THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
AGIMAK RIVER CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-242/C
TOWNSHIP OF IGNACE
ONTARIO
G.W.P. No. 6836-14-00

GEOCRES Number: 52G-16

Latitude 49.424034 ° , Longitude -91.625292 °

Report

to

HATCH Corporation

Date: February 8, 2018
File: 17077

THURBER

TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

THURBER

APPENDICES

THURBER

FOUNDATION INVESTIGATION AND DESIGN REPORT
AGIMAK RIVER CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-242/C
TOWNSHIP OF IGNACE
ONTARIO

G.W.P. No. 6836-14-00

GEOCRES Number: 52G-16

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 Agimak River Culvert on Highway 599, located in the Township of Ignace, Ontario.

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 2.3 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 north-south direction with the culvert perpendicular to the centreline of the highway. The culvert allows the Agimak River to flow in an easterly direction beneath the highway.

The Ontario Structural Inspection Manual (OSIM) prepared by MTO on November 2, 2015, indicates that the existing structure is a 26 m long, two-span open footing, timber structure culvert. Each span is 1.8 m wide. The culvert is 1.8 m in height. The grade level of Highway 599 at the existing culvert is at an approximate Elevation 433.2 m. The height of the existing fill cover is approximately 1.5 m. The culvert invert is at approximately Elevation 429.66 m at the inlet (west end) and 429.54 m at the outlet (east end). The upstream and downstream water levels at Agimak River were measured at Elevations 430.36 and 430.12, respectively, in April 2016, as shown on drawings provided by Hatch.

The lands surrounding Agimak River and the culvert at the site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography is generally of low relief and consists of organic terrain. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist of organic deposits of peat overlying outwash plains of sand and gravel. 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 7 and August 1, 2017, and consisted of drilling and sampling eight (8) boreholes, designated as Boreholes AG17-01 to AG17-08. Boreholes AG17-01 to AG17-04 were drilled along the culvert alignment. Boreholes AG17-01 and AG17-04 were drilled at the inlet and outlet, respectively, and terminated at 12.8 m and 4.3 m depth (Elevations 419.1 and 426.0), respectively. Boreholes AG17-02 and AG17-03 were drilled through the highway embankment, and terminated at 14.3 m and 20.0 m (Elevations 418.9 and 413.3). Borehole AG17-04 was terminated upon casing refusal. Due to the site constraints and difficult access to the borehole location, the drilling operations for Borehole AG17-04 were conducted using portable tripod equipment. The tripod equipment allowed us to drill at the proposed borehole location, however it encountered refusal and was not able to advance further. Multiple attempts were made in the area to advance the borehole deeper, but were unsuccessful.

Boreholes AG17-05 to AG17-08 were drilled through the paved section of Highway 599, to the north and south of the existing culvert, at approximately 10.0 m intervals. These boreholes were advanced to assess the existence and extents of any frost taper near the culvert. Boreholes AG17-05 to AG17-08 were terminated at depths ranging from 3.7 m to 6.7 m (Elevations 426.4 to 430.0). Borehole AG17-06 was located 10.0 m south of the centreline of the existing culvert, near the alignment of the proposed river 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 on the highway platform and at the culvert inlet were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. The borehole drilled at the outlet was advanced using tripod equipment. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A Dynamic Cone Penetration Test (DCPT) was carried out in Borehole AG17-02 beyond the sampled depth of 14.3 m (Elevation 418.9) and advanced to refusal reached at approximately 23.1 m depth (Elevation 410.1). A DCPT, numbered AG17-02 DCPT, was conducted in proximity to Borehole AG17-02 to further assess the subsurface/soil conditions. This DCPT was conducted from 3.0 m (Elevation 430.2) and terminated upon refusal at 21.6 m depth (Elevation 411.6).

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 in the open boreholes were observed throughout the drilling operations and upon completion of drilling. A piezometer was installed in Borehole AG17-01 on June 8, 2017, and a piezometric reading was taken on June 9, 2017. The piezometer was decommissioned on June 9, 2017. Upon completion of drilling, 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
AG17-01	12.8 / 419.1	12.8 / 419.1	Screen from 12.8 m to 9.8 m, sand from 12.8 to 9.2 m, borehole sloughed from 9.2 m to surface.
AG17-02	23.1 / 410.1(1)	None installed	Borehole backfilled with auger cuttings to 4.0 m, bentonite holeplug to 1.0 m, concrete to 0.2 m, then asphalt patch to surface.
AG17-02 DCPT	21.6/411.6	None installed	Borehole backfilled with slough to 0.9 m, concrete to 0.2 m, then asphalt patch to surface.
AG17-03	20.0 / 413.3	None installed	Borehole caved to 2.3 m. Borehole backfilled with auger cuttings to 1.5 m, concrete to 1.2 m, granular to 0.2 m, then asphalt patch to surface.
AG17-04	4.3 / 426.0	None installed	Borehole backfilled with sand and auger cuttings to surface.
AG17-05	3.7 / 429.2	None installed	Borehole backfilled with auger cuttings to 0.3 m, concrete to 0.2 m, then asphalt to surface.
AG17-06	6.7 / 426.4	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to surface.
AG17-07	3.7 / 429.8	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to surface.
AG17-08	3.7 / 430.0	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to surface.

(1) Dynamic Cone Penetration Test

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 river 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 silt and sand mixed with organics, underlain by layers of native sand, silt, and sand and gravel. Deposits of silty sand and sandy silt were also encountered within and beneath the sand deposits. Descriptions of the individual strata are presented below.

5.1 Asphalt

The boreholes that were drilled through the paved portion of Highway 599 encountered approximately 25 mm to 40 mm of asphalt at the ground surface. The ground surface elevations of the boreholes drilled on the highway platform ranged from 432.9 to 433.7.

5.2 Embankment Fill

Embankment fill was encountered below the asphalt in Boreholes AG17-02, AG17-03 and AG17-05 to AG17-08 drilled on Highway 599. Embankment fill was also encountered surficially in Borehole AG17-01, drilled at the inlet. The embankment fill generally consisted of sand to sand and gravel, containing trace silt and clay and occasional cobbles.

The granular embankment fill typically extended to depths ranging from 2.0 m to 3.5 m (Elevations 429.7 to 431.1) in the boreholes.

SPT 'N' values in the granular fill ranged from 3 to 45 blows for 0.3 m penetration, indicating a very loose to dense relative density. Measured moisture contents ranged from 2 percent to 14 percent.

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

Soil Particle	Sand Fill (percent)	Sand and Gravel Fill (percent)
Gravel	7 to 17	27 to 49
Sand	79 to 90	48 to 66
Silt & Clay	3 to 6	3 to 7

5.3 Silt and Sand with organics

A layer of silt and sand mixed with organics was encountered beneath the embankment fill in Boreholes AG17-01, and AG17-06 to AG17-08. This layer is described as dark brown to black in colour. The silt and sand with organics ranged in thickness from 0.3 m to 1.1 m.

The depth to the base of the layer of silt and sand with organics ranged from 2.3 m to 4.5 m (Elevations 428.6 to 430.6), respectively.

SPT 'N' values recorded in the silt and sand with organics were 2 and 4 blows for 0.3 m penetration, indicating a very loose to loose state.

Measured moisture contents in the silt and sand with organics, ranged from 15 percent to 25 percent.

5.4 Sand and Silty Sand

Layers of native brown to grey sand containing trace to some gravel, trace silt to silty and trace to some clay, were encountered below the silt and sand with organics in most of the boreholes and sand and gravel (described in Section 5.5 in Boreholes AG17-02 and AG17-03). The thickness of the upper sand, where penetrated through, was between 1.6 m and 2.0 m in Boreholes AG17-01, AG17-02, and AG17-03, with the base depth varying between 4.3 m and 7.2 m (Elevations 427.6 to 426.1). A lower layer of sand was encountered at 9.8 m and 8.7 m depth (Elevation 422.1 and 424.6) in Boreholes AG17-01, and AG17-03 respectively. This lower sand unit was penetrated through in AG17-03 with a base depth of 18.5 m (Elevation 414.8) and a thickness of 9.8 m.

Brown to gray sand to silty sand containing trace clay and occasional organics, was encountered in Boreholes AG17-05 to AG17-08.

Borehole AG17-01 was terminated within the lower sand layer at 12.8 m depth (Elevation 419.1). Boreholes AG17-05 to AG17-08 were terminated within the upper sand to silty sand layer at 3.7 m and 6.7 m depth (Elevations 426.4 to 430.0).

SPT 'N' values measured in the sand and silty sand ranged from 4 to 26 blows per 0.3 m of penetration, indicating a loose to compact state.

Moisture contents of the sand and silty sand ranged from 4 percent to 24 percent.

The results of a grain size analyses conducted on sand samples are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B3 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Sand (percent)
Gravel	0 to 8
Sand	70 to 94
Silt & Clay	6 to 22

5.5 Sand and Gravel

An upper layer of brown sand and gravel containing trace silt were encountered surficially in Borehole AG17-04 and at 3.0 m and 3.5 m depth (Elevations 430.2 and 429.8) in Boreholes AG17-02 and AG17-03, respectively. The thickness of the sand and gravel layer was 1.4 m and 2.1 m in Boreholes AG17-02 and AG17-03, respectively.

The depth to the base of the upper sand and gravel layer was 4.4 m and 5.6 m (Elevations 428.8 and 427.7) in Boreholes AG17-02 and AG17-03, respectively.

Borehole AG17-04 was terminated within the upper layer of sand and gravel at 4.3 m depth (Elevation 426.0) upon casing refusal. Borehole AG17-03, was terminated within the lower layer of sand and gravel at 20.0 m depth (Elevation 413.3), upon auger refusal.

SPT 'N' values measured in the upper sand and gravel ranged from 6 to 27 blows per 0.3 m of penetration, indicating a loose to compact state.

A lower layer of sand and gravel was encountered in Borehole AG17-03, at 18.5 m depth (Elevation 414.8).

SPT 'N' values, up to 100 blows per 0.1 m of penetration, indicating a very dense state, were measured in the lower sand and gravel unit.

Moisture contents of the sand and gravel layers ranged from 7 percent to 22 percent.

