



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT, 23+049 HAVILLAND
HIGHWAY 17 NEAR GOULAIS RIVER
SAULT STE MARIE AREA
G.W.P. 545-00-00**

GEOCRES Number: 41K-99

Report

to

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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 borehole location plan, stratigraphic profiles, 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 6.3 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Havilland. A 1.05 m diameter by 50.6 m long corrugated steel pipe culvert (CSP) is present at the site and covered with approximately 10 m of fill. The culvert conveys water under Highway 17 from west to east. The invert elevation is 253.2 m at the east end and 255.8 m at the west end.

The grade of the existing Highway 17 in the vicinity of the culvert is at 264.3 m geodetic.

The culvert is located within a fill section. The embankment is constructed with side slopes approximately 1.6 horizontal to 1 vertical (1.6H:1V). The west side slope at the crossing was noted to be rock lined with boulder sized particles. The embankment fill height is approximately 10.8 m at the east side and approximately 9.0 m at the west side. The existing roadway cross-section includes three 3.5 m lanes (two lanes in the southbound direction), a 2.2 m northbound paved shoulder, a 1.0 m 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 has a slight curve at the site with a profile sloping down to the south at 1.7%.

The site is located in a rural area of rolling topography with forests, swamps and creeks. 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

This borehole investigation and field testing program was carried out between January 7 and January 17, 2016. The program consisted of drilling and sampling eight boreholes (numbered 15-21, 15-22, 15-23, 15-24, 15-25, 15-26, 15-27, and 15-28) to depths ranging from 4.2 to 18.7 m. Of these boreholes, one was located near the culvert outlet (15-21), one located near the culvert inlet (15-24), two (15-22 and 15-23) were located through the embankment on opposite sides of the road near the culvert, and four were drilled for potential widening/detour at the toe of slope at approximately 50 m spacing north and south of the culvert alignment on both sides of the highway (15-25, 15-26, 15-27, and 15-28).

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, as well as the detour boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). In-situ shear vane testing was performed in cohesive soils with an MTO N-sized vane.

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 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.

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 at the culvert consist of granular and clayey embankment fill overlying sand and silt, and gravelly deposits. The subsurface conditions found 50 m north and south of the culvert site was generally found to include a sandy silt over a clay layer overlying a silty sand layer. Bedrock was not encountered in any of the eight boreholes. More detailed descriptions of the individual strata are presented below.

5.2 Granular Fill

A layer of asphalt 60 to 90 mm in thickness was encountered at ground surface in Boreholes 15-22 and 15-23 which were drilled through the roadway.

A 0.3 m thick sand with gravel and recycled asphalt product (RAP) fill likely placed as part of a past pavement rehabilitation was found immediately below the asphalt. Sand with silt and gravel with occasional cobbles extended to a depth of 2.3 m and 1.5 m below surface (elevations 262.0 m and 263.1 m) in Boreholes 15-22 and 15-23 respectively.

The moisture content of the granular fill ranged from 3% to 9%. 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	39
Sand	50
Silt and Clay	11

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 granular fill in Boreholes 15-22 and 15-23. The thickness of the embankment fill ranged from 7.5 m to 8.5 m. The base of the embankment fill was encountered at elevations ranging from 253.5 m to 255.6 m.

The upper portions of the fill were observed to range from sand with silt and gravel to sandy silt while the lower portion was sandy clay. Trace to some organics were noted in the embankment fill. In Borehole 15-22 a 0.9 m thick layer of sand fill with gravel and occasional cobbles was found below the sandy clay fill.

The SPT N-value for the sand and silt embankment fill ranged from 3 to 42 blows per 0.3 m penetration, indicating a very loose to dense state. The water contents of the recovered sand and silt fill samples ranged between 6% and 35%. The colour of the sand and silt fill is brown to reddish brown.

The SPT N-value for the sandy clay fill ranged from 5 to 16 blows per 0.3 m penetration, indicating a firm to very stiff state. The water contents of the recovered sandy clay embankment fill samples ranged between 17% and 36%. The colour of the sandy clay fill is brown to reddish brown.

The SPT N-value for the lower sand with gravel, occasional cobbles found in Borehole 15-22 was 73 blows per 0.3 m penetration, indicating a very dense state. Sample recovery was poor thus water content and grain size analysis could not be conducted. Field observations describe this material as moist with a brown colour.

The results of grain size analyses conducted on five samples of the embankment fill are presented on Fig. No 2 and Fig. No 3 in Appendix C. The results are summarized in the following table.

Soil Particles	%
<u>Silty Sand Fill</u>	
Gravel	9 to 35
Sand	53 to 66
Silt and Clay	12 to 38
<u>Sandy Clay Fill</u>	
Gravel	3 and 5
Sand	30 and 34
Silt	44 and 37
Clay	23 and 24

Atterberg limit testing was carried out on two samples of the sandy clay fill. The samples can be classified as clay of low plasticity (CL). The results are presented on Fig. No 8 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	18 and 16
Liquid Limit	26 and 27
Plasticity Index	8 and 11

5.4 Topsoil

Topsoil, 25 mm to 75 mm in thickness, was encountered in all off-road boreholes. 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 Sandy Silt

A soil deposit generally described as sandy silt was encountered in Boreholes 15-25, 15-26, 15-27, and 15-28 just below the base of the embankment fill, and just below the topsoil. This layer was observed to range from 0.5 m to 1.7 m in thickness with the elevation of the base of the unit ranging from 261.8 m to 263.9 m.

The SPT N-value for this deposit was 4 to 21 blows per 0.3 m penetration, indicating a very loose to compact state. The water contents of the recovered samples ranged between 14% and 22%. The colour of this deposit is brown.

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

Soil Particles	%
Gravel	0 and 2
Sand	24 and 47
Silt	65 and 48
Clay	11 and 3

5.6 Clay

Clay was encountered underlying the sandy silt deposit in all four widening boreholes (15-25, 15-26, 15-27, and 15-28). Where encountered, the thickness ranged from 0.2 m to 2.9 m. The elevation of the underside of this clay ranged from at 258.9 m to 263.7 m. This deposit contained occasional to frequent silt, sand and gravel seams. A 0.6 m thick silty sand layer was found within the deposit in Borehole 15-26.

The SPT N-value in the clay deposit was 4 to 14 blows per 0.3 m penetration. In conjunction with measured field vane shear strengths ranging from 91 to greater than 106 kPa, the clay was found to have a typically stiff to very stiff consistency. The sensitivity ranged from 3 to 5. The

colour of the clay is brown to reddish brown. The water content of the recovered clay samples ranged from 32% to 53%; the silty sand layer in 15-26 had a water content of 22%.

The results of grain size analysis conducted on two samples of the clay are presented on Fig. No 5 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	0 and 14
Sand	13 and 23
Silt	49 and 33
Clay	38 and 30

Atterberg limit testing was carried out on two samples of the clay. This soil can be classified as clay of low (CL) to intermediate plasticity (CI). The results are presented on Fig. No 8 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	15 and 16
Liquid Limit	31 and 38
Plasticity Index	16 and 22

5.7 Silty Sand

A native soil deposit ranging from silty sand to sand with silt and gravel was encountered in all boreholes. This soil was found just below the topsoil in the inlet and outlet holes, and beneath the base of the embankment fill in the roadway holes. In all four widening boreholes this layer was found below the native clay layer. All boreholes were terminated in this layer at elevation ranging from 245.6 m to 256.9 m. This layer was at least 4.0 m to 6.8 m in thickness. A 0.3 m thick gravel layer was noted within the unit in Borehole 15-21. A similar layer 1.2 m thick was noted at the base of the hole in Borehole 15-22.

