



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
RAINY RIVER TRIBUTARY NO. 2 CULVERT REPLACEMENT
HIGHWAY 602
RAINY RIVER DISTRICT, ONTARIO**

G.W.P. No. 6602-15-00, SITE No. 45-280/C

GEOCRES Number: 52C-50

Report

to

HATCH

Date: December 21, 2016
File: 13372/15760



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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 Rainy River Tributary No. 2 Culvert on Highway 602, located in the geographical Township of Roddick, near Fort Frances, 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 to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-002.

2. SITE DESCRIPTION

The site is located on Highway 602, approximately 12 km south of Highway 11, in the geographical Township of Roddick, Ontario. The culvert allows Rainy River Tributary No. 2 to flow from north to south under Highway 602 towards Rainy River. Highway 602 generally runs in an east-west direction at the culvert site.

The Terms of Reference indicates that the existing structure is a 15.4 m long, 3 m span, single cell open footing concrete box culvert, with a height of fill of 2.5 m above the culvert. An Ontario Structure Inspection Manual (OSIM) report prepared in 2015 notes severe wide cracking up to 170 mm wide through the foundation and continued settlement, and that the structure was considered to be in overall poor condition. Ongoing patching work has been required to address settlement of the structure. Photographs provided by Hatch of the interior of the culvert show that

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significant scour has occurred along and below the concrete footings of the culvert (Photo 5 in Appendix D). The scour and erosion of the foundation subgrade has likely led to push out of the culvert walls and settlement of the structure. The culvert was reportedly constructed in 1937.

The grade level of Highway 602 at the existing culvert is at an approximate Elevation of 337 m.

Naturally low-lying areas are present near the inlet and outlet of the culvert, with vegetation consisting of grass, shrubs and frequent trees. Photographs in Appendix D show the general nature of the site and the existing culvert, as well as foundation scour and cracks.

Based on published geological information, the culvert lies within an area of glaciomarine deposits of silt and clay, with minor sand basin and quiet water deposits. The bedrock at the site consists of metasedimentary rocks.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out from July 19 to 22, 2016, and consisted of drilling and sampling four (4) boreholes, designated as Boreholes 16-01 to 16-04. Boreholes 16-01 and 16-04 were located near the culvert inlet and outlet respectively. Both boreholes were advanced near the base of the highway embankment. Boreholes 16-02 and 16-03 were advanced through the Highway 602 embankment, near the existing culvert alignment.

An additional borehole investigation was carried out for a sheet-pile abutment culvert option between October 23 and 25, 2016, consisting of drilling two boreholes on the highway shoulders, i.e. 16-02A and 16-03A, in the vicinity of Boreholes 16-02 and 16-03. These two additional boreholes were drilled deeper to Elevation 315.1 m.

Utility clearances were obtained prior to the start of drilling. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 16 was used for the boreholes. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix C.

A portable tripod drill rig was used to advance Boreholes 16-01 and 16-04 using NW casing and wash boring techniques, and a track-mounted CME 55 drill rig was used to advance Boreholes 16-02 and 16-03 using hollow stem augers. Boreholes 16-01 and 16-04 were advanced to depths of 3.7 m until encountering refusal where there was no further penetration of the tripod casing with the wash-bore method. Boreholes 16-02 and 16-03 were advanced to depths of 15.8 m each.



Borehole 16-02 was extended beyond 15.8 m depth by conducting a Dynamic Cone Penetration Test (DCPT) to a depth of 27.4 m. In all boreholes, 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). Field vane shear testing using an MTO 'N' size vane was also carried out in firm cohesive soils.

The additional investigation was carried out using a CME 750 ATV drill rig in conjunction with continuous flight hollow stem augers. Boreholes 16-02A and 16-03A were both advanced with sampling to a depth of 21.9 m. Dynamic Cone Penetration Test (DCPT) was conducted in Borehole 16-03A below the sampled portion to a depth of 34.5 m.

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 on completion of drilling in general accordance with Ontario Regulation 903.

Completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
16-01	3.7 / 328.9	Bentonite holeplug from 3.7 m to ground surface.
16-02	15.8 / 321.2	Bentonite holeplug and cuttings from 15.8 m to 0.1 m, then asphalt patch to ground surface.
16-02A	21.9 / 315.1	Bentonite holeplug, dry concrete and asphalt patch to ground surface.
16-03	15.8 / 321.2	Bentonite holeplug and cuttings from 15.8 m to 0.1 m, then asphalt patch to ground surface.
16-03A	21.9 / 315.1	Bentonite holeplug, dry concrete and asphalt patch to ground surface.
16-04	3.7 / 328.9	Bentonite holeplug from 3.7 m to ground surface.



4. LABORATORY TESTING

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing embankment fill near the culvert elevation, and a sample of the surface water from the tributary 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 C. 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 bituminous surface treatment overlying granular fill and silty clay fill, which was in turn underlain by native soil consisting of silty clay. Topsoil was also noted at the surface of the boreholes located at the base of the embankment. Descriptions of the individual strata are presented below.

5.1 Bituminous Surface Treatment

Boreholes 16-02 and 16-03 were drilled through the existing lanes on Highway 602, which contained bituminous surface treatment at the ground surface. The surface treatment thickness measured in the boreholes was 50 mm.

5.2 Granular Fill

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Granular fill ranging in composition from sand with some gravel to gravelly sand was encountered below the surface treatment in Boreholes 16-02 and 16-03 and at the ground surface in 16-02A and 16-03A. The granular fill ranged in thickness from 1.3 to 2.3 m, and extended to depths ranging from 1.4 to 2.3 m (Elev. 334.7 to 335.6 m). SPT 'N' values within the granular fill ranged from 6 to 23 blows per 0.3 m penetration, indicating a loose to compact relative density.

The measured moisture content of the granular fill ranged typically from 3% to 12%. The results of grain size analyses conducted on four samples of the fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B1 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	12 to 34
Sand	57 to 81
Silt and Clay	4 to 10

5.3 Silty Clay Fill

Embankment fill consisting of silty clay that was sandy with trace gravel was encountered below the granular fill in Boreholes 16-02, 16-03, 16-02A and 16-03A. The cohesive fill contained trace rootlets and decayed wood pieces at the top of the layer in 16-02A and 16-03A. The silty clay fill ranged in thickness from 2.3 to 3.5 m, and extended to depths from 4.6 to 4.9 m (Elev. 332.1 to 332.4 m). SPT 'N' values measured in the silty clay fill ranged from 5 to 10 blows per 0.3 m penetration, indicating a firm to stiff consistency.

The measured moisture content of the silty clay fill ranged from 14% to 25%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay fill are presented on the Record of Borehole sheets and on Figures B2 and B5 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0 to 3
Sand	24 to 37
Silt	29 to 39
Clay	29 to 46
Soil Property	Percentage (%)
Liquid Limit	47
Plasticity Limit	20 to 22



5.4 Topsoil / Sandy Silty Clay

The top 0.6 to 0.7 m of native soil at Boreholes 16-01 and 16-04 consisted of topsoil mixed with sandy, silty clay. In Borehole 16-04, the topsoil was underlain by sandy, silty clay with some roots and trace gravel, extending to a depth of 1.4 (Elev. 331.2 m). SPT 'N' values measured in these surficial soils were 5 to 13 blows per 0.3 m penetration, indicating a firm to stiff consistency. Moisture contents of 32 to 34% were measured in the surficial soils.

The results of grain size analyses conducted on two samples of the sandy, silty clay / topsoil are presented on the Record of Borehole sheets and on Figure B3 in Appendix B. The results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	29 to 36
Silt	22 to 35
Clay	36 to 40

The topsoil thickness may vary in other areas of the site and this limited data should not be relied upon for estimating stripping quantities.

5.5 Silty Clay

Underlying the embankment fill and topsoil / sandy silty clay layers, the native soil consisted of silty clay in all of the boreholes. The silty clay contained some sand, trace gravel, and occasional roots and wood fragments immediately below the fill in Borehole 16-03. All six boreholes drilled at the site were terminated within the silty clay at depths ranging from 3.7 to 21.9 m (Elev. 315.1 to 328.9 m). A Dynamic Cone Penetration Test was conducted at the base of Boreholes 16-02 and 16-03A, where cone refusal of greater than 100 blows per 0.3 m penetration was encountered at depths of 27.4 m and 34.5 m (Elev. 309.6 m and 302.5 m), respectively.

Measured SPT 'N' values in the silty clay ranged from 4 to 23 blows per 0.3 m penetration. In conjunction with in-situ field vane tests, which measured undrained shear strengths ranging from 45 to greater than 100 kPa, the silty clay was found to have a typically firm to very stiff consistency.

The measured moisture content of samples recovered from the silty clay ranged from 24% to 38%, with the exception of one sample below the fill, where the presence of organic material (wood and roots) likely contributed to a moisture content of 234%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay are presented on the



Record of Borehole sheets and on Figures B4a, B4b, B6a and B6b in Appendix B. The results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	15 to 19
Silt	22 to 34
Clay	47 to 61
Soil Property	Percentage (%)
Liquid Limit	36 to 52
Plasticity Limit	14 to 25

The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate to high plasticity (CI to CH).

Two incremental loading consolidation tests were carried out on the undisturbed silty clay samples recovered using Shelby Tube samplers. The results of the two consolidation tests are included in Appendix B.

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and the open boreholes were found to be dry upon completion of drilling.

Water level measurements near the inlet and outlet of the culvert were reported on the drawings provided by Hatch, which indicate a creek level at Elevation 332.46 to 332.03 m on April 26, 2016. The groundwater level should be assumed to reflect the local creek water level. These water levels are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the silty clay embankment fill from Borehole 16-03, 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	
			16-03, SS#4, 10'-12'	Rainy River Tributary 2
			(Silty Clay Fill)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.02
Chloride	µg/g	mg/L	43	3
Sulphate	µg/g	mg/L	46	20
pH	No unit	No unit	7.47 – 8.32	7.90
Electrical Conductivity	µS/cm	µS/cm	185	179
Resistivity	Ohms.cm	Ohms.cm	5400	5600
Redox Potential	mV	mV	306	278

7. MISCELLANEOUS

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

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Omar Ali 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 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.



Mark Farrant, P.Eng.
Project Manager, Geotechnical Engineer



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



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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 detailed design of the proposed Rainy River Tributary No. 2 Culvert replacement on Highway 602, in the geographical Township of Roddick, Rainy River District, 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 MTO Plan E-1450-602-1, titled "Crossing at Rainy River Tributary No. 2 and Highway 602", dated May 2016, presenting survey data collected in April 2016. Based on the MTO Terms of Reference, the existing structure is a 15.4 m long, 3 m span, single cell open footing concrete box culvert, with a height of fill of 2.5 m above the culvert. The MTO survey plan shows the top of obvert at approximate Elevation 334.2 m. The culvert invert is shown at approximate Elevation 332 m. The finished road grade at the culvert location is shown at approximate Elev. 337 m, which indicates approximately 5 m of fill above the culvert invert.

An Ontario Structure Inspection Manual (OSIM) report prepared in 2015 notes severe wide

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cracking up to 170 mm wide through the foundation and continued settlement, and that the structure was considered to be in overall poor condition. Ongoing patching has been required to address settlement of the structure. It is anticipated that settlement of the silty clay foundation soils would have occurred after 5 m of embankment fill was placed when the culvert was constructed in 1937, and that this settlement is now complete. The more recent settlement appears to be related to scour and erosion of the foundation, leading to push out of the culvert walls, and settlement of the structure.

The General Arrangement drawing was not available at the time of preparation of this report. Based on discussion with Hatch, the invert and alignment of the replacement culvert will likely remain the same as for the existing culvert, and no grade raise will be required. However, lengthening of the culvert and placement of additional fill may be required to widen the embankment slopes.

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

Selected photographs of the culvert area are included in Appendix D for reference.

9. CULVERT DESIGN

9.1 Culvert Alternatives

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

Based on the Terms of Reference, several culvert replacement options are being considered for this site, as listed below:

- Pre-cast Concrete Box Culvert
- Round Corrugated Steel Pipe (CSP)
- Sheet Pile Walls with Pre-cast Concrete Panels

Recommendations for the design and installation of each of these replacement culvert options are presented below.

A comparison of the advantages and disadvantages of these culvert types is included in Appendix E.



9.2 Foundation Design for Culverts

It is anticipated that the invert level of the replacement culvert will be similar to the invert of the existing culvert. There is approximately 5 m of fill above the existing culvert invert. Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical capacities for the culvert and wingwalls (if required), 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 Box Culvert

If the replacement culvert will be constructed on the same alignment as the existing culvert with no grade raise, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, 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 must be carried out in the dry. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The invert level of the existing culvert is approximately 332 m. Therefore, the underside of the bedding layer should be placed on the undisturbed soils at or below an approximate elevation of 331.6 m. The native soils at that level consist of firm to stiff silty clay.

The following geotechnical capacities could be used for design of a box culvert of 4 to 5 m in width and founded at or below Elev. 331.6 m on the firm to stiff silty clay subgrade:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa.

The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for factored ULS, and 0.8 for SLS, both



adopted for typical degree of understanding, were used to obtain the above values as per CHBDC (2014) Section 6.9.

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

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

Resistance to lateral forces / sliding resistance between the concrete slabs and the underlying Granular A or B Type II 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.

9.2.2 Corrugated Steel Pipe Culvert

Replacement of the culvert with a CSP on the same alignment may be considered for this site. In order to accommodate the hydraulic requirements, multiple pipes may be required. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

If this alternative is selected, the CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per 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 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.

