



THURBER ENGINEERING LTD.

**FINAL
FOUNDATION INVESTIGATION REPORT
CULVERT SITE 27-363/C
HIGHWAY 417, CASSELMAN ON**

G.W.P. 451-98-00

Geocres No.: 31G-272

Report to:

Ainley Group

Latitude: 45.301524
Longitude: -75.081411

November 2018
Thurber File: 18310

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for Culvert 27-363/C beneath at the W-N/S and N-E ramps of the Highway 417/County Road 7 Interchange. The culvert is located approximately 150 m west of County Road 7 within the Township of Cambridge. Thurber Engineering Limited (Thurber) carried out the investigation as a sub-consultant to Ainley Graham & Associates Limited (Ainley) under Agreement No. 4016-E-0036.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed throughout the investigation. No previous foundation investigation information was available for the subject culvert site within the Geocres Library.

2 SITE DESCRIPTION

The existing culvert is a corrugated steel sectional plate arch culvert servicing the Leo Denis Municipal Drain and is understood to have been constructed in 1971. The culvert is reported to be 3.4 m wide by 2.2 m high and approximately 59 m long with a generally northeast to southwest alignment. The flow through the culvert is to the southwest.

At the location of the culvert, the W-N/S ramp is a 4.8 m wide single-lane ramp with a 3.0 m wide paved outside shoulder and the N-E ramp is a 4.8 m wide single-lane ramp with a 3.0 m wide paved inside shoulder. The ramp embankment fill heights are approximately 2.2 m and 1.8 m above the culvert with the road surface at approximate elevations of 65.8 m and 66.3 m for the N -E and W-N/S ramps, respectively. The existing embankment side slopes are inclined flatter than 2H:1V. The land adjacent to the ramp is mainly undeveloped fields of grass. No signs of erosion or slope instability were noted on the existing highway embankments during the field investigation. The roadway surface over the culvert was generally in good condition with no dips or bumps noted during the field investigation. The existing culvert, however, did show some signs of corrosion. Traffic volumes are understood to be 3029 AADT (2014) and 1306 AADT (2014) for the W-N/S and N -E ramps, respectively.

Select photographs of the existing conditions near the culvert are included in Appendix D for reference.

FINAL

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out on September 14th, 2017 for the on-road investigation and between June 19th and 27th, 2018 for the off-road investigation. Drilling consisted of advancing four boreholes identified as 17-13 through 17-16. The drilling was performed using a track mounted CME 55 drill rig for off-road Boreholes 17-13 and 17-16 and a truck mounted CME 55 drill rig for on-road Boreholes 17-14 and 17-15. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting, and elevation of the boreholes from the current investigation are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A. The individual Record of Borehole sheets are provided in Appendix B and summarized in Table 3-1. The termination depth of each of the boreholes is also provided, below. The borehole elevations were surveyed using geodetic benchmark GBM 00819758419 (elev. 71.241 m) and a Trimble Catalyst with centimetre precision in conjunction with a Nikon-AP-8 with an accuracy of +/- 1.5 mm. Borehole locations were measured off existing site features and translated to northings and eastings based on the available base plans. The site is within MTM Zone 8.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
17-13	Near Culvert inlet	5 019 182.7	180 806.4	63.1	8.8
17-14	N-E ramp shoulder	5 019 174.2	180 793.5	65.8	12.9
17-15	W-N/S ramp shoulder	5 019 163.1	180 763.3	66.3	12.9
17-16	Near Culvert outlet	5 019 145.6	180 761.0	63.0	6.3

The boreholes were advanced through soil using hollow stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Bedrock was cored with NQ size coring equipment.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil and rock samples for transport for further laboratory examination and testing.

A 19 mm diameter standpipe piezometer was installed in Borehole 17-13 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole 17-13, provided in Appendix B. Following completion of the field investigation, the remaining

boreholes were backfilled in accordance with MOE requirements (O.Reg. 903, as amended).

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and determination of natural moisture content. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil recovered from within the Boreholes was selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Locations and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is provided in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a granular embankment fill overlying native deposits of glacial till. Bedrock was encountered within the depth of investigation in Boreholes 17-13, 17-14, and 17-15.

5.1 Embankment Fill

5.1.1 Asphalt

Boreholes 17-14 and 17-15 were drilled through the existing W-N/S and N-E ramps, respectively and encountered a layer of asphalt at the surface with a thickness of 100 mm.

5.1.2 Fill: Gravel with Silt and Sand to Silty Gravel with Sand

Below the surficial asphalt in Boreholes 17-14 and 17-15 and at surface in Borehole 17-13 was a layer of fill consisting of gravel with varying amounts of silt and sand. Occasional to frequent cobbles and boulders were observed in the fill in Borehole 17-13. The underside of this fill ranged from 0.6 to 1.4 m below the existing roadway surface (elev. 64.9 to 65.2 m) in Boreholes 17-14 and 17-15, and 2.1 m below ground surface (elev. 61.0 m) in Borehole 17-13.

The SPT 'N' values ranged from 8 to 37 in the layer, indicating a relative density of loose to dense. The moisture content for the samples tested ranged from 3% to 15%.

The results of grain size analyses conducted on two samples of the gravel fill are summarized in Table 5-1 and illustrated on Figure C1 in Appendix C.

Table 5-1 Gradation Results for Gravel Fill

Soil Particle	Percentage (%)
Gravel	39 – 45
Sand	28 – 43
Silt	12 – 33
Clay	

5.1.3 Fill: Silty Sand with Gravel

A layer of silty sand with varying amounts of gravel was encountered below the gravel fill in Boreholes 17-14 and 17-15 and at surface in Borehole 17-16. The layer has a thickness ranging from 1.5 to 4.3 m, extending to elevations ranging from 60.9 to 61.5 m.

The SPT 'N' values ranged from 11 to 27, indicating a compact relative density. The moisture content for the samples ranged from 3% to 15%. The results of grain size analyses conducted on four samples from this layer are summarized in Table 5-2 and illustrated on Figure C1 in Appendix C.

