



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION REPORT
REPLACEMENT OF STRUCTURAL CULVERT No. 29-232/C
MUSKRAT CREEK CROSSING OF HIGHWAY 17
RENFREW COUNTY
W.P. 4113-01-01
AGREEMENT NUMBER: 4014-E-0014**

GEOCRES NUMBER: 31F-201

SUBMITTED TO

WSP CANADA

LOCATION:

LATITUDE: 45.58687°

LONGITUDE: -76.83145°

APRIL 2018

19-5161-263



Table of Contents

PART 1: FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION	1
3	SITE INVESTIGATION	2
3.1	Field Investigation	2
3.2	LABORATORY TESTING	3
4	DESCRIPTION OF SUBSURFACE CONDITIONS	4
4.1	Overview / General	4
4.2	Asphalt.....	4
4.3	Topsoil.....	4
4.4	Fill.....	4
4.5	Sand with Silt / Silty Sand	5
4.6	Clay	5
4.7	Silt with Sand	5
4.8	Silty Sand with Gravel Till	6
4.9	Granite Bedrock.....	6
4.10	Groundwater Conditions	6
5	MISCELLANEOUS	7

APPENDICES

Appendix A	Borehole Locations and Soil Strata Drawings
	Preliminary General Arrangement Drawing
Appendix B	Record of Borehole Sheets
Appendix C	Laboratory Test Results
Appendix D	Seismic Cone Penetration Testing Results
Appendix E	Site Photographs

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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 the replacement of the Muskrat Creek Culvert located on Highway 17, within Renfrew County. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP) as part of Agreement No. 4014-E-0014.

No previous foundation investigation information for the subject culvert was available. A General Arrangement (GA) drawing and base plan mapping were provided by WSP for the preparation of this report.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

Culvert 29-232/C is located on Highway 17, approximately 5.7 km east of Cobden, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

The existing culvert is a cast-in-place, concrete, open bottom, rigid frame culvert, with an internal span of 3.1 m, a height of 1.8 m and an approximate length of 25 m. Water flow is from north to south below the highway. The December 2017 Preliminary GA drawing, also provided in Appendix A, indicates that the elevation of the top of the existing stream bed ranges from Elevation 146.7 m at the inlet to 147.0 m at the outlet.

It is noted that for project orientation purposes, Highway 17 within the project limits, will be assumed to run west-east. Based on the preliminary GA drawing, the Highway 17 cross-section consists of two 3.75 m wide lanes with granular shoulders ranging from 2.5 m to 2.9 m in width. A three-cable guide rail system is present along both sides of the highway in the vicinity of the culvert.

The slopes of the embankment were observed to be covered with wild grass and brush; no signs of settlement or instability were noted. The embankment slopes were graded with slopes ranging from approximately 2.0H:1V to 2.5H:1V (Horizontal:Vertical). The elevation at the centreline of the roadway was surveyed at approximately 149.7 m. The elevation of the top of the culvert was approximately 149.1 m and 149.0 m at the inlet and outlet respectively, providing for 600 to 700 mm of cover.

The site is located within a physiographic region known as the Muskrat Lake Ridges which is characterized as a steep scarp composed of Precambrian rocks overlain by a thin overburden deposit of sand and gravel. (Chapman and Putnam 1984)

The lands surrounding the culvert include, forest, brush, swampy areas and farm fields. The creek channel both upstream and downstream of the culvert is a narrow meandering channel within a swampy area. The water level was fairly low with little visible flow at the time of the field investigation (see Photos 2, 3 and 4 in Appendix E). The storm water drainage in the area is to existing culverts and ditches.

Site photographs showing the general conditions at the site, along the highway embankment and at the inlet and outlet are presented in Appendix E.

3 SITE INVESTIGATION

3.1 Field Investigation

A field investigation was carried out between June 23 and 24, 2015, and included advancing four boreholes. Due to the shallow termination depth of Borehole 601, an additional borehole, Borehole 601A, was advanced approximately 1.5 m north and west of Borehole 601.

A supplemental investigation was carried out on May 23, 2017, to further assess the very loose to loose silt and sand deposits that had been identified in the boreholes. The supplemental investigation included advancing four seismic cone penetration tests (SCPT) through the roadway, two on each side of the existing culvert. Pore pressure dissipation tests and shear wave velocity measurements were carried out in each SCPT test hole. A copy of the Seismic Cone Penetration Testing Results is provided in Appendix D.

The approximate locations and elevations of the test holes are shown on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Test Hole Summary

Test Hole	Type	Location	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (m)	Depth (m)
601	Borehole	Culvert Inlet	45.58692	-76.83132	148.8	3.4
601A	Borehole	Culvert Inlet	45.58694	-76.83132	148.2	2.3
602	Borehole	Highway 17 Westbound	45.58681	-76.83134	149.6	9.1
603	Borehole	Highway 17 Eastbound	45.58685	-76.83145	149.6	9.2
604	Borehole	Culvert Outlet	45.58674	-76.83147	148.6	7.6
17-01	SCPT	Highway 17 Westbound	45.58707	-76.83162	149.6	4.8
17-02	SCPT	Highway 17 Westbound	45.58688	-76.83141	149.7	6.7
17-03	SCPT	Highway 17 Eastbound	45.58679	-76.83138	149.7	8.0
17-04	SCPT	Highway 17 Eastbound	45.58660	-76.83117	149.7	7.3

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to obtain utility locates/clearances for the intended borehole locations.

Boreholes 602 and 603 were advanced through the roadway embankment with a CME truck mounted drill rig using hollow stem augers. The inlet and outlet boreholes (Boreholes 601, 601A and 604) were advanced with portable drilling equipment using a full weight hammer, tripod and casing with washboring.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing. Bedrock was cored in all boreholes except Borehole 602 with NQ size coring equipment following ASTM Standard D6032-08. Bedrock core samples were stored in core boxes for transport.

A 25 mm inside diameter PVC piezometer was installed in Borehole 604 to measure the groundwater level at the site. Piezometer construction details are illustrated on the Record of Borehole sheet for Borehole 604, provided in Appendix B. The piezometer was decommissioned on December 16, 2015, after the water levels were measured.

The four SCPT test holes were advanced to refusal with a 30 Ton CPT truck mounted drill rig. Further details regarding the equipment and methodology are provided in Appendix D. The pavement structure at the SCPT test holes was pre-augered to a depth of approximately 1.5 m before advancing the cone.

The test holes without a piezometer were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Test holes advanced within the paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the test holes and ground surface elevations at the borehole locations were surveyed by Thurber. The vertical datum used was a round iron bar identified on the plans provided by WSP, as a horizontal control point (HCP) and as having a geodetic elevation of 148.708 m. The location of the TBM, located at Station 18+872, is indicated on Drawing No. 1 in Appendix A.

3.2 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses, and Atterberg Limits testing were also carried out on selected samples to MTO and ASTM standards. All recovered bedrock core was logged and core recoveries and RQD values were measured.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on two soil samples. A copy of the chemical analysis results is provided in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / 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 area is presented on Drawing No. 1 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 stratigraphy within the highway adjacent to the culvert is characterized by an asphalt pavement structure, overlying sand with silt and gravel fill, overlying sand with silt and gravel overlying silt with sand, underlain by bedrock.

The bedrock profile varies considerably across the site from the south to north. The depth below existing grade to the bedrock surface ranged from 1.2 m to 2.7 m at the culvert inlet. At the culvert outlet the depth to the bedrock surface ranged from 6.7 m to 7.8 m.

More detailed descriptions of the individual strata are presented below.

4.2 Asphalt

Two boreholes were advanced through the Highway 17 pavement structure. The thickness of the asphalt was measured as 250 mm and 300 mm.

4.3 Topsoil

A layer of topsoil with a thickness of 150 mm was encountered in the outlet Borehole 604. Topsoil thickness may vary between boreholes and in other areas of the site.

4.4 Fill

A granular fill layer consisting predominantly of sand and gravel with varying amounts of silt was encountered below the surficial materials in all boreholes. The top of this layer ranges from Elevation 148.2 m to 149.4 m. The thickness of the layer ranged from 1.2 m to 2.2 m. The SPT 'N' values generally ranged from 5 to 26; indicating a loose to compact condition. One SPT conducted within the pavement structure base material resulted in 100 blows for 225 mm of penetration.

The moisture content of the samples tested ranged from 2% to 24%. The results of grain size analysis conducted on four samples of the fill material are summarized in Table 4-1 and are illustrated on Figure 1 in Appendix C.

Table 4-1: Gradation Results for Granular Fill

Soil Particles	%
Gravel	20 to 46
Sand	43 to 69
Silt and Clay	9 to 13

4.5 Sand with Silt / Silty Sand

A stratum of sand with silt to silty sand was encountered beneath the fill materials in boreholes 601, 602 and 603. The top of this layer ranges from Elevation 146.8 m to 147.3 m. The thickness of the layer ranged from 0.6 m to 2.9 m. The SPT 'N' values ranged from 2 to 21; indicating a very loose to compact condition; but typically very loose.

The moisture content for the samples tested ranged from 19% to 46%. A trace amount of organic matter was identified within this deposit in Borehole 603. The results of grain size analysis conducted on three samples of this material are summarized in Table 4-2 and are illustrated on Figure 2 in Appendix C.

Table 4-2: Gradation Results for Sand with Silt

Soil Particles	%
Gravel	0 to 19
Sand	33 to 90
Silt and Clay	9 to 48

4.6 Clay

A thin stratum of clay was encountered below the sand with silt stratum in Borehole 602. This layer was encountered at Elevation 144.7 m and has a thickness of 300 mm. The moisture content of the sample tested was 23%. Insufficient sample recovery limited the amount of laboratory testing that could be conducted on this material.

4.7 Silt with Sand

A stratum of silt with sand was encountered beneath the fill materials in Borehole 604, beneath the sand with silt stratum in Borehole 603 and below the clay layer in Borehole 602. The top of this layer ranges from Elevation 144.3 m to 146.2 m. The thickness of the layer ranged from 1.5 m to 4.3 m. The SPT 'N' values ranged from 1 to 15; indicating a very loose to compact condition; but typically very loose to loose.

The moisture content for the samples tested ranged from 13% to 27%. The results of grain size analysis conducted on five samples of this material are summarized in Table 4-3 and are illustrated on Figure 3 in Appendix C.

Table 4-3: Gradation Results for Silt with Sand

Soil Particles	%
Gravel	0 to 4
Sand	14 to 41
Silt	39 to 79
Clay	6 to 17

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

4.8 Silty Sand with Gravel Till

A glacial till layer consisting predominantly of silty sand with frequent boulders was encountered in Borehole 602. This layer was encountered at Elevation 142.8 m. Borehole 602 was terminated in this layer. An SPT 'N' value of 14 was obtained at one test depth. Below that depth, 100 blows resulted in 0 mm of penetration due to an inferred boulder.

The moisture content for the samples tested was 10% and 24%. The results of a grain size analysis test completed on a single sample of this material indicated a gravel content of 0%, a sand content of 68%, and a fines content (combined silt and clay size particles) of 32%. The results of grain size analysis are illustrated on Figure 4 in Appendix C.

4.9 Granite Bedrock

The overburden materials were underlain by a grey granite bedrock. All boreholes except Borehole 602 were advanced into bedrock by coring with NQ-size coring equipment. The bedrock profile varies considerably across the site from the north (inlet) to south (outlet).

A summary of the bedrock surface elevation is provided in Table 4-1.

Table 4-4: Bedrock Summary

Borehole	Location	Ground Surface Elevation (m)	Depth Below Existing Grade (m)	Top of Bedrock Elevation (m)
601	Culvert Inlet	148.8	2.7	146.1
601A	Culvert Inlet	148.2	1.2	146.9
603	Highway 17 Eastbound	149.6	7.8	141.8
604	Culvert Outlet	148.6	6.7	141.9

The bedrock was noted as being slightly weathered to fresh with a fracture index of 1 fracture per 0.3 m.

The total core recovery ranged from 80% to 97%, the solid core recovery ranged from 67% to 86% and the RQD values ranged from 46% to 68%. Based on the RQD values the rock mass quality ranges from poor to fair.

4.10 Groundwater Conditions

The groundwater levels were measured in the piezometer installed in Borehole 604 on December 16, 2015, at a depth of 0.93 m; corresponding to Elevation 147.7 m.

The water level in Muskrat Creek was measured at the time of Thurber's 2015 field investigation at a depth of 1.5 m below the top of the culvert at the inlet; corresponding to Elevation 147.5 m. The groundwater level in the area of the culvert is expected to reflect the water level in Muskrat Creek.

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

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by WSP Canada. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. ConeTec Investigation Ltd. supplied and operated the Seismic Cone Penetration Testing equipment. George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the pre-auguring required for SCPT testing at the site. The drilling, sampling and SCPT testing operations in the field were supervised on a full-time basis by Mr. Simon Paxton and Mr. Christopher Murray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.
Geotechnical Engineer



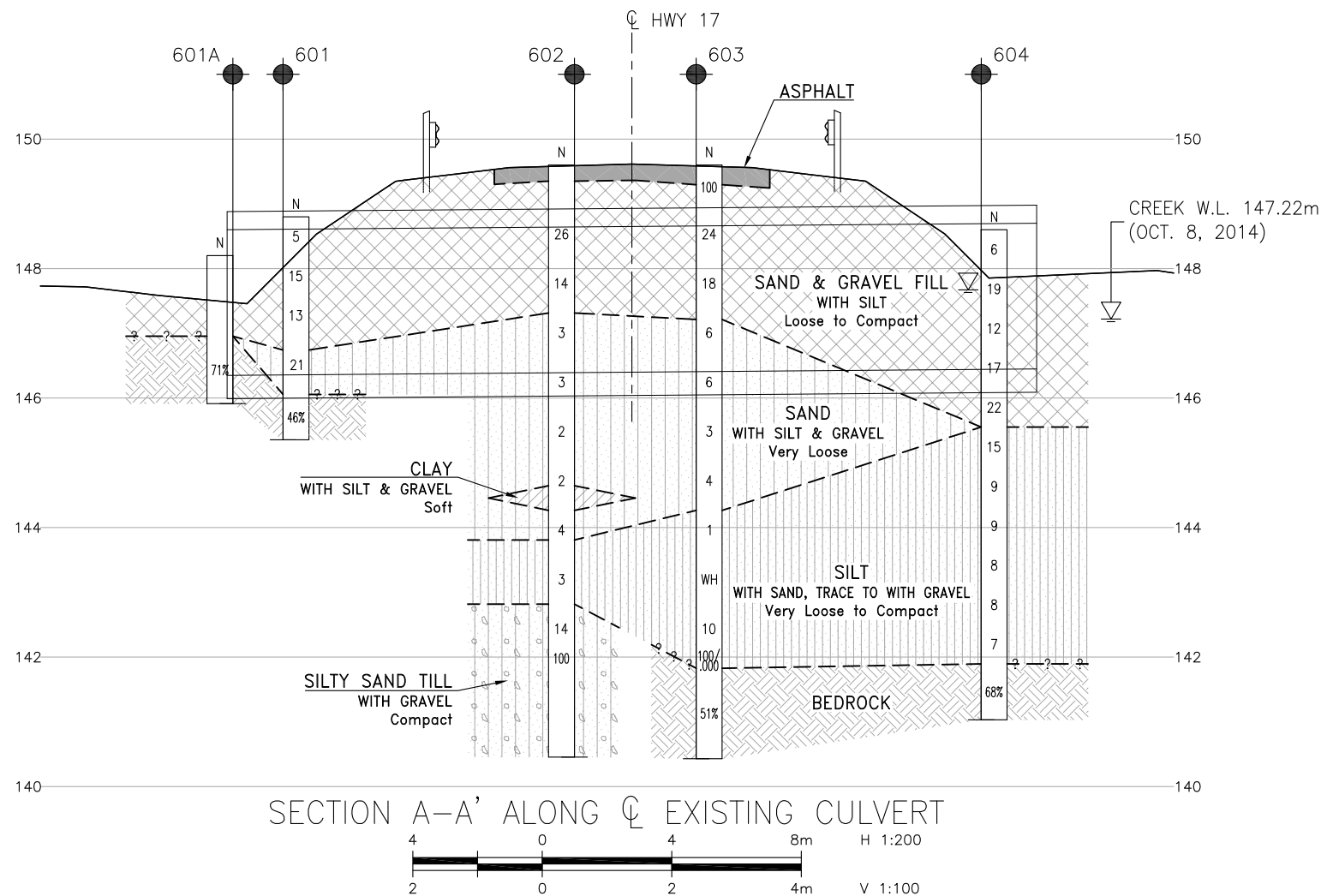
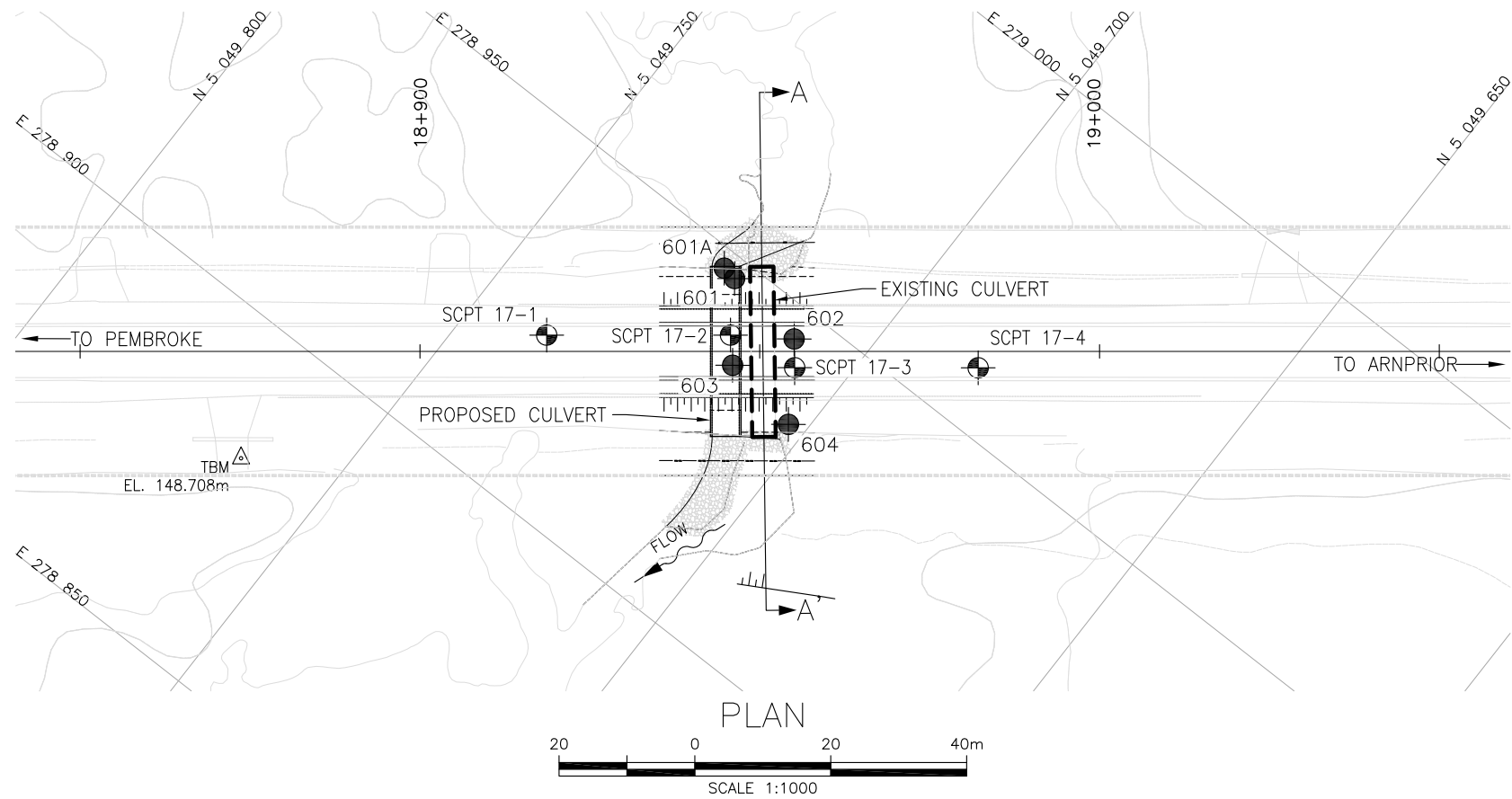
Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer



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

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS PRELIMINARY GENERAL ARRANGEMENT DRAWING



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

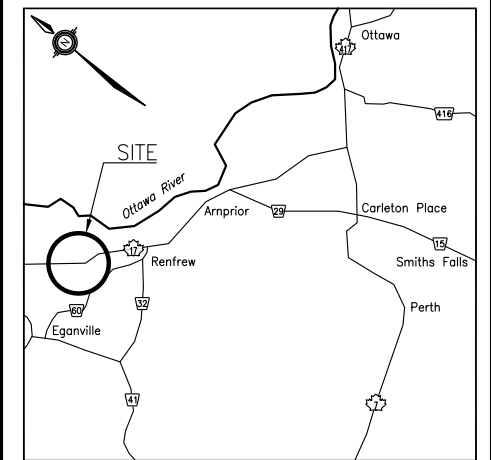


CONT No
WP No 4113-01-01

HIGHWAY 17
MUSKRAT CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



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KEYPLAN

LEGEND

●	Borehole
⊕	SCPT Hole
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

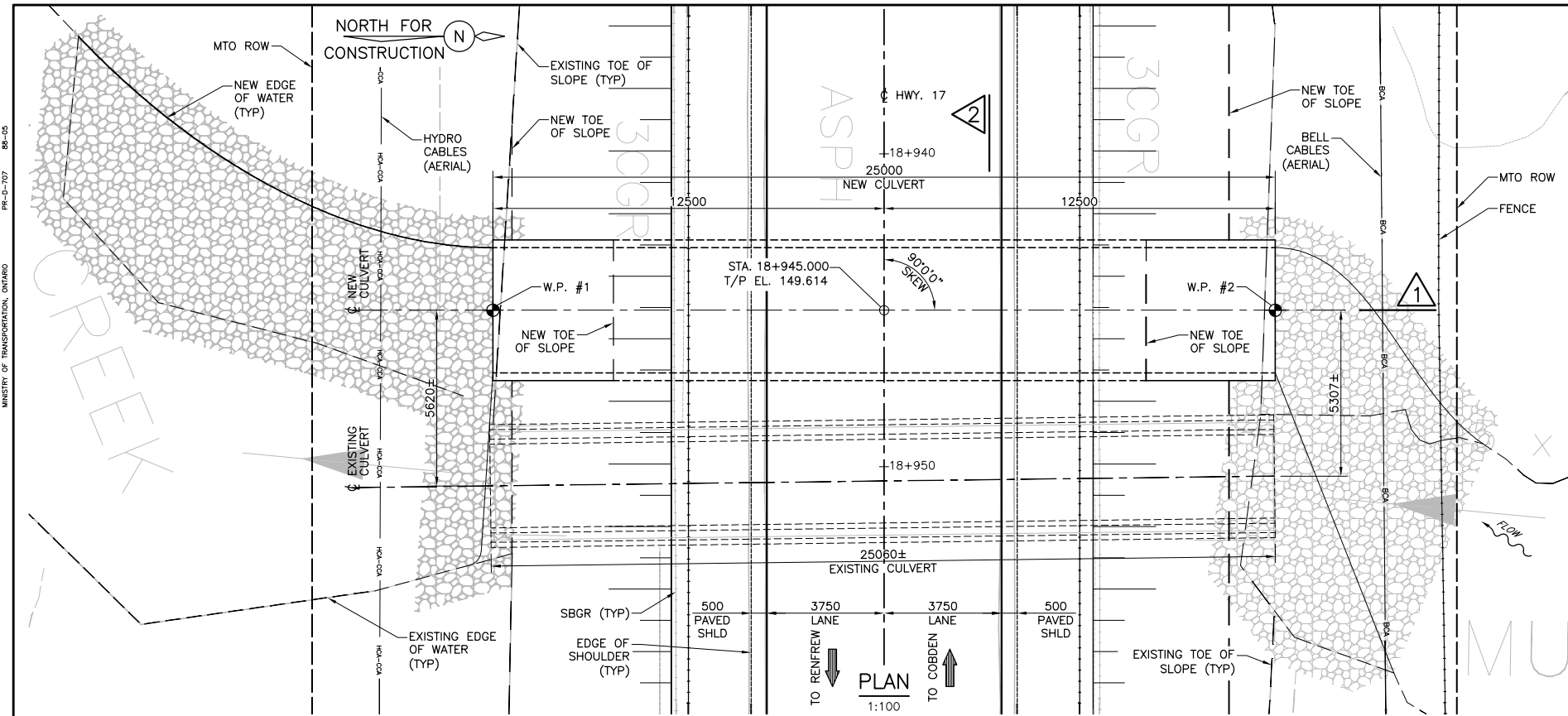
NO	ELEVATION	NORTHING	EASTING
601	148.800	5049722.054	278947.074
601A	148.200	5049724.194	278947.344
602	149.600	5049709.674	278945.473
603	149.600	5049714.416	278936.843
604	148.600	5049702.590	278935.053
SCPT 17-1	149.6	5 049 738.7	278 923.5
SCPT 17-2	149.7	5 049 717.4	278 940.2
SCPT 17-3	149.7	5 049 707.0	278 942.2
SCPT 17-4	149.7	5 049 685.7	278 958.8

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.
- Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRES No. 31F-201

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK KP	SITE 29-232/C/STRUCT
LOAD	DATE	APR 2018	DWG 1



SCOPE OF WORK:

THE FOLLOWING SCOPE OF WORK IS NOT INTENDED TO BE AN EXHAUSTIVE LIST OF ALL ITEMS REQUIRED TO COMPLETE THE REHABILITATION WORK, NOR IS IT INTENDED TO PROVIDE A SEQUENCE OF CONSTRUCTION ACTIVITIES.

