



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT, 11+730 FENWICK  
HIGHWAY 17 NEAR GOULAIS RIVER  
SAULT STE MARIE AREA  
G.W.P. 545-00-00**

**GEOCRES Number: 41K-100**

**Report**

**to**

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19-5308-95



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**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 was available for the subject culvert.

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 and 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 3.8 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Fenwick. A 750 mm diameter by 43.0 m long corrugated steel pipe culvert (CSP) is present at the site and covered with approximately 5 m of fill. The culvert conveys storm water under Highway 17 from west to east. The invert elevation is 255.4 m at the east end or left and 258.3 m at the west end or right.

The grade of the existing Highway 17 in the vicinity of the culvert is at 262.8 m geodetic. The profile slopes down to the south. The culvert is located on a curve within a fill section. The embankment is constructed with side slopes approximately 3 horizontal to 1 vertical (3H:1V) and 2 horizontal to 1 vertical (2H:1V) corresponding to the west and east slopes, respectively.

The embankment fill height is approximately 4.5 m at the west side and approximately 7.4 m at the east side.

The road includes a single 3.5 m wide lane in each direction, a 3.0 m wide gravel shoulder on the west side and a 2.0 m wide paved shoulder on the east. A guide rail is present on the east side. The site is located in a rural area with forests, swamps, and creeks. The local topography 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 of 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 18 and January 19, 2016. The program consisted of drilling and sampling four boreholes (numbered 15-29, 15-30, 15-31, and 15-32) to depths ranging from 11.0 to 18.9 m. Of these boreholes, one was located near the culvert inlet (15-32), one located near the culvert outlet (15-29), and two (15-30 and 15-31) were located through the embankment on opposite sides of the road near the culvert.

Prior to the start of drilling, utility locates were obtained. Buried utilities were noted in close proximity to both the inlet and outlet at this site, borehole locations were established in the field accordingly. 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 and asphalt patch where required.

#### **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.

#### **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 sandy silt embankment fill overlying a silt layer underlain by a silty sand deposit. Bedrock was not encountered in any of the four boreholes. More detailed descriptions of the individual strata are presented below.

##### **5.2 Granular Fill**

Boreholes 15-30 and 15-31 were drilled through the shoulders of the roadway; paved shoulders were noted in the northbound direction with an asphalt thickness of 60 mm.

Sand with gravel fill extended to a depth of 0.8 m to 1.5 m below the road surface. A lower layer described as silty sand with gravel fill extended to a depth of 1.5 m to 2.3 m below the road surface. The base of the granular fill was encountered at elevations ranging from 260.7 to 261.1 m.

The moisture content of the upper granular fill ranged from 4% to 7%, while the lower granular fill was 9% to 13%. Gradation testing on one sample of the granular fill indicated 21% gravel, 68% sand and 11% fines (Figure 1 Appendix C). The ground was frozen at the time of the field investigation thus the relative density of the granular fill could not be determined reliably.

### 5.3 Embankment Fill

Embankment fill was encountered below the granular fill in Boreholes 15-30 and 15-31. The thickness of the embankment fill ranged from 2.4 to 3.1 m. A 1.2 m layer of silty sand fill was also encountered at the surface of Borehole 15-29. The base of the embankment fill was encountered at elevations ranging from 255.0 to 258.4 m.

The embankment fill was observed to be silty sand to sandy silt.

In Boreholes 15-30 and 15-31, the SPT N-values for the embankment fill ranged from 11 to 22 blows per 0.3 m penetration, indicating a compact state. The water content of the fill samples ranged between 12% and 16%. The SPT N-values for the fill found at the outlet ranged from 3 to 6 blows per 0.3 m penetration, indicating a loose state. The water content of the recovered outlet fill samples ranged between 16% and 23%. The colour of the embankment fill is brown.

The results of grain size analyses conducted on three samples of the fill are presented on Fig. No 2 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	5 to 10
Sand	34 to 53
Silt	37 to 53
Clay	5 to 8

### 5.4 Topsoil

Topsoil, 25 to 75 mm in thickness was encountered at the inlet and outlet boreholes (15-29 and 15-32). The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating quantities or quality.

### 5.5 Silt to Sandy Silt

A native soil deposit ranging from silty trace sand to sandy silt was encountered in all boreholes. This soil was found below topsoil in 15-32 and below the embankment fill in 15-29, 15-30 and 15-31. This layer was observed to range from 0.6 m to 1.7 m in thickness with the base elevation ranging from 254.4m to 257.9 m.

The SPT N-value for this deposit was 5 to 22 blows per 0.3 m penetration, indicating a loose to compact state. The water contents of the recovered samples ranged between 19% and 36%. The colour of this deposit is brown. This layer in Borehole 15-29 contained some organics which accounted for the low SPT N-value of 5 blows per 0.3 m penetration and the high water content of 36%.

The results of grain size analysis conducted on four samples of the sandy silt are presented on Fig. No 3 in Appendix C. The results are summarized in the following table.

<b>Soil Particles</b>	<b>%</b>
Gravel	0 to 5
Sand	5 to 47
Silt	49 to 93
Clay	1 to 4

Atterberg limit testing was carried out on two samples of the sandy silt. One sample was found to be non-plastic (Borehole 15-32 SS2), and one sample (Borehole 15-29 SS3) was classified as sandy silt (ML/OL). The results are presented on Fig. No 5 in Appendix C and summarized in the table below.

<b>Test</b>	<b>%</b>
<b>Plastic Limit</b>	NP and 28
<b>Liquid Limit</b>	NA and 33
<b>Plasticity Index</b>	NA and 5

## 5.6 Silty Sand

A native soil deposit typically ranging from silty sand to sandy silt was encountered in all boreholes. This soil was found just below the silt layer. All four boreholes were terminated within this deposit at elevations ranging from 244.1 m to 247.6 m.

The SPT N-value for this deposit was 11 to 73 blows per 0.3 m penetration, indicating a compact to very dense state. The water contents of the recovered samples ranged between 2% and 25%. The colour of this deposit is brown.

Grain size analyses conducted on nine samples of the soil are presented on Fig. No 4 and Fig. No 5 in Appendix C. These results are summarized in the following table.

