



Terraprobe

*Consulting Geotechnical & Environmental Engineering
Construction Materials Inspection & Testing*

**FOUNDATION INVESTIGATION & DESIGN REPORT
CULVERTS & CULVERT EXTENSIONS
HIGHWAY 406 TWINNING
PORT ROBINSON ROAD TO EAST MAIN STREET
AGREEMENT No. 2008-E-0016, W.P. 280-99-00
GEOCRES No. 30M3-269**

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TABLE OF CONTENTS

Part 1

1	INTRODUCTION.....	1
2	SITE DESCRIPTION & PHYSIOGRAPHY.....	2
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING.....	7
5	DESCRIPTION OF SUBSURFACE CONDITIONS.....	7
5.1	Culvert #2 (Hwy 406 Sta. 10+307).....	8
5.1.1	Topsoil.....	8
5.1.2	Fill – Sandy Gravel.....	8
5.1.3	Fill – Silty Clay.....	8
5.1.4	Silty Clay.....	9
5.1.5	Silty Clay Till.....	9
5.1.6	Water Levels.....	10
5.2	Culvert #5 (Hwy 406 Sta. 10+777).....	10
5.2.1	Topsoil.....	10
5.2.2	Fill – Sand and Gravel.....	10
5.2.3	Fill – Silty Clay.....	11
5.2.4	Silty Clay.....	11
5.2.5	Silty Clay Till.....	12
5.2.6	Water Levels.....	12
5.3	Culvert #6 (Highway 406 Sta. 11+499).....	13
5.3.1	Topsoil.....	13
5.3.2	Fill – Sand and Gravel.....	13
5.3.3	Fill – Silty Clay.....	13
5.3.4	Silty Clay.....	14
5.3.5	Silty Clay Till.....	15
5.3.6	Water Levels.....	15
5.4	Culvert #8 (Highway 406 Sta. 12+338).....	16
5.4.1	Topsoil.....	16
5.4.2	Fill – Silty Clay.....	16
5.4.3	Silty Clay.....	16
5.4.4	Silty Clay to Clayey Silt Till.....	17
5.4.5	Water Levels.....	18
5.5	Culvert #9 (Highway 406 Sta. 12+476).....	19
5.5.1	Topsoil & Peat.....	19
5.5.2	Fill – Silty Clay.....	19
5.5.3	Silty Clay.....	19
5.5.4	Clayey Silt to Silty Clay Till.....	20
5.5.5	Water Levels.....	21



5.6	Culvert #24 (Highway 406 Sta. 14+152).....	22
5.6.1	Silty Clay	22
5.6.2	Silt	23
5.6.3	Water Levels.....	23
5.7	Culvert #48 (Highway 406 Sta. 15+712).....	24
5.7.1	Topsoil.....	24
5.7.2	Fill – Gravelly Sand	24
5.7.3	Fill – Silt.....	24
5.7.4	Fill – Silty Clay	24
5.7.5	Silty Clay	25
5.7.6	Silt	26
5.7.7	Water Levels.....	27
5.8	Culvert #35 (Port Robinson Road Sta. 9+704)	27
5.8.1	Topsoil.....	27
5.8.2	Flexible Pavement	27
5.8.3	Fill – Sandy Gravel.....	28
5.8.4	Fill – Silty Sand	28
5.8.5	Fill – Silty Clay	28
5.8.6	Silty Clay	28
5.8.7	Silt	30
5.8.8	Clayey Silt	30
5.8.9	Water Levels.....	30
5.9	Culvert #49 (Highway 406 NBL Sta. 5+839).....	31
5.9.1	Topsoil.....	31
5.9.2	Flexible Pavement	31
5.9.3	Fill – Silty Clay	31
5.9.4	Silty Clay	32
5.9.5	Silt	33
5.9.6	Clayey Silt	33
5.9.7	Water Levels.....	34
5.10	Miscellaneous	34

Part 2

6	DISCUSSION AND RECOMMENDATIONS	36
6.1	General.....	36
7	STRUCTURE FOUNDATIONS	38
8	LATERAL EARTH PRESSURE.....	41
9	EXCAVATION.....	42
10	GROUND WATER CONTROL.....	43
11	EMBANKMENT STABILITY	44
12	SETTLEMENT	46



