THURBER ENGINEERING LTD.

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

GEOCRES Number: 41K-97

Report

to

WSP Canada Inc.

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September 16, 2016
19-5308-95

THURBER

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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 for the subject culvert was available.

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

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

2 SITE DESCRIPTION

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

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

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

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

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

3 SITE INVESTIGATION AND FIELD TESTING

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

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

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

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

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

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

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

4 LABORATORY TESTING

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

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

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

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

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

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

5.2 Pavement Structure

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

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

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

Soil Particles	%
Gravel	38
Sand	58
Silt and Clay	4

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

5.3 Embankment Fill

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

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

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

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

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

5.4 Topsoil

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

5.5 Cobbles and Gravel

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

5.6 Silty Sand

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

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

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

This material can be classified as SM.

5.7 Silt to Silty Sand

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

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

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

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

This soil may be classified as ML to SM.

5.8 Clay (CL)

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

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

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

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

Soil Particles	%
Gravel	0
Sand	11
Silt	74
Clay	15

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

Test	%
Plastic Limit	17
Liquid Limit	25
Plasticity Index	8

5.9 Sand with Silt

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

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

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

Soil Particles	%
Gravel	0
Sand	89
Silt and Clay	11

This material can be classified as SP.

5.10 Groundwater Conditions

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

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

6 MISCELLANEOUS

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

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

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

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

Justin A. Gray
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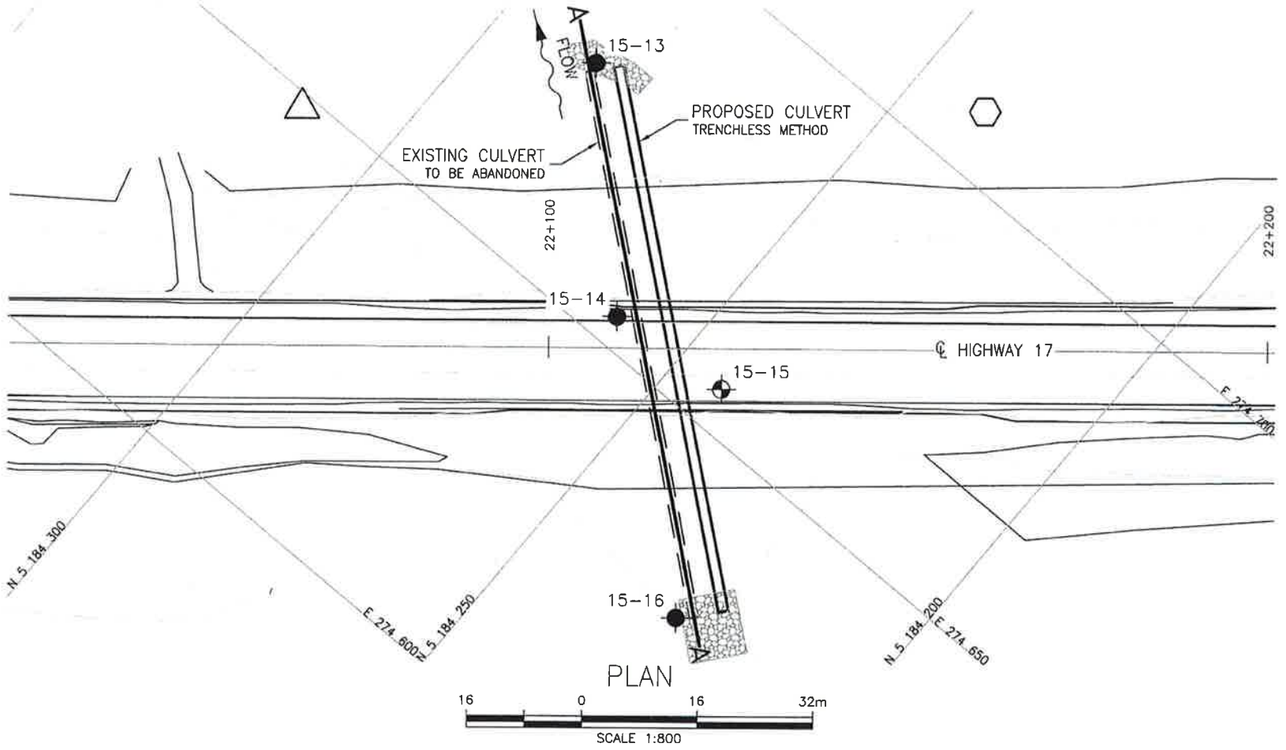
Review Principal, Designated MTO Contact