<b>Soil Particles</b>	<b>%</b>
Gravel	0 to 1
Sand	36 to 93
Silt and Clay	7 to 64

## **5.7 Groundwater Conditions**

Groundwater was not observed in any of the boreholes during drilling and all four boreholes were dry upon completion of drilling. However, in Borehole 15-29 which was left open overnight following the completion of drilling the water level in was measured at elevation 255.9 m. At the time of investigation surface water was not present in the inlet of the culvert or associated ditches. Surface water at the outlet was observed at elevation 256.3 m on January 19, 2016.

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 Stantec (Ottawa) 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.



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**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 carrying drainage under Highway 17 near Goulais River, Ontario, approximately 3.8 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Fenwick.

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 750 mm diameter by 43.0 m long corrugated steel pipe culvert (CSP) is present at the site. The flow in the culvert is from west to east. The site is located on a horizontal curve with the profile sloping downward to the south. The existing roadway cross-section is approximately 13.0 m from rounding to rounding with three cable guide rail present on both sides of the highway.

The borehole information indicates that the base of the embankment fill ranges from 255.0 m to 258.4 m. The fill was observed to consist of compact sand with silt and gravel to sandy silt some gravel. The native material observed immediately beneath the fill consisted of silt some sand. It was typically compact. Frost depth at this site is 2.0 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 feasible but not geotechnically preferred due to the relatively deep excavation that may be required for footing construction and possible dewatering

#### Concrete Box (Closed) Culvert

Concrete box (closed) culverts are considered feasible at this site.

#### Recommended Culvert

Given the fact that the existing culvert consists of a 750 mm diameter CSP, replacement with a single pipe of similar diameter is technically feasible. 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 1000 mm diameter by 40 m long circular pipe offset approximately 3 m to the south of the existing culvert alignment. The planned invert elevations are 258.06 m and 256.40 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.
4. Open cut with a single lane, traffic lights, and temporary grade lowering and roadway protection.
5. Open cut with a single lane, traffic lights, and temporary grade lowering with minor driving lane widening to the west: roadway protection will be required.
6. Open cut with a single lane, traffic lights, and temporary platform widening.
7. Trenchless methods.

Options 1 and 2 are not considered feasible at this site while Options 4 and 6 include temporary modifications to vertical and horizontal alignments. Given the existing curve and sloping profile, it is anticipated that these temporary modifications will be very difficult. Table E-1 in Appendix E provides a comparison of Options 3, 5 and 7.

Based on our understanding of the project and the existing conditions at the site Option 7 is considered the preferred option. It would eliminate an excavation in excess of 8 m depth and allow the culvert to be replaced with minimal impact to traffic.

Should circumstances arise which preclude trenchless methods, the culvert replacement should be facilitated by open cut with a single lane of traffic and roadway protection.

### **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 oversized obstructions are encountered.

Microtunnelling is 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 was observed in one borehole during the investigation. 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 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 embankments are sloped at approximately 2H:1V or flatter and exhibit 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**

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.

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

A sample of the native sand with silt (Borehole 15-32, SS3) 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 included in Appendix C and summarized in the following table.

### Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
15-32	SS3	1.5	5.3	8780	61	11

