THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
PRATT CREEK CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-244/C
DISTRICT OF KENORA
ONTARIO
G.W.P. No. 6836-14-00

GEOCRES Number: 52G-18

Latitude 49.506939 ° , Longitude -91.497888 °

Report

to

HATCH Corporation

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TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

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APPENDICES

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FOUNDATION INVESTIGATION AND DESIGN REPORT
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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 Pratt Creek Culvert on Highway 599, located in the District of Kenora.

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

Thurber was retained by Hatch Corporation (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0030.

2. SITE DESCRIPTION

The site is located on Highway 599, approximately 17.2 km north of the intersection of Highway 599 and Highway 17 in Ignace, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and Soil Strata Drawings in Appendix D.

Highway 599 runs in a general east-west direction with the culvert generally crossing the highway at a 45 degree angle. The culvert allows Pratt Creek to flow in a south direction beneath the highway.

The Ontario Structural Inspection Manual (OSIM) prepared by MTO on November 2, 2015 indicates that the existing structure is a 28 m long, two span open footing, timber structure culvert. Each span is 1.8 m wide, resulting in a total culvert width of 3.6 m. The culvert is 2.8 m in height.

The grade level of Highway 599 at the existing culvert is at an approximate Elevation of 422.9 m. The height of the existing fill cover is approximately 1.5 m. The culvert invert is at approximately Elevation 419.4 m at the inlet and 419.5 m at the outlet. The upstream and downstream water levels of Pratt Creek were measured at Elevation 419.93 m and 419.23 m, respectively, in April, 2016, as shown on drawings provided by Hatch.

The lands surrounding the Pratt Creek Culvert site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography is generally of low relief and consists of long ridges, short mounds and extensive plains. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist largely of sand and fine gravel with the granular deposits which may include coarse gravel strata locally. Bedrock in the area has been identified as granodiorite to granite bedrock.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out between June 20 and August 1, 2017 and consisted of drilling and sampling eight (8) boreholes, designated as Boreholes PR17-01 to PR17-08, to depths ranging from 2.3 m to 14.6 m (Elevations 420.6 to 408.3) below the existing ground surface. Two attempts were made to advance PR17-04 to an appropriate depth and are designated as PR17-04A and PR17-04B.

Boreholes PR17-01 and PR17-04 were drilled near the inlet and outlet of the existing culvert, and all other boreholes were drilled through the paved section of Highway 599. Boreholes PR17-05 to PR17-08 were drilled east and west of the existing culvert, and drilled generally at 10 m intervals, to assess the existence and extents of any frost taper near the culvert. Also, Borehole PR17-06 was located approximately 11.4 m west of the centreline of the existing culvert, near the alignment of the proposed creek diversion pipe.

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

The boreholes were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Dynamic Cone Penetration Tests (DCPT) were carried out in Boreholes PR17-02 and PR17-04B beyond the sampled depths of 14.6 m and 12.8 m (Elevations 408.5 and 410.1) and extended to refusal reached at approximately 18.5 m depth (Elevations 404.6 and 404.4).

A DCPT, numbered PR17-02 DCPT, was conducted in proximity to Borehole PR17-02 to further assess the subsurface/soil conditions. This DCPT was conducted from 3.0 m to refusal reached at 17.7 m depth (Elevation 405.4).

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 and upon completion of drilling. A piezometer was installed in Borehole PR17-04B on July 14, 2017, and a piezometer reading was taken on July 19, 2017. The piezometer was decommissioned on July 19, 2017. Upon completion of drilling operations, the boreholes were backfilled in general accordance with Ontario Regulation 903. Completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
PR17-01	12.8 / 408.3	None installed	Borehole backfilled with bentonite holeplug to 10.7 m, auger cuttings from 10.7 m to 3.0 m, then bentonite holeplug to surface.
PR17-02	18.5 / 404.6(1)	None installed	Borehole backfilled with auger cuttings to 1.0 m, concrete to from 1.0 m to 0.2 m, then asphalt to surface.
PR17-02 DCPT	17.7 / 405.4(1)	None installed	Borehole backfilled with auger cuttings to 0.9 m, gravel from 0.9 m to 0.6 m, concrete from 0.6 m to 0.2 m, then asphalt to surface.

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
PR17-03	12.2 / 410.6	None installed	Borehole backfilled with aggregate to 1.5 m, concrete from 1.5 m to 0.1 m then asphalt to surface.
PR17-04A	2.3 / 420.6	None installed	Borehole backfilled with auger cuttings to surface.
PR17-04B	18.5 / 404.2(1)	12.2 / 410.7	Screened from 12.2 m to 9.2 m, sand backfill from 12.8 m to 8.6 m, bentonite holeplug from 8.6 m to surface.
PR17-05	3.7 / 420.1	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete from 0.9 m to 0.2 m, then asphalt to surface.
PR17-06	8.2 / 415.1	None installed	Borehole backfilled with auger cuttings to 1.7 m, gravel from 1.7 m to 0.6 m, concrete from 0.6 m to 0.2 m, then asphalt to surface.
PR17-07	3.7 / 419.1	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete from 0.9 m to 0.2 m, then asphalt to surface.
PR17-08	3.7 / 418.9	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete from 0.9 m to 0.2 m and asphalt to surface.

(1) DCPT

4. LABORATORY TESTING

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

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

5. DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general, the subsurface conditions encountered in the boreholes below the existing embankment fill typically consist of native sand, silty sand, sandy silt and gravelly sand layers. Cobbles and boulders were frequently encountered within the native sand and gravelly sand deposits depth at this site. Descriptions of the individual strata are presented below.

5.1 Topsoil

Topsoil was encountered in Borehole PR17-01 and was approximately 200 mm thick.

The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

5.2 Asphalt

The boreholes that were drilled through the paved portion of Highway 599 encountered approximately 25 mm to 40 mm of asphalt at the ground surface. The ground surface elevations of the boreholes drilled on the highway platform ranged from 422.6 to 423.8.

5.3 Embankment Fill

Embankment fill was encountered below the asphalt in five boreholes drilled on Highway 599, below the topsoil layer in Borehole PR17-01, and at the surface in Boreholes PR17-04A and PR17-04B. The embankment fill generally consisted of gravelly sand, silty sand, and sand and gravel containing trace to some silt and clay. Occasional wood pieces were encountered within the fill in PR17-03.

The embankment fill typically extended to depths ranging from 1.8 m to 4.6 m (Elevations 420.8 to 418.3).

Boreholes PR17-04A, PR17-05 and PR17-07 were terminated within the fill at depths ranging from 2.3 m to 3.7 m (Elevations 420.6 to 419.1).

SPT 'N' values in the fill ranged from 0 (weight of hammer) to 52 blows for 0.3 m penetration, indicating a very loose to very dense relative density. Higher blow counts 110 blows per 0.3 m of penetration and 50 blows per 0.125 m of penetration, were recorded within the fill in Boreholes PR17-02 and PR17-03, indicating a very dense state. However, these values are likely a result of cobbles or large gravel present within the fill. Measured moisture contents ranged from 2 percent to 21 percent.

The results of grain size distribution analyses conducted on samples of the fill are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figures B1 to B3 in Appendix B.

Soil Particle	Silty Sand/Sand Fill (percent)	Gravelly Sand Fill (percent)	Sand and Gravel Fill (percent)
Gravel	0 to 8	15 to 26	35 to 42
Sand	59 to 65	47 to 54	49 to 55
Silt	29 to 31	18 to 27	-
Clay	4	2 to 3	-
Silt & Clay	-	38	8 to 10

5.4 Silty Sand with organics

A layer of dark brown silty sand mixed with organics was encountered beneath the embankment fill in Borehole PR17-01, at 2.4 m depth (Elevation 418.7). The silty sand mixed with organics was approximately 1.2 m thick.

The depth to the base of this layer was approximately 3.6 m (Elevation 417.5).

SPT 'N' values recorded in the silty sand with organics were 2 and 3 blows for 0.3 m penetration, indicating a very loose relative density. Measured moisture contents in the silty sand with organics were 39 percent and 96 percent.

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5.5 Silty Sand to Sand

Layers of silty sand to sand containing trace to some silt, trace to some gravel, and trace clay, were encountered at depths ranging from 3.6 m to 4.6 m (Elevations 417.5 to 419.3) in Boreholes PR17-01 to PR17-03, PR17-04B, and PR17-06. Where fully penetrated, in Boreholes PR17-01, PR17-03 and PR17-06, the thickness of the silty sand to sand was 6.2 m, 3.4 m and 2.1 m, respectively.

The depth to the base of the native silty sand to sand was at 9.8 m, 7.6 m and 6.1 m (Elevations 411.3, 415.2 and 417.2) in Boreholes PR17-01, PR17-03 and PR-17-06, respectively.

Boreholes PR17-02 and PR17-04B were terminated within the silty sand to sand layers at 14.6 m and 12.8 m depth, (Elevations 408.5 and 410.1), respectively.

SPT ‘N’ values recorded in the silty sand to sand ranged from 0 (weight of hammer) to 28 blows for 0.3 m penetration, typically 0 to 12, indicating a very loose to compact relative density. A higher blow count of 53 blows per 0.3 m of penetration, was recorded in Borehole PR17-01 towards its base, however is likely a result of presence of cobbles or boulders. Based on DCPT testing in Borehole PR17-02, the very loose conditions encountered in the boreholes, from approximate Elevations 413.0 to 417.0, with SPT ‘N’ values of 0 to 3, may have been the result of hydraulic disturbance during the drilling operations. Measured moisture contents of the silty sand to sand ranged from 6 percent to 33 percent.

The results of grain size distribution analyses conducted on samples of the silty sand to sand are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B4 in Appendix B.

Soil Particle	Sand (percent)	Silty Sand (percent)
Gravel	3 to 10	0
Sand	83 to 90	53 to 71
Silt	-	25 to 45
Clay	-	2 to 8
Silt & Clay	7	-

5.6 Silt and Sand to Sandy Silt

Layers of silt and sand to sandy silt, consisting of trace to some clay and trace gravel were encountered at 6.1 m and 1.8 m depth (Elevations 417.2 and 420.8) in Boreholes PR17-06 and PR17-08, respectively.

Boreholes PR17-06 and PR17-08 both terminated within the silt and sand to sandy silt layers at depths of 8.2 m and 3.7 m (Elevations 415.1 and 418.9), respectively.

SPT ‘N’ values recorded in the silt and sand to sandy silt ranged from 2 to 3 blows for 0.3 m penetration, indicating a very loose relative density. Measured moisture contents in the silt, and sand and silt ranged from 12 percent to 20 percent.

The results of grain size analyses conducted on samples of the sandy silt, and sand and silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Soil Particle	Silt and Sandy Silt (percent)
Gravel	0 to 5
Sand	22 to 44
Silt	47 to 66
Clay	4 to 12

5.7 Gravelly Sand/Sand and Gravel with Cobbles and Boulders

Layers of gravelly sand and, sand and gravel containing cobbles and boulders were encountered at depths of 9.8 m and 7.6 m (Elevations 411.3 and 415.2) in Boreholes PR17-01 and PR17-03, respectively. Coring was required to advance the borehole through cobbles and boulders within this layer.

Boreholes PR17-01 and PR17-03 were both terminated within this layer at depths of 12.8 m and 12.2 m (Elevations 408.3 and 410.6), respectively.

SPT ‘N’ values in the sand and gravel layer ranged from 21 to 28 blows for 0.3 m penetration of the sampler, indicating a compact state. Measure moisture contents in the gravelly sand/sand and gravel ranged from 7 percent to 9 percent.