The results of a grain size analyses conducted on a sand and gravel sample are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B4 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Sand and Gravel (percent)
Gravel	41
Sand	56
Silt & Clay	3

5.6 Silt to Sandy Silt

A deposit of brown to grey silt to sandy silt containing trace to some clay, were encountered at 4.3 m and 6.4 m depth (Elevations 427.6 and 426.8) in Boreholes AG17-01 and AG17-02, respectively. The thickness of the sandy silt was 5.5 m in Borehole AG17-01. A 1.5-m thick layer of sandy silt was encountered within the sand at 7.2 m depth (Elevation 426.1) in Borehole AG17-03.

The depth to the base of the sandy silt was at 9.8 m (Elevation 422.1) in Borehole AG17-01.

Borehole AG17-02 was terminated within the silt layer at 14.3 m depth (Elevation 418.9).

SPT ‘N’ values recorded in the silt and sandy silt ranged from 0 to 15 blows for 0.3 m penetration, indicating a loose to compact relative density. Measure moisture contents in the silt and sandy silt ranged from 11 percent to 18 percent. The very loose conditions (SPT ‘N’ values of 0 to 1) were noted within approximate Elevations 419.0 to 426.0, and may have been the result of hydraulic ground disturbance during drilling operations. Moisture contents of the silt to sandy silt deposit ranged from 11 percent to 18 percent.

The results of grain size analyses conducted on samples of the silt to sandy 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 (percent)	Sandy Silt (percent)
Gravel	0	0
Sand	5	32 to 43
Silt	81	55 to 64
Clay	14	2 to 4

5.7 Auger Refusal and/or Probable Bedrock

Auger refusal and probable bedrock was encountered below the lower layer of sand and gravel, at 20.0 m depth (Elevation 413.3) in Borehole AG17-03. Casing refusal occurred at a depth of 4.3 m in Borehole AG17-04 where tri-pod equipment was used to auger the hole.

DCPT’s conducted in and near Borehole AG17-02, were terminated upon refusal at 23.1 m and 21.6 m depth (Elevations 410.1 and 411.6).

5.8 Groundwater Conditions

Groundwater conditions were observed during drilling and upon completion of drilling. A piezometer was installed in Borehole AG17-01. The piezometer was decommissioned upon taking a water level measurement. The groundwater levels measured in the open boreholes and the piezometer are summarized in Table 5.2.

Table 5.2 - Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
AG17-01	June 9, 2017	1.0	430.9	Piezometer
AG17-02	June 7, 2017	2.7	430.5	Open borehole
AG17-03	June 11, 2017	-	-	Caved-in to 2.3 m
AG17-04	June 9, 2017	0.3	430.0	Open borehole
AG17-05	June 8, 2017	2.7	430.2	Open borehole
AG17-06	June 8, 2017	2.6	430.5	Open borehole
AG17-07	June 8, 2017	2.7	430.8	Open borehole
AG17-08	June 8, 2017	2.7	431.0	Open borehole

The upstream and downstream water levels at Agimak River were measured at Elevations 430.36 and 430.12, respectively, in April 2016, as shown on drawings provided by Hatch. The groundwater level should be assumed to reflect the local river 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 sand fill from Borehole AG17-02 and a sample of the river 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.

THURBER

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			AG17-02 SS 4 Depth 2.3 m	Agimak River (upstream)
			(Soil Sample)	(River Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	150	7.8
Sulphate	µg/g	mg/L	6.1	1.9
pH	No unit	No unit	8.33	7.26
Electrical Conductivity	µS/cm	µS/cm	213	56
Resistivity	Ohms.cm	Ohms.cm	4690	17700
Redox Potential	mV	mV	290	345

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, P. Geo, and Stephen Hillier, EIT 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 Mr. Jason Lee, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER

Thurber Engineering Ltd.

Cory Zanatta, B.A.Sc.
Geotechnical EIT

LICENSED PROFESSIONAL ENGINEER
J. P. K. LEE
100086735
Feb 8/18
PROVINCE OF ONTARIO

Jason Lee, P.Eng.
Principal/Senior Geotechnical Engineer

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

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

FOUNDATION INVESTIGATION AND DESIGN REPORT
AGIMAK RIVER CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-242/C
TOWNSHIP OF IGNACE
ONTARIO

G.W.P. No. 6836-14-00

GEOCRES Number: 52G-16

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 Agimak River culvert replacement located on Highway 599, approximately 2.3 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 3.6 m wide and 26 m long. The estimated culvert invert is at approximately Elevations 429.6 m at the inlet (west end) and 429.5 m at the outlet (east end). The existing road grade at the culvert location is at about Elevation 433.2 m, which indicates approximately 1.5 m of fill above the top of the culvert. The highway embankment is up to 3.5 m in height.

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

1. Multiple CSP Pipe Culvert

   Two circular CSP pipes are being considered to provide increased hydraulic opening. The CSPs are likely to be approximately 3.6-m diameter each. The proposed founding level (bottom of bedding base) of the CSP pipes is near Elevation 428.5.

2. Single Span Precast Concrete Box Culvert

   A single cell precast concrete box culvert is another option for this site. Information provided by Hatch indicates that a 6.0 m x 2.7 m box culvert is being considered. The proposed founding level (bottom of bedding base) of the box culvert is near Elevation 428.2.

3. Sheet Pile Culvert

   A culvert consisting of two parallel sheet pile walls supporting a slab consisting of precast concrete panels might be an option at this site. The proposed structure will have a span of 6.4 m, a height of about 2.8 m, and a sheet pile wall length of approximately 21.6 m of which 18.0 m will be capped by precast panels.

The alignment of the replacement culvert will remain largely the same as for the existing culvert. Grade raise of about 520 mm 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 10.0 m south of the existing culvert centreline with an invert elevation of approximately 429.6.

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

9. CULVERT DESIGN

9.1 Culvert Replacement Options

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

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

- Concrete Pipe, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings
- Precast Concrete Slabs Supported on Sheet Pile Abutments (Sheet pile culvert)

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. From a foundations and constructability perspective, use of the SPCSP, CSP, precast box culvert or sheet pile culvert are 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;

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

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

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

9.2 Foundation Design for Culverts

In general, the subsurface conditions encountered in the boreholes drilled through the highway platform consists of embankment fill, typically sand to sand and gravel, underlain by layers of native sand, silt and, sand and gravel. A layer of silt and sand with organics was encountered below the fill in three boreholes drilled on the roadway (Boreholes AG17-06 to AG17-08) and in Borehole AG17-01, drilled at the culvert inlet. The thickness of the fill encountered at the boreholes drilled along the existing culvert alignment (Boreholes AG17-01 to AG17-04) varied from 2.0 m to 3.5 m. The water levels in river, indicated in the available data, were at Elevations 430.36 and 430.12, in the inlet and outlet, respectively, in April 2016. The groundwater level measured in the installed piezometer was at Elevation 430.9 m.

The founding soils encountered at the proposed founding elevations 428.2 and 428.5 (base of bedding), generally consist of native loose to compact sand and gravel, and compact 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 multiple SPCSPs or CSPs on the same alignment as the existing culvert may be considered for this site. Since there is a proposed grade raise of 520 mm, 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 the settlement is expected to be 20 mm to 30 mm. The culvert must be designed to accommodate the estimated settlement.

If this alternative is selected, the SPSCPs or CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II. The underside of the bedding layer should be placed at or below Elevations 428.5, which corresponds to native loose to compact sand and gravel and compact 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 and replaced with granular material. Culvert subgrade preparation and placement and compaction of the granular bedding must be carried out in the dry. Adequate preparation of the subgrade will be essential for performance of the culvert.

9.2.2 Precast Concrete Box Culvert

Replacement of the culvert with 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 20 mm to 30 mm.

Based on available information, it is anticipated that the proposed inlet and outlet founding levels (bottom of levelling course) of the culvert are at approximate Elevations 428.2 and 428.1, respectively.

The founding elevations will expose compact sand, and loose to compact sand and gravel.

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 428.2 and 428.1 m on the native compact sand and/or loose to compact sand and gravel:

- Factored Geotechnical Resistance at ULS of 160 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 110 kPa.

The above values of the geotechnical resistance and reaction were based on a box culvert width of 6.0 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 and Bridge Design Code (CHBDC) 2014, Sec. 6.9.

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

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

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

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

9.2.3 Steel Sheet Pile Walls

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

The current design proposes steel sheet pile walls installed adjacent to the culvert in lieu of conventional wingwalls or headwalls. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill. The design and installation of all sheet piles should be conducted as described below.

Vertical, factored geotechnical resistance at Ultimate Limit States (ULSf) and geotechnical resistance at Serviceability Limit States (SLS) for a sheet pile section driven to refusal is presented in Table 9.1. The geotechnical resistance values have been reduced to account for the possibility that the sheet piles may encounter refusal in the cobbles and boulders. Sheet piles should be driven to refusal at or below the specified elevations noted in Table 9.1.

Table 9.1 – Recommended Axial Resistances of Steel Sheet Pile

Sheet Pile Section	Estimated Sheet pile Length (m) from Elevation 431.7	Approximate Pile Toe Elevation (m)	Factored ULS Resistance per meter width (kN/m)	SLS Resistance (kN/m)
SKZ-22	18	413.5 to 415.0	400	300

The SLS values are based on a vertical pile settlement of 25 mm at the base of the embankment fill.

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

- 247 kN/m (SLS)
- 330 kN/m (ULS)

Sheet pile installation should be in accordance with OPSS 903.

Sheet piles should be driven to the specified elevation noted in Table 9.1. The appropriate pile driving note is "Sheet piles to be driven to El. 413.5 or refusal below El. 415.0". An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

9.2.3.1 Sheet Pile Lateral Resistance

Design for lateral resistance of the sheet piles may be carried out using the earth pressure coefficients (K_a = active, K_o = at rest, K_p = passive) and soil unit weights provided in Table 9.2 below and Table 10.1 in Section 10.

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

$k_s = n_h z$ (kN/m³)

where z = depth of embedment of pile in metres

n_h = coefficient related to soil density, see table below (kN/m³)

For soil-spring analysis, the spring constant, K_s, may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³) and L is the length (m) of the pile segment or element used in the analysis.

