion pipe at the proposed depths of about 9 m to 10 m. For replacement of a 4.4 m diameter existing culvert, multiple pipes may be required for trenchless installation to provide adequate hydraulic opening. The invert elevation of the replacement pipe should be above Elevation 267.8 m due to the presence of cobbles, boulders and/or probable bedrock near the culvert inlet.

Trenchless methods that are typically considered to install pipes under highways include:

- Jack and bore
- Pipe ramming

- Microtunnelling (MTBM)
- Hand Mining
- Horizontal Directional Drilling

Selection of an appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation.

The excavation through the water bearing gravelly sand to sand is considered as flowing conditions for the face of the excavation during the trenchless installation. Therefore, jack and bore, and hand mining methods are not considered feasible due to presence of these non-cohesive soils at the target depth and the increased risk due to presence of groundwater by creating unstable flowing conditions at the face of the installation. Depending on the selected diameter for the replacement pipe, pipe Ramming and Microtunnelling are considered feasible methods for this installation.

The recommended minimum distance between the existing and the new pipes is 1 to 2 times the pipe diameter.

Monitoring of the roadway surface should be carried out during trenchless installation. The settlement monitoring program and condition survey should follow MTO's Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application. A copy of this document is attached in Appendix G.

11. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401 for a CSP or OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS.PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS.PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed to be a triangular distribution. 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 = bulk 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 11.1 below.

Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	**OPSS Granular A or Granular B Type II ϕ = 35°; g = 22.8 kN/m^3**		**OPSS Granular B Type I (modified) ϕ = 32°; g = 21.2 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.

In general the lateral earth pressure applied to a retaining structure (e.g., headwalls and/or vertical side walls of the culverts) depends on the lateral movement of the structure to activate active, passive or at rest earth pressure. If the wall support does not allow lateral movement (restrained stem) such as in a box culvert configuration, at rest earth pressures should be assumed for geotechnical design. If the wall support allows lateral movements (unrestrained stem) such as in concrete headwalls, active earth pressure should be used in the design of the wall. The minimum lateral movement to allow active pressures to develop within the backfill is outlined in Section C6.12 of the Commentary on CHBDC 2014.

The use of a material with a high friction angle and low active pressure coefficient (e.g., Granular A or 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 lateral pressure representing the compaction surcharge should be added in design of retaining walls and vertical side walls of the culverts. The magnitude of the lateral pressure should be 12 kPa at the top of fill which linearly decreases to zero at a depth of 1.7 m (for Granular B Type I) or at a depth of 2.0 m (for Granular A or B Type II).

If the wall is retaining sloping backfill, appropriate earth pressure parameters from Table 11.1 for sloping backfill should be used.

12. SEISMIC CONSIDERATIONS

The stratigraphy of the site is typically firm to stiff silty clay to clay underlain by a compact silt to silty sand over bedrock at a depth of about 16 m. This corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC 2014. The reference peak ground acceleration and velocity, PGA and PGV for a 2%, 5% and 10% probabilities of exceedance (equivalent of return periods of 475, 975 and 2475, respectively) in 50 years for Site Class C at the project site, based on the National Building Code of Canada (NBCC) 2015, are estimated and summarized in Table 12.1 below.

Table 12.1 – Seismic Hazard Values for Reference Ground Conditions Site Class C

Return Period (Years)	Probability of Exceedance	Coefficient of PGA_{ref}	Coefficient of PGV_{ref}
475	10% in 50 Years	0.010	0.007
975	5% in 50 Years	0.018	0.013
2475	2% in 50 Years	0.036	0.025

Retaining structures should be designed using active (K_{AE}) earth pressure coefficient that incorporate the effects of earthquake loading, in accordance with Clause 4.6.5 of the CHBDC 2014. The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total active earth pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_a \gamma' d + (K_{AE} - K_a) \gamma' (H-d)$$

where $\sigma_h(d)$ = the lateral earth pressure at depth d, (kPa)
K_a = either the static active earth pressure coefficient (K_a)
K_{AE} = the seismic active earth pressure coefficient;
γ' = the effective unit weight of the backfill soil (kN/m³), taken as soil unit weight given above;
d = the depth below the top of the wall (m); and
H = the total height of the wall above its toe (m).

The coefficients of horizontal earth pressure for seismic loading presented in Table 12.2 may be used:

Table 12.2 – Active Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m³	OPSS Granular B Type I (modified) $\phi = 32°$, $\gamma = 21.2$ kN/m³
Active (K_{AE})*	0.28	0.32

* After Mononobe and Okabe.

Liquefaction is not considered to be a concern due to the relatively low PGA for the site.

13. TEMPORARY PROTECTION SYSTEM

The temporary roadway protection system should be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2, provided that any nearby utility/structure can tolerate this magnitude of deformation.

Options for roadway protection are a soldier pile-lagging system or sheet piles. The existing embankment is fairly high (in the order of 9 m high). Therefore, a suitable anchor or bracing system may be required for the roadway protection.

The soil parameters in Table 13.1 may apply for design of the temporary roadway protection system with horizontal backfill.

Table 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Gravelly Sand/Silty Clay
γ	21 kN/m^3	22 kN/m^3
γ_w	10 kN/m^3	10 kN/m^3
K_a	0.33	0.33
K_p	3.0	3.0
K_0	0.5	0.5

Full hydrostatic pressure should be considered assuming a water level at least equal to the design stream water level.

The design of 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 retaining system, 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 RESTORATION

The existing Highway 588 embankment is approximately 5.5 m above the culvert at the site location and the embankment slopes appear to be performing satisfactorily. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

It is anticipated that there will be no grade raise or embankment widening at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. Any settlement due to changes in the culvert configuration is expected to be less than 25 mm. Additional settlement would be induced if the final configuration includes additional fill adjacent to the culvert barrels.

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

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

15. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and 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 should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

A concrete cut-off wall and a clay seal should be used at the inlet to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and 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 lieu of a compacted clay seal.

16. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be low due to the low concentrations of sulphate and chloride in the samples tested.
- The potential for soil or water corrosion on metal is considered to be mild.
- Appropriate protection measures are recommended if metal structural elements are used.
- The effect of road de-icing salt should be considered in the choice of concrete and metal structure elements.

- The embankment fill is about 9 m high at the site. For temporary open excavation, the roadway protection system may need bracing or anchoring to minimize the lateral movement of the roadway protection system.

17. OTHER CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix F.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.
- Boreholes 17-12 to 17-15 (adjacent to the culvert inlet) were terminated at depths ranging between 0.9 m and 2.4 m. Placement of the replacement structure and/or diversion pipe below Elevation 267.8 m may encounter probable bedrock or a layer of cobbles and boulders.

