



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION REPORT  
CULVERT REHABILITATION  
HIGHWAY 406, NORTH OF PORT ROBINSON ROAD  
CITY OF THOROLD, ONTARIO  
G.W.P. 2063-17-00, SITE 34X-0294**

**GEOCRES NO. 30M3-318**

**Latitude: 43.041765°  
Longitude: -79.235657°**

**Report**

**to**

**Ontario Ministry of Transportation**

Date: February 6, 2020  
File: 20000



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**PART 1: FACTUAL INFORMATION**

**1.0 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed partial culvert replacement located on Highway 406 NBL, north of Port Robinson Road, at approximate Station 15+712, in Thorold, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions was developed for the site, based on the data obtained from the investigation, to describe the geotechnical conditions influencing design and construction of the replacement culvert.

Thurber was retained by The Ontario Ministry of Transportation (MTO) to carry out this foundation investigation under the MTO Assignment Number 2016-E-0076.

During the preparation of this report and in addition to the boreholes drilled, reference has been made to information on subsurface conditions contained in previous foundation reports prepared for nearby sites. The titles of these reports are listed as follows:

- Foundation Investigation Report for Culverts and Culvert Extensions, Highway 406 Twinning, Port Robinson Road to East Main Street, W.P. 280-99-00, GEOCRES No. 30M3-269, dated February 25, 2011, prepared by Terraprobe. (Reference 1).



- Foundation Investigation and Design Report for High Fills at Port Robinson, Highway 406 Twinning, Port Robinson Road to East Main Street, W.P. 280-99-00, GEOCRETS No. 30M3-264, dated September 30, 2010, prepared by Terraprobe. (Reference 2).

## **2.0 SITE DESCRIPTION**

The existing culvert is located approximately 170 m north of Port Robinson Road, crossing under Highway 406 in Thorold, Ontario.

The culvert runs in a general northeast-southwest direction with its alignment in a skewed angle (55 degrees) to the centreline of the highway. The culvert allows the creek to flow in northeasterly direction beneath the highway. The lands surrounding the existing culvert consist of agricultural lands, with trees and bushes along the east and west sides of Highway 406. The terrain is generally flat.

Originally, an open footing culvert was built in 1968 and measured 3.65 m in width, 2.52 m in height and 56.6 m in length. As part of the Highway 406 twinning project, in 2013, the culvert was extended to the west by installing a new rigid frame box culvert. The culvert extension measured 35.5 m. Based on recent culvert inspection reports, the culvert appears to have experienced settlement, resulting in cracks at the mid-section. Scour has also been noted at some locations. The total length of the culvert is 92.1 m. The Highway 406 grade at the existing culvert is at approximate Elevation 182.0 m. The culvert inlet invert level is at approximate Elevation 176.5. The maximum height of the embankment fill at the culvert is approximately 5.3 m.

It is understood that the current project requirements involve replacement of the east portion of the existing open footing culvert, under Highway 406 northbound lane (NBL), with a concrete box culvert along the same alignment. The approximate length of the east culvert replacement is approximately 55.5 m.

Selected photographs of the culvert area are included in Appendix E for reference.

The site is situated within the physiographic region known as the Haldimand Clay Plain, which is characterized by glacio-lacustrine deposits laid down by the glacial Lake Warren during the Wisconsinian Age. These deposits consist of silts and clays and are generally underlain by a glacial till, which in turn overlies dolomitic limestone bedrock.



### 3.0 SITE INVESTIGATION AND FIELD TESTING

The present borehole investigation and field testing program for this site were carried out between October 28 to 31, 2019, and consisted of drilling and sampling four (4) boreholes, designated as Boreholes 19-01 to 19-04. All the boreholes were drilled from the east shoulder of Highway 406 SBL to the culvert outlet, which is located on the east side of Highway 406 NBL. Boreholes 19-01 and 19-02 were drilled from the Highway 406 platform and were terminated at 17.8 m depth (Elevations 163.7 and 164.2). Boreholes 19-03 and 19-04, were drilled within the outlet zone and terminated at 14.3 m depth (Elevations 162.4 and 164.3). The Records of Borehole sheets from the present investigation are provided in Appendix A.

A previous geotechnical investigation was carried out at this site between July 13 and July 14, 2010 (Reference 1) and consisted of advancing three boreholes (numbered C10-1, C10-2 and C10-3) near the existing culvert alignment. The boreholes were drilled and sampled to depths ranging from 12.7 m to 23.4 m (Elevations 158.3 to 164.4). The Record of Borehole sheets of the previous investigation at this site are included in Appendix D1.

The approximate locations of the boreholes from the present and previous investigations are shown on the Borehole Locations Plan and Soil Strata Drawing in Appendix F and in Figure 1 “Borehole Location Plan” following the report text.

The coordinates and elevations of the boreholes are given on this drawing and on the individual Record of Borehole Sheets in Appendices A and D1. Thurber surveyed the current boreholes in the field, and obtained the borehole coordinates and ground surface elevations. Coordinates of boreholes are related to MTM NAD 83 Zone 10. The survey equipment used was a Trimble R10 GNSS system, with a horizontal precision of 3 mm RMS, and a vertical precision of 3.5 mm RMS.

Lane closures and traffic control were implemented during drilling of the boreholes for the current investigation. Prior to commencement of drilling, utility clearances were obtained for all borehole locations.

The current boreholes were advanced using a track-mounted drill rig equipped with hollow stem augers. Soil samples were obtained at selected intervals using a 50 mm outside diameter split-spoon sampler driven in conjunction with the Standard Penetration Test (SPT). The SPT was performed in accordance with ASTM D1586.



In the cohesive deposits, the undrained shear strength of the material was measured in-situ by means of field vane tests (MTO N-Vane), and undisturbed soil samples were collected using thin-walled Shelby tube samplers.

In addition to the above field investigation, a Cone Penetration Test (CPTu) labelled CPT19-05, was conducted at the site on November 22, 2019. The CPTu was advanced to 29.2 m depth (Elevation 152.9). The piezocone penetrometer consists of a metal rod equipped with electronic sensors at its tip, which is statically pushed into the ground by a drill rig to continuously measure the tip resistance, sleeve friction, dynamic pore water pressure, temperature and cone inclination. The CPTu included pore pressure dissipation tests at selected depths in the silty clay in order to obtain horizontal coefficient of consolidation values. All CPTu testing was performed in accordance with the current ASTM D5778 standard. The approximate location of the CPTu is shown on the Borehole Location Plan and Stratigraphic Drawing in Appendix F. The inferred stratigraphy and results of the pore pressure dissipation tests are provided in ConeTec's report included in Appendix C.

The objectives of the CPTu and borehole drilling were to provide more detailed information about the subsurface stratigraphy and consolidation characteristics of the compressible cohesive (silty clay) soils, as well as to collect undisturbed soil samples for laboratory testing.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of subsurface utilities, supervised the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

During the present investigation, groundwater conditions in the open boreholes were observed throughout the drilling operations. A standpipe piezometer (25 mm diameter) was installed and enclosed in filter sand columns in Borehole 19-04, to permit groundwater level monitoring. The details of the piezometer installation are shown in Table 3.1.

**Table 3.1 – Piezometer Details**

Borehole	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth/ Elevation (m)	Completion Details
19-04	14.3/162.4	13.9/162.8	Piezometer with 3.0 m slotted screen installed with sand filter from 14.3 m to 10.2 m, bentonite holeplug from 10.2 m to 9.1 m, grout from 9.1 m to 1.5 m, bentonite from 1.5 m to 0.6 m, then sand to ground surface.

All remaining boreholes without piezometer installations were backfilled upon completion of drilling in general conformance with O.Reg. 903 as amended by O.Reg.128/03. The piezometer was decommissioned following groundwater monitoring in general conformance with O.Reg. 903. Asphalt was reinstated in Boreholes 19-01 and 19-02 drilled on the highway platform.

#### **4.0 LABORATORY TESTING**

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. Selected samples were subjected to grain size distribution analyses (sieve and/or hydrometer), Atterberg Limits testing and Specific Gravity. Geotechnical laboratory testing results of the present investigation are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B1.

Laboratory test conducted during the previous investigation is presented in Appendix D.

During the present investigation, two selected soil samples were subjected to One-Dimension Consolidation Test from Boreholes 19-02 and 19-03. Consolidation tests were carried out in accordance with Standard Test Method for One-Dimensional Consolidation Properties of Soils, ASTM D 2435-11, method A. Each of the soil specimen in the current investigation was left to creep in one of the load steps. The results of these tests are included in Appendix B3.

Five One-dimension consolidation tests were performed on soil specimens retrieved from Boreholes C10-1, C11-3, C12-3, PR1 and PR5 drilled in the vicinity of the culvert during the previous investigations (References 1 and 2). The results of the consolidation tests from the previous investigations, are presented in Appendices D1 to D4. The borehole locations where





consolidation tests were conducted during the present and previous investigations are shown on Figure 1.

In order to assess the potential for sulphate attack on a concrete culvert, as well as the potential for metal corrosion associated with the structure, two samples of the native soils were collected and submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing for corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B2.

## **5.0 DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendices A and D1, and on the Borehole Locations and Soil Strata drawings in Appendix F. A general description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions. It must be recognized and anticipated that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface stratigraphy encountered on the highway grade consists of asphalt and concrete overlying compact gravelly sand and soft to very stiff silty clay embankment fill. Below and beyond the highway embankment, the native soils consist of topsoil overlying an extensive deposit of native upper silty clay. A layer of silt was contacted below the upper silty clay. The silt is underlain by a lower layer of silty clay. Groundwater levels are generally in the order of 0 to 1.5 m (Elevations 177.0 to 177.4) below original ground surface. A groundwater level was measured at 0.1 m (Elevation 176.8) above the ground surface in Borehole 19-04, drilled at the culvert outlet.

More detailed descriptions of the individual stratum are presented below.

### **5.1 Topsoil**

Topsoil was encountered surficially in Boreholes 19-03, C10-1 and C10-3. The thickness of the topsoil was 75 mm in Borehole 19-03, and 230 mm in Boreholes C10-1 and C10-3.

The topsoil thickness may vary between and beyond the borehole locations, and the data is not intended for the purpose of estimating quantities.



## **5.2 Pavement Structure**

Pavement structure consisting of approximately 125 mm of asphalt overlying granular (sand and gravel) road base was encountered in Boreholes 19-01 and 19-02 advanced through the Highway 406 platform. The granular fill ranged in thickness from 300 mm to 600 mm. A 300-mm thick layer of concrete was contacted below the asphalt in Borehole 19-02.

SPT 'N' values recorded in the granular road base were 9 and 35 blows per 0.3 m of penetration indicating loose to dense condition. The natural moisture contents measured on samples of the granular road base ranged from 3 percent to 25 percent.

## **5.3 Embankment Fill**

The existing embankment fill consisted on layers of cohesionless and cohesive soils.

Cohesionless fill was contacted surficially in Boreholes 19-04 and C10-2, and consisted of reddish brown to brown sand and gravel, and gravelly sand containing some silt and trace clay. The thickness of the cohesionless fill varied from 100 mm to 700 mm.

Cohesive fill was contacted below the topsoil and/or pavement structure in Boreholes 19-01 to 19-03 and C10-3, and below the cohesionless fill in Boreholes 19-04 and C10-2. The cohesive fill consisted on reddish brown, brown and dark brown silty clay containing trace sand to sandy, trace gravel, occasional organics and grey silt lenses. The thickness of the silty clay fill ranged from 1.4 m to 4.9 m.

The depth to the base of the embankment fill ranged from 1.5 m to 5.6 m (Elevations 175.2 to 177.8).

An SPT 'N' value measured in the gravelly sand fill was 17 blows per 0.3 m of penetration, indicating a compact state. SPT 'N' values measured in the silty clay fill varied from 3 to 19 blows per 0.3 m of penetration, indicating a soft to very stiff consistency. The natural moisture contents measured on a sample of the cohesionless fill was 6 percent. Moisture contents measured on the silty clay fill samples ranged from 16 percent to 38 percent.

The results of grain size analyses conducted on samples of the silty clay fill during the present investigation, are provided on the Record of Borehole sheets in Appendix A, and illustrated on Figure B1 of Appendix B1. Grain size analyses results of the gravelly sand fill and silty clay fill



from the previous investigation, are presented in Figures B7-1 and B7-2 of Appendix D1. The results are summarized as follows:

Soil Particle	Silty Clay Fill (Percent)	Gravelly Sand Fill (Percent)
Gravel	0	26
Sand	3 to 19	56
Silt	38 to 59	14
Clay	28 to 43	4

The results of Atterberg Limits tests conducted on samples of the silty clay fill during the present investigation, are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figure B5 of Appendix B1. The results of Atterberg Limits tests from the previous investigation are presented in Figure B7-3 of Appendix D1. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	37 to 44
Plasticity Index	17 to 22

The results of the Atterberg Limits testing indicate that the silty clay fill has a medium plasticity with a group symbol of CI.

#### 5.4 Clayey Silt

An 800-mm thick layer of native brown to grey clayey silt containing trace sand, trace gravel and occasional organics and rootlets was contacted below the embankment fill in Boreholes 19-01 and 19-02.

The depth to the base of the clayey silt was at 4.5 m and 5.3 m (Elevations 177.0 and 176.7) in Boreholes 19-01 and 19-02, respectively

The SPT 'N' values recorded in the clayey silt were 9 blows per 0.3 m of penetration, indicating a stiff consistency. The natural moisture contents measured on samples of clayey silt were 22 percent and 26 percent.



## 5.5 Upper Silty Clay

An upper deposit of native brown to grey silty clay was encountered below the silty clay fill and clayey silt, at depths ranging from 1.5 m and 5.6 m (Elevations 175.2 to 177.0) in all the boreholes, except in Borehole C10-1, where it was encountered below the topsoil at 0.2 m (Elevation 176.9). The silty clay contained trace sand, trace gravel and thin silt lenses. The thickness of the upper silty clay ranged from 9.4 m to 12.5 m.

An over-consolidated weathered crust, extending to approximately 5.7 to 10 m depths (Elevations 171.0 to 173.0 m), was encountered in Boreholes 19-01 to 19-04, C10-1 and C10-2. Within this crust, SPT 'N' values typically ranged from 8 to 22 blows for 0.3 m of penetration indicating a stiff to very stiff consistency. Locally, in Borehole C10-3, the SPT 'N' values ranged up to 31 blows for 0.3 m of penetration, indicating a hard consistency.

Below the crust, a lightly over-consolidated silty clay zone was encountered below approximately Elevations 171.0 to 174.0 m, with depths of the base ranging from about 10.5 to 16.3 m. SPT 'N' values typically ranged between 0 and 6 blows per 0.3 m penetration within this zone. Vane shear tests (VST) conducted in the lightly over-consolidated silty clay measured in-situ undrained shear strength in the range of 55 kPa to 110 kPa, which corresponds to a stiff to very stiff consistency. An in-situ undrained shear strength of 48 kPa was measured in one borehole from the previous investigation, indicating a firm consistency.

Moisture contents measured on the upper silty clay samples ranged from 17 percent to 49 percent.

The results of grain size analyses conducted on samples of the upper silty clay during the present investigation, are provided on the Record of Borehole sheets in Appendix A, and illustrated on Figures B2 and B3 of Appendix B1. Grain size analyses results of the upper silty clay from the previous investigation, are presented in Figures B7-4 and B7-5 of Appendix D1. The results are summarized as follows:



Soil Particle	Upper Silty Clay (Percent)
Gravel	0 to 1
Sand	0 to 41
Silt	30 to 82
Clay	18 to 57

The results of Atterberg Limits tests conducted on samples of the upper silty clay during the present investigation, are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figures B6 and B7 of Appendix B1. The results of Atterberg Limits tests from the previous investigation are presented in Figures B7-6 and B7-7 of Appendix D1. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	22 to 42
Plasticity Index	7 to 23

The results of the Atterberg Limits testing indicate that the upper silty clay has a low to medium plasticity with group symbols of CL and CI.

The results of two oedometer (one-dimensional consolidation) tests carried out on undisturbed silty clay samples of the present investigation, collected from depths ranging from 7.9 to 9.5 m, are summarized on the borehole logs and in Table 5.1 below. Two time-dependent creep tests were carried out for approximately 216 to 266 hours under constant loading stress for the measurement of coefficient of secondary consolidation ( $C_{\alpha}$ ). The detailed test results are also presented in Appendix B3.

**Table 5.1 - Oedometer Test Results**

<b>Borehole</b>	<b>19-02</b>	<b>19-03</b>
<b>Sample No.</b>	TW12	TW9
<b>Depth (m)</b>	9.45	7.9
<b>Elevation (m)</b>	172.6	170.7
<b>Soil Type</b>	Silty Clay	Silty Clay
<b>Clay Content (%)</b>	48	51
<b>Moisture Content (%)</b>	27	30
<b>Liquid Limit (%)</b>	39	39
<b>Plasticity Index (%)</b>	21	21
<b><math>\gamma</math> - Unit Weight (kN/m<sup>3</sup>)</b>	18.9	18.6
<b>G<sub>s</sub> - Specific Gravity</b>	2.74	2.79
<b>e<sub>o</sub> - Initial Void Ratio</b>	0.884	0.98
<b>P'<sub>0</sub> - In situ effective vertical stress (kPa)</b>	120	131
<b>P'<sub>c</sub> - Preconsolidation Pressure (kPa)</b>	242	230
<b>OCR - Overconsolidation Ratio</b>	2.02	1.75
<b>C<sub>c</sub> - Compression Index</b>	0.327	0.399
<b>C<sub>r</sub> - Recompression Index</b>	0.016	0.034
<b>C<sub><math>\alpha</math></sub> - Secondary Compression Index</b>	0.0080	0.0025
<b>C<sub>v</sub> - Coefficient of Consolidation in NC range (m<sup>2</sup>/yr)</b>	4.87	3.88
<b>C<sub>vr</sub> - Coefficient of Consolidation in OC range (m<sup>2</sup>/yr)</b>	15.11	11.86

Results of consolidation tests conducted during the previous investigations (References 1 and 2) and the associated borehole logs are included in Appendices D1 to D4.

The over-consolidation ratios (OCR) inferred from piezocone test show that this deposit is heavily over-consolidated with OCR values ranging from 10 to 4.1 from 4.5 m to 10.0 m depth, 6.2 to 2.3 from 10.0 m to 11.8 m and 2.9 to 1.1 from 11.8 m to 17.0 m. The behaviour observed from the pore pressure dissipation tests indicated that this deposit grades from over-consolidated to slightly over-consolidated.



In addition to the vertical coefficients of consolidation ( $C_v$ ) obtained from the oedometer tests, the horizontal coefficients of consolidation ( $C_h$ ) were measured at various depths in the Cone Penetration Test CPT19-05. Table 5.2 summarizes the results of the pore water dissipation tests.

**Table 5.2 - Pore Pressure Dissipation Test Results**

Piezocone (CPT19-05)	
Depth (m)	$C_h^{(1)}$ (cm <sup>2</sup> /min)
6.4	-
9.4	1.4
13.1	1.2
17.7	27.0
22.9	0.5
29.175	-

<sup>(1)</sup> Houlsby and Teh, 1991

## 5.6 Silt

Brown to grey silt containing trace to some clay and trace sand was contacted below the upper silty clay at depth ranging from 10.5 m to 16.3 m (Elevations 162.7 to 166.6) in all the boreholes. The thickness of the silt was 3.0 m in Boreholes C10-2 and C10-3. The depth to the base of the silt was at 19.2 m and 16.2 m (Elevations 162.5 and 162.3) in Boreholes C10-2 and C10-3, respectively.

A 1.2-m thick layer of silt was encountered within the upper silty clay at 4.4 m depth (Elevation 172.7) in Borehole C10-1.

Boreholes 19-01 to 19-04 and C10-1 were terminated within the silt at depths ranging from 12.7 m and 17.8 m (Elevations 162.4 and 164.4).

Based on the SPT 'N' values ranging typically from 0 to 11 blows per 0.3 m of penetration, the silt is in a very loose to compact state. SPT 'N' values of 21 and 37 blows per 0.3 m of penetration, indicating a compact to dense state, were measured in Boreholes C10-1 and C10-3. Moisture contents measured in the silt ranged from 19 percent to 34 percent.



The results of grain size distribution analyses carried out on samples of the silt, during the present investigation, are presented on the Record of Borehole sheets included in Appendix A. Grain size distribution curves of the silt samples tested are presented on Figure B4 Appendix B1. Grain size analyses results of the silt samples from the previous investigation, are presented in Figure B7-8 of Appendix D1. The results are summarized as follows:

Soil Particle	Silt (Percent)
Gravel	0 to 1
Sand	0 to 4
Silt	77 to 92
Clay	7 to 19

## 5.7 Lower Silty Clay

A lower layer of brown silty clay containing sand was encountered below the silt at 19.2 m and 16.2 m depth (Elevations 162.5 and 162.3) in Boreholes C10-2 and C10-3.

Boreholes C10-2 and C10-3 were terminated within the lower silty clay at 23.4 m and 17.3 m depth (Elevations 158.3 and 161.2).

SPT 'N' values measured in the lower silty clay ranged from 8 to 33 blows per 0.3 m of penetration, indicating a stiff to hard consistency. Moisture contents measured in the lower silty clay samples ranged from 17 percent to 22 percent.

Grain size analyses results of the lower silty clay from the previous investigation, are presented in Figure B7-5 of Appendix D1. The results are summarized as follows:

Soil Particle	Silty Clay (Percent)
Gravel	0
Sand	7
Silt	74
Clay	19

The results of Atterberg Limits tests from the previous investigation are presented in Figure B7-7 of Appendix D1. The results are summarized as follows:





Index Property	Percentage (%)
Liquid Limit	24
Plasticity Index	8

The results of the Atterberg Limits testing indicate that the silty clay has a low plasticity with a group symbol of CL.

## 5.8 Groundwater Conditions

Groundwater levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. Standpipe piezometers were installed in Borehole 19-04 during the present investigation, and in Boreholes C10-1 and C10-3 in the previous investigation, to permit monitoring of groundwater levels. Water levels measured in the installed piezometers and open boreholes are presented in Table 5.3 below.

**Table 5.3 - Groundwater Level Measurements**

Borehole	Date	Groundwater Level		Comments
		Depth (m)	Elev. (m)	
19-01	October 28, 2019	7.5	174.0	Borehole caved to 11.5 m Open borehole
19-03	October 30, 2019	13.3	165.3	Open borehole
19-04	October 31, 2019	0.4	176.3	Open borehole
	November 22, 2019	0.1 <sup>(1)</sup>	176.8	Piezometer
C10-1	July 13, 2010	7.3	169.8	Open borehole
	July 19, 2010	0.1	177.0	Piezometer
	August 6, 2010	0.0	177.1	Piezometer
	August 13, 2010	0.0	177.1	Piezometer
	August 23, 2010	0.0	177.1	Piezometer
C10-2	July 14, 2010	Dry	-	Open borehole
C10-3	July 14, 2010	8.5	170.0	Open borehole
	July 20, 2010	1.5	177.0	Piezometer
	July 27, 2010	1.1	177.4	Piezometer
	August 6, 2010	1.1	177.4	Piezometer

<sup>(1)</sup>Groundwater measured above ground surface (Artesian condition)



Artesian conditions were noted in Borehole 19-04, where groundwater level was measured at 0.1 m (Elevation 176.8) above the ground surface

The values shown in Table 5.3 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 periods of significant or prolonged precipitation.

## 6.0 CORROSIVITY AND SULPHATE TEST RESULTS

Two selected soil samples were submitted for analytical testing of corrosivity parameters including sulphate content. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B2.

**Table 6.1 – Analytical Corrosivity Test Results**

Sample ID	Depth (m)	Soil Sample Description	Sulphide (percent)	Chloride (µg/g)	Sulphate (µg/g)	pH	Resistivity (ohm.cm)	Redox Potential (mV)	Electrical Conductivity (µS/cm)
19-02 SS6	3.6 to 4.8	Silty clay fill	< 0.02	17	270	8.76	4650	252	215
19-03 SS5	3.0 to 3.6	Silty clay	< 0.02	590	15	8.92	3830	319	261

## 7.0 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the boreholes in the field and obtained the borehole coordinates and ground surface elevations.

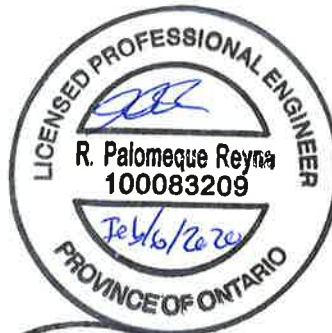
Landshark Drilling from Brantford, Ontario supplied and operated the drilling and sampling equipment for the field program. ConeTec Investigations Ltd. supplied and operated the piezocone penetrometer equipment.



Full time supervision of the field activities was carried out by Mr. John Zoldy EIT and Ms. Eckie Siu of Thurber. Overall supervision of the field program was performed by Mr. Stephane Loranger, CET of Thurber.

Interpretation of the field data and preparation of the report were carried out by Ms. Rocio Palomeque Reyna. The report was reviewed by Mr. Matthew Boucher, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.



Rocio Palomeque Reyna, P.Eng.  
Geotechnical Engineer



Matthew Boucher, P.Eng.  
Senior Geotechnical Engineer



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



HIGHWAY 406 AND PORT ROBINSON ROAD  
BOREHOLE LOCATION PLAN  
(N.T.S. SCHEMATIC ONLY)

- BOREHOLES BY THURBER
- BOREHOLES BY TERRAPROBE (2011)
- CPT Location

FIGURE 1



**Appendix A**  
**Record of Borehole Sheets**  
**Present Investigation**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


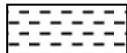



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	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	SILTS AND CLAYS W <sub>L</sub> < 50%	ML	Inorganic silts and 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. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
<b>Fresh (FR)</b>	No visible signs of weathering.		
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>						
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty Can be peeled by a pocket knife, crumbles under firm blows of geological pick. Indented by thumbnail	
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750		
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150		
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen					
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.					



# RECORD OF BOREHOLE No 19-01

1 OF 2

METRIC

W.P. 2063-17-00 LOCATION MTM NAD 83 Zone10: N 4 766 916.9 E 326 338.1 ORIGINATED BY JZ  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY BH  
DATUM Geodetic DATE 2019.10.28 - 2019.10.28 LATITUDE 43.041765 LONGITUDE -79.235657 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
181.5	GROUND SURFACE											
0.0	ASPHALT (125mm)											
0.1	SAND and GRAVEL, trace silt Dense Moist (FILL)		1	SS	35		181					
180.8												
0.7	Silty CLAY, some sand, trace gravel, grey silt lenses Stiff to Soft Reddish Brown to Brown Moist (FILL)		2	SS	10		180					
			3	SS	6							
			4	SS	7		179					
			5	SS	4		178					
177.8												
3.7	Clayey SILT, trace sand, trace gravel, occasional organics, occasional rootlets Stiff Dark Brown to Grey Moist		6	SS	9		177					
177.0												
4.5	Silty CLAY, trace sand, trace gravel Very Stiff to Stiff Brown Moist		7	SS	14		176					
			8	SS	12							
			9	SS	16		175					
							174					
	Grey silt lenses Brown to Grey		10	SS	9		173					
			11	TW	-							
							172					
	Firm Wet		12	SS	6							

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

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

## METRIC

SOIL PROFILE			SAMPLES		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES
182.1	GROUND SURFACE				
0.0	ASPHALT (125mm)				
0.1					
181.6	CONCRETE (300mm)				
0.4	SAND and GRAVEL, trace to some silt, trace clay		1	SS	9
181.4	Loose Brown Moist (FILL)		2	SS	19
0.7	Silty CLAY, trace sand Very Stiff to Stiff Dark Brown to Brown Moist (FILL)		3	SS	15
			4	SS	13
			5	SS	11
			6	SS	11
177.6	Clayey SILT, trace sand, trace gravel, occasional organics, occasional rootlets		7	SS	9
4.5	Stiff Grey Moist		8	SS	19
176.7	Silty CLAY, trace sand Very Stiff to Stiff Brown Moist		10	SS	21
5.3			11	SS	12
	Grey Moist to Wet		12	TW	-

DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
SHEAR STRENGTH kPa			WATER CONTENT (%)			γ			
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
20	40	60	80	100	20	40	60	kN/m <sup>3</sup>	GR SA SI CL

182											
181											
180											
179											
178											
177											
176											
175											
174											
173											

OED:  
 $e_0=0.884$   
 $P_c=242\text{ kPa}$

0    2    50    48

(%) STRAIN AT FAILURE

## METRIC

[illegible]

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

# RECORD OF BOREHOLE No 19-03

1 OF 2

METRIC

W.P. 2063-17-00 LOCATION MTM NAD 83 Zone10: N 4 766 947.8 E 326 381.1 ORIGINATED BY ES  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY BH  
DATUM Geodetic DATE 2019.10.30 - 2019.10.30 LATITUDE 43.042042 LONGITUDE -79.235127 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			GR	SA	SI	CL
SHEAR STRENGTH kPa								WATER CONTENT (%)													
○ UNCONFINED      + FIELD VANE																					
● QUICK TRIAXIAL      × LAB VANE																					
178.6	GROUND SURFACE																				
0.0	TOPSOIL (75mm)		1	SS	5		178														
0.1			2	SS	6		177											0 19 53 28			
			3	SS	6		176														
			4	SS	7		175														
							174														
175.5	Silty <b>CLAY</b> , sand seams Stiff to Very Stiff Brown Moist		5	SS	12		173														
3.1			6	SS	12		172														
			7	SS	8		171														
							170														
							169														
	Wet		8	SS	6																
			9	TW	-													0 0 49 51			
																		OED: e <sub>s</sub> =0.98 P <sub>c</sub> =230 kPa C <sub>c</sub> =0.399 C <sub>u</sub> =0.034 G <sub>s</sub> =2.79			
			10	SS	3													0 0 44 56			

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-03

2 OF 2

METRIC

W.P. 2063-17-00 LOCATION MTM NAD 83 Zone10: N 4 766 947.8 E 326 381.1 ORIGINATED BY ES  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY BH  
DATUM Geodetic DATE 2019.10.30 - 2019.10.30 LATITUDE 43.042042 LONGITUDE -79.235127 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)						
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE			w <sub>p</sub> w      w <sub>L</sub>					
						● QUICK TRIAXIAL      × LAB VANE											
	Continued From Previous Page																
	Silty <b>CLAY</b> , occasional silt seams Stiff Brown to Grey Wet		11	SS	3		168										
							167										
166.1			12	TW	-		166								0   0   78   22		
12.5	<b>SILT</b> , trace clay, trace sand Very Loose Brown Wet						165										
			13	SS	0												
164.3																	
14.3	END OF BOREHOLE AT 14.3m. WATER LEVEL AT 13.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH GROUT AND HOLEPLUG TO SURFACE. Note: 1. Consolidation test was performed in TW9.																

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

## METRIC

[illegible]

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

## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W P W W L	WATER CONTENT (%)			
	Continued From Previous Page												
162.7	Silty <b>CLAY</b> , trace sand Stiff Brown Moist to Wet												
14.0													
162.4													
14.3													
	<b>SILT</b> , trace clay, trace sand, trace gravel Compact Brown Wet		12	SS	11								1 4 77 18
<p>END OF BOREHOLE AT 14.3m. WATER LEVEL AT 0.4m UPON COMPLETION.</p> <p>Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.</p> <p>WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) 2019.11.22    0.1 *         176.8 *Above Ground Surface (Artesian Condition)</p>													