Table 9.2 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m³)	n_h (kN/m³)	K_a	K_o	K_p
	Top	Bottom					
Sand/Sand & Gravel Fill	433.3	430.9	21	1,500*	0.31	0.47	1.3*
Sand/Sand & Gravel Fill	430.9	428.9	11	1,000*	0.31	0.47	1.3*
Sand and Gravel	429.8	427.7	11	3,000	0.31	0.47	3.3
Sand	427.7	426.1	10	2,000	0.33	0.50	3.0
Silt	426.1	418.9	9	1,500	0.35	0.52	2.9
Sand	418.9	414.8	10	2,500	0.31	0.47	3.3
Sand and Gravel	414.8	413.3	11	10,000	0.28	0.44	3.6

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

9.2.3.2 Construction Consideration for Sheet Piles

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

Occasional cobbles were noted during the investigation and may be encountered during driving the sheet piles through the existing embankment fill. Any rock fill/erosion protection materials if present at the culvert site, as well as any visible obstructions along the sides of the culvert should be removed prior to driving the sheet piles.

The sheet pile alignment should be strategically located to avoid encountering existing ancillary structures.

Use of tip protection is not recommended for the sheet piles at this site.

In light of the loose foundation sands and silts, vibratory methods should not be used at this site to install the sheet piles.

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

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

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

9.2.3.3 Downdrag

Downdrag on the piles is not considered to be an issue at this site.

9.2.4 Culvert Headwall / Wingwalls

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

The borehole information indicates that the founding soils at the inlet and outlet generally consist of loose to compact sand and gravel and, compact sand underlain by loose to compact sandy silt. A layer of sand and silt mixed with organics was encountered in the inlet zone, just above the founding soils.

9.2.4.1 RSS Walls

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

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

If sand and silt with organics is encountered along the alignment of the RSS wall, it must be removed down to native sand. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native sand/sand and gravel at or below approximate Elevation 428.5 or lower. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (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.

Anticipated settlement of 20 mm to 30 mm is anticipated for the RSS. The RSS wall supplier must be consulted if the proprietary can accommodate the settlement.

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 river, the wall may be subjected to flooding. The RSS supplier should be made aware that for submerged conditions the RSS strips may need to be longer than the usual 70% of fill height and the strips must be corrosion resistant.

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

9.2.4.2 Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on compact sand/sand and gravel subgrade. All topsoil, organics or soft soils encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.5 m at this site) and founded at Elevations 428.5 or lower. A factored geotechnical resistance at ULS of 160 kPa and a geotechnical reaction at SLS of 110 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the 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 0.45.

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

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

9.3 Settlement

Embankment grade raise, approximately 520 mm, is anticipated as part of the culvert replacement. It is recommended that the underlying layer of silt and sand mixed organics, encountered below the fill, be excavated. The estimated settlements after culvert construction and embankment reconstruction at this site is estimated to be 20 mm to 30 mm.

The culvert must be designed to accommodate the estimated 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 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 2.3 m to 3.5 m of granular and sand fill overlying native cohesionless deposits to at least 20 m north and south of the centreline of the existing culvert. Silty sand mixed with topsoil/organics was encountered below the base of fill in three boreholes drilled on the roadway. The majority of 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 above the silty sand mixed with organics.

The silty sand mixed with topsoil/organics underlying the fill are frost susceptible; therefore, it is recommended to be excavated or removed if encountered within the culvert excavation. 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 beyond the proposed excavations for the new culvert does not contain frost susceptible soils within the frost penetration depth (2.5 m), a new frost taper 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 river 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 river 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. Any remaining fill, topsoil, river bed deposits, disturbed soils and any deleterious materials within the replacement culvert and headwall footprint at the subgrade level must be removed and replaced with well compacted granular materials. However, sub-excavation should not exceed 0.5 m if these soils (loose, soft, organics, deleterious) extends deeper.

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, sand and gravel and silt 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, sand and gravel; and will extend into the underlying sand and silt mixed with organics.

Excavation for culvert replacement will be carried out below the river water level indicated at Elevation 430.12 in the GA drawing. Groundwater level was measured at Elevation 430.9 in the piezometer installed in Borehole AG17-01. 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 river diversion along with the use of sumps/pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. The use of interlocking and watertight, steel sheet pile cofferdam is a feasible option for this site. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native 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; the closest boreholes to the cofferdam locations are Boreholes AG17-01 and AG17-04. Record of Boreholes Sheets of these boreholes are included in Appendix B.

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

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

12. STREAM DIVERSION PIPE

A stream diversion pipe consisting of a 1.5-m diameter CSP may be used to facilitate construction of the CSP culvert and box culvert replacement options, as indicated on the Preliminary General Arrangement drawings provided by Hatch. The diversion pipe is shown to be located approximately 10.0 m to the south of the centreline of the existing culvert with the invert at approximate Elevation 429.6 m. Below the invert level, the subgrade will consist of at least 1.0 m of silt and sand mixed with organics, as documented in Borehole AG17-06.

The silt and sand mixed with organics should be sub-excavated where encountered, however sub-excavation should not exceed 0.3 m if the silt and sand mixed with organics extends deeper.

The silt and sand mixed with organics should then be replaced with a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements, 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. The installation of the diversion pipe in open cut should follow OPSD 802.014 (Flexible Pipe Embedment in Embankment) and as per the requirements of the CHBDC.

13. TEMPORARY PROTECTION SYSTEM

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

Interlocking sheet piles or a soldier pile and lagging wall could be considered at this site. The soil parameters in Table 13.1 may be used for design of the temporary roadway protection system with horizontal backfill.

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

Table 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silt to Sand	Native Sand and Gravel
Angle of Internal Friction (ϕ)	30º	30º	32º
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 the presence of the sensitive sand/silt deposits vibratory methods must not be used at this site to install or extract the sheet piles and H-piles (if used). A NSSP to this effect is provided in Appendix F.

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

14. EMBANKMENT WIDENING AND RESTORATION

It is anticipated that there will be a grade raise of 520 mm at this site for the culvert replacement. Also, widening of the embankment, approximately 1.0 m on each side, is planned at this site.

Based on the GA drawings, the sides of the embankment fill near the culvert will be contained by sheet pile walls installed along the edges of the road.

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

Settlement due to changes in the culvert configuration is expected to be 20 mm to 30 mm. The settlement will be immediate in nature and is anticipated to be completed by the end of construction. Inspection of the roadway surface and padding of the asphalt at the approaches to re-establish grades as necessary should be implemented during and after construction.

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 averaged soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site include loose to compact granular fill underlain by silt and sand mixed with organics. Below the silt and sand mixed with organics, layers of native cohesionless soils consisting compact to very loose sand, sandy silt and, sand and gravel were encountered. This would correspond to a Seismic Site Class E 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 0.070 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	0.34	0.36
At Rest (K_{OE})**	0.52	0.56	0.59

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

The site is underlain by loose to compact sandy silt, sand, and sand 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 river water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

RSS walls must be protected for scour and erosion.

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

The ground in front of the sheet pile should be properly compacted and re-graded following removal of the existing timber culvert, and protected from river erosion so that the sheet piles do not lose lateral support.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the native soil and river 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 mild to moderate.
- 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:

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the river 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. DETAILED DESIGN INVESTIGATION

For detailed design of the culvert, the following additional investigation is recommended:

- Borehole AG17-04, drilled at the outlet, which was advanced with a tri-pod, encountered refusal and was unable to be advanced below 4.3 m depth. An additional deeper borehole is recommended at the outlet of the proposed culvert, using a drill rig that can core through the obstructions to determine if the sheet piles near the outlet can be driven to the design depth.

THURBER

20. 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.

Thurber Engineering Ltd.

Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer

Jason Lee, P.Eng.
Principal/Senior Geotechnical Engineer

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

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-01

METRIC

GWP# 6836-14-00 | LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 170.8 E 404 517.0 | ORIGINATED BY BRM

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

DATUM Geodetic | DATE 2017.06.08 - 2017.06.08 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
431.9	GROUND SURFACE					
0.0	**SAND**, trace gravel, trace clay Very Loose to Compact Light Brown Moist (FILL)	1	SS	3		
		2	SS	10	431	
		3	SS	2		
429.9 / 2.0	**SAND** and **SILT**, with organics Very Loose Dark Brown Wet				430	
429.6 / 2.3	**SAND**, some silt and clay, trace gravel Compact Grey Wet	4	SS	12		8 70 22 (SI+CL)
		5	SS	15	429	
					428	
427.6 / 4.3	Sandy **SILT**, trace clay Loose to Very Loose Grey Wet	6	SS	4	427	
					426	
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 426.0m to 423.0m	7	SS	1	425	
		8	SS	0	424	0 43 55 2
					423	
	Compact	9	SS	15		
422.1 / 9.8	**SAND**, trace silt and clay				422	

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; STRAT PLOT; GROUND WATER CONDITIONS.

Continued Next Page

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-01

METRIC

GWP# 6836-14-00
LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 170.8 E 404 517.0
ORIGINATED BY BRM

HWY 599
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN

DATUM Geodetic
DATE 2017.06.08 - 2017.06.08
CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Continued From Previous Page									
	SAND, trace silt and clay Compact Brown Wet									
		10	SS	16	421	o				
					420					
		11	SS	20		o	0	94	6 (SI+CL)	
419.1 12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL MEASURED AT 1.2m. Well installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.									