Appendix A

Borehole Locations and Soil Strata Drawings

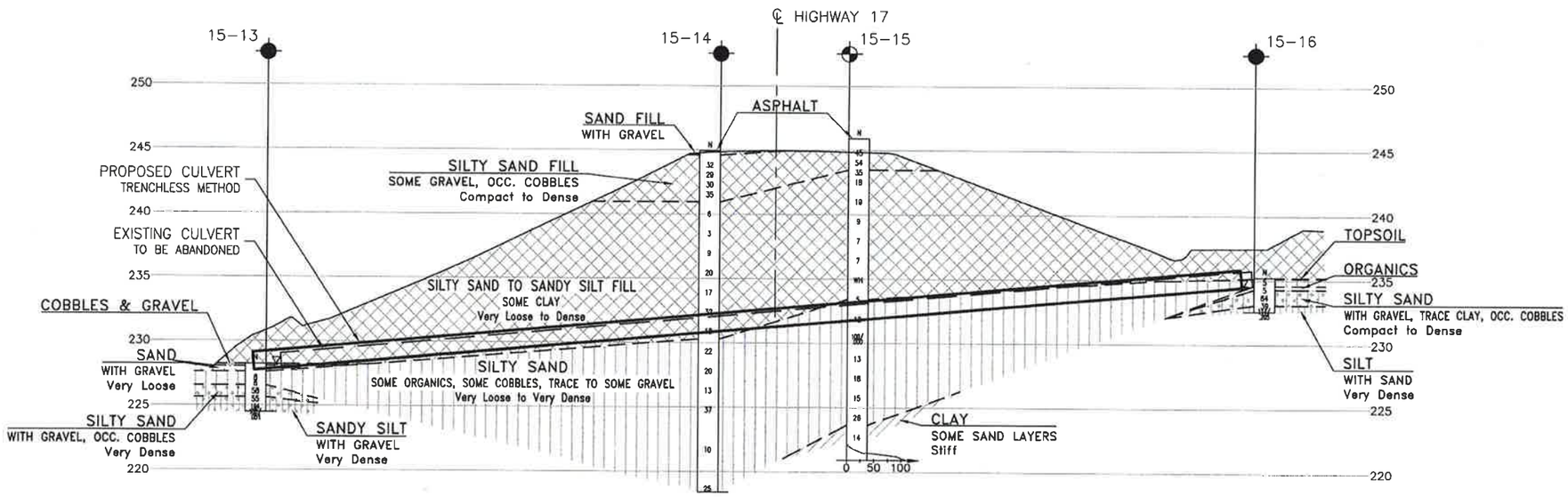
19-5308-95



PLAN

16 0 16 32m

SCALE 1:800



SECTION ALONG A-A

8 0 8 16m

SCALE 1:400

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

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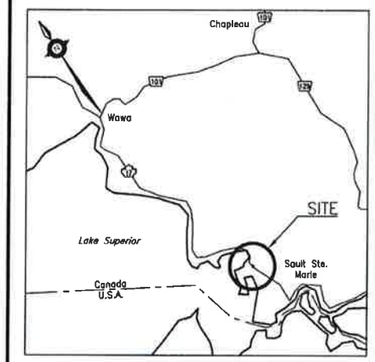
CONT No
WP No

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

SHEET

WSP

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
15-13	228.2	5 184 285.3	274 679.2
15-14	244.9	5 184 260.3	274 654.1
15-15	245.9	5 184 242.7	274 655.7
15-16	235.2	5 184 227.1	274 627.4

-NOTES-

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-97

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	JG	CHK –	CODE	LOAD	DATE SEP 2016
DRAWN	MFA	CHK JG	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\18\53GB\95\1e0895-PlanProfile(Culvert 56).dwg
PLOTDATE: 9/7/2016 2:19 PM

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Appendix B

Record of Borehole Sheets

19-5308-95

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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.

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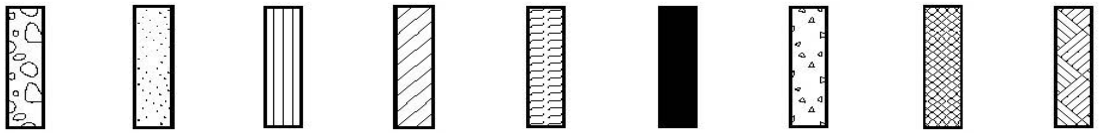
STRATA PLOT:
Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



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

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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

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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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-13 1 OF 1 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 285.3 E 274 679.2 ORIGINATED BY CAM

HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML

DATUM Geodetic DATE 2016.01.25 - 2016.01.25 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
228.2											
0.0	**COBBLES AND GRAVEL** (150 mm)										
0.2	**SAND** with gravel Very Loose Brown		1	AS			228				
227.6											
0.6	Wet **SILTY SAND** with organics Loose Greyish brown Wet		2	SS	8		227				
226.5			3	SS	6						
1.7	**SILTY SAND** with gravel, occassional cobble Very Dense Greyish brown Wet		4	SS	58		226				18 62 20 (SI+CL)
225.6											
2.6	**SILT** with sand to **SILTY SAND** with gravel Very Dense Greyish brown Wet		5	SS	55						
			6	SS	194		225				
224.5			7	SS	100/ 51 mm						
3.7	End of Borehole at 4.27 m Groundwater at Surface Borehole Cave at 0.1 m										

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

20 15 5 10 (%) STRAIN AT FAILURE

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-14 1 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG

DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.9											
0.0	**ASPHALT** (90 mm)										
0.1 244.8	Sand with gravel										
0.3	**FILL**										
	Silty sand some gravel occasional cobble Compact to Dense Brown Moist **FILL**		1	AS			244				
			2	SS	32						
			3	SS	29		243				10 77 13 (SI+CL)
			4	SS	30						
			5	SS	35		242				
240.9											
4.0	Silty sand to sandy silt Very loose to Dense Brown Moist **FILL**		6	SS	6		241				
			7	SS	3		240				
			8	SS	9		239				
	some clay		9	SS	20		238				2 41 57 (SI+CL)
							237				
							236				
							235				

Continued Next Page

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

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-14 2 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG

DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							20 40 60 80 100	20 40 60		
			10	SS	17		234		○		
			11	SS	32		233		○		
			12	SS	18		232				
	wet						231		○		
230.3											
14.6	**SILTY SAND** trace gravel Compact Greyish brown Wet		13	SS	22		230		○		9 71 20 (SI+CL)
228.3							229				
16.6	**SILTY SAND** to **SILT** with sand Compact to Dense Reddish Brown Wet		14	SS	20		228		○		
			15	SS	13		227		○		0 21 71 8
							226				
							225				

Continued Next Page

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

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-14 3 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 260.3 E 274 654.1 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG

DATUM Geodetic DATE 2016.04.02 - 2016.04.02 CHECKED BY FJG

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

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

$\overset{20}{15\oplus 5}$ (%) STRAIN AT FAILURE
10

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-15 1 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 242.7 E 274 655.7 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML

DATUM Geodetic DATE 1931.01.16 - 2016.01.31 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.9											
0.0	**ASPHALT** (100 mm)										
0.1	Sand with gravel **FILL**		1	AS					○		38 58 4 (SI+CL)
245.3							245				
0.6	Silty sand some gravel occasional cobble Dense to very dense Brown Moist **FILL**		2	SS	45				○		
			3	SS	54		244		○		
243.5											
2.4	Silty sand to sandy silt Dense to very loose Brown Moist **FILL**		4	SS	35				○		3 58 39 (SI+CL)
			5	SS	18		243		○ ○		
							242				
			6	SS	19		241		○		4 80 16 (SI+CL)
							240				
			7	SS	9				○		
							239				
			8	SS	7		238		○		
	some clay		9	SS	7		237		○		
							236				

Continued Next Page

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

$15 \oplus \frac{20}{10} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-15 2 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 242.7 E 274 655.7 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML

DATUM Geodetic DATE 1931.01.16 - 2016.01.31 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
			10	SS	WH		235				
							234				
233.4			11	SS	5						
12.5	**Silty SAND** trace organics/roots Loose to very dense Greyish brown Wet						233				
			12	SS	12		232				1 78 21 (SI+CL)
	frequent cobbles						231				
			13	SS	100/ 0 mm		230				
229.4											
16.5	**SILTY SAND** to **SILT** with sand Compact Greyish Brown to Reddish Brown Wet		14	SS	13		229				0 15 83 2
							228				
			15	SS	18		227				
							226				

Continued Next Page

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

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE
10

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-15 3 OF 3 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 242.7 E 274 655.7 ORIGINATED BY JAG

HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML

DATUM Geodetic DATE 1931.01.16 - 2016.01.31 CHECKED BY FJG

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

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

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-16 1 OF 1 METRIC

GWP# 545-00-00 LOCATION Culvert 22+113, Highway 17 Goulais River N 5 184 227.1 E 274 627.4 ORIGINATED BY CAM

HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML

DATUM Geodetic DATE 2016.01.26 - 2016.01.26 CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
235.2												
0.0 / 0.1	**TOPSOIL** (50 mm)											
	SILTY SAND some gravel Loose Brown		1	SS	5	▽	235			○		
234.6 / 0.6	Wet											
234.3 / 0.9	**ORGANICS** Soft Black Wet		2	SS	5					○	○	
	SILTY SAND with gravel, trace clay, occasional cobbles Compact to very dense Greyish brown		3	SS	64		234			○		
233.1 / 2.1	Wet		4	SS	39					○		
	SILT with sand Very Dense Greyish brown		5	SS	114/ 203 mm		233			○	○	0 28 68 4
232.6 / 2.6	Moist End of Borehole at 2.64 m Groundwater at 0.6 m Borehole open to 1.1 m upon completion											

