



THURBER ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT
MOOSE CREEK CULVERT REPLACEMENT
HIGHWAY 622, SITE No. 45-258/C
UNSURVEYED TERRITORY, DISTRICT OF RAINY RIVER
G.W.P. No. 6845-14-00**

GEOCRES No.: 52B-31

Report

to

Hatch

Date: March 14, 2017
File: 13983

TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

1.	INTRODUCTION	1
2.	SITE DESCRIPTION	1
3.	INVESTIGATION PROCEDURES	2
4.	LABORATORY TESTING	4
5.	DESCRIPTION OF SUBSURFACE CONDITIONS	4
5.1	Asphalt and Topsoil	4
5.2	Gravelly Sand Fill	5
5.3	Rockfill.....	5
5.4	Silt to Sand and Silt	5
5.5	Groundwater Conditions	6
6.	CORROSIVITY AND SULPHATE TEST RESULTS.....	7
7.	MISCELLANEOUS	7

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8.	GENERAL.....	9
9.	CULVERT DESIGN	10
9.1	Culvert Alternatives.....	10
9.2	Foundation Design for Culverts	11
9.2.1	Concrete Pipe or Corrugated Steel Pipe Culvert	11
9.2.2	Concrete Box Culvert	12
9.2.3	Culvert Headwalls	13
9.3	Settlement and Stability	15
9.4	Frost Cover.....	16
10.	LATERAL EARTH PRESSURES	16
11.	SEISMIC CONSIDERATIONS	17
12.	CULVERT CONSTRUCTION CONSIDERATIONS.....	18
12.1	Subgrade Preparation	18
12.2	Bedding and Backfilling	19
12.3	Excavation and Groundwater Control.....	20
13.	Stream Diversion Pipe	20
14.	TEMPORARY PROTECTION SYSTEM	21
15.	EMBANKMENT RESTORATION	22
16.	SCOUR AND EROSION PROTECTION.....	22

17. CORROSION AND SULPHATE ATTACK POTENTIAL	23
18. CONSTRUCTION CONCERNS	23
19. CLOSURE	24

APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical and Analytical Laboratory Test Results
Appendix C	Selected Site Photographs
Appendix D	Borehole Location Plan and Soil Strata Drawing
Appendix E	List of Specifications and Suggested Wording for NSSP
Appendix F	Comparison of Alternative Culvert Types

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MOOSE CREEK CULVERT REPLACEMENT
HIGHWAY 622, SITE No. 45-258/C
UNSURVEYED TERRITORY, DISTRICT OF RAINY RIVER
G.W.P. No. 6320-11-00**

GEOCRES No: 52B-31

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 Moose Creek Culvert on Highway 622, located in Unsurveyed Territory in the District of Rainy River, Ontario.

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

Thurber was retained by Hatch Ltd. (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-05.

The information on the existing Moose Creek Culvert has been provided on the Survey Plan B-485914-0-2/E-485914-622-1 prepared by MTO Geomatic Section, dated April 2016 and in the Terms of Reference for this project.

2. SITE DESCRIPTION

The Moose Creek Culvert site is located on Highway 622, approximately 26 km north of Highway 11B in the Unsurveyed Territory of the District of Rainy River, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location Plan and Soil Strata Drawing in Appendix D.

Highway 622 runs in a general northwest-southeast direction with the culvert perpendicular to the centreline of the highway. Moose Creek flows from northeast to southwest in a meandering course crossing the highway and drains into Eye Lake.

The existing structure is a corrugated steel pipe (CSP) culvert with a diameter of 3.8 m and a length of 35 m constructed in 1985. The highway embankment is approximately 6.6 m high with approximately 3.5 m of fill present above the culvert. The grade level of Highway 622 at the centreline of the existing culvert is at approximate Elevation 431.8 m. The culvert invert was indicated approximately at Elevation 424.3 m at the inlet and Elevation 424.6 at the outlet. The creek water level was measured at Elevation 426.1 m in April 2016.

The MTO Structure Inspection Report generated on November 2, 2015 with a documented site visit of June 2, 2015, concluded that the culvert structure was “in overall poor condition with medium to severe corrosion of the barrel in isolated locations”.

The culvert is situated within the flood plain of Moose Creek which consists of marsh lands on each side of the highway embankment. The lands outside of the flood plain are covered by heavily forested areas consisting of a mixture of mature trees and brush. Local topography at the culvert site is generally of low relief with bedrock outcrops visible along Highway 622 approximately 180 m and 140 m, southeast and northwest of the site, respectively. Rock fill was noted near the embankment toes and the existing culvert. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist of organic deposits of mainly peat/muck and thin glacial deposits bordering with areas of undulating to rolling bedrock knobs. Bedrock in the area has been identified as massive to foliated granodiorite to granite of the Quetico Subprovince of the Superior Province.

3. INVESTIGATION PROCEDURES

The borehole investigation and field program was carried out on between August 30 and September 10, 2016, during which a total of six (6) boreholes, designated as Boreholes 16-25 to 16-30, were advanced on site. Boreholes 16-28 and 16-25 were located near the inlet and outlet of the existing culvert while the remaining boreholes were drilled from the top of Highway 622. Boreholes 16-27 and 16-26 were located northwest and southeast of the culvert and drilled to a depth of 15.8 m. Boreholes 16-29 and 16-30 were located approximately 15 m northwest and southeast of the culvert for a frost taper investigation and drilled to depths of 13.7 m and 15.8 m, respectively.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were derived from cross sections and topographic drawings provided to Thurber by Hatch (MTO Survey Plan B-485914-0-2 / E-485914-622-1). The coordinate system MTM NAD

83, Zone 16 was used to establish locations of the boreholes. The approximate locations of the boreholes are shown on the Borehole Location Plan and Soil Strata Drawings included in Appendix D.

A rubber track mounted CME 55 drill rig was used to advance the boreholes from the top of the embankment (Boreholes 16-26, 16-27, 16-29 and 16-30) using hollow stem augers and wash boring techniques. Boreholes 16-25 and 16-28 at the toe of the embankment were drilled using a portable tripod drill rig using wash boring techniques.

Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) procedures as per ASTM D1586. The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes throughout the drilling operations. The boreholes were backfilled in general accordance with Ontario Regulation 903.

Completion details of the borehole are summarized in the table below.

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
16-25	5.8 / 420.6	Borehole backfilled with bentonite holeplug and cuttings to surface.
16-26	15.8 / 416.0	Borehole backfilled with bentonite holeplug and cuttings and surface reinstated with asphalt.
16-27	15.8 / 415.9	Borehole backfilled with bentonite holeplug and cuttings to 0.1 m and surface reinstated with asphalt.
16-28	5.6 / 420.8	Borehole backfilled with bentonite holeplug and cuttings to surface.
16-29	13.7 / 418.0	Borehole backfilled with bentonite holeplug and cuttings and surface reinstated with asphalt.
16-30	15.8 / 416.0	Borehole backfilled with bentonite holeplug and cuttings to 0.1 m and surface reinstated with asphalt.

4. LABORATORY TESTING

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are enclosed 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" drawings 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 should 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 gravelly sand to gravel with cobbles and boulders, underlain by a deposit of silt with varying content of sand. Descriptions of the individual strata are presented below.

5.1 Asphalt and Topsoil

Approximately 25 mm to 50 mm of asphalt was encountered in Boreholes 16-26, 16-27, 16-29 and 16-30 which were drilled from the top of the embankment.

In Boreholes 16-28 and 16-25 located at the inlet and outlet of the culvert, a layer of topsoil approximately 200 mm in thickness was encountered. The topsoil thickness may vary across the site.

5.2 Gravelly Sand Fill

Underlying the asphalt was a granular fill, consisting of gravelly sand with trace to some silt, trace clay, trace organics and occasional cobbles. The gravelly sand fill thickness varied from 0.9 m to 1.5 m in the boreholes drilled from the top of the embankment. Borehole 16-28 drilled at the east toe of the embankment encountered approximately 0.6 m of fill. The base of the gravelly sand fill ranged from depths of 0.8 m to 1.5 m or from Elevation 425.6 m to Elevation 430.9 m. The relative density of the gravelly sand fill ranged from loose to very dense. The recorded SPT 'N' values greater than 50 blows per 0.125 m of penetration were likely indicative of the presence of cobbles in the fill.