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.06.09	1.0	430.9

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; 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, × ³: Numbers refer to Sensitivity   20 / 15 – 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AG17-02

METRIC

GWP# 6836-14-00
LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 160.3 E 404 525.2
ORIGINATED BY BRM

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

DATUM Geodetic
DATE 2017.06.07 - 2017.06.07
CHECKED BY RPR

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
433.2	GROUND SURFACE
0.0	**ASPHALT:** (25mm)
	SAND, trace gravel, trace silt, trace clay Dense to Compact Brown Moist (FILL)
	Very Loose
430.2 / 3.0	**SAND** and **GRAVEL**, trace silt Loose Brown Wet
428.8 / 4.4	**SAND**, some silt Compact to Loose Grey Wet
426.8 / 6.4	**SILT**, some clay, trace sand Loose Grey Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	GS		
2	SS	32	
3	SS	13	
4	SS	3	7 90 3 (SI+CL)
5	SS	6	
6	SS	14	
7	SS	9	
8	SS	7	
9	SS	7	0 5 81 14

Elevation scale: 433, 432, 431, 430, 429, 428, 427, 426, 425, 424

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 AG17-02

METRIC

GWP# 6836-14-00
LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 160.3 E 404 525.2
ORIGINATED BY BRM

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

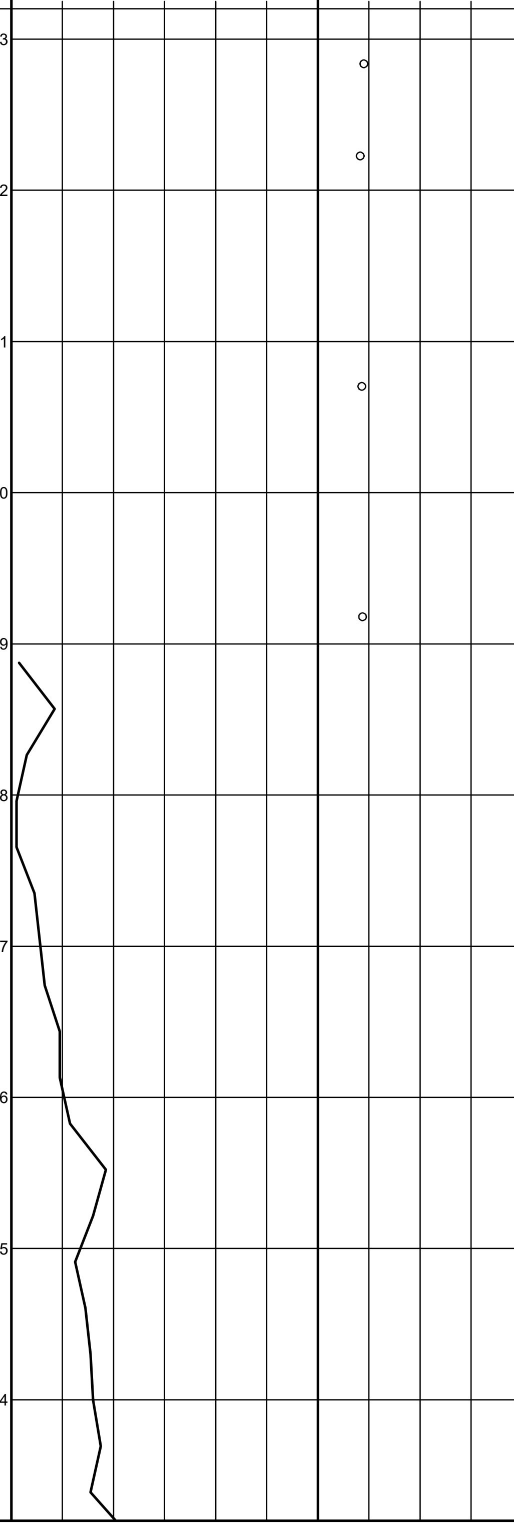
DATUM Geodetic
DATE 2017.06.07 - 2017.06.07
CHECKED BY RPR

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

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
	SILT, some clay, trace sand Compact to Very Loose Grey Wet			
		10	SS	13
	Low SPT "N" values due to hydraulic ground disturbance below elevation 421.0m	11	SS	0
418.9		12	SS	0
14.3	End of sampling at 14.3m and start DCPT			

Elevation scale: 423, 422, 421, 420, 419, 418, 417, 416, 415, 414



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AG17-02

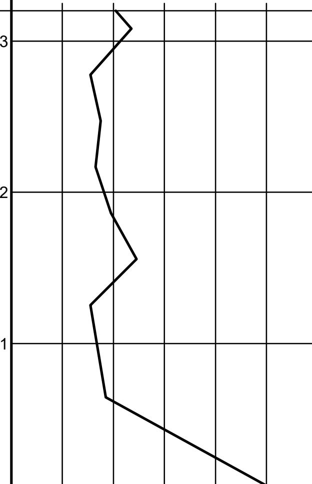
METRIC

GWP# 6836-14-00 LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 160.3 E 404 525.2 ORIGINATED BY BRM

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

DATUM Geodetic DATE 2017.06.07 - 2017.06.07 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				
410.1 / 23.1	END OF BOREHOLE AT 23.1m UPON DCPT REFUSAL. WATER LEVEL MEASURED AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 4.0m, BENTONITE HOLEPLUG TO 1.0m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										



ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

+ 3, × 3: Numbers refer to Sensitivity

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

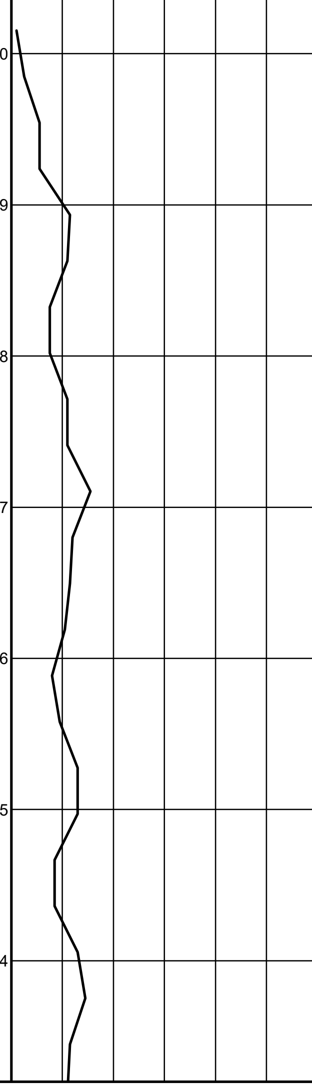
Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AG17-02 DCPT 1 OF 3 METRIC

GWP# 6836-14-00
LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 161.5 E 404 525.3
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	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
433.2	GROUND SURFACE										
0.0	Auger to 3.0m						433				
							432				
							431				
430.2 / 3.0	Start DCPT from 3.0m						430				
							429				
							428				
							427				
							426				
							425				
							424				



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

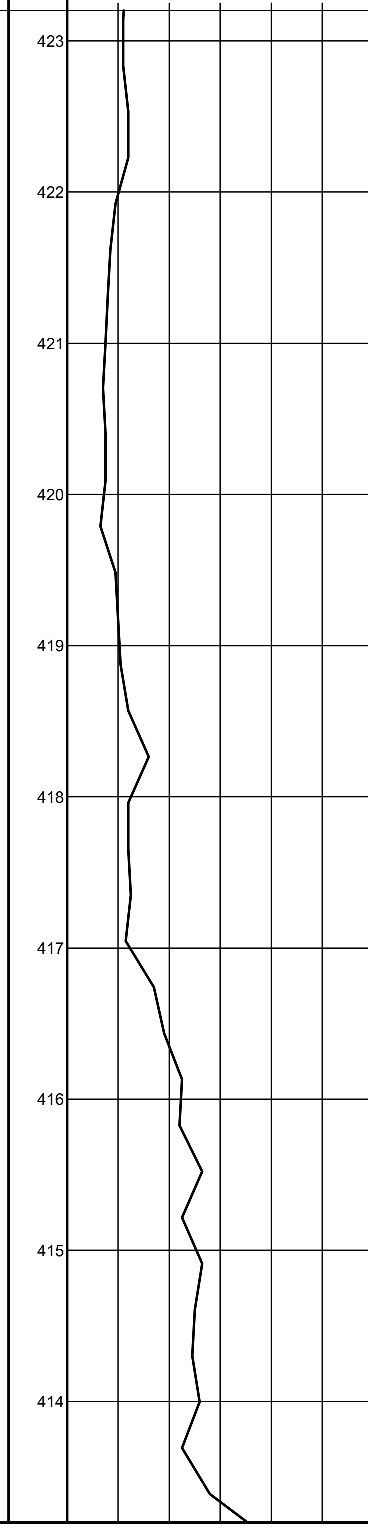
Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-02 DCPT METRIC

GWP#	6836-14-00	LOCATION	Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 161.5 E 404 525.3	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										



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

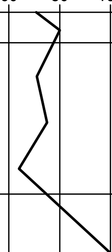
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AG17-02 DCPT METRIC

GWP# 6836-14-00	LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 161.5 E 404 525.3	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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
							413				
							412				
411.6 21.6	END OF DCPT AT 21.6m UPON REFUSAL. BOREHOLE BACKFILLED WITH SLOUGH TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										

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

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

RECORD OF BOREHOLE No AG17-03 — 1 OF 3 — METRIC

GWP# 6836-14-00 | LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 168.9 E 404 529.5 | ORIGINATED BY SMP

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

DATUM Geodetic | DATE 2017.06.11 - 2017.06.11 | CHECKED BY RPR

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/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

ELEV / DEPTH	DESCRIPTION
433.3	GROUND SURFACE
0.0	**ASPHALT:** (40mm)
0.0	**SAND** and **GRAVEL**, trace silt, trace clay, occasional cobbles Compact to Dense (FILL) Auger grinding at 1.4m
429.8 / 3.5	**SAND** and **GRAVEL**, trace silt Compact Brown Moist
427.7 / 5.6	**SAND**, some silt to silty, trace gravel Loose Brown Wet
426.1 / 7.2	Sandy **SILT**, trace clay Loose Brown to Grey Wet
424.6 / 8.7	Compact

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	28				
2	SS	45	27	66	7 (SI+CL)	
3	SS	29				
4	SS	17				
5	SS	18	49	48	3 (SI+CL)	
6	SS	27				
7	SS	7				
8	SS	5	0	32	64	4
9	SS	16				

Elevation scale: 433, 432, 431, 430, 429, 428, 427, 426, 425, 424

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 AG17-03

METRIC

GWP# 6836-14-00 | LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 168.9 E 404 529.5 | ORIGINATED BY SMP

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

DATUM Geodetic | DATE 2017.06.11 - 2017.06.11 | CHECKED BY RPR

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace gravel, trace silt, trace clay Loose to Compact Grey Wet						423	
			10	SS	6		422	
			11	SS	8		421	
							420	
			12	SS	28		419	
			13	SS	17		418	
							417	
			14	SS	26		416	2 90 8 (SI+CL)
414.8			15	SS	50/ 0.100		415	
18.5	**SAND** and **GRAVEL**, trace silt Very Dense Grey to Brown Wet						414	
413.3			16	SS	100/			

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m^3

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-03

METRIC

GWP# 6836-14-00 LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 168.9 E 404 529.5 ORIGINATED BY SMP

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.11 - 2017.06.11 CHECKED BY RPR

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
20.0	END OF BOREHOLE AT 20.0m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE CAVED TO 2.3m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 1.5m, CEMENT TO 1.2m, AUGER CUTTINGS MIXED WITH CEMENT TO 0.5m, GRANULAR TO 0.2m, THEN ASPHALT PATCH TO SURFACE.				0.100						

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-04

METRIC

GWP# 6836-14-00 LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 159.9 E 404 539.8 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Tripod COMPILED BY AN

DATUM Geodetic DATE 2017.06.09 - 2017.06.09 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
430.3	GROUND SURFACE						
0.0	**SAND** and **GRAVEL**, trace silt, trace clay Loose to Compact Brown Moist to Wet	1	SS	6	∇	430	
		2	SS	8			
		3	SS	10		429	
		4	SS	7		428	41 56 3 (SI+CL)
		5	SS	19			
		6	SS	11		427	
426.0 / 4.3	Unable to advance casing below 4.3m depth	7	SS	15			
	END OF BOREHOLE AT 4.3m. WATER LEVEL MEASURED AT 0.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.						