The underside of the bedding layer should be placed at or below Elev. 331.6, which corresponds to firm to stiff silty clay subgrade.

The modulus of subgrade reaction of 15 MN/m^3 could be used in the design of the pipe culverts founded on the native undisturbed silty clay subgrade. It is assumed that all peat,



organics and soft soils will be removed from the pipe subgrade and replaced with granular fill compacted as per OPSS.PROV 501.

9.2.3 Culvert Wingwalls

If wingwalls are required, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant of settlement.

Borehole information indicates that the founding conditions at the wall locations generally consist of the firm to stiff silty clay deposit.

9.2.3.1 RSS Walls

According to the MTO RSS manual, RSS walls at this site may be specified as “Low Performance” and “Low Appearance”. The Ministry may wish to specify a higher performance and appearance level. 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 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.

To provide an acceptable foundation performance, the RSS mass should be founded on a 500 mm thick engineered fill pad resting on the firm to very stiff silty clay subgrade at or below an approximate elevation of 331 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement). Engineered fill pads placed under the RSS mass 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 consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for factored ULS, and 0.8 for SLS, both adopted for typical degree of understanding, were used to obtain the above values as per CHBDC (2014) Section 6.9.



If these geotechnical resistances are not adequate to support the proposed RSS walls, Thurber should be contacted for additional assessment of alternate measures to accommodate an RSS system.

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, 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 must be carried out in the dry.

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

Global stability of the RSS walls will be analyzed if they are selected and when the detailed configurations of the walls are known.

9.2.3.2 Foundation for Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the firm to very stiff silty clay subgrade. Any organic or soft soil must 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 Elev. 331 m or lower. A factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4. If higher geotechnical resistances are required,



the concrete footings may be founded on well-compacted engineered fill pad constructed in the silty clay.

The concrete retaining wall must 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 0.30 for stiff to very stiff silty clay.

Lateral earth pressures acting on the concrete retaining wall 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.

9.2.4 Pre-cast Concrete Panels Supported on Sheet Pile Abutments

A culvert consisting of two parallel sheet pile walls capped with pre-cast concrete panels is considered feasible at this site. The sheet piles will provide containment and resistance to lateral earth pressures from the embankment fill. A preliminary General Arrangement drawing indicates that the streambed level or top of river stone will be at Elevation 331.3 to 331.4 m, and the top of sheet piles or the underside of the concrete panel will be located at Elevation 335.0 m.

9.2.4.1 Axial Resistance of Sheet Piles

Driven steel sheet piles will develop resistance to vertical loads through frictional resistance along the sides of the sheet piles within the native firm to very stiff silty clay.

Hatch indicated that the axial design loads for a SKZ-22 sheet pile section will be in the order of 350 kN/m for ULS and 275 kN/m for SLS. Based on this information, a SKZ-22 section sheet pile driven to Elev. 316 m or 15 m below streambed level is expected to achieve a factored ULS resistance of 350 kN/m width and a SLS resistance of 300 kN/m width.

The SLS values are based on a vertical pile settlement of 25 mm at the base of the embankment fill. Elastic compression of the sheet pile will be in addition to this settlement.

The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for factored ULS, and 0.8 for SLS, both adopted for typical degree of understanding, were used to obtain the above values as per CHBDC (2014) Section 6.9.



Boreholes 16-02 and 16-03 were drilled to Elev. 321.2 m or approximately 5 m above the recommended sheet pile tip elevation, which has triggered the additional investigation to confirm the soil conditions below Elev. 321.2 m. The soil conditions in the two additional deep boreholes 16-02A and 16-03A were found to be similar to those in Boreholes 16-02 and 16-03. The two additional boreholes were advanced to Elev. 315.1 m or approximately 1 m below the recommended tip elevation of the sheet piles.

9.2.4.2 Pile Installation

Pile installation should be in accordance with OPSS.PROV 903.

Sheet piles should be driven to the specified elevation noted above, i.e. 316 m. The appropriate pile driving note is "Sheet piles to be driven to Elevation 316 m". An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

Tip protection should not be used for sheet piles at this site as the load bearing sheet piles will derive vertical resistance almost entirely from shaft friction.

Design of the permanent sheet pile walls must consider environmental conditions such as road salts or fluctuating water levels that may cause long term corrosion and reduce the service life of the structure.

The sheet piles will be driven through the embankment fill. It should be recognized that fill materials including embankment fills are heterogeneous in nature and may contain obstructions such as wood, boulders or rock fill. If such obstructions are encountered at the proposed location of the sheet pile walls, they will have to be removed to facilitate sheet pile installation. Suggested text for an NSSP is included in Appendix G.

9.2.4.3 Lateral Resistance of Sheet Pile Wall

The depth of penetration of the sheet piles will be governed not only by the axial resistance/capacity, but also by the lateral pressure imposed by the soils retained behind the sheet piles. The sheet pile design must satisfy the lateral stability requirement.

The ultimate lateral resistance of a steel sheet pile wall may be assessed using the expression presented in Section 11 and the following earth pressure coefficients:



Table 9.1 – Soil Parameters for Lateral Sheet Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m ³)	K_a	K_o	K_p
	Top	Bottom				
Granular Fill	337	335	21	0.33	0.5	3.0
Silty Clay Fill – above water level	335	332	19	0.41	0.58	2.45
Native Silty Clay – below water level	332	321	9	0.41	0.58	2.45

For soil-spring analysis, the spring constant, K_s , may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³) and L is the length (m) of the pile segment or element used in the analysis. For the firm to stiff silty clay at the site, a k_s value of 2,000 kN/m² is recommended for analysis. This value may be assumed to be constant with depth.

To maintain the computed passive resistance, protection must be provided in front of the sheet piles to prevent material loss due to creek erosion.

9.2.5 Recommended Foundation

From a geotechnical perspective, the concrete box culvert or round CSP culvert are feasible culvert options for this site in view of the relatively shallow excavations, relatively low-cost, and conventional construction techniques required. However, if wingwalls are not used, the culvert will be extended into the unconsolidated silty clay. Both options will need to be designed for settlement up to 65 to 70 mm at the inlet and outlet.

Sheet-pile culvert option is also a feasible alternative.

9.2.6 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m.

Frost treatment/taper for a culvert should be in accordance with OPSD 803.031 for a pipe culvert and with OPSD 803.010 for a box culvert.

9.2.7 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, creekbed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with granular material compacted as per OPSS.PROV 501. If the replacement culvert is longer than the existing length of 15.4, then topsoil and organic material must be removed from the inlet and outlet areas and subexcavated to the firm to stiff silty clay.

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

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 well compacted granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

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

9.2.8 Settlement

Although it is anticipated that the replacement culvert will have approximately the same alignment as the existing culvert and no grade raise, the culvert may be lengthened by approximately 7 m to the north and south of the existing inlet and outlet. The lengthening of the culvert will require placement of additional fill to widen the embankment slopes.

The placement of additional fill will induce settlement of the native silty clay, as shown on the settlement profile (Figure 1) included in Appendix F. Based on the results of the two consolidation tests, the maximum settlement caused by the two wedges of additional fill beyond the existing embankment footprint is in the order of 65 to 70 mm in the widened footprint areas, and 15 to 20 mm at the centreline of the existing embankment. 50% of the estimated settlement is anticipated to occur over 7 to 8 months after completion of the fill placement, and the remainder is estimated to occur within 3 to 4 years after construction.

The replacement culvert must be designed to tolerate the estimated settlement induced by the placement of additional fill. One option to accommodate the settlement is to use an oversized replacement culvert.



9.3 Construction Considerations

Detailed construction sequencing was not available at the time of preparation of this report. However, it is anticipated that one lane of traffic must be maintained, which requires staged construction.

Staged construction sequencing will likely require the following:

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

10. 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 silty clay at this site are classified as Type 3 soils above the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas and cohesionless soils should be classified as Type 4 soils below the water level.

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 deposit.

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. Although the permeability of the native silty clay is expected to be relatively low, seepage should be anticipated from the embankment fill and the foundation soils adjacent to the creek. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within an enclosure will be required to lower the water level to a minimum 0.5 m below the base of excavation and maintain dry excavation during the course of staged construction.

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 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, 803.010 or 802.034, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP and 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 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.

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.

Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (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.

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.

12. SEISMIC CONSIDERATIONS

In accordance with the CHBDC, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy at this site includes predominantly intermediate plastic firm to very stiff silty clay. This 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 a 2,475-year return period seismic event at this site is 0.038 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC, 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 the table below may be used:

Condition	Earth Pressure Coefficient (K_E)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ$, $\gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) $\phi = 32^\circ$, $\gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ$, $\gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33	0.35
Passive (K_{PE})	3.6	3.2	2.9
At Rest (K_{OE})**	0.49	0.53	0.56

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

** After Woods

Client: Hatch

Date: December 21, 2016

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E file: H:\15000-15999\15760 NWR Foundations Retainer Assignment 2 - Rainy River\Reports & Memos\Rainy River Tributary No 2 Culvert - FIDR FINAL.docx



Given the firm to very stiff silty clay foundation and the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

13. EMBANKMENT RESTORATION

Based on discussions with Hatch, it is anticipated that the culvert will be lengthened and the embankment side slopes will be flattened. Provided that the embankment is reconstructed with side slope inclined at not steeper than 2H:1V, the restored embankment slopes should remain stable. Settlement of the embankment in the order of 65 to 70 mm should be expected due to the placement of additional fill, as discussed in Section 9.2.8.

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 or B Type II material.

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.

14. 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 or clay seal should be used 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 place of a compacted clay seal.

15. TEMPORARY PROTECTION SYSTEM



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

Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles.

The following parameters may apply for design of the temporary roadway protection system with horizontal backfill.

Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Granular Fill	Silty Clay Fill or Native Silty Clay
γ (bulk unit weight)	20 kN/m ³	19 kN/m ³
γ' (submerged unit weight)	10 kN/m ³	9 kN/m ³
Active earth pressure coefficient, K_a	0.33	0.41
Passive earth pressure coefficient, K_p	3.0	2.4

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

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

16. CORROSION AND SULPHATE ATTACK POTENTIAL

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

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



17. CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction and subgrade preparation in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system.
- 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.



18. CLOSURE

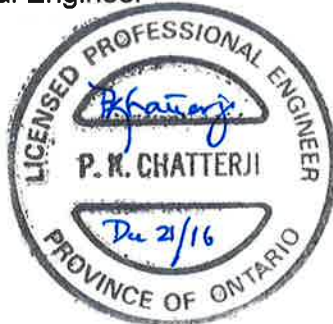
Engineering analysis and preparation of this report was carried out by Mr. Mark Farrant P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Mark Farrant, P.Eng.

Project Manager, 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

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


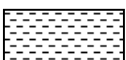

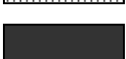

ROCK WEATHERING CLASSIFICATION

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		Field Estimation of Hardness*
	(MPa)	(psi)	
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.

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 16-01

1 OF 1

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 697.4 E 267 078.5 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.07.22 - 2016.07.22 CHECKED BY MEF

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									
								20 40 60 80 100									
332.6	GROUND SURFACE																
0.0	TOPSOIL , mixed with sandy silty clay, some roots Firm Grey Moist Silty CLAY , some sand, trace gravel Firm to Stiff Grey Moist (Cl)		1	SS	5											0 29 35 36	
332.0																	
0.6			2	SS	5												
			3	SS	5												
			4	SS	14												
			5	SS	8												
328.9							329										
3.7	END OF BOREHOLE AT 3.7m DUE TO TRIPOD CASING REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02

1 OF 3

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 690.0 E 267 085.4 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.07.19 - 2016.07.20 CHECKED BY MEF

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						WATER CONTENT (%)						
								20 40 60 80 100						20 40 60						
								<div><div></div><div></div><div></div><div></div><div></div></div>												
337.0	GROUND SURFACE																			
0.0 0.1	ASPHALT: (50mm)																			
	SAND, some gravel, some silt Brown Moist (FILL)		1	GS																
	Compact to Loose		1	SS	23		336													12 78 10 (SI+CL)
			2	SS	8		335													
334.8																				
2.2	Silty CLAY, sandy, trace gravel Firm Grey Moist (FILL)		3	SS	6		334													2 36 30 32
			4	SS	6		333													
332.4																				
4.6	Silty CLAY, some sand, trace gravel Firm Grey Wet (CI to CH)		5	SS	6		332													
			6	SS	5		331													
			7	SS	5		329													0 17 22 61
			8	SS	5		328													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02

2 OF 3

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 690.0 E 267 085.4 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.07.19 - 2016.07.20 CHECKED BY MEF

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	WATER CONTENT (%)					
	Continued From Previous Page													
	Silty CLAY , some sand, trace gravel Firm Grey Wet (Cl to CH)		9	SS	4		326							
							325	(>100)						
			10	SS	7		324							
							323							
			11	SS	5		323							0 18 24 58
							322	(>100)						
			12	SS	7		321							
321.2							320							
15.8	End of sampling at 15.8m and start DCPT						319							
							318							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02

3 OF 3

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 690.0 E 267 085.4 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.07.19 - 2016.07.20 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)	W _p	W	W _L		
	Continued From Previous Page							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60					
309.6	27.4													
	END OF BOREHOLE AT 27.4m. BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT PATCH TO SURFACE.													