STAGE 1:

1. INSTALL ENVIRONMENTAL PROTECTION, COFFERDAMS, TEMPORARY CONCRETE BARRIERS AND TRAFFIC CONTROL MEASURES. TEMPORARILY WIDEN SHOULDERS AND PAVE ROADWAY.
2. INSTALL GABION WALL RETAINING SYSTEM ON THE NORTH PORTION OF THE NEW CULVERT.
3. DETOUR TRAFFIC TO NORTH SIDE OF THE STRUCTURE.

STAGE 2:

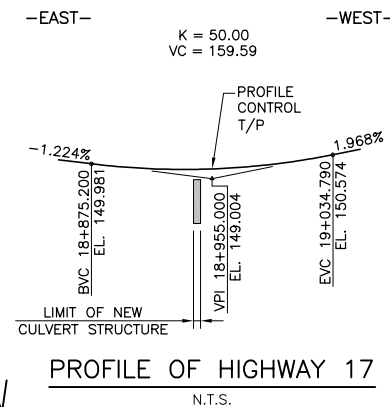
4. INSTALL PROTECTION SYSTEMS AND TEMPORARY FLOW PASSAGE SYSTEMS AND TEMPORARY SUPPORTS AS REQUIRED.
5. REMOVE EXISTING ASPHALT, EXCAVATE FOR NEW CULVERT CONSTRUCTION.
6. INSTALL BEDDING AND CONSTRUCT SOUTH PORTION OF NEW CULVERT.
7. BACKFILL CULVERT, GRADE, TEMPORARILY WIDEN SHOULDERS AND PAVE ROADWAY.

STAGE 3:

8. RELOCATE TEMPORARY CONCRETE BARRIERS AND DETOUR TRAFFIC TO SOUTH SIDE OF STRUCTURE.
9. REPEAT STEPS 4 TO 7 FOR THE NORTH PORTIONS OF THE EXISTING AND NEW CULVERT.
10. BACKFILL CULVERT.
11. INSTALL SUBSTRATE RIVERSTONE AND REALIGN CREEK INTO NEW CULVERT.
14. REMOVE TEMPORARY FLOW PASSAGE SYSTEM AND INFILL EXISTING CULVERT.
15. REMOVE PROTECTION SYSTEM AND REMOVE TEMPORARY WIDENINGS. PAVE ROADWAY.
16. REMOVE TRAFFIC CONTROL MEASURES, ASSOCIATED ENVIRONMENTAL PROTECTION MEASURES AND OPEN ROADWAY TO NORMAL TRAFFIC.

SUBSTRATE RIVERSTONE GRADATION	
% PASSING	STONE DIA. (mm)
100	225
75	200
50	150
30	75
20 (MIN)*	GRANULAR "A"
*FILL ALL VOIDS WITH GRANULAR "A"	

W.P. No.	NORTHING	EASTING
1	5049708.768	278927.982
2	5049724.175	278947.670

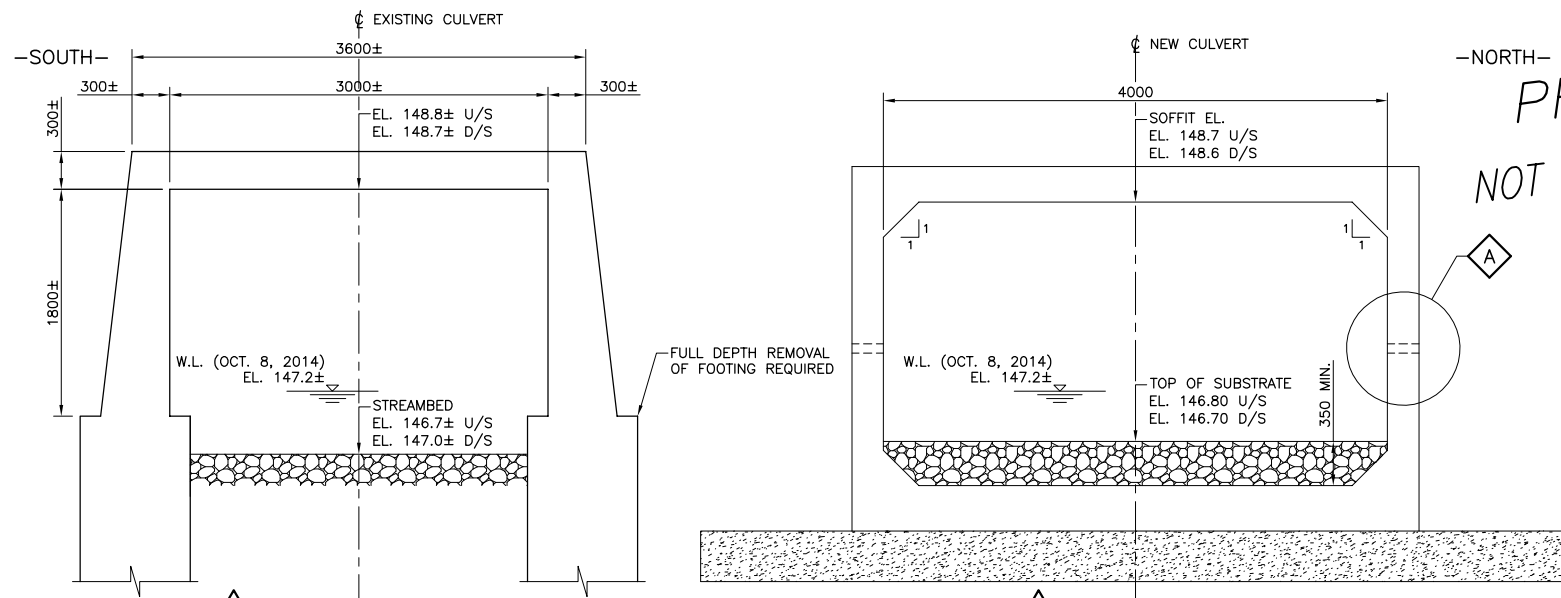


PROFILE OF HIGHWAY 17

N.T.S.

1 SECTION

1:100 EXISTING CULVERT AND STREAMBED NOT SHOWN FOR CLARITY



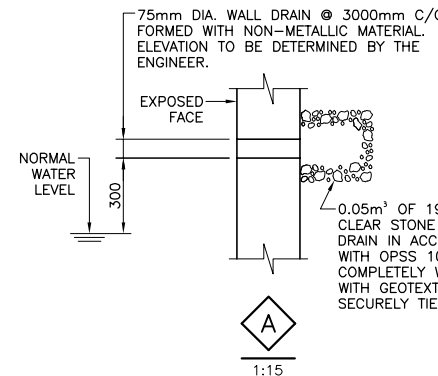
2 EXISTING CULVERT

1:30

2 NEW CULVERT

1:30

PRELIMINARY
2017/12/7
NOT FOR CONSTRUCTION



1:15

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

DISTRICT	CONT. No. WP No. 4113-01-01	
HWY 17 CULVERT REPLACEMENT MUSKRAT CREEK CULVERT SITE NO. 29-232/C	GENERAL ARRANGEMENT	SHEET
		METRIC

GENERAL NOTES:

1. CLASS OF CONCRETE

CLASS OF CONCRETE SHALL BE 30 MPa.

2. CLEAR COVER TO REINFORCING STEEL

BOTTOM OF TOP SLAB	40 ±10 FOR SLABS ≤ 300 THICK
	50 ±10 FOR SLABS > 300 THICK
BOTTOM OF BOTTOM SLAB	100 ±25
REMAINDER	60 ±20 UNLESS OTHERWISE NOTED

3. 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 AND UNLESS INDICATED OTHERWISE.

4. CONSTRUCTION NOTES

THE DESIGN-BUILDER SHALL VERIFY ALL DIMENSIONS AND ELEVATIONS OF THE EXISTING STRUCTURE AND ALL DETAILS ON SITE.

FOR STAGING AND MAINTENANCE OF TRAFFIC SEE GRADING DRAWINGS AND SPECIFICATIONS.

THE DESIGN-BUILDER IS RESPONSIBLE FOR THE DESIGN AND INSTALLATION OF ALL TEMPORARY STRUCTURES, CONSTRUCTION PLATFORMS AND DEBRIS CONTAINMENT SYSTEMS ECT.

ALL ELEVATIONS ARE TO GEODETIC DATUM.

BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF CULVERT KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 500mm.

THE PROPONENT SHALL REVIEW ALL FACTUAL GEOTECHNICAL DATA.

UTILITIES SHOWN ON DRAWING ARE REPRESENTATIVE ONLY. DESIGN-BUILDER TO PERFORM LOCATES.

THE DESIGN-BUILDER SHALL DESIGN PROTECTION SYSTEMS AND TEMPORARY FLOW PASSAGE SYSTEMS TO PERMIT EXCAVATION, REMOVAL AND RECONSTRUCTION OF THE CULVERT, BACKFILLING OPERATIONS AND AS REQUIRED TO COMPLETE THE WORK. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DETERMINING THE REQUIRED LENGTH AND DEPTH OF ALL PROTECTION SYSTEMS.

5. DESIGN NOTES

THE CULVERT SHALL BE DESIGNED TO THE FOLLOWING MINIMUM CRITERIA:

SOFFIT ELEVATION	EL. 148.7 U/S
	EL. 148.6 D/S

CLEAR SPAN	4000mm
FROST DEPTH	1900mm
TOP OF CLAY SEAL	300mm ABOVE HIGH WATER LINE
STREAMBED ELEVATIONS	SHALL BE AS NOTED ON DRAWINGS.

APPLICABLE STANDARD DRAWINGS:

OPSD 3101.150	WALLS ABUTMENT, BACKFILL MINIMUM GRANULAR REQUIREMENTS
OPSD 3102.100	WALL ABUTMENT BACKFILL DRAIN
OPSD 3941.200	FIGURES IN CONCRETE, SITE NUMBER AND DATE LAYOUT

LIST OF DRAWINGS:

1. GENERAL ARRANGEMENT
2. BOREHOLE LOCATIONS AND SOIL STRATA
3. STAGING 1
4. STAGING II

LIST OF ABBREVIATIONS

D/S	DENOTES DOWNSTREAM
SHLD	DENOTES SHOULDER
C.J.	DENOTES CONSTRUCTION JOINT
U/S	DENOTES UPSTREAM
W.P.	DENOTES WORK POINT
W.L.	DENOTES WATER LEVEL
T/P	DENOTES TOP OF PAVEMENT

REVISIONS		DESCRIPTION	
DESIGN	JT	CHK NB	CODE S6-14
DRAWN	AN	CHK JT	SITE 29-232/C STRUCT
		LOAD CL-625-ONT	
		DATE DEC 2017	
		SCHEME	
		DWG 1	

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).

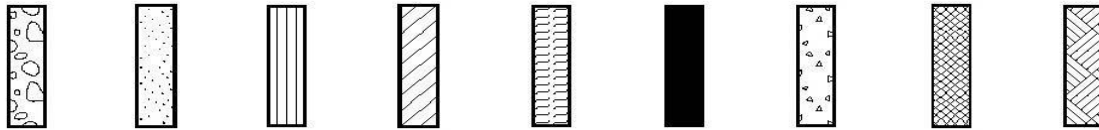
DYNAMIC CONE PENETRATION TEST (DCPT):

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 601

1 OF 1

METRIC

W.P. 4113-01-01 LOCATION 29-232/C Muskrat Creek Culvert, MTM Zone 9: N 5 049 722.1 E 278 947.1 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable BQ/NQ Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.19 - 2015.10.20 CHECKED BY KP

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							
148.8														
0.0	Gravel and sand with silt Loose to compact Brown FILL		1	SS	5									
			2	SS	15		148							
			3	SS	13		147							46 43 11 (SI+CL)
146.8														
2.1	SILTY SAND (SM) with gravel Compact Grey		4	SS	21									19 33 48 (SI+CL)
146.1														
2.7	BEDROCK Granite Slightly weathered Poor quality Grey		1	RUN			146							RUN #1 TCR=96% SCR=86% RQD=46%
145.4														
3.4	End of Borehole													

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 601A

1 OF 1

METRIC

W.P. 4113-01-01 LOCATION 29-232/C Muskrat Creek Culvert, MTM Zone 9: N 5 049 724.2 E 278 947.3 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable BQ/NQ Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.21 - 2015.10.21 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT 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				WATER CONTENT (%)				
148.2	Advanced NQ Casing to 600 mm							20	40	60	80	100	W P	W	W L	GR SA SI CL
0.0	Gravel and sand with silt Loose to compact Brown FILL (Inferred)						148									RUN #1 TCR=90% SCR=80% RQD=71%
146.9							147									
1.2	BEDROCK Granite Slightly weathered Fair quality Grey		1	RUN												
145.9							146									
2.3	End of Borehole															

RECORD OF BOREHOLE No 602

1 OF 1

METRIC

W.P. 4113-01-01 LOCATION 29-232/C Muskrat Creek Culvert, MTM Zone 9: N 5 049 709.7 E 278 945.5 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE HSA COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.16 - 2015.10.16 CHECKED BY KP

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						
								UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
							WATER CONTENT (%)							
							PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT 							

ONTMT4S 19-5161-263 MUSKRAT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

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

RECORD OF BOREHOLE No 603

1 OF 1

METRIC

W.P. 4113-01-01 LOCATION 29-232/C Muskrat Creek Culvert, MTM Zone 9: N 5 049 714.4 E 278 936.8 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE HSA COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.22 - 2015.10.22 CHECKED BY KP

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					
								○ UNCONFINED + FIELD VANE					
								● QUICK TRIAXIAL × LAB VANE					
				WATER CONTENT (%)									
149.6													
0.0	300 mm ASPHALT												
149.3													
0.3	Sand with silt and gravel Compact Brown FILL		1	SS	100/ 225mm		149						20 69 11 (SI+CL)
			2	SS	24								
			3	SS	18		148						
147.2													
2.4	SAND (SP-SM) with silt Very loose to loose Brown - trace organic matter		4	SS	6		147						2 89 9 (SI+CL)
			5	SS	6		146						
			6	SS	3								
			7	SS	4		145						
144.3													
5.3	SILT (ML) with sand Very loose to compact Grey		8	SS	1		144						0 20 74 6
			9	SS	WH		143						
			10	SS	10								
141.8			11	SS	100/ 150mm		142						
7.8	BEDROCK Granite Slightly weathered Fair quality Grey		1	RUN			141						RUN #1 TCR=80% SCR=67% RQD=51%
140.4													
9.2	End of Borehole												

ONTMT4S 19-5161-263 MUSKRAT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

RECORD OF BOREHOLE No 604

1 OF 1

METRIC

W.P. 4113-01-01 LOCATION 29-232/C Muskrat Creek Culvert, MTM Zone 9: N 5 049 702.6 E 278 935.1 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable NQ Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.20 - 2015.10.21 CHECKED BY KP

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							
148.6								20	40	60	80	100			
0.0	150 mm TOPSOIL							20	40	60	80	100			
0.2	Silty sand with gravel Loose to compact Brown FILL		1	SS	6		148								
			2	SS	19										
			3	SS	12		147								36 51 13 (SH+CL)
			4	SS	17										
146.2															
2.4	SILT (ML) with sand Loose to compact Grey		5	SS	22		146								
			6	SS	15		145								
			7	SS	9										4 35 61 (SH+CL)
			8	SS	9		144								
			9	SS	8										
			10	SS	8		143								3 41 39 17
			11	SS	7		142								
141.9															
6.7	BEDROCK Granite Slightly weathered Fair quality Grey		1	RUN											RUN #1 TCR=97% SCR=82% RQD=68%
141.0															
7.6	End of Borehole Groundwater level was measured in piezometer at 0.93 m BGS (elev. 147.7 m) on 2015/12/16														

ONTMT4S 19-5161-263 MUSKRAT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

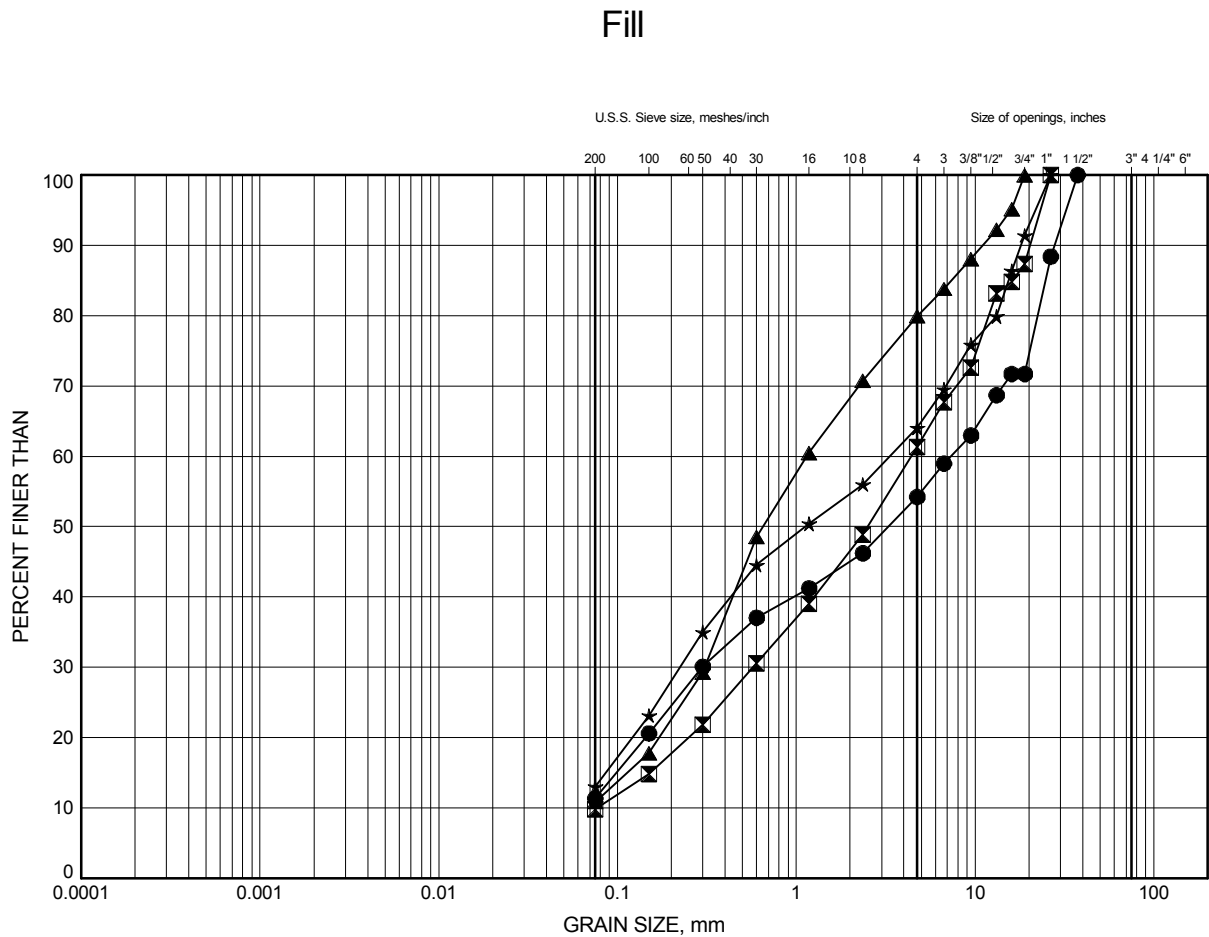
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 5 10 (%) STRAIN AT FAILURE

APPENDIX C
LABORATORY TEST RESULTS

Site 29-323C - Muskrat Creek

GRAIN SIZE DISTRIBUTION

FIGURE 1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	601	1.52	147.30
⊠	602	1.83	147.80
▲	603	1.07	148.54
★	604	1.52	147.08

Date .. November 2017

W.P. .. 4113-01-01



Prep'd .. KCP

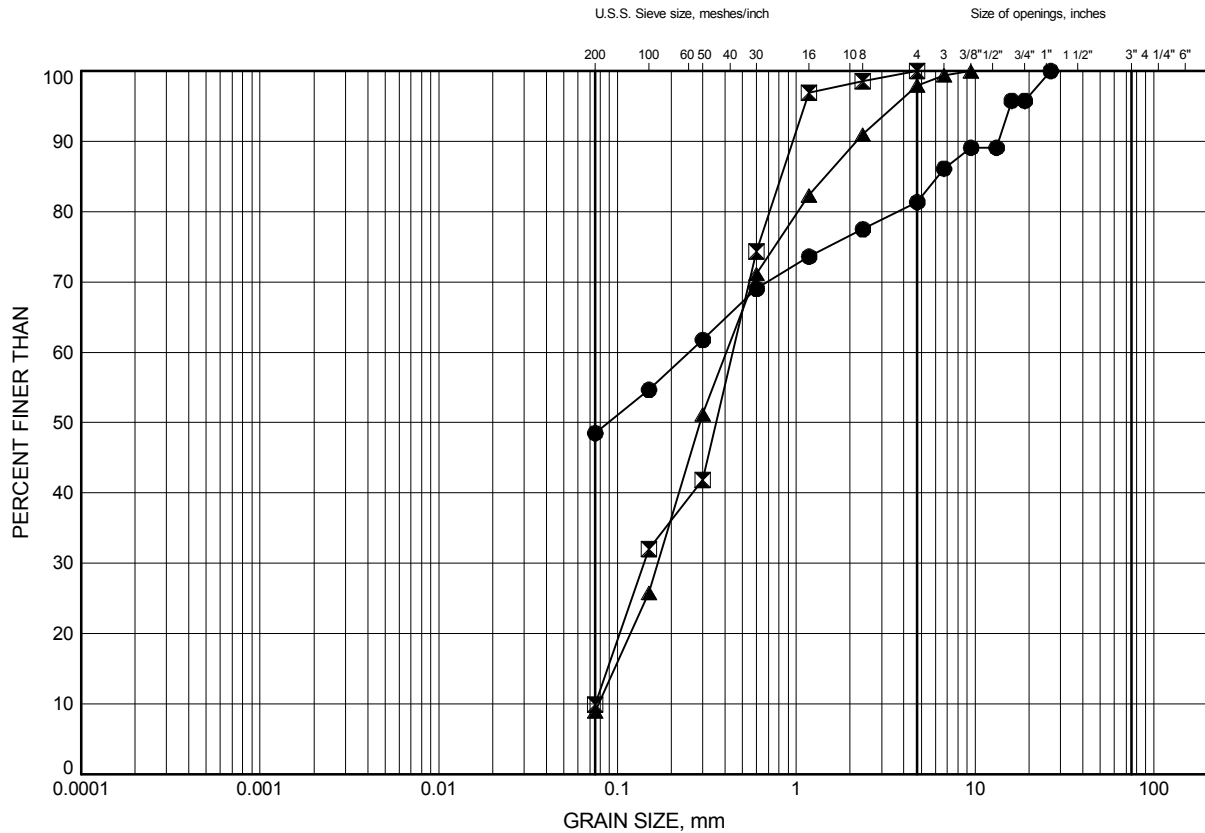
Chkd. .. PC

Site 29-323C - Muskrat Creek

GRAIN SIZE DISTRIBUTION

FIGURE 2

Sand with Silt / Silty Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	601	2.29	146.53
⊠	602	3.35	146.28
▲	603	3.17	146.44

Date November 2017
W.P. 4113-01-01



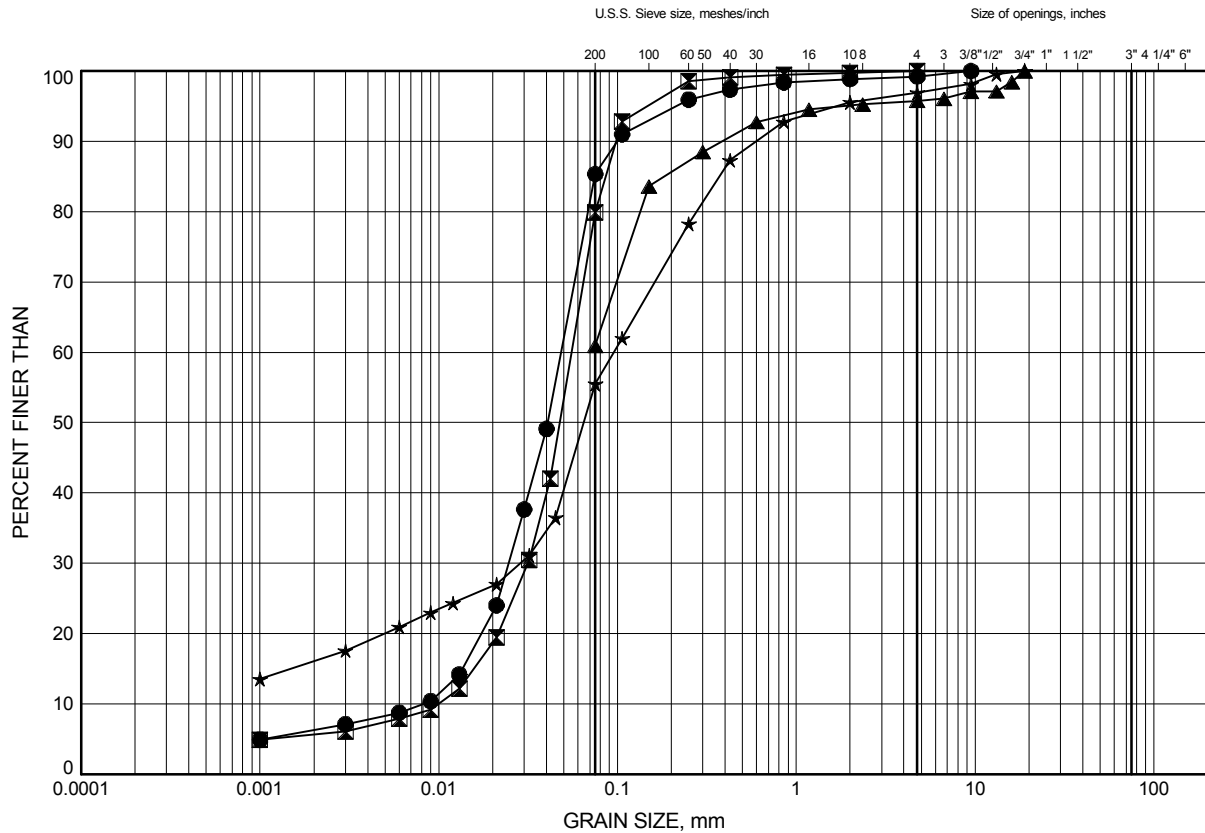
Prep'd KCP
Chkd. PC

Site 29-323C - Muskrat Creek

GRAIN SIZE DISTRIBUTION

FIGURE 3

Silt with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	602	6.40	143.23
⊠	603	5.64	143.97
▲	604	3.96	144.64
★	604	5.79	142.81