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



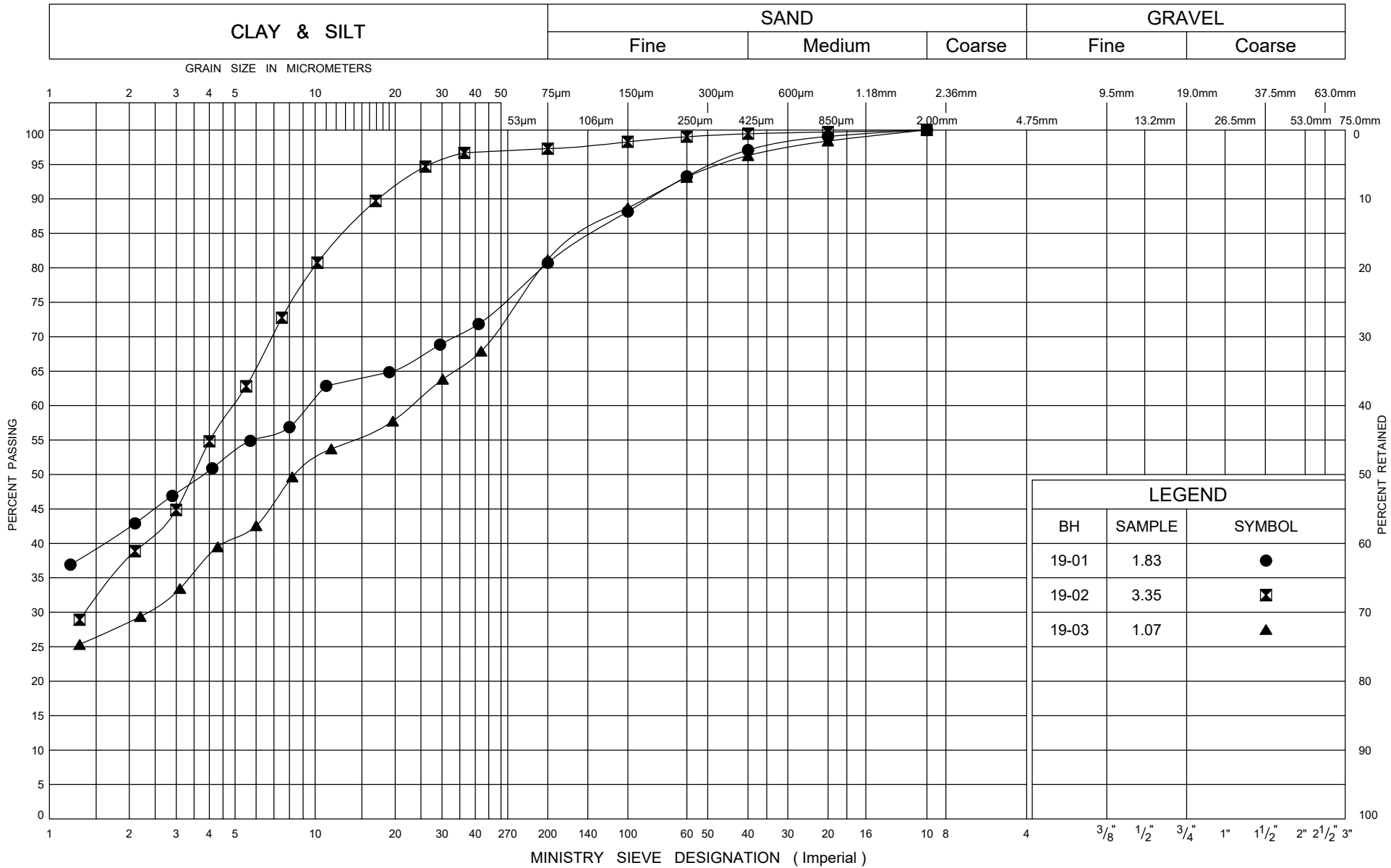


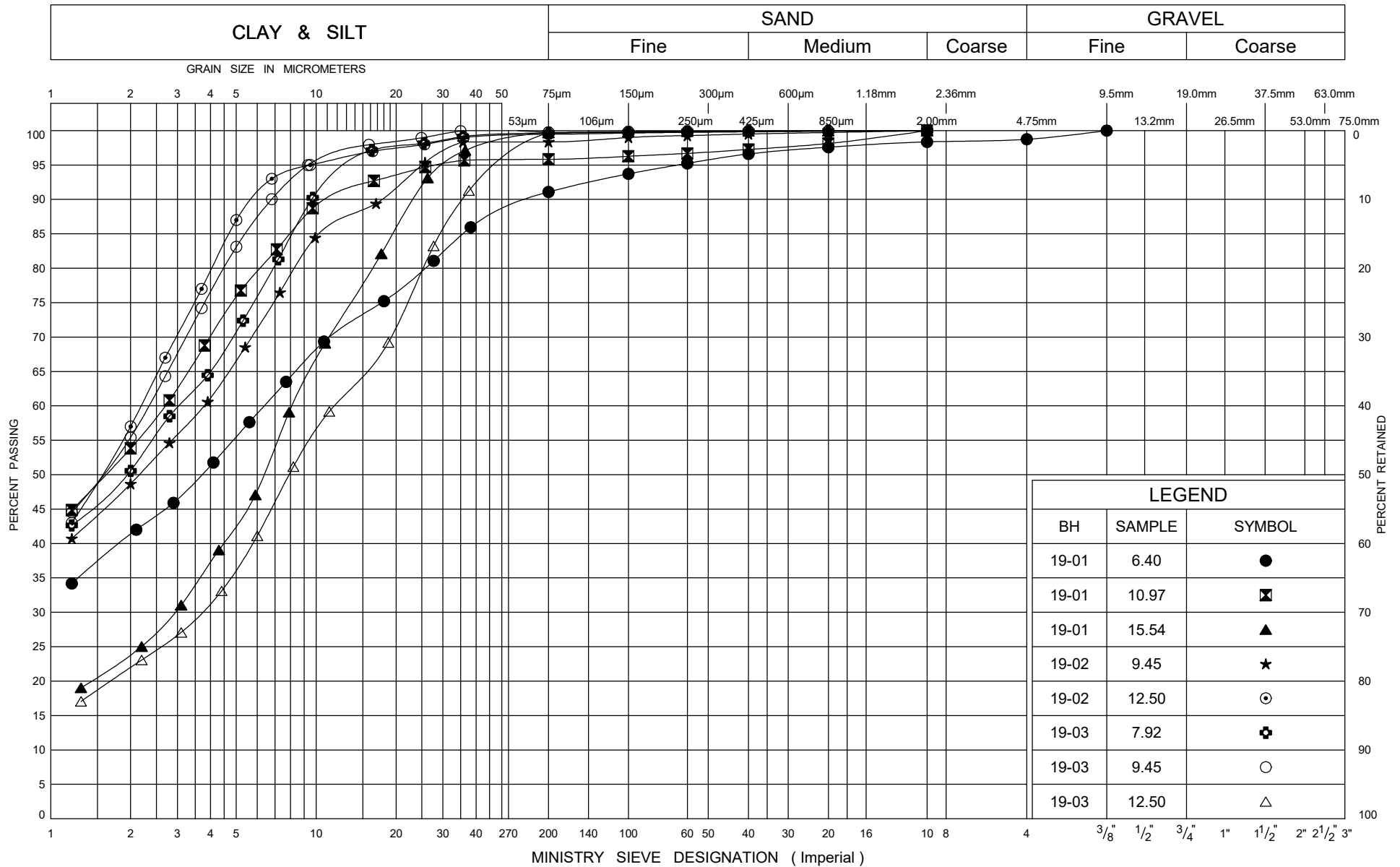
## **Appendix B**

### **Geotechnical and Analytical Laboratory Test Results Present Investigation**



**Appendix B1**  
**Grain Size Analysis and Atterberg Limit Test**





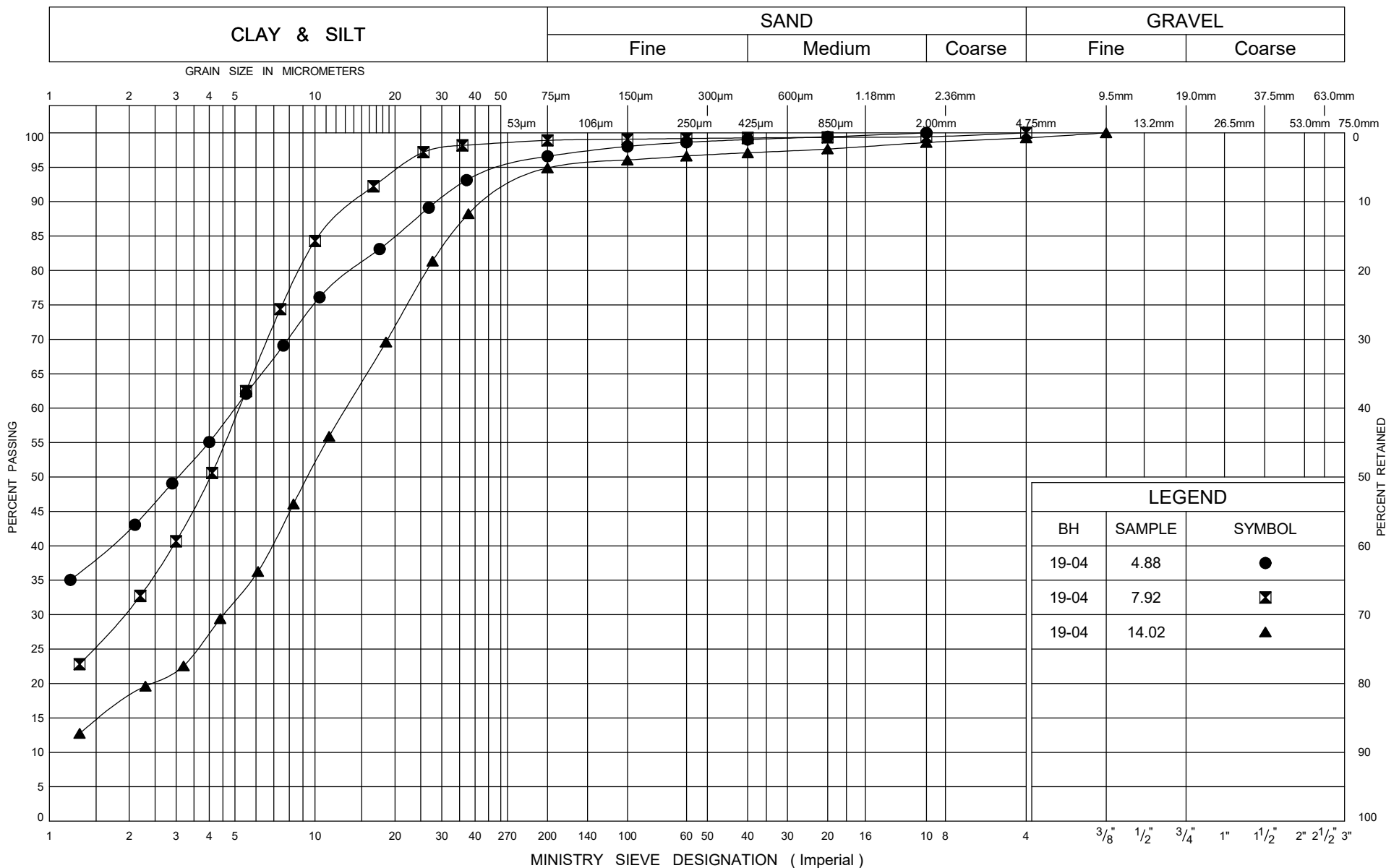
Ministry of  
Transportation

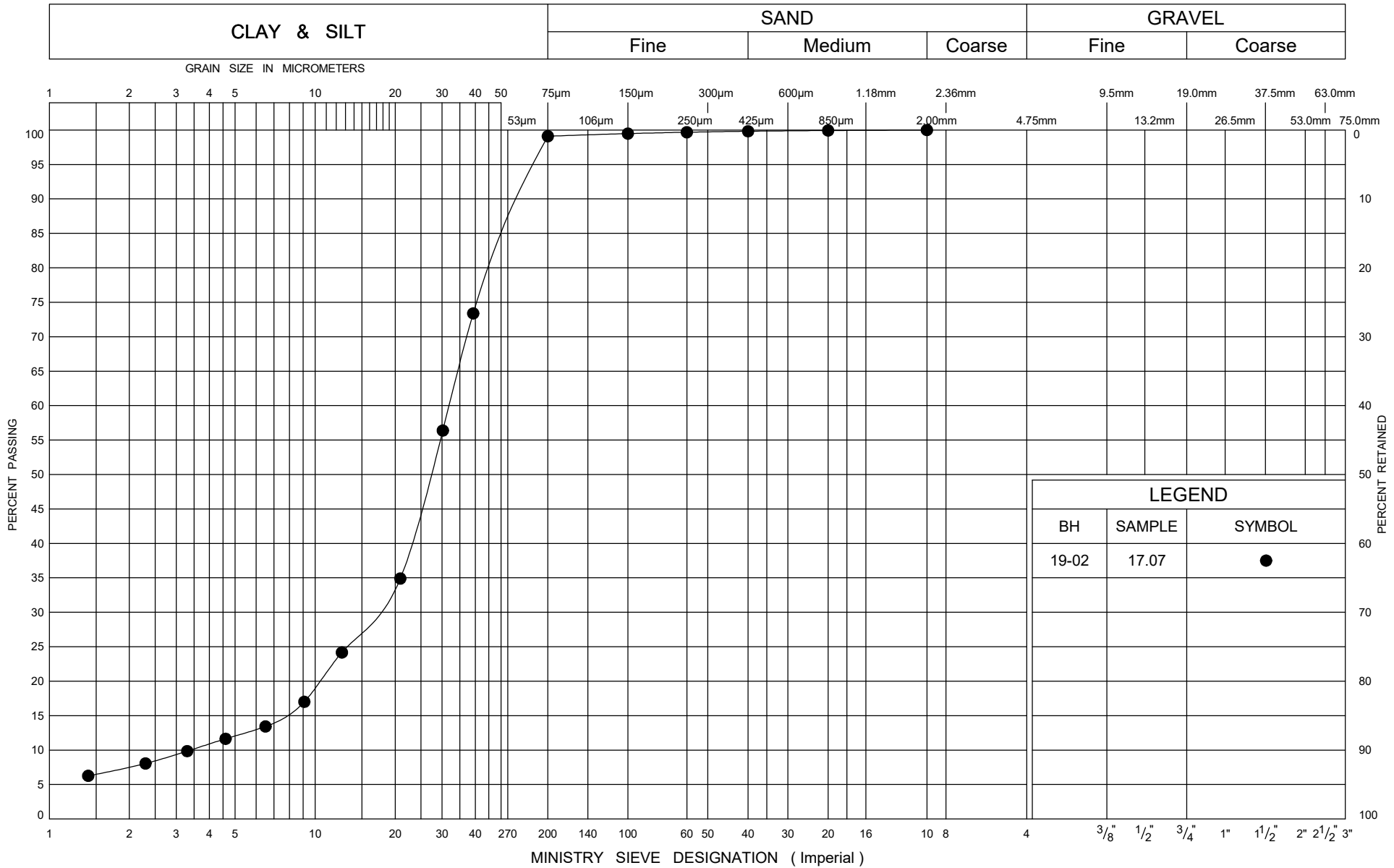
## GRAIN SIZE DISTRIBUTION

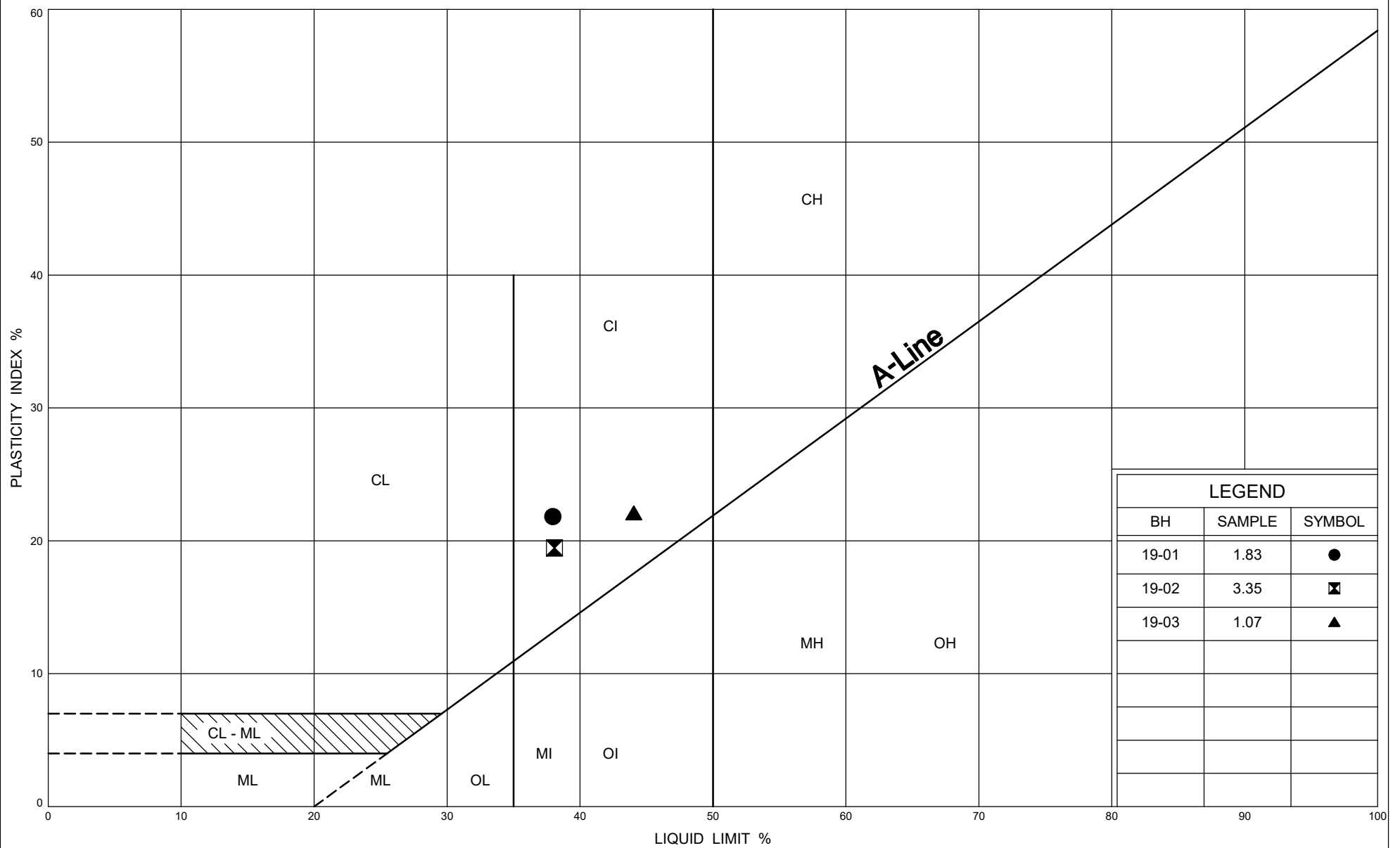
Silty CLAY

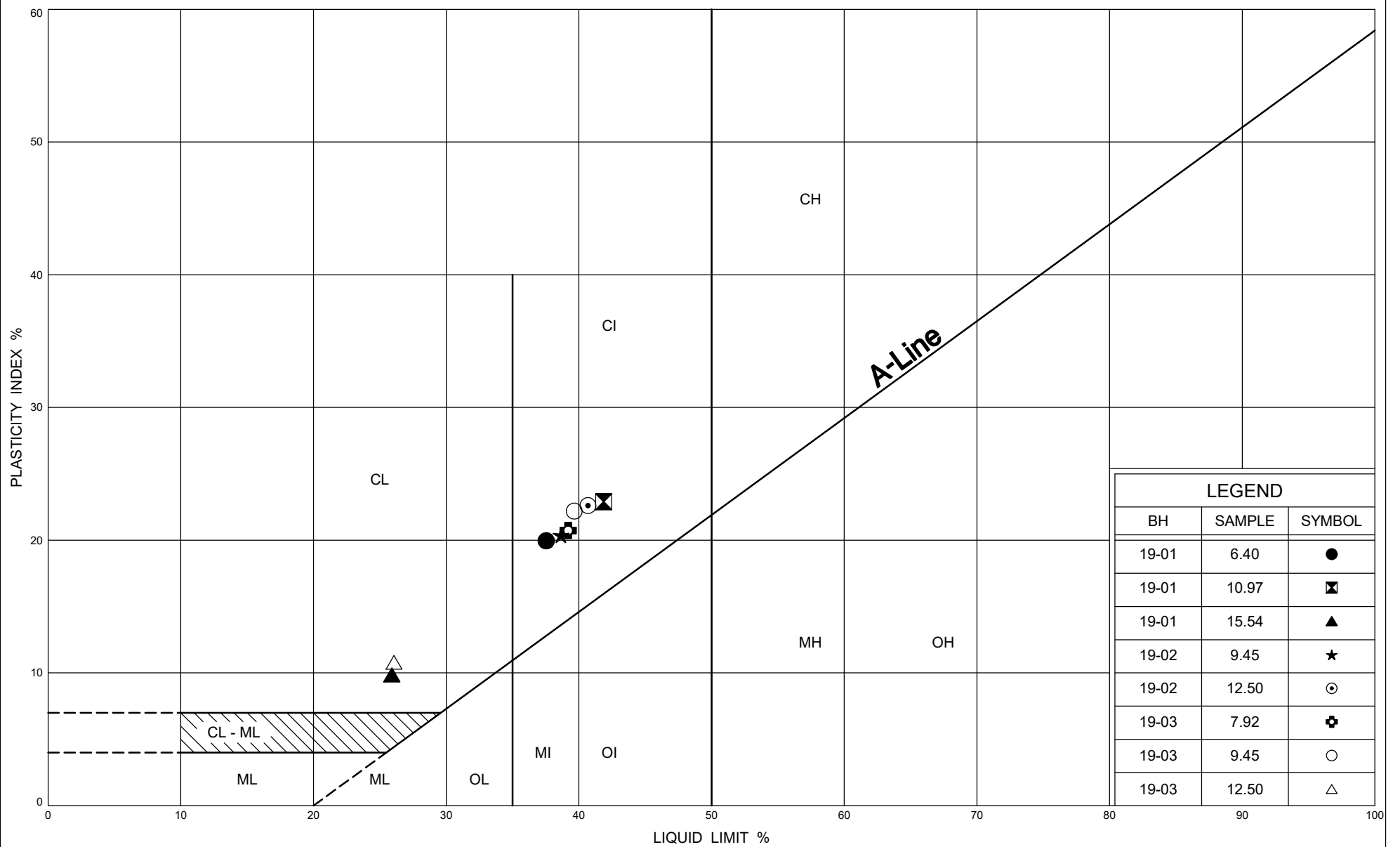
FIG No B2

W P 2063-17-00

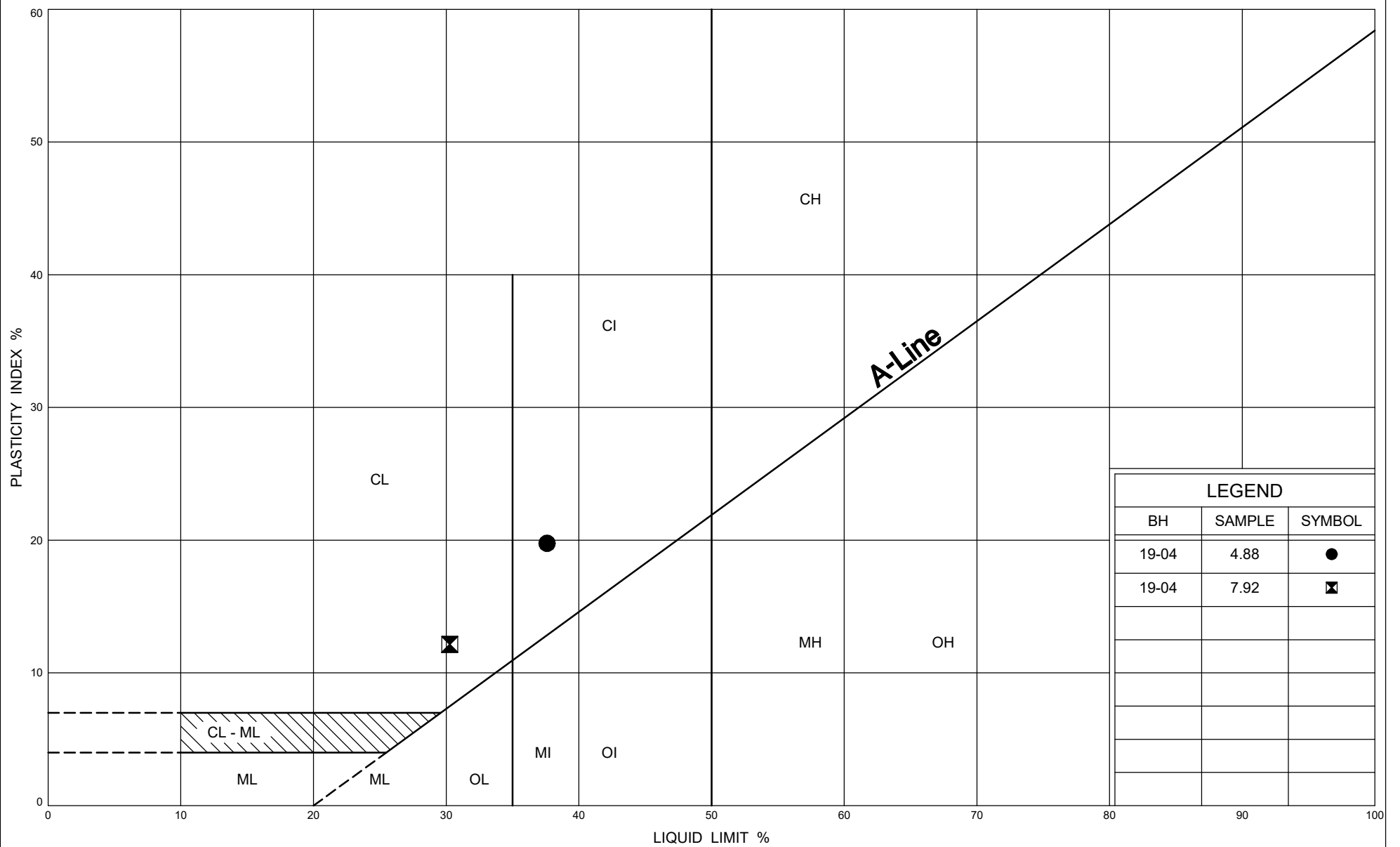














**Appendix B2**  
**Analytical Laboratory Test Results for Corrosivity**



## FINAL REPORT

CA14210-NOV19 R1

Prepared for

**Thurber Engineering Ltd.**

## First Page

### CLIENT DETAILS

Client **Thurber Engineering Ltd.**

Address **103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7, Canada**

Contact **Rocio Palomeque**

Telephone **905-829-8666 x 263**

Facsimile

Email **rreyna@thurber.ca**

Project

Order Number

Samples **Soil (2)**

### LABORATORY DETAILS

Project Specialist **Brad Moore Hon. B.Sc**

Laboratory **SGS Canada Inc.**

Address **185 Concession St., Lakefield ON, K0L 2H0**

Telephone **705-652-2143**

Facsimile **705-652-6365**

Email **brad.moore@sgs.com**

SGS Reference **CA14210-NOV19**

Received **11/07/2019**

Approved **11/14/2019**

Report Number **CA14210-NOV19 R1**

Date Reported **11/14/2019**

### COMMENTS

Temperature of Sample upon Receipt: 18 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

Chain of Custody Number: 002535

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

### SIGNATORIES

Brad Moore Hon. B.Sc

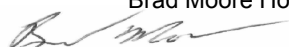




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QC Summary..... 5-6

Legend..... 7

Annexes..... 8



# FINAL REPORT

CA14210-NOV19 R1

**Client:** Thurber Engineering Ltd.

**Project:**

**Project Manager:** Rocío Palomeque

**Samplers:** N/A

## PACKAGE: - Corrosivity Index (SOIL)

<b>Sample Number</b>	5	6
<b>Sample Name</b>	19-02 SS6 12'-16"	19-03 SS5 10'-12'
<b>Sample Matrix</b>	Soil	Soil
<b>Sample Date</b>	29/10/2019	30/10/2019

Parameter	Units	RL		Result	Result
Corrosivity Index					
Corrosivity Index	none	1		4	4
Soil Redox Potential	mV	-		252	319
Sulphide	%	0.02		< 0.02	< 0.02
pH	pH Units	0.05		8.76	8.92
Resistivity (calculated)	ohms.cm	-9999		4650	3830

## PACKAGE: - General Chemistry (SOIL)

<b>Sample Number</b>	5	6
<b>Sample Name</b>	19-02 SS6 12'-16"	19-03 SS5 10'-12'
<b>Sample Matrix</b>	Soil	Soil
<b>Sample Date</b>	29/10/2019	30/10/2019

Parameter	Units	RL		Result	Result
General Chemistry					
Conductivity	uS/cm	2		215	261

## PACKAGE: - Metals and Inorganics (SOIL)

<b>Sample Number</b>	5	6
<b>Sample Name</b>	19-02 SS6 12'-16"	19-03 SS5 10'-12'
<b>Sample Matrix</b>	Soil	Soil
<b>Sample Date</b>	29/10/2019	30/10/2019

Parameter	Units	RL		Result	Result
Metals and Inorganics					
Moisture Content	%	0.1		21.6	17.3
Sulphate	µg/g	0.4		270	15



FINAL REPORT

CA14210-NOV19 R1

Client: Thurber Engineering Ltd.

Project:

Project Manager: Rocío Palomeque

Samplers: N/A

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6
Sample Name	19-02 SS6 12'-16"	19-03 SS5 10'-12'
Sample Matrix	Soil	Soil
Sample Date	29/10/2019	30/10/2019

Parameter	Units	RL		Result	Result
Other (ORP)					
Chloride	µg/g	0.4		17	590

## QC SUMMARY

### Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0141-NOV19	µg/g	0.4	<0.4	6	20	100	80	120	114	75	125
Sulphate	DIO0141-NOV19	µg/g	0.4	<0.4	2	20	97	80	120	91	75	125

### Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0018-NOV19	%	0.02	<0.02	5	20	112	80	120			

### Conductivity

Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0137-NOV19	uS/cm	2	< 2	3	10	101	90	110	NA		





FINAL REPORT

CA14210-NOV19 R1

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-1ENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0137-NOV19	pH Units	0.05	NA	0		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

## LEGEND

### FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --



Environment, Health & Safety - Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Fax: 705-652-6365 Web: www.sgs.com/environment  
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361

No: 002535  
Page 1 of 1

# Request for Laboratory Services and CHAIN OF CUSTODY

## Laboratory Information Section - Lab use only

Received By: Amel A1-Monclack  
Received Date (mm/dd/yyyy): 14-07-19 (mm/dd/yyyy)  
Received Time: 14:15

Received By (signature): [Signature]  
Custody Seal Present: Yes  
Custody Seal Intact: Yes

Cooling Agent Present: Yes  
Temperature Upon Receipt (°C): 18.0

LAB LIMS #: CA14210-NDU19

## REPORT INFORMATION

Company: Thurber Engineering  
Contact: Rocio Palomares  
Address: 103-2010 Winston Park Drive

Phone: 905-824-9666 X260

Fax:

Email: reynera@thurber.ca

## INVOICE INFORMATION

☒ (same as Report Information)

Company: \_\_\_\_\_

Contact: \_\_\_\_\_

Address: \_\_\_\_\_

Phone: \_\_\_\_\_

Email: \_\_\_\_\_

## REGULATIONS

### Regulation 153/04:

☐ Table 1 ☐ Res/Park ☐ Soil Texture: \_\_\_\_\_  
☐ Table 2 ☐ Ind/Com ☐ Coarse  
☐ Table 3 ☐ Agri/Other ☐ Medium  
☐ Table \_\_\_\_\_ ☐ Fine

### Other Regulations:

☐ Reg 347/558 (3 Day min TAT)  
☐ PWQO ☐ MMER  
☐ CCME ☐ Other: \_\_\_\_\_  
☐ MISA

### Sewer By-Law:

☐ Sanitary  
☐ Storm  
Municipality: \_\_\_\_\_

## RECORD OF SITE CONDITION (RSC)

☐ YES ☐ NO

## SAMPLE IDENTIFICATION

1	14-02 556	12'-6"	0.2/24/19	1	Soil
2					
3	14-03 555	10'-12'	0.2/30/19	1	Soil
4					
5					
6					
7					
8					
9					
10					
11					
12					

Observations/Comments/Special Instructions

Sampled By (NAME):

Signature:

Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ (mm/dd/yyyy)

Pink Copy - Client

Relinquished by (NAME):

Signature:

Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ (mm/dd/yyyy)

Yellow & White Copy - SGS

Field Filtered (Y/N)

Metals & Inorganics

PHC F1-F4 ☐ VOC ☐  
BTEX ☐ BTEX/F1 ☐ F2-F4 ☐

PAH ☐ ABN ☐ SVOC(all) ☐

PCB Total ☐ Aroclor ☐

Pesticides OC ☐ OP ☐

TCLP M&I ☐ VOC ☐ PCB ☐  
B(a)P ☐ ABN ☐ Ignit. ☐

Water Pkg Gen. ☐ Ext. ☐

Sewer Use:

Corrosivity

## ANALYSIS REQUESTED

NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

Specify Due Date:

Rush Confirmation ID:

☒ Regular TAT (5-7 days)

RUSH TAT (Additional Charges May Apply): ☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

## TURNAROUND TIME (TAT) REQUIRED

TATs are quoted in business days (exclude statutory holidays & weekends).  
Samples received after 6pm or on weekends: TAT begins next business day

Quotation #: \_\_\_\_\_ P.O. #: \_\_\_\_\_

Project #: \_\_\_\_\_ Site Location/ID: \_\_\_\_\_

## PROJECT INFORMATION



## **Appendix B3**

### **One-Dimension Consolidation Test Results**

## Consolidation Test Report

CLIENT: MTO

FILE NUMBER: 20000

PROJECT: Highway 406 Culvert

REPORT DATE: December 6, 2019

TEST DATES: November 08, 2019 - November 26, 2019

SAMPLE: BH 19-02 TW12 30'-32'  
Silty clay, trace sand, brown, moist.  
LL=39, PL=18,  $I_p = 21$ .

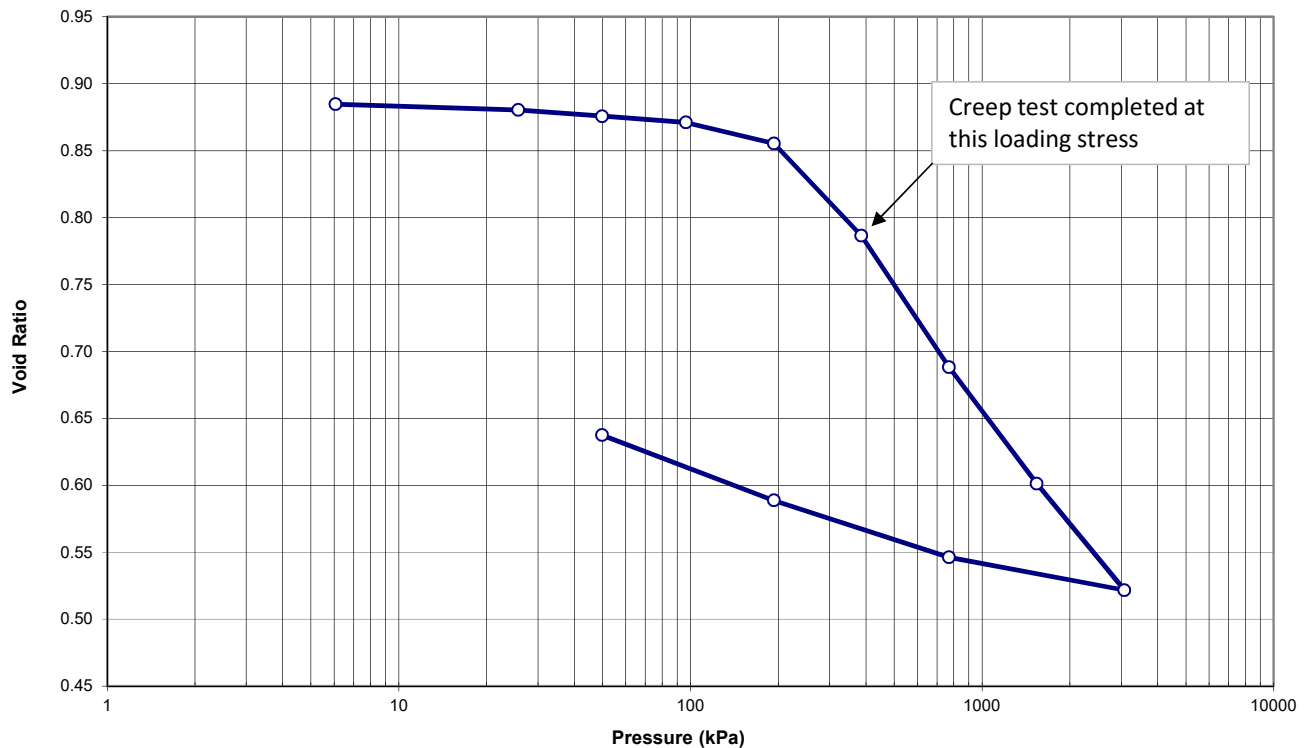
PROCEDURE: Test carried out in accordance with Standard Test Method for One-Dimensional Consolidation Properties of Soils, ASTM D 2435-11, method A

	Start of Test	End of Test
Wet Dens. ( $\text{kg/m}^3$ )	1928.1	2064.1
Dry Dens. ( $\text{kg/m}^3$ )	1456.4	1675.5
Moisture Cont. (%)	32.4	23.2
Void Ratio	0.884	0.638

Note: A Specific Gravity (Gs) of 2.74 was obtained for the void ratio and saturation calculations.

Void Ratio vs. Pressure

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-02 TW12 30'-32'



## Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-02 TW12 30'-32'

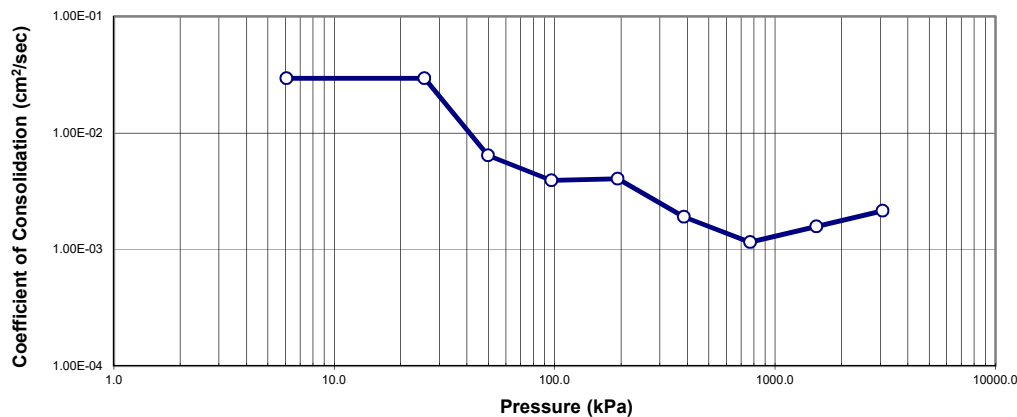
**TRIMMING:** The Specimen was manually trimmed to the size of consolidation ring, then mounted in a fixed ring consolidometer.

**LOADING:** A seating load of 6.1 kPa was applied and the consolidometer was flooded with distilled water. Sample was monitored to ensure no swelling effect occurred before the start of the test. Subsequent loads were applied after a constant load increment duration of 24 hours.

**CALCULATIONS:** Coefficients of Consolidation were calculated by the square root time method.

Pressure (kPa)	Corr. H. (mm)	Avg. H. (mm)	D <sub>90</sub> (mm)	t <sub>90</sub> (min)	c <sub>v</sub> (cm <sup>2</sup> /s)	Void Ratio	m <sub>v</sub> (m <sup>2</sup> /kN)	k (cm/s)
0.0	25.400					0.884		
6.1	25.409	25.405	-0.027	0.77	2.94E-02	0.885	-5.84E-05	-1.69E-07
25.7	25.351	25.380	-0.127	0.77	2.94E-02	0.880	1.16E-04	3.36E-07
49.9	25.287	25.319	-0.096	3.53	6.41E-03	0.876	1.04E-04	6.56E-08
96.6	25.225	25.256	-0.113	5.76	3.91E-03	0.871	5.24E-05	2.01E-08
193.2	25.013	25.119	-0.188	5.52	4.04E-03	0.855	8.70E-05	3.45E-08
385.7	24.083	24.548	-0.550	11.22	1.90E-03	0.786	1.93E-04	3.59E-08
770.7	22.759	23.421	-0.850	16.81	1.15E-03	0.688	1.43E-04	1.62E-08
1540.7	21.588	22.174	-0.830	11.02	1.58E-03	0.601	6.68E-05	1.03E-08
3081.4	20.515	21.052	-0.735	7.29	2.15E-03	0.522	3.23E-05	6.80E-09
770.7	20.846	20.681				0.546		
193.2	21.420	21.133				0.589		
49.9	22.078	21.749				0.638		

**Coefficient of Consolidation vs. Pressure**



Notes: C<sub>v</sub> and k calculated using t<sub>90</sub> values

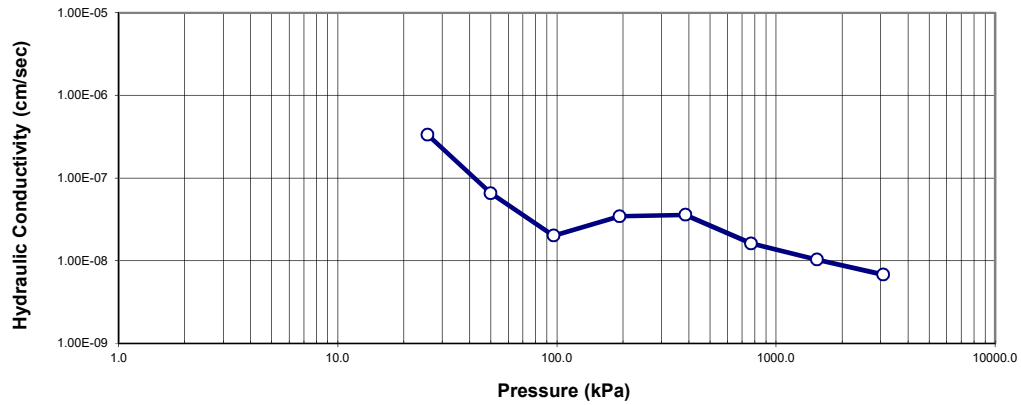
# Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-02 TW12 30'-32'

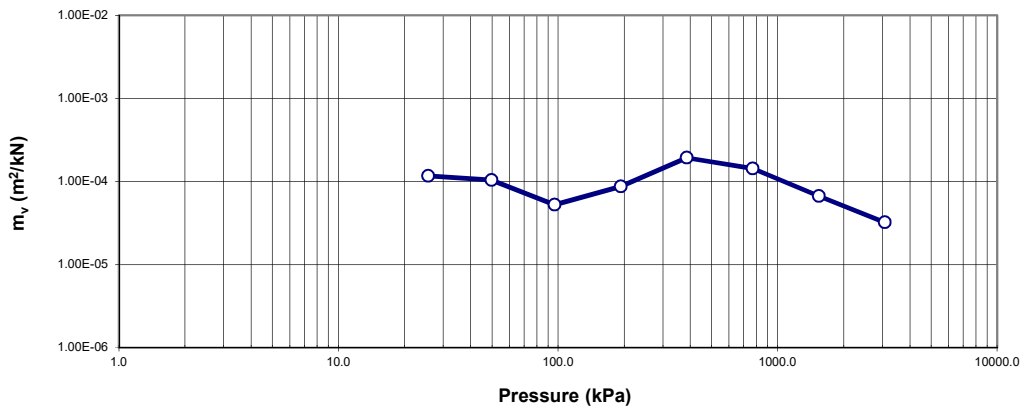
**Hydraulic Conductivity vs. Pressure**

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-02 TW12 30'-32'



**$m_v$  vs. Pressure**

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-02 TW12 30'-32'



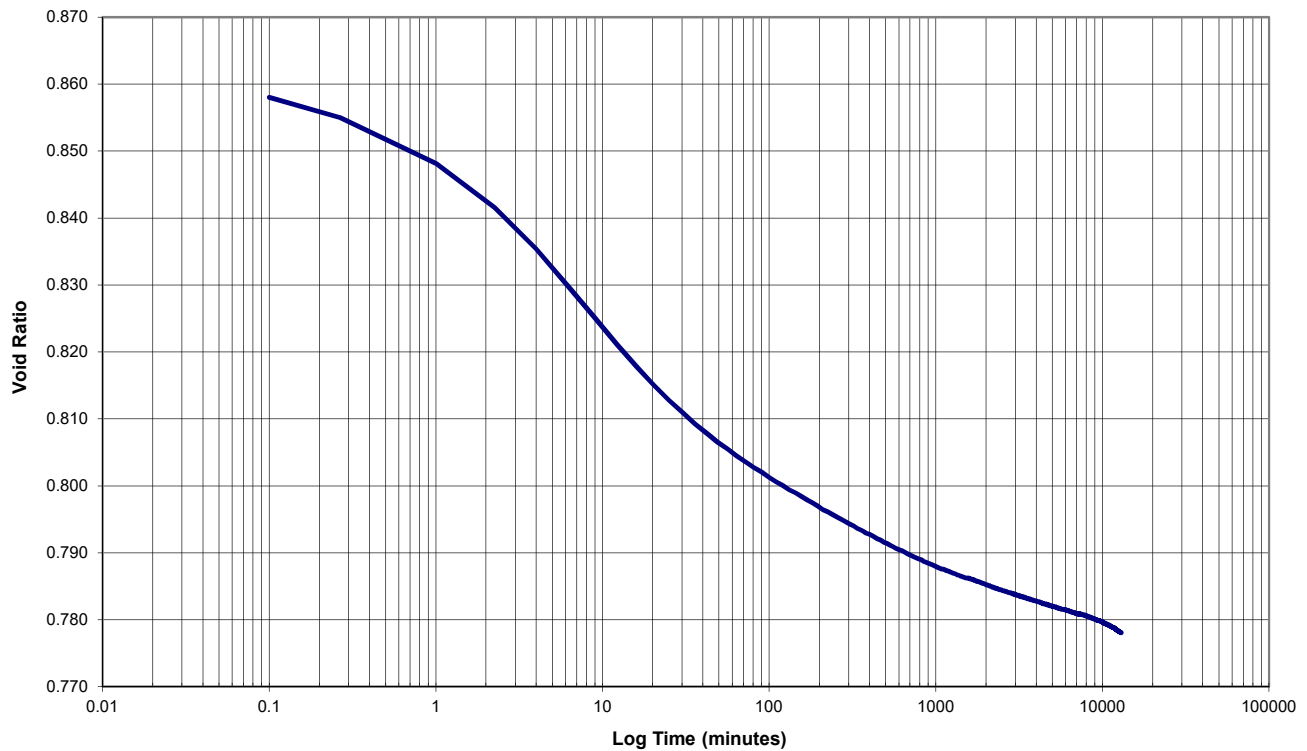
## Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-02 TW12 30'-32'

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-02 TW12 30'-32'

### Void Ratio vs. Log Time at 385.7 kPa - Creep Stage Duration of 9 Days





## Consolidation Test Report

CLIENT: MTO

FILE NUMBER: 20000

PROJECT: Highway 406 Culvert

REPORT DATE: 6-Dec-2019

TEST DATES: November 07, 2019 - November 27, 2019

SAMPLE: BH 19-03 TW9 25'-27'  
Silty clay, trace sand, brown, moist.  
LL=39, PL=18,  $I_p = 21$ .

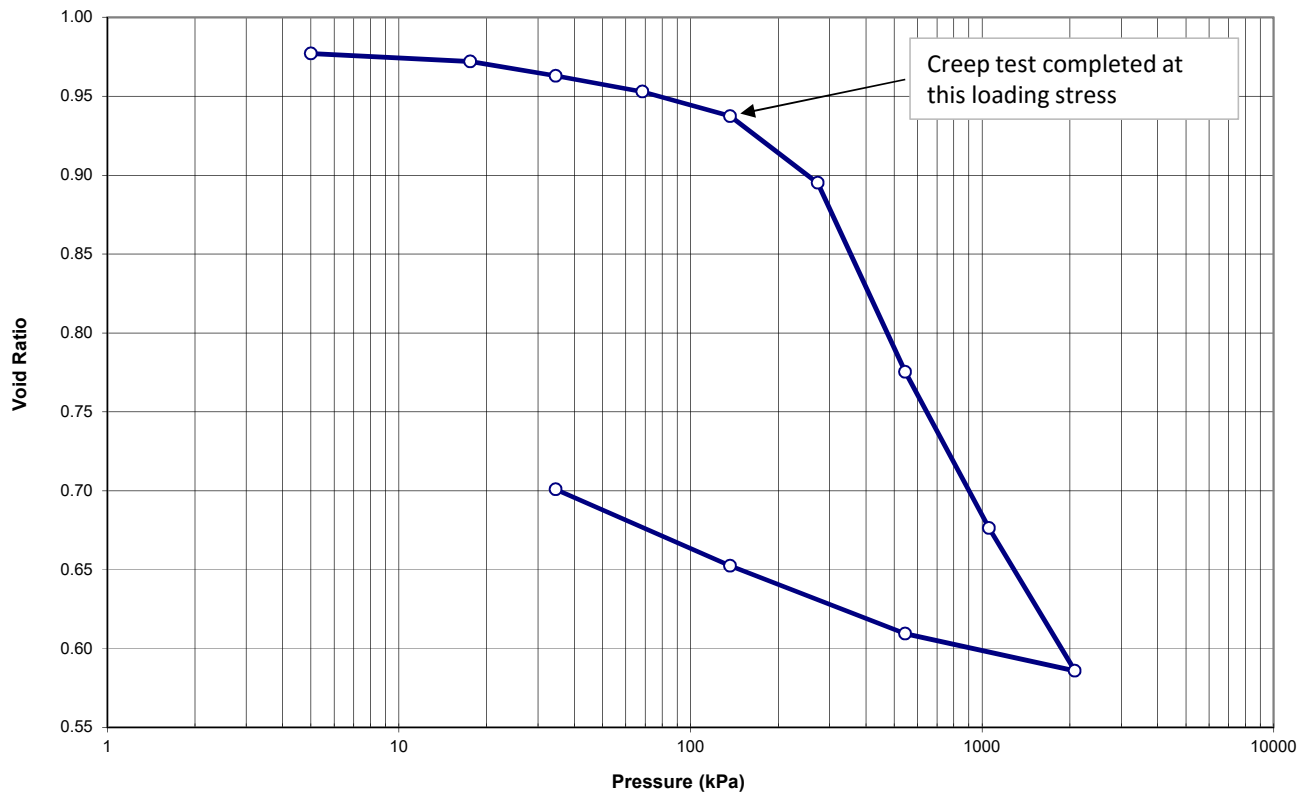
PROCEDURE: Test carried out in accordance with Standard Test Method for One-Dimensional Consolidation Properties of Soils, ASTM D 2435-11, method A

	Start of Test	End of Test
Wet Dens. ( $\text{kg/m}^3$ )	1894.6	2057.5
Dry Dens. ( $\text{kg/m}^3$ )	1406.9	1637.9
Moisture Cont. (%)	34.7	25.6
Void Ratio	0.980	0.701

Note: A Specific Gravity (Gs) of 2.79 was obtained for the void ratio and saturation calculations.