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 slightly lower compared to what is considered the normal range for soil pH of 5.5 to 9.0. 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 or native soils may contain cobbles or 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  
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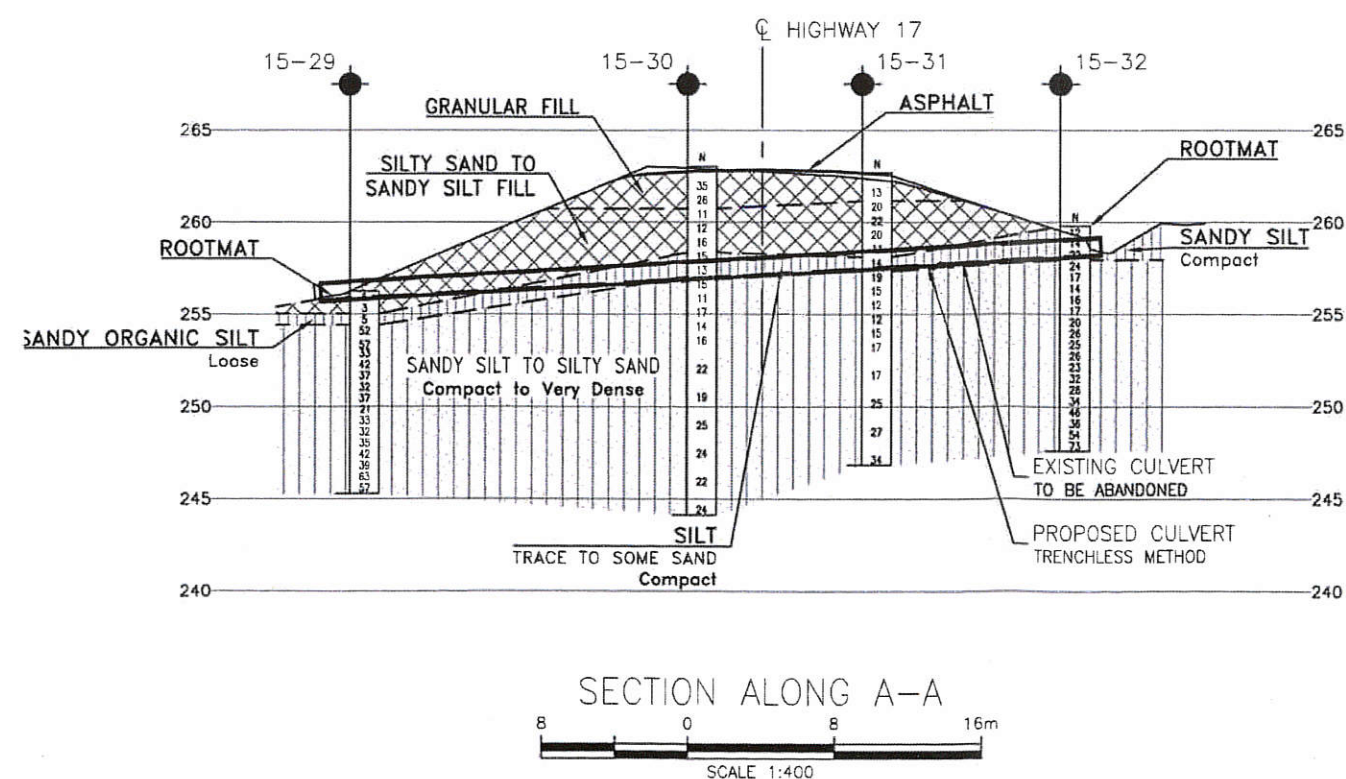
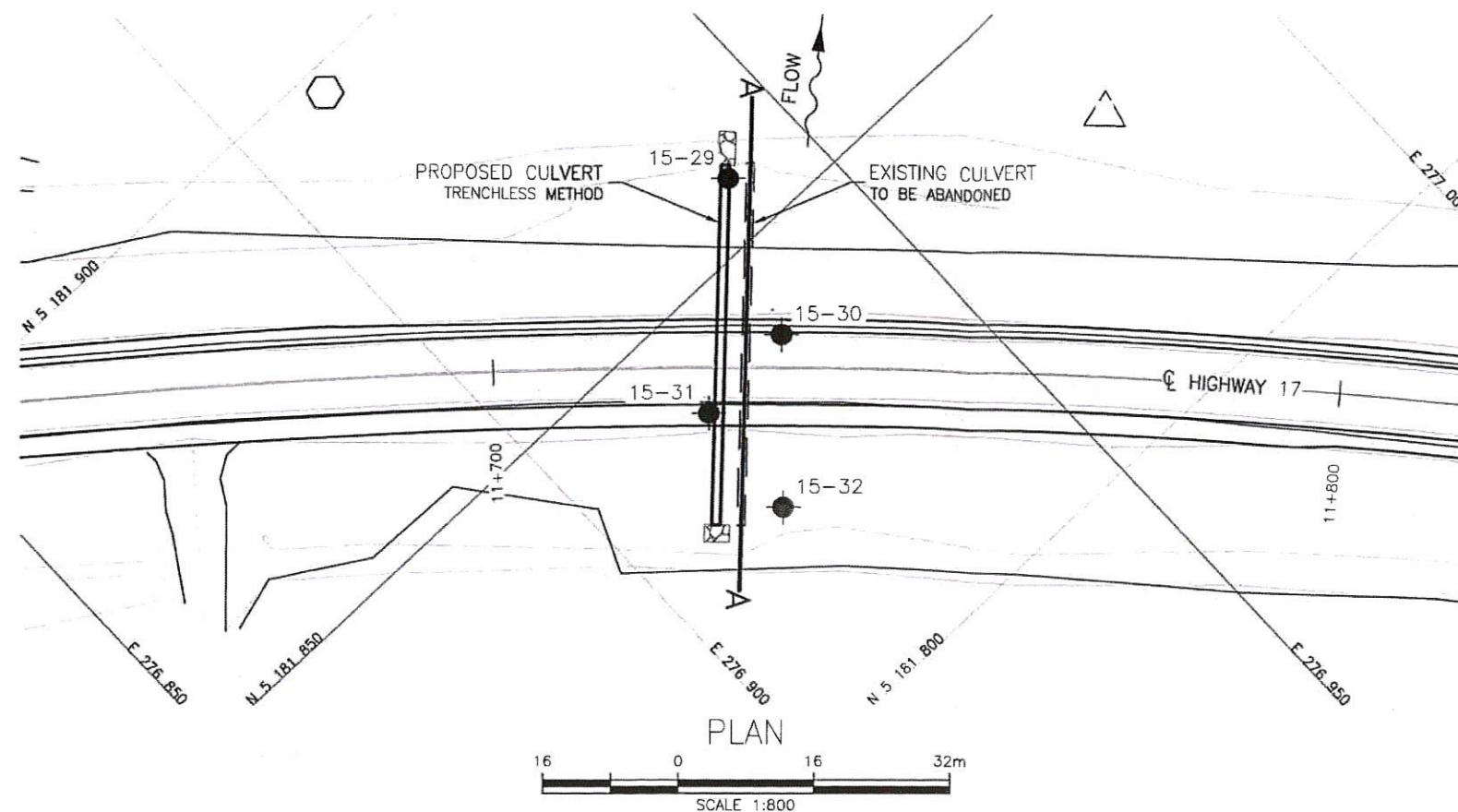


P.K. Chatterji, P.Eng.  
Principal, Designated MTO Contact

## **Appendix A**

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

19-5308-95



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

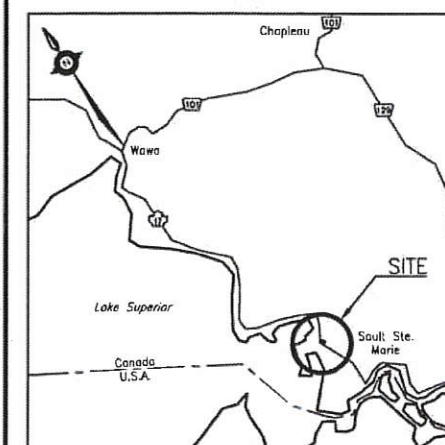


CONT No  
WP No






HIGHWAY 17  
11+730  
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
	Water Level
	Head Artesian Water
	Piezometer
90°	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
15-29	256.2	5 181 857.1	276 939.6
15-30	263.0	5 181 839.3	276 931.5
15-31	262.7	5 181 838.4	276 916.9
15-32	259.8	5 181 824.3	276 917.7