Date November 2017
W.P. 4113-01-01



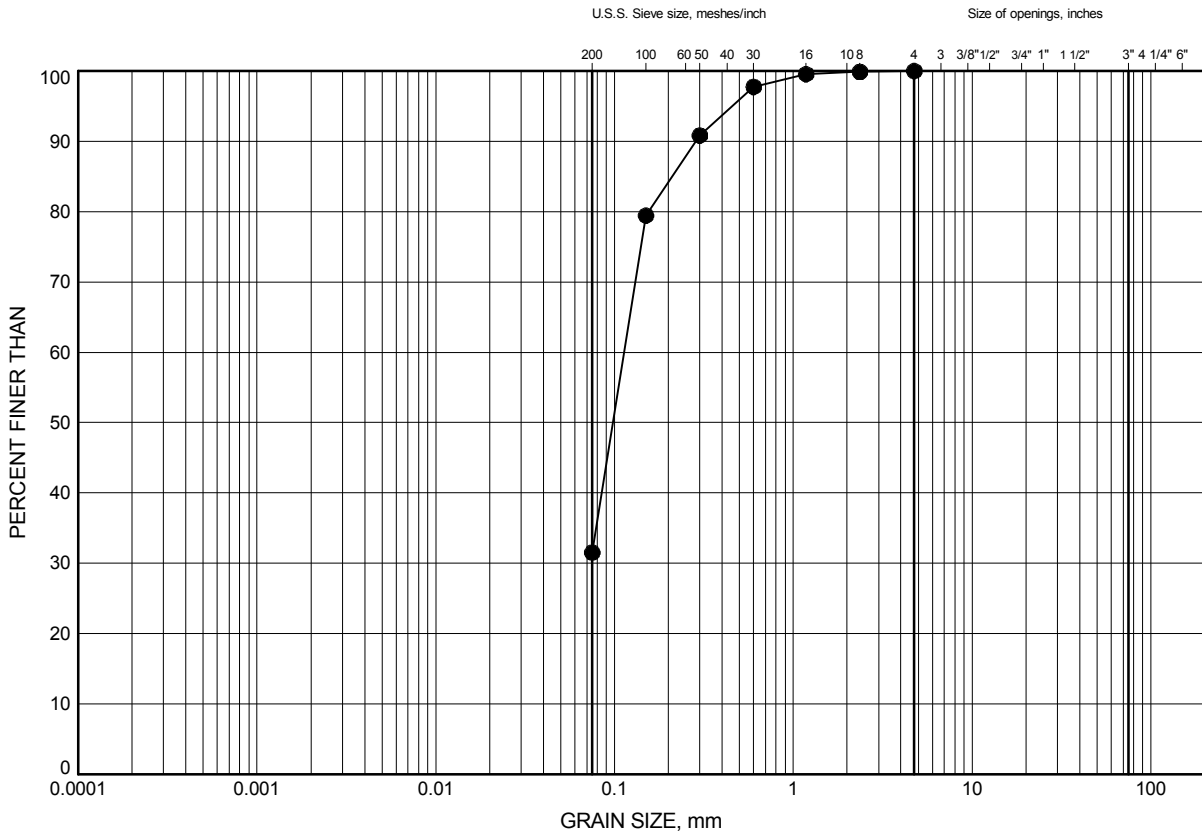
Prep'd KCP
Chkd. PC

Site 29-323C - Muskrat Creek

GRAIN SIZE DISTRIBUTION

FIGURE 4

Silty Sand: Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	602	7.09	142.54

Date January 2018
W.P. 4113-01-01



Prep'd KCP
Chkd. PC

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO:
Project: 19-5161-263
Custody:

Report Date: 13-Nov-2015
Order Date: 10-Nov-2015

Order #: 1546148

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

Paracel ID	Client ID
1546148-01	BH704 SS4 6' to 8'
1546148-02	BH601 SS4 6' to 8'
1546148-03	BH501 SS6 10.5' to 12.5'

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Nov-15	12-Nov-15
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	11-Nov-15	11-Nov-15
Resistivity	EPA 120.1 - probe, water extraction	12-Nov-15	12-Nov-15
Solids, %	Gravimetric, calculation	12-Nov-15	12-Nov-15

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Client PO:

Project Description: 19-5161-263

Client ID:		BH704 SS4 6' to 8'	BH601 SS4 6' to 8'	BH501 SS6 10.5' to 12.5'	-
Sample Date:		22-Oct-15	19-Oct-15	27-Oct-15	-
Sample ID:		1546148-01	1546148-02	1546148-03	-
MDL/Units		Soil	Soil	Soil	-
Physical Characteristics					
% Solids	0.1 % by Wt.	81.9	76.3	91.8	-
General Inorganics					
pH	0.05 pH Units	7.56	7.73	7.99	-
Resistivity	0.10 Ohm.m	25.3	31.2	157	-
Anions					
Chloride	5 ug/g dry	129	70	6	-
Sulphate	5 ug/g dry	27	112	7	-

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

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									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	7.0	5	ug/g dry	7.1			0.5	20	
Sulphate	24.3	5	ug/g dry	25.1			3.6	20	
General Inorganics									
pH	8.11	0.05	pH Units	7.99			1.5	10	
Resistivity	24.8	0.10	Ohm.m	25.3			1.9	20	
Physical Characteristics									
% Solids	78.2	0.1	% by Wt.	77.6			0.7	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	100	5	ug/g	7.1	93.3	78-113			
Sulphate	104	5	ug/g	25.1	79.1	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

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

SEISMIC CONE PENETRATION TEST RESULTS

PRESENTATION OF SITE INVESTIGATION RESULTS

Highway 17 – Muskrat Creek Culvert

Prepared for:

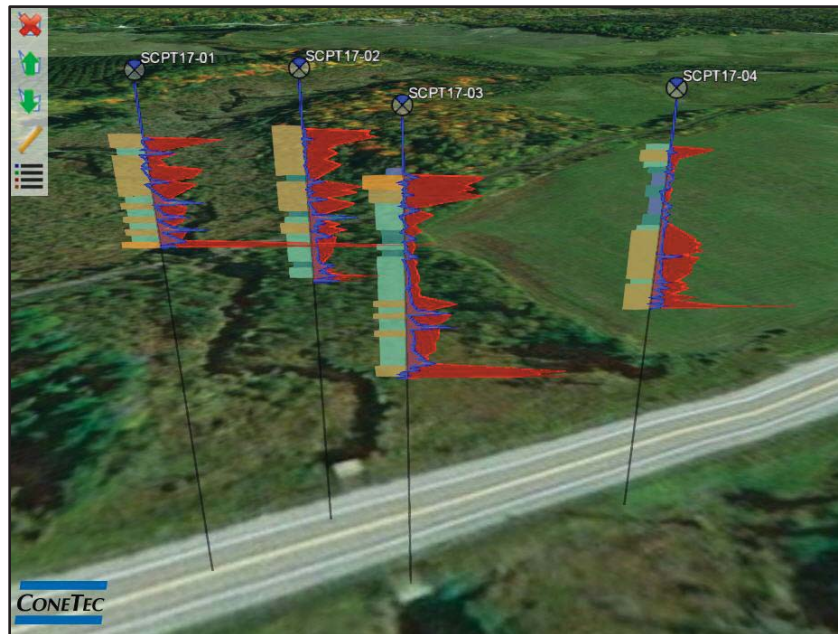
Thurber Engineering Ltd.

ConeTec Job No: 17-05021

Project Start Date: 23-May-2017

Project End Date: 23-May-2017

Report Date: 25-May-2017



Prepared by:

ConeTec Investigations Ltd.
9033 Leslie Street, Unit 15
Richmond Hill, ON L4B 4K3

Tel: (905) 886-2663

Fax: (905) 886-2664

Toll Free: (800) 504-1116

Email: conetecON@conetec.com

www.conetec.com

www.conetecdataservices.com



Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Investigations Ltd. for Thurber Engineering Ltd. on Highway 17 at the Muskrat Creek Culvert. The program consisted of four seismic cone penetration tests (SCPT) performed on May 23, 2017.

Project Information

Project	
Client	Thurber Engineering Ltd.
Project	Highway 17 - Muskrat Creek Culvert
ConeTec project number	17-05021

A map from Google Earth including the SCPT test locations is presented below.



Rig Description	Deployment System	Test Type
CPT truck rig (C3)	30 ton rig cylinder	SCPT

Coordinates		
Test Type	Collection Method	EPSG Number
SCPT	Consumer grade GPS	32618

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	Advanced CPT plots displaying I_c , $S_u(Nkt)$, and $N1(60) I_c$, along with seismic CPT plots are provided.

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm ²)	Sleeve Area (cm ²)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
379:T1500F15U500	379	15	225	1500	15	500
Cone 379 was used for both CPT soundings.						

Interpretation Tables	
Additional information	<p>The Normalized Qtn Soil Behaviour Type (SBT-Qtn) classification chart (Robertson, 2009) was used to classify the soil for this project. A detailed set of CPT interpretations were generated and are provided in Excel format files in the release folder. The CPT interpretations are based on values of corrected tip (q_t), sleeve friction (f_s) and pore pressure (u_2).</p> <p>Soils were classified as either drained or undrained based on the Normalized Qtn Soil Behaviour Type (SBT-Qtn) classification chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures – clayey silt to silty clay (zone 4).</p>

Limitations

This report has been prepared for the exclusive use of Thurber Engineering Ltd. (Client) for the project titled “Highway 17 - Muskrat Creek Culvert”. The report’s contents may not be relied upon by any other party without the express written permission of ConeTec Investigations Ltd. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

The cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd. of Richmond, British Columbia, Canada.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm² and 15 cm² tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first Appendix. The 15 cm² penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm² piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u₂" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meets or exceeds those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

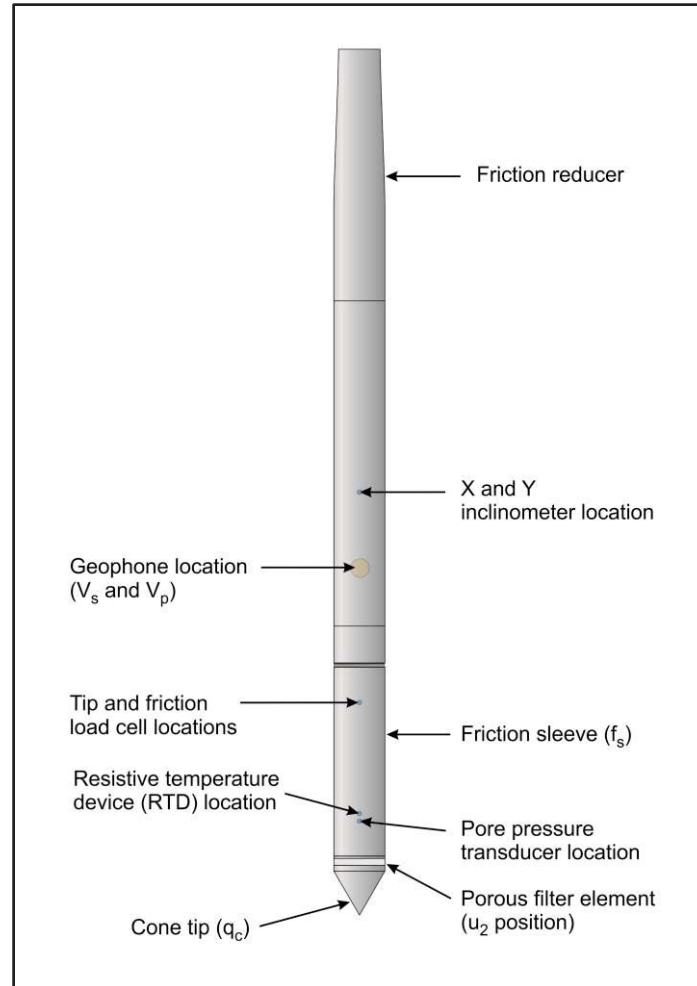


Figure CPTu. Piezocone Penetrometer (15 cm²)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording intervals are either 2.5 cm or 5.0 cm depending on project requirements; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerine or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerine under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behaviour type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

$$q_t = q_c + (1-a) \cdot u_2$$

where: q_t is the corrected tip resistance

q_c is the recorded tip resistance

u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)

a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (R_f) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high

friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of interpretation files were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the interpretation methods used is also included in the data release folder.

For additional information on CPTu interpretations, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

Shear wave velocity testing is performed in conjunction with the piezocone penetration test (SCPTu) in order to collect interval velocities. For some projects seismic compression wave (V_p) velocity is also determined.

ConeTec's piezocone penetrometers are manufactured with a horizontally active geophone (28 hertz) that is rigidly mounted in the body of the cone penetrometer, 0.2 meters behind the cone tip.

Shear waves are typically generated by using an impact hammer horizontally striking a beam that is held in place by a normal load. In some instances an auger source or an imbedded impulsive source maybe used for both shear waves and compression waves. The hammer and beam act as a contact trigger that triggers the recording of the seismic wave traces. For impulsive devices an accelerometer trigger may be used. The traces are recorded using an up-hole integrated digital oscilloscope which is part of the SCPTu data acquisition system. An illustration of the shear wave testing configuration is presented in Figure SCPTu-1.

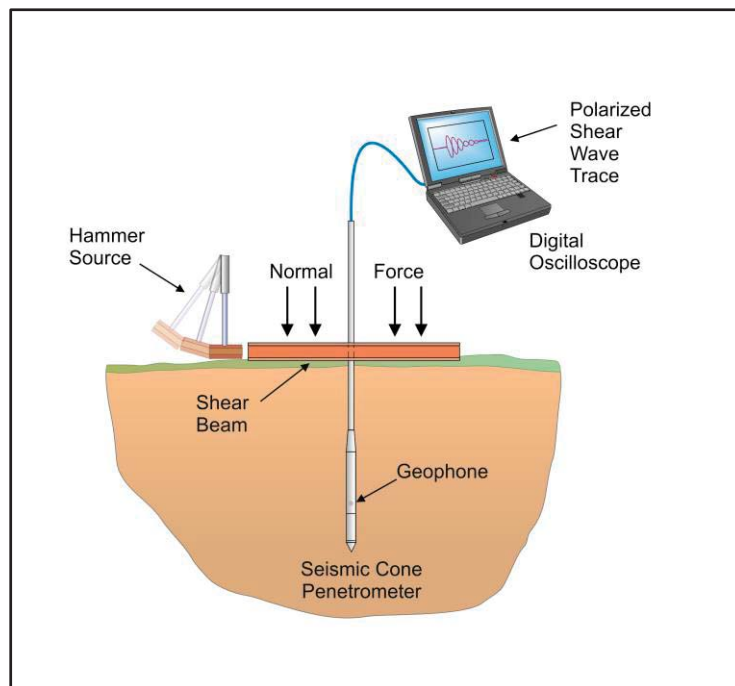


Figure SCPTu-1. Illustration of the SCPTu system

All testing is performed in accordance to ConeTec's SCPTu operating procedures.

Prior to the start of a SCPTu sounding, the procedures described in the Cone Penetration Test section are followed. In addition, the active axis of the geophone is aligned parallel to the beam (or source) and the horizontal offset between the cone and the source is measured and recorded.

Prior to recording seismic waves at each test depth, cone penetration is stopped and the rods are decoupled from the rig to avoid transmission of rig energy down the rods. Multiple wave traces are recorded for quality control purposes. After reviewing wave traces for consistency the cone is pushed to the next test depth (typically one meter intervals or as requested by the client). Figure SCPTu-2 presents an illustration of a SCPTu test.

For additional information on seismic cone penetration testing refer to Robertson et.al. (1986).

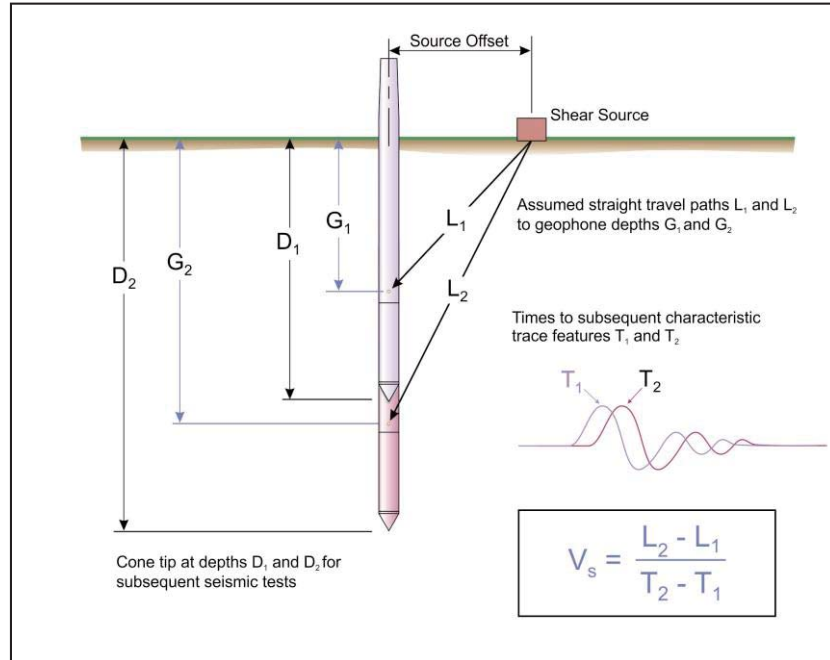


Figure SCPTu-2. Illustration of a seismic cone penetration test

Calculation of the interval velocities are performed by visually picking a common feature (e.g. the first characteristic peak, trough, or crossover) on all of the recorded wave sets and taking the difference in ray path divided by the time difference between subsequent features. Ray path is defined as the straight line distance from the seismic source to the geophone, accounting for beam offset, source depth and geophone offset from the cone tip.

The average shear wave velocity to a depth of 30 meters (V_{s30}) has been calculated and provided for all applicable soundings using an equation presented in Crow et al., 2012.

$$V_{s30} = \frac{\text{total thickness of all layers (30m)}}{\sum(\text{layer traveltimes})}$$

The layer travel times refers to the travel times propagating in the vertical direction, not the measured travel times from an offset source.

Tabular results and SCPTu plots are presented in the relevant appendix.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

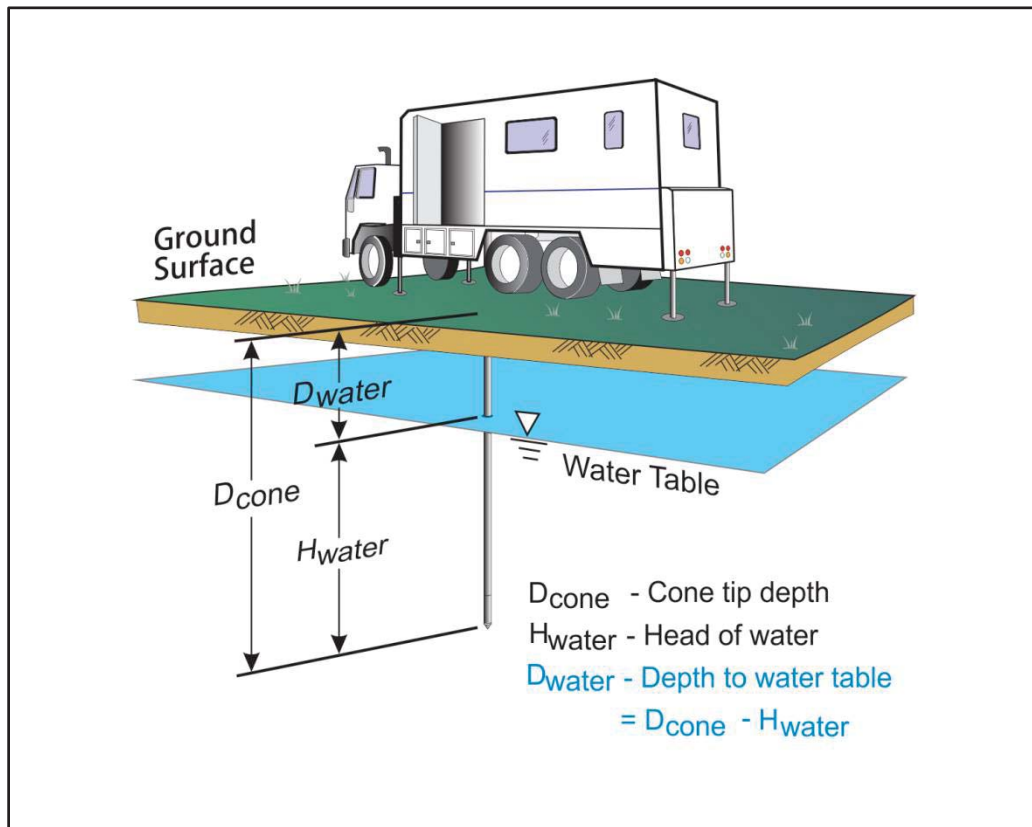


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behaviour.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

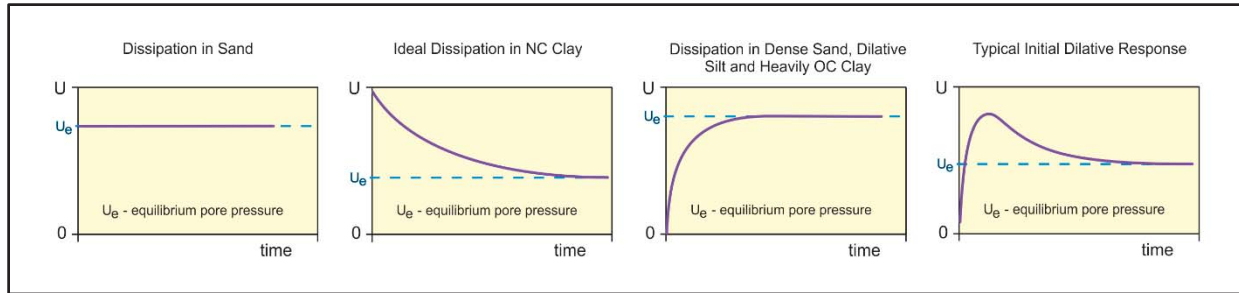


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve of Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100} . In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100} . A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T^*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

- T^* is the dimensionless time factor (Table Time Factor)
- a is the radius of the cone
- I_r is the rigidity index
- t is the time at the degree of consolidation

Table Time Factor. T^* versus degree of dissipation (Teh and Houlsby, 1991)

Degree of Dissipation (%)	20	30	40	50	60	70	80
$T^* (u_2)$	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50} , dissipation tests must be taken to a pressure less than u_{50} . The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100} . To estimate u_{50} , both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby, 1991), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50} . In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r , the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50} , other methods should be applied to confirm the results for c_h .

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

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Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", *Geotechnique*, 41(1): 17-34.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots displaying I_c , $S_u(N_{kt})$, and $N1(60)I_c$
- Seismic Cone Penetration Test Plots
- Seismic Cone Penetration Test Tabular Results
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and Standard Cone Penetration Test Plots



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Start Date: 23-May-2017
End Date: 23-May-2017

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface ¹ (m)	Final Depth (m)	Northing ² (m)	Easting (m)	Elevation ³ (m)	Refer to Notation Number
SCPT17-01	17-05021_SP01	23-May-2017	379:T1500F15U500	1.5	4.750	5049789	357129	149.6	
SCPT17-02	17-05021_SP02	23-May-2017	379:T1500F15U500	1.7	6.700	5049779	357140	149.6	
SCPT17-03	17-05021_SP03	23-May-2017	379:T1500F15U500	1.7	8.025	5049767	357132	149.6	
SCPT17-04	17-05021_SP04	23-May-2017	379:T1500F15U500	1.5	7.325	5049744	357150	149.7	

1. The assumed phreatic surface was based on pore pressure dissipation tests. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were collected with a consumer grade GPS device in datum WGS84/UTM Zone 18 North.
3. Elevations were provided by the client.