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-03 TW9 25'-27'

Void Ratio vs. Pressure



## Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-03 TW9 25'-27'

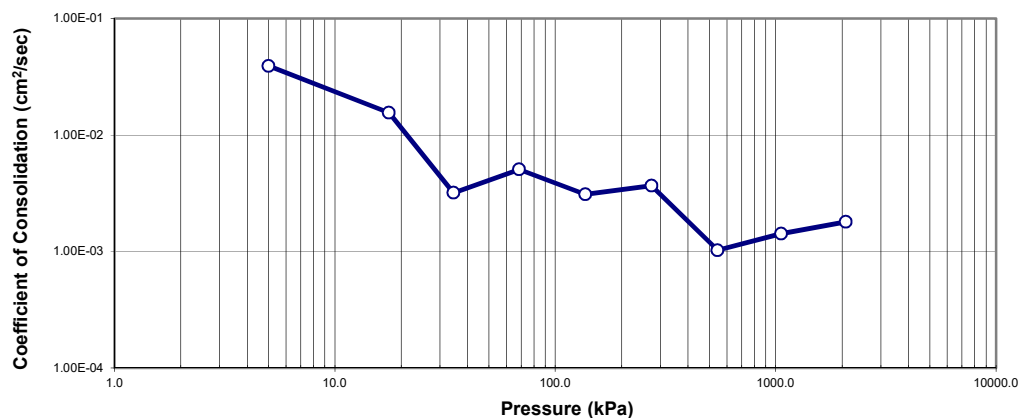
TRIMMING: The Specimen was manually trimmed to the size of consolidation ring, then mounted in a fixed ring consolidometer.

LOADING: A seating load of 5.0 kPa was applied and the consolidometer was flooded with distilled water. Sample was monitored to ensure no swelling effect occurred before the start of the test. Subsequent loads were applied after a constant load increment duration of 24 hours.

CALCULATIONS: Coefficients of Consolidation were calculated by the square root time method.

Pressure (kPa)	Corr. H. (mm)	Avg. H. (mm)	D <sub>90</sub> (mm)	t <sub>90</sub> (min)	c <sub>v</sub> (cm <sup>2</sup> /s)	Void Ratio	m <sub>v</sub> (m <sup>2</sup> /kN)	k (cm/s)
0.0	20.000					0.980		
5.0	19.970	19.985	-0.040	0.36	3.92E-02	0.977	3.00E-04	1.15E-06
17.6	19.919	19.945	-0.077	0.90	1.56E-02	0.972	2.03E-04	3.09E-07
34.5	19.827	19.873	-0.085	4.37	3.19E-03	0.963	2.73E-04	8.56E-08
68.5	19.726	19.777	-0.092	2.72	5.08E-03	0.953	1.50E-04	7.46E-08
136.9	19.569	19.648	-0.146	4.41	3.09E-03	0.937	1.16E-04	3.53E-08
273.2	19.142	19.356	-0.214	3.61	3.67E-03	0.895	1.60E-04	5.76E-08
545.5	17.932	18.537	-0.825	11.83	1.03E-03	0.775	2.32E-04	2.34E-08
1057.7	16.931	17.432	-0.680	7.56	1.42E-03	0.676	1.09E-04	1.52E-08
2080.1	16.018	16.475	-0.620	5.34	1.80E-03	0.586	5.27E-05	9.29E-09
545.5	16.255	16.137				0.609		
136.9	16.690	16.473				0.652		
34.5	17.179	16.935				0.701		

Coefficient of Consolidation vs. Pressure



Notes: C<sub>v</sub> and k calculated using t<sub>90</sub> values

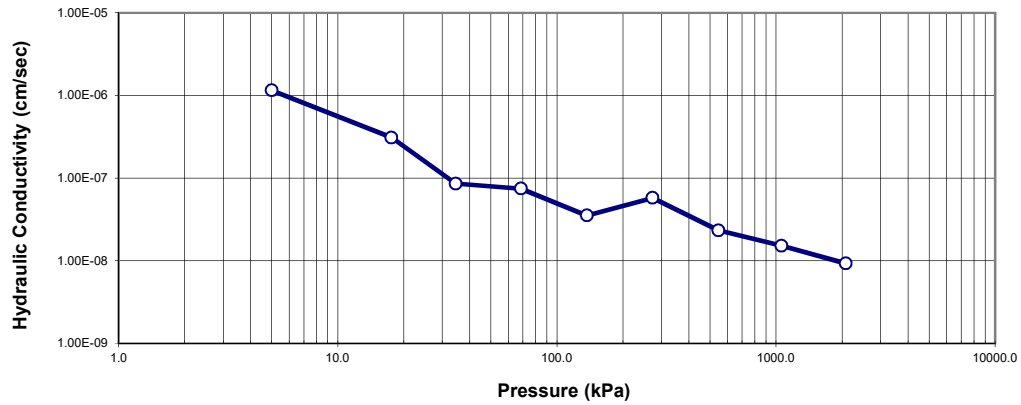
# Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-03 TW9 25'-27'

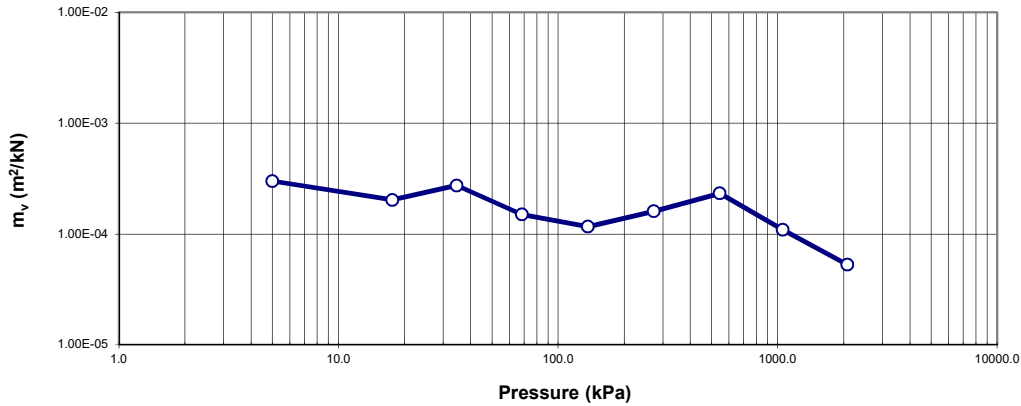
**Hydraulic Conductivity vs. Pressure**

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-03 TW9 25'-27'



**$m_v$  vs. Pressure**

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-03 TW9 25'-27'



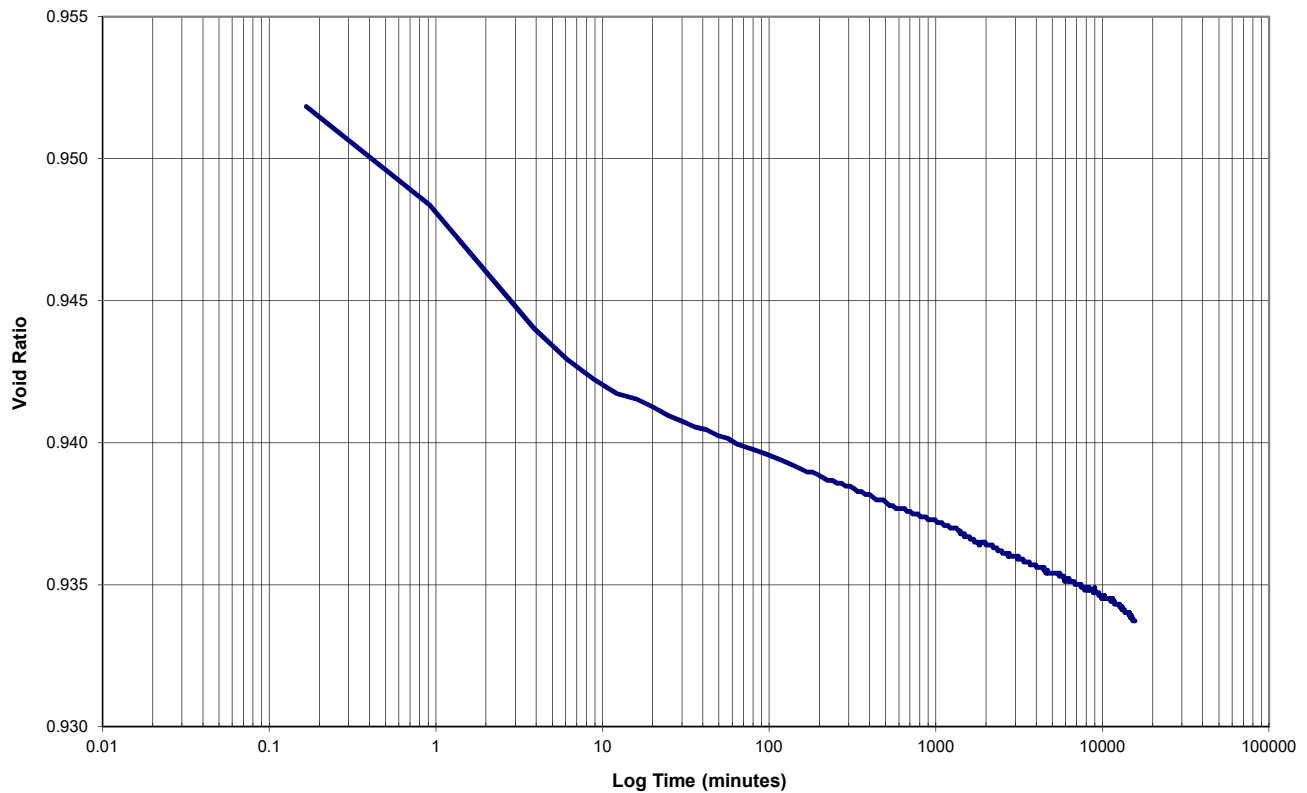
## Consolidation Test Report

Highway 406 Culvert  
20000

BH 19-03 TW9 25'-27'

Project #: 20000  
Client: MTO  
Project Name: Highway 406 Culvert  
Sample: BH 19-03 TW9 25'-27'

### Void Ratio vs. Log Time at 193.6 kPa - Creep Stage Duration of 11 Days





## **Appendix C**

### **Cone Penetration Test (CPTu) Report**

# PRESENTATION OF SITE INVESTIGATION RESULTS

## Highway 406 Welland Culvert

*Prepared for:*

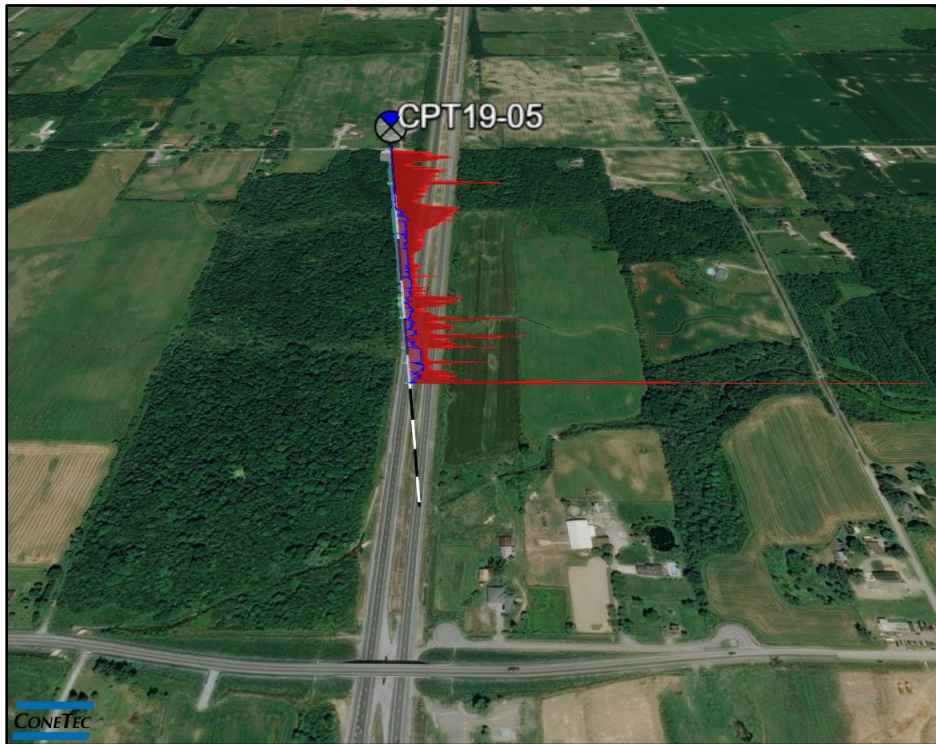
Thurber Engineering

ConeTec Job No: 19-05081

Project Start Date: 22-Nov-2019

Project End Date: 22-Nov-2019

Report Date: 29-Nov-2019



*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

ConeTecON@conetec.com  
www.conetec.com  
www.conetecdataservices.com



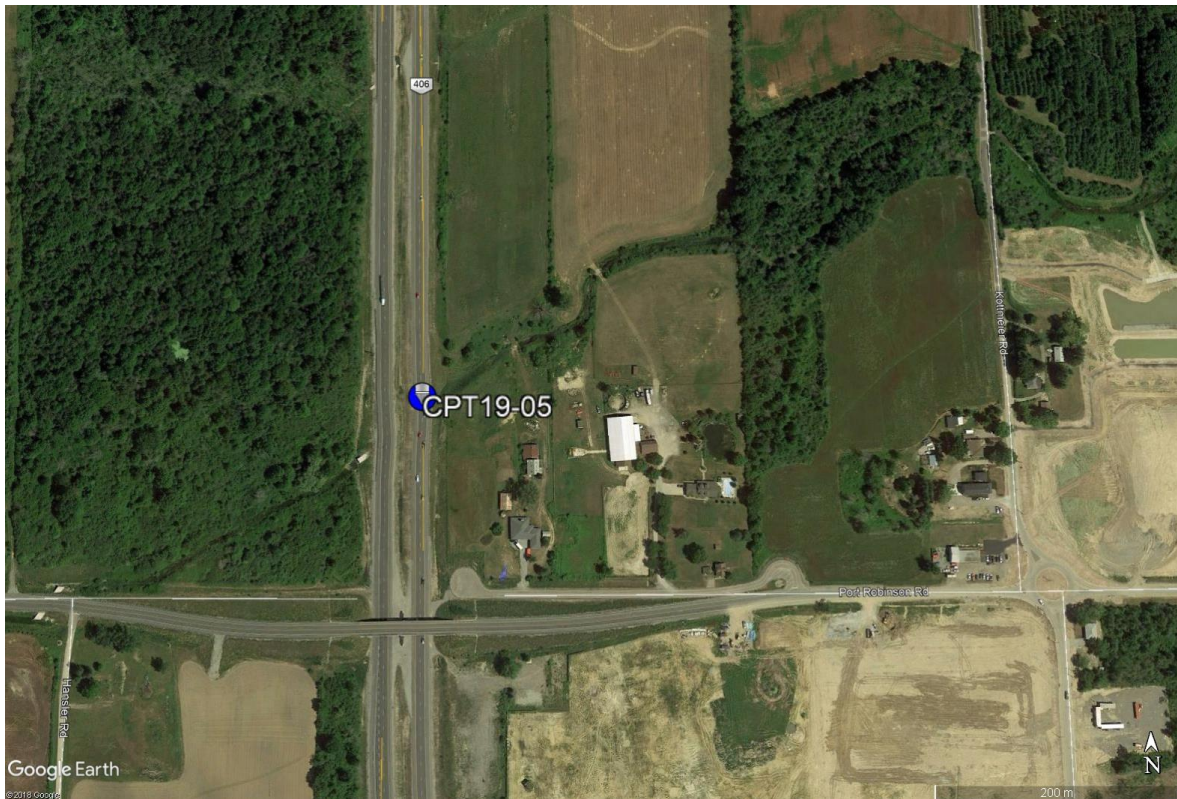
## Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Investigations Ltd. for Thurber Engineering on Highway 406 Welland Culvert South-West of Niagara Falls, On. The program consisted of one cone penetration test (CPTu),

## Project Information

Project	
Client	Thurber Engineering
Project	Highway 406 Welland Culvert
ConeTec project number	19-05081

An aerial overview from Google Earth including the CPTu test locations is presented below.



Rig Description	Deployment System	Test Type
CPT truck rig (C-3)	30 ton rig cylinder	CPTu

Coordinates		
Test Type	Collection Method	EPSG Number
CPTu	Consumer grade GPS	32617

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm <sup>2</sup> )	Sleeve Area (cm <sup>2</sup> )	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
408:T1500F15U500	408	15	225	1500	15	500
Cone 408 was used for all CPT soundings.						

Cone Penetration Test (CPTu)	
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	<ul style="list-style-type: none"> <li>Advanced plots with <math>I_c</math>, <math>S_u</math>, <math>\phi</math> and <math>N1(60)</math></li> <li>Soil Behaviour Type (SBT) scatter plots</li> </ul>

Calculated Geotechnical Parameter Tables	
Additional information	<p>The Normalized Soil Behaviour Type Chart based on <math>Q_{tn}</math> (SBT <math>Q_{tn}</math>) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPTu parameters have been generated and are provided in Excel format files in the release folder. The CPTu parameter calculations are based on values of corrected tip resistance (<math>q_t</math>) sleeve friction (<math>f_s</math>) and pore pressure (<math>u_2</math>).</p> <p>Soils were classified as either drained or undrained based on the <math>Q_{tn}</math> Normalized Soil Behaviour Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures (zone 4).</p>



## Limitations

This report has been prepared for the exclusive use of Thurber Engineering (Client) for the project titled “Highway 406 Welland 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.

Cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd., a subsidiary of ConeTec.

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 5 cm<sup>2</sup>, 10 cm<sup>2</sup> and 15 cm<sup>2</sup> 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 cm<sup>2</sup> penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm<sup>2</sup> piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross-sectional area (typically forty-four millimeter diameter over a length of thirty-two millimeter with tapered leading and trailing edges) located at a distance of 585 millimeters 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 sixty-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 "u<sub>2</sub>" position ([ASTM Type 2](#)). The filter is six millimeters 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](#).

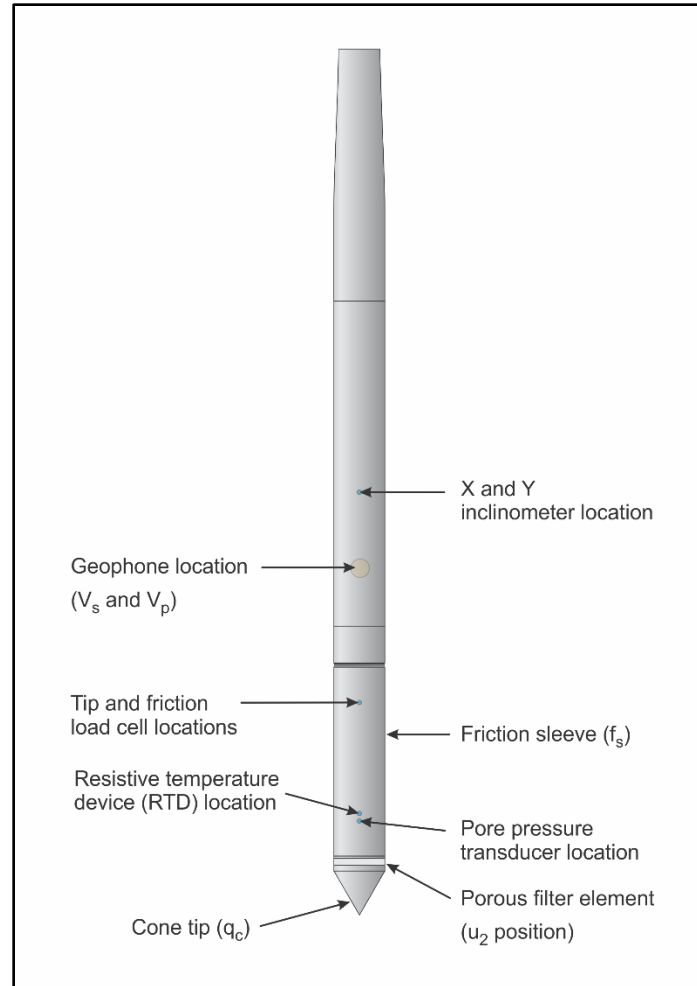


Figure CPTu. Piezocone Penetrometer (15 cm<sup>2</sup>)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a sixteen 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 interval is 2.5 centimeters; 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 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 two centimeters per second, within acceptable tolerances. Typically, one-meter length rods with an outer diameter of 38.1 millimeters 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 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 et al. \(1986\)](#) and Robertson (1990, 2009). It should be noted that it is not always possible to accurately identify a soil behaviour 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 files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to [Robertson et al. \(1986\)](#), [Lunne et al. \(1997\)](#), [Robertson \(2009\)](#), [Mayne \(2013, 2014\)](#) and [Mayne and Peuchen \(2012\)](#).

### References

ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM International, West Conshohocken, PA. DOI: [10.1520/D5778-12](#).

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, "Cone Penetration Testing in Geotechnical Practice", Blackie Academic and Professional.

Mayne, P.W., 2013, "Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests", Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420. DOI: [10.1061/9780784412770.027](#).

Mayne, P.W. and Peuchen, J., 2012, "Unit weight trends with cone resistance in soft to firm clays", Geotechnical and Geophysical Site Characterization 4, Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Mayne, P.W., 2014, "Interpretation of geotechnical parameters from seismic piezocone tests", CPT'14 Keynote Address, Las Vegas, NV, May 2014.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27: 151-158. DOI: [10.1139/T90-014](#).

Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", Canadian Geotechnical Journal, Volume 46: 1337-1355. DOI: [10.1139/T09-065](#).

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 ( $t$ ).

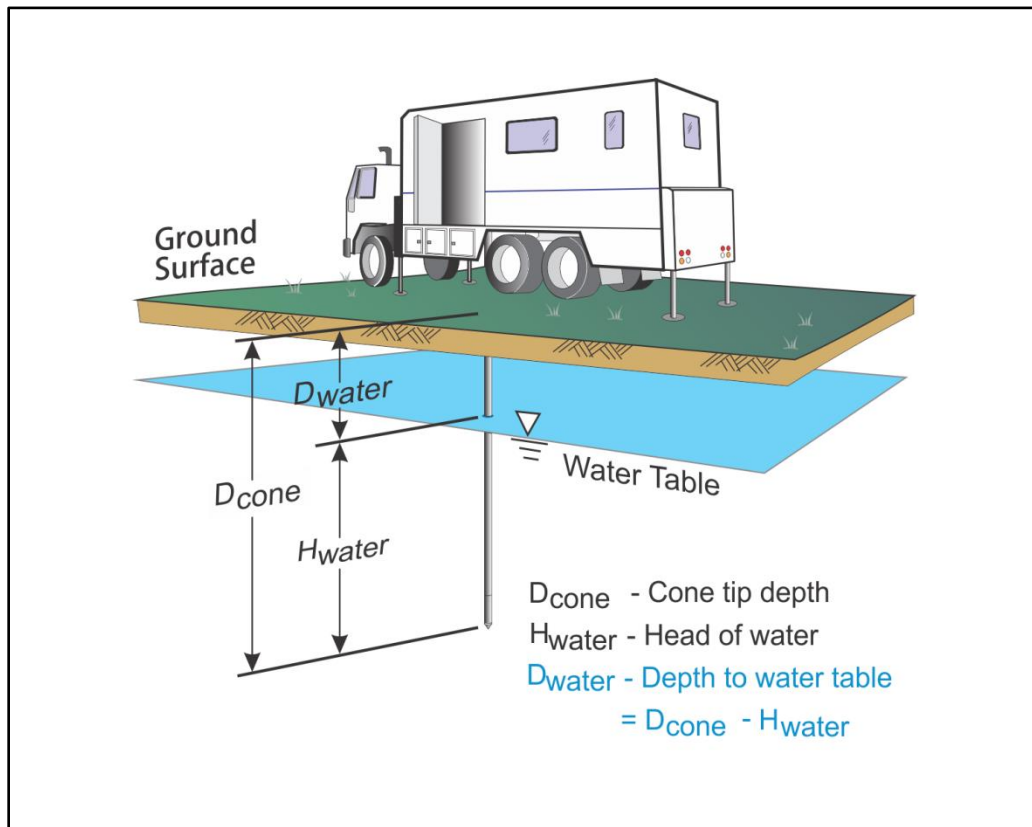


Figure PPD-1. Pore pressure dissipation test setup

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.

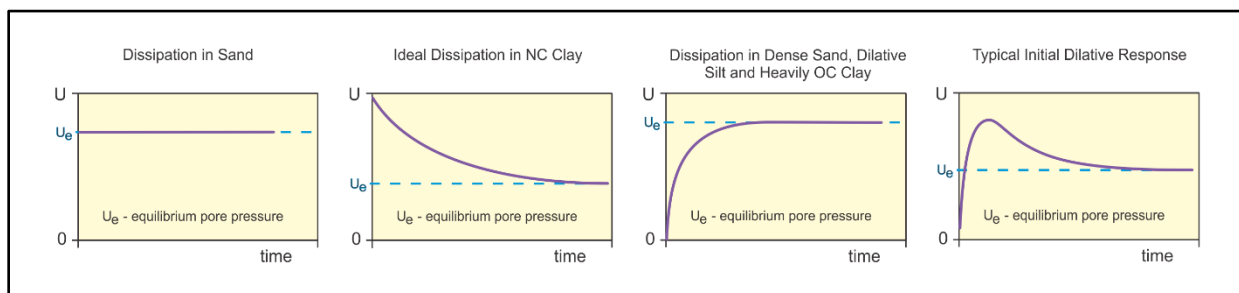


Figure PPD-2. Pore pressure dissipation curve examples

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 in [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.

### References

Burns, S.E. and Mayne, P.W., 1998, "Monotonic and dilatatory pore pressure decay during piezocone tests", Canadian Geotechnical Journal 26 (4): 1063-1073. DOI: [1063-1073/T98-062](https://doi.org/10.1139/T98-062).

Burns, S.E. and Mayne, P.W., 2002, "Analytical cavity expansion-critical state model cone dissipation in fine-grained soils", Soils & Foundations, Vol. 42(2): 131-137.

Jones, G.A. and Van Zyl, D.J.A., 1981, "The piezometer probe: a useful investigation tool", Proceedings, 10<sup>th</sup> International Conference on Soil Mechanics and Foundation Engineering, Vol. 3, Stockholm: 489-495.

Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, "Estimating coefficient of consolidation from piezocone tests", Canadian Geotechnical Journal, 29(4): 539-550. DOI: [10.1139/T92-061](https://doi.org/10.1139/T92-061).

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, "An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils", Canadian Geotechnical Journal, 36(2): 369-381. DOI: [10.1139/T98-105](https://doi.org/10.1139/T98-105).

Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", Geotechnique, 41(1): 17-34. DOI: [10.1680/geot.1991.41.1.17](https://doi.org/10.1680/geot.1991.41.1.17).



The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots with  $I_c$ ,  $S_u(N_{kt})$  and  $N1(60)I_c$
- Soil Behaviour Type (SBT) Scatter Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

## Cone Penetration Test Summary and Standard Cone Penetration Test Plots



Job No: 19-05081  
Client: Thurber Engineering  
Project: Highway 406 Welland Culvert  
Start Date: 22-Nov-2019  
End Date: 22-Nov-2019

### ***CONE PENETRATION TEST SUMMARY***

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface <sup>1</sup> (m)	Final Depth (m)	Northing <sup>2</sup> (m)	Easting <sup>2</sup> (m)	Refer to Notation Number
CPT19-05	19-05081_CP05	22-Nov-2019	408:T1500F15U500	4.2	29.200	4766985	643739	

1. The assumed phreatic surface was based on the dynamic pore pressure response. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were acquired using a consumer grade GPS. WGS84 / UTM Zone 17 North



# Thurber Engineering

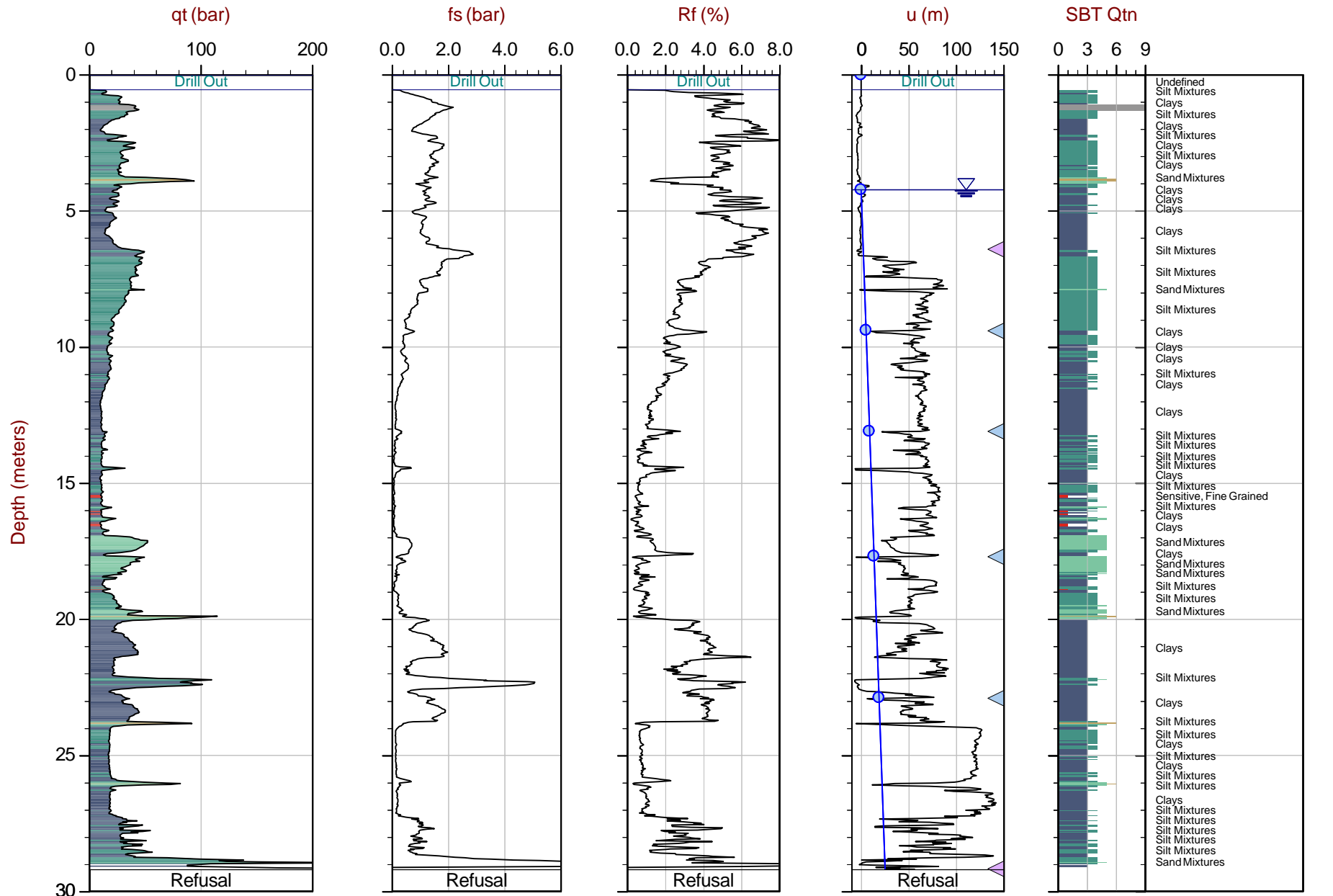
Job No: 19-05081

Date: 2019-11-22 10:36

Site: Highway 406 Welland Culvert

Sounding: CPT19-05

Cone: 408:T1500F15U500



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



# Thurber Engineering

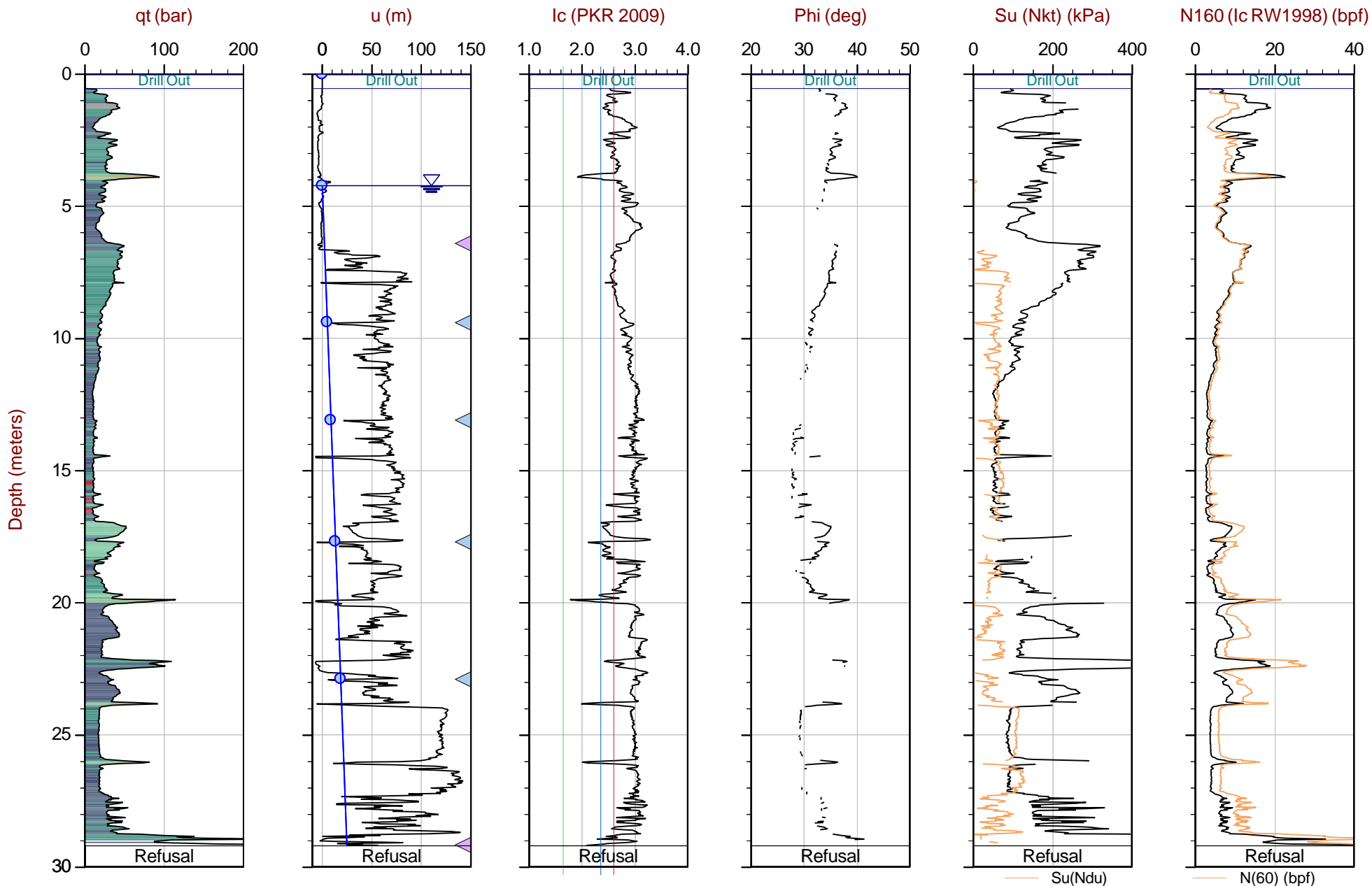
Job No: 19-05081

Date: 2019-11-22 10:36

Site: Highway 406 Welland Culvert

Sounding: CPT19-05

Cone: 408:T1500F15U500



Max Depth: 29.200 m / 95.80 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

File: 19-05081\_CP05.COR

Unit Wt: SBTQtn(PKR2009)

Su Nkt/Ndu: 15.0 / 9.0

SBT: Robertson, 2009 and 2010

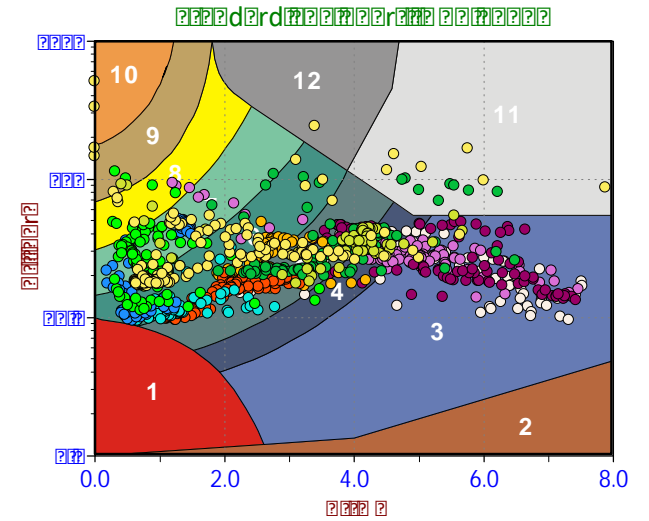
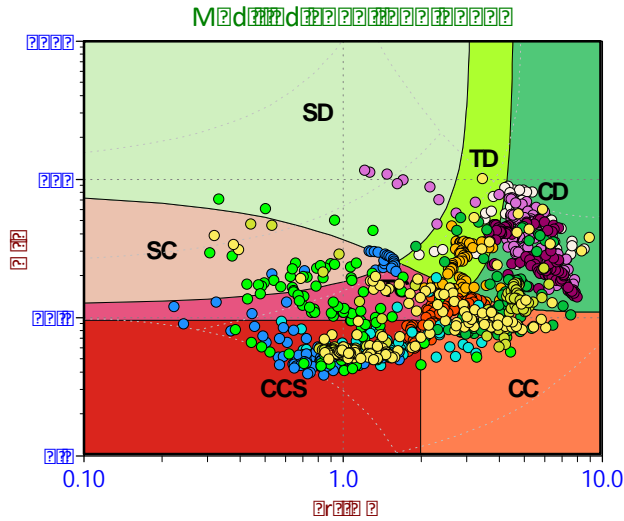
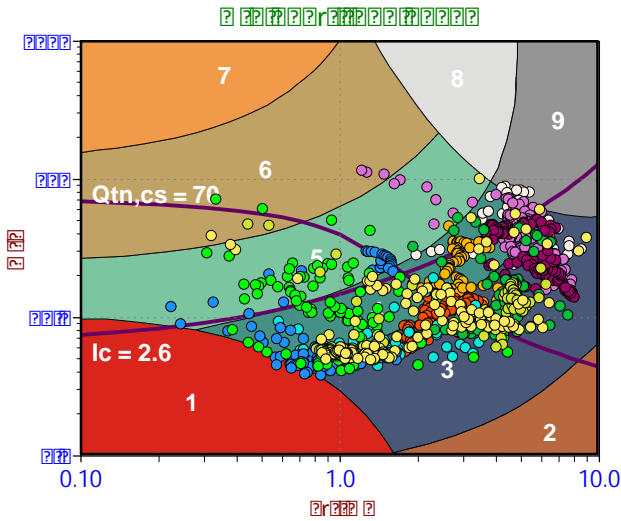
Coords: UTM 11N: 4766985m E: 643739m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq)    ● Assumed Ueq    ▲ Dissipation, Ueq achieved    ▲ Dissipation, Ueq not achieved    ▲ Dissipation, Ueq assumed    — 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.