13	CULVERT BEDDING & BACKFILL	49
14	EMBANKMENT CONSTRUCTION.....	49
15	EROSION PROTECTION.....	50
16	TEMPORARY SHORING.....	51
17	SEISMIC REQUIREMENTS	53
18	CONSTRUCTION CONCERNS.....	53

Table

Table 1 – List of Standard Specifications Referenced in Report

Appendices

Culvert #2

Appendix A1 – Record of Borehole Sheets

Appendix B1 – Laboratory Test Results

Appendix C1 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #5

Appendix A2 – Record of Borehole Sheets and Test Pit Logs

Appendix B2 – Laboratory Test Results

Appendix C2 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #6

Appendix A3 – Record of Borehole Sheets and Test Pit Logs

Appendix B3 – Laboratory Test Results

Appendix C3 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #8

Appendix A4 – Record of Borehole Sheets and Test Pit Logs

Appendix B4 – Laboratory Test Results

Appendix C4 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #9

Appendix A5 – Record of Borehole Sheets and Test Pit Logs

Appendix B5 – Laboratory Test Results

Appendix C5 – Drawing titled “Borehole Locations and Soil Strata”



Culvert #24

Appendix A6 – Record of Borehole Sheets

Appendix B6 – Laboratory Test Results

Appendix C6 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #48

Appendix A7 – Record of Borehole Sheets and Test Pit Logs

Appendix B7 – Laboratory Test Results

Appendix C7 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #35

Appendix A8 – Record of Borehole Sheets and Test Pit Logs

Appendix B8 – Laboratory Test Results

Appendix C8 – Drawing titled “Borehole Locations and Soil Strata”

Culvert #49

Appendix A9 – Record of Borehole Sheets

Appendix B9 – Laboratory Test Results

Appendix C9 – Drawing titled “Borehole Locations and Soil Strata”

Appendix D

Slope Stability Data and Results

Appendix E

Comparison of Foundation Alternatives



DESIGN SUMMARY

This project (W.P. 280-99-00) is the Ministry of Transportation of Ontario undertaking to twin Highway 406 from 0.2 km north of Port Robinson Road to its current terminus at East Main Street.

Terraprobe carried out the investigation as a sub-consultant to Giffels Associates Limited/IBI Group (Giffels), under the Ministry of Transportation Ontario (MTO) Agreement Number 2008-E-0016.

The project is located in the Regional Municipality of Niagara, City of Thorold and City of Welland, Ontario. Approximately 6.5 km of two lane staged freeway will be twinned from Sta. 10+000 to Sta. 6+400. Within the project limits Highway 406 has signalized intersections at Merritt Road, Woodlawn Road and East Main Street and one un-signalized intersection at Port Robinson Road.

Foundation investigations and design recommendations are required for nine culverts. At five sites culvert replacements/new culverts are required and at the remaining four sites culvert extensions are required.

The main design recommendations are:

- The predicted settlement at culvert sites 2, 5 and 35 will be less than 25 mm for the recommended geotechnical resistance at SLS.
- At culvert sites 6, 8, 9, 24, 48 and 49 the total consolidation settlement of the underlying soils is predicted to exceed 25 mm and culvert cambering is recommended.
- Weak foundation soils and settlement sensitive soils exist and closed bottom concrete culverts or pipe culverts are known to provide better solutions.
- Pile foundations are not being recommended. This foundation scheme is costly and requires lengthy construction times. Accessibility at some sites with heavy pile driving equipment could also be problematic because of the weak underlying soils.
- Local earth fill embankments should be constructed at 3H:1V side slopes.

Notwithstanding the foregoing the designer is advised to review this report in its entirety to ensure that the geotechnical recommendations provided herein are adequately addressed in the designs and contract documents.



FOUNDATION INVESTIGATION REPORT
CULVERTS & CULVERT EXTENSIONS
HIGHWAY 406 TWINNING
ONTARIO
AGREEMENT No. 2008-E-0016, W.P. 280-99-00, SITE:
GEOCRES No. 30M3-269
PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from foundation investigations conducted at a number of sites on Highway 406 where either culvert extensions or replacements are required. The project area extends from East Main Street, City of Welland to about 1.0 km north of Port Robinson Road, City of Thorold, Ontario.