Table 5-2 Gradation Results for Silty Sand to Silty Sand with Gravel Fill

Soil Particle	Percentage (%)
Gravel	0 – 33
Sand	44 – 77
Silt	18 – 26
Clay	

5.2 Silty Sand to Sandy Silt (Glacial Till)

Below the fill materials in all boreholes was a deposit of glacial till consisting of a heterogenous mixture of silty sand to sandy silt with varying amounts of gravel. It should be noted that the lower 1.2 m of the glacial till in Borehole 17-15 consisted of primarily gravel with some sand and silt. Frequent cobbles and boulders were encountered in Borehole 17-13. Borehole 17-16 was terminated within the glacial till at a final depth of 6.3 m below the existing ground surface (elev. 56.7 m). The thickness of this layer in Boreholes 17-13 to 17-15 ranged from 3.2 to 4.2 m with base elevations ranging from 56.7 to 57.8 m.

The SPT 'N' values ranged from 6 blows per 300 mm of penetration to 100 blows for 125 mm of penetration, indicating a relative density of loose to very dense.

The moisture content for the samples tested ranged from 5% to 16%. The results of grain size analyses conducted on six samples of the glacial till are summarized in Table 5-3 and illustrated in Figure C2 in Appendix C.

Table 5-3 Gradation Results for Glacial Till

Soil Particle	Percentage (%)	
Gravel	15 – 35	
Sand	31 – 46	
Silt	35 – 40	24 – 33
Clay	7 – 10	

Atterberg Limits testing conducted on three samples of this material indicated a non-plastic silt (ML) material.

Glacial till inherently contains cobbles and boulders.

5.3 Bedrock

Bedrock was proven by coring in Boreholes 17-13 to 17-15, inclusive. Information on the bedrock surface is summarized in Table 5-4.

Table 5-4 Summary of Bedrock Elevations

Borehole No.	Depth to Bedrock (m)	Bedrock Elevation (m)
17-13	5.3	57.8
17-14	9.1	56.7
17-15	9.0	57.3

The bedrock encountered within Boreholes 17-13 through 17-15 consisted of slightly weathered to fresh limestone with black shale partings. The total core recovery (TCR) ranged from 81% to 100%, the solid core recovery (SCR) ranged from 77% to 100% with one value of 29%, and the rock quality designation (RQD) ranged from 62% to 100% with one value of 0%. Based on the RQD values, the bedrock is classified as very poor to excellent quality but is predominantly excellent.

Unconfined Compressive Strength (UCS) testing was carried out on the bedrock. The results of UCS testing carried out on three samples of the rock core ranged from 105 to 140 MPa, indicating the intact limestone bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

5.4 Groundwater

The groundwater level measured in the standpipe piezometer in Borehole 17-13 was recorded at a depth of 0.8 m (elev. 62.3 m) on August 3, 2018.

The water level in Borehole 17-16 was observed at 5.5 m below ground surface (elev. 57.5 m) during drilling. It is likely that this groundwater level has been affected by drilling operations.

The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 61.6 m on June 20, 2018. It is expected that the groundwater level will likely reflect the water level in the creek.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.5 Analytical Testing

One sample of the native soil was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, sulphide content, resistivity and conductivity. Results of the analyses are summarized in Table 5-5:

Table 5-5 Summary of Analytical Testing

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
17-13 (SS3)	1.5 – 2.1	87	7.9	1,710	583	227	0.19

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevations were surveyed by Thurber following completion of the field program.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. Beaconlite of Ottawa, Ontario supplied the traffic control equipment and personnel for TL-12 shoulder closures for the boreholes in conformance with Ontario Book 7 requirements. The field investigation was supervised on a full-time basis by either Mr. Justin Gray, E.I.T. or Miss Katya Edney, P.Eng. of Thurber. Overall supervision of the investigation program was conducted by Dr. Fred Griffiths, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Miss Allison Chow and Dr. Fred Griffiths, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