THURBER

60 YEARS

18. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Mehdi Mostakhdemi, M.Sc., P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT[(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

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	(psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

<u>UNIFIED SOILS CLASSIFICATION</u>

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

RECORD OF BOREHOLE No 17-09

METRIC

W.P. ______ LOCATION Sitch Creek N 5 350 696.3 E 326 810.1 ORIGINATED BY AHF

HWY 588 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.05.03 - 2017.05.03 CHECKED BY CZ

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	Water content (%)	GR	SA	SI	CL
272.4	GROUND SURFACE									
0.0	Silty **CLAY**, some sand, trace gravel, roots and rootlets, Firm to Very Stiff, Brown, Moist (FILL)(CI)	1	SS	4						
		2	SS	4						
		3	SS	5						
		4	SS	15		Wp–w–WL plotted	2	15	40	43
	Rock fragments in split spoon	5	SS	18						
		6	SS	6						
267.8 / 4.6	Silty **CLAY**, some sand, trace organics, Firm, Grey, Wet (CL)	7	SS	5	▽	Wp–w–WL plotted	0	20	58	22
		8	SS	8						
		9	SS	8						
265.3 / 7.2	**SILT**, some sand, trace clay, Compact, Grey, Wet	10	SS	14			0	14	81	5
	Rock fragments in split spoon	11	SS	10						
262.7 / 9.8	END OF BOREHOLE AT 9.8m UPON									

Elevation scale: 272, 271, 270, 269, 268, 267, 266, 265, 264, 263

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+^{3}, ×^{3}: Numbers refer to Sensitivity

20 / 15 ◯ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-09

METRIC

W.P. ______ LOCATION Sitch Creek N 5 350 696.3 E 326 810.1 ORIGINATED BY AHF

HWY 588 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.05.03 - 2017.05.03 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	AUGER REFUSAL AND SPLIT SPOON BOUNCING ON PROBABLE BEDROCK. GROUNDWATER LEVEL AT 5.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m AND CUTTINGS TO SURFACE.										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 - 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-10

METRIC

W.P.		ORIGINATED BY	ES
HWY	588	COMPILED BY	AN
DATUM	Geodetic	CHECKED BY	CZ
LOCATION	Sitch Creek N 5 350 677.0 E 326 800.7		
BOREHOLE TYPE	Hollow Stem Augers/NQ Coring		
DATE	2017.04.09 - 2017.04.09		

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
278.2	GROUND SURFACE						
0.0	**ASPHALT:** (25mm)				278		
0.0	**SAND**, some gravel, some fines Loose to Compact Brown Moist (FILL)	1	GS			o	
		1	SS	19	277	o	18 64 18 (SI+CL)
		2	SS	21	276	o	
		3	SS	24	275	o	
		4	SS	16	274	o	
		5	SS	21	273	o	
		6	SS	33	272, 271	o	14 67 13 6
		7	SS	8	270	o	
269.3 / 8.8	**CLAY**, trace sand, occasional sand seams Stiff Brown Moist (CH)	8	SS	9	269	wP–w–wL	0 4 45 51

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT wP, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wL; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3; GROUND WATER CONDITIONS; STRAT PLOT

RECORD OF BOREHOLE No 17-10

METRIC

W.P.		ORIGINATED BY	ES
HWY 588	LOCATION Sitch Creek N 5 350 677.0 E 326 800.7	COMPILED BY	AN
DATUM Geodetic	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	CHECKED BY	CZ
	DATE 2017.04.09 - 2017.04.09		

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	(continued)	9	SS	8	~24		
265.9 / 12.3	**SILT**, trace sand Compact Dark Grey Wet	10	SS	12	~20		
264.9 / 13.3	**SILT** and **SAND** to Silty **SAND**, trace to some clay, trace gravel Compact Dark Grey Wet	11	SS	10	~22		1 47 47 5
		12	SS	18	~14	FI: >20	10 46 32 12
262.3 / 15.8	**COBBLES / FRACTURED BEDROCK**	1	RUN			>20, 2	RUN #1 TCR=65% SCR=23% RQD=23%
261.7 / 16.4	**BEDROCK**, medium strong, grey: (Granite) Occasional quartz interbeds Horizontal fracture (25mm) at 16.9m, 17.2m, 17.3m and 17.4m Sub-vertical fracture (150mm) at 17.9m Sub-vertical fracture (25mm) at 18.8m and (75mm) at 19.0m Horizontal fracture (25mm) at 18.7m, 18.9m, 19.1m and 19.2m Quartz layer (150mm) at 18.8m	2	RUN			0, >20, 2, 1, 2	RUN #2 TCR=100% SCR=85% RQD=77%
		3	RUN			0, 1, 3, 3, 0	RUN #3 TCR=100% SCR=94% RQD=81%
258.7 / 19.5	END OF BOREHOLE AT 18.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.4m,						

Elevation scale: 268, 267, 266, 265, 264, 263, 262, 261, 260, 259. Dynamic cone penetration: >> at approx. 268 and 266.5.

Continued Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-10

METRIC

W.P. ________ LOCATION Sitch Creek N 5 350 677.0 E 326 800.7 ORIGINATED BY ES

HWY 588 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.04.09 - 2017.04.09 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	CUTTINGS TO 0.9m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-17840.GPJ 2015TEMPLATE(MTO).GDT 6/2/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-11

METRIC

W.P.		LOCATION	Sitch Creek N 5 350 676.0 E 326 790.8	ORIGINATED BY	ES
HWY	588	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.04.08 - 2017.04.08	CHECKED BY	CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
277.7	GROUND SURFACE							
0.0	**ASPHALT:** (25mm)							
	SAND, some to trace gravel, some fines Compact to Dense Brown Moist (FILL)		1	GS				
							277	
			1	SS	27			17 67 16 (SI+CL)
							276	
			2	SS	50			
			3	SS	16		275	
			4	SS	12			
							274	
							273	
			5	SS	39			
							272	
			6	SS	11			
							271	
							270	
			7	SS	25			
269.0 8.7	Gravelly **SAND**, trace fines Compact Brown Wet						269	
			8	SS	18			27 70 3 (SI+CL)
							268	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³ : Numbers refer to Sensitivity

20 / 15 ◯ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-17840.GPJ 2015TEMPLATE(MTO).GDT 6/2/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-11

METRIC

W.P. ______ LOCATION Sitch Creek N 5 350 676.0 E 326 790.8 ORIGINATED BY ES

HWY 588 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.04.08 - 2017.04.08 CHECKED BY CZ

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
267.0 / 10.7	**SAND**, medium grained, trace gravel Compact Brown Wet	9	SS	10	267		
265.9 / 11.7	**SILT**, some sand, trace gravel Brown Wet				266		
265.3 / 12.4	Sandy **GRAVEL**, trace clay Dense Brown Wet	10	SS	31	265		
264.4 / 13.3	**SILT**, some sand to sandy, trace clay to clayey, trace gravel Compact Dark Grey Wet	11	SS	21	264		
		12	SS	15	263, 262		
261.5 / 16.2	**COBBLES / FRACTURED BEDROCK**					FI >20	RUN #1 TCR=100% SCR=78% RQD=78%
261.2 / 16.5	**BEDROCK**, medium strong, occasional quartz interbeds: (Granite) Sub-vertical fracture (25mm to 75mm) at 16.5m, 16.8m and 17.1m	1	RUN		261	3 2 2 1	
	Sub-vertical fracture (25mm) at 17.9m and 18.3m Horizontal fracture (25mm) at 18.1m Quartz interbed (75mm) at 18.6m	2	RUN		260, 259	4 2 4 4 1	RUN #2 TCR=88% SCR=88% RQD=88%
258.5 / 19.2	END OF BOREHOLE AT 19.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CEMENT TO 0.1m, THEN ASPHALT TO						

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

+³, ×³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-11

METRIC

W.P. ______ LOCATION Sitch Creek N 5 350 676.0 E 326 790.8 ORIGINATED BY ES

HWY 588 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.04.08 - 2017.04.08 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m 3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	SURFACE.										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-12

METRIC

W.P. ______ LOCATION Sitch Creek N 5 350 651.6 E 326 798.9 ORIGINATED BY AHF

HWY 588 BOREHOLE TYPE Tripod COMPILED BY AN

DATUM Geodetic DATE 2017.04.29 - 2017.04.29 CHECKED BY CZ

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
269.6	GROUND SURFACE										
0.0	Silty **CLAY**, trace sand and gravel Soft to Hard Brown Wet		1	SS	3				○ (~38)		
							269				
	Split spoon bouncing		2	SS	60/ 0.133				○ (~21)		
268.0 / 1.5	Silty **SAND**, gravelly Very Dense Brown Wet		3	SS	113		268		○ (~10)		
267.5 / 2.1	END OF BOREHOLE AT 2.1m UPON REFUSAL OF TRIPOD EQUIPMENT. WATER LEVEL AT SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-13