The SPT N-value for this deposit was 2 to greater than 100 blows per 0.3 m penetration, indicating a very loose to very dense state. The deposit is generally dense. The water contents of the recovered samples ranged between 4% and 25%. The colour of this deposit is brown to reddish brown.

Grain size analyses conducted on six samples of the soil are presented on Fig. No 6 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	6 to 30
Sand	32 to 77
Silt and Clay	7 to 59

A grain size analysis conducted on two samples of the gravel layer found in Borehole 15-21 and 15-22 are presented on Fig. No 7 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	46 and 44
Sand	40 and 43
Silt and Clay	14 and 13

5.8 Groundwater Conditions

Groundwater was observed in Boreholes 15-21, 15-26, 15-27 and 15-28. The results are summarized in the following table.

Borehole	Depth of observed water (m)	Elevation of observed water (m)
15-21	0.9	253.8
15-26	0.9	262.7
15-27	0.5	262.9
15-28	0.5	262.2

A 25 mm inside diameter PVC piezometer was installed in Borehole 15-24. The piezometer was recorded as dry to 4.16 m on January 11, 2016 and February 19, 2016; corresponding to an elevation of 253.2 m. The piezometer was decommissioned on February 19, 2016.

The water level at the inlet was at an elevation of 255.9 m on January 11, 2016. The water level at the outlet was at an elevation of 254.2 m on January 14, 2016. The groundwater level in the area of the culvert is expected to reflect the water level in the ditches.

These observations are short-term readings and seasonal fluctuations of the groundwater level are to be expected, and must be taken into consideration. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

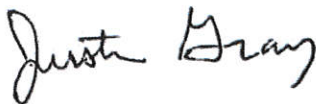
6 MISCELLANEOUS

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

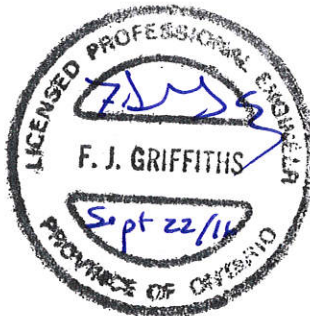
Marathon Drilling Ltd. of Greely, Ontario, supplied and operated a truck-mounted CME 55 drill rig to carry out the drilling, sampling and in-situ testing operations on the existing highway platform. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario, supplied and operated the portable drill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



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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 under Highway 17, approximately 6.3 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 1.05 m diameter by 50.6 m long corrugated steel pipe culvert (CSP) is present at the site. The water at the site flows from west to east. 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 253.5 m to 255.6 m. The majority of the excavation for a new culvert would therefore be within the fill which was observed to consist of loose to dense silty sand with gravel to sandy silt over stiff sandy clay. Occasional cobbles were noted in the fill. The native material observed immediately beneath the fill consisted of compact sandy silt underlain by a compact to very dense sand with silt and gravel to silty sand material.

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 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 1050 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 1200 mm diameter by 51 m long circular pipe offset approximately 3 m to the north of the existing culvert alignment. The planned invert elevations are 259.9 m and 256.4 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 temporary grade lowering.
4. Open cut with a single lane, traffic lights, and detour with temporary widening to the west including culvert extension.
5. Open cut with a single lane, traffic lights, grade lowering combined with temporary widening to the west including culvert extension.
6. Open cut with a single lane, traffic lights and roadway protection.
7. Trenchless methods.

Options 1 and 2 are not considered feasible at this site. Table E-1 in Appendix E provides a comparison of Options 3, 4, 5, 6 and 7.

Based on our understanding of the project and the existing conditions at the site Option 7 is considered the preferred method. It would eliminate an excavation in excess of 10 m depth and allow the culvert to be replaced with minimal impact on 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 Methods". 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 risky due to the native non-cohesive silt and sand beneath the fill, which under the presence of groundwater could create 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. 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 excessive settlement of the pavement surface. The alignment control can be adversely affected if oversized obstructions are encountered.

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

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

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.

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 excavation is the responsibility of the contractor. 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. In addition, the west side of the embankment was noted to be rock lined with boulder sized particles. These will need to be removed from the area of the exit pit and trenchless installation. 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 $\Phi = 29^\circ$ $\gamma = 19 \text{ kN/m}^3$		Clay Embankment Fill $\Phi = 27^\circ$ $\gamma = 19 \text{ kN/m}^3$	
Surface Behind Wall	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	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	0.38	0.70
At-rest Earth Pressure Coefficient, K_o (Restrained Wall)	0.43	-	0.47	-	0.50	-	0.52	-	0.55	-
Passive Earth Pressure Coefficient, K_p (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-	2.9	-	2.7	-

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

Indications of ground water were observed in several of the boreholes at the time of drilling. It is noted however that ground water 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 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 1.6H:1V or flatter and exhibit no signs of instability. It is recommended that the embankment slope be reinstated at 2H:1V to ensure stability.

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.

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. In addition, the slopes on the site were observed to be steeper than 2H:1V with boulders present at surface

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 silty sand some clay (Borehole 15-23, SS11) 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 presented 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)
15-23	SS11	7.9	6.1	7200	747	22

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, although road salt may create a 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 and portions of the underlying soils were observed to contain occasional cobbles and the fill may contain other obstructions. The west side slope was noted to contain boulders at surface. 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.

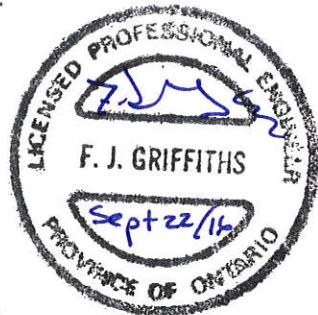
The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented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

Justin A. Gray
Geotechnical E.I.T.