The measured moisture content of the gravelly sand fill generally ranged from 2 percent to 15 percent. The results of grain size distribution analyses conducted on samples of the gravelly sand fill are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B1 in Appendix B.

Soil Particle	Percentage (%)
Gravel	30 to 38
Sand	50 to 60
Silt and Clay	10 to 13

5.3 Rockfill

Underlying the gravelly sand fill, rockfill was encountered in Boreholes 16-26, 16-27, 16-29, and 16-30, which were drilled through the top of the embankment. The rockfill contained cobbles and boulders as well as sand and gravel. The rockfill thickness varied from 4.6 m to 5.2 m and extended to depths of m to 5.5 to 6.1 m or from Elevation 425.6 m to Elevation 426.3 m. SPT 'N' values greater than 50 blows per 0.025 m of penetration were recorded within the rockfill and were likely indicative of the presence of cobbles and boulders. Casing was required to penetrate the cobbles and boulders. The approximate locations of the cobbles and boulders are shown on the borehole logs. A 590 mm diameter boulder was encountered at 4.3 m depth in Borehole 16-26.

5.4 Silt to Sand and Silt

A native deposit of silt with varying proportions of sand, clay and gravel were encountered in all boreholes beneath the embankment fill. The laboratory testing indicated that the deposit can be classified as silt, sandy silt and sand and silt. Occasional clayey silt lenses were encountered in

Boreholes 16-27 at depth, as well as cobbles and boulders were inferred during drilling in Boreholes 16-25 and 16-28.

All boreholes were terminated in this deposit at depths ranging from 5.6 m to 15.8 m, or Elevation 420.8 m to 415.9 m.

The recorded SPT 'N' values varied from 2 to in excess of 100 blows per 0.3 m of penetration, however, typically the SPT 'N' values ranged from 4 blows to 44 blows per 0.3 m penetration indicating a loose to dense relative density. The high 'N' values were recorded in the boreholes advanced at the toe of the embankment and may indicate presence of cobbles or boulders or rockfill. The measured moisture content of the silt typically ranged from 15 percent to 45 percent. The moisture content of two silt samples underlying the topsoil and fill in Boreholes 16-25 and 16-28, containing trace organics ranged from 55 percent to 72 percent.

The results of grain size analyses conducted on samples of the silt and sandy silt/sand and silt are provided on the Record of Borehole sheets in Appendix A and are summarized in the following table. The results are also presented on Figures B2 and B3 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)	
	Silt	Sandy Silt/Sand and Silt
Gravel	0	0 to 16
Sand	3 to 7	22 to 40
Silt	82 to 87	43 to 70
Clay	7 to 15	5 to 8

5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations. However, water was used to advance the boreholes and, therefore, the observation may not reflect the actual groundwater conditions. The water level in Moose Creek was measured at Elevation 426.1 m in April 2016. The groundwater level should be assumed to reflect the creek water level. It should be noted that the groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year such as spring or after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silt from Borehole 16-26, 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	
			16-26 SS#3, 6.1 m to 6.7 m	Moose Creek Water
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	39	0.52
Sulphate	µg/g	mg/L	8.3	0.31
pH	No unit	No unit	6.62 - 6.77	6.05
Electrical Conductivity	µS/cm	µS/cm	58	17
Resistivity	Ohms.cm	Ohms.cm	17200	5880
Redox Potential	mV	mV	224	203
Corrosivity Index	-	-	1	< 1

7. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained utility locates prior to drilling.

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. Troy MacKinnon of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. 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 Ms. Anna Piascik, P.Eng. and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Anna Piascik, P.Eng
Senior Geotechnical Engineer



Mark Farrant, P.Eng.
Geotechnical Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MOOSE CREEK CULVERT REPLACEMENT
HIGHWAY 622, SITE No. 45-258/C
UNSURVEYED TERRITORY, DISTRICT OF RAINY RIVER
G.W.P. No. 6320-11-00**

GEOCRES Number: 52B-31

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This section of the report provides an interpretation of the geotechnical data in the factual report, and presents foundation recommendations for design of the proposed Moose Creek Culvert replacement on Highway 622, located 26 km north of Highway 11B, in the Unsurveyed Territory, District of Rainy River.

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 and design-build contractor. The construction and 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 Moose Creek Culvert was obtained from the MTO Terms of Reference and the Survey Plan B-485914-0-2/E-485914-622-1 prepared by MTO Geomatic Section, dated April 2016.

As indicated on the Survey Plan, the existing culvert is a corrugated steel round pipe 3.8 m diameter, approximately 35 m in length, and constructed in 1985. At the culvert location, the highway embankment is approximately 6.6 m in height with some 3.5 m of earth fill above the culvert. The grade of Highway 622 at the centreline of the existing culvert was shown at an approximate Elevation 431.8 m. The culvert invert was indicated at Elevation 424.3 m at the inlet and Elevation 424.6 m at the outlet with the Moose Creek water level measured at Elevation

426.1 m in April 2016.

The General Arrangement drawing and information on the culvert design was not available at the time of preparation of this report. However, it is understood that the invert and alignment of the replacement culvert will remain the same as of the existing culvert and no grade raise or embankment widening will be required at the culvert location. No wingwalls/headwalls are present at the existing culvert and it is not known if any wingwalls/headwalls will be required for the replacement culvert.

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

9. CULVERT DESIGN

9.1 Culvert Alternatives

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising gravelly sand to gravel containing cobbles and boulders (possibly rockfill), underlain by a deposit of loose to dense silt containing varying proportions of sand.

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

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

- Concrete pipe or Corrugated steel pipe (CSP);
- Concrete box (closed) culvert composed of pre-case segments;
- Concrete open frame culvert on spread footings.

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F. From a foundation and constructability perspective, the use of CSP or precast concrete box culverts are preferred over the open footing option, based on the following considerations:

- Precast concrete box or pipe culverts would require shallower excavation compared with the open footing culvert;

- Precast concrete box or pipe segments can typically be installed more expeditiously than cast-in-place open footing culverts, resulting in shorter durations of dewatering operations and construction time; and
- Precast concrete box or pipe culverts are generally more tolerant of differential settlement along the culvert.

The open footing culvert is not recommended at this site due to the low available bearing capacity in the shallow foundation silt, the need for deeper excavation and additional dewatering effort during construction, as well as, potential for differential settlement between footings.

Recommendations for design and installation of concrete pipe or CSP and concrete box culverts are presented below.

9.2 Foundation Design for Culverts

The invert level of the existing culvert is at approximate Elevation 424.3 m to 424.6 m. The founding soils encountered at this level consist of loose to compact silts and sands. It is anticipated that the invert level of the replacement culvert will be similar to the invert of the existing culvert and no grade raise or embankment widening is proposed. There is approximately 3.5 m of fill above the existing culvert.

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

9.2.1 Concrete Pipe or Corrugated Steel Pipe Culvert

Replacement of the culvert with a concrete pipe or CSP on the same alignment may be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

If this alternative is selected, the concrete pipe or CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 424 m, which corresponds to compact silts and sands subgrade. Very loose to loose silt to sandy silt deposit was encountered in some boreholes within 0.5 to 1.0 m of this elevation. If similar soil conditions are encountered during subgrade preparation, the very loose to loose silts and sands deposit should be sub-excavated by at least 500 mm and replaced with compacted granular material to provide a uniformly competent subgrade condition. A geotextile separation layer should be used between the subgrade silt and the granular backfill or bedding granular.

9.2.2 Concrete Box Culvert

Replacement of the culvert with a concrete box culvert on the same alignment is considered a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

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 should be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation should be carried out in the dry. The subgrade surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 424 m, which corresponds to compact silts and sands subgrade. Very loose to loose silt to sandy silt deposit was encountered in some boreholes within 0.5 to 1.0 m of this elevation. If similar soil conditions are encountered during subgrade preparation, the very loose to loose silts and sands deposit should be sub-excavated by at least 500 mm and replaced with compacted granular material to provide a uniformly competent subgrade condition.

The following geotechnical resistances could be used for preliminary design of a 4 m and a 5 m wide box culvert founded at or below Elevation 424 m on compact silt subgrade:

Geotechnical Resistance	4 m wide Culvert	5 m wide Culvert
Factored Geotechnical Resistance at ULS	225 kPa	250 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	150 kPa	140 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Section 6.9.

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

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

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

9.2.3 Culvert Headwalls

If headwalls or wingwalls are proposed for 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.