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

Soil Particle	Sand and Gravel (percent)
Gravel	49
Sand	49
Silt and Clay	2

5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. A piezometer was also installed in Borehole PR17-04B. The piezometer was decommissioned upon taking a water level measurement. The groundwater levels measured in the open boreholes and in the piezometer are summarized in Table 5.1 below.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
PR17-01	July 11, 2017	0.9	420.2	Open borehole
PR17-02	June 21, 2017	3.5	419.6	Open borehole
PR17-03	July 13, 2017	2.4	420.4	Open borehole
PR17-04A	July 14, 2017	Dry	-	Open borehole
PR17-04B	July 19, 2017	3.0	419.9	Piezometer
PR17-05	June 21, 2017	Dry	-	Open borehole
PR17-06	June 21, 2017	3.5	419.8	Open borehole
PR17-07	June 20, 2017	2.9	419.9	Open borehole
PR17-08	June 20, 2017	2.9	419.7	Open borehole

The upstream and downstream water levels of Pratt Creek were measured at Elevation 419.93 m and 419.23 m, respectively, in April, 2016, as shown on drawings provided by Hatch. The groundwater level should be assumed to reflect the local creek water level.

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silty sand from Borehole PR17-02, and a sample of the creek water, taken from the inlet area, 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	
			PR17-02 SS 7 Depth 6.1 m (Soil Sample)	Pratt Creek (Creek Water)
Sulphide	%	mg/L	0.02	<0.006
Chloride	µg/g	mg/L	6.9	2.9
Sulphate	µg/g	mg/L	26	1.2
pH	No unit	No unit	8.25	7.81
Electrical Conductivity	µS/cm	µS/cm	49	78
Resistivity	Ohms.cm	Ohms.cm	20300	12700
Redox Potential	mV	mV	325	272

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. Ryan McCourt of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, EIT of Thurber.

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for design of the proposed Pratt Creek Culvert replacement located on Highway 599, approximately 17.2 km north of the intersection of Highway 599 and Highway 17 in Ignace, Ontario.

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

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO dated November 2, 2015. The existing structure is a two-span open footing timber culvert. The culvert is approximately 5.4 m wide and 28 m long. The estimated culvert invert levels at the inlet and outlet are approximately at Elevations 419.4 and 419.5. The existing road grade at the culvert location is at about Elevation 423.3 m, which indicates approximately 1.3 m to 1.5 m of fill above the top of the culvert. The highway embankment is up to approximately 4.6 m in height.

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

1. Single CSP Pipe Culvert

   A circular CSP pipe is being considered to provide increased hydraulic opening. The CSP is likely to be approximately 3.6-m in diameter. The proposed founding level (bottom of bedding base) of the CSP pipes is near Elevation 418.3 to 418.4.

2. Single Span Precast Concrete Box Culvert

   A single cell precast concrete box culvert is an option for this site. Information provided by Hatch indicates that a 3.6 m x 2.4 m box culvert is being considered. The proposed founding level (bottom of bedding base) of the box culvert is near Elevations 418.0 to 418.1.

The alignment of the replacement culvert will remain largely the same as for the existing culvert. Grade raise of about 1.36 m is proposed at the culvert location.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary roadway protection system. For CSP culvert and box culvert options, a temporary stream diversion pipe (CSP) is planned during construction, approximately 11.4 m west of the existing culvert centreline with an invert elevation of approximately 419.2.

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

9. CULVERT DESIGN

9.1 Culvert Replacement Options

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

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

- Concrete Pipe, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)

- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings
- Precast Concrete Slabs Supported on Sheet Pile Abutments (Sheet pile culvert)

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

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

- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast-in-place open footing culvert, resulting in shorter durations for dewatering and construction;

- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis;

A sheet pile system culvert is not recommended at this site since this option is likely to be more expensive and there is evidence of cobbles and boulders in the embankment fill and the underlying native sand and gravel will impede the installation of sheet piles. Recommendations for sheet piles as a culvert replacement are not presented in the report.

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

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

9.2 Foundation Design for Culverts

In general, the subsurface conditions encountered in the boreholes drilled through Highway 599 platform generally consists of very loose to compact granular embankment fill (approximately 2.4 m to 4.6 m thick), underlain by layers of native very loose to compact sand, silty sand, and gravelly sand. A layer of silty sand with organics was encountered near the base of the embankment fill in one borehole drilled at the culvert inlet. Cobbles and boulders (up to 280 mm in size) were encountered within the native sand and gravel sand layers below 7.0 m depth in two boreholes. Use of rock coring equipment was required to penetrate the cobbles and boulders. The creek level was measured at Elevations 419.93 and 419.23, in the inlet and outlet, respectively, in April 2016. Groundwater measured in the piezometer on July 19, 2017 was at Elevation 419.9.

The founding soils encountered at the proposed founding elevations 418.0 to 418.4 (bottom of bedding base), generally consist of native loose to compact sand and silty sand.

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

9.2.1 Corrugated Steel Pipe Culvert

Replacement of the culvert with an SPCSP or CSP on the same alignment as the existing culvert may be considered for this site. Since there is a proposed grade raise of 1.36 m at the culvert, it is anticipated that the subgrade soils within the culvert footprint will be subjected to additional loading due to the culvert replacement and new fill. Settlement due to the new load is anticipated at the site, however this immediate settlement will be in the range of 25 mm to 30 mm. The culvert must be designed to accommodate the estimated settlement.

If this alternative is selected, the SPSCP or CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II. The underside of the bedding layer should be placed at or below Elevations 418.4 to 418.3, which corresponds to native loose to compact sand and silty sand. Geotextile should be placed between the founding soils and the granular layer of bedding material.

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

9.2.2 Precast Concrete Box Culvert

Replacement of the existing culvert with a precast concrete box culvert on the same alignment is considered a viable alternative for this site. Since there is grade raise proposed, it is anticipated that the subgrade soils within the culvert footprint will be subjected to additional loading due to the culvert replacement. Therefore, settlement of the underlying soils is expected to be 25 mm to 30 mm, as the culvert must be designed to accommodate this immediate settlement.

Based on available information, it is anticipated that the proposed inlet and outlet founding levels (bottom of bedding base) of the culvert are at Elevations 418.1 and 418.0, respectively.

The founding elevations will expose loose to compact sand and silty sand. It must be noted that a layer of silty sand with organics, extending to Elevation 417.5, was encountered below the fill in Borehole PR17-01, drilled at the culvert inlet. This layer with organics has to be removed and replaced with granular material.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A. Geotextile should be placed between the founding soils and the granular layer of bedding material. Subgrade preparation should also be conducted as indicated in Section 11.1.

The following geotechnical capacities could be used for design of a box culvert founded at or below Elevations 418.1 to 418.0 m on the native loose to compact sand and silty sand:

- Factored Geotechnical Resistance at ULS of 180 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 140 kPa.

The above values of the geotechnical resistance and reaction were based on a box culvert width of 3.6 m.

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

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and Bridge Design Code (CHBDC) 2014, Sec. 6.9.

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

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

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.35.

Immediate settlement, 25 mm to 30 mm, is anticipated due to the placement of new fill at the site. The culvert must be designed to accommodate the estimated settlement.

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

9.2.3 Culvert Headwall / Wingwalls

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

The borehole information indicates that the founding soils at or below Elevation 417.5, at the inlet and outlet generally consist of very loose to compact sand over layers of sand and gravel. A 1.2-m thick layer of silty sand with organics was encountered below the fill at the inlet area from Elevations 418.7 to 417.5.

9.2.3.1 RSS Walls

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

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

If sand and silt with organics is encountered along the alignment of the RSS wall, it must be removed down to native sand and replaced with granular fill compacted as per OPSS 501. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native sand at approximate Elevation 417.5. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement). The engineered fill pad placed under the RSS mass must consist of OPSS.PROV 1010 Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

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

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

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

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

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

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

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

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

9.2.3.2 Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on very loose to compact sand/silty sand subgrade, encountered below the fill. All topsoil, organics or soft soils encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.5 m at this site) and founded on the native loose to compact sand at or below Elevation 417.5. A factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the wall footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to sliding between precast concrete and the underlying sand, and sand and gravel should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.4.

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

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

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9.3 Settlement

Embankment grade raise, approximately 1.36 m, is anticipated as part of the culvert replacement. It is recommended that the underlying layer of silty sand with organics, encountered below the fill in Borehole PR17-01, be excavated. The estimated settlements after culvert construction and embankment reconstruction at this site is estimated to be 25 mm to 30 mm.

The culvert must be designed to accommodate the estimated immediate settlement.

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

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.5 m, as per OPSD 3090.100. The base of any retaining wall footings, if employed, should be provided with a minimum of 2.5 m of earth cover as protection against frost action. The pipe and box culvert options do not require frost cover/protection.

The frost taper investigation indicated the presence of 1.8 m to more than 4.0 m of sand and, sand and gravel fill overlying layers of native sand, gravelly sand and, silty sand, to approximately 20 m north and south of the centreline of the existing culvert. The granular fill and the native cohesionless soils are not frost susceptible. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment fill and base material.

As the frost penetration line is below the top of culvert, frost treatment/taper for the culvert would normally be provided as per OPSD 803.031. Since the existing embankment material beyond the excavations for the existing culvert does not contain frost susceptible soils within the frost penetration depth (2.5 m), a new frost tapper does not appear to be warranted.

10. LATERAL EARTH PRESSURES

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

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

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

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

Table 10.1 – Lateral Earth Pressure Coefficients (K)

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

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

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

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

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added.

11. CULVERT CONSTRUCTION CONSIDERATIONS

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

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, 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 and headwall subgrade preparation and foundation preparation must be carried out in the dry.

11.1 Subgrade Preparation

Performance of the replacement culvert and any headwalls will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. The sand and silt mixed with organics observed below the embankment fill in Boreholes PR17-01, from Elevations 418.7 to 417.5, if encountered, must be removed to expose the underlying competent sand and silty sand subgrade. Any remaining fill, topsoil, creek bed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint at the subgrade level must be removed and replaced with well compacted granular materials.

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

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

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

11.2 Culvert Bedding and Backfill

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

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.014, and as per the requirements of the CHBDC.

Backfilling for the culvert should be in accordance with OPSS 501, OPSS 902, and as per the CHBDC requirements. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

11.3 Excavation and Groundwater Control

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native sand, silty sand/sandy silt and gravelly sand at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits and alluvium/muskeg/organics, should be classified as Type 4 soils.

Excavation for culvert construction should be carried out in accordance with OPSS 902. Excavations for culvert replacement will be carried out through the existing embankment fill and native sand and silty sand; at the inlet area will extend into the underlying sand and silt mixed with organics.

Excavation for culvert replacement will be carried out below the creek water level indicated at Elevation 419.9 in the GA drawing. Groundwater level was measured at Elevation 419.9 in the piezometer installed in Borehole PR17-4B. In order to construct a pipe or a box culvert in the dry, diversion of the lake/creek flow will be required. Given the relatively high permeability of the embankment fill materials, water inflow/seepage into the excavation should be anticipated from the embankment fill. A combination of cofferdam enclosures and creek diversion along with the use of sumps/pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. The use of interlocking and watertight, steel sheet pile cofferdam is a feasible option for this site. Presence of cobbles and boulders may be encountered during sheet pile installation. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.

Installation of a temporary cofferdam is planned at the inlet and outlet of the culvert. Boreholes were not drilled at the proposed cofferdam location, and the closest boreholes to the cofferdam locations are Boreholes PR17-01, PR17-04A and PR17-04B. Record of Boreholes Sheets of these boreholes are included in Appendix B.

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

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

12. STREAM DIVERSION PIPE

A stream diversion pipe consisting of a CSP may be used to facilitate construction of the CSP culvert and box culvert replacement options, as indicated on Preliminary General Arrangement drawings. The diversion pipe is shown to be located approximately 11.4 m to the west of the centreline of the existing culvert with the invert at approximate Elevation 419.2 m. Below the invert level, the subgrade will consist of native loose sand, as documented in Borehole PR17-06.

Organics, soft soils and deleterious material should be sub-excavated from the trench base where encountered. The pipe should be placed on 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II, or clear stone if wet. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

The stream diversion pipe could be installed within the temporary open cut excavations, or alternatively within a shored trench.

13. TEMPORARY PROTECTION SYSTEM

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

Interlocking sheet piles or a soldier pile and lagging wall could be considered at this site. It should be noted however, that occasional cobbles and boulders are encountered in the embankment fill and in the native soils below 7.0 m depth. Accordingly, sheet piles may encounter these obstructions. The soil parameters in Table 13.1 may be used for design of the temporary roadway protection system with horizontal backfill.