Dynamic cone penetration resistance plot (20, 40, 60, 80, 100); Shear strength kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; Water content (%) 20 40 60 — plastic limit w_P, natural moisture content w, liquid limit w_L; Unit weight γ kN/m³

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-05

METRIC

GWP# 6836-14-00	LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 145.1 E 404 525.1	ORIGINATED BY BRM
HWY 599	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2017.06.08 - 2017.06.08	CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
432.9	GROUND SURFACE						
0.0	**ASPHALT:** (25mm)						
	SAND, trace silt, trace clay, trace gravel Brown Moist (FILL)	1	GS				
						432	7 87 6 (SI+CL)
		2	GS				
		3	GS			431	
430.6 / 2.3	Silty **SAND**, trace clay, occasional organics Brown Moist	4	GS		∇		
						430	
	Loose	1	SS	4			
429.2 / 3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL MEASURED AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.3m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.						

Plot columns: 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 AG17-06 1 OF 1 METRIC

GWP# 6836-14-00 LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 155.1 E 404 524.9 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.08 - 2017.06.08 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
433.1	GROUND SURFACE										
0.0	**ASPHALT:** (25mm)										
0.0	**SAND** and **GRAVEL**, trace silt, trace clay Compact to Very Loose Brown Moist to Wet (FILL)	1	GS			○					
		1	SS	15		○					
		2	SS	7		○		31	63	6 (SI+CL)	
		3	SS	3	▽	○					
		4	SS	4		○					
429.7 3.4	**SAND** and **SILT**, with organics Loose Dark Brown to Black Wet										
428.6 4.5	**SAND**, trace clay, trace gravel Compact to Loose Grey Wet	5	SS	11		○					
		6	SS	7		○					
426.4 6.7	END OF BOREHOLE AT 6.7m. WATER LEVEL MEASURED AT 2.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										

ELEVATION SCALE: 433, 432, 431, 430, 429, 428, 427

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

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-07

METRIC

GWP# 6836-14-00 | LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 175.3 E 404 530.0 | ORIGINATED BY BRM

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

DATUM Geodetic | DATE 2017.06.08 - 2107.06.08 | CHECKED BY RPR

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
433.5	GROUND SURFACE										
0.0	**ASPHALT:** (25mm)										
	SAND and **GRAVEL**, trace silt, trace clay, Brown, Moist (FILL)	1	GS			433	~0				
		2	GS				~3	30	64	6 (SI+CL)	
		3	GS			432	~0				
431.1 / 2.4	**SAND** and **SILT**, with organics, Dark Brown, Wet	4	GS		▽	431	~14				
430.5 / 3.0	**SAND**, trace gravel, Loose, Brown, Moist	1	SS	5		430	~1				
429.8 / 3.7	END OF BOREHOLE AT 6.7m. WATER LEVEL MEASURED AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT 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

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AG17-08

METRIC

GWP# 6836-14-00 LOCATION Agimak River Culvert, MTM NAD 83 Zone 16 N 5 477 185.3 E 404 530.1 ORIGINATED BY BRM

HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.06.08 - 2017.06.08 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
433.7	GROUND SURFACE										
0.0	**ASPHALT:** (25mm)										
	SAND, some gravel, trace silt, trace clay, Brown, Moist (FILL)		1	GS					~0		
							433				
			2	GS					~2		
							432				
			3	GS					~5		17 79 4 (SI+CL)
431.0 / 2.7	**SAND** and **SILT**, with organics, Dark Brown, Wet		4	GS		▽	431		~25		
430.6 / 3.1	**SAND**, trace gravel, Loose, Brown, Moist		1	SS	9				~7		
430.0 / 3.7	END OF BOREHOLE AT 6.7m. WATER LEVEL MEASURED AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.										

Legend: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

+³, ×³: Numbers refer to Sensitivity

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

THURBER

Appendix B

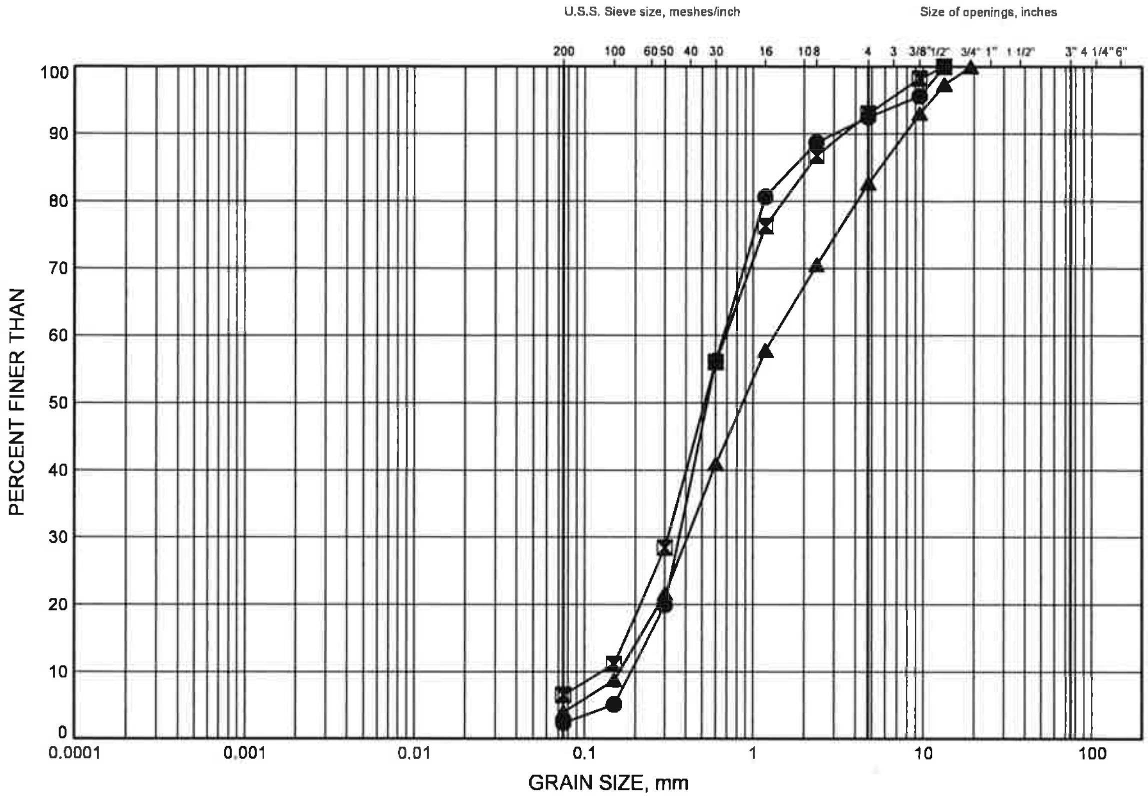
Geotechnical and Analytical Laboratory Test Results

Agimak River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AG17-02	2.6	430.6
⊠	AG17-05	0.9	432.0
▲	AG17-08	1.9	431.8

Date September 2017

GWP# 6836-14-00

THURBER

Prep'd AN

Chkd. RPR

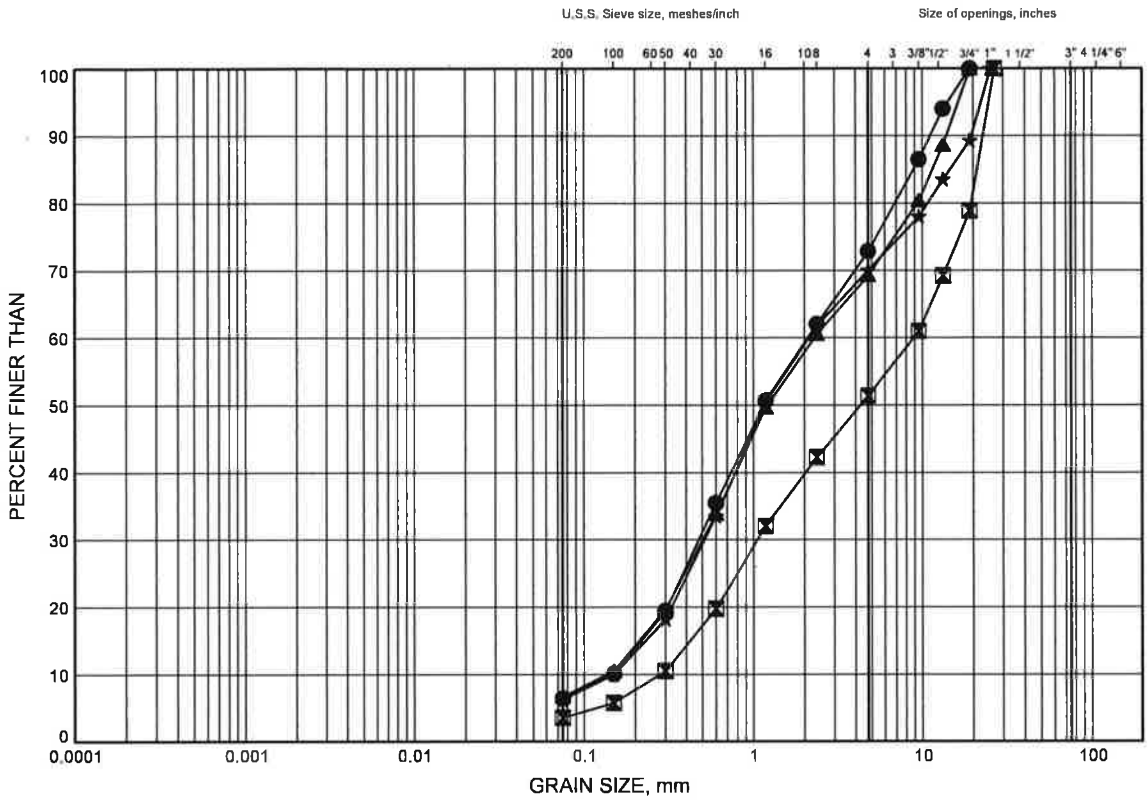
GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 9/7/17