METRIC

W.P.		LOCATION	Sitch Creek N 5 350 647.3 E 326 797.4	ORIGINATED BY	STH
HWY	588	BOREHOLE TYPE	Tripod - Donut Hammer	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.07.05 - 2017.07.05	CHECKED BY	CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.7	GROUND SURFACE										
0.0	Silty **SAND**, organics		1	SS	50/ 0.150	∇					
268.4 / 0.3	Dark Brown Moist to Wet split spoon bouncing										
	Gravelly, silty **SAND**, some organics						268				
267.8 / 0.9	Dark Brown Wet										
	END OF BOREHOLE AT 0.9m UPON AUGER REFUSAL. WATER LEVEL AT 0.3m BELOW SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-14

METRIC

W.P.		LOCATION	Sitch Creek N 5 350 647.3 E 326 797.1	ORIGINATED BY	STH
HWY	588	BOREHOLE TYPE	Tripod - Donut Hammer	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.07.05 - 2017.07.05	CHECKED BY	CZ

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.7	GROUND SURFACE										
0.0	Silty **SAND**, organics						268				
267.8 0.9	END OF BOREHOLE AT 0.9m UPON AUGER REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-15

METRIC

W.P.
LOCATION Sitch Creek N 5 350 646.3 E 326 798.5
ORIGINATED BY STH
HWY 588
BOREHOLE TYPE Tripod - Donut Hammer
COMPILED BY AN
DATUM Geodetic
DATE 2017.07.05 - 2017.07.05
CHECKED BY CZ

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.8	GROUND SURFACE										
0.0	**SILT**, organics Dark Brown Wet					∇					
0.2	Gravelly, silty **SAND**, organics Compact Dark Brown Wet		1	SS	9		268				
267.2 1.5	Silty **CLAY**, some sand, some gravel Hard Brown Wet		2	SS	65		267				
266.6 2.1	Silty **SAND** Very Dense Brown Wet		3	SS	53/ 0.100						
266.3 2.4	END OF BOREHOLE AT 2.4m UPON SPLIT SPOON REFUSAL. WATER LEVEL AT 0.2m BELOW SURFACE. BOREHOLE BACKFILLED WITH BENTONIE HOLEPLUG TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

15-(20/10)-5 (%) STRAIN AT FAILURE

THURBER

60 YEARS

Appendix B

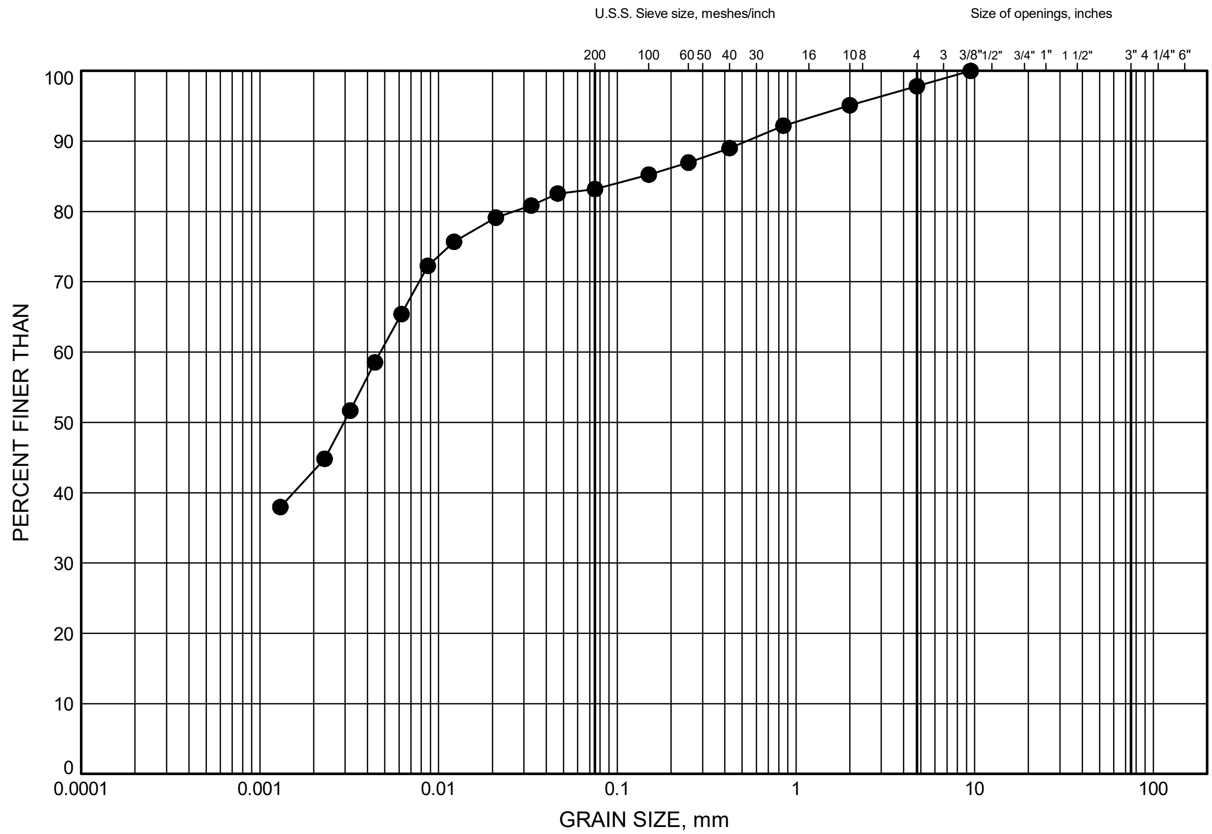
Geotechnical and Analytical Laboratory Test Results

Sitch Creek

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty Clay Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	2.6	269.8

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. MM

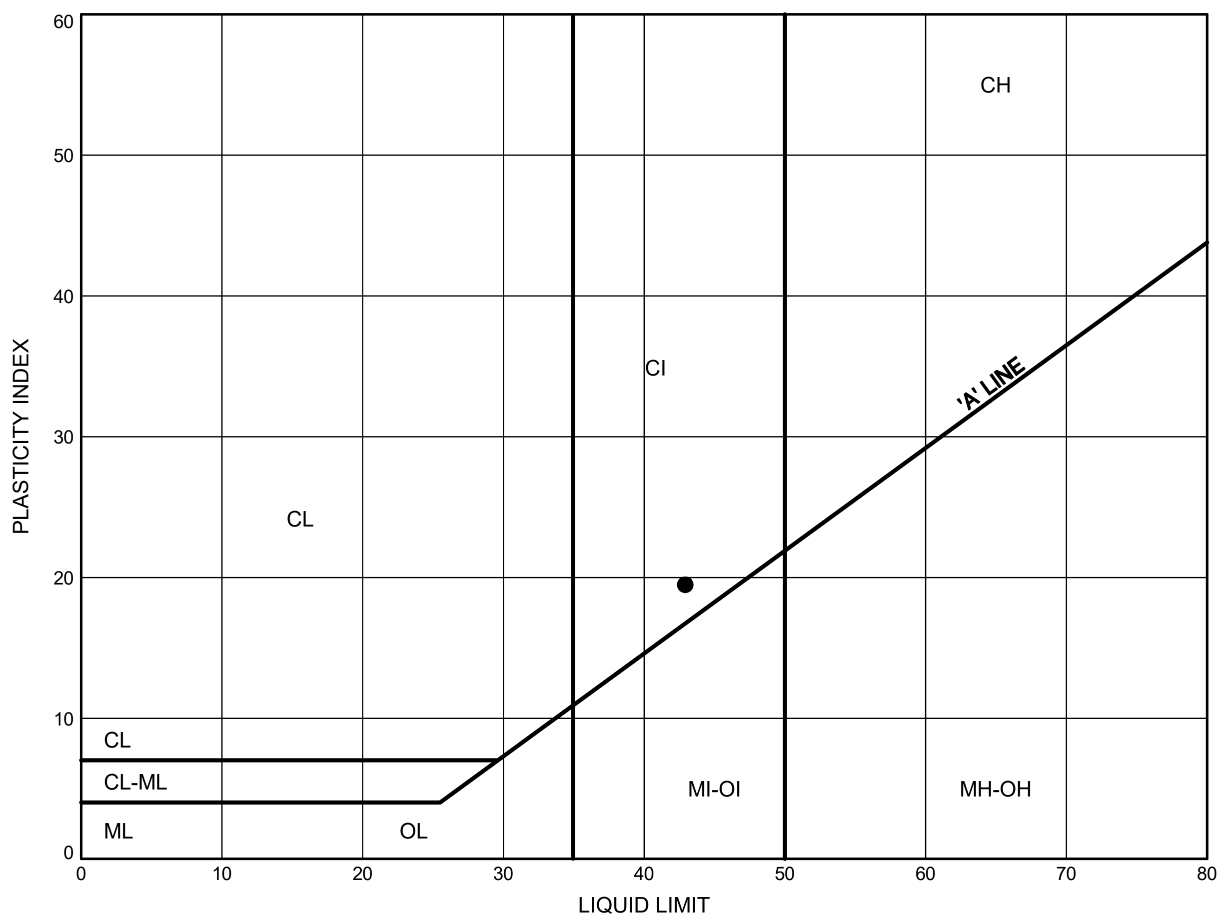
GRAIN SIZE DISTRIBUTION - THURBER MTO-17840.GPJ 6/2/17