ONTMT4S 13372-MTO-GPJ 2015TEMPLATE(MTO).GDT 12/20/16

RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 685.0 E 267 078.4 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.07.19 - 2016.07.19 CHECKED BY MEF

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					
								20 40 60 80 100					
337.0	GROUND SURFACE												
0.0 0.1	ASPHALT: (50mm)												
	Gravelly SAND, trace silt Loose Greyish Brown Moist (FILL)		1	GS									34 57 9 (SI+CL)
			1	SS	9		336						
335.6													
1.4	Silty CLAY, sandy, trace gravel Firm to Stiff Greyish Brown Moist (FILL)		2	SS	6		335						
			3	SS	8								0 32 39 29
			4	SS	6		334						
							333						
332.1			5	SS	10		332						
4.9	Silty CLAY, some sand, trace gravel Firm to Stiff Grey Moist (CI to CH) some roots and wood fragments from 4.9 to 5.2m												
			6	SS	6		331						
							330						
			7	SS	9		329						0 16 26 58
							328						
			8	SS	7								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 685.0 E 267 078.4 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.07.19 - 2016.07.19 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L						
	Continued From Previous Page							● QUICK TRIAXIAL × LAB VANE								
	Silty CLAY , some sand, trace gravel Firm to Stiff Grey Moist (Cl to CH)		9	SS	8		326									
								(>100)								
			10	SS	9		325									
							324									
			11	SS	7		323									
								(>100)								
			12	SS	6		322									
321.2																
15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN AND DRY TO 15.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT PATCH TO SURFACE.															

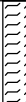


ONTMT4S 13372-MTO.GPJ 2015TEMPLATE(MTO).GDT 12/20/16

RECORD OF BOREHOLE No 16-04

1 OF 1

METRIC

GWP# 6602-15-00 LOCATION Rainy River Tributary 2 Culvert N 5 378 676.5 E 267 085.7 ORIGINATED BY OA
 HWY 602 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.07.22 - 2016.07.22 CHECKED BY MEF

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									
332.6	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL, mixed with sandy silty clay, some roots Firm Grey Moist		1	SS	6		332							○			
331.9																	
0.7	Sandy, Silty CLAY, trace gravel, some roots Stiff Grey Moist		2	SS	13									○			2 36 22 40
331.2																	
1.4	Silty CLAY, sandy to some sand, trace gravel, some roots and topsoil in top 0.6m Stiff to Very Stiff Grey Moist (Cl)		3	SS	12		331							○			
			4	SS	19		330							○			
			5	SS	23									○			0 18 30 52
328.9							329							○			
3.7	END OF BOREHOLE AT 3.7m DUE TO TRIPOD CASING REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

+³, ×³: Numbers refer to
Sensitivity

20
15
10




(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02A

1 OF 3

METRIC

W.P. 6602-15-00 LOCATION N 5 378 691.1 E 267 086.0 ORIGINATED BY TM
HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2016.10.23 - 2016.10.24 CHECKED BY KS

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									
337.0	GROUND SURFACE																
0.0	Gravelly SAND , trace silt Compact to Loose Brown Moist (FILL)		1	SS	12												
			2	SS	8												
			3	SS	6												
334.7	Trace to some clay																
2.3	Silty CLAY , sandy, trace gravel, trace organics (rootlets, decayed wood) Firm to Stiff Brown to Grey Moist (FILL)		4	SS	5												
			5	SS	8												
332.4																	
4.6	Silty CLAY , some sand Stiff to Very Stiff Grey Moist		6	SS	7												
			1	TW													
			7	SS	7												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02A

2 OF 3

METRIC

W.P. 6602-15-00 LOCATION N 5 378 691.1 E 267 086.0 ORIGINATED BY TM
 HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.10.23 - 2016.10.24 CHECKED BY KS

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 (%)					
								20 40 60 80 100	W _p W W _L								
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
	Continued From Previous Page							20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					GR SA SI CL		
			9	SS	9		326										
							325										
			10	SS	8										0 18 33 49		
							324										
			11	SS	6		323										
							322										
			12	SS	5												
							321										
			13	SS	5		320										
							319										
			2	TW													
							318										

Continued Next Page

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

RECORD OF BOREHOLE No 16-02A

3 OF 3

METRIC

W.P. 6602-15-00 LOCATION N 5 378 691.1 E 267 086.0 ORIGINATED BY TM
 HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.10.23 - 2016.10.24 CHECKED BY KS

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									
	Continued From Previous Page		14	SS	4												
			15	SS	4												
315.1							316										
21.9	END OF BOREHOLE AT 21.9m. WATER LEVEL AT 21.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, DRY CONCRETE, AND COLD PATCH ASPHALT TO SURFACE.																

ONTMT4S MTO-15760.GPJ 2015TEMPLATE(MTO).GDT 12/20/16

RECORD OF BOREHOLE No 16-03A

1 OF 4

METRIC

W.P. 6602-15-00 LOCATION N 5 378 684.1 E 267 077.7 ORIGINATED BY TM
 HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.10.24 - 2016.10.25 CHECKED BY KS

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				W P W W L				GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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337.0	GROUND SURFACE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P		W		W L			GR	SA	SI	CL
Continued From Previous Page								○ UNCONFINED + FIELD VANE	WATER CONTENT (%)											
							20	40	60	80	100	20	40	60						
										(>100)										
			9	SS	6		326						○							
										(>100)										
			10	SS	8		325						○							
							324			(>100)										
			11	SS	7		323						○					0 19 34 47		
							322			(>100)										
			2	TW			321													
								1.5												
			12	SS	7		320						○							
							319		1.2											
			13	SS	11		318						○							
										(>100)										

+ 3, × 3: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-03A

4 OF 4

METRIC

W.P. 6602-15-00 LOCATION N 5 378 684.1 E 267 077.7 ORIGINATED BY TM
HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2016.10.24 - 2016.10.25 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W P	W	W L	WATER CONTENT (%)		
	Continued From Previous Page													
302.5														
34.5	END OF BOREHOLE AT 34.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, DRY CONCRETE, AND COLD PATCH ASPHALT TO SURFACE.													

ONTMT4S MTO-15760.GPJ 2015TEMPLATE(MTO).GDT 12/20/16



Appendix B

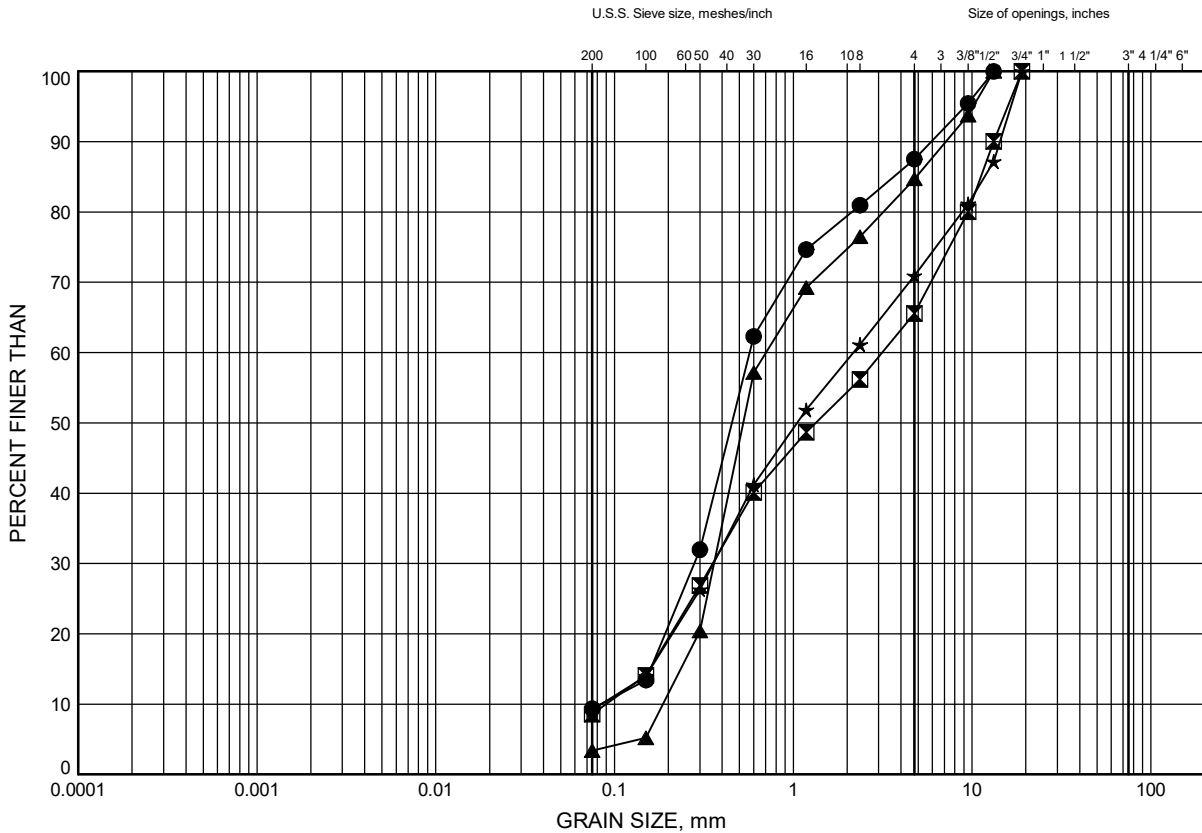
Geotechnical and Analytical Laboratory Test Results

Rainy River Tributary 2 Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

Granular Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	1.07	335.93
⊠	16-03	0.30	336.70
▲	16-02A	1.07	335.93
★	16-03A	0.30	336.70

Date December 2016

GWP# 6602-15-00



Prep'd MFA

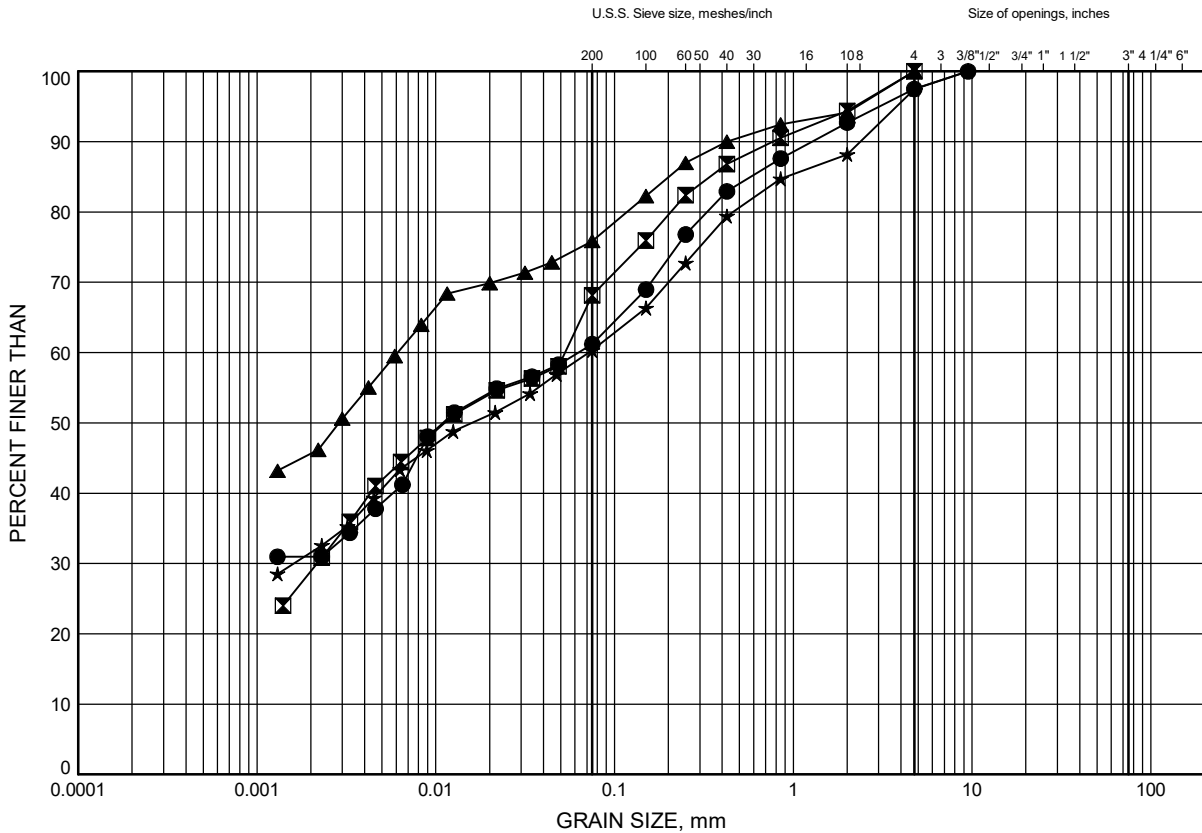
Chkd. MEF

Rainy River Tributary 2 Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty Clay Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	3.35	333.65
⊠	16-03	2.59	334.41
▲	16-02A	3.35	333.65
★	16-03A	2.59	334.41