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

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

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

Appendix C

Laboratory Test Results

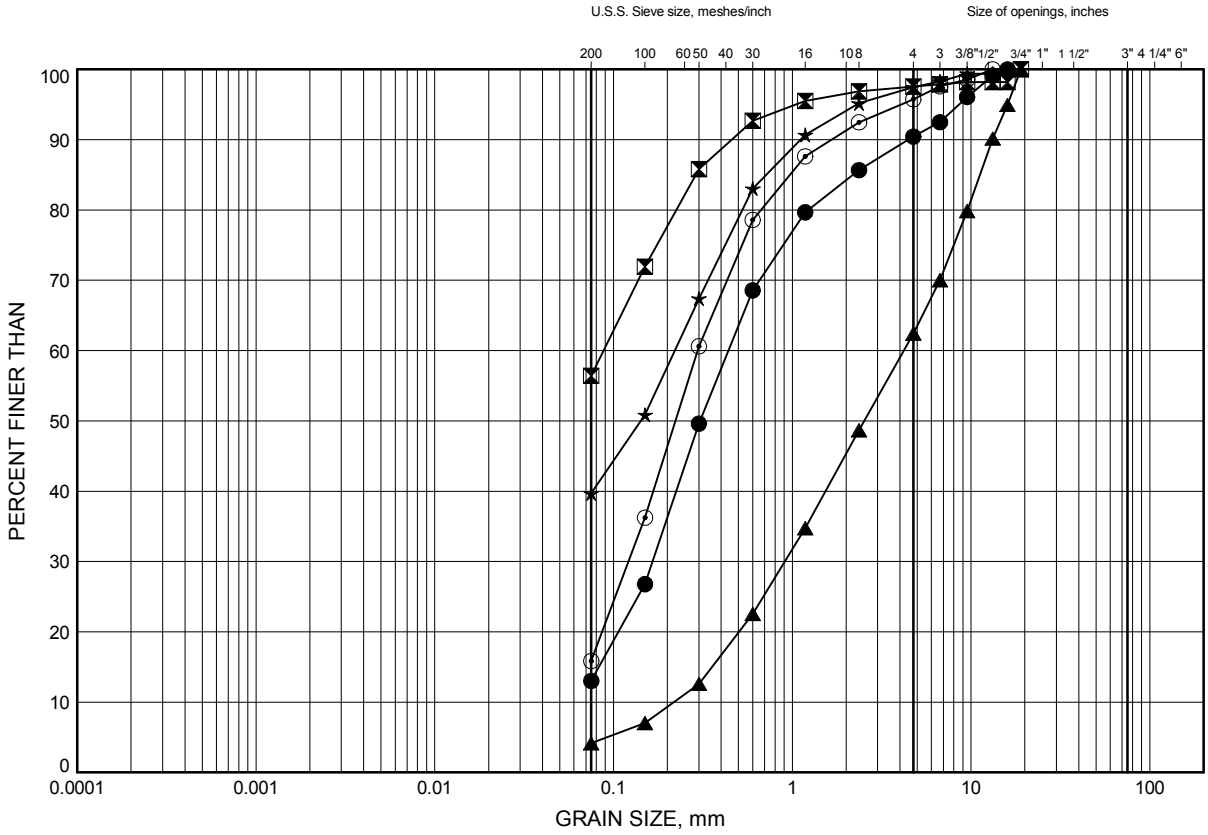
19-5308-95

Culvert 22+113, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 1

Pavement and Embankment Fill



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

LEGEND

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

Date May 2016

GWP# 545-00-00