Sitch Creek

ATTERBERG LIMITS TEST RESULTS

FIGURE B2

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	2.6	269.8

THURBALT MTO-17840.GPJ 6/2/17

Date June 2017

W.P.

THURBER

Prep'd MFA

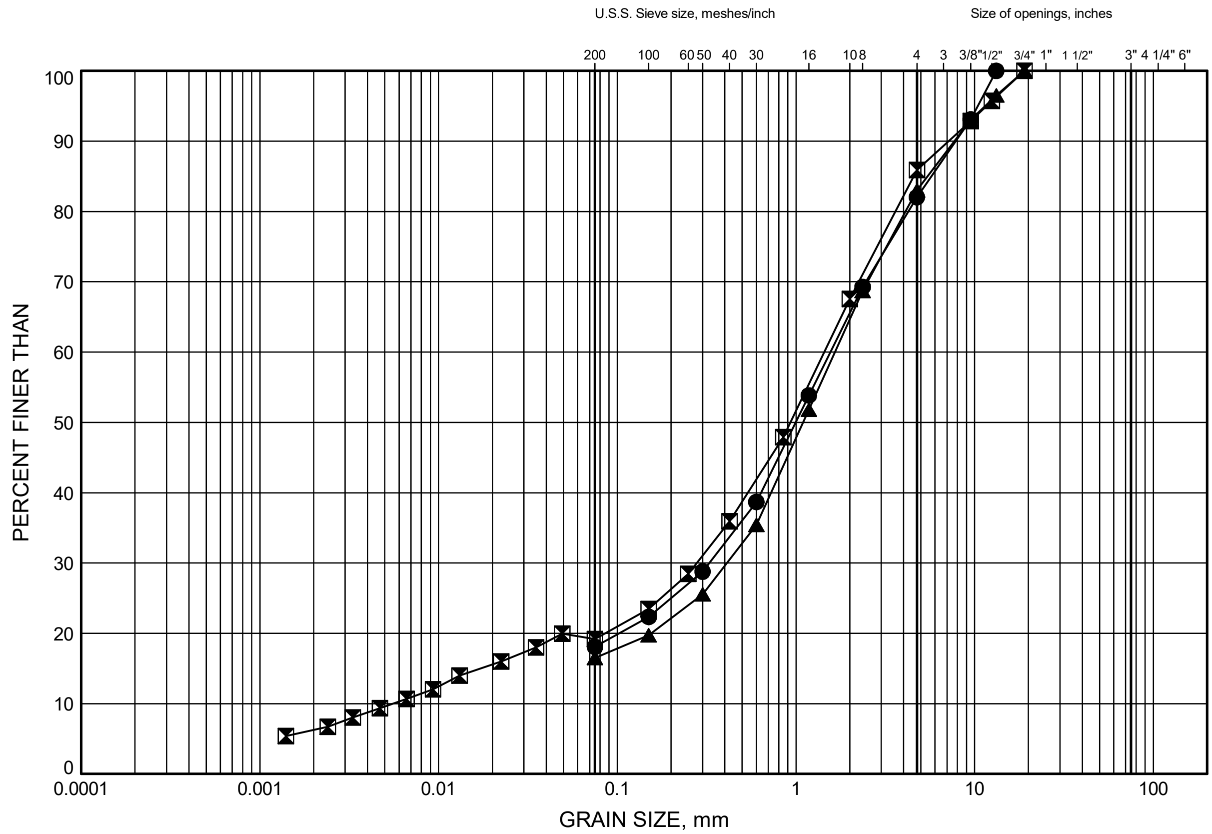
Chkd. MM

Sitch Creek

GRAIN SIZE DISTRIBUTION

FIGURE B3

Sand Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-10	1.1	277.1
⧗	17-10	6.4	271.8
▲	17-11	1.1	276.6

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. MM

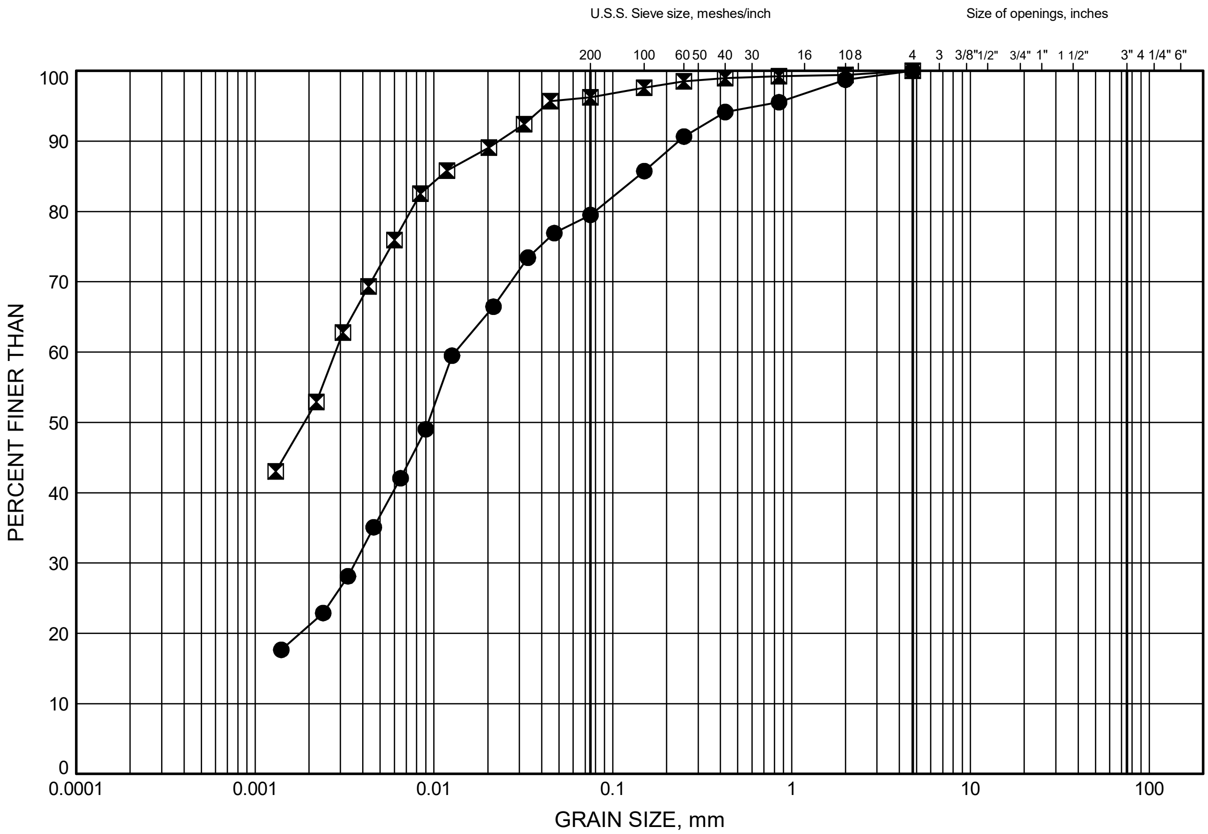
GRAIN SIZE DISTRIBUTION - THURBER MTO-17840.GPJ 6/2/17