## Soil Behaviour Type (SBT) Scatter Plots



#### Depth Ranges

- >0.0 to 2.5 m
- >2.5 to 5.0 m
- >5.0 to 7.5 m
- >7.5 to 10.0 m
- >10.0 to 12.5 m
- >12.5 to 15.0 m
- >15.0 to 17.5 m
- >17.5 to 20.0 m
- >20.0 to 22.5 m
- >22.5 to 25.0 m
- >25.0 m

#### Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

#### Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

#### Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand



## Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots



Job No: 19-05081  
Client: Thurber Engineering  
Project: Highway 406 Welland Culvert  
Start Date: 22-Nov-2019  
End Date: 22-Nov-2019

### ***CPT<sub>u</sub> PORE PRESSURE DISSIPATION SUMMARY***

Sounding ID	File Name	Cone Area (cm <sup>2</sup> )	Duration (s)	Test Depth (m)	Estimated Equilibrium Pore Pressure U <sub>eq</sub> (m)	Calculated Phreatic Surface (m)	Estimated Phreatic Surface (m)	t <sub>50</sub> <sup>a</sup> (s)	Assumed Rigidity Index (I <sub>r</sub> )	c <sub>h</sub> <sup>b</sup> (cm <sup>2</sup> /min)
CPT19-05	19-05081_CP05	15	3405	6.400	Not Achieved					
CPT19-05	19-05081_CP05	15	740	9.400	5.2		4.2	497	100	1.4
CPT19-05	19-05081_CP05	15	1010	13.100	8.9		4.2	598	100	1.2
CPT19-05	19-05081_CP05	15	310	17.700	13.5		4.2	26	100	27.0
CPT19-05	19-05081_CP05	15	3020	22.900	18.7		4.2	1447	100	0.5
CPT19-05	19-05081_CP05	15	405	29.175	Not Achieved					

a. Time is relative to where u<sub>max</sub> occurred.

b. Houlsby and Teh, 1991.



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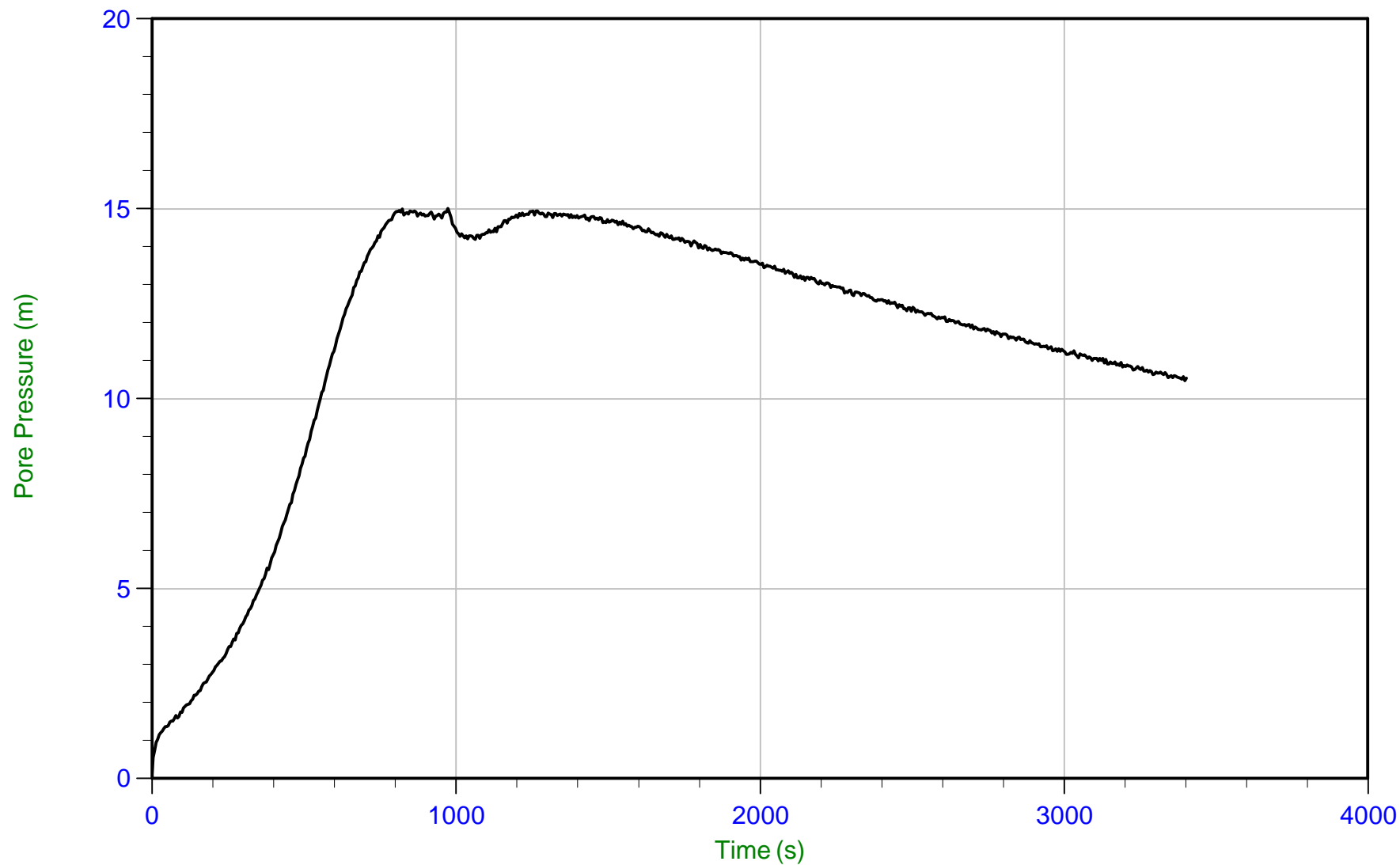
Job No: 19-05081

Date: 11/22/2019 10:36

Site: Highway 406 Welland Culvert

Sounding: CPT19-05

Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



Trace Summary:

Filename: 19-05081\_CP05.PPF

Depth: 6.400 m / 20.997 ft

Duration: 3405.0 s

u Min: 0.0 m

u Max: 15.0 m

u Final: 10.5 m



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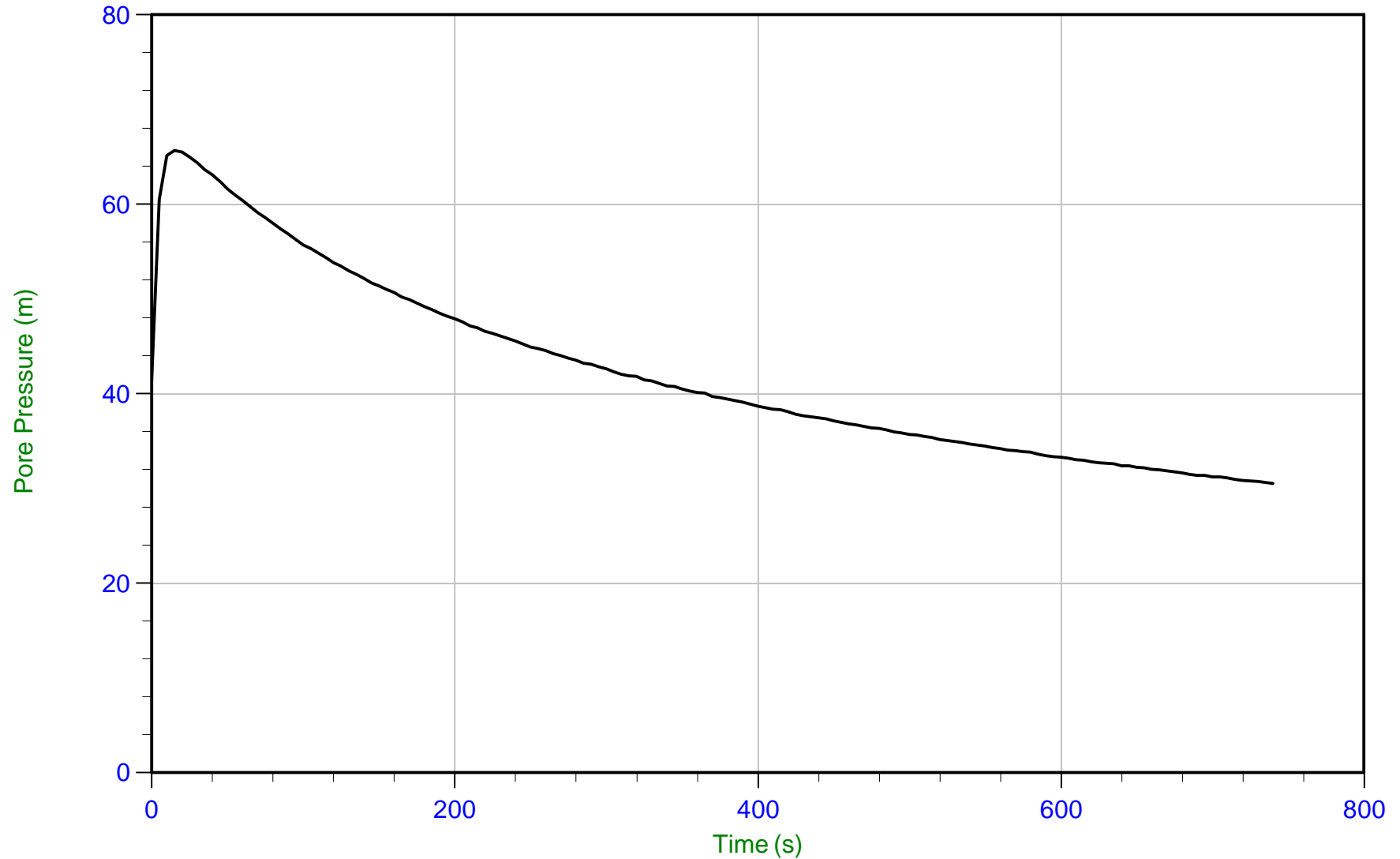
Job No: 19-05081

Date: 11/22/2019 10:36

Site: Highway 406 Welland Culvert

Sounding: CPT19-05

Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



### Trace Summary:

Filename: 19-05081\_CP05.PPF

Depth: 9.400 m / 30.840 ft

Duration: 740.0 s

u Min: 30.5 m

u Max: 65.7 m

u Final: 30.5 m

WT: 4.226 m / 13.865 ft

Ueq: 5.2 m

U(50): 35.42 m

T(50): 497.4 s

Ir: 100

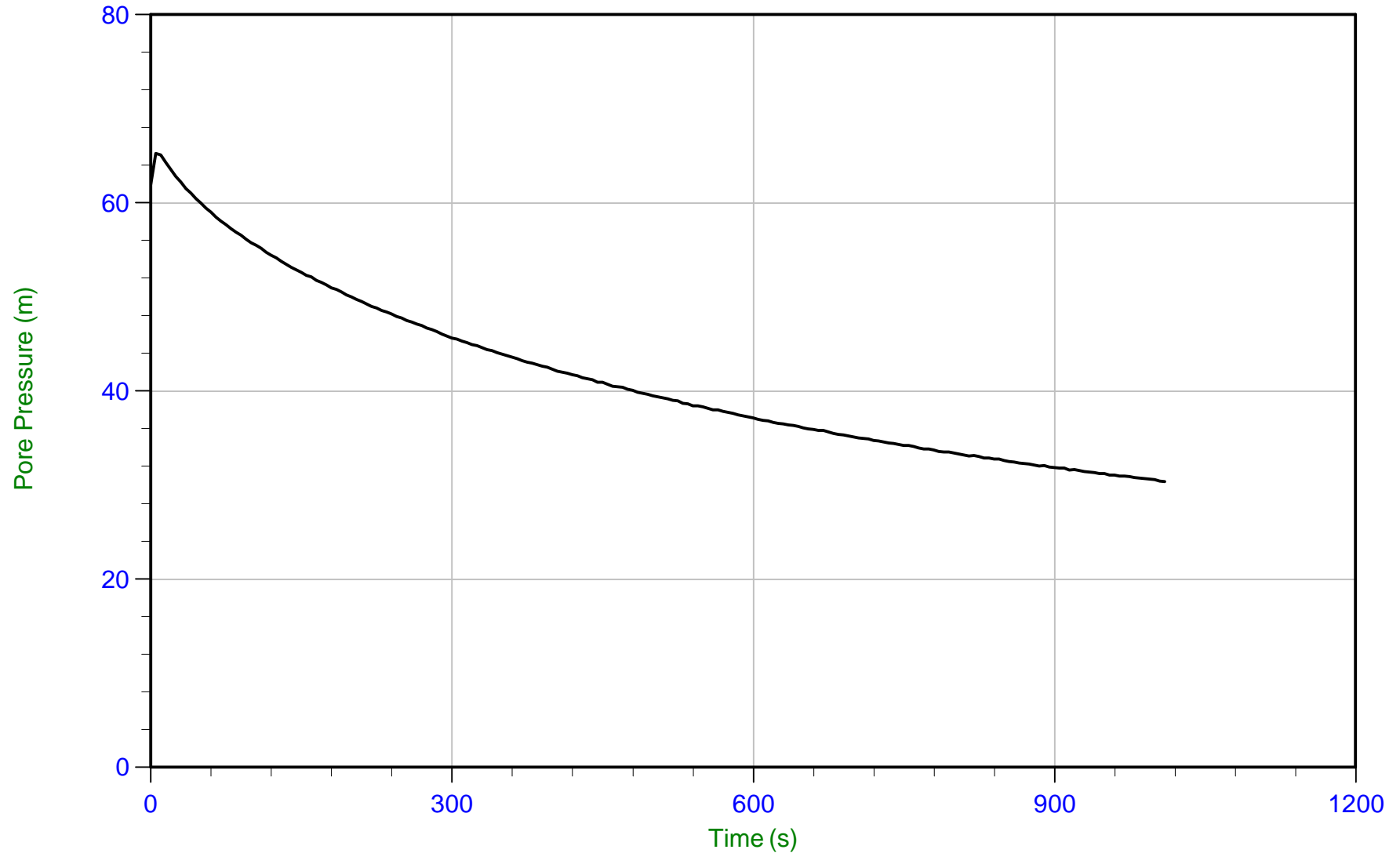
Ch: 1.4 cm<sup>2</sup>/min



## Thurber Engineering

Job No: 19-05081  
Date: 11/22/2019 10:36  
Site: Highway 406 Welland Culvert

Sounding: CPT19-05  
Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



### Trace Summary:

Filename: 19-05081\_CP05.PPF  
Depth: 13.100 m / 42.978 ft  
Duration: 1010.0 s

u Min: 30.4 m  
u Max: 65.3 m  
u Final: 30.4 m

WT: 4.226 m / 13.865 ft  
Ueq: 8.9 m  
U(50): 37.07 m

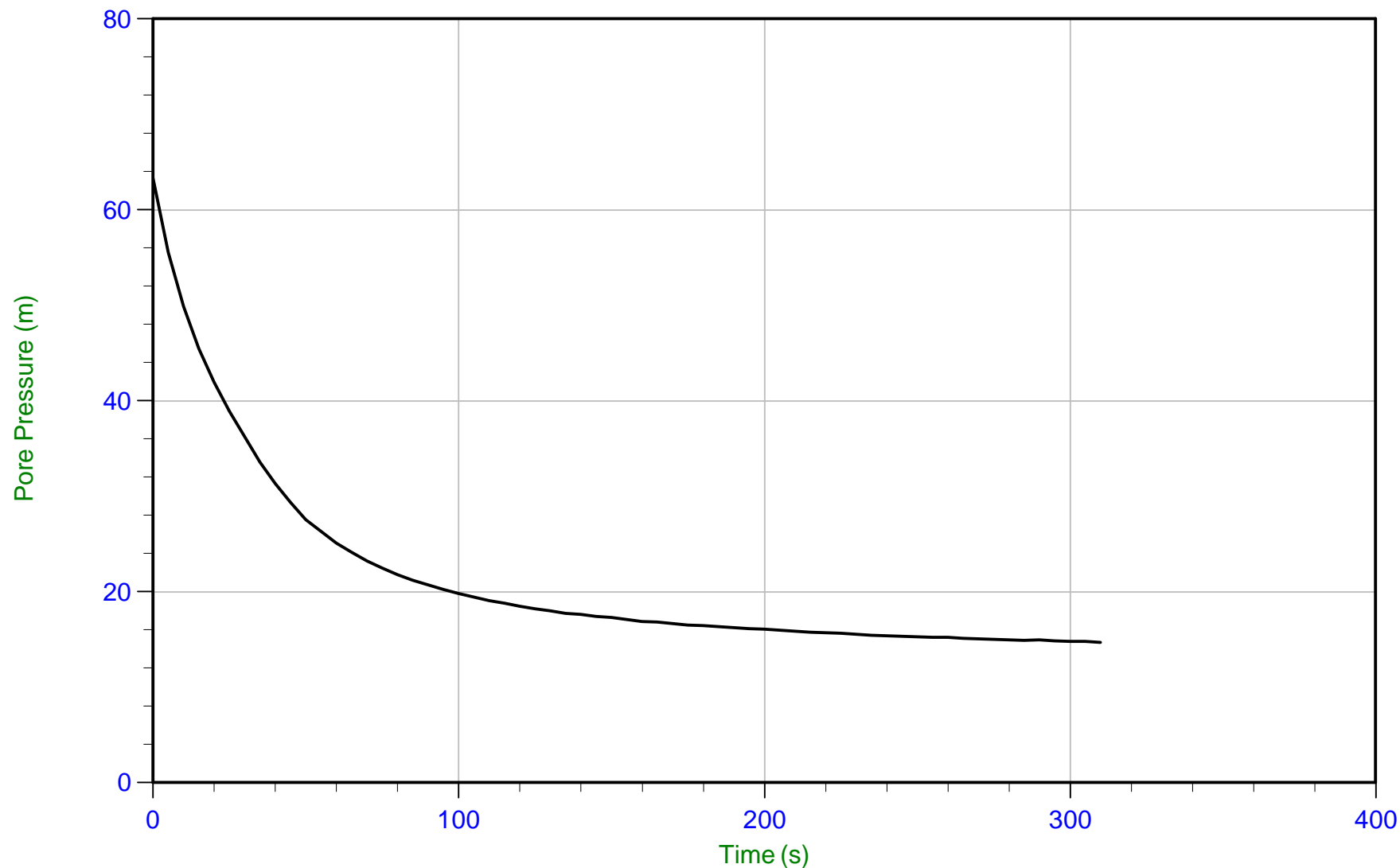
T(50): 598.1 s  
Ir: 100  
Ch: 1.2 cm<sup>2</sup>/min



## Thurber Engineering

Job No: 19-05081  
Date: 11/22/2019 10:36  
Site: Highway 406 Welland Culvert

Sounding: CPT19-05  
Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



### Trace Summary:

Filename: 19-05081\_CP05.PPF  
Depth: 17.700 m / 58.070 ft  
Duration: 310.0 s

u Min: 14.7 m  
u Max: 63.3 m  
u Final: 14.7 m

WT: 4.226 m / 13.865 ft  
Ueq: 13.5 m  
U(50): 38.40 m

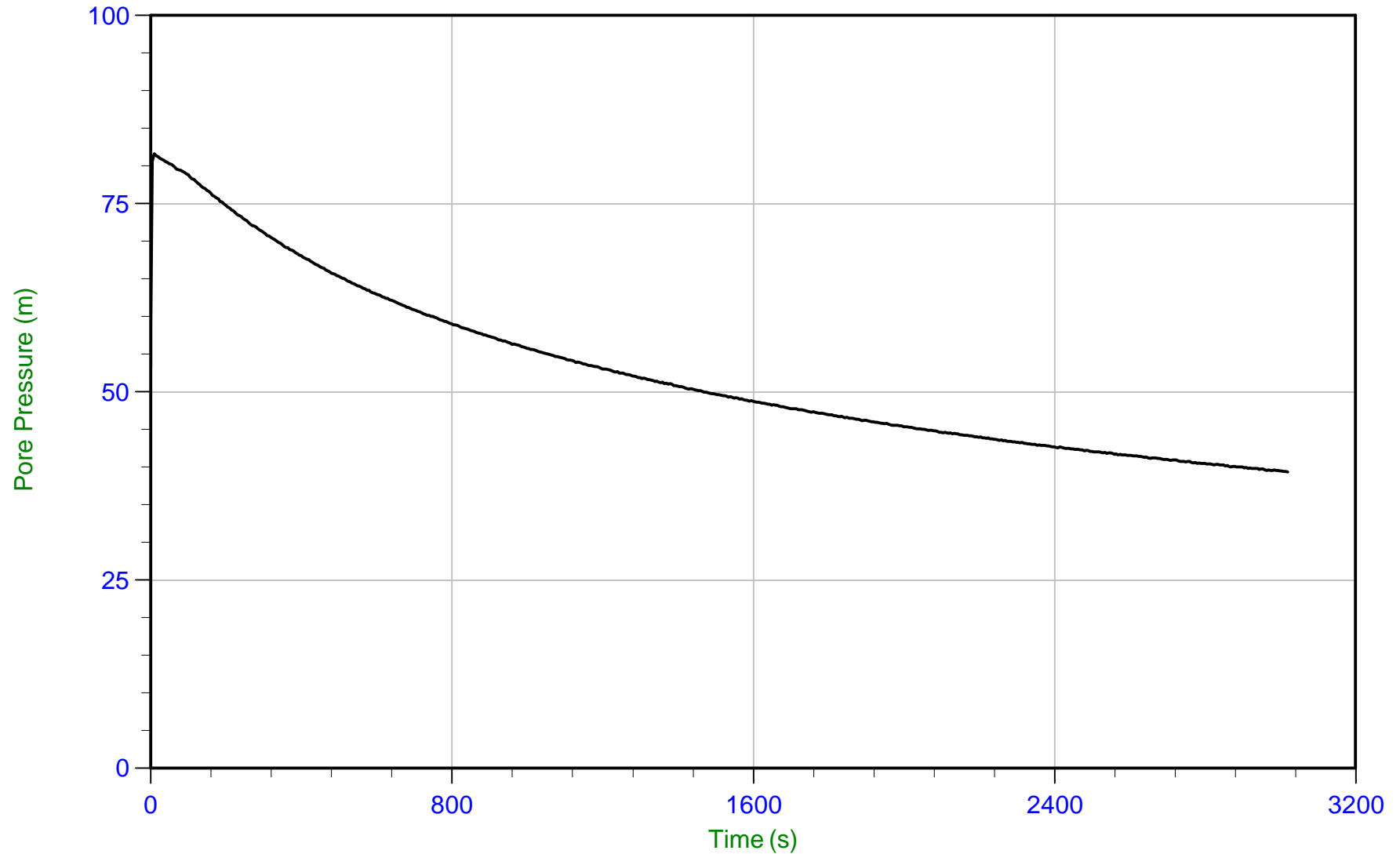
T(50): 26.0 s  
Ir: 100  
Ch: 27.0 cm<sup>2</sup>/min



## Thurber Engineering

Job No: 19-05081  
Date: 11/22/2019 10:36  
Site: Highway 406 Welland Culvert

Sounding: CPT19-05  
Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



### Trace Summary:

Filename: 19-05081\_CP05.PPF  
Depth: 22.900 m / 75.130 ft  
Duration: 3020.0 s

u Min: 39.4 m  
u Max: 81.7 m  
u Final: 39.4 m

WT: 4.226 m / 13.865 ft  
Ueq: 18.7 m  
U(50): 50.17 m

T(50): 1447.2 s  
Ir: 100  
Ch: 0.5 cm<sup>2</sup>/min



*Thurber Engineering*

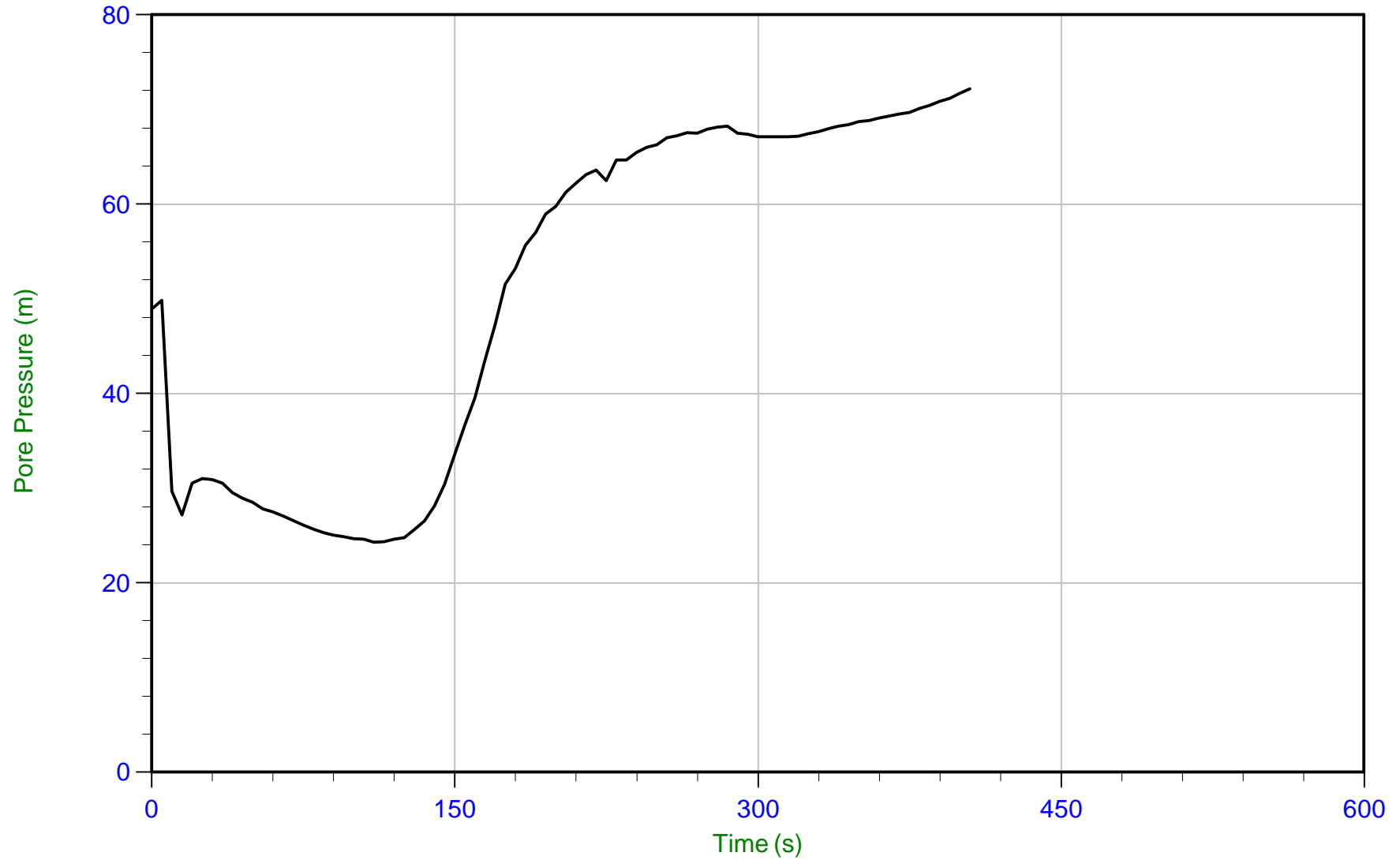
Job No: 19-05081

Date: 11/22/2019 10:36

Site: Highway 406 Welland Culvert

Sounding: CPT19-05

Cone: 408:T1500F15U500 Area=15 cm<sup>2</sup>



Trace Summary:

Filename: 19-05081\_CP05.PPF

Depth: 29.175 m / 95.717 ft

Duration: 405.0 s

u Min: 24.3 m

u Max: 72.2 m

u Final: 72.2 m





**Appendix D**  
**Record of Borehole Sheets and Geotechnical Laboratory Test Results**  
**Previous Investigation**



**Appendix D1**  
**Boreholes C10-1 to C10-3**

# RECORD OF BOREHOLE No C10-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766880.1 E:326317.5 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.13.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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Continued Next Page

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN) GPJ ONTARIO MOT.GDT 09/10/10

RECORD OF BOREHOLE No C10-1

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766880.1 E:326317.5 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.13.10 CHECKED BY RA

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
	Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.  Water Level Readings: Date Depth(m) Elevation(m) July.19.10 0.1 177.0 Aug.06.10 0.0 177.1 Aug.13.10 0.0 177.1 Aug.23.10 0.0 177.1																

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/10/10

# RECORD OF BOREHOLE No C10-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766912.0 E:326352.7 ORIGINATED BY BL  
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB  
 DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
181.7	Ground Surface													
0.0	FILL - Gravelly Sand, some silt, trace clay, compact, reddish brown, damp to moist		1	SS	17		181							26 56 14 4
181.0			2	SS	5									
0.7	FILL - Silty Clay, trace sand, soft to stiff, brown, damp to moist		3	SS	4		180							
			4	SS	12									
			5	SS	4		179							0 3 57 40
			6	SS	3		178							
			7	SS	6		177							
176.1							176							
5.6	SILTY CLAY trace sand, brown, damp to moist		8	SS	19		175							
			9	SS	16		174							
							173							
	very stiff — firm to stiff		10	SS	3		172							0 4 57 39
			11	SS	WOH		171							
							170							
			12	SS	WOH		169							
							168							
			13	SS	4		167							

Continued Next Page

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

○ 3% STRAIN AT FAILURE




ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ, ONTARIO MOT.GDT, 09/13/10

# RECORD OF BOREHOLE No C10-2

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766912.0 E:326352.7 ORIGINATED BY BL  
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB  
 DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
								20	40	60						80	100			
								○ UNCONFINED	+	FIELD VANE										
						● QUICK TRIAXIAL	x	LAB VANE				WATER CONTENT (%)								
						20	40	60	80	100	10	20	30							
165.5	SILT trace sand, frequent silty clay seams and partings, very loose, brown, wet		14	SS	1		166													
16.2																				
			15	SS	WOH			165												
								164												
								163												
162.5	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist							162												
19.2									161											
					16		SS	8												
					17		SS	12		160										
158.3								159												
23.4	End of Borehole		18	SS	24															
	Sampler wet at 10.7m.  Unable to push vane beyond 20.3m.  Borehole was dry (not stabilized) and hole open to full depth on completion.																			

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/13/10

RECORD OF BOREHOLE No C10-3

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766953.3 E:326381.6 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
178.5	Ground Surface													
178.3	230mm TOPSOIL		1	SS	7									
0.2	FILL - Silty Clay, trace sand to sandy, trace organics, firm to stiff, brown, moist		2	SS	11									
			3	SS	14									
176.4	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist		4	SS	31									
2.1			5	SS	31								0 8 54 38	
			6	SS	31								0 4 59 37	
			7	SS	26									
			8	SS	15								0 3 55 42	
	firm to very stiff		9	TW	PH									
	frequent silt layers		10	SS	7		1.6							
			11	SS	16		1.6							
			12	SS	8		1.8							
			13	SS	9		1.7						0 0 82 18	
165.3	SILT trace clay, loose to compact, brown, wet						1.0							
13.2														

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/13/10

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No C10-3

2 OF 2

METRIC

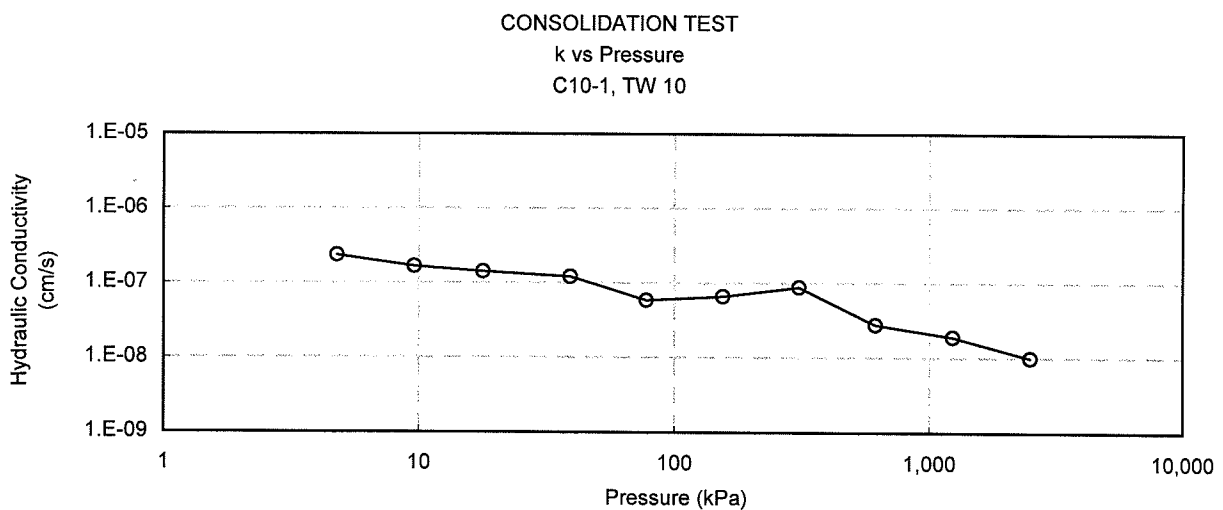
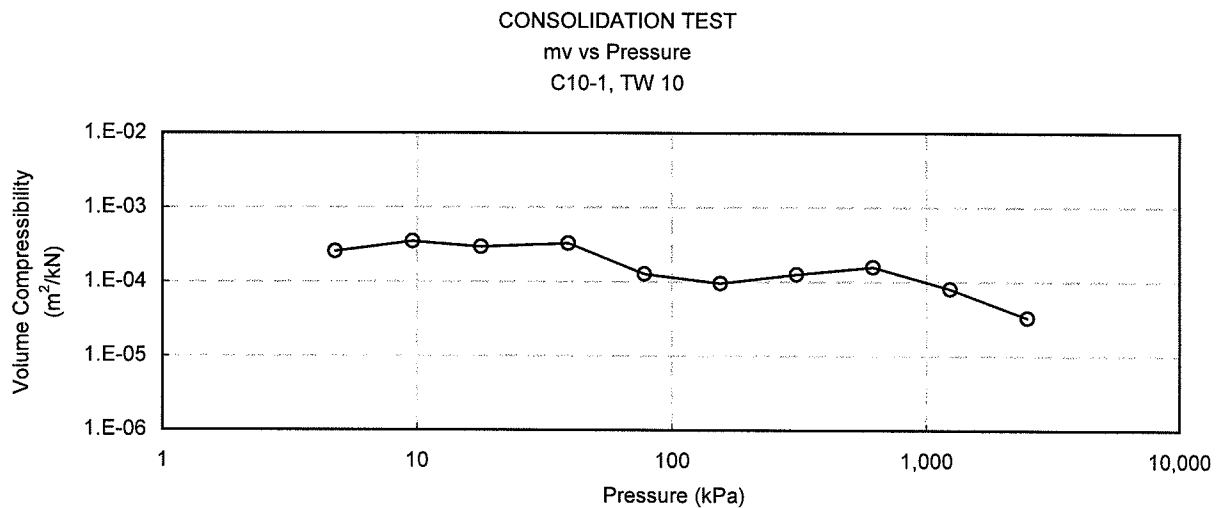
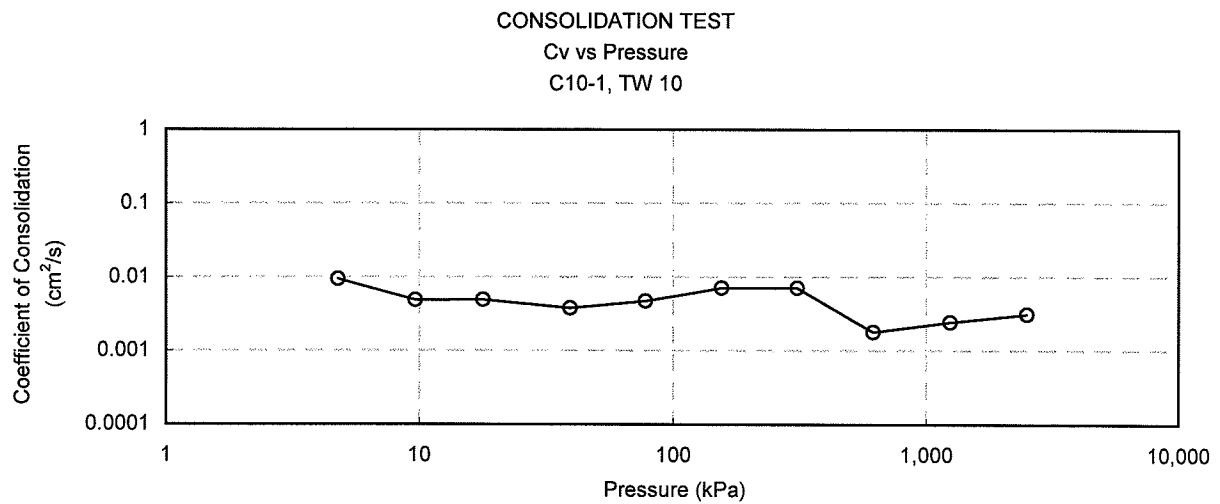
W.P. 280-99-00 LOCATION Coords: N:4766953.3 E:326381.6 ORIGINATED BY PK  
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
 DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>				
162.3			14	SS	21		163											
16.2	SILTY CLAY trace sand, hard, brown, damp to moist						162											
161.2			15	SS	33													
17.3	End of Borehole																	
	Sampler wet at 9.1m.  Water level at 8.5m (not stabilized) and hole open to 15.2m on completion.  Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.  Water Level Readings: Date Depth(m) Elevation(m) July.20.10 1.5 177.0 July.27.10 1.1 177.4 Aug.06.10 1.1 177.4																	



# HWY 406 TWINNING - CULVERT#10

FIGURE B7-11



Project No. : 1-09-4135  
Date : November 2010



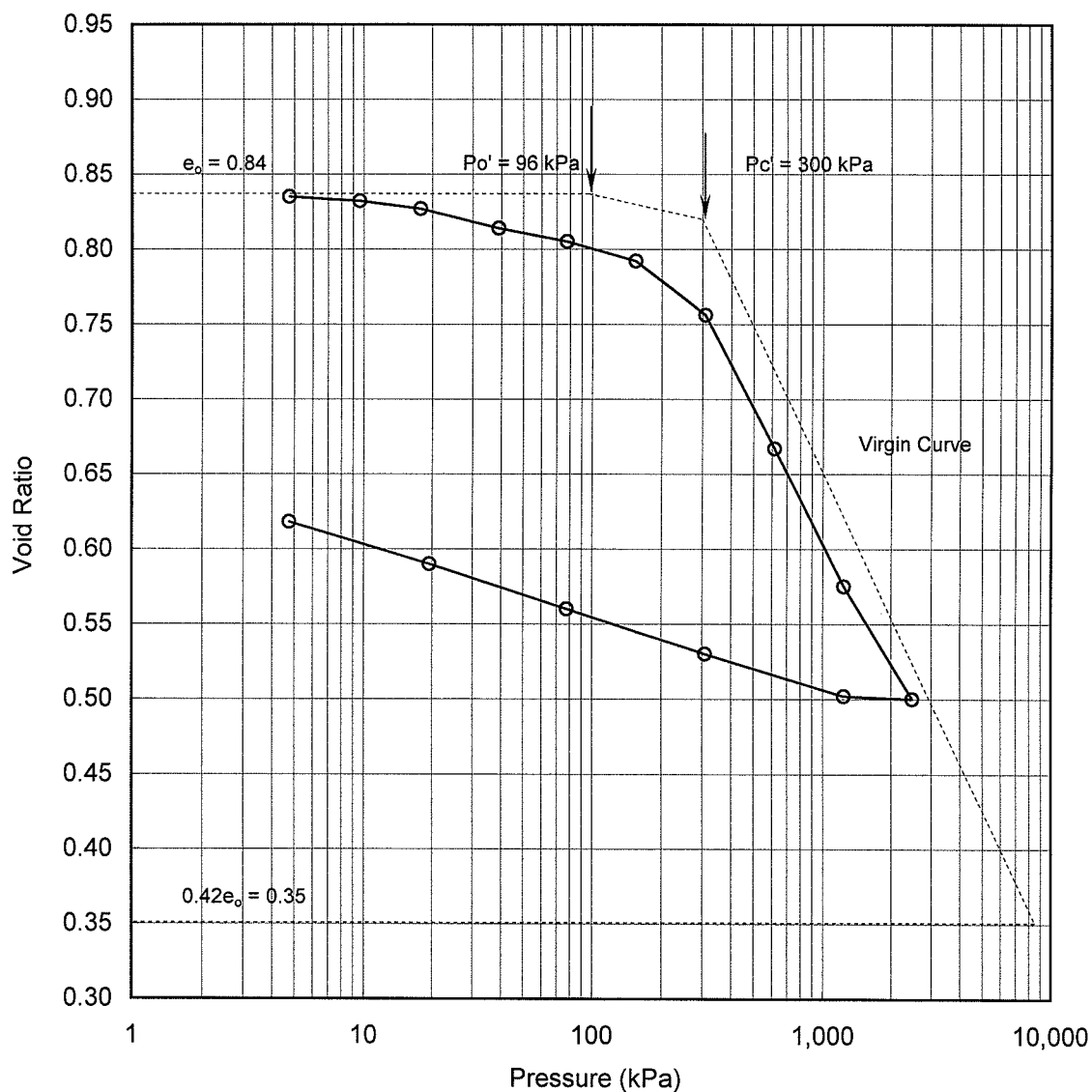
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

C10-1, TW 10



Soil Type : Silty Clay

$e_o =$	0.84	$\omega_L =$	35%	$P_{o'} =$	96 kPa
$\omega =$	22%	$\omega_p =$	19%	$P_{c'} =$	300 kPa
$\gamma =$	20.7 kN/m <sup>3</sup>	PI =	17%	Cc =	0.323
Gs =	2.81			Cr =	0.034

Project No. : 1-09-4135  
 Date : November 2010



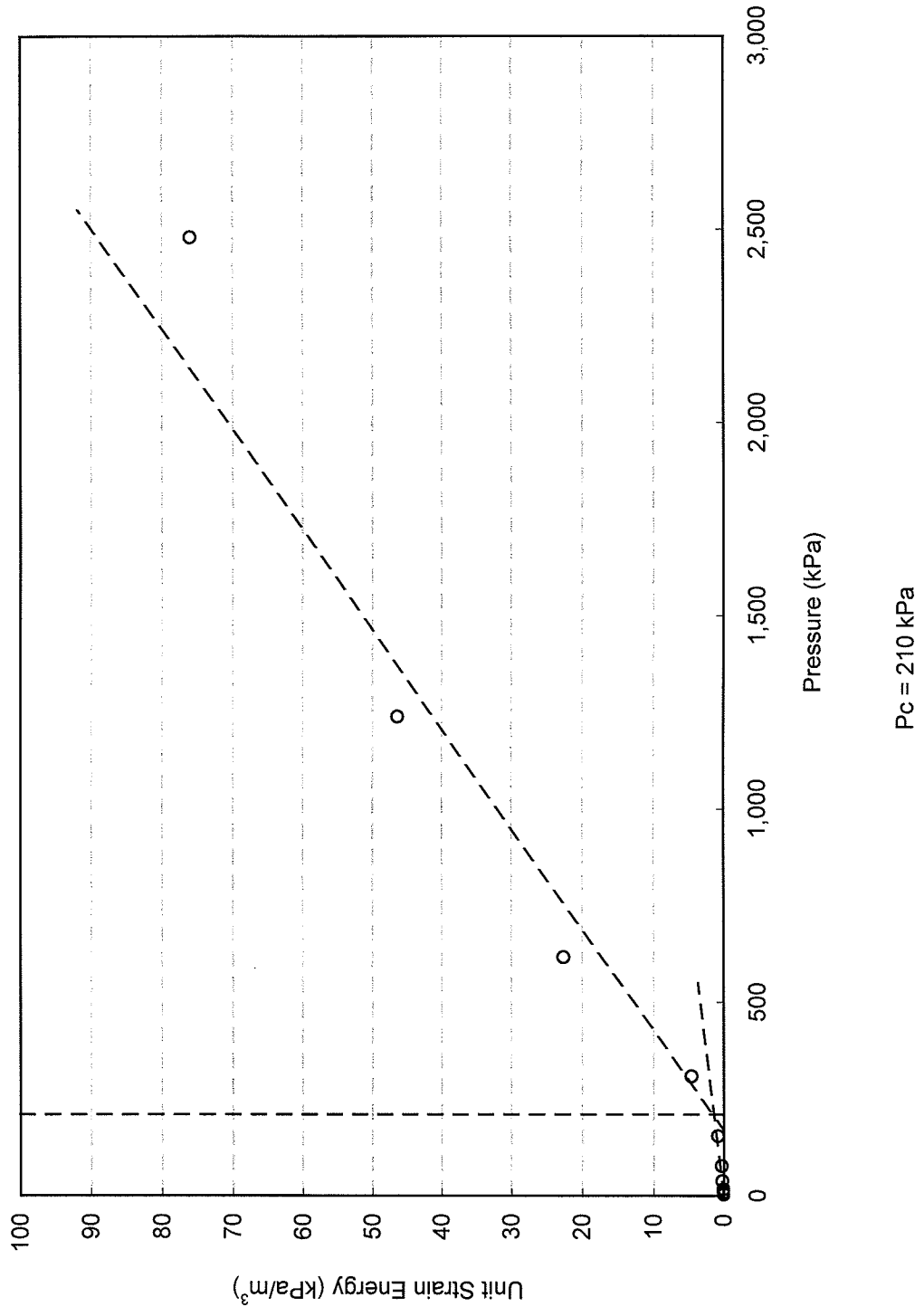
Terraprobe Inc.