THURBER

Prep'd JAG

Chkd. FJG

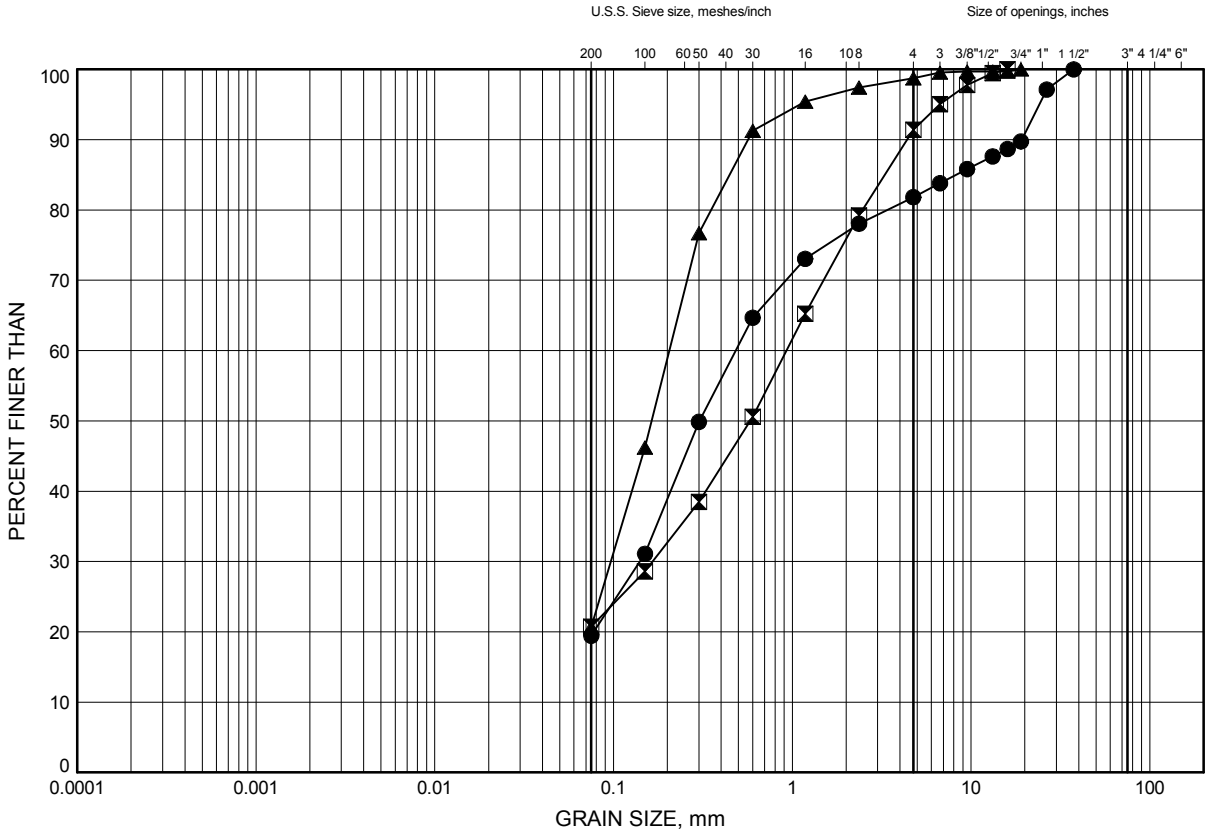
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 5/5/16

Culvert 22+113, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 2

Silty Sand



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

LEGEND

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

Date May 2016

GWP# 545-00-00

THURBER

Prep'd JAG

Chkd. FJG

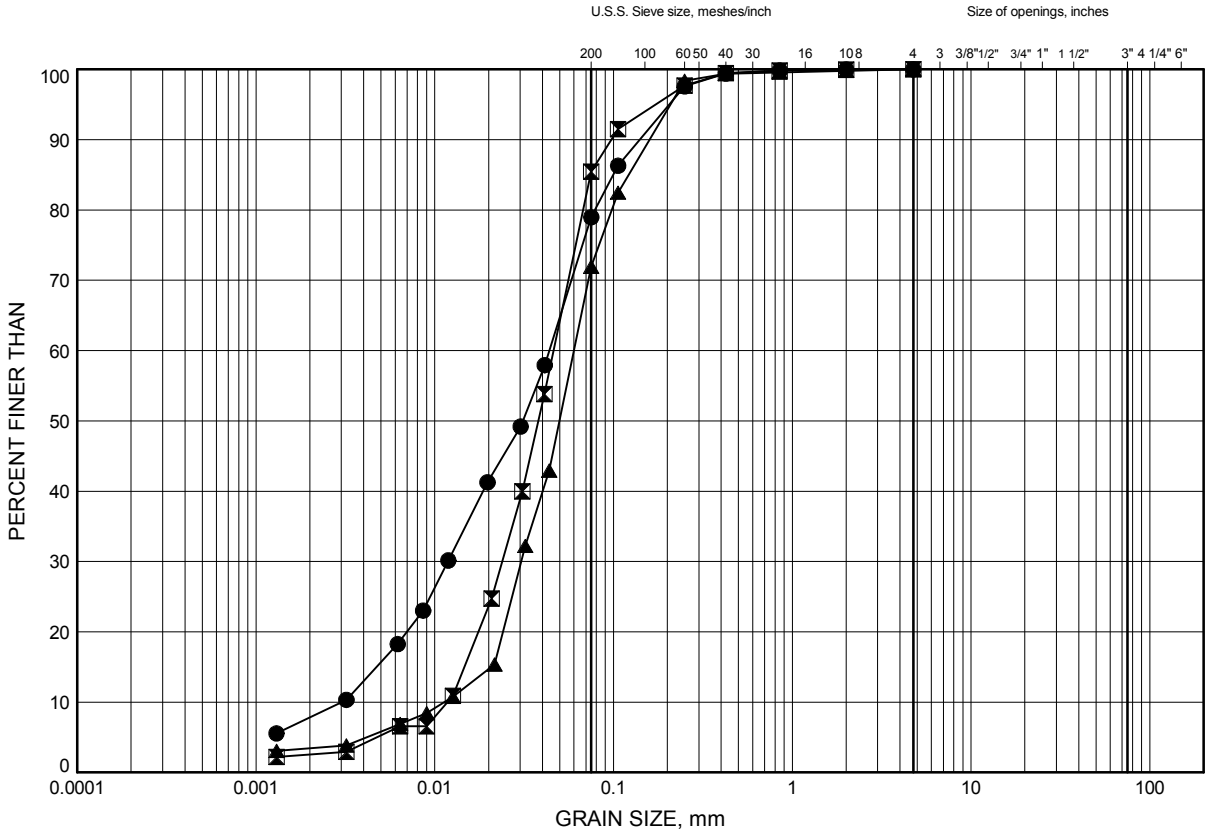
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 5/5/16