Allison Chow, B.A.Sc.
Geotechnical Engineer-in-Training



Dr. Fred Griffiths, P.Eng.
Senior Associate
Senior Geotechnical Engineer

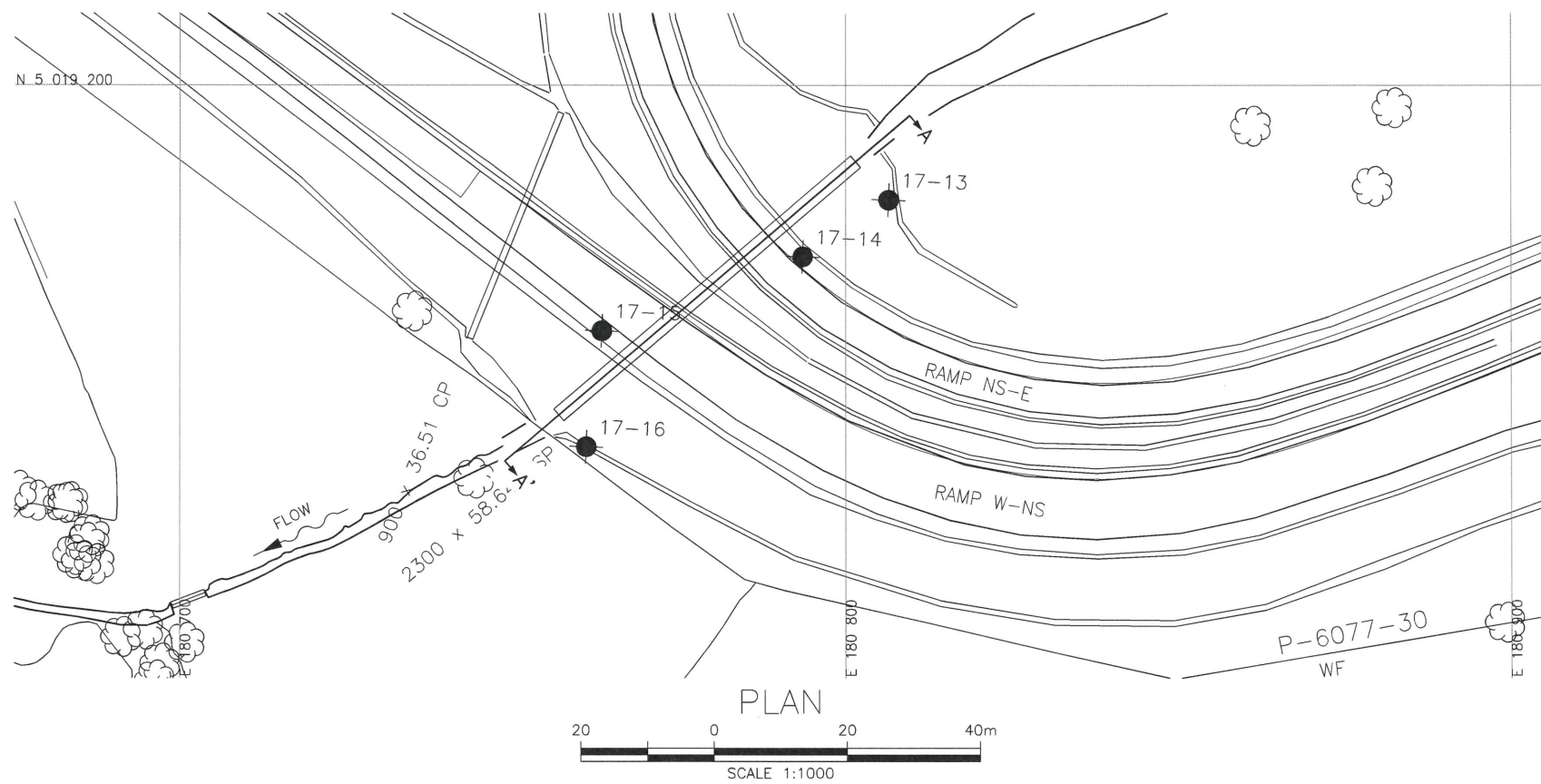


Dr. P.K. Chatterji, P.Eng.
Review Principal
Senior Geotechnical Engineer

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Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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



CONT No
GWP No 451-98-00

HIGHWAY 417
CULVERT 27-363/C
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEYPLAN

LEGEND

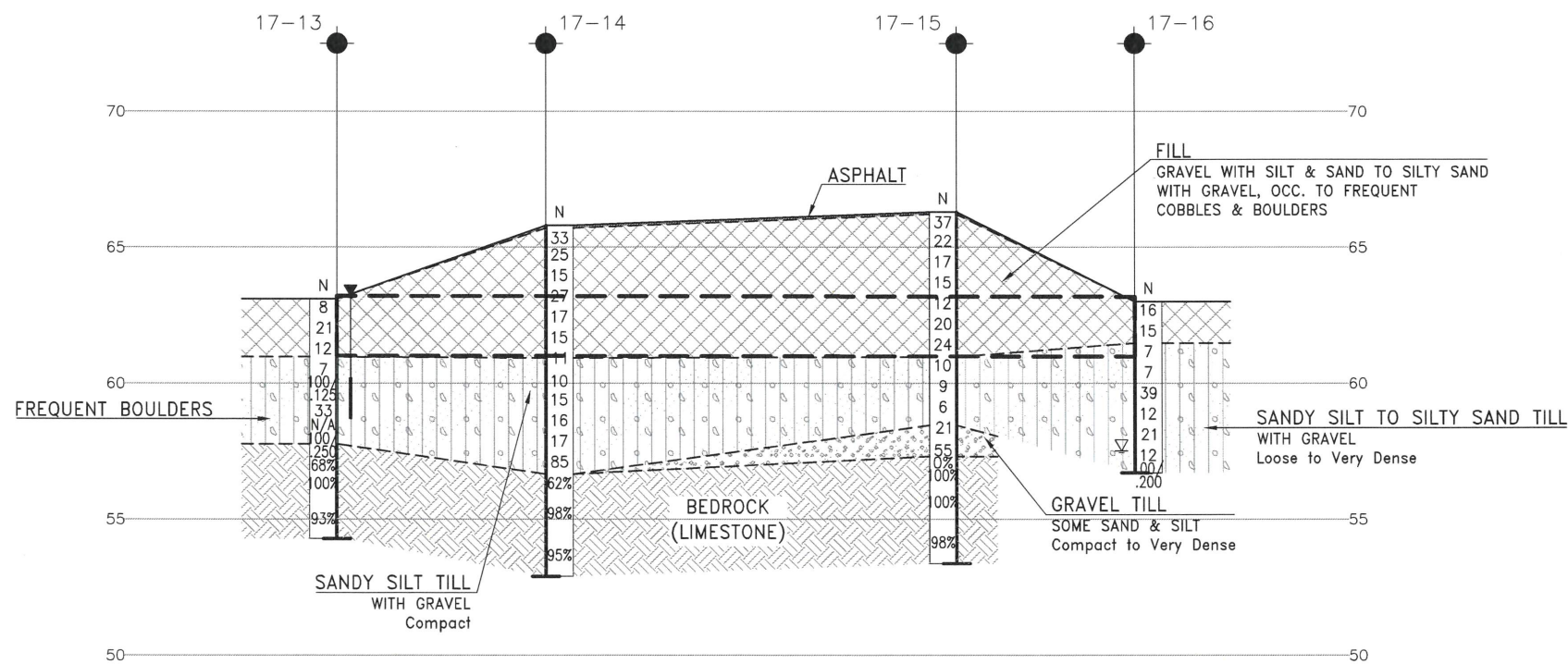
●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
⊥	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-13	63.1	5 019 182.7	180 806.4
17-14	65.8	5 019 174.2	180 793.5
17-15	66.3	5 019 163.1	180 763.3
17-16	63.0	5 019 145.6	180 761.0

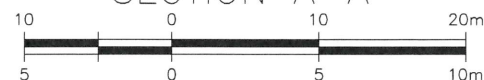
NOTES

- 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.
- Coordinate system is MTM NAD 83 Zone 8.

GEOCRES No. 31G-272



SECTION A-A'