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

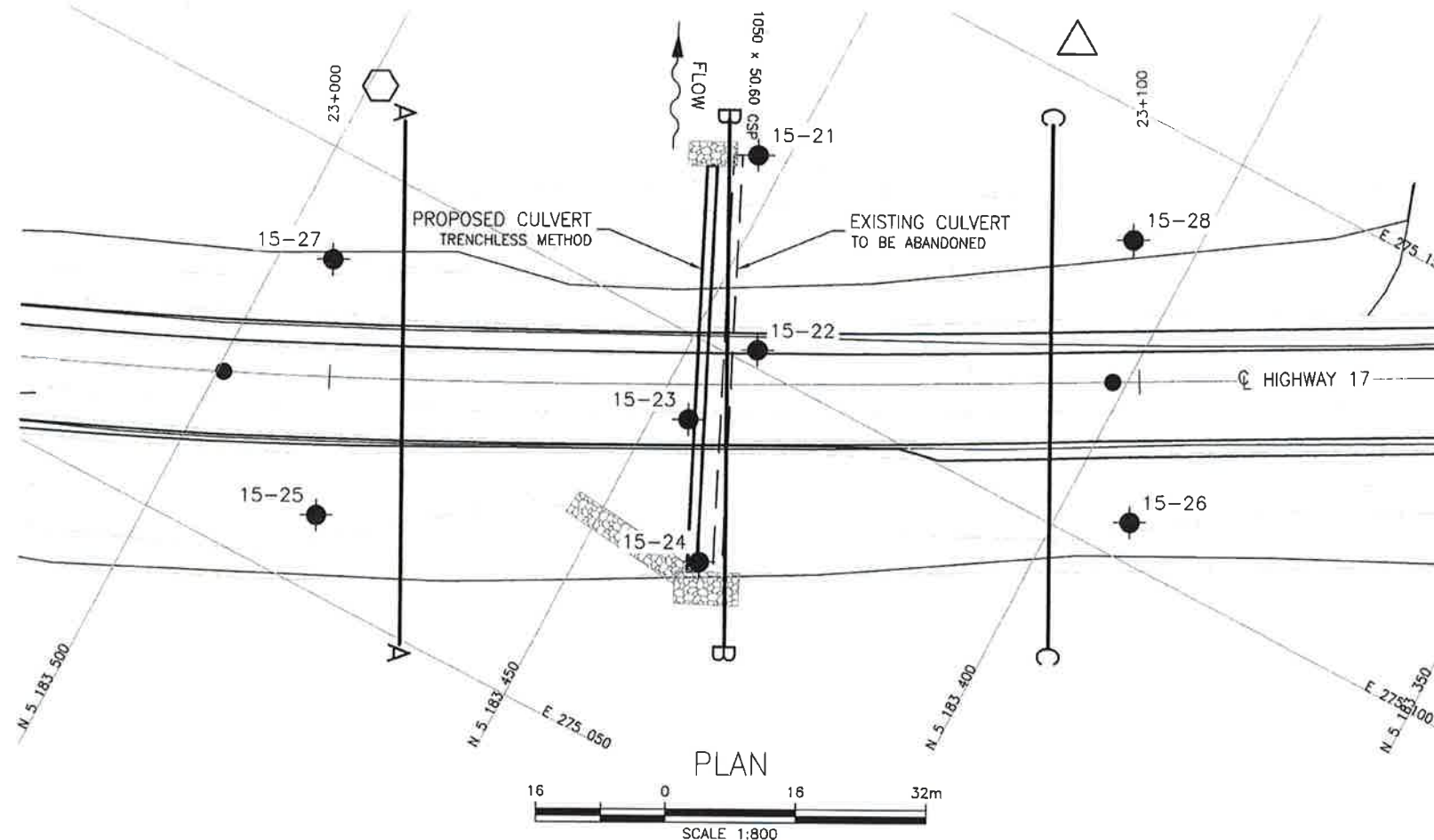


P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact

Appendix A

Borehole Locations and Soil Strata Drawings

19-5308-95



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

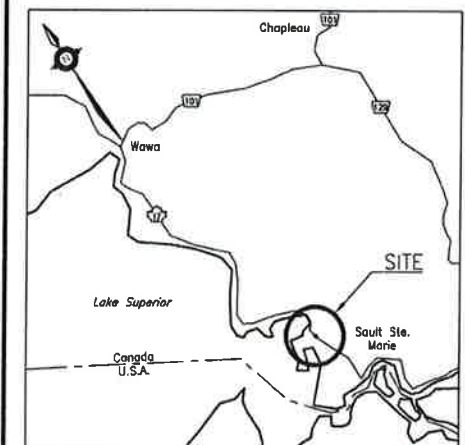


CONT No
WP No

HIGHWAY 17
23+049
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

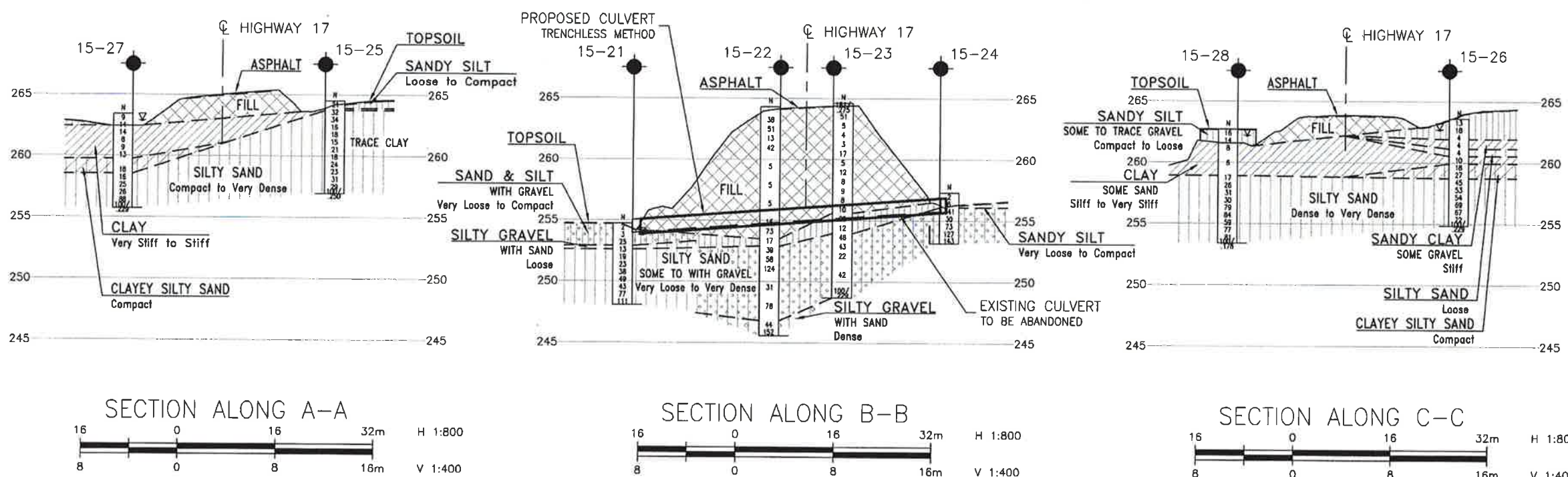
- Borehole
- ⊕ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- PZ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
15-21	254.7	5 183 453.4	275 123.3
15-22	264.3	5 183 442.2	275 102.0
15-23	264.6	5 183 445.7	275 090.5
15-24	257.3	5 183 436.3	275 075.6
15-25	264.5	5 183 480.9	275 058.7
15-26	263.6	5 183 391.6	275 104.6
15-27	263.4	5 183 493.8	275 087.5
15-28	262.7	5 183 407.5	275 135.6

-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-99



DATE	BY	DESCRIPTION
DESIGN	JG	CHK -
DRAWN	MFA	CHK JG
DATE	SEP 2016	
FILENAME	H:\Drawing\1\15308\95\Loc0815-PlanProfile(Culvert 80).dwg	
PLOTDATE	9/7/2016 4:03 PM	

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.

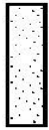


STRATA PLOT:

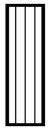
Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



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 15-21

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 453.4 E 275 123.3 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.01.13 - 2016.01.14 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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)								
								20 40 60 80 100					w _p w w _L								
254.7																					
0.0		TOPSOIL (25 mm)																			
		SILTY SAND with gravel to sandy SILT Very Loose to compact Brown Wet		1	SS	2		254													
				2	SS	3															
				3	SS	25															
252.9								253													
1.8		GRAVEL, silty with sand																			
252.6		Loose Brown Wet		4	SS	13															
2.1		SILTY SAND Compact to Very Dense Brown Wet to Moist		5	SS	19		252													
				6	SS	23															
				7	SS	38		251													
				8	SS	49															
				9	SS	43		250													
				10	SS	77															
		some gravel		11	SS	111		249													
248.1																					
6.7		End of Borehole at 6.65 m Groundwater at 0.9 m Cave at 1.3 m upon completion																			

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

RECORD OF BOREHOLE No 15-22

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 442.2 E 275 102.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.09.01 - 2016.09.01 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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)						
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
264.3																
0.0	ASPHALT, (60 mm)															
264.0	Sand with gravel with RAP FILL		1	AS			264									
0.3	Sand with silt and gravel, occasional cobbles Dense to Very Dense Brown Moist FILL		2	SS	38		263									
			3	SS	51		262								39 50 11 (SI+CL)	
262.0							262									
2.3	Silty Sand with gravel to sandy silt trace organics Loose to dense Brown to Reddish Brown Moist to Wet FILL		4	SS	13		261								18 66 16 (SI+CL)	
			5	SS	42		260									
			6	SS	5		259									
258.2							258									
6.1	Sandy clay trace gravel trace organics firm to very stiff Reddish Brown Wet FILL		7	SS	5		257									
			8	SS	5		256								3 30 44 23	
			9	SS	16		255									
254.4																