Date December 2016

GWP# 6602-15-00



Prep'd MFA

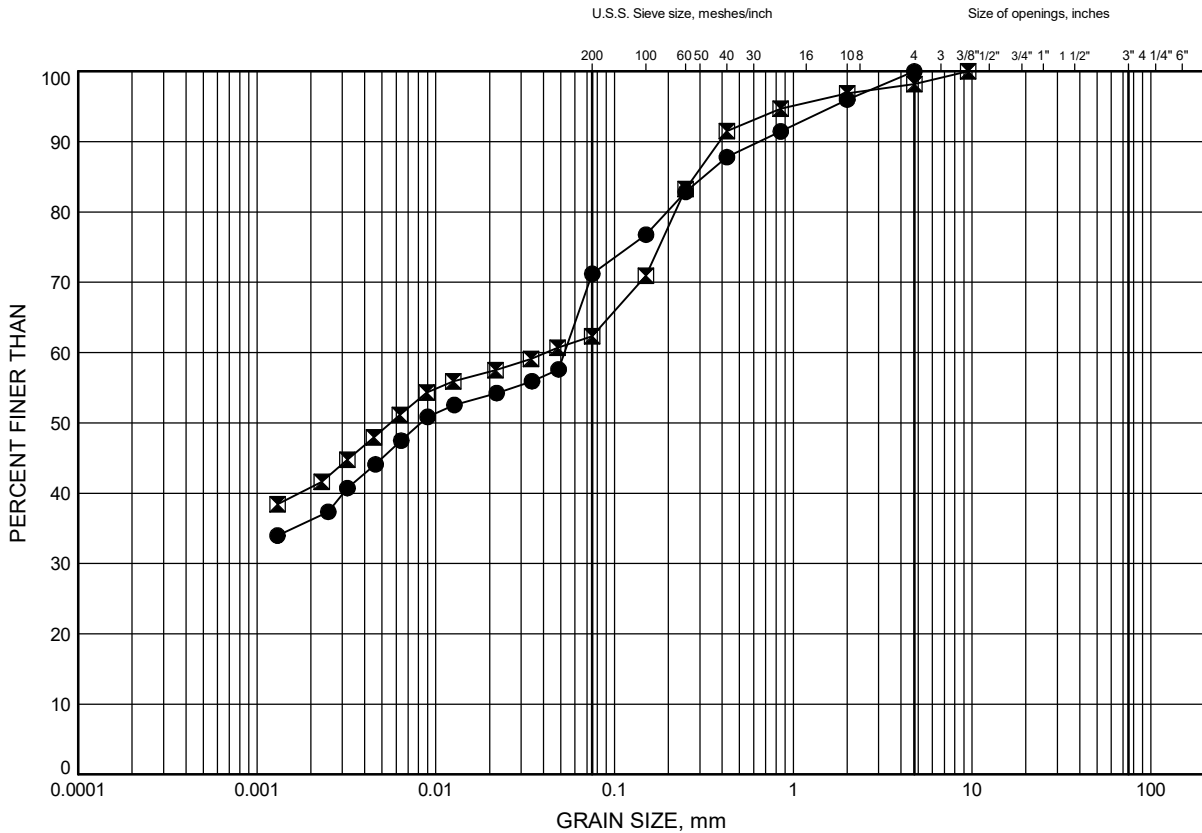
Chkd. MEF

Rainy River Tributary 2 Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy, Silty Clay/Topsoil



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	0.30	332.30
⊠	16-04	1.07	331.53

Date December 2016

GWP# 6602-15-00



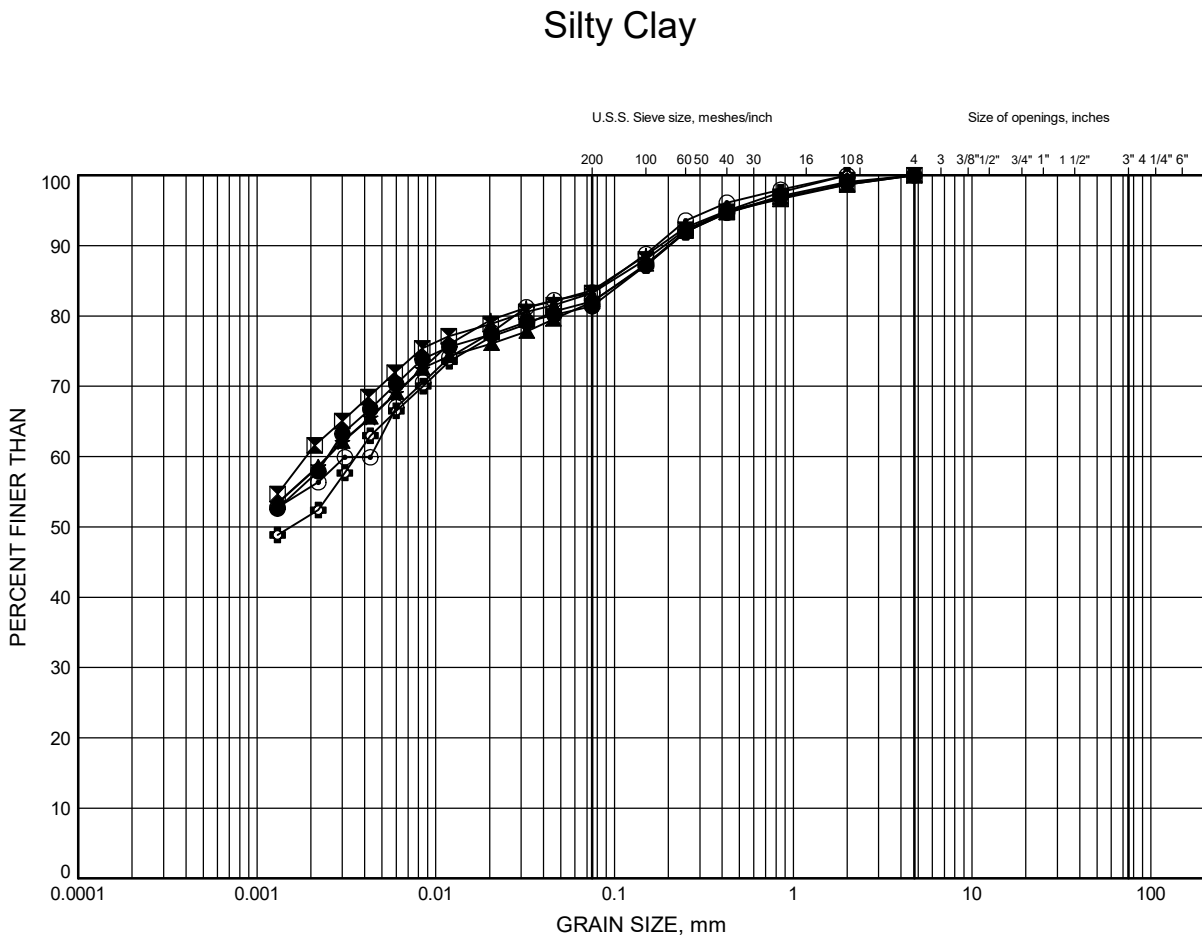
Prep'd MFA

Chkd. MEF

Rainy River Tributary 2 Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4a



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	2.59	330.01
⊠	16-02	7.92	329.08
▲	16-02	14.02	322.98
★	16-03	7.92	329.08
⊙	16-03	12.50	324.50
⊕	16-04	3.35	329.25

Date December 2016

GWP# 6602-15-00



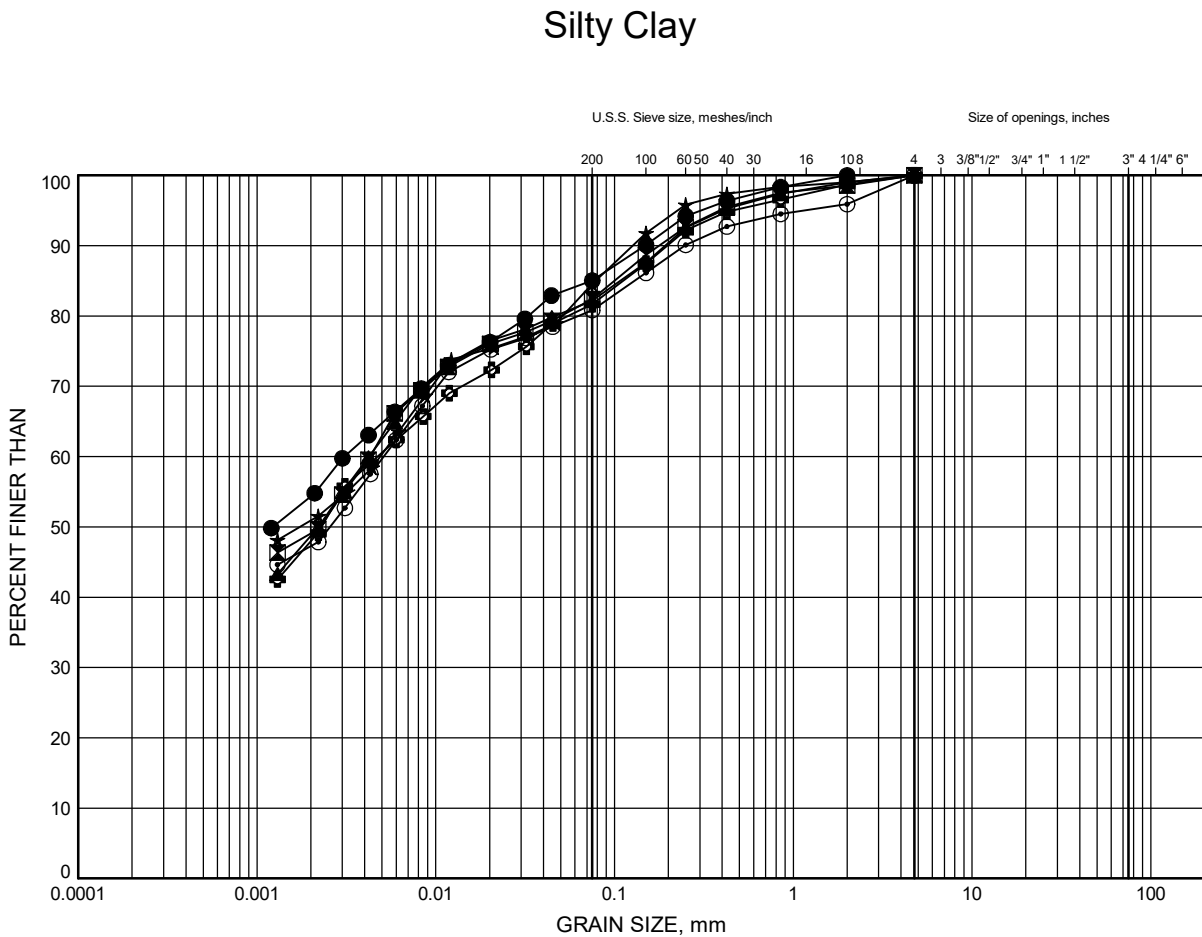
Prep'd MFA

Chkd. MEF

Rainy River Tributary 2 Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4b



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02A	7.92	329.08
⊠	16-02A	12.50	324.50
▲	16-02A	20.12	316.88
★	16-03A	7.92	329.08
⊙	16-03A	14.02	322.98
⊕	16-03A	21.64	315.36

Date December 2016

W.P. 6602-15-00



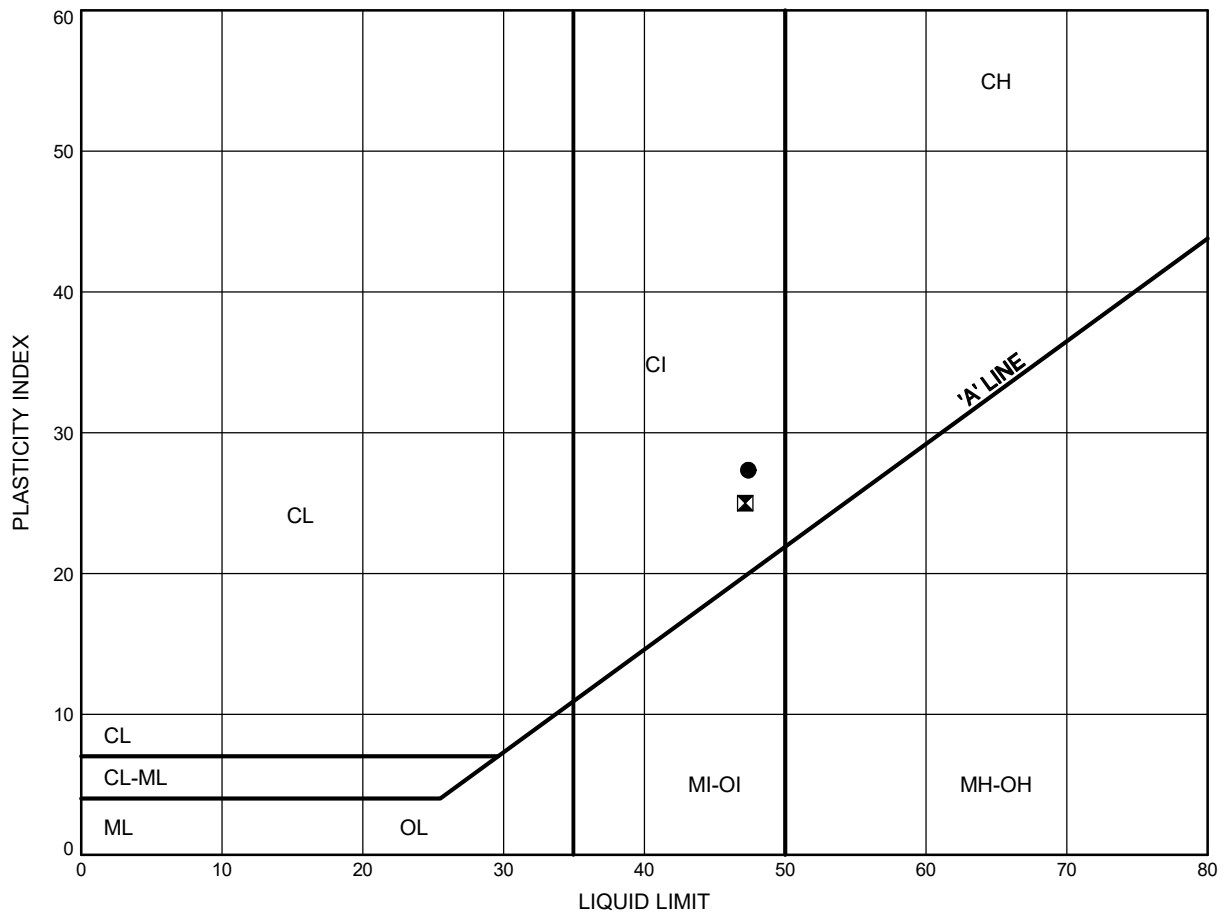
Prep'd MFA

Chkd. MEF

Rainy River Tributary 2 Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02A	3.35	333.65
⊠	16-03A	2.59	334.41