Agimak River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

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)
●	AG17-03	1.0	432.3
⊠	AG17-03	3.1	430.2
▲	AG17-06	1.8	431.3
★	AG17-07	1.1	432.4

GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 9/7/17

Date September 2017

GWP# 6836-14-00

THURBER

Prep'd AN

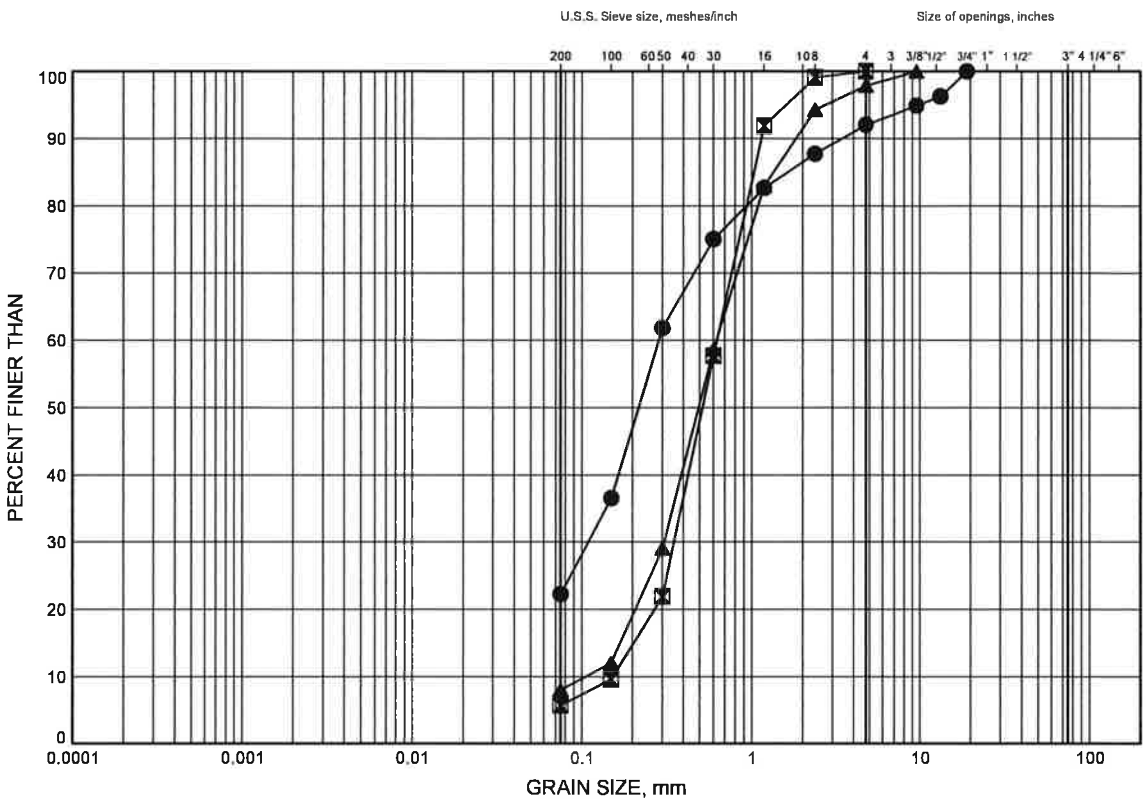
Chkd. RPR

Agimak River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AG17-01	2.6	429.3
⊠	AG17-01	12.5	419.4
▲	AG17-03	16.9	416.4

GRAIN SIZE DISTRIBUTION - THURBER MTO-17077.GPJ 9/7/17

Date September 2017

GWP# 6836-14-00

THURBER

Prep'd AN

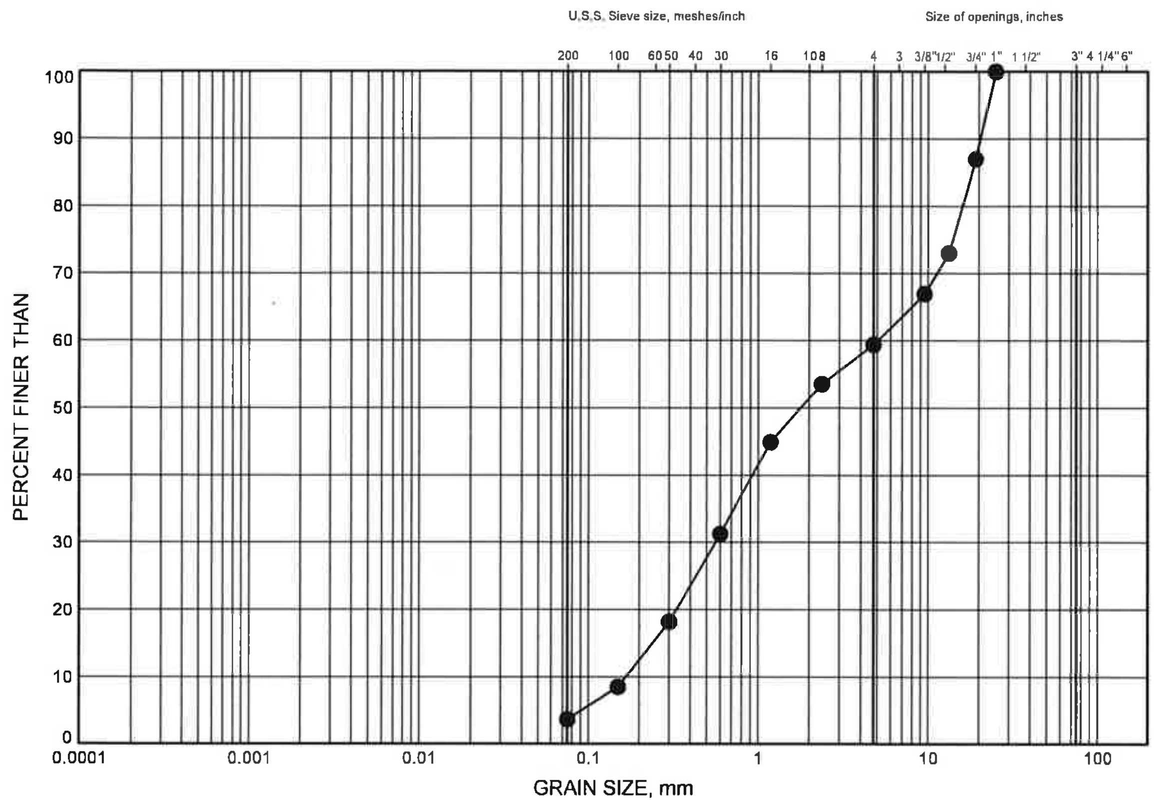
Chkd. RPR

Agimak River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND and GRAVEL

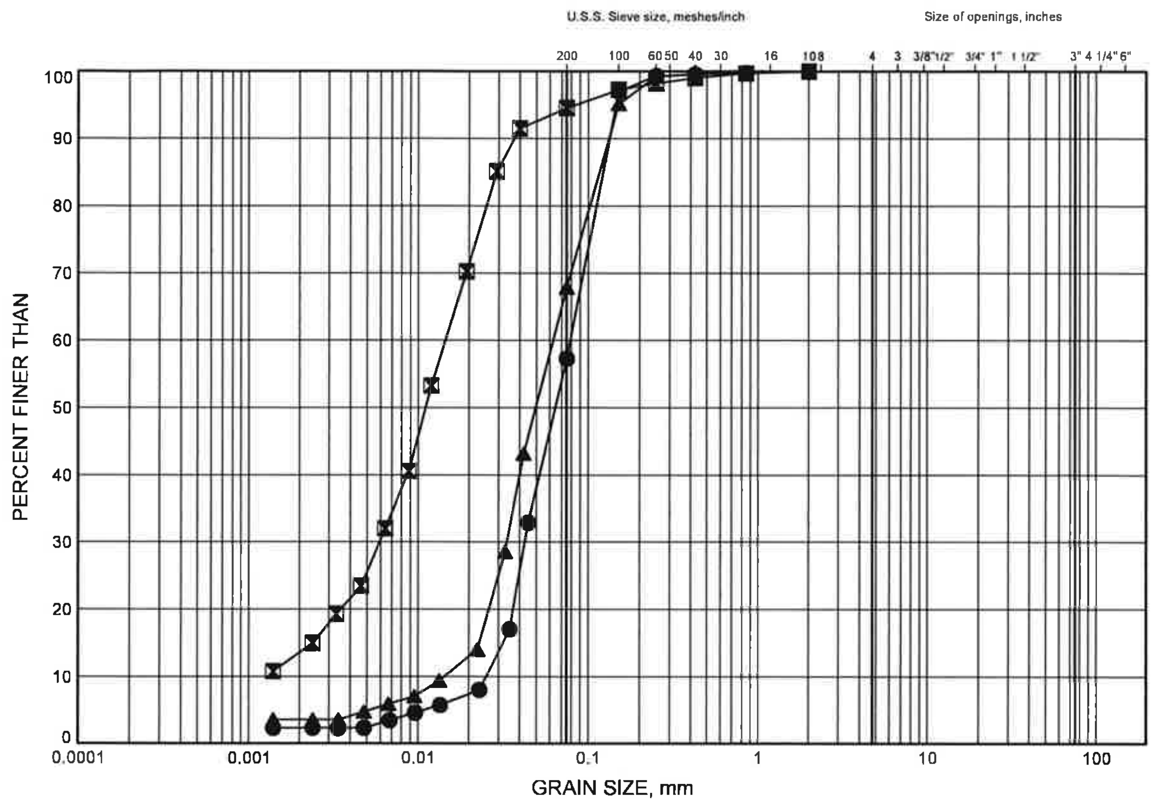


Agimak River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILT, Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AG17-01	7.9	424.0
⊠	AG17-02	9.4	423.8
▲	AG17-03	7.9	425.4