Continued Next Page





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

RECORD OF BOREHOLE No 15-22

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 442.2 E 275 102.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.09.01 - 2016.09.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100										PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L		
								SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
9.9	Continued From Previous Page Sand with gravel occasional cobbles Very Dense Brown Moist FILL		10	SS	73		254													
253.5																				
10.8	Sandy SILT Compact Brown Moist		11	SS	17		253													
252.9																				
11.4	SAND with silt and gravel to SILTY SAND Dense to very dense Reddish Brown Moist		12	SS	39		252													
			13	SS	58															
			14	SS	124		251													
							250													
			15	SS	31															
							249													
			16	SS	78		248													
							247													
246.8																				
17.5	GRAVEL, silty with sand Dense to very dense Brown		17	SS	44															
			18	SS	152		246													
245.6																				
18.7	End of Borehole at 18.7 m Borehole Dry Upon Completion Cave at 12.0 m Upon Completion																			

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

RECORD OF BOREHOLE No 15-23

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 445.7 E 275 090.5 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.07.01 - 2016.07.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L							
264.6														
0.0														
264.3	ASPHALT (90 mm)													
0.1														
264.3	Sand with gravel and RAP FILL		1	SS	181/275mm									
0.3														
	Sand with silt and gravel, occasional cobbles Very Dense Brown Dry FILL		2	SS	51									
263.1														
1.5	Silty sand to Sand with silt and gravel Very loose to compact Brown Moist to wet FILL		3	SS	5									
			4	SS	4									
			5	SS	3									
	with organics		6	SS	17									
			7	SS	5									
			8	SS	12									
			9	SS	8									
257.8														
6.9	Sandy clay to silty sand occasional clay layers Stiff Brown Moist FILL		10	SS	9									
			11	SS	8									
			12	SS	10									
255.6														
9.0	Sandy SILT Compact Brown Wet		13	SS	29									

Continued Next Page

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

RECORD OF BOREHOLE No 15-23

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 445.7 E 275 090.5 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.07.01 - 2016.07.01 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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		GR	SA	SI	CL	
Continued From Previous Page																					
254.0	Sandy SILT Compact Brown Wet		14	SS	12		254						○				9	32	52	7	
10.7	SAND with silt and gravel Compact to very dense Brown Moist		15	SS	46		253						○				30	58	12 (SI+CL)		
			16	SS	43								○								
			17	SS	22								○								
			18	SS	42								○								
			19	SS	100/ 229mm									○							
248.7							251														
15.9	End of Borehole at 15.9 m due to auger refusal Borehole dry upon completion Borehole open upon completion						250														
							249														

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 15-24

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 436.3 E 275 075.6 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML
 DATUM Geodetic DATE 2016.08.01 - 2016.11.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										20 40 60		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
257.3																				
0.0 0.1	TOPSOIL (50 mm)																			
	Sandy SILT with organics Very loose to loose Brown Wet		1	SS	2		257													
			2	SS	6															
256.1																				
1.2	SILTY SAND with gravel Compact to very dense Brown Wet		3	SS	141		256													
			4	SS	30															
			5	SS	73		255													
			6	SS	127		254													
			7	SS	143															
253.2																				
4.2	End of Borehole at 4.16 m Borehole dry upon completion Borehole open upon completion																			

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

RECORD OF BOREHOLE No 15-25

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 480.9 E 275 058.7 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.11.01 - 2016.11.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w P w w L							
264.5														
0.0														
0.1	TOPSOIL (50 mm)													
	Sandy SILT		1	SS	21									
	Compact													
263.9	Brown						264							
260.0														
0.8	CLAY		2	SS	32									
	Very Stiff													
	Reddish Brown													
	SILTY SAND													
	Compact to very dense		3	SS	34		263							
	Brown to reddish brown													
	Moist													
			4	SS	16									
			5	SS	18		262							
	trace clay		6	SS	15									
			7	SS	21		261							
			8	SS	18		260							
			9	SS	24									
			10	SS	23		259							
			11	SS	31		258							
			12	SS	29									
			13	SS	100		257							
256.9														
7.6	End of Borehole at 7.57 m Borehole dry upon completion Borehole open upon completion				250 mm									

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

RECORD OF BOREHOLE No 15-26

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 391.6 E 275 104.6 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.12.01 - 2016.12.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100							
263.6															
0.0	TOPSOIL (25 mm)		1	SS	13		263								0 24 65 11
	Sandy SILT Compact to loose Brown Moist to wet		2	SS	18										
			3	SS	4										
262.0			4	SS	4										
1.7	CLAY (Cl), sandy some gravel Firm Brown occasional sand seams		5	SS	4										
261.2			6	SS	10										
2.4	SILTY SAND occasional clay seams Loose Brown Wet		7	SS	18										
260.6			8	SS	27										
3.0	CLAY occasional sand seams Stiff Brown		9	SS	45										
260.0			10	SS	53										
3.7	SILTY SAND, clayey Compact Brown Moist		11	SS	54										
			12	SS	69										
258.8			13	SS	67										
4.9	SILTY SAND Dense to very dense Brown Moist		14	SS	72										
			15	SS	100/										
254.9					229m										
8.8	End of Borehole at 8.76 m Groundwater at 0.9 m upon completion Borehole open upon completion														

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

RECORD OF BOREHOLE No 15-27

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 493.8 E 275 087.5 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.01.14 - 2016.01.15 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20 40 60 80 100							20 40 60		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							w P w w L		
263.4						▽											
0.0	TOPSOIL (75 mm) Sandy SILT Loose to Compact Brown Moist		1	SS	9		263										2 47 48 3
0.1																	
262.5		2	SS	14													
0.9	CLAY (CL) with frequent silty sand seams Stiff Brown to Reddish Brown		3	SS	14		262										
			4	SS	8												
			5	SS	9		261										
			6	SS	13		260										
			259.8		7		GS										
3.7	SILTY SAND, clayey Compact Brown to reddish brown Moist to Wet		8	SS	18		259										
258.5																	
4.9	SILTY SAND Compact to Very Dense Brown Moist		9	SS	16		258										
			10	SS	25												
			11	SS	26	257											
			12	SS	88												
			255.7		13	SS	100/ 229 mm	256									
7.7	End of Borehole at 7.7 m Groundwater at 0.5 m upon completion Borehole open upon completion																

+³, ×³: Numbers refer to
Sensitivity


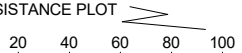

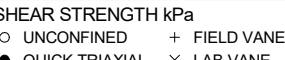
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 15-28

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 23+049, Highway 17 Goulais River N 5 183 407.5 E 275 135.6 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.01.16 - 2016.01.17 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
262.7													
0.0	TOPSOIL (50 mm)												
	Sandy SILT some to trace gravel Compact Brown Wet		1	SS	16								
261.8			2	SS	14								
0.9	CLAY (CL) some sand Stiff to Very Stiff Brown to Reddish Brown		3	SS	8								
			4	SS	6								
258.9			5	SS	17								
3.8	SILTY SAND Very Dense Brown Wet to Moist		6	SS	26								
			7	SS	31								
			8	SS	30								
			9	SS	79								
			10	SS	84								
			11	SS	59								
			12	SS	77								
			13	SS	81								
253.4			14	SS	100/								
9.3	End of Borehole at 30.58 m Free Water at 0.5 m				178 mm								