Date December 2016
W.P. 6602-15-00

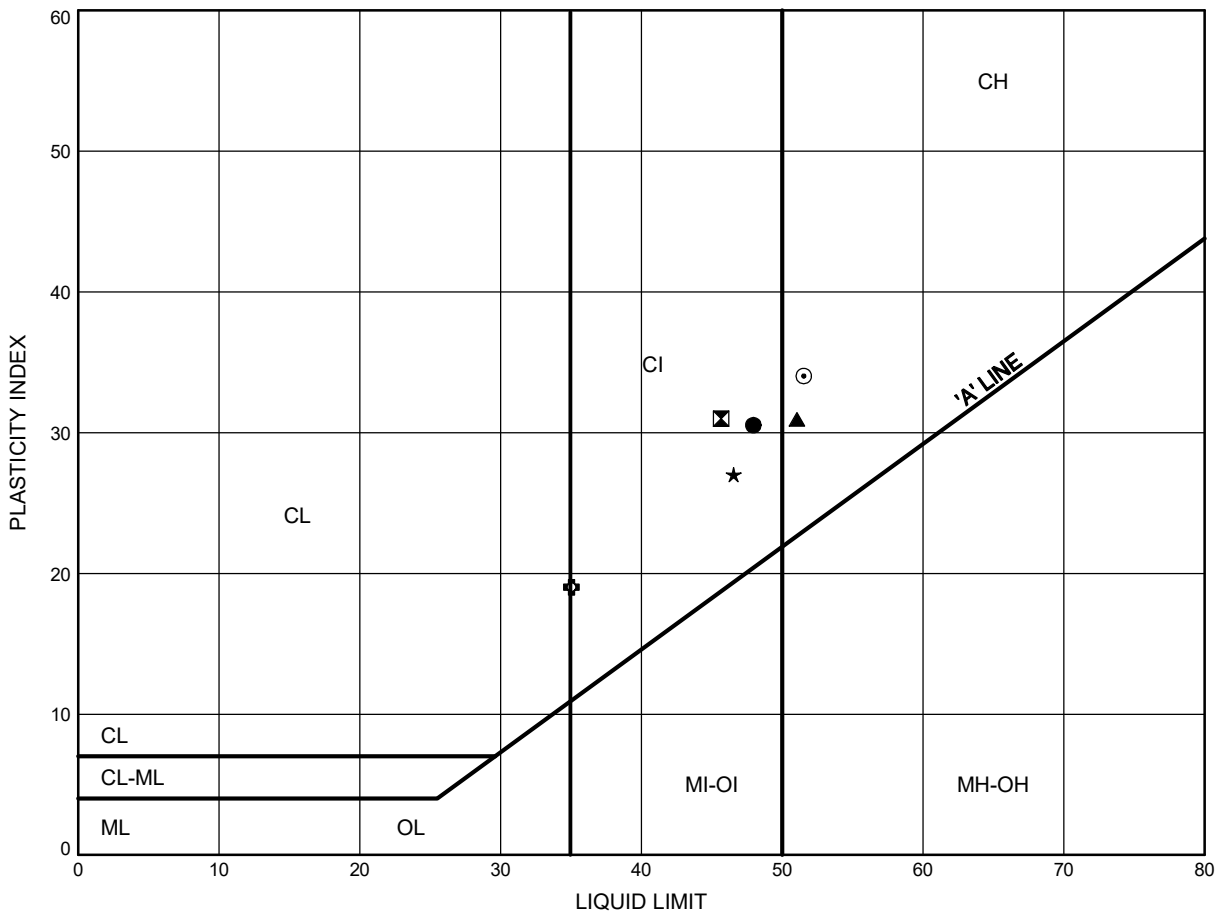


Prep'd MFA
Chkd. MEF

Rainy River Tributary 2 Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B6a

Silty Clay



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	2.59	330.01
⊠	16-02	7.92	329.08
▲	16-02	14.02	322.98
★	16-03	7.92	329.08
⊙	16-03	12.50	324.50
⊕	16-04	3.35	329.25

Date December 2016
 GWP# 6602-15-00

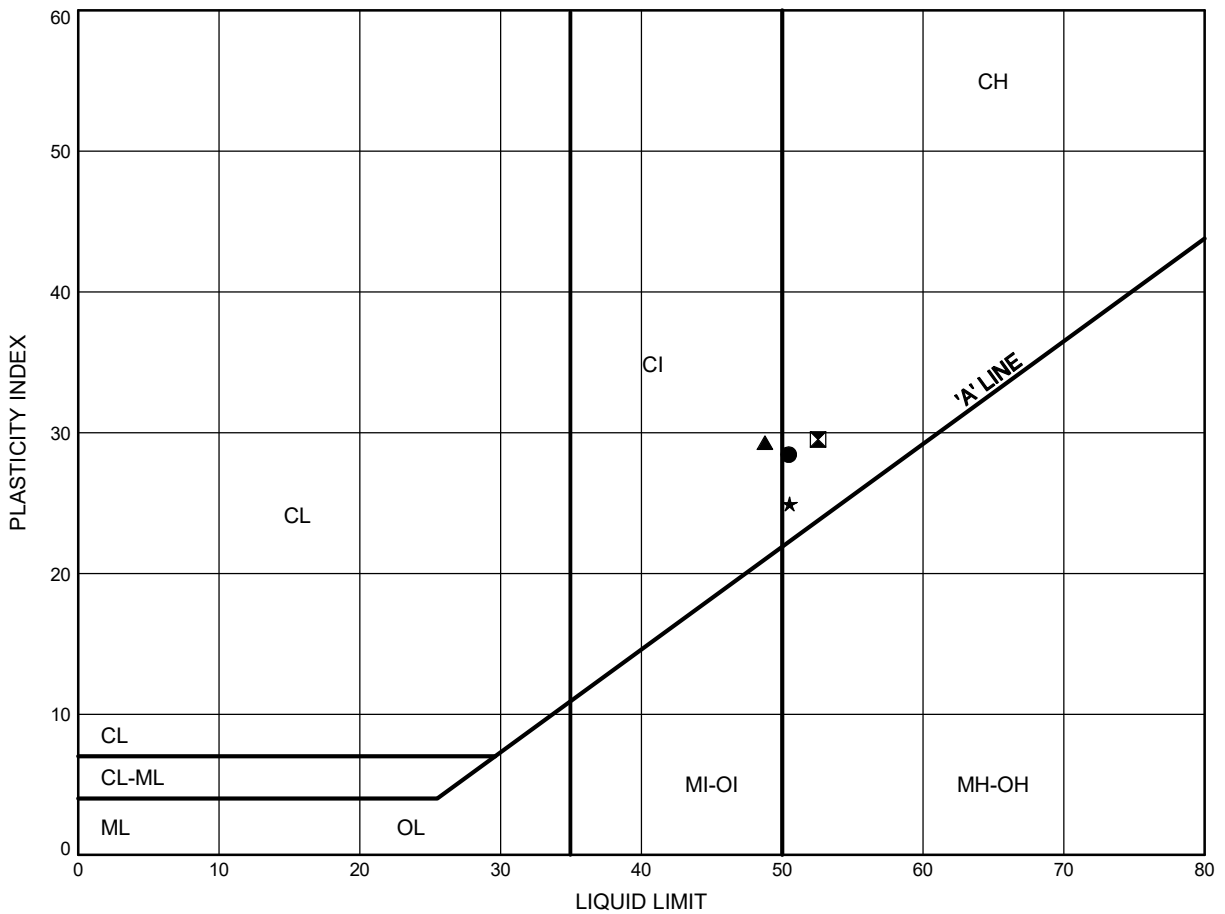


Prep'd MFA
 Chkd. MEF

Rainy River Tributary 2 Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B6b

Silty Clay



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02A	7.92	329.08
⊠	16-02A	20.12	316.88
▲	16-03A	7.92	329.08
★	16-03A	21.64	315.36

Date December 2016
 W.P. 6602-15-00

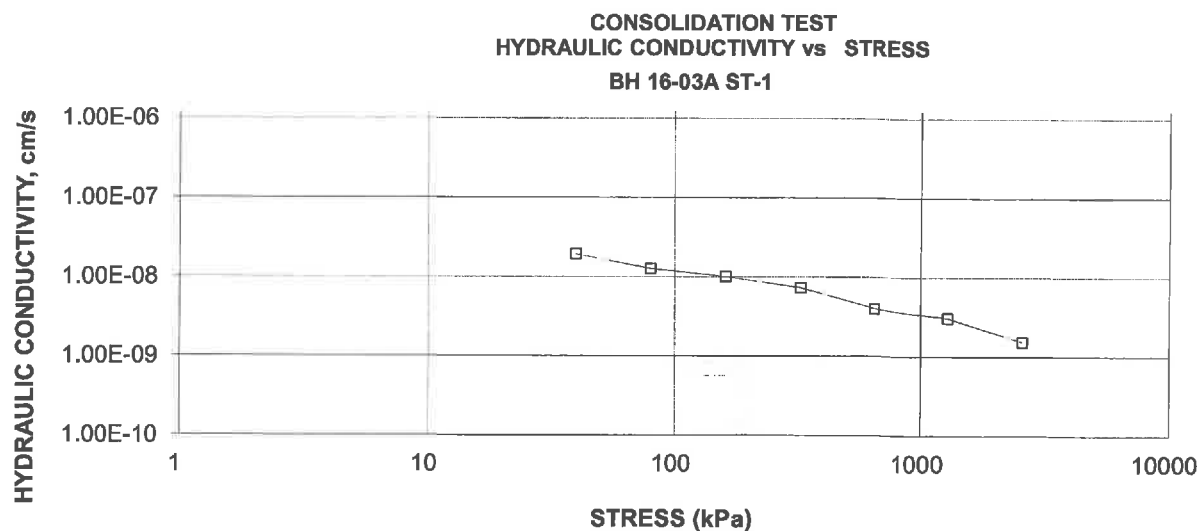
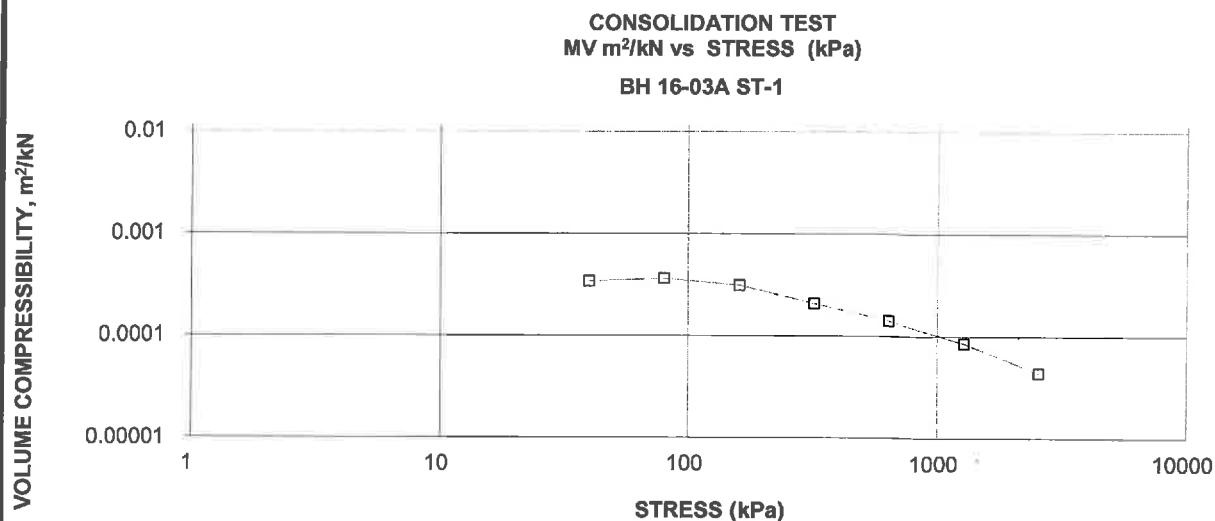
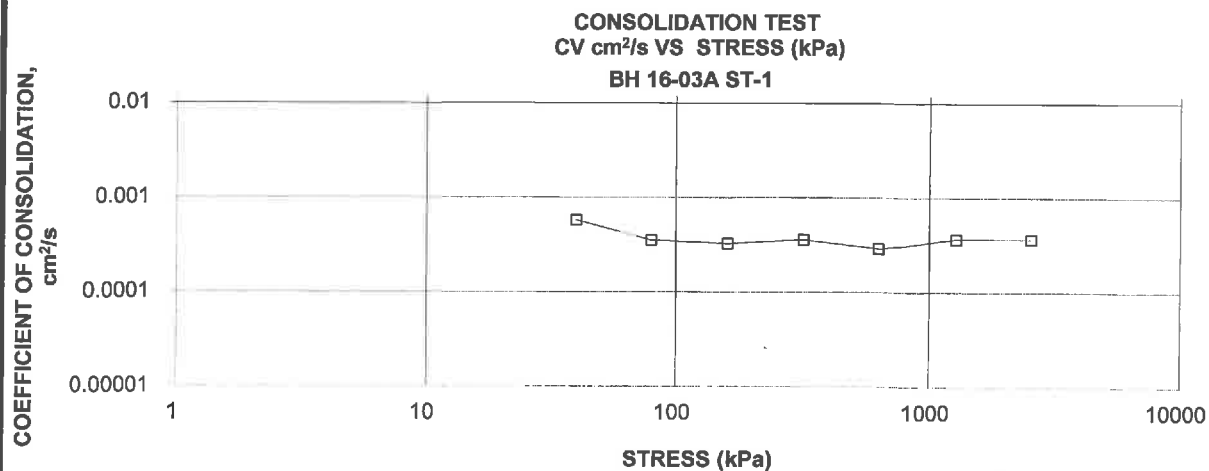