Alternatively, extension of the culvert (either CSP or concrete box) beyond the embankment toes could be considered to avoid the headwall/wingwall construction.

The borehole information indicates that the founding conditions at the inlet and outlet generally consist of loose to compact silts and sands. Very loose to loose silt to sandy silt deposit was encountered in borehole 16-25 and 16-28 near the existing culvert ends. If similar soil conditions are encountered during subgrade preparation, the very loose to loose silts and sands deposit should be sub-excavated by 500 mm and replaced with compacted granular material to provide a uniformly competent subgrade condition. A geotextile separation layer should be used between the subgrade silt and the granular fill.

9.2.3.1 RSS Walls

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

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

The RSS mass should be founded on a minimum 0.5 m thick engineered fill layer resting on the native sand and silt subgrade at or below an approximate elevation of 422.0. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 225 kPa and a geotechnical reaction at SLS of 150 kPa (for up to 25 mm of settlement). Engineered fill layer placed under the RSS mass should consist of OPSS.PROV Granular A or Granular B Type II compacted to 100 percent of its SPMDD at a moisture content within 2 percent of optimum. The engineered layer should extend at least 300 mm beyond the limits of the RSS mass and levelling strip.

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

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

Topsoil, 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 should be carried out in the dry.

A geotextile filter fabric should be incorporated in the RSS design to prevent loss of fines from the granular material behind the wall subject to fluctuating water levels.

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

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

9.2.3.2 Foundation for Concrete Walls

Any concrete headwalls, if required, may be supported on spread footings founded on the compact sands and silts subgrade. Any organic or soft soil should be removed from the wall subgrade and replaced with granular fill compacted as per OPSS.PROV 501. The walls should be provided with sufficient frost cover and founded at Elevation 422.0 m or lower. A factored geotechnical resistance at ULS of 225 kPa and a geotechnical reaction at SLS of 150 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The concrete retaining wall should be designed against various modes of failure including translation and overturning. Resistance to sliding between precast concrete footing and the underlying native silty clay should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for compact silt/sandy silt.

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

9.3 Settlement and Stability

It is anticipated that the replacement culvert will be constructed approximately on the same alignment and with similar opening size as the existing culvert with no grade raise on the overlying embankment or embankment widening. Therefore, changes in the loading conditions on the foundation soils consisting of loose to compact sands and silts are not expected to be significant. The post construction settlements after culvert construction and embankment reconstruction at this site are estimated to be less than 25 mm. The post-construction settlements will essentially be complete at the end of construction.

Considering the subsurface conditions and the embankment height up to 6.6 m above the culvert invert, the granular fill embankment will be stable at side slopes inclined at 2 horizontal to 1 vertical, or flatter.

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m. Frost cover/protection is not required for the pipe and box culverts.

The frost taper investigation in Boreholes 16-29 and 16-30 indicated the presence 6.1 m of gravelly sand and gravel fill extending at least 15 m away from the culvert to the northeast and southwest.

As the top of the CSP or box culvert will be below the depth of frost penetration, frost treatment or a frost taper will not be required.

10. LATERAL EARTH PRESSURES

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

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

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

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

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

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

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

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

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

11. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site includes very loose to compact silts and sands. The harmonic mean of the typical N_{60} values is between 15 blows and 50 blows, which corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for 2 percent in 50 year probability of exceedance at this site is 0.042 g as per the National Building Code of Canada (NBCC).

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

Table 11.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.51	0.55

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

** After Woods

The presence of very loose to loose saturated silts and sands should be considered as prone to liquefaction; however, in view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

12. CULVERT CONSTRUCTION CONSIDERATIONS

12.1 Subgrade Preparation

Performance of the replacement culvert 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, peat, organic creek bed deposits, disturbed soils and any deleterious materials within the footprint of the replacement culvert should be removed and replaced with granular material compacted as per OPSS.PROV 501. The topsoil noted in Boreholes 16-25 and 16-28 drilled immediately outside of the embankment toes, and any organic or deleterious materials, if encountered, should be removed from the footprint of the culvert excavation to expose the underlying native compact silts and sands.

In the event that subgrade subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.5 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 for Granular A or Granular B Type II placed in accordance with OPSS.PROV.206, and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction and subgrade preparation should be carried out in the dry.

12.2 Bedding and Backfilling

The bedding material should be placed on the prepared subgrade as soon as practical following inspection and approval. The subgrade preparation to receive the bedding material should be carried out in the dry.

Considering high permeability of the embankment and underlying native silts and sands at this site, there is a potential for groundwater seepage and surface water flow at the subgrade and bedding level. In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the proposed pipe or box culvert. This is in addition to any foundation subexcavation to remove loose soils which will be replaced by granular backfill.

Bedding requirements should follow OPSS 802.014 (Flexible Pipe Embedment in Embankments) for CSP pipe culvert, and OPSS 803.010 (Backfill and Cover for Concrete Box Culverts) for box culvert. In addition, the surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A, as per OPSS 422.

The bedding materials should be compacted as specified in OPSS.PROV 501.

A separation layer consisting of a non-woven geotextile should be placed between the subgrade soil and the underside of the bedding material. The geotextile should meet the specifications for OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres.

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

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. Existing rockfill may be used as backfill as long as the rock sizes are less than 300 mm diameter. Sorting of the existing rockfill may be required to remove pieces that are larger than 300 mm diameter. The surface of the rockfill should be chinked below the pavement base, and the rockfill should be compacted as per OPSS 206. If sorting of the rockfill is not practical, then imported granular fill is recommended. Reference should be made to the backfill arrangements stipulated in OPSS 802.014 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 421 for a CSP and OPSS 422 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 400 mm on both sides of the culvert at all times. Heavy compaction equipment

should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

12.3 Excavation and Groundwater Control

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silts and sands at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits and peat that are anticipated in the inlet and outlet areas should also 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 will extend into the native silts and sands deposit. Moreover, excavations for culvert replacement will be carried out below the creek water level, and diversion of the creek flow will be required. Given the relatively high permeability of the embankment fill materials and native silts and sands, seepage should be anticipated from the embankment fill and the native silts and sands adjacent to the creek. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with the use of well points/relief wells within an enclosure will be required to maintain relatively dry excavations during the course of staged construction. Cofferdams should be designed in accordance with OPSS 539 by a licensed Professional Engineer experienced in shoring design. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native silt soils. Dewatering of all excavation should be carried out in accordance with OPSS. PROV 517.

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

13. STREAM DIVERSION PIPE

A temporary CSP stream diversion pipe may be required to accommodate creek water flow during culvert replacement. The invert of the diversion pipe may be assumed to be near the invert of the existing culvert.

The temporary CSP should be placed on a minimum 150 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements 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 should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

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

14. TEMPORARY PROTECTION SYSTEM

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

It will be difficult to drive sheet piles through the embankment fill due to the presence of cobbles and boulders or possible rockfill. Drilled-in soldier piles may be required for roadway protection. The soil parameters in the table below may apply for design of the temporary roadway protection system with horizontal backfill.

Soil Parameter	Existing Fill	Native Silts and Sands
Bulk Unit Weight (γ)	20 kN/m ³	20 kN/m ³
Submerged Unit Weight (γ_w)	10 kN/m ³	10 kN/m ³
Coefficient of Active Earth Pressure (K_a)	0.33	0.33
Coefficient of Passive Earth Pressure (K_p)	3.0	3.0

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

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 wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

15. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slope should remain stable. As discussed in Section 9.3, if all very loose to loose soils are removed from under the culvert footprint, settlement of the embankment under the existing culvert footprint should be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Existing rockfill may be used as embankment fill as long as the rock sizes are less than 300 mm diameter. Sorting of the existing rockfill may be required to remove pieces that are larger than 300 mm diameter. The surface of the rockfill should be chinked below the pavement base, and the rockfill should be compacted as per OPSS 206. If sorting of the rockfill is not practical, then imported granular fill is recommended.

Fill placement along the culvert should follow the requirements of OPSD 208.010 (Benching of Earth Slopes) to integrate the existing and new embankment fill.

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

16. 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.

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

17. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested.
- The potential for soil or surface water corrosion on metal is considered to be mild.
- Corrosion consideration from the use of road salt should be considered.

18. CONSTRUCTION CONCERNS

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

- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- 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. Suggested wording for an NSSP on groundwater and dewatering is included in Appendix E.
- Cobbles, boulders, possible rockfill or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix E.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19. CLOSURE

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

Thurber Engineering Ltd.