-NOTES-

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

GEOCRES No. 41K-100

REVISIONS									
	DATE	BY							
	DESIGN	JG	CHK	-					
	DRAWN	MFA	CHK	JG	SITE	LOAD		DATE	SEP 2016
						STRUCT	INWG		

**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.

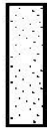


### STRATA PLOT:

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 15-29

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 857.1 E 276 939.6 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.19 - 2016.01.19 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									
						○ UNCONFINED + FIELD VANE				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT							
						● QUICK TRIAXIAL × LAB VANE				W P W W L							
						20 40 60 80 100				WATER CONTENT (%)							
256.2																	
0.0	ROOTMAT (25 mm)																
	SILTY SAND trace gravel		1	SS	6		256										
	Loose to very loose																
	Brown																
	Moist to Wet																
	FILL		2	SS	3												
255.0																	
1.2	SANDY ORGANIC SILT						255										
	Loose		3	SS	5												
	Brown																
	Wet																
254.4																	
1.8	SILTY SAND to SANDY SILT																
	Dense to Very Dense		4	SS	52		254										
	Brown																
	Moist																
			5	SS	57												
			6	SS	33		253										
			7	SS	42												
			8	SS	37		252										
			9	SS	32		251										
			10	SS	37												
			11	SS	21		250										
			12	SS	33												
			13	SS	32		249										
			14	SS	35		248										
			15	SS	42												
			16	SS	39		247										

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 15-29

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 857.1 E 276 939.6 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.19 - 2016.01.19 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	W <sub>p</sub>	W	W <sub>L</sub>			
	Continued From Previous Page		17	SS	63												
			18	SS	57												
245.3																	
11.0	End of Borehole at 11 m Borehole Open Upon Completion Borehole Dry Upon Completion on 2016.01.19 Water in Open Borehole at 0.3 m on 2016.01.20																

# RECORD OF BOREHOLE No 15-30

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 839.3 E 276 931.5 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.19 - 2016.01.19 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				w <sub>P</sub> w                      w <sub>L</sub>								
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE												
263.0																				
0.0																				
0.1																				

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 15-30

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 839.3 E 276 931.5 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.19 - 2016.01.19 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
	Continued From Previous Page							20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>				
			14	SS	22		252												
							251												
			15	SS	19		250												
			16	SS	25		249												
							248												
			17	SS	24		247												
			18	SS	22		246												
							245												
			19	SS	24														
244.1																			
18.9	End of Borehole at 18.9 m Borehole Open Upon Completion Borehole Dry Upon Completion																		

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

# RECORD OF BOREHOLE No 15-31

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 838.4 E 276 918.9 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.18 - 2016.01.18 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)								
								○ UNCONFINED      + FIELD VANE					w P      w      w L								
								● QUICK TRIAXIAL      × LAB VANE													
							20	40	60	80	100		20	40	60		GR	SA	SI	CL	
262.7																					
0.0	SAND with gravel FILL		1	AS																	
261.9							262														
0.8	SILTY SAND with gravel Compact Brown Moist FILL		2	SS	13																
261.1																					
1.5	SANDY SILT trace gravel Compact Brown Moist FILL		3	SS	20		261											5	34	53	8
			4	SS	22		260														
			5	SS	20		259														
258.9																					
3.8	SILTY SAND Compact Brown Moist FILL		6	SS	11		258														
258.1																					
4.6	SILT trace sand Compact Brown Wet		7	SS	14		257											0	5	93	2
257.3																					
5.3	SILTY SAND to SAND with silt Compact to Dense Brown Wet to Dry		8	SS	19		256														
			9	SS	15		255											0	53	47	(SI+CL)
			10	SS	12		254														
			11	SS	12		253														
			12	SS	15																
			13	SS	17																

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 15-31

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 838.4 E 276 918.9 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.18 - 2016.01.18 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			20    40    60    80    100	W <sub>P</sub> W                      W <sub>L</sub>	WATER CONTENT (%)						
								SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE								
	Continued From Previous Page							20    40    60    80    100							GR   SA   SI   CL	
			14	SS	17		252					○				
							251									
			15	SS	25		250					○				
			16	SS	27		249					○			0   93       7 (SI+CL)	
							248									
			17	SS	34		247					○				
246.8																
15.8	End of Borehole at 15.85 m Borehole Open Upon Completion Borehole Dry Upon Completion															

0 93 7  
(SI+CL)

# RECORD OF BOREHOLE No 15-32

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 824.3 E 276 917.7 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.18 - 2016.01.18 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							WATER CONTENT (%)
								<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>							
259.8															
0.0	ROOTMAT (75 mm)  SANDY SILT Compact Brown Moist		1	SS	12		259								0 47 49 4
0.1			2	SS	14										
			3	SS	22										
257.9	SILTY SAND Compact to Very Dense Brown Moist		4	SS	24		258								0 73 27 (SI+CL)
1.8			5	SS	17		257								
			6	SS	14										
			7	SS	16		256								
			8	SS	17										
			9	SS	20		255								
			10	SS	26		254								
			11	SS	25										
			12	SS	26		253								
			13	SS	23		252								
			14	SS	32										
			15	SS	28		251								
			16	SS	34										
						250									

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 15-32

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 11+730, Highway 17 Goulais River N 5 181 824.3 E 276 917.7 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML  
 DATUM Geodetic DATE 2016.01.18 - 2016.01.18 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										
	Continued From Previous Page		17	SS	46													
			18	SS	36		249											
			19	SS	54													
			20	SS	73		248											
247.6																		
12.2	End of Borehole at 12.19 m Borehole Open Upon Completion Borehole Dry Upon Completion																	