Prep'd MFA
 Chkd. MEF

CONSOLIDATION TEST SUMMARY ASTM D2435/D2435M					FIGURE		
SAMPLE IDENTIFICATION							
Project Number	1541891(9000)	Sample Number	ST-1				
Borehole Number	16-03A	Sample Depth, m	9.15-9.76				
TEST CONDITIONS							
Test Type	Laboratory Standard	Load Duration, hr	24				
Oedometer Number	7						
Date Started	11/04/2016						
Date Completed	11/12/2016						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.26	Unit Weight, kN/m ³	19.23				
Sample Diameter, cm	4.97	Dry Unit Weight, kN/m ³	14.85				
Area, cm ²	19.43	Specific Gravity, measured	2.74				
Volume, cm ³	24.43	Solids Height, cm	0.695				
Water Content, %	29.49	Volume of Solids, cm ³	13.50				
Wet Mass, g	47.90	Volume of Voids, cm ³	10.93				
Dry Mass, g	36.99	Degree of Saturation, %	99.9				
TEST COMPUTATIONS							
	Corr.		Average				
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.257	0.809	1.257				
4.89	1.258	0.811	1.258				
9.89	1.260	0.814	1.259				
19.88	1.258	0.811	1.259				
39.92	1.249	0.798	1.254	577	5.77E-04	3.41E-04	1.93E-08
79.90	1.231	0.772	1.240	923	3.53E-04	3.64E-04	1.26E-08
159.89	1.200	0.727	1.215	960	3.26E-04	3.13E-04	1.00E-08
319.88	1.158	0.667	1.179	821	3.59E-04	2.07E-04	7.29E-09
639.91	1.101	0.585	1.130	936	2.89E-04	1.41E-04	3.99E-09
1279.92	1.033	0.486	1.067	658	3.67E-04	8.54E-05	3.07E-09
2559.84	0.963	0.386	0.998	578	3.65E-04	4.34E-05	1.55E-09
1279.92	0.977	0.406	0.970				
319.88	1.015	0.460	0.996				
79.90	1.062	0.529	1.038				
9.89	1.127	0.622	1.095				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>k calculated using cv based on t₉₀ values.</p> <p>Specimen taken 8.5-13.5cm from bottom of the tube.</p>							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.13	Unit Weight, kN/m ³	20.89				
Sample Diameter, cm	4.97	Dry Unit Weight, kN/m ³	16.56				
Area, cm ²	19.43	Specific Gravity, measured	2.74				
Volume, cm ³	21.90	Solids Height, cm	0.695				
Water Content, %	26.09	Volume of Solids, cm ³	13.50				
Wet Mass, g	46.64	Volume of Voids, cm ³	8.40				
Dry Mass, g	36.99						
Prepared By: LH				Golder Associates		Checked By:	

CONSOLIDATION TEST SUMMARY

FIGURE

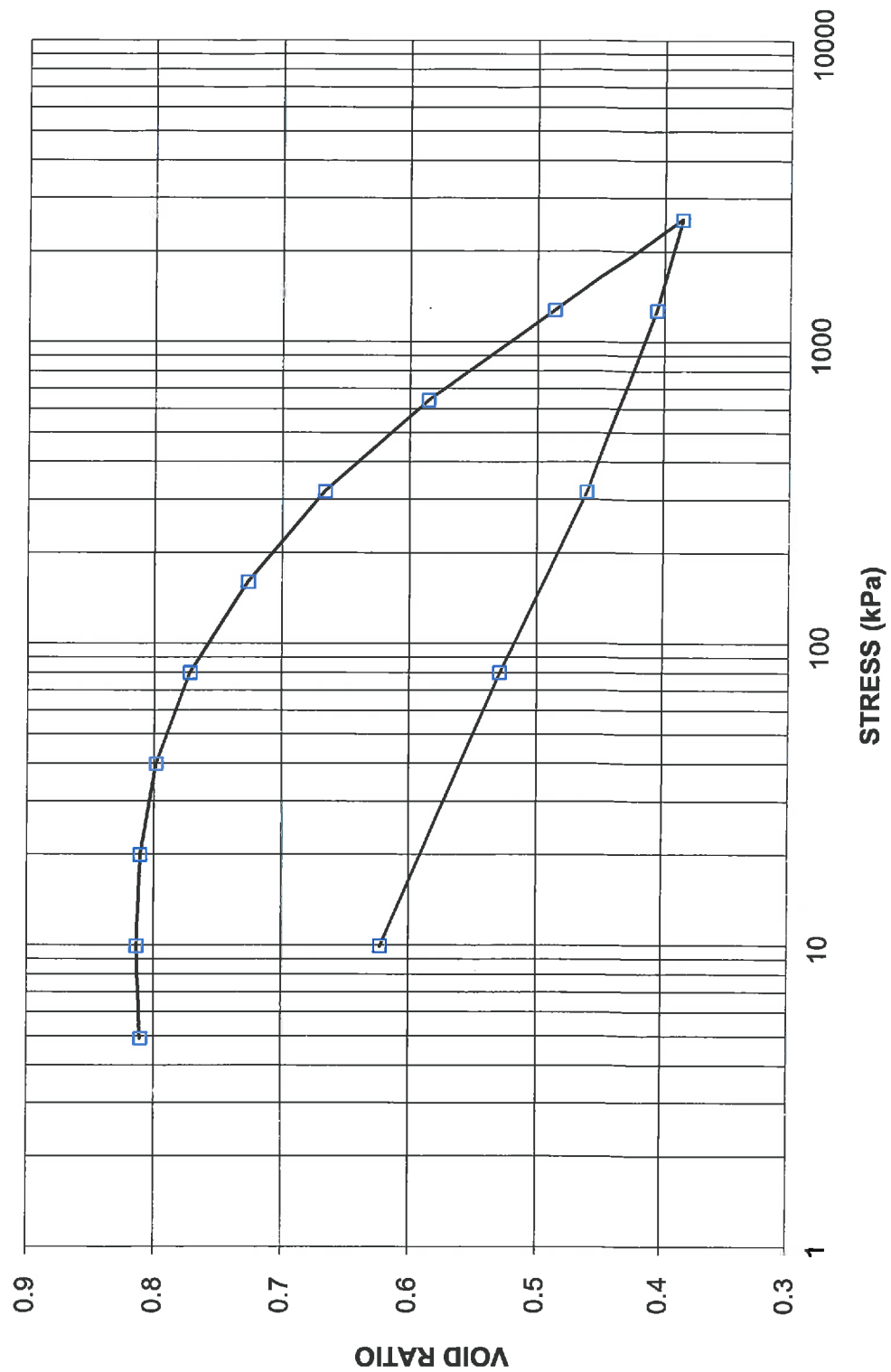


bb

**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-03A ST-1**



Project No. 1541891(9000)

Prepared By: LH

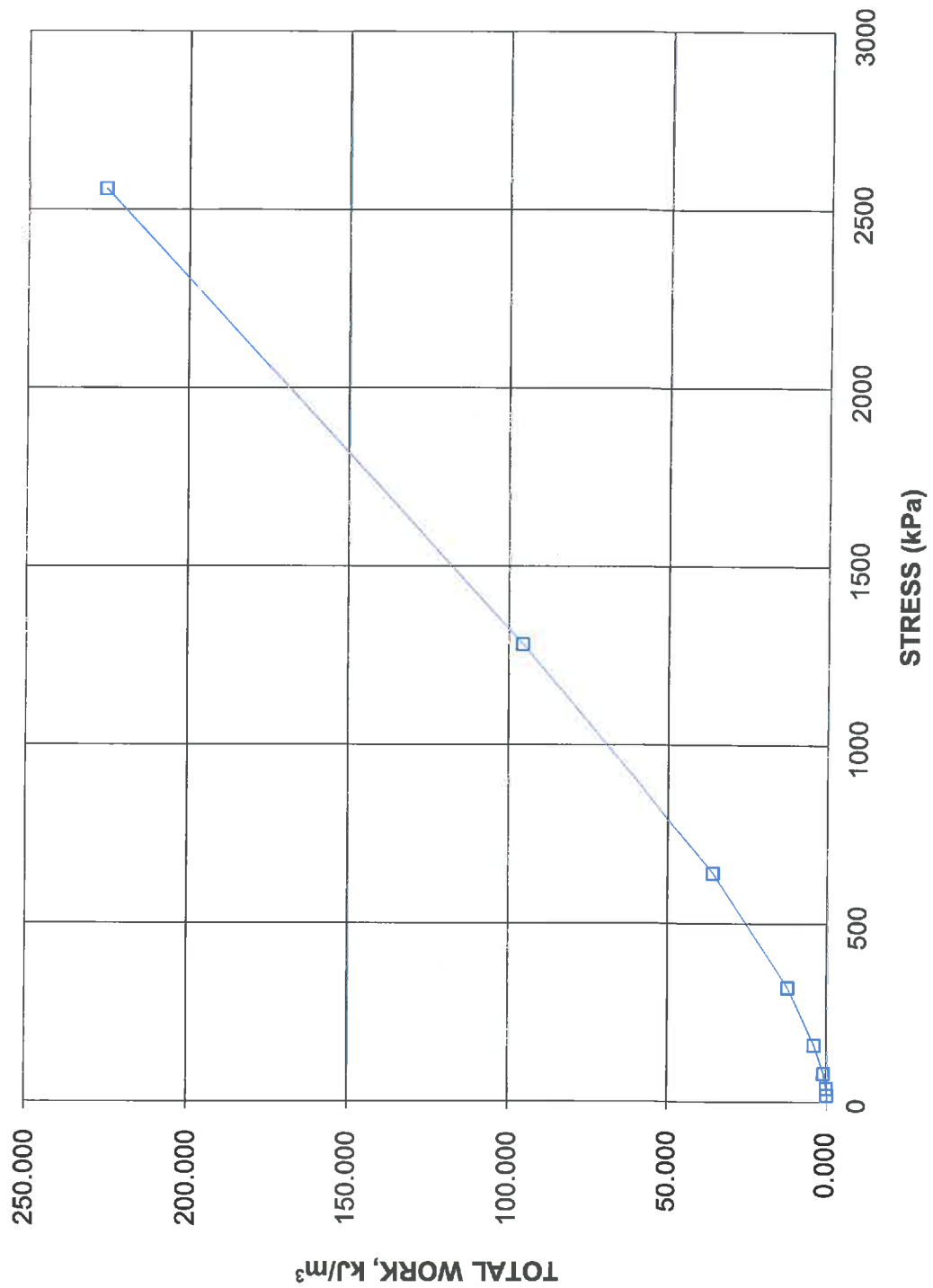
Golder Associates

Checked By: *[Signature]*

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH 16-03A ST-1**



Project No. 1541891(9000)