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

Table 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Sand/Silty Sand	Native Gravelly Sand/Sand and Gravel
Angle of Internal Friction (ϕ)	30°	30°	32°
Bulk Unit Weight (γ)	20 kN/m^3	20 kN/m^3	21 kN/m^3
Submerged Unit Weight (γ_w)	10 kN/m^3	10 kN/m^3	11 kN/m^3
Coefficient of Active Earth Pressure (K_a)	0.33	0.33	0.31
Coefficient of Passive Earth Pressure (K_p)	3.0	3.0	3.2

Given that the foundation soils consist of loose to compact sands, vibratory methods must not be used at this site to install or extract the sheet piles and H-piles (if used). A NSSP to this effect is provided in Appendix G.

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

14. EMBANKMENT WIDENING AND RESTORATION

It is anticipated that there will be a grade raise of 1.36 m at this site for the culvert replacement. Also, widening of the embankment, approximately 1.0 m on each side, is planned at this site.

Cross sections from Stations 18+260, 18+265 and 18+270 provided by Hatch, indicate that the proposed widening of the highway embankment extends into the creek on the southwest and northeast sides of the culvert. The use of a retaining systems (e.g., retaining wall, gabion wall) may be required on the south sides of the culvert to avoid embankment encroachment into the creek. Recommendations for retaining walls are provided in Section 9.2.3 of this report. The soils encountered in the area, indicate the presence of very loose to compact native sand.

At the time of preparation of this report, it was understood that the design does not contemplate the construction of a retaining wall at this location. A slope stability analysis has been conducted for the embankment widening into the creek on the southwest side (critical section) of the Pratt Creek culvert, without a retaining wall. For the purpose of embankment stability analyses, the commercially available slope stability program GEO-SLOPE and employing the Morgenstern-Price method. For global stability a minimum Factor of Safety (F.S.) of 1.3 is considered appropriate for end of construction conditions.

The computed factors of safety for two scenarios (two different water levels in the creek) are summarized in Table 14.1. Selected slope stability computation outputs are included in Figures E1 and E2 of Appendix E.

Table 14.1 –Computed Factors of Safety

Case	Water level in the Creek	Factor of Safety	Slope Stability Output
Case 1	419.9 (April 2016)	1.294	Figure E1
Case 2	420.8 (25-year return)	1.281	Figure E2

From a geotechnical perspective, the Factors of Safety (F.S.) of 1.29 and 1.28 obtained are considered marginally acceptable for long term (drained) conditions in cohesionless soils.

The hydraulics and environmental requirements for the proposed embankment widening should be reviewed. Appropriate erosion protection should be provided for the widened embankment slope. Design of the erosion protection measures considering hydrologic and hydraulic factors should be carried out by specialists experienced in this field.

Outside the above area, the restored embankment slopes should remain stable, provided that the embankment side slopes are constructed not steeper than 2H:1V.

Settlement due to changes in the culvert configuration is expected to be 25 mm to 30 mm. This immediate settlement was estimated considering that, as discussed in Section 9.3, all the silty sand with organics is removed from under the culvert footprint, specially in the inlet area.

Embankment widening and restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Where new embankment fill is placed against existing embankment slopes or on sloping ground surface steeper than 3H : 1V, the existing fill slope must be benched in accordance with OPSD 208.010.

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

15. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site include very loose to compact granular fill underlain by layers of native cohesionless soils consisting compact to loose sand, sandy silt, gravely sand and, sand and gravel. This would correspond to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.054 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 15.1 may be used:

Table 15.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II ϕ = 35°, γ = 22.8 kN/m^3	**OPSS Granular B Type I** ϕ = 32°, γ = 21.2 kN/m^3	**Existing Fill** ϕ = 30°, γ = 20 kN/m^3
Active (K_{AE})*	0.29	0.33	0.36
At Rest (K_{OE})**	0.50	0.54	0.57

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

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

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

16. SCOUR AND EROSION PROTECTION

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

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

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

If RSS walls/concrete wall are selected for the culvert replacement design, adequate scour and erosion protection must be provided for the bases of the walls so that they are not undermined by creek flow.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

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

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

18. CONSTRUCTION CONCERNS

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

- An effective dewatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (e.g., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng., and Mr. Jason Lee, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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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.

<u>UNIFIED SOILS CLASSIFICATION</u>

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

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.

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

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

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 percentage 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.

STRENGTH CLASSIFICATION

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

THURBER

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-01

METRIC

GWP# 6836-14-00 LOCATION Pratt Creek Culvert N 5 486 563.3 E 196 349.2 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.25 - 2017.07.11 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
421.1	GROUND SURFACE							
0.0	**TOPSOIL:** (200mm) Dark Brown Moist					421		
0.2	Silty **SAND**, trace clay Very Loose Brown Wet (FILL)	1	SS	4	∇			
		2	SS	0		420		0 65 31 4
		3	SS	0		419		
418.7 / 2.4	Silty **SAND**, with organics Very Loose Dark Brown Moist	4	SS	2			99	
		5	SS	3		418		
417.5 / 3.6	**SAND**, trace to some silt and clay, trace to some gravel Very Loose Dark Brown Moist					417		
		6	SS	1		416		
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 417.0m to 414.5m Grey Wet					415		
	Cobbles and boulders	7	SS	0		414		
	Compact	8	SS	20		413		
	Very Dense	9	SS	53		412		10 83 7 (SI+CL)
411.3 / 9.8	**SAND** and **GRAVEL**, with cobbles		RUN					

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity; (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-01

METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 563.3 E 196 349.2 | ORIGINATED BY BRM

HWY 599 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.06.25 - 2017.07.11 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SAND and **GRAVEL**, with cobbles and boulders Brown Wet Boulder (280cm) at 10.5m CORED THROUGH COBBLES AND BOULDER BELOW 9.8m.						411 410 409				
408.3	Cobble (200cm) at 12.3m										
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 0.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 10.7mm, AUGER CUTTINGS FROM 10.7m TO 3.0m, BENTONITE TO SURFACE.										

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

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

RECORD OF BOREHOLE No PR17-02

METRIC

GWP#	6836-14-00	LOCATION	Pratt Creek Culvert N 5 486 552.6 E 196 335.3	ORIGINATED BY	BRM
HWY	599	BOREHOLE TYPE	Hollow Stem Augers/Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.06.21 - 2017.06.21	CHECKED BY	RPR

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
423.1	GROUND SURFACE						
0.0	**ASPHALT:** (25mm)					423	
	SAND and **GRAVEL**, trace to some silt and clay: (FILL) Very Dense to Compact Brown Damp (FILL)	1	GS				
		2	SS	52		422	35 55 10 (SI+CL)
		3	SS	22		421	
		4	SS	17		420	
419.4		5	SS	110	∇		
3.7	Silty **SAND**, trace clay Loose Brown Wet					419	
		6	SS	8		418	
	Grey					417	
		7	SS	5		416	0 71 25 4
		8	SS	6		415	
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 414.5m to 413.0m Very Loose					414	
		9	SS	0			

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

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity — 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PR17-02

METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 552.6 E 196 335.3 | ORIGINATED BY BRM

HWY 599 | BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test | COMPILED BY AN

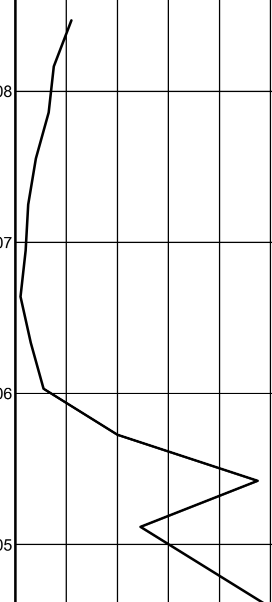
DATUM Geodetic | DATE 2017.06.21 - 2017.06.21 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page									
	Silty **SAND**, trace clay Compact to Loose Grey Wet						413			
			10	SS	14		412	~20		
			11	SS	28		411	~20		
			12	SS	7		410 / 409	~20		0 61 31 8
408.5 14.6	End of sampling at 14.6m and start DCPT						408 / 407 / 406 / 405			
404.6 18.5	END OF BOREHOLE AT 18.5m UPON DCPT REFUSAL. WATER LEVEL AT 3.5m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 1.0m, CEMENT TO 0.2m, THEN ASPHALT TO SURFACE.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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



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

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

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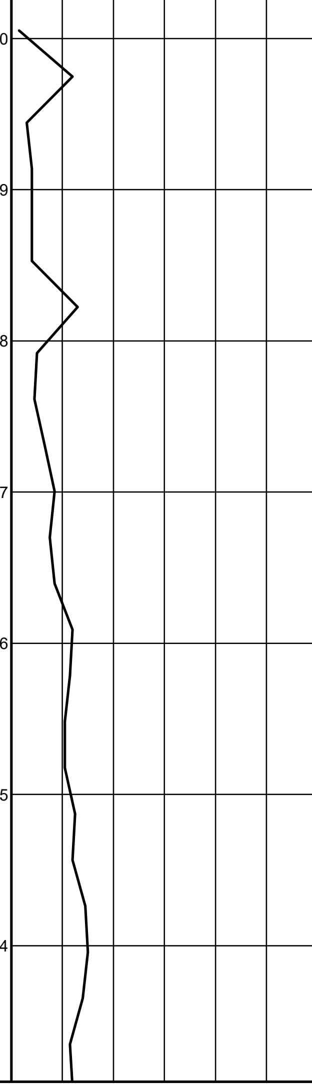
Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-02 DCPT 1 OF 2 METRIC

GWP# 6836-14-00	LOCATION Pratt Creek Culvert N 5 486 551.6 E 196 332.9	ORIGINATED BY BRM
HWY 599	BOREHOLE TYPE Dynamic Cone Penetration Test	COMPILED BY AN
DATUM Geodetic	DATE 2017.08.01 - 2017.08.01	CHECKED BY RPR

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
423.1	GROUND SURFACE										
0.0	Auger to 3.0m						423				
							422				
							421				
420.1 / 3.0	Start DCPT from 3.0m						420				
							419				
							418				
							417				
							416				
							415				
							414				



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+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

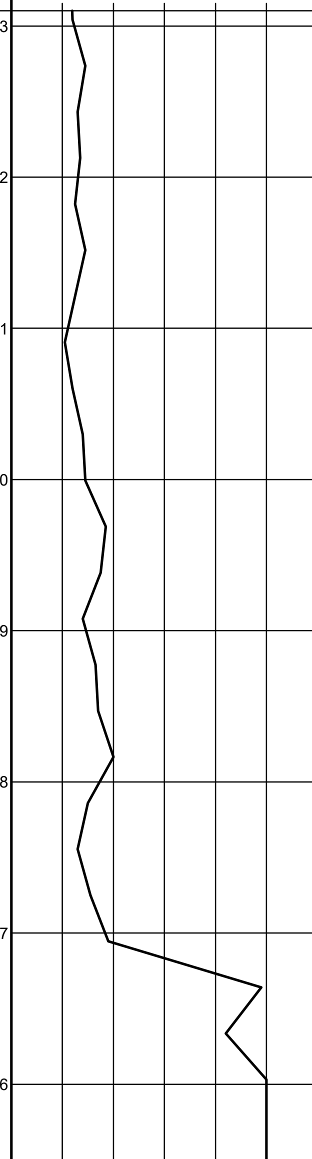
RECORD OF BOREHOLE No PR17-02 DCPT METRIC

GWP# 6836-14-00
LOCATION Pratt Creek Culvert N 5 486 551.6 E 196 332.9
ORIGINATED BY BRM

HWY 599
BOREHOLE TYPE Dynamic Cone Penetration Test
COMPILED BY AN

DATUM Geodetic
DATE 2017.08.01 - 2017.08.01
CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page						413 412 411 410 409 408 407 406				
405.4 17.7	END OF DCPT AT 17.7m UPON REFUSAL. BOREHOLE BACKFILLED WITH SLOUGH TO 0.9m, GRAVEL TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										