Anna Piascik, P.Eng
Senior Geotechnical Engineer



Mark Farrant, P.Eng.
Geotechnical Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 16-25

1 OF 1

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 230.4 E 400 573.0 ORIGINATED BY TM
 HWY 622 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.09.10 - 2016.09.10 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
426.4	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL: (200mm)							20	40	60	80	100					
0.2	SILT, trace sand to sandy, trace clay, trace gravel, occasional cobbles and boulders Loose to Very Dense Brown Wet		1	SS	2		426										
			2	SS	4		425										
			3	SS	9		424										
			4	SS	3		423										
			5	SS	33		422										
			6	SS	50/ 0.025		421										
420.6			7	SS	50/ 0.150												
5.8	END OF BOREHOLE AT 5.8m DUE TO SPOON REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 3/14/17

RECORD OF BOREHOLE No 16-26

1 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 233.5 E 400 593.6 ORIGINATED BY TS
 HWY 622 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.30 - 2016.09.01 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
431.8	GROUND SURFACE							20	40	60	80	100		
0.0	ASPHALT: (25mm)		1	GS			431							
430.9	Gravelly SAND , trace to some silt, occasional cobbles Compact to Very Dense Moist (FILL) Possible cobble at 0.3m		1	SS	16/ 0.025									33 55 12 (SI+CL)
0.9	ROCKFILL , with sand and gravel Auger refusal at 0.9m, switched to NW Casing and NQ Coring Cobbles and boulders						430							
							429							
			2	SS	50/ 0.100		428							
	590mm diameter boulder noted at 4.3m						427							
426.3							426							
5.5	SILT , trace sand to sandy, trace to some clay, trace gravel Compact to Dense Grey Wet		3	SS	21		425							
							424							
			4	SS	38		423							
							422							
			5	SS	29									0 22 70 8

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-26

2 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 233.5 E 400 593.6 ORIGINATED BY TS
 HWY 622 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.30 - 2016.09.01 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			kN/m ³	GR SA SI CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
	Continued From Previous Page							20	40	60	80	100									
416.0 15.8	SILT, trace sand to sandy, trace to some clay, trace gravel Dense Grey Wet						421														
			6	SS	37																
			7	SS	30																
			8	SS	31																
			9	SS	27																
	END OF BOREHOLE AT 15.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.						416														

ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 3/14/17

RECORD OF BOREHOLE No 16-27

1 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 245.3 E 400 590.0 ORIGINATED BY TM
 HWY 622 BOREHOLE TYPE Solid Stem Augers/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2016.09.08 - 2016.09.08 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
431.7	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (50mm)																	
	Gravelly SAND, trace to some silt, occasional cobbles Very Dense Brown Moist (FILL)		1	SS			431											38 50 12 (SI+CL)
			2	SS	50/ 0.125													
430.2			3	SS	50/ 0.025		430											
1.5	ROCKFILL with sand and gravel Auger refusal at 1.5m, switched to NW Casing and NQ Coring																	
	Cobbles between 1.5m to 2.1m						429											
	Boulders between 3.0m to 4.3m						428											
							427											
	Boulders between 4.9m to 6.7m						426											
425.6							425											
6.1	SILT, trace to some clay, trace sand, trace gravel, decayed wood, rootlets in the upper 1.0m zone Loose to Compact Brown Wet		4	SS	4		424											
							423											
			5	SS	23		422											0 6 84 10

Continued Next Page

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

RECORD OF BOREHOLE No 16-27

2 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 245.3 E 400 590.0 ORIGINATED BY TM
 HWY 622 BOREHOLE TYPE Solid Stem Augers/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2016.09.08 - 2016.09.08 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
	Continued From Previous Page													
415.9 														



ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 3/14/17

RECORD OF BOREHOLE No 16-28

1 OF 1

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 245.4 E 400 613.0 ORIGINATED BY TM
 HWY 622 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.09.09 - 2016.09.09 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
426.4	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (200mm)							20	40	60	80	100						
0.2	Gravelly SAND , some silt, trace organics, trace rootlets, decayed wood		1	SS	6		426										34 56 10 (SI+CL)	
425.6	Compact Brown Wet (FILL)																	
0.8	Sandy SILT , trace to some gravel, trace clay, trace organics, rootlets, decayed wood in the upper 0.5m zone, occasional cobbles		2	SS	16		425										16 36 43 5	
	Hard Brown Wet																	
				3	SS	5		424										
				4	SS	5		423										
			5	SS	30/ 0.025		422										0 33 61 6	
420.8	END OF BOREHOLE AT 5.6m UPON SPOON REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.		6	SS	50/ 0.150		421											

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-29

2 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 251.5 E 400 581.0 ORIGINATED BY TS
 HWY 622 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.30 - 2016.08.31 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
	Continued From Previous Page		3	SS	27									
	SILT, trace to some clay, trace sand, trace gravel Compact to Dense Grey Wet						421							
							420							
		4	SS	36										
			5	SS	33									
418.0							418							
13.7	END OF BOREHOLE AT 13.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS THEN ASPHALT COLD PATCH TO SURFACE.													

RECORD OF BOREHOLE No 16-30

1 OF 2

METRIC

WP# 6845-14-01 LOCATION Moose Creek Culvert N 5 417 227.1 E 400 602.8 ORIGINATED BY TM
HWY 622 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2016.09.07 - 2016.09.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE											
431.8	GROUND SURFACE																		
0.0	ASPHALT: (50mm)		1	SS															
	Gravelly SAND , some silt, occasional cobbles																		
	Compact to Very Dense																		
430.9	Brown Moist (FILL)		2	SS	50/0.125														
0.9	ROCKFILL , with sand and gravel																		
	No recovery Auger grinding on boulder		3	SS	50/0.125													No recovery	
	Boulders from 1.5m to 5.5m																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE
	Continued From Previous Page		NUMBER	TYPE	"N" VALUES
	SILT , trace to some sand to sand and silt, trace to some clay Dense Grey Wet		7	SS	44
			8	SS	36
			9	SS	36
			10	SS	14
416.0	END OF BOREHOLE AT 15.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS, THEN TOPPED WITH ASPHALT COLD PATCH TO SURFACE.				
15.8					