Prepared By: LH

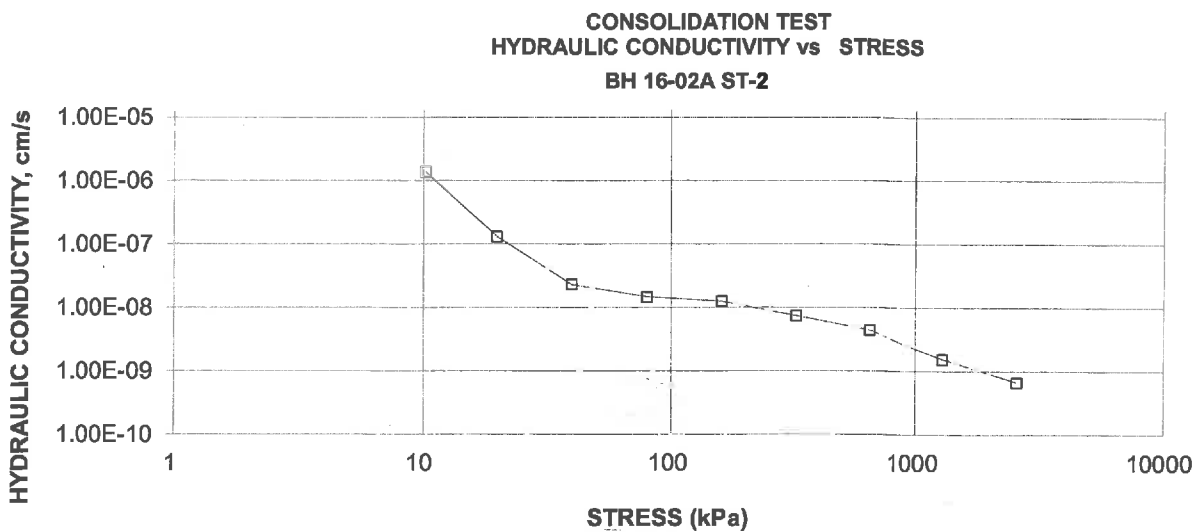
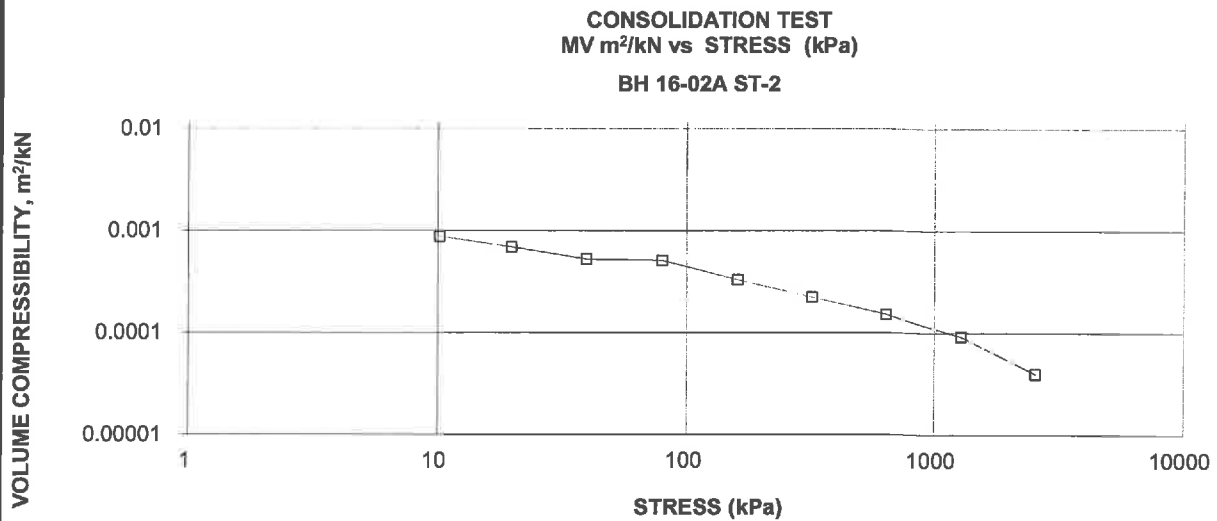
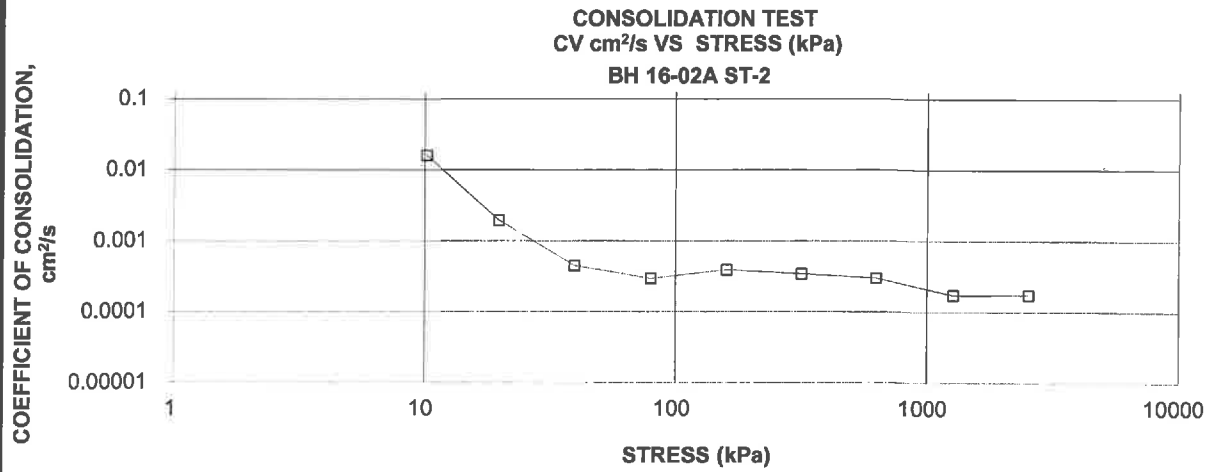
Golder Associates

Checked By: *sh*

CONSOLIDATION TEST SUMMARY					FIGURE		
ASTM D2435/D2435M							
SAMPLE IDENTIFICATION							
Project Number	1541891(9000)	Sample Number	ST-2				
Borehole Number	16-02A	Sample Depth, m	18.29-18.90				
TEST CONDITIONS							
Test Type	Laboratory Standard	Load Duration, hr	24				
Oedometer Number	8						
Date Started	11/04/2016						
Date Completed	11/12/2016						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.26	Unit Weight, kN/m ³	19.11				
Sample Diameter, cm	4.97	Dry Unit Weight, kN/m ³	14.59				
Area, cm ²	19.43	Specific Gravity, measured	2.76				
Volume, cm ³	24.43	Solids Height, cm	0.678				
Water Content, %	30.96	Volume of Solids, cm ³	13.17				
Wet Mass, g	47.59	Volume of Voids, cm ³	11.26				
Dry Mass, g	36.34	Degree of Saturation, %	99.9				
TEST COMPUTATIONS							
	Corr.	Average					
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.257	0.855	1.257				
4.80	1.267	0.869	1.262				
10.19	1.261	0.861	1.264	21	1.61E-02	8.78E-04	1.39E-06
19.80	1.252	0.848	1.257	173	1.93E-03	6.91E-04	1.31E-07
39.81	1.239	0.829	1.246	735	4.48E-04	5.25E-04	2.30E-08
79.79	1.214	0.791	1.226	1084	2.94E-04	5.09E-04	1.47E-08
159.80	1.181	0.742	1.197	778	3.90E-04	3.28E-04	1.26E-08
319.80	1.136	0.676	1.158	833	3.41E-04	2.22E-04	7.43E-09
639.80	1.075	0.587	1.106	872	2.97E-04	1.51E-04	4.41E-09
1279.91	1.001	0.478	1.038	1326	1.72E-04	9.18E-05	1.55E-09
2559.80	0.938	0.384	0.969	1148	1.74E-04	3.95E-05	6.72E-10
1279.91	0.949	0.400	0.943				
156.92	1.012	0.494	0.981				
39.76	1.059	0.563	1.036				
9.80	1.108	0.635	1.084				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>k calculated using cv based on t₉₀ values.</p> <p>Specimen taken 10-15cm from the top of tube.</p>							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.11	Unit Weight, kN/m ³	21.09				
Sample Diameter, cm	4.97	Dry Unit Weight, kN/m ³	16.55				
Area, cm ²	19.43	Specific Gravity, measured	2.76				
Volume, cm ³	21.53	Solids Height, cm	0.678				
Water Content, %	27.41	Volume of Solids, cm ³	13.17				
Wet Mass, g	46.30	Volume of Voids, cm ³	8.37				
Dry Mass, g	36.34						
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CONSOLIDATION TEST SUMMARY

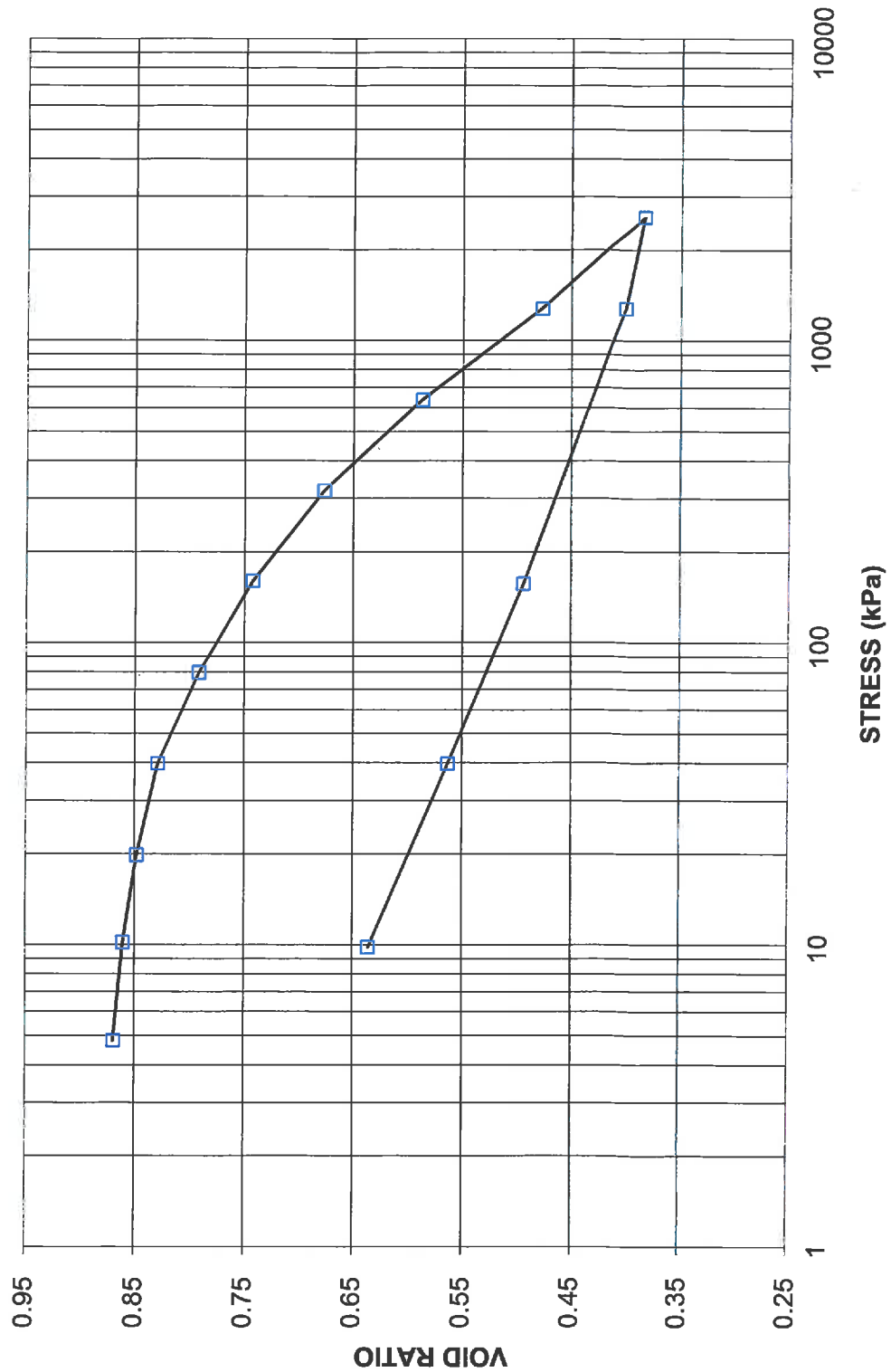
FIGURE



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-02A ST-2**



Project No. 1541891(9000)

Prepared By: LH

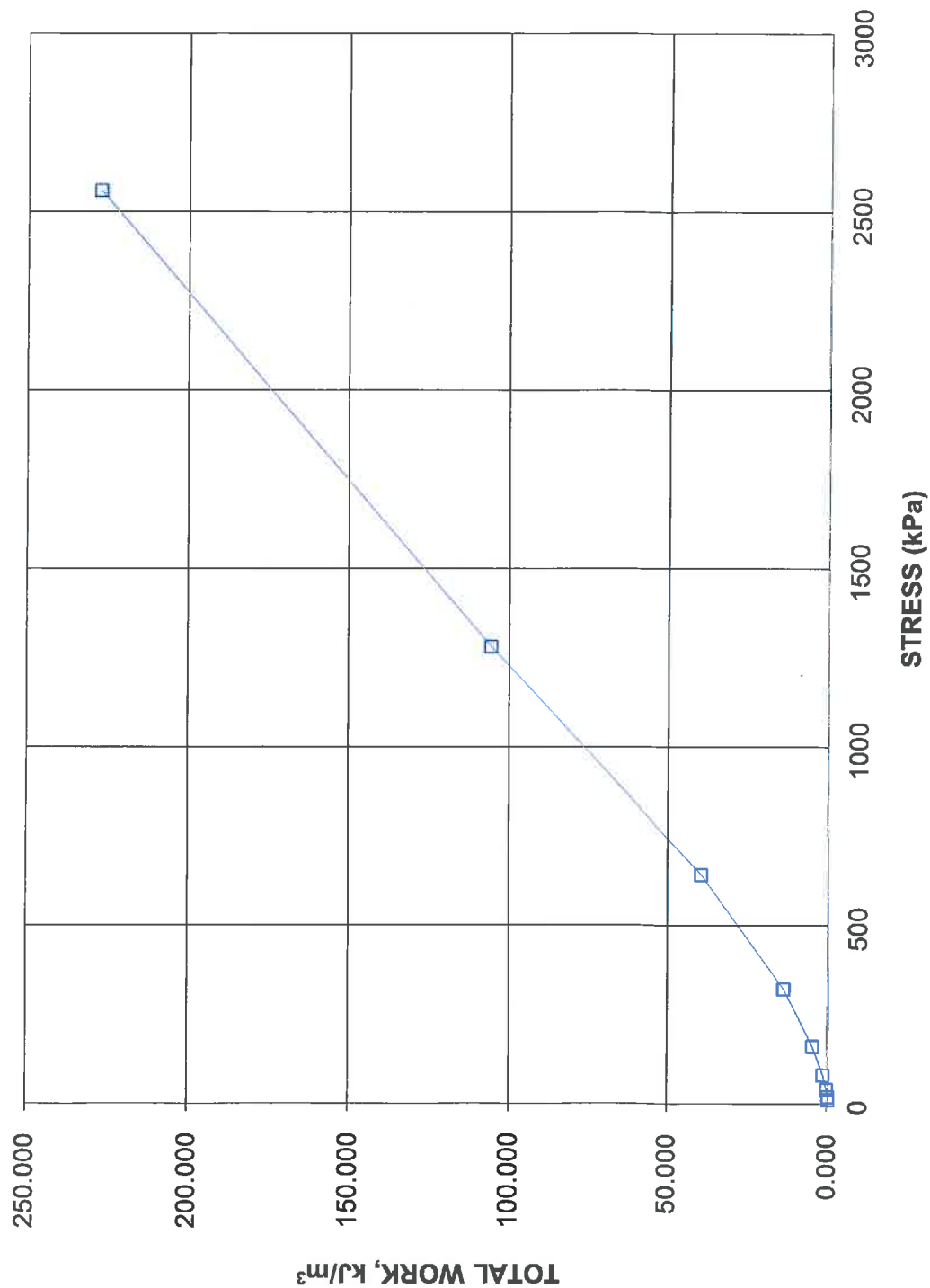
Golder Associates

Checked By: *shl*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 16-02A ST-2