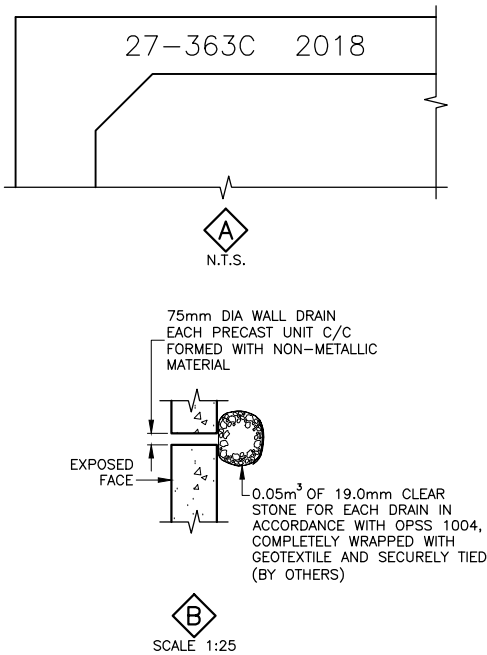
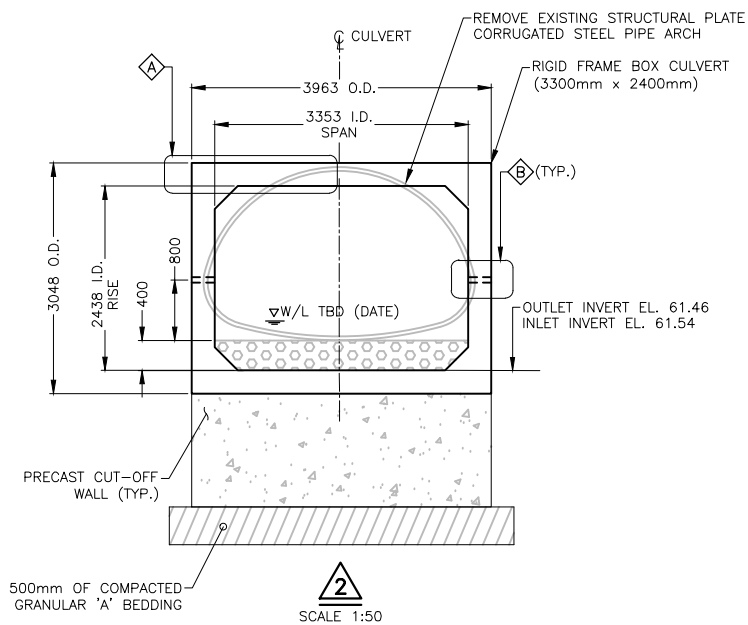
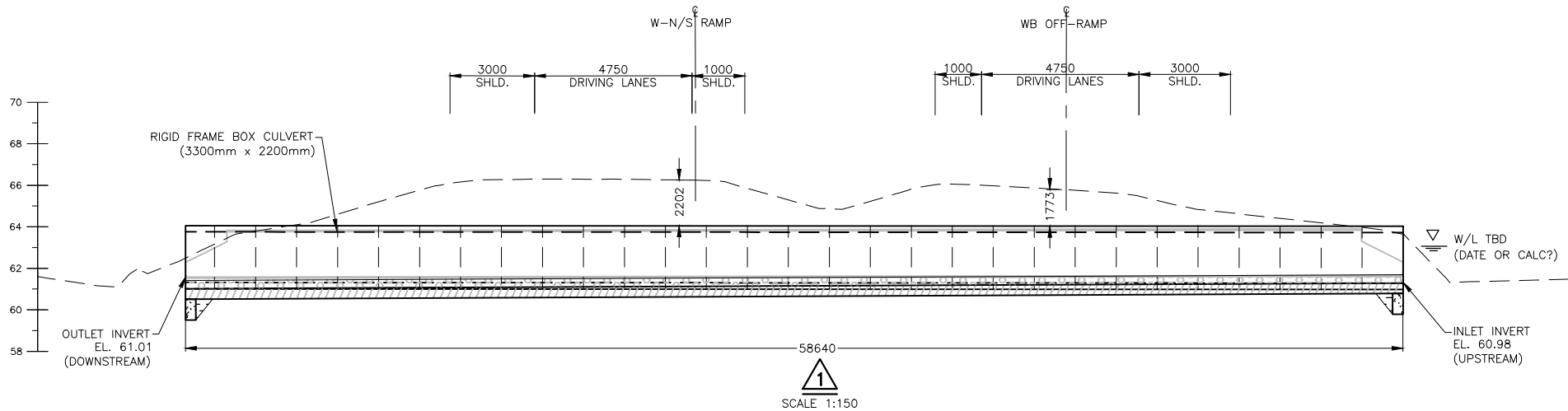
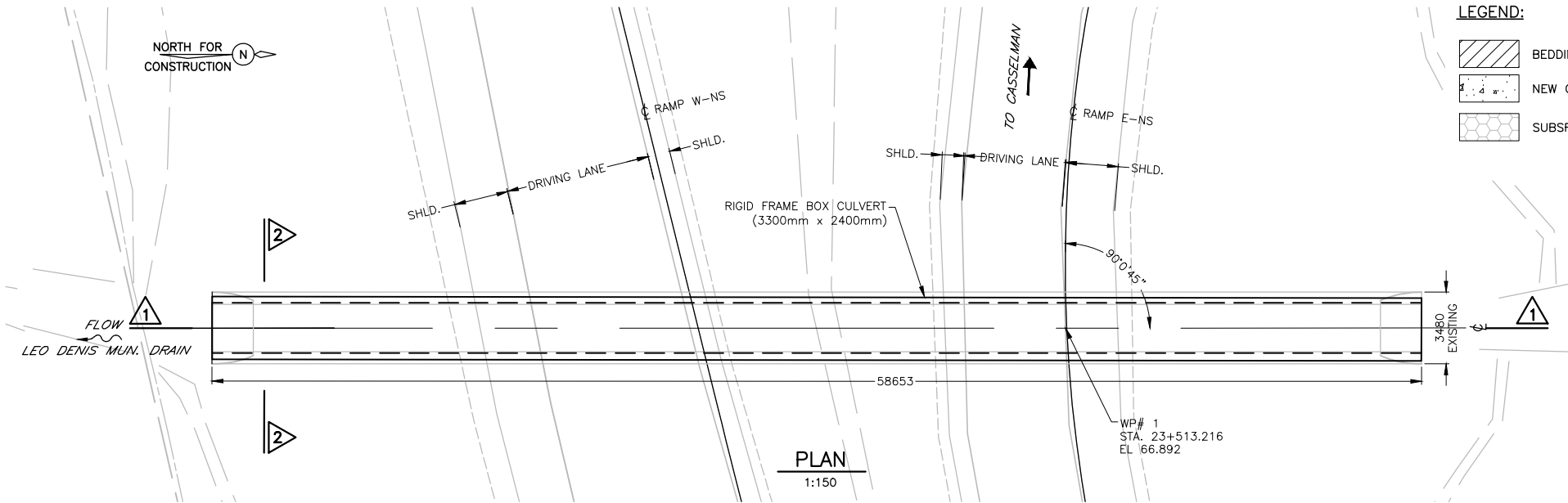


H 1:500

V 1:250

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KE	CHK PC	CODE
DRAWN	MFA	CHK KE	SITE
			LOAD
			STRUCT
			DWG 1
			DATE NOV 2018

