



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT, 22+113 HAVILLAND  
HIGHWAY 17 NEAR GOULAIS RIVER  
SAULT STE MARIE AREA  
G.W.P. 545-00-00**

**GEOCRES Number: 41K-97**

**Report**

**to**

**WSP Canada Inc.**

Thurber Engineering Ltd.  
104, 2460 Lancaster Road  
Ottawa, Ontario  
K1B 4S5  
Phone: (613) 247-2121  
Fax: (613) 247-2185

September 16, 2016  
19-5308-95



## TABLE OF CONTENTS

### **PART 1 FACTUAL INFORMATION**

1	INTRODUCTION.....	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS.....	3
5.1	General.....	3
5.2	Pavement Structure.....	4
5.3	Embankment Fill.....	4
5.4	Topsoil.....	5
5.5	Cobbles and Gravel .....	5
5.6	Silty Sand .....	5
5.7	Silt to Silty Sand .....	5
5.8	Clay (CL) .....	6
5.9	Sand with Silt.....	7
5.10	Groundwater Conditions .....	7
6	MISCELLANEOUS.....	9

### **PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS**

7	GENERAL.....	10
8	CULVERT FOUNDATIONS.....	11
8.1	General.....	11
8.2	Culvert Alternatives .....	11
8.3	Construction Methodology Alternatives.....	12
8.4	Recommended Approach .....	13
9	RECOMMENDATIONS .....	13
9.1	Entry and Exit Pits .....	14
9.2	Dewatering .....	15
9.3	Embankment Reinstatement.....	16
9.4	Erosion Control.....	16
9.5	Cement Type and Corrosion Potential .....	16
10	CONSTRUCTION CONCERNS .....	17



11	CLOSURE.....	19
----	--------------	----

## **APPENDICES**

APPENDIX A	Borehole Locations and Soil Strata Drawings
APPENDIX B	Record of Borehole Sheets
APPENDIX C	Laboratory Test Results
APPENDIX D	Selected Photographs of Culvert Location
APPENDIX E	Table E-1: Comparison of Construction Methodology Alternatives NSSP's

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT, 22+113 HAVILLAND  
HIGHWAY 17 NEAR GOULAIS RIVER  
SAULT STE MARIE AREA  
G.W.P. 545-00-00**

**GEOCRES Number: 41K-97**

**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for replacement of a culvert under Highway 17 near Goulais River, Ontario.

No previous foundation investigation information for the subject culvert was available.

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

Thurber was retained by WSP Canada Inc. (WSP) to carry out this foundation investigation under MTO Agreement Number 5014-E-0008.

**2 SITE DESCRIPTION**

The culvert site is located on Highway 17, approximately 7.2 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Havilland. A 1.22 m diameter by 77.5 m long corrugated steel pipe culvert (CSP) is present at the site and covered with approximately 13 m of fill. The culvert conveys water from west to east, towards the nearby Stokely Creek. The invert elevation is 227.8 m at the east end and 234.2 m at the west end.

The grade of the existing Highway 17 in the vicinity of the culvert is at 245.0 m geodetic. The culvert is located within a fill section. The embankment is constructed with side slopes approximately 2 horizontal to 1 vertical (2H:1V) and 2.6 horizontal to 1 vertical (2.6H:1V), corresponding to the east and west slopes respectively. The embankment fill height is approximately 14.6 m at the east side and approximately 12.5 m at the west side.

The existing roadway cross-section includes three 3.5 m wide lanes (two lanes in the southbound direction), a 2.2 m wide northbound paved shoulder, a 1.0 m wide southbound paved shoulder and 0.5 m rounding on both sides. Three cable guide rail is present on both sides of the highway. The AADT is reported to be 2650. The highway profile slopes down to the north at approximately 5.2%. Although the site is in a tangent section a curve begins less than 200 m to the north. The outlet for a second culvert which drains the south bound ditch to the south of the site is in close proximity to the inlet of the main culvert, see photo 6 in Appendix D. Subdrains are present on the south bound side in the earth cuts to the north and south of the site.

The site is located in a rural area with forests, swamps and creeks. The local topography is rolling with undulating hills and valleys. Selected photographs of the culvert site are attached in Appendix D.

The surficial geology of the area is typical of the Wisconsin glaciation. Soil cover consists primarily glaciolacustrine (clay, silt, and sand) deposits underlain by glacial till.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The borehole investigation and field testing program was carried out between January 25 and February 4, 2016. The program consisted of drilling and sampling four boreholes (numbered 15-13, 15-14, 15-15, and 15-16) to depths ranging from 2.6 m to 26.5 m. Of these boreholes, one was located near the culvert inlet (15-16), one located near the culvert outlet (15-13), and two (15-14 and 15-15) were located through the embankment on opposite sides of the road near the culvert.

Prior to the start of drilling, the borehole locations were established in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently determined by Thurber based on elevation data provided by WSP.

A truck-mounted drill rig equipped with hollow stem augers was used to drill and sample the boreholes on the roadway, and a portable tripod drill rig was used to drill and sample the culvert inlet and outlet boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT).

Results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix B.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled

containers, and transported the samples to Thurber's laboratory for further examination and testing.

The boreholes were backfilled with soil cuttings mixed with bentonite and topped to surface with the existing granular material or where required with asphalt patch.

#### **4 LABORATORY TESTING**

All recovered soil samples were subjected to Visual Identification and to Natural Moisture Content determination. Selected soil samples were subjected to Grain Size Distribution analyses (sieve and hydrometer) and Atterberg Limit testing. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix B and on the Figures in Appendix C.

One soil sample was submitted to Paracel Laboratories Ltd. (Ottawa) for analysis of pH, resistivity, and soluble sulphate and chloride. The results of the chemical testing can be found in Appendix C.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

##### **5.1 General**

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert replacement alignment is presented on the Borehole Locations and Soil Strata Drawing in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes consist of granular and silty sand embankment fill overlying sand and silt deposits underlain by clay or sand. Bedrock was not encountered in any of the four boreholes. More detailed descriptions of the individual strata are presented below.

Severe erosion was observed on the slope above the outlet of the culvert, severe erosion was also noted above the inlet and may be indicative of separation of culvert sections, see Photo 7 in Appendix D.

## 5.2 Pavement Structure

A layer of asphalt 90 and 100 mm in thickness was encountered at ground surface in Boreholes 15-14 and 15-15 which were drilled through the roadway.

Sand with gravel fill likely placed as part of the pavement structure extended to a depth of 0.3 m and 0.6 m below surface (elevations 244.6 m and 245.3 m) in Boreholes 15-14 and 15-15 respectively.

The moisture content of the granular fill ranged from 1% to 3%. The results of grain size analysis conducted on one sample of the granular material are presented on Fig. No 1 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	38
Sand	58
Silt and Clay	4

The ground was frozen at the time of the field investigation thus the relative density of this layer could not be determined reliably.

## 5.3 Embankment Fill

Embankment fill was encountered below the pavement granulars in Boreholes 15-14 and 15-15. The thickness of the embankment fill ranged from 11.9 to 14.3 m. The base of the embankment fill was encountered at elevations ranging from 230.3 to 233.4 m.

The upper portions of the fill was observed to be silty sand with some gravel while the lower portion was silty sand to sandy silt. The fill included occasional cobbles in the upper portion.

The SPT N-value for the embankment fill ranged from weight-of-hammer (WH) to 54 blows per 0.3 m penetration, indicating a very loose to very dense state. It should be noted that the SPT testing in the upper most portions of the fill was likely through frozen soils. The water content of the recovered embankment fill samples ranged between 6% and 23%. The colour of the embankment fill is brown.

The results of grain size analyses conducted on four samples of the fill are presented on Fig. No 1 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	2 to 10
Sand	41 to 80
Silt and Clay	13 to 57

#### 5.4 Topsoil

Topsoil, 50 mm in thickness, was encountered in one borehole (15-16) drilled at the inlet. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities or quality.