Prepared By : HW  
 Checked By : RA

# HWY 406 TWINNING - CULVERT#10

FIGURE B7-13

## CONSOLIDATION TEST Unit Strain Energy vs Pressure C10-1, TW 10



Project No. : 1-09-4135  
Date : November 2010



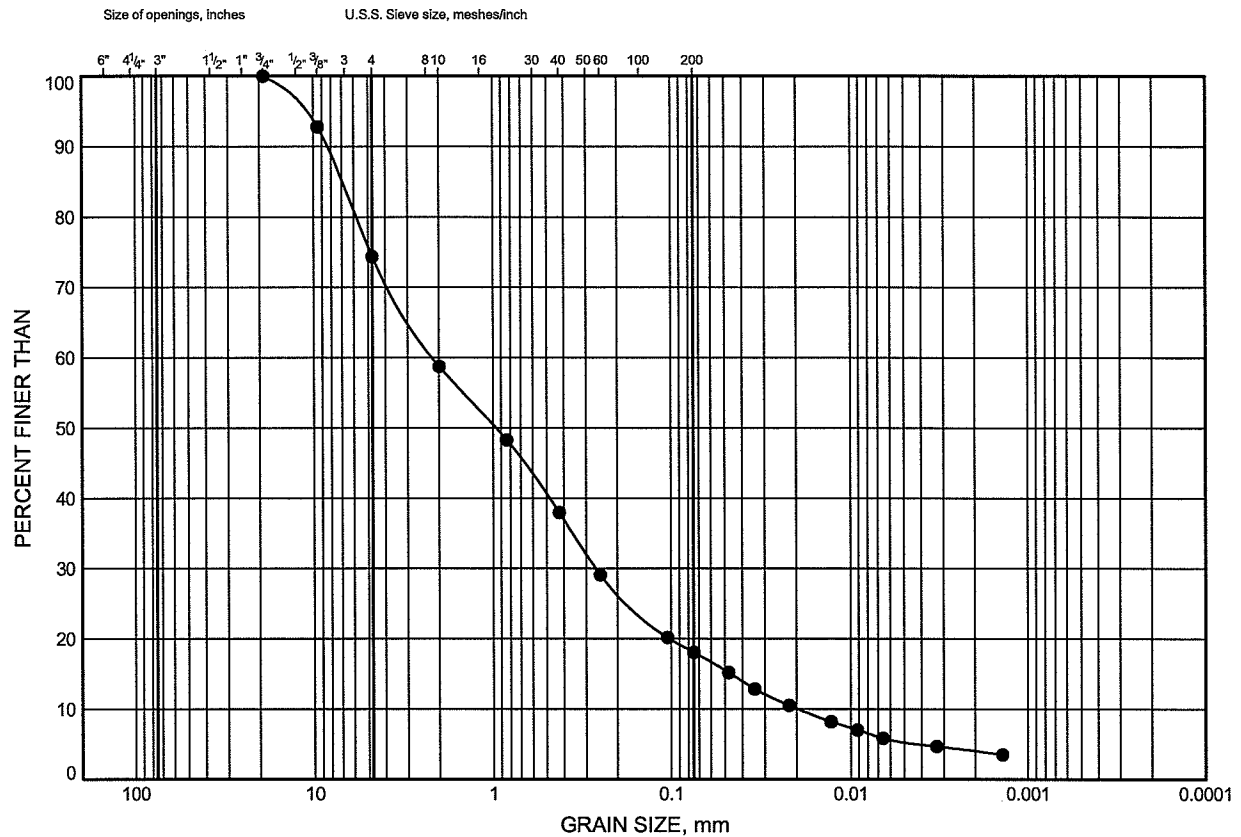
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

# GRAIN SIZE DISTRIBUTION

FIGURE B7-1

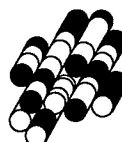
## FILL - Gravelly Sand



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	0.3	181.4

Date November 2010  
Project 1-09-4135

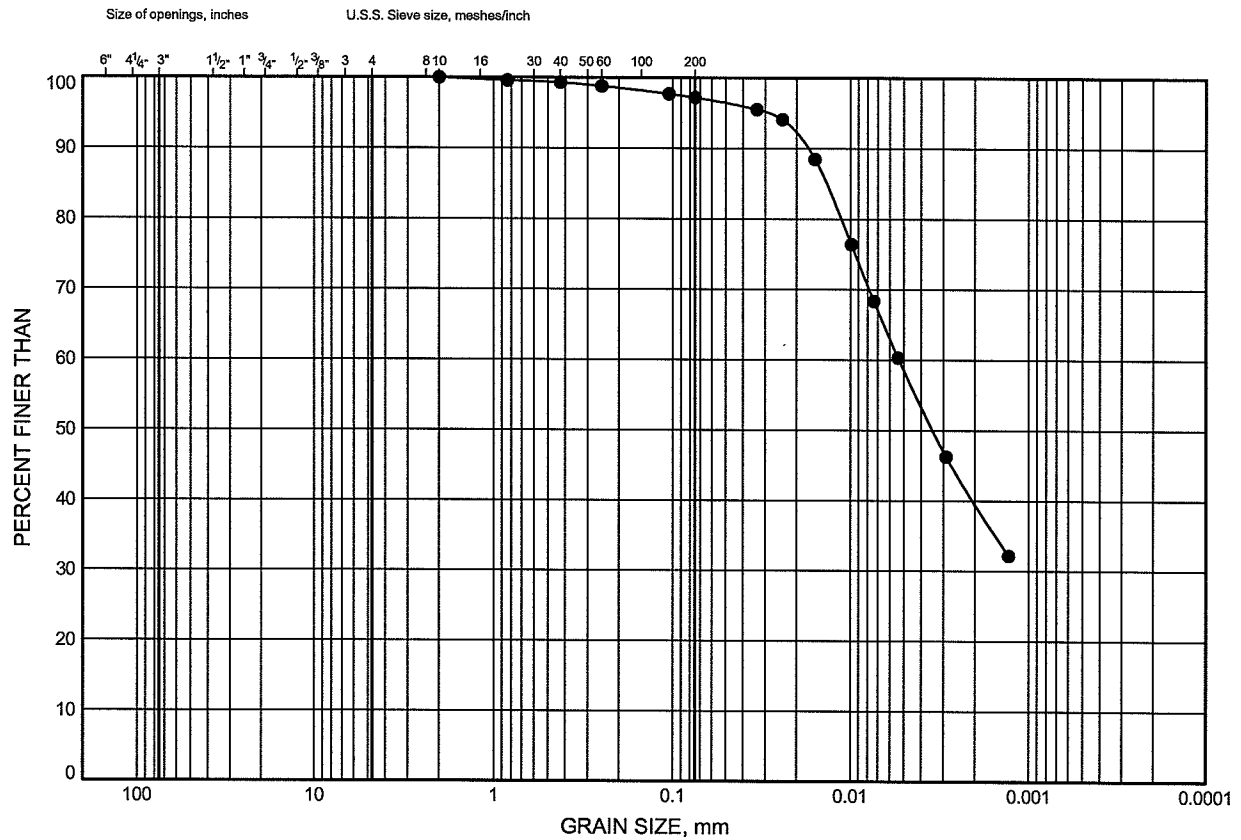


Prep'd K.L.  
Chkd. M.P.

# GRAIN SIZE DISTRIBUTION

FIGURE B7-2

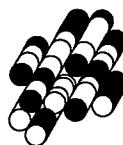
## FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	3.2	178.5

Date November 2010  
Project 1-09-4135

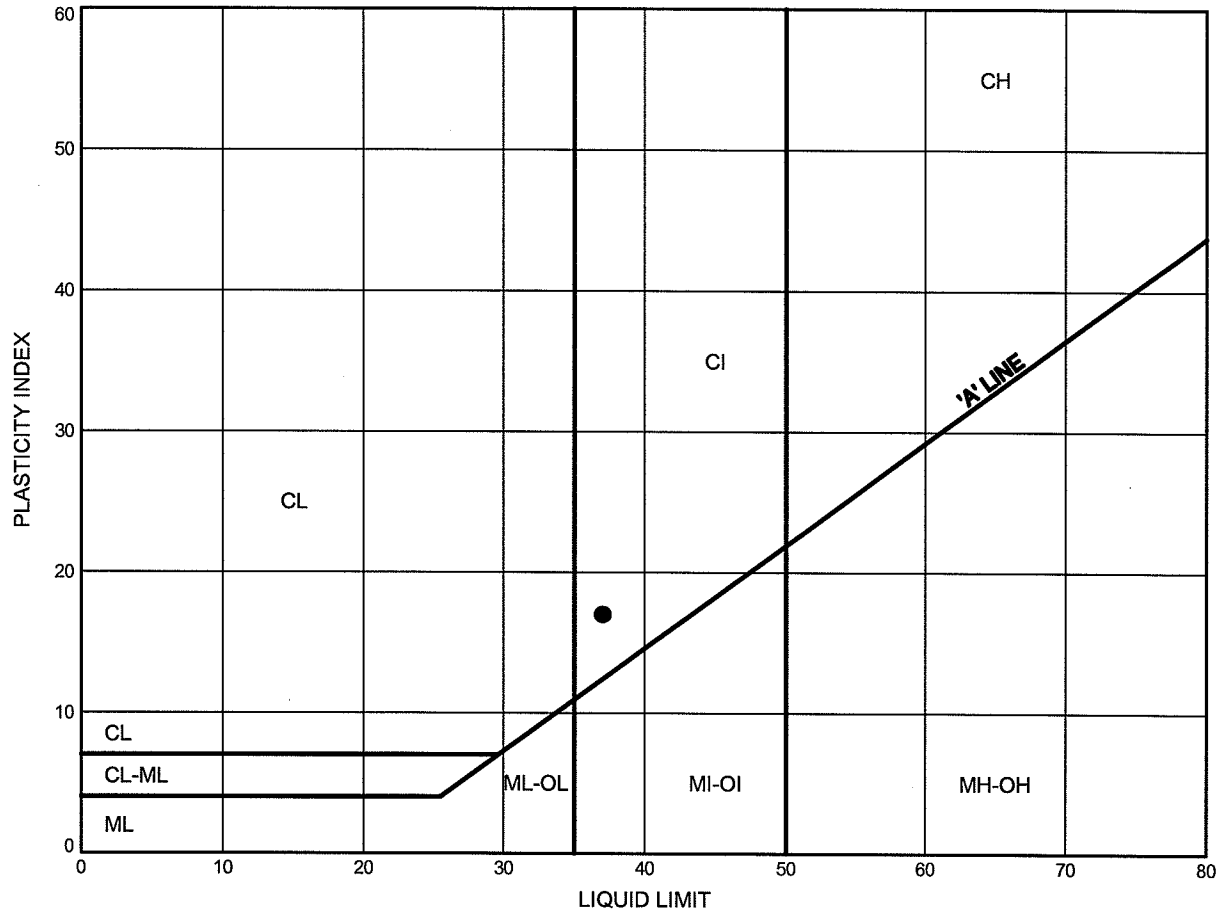


Prep'd K.L.  
Chkd. M.P.

# ATTERBERG LIMITS TEST RESULTS

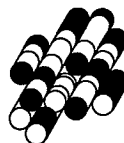
FIGURE B7-3

## FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	3.2	178.5

Date November 2010  
Project 1-09-4135

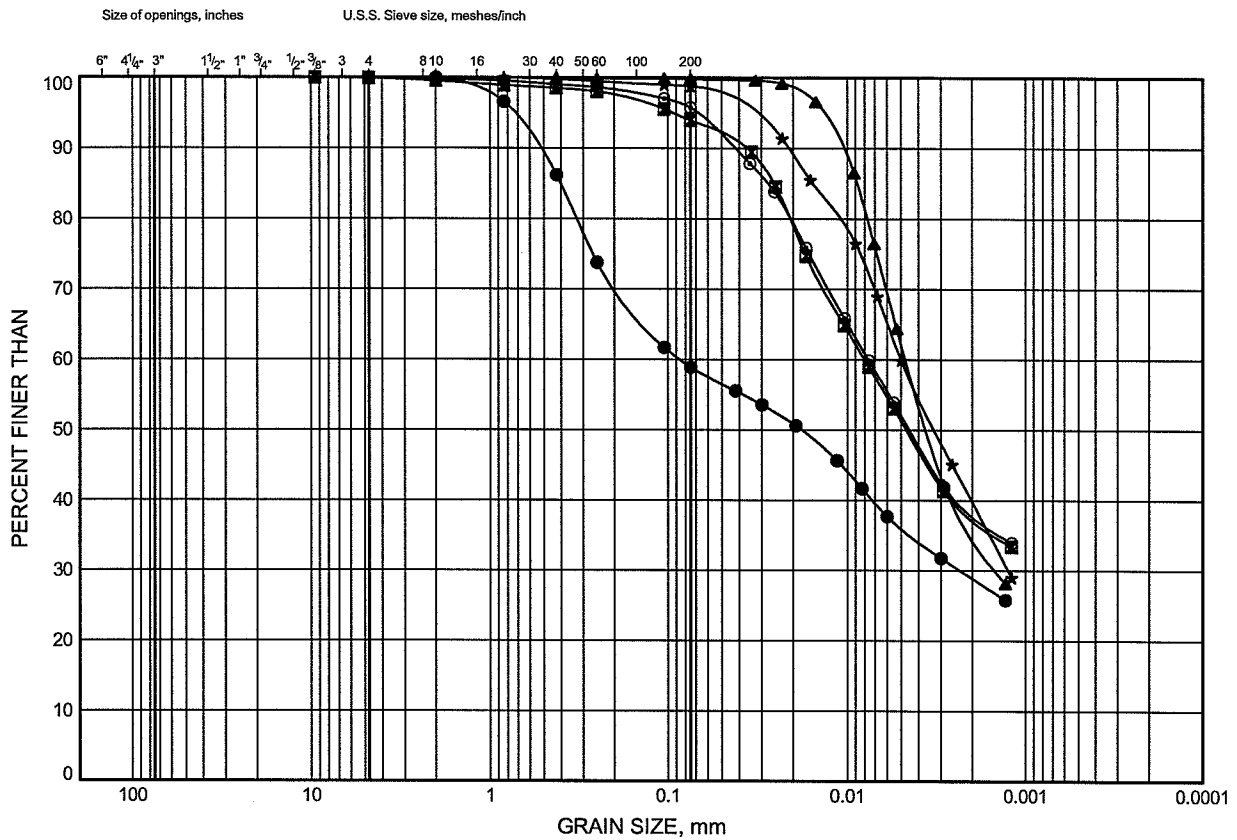


Prep'd K.L.  
Chkd. M.P.

# GRAIN SIZE DISTRIBUTION

FIGURE B7-4

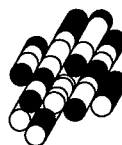
## SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-1	1.0	176.1
■	C10-1	2.5	174.6
▲	C10-1	7.8	169.3
★	C10-1	9.3	167.8
⊙	C10-2	9.3	172.4

Date November 2010  
Project 1-09-4135

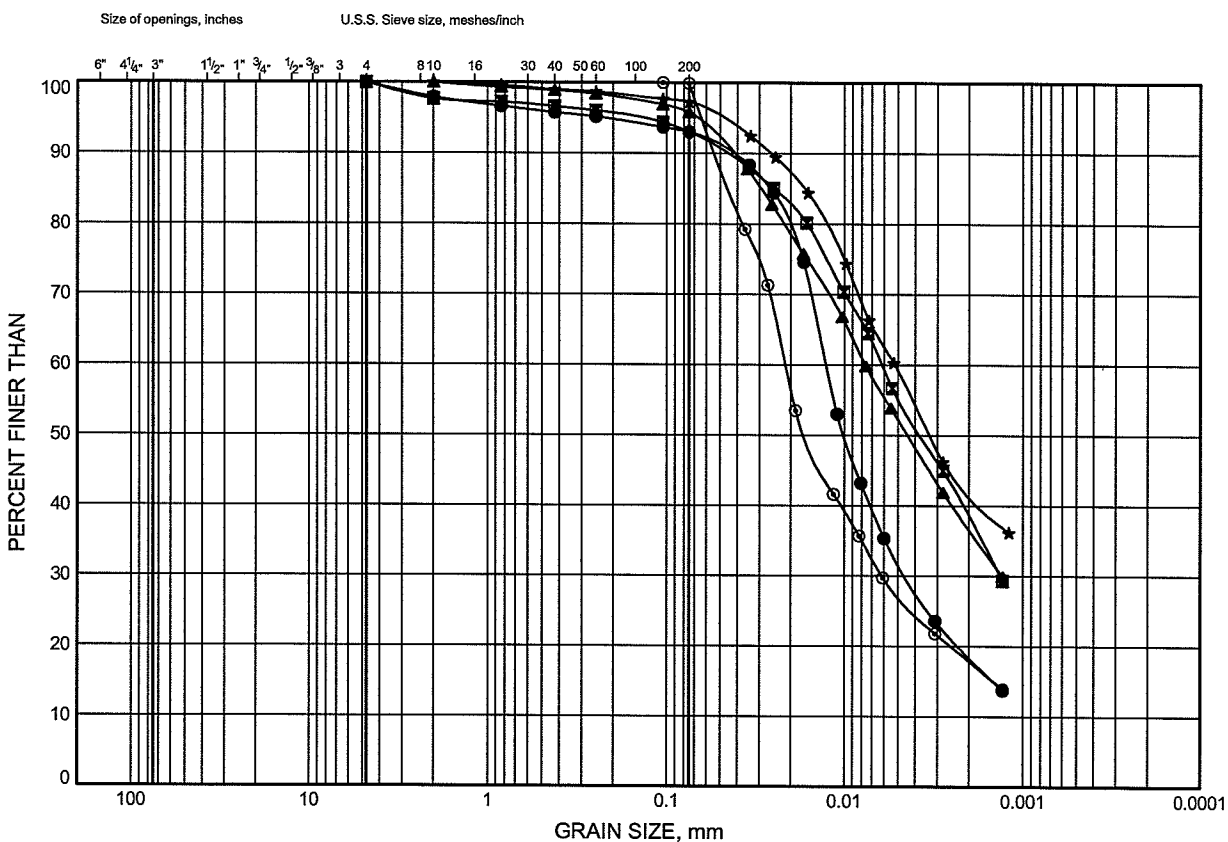


Prep'd K.L.  
Chkd. M.P.

# GRAIN SIZE DISTRIBUTION

FIGURE B7-5

## SILTY CLAY

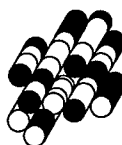


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	21.5	160.2
■	C10-3	3.2	175.3
▲	C10-3	4.0	174.5
★	C10-3	6.3	172.2
⊙	C10-3	10.9	167.6

Date November 2010

Project 1-09-4135



Prep'd K.L.

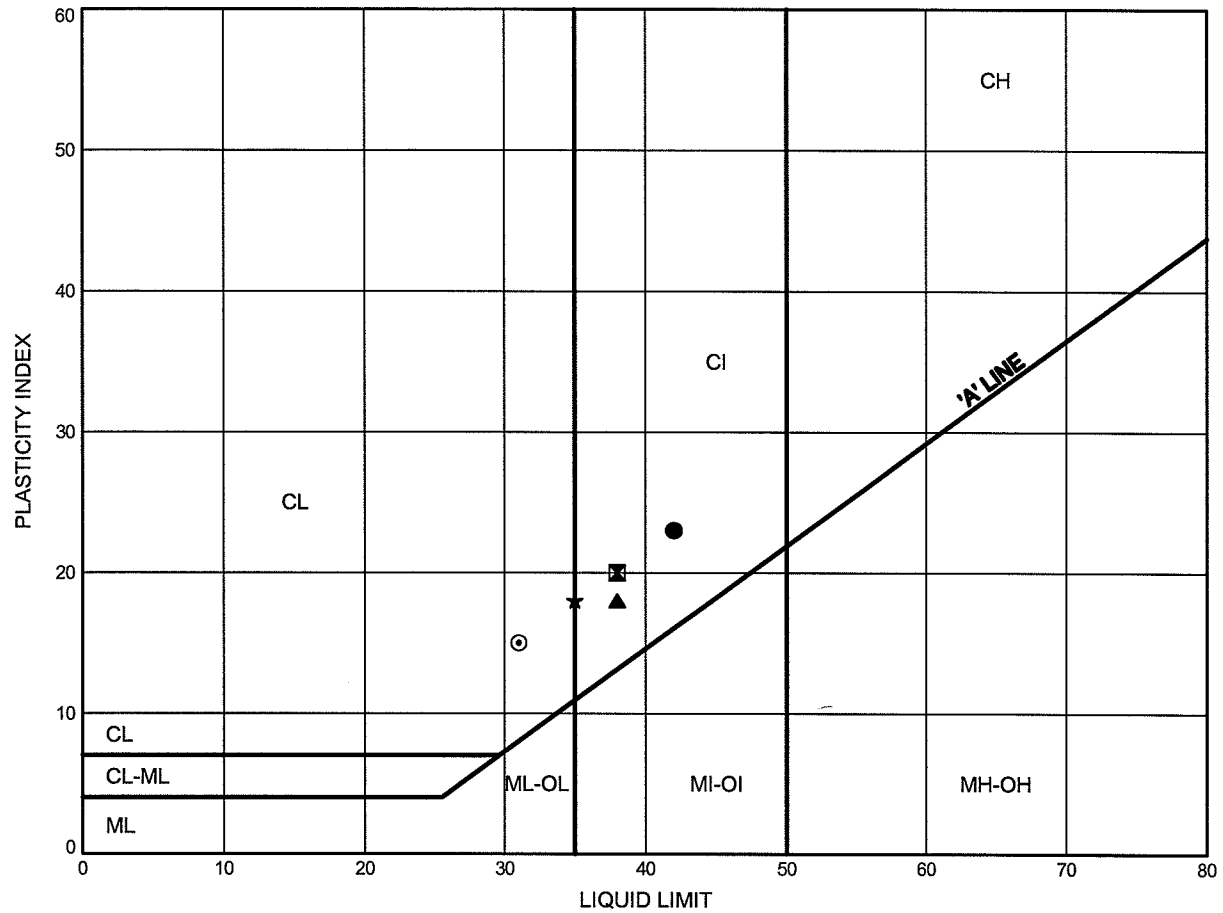
Chkd. M.P.



# ATTERBERG LIMITS TEST RESULTS

FIGURE B7-6

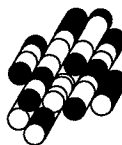
## SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-1	1.0	176.1
⊠	C10-1	2.5	174.6
▲	C10-1	7.8	169.3
★	C10-1	9.3	167.8
⊙	C10-2	9.3	172.4

Date November 2010

Project 1-09-4135



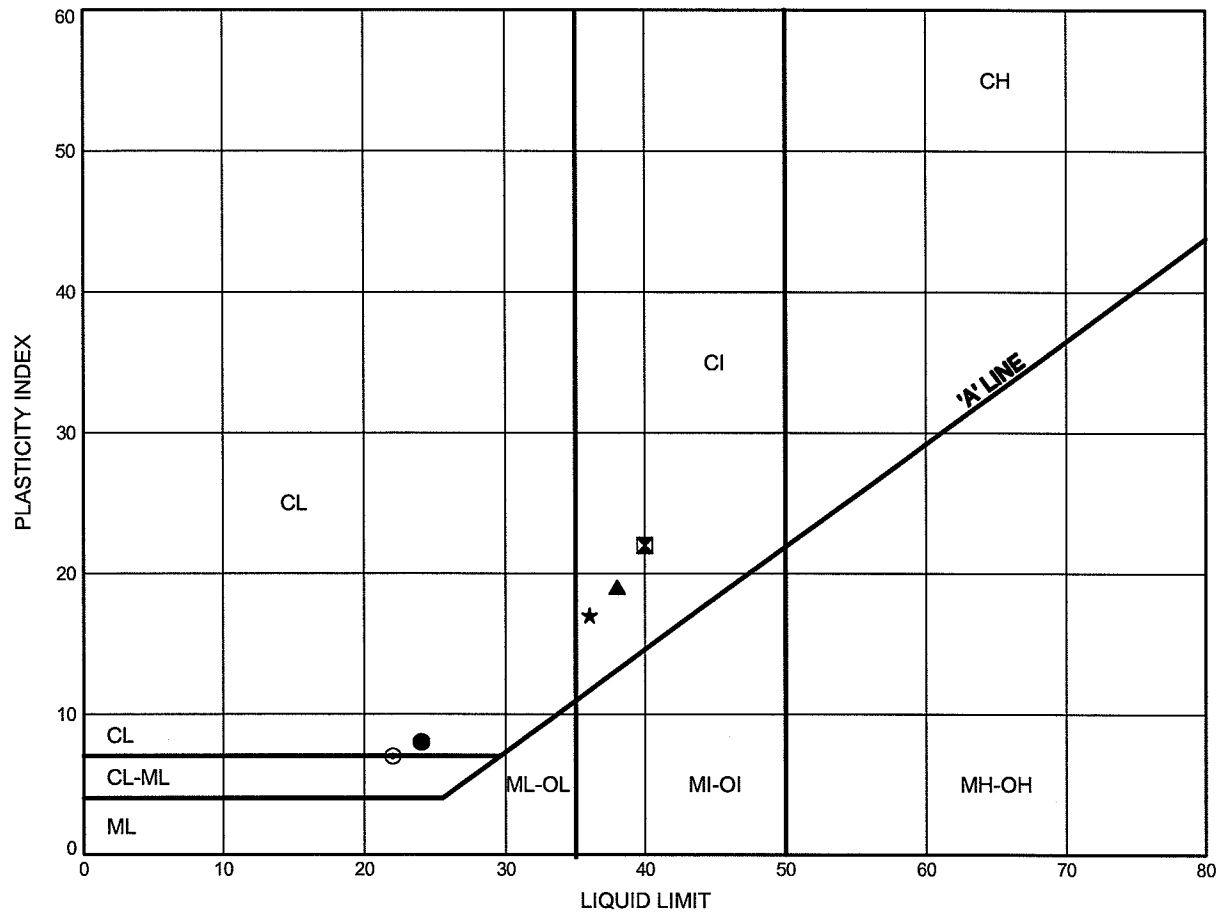
Prep'd K.L.

Chkd. M.P.

# ATTERBERG LIMITS TEST RESULTS

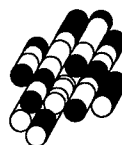
FIGURE B7-7

## SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	21.5	160.2
⊠	C10-3	3.2	175.3
▲	C10-3	4.0	174.5
★	C10-3	6.3	172.2
⊙	C10-3	10.9	167.6

Date November 2010  
Project 1-09-4135

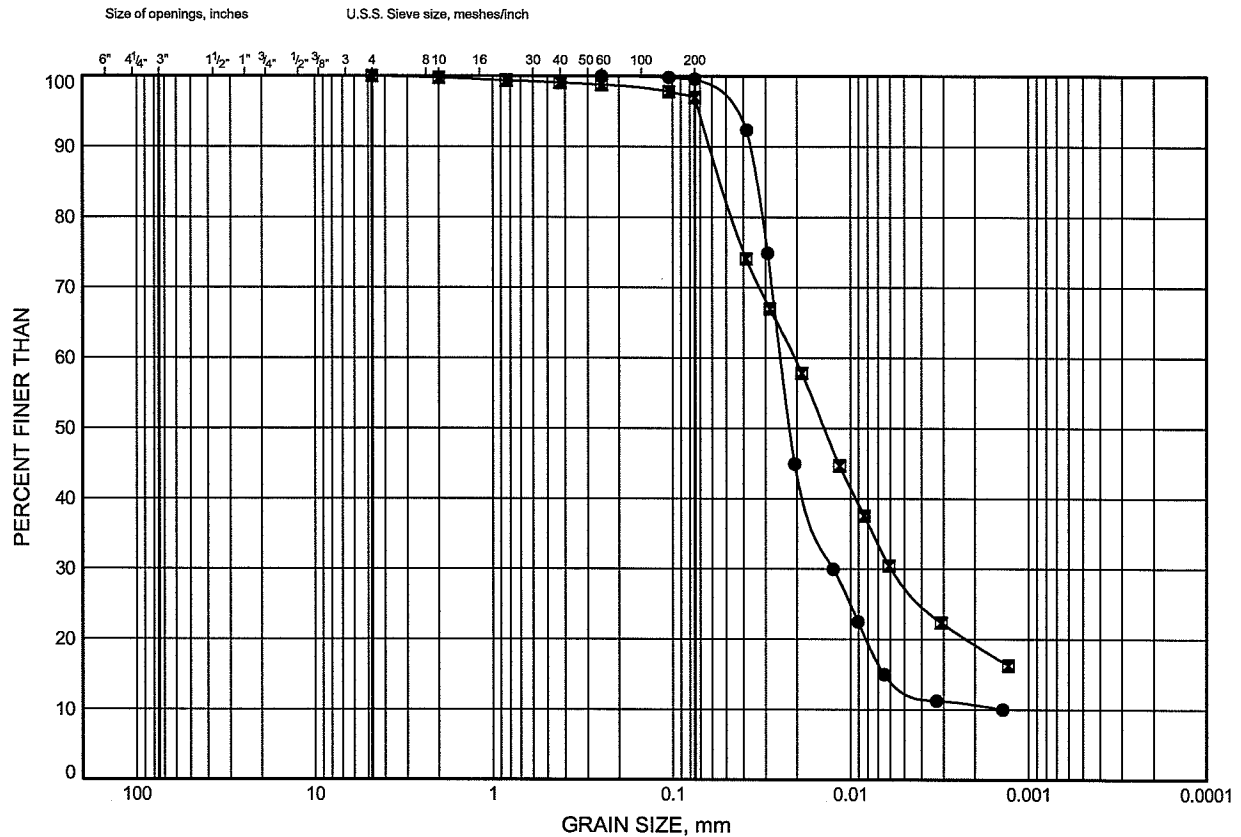


Prep'd K.L.  
Chkd. M.P.

# GRAIN SIZE DISTRIBUTION

FIGURE B7-8

## SILT



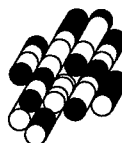
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL    BOREHOLE    DEPTH (m)    ELEVATION (m)

●	C10-1	10.9	166.2
■	C10-2	17.0	164.7

Date November 2010

Project 1-09-4135



Prep'd K.L.

Chkd. M.P.