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

Appendix C

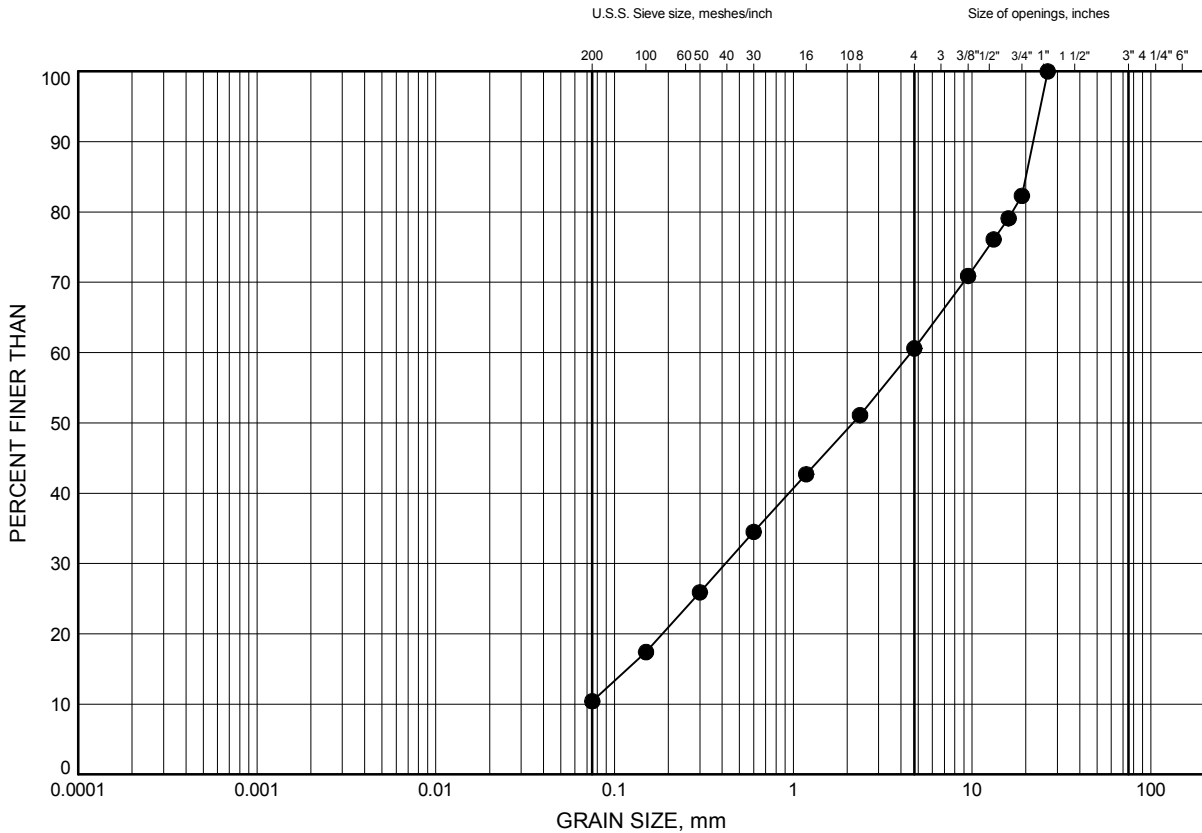
Laboratory Test Results

19-5308-95

Culvert 23+049, 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)
●	15-22	1.83	262.48

Date May 2016
 GWP# 545-00-00

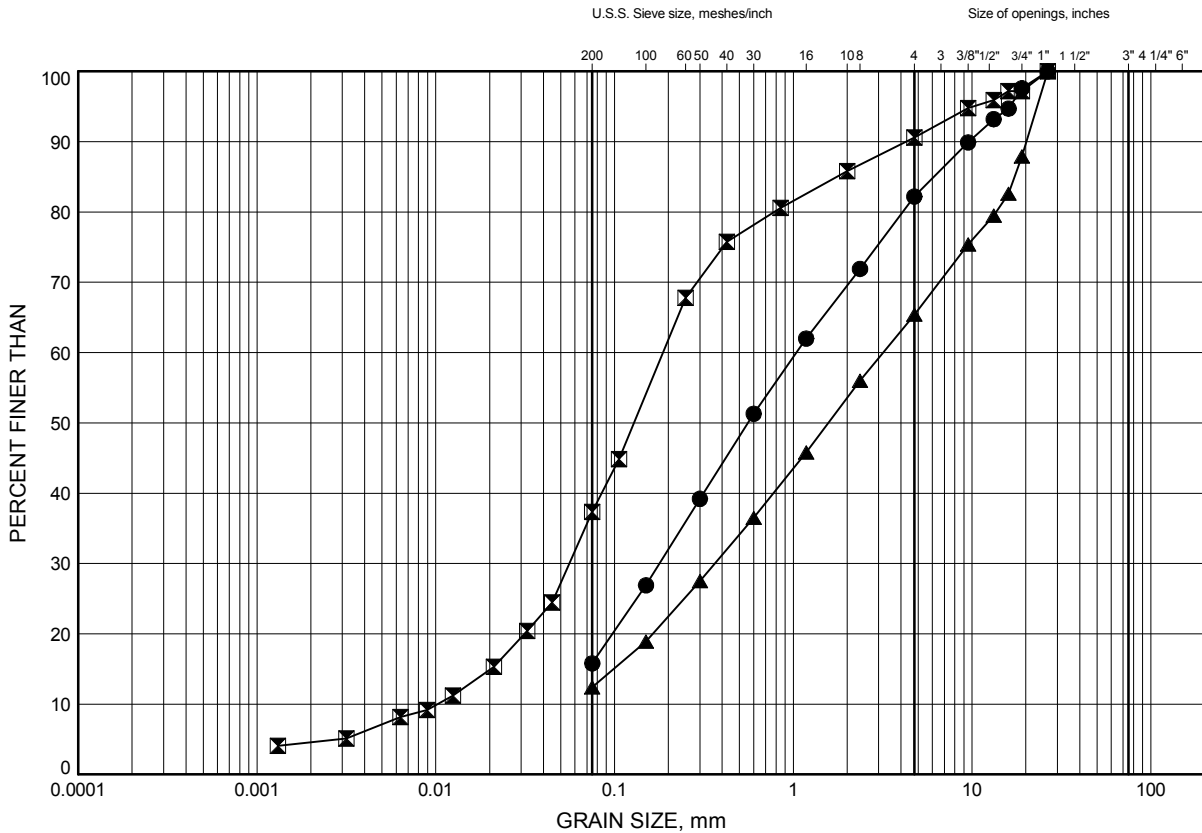


Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 2

Non-Cohesive Embankment Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-22	3.35	260.96
□	15-23	4.88	259.75
▲	15-23	6.40	258.23