## **Appendix C**

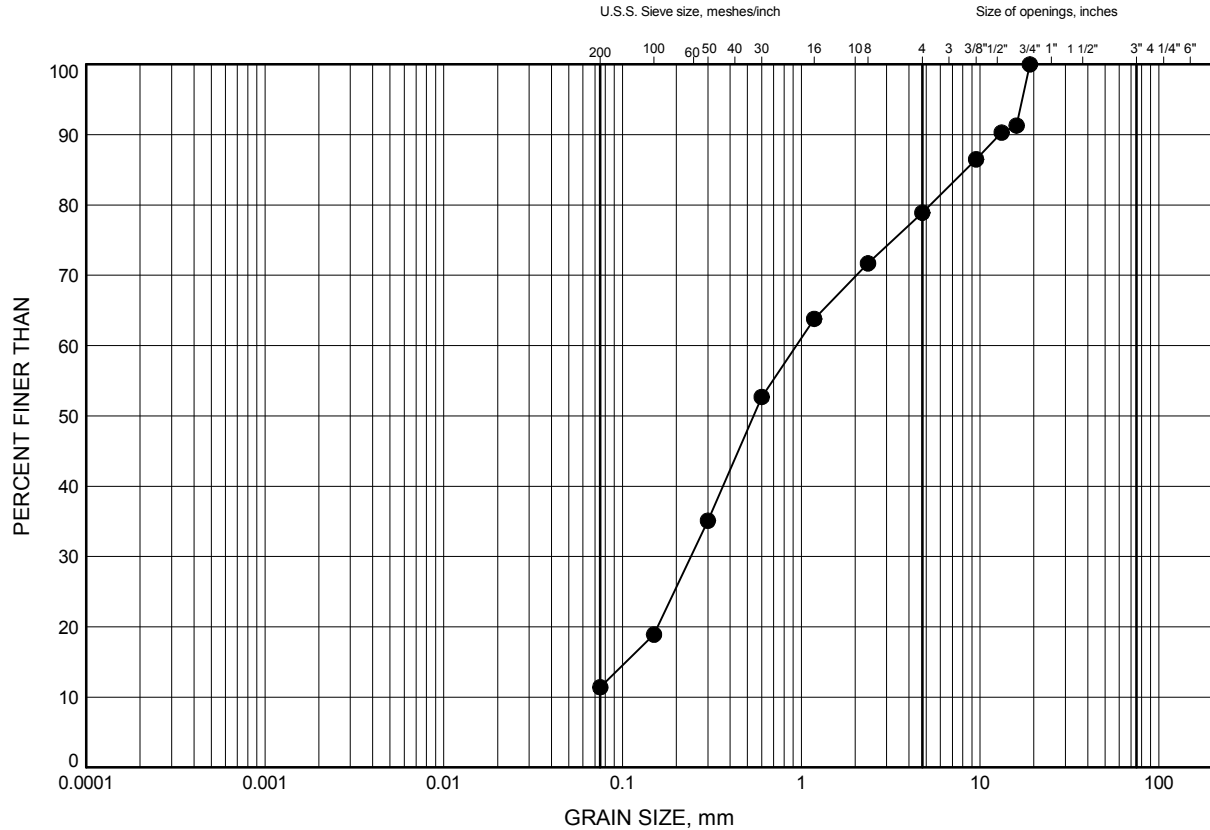
### **Laboratory Test Results**

19-5308-95

Culvert 11+730, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

FIGURE 1

**Granular Fill**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-30	1.83	261.19

Date . March 2016.....  
 GWP# . 545-00-00.....

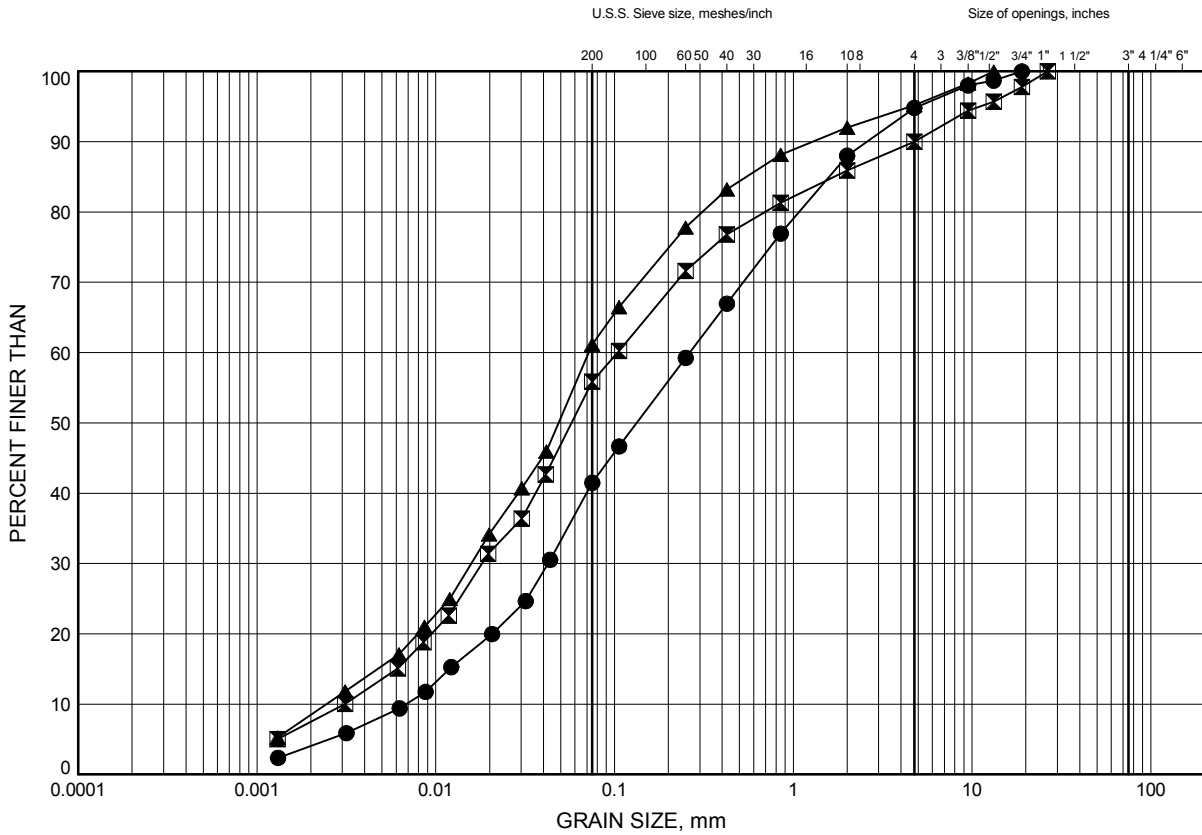


Prep'd .....JAG.....  
 Chkd. ....FJG.....