Sitch Creek

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silty Clay to Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	4.9	267.5
⧗	17-10	9.4	268.7

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. MM

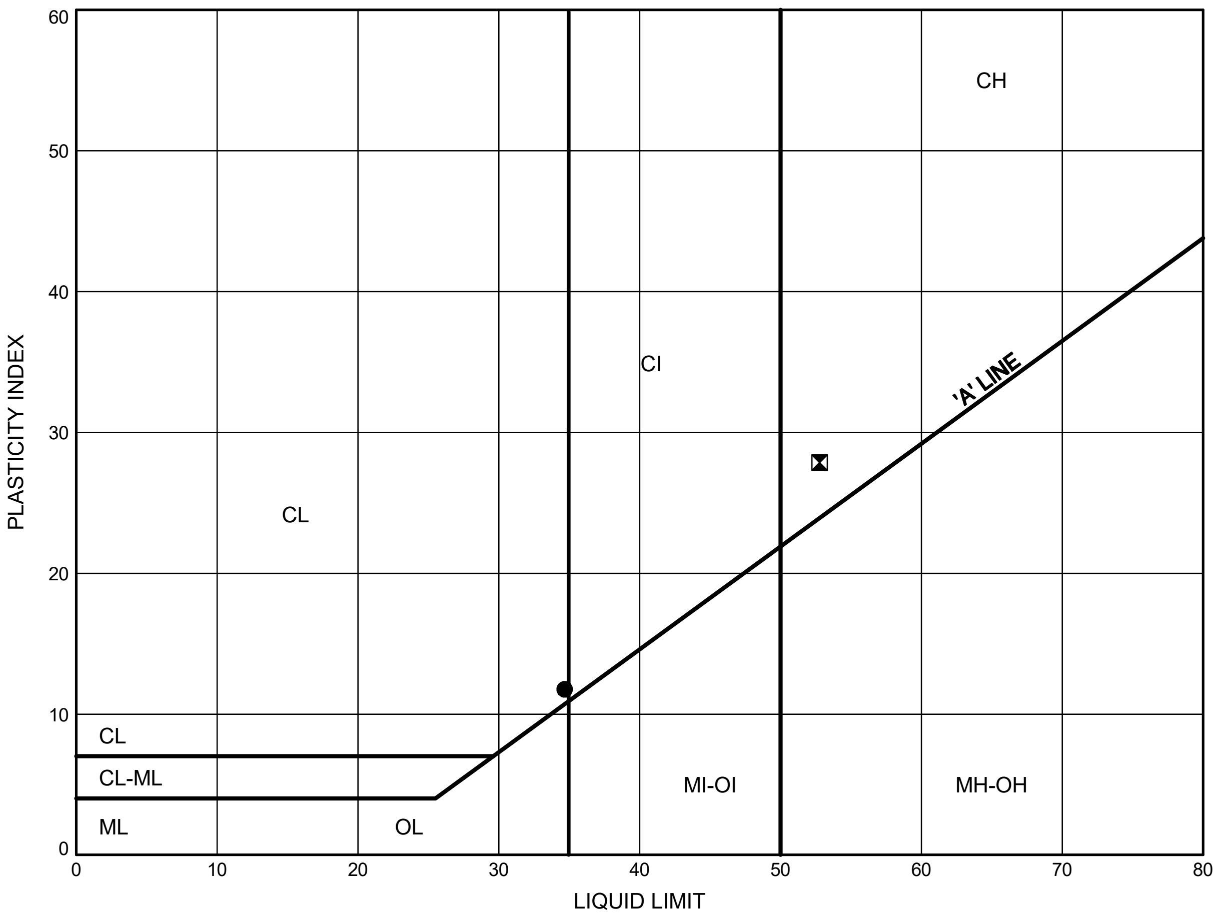
GRAIN SIZE DISTRIBUTION - THURBER MTO-17840.GPJ 6/2/17

Sitch Creek

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay to Clay



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	4.9	267.5
⊠	17-10	9.4	268.7

THURBALT MTO-17840.GPJ 6/2/17

Date June 2017

W.P.

THURBER

Prep'd MFA

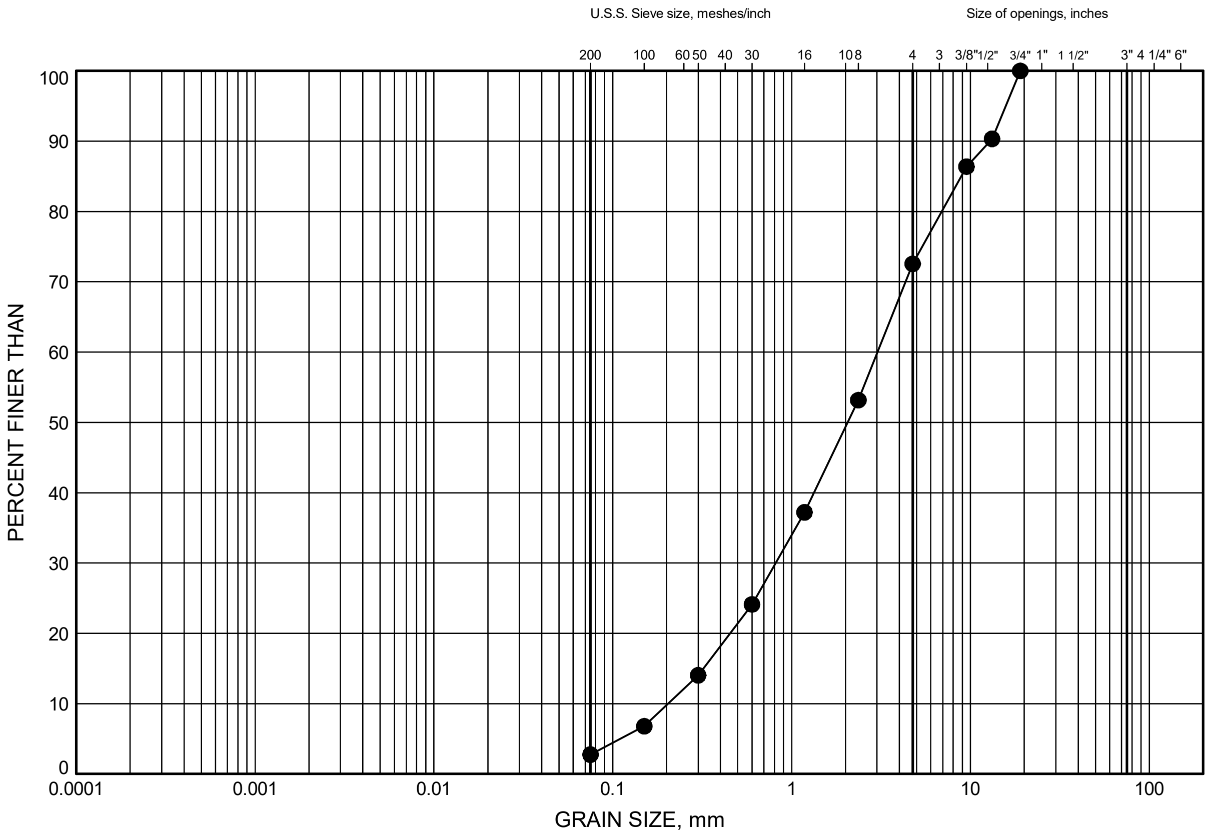
Chkd. MM

Sitch Creek

GRAIN SIZE DISTRIBUTION

FIGURE B6

Gravelly Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-11	9.4	268.2

Date June 2017

W.P.