The purpose of this investigation was to explore the subsurface conditions at nine culvert sites and based on the data obtained, to provide borehole and test pit location plans, records of boreholes and test pits, stratigraphic profiles, laboratory test results and a description of the subsurface conditions. Models of the subsurface conditions were developed from the data obtained.

Terraprobe conducted the investigation as a sub-consultant to Giffels Associates Ltd./IBI Group, under the Ministry of Transportation Ontario (MTO) Agreement Number 2008-E-0016.

For reporting purposes the investigated sites are identified as:

- **Culvert #2:** Highway 406 - Sta. 10+307. An 800 mm diameter CSP culvert currently exists at this site.
- **Culvert #5:** Highway 406 - Sta. 10+777. A 1,850x1,250 RFB culvert is located at this site.
- **Culvert #6:** Highway 406 - Sta. 11+499. A 2,450x1,250 RFB culvert is located at this site.
- **Culvert #8:** Highway 406 - Sta. 12+338. A 3,050x1,850 RFB culvert is located at this site.
- **Culvert #9:** Highway 406 - Sta. 12+476. A 1,860x1,000 RFB culvert is located approximately 50 m north of this site.
- **Culvert #24:** Highway 406 - Sta. 14+152. A 2,000x1,250 RFB culvert is located at this site.
- **Culvert #48:** Highway 406 - Sta. 15+712. A 3,650x2,520 RFO culvert is located at this site.
- **Culvert #35:** Port Robinson Road - Sta. 9+704. Twin 2,500 mm CSP culverts currently exist at this site.
- **Culvert #49:** Highway 406 - Sta. 5+839. A 1,220x1,220 concrete culvert is located at this site.



2 SITE DESCRIPTION & PHYSIOGRAPHY

The south limit of the project is Sta. 10+000 located at the existing Highway 406 terminus at East Main Street in the City of Welland. The north limit is about Sta. 6+400 approximately 1.0 km north of Port Robinson Road in the City of Thorold. This approximately 6.5 km long route traverses across generally flat terrain and crosses Woodlawn Road, Merritt Road and Port Robinson Road. There is an at grade railway intersection (Trillium Railway) about 265 m south of Woodlawn Road. The alignment also crosses the Welland River and Old Welland Canal.

The project area is located between the Niagara Escarpment and Lake Erie in the physiographic region of Southern Ontario referred to as the Haldimand Clay Plain. The Haldimand Clay Plain is best described as falling into a series of parallel belts with the highest ground adjacent to the Escarpment. Generally this region is flat and poorly drained although it includes several distinctive landforms such as dunes, cobble, clay and sand beaches, limestone pavements and back-shore wetland basins¹.

The Niagara Region is underlain by a sequence of very gently south-dipping dolostones, limestones, shales and sandstones overlying Precambrian basement rock. The key elements in the bedrock geology of the region are the multiple layers of softer sedimentary limestones, shale, sandstone and dolostone.

The bedrock units within the project limits consist of the Salina Formation and Guelph Formation of Upper Silurian Age². The Salina Formation consists essentially of easily weathered, grey, very finely crystalline, laminated argillaceous dolostone with grey, calcareous shale partings and gypsum veins and lenses of varying thicknesses. The Guelph Formation consists essentially of unweathered, grey, laminated argillaceous dolostone.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at the nine culvert sites are outlined below:

Culvert #2: Three boreholes numbered C2-1, C2-2 and C2-3, drilled and sampled to depths ranging from 12.7 m to 19.1 m during the period of June 21, 2010 to July 21, 2010. The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing in Appendix C1.

Culvert #5: Two boreholes drilled and sampled to depths of 13.6 m and 14.1 m and one shallow test pit dug to a depth of 0.3 m during the period of June 17, 2010 to July 20, 2010. The boreholes were numbered C3-1 and C3-2 and the shallow test pit was numbered TP 3-1. Their approximate locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C2.