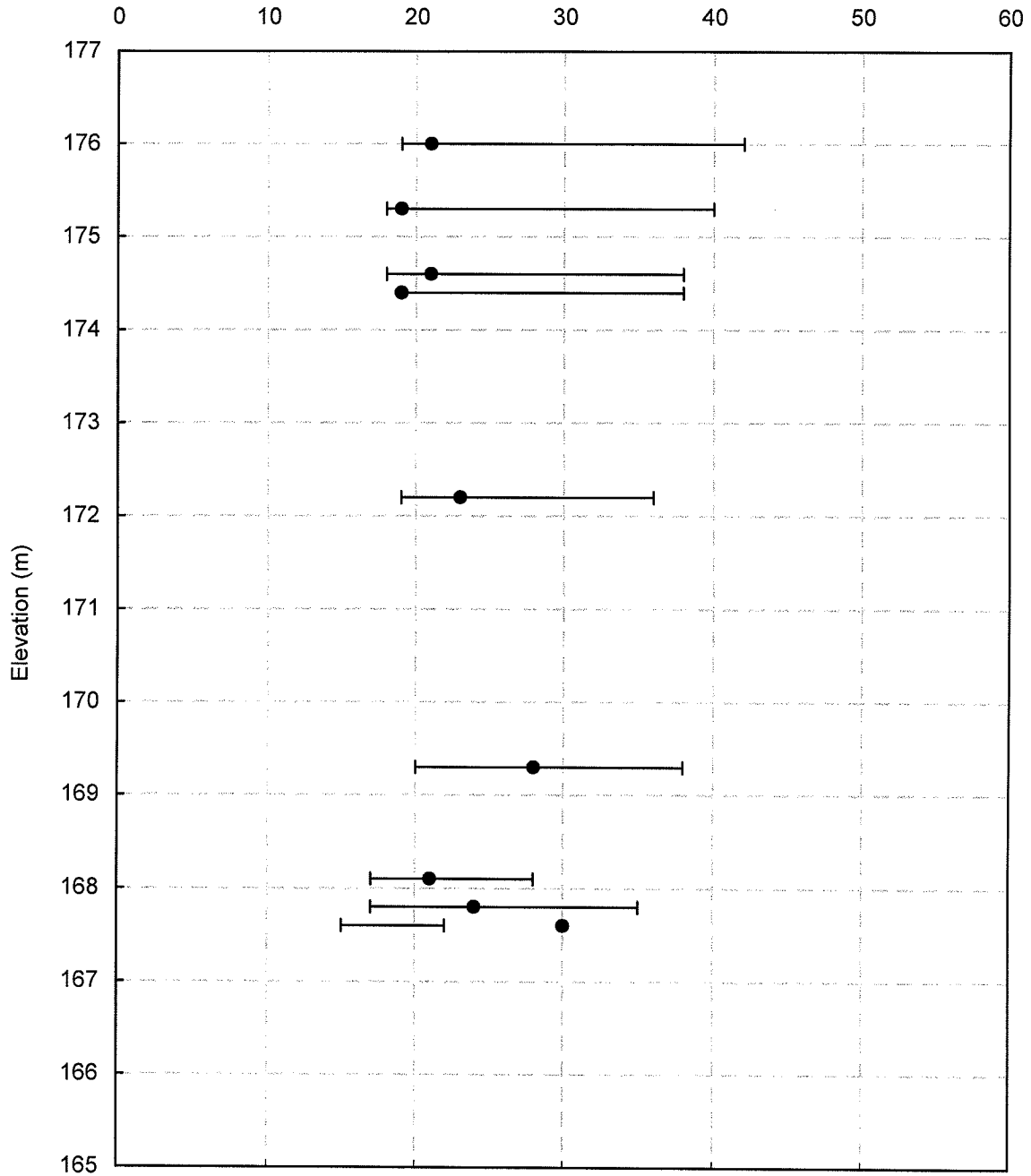
# ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B7-9

## HWY 406 TWINNING - CULVERT #10

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



**Terraprobe Inc.**

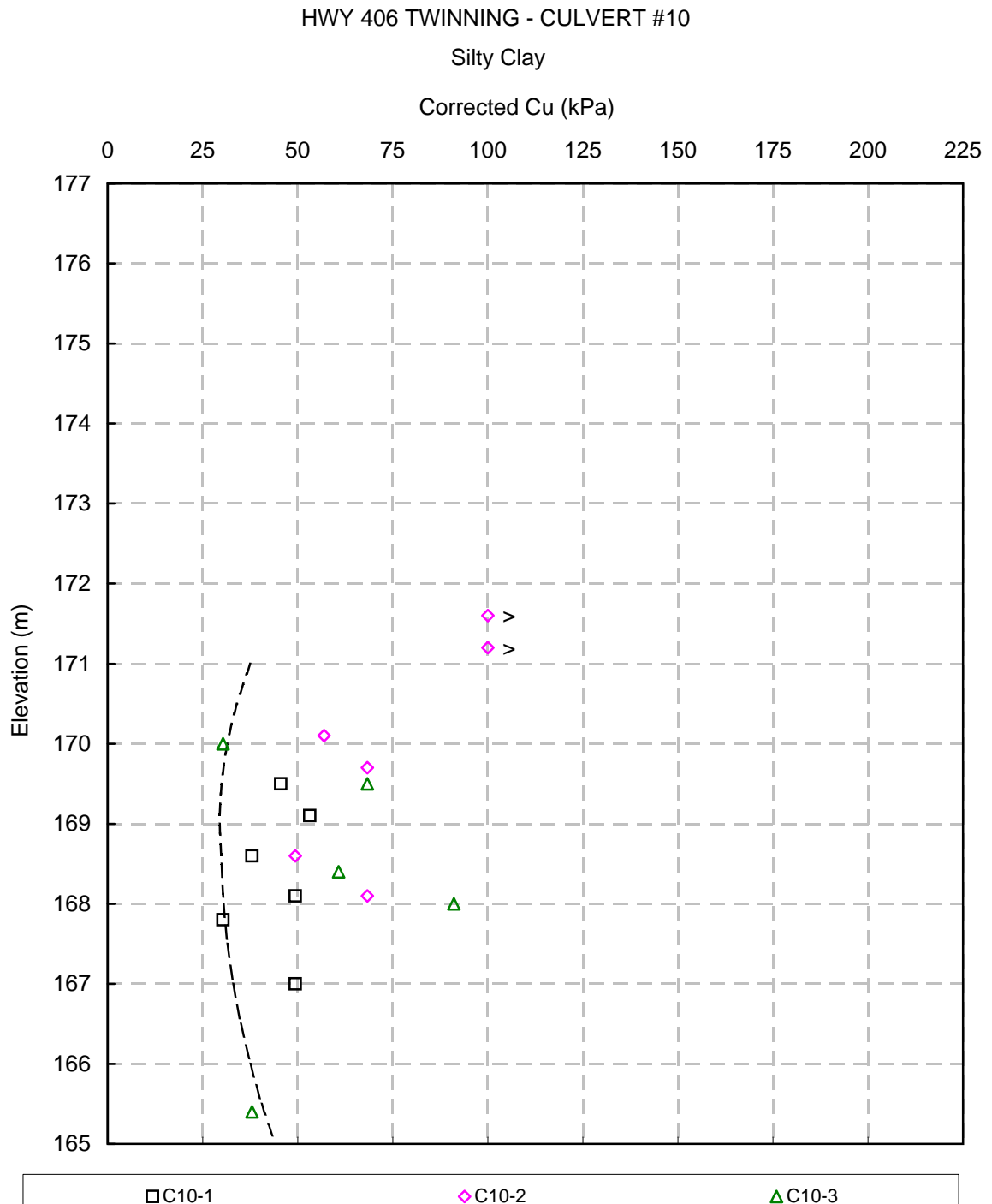
Prepared By : HW

Checked By : RA

# CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B7-10

C:\Documents and Settings\Admin\My Documents\Marc P\Projects 2009\Hwy 406 Expansion\1-09-4135 (Hwy 406 Foundations)\Culverts and Retaining Walls\Culverts\Lab Results\1-09-4135C10 Soil Parameter Estimation.xls



## Field Shear Vane Correction

Morris & Williams (1994)  
 $(\mu = 1.18 \text{ EXP}(-0.08 \text{ Ip}) + 0.57)$

## Applied Correction Factors

0.78 (Elev.>174m)      0.95 (Elev.<174m)

Project No. : 1-09-4135

Date : November, 2010



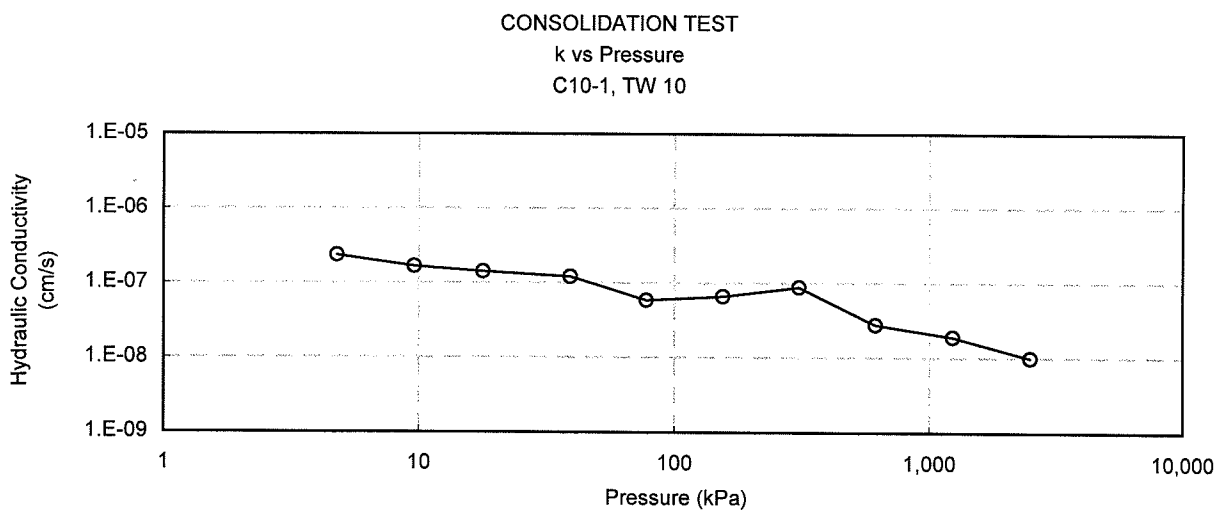
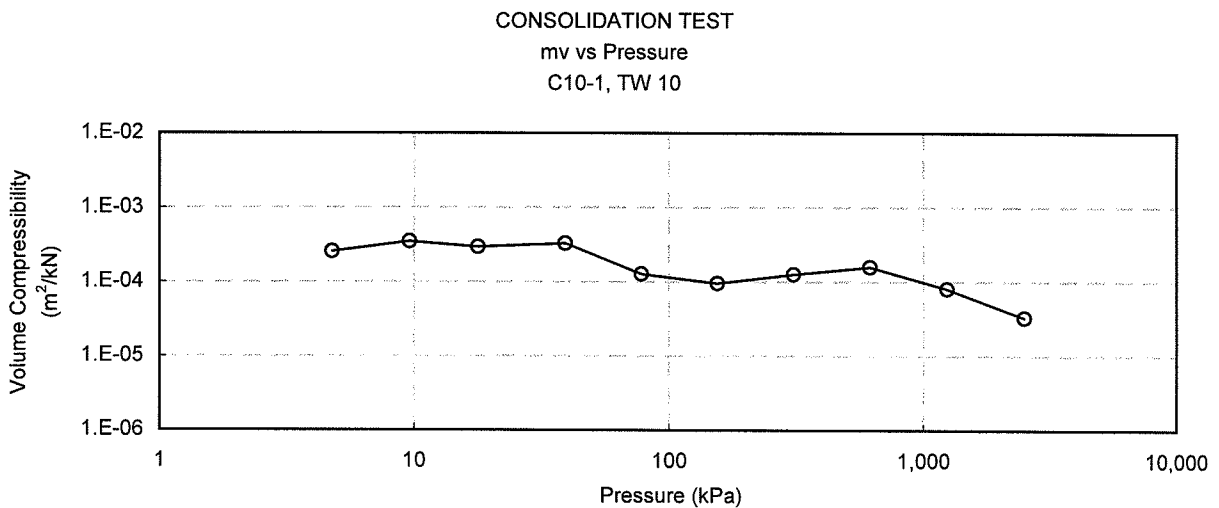
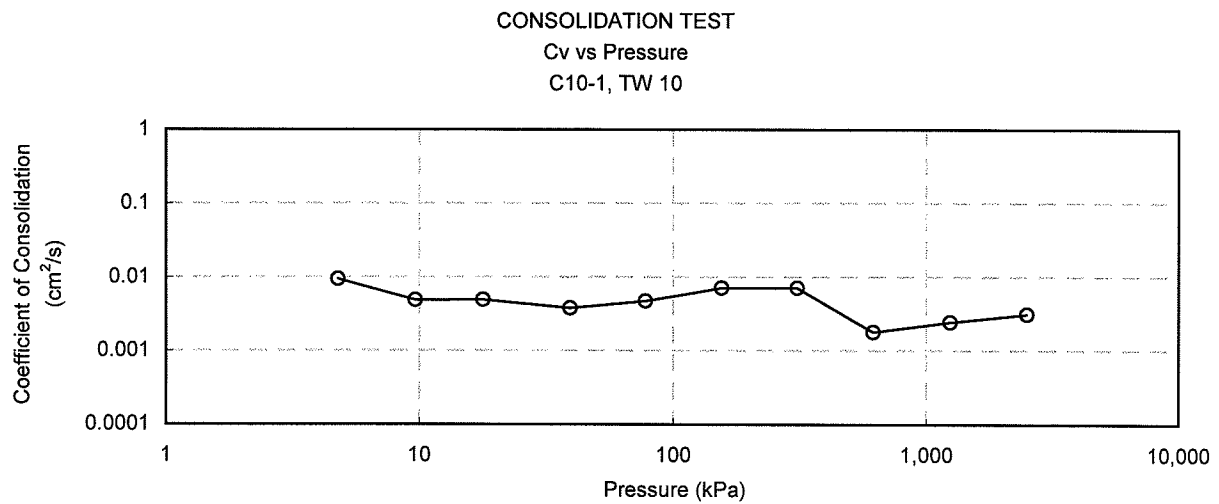
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# HWY 406 TWINNING - CULVERT#10

FIGURE B7-11



c:\Documents and Settings\Admin\My Documents\Marc P\Projects 2009\Hwy 406 Expansion\1-09-4135 (Hwy 406 Foundations)\Culverts and Retaining Walls\Culverts\Lab Results\1-09-4135 Consolidation Results.xls

Project No. : 1-09-4135  
Date : November 2010



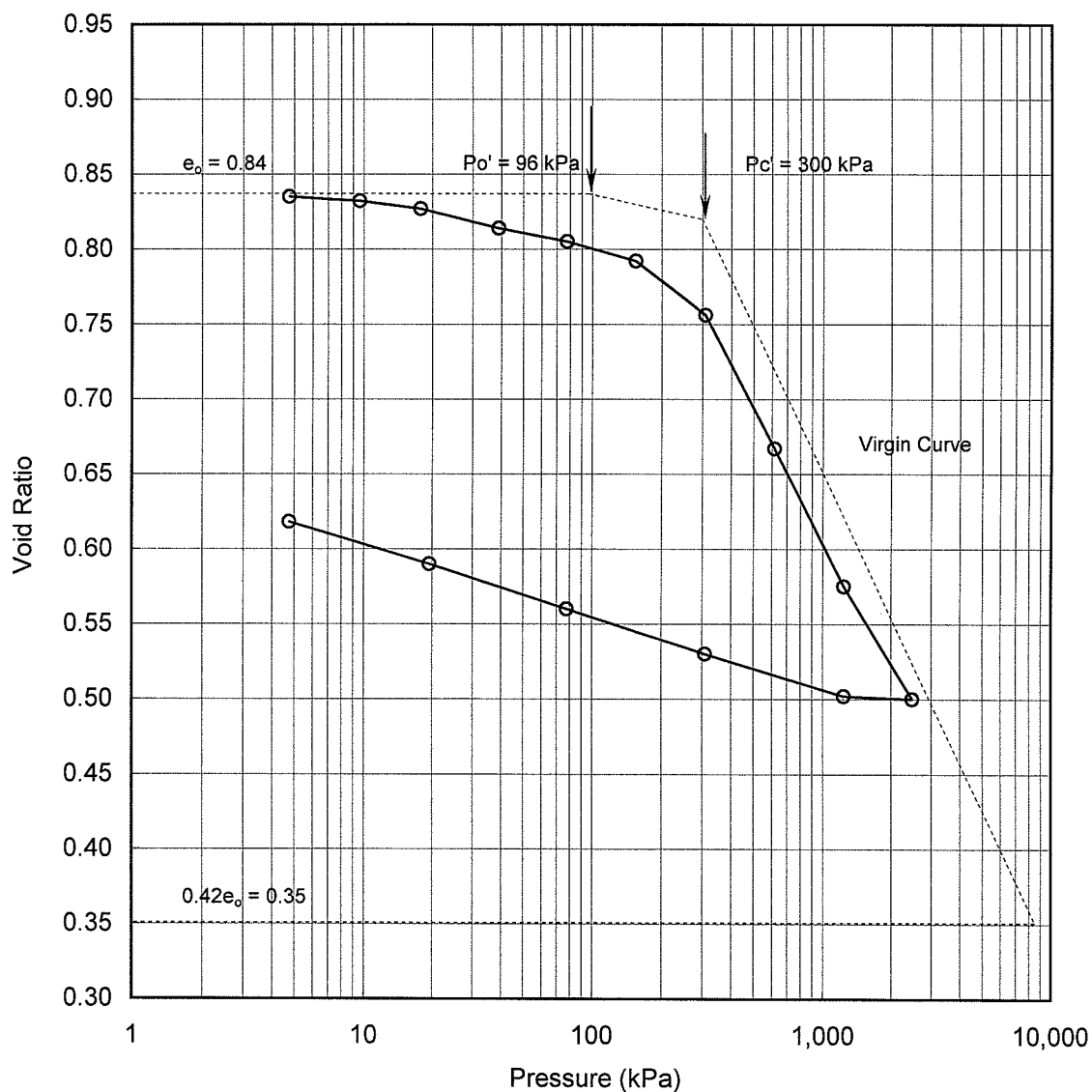
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

C10-1, TW 10



Soil Type : Silty Clay

$e_o =$	0.84	$\omega_L =$	35%	$P_{o'} =$	96 kPa
$\omega =$	22%	$\omega_p =$	19%	$P_{c'} =$	300 kPa
$\gamma =$	20.7 kN/m <sup>3</sup>	PI =	17%	Cc =	0.323
Gs =	2.81			Cr =	0.034

Project No. : 1-09-4135  
 Date : November 2010



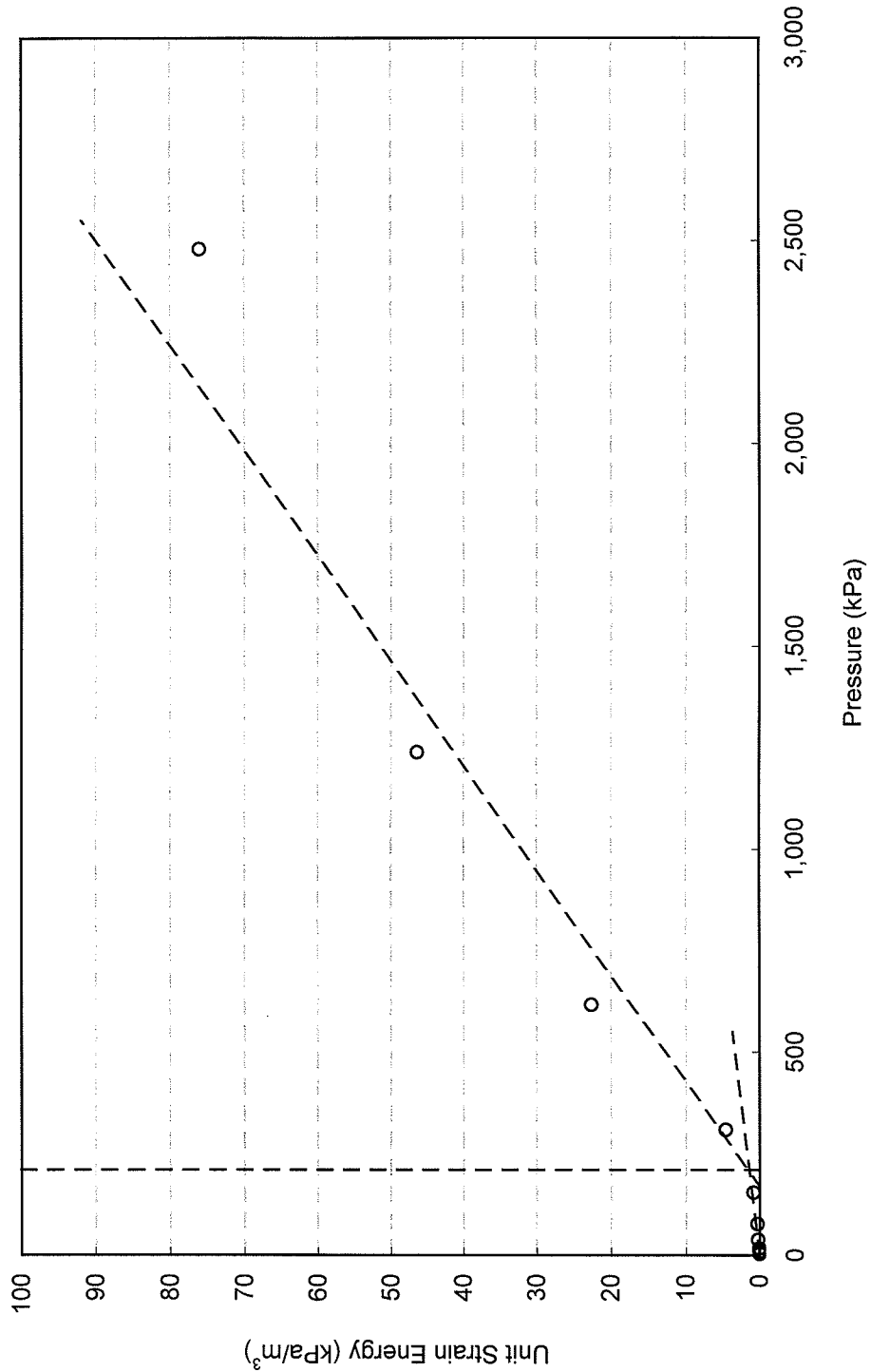
Terraprobe Inc.

Prepared By : HW  
 Checked By : RA

# HWY 406 TWINNING - CULVERT#10

FIGURE B7-13

## CONSOLIDATION TEST Unit Strain Energy vs Pressure C10-1, TW 10



Project No. : 1-09-4135  
Date : November 2010



**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA





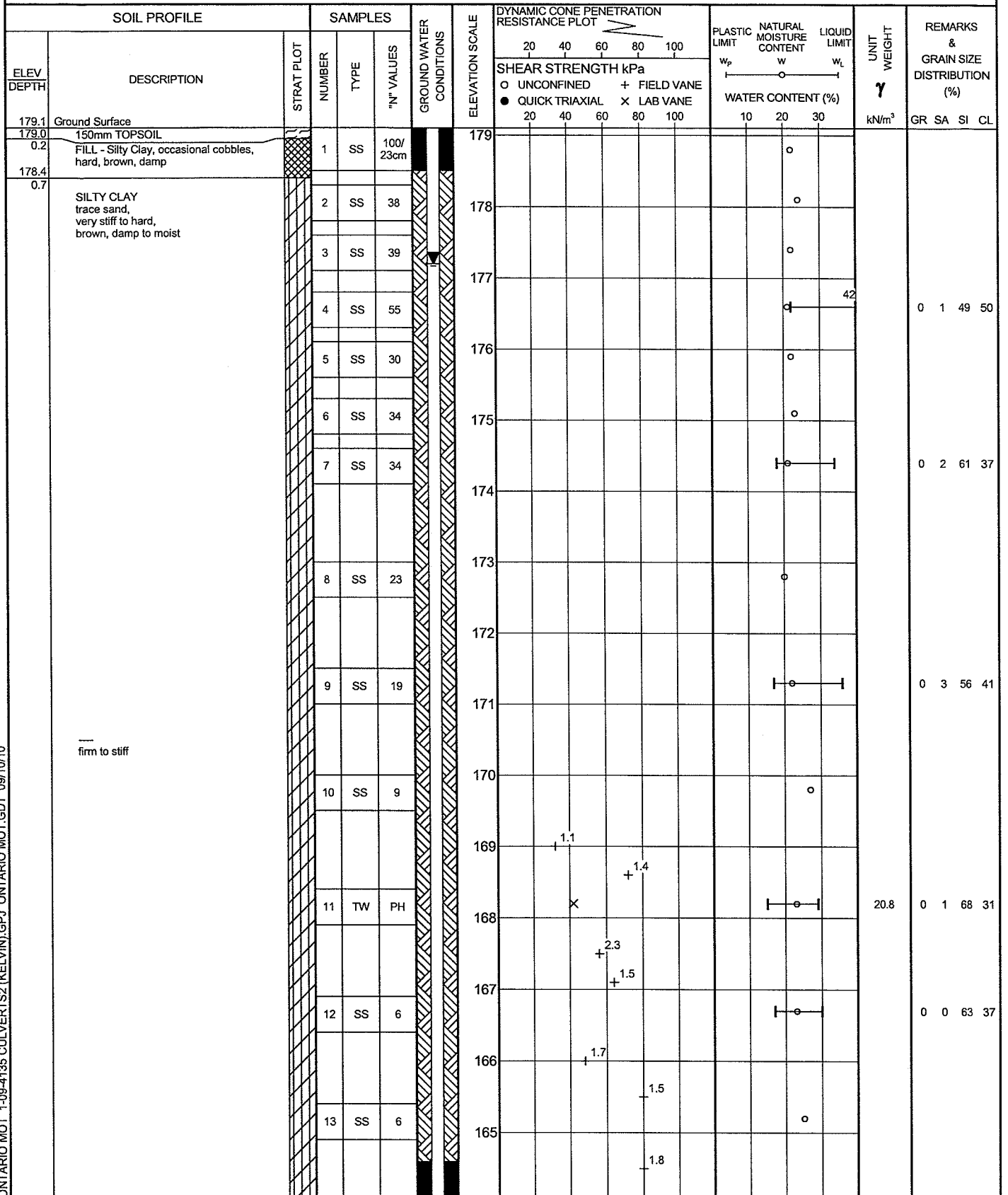
**Appendix D2**  
**Borehole C11-3**

# RECORD OF BOREHOLE No C11-3

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766795.7 E:326063.9 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.09.10 - 07.12.10 CHECKED BY RA



ONTARIO MOT. 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/10/10

Continued Next Page

+3, X3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-3

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766795.7 E:326063.9 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.09.10 - 07.12.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						
							20	40	60	80	100					
163.6			14	SS	5										July 09	
15.5	SILT trace clay, loose, brown, wet														July 12	
162.1			15	SS	6											
17.0	CLAYEY SILT trace sand, trace gravel, firm to hard, brown, damp to moist															
			16	SS	11											
			17	SS	59										0 0 86 14	
158.8	End of Borehole															
20.3	Consolidation test performed on TW 11.  Water level at 17.4m (not stabilized) and hole open to 13.7m on completion.  SS1 - Sampler bouncing, probably on a cobble.  Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.  Water Level Readings: Date      Depth(m)      Elevation(m) July.19.10      5.1      174.0 July.26.10      3.5      175.6 Aug.06.10      2.0      177.1 Aug.13.10      1.9      177.2															

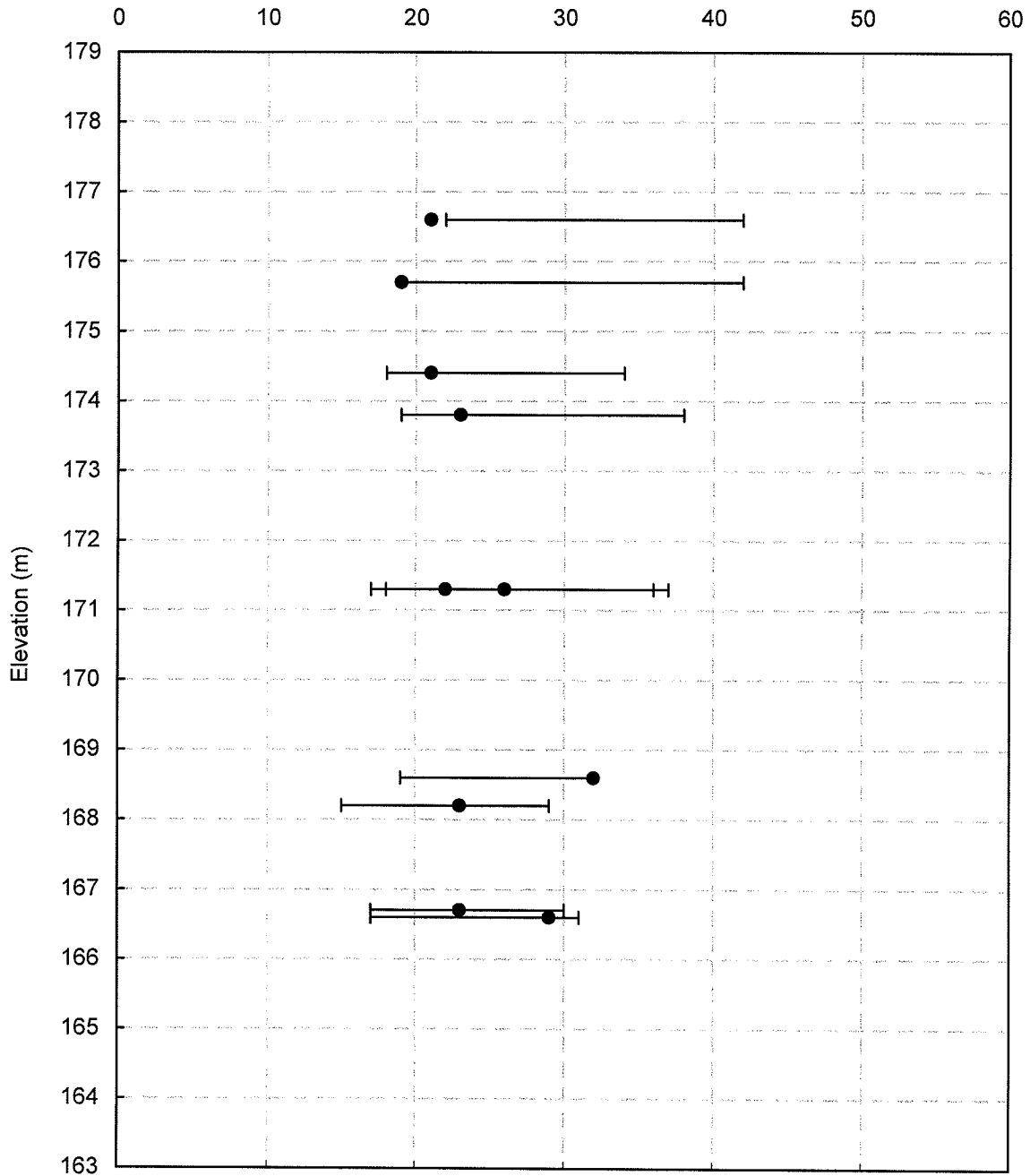
# ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B8-11

HWY 406 TWINNING - CULVERT #11

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



**Terraprobe Inc.**

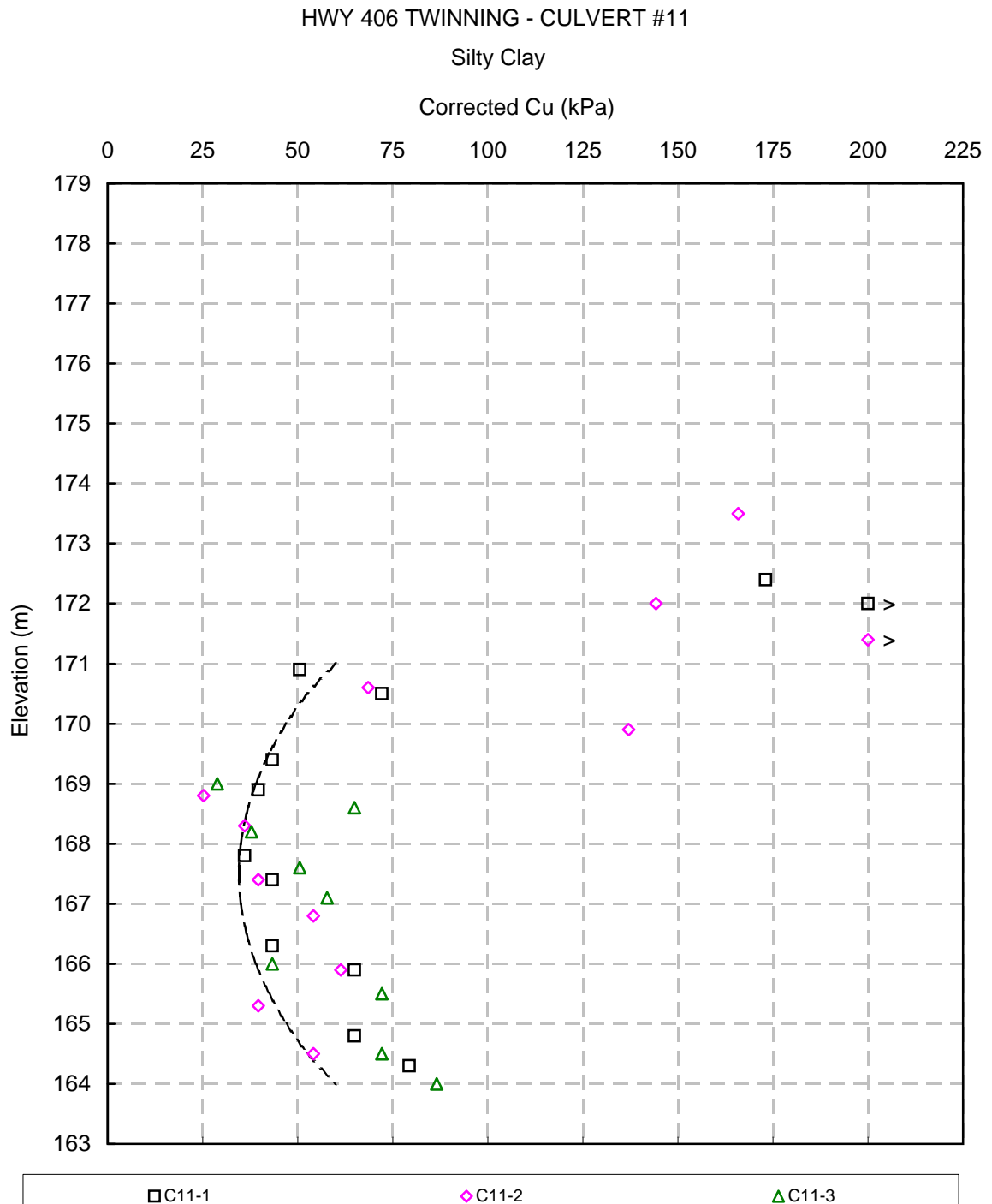
Prepared By : HW

Checked By : RA

# CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B8-12

C:\Documents and Settings\Admin\My Documents\Marc P\Projects 2009\Hwy 406 Expansion\1-09-4135 (Hwy 406 Foundations)\Culverts and Retaining Walls\Culverts\Lab Results\1-09-4135C11 Soil Parameter Estimation.xls



## Field Shear Vane Correction

Morris & Williams (1994)  
 $(\mu = 1.18 \text{ EXP}(-0.08 I_p) + 0.57)$

## Applied Correction Factors

0.78 (Elev.>175m)      0.90 (Elev.<175m)

Project No. : 1-09-4135

Date : November, 2010



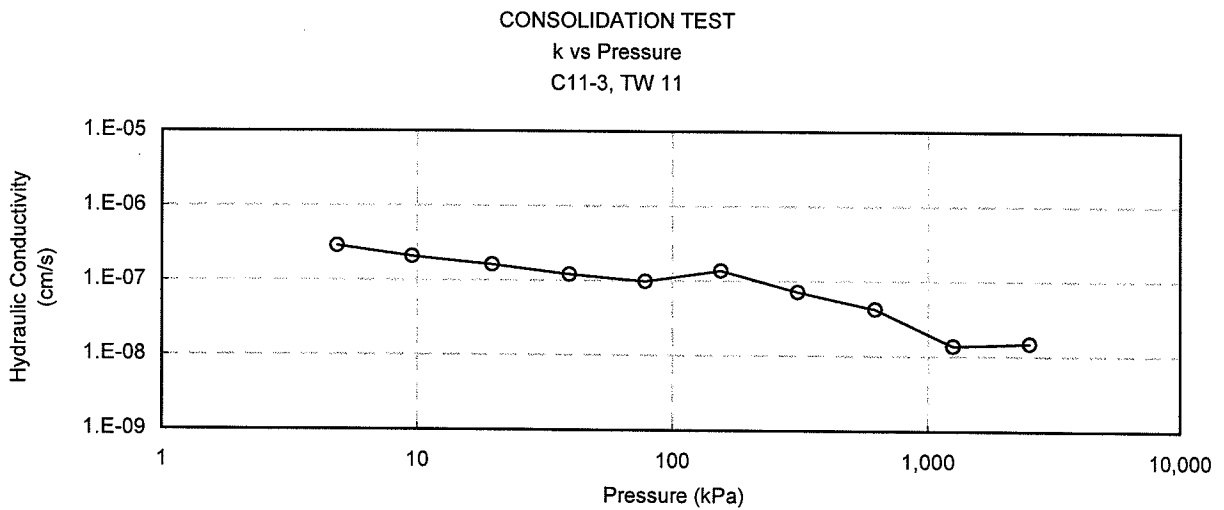
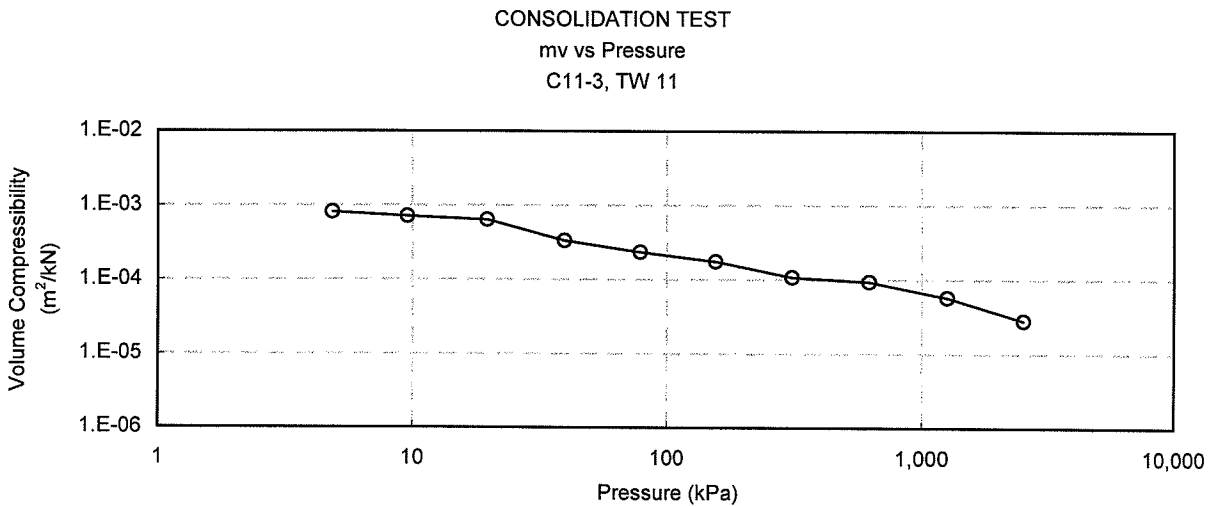
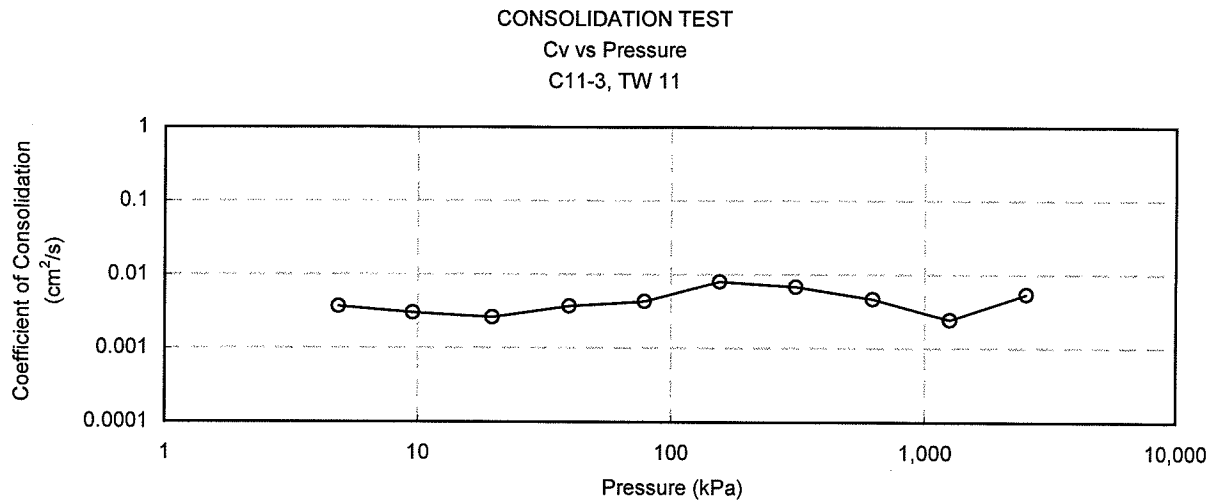
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# HWY 406 TWINNING - CULVERT#11

FIGURE B8-13



C:\Documents and Settings\Admin\My Documents\Marc P\Projects 2009\Hwy 406 Expansion\1-09-4135 (Hwy 406 Foundations)\Culverts and Retaining Walls\Culverts\Lab Results\1-09-4135 Consolidation Results.xls

Project No. : 1-09-4135  
Date : November 2010



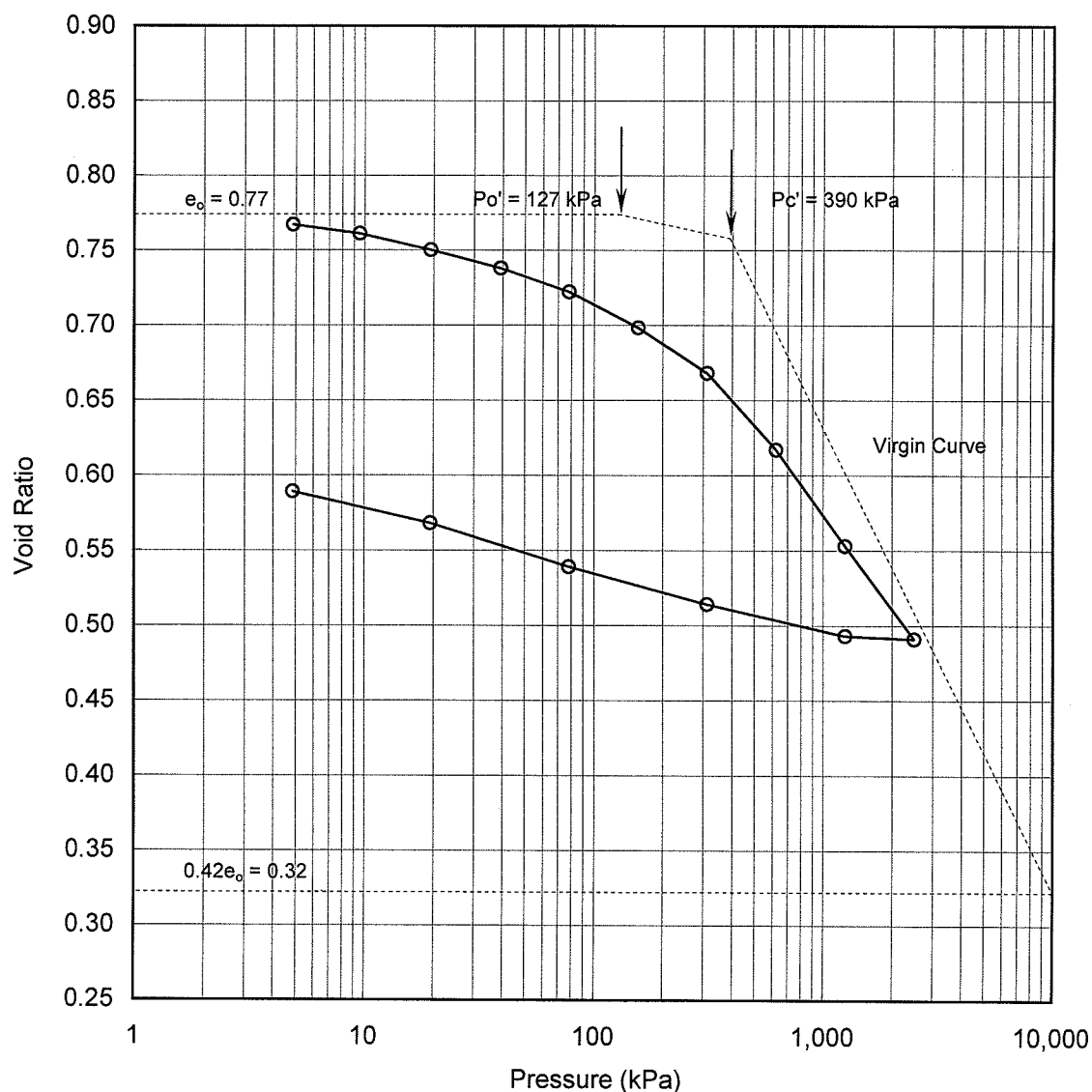
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

C11-3, TW 11



Soil Type : Silty Clay

$e_o =$	0.77	$\omega_L =$	29%	$Po' =$	127 kPa
$\omega =$	22%	$\omega_P =$	14%	$Pc' =$	390 kPa
$\gamma =$	20.8 kN/m <sup>3</sup>	$PI =$	14%	$Cc =$	0.309
$G_s =$	2.76			$Cr =$	0.033

Project No. : 1-09-4135  
 Date : November 2010



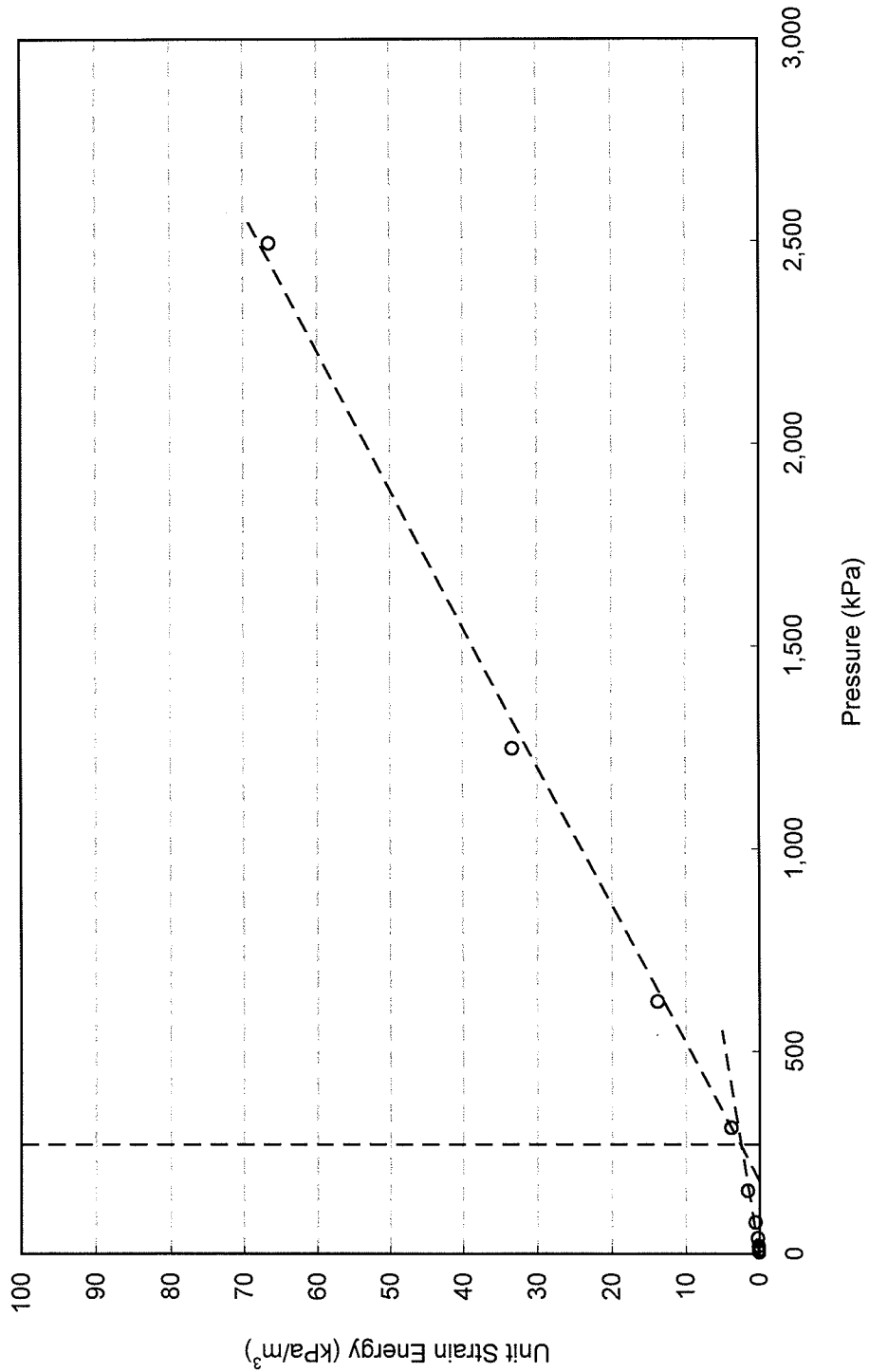
Terraprobe Inc.