Thurber Engineering

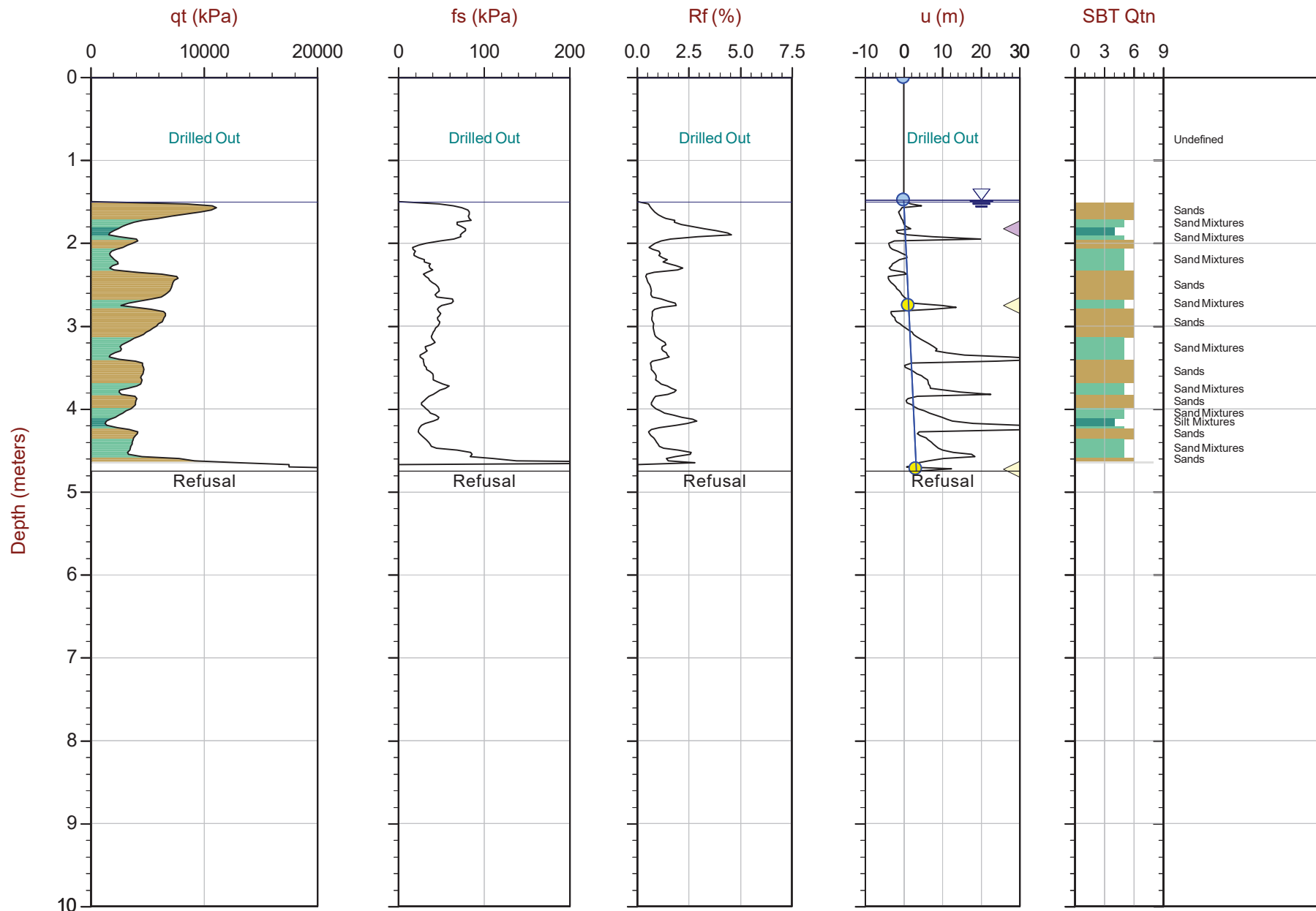
Job No: 17-05021

Date: 2017-05-23 11:34

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-01

Cone: 379:T1500F15U500



Max Depth: 4.750 m / 15.58 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: Every Point

File: 17-05021_SP01.COR

Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010

Coords: UTM 18N N: 5049789m E: 357129m Elev: 149.6m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

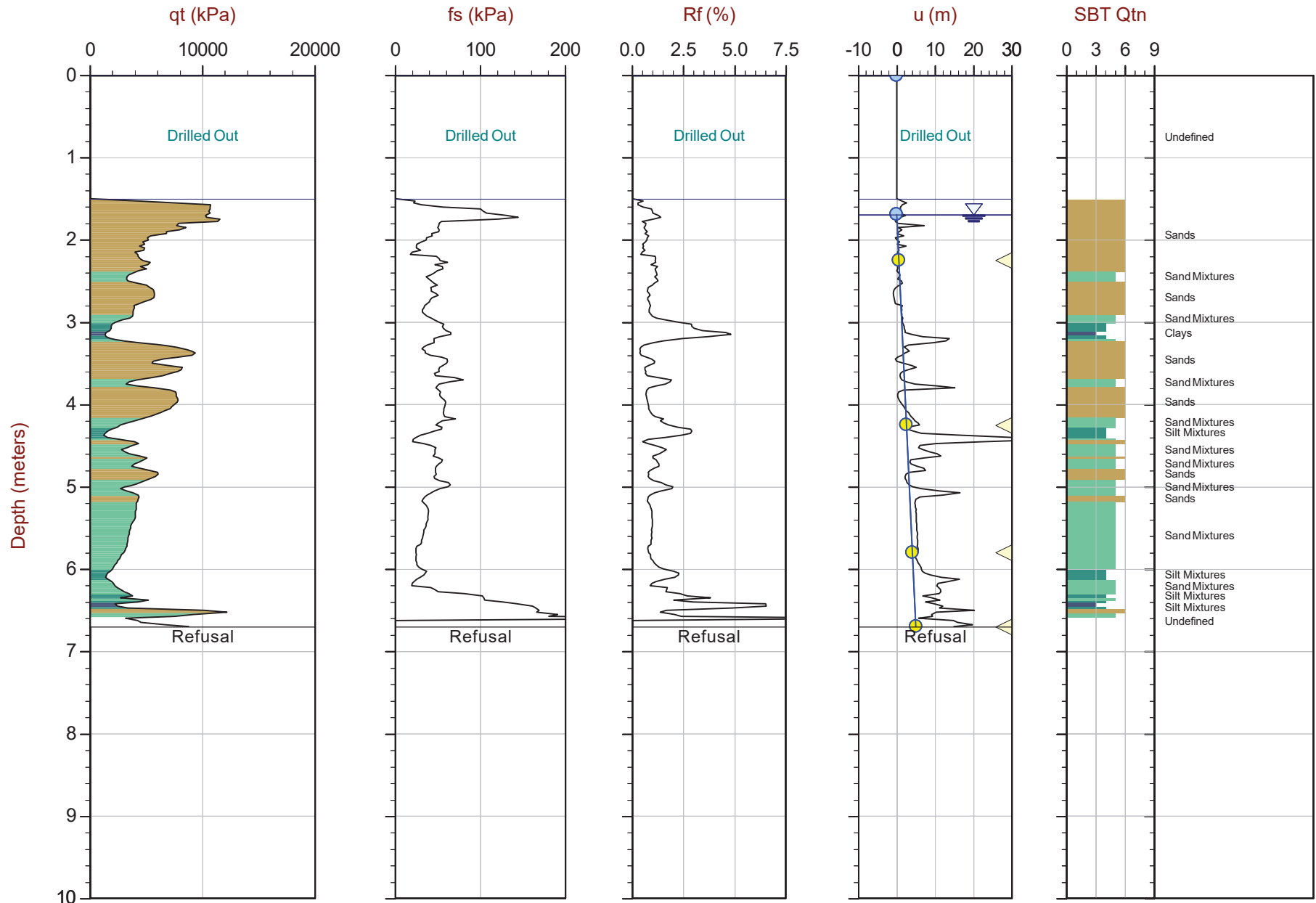
Job No: 17-05021

Date: 2017-05-23 10:19

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02

Cone: 379:T1500F15U500



Max Depth: 6.700 m / 21.98 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: Every Point

File: 17-05021_SP02.COR

Unit Wt: SBTQtn(PKR2009)

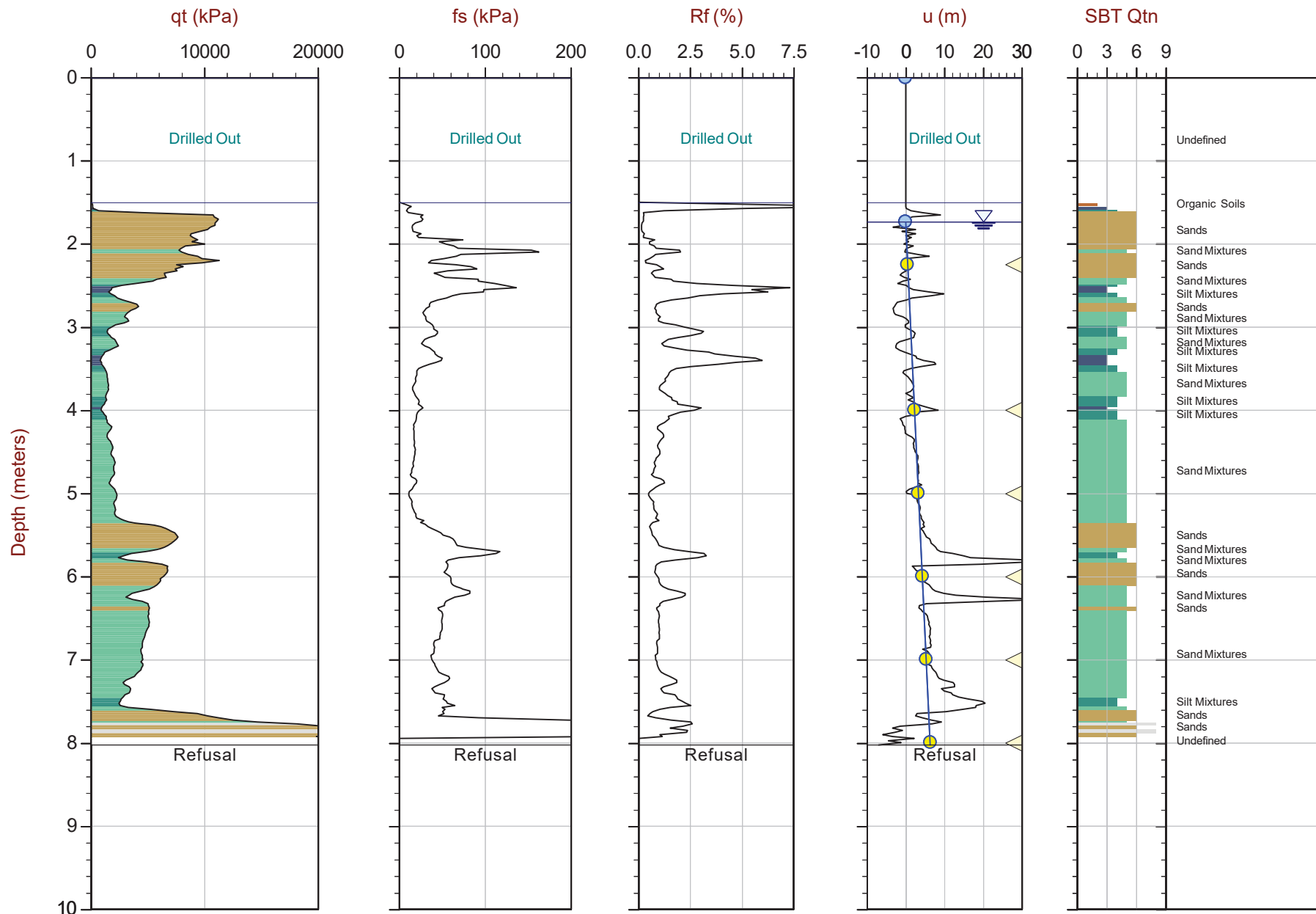
SBT: Robertson, 2009 and 2010

Coords: UTM 18N N: 5049779m E: 357140m Elev: 149.6m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Max Depth: 8.025 m / 26.33 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: Every Point

File: 17-05021_SP03.COR

Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010

Coords: UTM 18N N: 5049767m E: 357132m Elev: 149.6m

Sheet No: 1 of 1

- Equilibrium Pore Pressure (U_{eq})

- Assumed Ueq

◀ Dissipation, U_{eq} achieved

◀ Dissipation, U_{eq} not achieved

— Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

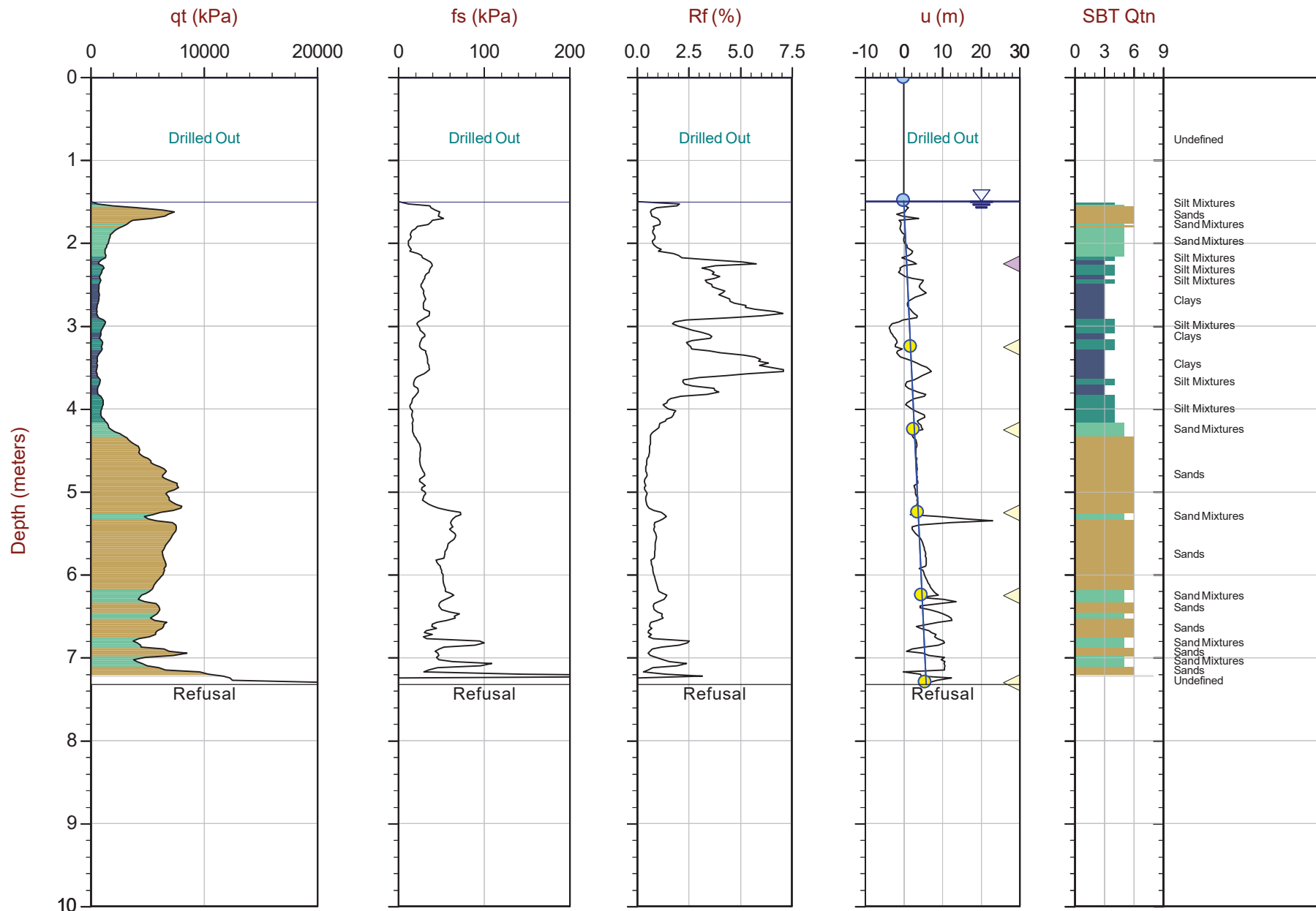
Job No: 17-05021

Date: 2017-05-23 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500



Max Depth: 7.325 m / 24.03 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: Every Point

File: 17-05021_SP04.COR

Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010

Coords: UTM 18N N: 5049744m E: 357150m Elev: 149.7m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Advanced Cone Penetration Test Plots with I_c , $S_u(N_{kt})$, and $N1(60)I_c$



Thurber Engineering

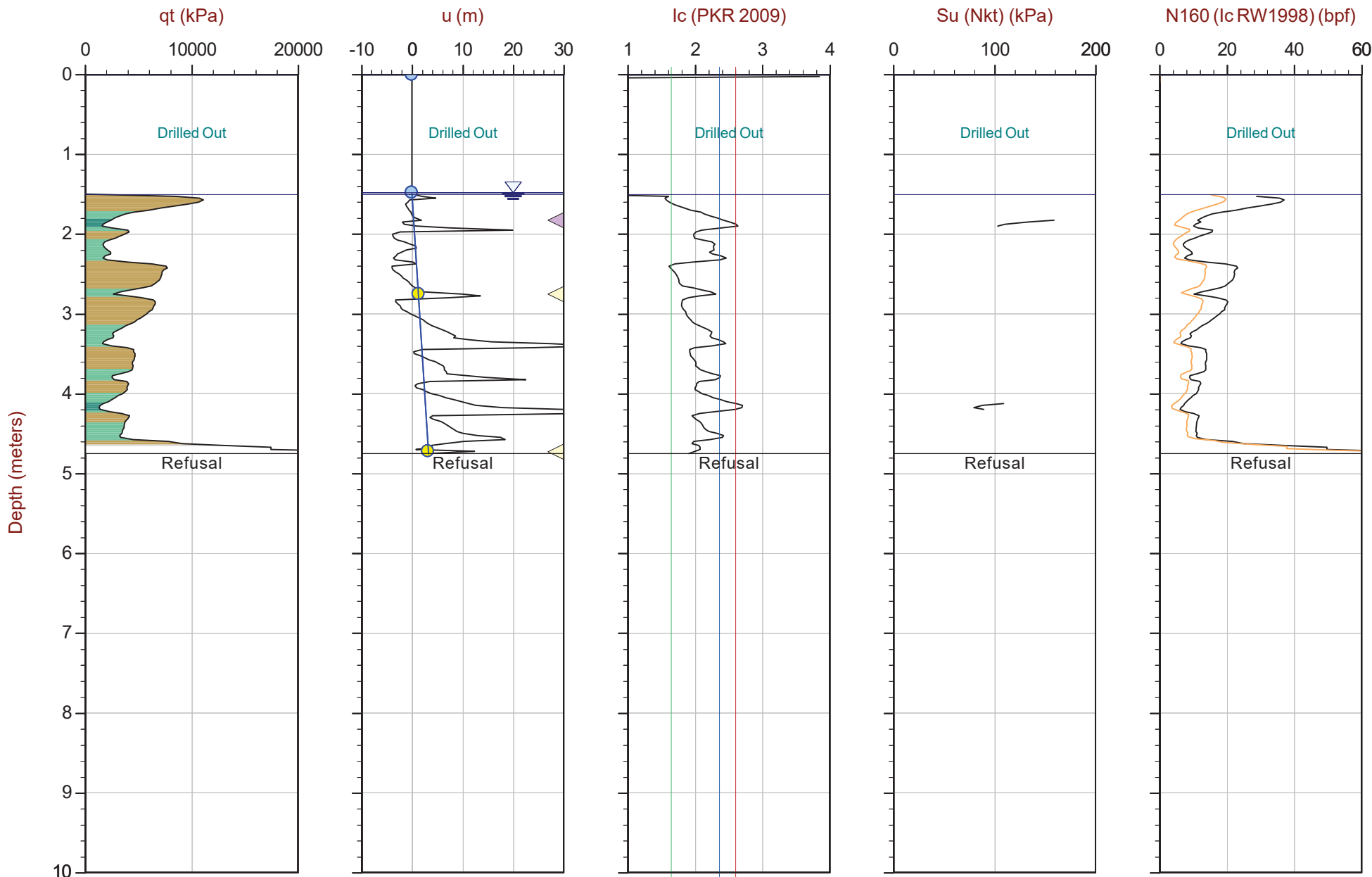
Job No: 17-05021

Date: 2017-05-23 11:34

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-01

Cone: 379:T1500F15U500



Max Depth: 4.750 m / 15.58 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

File: 17-05021_SP01.COR

Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010

Coords: UTM 18N N: 5049789m E: 357129m Elev: 149.6m

Sheet No: 1 of 1

— N(60) (bpf)

● Equilibrium Pore Pressure (Ueq)

● Assumed Ueq

◀ Dissipation, Ueq achieved

◀ Dissipation, Ueq not achieved

— Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

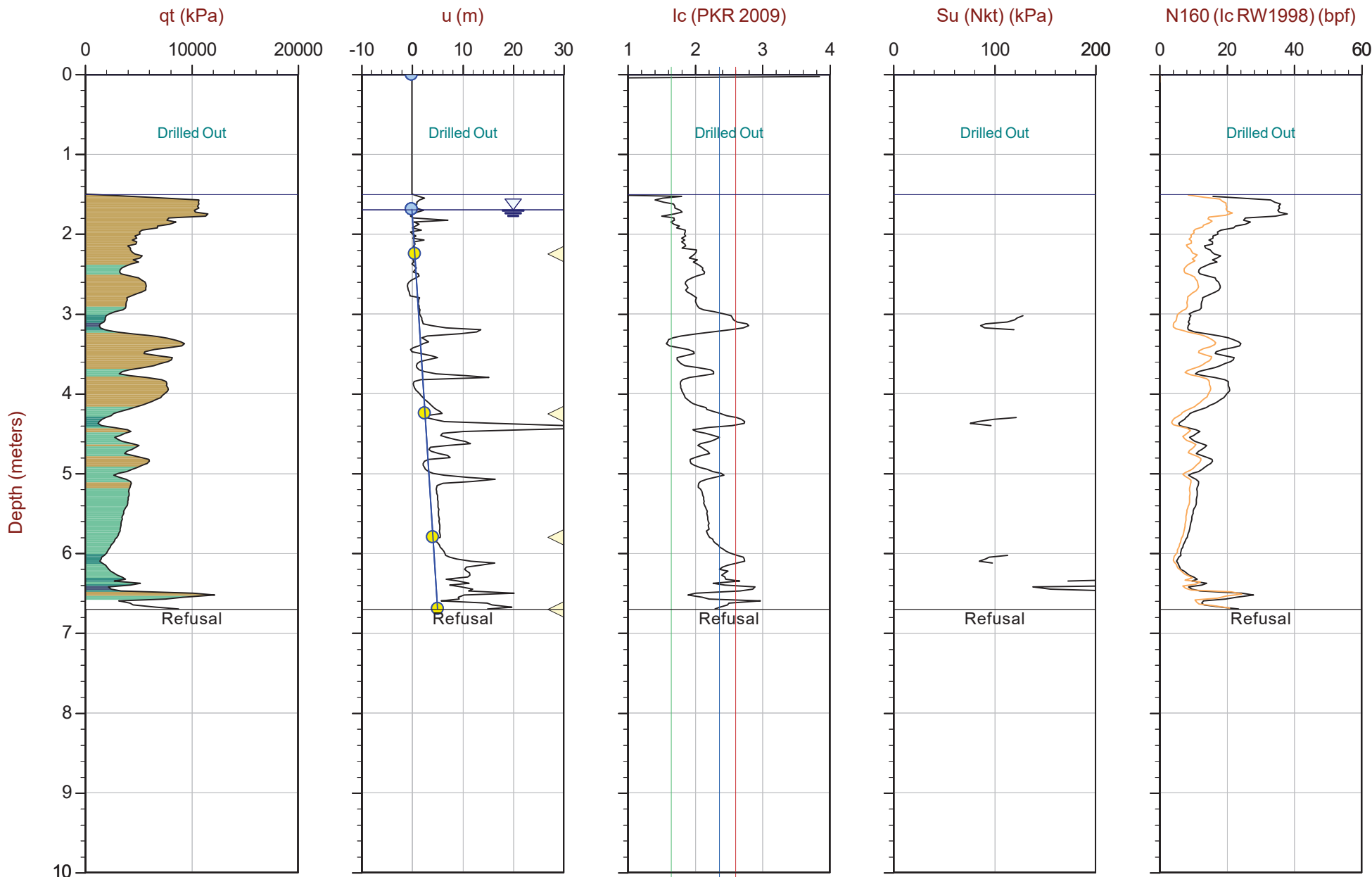
Job No: 17-05021

Date: 2017-05-23 10:19

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02

Cone: 379:T1500F15U500



Max Depth: 6.700 m / 21.98 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: EveryPoint

File: 17-05021_SP02.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 18N N: 5049779m E: 357140m Elev: 149.6m
Sheet No: 1 of 1

— N(60) (bpf) ● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

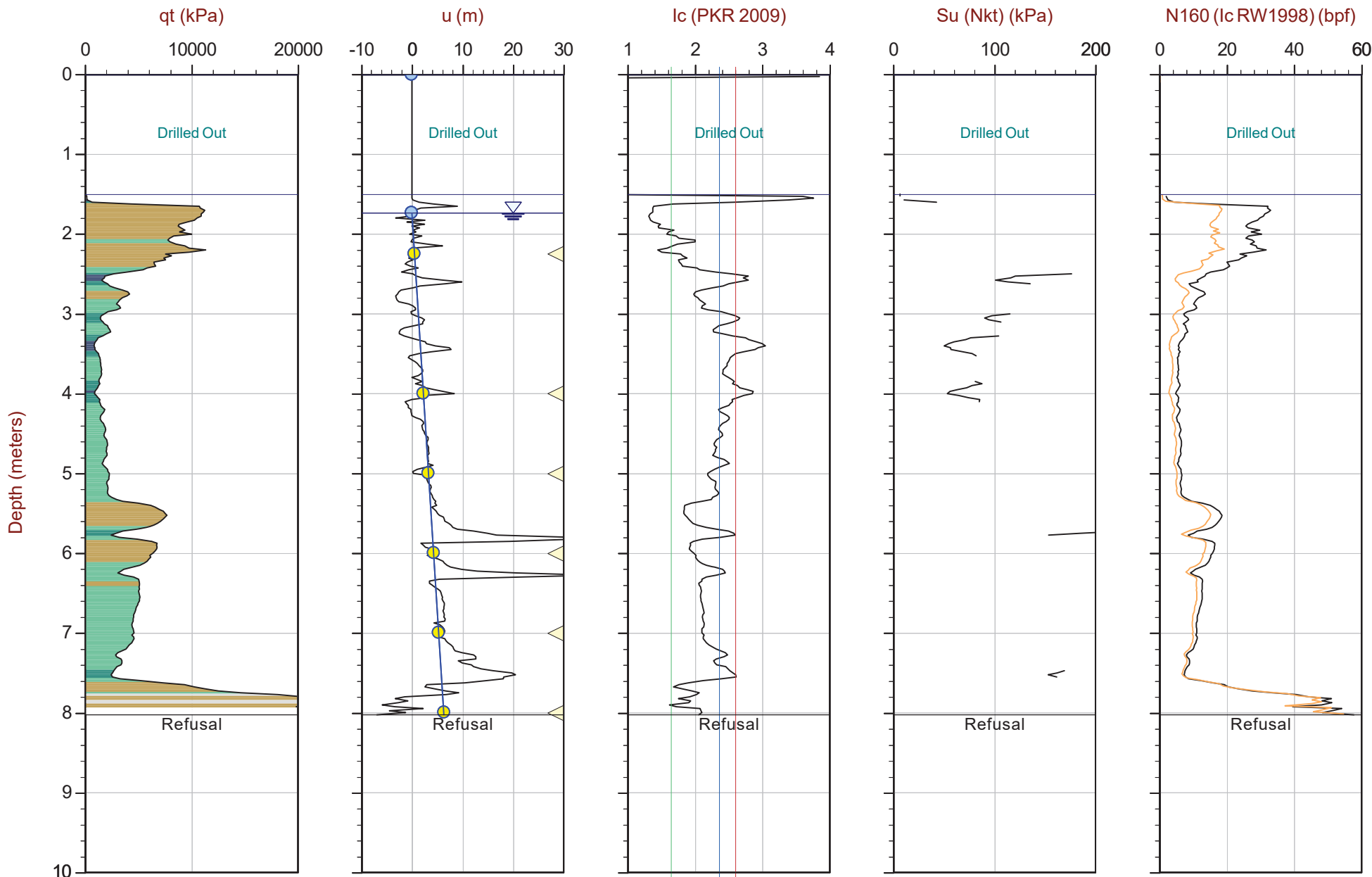
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Date: 2017-05-23 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500