THURBER

Prep'd MFA

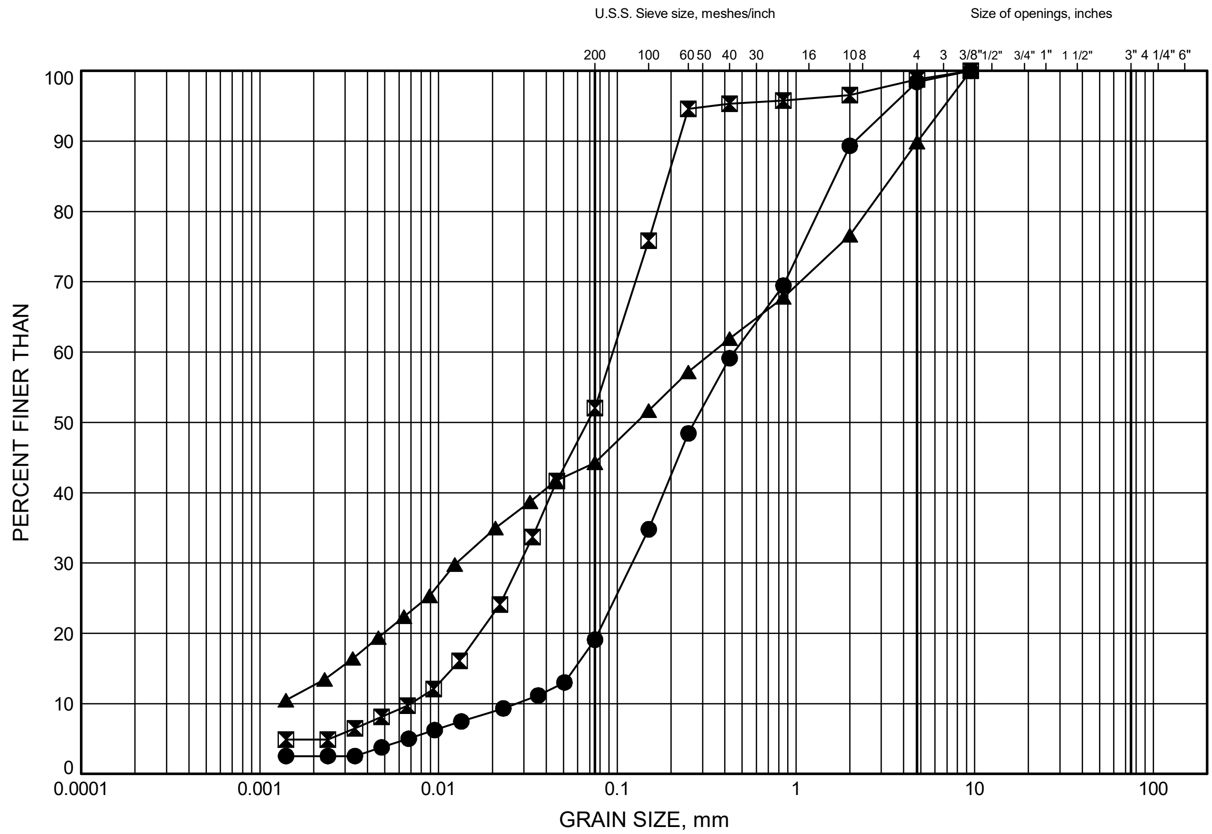
Chkd. MM

Sitch Creek

GRAIN SIZE DISTRIBUTION

FIGURE B7

Silt to Silty Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-08	9.4	256.2
⧗	17-10	14.0	264.2
▲	17-10	15.5	262.6

GRAIN SIZE DISTRIBUTION - THURBER MTO-17840.GPJ 6/2/17

Date June 2017

W.P.