Date May 2016
 GWP# 545-00-00



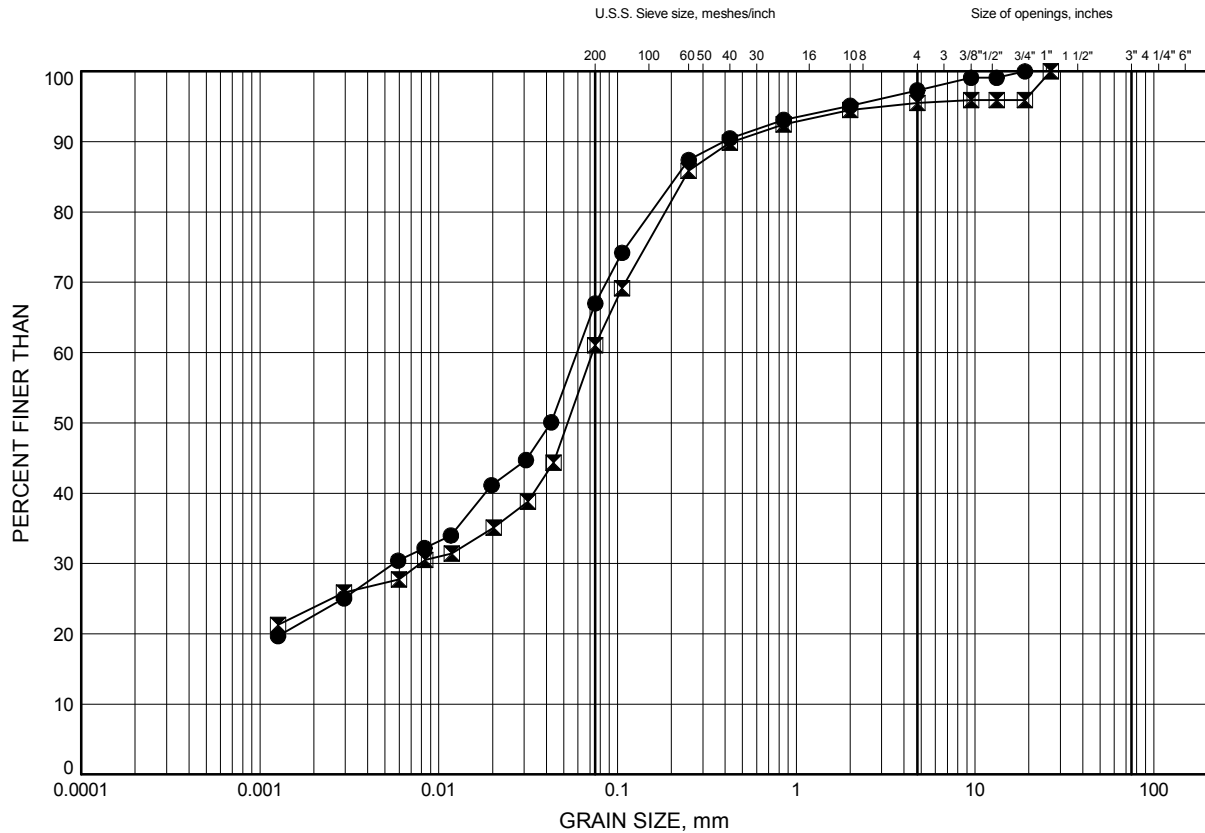
Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 3

Cohesive Embankment Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-22	7.92	256.39
⊠	15-23	8.69	255.94

Date May 2016
GWP# 545-00-00

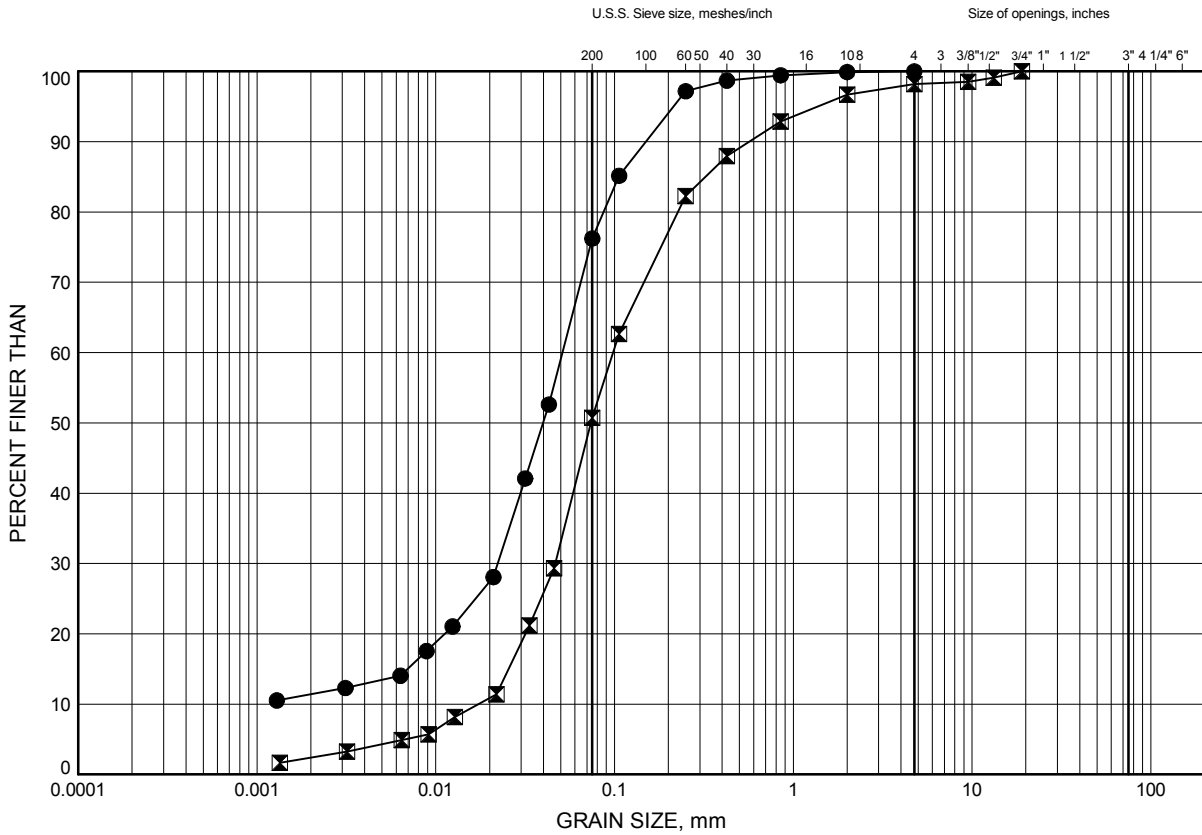


Prep'd JAG
Chkd. FJG

Culvert 23+049, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 4

Sandy Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-26	0.91	262.73
◻	15-27	0.34	263.07