Date October 2017

GWP# 6836-14-00

THURBER

Prep'd AN

Chkd. RPR

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

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

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

THURBER

Appendix C

Selected Site Photographs

Photo 1: Highway 599 at Agimak River Culvert looking south

THURBER

Photo 2: Highway 599 at Agimak River Culvert looking north

THURBER

Photo 3: Agimak River Culvert inlet

THURBER

Photo 4: Agimak River culvert outlet

THURBER

Appendix D

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

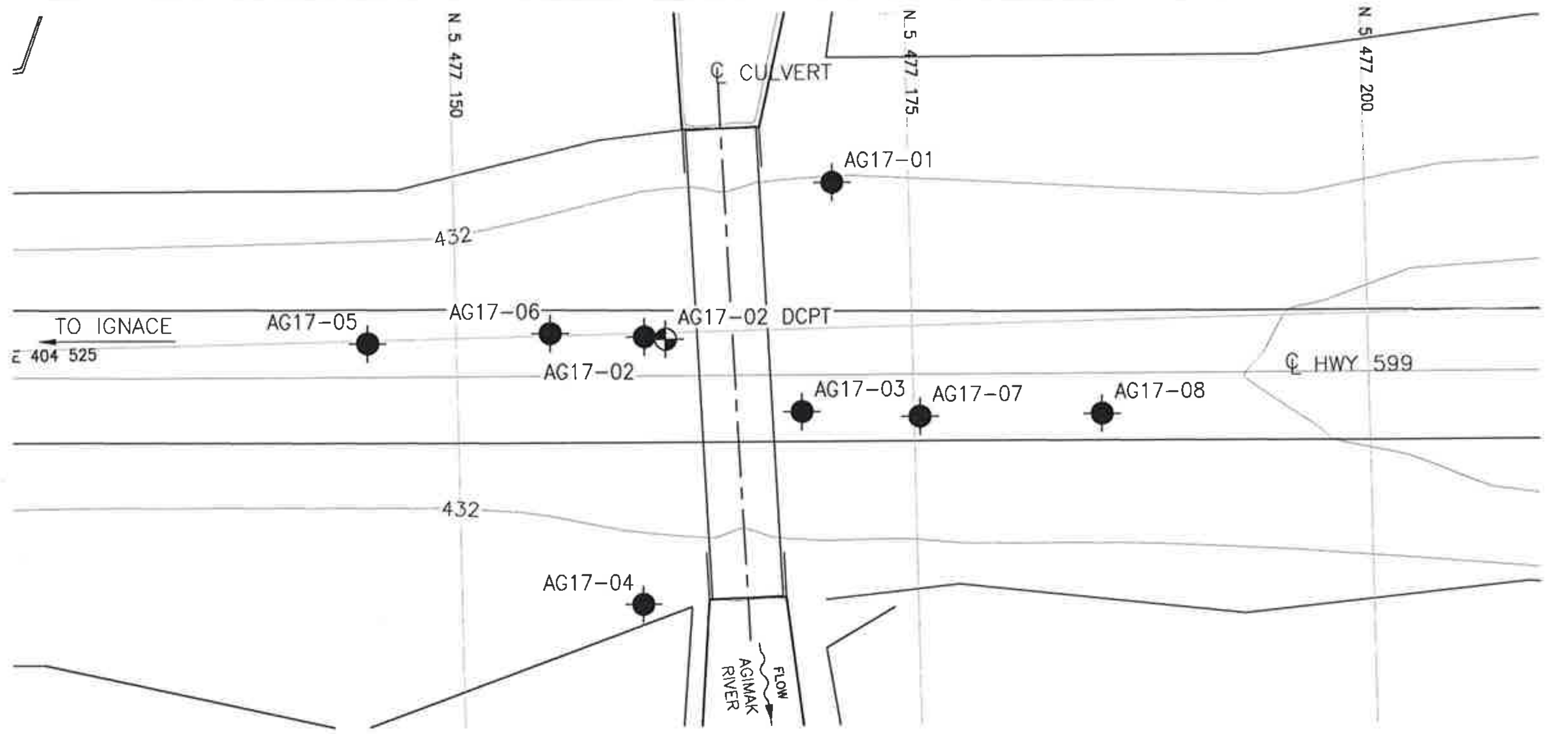
CONT No 2017-6036
WP No 6836-14-01

HIGHWAY 599
AGIMAK RIVER CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 9

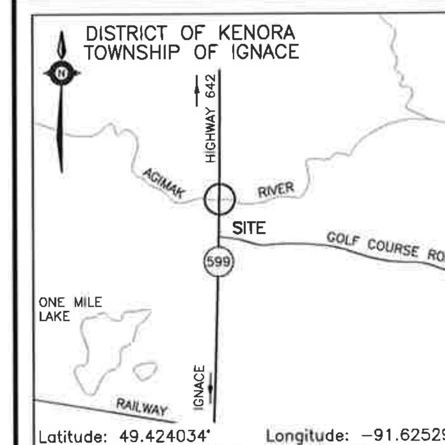
HATCH

THURBER ENGINEERING LTD.

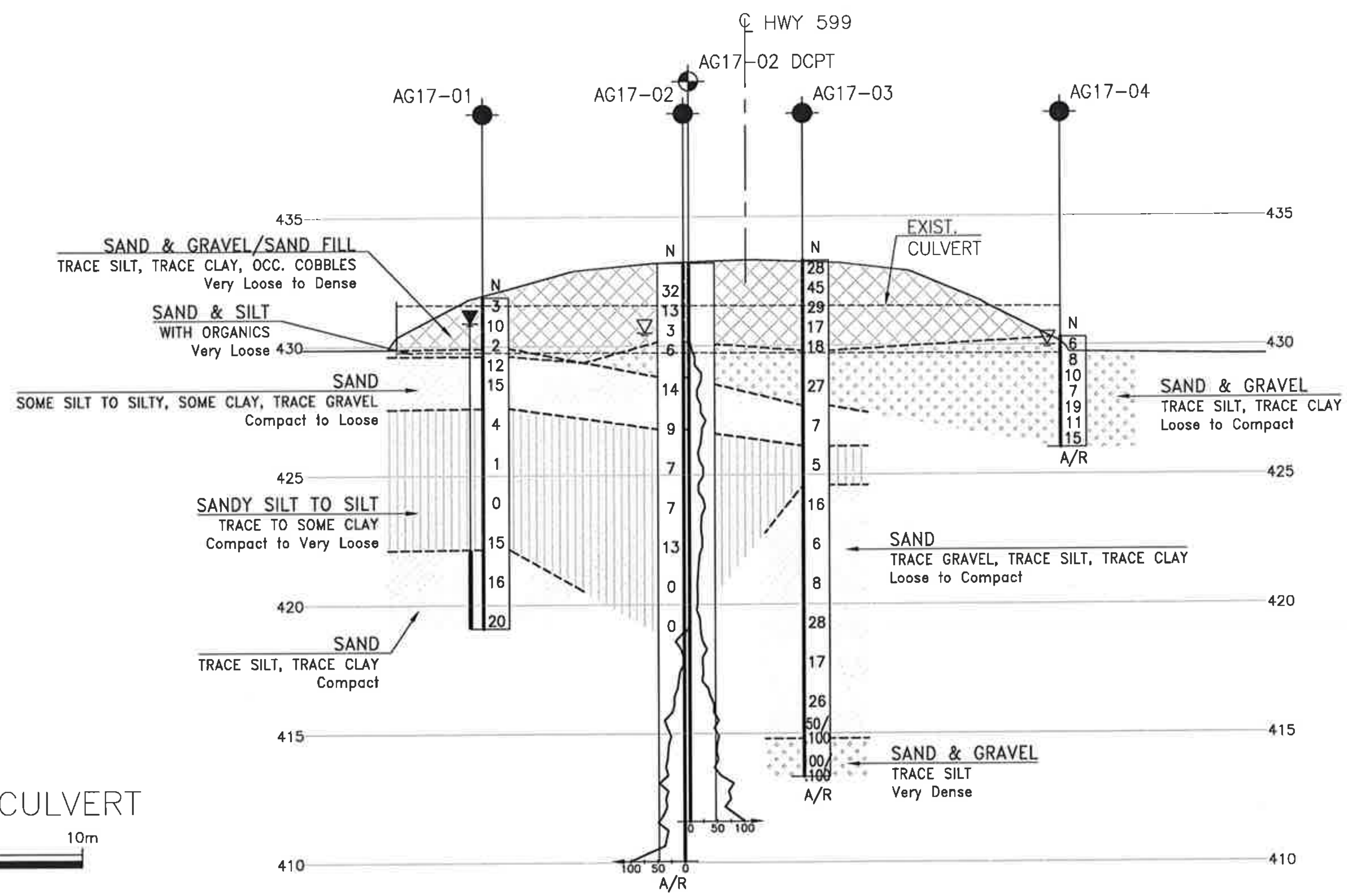


PLAN

SCALE 1:400



KEYPLAN



PROFILE ALONG ℄ CULVERT

SCALE 1:250

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/Casing/DCPT Refusal

NO	ELEVATION	NORTHING	EASTING
AG17-01	431.9	5 477 170.8	404 517.0
AG17-02	433.2	5 477 160.3	404 525.2
AG17-02 DCPT	433.2	5 477 161.5	404 525.3
AG17-03	433.3	5 477 168.9	404 529.5
AG17-04	430.3	5 477 159.9	404 539.8
AG17-05	432.9	5 477 145.1	404 525.1
AG17-06	433.1	5 477 155.1	404 524.9
AG17-07	433.5	5 477 175.3	404 530.0
AG17-08	433.7	5 477 185.3	404 530.1

-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 16.