#### 5.5 Cobbles and Gravel

A thin layer (150 mm thick) was observed at ground surface in Borehole 15-13 which was drilled near the outlet.

#### 5.6 Silty Sand

A native soil deposit ranging from silty sand to silty sand with gravel was encountered in all boreholes. This deposit was found just below an organic layer in the inlet hole and below the cobbles and gravel of the creek bed in the outlet hole and beneath the base of the embankment fill. This layer was observed to range from 2.0 m to 4.0 m in thickness with the base elevation of the base of the unit ranging from 225.6 m to 233.1 m. This deposit contained trace organic material in Borehole 15-13 and 15-15. A discrete organic interlayer was noted to be 300 mm thick in Borehole 15-16. Occasional to frequent cobbles were observed deeper within this unit. The SPT N-value for this deposit was 5 to greater than 100 blows per 0.3 m penetration, indicating a loose to very dense state. The water contents of the recovered samples ranged between 9% and 22%. The organic interlayer in Borehole 15-16 had a moisture content of 52%. The colour of this deposit is generally greyish brown.

Grain size analyses conducted on three samples of the soil are presented on Fig. No 2 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	1 to 18
Sand	62 to 78
Silt and Clay	20 to 21

This material can be classified as SM.

#### 5.7 Silt to Silty Sand

A native soil deposit ranging from silt with sand to silty sand with gravel was encountered in all boreholes. This deposit was found just below the silty sand layer in all boreholes. This layer



where fully penetrated was observed to range from 5.8 m to 6.0 m in thickness with the elevation of the base of the unit ranging from 222.3 m to 223.6 m, where fully penetrated. The SPT N-value for this deposit was 13 to greater than 100 blows per 0.3 m penetration, indicating a compact to very dense state. Both the inlet and outlet boreholes were terminated within this layer upon SPT refusal. The water content of the recovered samples ranged between 8% and 24%. The colour of this deposit is greyish brown to reddish brown.

Grain size analyses conducted on three samples of the soil are presented on Fig. No 3 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	15 to 28
Silt	68 to 83
Clay	2 to 8

This soil may be classified as ML to SM.

## 5.8 Clay (CL)

Clay with some sand layers was encountered underlying the silt and sand deposit in Borehole 15-15. Borehole 15-15 was terminated 1.2 m into this deposit at an elevation 222.4 m.

The SPT N-value in the clay deposit was 14 blows per 0.3 m penetration, indicating a stiff consistency. Sampling ceased in this layer in Borehole 15-15, however a dynamic cone (DCPT) was driven 1.5 m further to assess the consistency of the soils at the base of the borehole. The DCPT revealed the blow count of the material below the clay ranged from 12 to 110 blows per 0.3 m penetration, indicating the presence of compact (or stiff, if cohesive) to very dense (or hard) material.

The colour of the clay is reddish brown. The water content of the recovered clay sample was 25%.

The results of a grain size analyse conducted on a sample of the clay are presented on Fig. No 4 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	11
Silt	74
Clay	15

Atterberg limit testing was carried out on a sample of the clay. The liquid limit was 25% and the plasticity index was 8%. The sample can be classified as clay of low plasticity (CL). The results are presented on Fig. No 6 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	17
Liquid Limit	25
Plasticity Index	8

### 5.9 Sand with Silt

A layer of sand with silt was encountered underlying the silt and sand deposit in Borehole 15-14. Borehole 15-14 was terminated 3.9 m into this material at elevation 218.4 m.

SPT N-values measured within this layer were 10 and 25 blows per 0.3 m penetration, indicating a compact state. The colour of this deposit was brown.

The moisture content of the samples tested was 19% and 23%. One sample of this deposit were subjected to gradation analysis. The results are summarized in the table below and presented on Fig. No 6 in Appendix C.

Soil Particles	%
Gravel	0
Sand	89
Silt and Clay	11

This material can be classified as SP.

### 5.10 Groundwater Conditions

Groundwater was observed in Boreholes 15-13 and 15-16 at depths of 0.0 m and 0.6 m respectively at the time of drilling. The elevation of the observed ground water ranged from 228.2 m to 234.6 m.

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Local high water levels and the effects of heavy rainfalls must also be taken into consideration.


## 6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling.

Marathon Drilling Ltd. of Greely, Ontario, supplied and operated a truck-mounted CME 55 drill rig to carry out the drilling, sampling and in-situ testing operations on the existing highway platform. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario, supplied and operated the portable drill rig.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Justin Gray E.I.T. and Mr. Chris Murray E.I.T. of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory.

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Justin Gray E.I.T. and Dr. Fred Griffiths P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

  
Justin A. Gray  
Geotechnical E.I.T.



Fred J. Griffiths, P.Eng.  
Senior Associate, Senior Foundations Engineer



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

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT, 22+113 HAVILLAND  
HIGHWAY 17 NEAR GOULAIS RIVER  
SAULT STE MARIE AREA  
G.W.P. 545-00-00**

**GEOCRES Number: 41K-97**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This report presents interpretation of the geotechnical data in the factual report and presents a foundation assessment and evaluation of feasible methods for replacement of a culvert under Highway 17 approximately 7.2 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Havilland.

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 factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

A 1.22 m diameter by 77.50 m long corrugated steel pipe culvert (CSP) is present at the site. The stream at the site flows from west to east. The site is in a tangent section of the highway that slopes up at 5.2% to the south, a curve begins less than 200 m to the north. The existing roadway cross-section is approximately 14.7 m wide from rounding to rounding with three cable guide rail on both sides of the highway

The borehole information indicates that the base of the embankment fill ranges from 230.3 m to 233.4 m. The majority of the excavation for a new culvert would therefore be within the fill which was observed to consist of dense silty sand some gravel over loose to compact silty sand to sandy silt. Occasional cobbles were noted in the fill. The native material observed immediately beneath the fill consisted of silty sand to silt with sand. It was typically compact and was observed to contain trace organic material and cobbles. Below this native material was a

compact sand with silt or stiff clay layer. Frost depth at this site is 2.0 m. Groundwater levels at the time of the investigation were noted at an elevation ranging from 228.2 m to 234.6 m.

This report presents an evaluation of the feasible methods for the replacement of the culvert. The discussions and recommendations presented in this report are based on information provided by WSP and on the factual data obtained during the course of this investigation.

## **8 CULVERT FOUNDATIONS**

### **8.1 General**

It was determined by WSP that installing a culvert liner is insufficient to meet project needs and the culvert will need to be replaced. The following sections address replacement of the existing culvert. During the design process it has been assumed that the replacement culvert will be installed along the existing culvert alignment, however it was understood that it may be preferable to re-align the culvert to one side or the other to allow flow to continue through the existing culvert during construction of the replacement culvert as long as the old and new culvert are spaced at least one culvert diameter apart. It is noted that the existing culvert is considered a non-structural culvert.

### **8.2 Culvert Alternatives**

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides foundation recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below along with comments on feasibility from a foundations perspective.

#### Circular Pipes (Concrete, Steel, HDPE)

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible.

#### Concrete, Open Footing Culvert

Concrete open footing culverts are considered feasible but not geotechnically preferred due to the relatively deep excavation that will be required for footing construction and possible dewatering.

#### Concrete Box (Closed) Culvert

Concrete box (closed) culverts are considered feasible but not geotechnically preferred due to the relatively deep excavation that will be required for footing construction and possible dewatering.

### Recommended Culvert

Given the fact that the existing culvert consists of a 1220 mm diameter CSP, replacement with a single pipe of similar diameter is both technically feasible and cost effective. The report herein focuses on providing foundation recommendations related to the design and construction of circular pipe culverts. Contract drawings provided by WSP indicate the planned replacement culvert is to consist of a 1400 mm diameter by 74 m long circular pipe offset approximately 4 m to the south of the existing culvert alignment. The planned invert elevations are 234.25 m and 227.87 m at the upstream and downstream ends respectively.