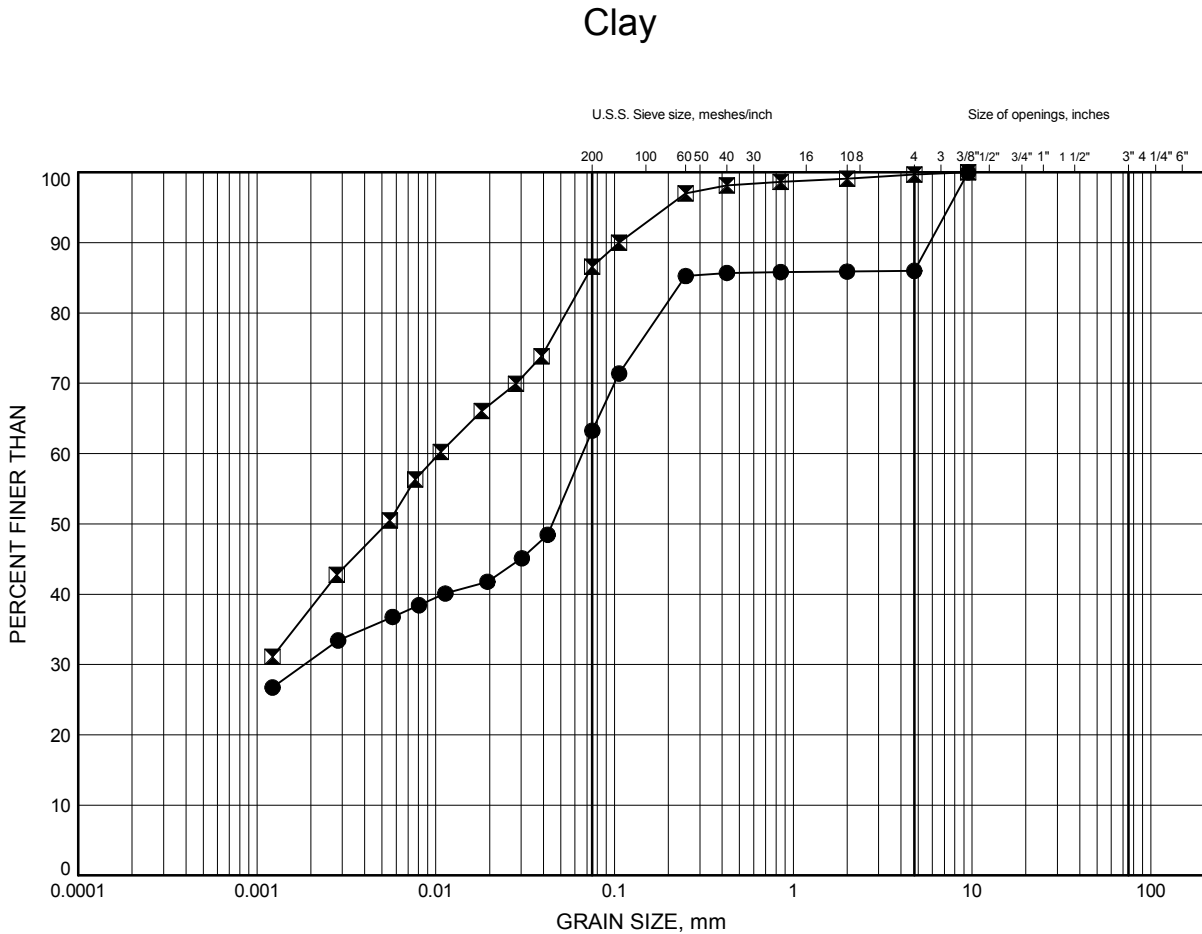
Date May 2016
 GWP# 545-00-00



Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-26	2.13	261.52
⊠	15-28	2.74	259.98

Date May 2016
 GWP# 545-00-00

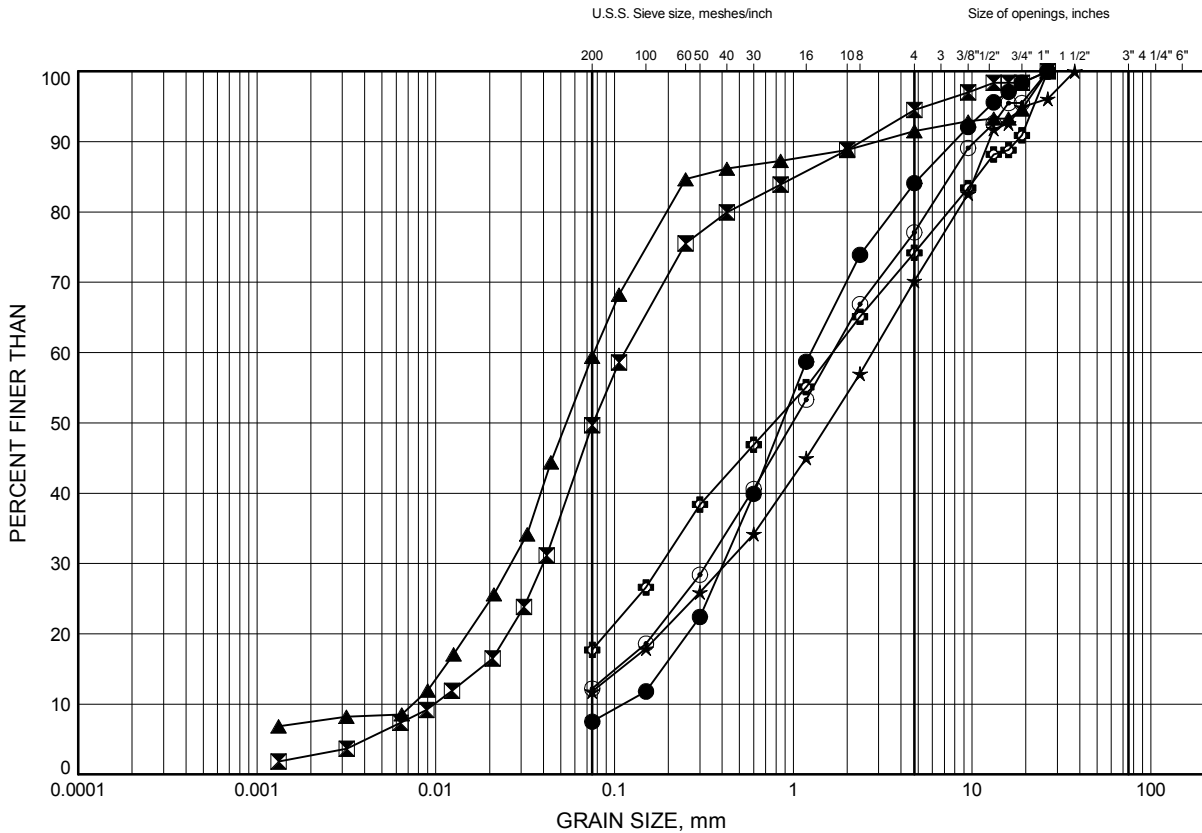


Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 6

Sand with Silt and Gravel to Silty Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-22	12.50	251.81
⊠	15-22	14.78	249.53
▲	15-23	10.21	254.42
★	15-23	11.73	252.89
⊙	15-23	14.02	250.61
⊕	15-24	2.74	254.58

Date May 2016
 GWP# 545-00-00

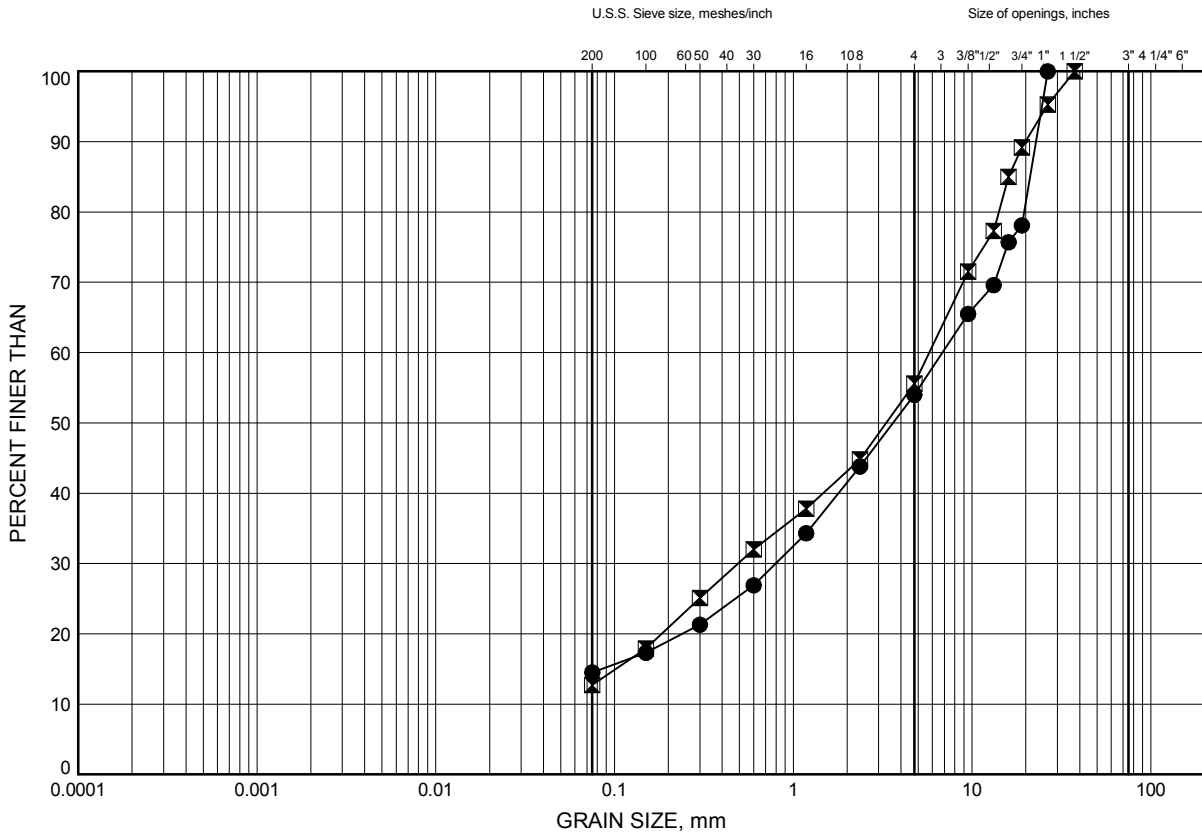


Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 7

Gravel, Silty with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-21	2.13	252.62
⊠	15-22	18.44	245.87