THURBER

Prep'd MFA

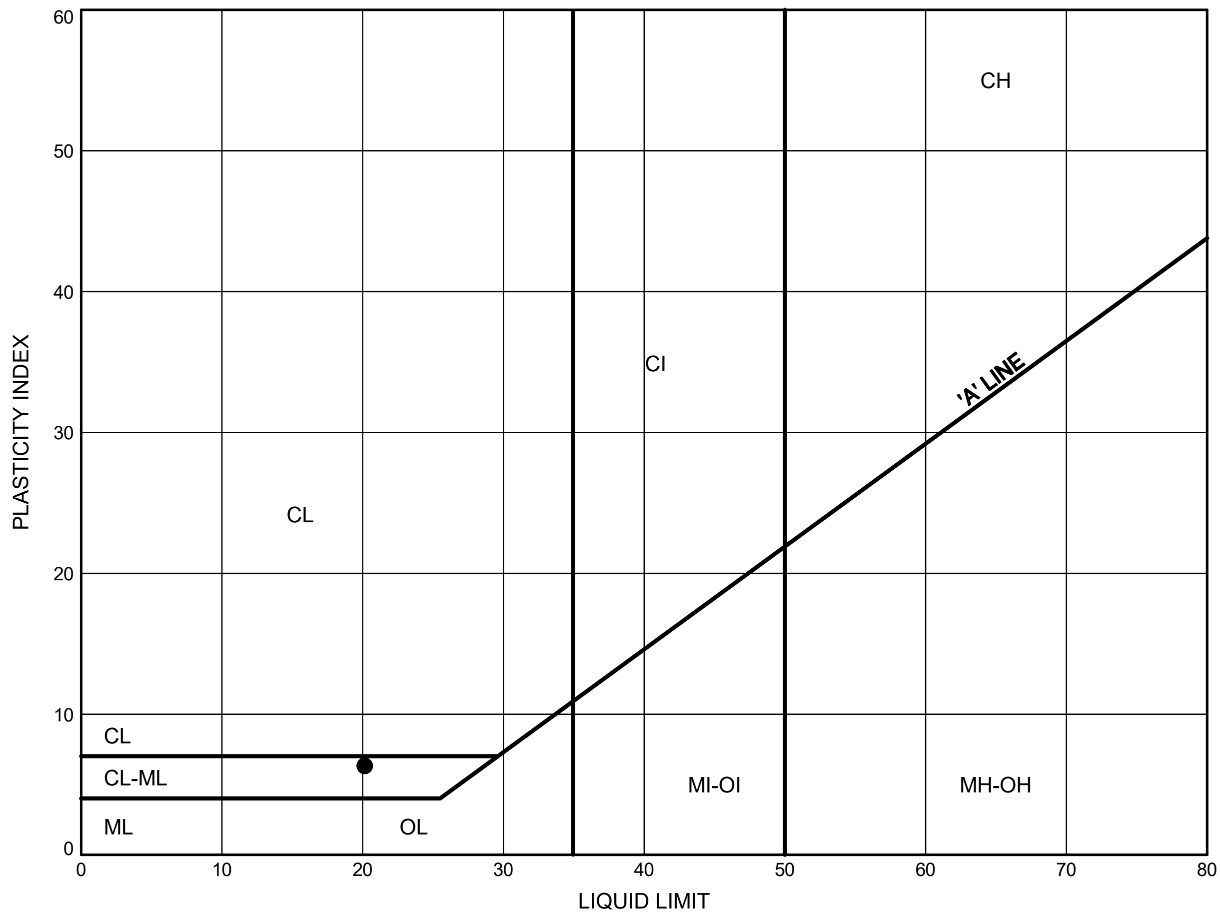
Chkd. MM

Sitch Creek

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-11	15.5	262.1

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. MM

THURBALT MTO-17840.GPJ 6/2/17

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	17792	**Date Drilled:**	09-Apr-17
Client:	MTO	**Date Tested:**	21-Apr-17
Project Name:	Sitch Creek Hwy 588	**Tester:**	WHW
Core Size:	NQ **BH No :** 17-10	**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	16.4	D	30.0	47.3	64.3	12.4	297.6	Granite	Extremely Strong
2	2	17.1	D	14.0	47.1	73.0	5.8	139.6	Granite	Very Strong
3	2	17.6	A	27.5	47.2	64.1	7.4	178.7	Granite	Very Strong
4	2	18.1	D	6.3	47.1	64.1	2.6	62.5	Granite	Strong
5	3	18.2	D	11.2	47.2	60.6	4.6	111.3	Granite	Very Strong
6	3	18.7	A	1.7	47.3	44.5	0.6	14.8	Granite	Weak
7	3	19.3	D	19.3	47.3	66.4	8.0	191.6	Granite	Very Strong
8										
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11										
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	17840	**Date Drilled:**	09-Apr-17
Client:	MTO	**Date Tested:**	21-Apr-17
Project Name:	Sitch Creek Culvert Hwy 588	**Tester:**	WHW
Core Size:	NQ **BH No :** 17-11	**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	16.7	D	13.2	47.1	75.0	5.5	131.4	Granite	Very Strong
2	1	17.0	D	12.1	47.1	128.0	5.0	121.1	Granite	Very Strong
3	1	17.3	A	20.3	47.1	68.0	5.3	126.2	Granite	Very Strong
4	2	17.8	A	11.1	47.1	54.0	3.5	82.9	Granite	Strong
5	2	18.1	D	5.8	47.1	103.0	2.4	57.7	Granite	Strong
6	2	18.4	A	11.2	47.1	66.0	3.0	71.1	Granite	Strong
7	2	18.6	D	16.4	47.1	115.0	6.8	163.7	Granite	Very Strong
8	2	18.9	D	38.5	47.1	151.0	16.0	384.2	Granite	Extremely Strong
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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17840

19-April-2017

Thurber Engineering Ltd.
Attn : Mark Farrant

103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 228
Fax:

Date Rec. : 12 April 2017
LR Report: **CA13544-APR17**
Reference: 17840 Mark Farrant

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	**1: Analysis Start Date**	**2: Analysis Start Time**	**3: Analysis Approval Date**	**4: Analysis Approval Time**	**5: MDL**	**7: Whitewood Creek Culvert**	**8: Sitch Creek Culvert Hwy 588**
Sample Date & Time						06-Apr-17 18:00	09-Apr-17 18:30
Temperature Upon Receipt [°C]					---	13.0	13.0
pH [no unit]	13-Apr-17	08:53	17-Apr-17	14:39	0.05	7.46	7.25
Conductivity [uS/cm]	13-Apr-17	08:53	17-Apr-17	14:39	2	129	90
Resistivity (calculated) [Ohms.cm]	17-Apr-17	16:09			---	7750	11100
Redox Potential [mV]	12-Apr-17	13:31	13-Apr-17	11:41	---	295	303
Chloride [mg/L]	12-Apr-17	16:30	13-Apr-17	12:41	0.04	7.3	3.0
Sulphate [mg/L]	12-Apr-17	16:30	13-Apr-17	12:41	0.04	3.2	3.0
Sulphide [mg/L]	13-Apr-17	10:15	17-Apr-17	10:30	0.006	< 0.006	< 0.006

Temperature of Sample upon Receipt: 13 degrees C
Cooling Agent Present: No
Custody Seal Present: No

Deanna Edwards

Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

OnLine LIMS

0000970998

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Method Descriptions

Parameter	Units	SGS Method Code	Reference Method Code
Anions by IC	mg/L	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	uS/cm	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	no unit	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential	mV		SM 2580
Sulphide by SFA	mg/L	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500

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Project : 17840
LR Report : **CA13544-APR17**

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0140-APR17												
Chloride	0.04	mg/L	<0.04		4	20	100	80	120	104	75	125
Sulphate	0.04	mg/L	<0.04		2	20	98	80	120	107	75	125
Conductivity - QCBatchID: EWL0169-APR17												
Conductivity	2	uS/cm	2		3	10	97	90	110	NA		
pH - QCBatchID: EWL0169-APR17												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0152-APR17												
Redox Potential	no	mV	NA		4	20	104	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0110-APR17												
Sulphide	0.006	mg/L	<0.006		ND	20	81	80	120	NV	75	125

OnLine LIMS

0000970998

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Project : 17742/17840

24-May-2017

Thurber Engineering Ltd
Attn : Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240
Fax:

Date Rec. : 17 May 2017
LR Report: **CA14528-MAY17**
Reference: 17742/17840 Cory Zanatta

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	**1: Analysis Start Date**	**2: Analysis Start Time**	**3: Analysis Approval Date**	**4: Analysis Approval Time**	**5: 17840 17-09 SS9**	**6: 17840 17-08 SS6**	**7: 17840 17-06 SS7**	**8: 17840 17-03 SS5**
Sample Date & Time					15-May-17	15-May-17	15-May-17	15-May-17
Temperature Upon Receipt [°C]	---	---	---	---	10.0	10.0	10.0	10.0
Corrosivity Index [none]	24-May-17	13:45	24-May-17	13:45	7.5	4.5	7.5	4.0
Soil Redox Potential [mV]	18-May-17	19:36	19-May-17	14:01	139	152	272	237
Sulphide [%]	23-May-17	12:52	23-May-17	13:09	0.67	0.53	0.51	< 0.02
% Moisture (wet wt) [%]	23-May-17	10:42	23-May-17	10:44	19.3	19.8	9.9	17.9
pH [no unit]	19-May-17	14:44	24-May-17	13:14	8.73	8.22	8.51	8.55
Chloride [µg/g]	19-May-17	12:04	23-May-17	11:42	16	5.9	15	25
Sulphate [µg/g]	19-May-17	12:04	23-May-17	11:42	54	68	200	61
Conductivity [uS/cm]	19-May-17	14:44	24-May-17	13:14	76	92	173	109
Resistivity (calculated) [Ohms.cm]	19-May-17	14:44	24-May-17	13:14	13200	10900	5780	9170

OnLine LIMS

0001007963

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Analysis	**9: 17840 17-02 SS6**	**10: 17840 17-07 SS7**	**11: 17792 17-03 SS3**	**12: 17792 17-02 SS4**
Sample Date & Time	15-May-17	15-May-17	15-May-17	15-May-17
Temperature Upon Receipt [°C]	10.0	10.0	10.0	10.0
Corrosivity Index [none]	7.5	7.5	2.0	1.0
Soil Redox Potential [mV]	200	256	278	315
Sulphide [%]	0.05	0.39	< 0.02	< 0.02
% Moisture (wet wt) [%]	18.9	14.1	20.1	10.9
pH [no unit]	8.68	8.47	7.40	6.03
Chloride [µg/g]	55	59	260	66
Sulphate [µg/g]	110	200	8.3	32
Conductivity [uS/cm]	157	200	384	150
Resistivity (calculated) [Ohms.cm]	6370	5000	2600	6670