+ ³, × ³: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PR17-03

METRIC

GWP# 6836-14-00 LOCATION Pratt Creek Culvert N 5 486 551.4 E 196 346.7 ORIGINATED BY STH
HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2017.07.13 - 2017.07.13 CHECKED BY RPR

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
422.8	GROUND SURFACE							
0.0	**ASPHALT:** (40mm)	1	GS				○	
	SAND and **GRAVEL**, trace to some silt and clay, Very Dense, Brown, Moist (FILL)					422		
		2	SS	50/ 0.125			○	
421.3	Auger resistance							
1.5	**SAND**, trace gravel, some silt and clay, Compact to Loose, Brown, Moist to Wet (FILL)	3	SS	23		421	○	8 59 33 (SI+CL)
					∇			
		4	SS	5		420	○	
	Occasional wood pieces at 3.0m	5	SS	4			○	
418.6						419		
4.2	**SAND** and **SILT**, trace clay, Compact, Grey, Moist					418		
		6	SS	10			○	0 53 45 2
						417		
		7	SS	21			○	
	Occasional cobbles, auger grinding					416		
415.2	Some gravel and cobbles from 7.0m to 7.6m							
7.6	**SAND** and **GRAVEL**, some silt and clay, Compact, Grey, Wet, Auger grinding	8	SS	28		415	○	
	Cored through cobbles and boulders (140mm)		RUN			414		
						413		

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PR17-03

METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 551.4 E 196 346.7 | ORIGINATED BY STH

HWY 599 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.07.13 - 2017.07.13 | CHECKED BY RPR

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
	SAND and **GRAVEL**, some silt and clay Compact Grey Wet Cored through cobbles and boulders (80mm, 280mm)			RUN			412						
			9	SS	21		411	o (approx. 8)		49	49	2 (SI+CL)	
410.6 12.2	END OF BOREHOLE AT 12.2m. WATER LEVEL AT 2.40m. BOREHOLE BACKFILLED WITH AGGREGATE TO 1.5m, CONCRETE TO 0.1m, THEN COLD MIX TO GROUND SURFACE.												

Dynamic cone penetration resistance plot: 20, 40, 60, 80, 100. Shear strength kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20, 40, 60, 80, 100. Plastic limit w_P, natural moisture content w, liquid limit w_L. Water content (%): 20, 40, 60.

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-04A

METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 545.3 E 196 334.8 | ORIGINATED BY STH

HWY 599 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.07.14 - 2017.07.14 | CHECKED BY RPR

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	WATER CONTENT (%) (Plastic limit w_P, Natural moisture content w, Liquid limit w_L) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
422.9	GROUND SURFACE										
0.0	**SAND** and **GRAVEL**, trace silt and clay Compact to Loose Brown Moist (FILL)		1	SS	10				○		
							422				
			2	SS	24				○		42 50 8 (SI+CL)
							421				
			3	SS	9						
420.6 2.3	END OF BOREHOLE AT 2.3m UPON AUGER REFUSAL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PR17-04B

METRIC

GWP#	6836-14-00	LOCATION	Pratt Creek Culvert N 5 486 544.7 E 196 333.2	ORIGINATED BY	STH
HWY	599	BOREHOLE TYPE	Hollow Stem Augers/Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.07.14 - 2017.07.14	CHECKED BY	RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	ELEVATION SCALE
422.9	GROUND SURFACE					
0.0	**SAND** and **GRAVEL**, trace silt, trace clay, occasional cobbles Compact Brown to Grey Moist (FILL)					
			1	GS		422
						421
						420
			2	SS	23	
						419
418.3 / 4.6	**SAND**, trace to some silt, trace to some gravel Very Loose to Compact Brown to Grey Wet					
			3	SS	12	418
						417
			4	SS	3	
						416
			5	SS	9	415
						414
			6	SS	12	
						413

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

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Ministry of Transportation
Ontario

THURBER

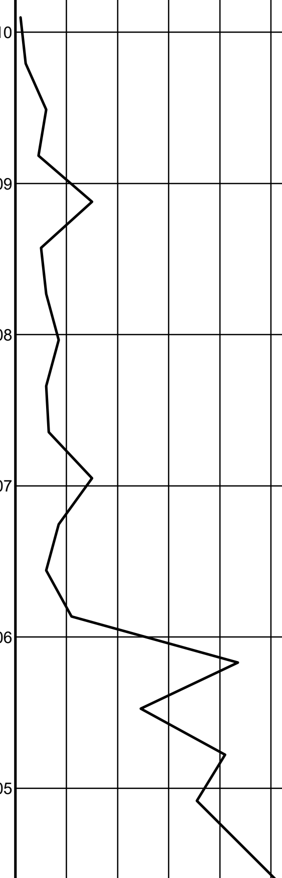
RECORD OF BOREHOLE No PR17-04B

METRIC

GWP# 6836-14-00
LOCATION Pratt Creek Culvert N 5 486 544.7 E 196 333.2
ORIGINATED BY STH
HWY 599
BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test
COMPILED BY AN
DATUM Geodetic
DATE 2017.07.14 - 2017.07.14
CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							
	SAND, trace gravel, trace silt, trace clay Compact Grey Wet							
			7	SS	10		412	
							411	
			8	SS				3 90 7 (SI+CL)
410.1 / 12.8	End of sampling and start DCPT						410	
							409	
							408	
							407	
							406	
							405	
404.4 / 18.5	END OF BOREHOLE AT 18.5m UPON DCPT REFUSAL. WELL INSTALLATION CONSISTS OF 19mm DIAMETER SCHEDULE 40 PVC PIPE WITH A 3.05m SLOTTED SCREEN WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.07.19 3.0 419.9							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100



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

UNIT WEIGHT γ kN/m³

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

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 10/24/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PR17-05

METRIC

GWP# 6836-14-00 LOCATION Pratt Creek Culvert N 5 486 548.0 E 196 319.1 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.21 - 2017.06.21 CHECKED BY RPR

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
423.8	GROUND SURFACE												
0.0	**ASPHALT:** (25mm)												
	Gravelly **SAND**, trace to some silt and clay, Very Loose, Brown, Moist (FILL)		1	GS				o					
							423						
			2	GS				o					
							422						
			3	GS				o		15	47	38 (SI+CL)	
			4	GS				o					
							421						
			1	SS	1			o					
420.1 / 3.7	END OF BOREHOLE AT 3.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-06

METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 551.1 E 196 328.7 | ORIGINATED BY BRM

HWY 599 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.06.21 - 2017.06.21 | CHECKED BY RPR

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
423.3	GROUND SURFACE						
0.0	**ASPHALT:** (25mm)						
0.0	**SAND** and **GRAVEL**, trace to some silt and clay; Dense to Compact; Brown; Moist; (FILL)	1	GS			plotted	
		2	SS	47		plotted	41 49 10 (SI+CL)
		3	SS	24		plotted	
	Wet	4	SS				No recovery
		5	SS	39	Water level ∇ (3.5m)	plotted	
419.3 / 4.0	**SAND**, some silt, occasional organics; Loose; Grey; Wet	6	SS	9		plotted	
417.2 / 6.1	Sandy **SILT**, some clay; Very Loose; Grey; Wet	7	SS	2		plotted	0 22 66 12
		8	SS	3		plotted	
415.1 / 8.2	END OF BOREHOLE AT 8.2m. WATER LEVEL AT 3.5m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 1.7m, GRAVEL TO 0.6m, CEMENT TO 0.2m, THEN ASPHALT TO SURFACE.						

Plot axes: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³. Elevation scale 423–416.

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-07 — 1 OF 1 — METRIC

GWP# 6836-14-00 | LOCATION Pratt Creek Culvert N 5 486 552.7 E 196 352.6 | ORIGINATED BY BRM

HWY 599 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.06.20 - 2017.06.20 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
422.8	GROUND SURFACE										
0.0	**ASPHALT:** (25mm)										
	SAND and **GRAVEL**, Brown, Moist (FILL)		1	GS			○				
			2	GS			○				
421.3 / 1.5	Gravelly **SAND**, some silt, trace clay, Very Loose, Grey to Brown, Moist to Wet (FILL)		3	GS		∇	○				
			4	GS			○				
			5	SS	4		○	26	54	18	2
419.1 / 3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL AT 2.9m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										

Elevation scale: 422, 421, 420

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 10/24/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PR17-08

METRIC

GWP# 6836-14-00 LOCATION Pratt Creek Culvert N 5 486 555.0 E 196 362.3 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.20 - 2017.06.20 CHECKED BY RPR

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT	GR	SA	SI	CL
422.6	GROUND SURFACE										
0.0	**ASPHALT:** (25mm)										
	Gravelly **SAND**, some silt to silty, trace clay, Brown, Moist (FILL)	1	GS				o	18	52	27	3
						422					
		2	GS				o				
						421					
420.8 / 1.8	**SAND** and **SILT**, trace gravel, trace clay, Very Loose, Brown to Grey, Moist	3	GS				o				
					▽						
		4	GS			420	o	5	44	47	4
		5	SS	3			o				
418.9 / 3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL AT 2.9m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.					419					

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

+ 3 , × 3 : Numbers refer to Sensitivity

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

THURBER

Appendix B

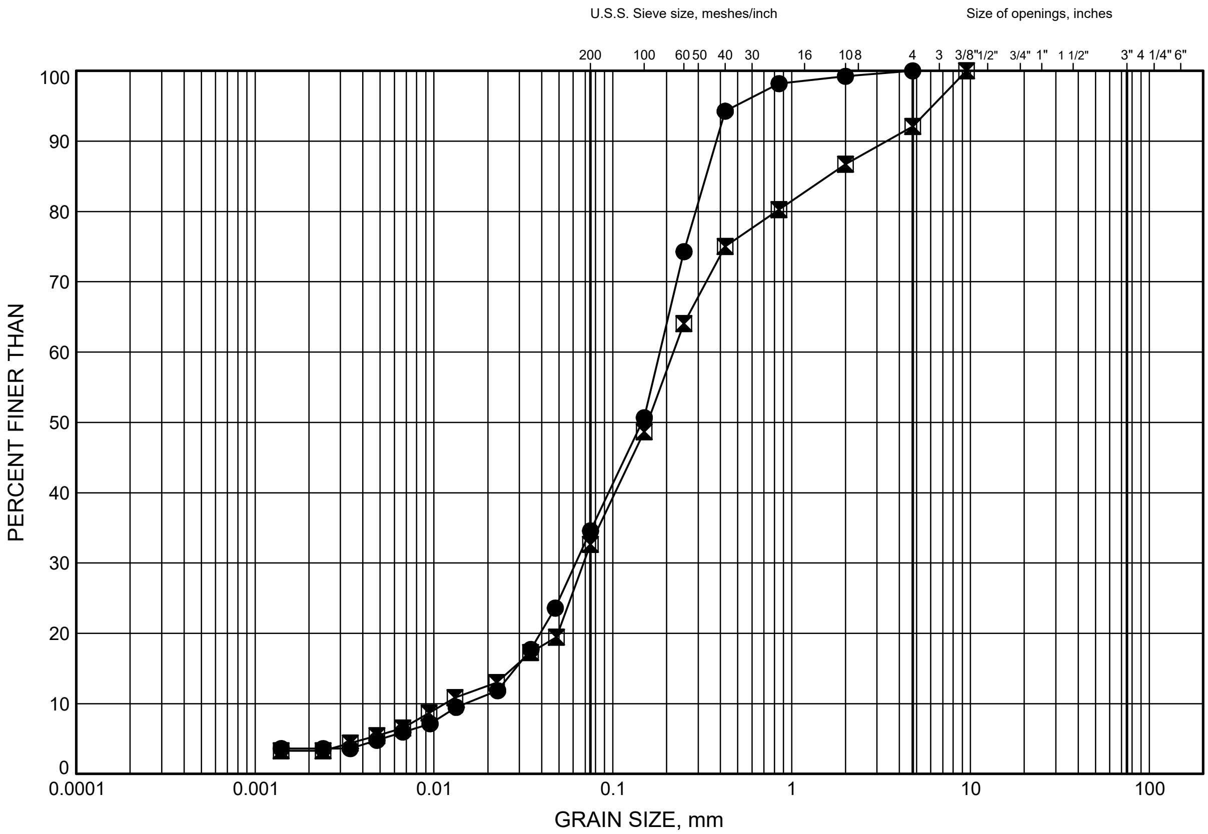
Geotechnical and Analytical Laboratory Test Results

Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to Silty SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-01	1.1	420.0
⧗	PR17-03	1.8	421.0

Date October 2017

GWP# 6836-14-00

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Prep'd AN

Chkd. RPR

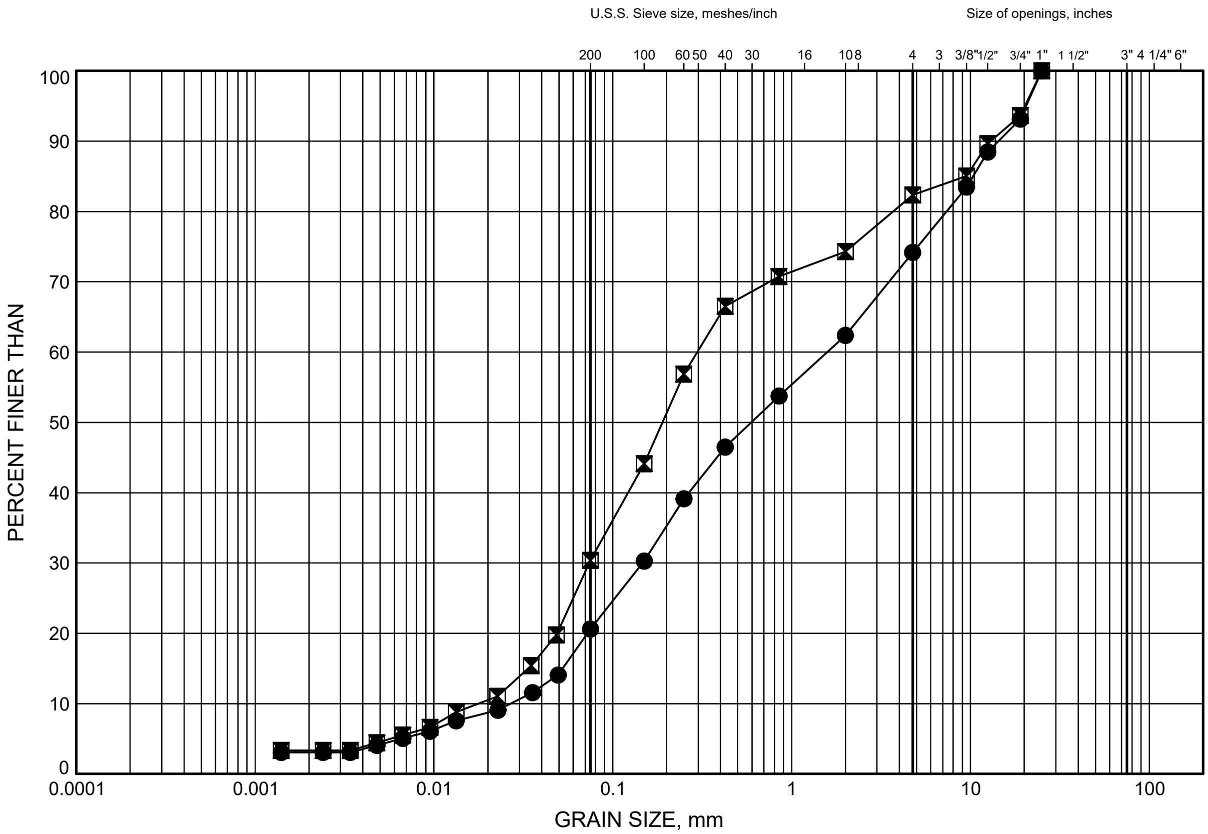
GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 10/24/17

Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-07	3.4	419.4
⧗	PR17-08	0.4	422.2

GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 10/24/17

Date October 2017

GWP# 6836-14-00

THURBER

Prep'd AN

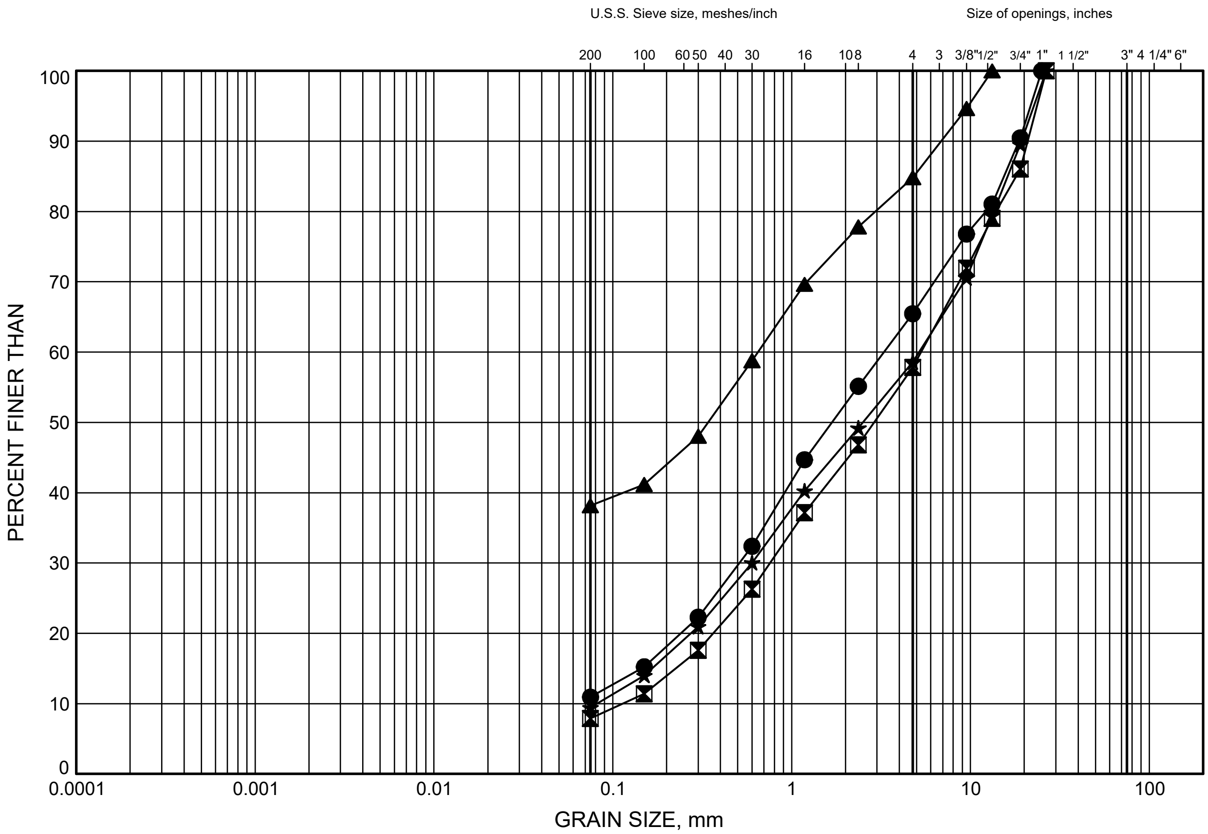
Chkd. RPR

Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND and GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-02	1.0	422.1
⧗	PR17-04A	1.1	421.8
▲	PR17-05	1.9	421.9
★	PR17-06	1.1	422.2

Date October 2017

GWP# 6836-14-00

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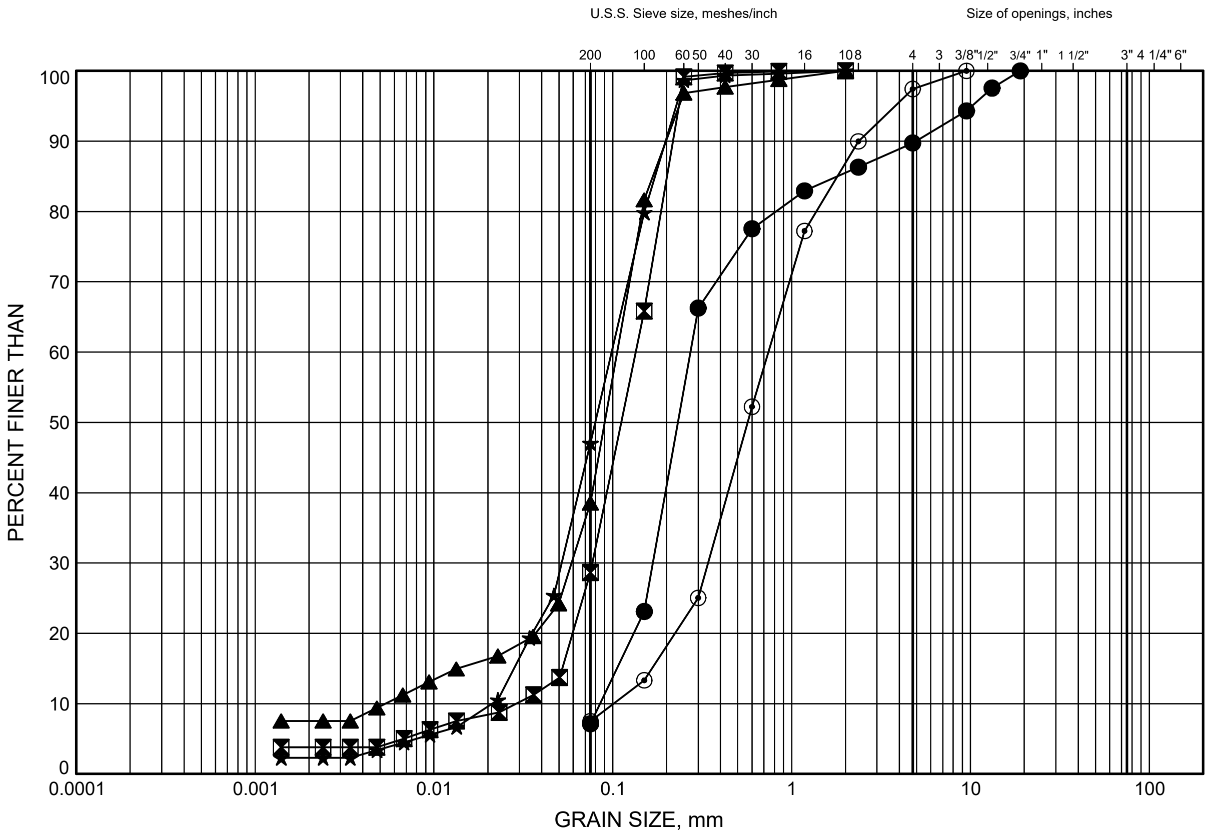
Chkd. RPR

Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silty SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-01	9.4	411.7
⧗	PR17-02	6.4	416.7
▲	PR17-02	14.0	409.1
★	PR17-03	5.0	417.8
⊙	PR17-04B	12.5	410.4