Culvert 11+730, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

**FIGURE 2**

**Embankment Fill**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-29	0.91	255.33
⊠	15-30	3.35	259.67
▲	15-31	1.83	260.84

Date March 2016  
 GWP# 545-00-00

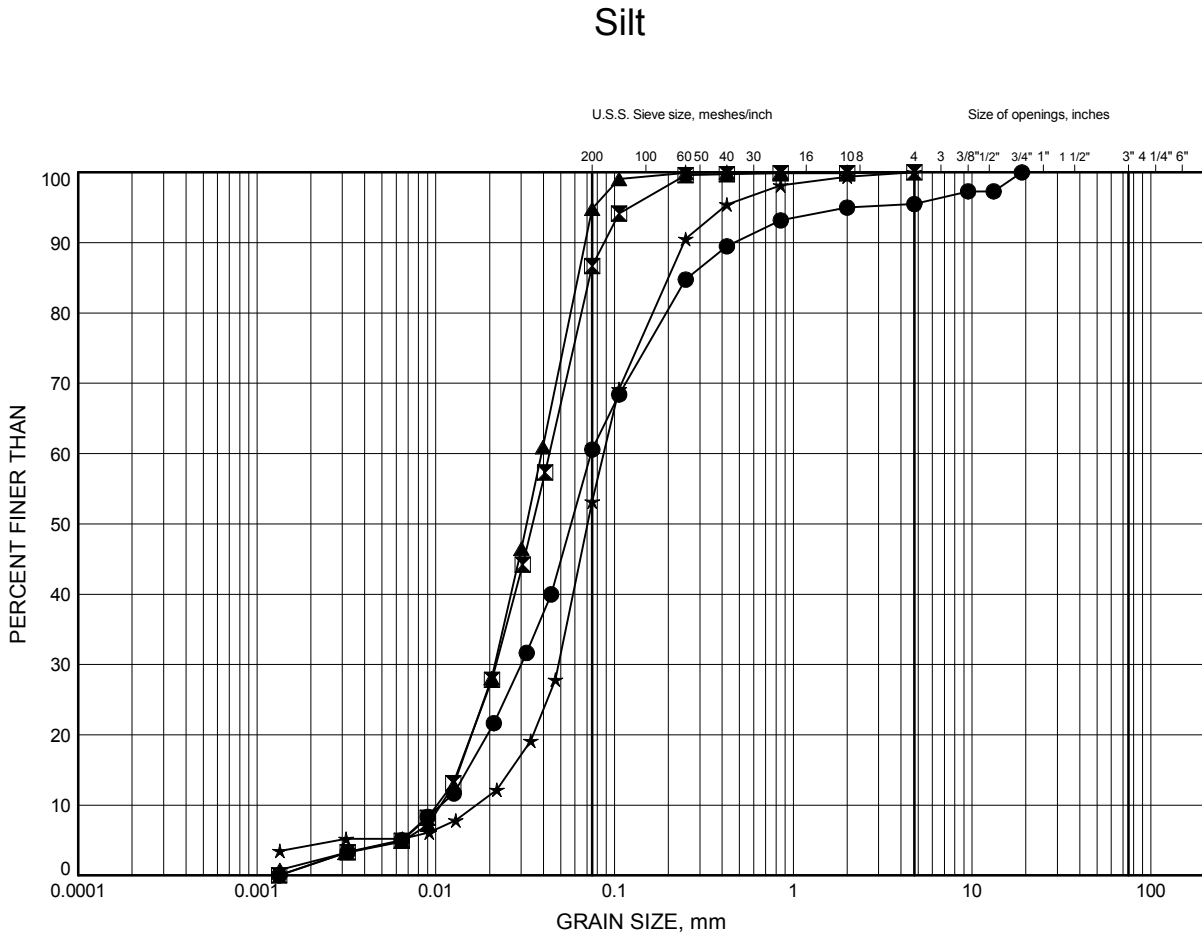


Prep'd JAG  
 Chkd. FJG

# Culvert 11+730, Highway 17 Goulais River

## GRAIN SIZE DISTRIBUTION

FIGURE 3



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-29	1.52	254.72
⊠	15-30	4.88	258.14
▲	15-31	4.88	257.79
★	15-32	0.91	258.86