Culvert 22+113, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 3

Silty Sand to Silt with Sand



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

LEGEND

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

Date May 2016

GWP# 545-00-00

THURBER

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Chkd. FJG

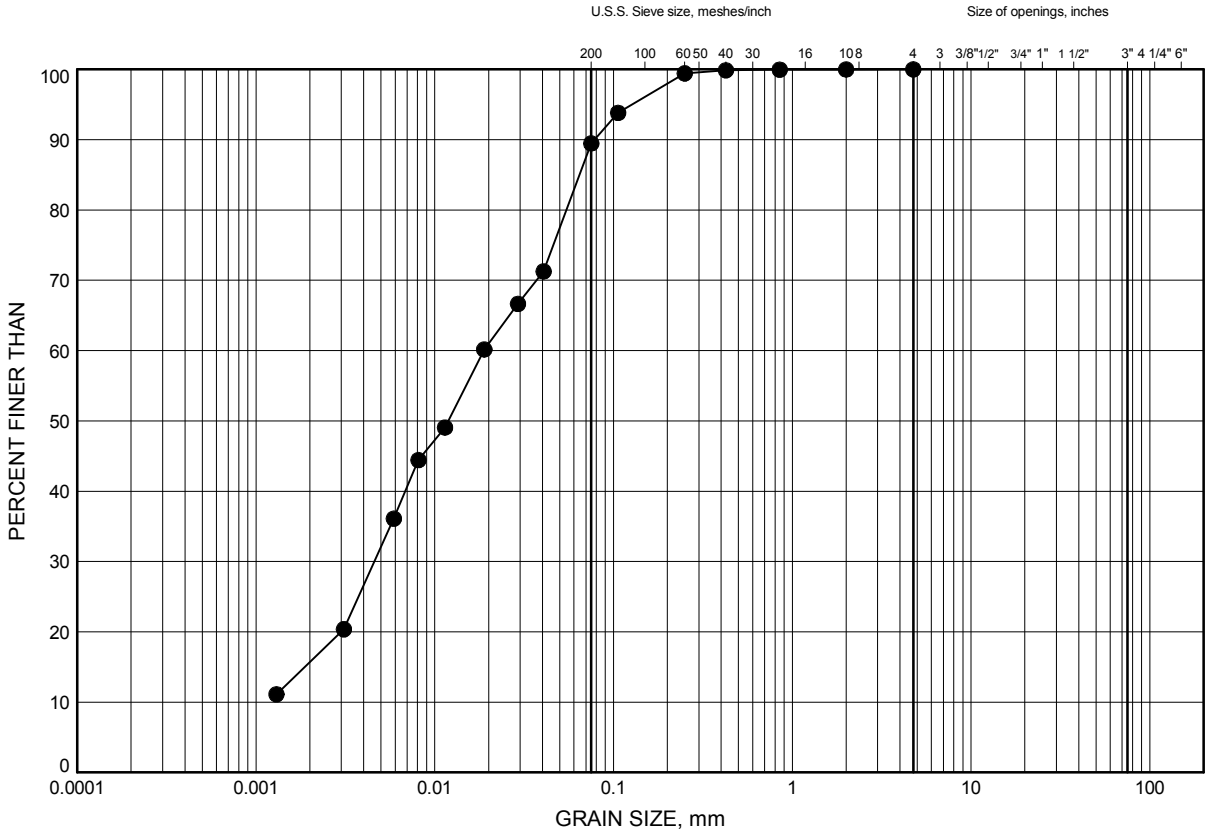
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 5/5/16