Temperature of Sample upon Receipt: 10 degrees C
Cooling Agent Present: Yes
Custody Seal Present: No

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

Deanna Edwards

Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

OnLine LIMS

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Project : 17742/17840

LR Report : **CA14528-MAY17**

Method Descriptions

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

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

Project : 17742/17840

LR Report : **CA14528-MAY17**

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0347-MAY17												
Chloride	0.4	µg/g	<0.4		12	20	97	80	120	97	75	125
Sulphate	0.4	µg/g	<0.4		5	20	97	80	120	86	75	125
Carbon/Sulphur - QCBatchID: ECS0026-MAY17												
Sulphide	0.02	%	<0.02		ND	20	117	80	120			
Conductivity - QCBatchID: EWL0361-MAY17												
Conductivity	2	uS/cm	< 2		0	10	96	90	110	NA		
pH - QCBatchID: EWL0361-MAY17												
pH	0.05	no unit	NA		0		100			NA		

OnLine LIMS

0001007963

Appendix C

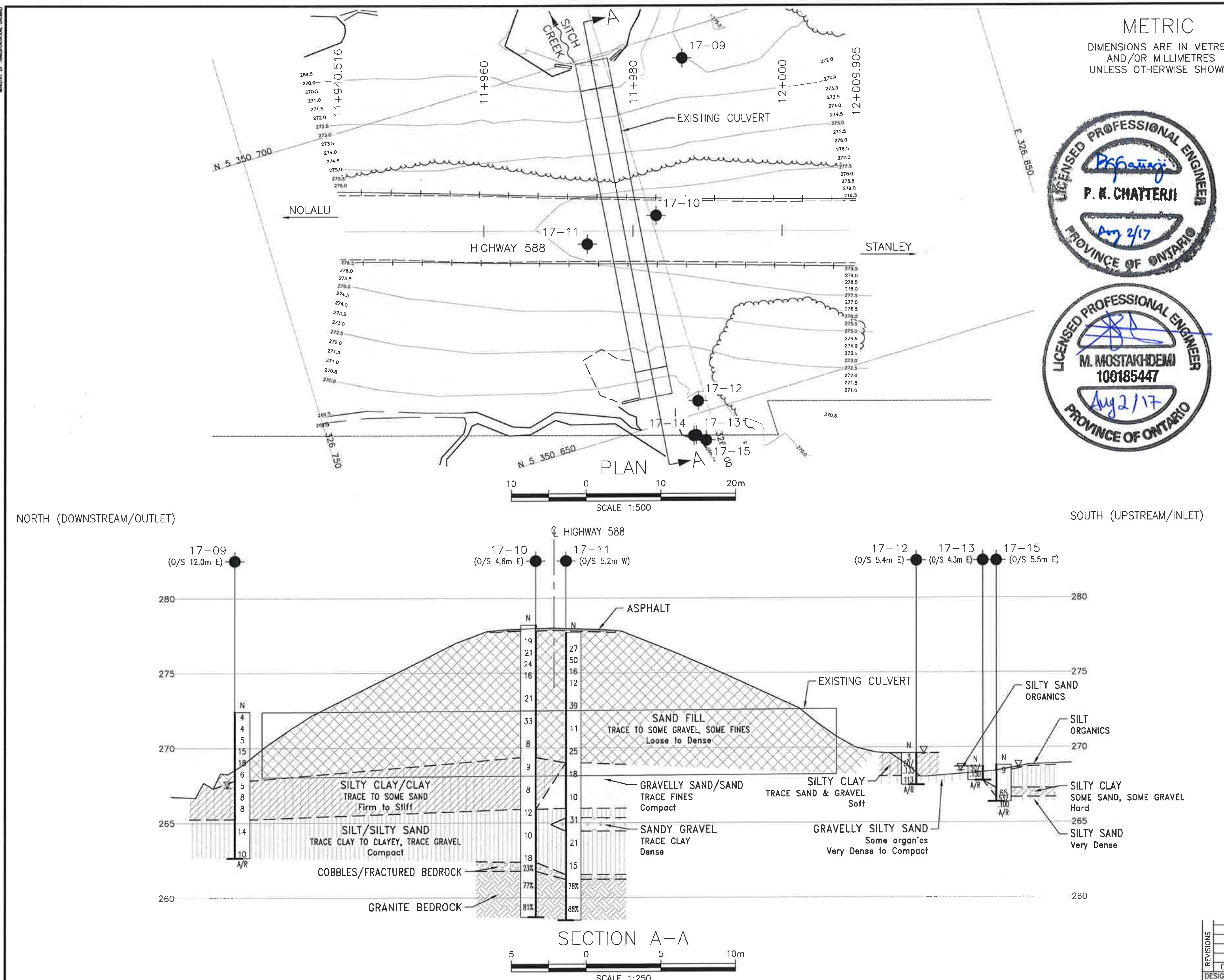
Selected Site Photographs

Photograph 1 – Sitch Creek Culvert, South End (Inlet)

Photograph 2 – Sitch Creek Culvert, North End (Outlet)

Appendix D

Borehole Locations and Soil Strata Drawing



CONT No
WP No

HIGHWAY 588
SITCH CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

THURBER ENGINEERING LTD.

KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
17-09	272.4	5 350 696.3	326 810.1
17-10	278.2	5 350 677.0	326 800.7
17-11	277.7	5 350 676.0	326 790.8
17-12	269.6	5 350 651.6	326 798.9
17-13	268.7	5 350 647.3	326 797.4
17-14	268.7	5 350 647.3	326 797.1
17-15	268.8	5 350 646.3	326 798.5

-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.

GEOCRES No. 52A-226

REVISIONS	DATE	BY	DESCRIPTION			
DESIGN CZ	CHK PKC	CODE	LOAD	DATE AUG 2017		
DRAWN MFA	CHK CZ	SITE	STRUCT	DWG 1		

FILENAME: H:\Drafting\17000\17840\TED-17840-BHPP-SC2.dwg
PLOTDATE: 8/2/2017 8:42 AM

Appendix E

Comparison of Foundation Alternatives

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
Advantages: i. Ease of construction. ii. Segmented pipes can accommodate some potential differential settlement along culvert axis.	Advantages: i. Relatively rapid installation and less disturbance to subgrade soils if precast segments are used. ii. Segmental option can accommodate some potential differential settlement along culvert axis.	Advantages: i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
Disadvantages: i. Multiple pipes may be needed to meet hydraulic design (capacity) requirements. ii. Temporary roadway protection system is required.	Disadvantages: i. More expensive than a CSP culvert. ii. Relatively large excavation required to install culvert. iii. Temporary roadway protection system required.	Disadvantages: i. Greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements. iii. More extensive roadway protection is required compared to the other two options. iv. More disturbance of creek.
FEASIBLE	**FEASIBLE**	**NOT RECOMMENDED**

Appendix F

List of Specifications and Suggested Wording for NSSP

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

- OPSS.PROV 206
- OPSS.PROV 209
- OPSS.PROV 422
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS.PROV 902
- OPSS.PROV 1004
- OPSS.PROV 1010
- OPSS.PROV 1205
- OPSS.511
- OPSS.1860
- OPSD.802.010
- OPSD.803.010
- OPSD.810.010

2. Suggested Wording for NSSP

- Suggested Text for NSSP on “Obstructions”

“Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native soils, or shallow bedrock. Such obstructions may impede excavation progress and/or sheetpile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.”

- Suggested Text for NSSP on “Groundwater and Dewatering”

"The Contractor is notified that the site has high groundwater levels and that these levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the Contractor must satisfy himself regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

Design and provision of an effective dewatering system is the responsibility of the Contractor. Subgrade preparation, culvert construction and backfilling must be carried out in the dry.