DRAWING NAME: K:\MTO\17804 - Highway 417 Reconstruction\451-98-00 Working CT\Structural\17804-1 - Site No.27-363C - General Arrangement.dwg
CREATED: 2018-07-13 4:18 PM
MODIFIED: 2018-07-13
MINISTRY OF TRANSPORTATION, ONTARIO
PR-D-707 88-05



FLOW DATA: EXISTING CULVERT

DURATION	PEAK FLOW "Q" (m3/S)	WATER LEVEL (m)
2 YR.	1.394	-
5 YR.	2.341	-

GENERAL NOTES

- CLASS OF CONCRETE
35MPa UNLESS OTHERWISE NOTED.
- CLEAR COVER TO REINFORCING STEEL
PRECAST CONCRETE 50±10
ALL EXPOSED CORNERS TO BE CHAMFERED 20mm.
- REINFORCING STEEL
REINFORCING STEEL SHALL BE GRADE 400W UNLESS OTHERWISE SPECIFIED.
UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES SHALL BE CLASS B.
BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS WHILE STIRRUPS AND TIES SHALL HAVE MINIMUM HOOK DIMENSIONS. ALL HOOKS SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWINGS SS12-1, UNLESS INDICATED OTHERWISE.

CONSTRUCTION NOTES

- PRECAST END UNITS SHALL BE EQUAL LENGTH. ALL INTERNAL UNITS SHALL BE EQUAL LENGTH.
- BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF STRUCTURE KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 500mm.
- NO PRECAST UNIT SHALL BE PLACED UNTIL THE DEPTH OF THE EXCAVATION AND THE CHARACTER OF THE FOUNDATION HAVE BEEN APPROVED BY THE QUALITY VERIFICATION ENGINEER. CARE SHALL BE TAKEN NOT TO DISTURB THE FOUNDING SOILS.
- DESIGN SOILS BEARING CAPACITIES MUST BE VERIFIED BY THE QUALITY VERIFICATION ENGINEER ON SITE:
AT SLS = ____ kPa (TBD)
AT ULS = ____ kPa (ALONG THE JOINTS) (TBD)

SCOPE OF WORK *

- INSTALL AND CONTINUOUSLY MONITOR TEMPORARY FLOW PASSAGE SYSTEM AND MANAGE FLOW OF WATER FOR DURATION OF THE WORK.
- COMPLETE PRECONSTRUCTION SURVEY.
- REMOVE DEBRIS AND CLEAN CULVERT SURFACES.
- SUPPLY AND INSTALL RIGID BOX CULVERT AND CUT-OFF WALLS.

* NOT INTENDED TO SHOW SEQUENCE OF WORK

LIST OF ABBREVIATIONS

WP#	WORKING POINT NUMBER
EL.	ELEVATION
TYP.	TYPICAL
SHLD.	SHOULDER
DIA.	DIAMETER
STA.	STATION
W/L	WATER LEVEL
I.D.	INNER DIAMETER
O.D.	OUTER DIAMETER

LIST OF DRAWINGS

- GENERAL ARRANGEMENT

DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION
DESIGN ###	CHK ###	CODE ###	LOAD ###	DATE	###
DRAWN ###	CHK ###	SITE ###	DWG	##	

Appendix B.

Record of Borehole Sheets



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).

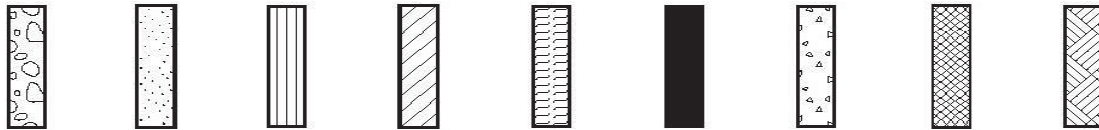
DYNAMIC CONE PENETRATION TEST (DCPT):

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

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.

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 (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 17-13

1 OF 1

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301652°, Long: -75.081065° Culvert Site 27-363/C MTM z8: N 5 019 182.7 E 180 806.4 ORIGINATED BY KE
HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY AC
DATUM Geodetic DATE 19.06.2018 - 19.06.2018 CHECKED BY FG

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			SHEAR STRENGTH kPa				W P W W L							
								○ UNCONFINED + FIELD VANE	WATER CONTENT (%)										
63.1							20	40	60	80	100								
0.0	SILTY GRAVEL with sand trace organics at surface occasional to frequent boulders and cobbles loose to compact grey-brown FILL		1	SS	8									○					
			2	SS	21									○					39 28 33 (SI+CL)
			3	SS	12									○					
61.0																			
2.1	SILTY SAND (SM) with gravel TILL frequent boulders loose to very dense grey		4	SS	7									○					
			5	SS	100/ 125 mm									○					
			6	SS	33									○					30 46 24 (SI+CL)
			7	NQ	N/A														
			8	SS	100/ 250 mm									○					
57.8																			
5.3	BEDROCK LIMESTONE with shale partings fresh to slightly weathered grey thinly bedded fine to medium grained very strong		1	NQ															RUN #1 TCR=100% SCR=100% RQD=68%
			2	NQ															RUN #2 TCR=100% SCR=100% RQD=100% UCS=140MPa
			3	NQ															RUN #3 TCR=100% SCR=100% RQD=93%
54.3																			
8.8	End of Borehole Water level in well at 0.8 mbgs (elev. 62.3 m) on 03/08/2018																		

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

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

RECORD OF BOREHOLE No 17-14

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301573°, Long: -75.081228° Culvert Site 27-363/C MTM z8: N 5 019 174.2 E 180 793.5 ORIGINATED BY JG
 HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG
 DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE								
								● QUICK TRIAXIAL × LAB VANE								
				WATER CONTENT (%)												
65.8	Paved Shoulder						20	40	60	80	100					
0.0	ASPHALT (100 mm)															
0.1	GRAVEL with silt and sand dense grey FILL		1	SS	33											
65.2	SILTY SAND compact brown FILL		2	SS	25											0 77 23 (SH+CL)
0.6																
			3	SS	15											
63.7	SILTY SAND with gravel compact grey FILL		4	SS	27											
2.1			5	SS	17											33 49 18 (SH+CL)
			6	SS	15											
60.9	SANDY SILT (ML) with gravel TILL compact grey		7	SS	11											
4.9			8	SS	10											
			9	SS	15											18 35 40 7 Non-plastic
58.5	SILTY SAND (SM) with gravel TILL compact to very dense grey		10	SS	16											
7.3			11	SS	17											
			12	SS	85											31 36 33 (SH+CL)
56.7	BEDROCK LIMESTONE grey fresh very strong		1	NQ												RUN #1 TCR=81% SCR=77% RQD=62%
9.1																