Date October 2017

GWP# 6836-14-00

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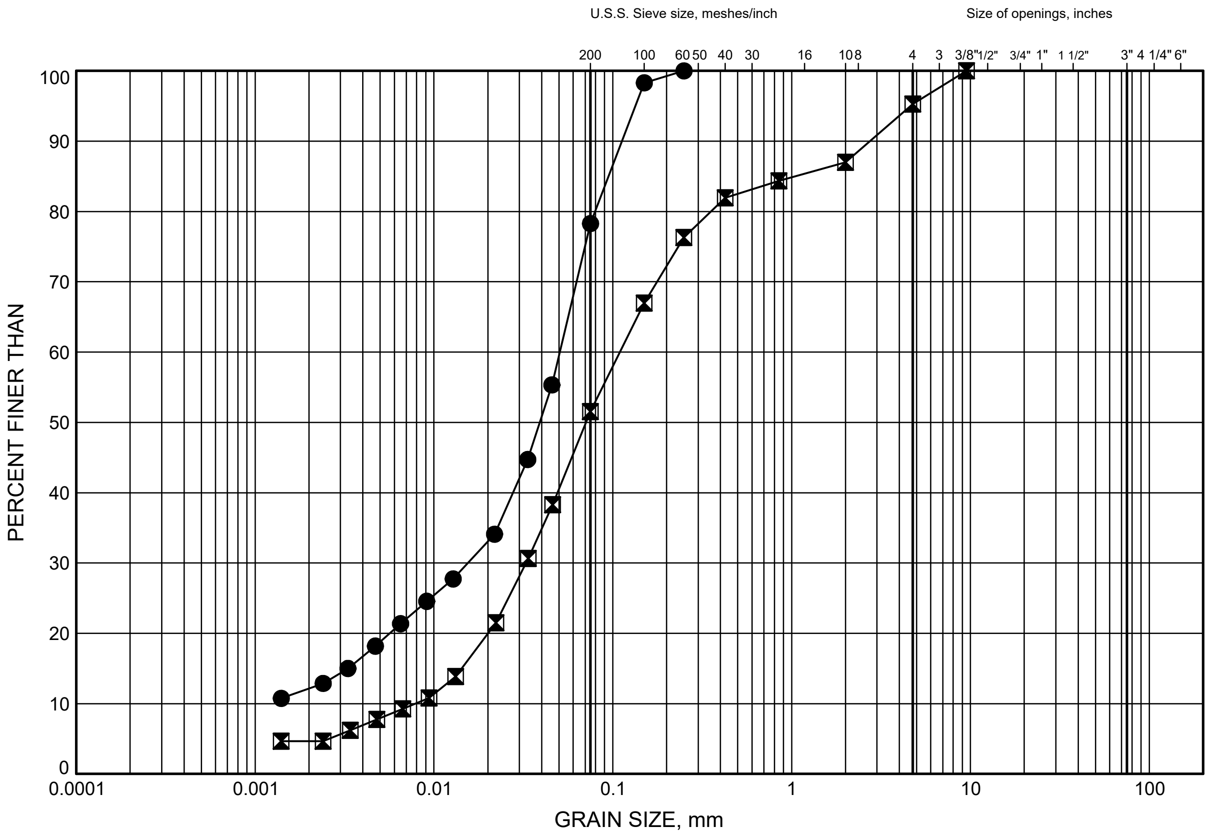
Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILT and SAND to Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-06	6.4	416.9
⧗	PR17-08	2.6	420.0

Date October 2017

GWP# 6836-14-00

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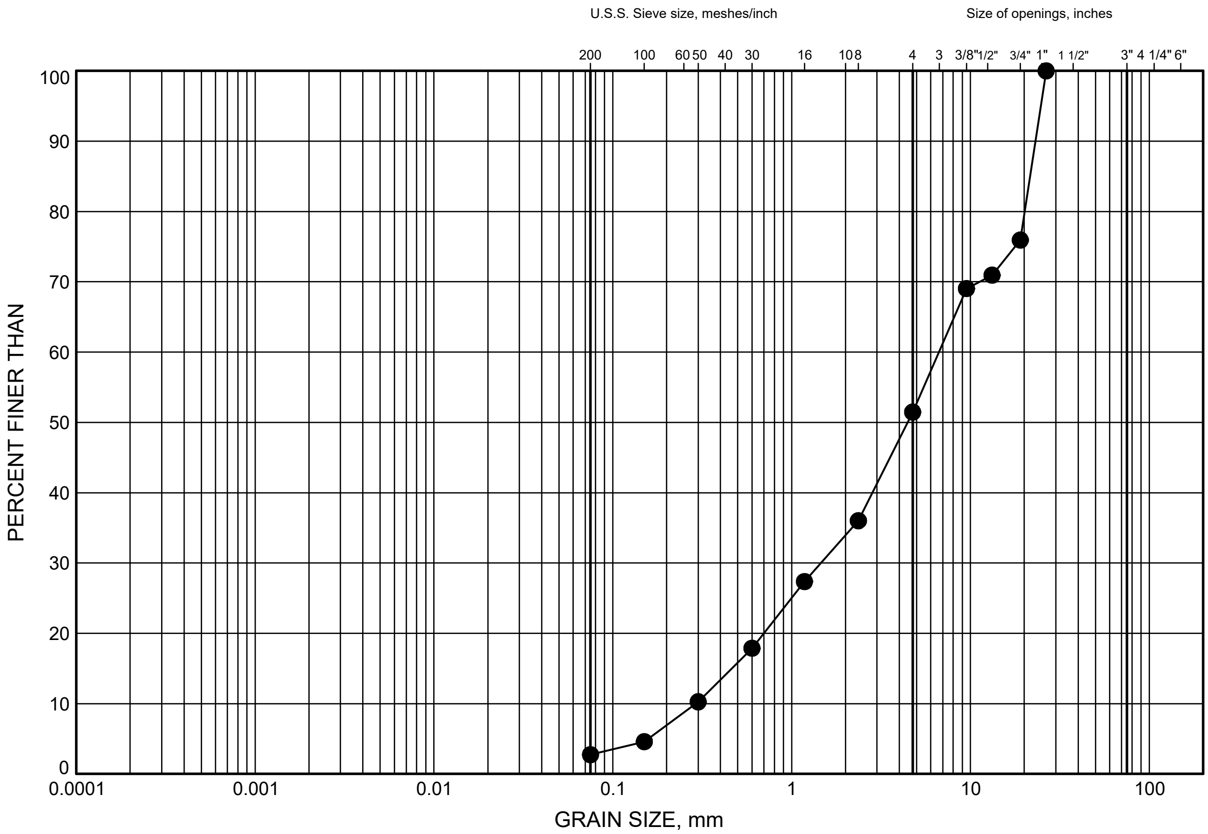
Chkd. RPR

Pratt Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND and GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR17-03	11.7	411.1

GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 10/24/17

Date October 2017

GWP# 6836-14-00

THURBER

Prep'd AN

Chkd. RPR

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

SGS

Attention: **Cory Zanatta**
Project#: **17077**

Client	**Thurber Engineering Ltd.**
SGS LIMS Number	**CA15302-AUG17**
Analysis Package:	**Corrosivity (Soil)**

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

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

Deanna Edwards

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

Certificate of Analysis

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

Attention: Cory Zanatta
Project#: 17077 Hwy 599

Client Thurber Engineering Ltd.
SGS LIMS Number CA15314-JUN17
Analysis Package: Corrosivity (Solution)

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

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

Deanna Edwards

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

THURBER

Appendix C

Selected Site Photographs

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Photo 1: Highway 599 at Pratt Creek Culvert looking west

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Photo 2: Highway 599 at Pratt Creek Culvert looking east

Photo 3: Pratt Creek Culvert outlet

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Photo 4: Pratt Creek Culvert inlet

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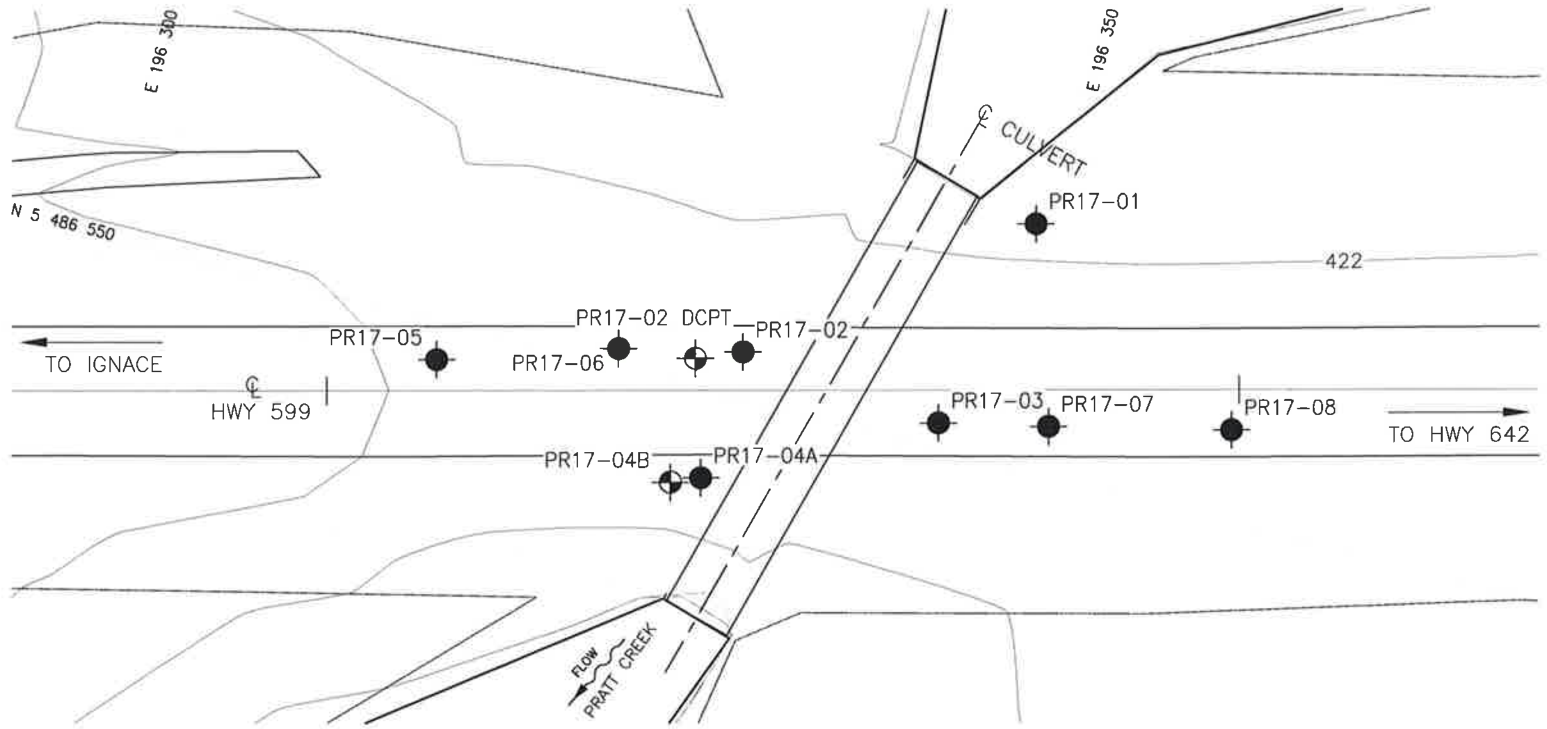
Appendix D