+³, ×³: Numbers refer to Sensitivity



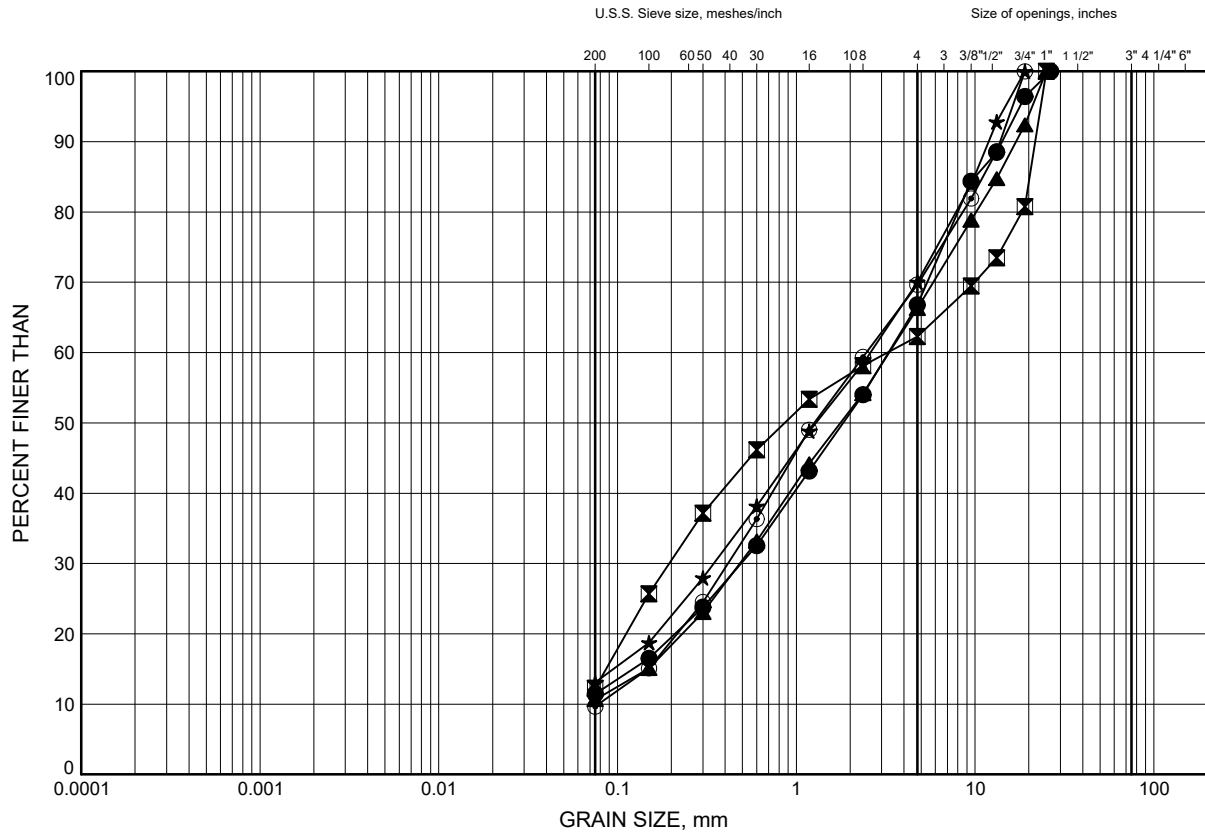
Appendix B

Geotechnical and Analytical Laboratory Test Results

Moose Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-26	1.00	430.80
⊠	16-27	0.30	431.40
▲	16-28	0.30	426.10
★	16-29	0.30	431.40
⊙	16-30	1.07	430.73

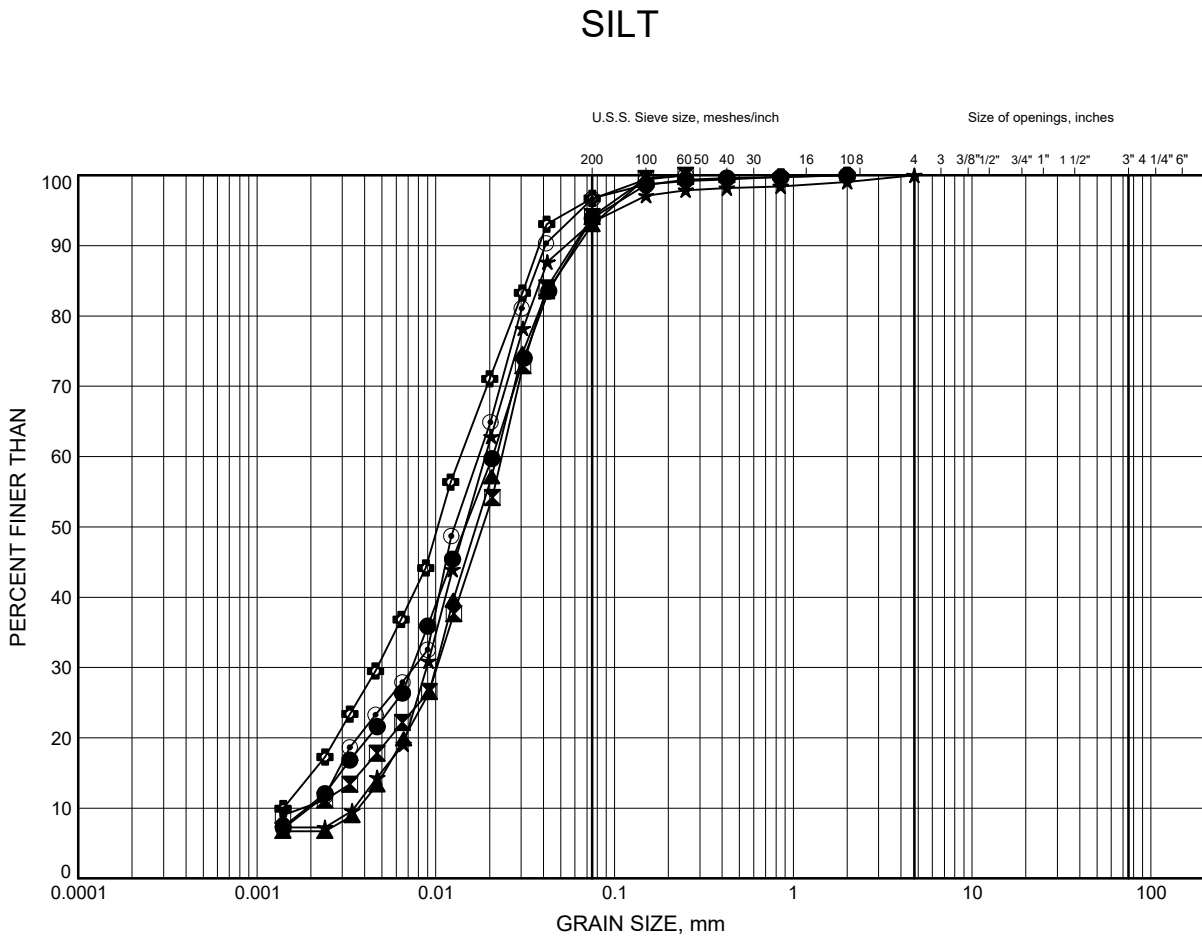
Date March 2017
WP# 6345-14-01



Prep'd AN
Chkd. AMP

Moose Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-26	14.02	417.78
⊠	16-27	9.45	422.25
▲	16-27	12.50	419.20
★	16-29	10.97	420.73
⊙	16-30	10.97	420.83
⊕	16-30	14.02	417.78

Date March 2017
WP# 6345-14-01

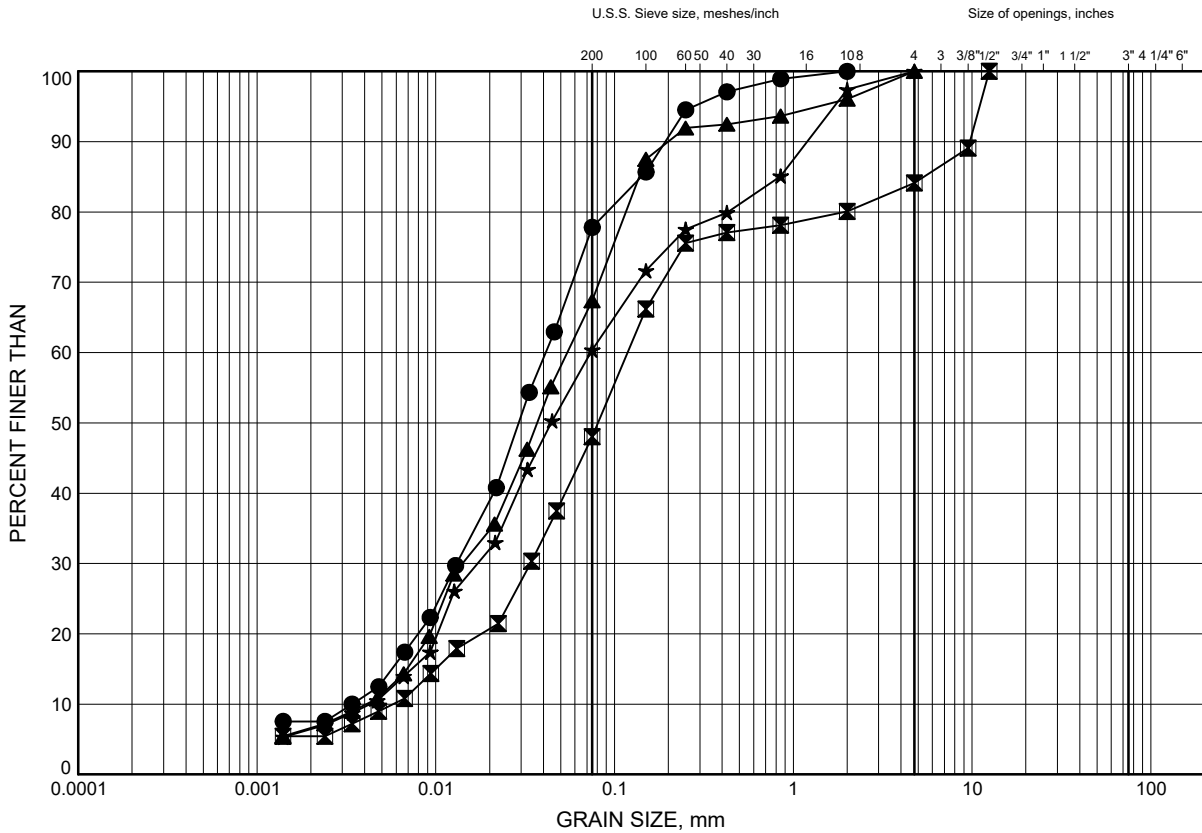


Prep'd AN
Chkd. AMP

Moose Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy SILT to SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-26	9.45	422.35
⊠	16-28	1.52	424.88
▲	16-28	4.67	421.73
★	16-30	7.92	423.88