¹ Chapman and Putnam, "The Physiography of South Ontario", 3rd Edition, 1984.

² Ontario Division of Mines, "Quaternary Geology Of The Welland Area", Preliminary Map P.796, 1972.



Culvert #6: Two boreholes (numbered C5-1 and C5-2) drilled and sampled to depths of 18.8 m and three shallow test pits (numbered TP 5-1, TP 5-2 and TP 5-3) dug to a depth of 0.3 m during the period of June 18, 2010 to July 05, 2010. A DCPT test was performed in Borehole C5-1 from 18.8 m to 19.4 m. The approximate borehole and test pit locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C3.

Culvert #8: Four boreholes drilled and sampled to depths ranging from 12.7 m to 20.3 m and four shallow test pits dug to depths ranging from 1.2 m to 1.8 m during the period of November 12, 2009 to July 26, 2010. The boreholes were numbered C6-1, C6-2, S-EW 10+025Rt and WE-S 10+360Lt and the shallow test pits were numbered TP 6-1 to TP 6-4. Their approximate locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C4.

Culvert #9: Four boreholes numbered C7-1 to C7-4 drilled and sampled to depths ranging from 12.6 m to 17.0 m and one shallow test pit (TP 7-1) dug to a depth of 1.2 m during the period of June 25, 2010 to July 07, 2010. The approximate borehole and test pit locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C5.

Culvert #24: Two boreholes numbered C9-1 and C9-2 drilled and sampled to depths ranging from 12.7 m to 13.6 m during the period of November 17, 2009 to November 18, 2009. A DCPT test was performed in Borehole C9-2 from 13.6 m to 17.1 m. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C6.

Culvert #48: Three boreholes drilled and sampled to depths ranging from 12.7 m to 23.4 m and two shallow test pits dug to depths ranging from 0.2 m to 0.6 m during the period of July 13, 2010 to July 14, 2010. The boreholes were numbered C10-1, C10-2 and C10-3 and the shallow test pits were numbered TP 10-1 and TP 10-2. Their approximate locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C7.

Culvert #35: Three boreholes (numbered C11-1, C11-2 and C11-3) drilled and sampled to depths ranging from 18.8 m to 23.4 m and one shallow test pit (TP 11-1) dug to a depth of 0.3 m during the period of July 08, 2010 to July 16, 2010. Their approximate locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C8.

Culvert #49: Three boreholes numbered C12-1, C12-2 and C12-3, drilled and sampled to depths ranging from 20.3 m to 21.8 m during the period of June 25, 2010 to July 15, 2010. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing in Appendix C9.

The borehole locations were marked in the field by surveyors from Callon Dietz Inc. who also provided Terraprobe with their coordinates and geodetic elevations. Access to some borehole locations was difficult due to locally steep slopes and existing structures. These boreholes were therefore relocated to be as close as feasible to the staked out location while allowing safe operation of the drill rig. Utility clearances were obtained by Terraprobe prior to drilling.



Samples of the overburden soils were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT), as specified in ASTM Method D1586. In the cohesive (clayey) deposits the undrained shear strength of the soil was measured in-situ by means of field vane tests using an MTO type field vane. Relatively undisturbed soil samples were also collected with thin-walled Shelby Tube samplers.

In addition to the testing outlined above, Dynamic Cone Penetration Tests (DCPTs) were conducted. This test consists of continuously driving into undisturbed ground a 50 mm diameter cone (60° vertex angle) attached to a drill rod, with a driving energy of 475 J per blow (63.5 kg hammer dropping freely a vertical distance of 0.76 m). The number of blows for each 300 mm of penetration is recorded and this provides an indication of the relative changes in the soil density/consistency with depth.

Ground water conditions in the open boreholes were observed throughout the drilling operations and standpipe piezometers consisting of 19 mm diameter PVC pipe with a slotted screen enclosed in sand were installed in selected boreholes to permit longer term ground water level monitoring. The remaining boreholes were abandoned in accordance with MOE Regulation 903 by sealing/grouting with a clay slurry mixture after drilling was complete.

The locations and completion details of the piezometers are provided in Tables 3.1 to 3.9.