Max Depth: 8.025 m / 26.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 17-05021_SP03.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 18N: 5049767mE: 357132m Elev: 149.6m
Sheet No: 1 of 1

— N(60) (bpf) ● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

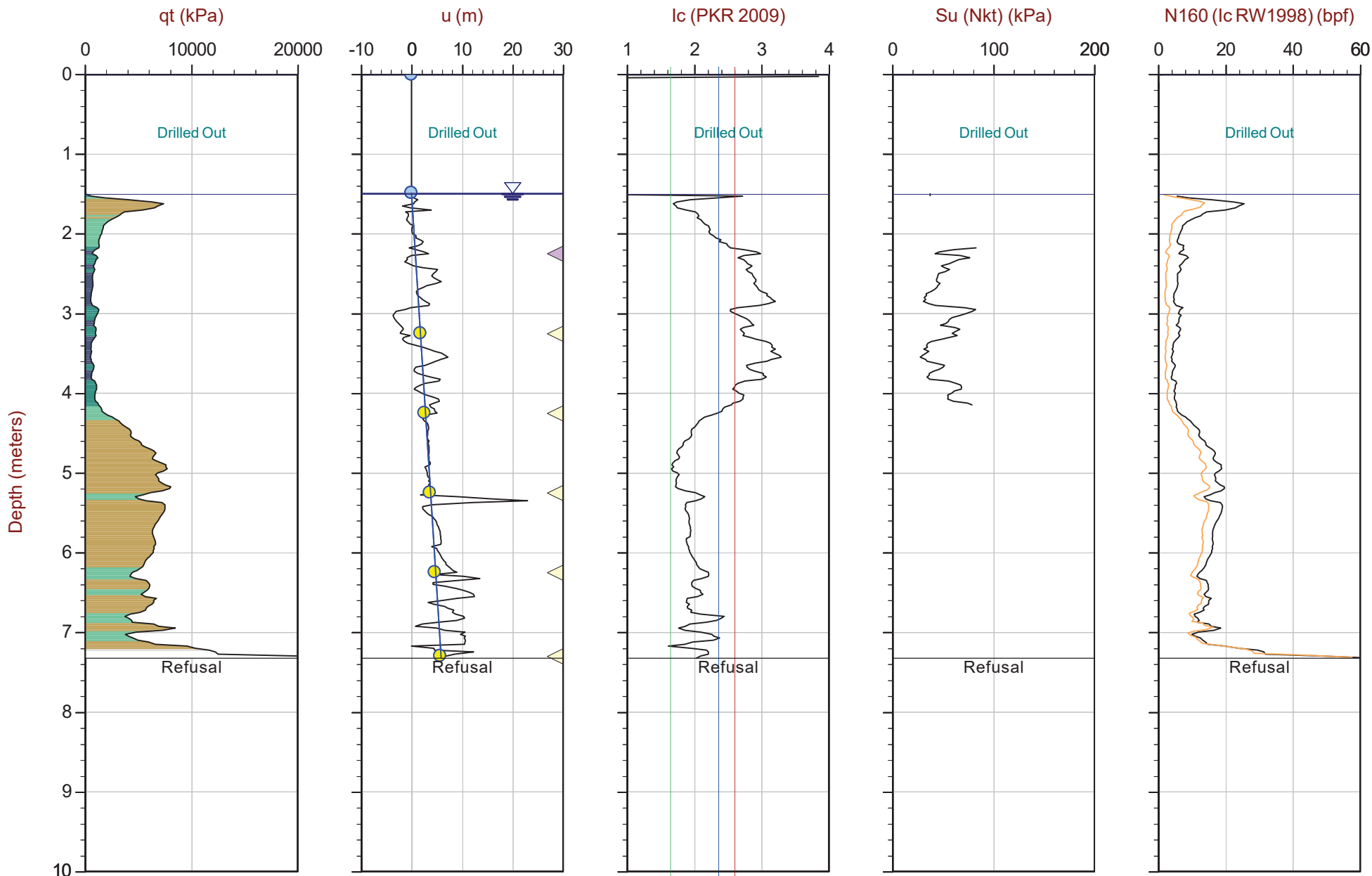
Job No: 17-05021

Date: 2017-05-23 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500



Max Depth: 7.325 m / 24.03 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

File: 17-05021_SP04.COR

Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010

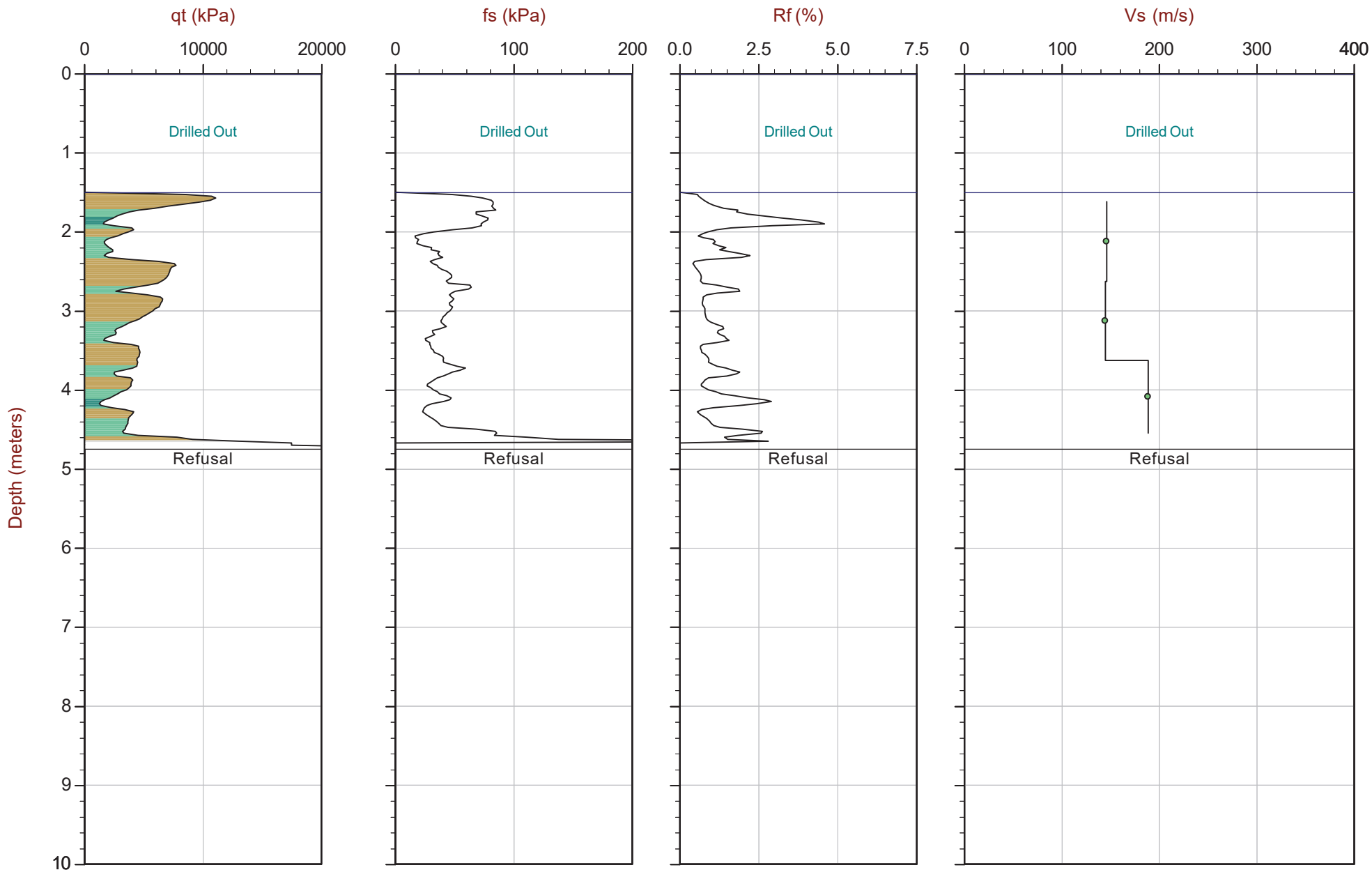
Coords: UTM 18N N: 5049744m E: 357150m Elev: 149.7m

Sheet No: 1 of 1

— N(60) (bpf) ● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▼ Dissipation, Ueq not achieved — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Plots



Max Depth: 4.750 m / 15.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: EveryPoint

File: 17-05021_SP01.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 18N N: 5049789m E: 357129m Elev: 149.6m
Sheet No: 1 of 1



Thurber Engineering

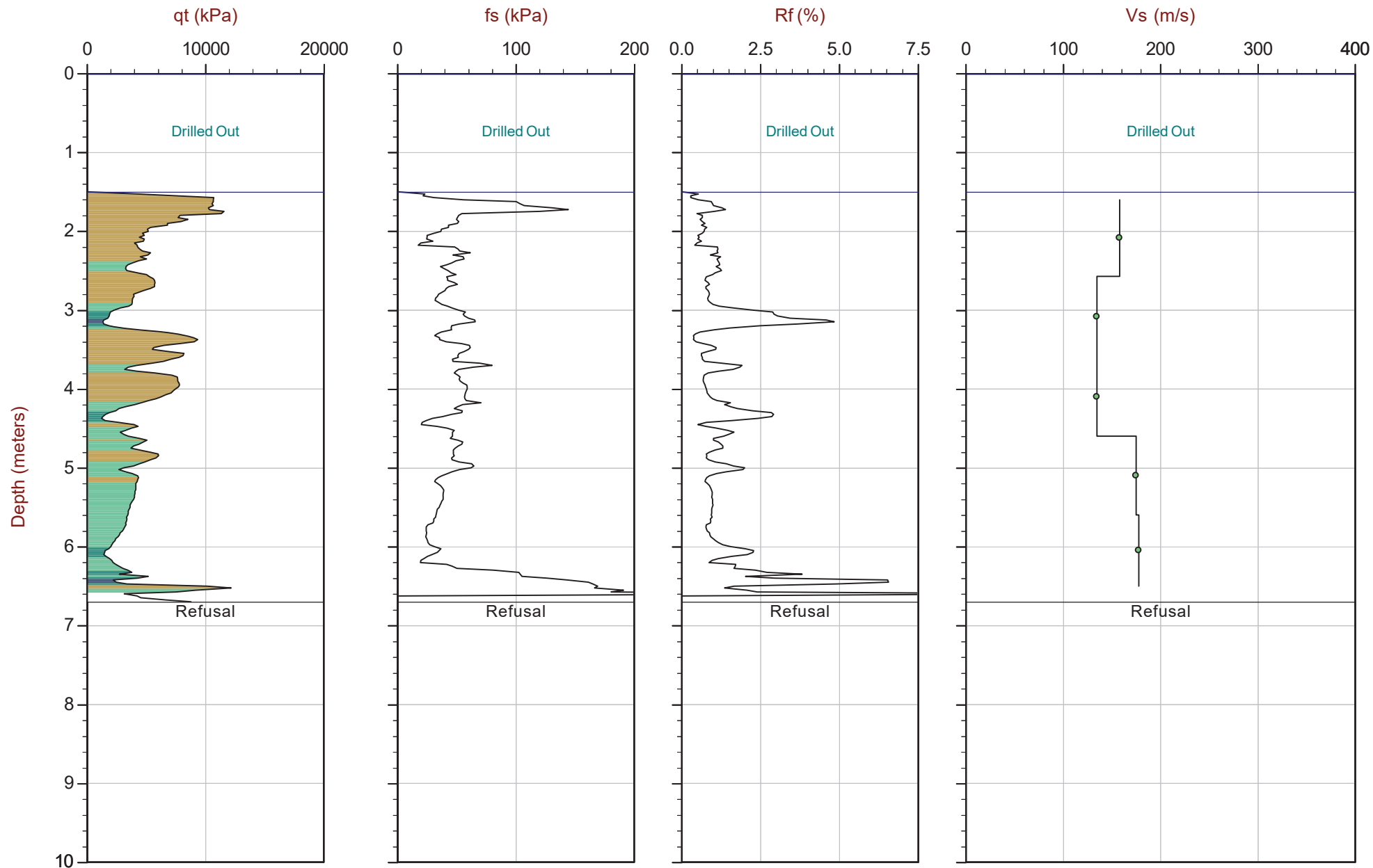
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Date: 2017-05-23 10:19

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02

Cone: 379:T1500F15U500



Max Depth: 6.700 m / 21.98 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 17-05021_SP02.COR
Unit Wt: SBTQtn(PKR2009)

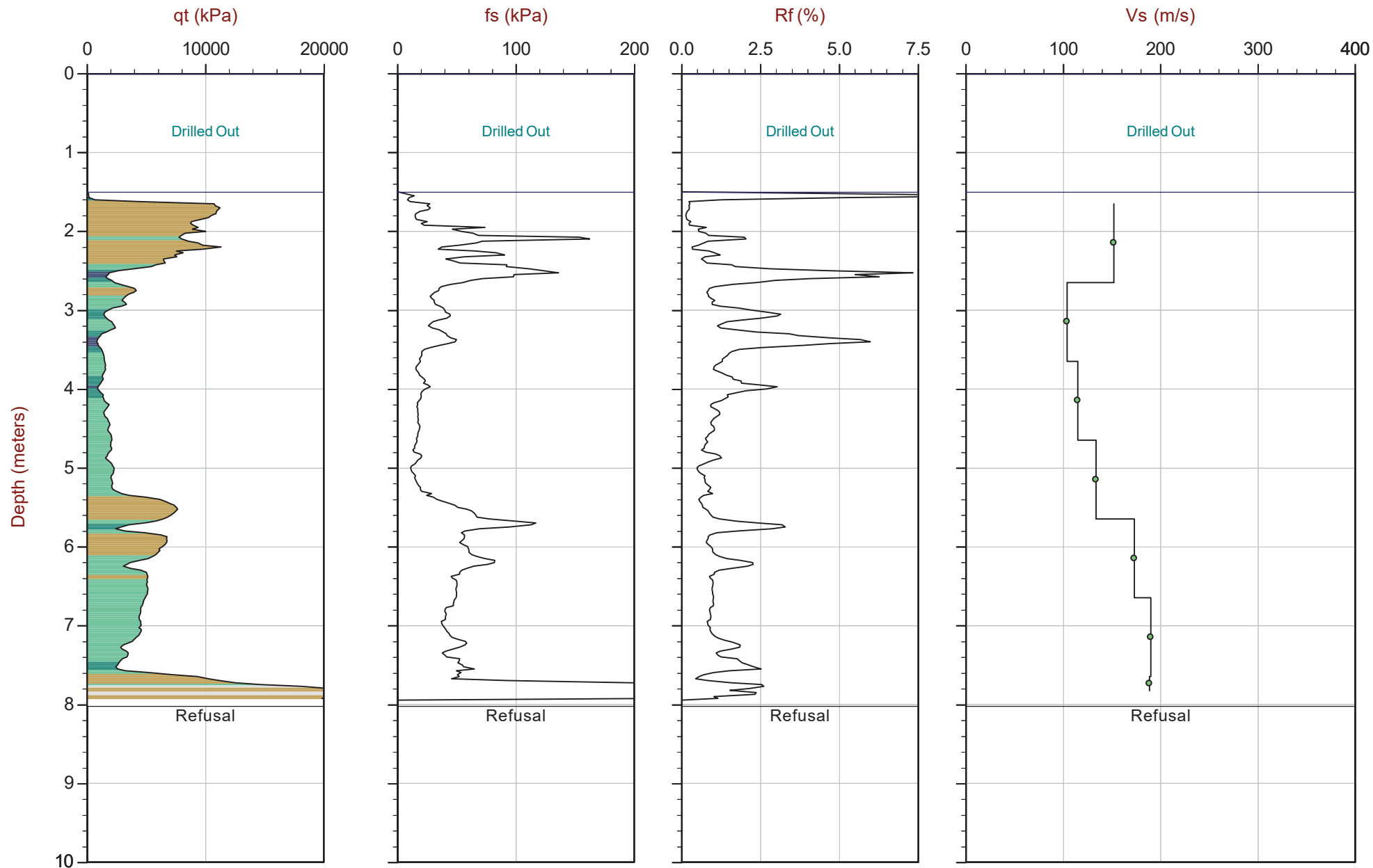
SBT: Robertson, 2009 and 2010
Coords: UTM 18N N: 5049779m E: 357140m Elev: 149.6m
Sheet No: 1 of 1



Thurber Engineering

Job No: 17-05021
Date: 2017-05-23 12:56
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03
Cone: 379:T1500F15U500



Max Depth: 8.025 m / 26.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: EveryPoint

File: 17-05021_SP03.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 18N N: 5049767m E: 357132m Elev: 149.6m
Sheet No: 1 of 1



Thurber Engineering

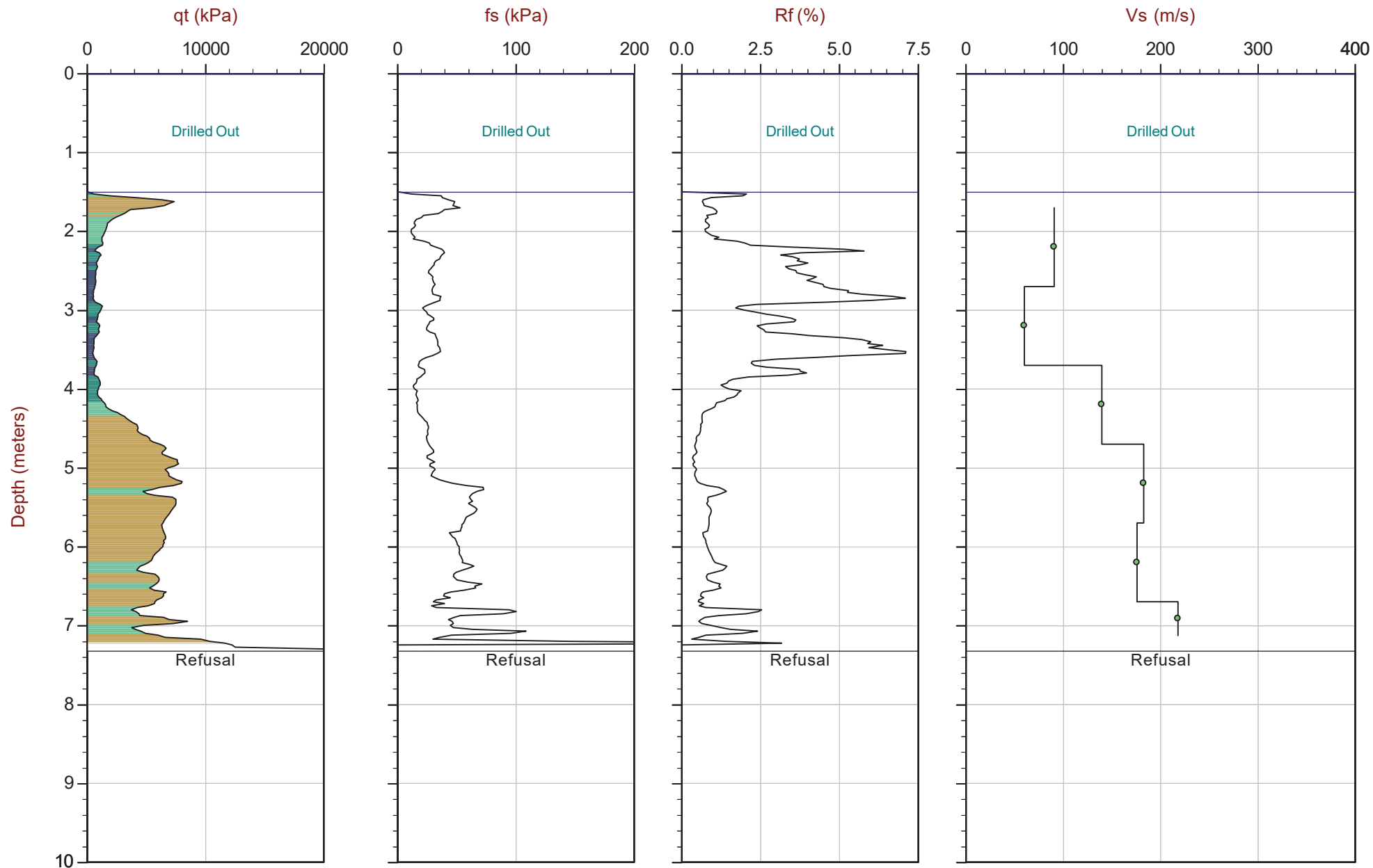
Job No: 17-05021

Date: 2017-05-23 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500



Max Depth: 7.325 m / 24.03 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 17-05021_SP04.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 18N N: 5049744m E: 357150m Elev: 149.7m
Sheet No: 1 of 1

Seismic Cone Penetration Test Tabular Results



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Sounding ID: SCPT17-01
Date: 23-May-2017

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.82	1.62	1.71			
2.83	2.63	2.69	0.98	6.69	146
3.83	3.63	3.67	0.98	6.80	145
4.75	4.55	4.58	0.91	4.82	189



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Sounding ID: SCPT17-02
Date: 23-May-2017

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.80	1.60	1.69			
2.77	2.57	2.63	0.94	5.92	158
3.80	3.60	3.64	1.01	7.51	135
4.80	4.60	4.63	0.99	7.33	135
5.80	5.60	5.63	0.99	5.69	175
6.70	6.50	6.52	0.90	5.03	178



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Sounding ID: SCPT17-03
Date: 23-May-2017

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.85	1.65	1.74			
2.85	2.65	2.71	0.97	6.35	152
3.85	3.65	3.69	0.98	9.45	104
4.85	4.65	4.68	0.99	8.60	115
5.85	5.65	5.68	0.99	7.43	134
6.85	6.65	6.67	1.00	5.76	173
7.85	7.65	7.67	1.00	5.25	190
8.03	7.83	7.85	0.18	0.95	189



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Sounding ID: SCPT17-04
Date: 23-May-2017

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.90	1.70	1.79			
2.90	2.70	2.76	0.97	10.69	91
3.90	3.70	3.74	0.99	16.37	60
4.90	4.70	4.73	0.99	7.11	140
5.90	5.70	5.73	0.99	5.43	183
6.90	6.70	6.72	1.00	5.65	176
7.33	7.13	7.15	0.43	1.97	218

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots



Job No: 17-05021
Client: Thurber Engineering
Project: Hwy 17 - Muskrat Creek Culvert
Start Date: 23-May-2017
End Date: 23-May-2017