Culvert 22+113, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 4

Clay (CL)



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

LEGEND

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

Date May 2016

GWP# 545-00-00

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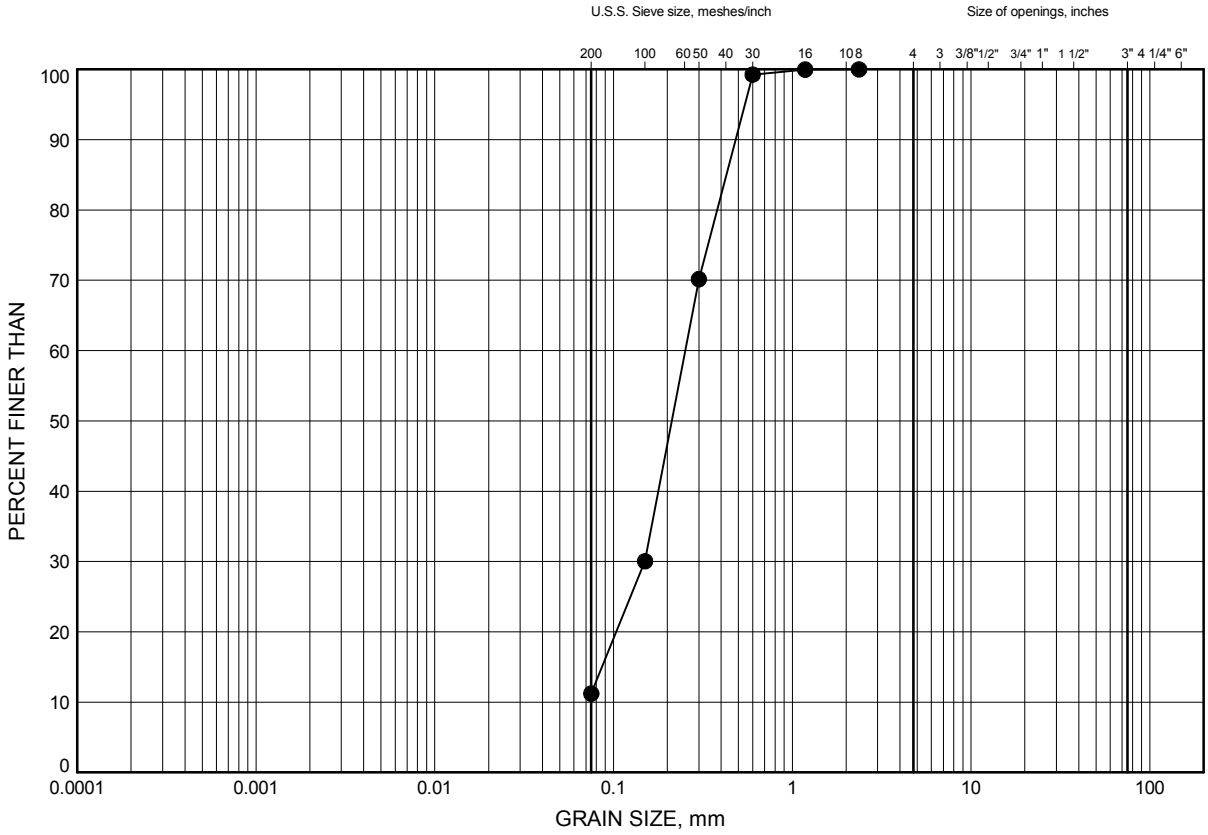
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 5/5/16