### **8.3 Construction Methodology Alternatives**

This section presents discussions on alternative construction methods for replacement of the culvert. In preparation of these recommendation the following options have been considered:

1. Open cut with full road closure: not feasible
2. Open cut with single lane, traffic lights: not feasible as embankment width is insufficient
3. Open cut with a single lane, traffic lights and roadway protection: feasible
4. Open cut with a single lane, traffic lights, and temporary grade lowering: not feasible without roadway protection.
5. Open cut with a single lane, traffic lights, and temporary platform widening: feasible with roadway protection.
6. Trenchless methods.

Options 1 and 2 are not considered feasible at this site. Options 4 and 5 include temporary modifications to the vertical and horizontal alignments. Given the sloping profile, the curve to the south, and the drainage features north and south of the site it is anticipated that these temporary modifications will be difficult. Option 5 would also include significant changes to the toe of slope at the culvert ends. Since Options 4 and 5 would require roadway protection there is no clear advantage versus Option 3. Table E-1 in Appendix E provides a comparison of Options 3, 5 and 6.

Based on our understanding of the project and the existing conditions at the site Option 6 is considered the preferred method. It would eliminate an excavation in excess of 14 m depth and allow the culvert to be replaced with minimal impact to traffic.

#### **8.4 Recommended Approach**

A trenchless technique is considered the preferred alternative. The discussion and recommendations provided below are based on the culvert replacement consisting of a circular pipe installed using a trenchless method.

### **9 RECOMMENDATIONS**

Trenchless installations should be carried out in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Method". A copy of this NSSP is attached in Appendix E.

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

- Jack and bore
- Pipe ramming
- Microtunnelling (MTBM)
- Hand Mining
- Horizontal Directional Drilling

Selection of an appropriate trenchless method must be the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the contractor is of primary importance for trenchless installation. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of oversized obstructions and disposal of cuttings.

Jack and bore is considered generally not feasible due to the presence of non-plastic soils in the target depth since this material could increase the risk under the presence of groundwater by creating unstable flowing conditions at the face of the installation.

During pipe ramming, the sleeve pipe is driven from the access point to the exit point using an air-powered percussion hammer. After the sleeve has been fully or partially driven, the soil is removed by augering. The pipe ramming technique can accommodate the removal of boulders up to a certain size. This method has versatility in accommodating a variety of subsurface conditions and is generally suitable for cohesionless soils with water seepage problems associated with low piezometric head. Under this condition dewatering is usually not required for this method. The Pipe Ramming technique does not require a backstop for reaction purposes. This technique has a further advantage in that there is only a small over-cut around the pipe, thus there is a lower potential to cause settlement of the pavement surface. The alignment control can be adversely affected if oversize obstructions are encountered



Microtunnelling is also considered feasible for this site; it is a closed face system designed to handle the flowing conditions.

Horizontal Directional Drilling is also considered feasible at this site. The method will require an initial directional drill advance and back reaming for enlargement of the hole and pipe installation. The process is carried out under fluid pressure to prevent instability of the hole during installation.

The size of the replacement pipe is too small for the hand mining approach.

Although the selection of a suitable trenchless technique is the responsibility of the contractor, in light of the materials and ground water conditions observed at this site, microtunneling and Horizontal Directional Drilling are the preferred methods at this site.

It should be noted that all trenchless methods will require a new alignment, and the clearance required between the existing and the new pipes for safe installation is typically between 1 to 2 pipe diameters.

Monitoring of the roadway surface should be carried out during the trenchless installation as specified in the NSSP.

### **9.1 Entry and Exit Pits**

The design of safe and stable entry and exit pits for the trenchless installation is the responsibility of the contractor. Depending on the selected installation method, temporary protection systems may be required to support temporary excavations at the entry and exit pits. All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native soil at this site are classified as Type 3 soil above the water level and Type 4 soil below the water level.

Sheet-piles or soldier pile & lagging walls are considered appropriate for protection systems at this site. The fill and native material below the fill was noted to include occasional cobbles. Suggested wording for an NSSP on "Obstructions" is found in Appendix E.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539, November 2009. The lateral movement of the temporary shoring system should meet Performance Level 2.

Earth pressures may be calculated using the parameters provided in the following table for static conditions.

### Earth Pressure Design Parameters – Static Conditions

Parameter	Soil Type							
	OPSS Granular A or OPSS Granular B Type II $\Phi = 35^\circ$ $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\Phi = 32^\circ$ $\gamma = 21.2 \text{ kN/m}^3$		OPSS SSM Fill $\Phi = 30^\circ$ $\gamma = 21 \text{ kN/m}^3$		Sand or Silty Sand or Sandy Silt $\Phi = 29^\circ$ $\gamma = 19 \text{ kN/m}^3$	
Surface Behind Wall	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)
Active Earth Pressure Coefficient, $K_a$ (Unrestrained Wall)	0.27	0.39	0.31	0.47	0.33	0.54	0.35	0.58
At-rest Earth Pressure Coefficient, $K_o$ (Restrained Wall)	0.43	-	0.47	-	0.50	-	0.52	-
Passive Earth Pressure Coefficient, $K_p$ (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-	2.9	-

In accordance with Clause C4.6.4 of the CHBDC (2014) and related commentary, retaining structures should be designed using earth pressure coefficients that include earthquake loading, however the Zonal Acceleration Ratio for the Sault Ste Marie area is 0.0.

## 9.2 Dewatering

Groundwater or indications of groundwater were observed in several of the boreholes at the time of drilling. It is noted however that groundwater levels do fluctuate and it is expected that groundwater and surface water will accumulate in the excavations during culvert construction. The groundwater level is expected to be largely governed by the water level in the stream, ditch and seasonal weather. Construction dewatering is the responsibility of the contractor who must provide effective dewatering to install the culvert in the dry or to keep the entry and exit pits dry. However, it is anticipated that sump pumps and/or creek diversion will be the most applicable

methods of dewatering at this site. A permit to take ground water is expected to be required as daily pumping rates may be over 50,000 litres per day.

### **9.3 Embankment Reinstatement**

The existing embankment is sloped at approximately 2H:1V or flatter and exhibits no signs of instability. Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS 206 and OPSD 208.010. The embankment material should consist of imported Granular B Type I or Select Subgrade material. Excavated granular fill with less than 25% fines may also be reused as backfill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction.

Provided the embankment fill is placed as recommended herein, embankment slopes matching the existing slopes, will remain stable.

### **9.4 Erosion Control**

Severe erosion of the slope material was noted above the inlet and outlet. Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field. Typically, rock protection should be provided over all surfaces with which flowing surface water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

It is recommended that a clay seal be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

Other storm sewer facilities were observed near the culvert inlet which may be contributing to the erosion concerns. These areas should be reviewed and provided with additional rock protection.

### **9.5 Cement Type and Corrosion Potential**

A sample of the native sand with silt (Borehole 15-15, SS10) was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for

degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are provided in Appendix C and summarized in the following table.

**Results of Chemical Analysis**

<b>Borehole</b>	<b>Sample</b>	<b>Depth (m)</b>	<b>pH</b>	<b>Resistivity (Ohm-cm)</b>	<b>Chloride (µg/g)</b>	<b>Sulphate (µg/g)</b>
15-15	SS10	11.0	7.4	5200	1200	9

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH measured was within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

## **10 CONSTRUCTION CONCERNS**

The recommended construction methodology includes trenchless methods in order to replace the culvert. Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of trenchless operations on the existing pavement surface due to loss of material or heave must be monitored. The Contractor's methodology selection must recognize and take into consideration these inherent risks. Contingency plans should be in place to manage any adverse impacts on the highway.
- Implementation of an adequate and effective surface water management and dewatering plan. Surface runoff should be diverted away from excavations at all times.
- The embankment fill was observed to contain cobbles and the fill may contain other obstructions. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the highway. The impact of obstructions on the pipe alignment should be assessed.