CPTu PORE PRESSURE DISSIPATION SUMMARY

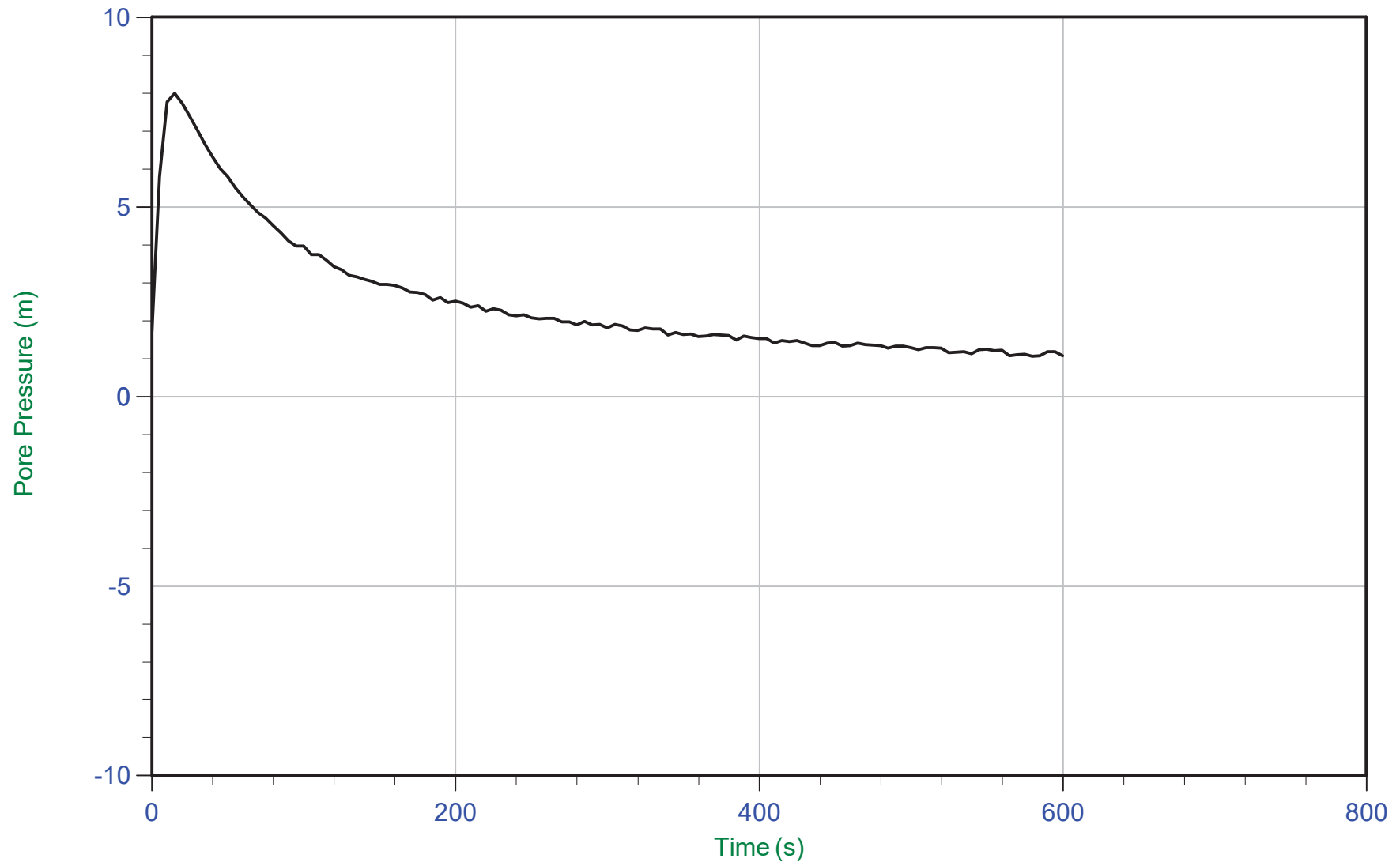
Sounding ID	File Name	Cone Area (cm ²)	Duration (s)	Test Depth (m)	Estimated Equilibrium Pore Pressure U _{eq} (m)	Calculated Phreatic Surface (m)
SCPT17-01	17-05021_SP01	15	600	1.825	Not Achieved	
SCPT17-01	17-05021_SP01	15	500	2.750	1.3	1.5
SCPT17-01	17-05021_SP01	15	350	4.725	3.1	1.6
SCPT17-02	17-05021_SP02	15	200	2.250	0.6	1.7
SCPT17-02	17-05021_SP02	15	250	4.250	2.6	1.7
SCPT17-02	17-05021_SP02	15	350	5.800	4.2	1.7
SCPT17-02	17-05021_SP02	15	300	6.700	5.1	1.6
SCPT17-03	17-05021_SP03	15	300	2.250	0.5	1.7
SCPT17-03	17-05021_SP03	15	350	4.000	2.3	1.7
SCPT17-03	17-05021_SP03	15	300	5.000	3.3	1.7
SCPT17-03	17-05021_SP03	15	250	6.000	4.3	1.7
SCPT17-03	17-05021_SP03	15	250	7.000	5.3	1.7
SCPT17-03	17-05021_SP03	15	250	8.000	6.4	1.6
SCPT17-04	17-05021_SP04	15	310	2.250	Not Achieved	
SCPT17-04	17-05021_SP04	15	450	3.250	1.8	1.5
SCPT17-04	17-05021_SP04	15	250	4.250	2.6	1.7
SCPT17-04	17-05021_SP04	15	300	5.250	3.6	1.6
SCPT17-04	17-05021_SP04	15	200	6.250	4.6	1.7
SCPT17-04	17-05021_SP04	15	300	7.300	5.6	1.7



Thurber Engineering

Job No: 17-05021
Date: 05/23/2017 11:34
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-01
Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 17-05021_SP01.PPF U Min: 1.1 m
Depth: 1.825 m / 5.987 ft U Max: 8.0 m
Duration: 600.0 s



Thurber Engineering

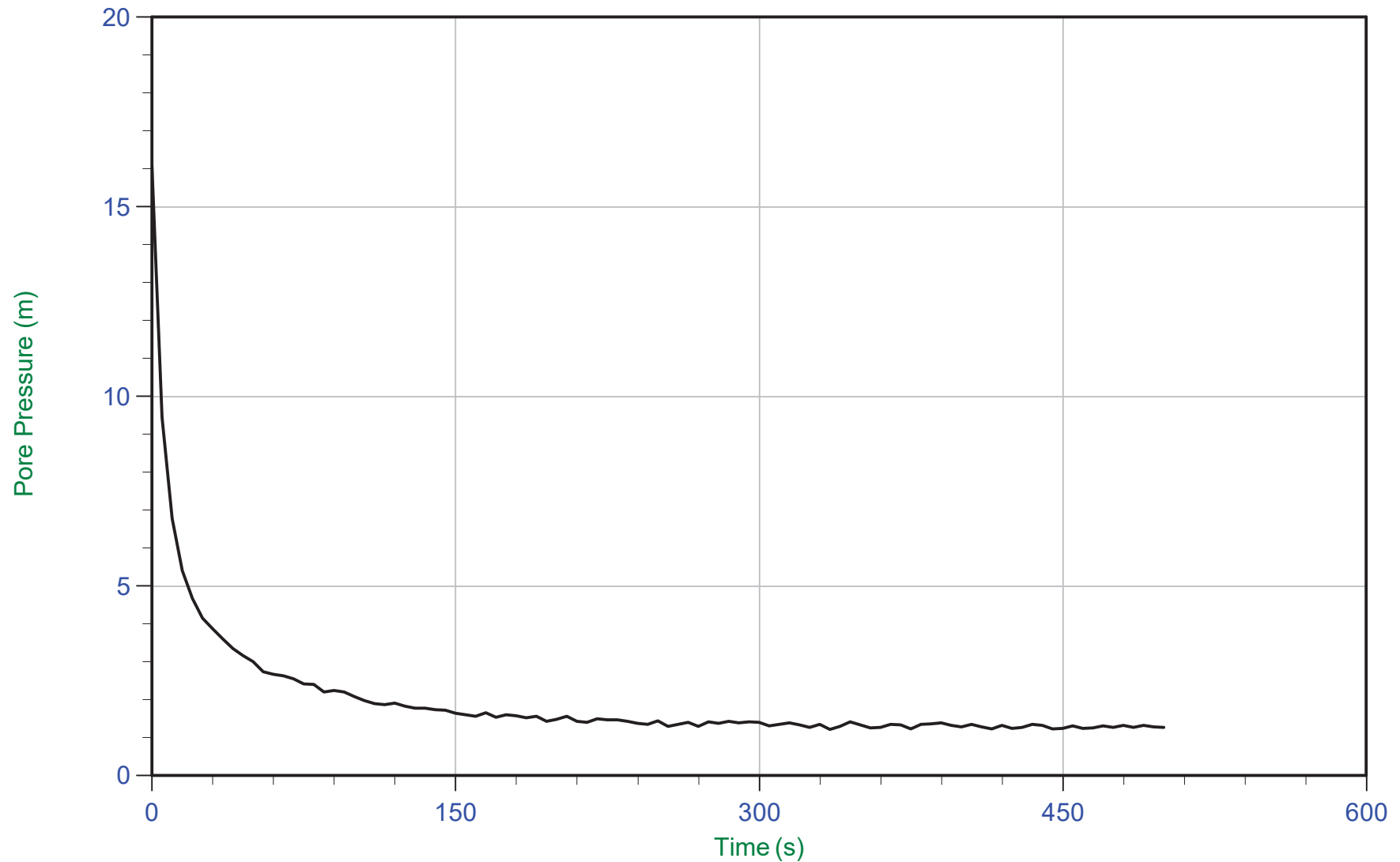
Job No: 17-05021

Date: 05/23/2017 11:34

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-01

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 17-05021_SP01.PPF U Min: 1.2 m WT: 1.481 m / 4.859 ft
 Depth: 2.750 m / 9.022 ft U Max: 16.1 m Ueq: 1.3 m
 Duration: 500.0 s



Thurber Engineering

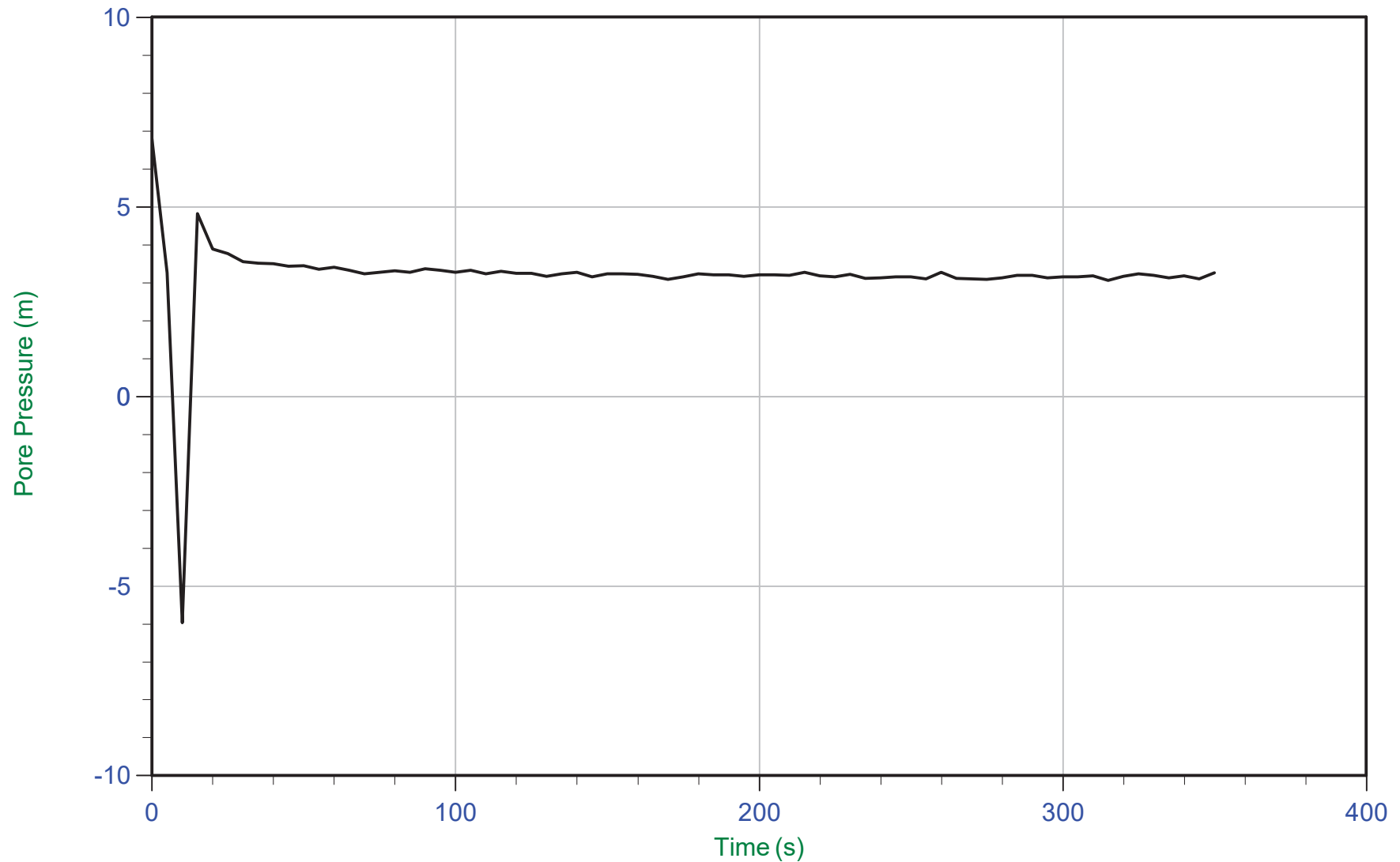
Job No: 17-05021

Date: 05/23/2017 11:34

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-01

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP01.PPF

Depth: 4.725 m / 15.502 ft

Duration: 350.0 s

U Min: -6.0 m

U Max: 6.8 m

WT: 1.585 m / 5.200 ft

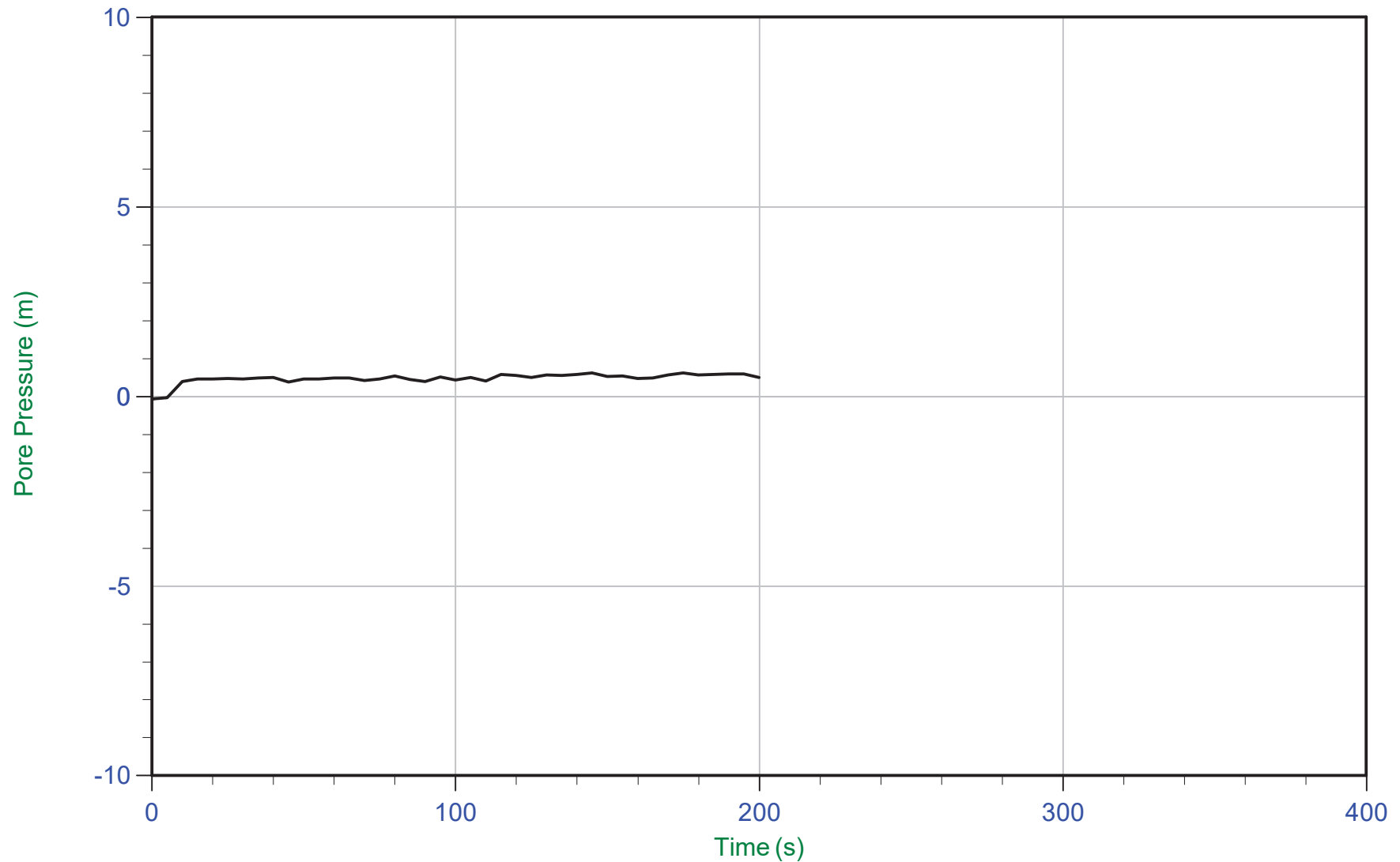
Ueq: 3.1 m



Thurber Engineering

Job No: 17-05021
Date: 05/23/2017 10:19
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02
Cone: 379:T1500F15U500 Area=15 cm²



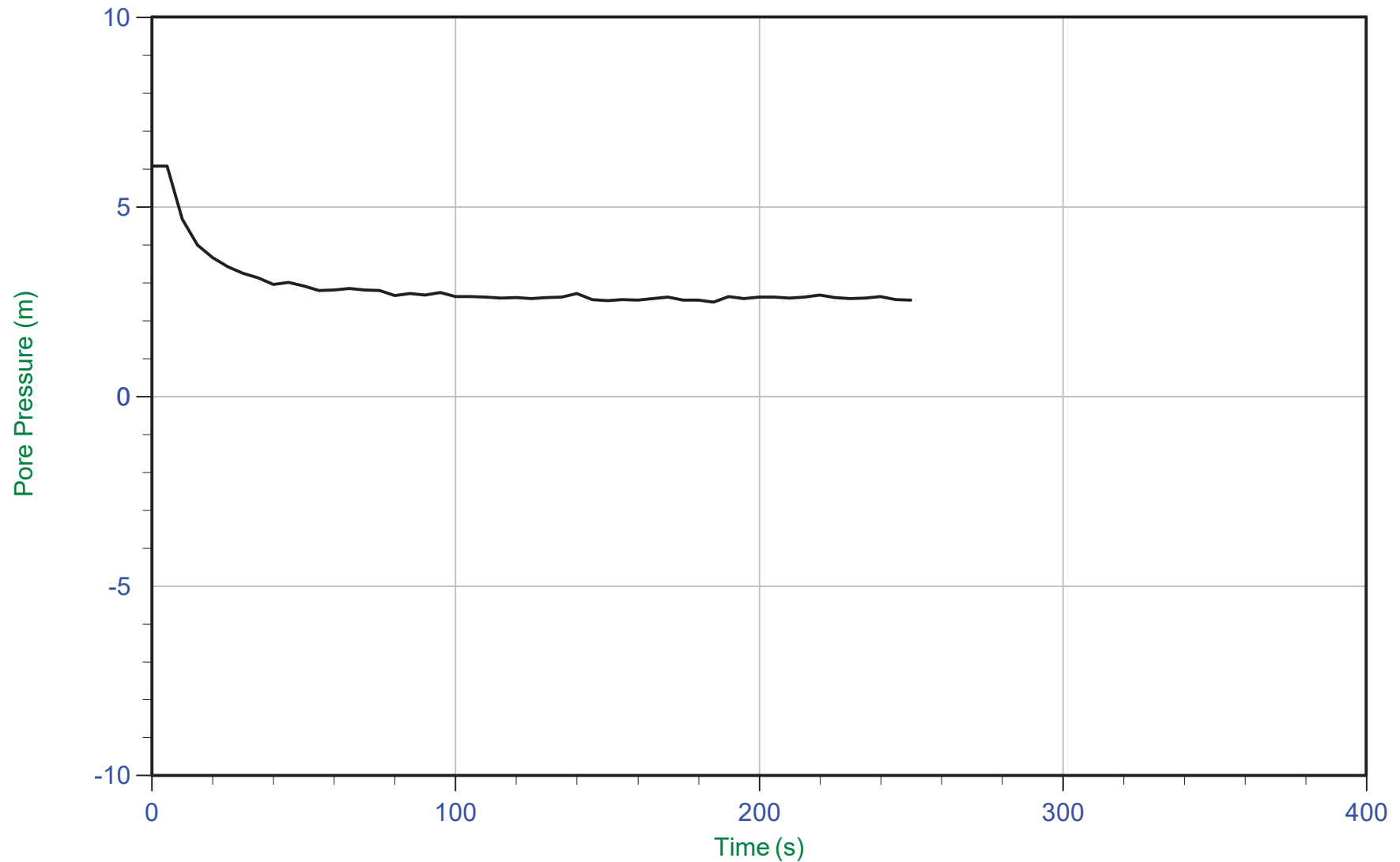
Trace Summary:	Filename: 17-05021_SP02.PPF	U Min: -0.1 m	WT: 1.693 m / 5.554 ft
	Depth: 2.250 m / 7.382 ft	U Max: 0.6 m	Ueq: 0.6 m
	Duration: 200.0 s		



Thurber Engineering

Job No: 17-05021
Date: 05/23/2017 10:19
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02
Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:	Filename: 17-05021_SP02.PPF	U Min: 2.5 m	WT: 1.675 m / 5.495 ft
	Depth: 4.250 m / 13.943 ft	U Max: 6.1 m	Ueq: 2.6 m
	Duration: 250.0 s		



Thurber Engineering

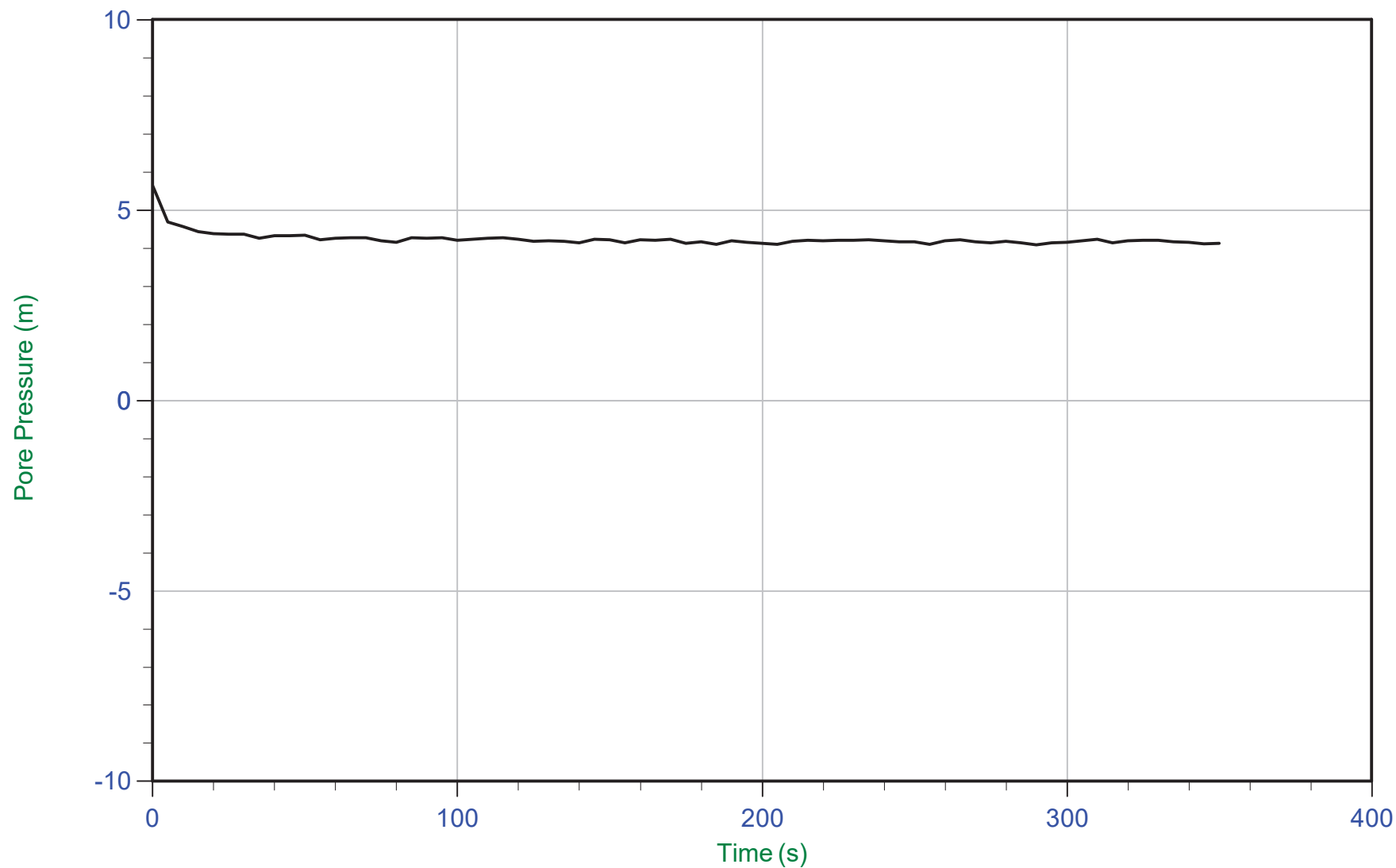
Job No: 17-05021

Date: 05/23/2017 10:19

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP02.PPF
Depth: 5.800 m / 19.029 ft
Duration: 350.0 s