Prepared By : HW  
 Checked By : RA

# HWY 406 TWINNING - CULVERT#11

FIGURE B8-15

## CONSOLIDATION TEST Unit Strain Energy vs Pressure C11-3, TW 11



Pc = 270 kPa

Project No. : 1-09-4135

Date : November 2010



**Terraprobe Inc.**

Prepared By : HW

Checked By : RA





**Appendix D3**  
**Borehole C12-3**

## 1 OF 2

METRIC

[illegible]

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/10/10

RECORD OF BOREHOLE No C12-3

2 OF 2

METRIC

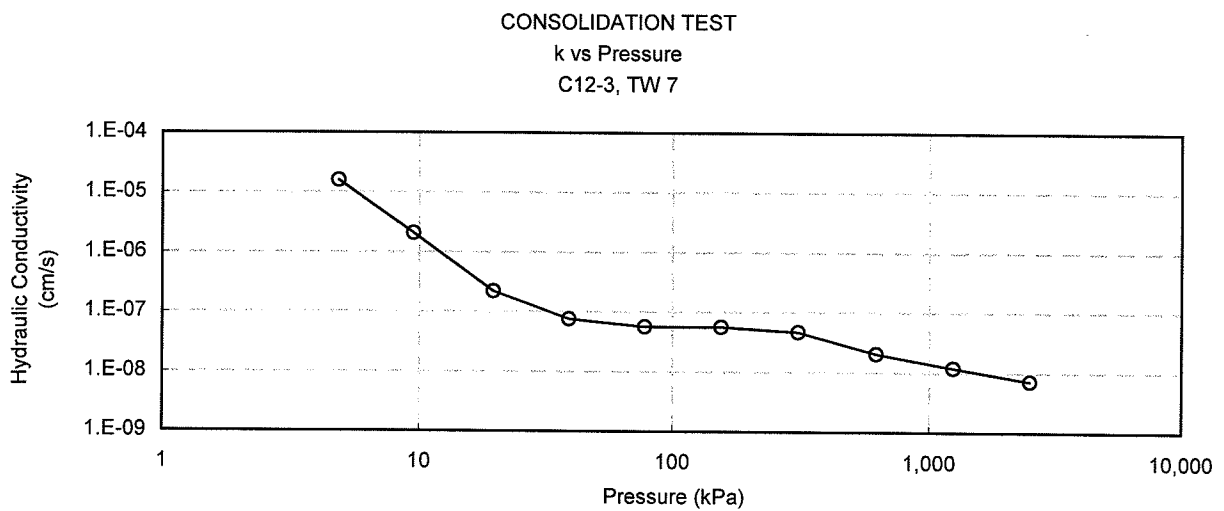
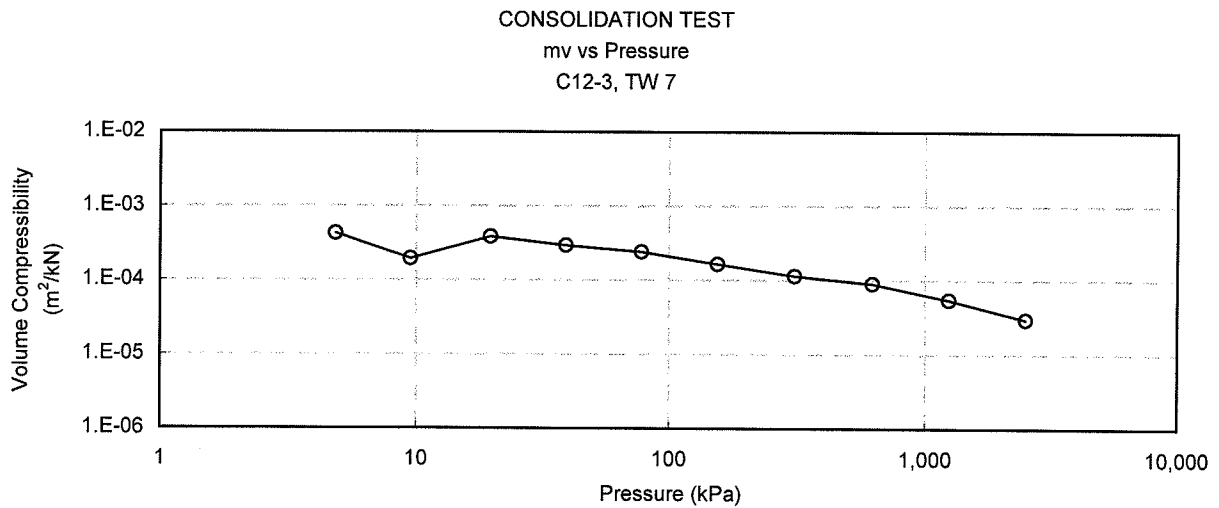
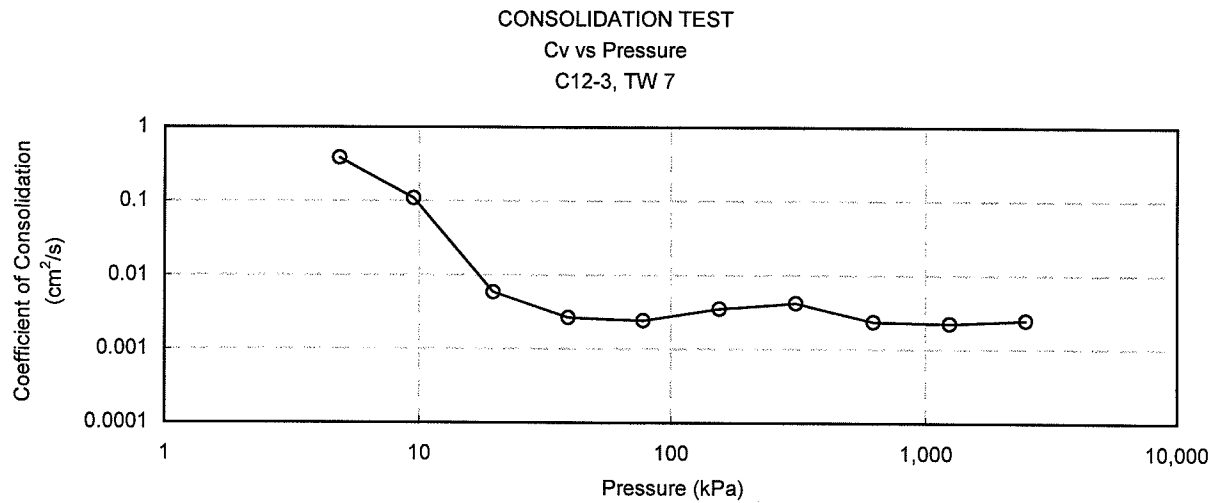
W.P. 280-99-00 LOCATION Coords: N:4767208.6 E:326322.1 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	×						
								● QUICK TRIAXIAL	×	LAB VANE						
								20 40 60 80 100								
163.6 16.2	SILT occasional silty clay seams and partings, compact, brown, wet		14	SS	7											
162.0 17.8			15	SS	12											
159.5 20.3	SILTY CLAY trace sand, trace gravel, very stiff to hard, brown, damp to moist		16	SS	24											
			17	SS	36											
		End of Borehole														
Sampler wet at 9.1m.  Consolidation test performed on TW 7.  Water level at 12.2m (not stabilized) and hole open to 15.2m on completion.  Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.  Water Level Readings: Date      Depth(m)      Elevation(m) July,20,10      2.8      177.0 July,28,10      2.8      177.0																

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/10/10

# HWY 406 TWINNING - CULVERT#12

FIGURE B9-10



Project No. : 1-09-4135  
Date : November 2010



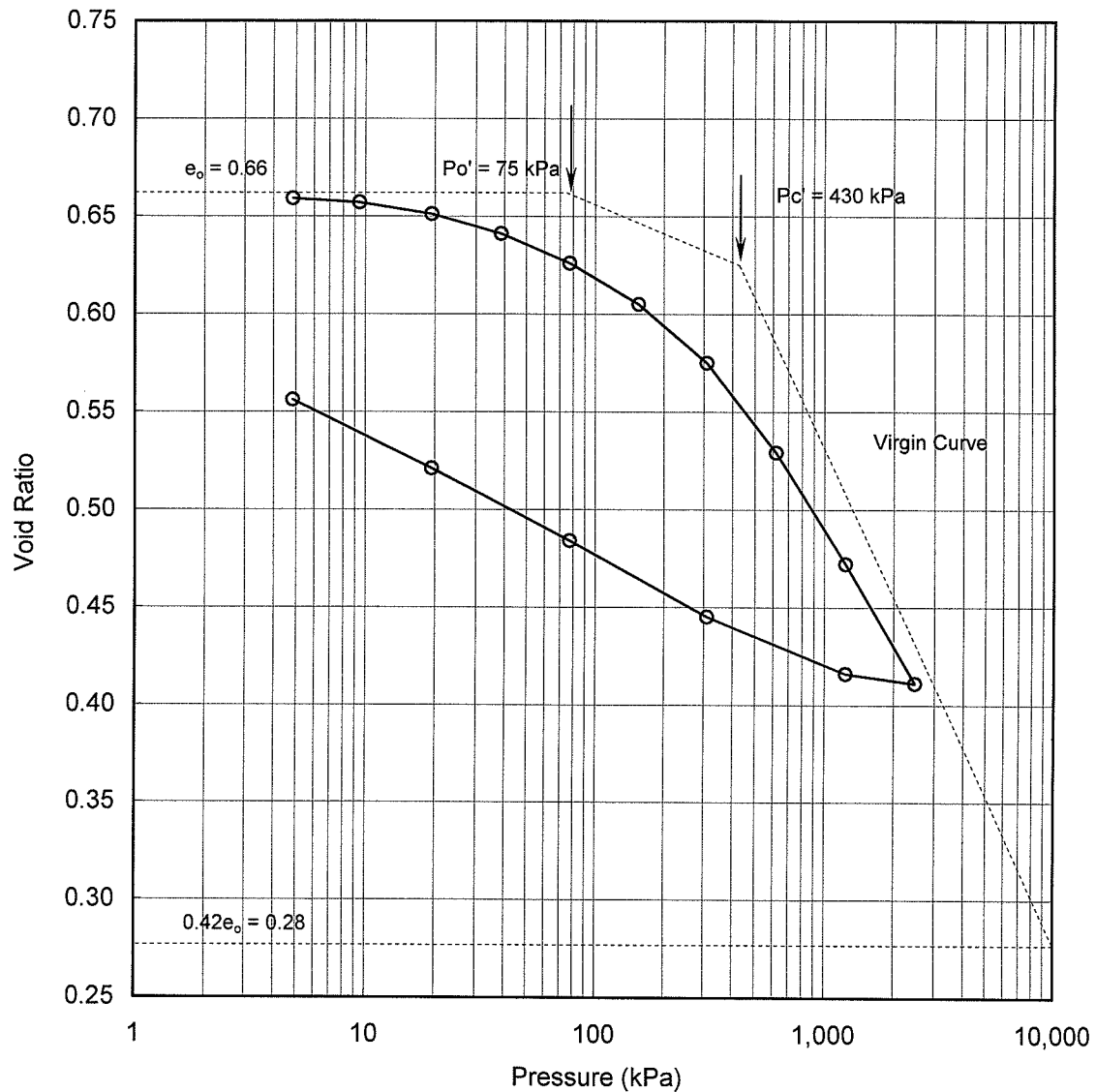
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

C12-3, TW 7



Soil Type : Silty Clay

$e_o =$	0.66	$\omega_L =$	31%	$P_{o'} =$	75 kPa
$\omega =$	21%	$\omega_p =$	17%	$P_c =$	430 kPa
$\gamma =$	21.1 kN/m <sup>3</sup>	PI =	14%	Cc =	0.255
Gs =	2.78			Cr =	0.049

Project No. : 1-09-4135  
 Date : November 2010



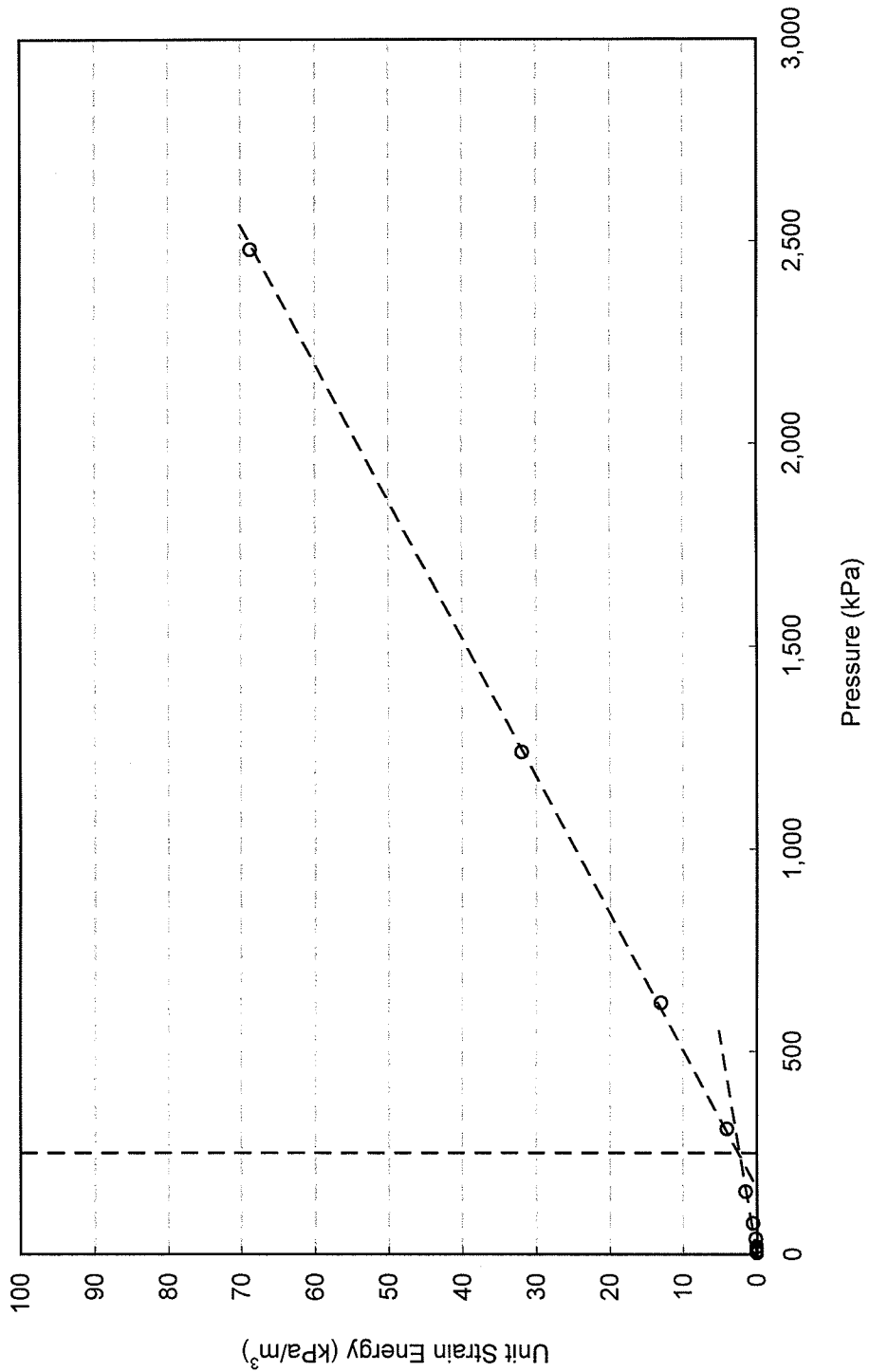
Terraprobe Inc.

Prepared By : HW  
 Checked By : RA

# HWY 406 TWINNING - CULVERT#12

FIGURE B9-12

## CONSOLIDATION TEST Unit Strain Energy vs Pressure C12-3, TW 7



Project No. : 1-09-4135

Date : November 2010



**Terraprobe Inc.**

Prepared By : HW

Checked By : RA



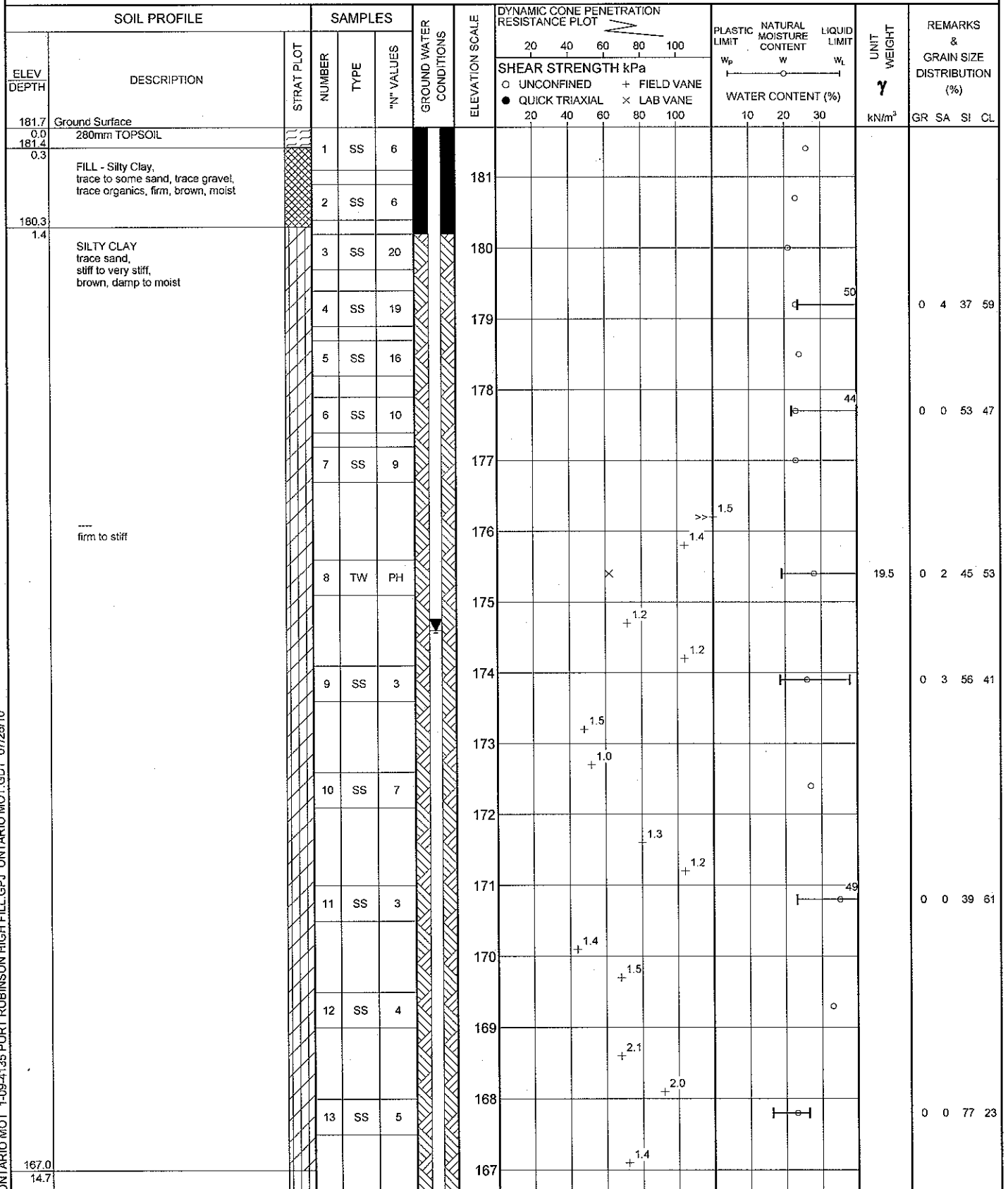
**Appendix D4**  
**Boreholes PR-1, PR-5**

RECORD OF BOREHOLE No PR1

1 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766747.4 E:326297.5 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 01.04.10 - 01.06.10 CHECKED BY RA



Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 PORT ROBINSON HIGH FILL GPJ ONTARIO MOT.GDT 07/25/10



2 OF 3

METRIC

ELEV DEPTH	SOIL PROFILE  DESCRIPTION	STRAT PLOT	SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT 	UNIT WEIGHT  	REMARKS & GRAIN SIZE DISTRIBUTION (%)
			NUMBER	TYPE						
							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	w_p w w_L WATER CONTENT (%) 10 20 30	γ kN/m³	GR SA SI

Station	Soil Description	Unit	SS	Gravel	Depth (m)	Notes
163.9	SILT trace sand, frequent silty clay seams and partings, loose, brown, wet	14	SS	4	166	0 0 84 16
17.8	SILT	15	SS	6	165	0 1 84 15
154.3	SILTY CLAY TO CLAYEY SILT trace sand, stiff to hard, brown / reddish brown, damp to moist	16	SS	15	164	
27.4	SILTY CLAY TO CLAYEY SILT	17	SS	12	163	
		18	SS	29	162	
		19	SS	32	161	
		20	SS	15	160	
		21	SS	10	159	
		22	SS	18	158	
	CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, moist (GLACIAL TILL)	23	SS	34	157	

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

○ 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No PR5

1 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766743.3 E:326398.5 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 12.21.09 - 12.22.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
181.2	Ground Surface													
181.0	300mm TOPSOIL													
0.2	FILL - Silty Clay, some sand, trace organics, firm, brown, moist		1	SS	4		181							
180.5														
0.7	SILTY CLAY trace sand, occasional gravel inclusions, stiff to very stiff, brown, moist		2	SS	8		180							
			3	SS	16									
			4	SS	14		179						49	0 1 45 54
			5	SS	11		178							
			6	SS	12		177							0 1 68 31
	firm to stiff		7	SS	3		176							
			8	SS	2		175							0 3 52 45
			9	TW	PH		174						19.7	0 3 57 40
			10	SS	0		173							
			11	SS	4		172							7 4 38 51
			12	SS	3		171							
			13	SS	5		170							
							169							0 0 60 40
							168							
							167							0 0 64 36

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 PORT ROBINSON HIGH FILL GPJ ONTARIO MOT.GDT 07/26/10

## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					
							20 40 60 80 100 20 40 60 80 100 10 20 30						

163.9 17.3		163.8 27.4	
SILT trace clay, loose to compact, brown, wet		CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, damp  (GLACIAL TILL)	
14	SS	6	
15	SS	26	
16	SS	8	
17	SS	17	
18	SS	16	
19	SS	15	
20	SS	9	
21	SS	9	
22	SS	25	
23	SS	31	

+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR5

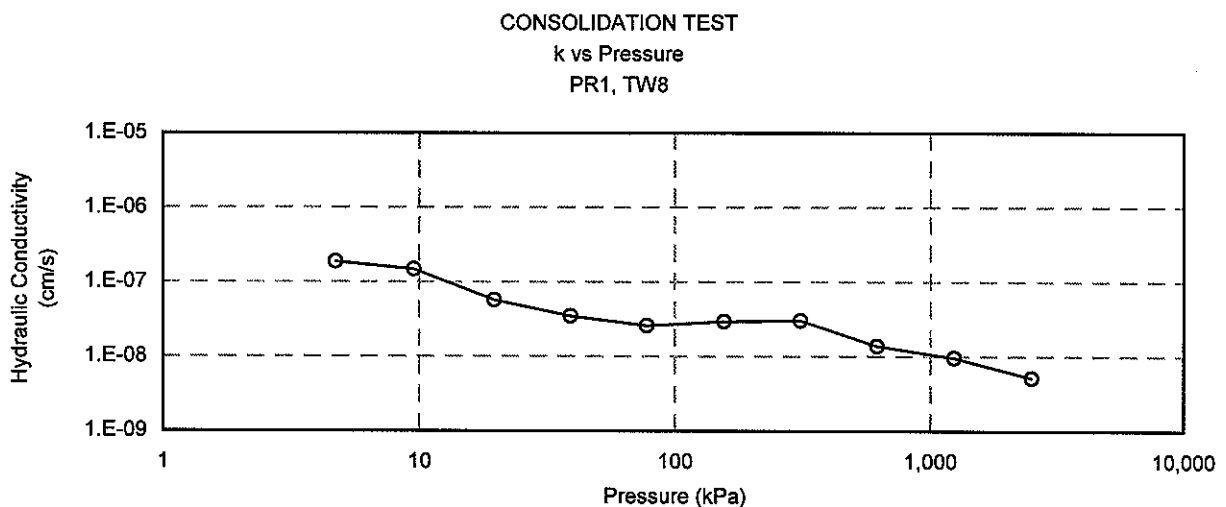
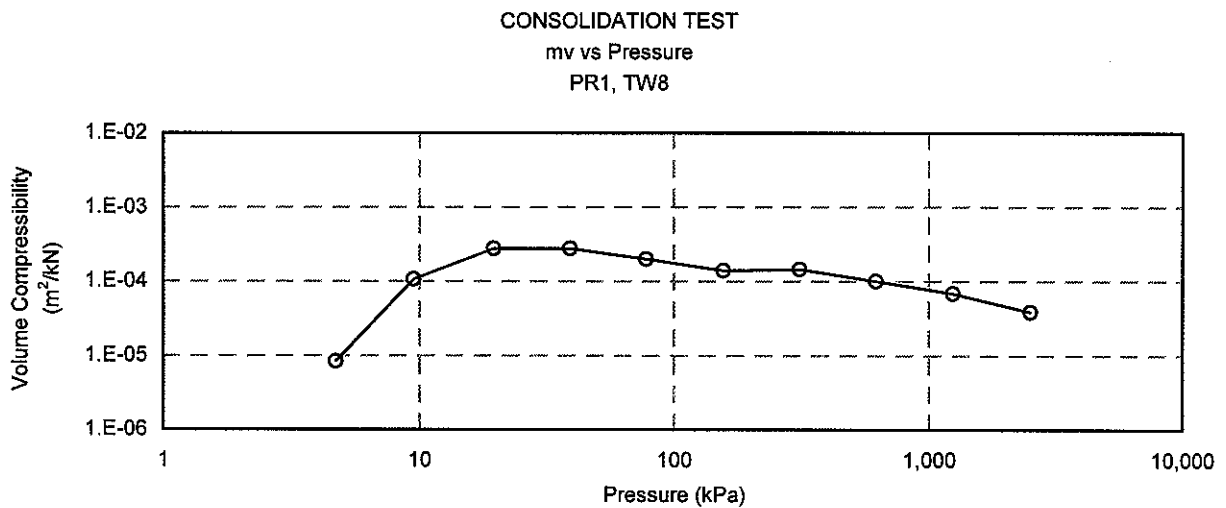
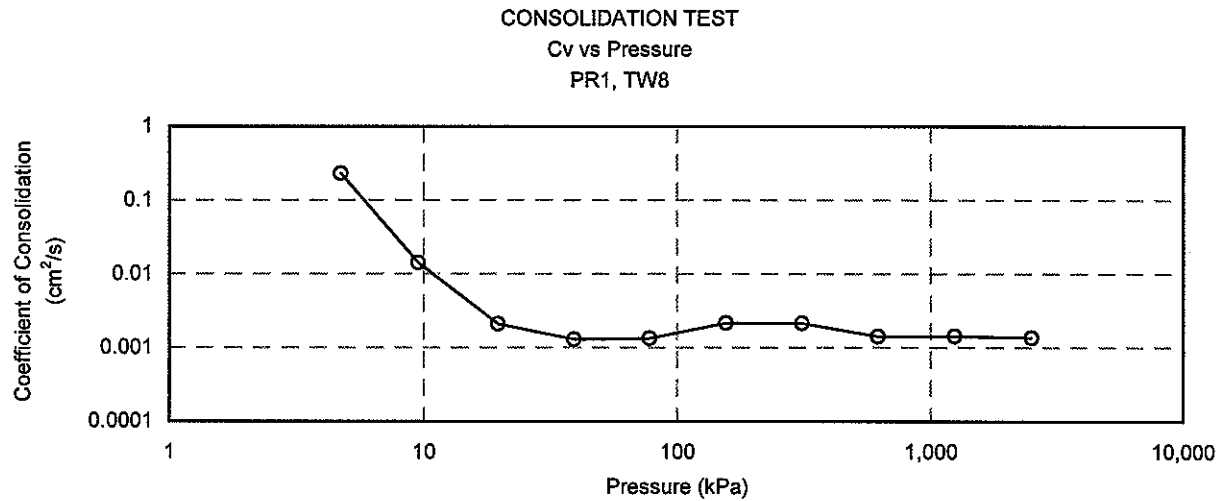
3 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766743.3 E:326398.5 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 12.21.09 - 12.22.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60
150.7 30.5	End of Borehole  Unable to push vane beyond 19.2m.  Resistance to augering at 28.9m.  No sample recovery at SS5 and SS23. Sampler redriven and disturbed sample collected.  Consolidation test performed on TW 9.  Sampler wet at 6.1m.  Borehole was dry (not stabilized) and hole open to full depth on completion.  Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.  Water Level Readings: Date      Depth(m)      Elevation(m) Jan.19.10      6.4      174.8 Jan.27.10      6.2      175.0 Feb.08.10      6.3      174.9 Feb.19.10      6.2      175.0		24	SS	92		151								

ONTARIO MOT 1-09-4135 PORT ROBINSON HIGH FILL GPJ ONTARIO MOT.GDT 07/26/10



C:\Documents and Settings\Hongjiu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

Project No. : 1-09-4135  
Date : July 2010



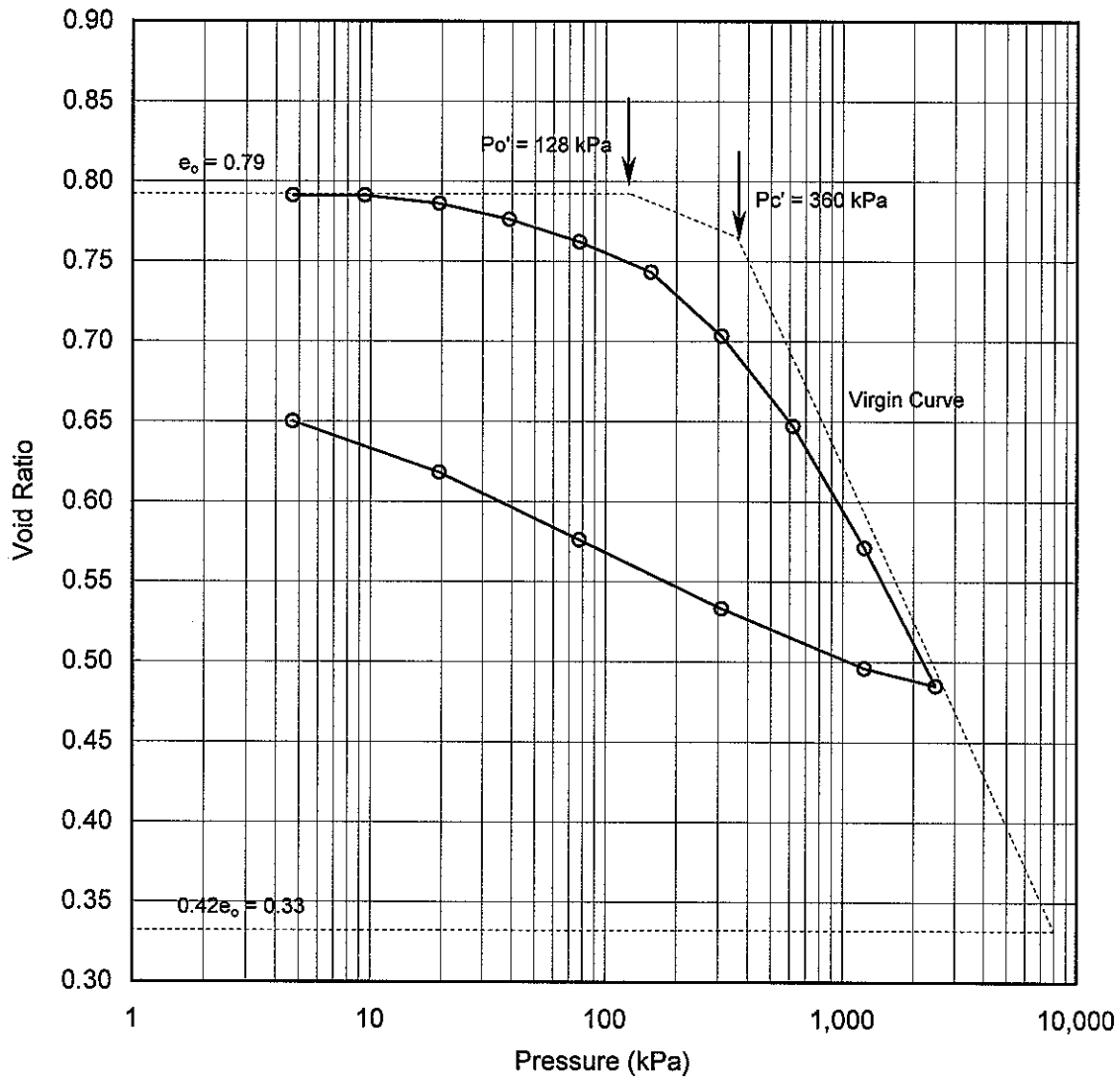
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

PR1, TW8



Soil Type : Silty Clay

$e_o =$	0.79	$\omega_L =$	40%	$P_o' =$	128 kPa
$\omega =$	28%	$\omega_p =$	19%	$P_c' =$	360 kPa
$\gamma =$	19.5 kN/m <sup>3</sup>	PI =	21%	Cc =	0.321
Gs =	2.78			Cr =	0.060

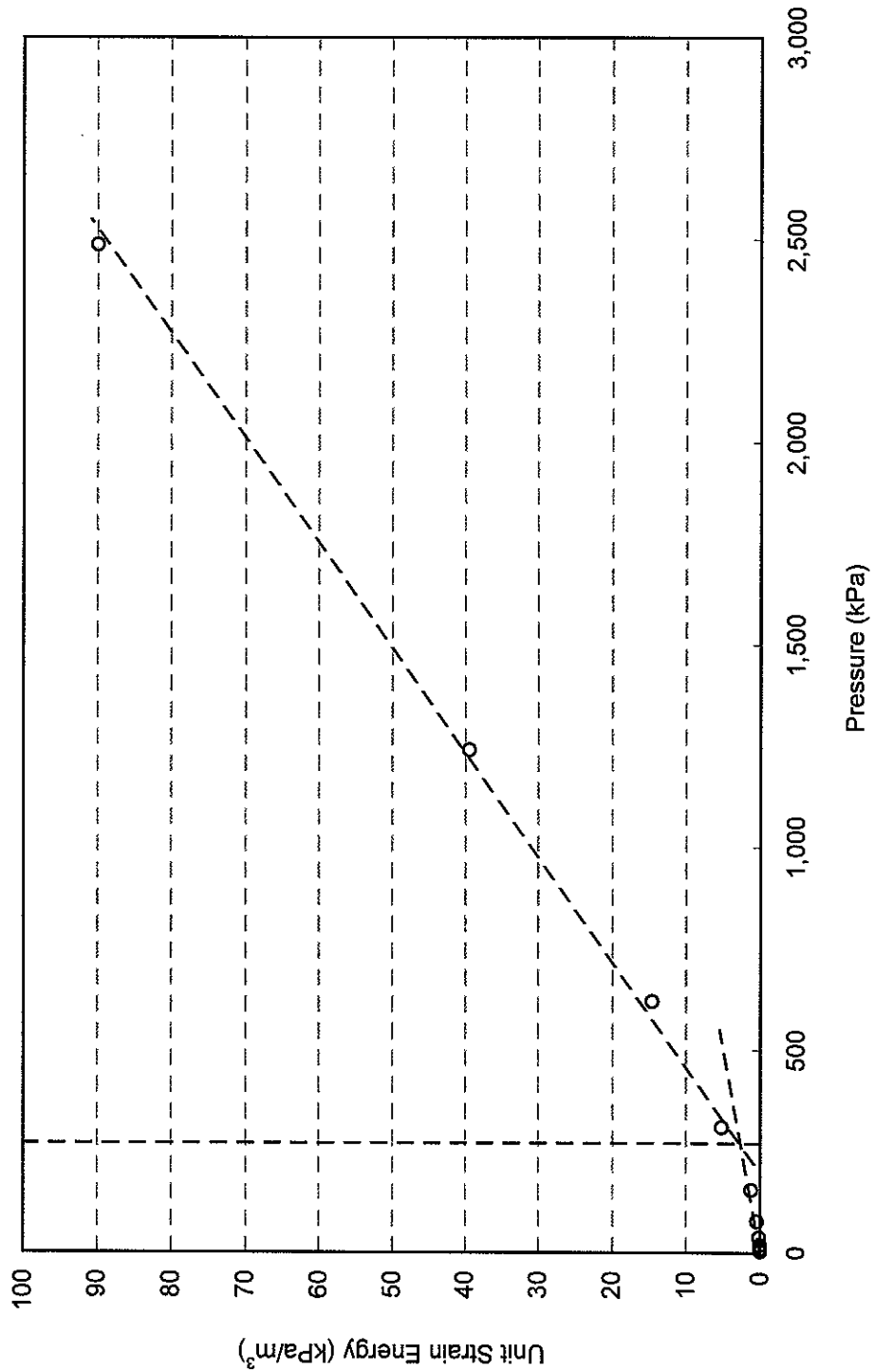
Project No. : 1-09-4135  
Date : July 2010



Terraprobe Inc.