- The Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the culvert alignment. Any discrepancies from the Contract Drawings must be reported to the Contract Administrator.

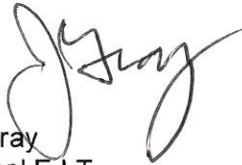
During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

## 11 CLOSURE

Preparation of this foundation design report was carried out by Mr. Justin Gray E.I.T., and Dr. Fred Griffiths P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

Justin A. Gray  
Geotechnical E.I.T.



Fred J. Griffiths, P.Eng.  
Senior Associate, Senior Foundations Engineer

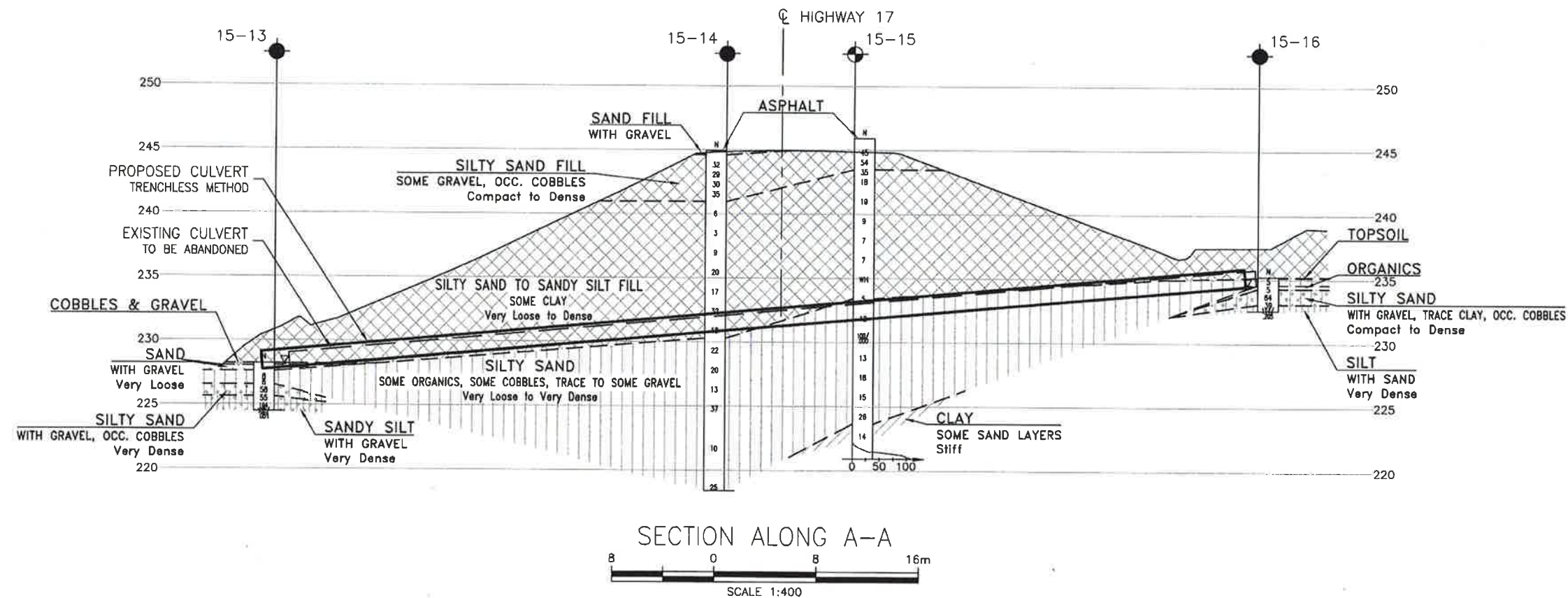
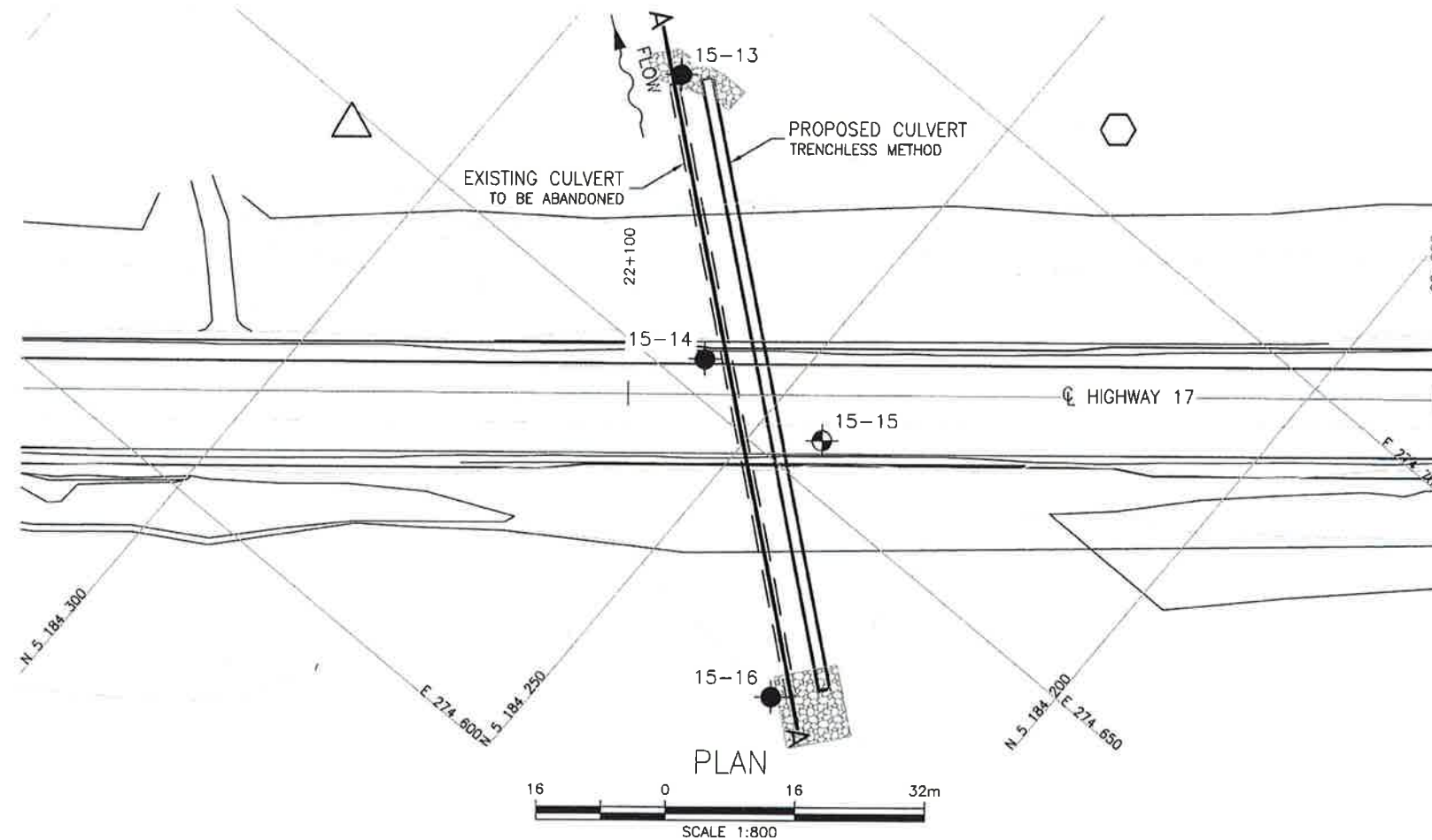