Continued Next Page

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

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE
<div>DYNAMIC CONE PENETRATION RESISTANCE PLOT</div> <div>SHEAR STRENGTH kPa</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>WATER CONTENT (%)</div> <div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div> <div>w p w w L</div> <div>UNIT WEIGHT γ</div> <div>REMARKS & GRAIN SIZE DISTRIBUTION (%)</div> <div>GR SA SI CL</div>					
Continued From Previous Page					
	BEDROCK LIMESTONE grey fresh very strong		2	NQ	
			3	NQ	
52.9					53
12.9	End of Borehole				

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-15

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301468°, Long: -75.081611° Culvert Site 27-363/C MTM z8: N 5 019 163.1 E 180 763.3 ORIGINATED BY JG
HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG
DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

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					
								<div><div><div>20406080100</div><div></div></div></div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>					
66.3	Paved Shoulder												
0.0	ASPHALT (100 mm)												
0.1	GRAVEL with silt and sand dense grey FILL		1	SS	37		66						
			2	SS	22								45 43 12 (SH+CL)
64.9	SILTY SAND compact brown FILL		3	SS	17		65						
1.4			4	SS	15		64						1 75 24 (SH+CL)
			5	SS	12		63						
62.8	SILTY SAND with gravel compact grey to brown FILL		6	SS	20		62						30 44 26 (SH+CL)
3.5			7	SS	24		61						
61.0	SANDY SILT (ML) with gravel TILL compact grey		8	SS	10		60						26 31 35 8 Non-plastic
5.3			9	SS	9								
			10	SS	6		59						
58.5			11	SS	21		58						
7.8	GRAVEL some sand and silt TILL compact to very dense grey		12	SS	55								
57.3			1	NQ			57						RUN #1 TCR=94% SCR=29% RQD=0% RUN #2 TCR=100% SCR=100% RQD=100%
9.0	BEDROCK LIMESTONE grey fresh very strong		2	NQ									

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

Continued Next Page

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

RECORD OF BOREHOLE No 17-15

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301468°, Long: -75.081611° Culvert Site 27-363/C MTM z8: N 5 019 163.1 E 180 763.3 ORIGINATED BY JG
 HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG
 DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

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




DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

RECORD OF BOREHOLE No 17-16

1 OF 1

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301311°, Long: -75.081635° Culvert Site 27-363/C MTM z8: N 5 019 145.6 E 180 761.0 ORIGINATED BY SOB
HWY 417 BOREHOLE TYPE HSA COMPILED BY AC
DATUM Geodetic DATE 27.06.2018 - 27.06.2018 CHECKED BY FG

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 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 (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
								20 40 60 80 100									20 40 60		
63.0																			
0.0	SILTY SAND some gravel compact grey-brown FILL		1	SS	16							○							
			2	SS	15		62					○							
61.5																			
1.5	SANDY SILT (ML) with gravel TILL loose to dense grey		3	SS	7		61					○							
			4	SS	7		60					○							
			5	SS	39							○				15 36 39 10			
																Non plastic			
			6	SS	12		59					○							
			7	SS	21		58					○							
57.7																			
5.3	SILTY SAND (SM) with gravel TILL trace clay compact to very dense grey		8	SS	12							○				35 41 24 (SI+CL)			
56.7			9	SS	100/		57					○							
6.3	End of Borehole Water level during drilling operations at 5.5 mbgs (elev. 57.5 m)				200 mm														

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

Appendix C.
Laboratory Testing

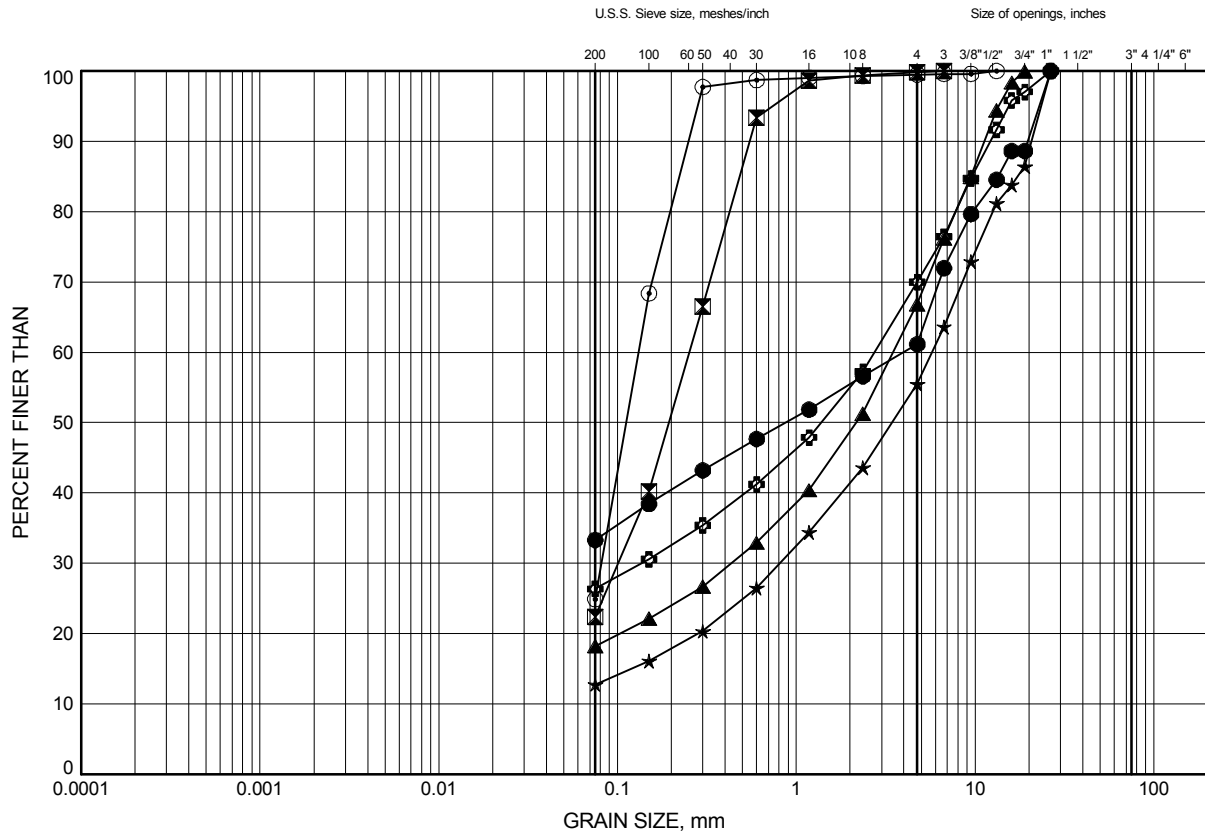
Appendix C.1
Particle Size Analysis Figures