U Min: 4.1 m
U Max: 5.6 m

WT: 1.648 m / 5.407 ft
Ueq: 4.2 m



Thurber Engineering

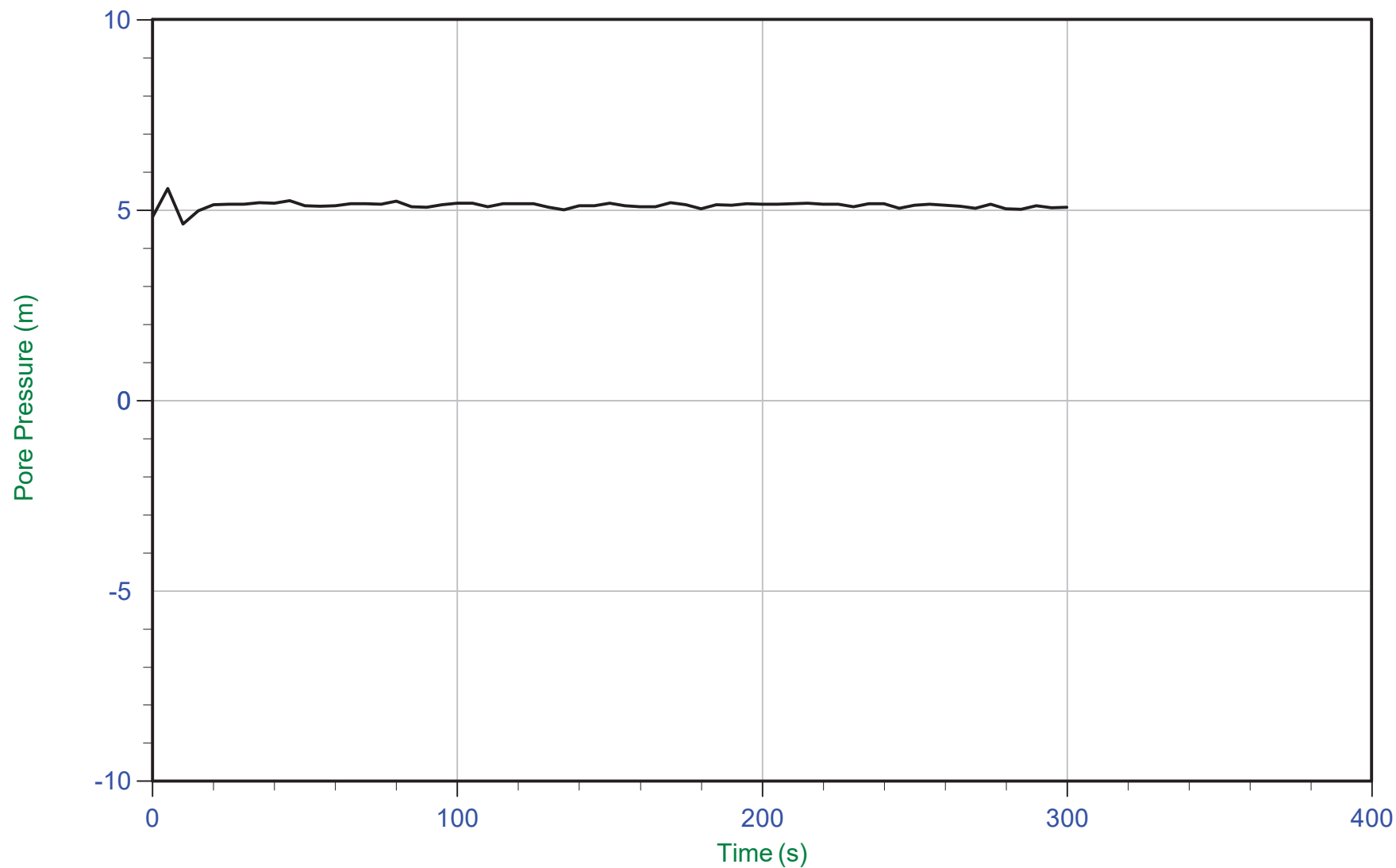
Job No: 17-05021

Date: 05/23/2017 10:19

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-02

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP02.PPF

Depth: 6.700 m / 21.981 ft

Duration: 300.0 s

U Min: 4.6 m

U Max: 5.6 m

WT: 1.603 m / 5.259 ft

Ueq: 5.1 m



Thurber Engineering

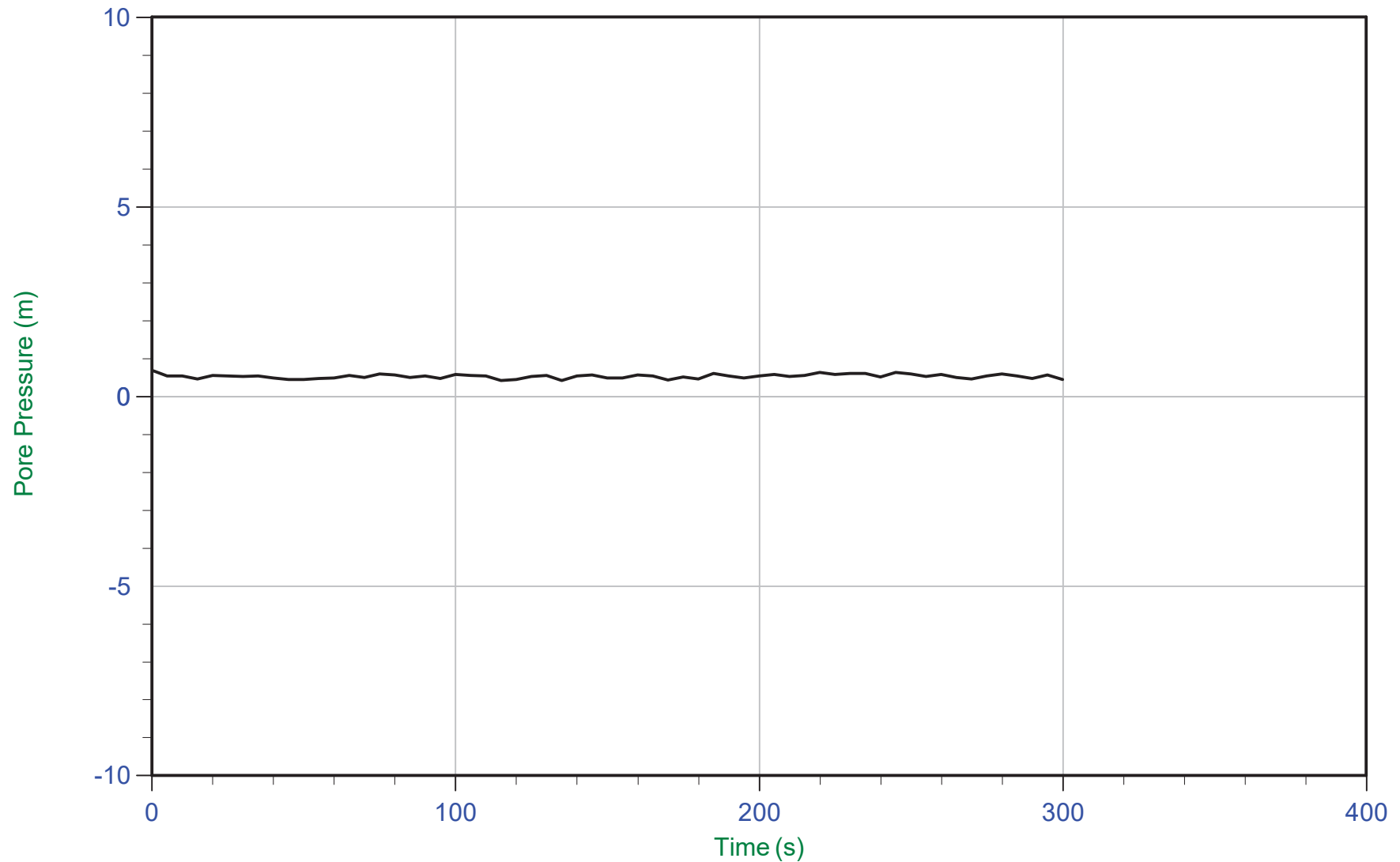
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:	Filename: 17-05021_SP03.PPF	U Min: 0.4 m	WT: 1.734 m / 5.689 ft
	Depth: 2.250 m / 7.382 ft	U Max: 0.7 m	Ueq: 0.5 m
	Duration: 300.0 s		



Thurber Engineering

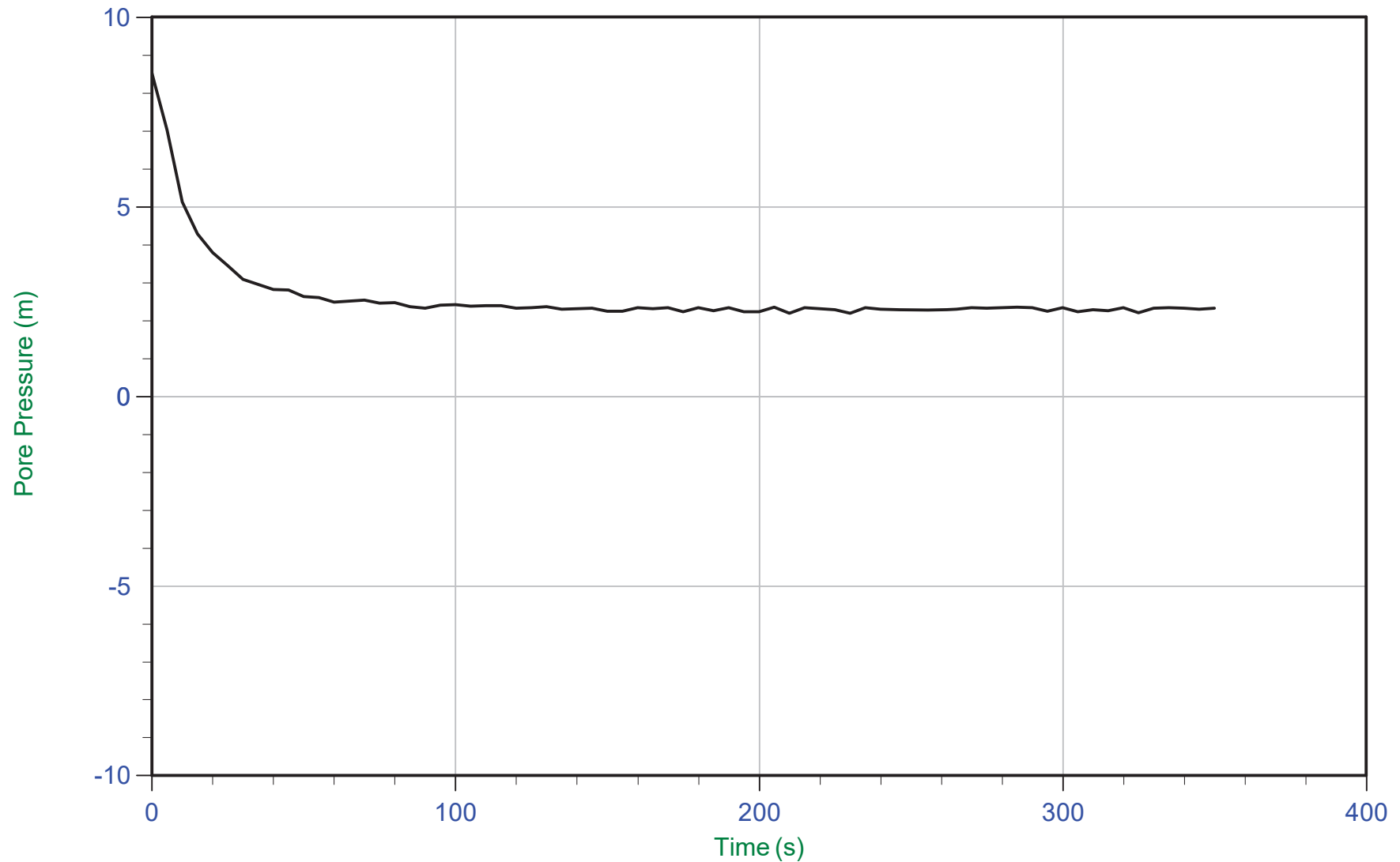
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP03.PPF

Depth: 4.000 m / 13.123 ft

Duration: 350.0 s

U Min: 2.2 m

U Max: 8.5 m

WT: 1.731 m / 5.679 ft

Ueq: 2.3 m



Thurber Engineering

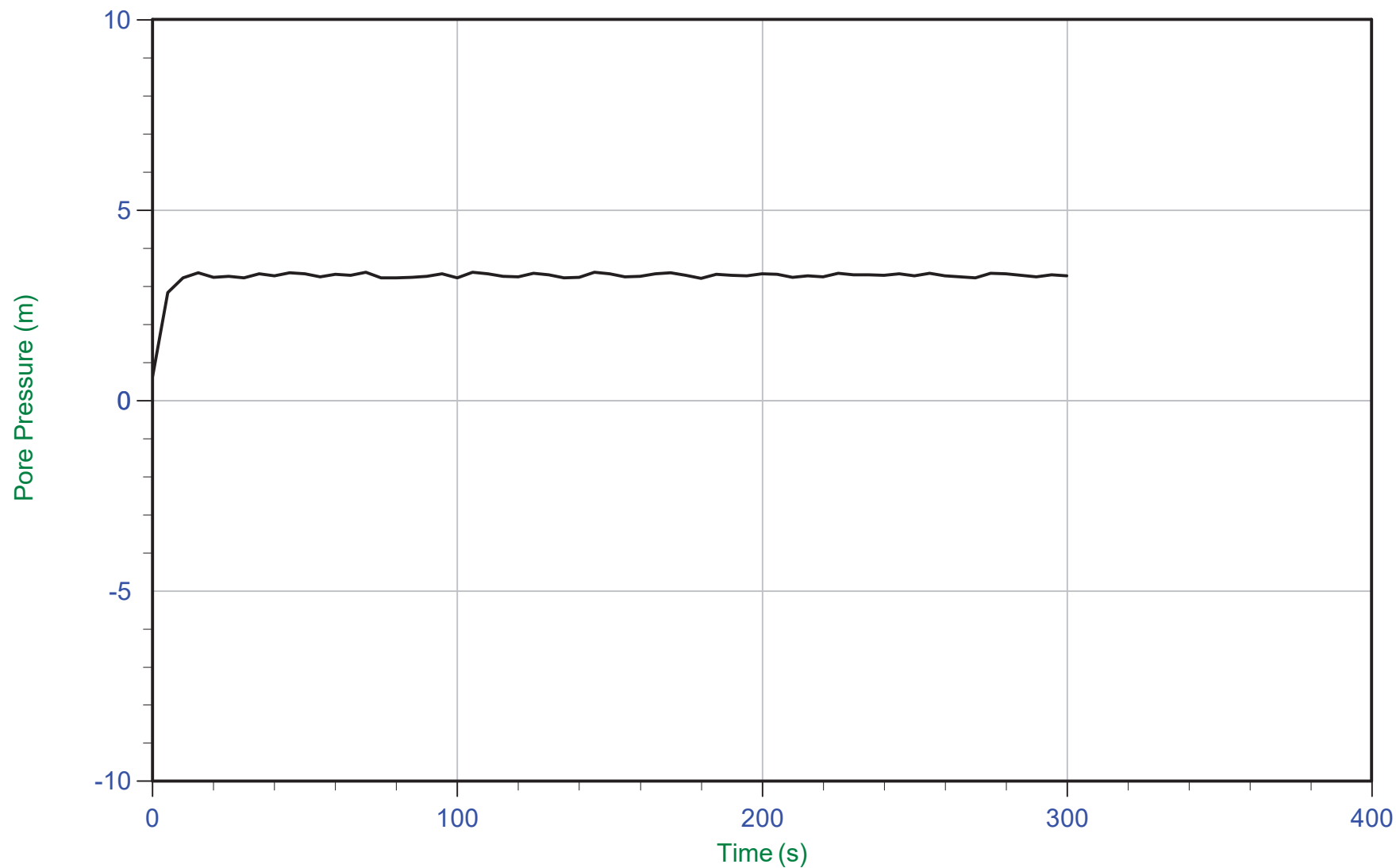
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP03.PPF
Depth: 5.000 m / 16.404 ft
Duration: 300.0 s

U Min: 0.6 m
U Max: 3.4 m

WT: 1.713 m / 5.620 ft
Ueq: 3.3 m



Thurber Engineering

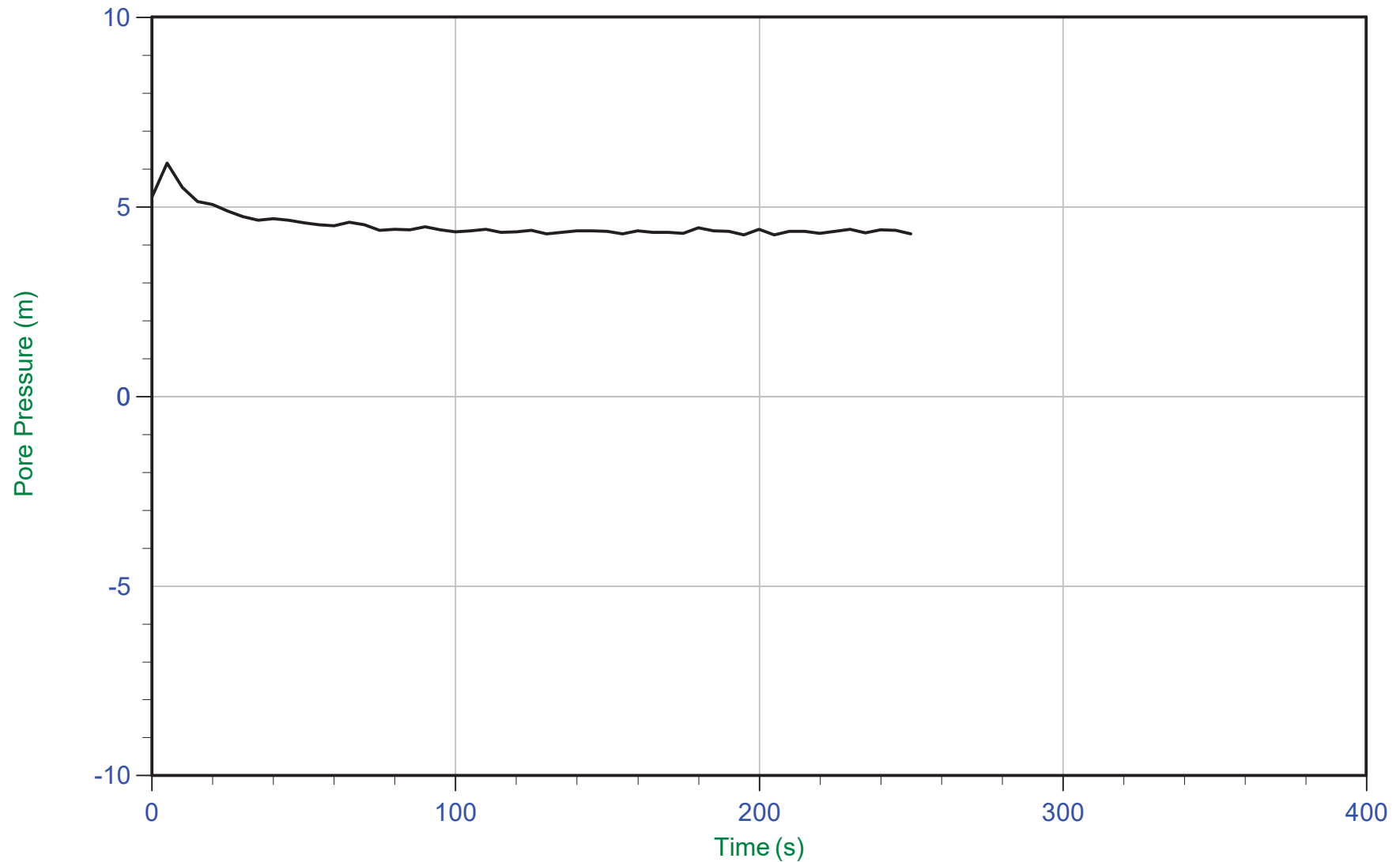
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:	Filename: 17-05021_SP03.PPF	U Min: 4.3 m	WT: 1.665 m / 5.463 ft
	Depth: 6.000 m / 19.685 ft	U Max: 6.2 m	Ueq: 4.3 m
	Duration: 250.0 s		



Thurber Engineering

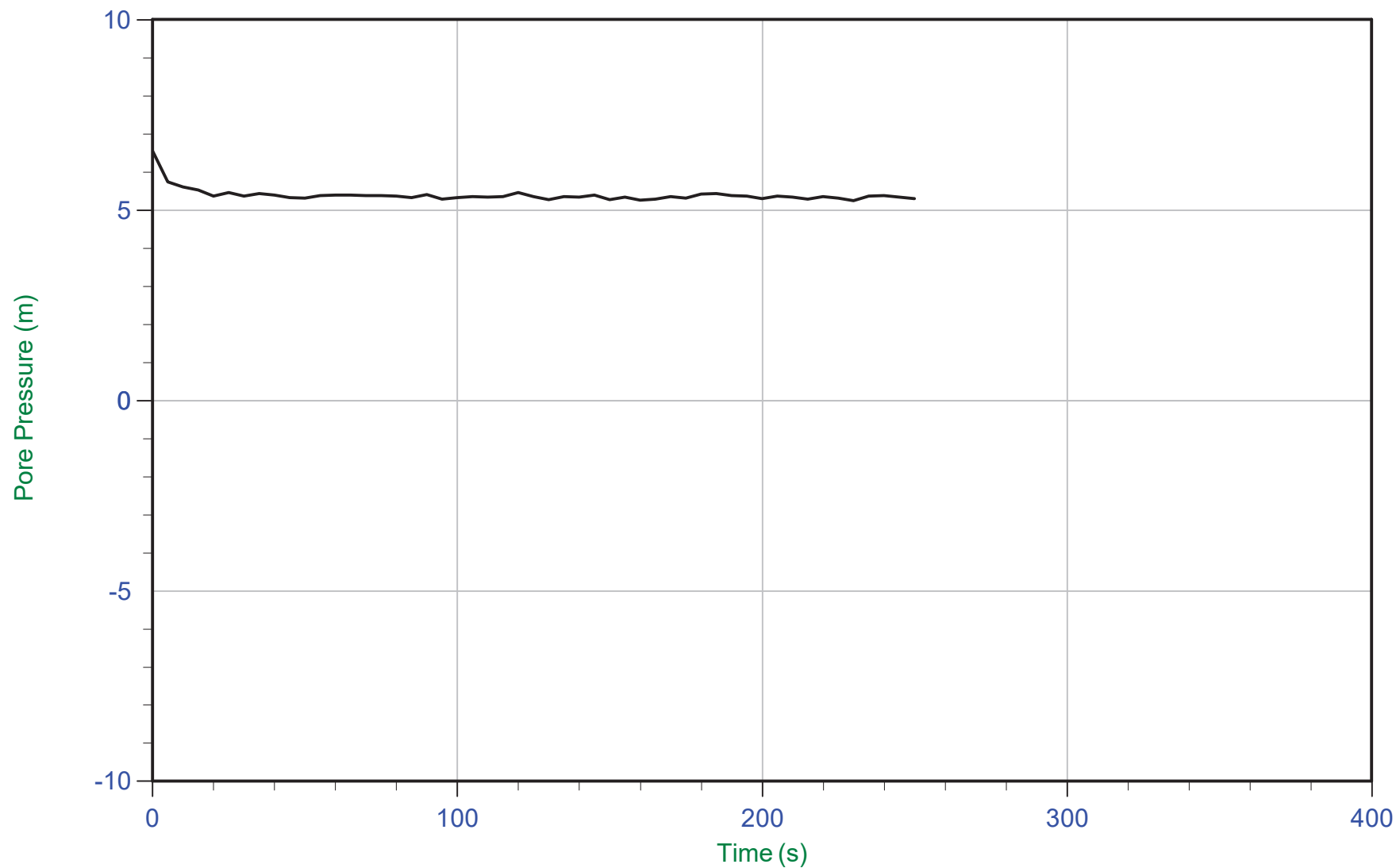
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP03.PPF

Depth: 7.000 m / 22.966 ft

Duration: 250.0 s

U Min: 5.3 m

U Max: 6.6 m

WT: 1.686 m / 5.531 ft

Ueq: 5.3 m



Thurber Engineering

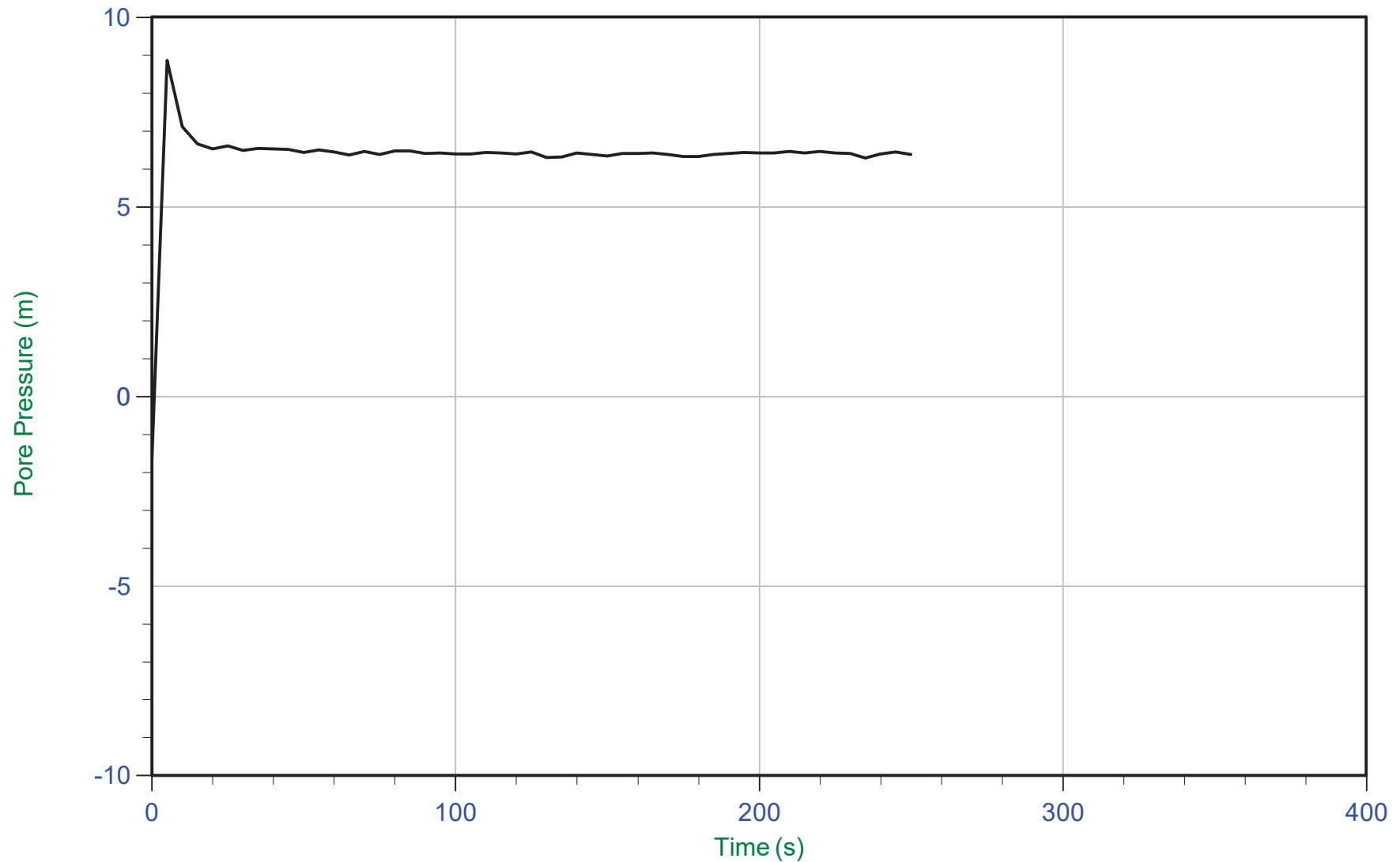
Job No: 17-05021

Date: 05/23/2017 12:56

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-03

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP03.PPF
Depth: 8.000 m / 26.246 ft
Duration: 250.0 s