P.K. Chatterji, P.Eng.  
Principal, Designated MTO Contact

## **Appendix A**

### **Borehole Locations and Soil Strata Drawings**

19-5308-95



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

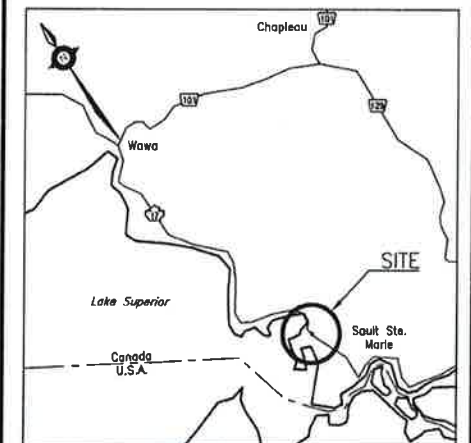


CONT No  
WP No

HIGHWAY 17  
22+113  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
15-13	228.2	5 184 285.3	274 679.2
15-14	244.9	5 184 260.3	274 654.1
15-15	245.9	5 184 242.7	274 655.7
15-16	235.2	5 184 227.1	274 627.4

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCREs No. 41K-97

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK	—
DRAWN	MFA	CHK	JG
CODE	LOAD	DATE	SEP 2016
SITE	STRUCT	DWG	1



## **Appendix B**

### **Record of Borehole Sheets**

19-5308-95



## **SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS**

### **TERMINOLOGY DESCRIBING COMMON SOIL GENESIS**

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

### **TERMINOLOGY DESCRIBING SOIL STRUCTURE:**

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

### **RECOVERY:**

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### **N-VALUE:**

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

### **DYNAMIC CONE PENETRATION TEST (DCPT):**

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

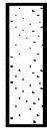


### STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders  
Cobbles  
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	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	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, 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.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit



## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
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 structures are preserved.

### 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 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

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

### STRENGTH CLASSIFICATION


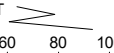













Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

# RECORD OF BOREHOLE No 15-13

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 285.3 E 274 679.2 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.25 - 2016.01.25 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS 	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								 20   40   60   80   100 ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				 w <sub>P</sub> w      w <sub>L</sub> 20   40   60				
228.2																
0.0	COBBLES AND GRAVEL (150 mm)															
0.2	SAND with gravel Very Loose Brown		1	AS			228									
227.6	Brown															
0.6	Wet															
	SILTY SAND with organics Loose Greyish brown		2	SS	8		227									
	Wet															
			3	SS	6											
226.5																
1.7	SILTY SAND with gravel, occassional cobble Very Dense Greyish brown		4	SS	58		226									
	Wet															
225.6																
2.6	SILT with sand to SILTY SAND with gravel Very Dense Greyish brown		5	SS	55											
	Wet															
			6	SS	194		225									
224.5			7	SS	100/											
3.7	End of Borehole at 4.27 m Groundwater at Surface Borehole Cave at 0.1 m				51 mm											

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 15-14

1 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG  
 DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								20 40 60 80 100					
244.9													
0.0													
244.6													
0.3													

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 15-14

2 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG  
 DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W <sub>P</sub>	W		W <sub>L</sub>				
								○ UNCONFINED					+ FIELD VANE							
	Continued From Previous Page					● QUICK TRIAXIAL					× LAB VANE									
							20	40	60	80	100	20	40	60						

Continued Next Page

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



# RECORD OF BOREHOLE No 15-14

3 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG  
 DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
					○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE																
	Continued From Previous Page		16	SS	37			20	40	60	80	100		20	40	60					
							224														
							223														
222.3																					
22.6	<b>SAND</b> with silt Compact Brown Wet		17	SS	10		222														
							221														
							220														
							219														
218.4			18	SS	25														0	89	11 (SI+CL)
26.5	End of Borehole at 26.52 m Cave at 12.2 m upon completion																				

ONTMT4S 19-5308-95.GPJ 2012TEMPLATE(MTO).GDT 9/15/16

# RECORD OF BOREHOLE No 15-15

1 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 242.7 E 274 655.7 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 1931.01.16 - 2016.01.31 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
245.9								20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

ONTMT4S 19-5308-95.GPJ 2012TEMPLATE(MTO).GDT 9/15/16

# RECORD OF BOREHOLE No 15-15

3 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 242.7 E 274 655.7 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 1931.01.16 - 2016.01.31 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				W <sub>p</sub> W      W <sub>L</sub>				
								20   40   60   80   100				20   40   60				
	Continued From Previous Page		16	SS	15											
							225									
			17	SS	26											
							224									
223.6																
22.3	CLAY (CL) some sand layers Stiff Reddish Brown Moist						223									
			18	SS	14											
222.4															0   11   74   15	
23.5	DCPT driven to 24.99 m															
220.9																
25.0	End of Borehole at 24.99 m Cave at 5.35 m upon completion															

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

# RECORD OF BOREHOLE No 15-16

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 227.1 E 274 627.4 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.26 - 2016.01.26 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L							
235.2														
0.0														
0.1	TOPSOIL (50 mm)						235							
	SILTY SAND some gravel		1	SS	5									
234.6	Loose													
0.6	Brown													
234.3	Wet		2	SS	5									
0.9	ORGANICS													
	Soft													
	Black													
	Wet													
	SILTY SAND with gravel, trace clay, occasional cobbles		3	SS	64									
	Compact to very dense													
	Greyish brown													
233.1	Wet		4	SS	39		234							
2.1	SILT with sand													
	Very Dense													
232.6	Greyish brown		5	SS	114/		233							
2.6	Moist													
	End of Borehole at 2.64 m													
	Groundwater at 0.6 m													
	Borehole open to 1.1 m upon completion													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

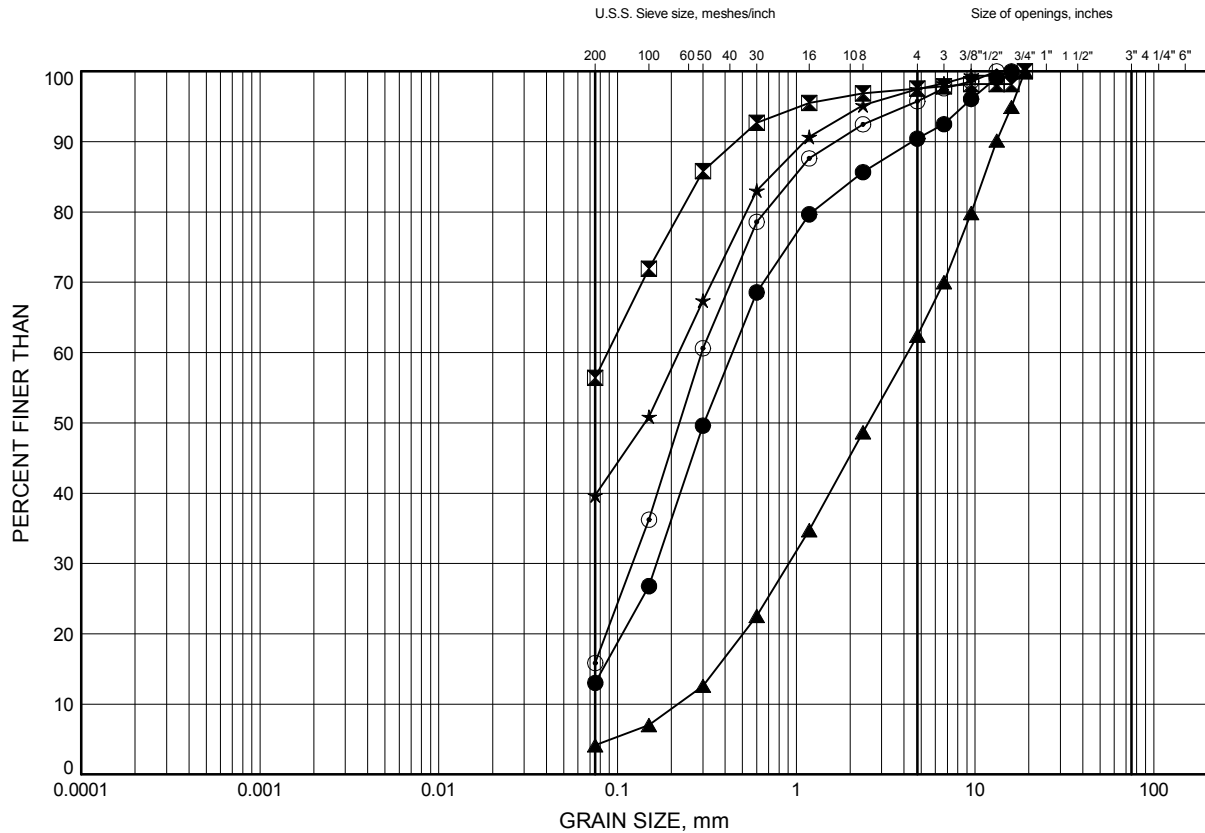
## **Appendix C**

### **Laboratory Test Results**

19-5308-95

## FIGURE 1

## Pavement and Embankment Fill



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-14	1.83	243.07
⊠	15-14	7.92	236.98
▲	15-15	0.46	245.44
★	15-15	2.59	243.31
⊙	15-15	4.88	241.02