Date March 2017
WP# 6345-14-01



Prep'd AN
Chkd. AMP

**SGS Canada Inc.**

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

Project : 13983**22-September-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

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

Phone: 905-829-8666 x 228
Fax:


Date Rec. : 16 September 2016
LR Report: CA14401-SEP16
Reference: 13983 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: 16-26 SS#3 20'-22'
Sample Date & Time					12-Sep-16
Temperature Upon Receipt [°C]	---	---	---	---	9.0
Corrosivity Index [none]	21-Sep-16	16:51	21-Sep-16	16:51	1
pH [no unit]	19-Sep-16	10:18	19-Sep-16	13:26	6.62
Soil Redox Potential [mV]	19-Sep-16	16:42	20-Sep-16	10:53	224
Sulphide [%]	21-Sep-16	11:12	21-Sep-16	11:40	< 0.02
% Moisture (wet wt) [%]	21-Sep-16	07:55	21-Sep-16	08:50	15.6
pH [no unit]	19-Sep-16	06:59	20-Sep-16	10:41	6.77
Chloride [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	39
Sulphate [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	8.3
Conductivity [µS/cm]	19-Sep-16	06:59	20-Sep-16	10:42	58
Resistivity (calculated) [Ohms.cm]	21-Sep-16	10:49	21-Sep-16	10:49	17200


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



SGS Canada Inc.

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

Project : 13983

LR Report : CA14401-SEP16

Temperature of Samples upon receipt 15 degrees C
No cooling agent present

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.

Temperature of Samples upon receipt 9 degrees C
Cooling agent present
Custody Seal not present

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

Project : 13983**LR Report :** CA14401-SEP16

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

Project : 13983

LR Report : CA14401-SEP16

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 (%)
						%	Low	High		Low	High	
Anions by IC - QCBatchID: DIO0260-SEP16												
Chloride	0.4	µg/g	<0.4		1	20	107	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		0	20	101	80	120	100	75	125
Carbon/Sulphur - QCBatchID: ECS0026-SEP16												
Sulphide	0.02	%	<0.02		4	20	106	80	120			
Conductivity - QCBatchID: EWL0235-SEP16												
Conductivity	2	uS/cm	< 2		ND	10				NA		
pH - QCBatchID: ARD0047-SEP16												
pH	0.05	no unit			0	20	100	80	120			

**SGS Canada Inc.**

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

Project : 13983**Thurber Engineering Ltd.****Attn : Mark Farrant**

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

Phone: 905-829-8666 x 228
Fax:

17-November-2016

Date Rec. : 19 September 2016**LR Report:** CA13496-SEP16**Reference:** 13983 Mark Farrant**Copy:** #1

CERTIFICATE OF ANALYSIS

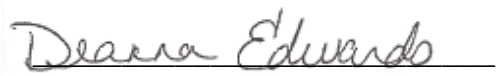
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Moose Creek Culvert
Sample Date & Time						09-Sep-16 10:00
Temperature Upon Receipt [°C]	---	---	--	--	---	19.0
pH [no unit]	20-Sep-16	07:23	21-Sep-16	11:11	0.05	6.05
Conductivity [µS/cm]	20-Sep-16	07:23	21-Sep-16	11:11	2	17
Resistivity (calculated) [Ohms.cm]	21-Sep-16	21-Sep-16			---	5880
Redox Potential [mV]	19-Sep-16	16:42	20-Sep-16	10:53	---	203
Chloride [mg/L]	20-Sep-16	07:42	21-Sep-16	10:05	0.04	0.52
Sulphate [mg/L]	20-Sep-16	07:42	21-Sep-16	10:05	0.04	0.31
Sulphide [mg/L]	20-Sep-16	11:00	21-Sep-16	09:09	0.006	< 0.006
Corrosivity Index [none]	21-Sep-16	11:48	21-Sep-16	11:48		< 1

Temperature of samples upon receipt 19 degrees C
Cooling Agent Present
Custody Seal Present and Intact

Sulphide bottle received broken, solution from the general bottle containing zero headspace was used to fill a new Sulphide bottle.

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

**SGS Canada Inc.**

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

Project : 13983**LR Report :** CA13496-SEP16**Method Descriptions**

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



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

Project : 13983

LR Report : CA13496-SEP16

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: DIO0257-SEP16												
Chloride	0.04	mg/L	<0.04		4	20	100	80	120	104	75	125
Sulphate	0.04	mg/L	<0.04		7	20	95	80	120	103	75	125
Conductivity - QCBatchID: EWL0255-SEP16												
Conductivity	2	µS/cm	< 2		0	10	99	90	110	NA		
pH - QCBatchID: EWL0255-SEP16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0252-SEP16												
Redox Potential	no	mV	NA		9	20	100	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0137-SEP16												
Sulphide	0.006	mg/L	<0.006		100	20	90	80	120	99	75	125