Site 27-363/C

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-13	1.1	62.1
⊠	17-14	1.1	64.7
▲	17-14	3.4	62.4
★	17-15	1.1	65.2
⊙	17-15	2.6	63.7
⊞	17-15	4.9	61.4

Date November 2018

GWP# 451-98-00



Prep'd KE

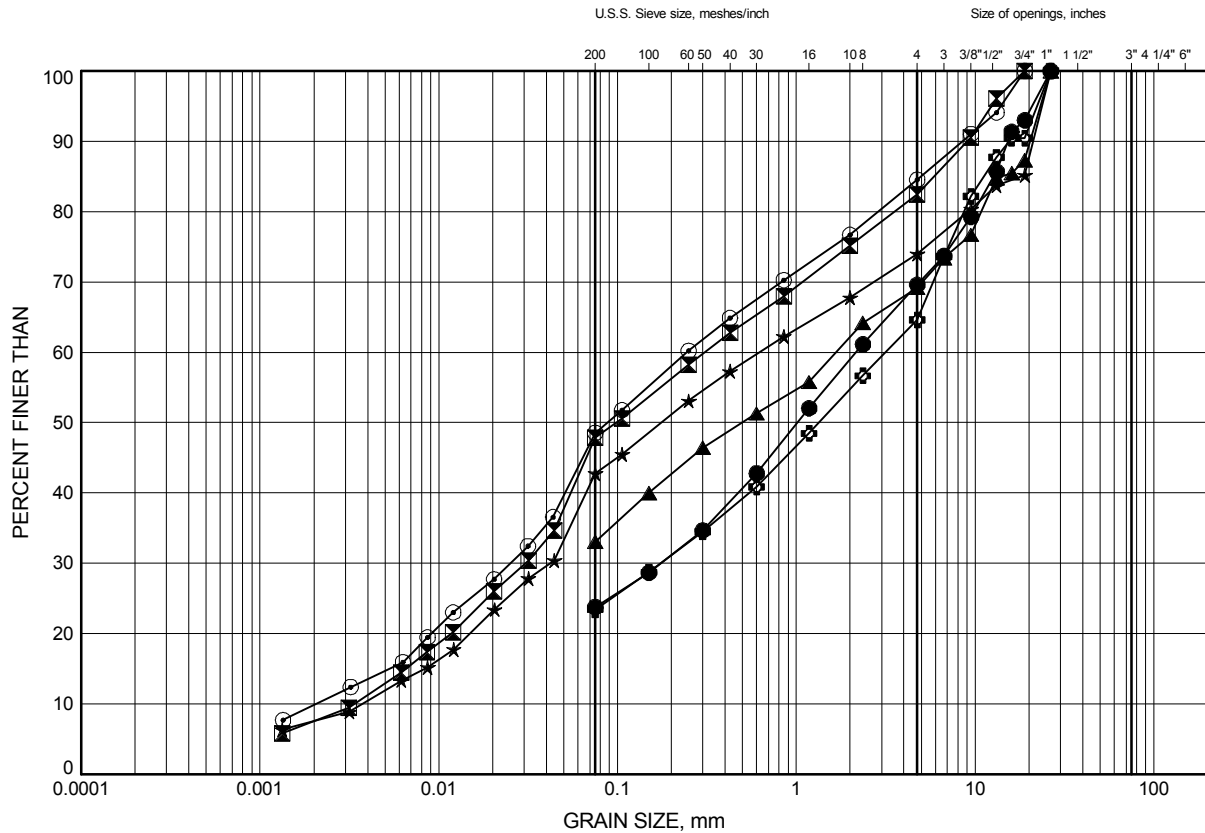
Chkd. FG

Site 27-363/C

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty Sand to Sandy Silt (GLACIAL TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-13	4.1	59.0
⊠	17-14	6.4	59.4
▲	17-14	8.7	57.1
★	17-15	7.2	59.1
⊙	17-16	3.4	59.7
⊕	17-16	5.6	57.4