Date May 2016

GWP# 545-00-00

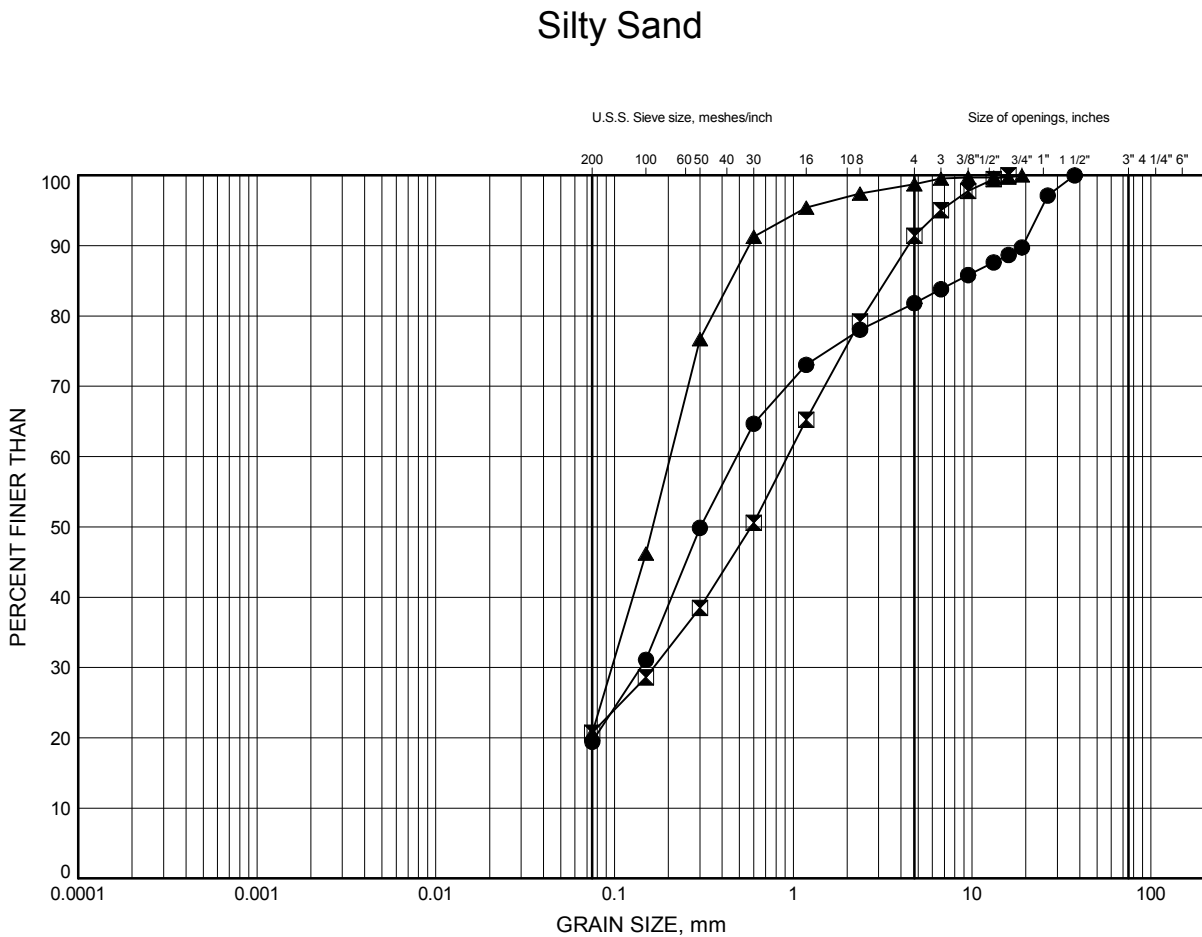


Prep'd JAG

Chkd. FJG

Culvert 22+113, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

**FIGURE 2**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-13	2.13	226.07
⊠	15-14	15.54	229.36
▲	15-15	14.02	231.88

Date May 2016  
 GWP# 545-00-00



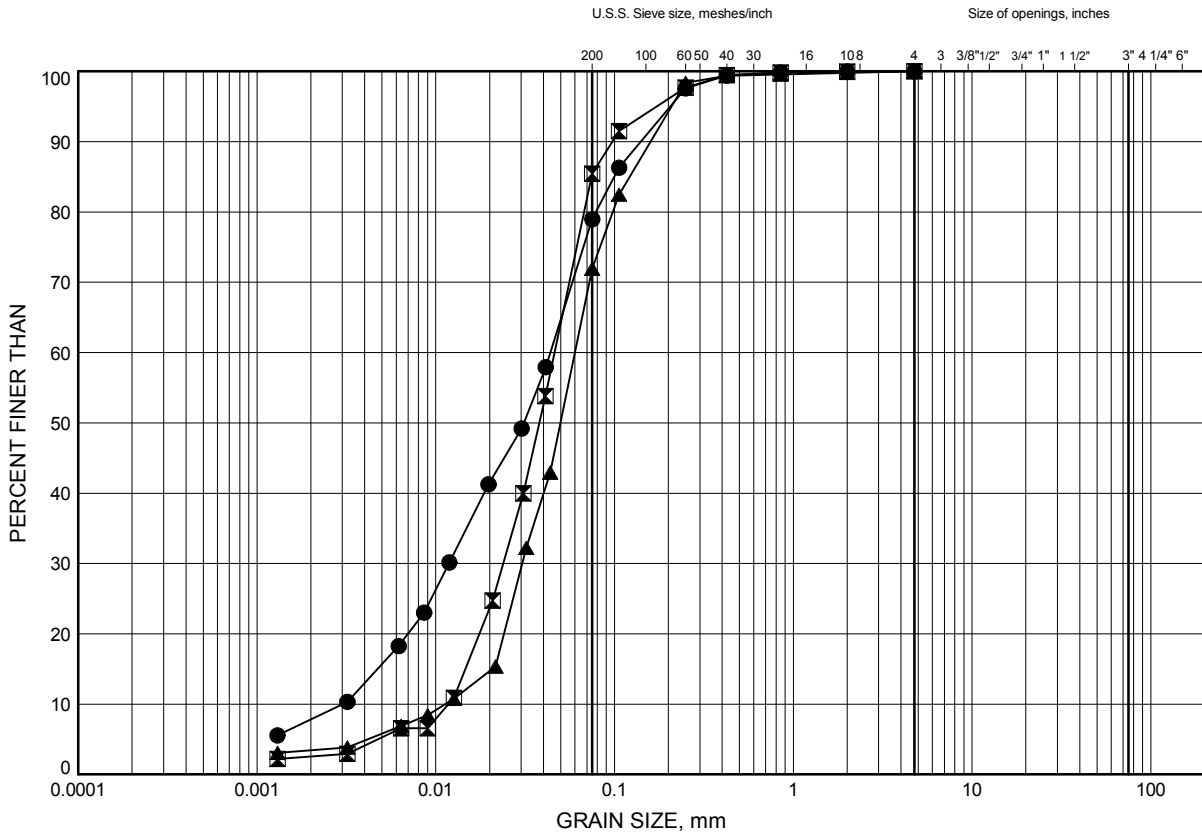
Prep'd JAG  
 Chkd. FJG



Culvert 22+113, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

FIGURE 3

**Silty Sand to Silt with Sand**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-14	18.59	226.31
⊠	15-15	17.07	228.83
▲	15-16	2.29	232.91