Appendix C

Selected Site Photographs



Photograph 1 –Moose Creek, looking west



Photograph 2 – East end of the existing culvert

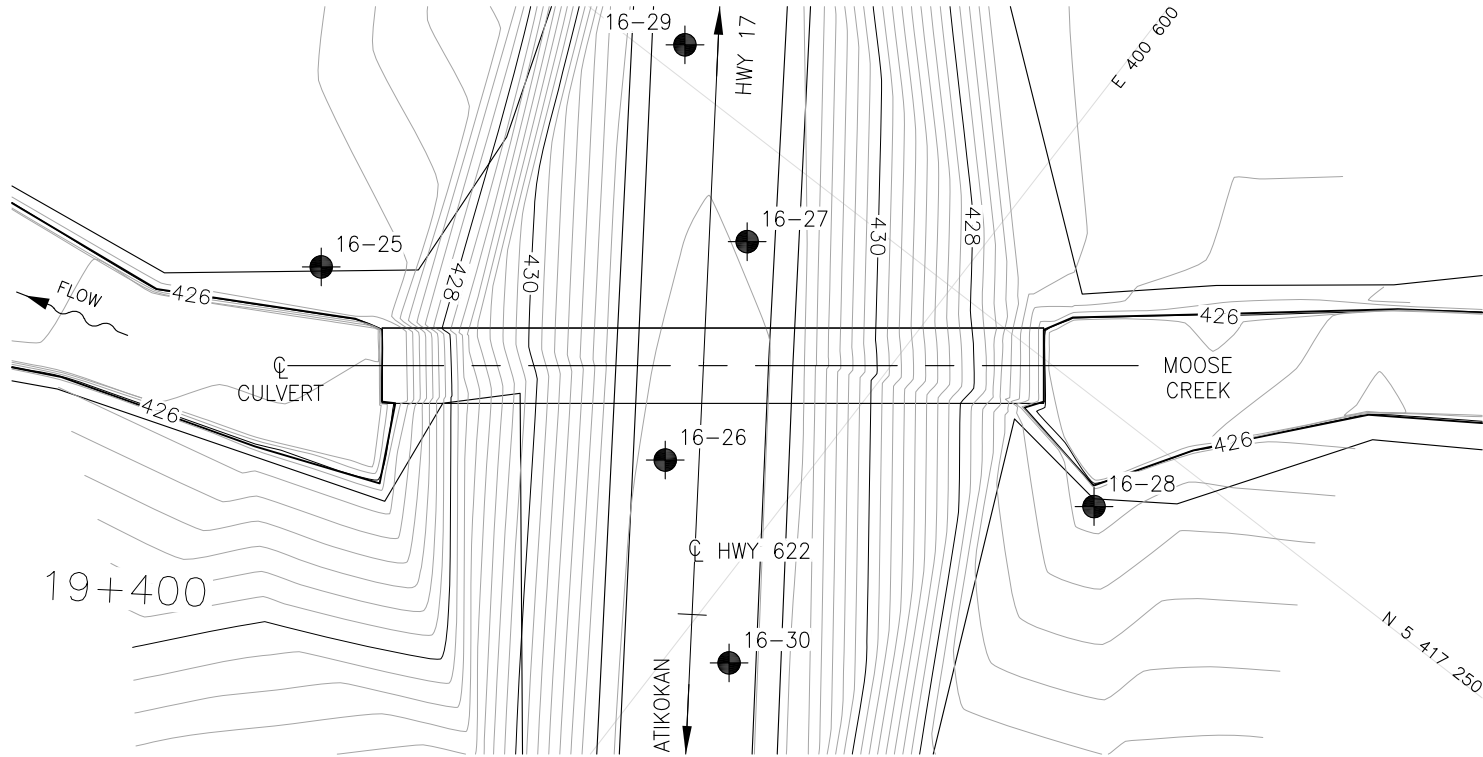


Photograph 3 –Rock fill at the toe of the embankment near the existing culvert

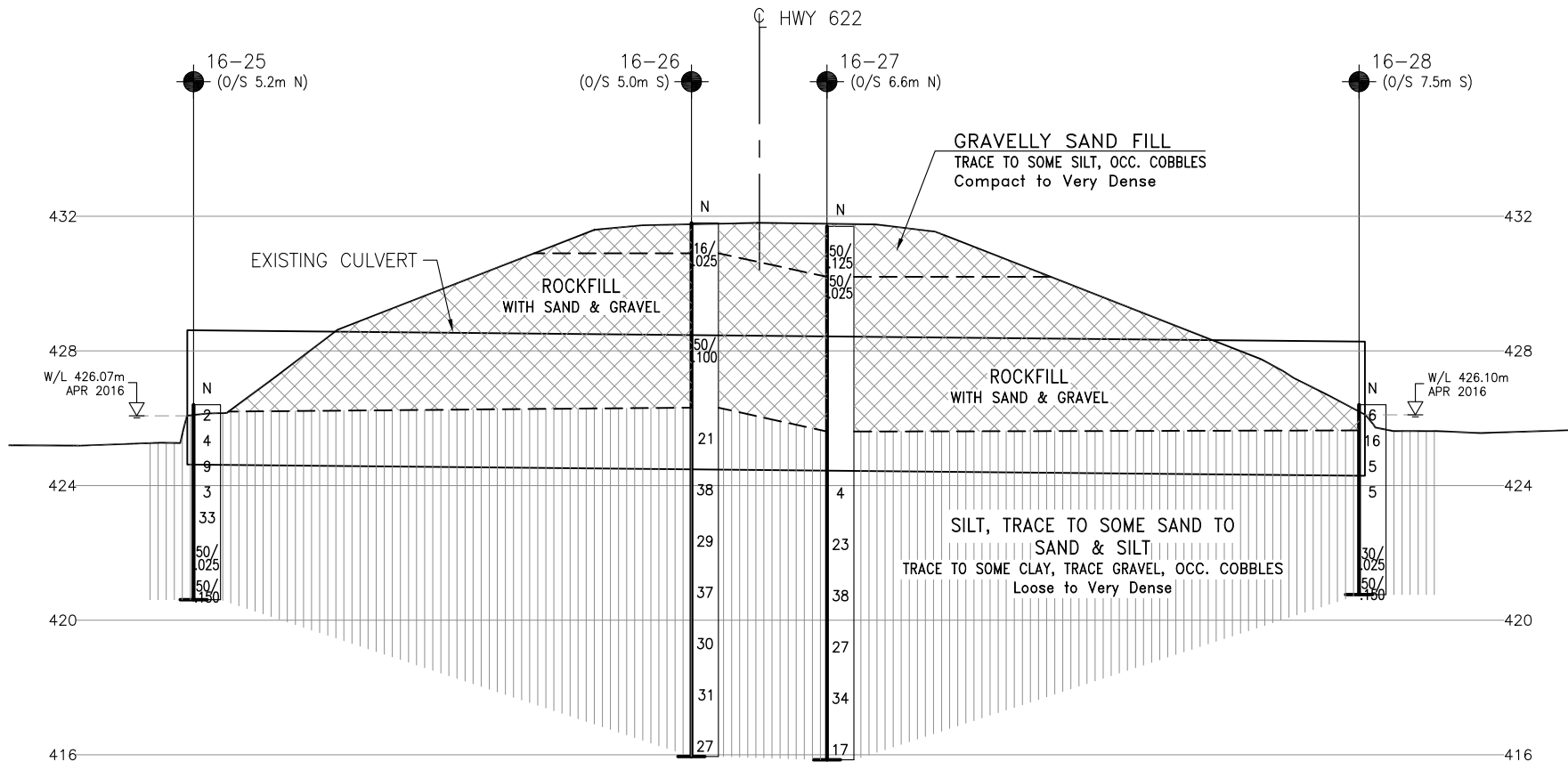


Appendix D

Borehole Locations and Soil Strata Drawing



PLAN
SCALE 1:400



SECTION ALONG CULVERT
SCALE 1:200

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



CONT No
WP No 6845-14-01

HIGHWAY 622
MOOSE CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

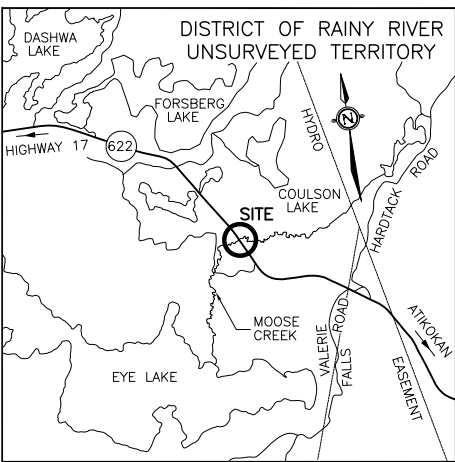


SHEET
10

HATCH



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
- W
Water Level
- W
Head Artesian Water
- P
Piezometer
- 90%
Rock Quality Designation (RQD)
- A/R
Auger Refusal

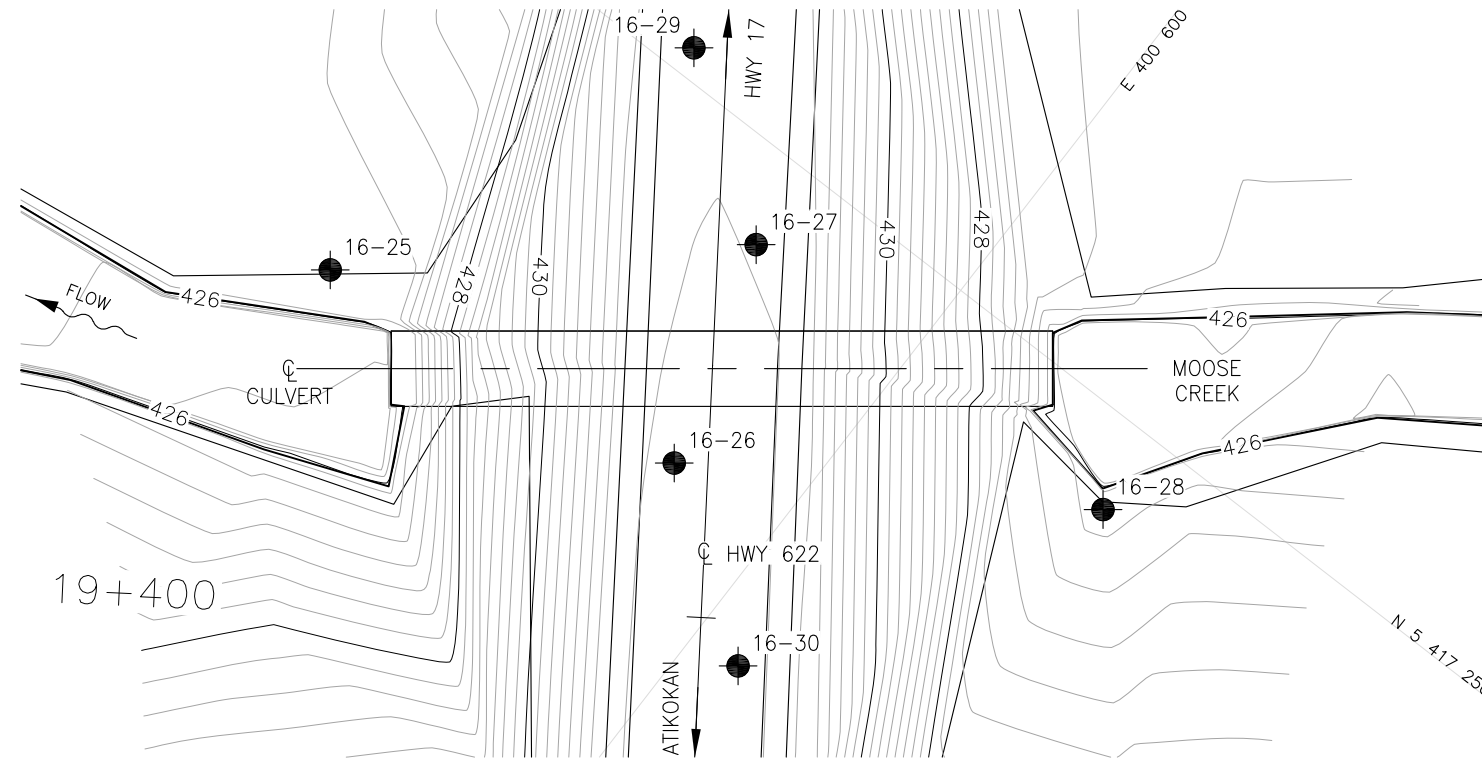
NO	ELEVATION	NORTHING	EASTING
16-25	426.4	5 417 230.4	400 573.0
16-26	431.8	5 417 233.5	400 593.6
16-27	431.7	5 417 245.3	400 590.0
16-28	426.4	5 417 245.4	400 613.0
16-29	431.7	5 417 251.5	400 581.0
16-30	431.8	5 417 227.1	400 602.8