Table 3.1 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #2)	
	Tip Depth/ Elevation (m)	Completion Details
C2-1	9.9/173.4	Hole sealed with silty clay cuttings to 9.9 m, piezometer with 1.5 m slotted screen installed with filter sand to 7.8 m, bentonite seal from 7.8 m to 7.2 m, silty clay cuttings from 7.2 m to 0.6 m and bentonite seal from 0.6 m to ground surface with a flush mounted casing installation.
C2-3	12.2/169.4	Hole sealed to 12.2 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 10.1 m, bentonite seal from 10.1 m to 9.5 m, silty clay cuttings from 9.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.



Table 3.2 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #5)	
	Tip Depth/ Elevation (m)	Completion Details
C3-1	12.2/171.0	Piezometer with 1.5 m slotted screen installed with filter sand to 10.4 m, bentonite seal from 10.4 m to 9.8 m, silty clay cuttings from 9.8 m to 0.6 m and bentonite seal from 0.6 m to ground surface with a flush mounted casing installation.
C3-2	13.7/170.1	Piezometer with 1.5 m slotted screen installed with filter sand to 11.6 m, bentonite seal from 11.6 m to 11.0 m, silty clay cuttings from 11.0 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

Table 3.3 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #6)	
	Tip Depth/ Elevation (m)	Completion Details
C5-1	18.3/172.1	Piezometer with 1.5 m slotted screen installed with filter sand to 16.4 m, bentonite seal from 16.4 m to 15.8 m, silty clay cuttings from 15.8 m to 0.6 m and bentonite seal from 0.6 m to ground surface with a flush mounted casing installation.
C5-2	15.2/172.0	Hole sealed to 15.2 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 13.1 m, bentonite seal from 13.1 m to 12.5 m, silty clay cuttings from 12.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

Table 3.4 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #8)	
	Tip Depth/ Elevation (m)	Completion Details
C6-1	9.1/170.1	Hole sealed to 9.1 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 7.0 m, bentonite seal from 7.0 m to 6.4 m, silty clay cuttings from 6.4 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C6-2	12.2/171.3	Hole sealed to 12.2 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 10.1 m, bentonite seal from 10.1 m to 9.5 m, silty clay cuttings from 9.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
S-EW 10+025Rt	18.8/164.8	Piezometer with 3.0 m slotted screen installed with filter sand to 15.1 m, bentonite seal from 15.1 m to 14.5 m, silty clay cuttings from 14.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
WE-S 10+360Lt	19.8/163.6	Piezometer with 3.0 m slotted screen installed with filter sand to 16.2 m, bentonite seal from 16.2 m to 15.5 m, silty clay cuttings from 15.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.



Table 3.5 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #9)	
	Tip Depth/ Elevation (m)	Completion Details
C7-1	16.7/164.3	Piezometer with 1.5 m slotted screen installed with filter sand to 14.6 m, bentonite seal from 14.6 m to 14.0 m, silty clay cuttings from 14.0 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C7-2	13.7/167.8	Piezometer with 1.5 m slotted screen installed with filter sand to 11.6 m, bentonite seal from 11.6 m to 11.0 m, silty clay cuttings from 11.0 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C7-4	12.2/169.8	Piezometer with 1.5 m slotted screen installed with filter sand to 10.0 m, bentonite seal from 10.0 m to 9.4 m, silty clay cuttings from 9.4 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

Table 3.6 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #24)	
	Tip Depth/ Elevation (m)	Completion Details
C9-1	7.6/167.3	Hole sealed to 7.6 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 5.5 m, bentonite seal from 5.5 m to 4.6 m, silty clay cuttings from 4.6 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C9-2	12.1/163.9	Piezometer with 1.5 m slotted screen installed with filter sand to 10.0 m, bentonite seal from 10.0 m to 9.4 m, silty clay cuttings from 9.4 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

Table 3.7 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #48)	
	Tip Depth/ Elevation (m)	Completion Details
C10-1	10.7/166.4	Piezometer with 1.5 m slotted screen installed with filter sand to 8.5 m, bentonite seal from 8.5 m to 7.9 m, silty clay cuttings from 7.9 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C10-3	14.6/163.9	Piezometer with 1.5 m slotted screen installed with filter sand to 12.5 m, bentonite seal from 12.5 m to 11.9 m, silty clay cuttings from 11.9 m to 0.6 m and bentonite seal from 0.6 m to ground surface.