GEOCRES No. 52G-16

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

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

REVISIONS

DATE	BY	DESCRIPTION		
DESIGN RPR	CHK JPL	CODE	LOAD	DATE JAN 2018
DRAWN AN	CHK RPR	SITE 48W-242C	STRUCT	DWG 2

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

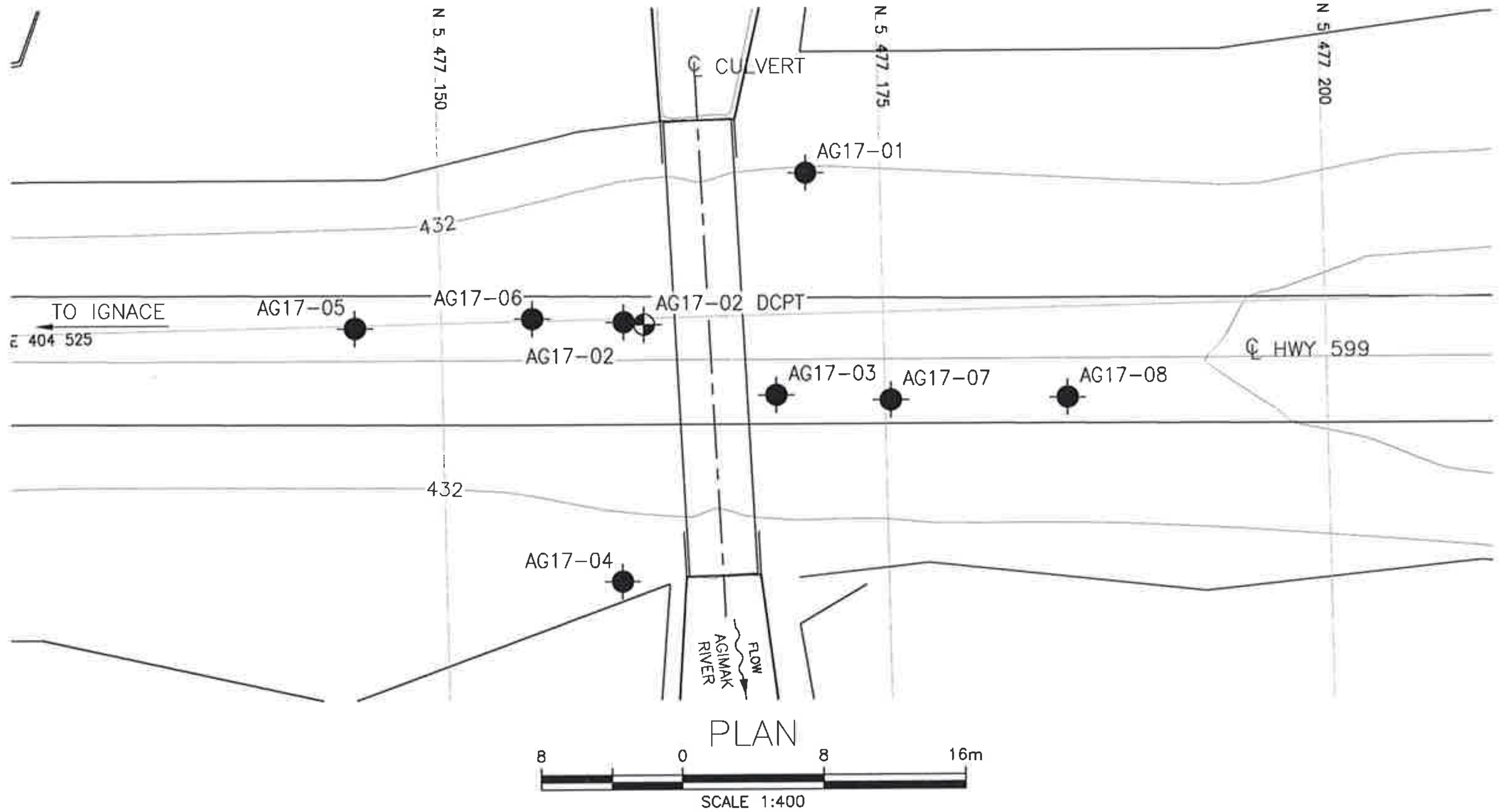
CONT No 2017-6036
WP No 6836-14-01

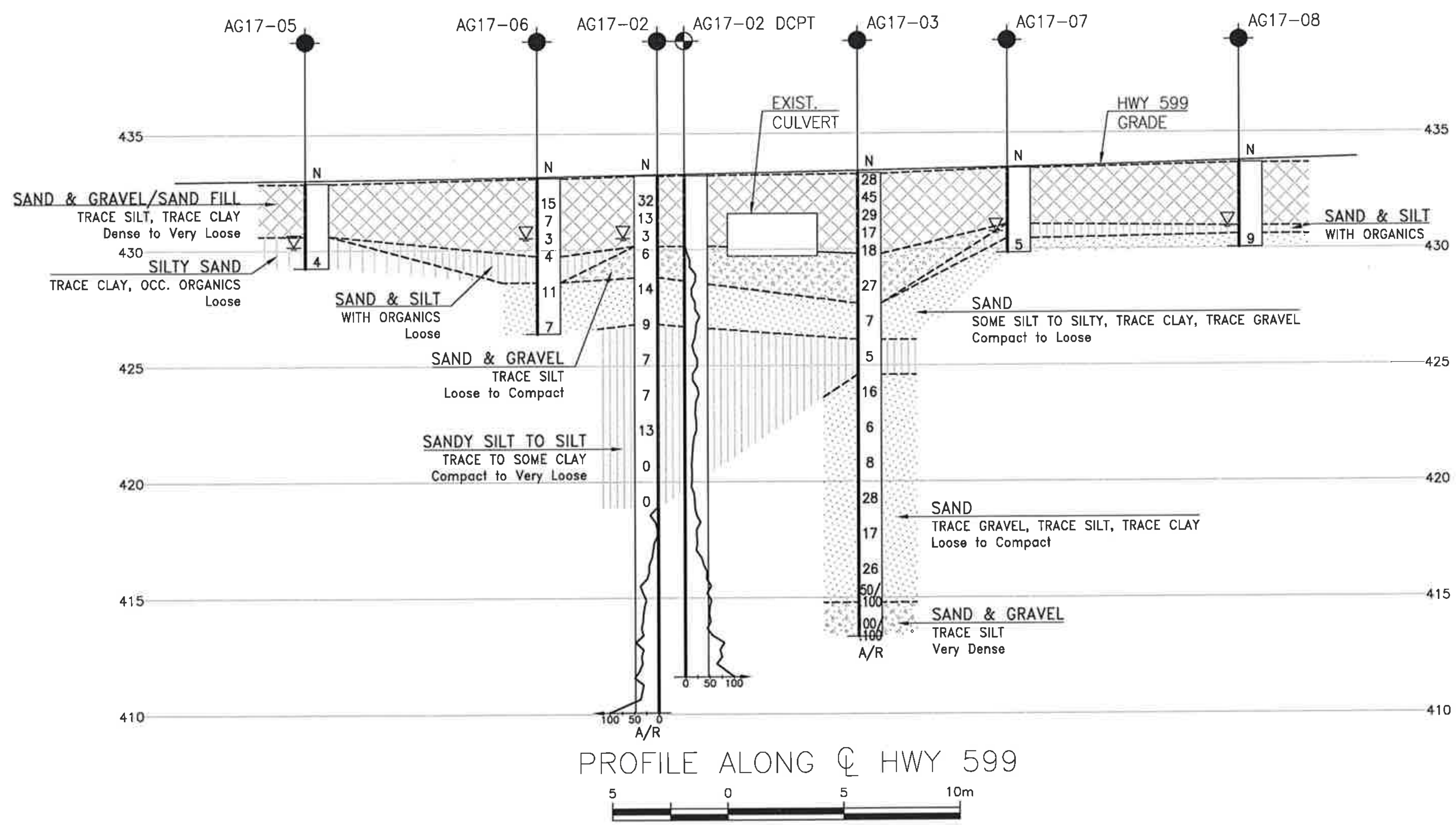
HIGHWAY 599
AGIMAK RIVER CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

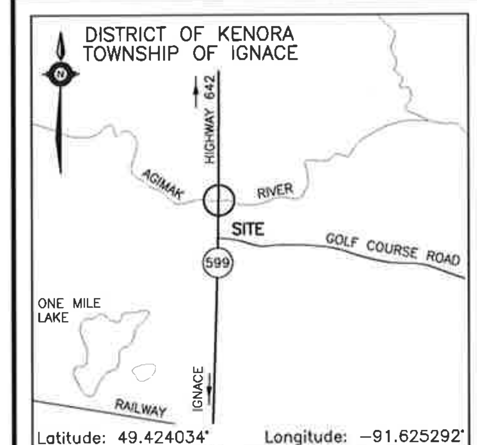
SHEET 10

HATCH

THURBER ENGINEERING LTD.







KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
AG17-01	431.9	5 477 170.8	404 517.0
AG17-02	433.2	5 477 160.3	404 525.2
AG17-02 DCPT	433.2	5 477 161.5	404 525.3
AG17-03	433.3	5 477 168.9	404 529.5
AG17-04	430.3	5 477 159.9	404 539.8
AG17-05	432.9	5 477 145.1	404 525.1
AG17-06	433.1	5 477 155.1	404 524.9
AG17-07	433.5	5 477 175.3	404 530.0
AG17-08	433.7	5 477 185.3	404 530.1

-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 16.

GEOCRES No. 52G-16

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

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN RPR	CHK JPL	CODE	LOAD	DATE JAN 2018	
DRAWN AN	CHK RPR	SITE 48W-242C	STRUCT	DWG 3	

FILENAME: H:\Drafting\17000\17077\ED-17077-PLPR-AC.dwg
PLOTDATE: 1/26/2018 5:15 PM

THURBER

Appendix E

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. vi. Less expensive than box culvert.
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. Unconventional design.
RECOMMENDED	**RECOMMENDED**	**NOT RECOMMENDED**	**FEASIBLE**

THURBER

Appendix F

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 903 — Construction specification for deep foundations
- 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 sheet pile 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.