-NOTES-

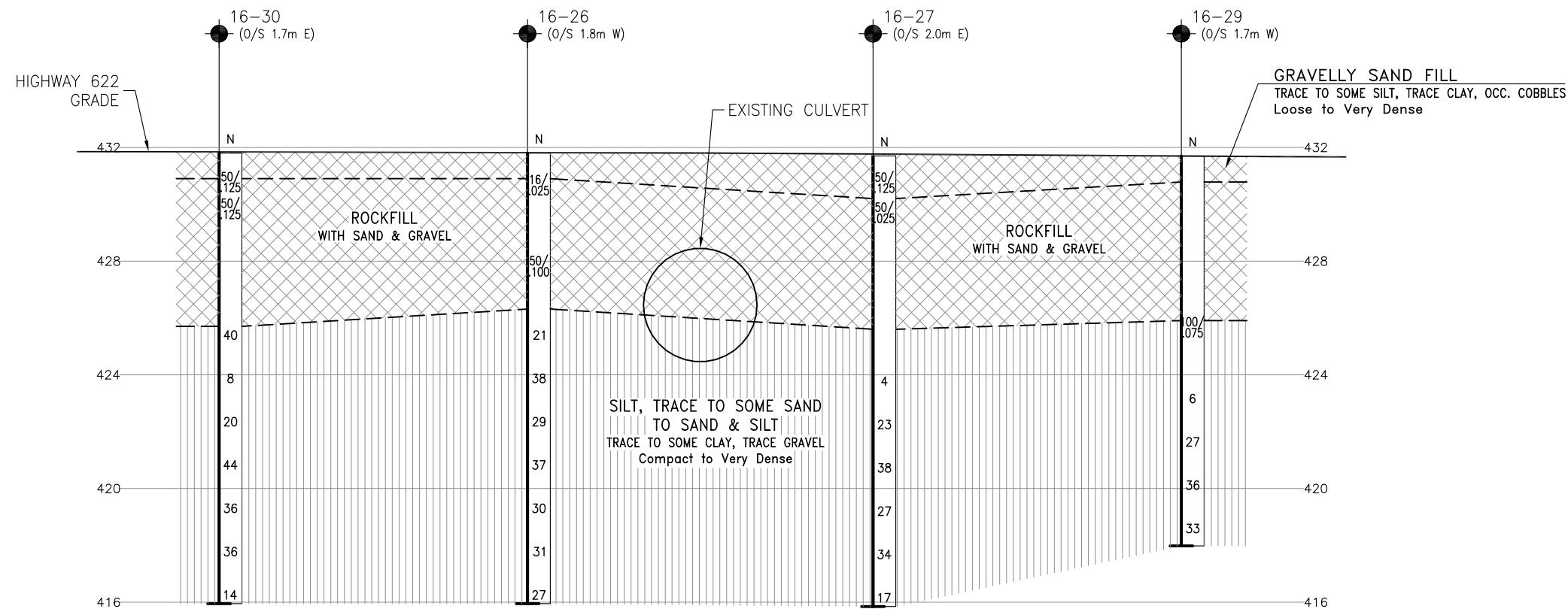
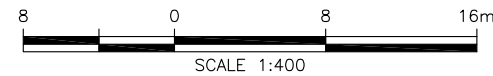
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- MTM, Zone 16 co-ordinate system was used to obtain borehole Northings and Eastings.

GEOCRES No. 52B-31

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AMP	CHK AEG	CODE
DRAWN	AN	CHK AMP	SITE
LOAD	DATE	MAR 2017	
STRUCT	DWG	2	



PLAN

SECTION ALONG \mathbb{C} HIGHWAY 622

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



CONT No
WP No 6845-14-01



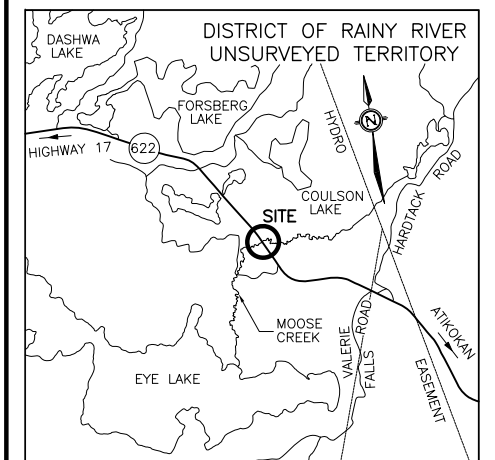
HIGHWAY 622
MOOSE CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
11

HATCH








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
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-25	426.4	5 417 230.4	400 573.0
16-26	431.8	5 417 233.5	400 593.6
16-27	431.7	5 417 245.3	400 590.0
16-28	426.4	5 417 245.4	400 613.0
16-29	431.7	5 417 251.5	400 581.0
16-30	431.8	5 417 227.1	400 602.8

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) MTM, Zone 16 co-ordinate system was used to obtain borehole Northings and Eastings.

GEOCRES No. 52B-31

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	AMP	CHK	AEG	CODE	LOAD		DATE	MAR 2017	
DRAWN	AN	CHK	AMP	SITE	STRUCT		DWG	3	



Appendix E

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 421
- OPSS PROV 422
- OPSS PROV 501
- OPSS.PROV 517
- OPSS PROV 539
- OPSS PROV 804
- OPSS PROV 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSS 1860
- OPSD 208.010
- OPSD 802.010
- OPSD 802.014
- OPSD 802.034
- OPSD 803.010

2. Suggested Wording for NSSP

- Suggested Text for NSSP on “Obstructions”

“The existing embankment at the Moose Creek Culvert site contains rockfill with cobbles and boulders, which may impede excavation progress. The Contractor shall be prepared to handle

such materials. The presence of rockfill in the embankment may also preclude the use of sheet piles for roadway protection. The Contractor shall select a suitable type of roadway protection that can be installed through rockfill."

- **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. "



Appendix F

Comparison of Alternative Culvert Types

COMPARISON OF ALTERNATIVE CULVERT TYPES

Proposed Works	Concrete Box (Closed) Culvert	Concrete Open Footing Culvert	Concrete Pipe or Corrugated Steel Pipe Culvert
Culvert Replacement	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if precast units are used. ii. Less requirement for geotechnical resistances as loading is spread over a larger width. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. More expensive than Concrete Pipe or CSP CSA alternatives. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively rapid installation if precast units are used. ii. May have less environmental issues such as those involving spawning fish species. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Requires higher soil geotechnical resistances to support strip footings. ii. Requires deeper excavation for strip footing construction. iii. Potentially more stringent unwatering requirements. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Concrete or Steel pipes may be more cost effective than concrete box or open footing culverts. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. May have shorter design life than concrete box or open footing culvert.
	FEASIBLE	NOT RECOMMENDED	FEASIBLE