Culvert 22+113, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 5

Sand with Silt



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

LEGEND

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

Date May 2016

GWP# 545-00-00

THURBER

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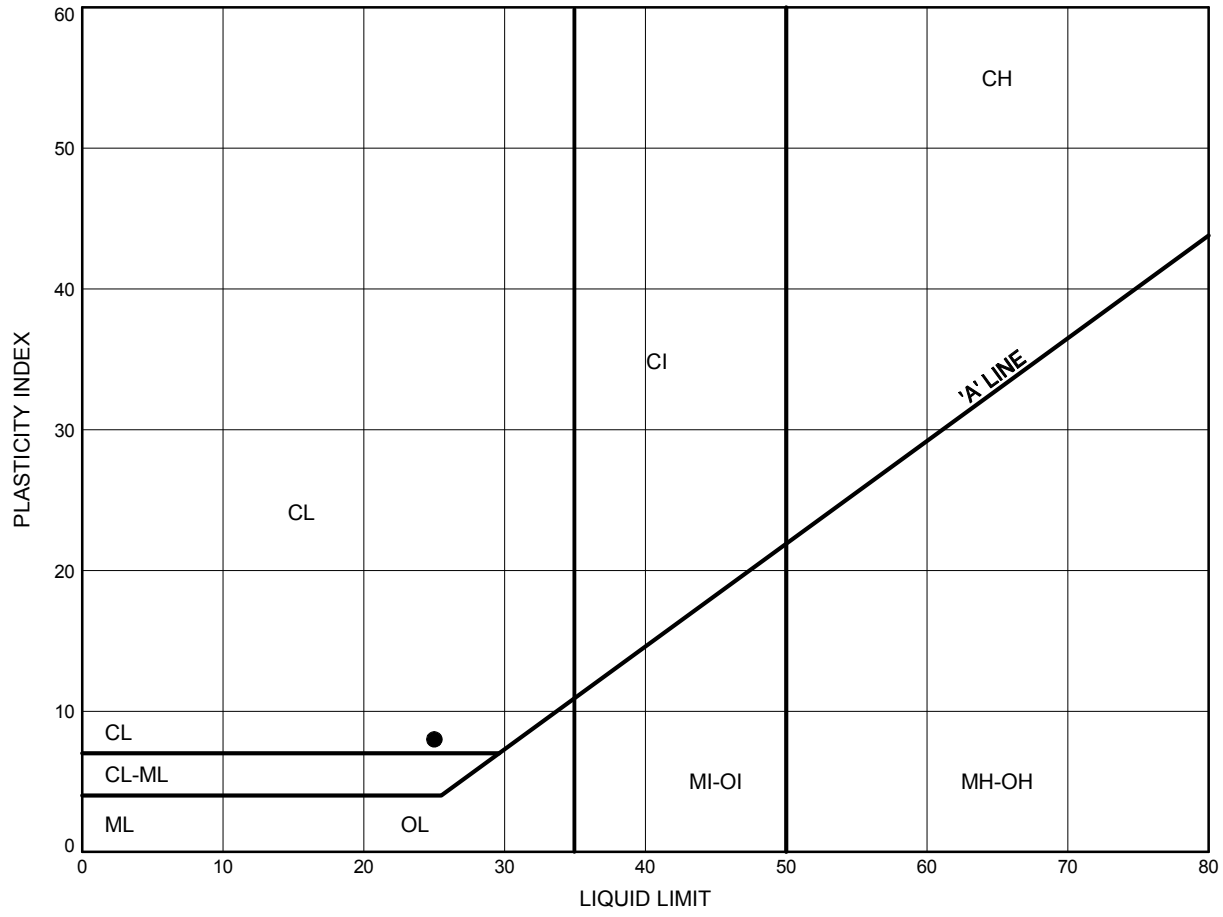
Chkd. FJG

GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 5/5/16

Culvert 22+113, Highway 17 Goulais River

ATTERBERG LIMITS TEST RESULTS

FIGURE 6



LEGEND

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

Date May 2016

GWP# 545-00-00

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THURBALT 19-5308-95.GPJ 5/5/16

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Certificate of Analysis

Thurber Engineering Ltd.

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

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

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

Order #: 1607256

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

Paracel ID	Client ID
1607256-01	BH15-15 SS10 (35-37')

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis
Report Date: 16-Feb-2016
Client: **Thurber Engineering Ltd.**
Order Date: 11-Feb-2016
Client PO:
Project Description: 19-5308-95

Analysis Summary Table

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

Certificate of Analysis

Report Date: 16-Feb-2016

Client: **Thurber Engineering Ltd.**

Order Date:11-Feb-2016

Client PO:

Project Description: 19-5308-95

	Client ID:	BH15-15 SS10 (35-37')	-	-	-
	Sample Date:	31-Jan-16	-	-	-
	Sample ID:	1607256-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	79.6	-	-	-
General Inorganics					
Conductivity	5 uS/cm	1920	-	-	-
pH	0.05 pH Units	7.35	-	-	-
Resistivity	0.10 Ohm.m	5.22	-	-	-
Anions					
Chloride	5 ug/g dry	1200	-	-	-
Sulphate	5 ug/g dry	9	-	-	-

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
Report Date: 16-Feb-2016
Client: **Thurber Engineering Ltd.**
Order Date:11-Feb-2016
Client PO:
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	17.6	5	ug/g dry	17.6			0.4	20	
Sulphate	14.4	5	ug/g dry	15.2			5.4	20	
General Inorganics									
Conductivity	690	5	uS/cm	673			2.6	6.2	
pH	7.77	0.05	pH Units	7.79			0.3	10	
Physical Characteristics									
% Solids	89.1	0.1	% by Wt.	90.8			1.9	25	

Method Quality Control: Spike

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

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Appendix D

Selected Photographs

19-5308-95

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

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

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

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

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

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

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