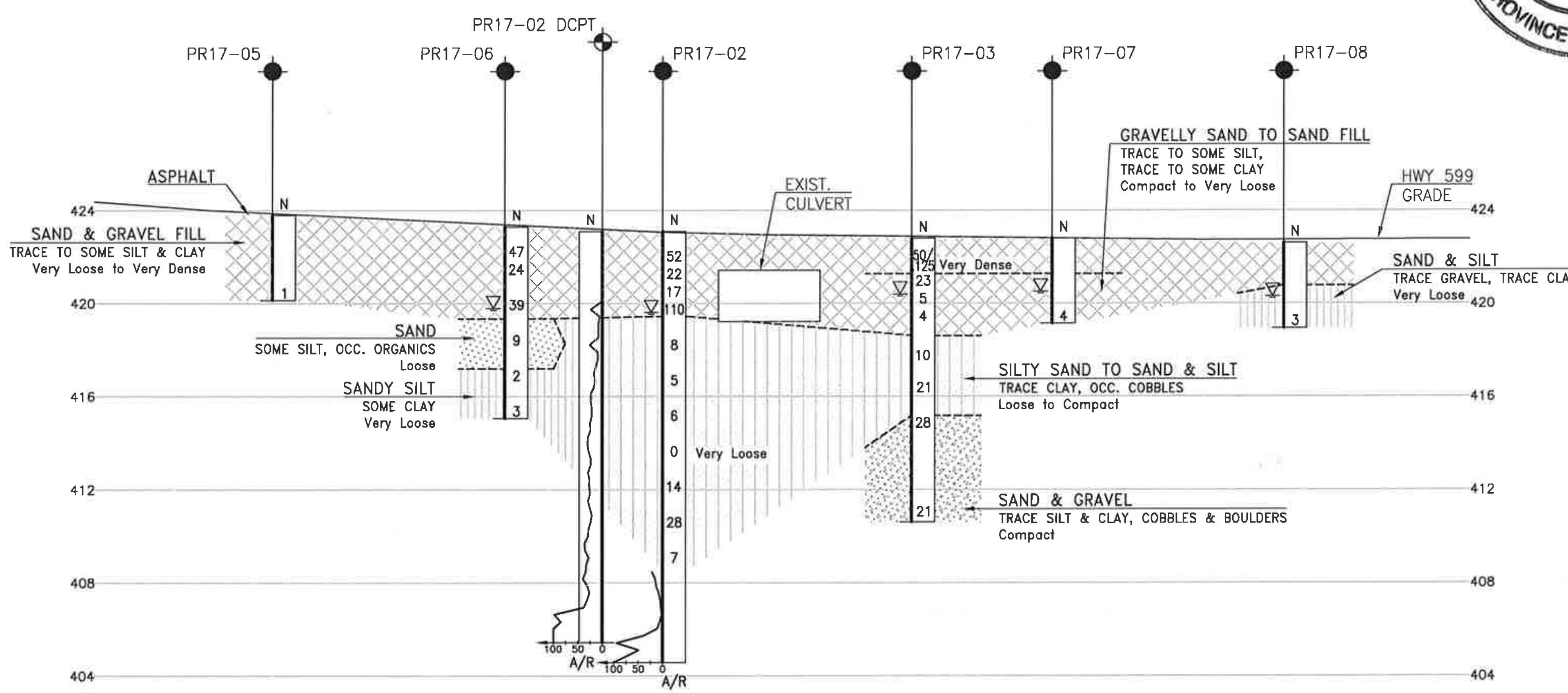
Borehole Locations and Soil Strata Drawings



PLAN

8 0 8 16m

SCALE 1:400



PROFILE ALONG ℄ HWY 599

5 0 5 10m

SCALE 1:250

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2017-6036
WP No 6838-14-01

HIGHWAY 599
PRATT CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

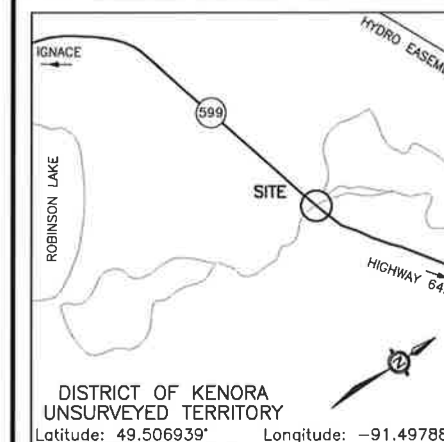
SHEET 42

HATCH

THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 6/18
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R. PALOMEQUEREYNA
100083209
Feb/8/18
PROVINCE OF ONTARIO



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
PR17-01	421.1	5 486 563.3	196 349.2
PR17-02	423.1	5 486 552.6	196 335.3
PR17-02 DCPT	423.1	5 486 551.6	196 332.9
PR17-03	422.8	5 486 551.4	196 346.7
PR17-04A	422.9	5 486 545.3	196 334.8
PR17-04B	422.9	5 486 544.7	196 333.2
PR17-05	423.8	5 486 548.0	196 319.1
PR17-06	423.3	5 486 551.1	196 328.7
PR17-07	422.8	5 486 552.7	196 352.6
PR17-08	422.6	5 486 555.0	196 362.3

-NOTES-

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

GEOCRES No. 52G-18

REVISIONS	DATE	BY	DESCRIPTION			
DESIGN RPR	CHK JPL	CODE		LOAD		DATE JAN 2018
DRAWN AN	CHK RPR	SITE 48W-244C		STRUCT		DWG 2

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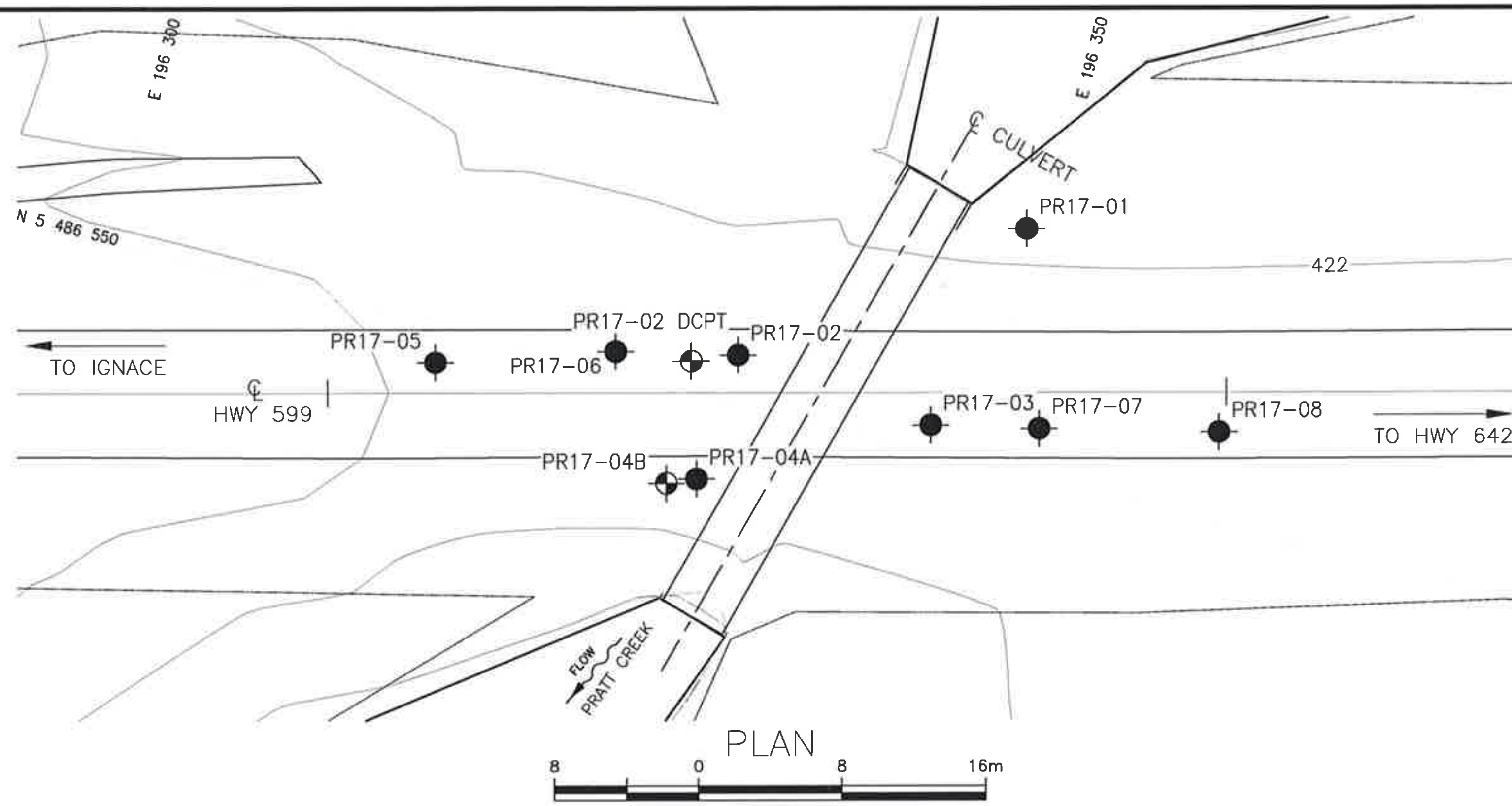
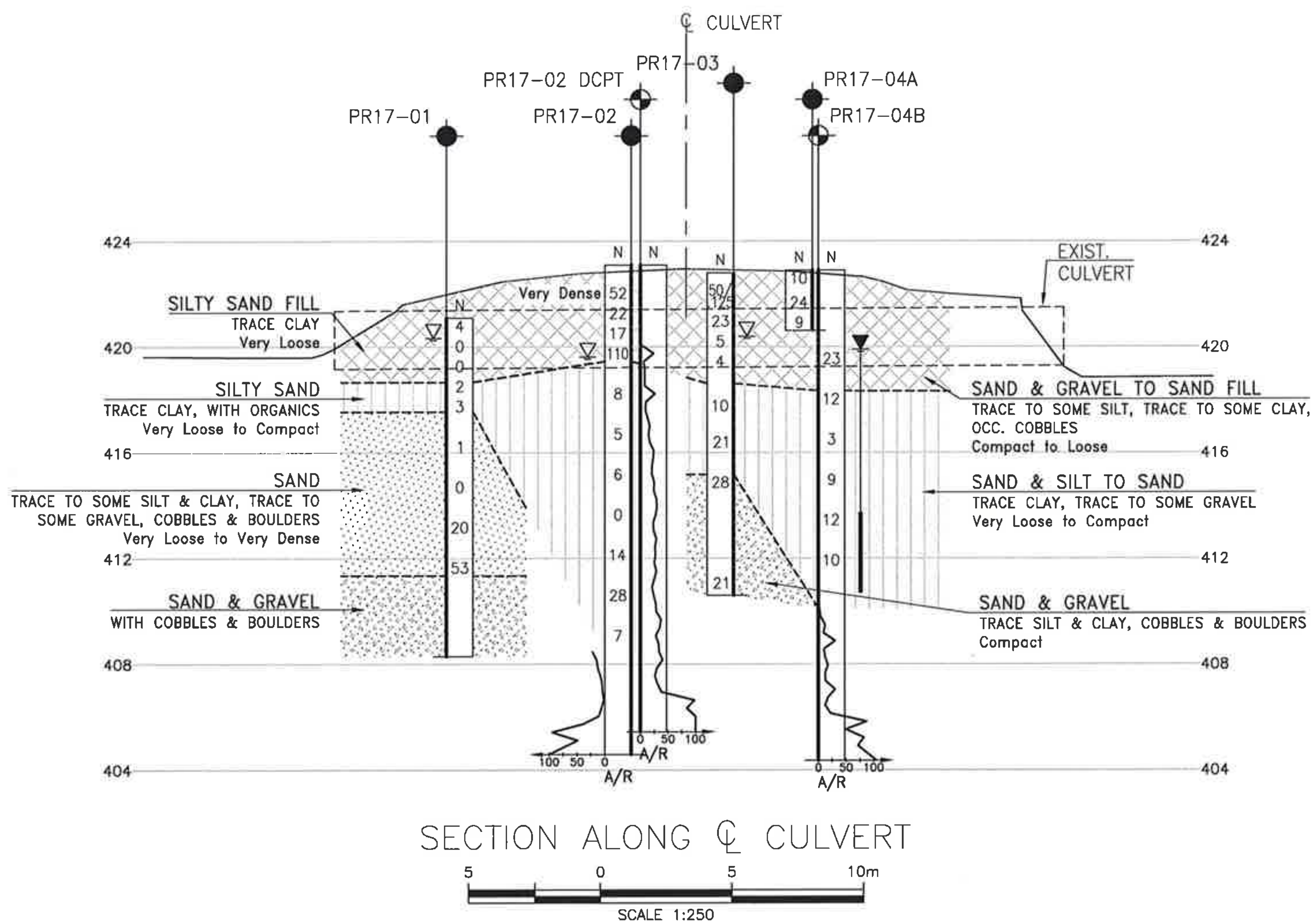
PLOTDATE: 1/26/2018 3:21 PM





METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

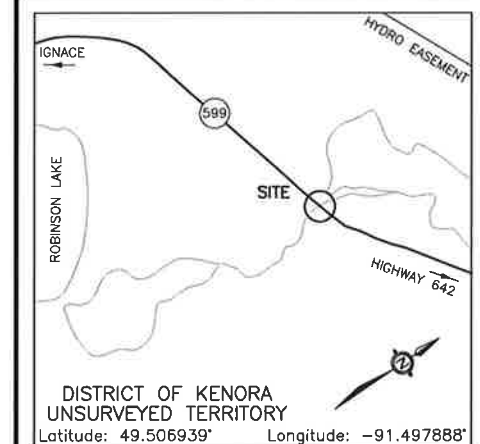
CONT No 2017-6036
WP No 6838-14-01

HIGHWAY 599
PRATT CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 43

HATCH

THURBER ENGINEERING LTD.