Prepared By : HW  
Checked By : RA

CONSOLIDATION TEST  
Unit Strain Energy vs Pressure  
PR1, TW8



$P_c = 270 \text{ kPa}$

Project No. : 1-09-4135

Date : July 2010

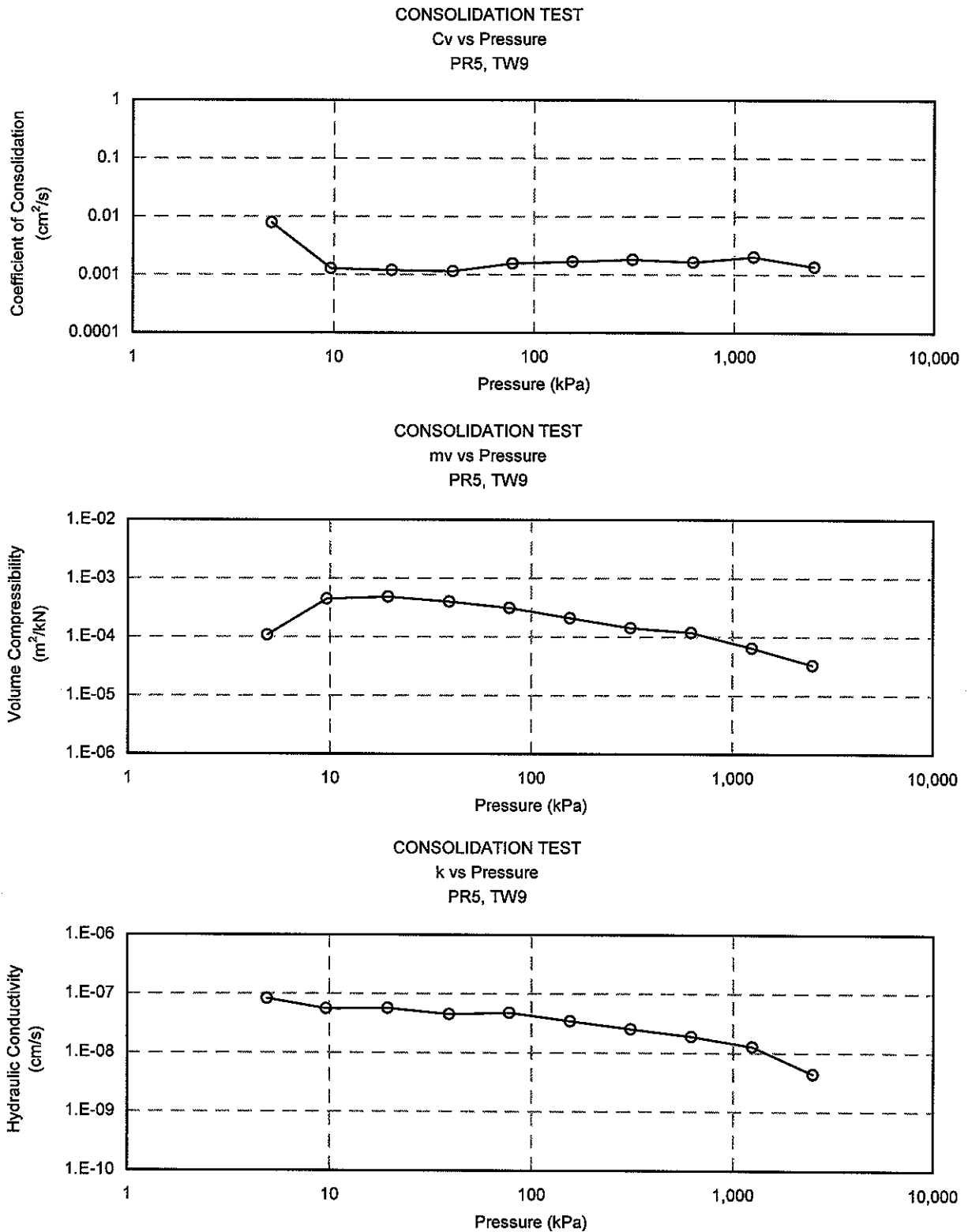


**Terraprobe Inc.**

Prepared By : HW

Checked By : RA





C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

Project No. : 1-09-4135  
Date : July 2010



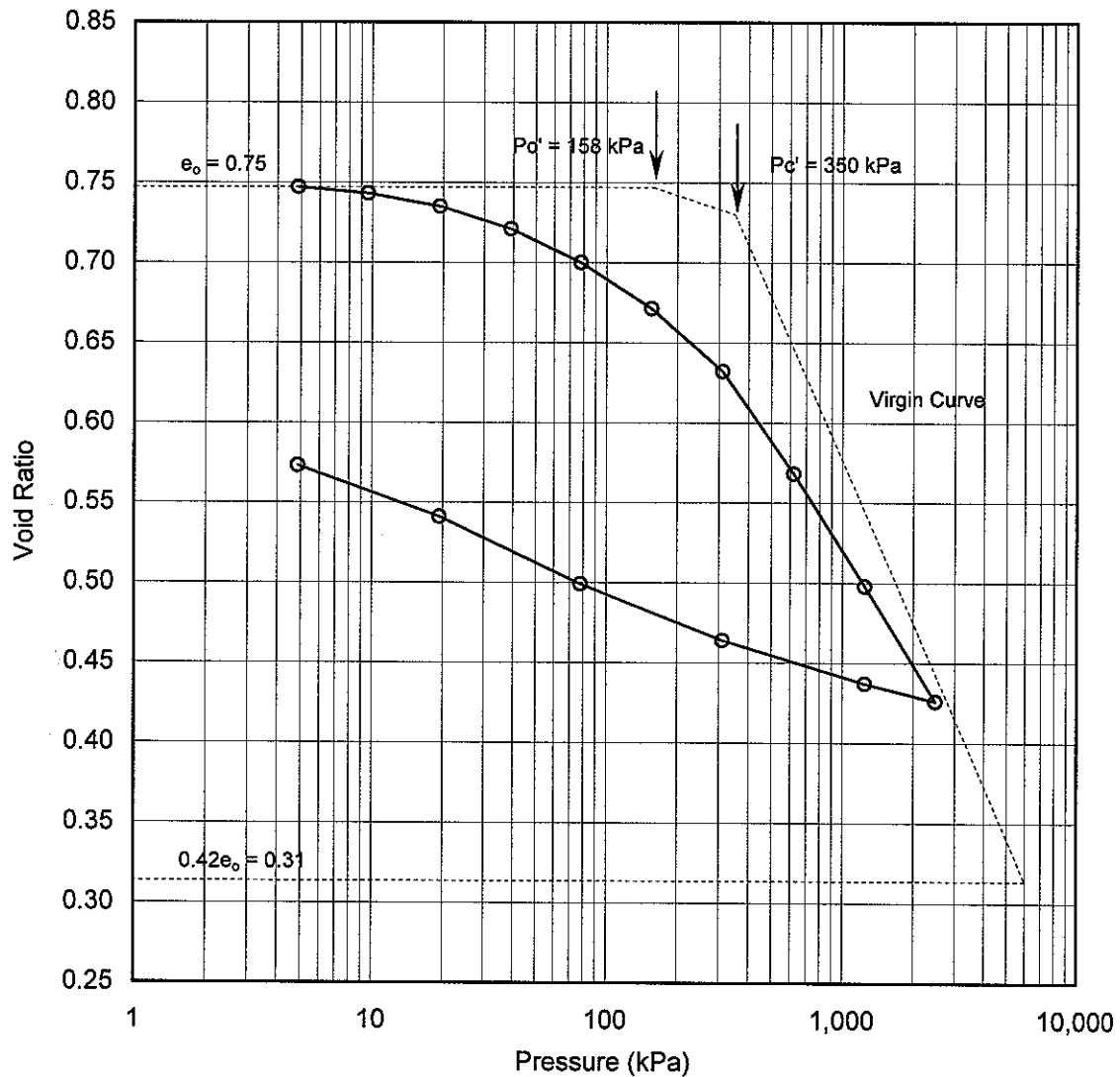
**Terraprobe Inc.**

Prepared By : HW  
Checked By : RA

## CONSOLIDATION TEST

e vs Pressure

PR5, TW9



Soil Type : Silty Clay

$e_o =$	0.75	$\omega_L =$	32%	$P_o' =$	158 kPa
$\omega =$	27%	$\omega_P =$	16%	$P_c' =$	350 kPa
$\gamma =$	19.7 kN/m <sup>3</sup>	PI =	15%	Cc =	0.337
Gs =	2.76			Cr =	0.049

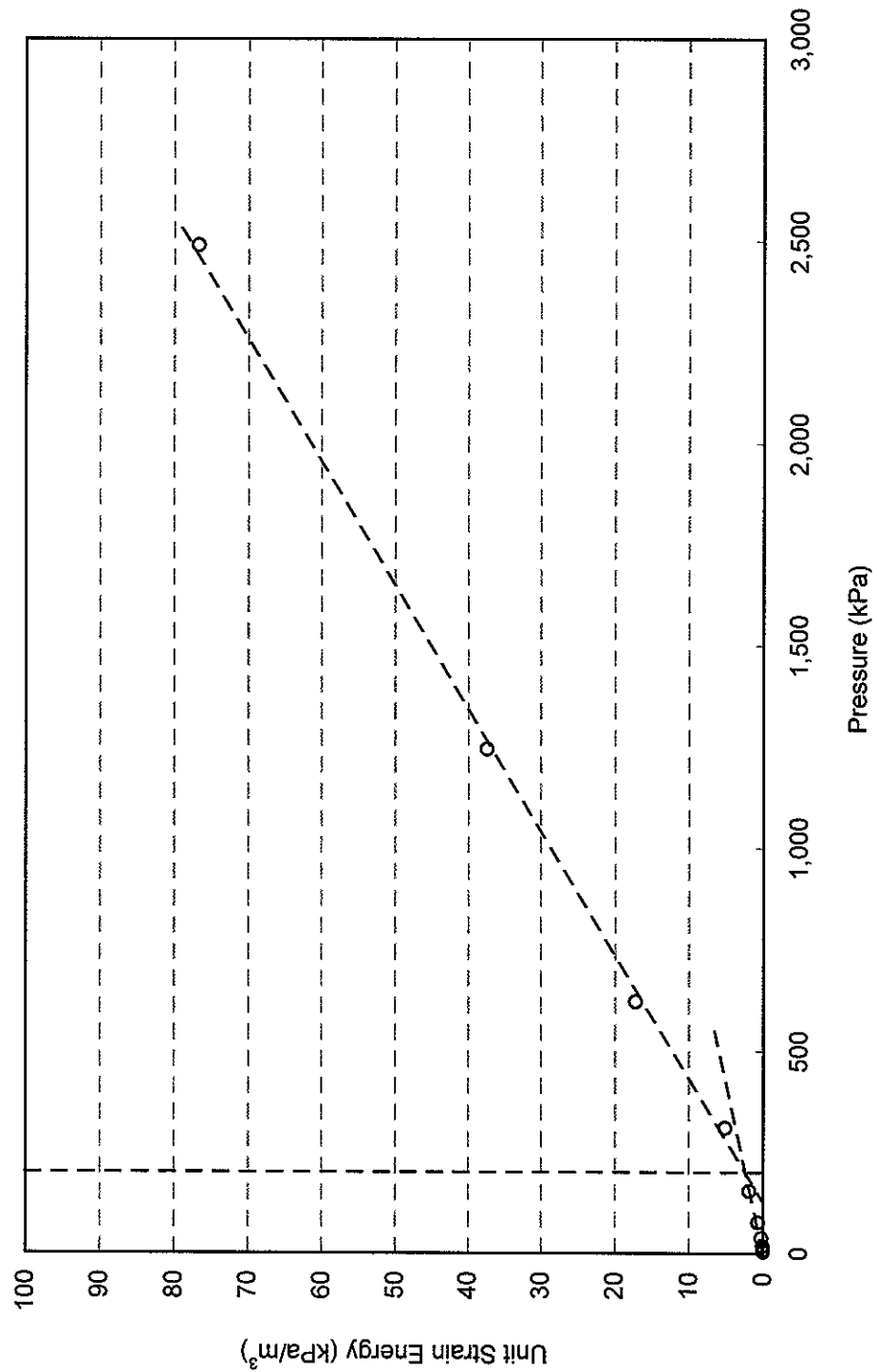
Project No. : 1-09-4135  
Date : July 2010



Terraprobe Inc.

Prepared By : HW  
Checked By : RA

CONSOLIDATION TEST  
Unit Strain Energy vs Pressure  
PR5, TW9



$P_c = 200 \text{ kPa}$

Project No. : 1-09-4135

Date : July 2010



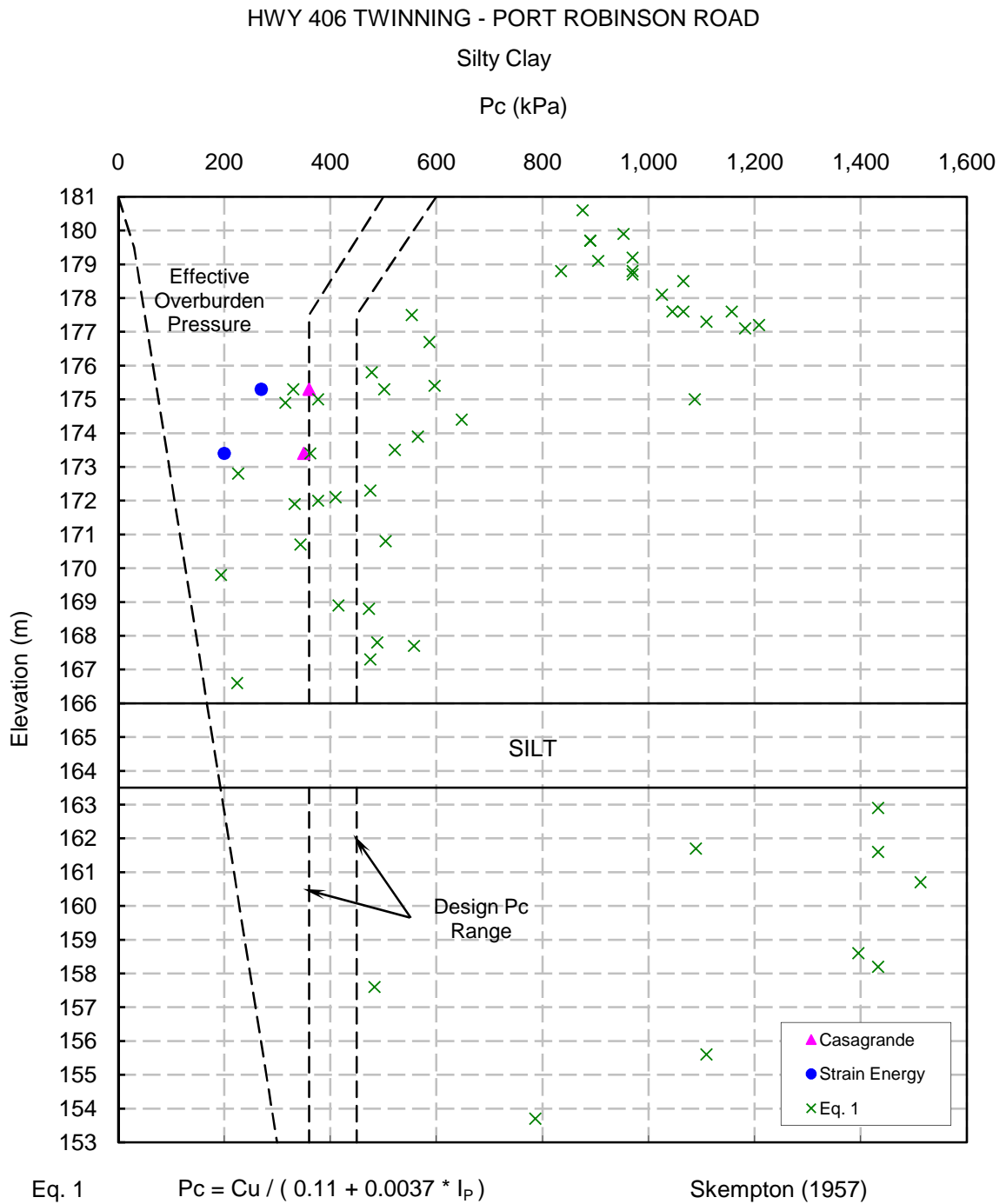
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# PREDICTED AND MEASURED PRECONSOLIDATION STRESS

FIGURE F1



Project No. : 1-09-4135

Date : September, 2010



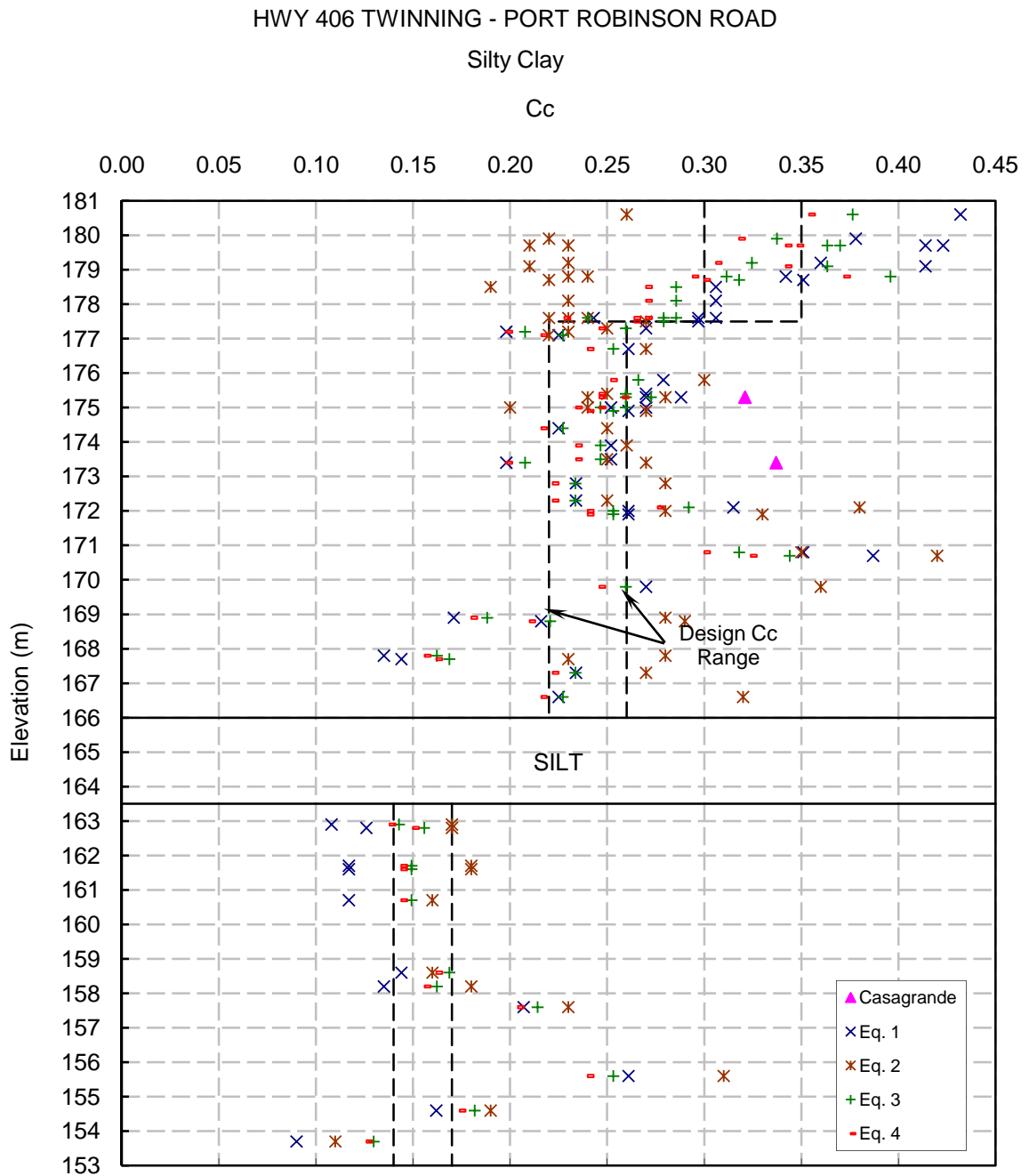
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# PREDICTED AND MEASURED COMPRESSION INDEX

FIGURE F2



Eq. 1  $Cc = 0.009 * (LL - 10)$

Terzaghi & Peck (1967)

Eq. 2  $Cc = 0.01 * \omega$

Osterberg (1972)

Eq. 3  $Cc = 0.002343 * LL * Gs$

Nagaraj & Murty (1985)

Eq. 4  $Cc = 0.006 * (LL + 1)$

Lav & Ansal (2001)

Project No. : 1-09-4135

Date : September, 2010



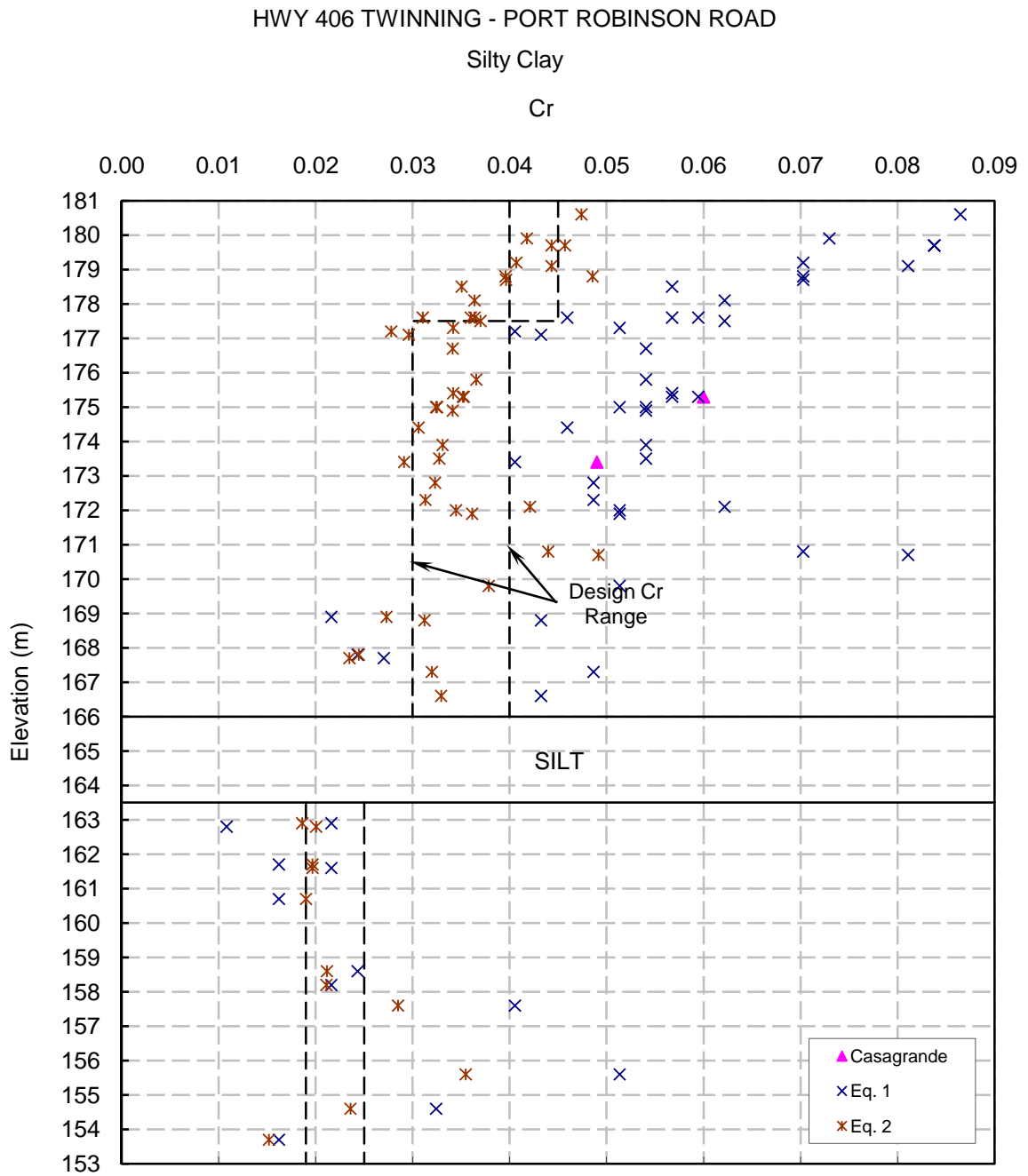
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# PREDICTED AND MEASURED RECOMPRESSION INDEX

FIGURE F3



Eq. 1  $Cr = Ip / 370$

Kulhawy & Mayne (1990)

Eq. 2  $Cr = Cc / 5 \sim Cc / 10$

Das (1993)

Project No. : 1-09-4135

Date : September, 2010



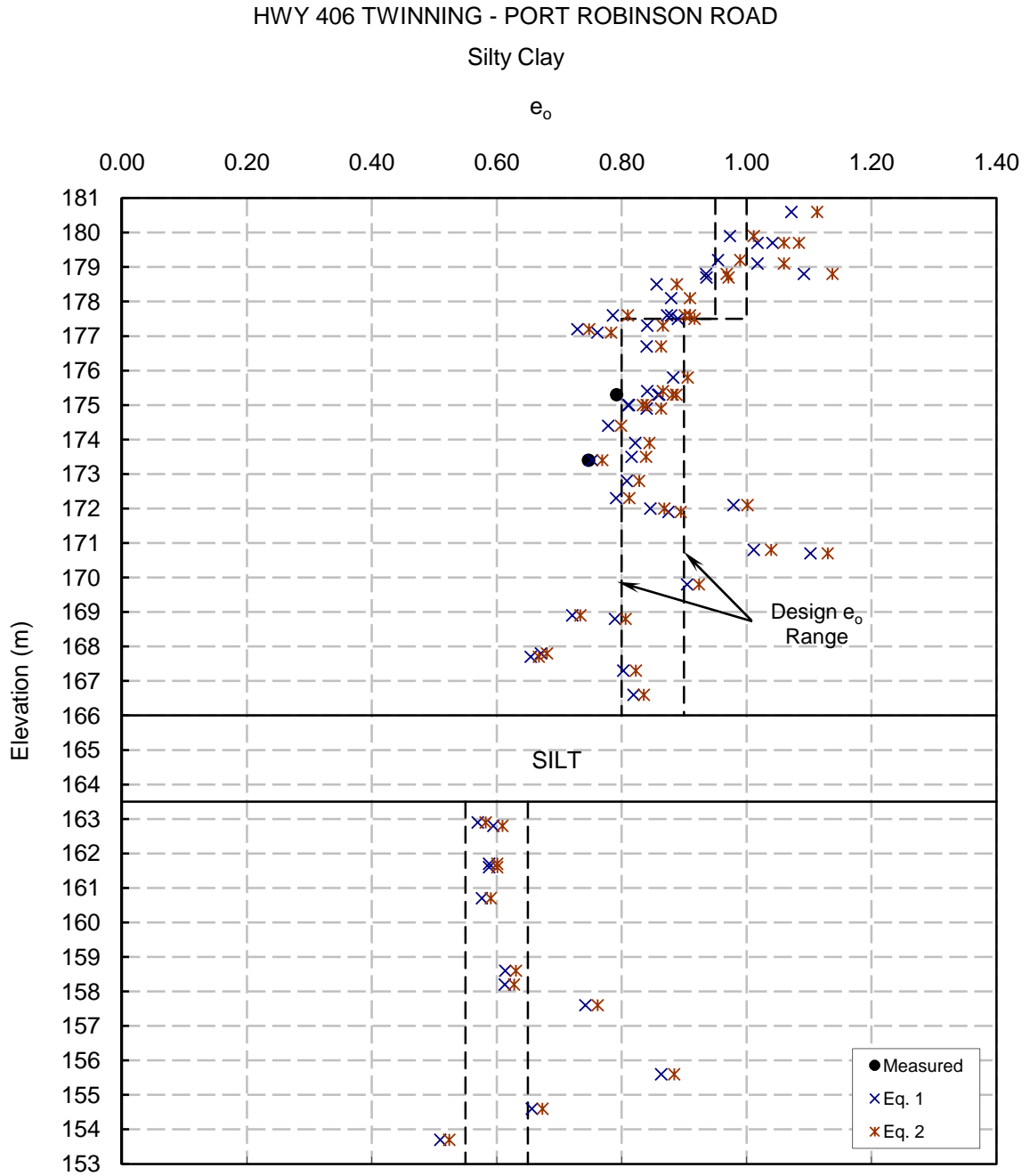
**Terraprobe Inc.**

Prepared By : HW

Checked By : RA

# PREDICTED AND MEASURED VOID RATIO

FIGURE F4



Eq. 1       $e_o = ( Cc - 0.256 ) / 0.43 + 0.84$

derived from Cozzolino (1961)

Eq. 2       $e_o = Cc / 0.40 - 0.001 * \omega + 0.25$

derived from Azzouz et al. (1976)

Project No. : 1-09-4135

Date :      September, 2010



**Terraprobe Inc.**

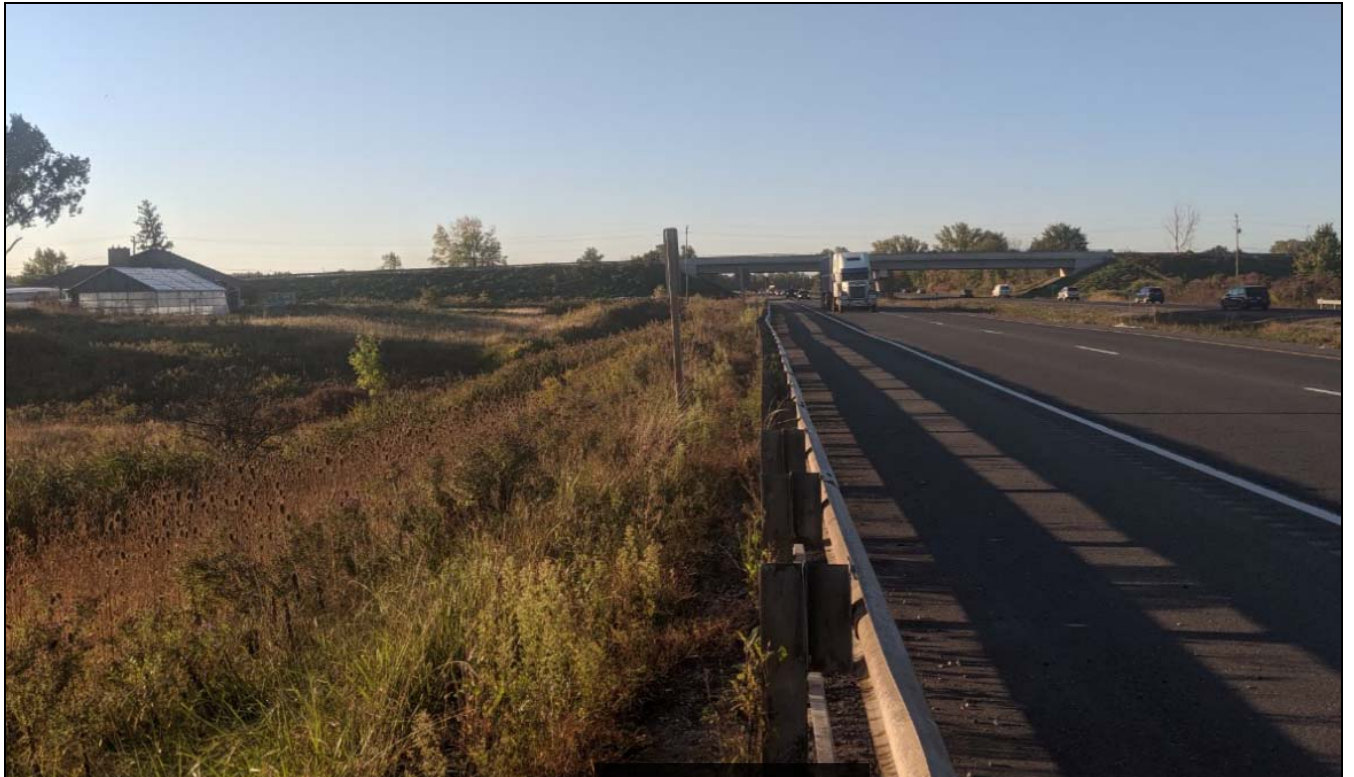
Prepared By : HW

Checked By : RA



**Appendix E**  
**Selected Site Photographs**





**Photo 1 - Highway 406 NBL at the culvert location, looking south towards Port Robinson Road**



**Photo 2- Looking south at Culvert outlet, east side of Hwy 406**



**Photo 3- Highway 406 NBL embankment, looking north**





**Photo 4 - East Embankment Slope at Culvert outlet**



**Photo 5 - Highway 406 NBL, looking north from north of culvert**



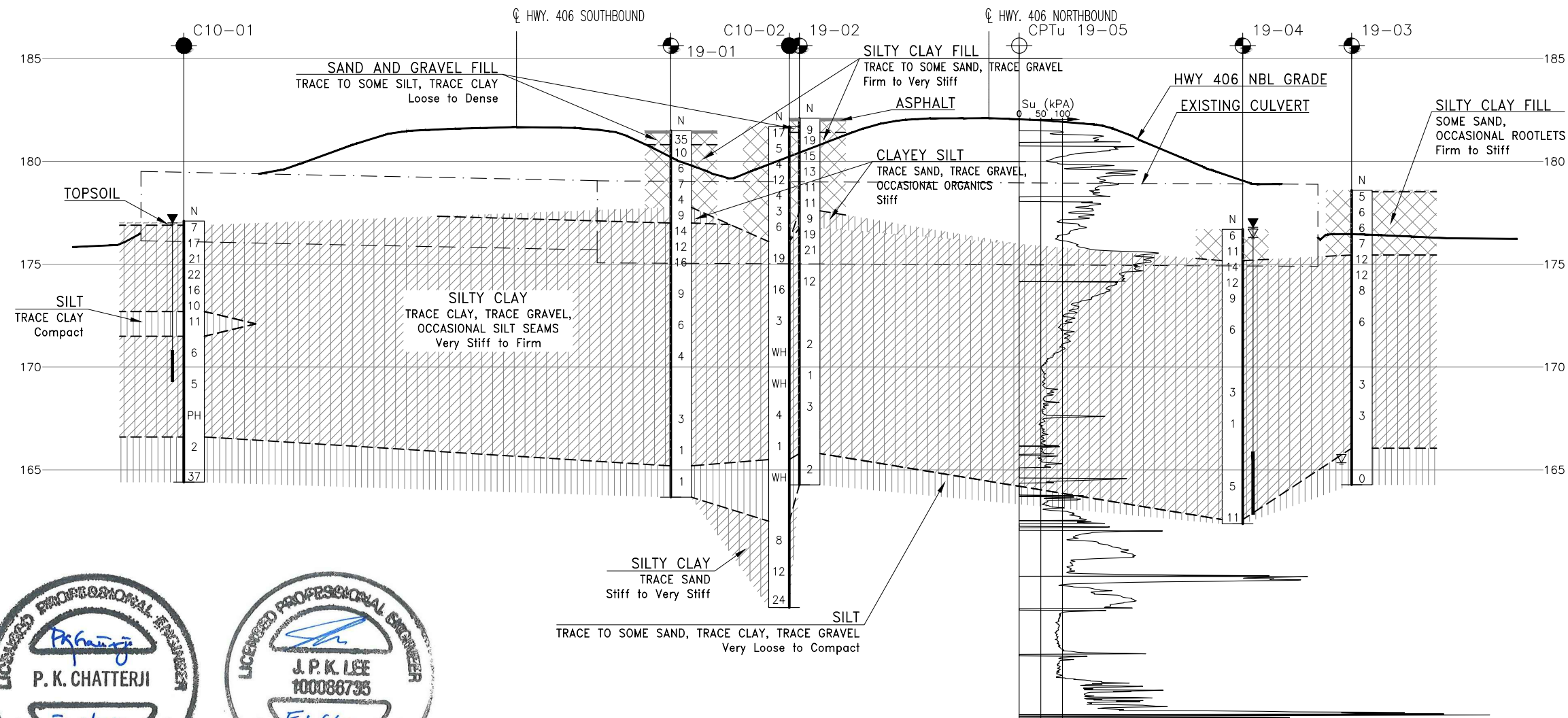
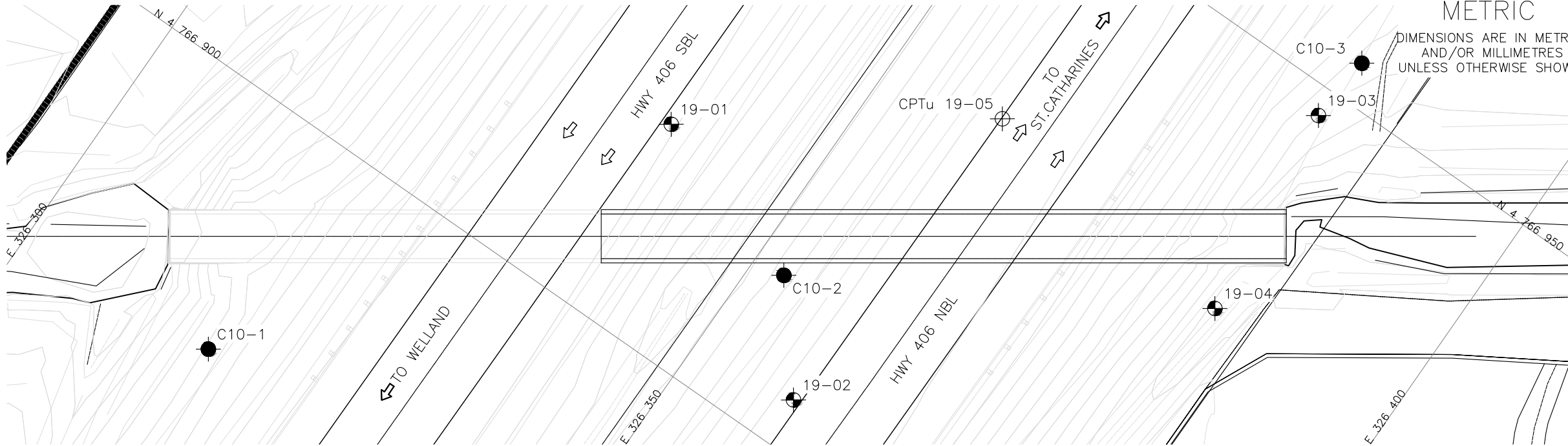


Photo 6- Looking west from Highway 406 NBL shoulder on top of the existing culvert

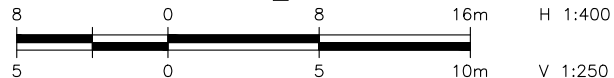


## **Appendix F**

### **Borehole Locations and Soil Strata Drawing**



PROFILE ALONG  $\phi$  OF CULVERT



METRIC

DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 2063-17-00

HIGHWAY 406  
CULVERT REPLACEMENT  
NORTH OF PORT ROBINSON ROAD  
BOREHOLE LOCATIONS AND SOIL STRATA



43.041765 KEYPLAN -79.235657

### LEGEND

- Borehole by Thurber (Current Investigation)
- Borehole by Terraprobe (2010)
- Cone Penetration Test (CPTu)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- WH Weight of Hammer
- Water Level (Open Borehole)
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
19-01	181.5	4 766 916.9	326 338.1
19-02	182.1	4 766 904.1	326 359.2
19-03	178.6	4 766 947.8	326 381.1
19-04	176.7	4 766 930.0	326 383.2
C10-01	177.1	4 766 880.1	326 317.5
C10-02	181.7	4 766 912.0	326 352.7
C10-03	178.5	4 766 953.3	326 381.6
CPT 19-05	182.1	4 766 932.7	326 360.1

### 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 10.

GEOCRES No. 30M3-318

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK	CODE
DRAWN	BH	CHK	RPR
SITE	34X-0294	STRUCT	DWG 1
LOAD	DATE	DEC	2019