Project No. 1541891(9000)

Prepared By: LH

Golder Associates

Checked By: *bl*

**SGS Canada Inc.**

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

Project : 13372**Thurber Engineering Ltd.****Attn : Mark Farrant**

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

Phone: 905-829-8666 x 228
Fax:

09-August-2016

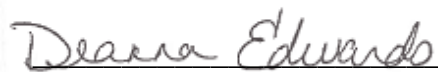
Date Rec. : 03 August 2016
LR Report: CA14114-AUG16
Reference: 13372

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: BH 16-03, SS4, 10'-12'
Sample Date & Time					19-Jul-16
Temperature Upon Receipt [°C]	---	---	---	---	24.2
Corrosivity Index [none]	09-Aug-16	13:34	09-Aug-16	14:29	1
pH [no unit]	08-Aug-16	11:40	09-Aug-16	09:32	7.47
Soil Redox Potential [mV]	08-Aug-16	18:47	09-Aug-16	08:28	306
Sulphide [%]	08-Aug-16	10:07	09-Aug-16	09:35	< 0.02
% Moisture (wet wt) [%]	05-Aug-16	07:02	05-Aug-16	09:08	15.8
pH [no unit]	04-Aug-16	09:56	04-Aug-16	15:49	8.32
Chloride [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	43
Sulphate [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	46
Conductivity [uS/cm]	04-Aug-16	09:56	04-Aug-16	15:50	185
Resistivity (calculated) [Ohms.cm]	09-Aug-16	13:33	09-Aug-16	14:29	5400


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 : 13372

LR Report : CA14114-AUG16

Temperature of Samples upon receipt 24 degrees C
No cooling agent present
Custody Seal not 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.

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

Project : 13372**LR Report :** CA14114-AUG16

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 : 13372

LR Report : CA14114-AUG16

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: DIO0053-AUG16												
Chloride	0.4	µg/g	<0.4		0	20	109	80	120	111	75	125
Sulphate	0.4	µg/g	<0.4		3	20	101	80	120	101	75	125
Carbon/Sulphur - QCBatchID: ECS0007-AUG16												
Sulphide	0.02	%	<0.02		NV	20	113	80	120			
Conductivity - QCBatchID: EWL0045-AUG16												
Conductivity	2	uS/cm	2		1	10	99	90	110	NA		
pH - QCBatchID: EWL0045-AUG16												
pH	0.05	no unit	NA		0		100			NA		

**SGS Canada Inc.**

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

Project : 13372**02-August-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. : 27 July 2016
LR Report: CA15443-JUL16
Reference: 13372

Copy: #1

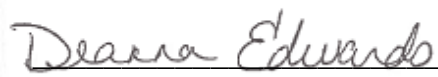
CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: Rainy River Tributary 2
Sample Date & Time					N/A
Temperature Upon Receipt [°C]	---	---	---	---	21.0
Corrosivity Index [none]	02-Aug-16	13:34	02-Aug-16	13:34	2
pH [no unit]	27-Jul-16	06:49	28-Jul-16	09:44	7.90
Redox Potential [mV]	27-Jul-16	13:39	02-Aug-16	10:55	278
Sulphide [mg/L]	29-Jul-16	13:00	29-Jul-16	12:19	< 0.02
Chloride [mg/L]	27-Jul-16	11:45	28-Jul-16	10:10	3
Sulphate [mg/L]	27-Jul-16	12:42	29-Jul-16	14:35	20
Conductivity [uS/cm]	27-Jul-16	06:49	28-Jul-16	09:44	179
Resistivity (calculated) [Ohms.cm]	27-Jul-16	06:49	02-Aug-16	13:33	5600

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.


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 : 13372**LR Report : CA15443-JUL16**

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 325.2
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 375.4
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 : 13372

LR Report : CA15443-JUL16

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 discrete analyzer - QCBatchID: DIO0458-JUL16												
Chloride	1	mg/L	<1		1	20	96	80	120	91	75	125
Sulphate	1	mg/L	1		1	20	93	80	120	109	75	125
Conductivity - QCBatchID: EWL0385-JUL16												
Conductivity	2	uS/cm	< 2		0	10	101	90	110	NA		
pH - QCBatchID: EWL0385-JUL16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0394-JUL16												
Redox Potential	no	mV	NA		1	20	107	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0211-JUL16												
Sulphide	0.02	mg/L	<0.02		0	20	92	80	120	NV	75	125



Appendix C

Borehole Locations and Soil Strata Drawing



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

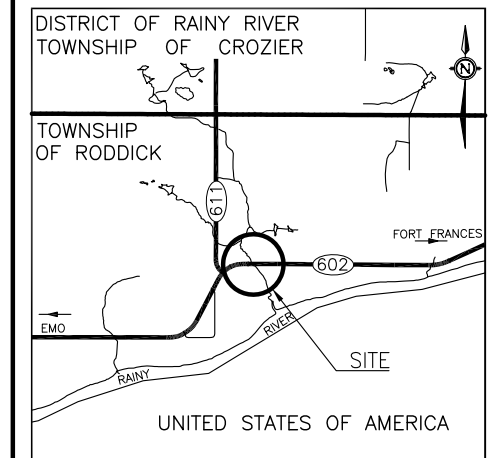


CONT No 6015-E-0018 ()
GWP No 6602-15-00

HIGHWAY 602
RAINY RIVER TRIBUTARY 2
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA






SHEET

HATCH



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

-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. 52C-50

[illegible]



Appendix D

Site Photographs



Photo 1: Culvert inlet, looking south



Photo 2: Culvert outlet, looking north



Photo 3: Looking east over culvert towards east approach



Photo 4: Looking west over culvert towards west approach



Photo 5: Cracking and push-out of culvert wall



Appendix E

Comparison of Construction Methodology Alternatives



COMPARISON OF FOUNDATION ALTERNATIVES

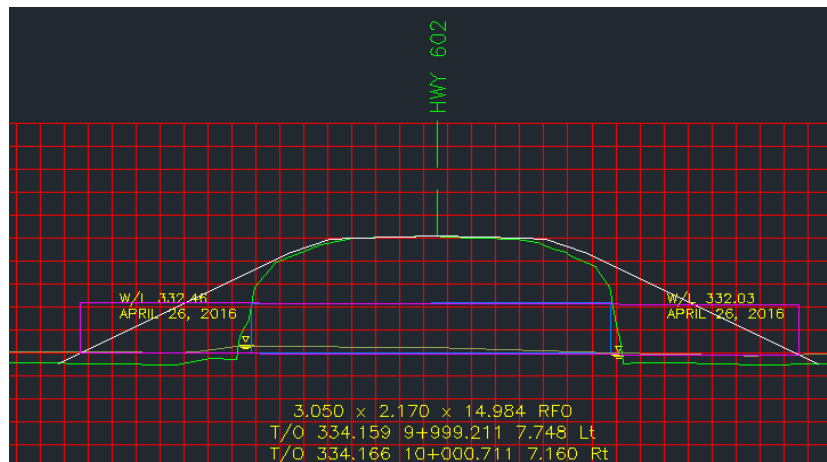
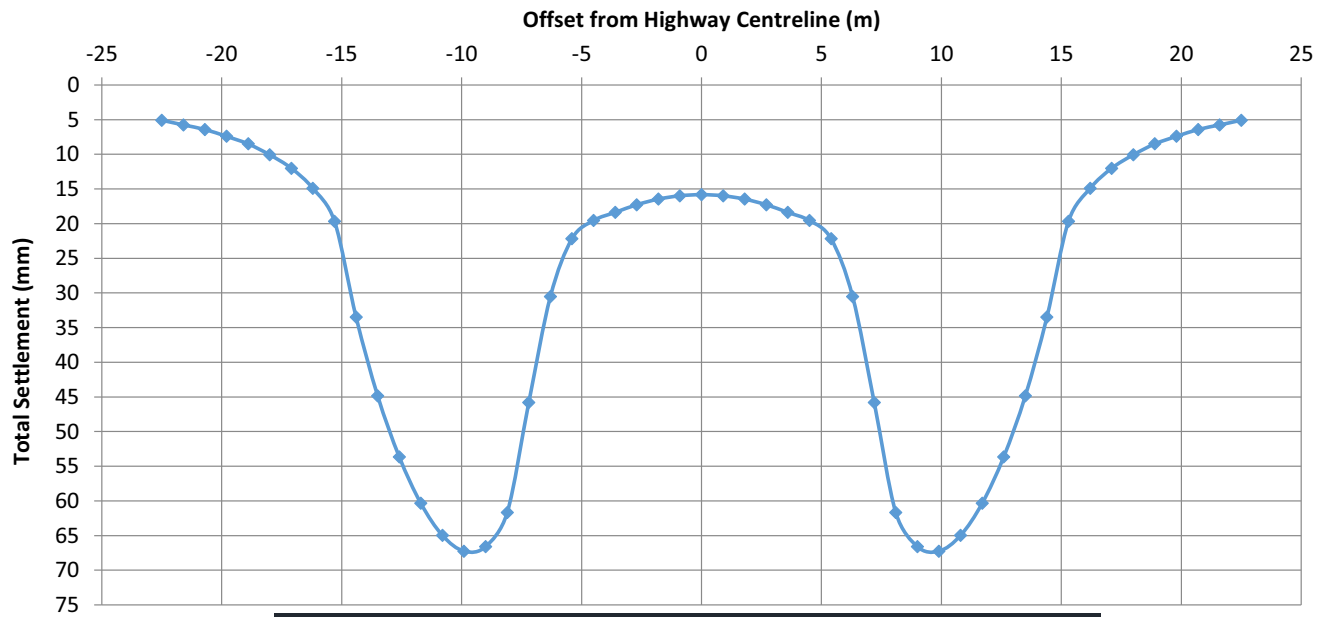
Concrete Box Culvert	Corrugated Steel Pipe (CSP) Culvert	Pre-cast Concrete Slab Supported on Sheet Pile Abutments
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Shallower excavation depths and shorter duration for dewatering. iii. Segmental option can accommodate some potential differential settlement along culvert axis. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Ease of construction. ii. Shallower excavation depths and shorter duration for dewatering. iii. Segmented pipes can accommodate potential differential settlement along culvert axis iv. Concrete or steel pipes may be more cost effective than concrete box culverts. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Minimizes potential for disturbance of creekbed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of piles could continue in freezing weather. v. Potentially minimizes volume of excavation and roadway protection requirements.
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Likely more expensive than a CSP culvert. ii. Excavation to place bedding material will extend below water level. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes may be needed to meet hydraulic requirements. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Potential for corrosion of sheet piles. ii. Less conventional construction. iii. Strut may be needed for lateral support of high sheet pile walls.
RECOMMENDED	RECOMMENDED	FEASIBLE



Appendix F

Figure 1 – Settlement Profile

Figure 1: Settlement in 20 Years





Appendix G

List of OPSS, OPSDs, and Suggested Text for Selected NSSP



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

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 401
- OPSS PROV 501
- OPSS 517
- OPSS 518
- OPSS PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 903
- OPSS PROV 1010
- OPSS PROV 1205
- OPSS 1860
- OPSD 802.010
- OPSD 802.034
- OPSD 803.010
- OPSD 803.031

2. Suggested Wording for NSSP on Dewatering

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



3. Suggested Text for NSSP on Installation of Steel Sheet Piles

Obstructions such as wood, boulders or rock fill may be present within the existing embankment fill. These obstructions may impede the driving of sheet piles and at some locations the sheet piles may not be able to penetrate these materials to reach the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the piles to the design depth. Vibrating equipment is not permitted for installation of sheet piles.