Date March 2016  
GWP# 545-00-00

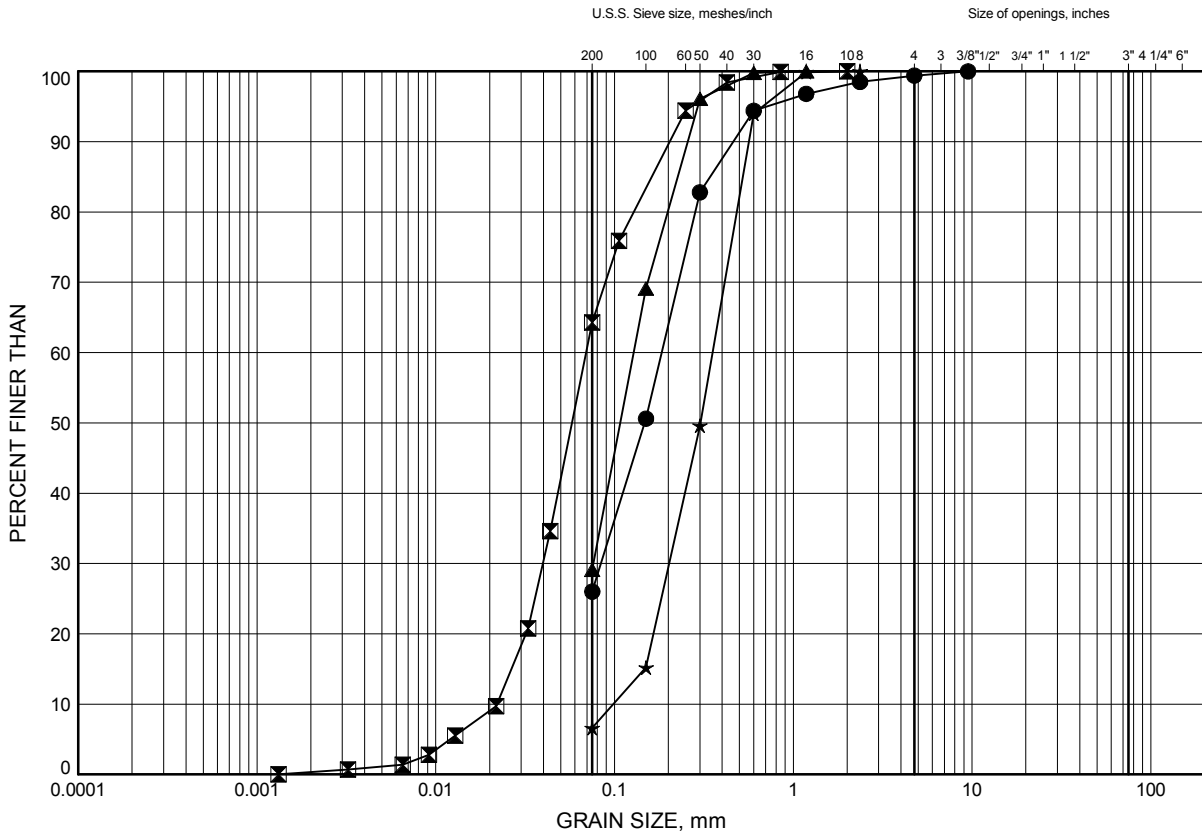


Prep'd JAG  
Chkd. FJG

Culvert 11+730, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

FIGURE 4

Silty Sand, Sandy Silt, and Sand with Silt



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-29	3.35	252.89
⊠	15-29	7.62	248.62
▲	15-30	7.92	255.10
★	15-30	15.54	247.48

Date March 2016  
 GWP# 545-00-00

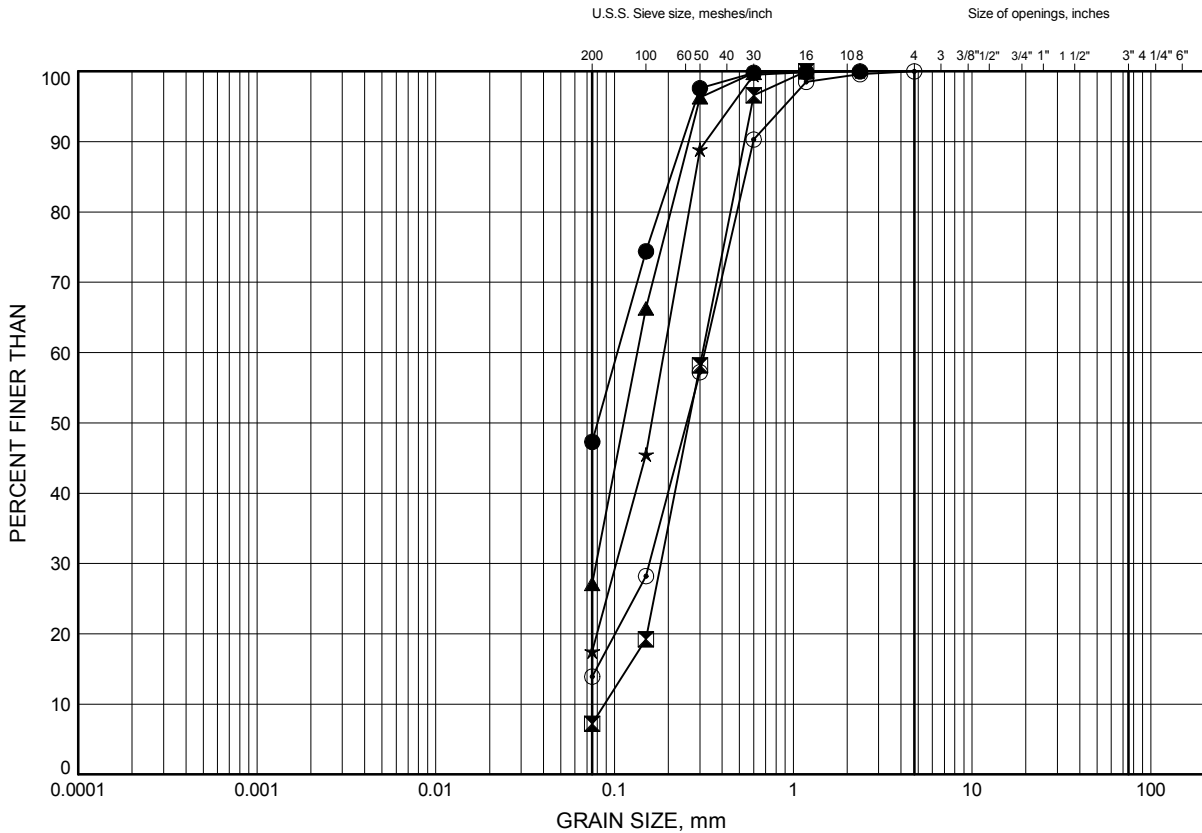


Prep'd JAG  
 Chkd. FJG

Culvert 11+730, Highway 17 Goulais River  
**GRAIN SIZE DISTRIBUTION**

FIGURE 5

Silty Sand, and Sand with Silt



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-31	6.40	256.27
⊠	15-31	14.02	248.65
▲	15-32	3.96	255.81
★	15-32	6.40	253.37
⊙	15-32	11.28	248.50