KEYPLAN

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 8/18
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R. PALOMEQUE REYNA
100083209
Feb/8/18
PROVINCE OF ONTARIO

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
PR17-01	421.1	5 486 563.3	196 349.2
PR17-02	423.1	5 486 552.6	196 335.3
PR17-02 DCPT	423.1	5 486 551.6	196 332.9
PR17-03	422.8	5 486 551.4	196 346.7
PR17-04A	422.9	5 486 545.3	196 334.8
PR17-04B	422.9	5 486 544.7	196 333.2
PR17-05	423.8	5 486 548.0	196 319.1
PR17-06	423.3	5 486 551.1	196 328.7
PR17-07	422.8	5 486 552.7	196 352.6
PR17-08	422.6	5 486 555.0	196 362.3

-NOTES-

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

GEOCRES No. 52G-18

REVISIONS	DATE	BY	DESCRIPTION

DESIGN RPR	CHK JPL	CODE	LOAD	DATE JAN 2018
DRAWN AN	CHK RPR	SITE 48W-244C	STRUCT	DWG 3

FILENAME: H:\Drafting\17000\17077\TED-17077-PLPR-PC.dwg
PLOTDATE: 1/26/2018 5:21 PM

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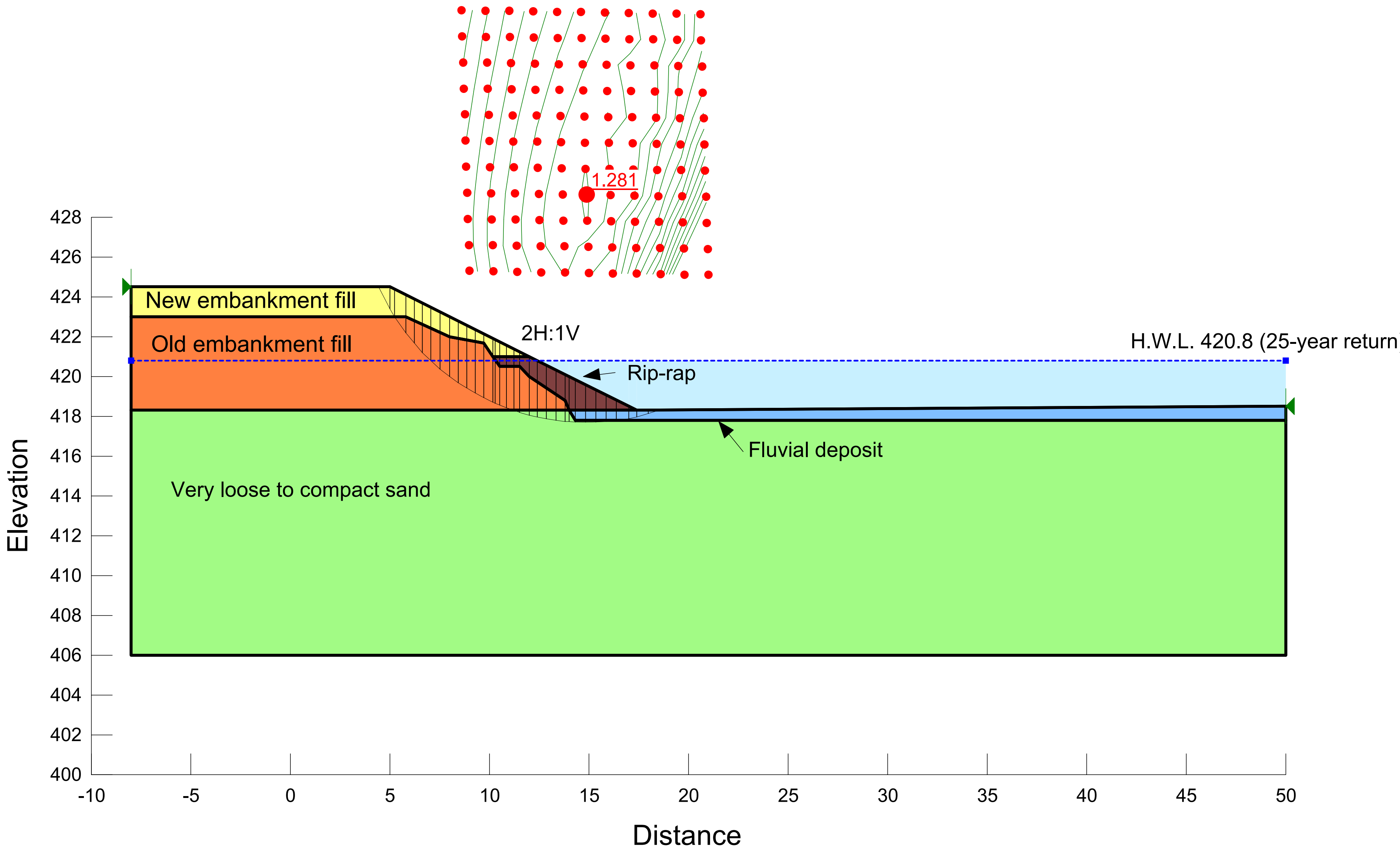
Appendix E

Slope Stability Output

Name: New embankment Fill Unit Weight: 22 kN/m³ Cohesion: 0 kPa Phi: 32 ° Phi-B: 0 ° Piezometric Line: 1
Name: Very loose to compact sand Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Old embankment fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 31 ° Phi-B: 0 ° Piezometric Line: 1
Name: Rip-rap Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 39 ° Phi-B: 0 ° Piezometric Line: 1
Name: Fluvial deposit Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 29 ° Phi-B: 0 ° Piezometric Line: 1

Project Number: 17077
Highway 599
Pratt Creek Culvert Replacement
Embankment height: 6 m approx



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Date: 2018-01-09 ,Time: 1:12:24 PM

Figure E2

Name: New embankment Fill Unit Weight: 22 kN/m³ Cohesion: 0 kPa Phi: 32 ° Phi-B: 0 ° Piezometric Line: 1
Name: Very loose to compact sand Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Old embankment fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 31 ° Phi-B: 0 ° Piezometric Line: 1
Name: Rip-rap Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 39 ° Phi-B: 0 ° Piezometric Line: 1
Name: Fluvial deposit Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 29 ° Phi-B: 0 ° Piezometric Line: 1

Project Number: 17077
Highway 599
Pratt Creek Culvert Replacement
Embankment height: 6 m approx

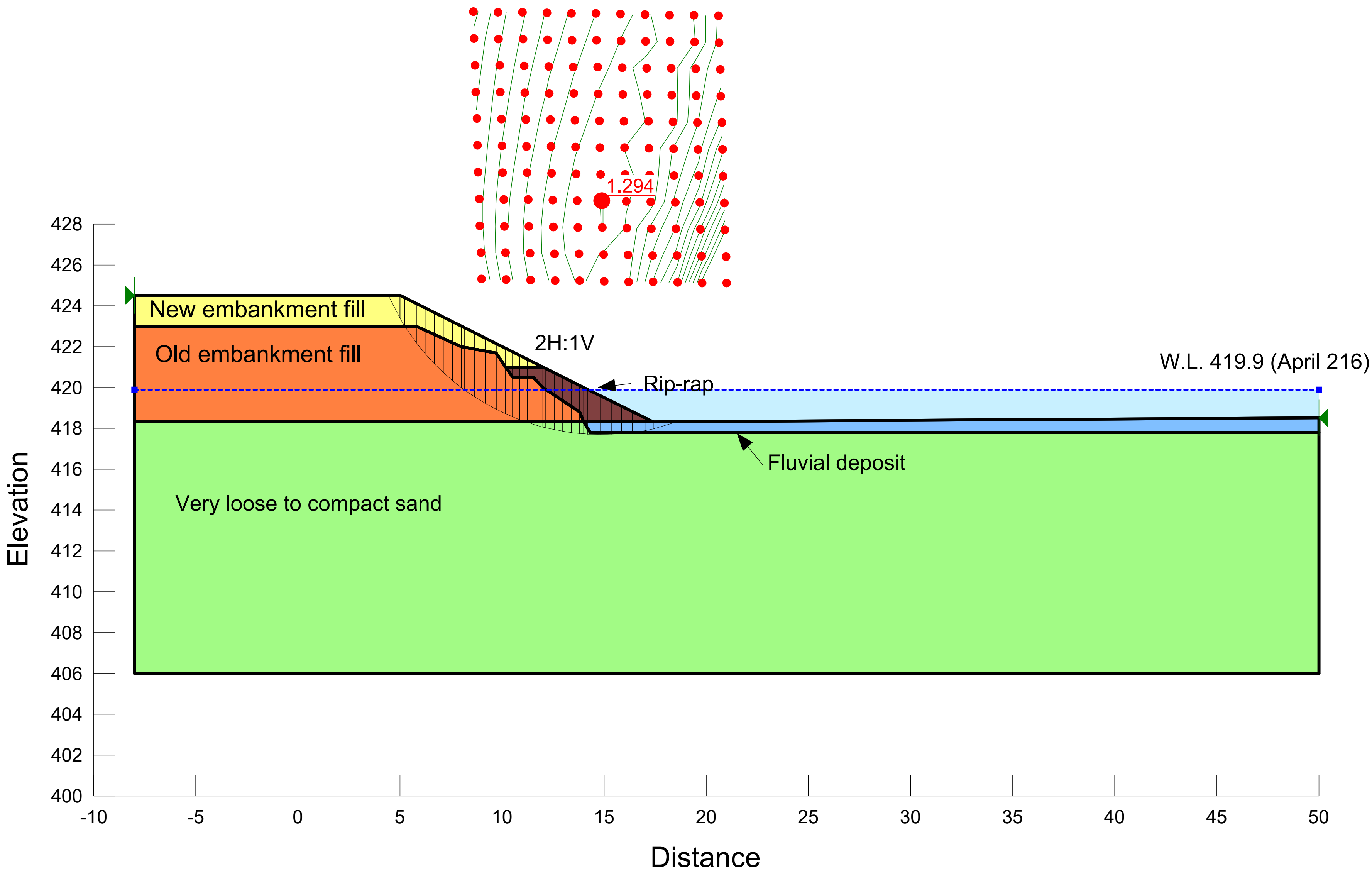

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Figure E1

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Appendix F

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

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

THURBER

Appendix G

List of Specifications and Suggested Wording for NSSP

THURBER

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

-	OPSS PROV 206	Construction specification for grading
-	OPSS PROV 209	Construction specification for embankments over swamps and compressible soils
-	OPSS PROV 501	Construction specification for compacting
-	OPSS.PROV 511	Construction specification for rip-rap, rock protection, and granular sheeting
-	OPSS.PROV 517	Construction specification for dewatering
-	SP 517F01	Amendment to OPSS 517
-	OPSS PROV 539	Construction specification for temporary protection systems
-	OPSS PROV 804	Construction specification for seed and cover
-	OPSS PROV 902	Construction specification for excavating and backfilling - Structures
-	OPSS PROV 1004	Material specification for aggregates - miscellaneous
-	OPSS PROV 1010	Material specification for aggregates - base, subbase, select subgrade, and backfill material
-	OPSS PROV 1205	Material specification for clay seal
-	OPSD 802.014	Flexible pipe embedment in embankment. original ground: earth or rock
-	OPSD 803.031	Frost treatment – pipe culverts, frost penetration line between top of pipe and bedding grade
-	OPSD 810.010	General rip-rap layout for sewer and culvert outlets
-	OPSD 3090.100	Foundation frost penetration depths for Northern Ontario

THURBER

2. Suggested Wording for NSSP on Dewatering

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

3. Suggested Wording for NSSP on Obstructions

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

4. NSSP On Use of Vibratory Equipment

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