Date November 2018

GWP# 451-98-00



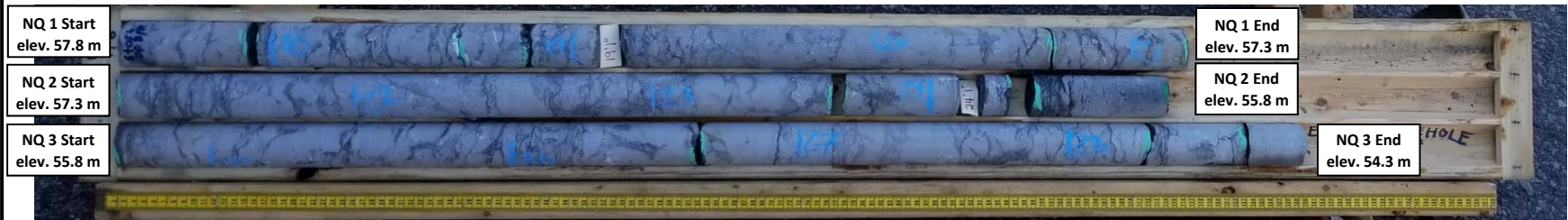
Prep'd KE

Chkd. FG

Appendix C.2

Rock Core Photos and Testing Results

Borehole 17-13
Run 1 to 3 (of 3)
Elevation 57.8 m to 54.3 m



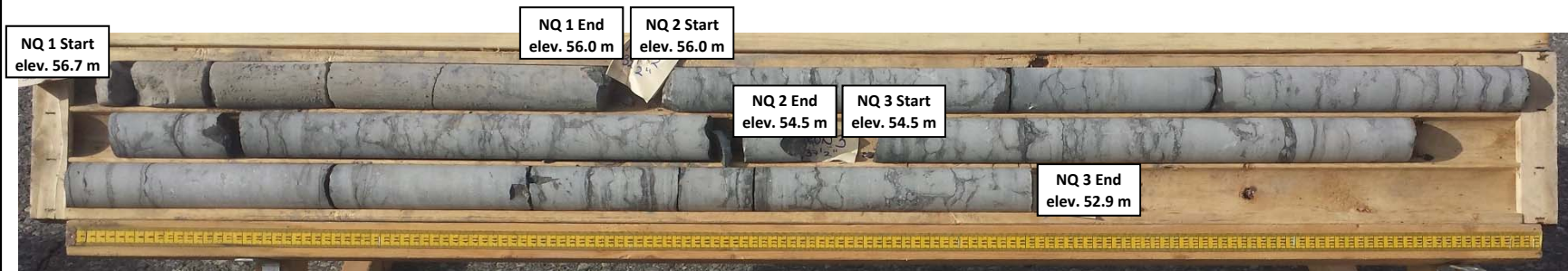
THURBER ENGINEERING LTD.

Foundation Investigation
Highway 417 Interchange 27-363/C
Foundations

GWP: 451-98-00

Project No.: 18310

Borehole 17-14
Run 1 to 3 (of 3)
Elevation 56.7 m to 52.9 m



Borehole 17-15
Run 1 to 4 (of 4)
Elevation 57.3 m to 53.4 m





Stantec

Stantec Consulting Ltd
2781 Lancaster Rd, Suite 100 A&B
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 722-2799

July 11, 2018
File: 122410864

Attention: Thurber Engineering Ltd., File #18310

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
17-1	Run 2 @ 22'4"	143.6	Well-formed cone on one end
17-5	Run 2 @ 36'4"	138.0	Well-formed cone on one end
17-10	Run 2 @ 53'7"	98.0	Reasonably well-formed cones on both ends
17-11	Run 3 @ 51'10"	127.4	Vertical cracking through both ends
17-13	Run 2 @ 23'10"	140.4	Specimen shattered

Sincerely,

Stantec Consulting Ltd

Denis Rodriguez
Laboratory Technician
Tel: 613-738-6075
denis.rodriguez@stantec.com



Stantec

Stantec Consulting Ltd
2781 Lancaster Rd, Suite 100 A&B
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 722-2799

November 6, 2017
File: 122410864

Attention: Thurber Engineering Ltd., File #18310

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes six rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
BH17-2 Run-2	35'9"	134.1	Two well-formed cones on either end
BH17-3 Run-2	33'6"	133.5	Two well-formed cones on either end
BH17-6 Run-3	41'2"	104.5	Well-formed cone on bottom, vertical cracks through top
BH17-7 Run-2	32'8"	152.7	Well-formed cone on bottom, vertical cracks through top
Bh17-14 Run-3	36'10"	105.2	Two well-formed cones on either end
BH17-15 Run-2	32'5"	107.5	No well-formed cones, cracks throughout core

Sincerely,

Stantec Consulting Ltd

Brian Prevost

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
brian.prevost@stantec.com

Appendix C.3
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Client PO: 18310
Project: Site 27-363/C
Custody: 39853

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018

Order #: 1826163

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

Paracel ID	Client ID
1826163-01	17-13, SS3, 5'-7'

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-363/C

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	27-Jun-18	27-Jun-18
Conductivity	MOE E3138 - probe @25 °C, water ext	27-Jun-18	29-Jun-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	26-Jun-18	27-Jun-18
Resistivity	EPA 120.1 - probe, water extraction	27-Jun-18	27-Jun-18
Solids, %	Gravimetric, calculation	27-Jun-18	27-Jun-18

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018

Order Date: 25-Jun-2018

Project Description: Site 27-363/C

Client ID:	17-13, SS3, 5'-7'	-	-	-
Sample Date:	06/19/2018 09:00	-	-	-
Sample ID:	1826163-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	91.3	-	-	-
----------	--------------	------	---	---	---

General Inorganics

Conductivity	5 uS/cm	583	-	-	-
pH	0.05 pH Units	7.90	-	-	-
Resistivity	0.10 Ohm.m	17.1	-	-	-

Anions

Chloride	5 ug/g dry	227	-	-	-
Sulphate	5 ug/g dry	87	-	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
 Order Date: 25-Jun-2018
Project Description: Site 27-363/C

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: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-363/C

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	265	5	ug/g dry	282			6.1	20	
Sulphate	146	5	ug/g dry	151			3.0	20	
General Inorganics									
Conductivity	293	5	uS/cm	290			1.1	6.2	
pH	7.89	0.05	pH Units	7.83			0.8	10	
Resistivity	34.1	0.10	Ohm.m	34.5			1.1	20	
Physical Characteristics									
% Solids	84.4	0.1	% by Wt.	85.3			1.0	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-363/C

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	374	5	ug/g	282	92.2	78-113			
Sulphate	254	5	ug/g	151	104	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-363/C

Qualifier Notes:

Login Qualifiers :

Asbestos - Limited quantity
Applies to samples: 17-13, SS3, 5'-7'

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.

Subcontracted Analysis

Thurber Engineering Ltd.
2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Tel: (613) 408-6795
Fax: (613) 247-2185

Paracel Report No **1826163**
Client Project(s): **Site 27-363/C**
Client PO: **18310**
Reference: **Standing Offer**
CoC Number: **39853**

Order Date: 25-Jun-18
Report Date: 05-Jul-18

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1826163-01	17-13, SS3, 5'-7'	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6,

Phone: 613-731-9577
Fax:613-731-9064

05-July-2018

Date Rec. : 27 June 2018
LR Report: CA12934-JUN18
Reference: Project#:1826163

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		05-Jul-18
2: Analysis Start Time		10:43
3: Analysis Completed Date		05-Jul-18
4: Analysis Completed Time		13:07
5: QC - Blank		<0.02
6: QC - STD % Recovery		85%
7: QC - DUP % RPD		11%
8: RL		0.02
9: 17-13, SS3, 5'-7'	19-Jun-18	0.19

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist
Environmental Services, Analytical

Appendix D.

Site Photographs



Photo 1. Looking east towards inlet.



Photo 2. Looking west from N/S-E ramp along culvert alignment



Photo 3. Looking south on W-N/S ramp towards culvert crossing



Photo 4. Looking west at culvert outlet