Date March 2016  
 GWP# 545-00-00

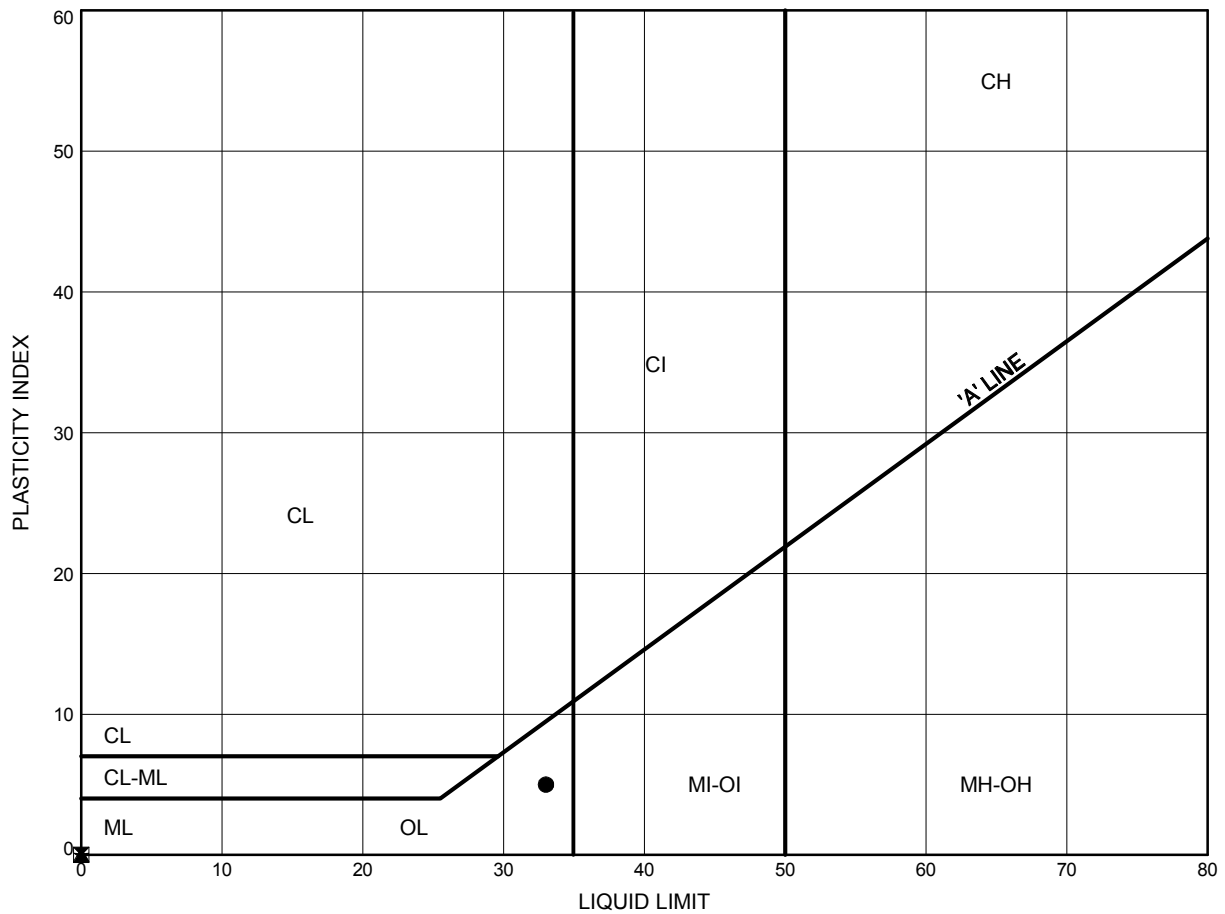


Prep'd JAG  
 Chkd. FJG

Culvert 11+730, Highway 17 Goulais River

# ATTERBERG LIMITS TEST RESULTS

FIGURE 6



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-29	1.52	254.72
⊠	15-30	3.35	259.67
▲	15-31	1.83	260.84
★	15-32	0.91	258.86

Date March 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: 27346

Report Date: 4-Feb-2016  
Order Date: 29-Jan-2016

**Order #: 1605367**

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

Paracel ID	Client ID
1605367-01	BH15-23 SS11 (25'-27')
1605367-02	BH15-3 SS8 (20'-22')
1605367-03	BH15-32 SS3 (4'-6')
1605367-04	BH15-33 GS3 (2.5'-3.5')

Approved By:



Dale Robertson, BSc  
Laboratory Director

## Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

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

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	3-Feb-16	3-Feb-16
Conductivity	MOE E3138 - probe @25 °C, water ext	2-Feb-16	3-Feb-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	1-Feb-16	1-Feb-16
Resistivity	EPA 120.1 - probe, water extraction	2-Feb-16	2-Feb-16
Solids, %	Gravimetric, calculation	30-Jan-16	30-Jan-16

**Certificate of Analysis**

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

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

<b>Client ID:</b>	BH15-23 SS11 (25'-27')	BH15-3 SS8 (20'-22')	BH15-32 SS3 (4'-6')	BH15-33 GS3 (2.5'-3.5')
<b>Sample Date:</b>	07-Jan-16	18-Jan-16	18-Jan-16	21-Jan-16
<b>Sample ID:</b>	1605367-01	1605367-02	1605367-03	1605367-04
<b>MDL/Units</b>	Soil	Soil	Soil	Soil

**Physical Characteristics**

% Solids	0.1 % by Wt.	85.0	84.7	79.0	85.3
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**General Inorganics**

Conductivity	5 uS/cm	1400	138	114	108
pH	0.05 pH Units	6.14	6.11	5.34	5.70
Resistivity	0.10 Ohm.m	7.17	72.4	87.8	92.3

**Anions**

Chloride	5 ug/g dry	747	73	61	14
Sulphate	5 ug/g dry	22	11	11	17

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-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: 04-Feb-2016

Order Date: 29-Jan-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	8.7	5	ug/g dry	8.4			2.5	20	
Sulphate	298	5	ug/g dry	335			11.5	20	
<b>General Inorganics</b>									
Conductivity	749	5	uS/cm	758			1.3	6.2	
pH	7.76	0.05	pH Units	7.79			0.4	10	
<b>Physical Characteristics</b>									
% Solids	77.8	0.1	% by Wt.	78.6			1.0	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-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	10.3		mg/L	0.8	94.3	78-113			
Sulphate	41.8		mg/L	33.5	83.3	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-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 – end of culvert**



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



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



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



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



## **APPENDIX E**

**Table E-1: Comparison of Construction Methodology Alternatives  
NSSP's**

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 grade lowering and lane widening (roadway protection required)	7. Trenchless installation horizontal directional drilling or microtunnelling
Advantages	Simple Construction  Surface and groundwater controlled by sump & pump techniques	Simple construction  Surface and groundwater controlled by sump & pump techniques	Avoids deep excavation through highway  Two lanes of traffic maintained throughout
Disadvantages		Multiple stages	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	Very high risk if oversized obstructions are encountered.  Risk if groundwater encountered
Summary	Feasible	May not be 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. "