Date May 2016
 GWP# 545-00-00

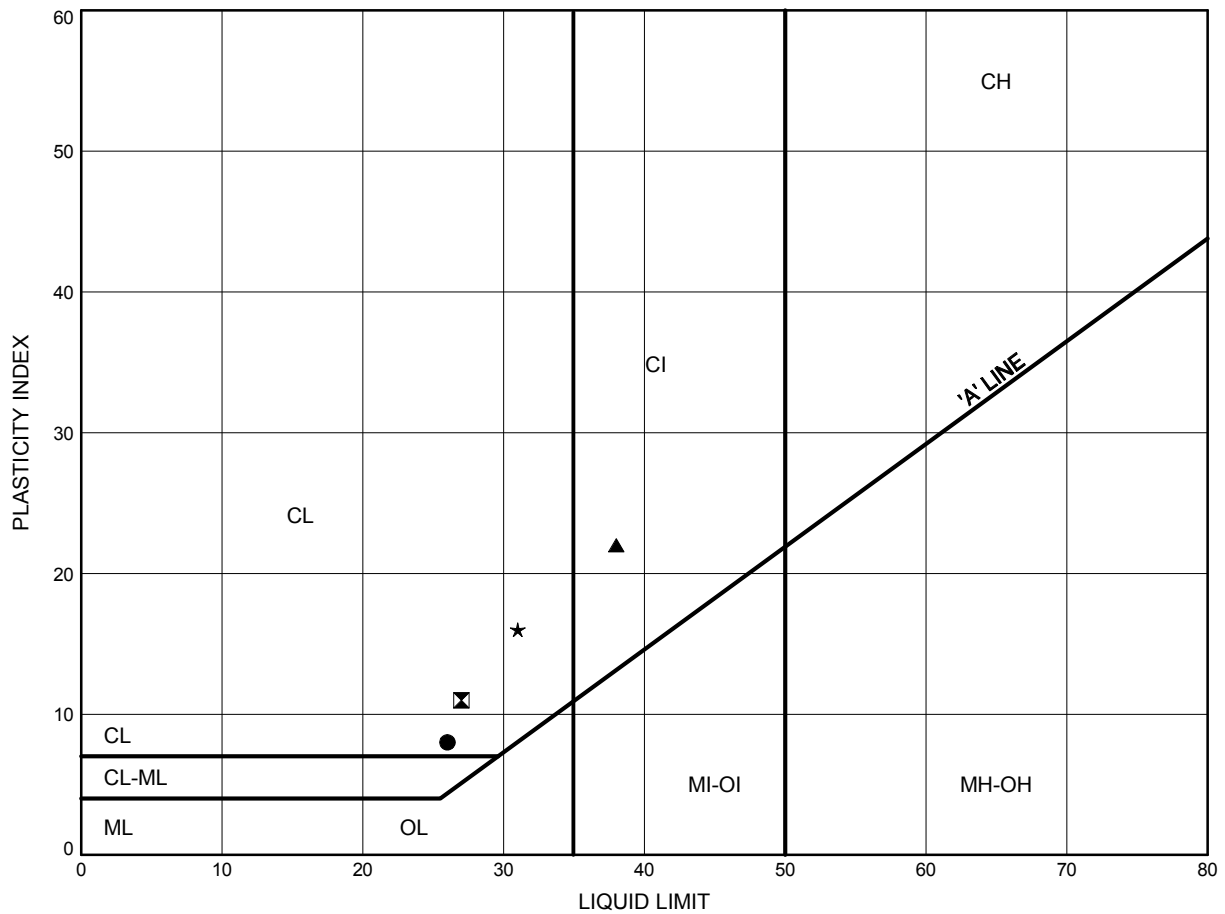


Prep'd JAG
 Chkd. FJG

Culvert 23+049, Highway 17 Goulais River

ATTERBERG LIMITS TEST RESULTS

FIGURE 8



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-22	7.92	256.39
⊠	15-23	8.69	255.94
▲	15-26	2.13	261.52
★	15-28	2.74	259.98

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: 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

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

Physical Characteristics

% Solids	0.1 % by Wt.	85.0	84.7	79.0	85.3
----------	--------------	------	------	------	------

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
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
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
Anions									
Chloride	8.7	5	ug/g dry	8.4			2.5	20	
Sulphate	298	5	ug/g dry	335			11.5	20	
General Inorganics									
Conductivity	749	5	uS/cm	758			1.3	6.2	
pH	7.76	0.05	pH Units	7.79			0.4	10	
Physical Characteristics									
% 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
Anions									
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 – looking toward end of culvert



Photo 3: Looking north at culvert crossing and west side slope.



Photo 4: Looking north towards culvert crossing.



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



Appendix E

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

Culvert Replacement
23+049 Havilland Township, Highway 17

Table E-1: Comparison of Construction Methodology Alternatives

Option	3. Open cut, staged with temporary grade lowering	4. Open cut, staged with temporary detour and culvert extension to the west	5. Open cut, staged with temporary grade lowering and temporary widening with culvert extension to the west	6. Open Cut, staged with roadway protection	7. Trenchless installation by pipe ramming, horizontal directional drilling or microtunnelling
Advantages	Less earth work than option 4.	Cross-section of highway conducive to widening to the west. Simple construction.	Cross-section of highway conducive to widening/grade lowering to the west. Simple construction. Requires shorter culvert extension than option 4.	Surface and groundwater better controlled.	Avoids deep excavation through highway. All lanes of traffic maintained.
Disadvantages	Multiple stages. Only one lane of traffic maintained. Deep excavation and large cut and fill quantities.	Multiple stages. Only one lane of traffic maintained. Requires culvert extension to allow for widening which may require work outside MTO ROW. Deep excavation and large cut and fill quantities.	Multiple stages. Only one lane of traffic maintained. Requires culvert extension to allow for widening which may require work outside MTO ROW. Deep excavation and large cut and fill quantities.	Only one lane of traffic maintained. Roadway Protection will likely require anchors or bracing.	Requires construction of entry and exit pits and access to toe of slope. Must maintain surface and groundwater control.
Relative Cost	Moderate	Moderate	Moderate	Moderate	Moderate
Risks & Consequences	Review of impact to horizontal curve and profile may preclude. Loose and wet materials at invert may require special dewatering techniques (well points). Excavation stability may require the installation of roadway protection.	Review of impact to horizontal curve and profile may preclude. Loose and wet materials at invert may require special dewatering techniques (well points). Excavation stability may require the installation of roadway protection.	Review of impact to horizontal curve and profile may preclude. Loose and wet materials at invert may require special dewatering techniques (well points). Excavation stability may require the installation of roadway protection.	Risk if oversized obstructions encountered.	Very high risk if oversized obstructions are encountered. Risk if groundwater encountered.
Summary	Feasible	Feasible	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. "