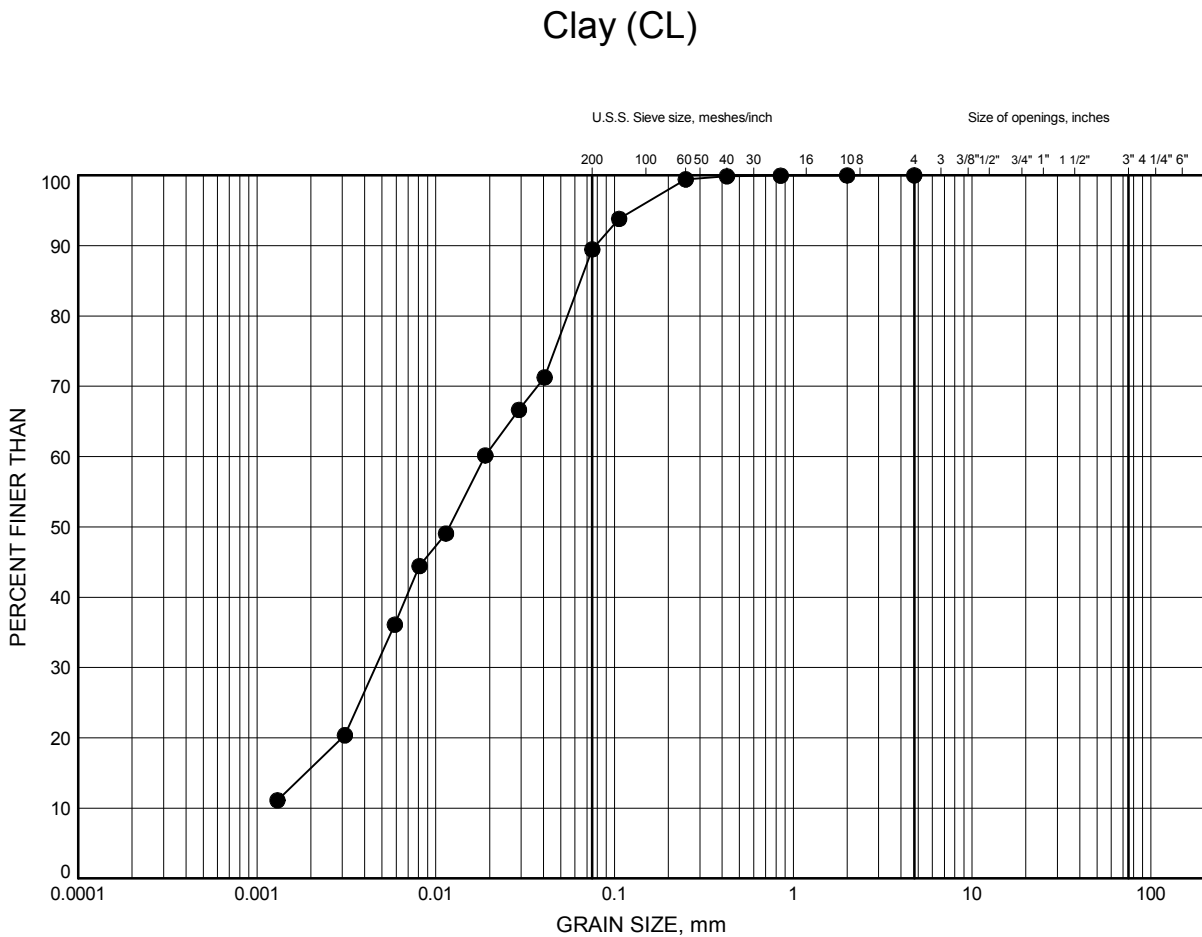
Date May 2016  
 GWP# 545-00-00



Prep'd JAG  
 Chkd. FJG

Culvert 22+113, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

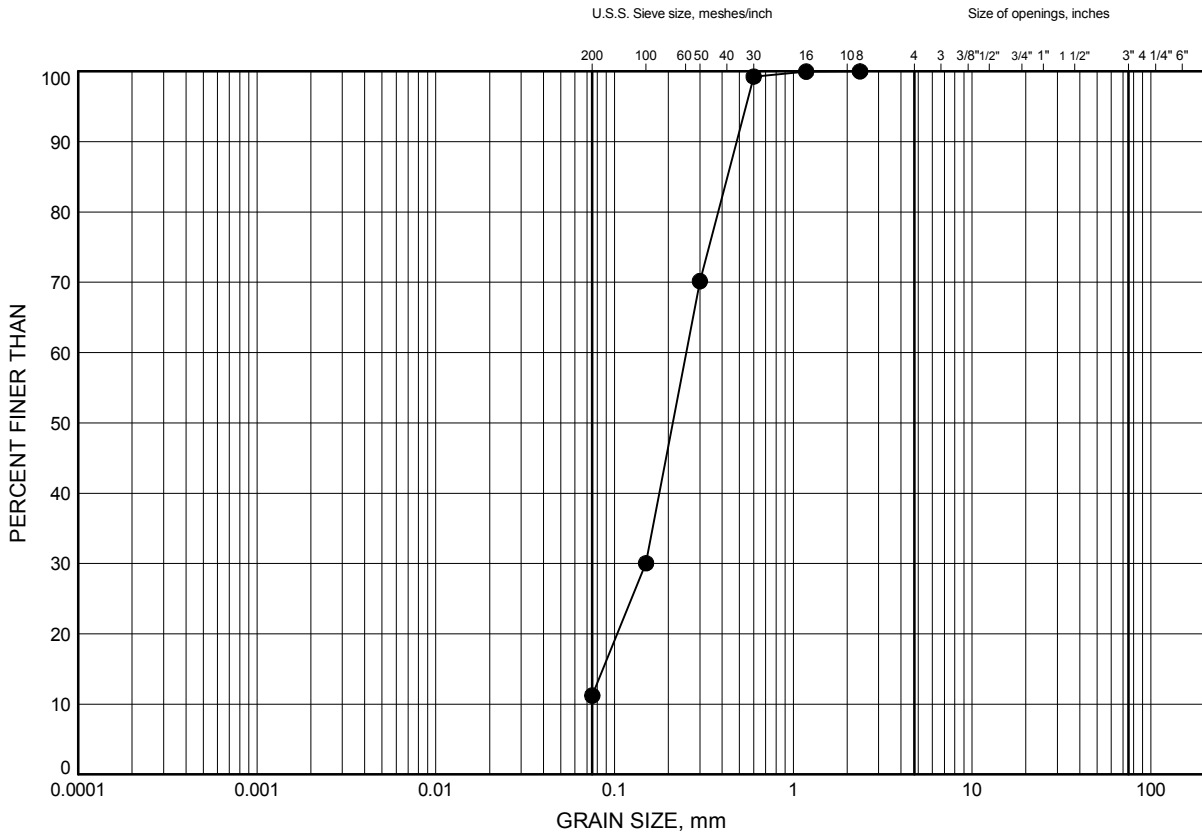
**FIGURE 4**



Culvert 22+113, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

FIGURE 5

**Sand with Silt**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-14	26.21	218.69

Date May 2016  
 GWP# 545-00-00

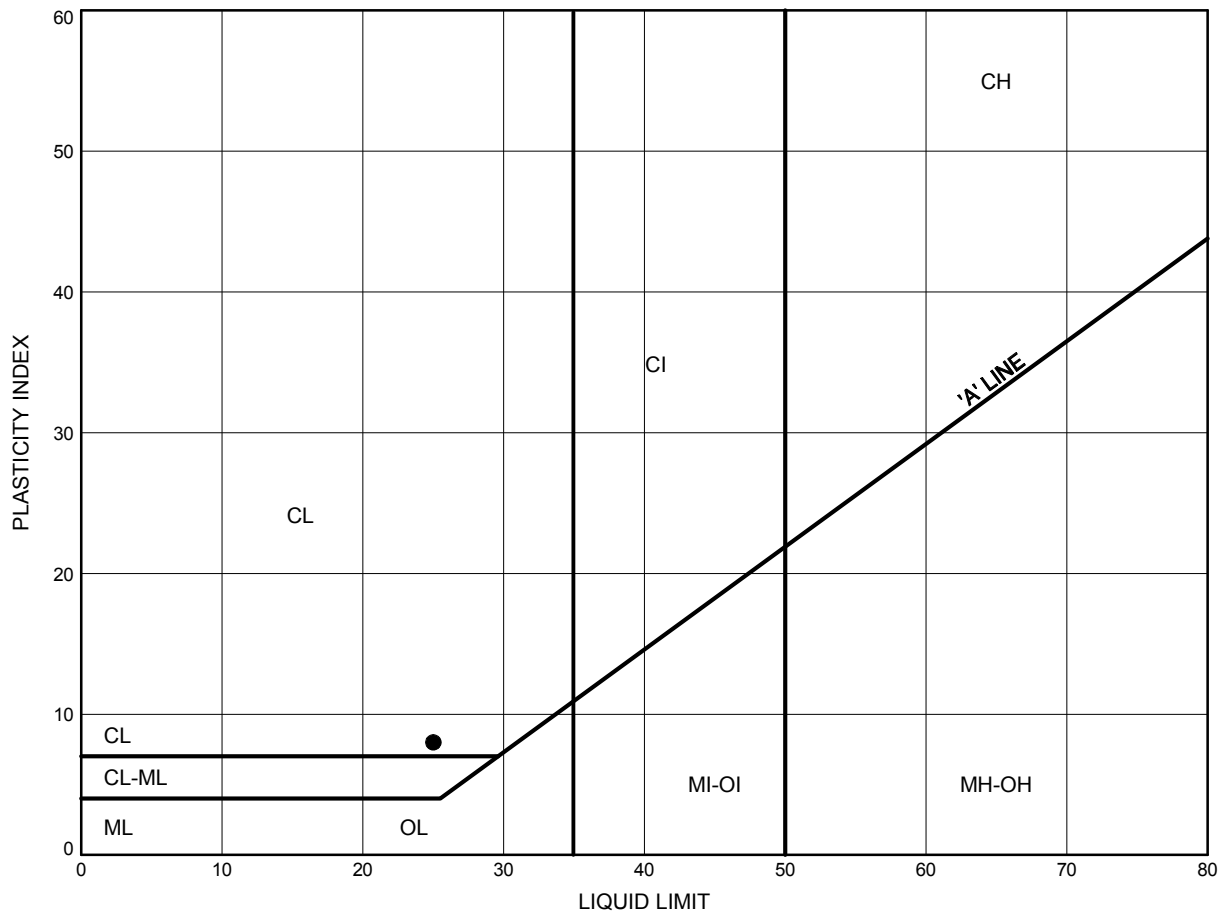


Prep'd JAG  
 Chkd. FJG

Culvert 22+113, Highway 17 Goulais River

# ATTERBERG LIMITS TEST RESULTS

FIGURE 6



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-15	23.16	222.74

Date May 2016  
GWP# 545-00-00



Prep'd JAG  
Chkd. FJG

## Certificate of Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B4S5  
Attn: Shawn Lapain

Client PO:  
Project: 19-5308-95  
Custody: 14041

Report Date: 16-Feb-2016  
Order Date: 11-Feb-2016

**Order #: 1607256**

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

**Paracel ID**

1607256-01

**Client ID**

BH15-15 SS10 (35-37')

Approved By:



Mark Foto, M.Sc.  
Lab Supervisor

## Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

Project Description: **19-5308-95****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Feb-16	12-Feb-16
Conductivity	MOE E3138 - probe @25 °C, water ext	12-Feb-16	12-Feb-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	12-Feb-16	12-Feb-16
Resistivity	EPA 120.1 - probe, water extraction	12-Feb-16	12-Feb-16
Solids, %	Gravimetric, calculation	12-Feb-16	12-Feb-16

**Certificate of Analysis**

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

**Project Description: 19-5308-95**

<b>Client ID:</b>	BH15-15 SS10 (35-37')	-	-	-
<b>Sample Date:</b>	31-Jan-16	-	-	-
<b>Sample ID:</b>	1607256-01	-	-	-
<b>MDL/Units</b>	Soil	-	-	-

**Physical Characteristics**

% Solids	0.1 % by Wt.	79.6	-	-	-
----------	--------------	------	---	---	---

**General Inorganics**

Conductivity	5 uS/cm	1920	-	-	-
pH	0.05 pH Units	7.35	-	-	-
Resistivity	0.10 Ohm.m	5.22	-	-	-

**Anions**

Chloride	5 ug/g dry	1200	-	-	-
Sulphate	5 ug/g dry	9	-	-	-

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

Project Description: **19-5308-95**

**Method Quality Control: Blank**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
<b>General Inorganics</b>									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						



Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

Project Description: **19-5308-95**

**Method Quality Control: Duplicate**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	17.6	5	ug/g dry	17.6			0.4	20	
Sulphate	14.4	5	ug/g dry	15.2			5.4	20	
<b>General Inorganics</b>									
Conductivity	690	5	uS/cm	673			2.6	6.2	