U Min: -1.6 m
U Max: 8.9 m

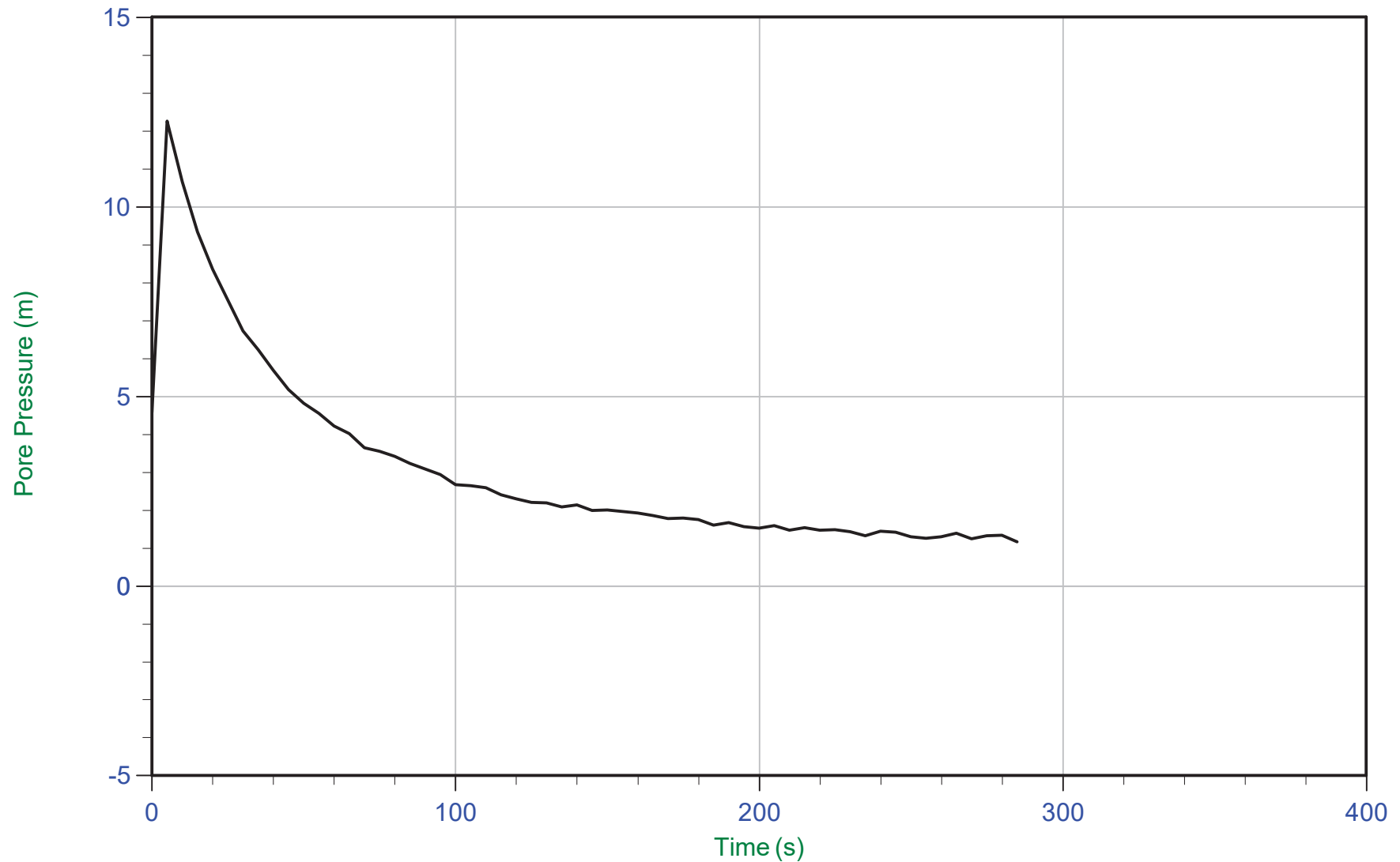
WT: 1.622 m / 5.321 ft
Ueq: 6.4 m



Thurber Engineering

Job No: 17-05021
Date: 05/23/2017 14:17
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04
Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 17-05021_SP04.PPF U Min: 1.2 m
Depth: 2.250 m / 7.382 ft U Max: 12.3 m
Duration: 285.0 s



Thurber Engineering

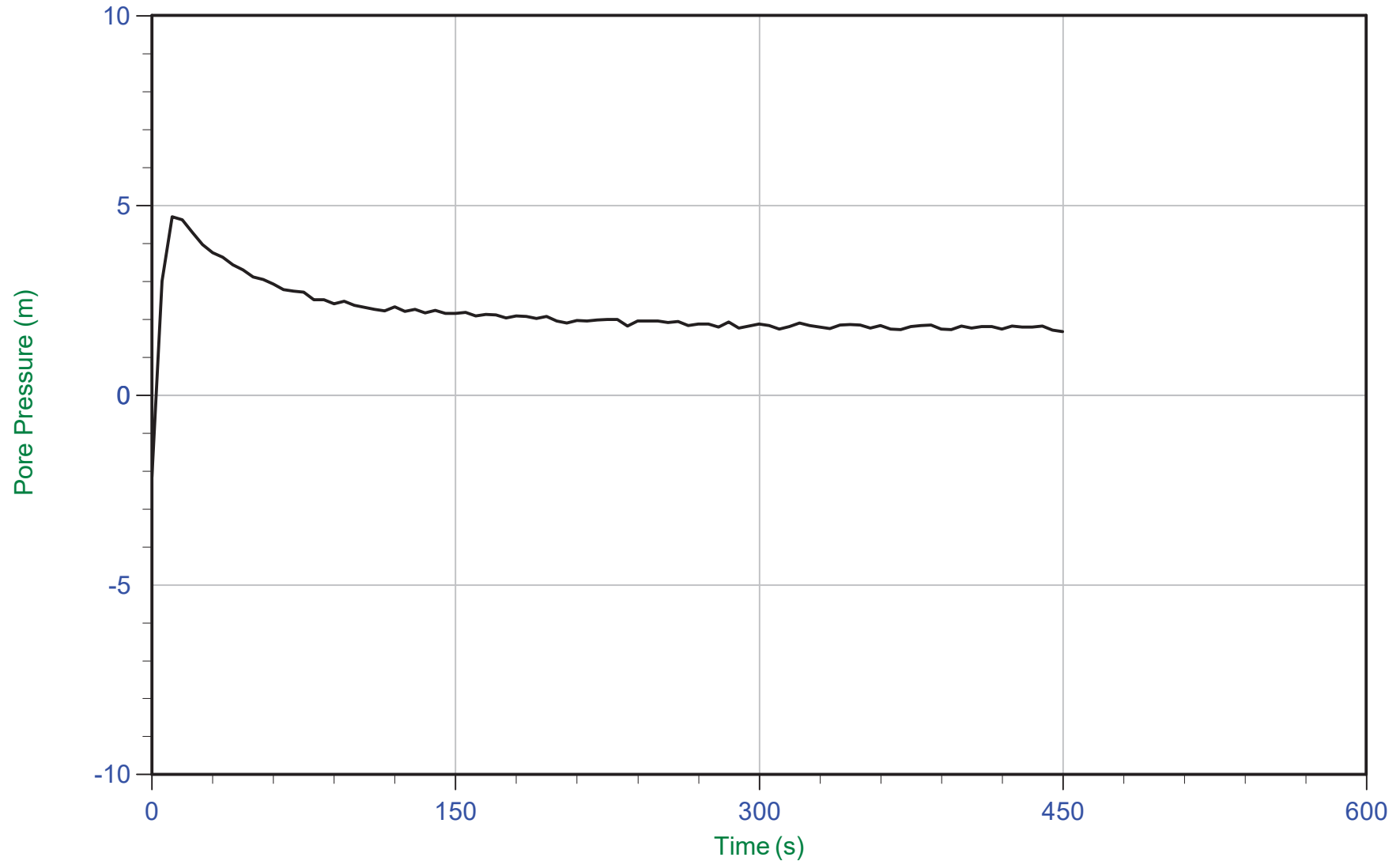
Job No: 17-05021

Date: 05/23/2017 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:	Filename: 17-05021_SP04.PPF	U Min: -2.2 m	WT: 1.490 m / 4.888 ft
	Depth: 3.250 m / 10.663 ft	U Max: 4.7 m	Ueq: 1.8 m
	Duration: 450.0 s		



Thurber Engineering

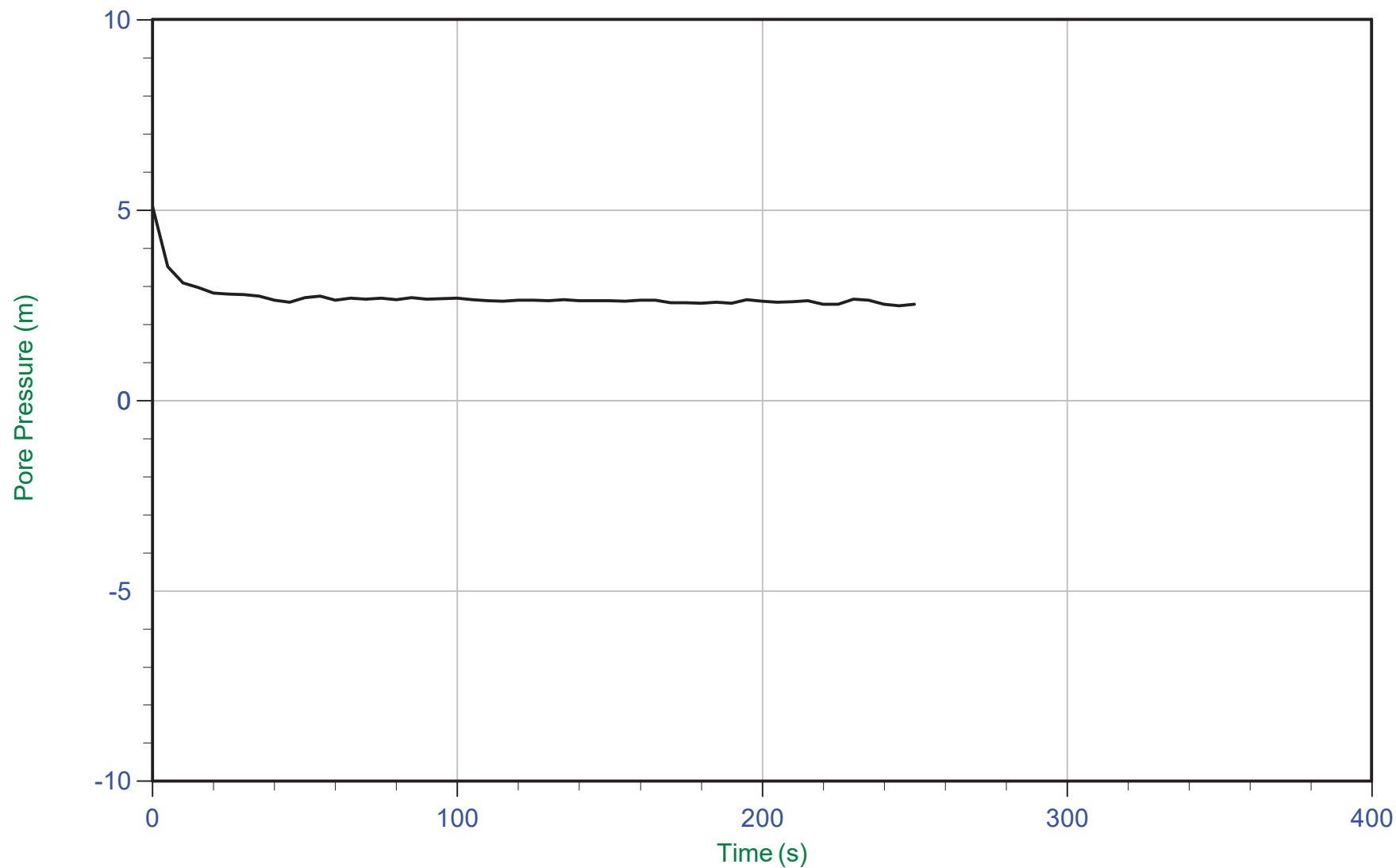
Job No: 17-05021

Date: 05/23/2017 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP04.PPF

Depth: 4.250 m / 13.943 ft

Duration: 250.0 s

U Min: 2.5 m

U Max: 5.1 m

WT: 1.675 m / 5.495 ft

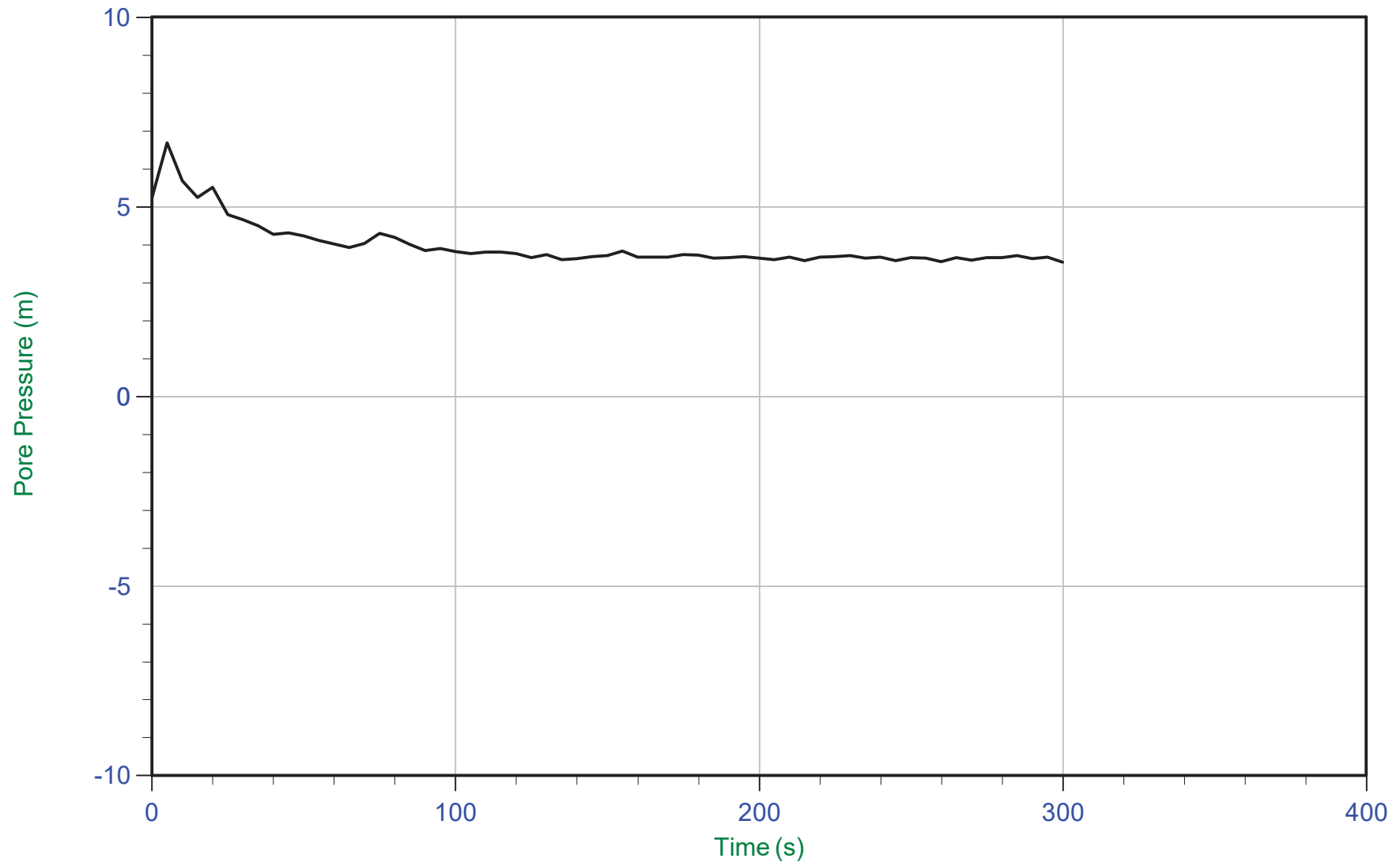
Ueq: 2.6 m



Thurber Engineering

Job No: 17-05021
Date: 05/23/2017 14:17
Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04
Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:	Filename: 17-05021_SP04.PPF	U Min: 3.5 m	WT: 1.635 m / 5.364 ft
	Depth: 5.250 m / 17.224 ft	U Max: 6.7 m	Ueq: 3.6 m
	Duration: 300.0 s		



Thurber Engineering

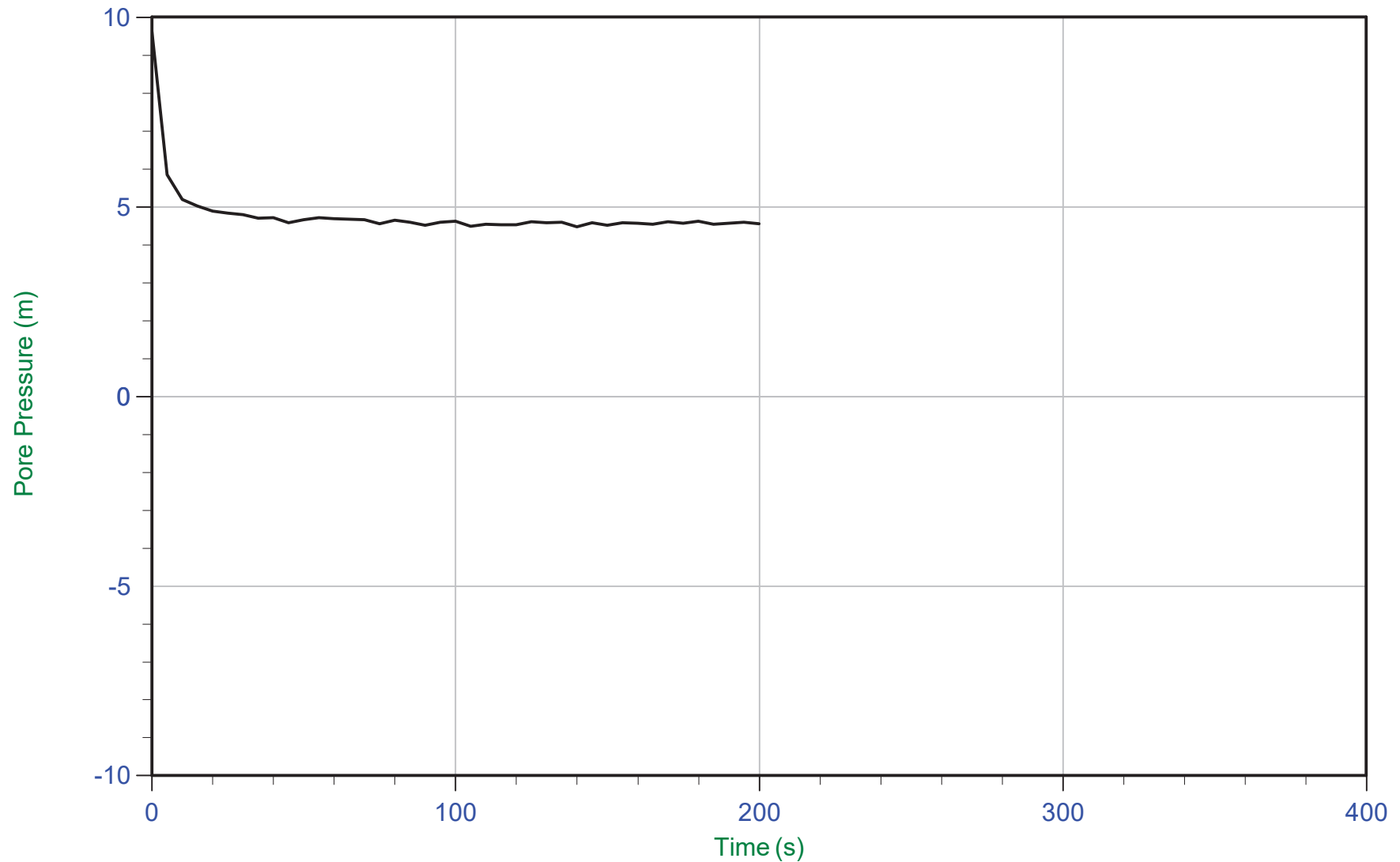
Job No: 17-05021

Date: 05/23/2017 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP04.PPF
Depth: 6.250 m / 20.505 ft
Duration: 200.0 s

U Min: 4.5 m
U Max: 9.6 m

WT: 1.684 m / 5.525 ft
Ueq: 4.6 m



Thurber Engineering

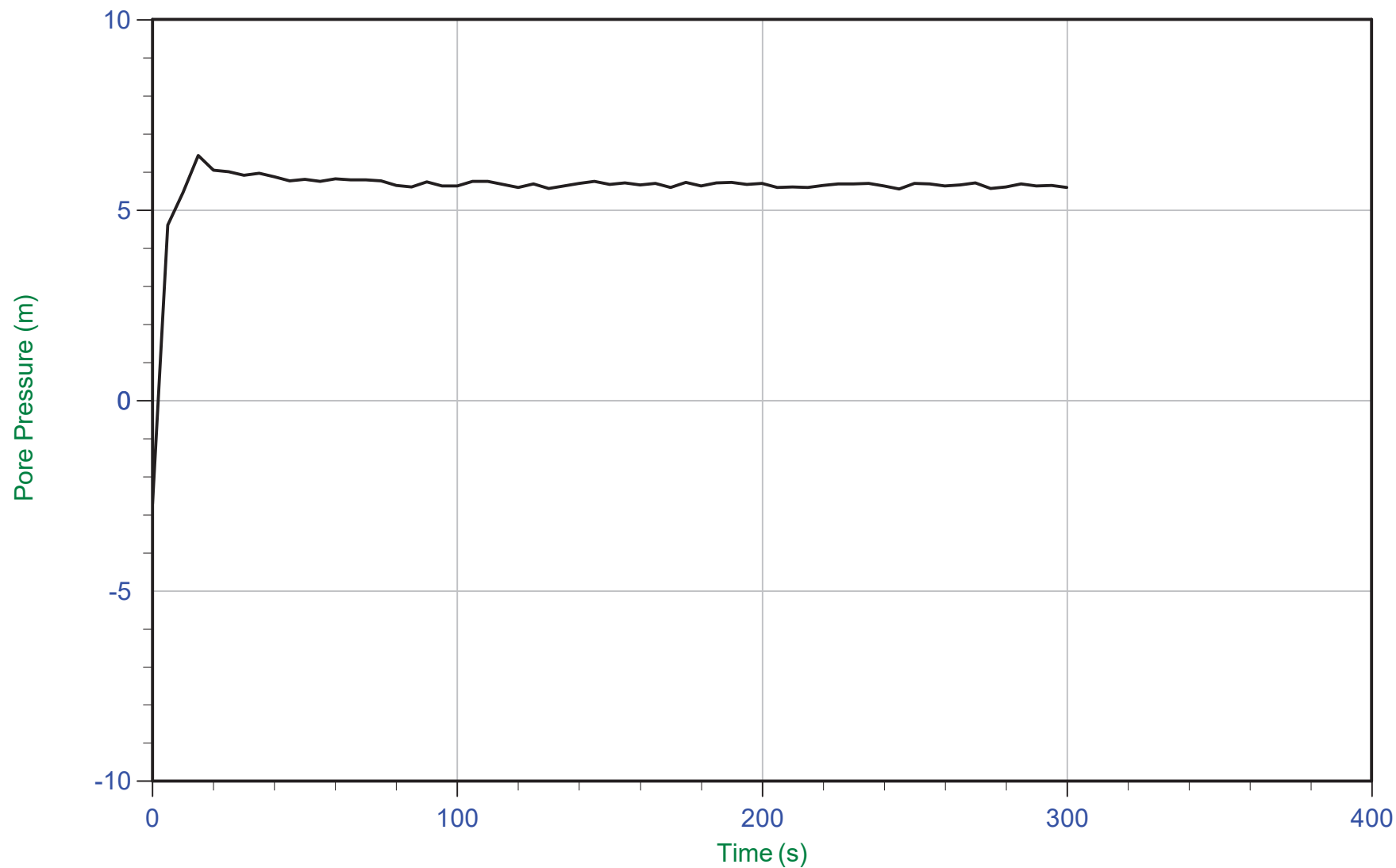
Job No: 17-05021

Date: 05/23/2017 14:17

Site: Hwy 17 - Muskrat Creek Culvert

Sounding: SCPT17-04

Cone: 379:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 17-05021_SP04.PPF

Depth: 7.300 m / 23.950 ft

Duration: 300.0 s

U Min: -2.7 m

U Max: 6.4 m

WT: 1.667 m / 5.469 ft

Ueq: 5.6 m

APPENDIX E
SITE PHOTOGRAPHS



Figure 1: Looking east along Highway 17 south embankment at the culvert outlet



Figure 2: Culvert 29-232/C outlet looking south



Figure 3: Culvert 29-232/C outlet looking northeast



Figure 4: Looking upstream at Culvert 29-232/C inlet