pH	7.77	0.05	pH Units	7.79			0.3	10	
<b>Physical Characteristics</b>									
% Solids	89.1	0.1	% by Wt.	90.8			1.9	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

Project Description: **19-5308-95**

**Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	11.7		mg/L	1.8	99.8	78-113			
Sulphate	11.8		mg/L	1.52	103	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 16-Feb-2016

Order Date: 11-Feb-2016

Project Description: **19-5308-95**

**Qualifier Notes:**

None

**Sample Data Revisions**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

## **Appendix D**

### **Selected Photographs**

19-5308-95

**Photo 1: West side – inlet end of culvert**



**Photo 2: East side – outlet end of culvert**



**Photo 3:** Looking south at culvert crossing.



**Photo 4:** Looking north towards culvert crossing.





**Photo 5:** Looking north at northbound slope.



**Photo 6:** Outlet of southbound ditch culvert



**Photo 7: Erosion above inlet, indicating separation of culvert section**





## **Appendix E**

**Table E-1: Comparison of Construction Methodology Alternatives  
NSSPs**

19-5308-95

Table E-1: Comparison of Construction Methodology Alternatives

Option	3. Open Cut, staged with roadway protection	5. Open cut, staged with temporary platform widening (roadway protection required)	6. Trenchless installation
Advantages	Surface and groundwater controlled by sump & pump techniques	Surface and groundwater controlled by sump & pump techniques	Avoids deep excavation through highway  Two lanes of traffic maintained throughout
Disadvantages	Depth of excavation greater than 14 m.  Very large excavation quantities  Roadway protection will require bracing or anchors due to depth of excavation	Depth of excavation greater than 14 m.  Very large excavation quantities  Large fill quantities to widen platform  Roadway protection will require bracing or anchors due to depth of excavation  May require culvert extension	Requires construction of entry and exit pits and access to toe of slope.  Must maintain surface and groundwater control
Relative Cost	Moderate	Moderate	High
Risks & Consequences	Risk if oversized obstructions encountered	Review of impact to horizontal curve and profile may preclude.  Risk if oversized obstructions encountered  Property may be needed.	Very high risk if oversized obstructions are encountered.  Risk if groundwater encountered
Summary	Feasible	Feasible	Preferred

### **Suggested NSSP Wording**

- Suggested Text for NSSP on “Obstructions”

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

- Suggested Text for NSSP on “Groundwater and Dewatering”

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

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