Table 3.8 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #35)	
	Tip Depth/ Elevation (m)	Completion Details
C11-1	16.8/161.1	Hole sealed to 16.8 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 14.7 m, bentonite seal from 14.7 m to 14.1 m, silty clay cuttings from 14.1 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C11-3	17.2/161.9	Piezometer with 1.5 m slotted screen installed with filter sand to 15.1 m, bentonite seal from 15.1 m to 14.5 m, silty clay cuttings from 14.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

Table 3.9 – Piezometer Installation Details

Piezometer Location	Piezometer Details (Culvert #49)	
	Tip Depth/ Elevation (m)	Completion Details
C12-2	15.2/164.6	Piezometer with 1.5 m slotted screen installed with filter sand to 13.1 m, bentonite seal from 13.1 m to 12.5 m, silty clay cuttings from 12.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
C12-3	15.2/164.6	Piezometer with 1.5 m slotted screen installed with filter sand to 13.1 m, bentonite seal from 13.1 m to 12.5 m, silty clay cuttings from 12.5 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

The drilling, sampling and in-situ testing operations were observed on a full time basis by members of Terraprobe's technical staff who logged the boreholes and processed the recovered soil and rock samples for transport to Terraprobe's Brampton laboratory for further examination and testing.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Select samples were also subjected to a laboratory testing programme consisting of gradation analysis and Atterberg Limits tests, consolidation tests, unit weight, and undrained shear strength testing with a laboratory vane. The results of this testing program are shown on the Record of Borehole sheets in Appendix A1 to A9 and the Figures in Appendix B1 to B9.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole Sheets and Test Pit Logs in Appendices A1 to A9. Details of the encountered soil stratigraphy are presented in these appendices and on the "Borehole Locations and Soil Strata" drawings in Appendices C1 to C9. An overall description of the stratigraphy at the culvert sites is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets and Test Pit Logs governs any interpretation of the site conditions.



5.1 Culvert #2 (Hwy 406 Sta. 10+307)

In general, the site is underlain by topsoil, fill material (sandy gravel and silty clay) and native overburden deposits of silty clay and silty clay till.

5.1.1 Topsoil

A 300 mm thick layer of topsoil was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.1.2 Fill – Sandy Gravel

Borehole C2-1 was advanced through the existing shoulder of Highway 406 where granular fill material consisting of sandy gravel was encountered. This fill extends to a depth of 1.4 m (Elev. ± 181.9 m) below ground surface.

The grain size distribution plot of a tested sample of this granular fill is depicted in Figure B1-1. The results show a grain size distribution consisting of 55% gravel, 34% sand, and 11% silt and clay size particles.

Standard Penetration tests in the granular fill gave ‘N’ values that ranged from 13 to 16 blows for 0.3 m penetration. Based on these results this fill is considered to have a compact relative density. The moisture content of samples of this fill ranged from 2% to 4% by weight.

5.1.3 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 0.7 m to 2.1 m below ground surface or to elevations of ± 181.2 m to ± 180.2 m.

A sample of the silty clay fill was subjected to a grain size distribution test and the results are presented in Figure B1-2. These results show a grain size distribution consisting of 0% gravel, 1% sand, 60% silt and 39% clay size particles.

A sample of the fill was also subjected to Atterberg Limits tests and the results are presented in Figure B1-3. The index values from these tests are summarized below:

Liquid Limit:	44%
Plastic Limit:	23%
Plasticity Index:	21%
Natural Moisture Content:	18%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in the silty clay fill gave ‘N’ values that ranged from 3 to 19 blows for 0.3 m penetration. Based on these results the fill is considered to have a soft to very stiff consistency. The moisture content of samples of this fill ranged from 16% to 28% by weight.



5.1.4 Silty Clay

A silty clay deposit was encountered across the site extending to depths ranging from 8.6 m to 10.6 m below ground surface or to elevations ranging from ± 173.5 m to ± 171.0 m.

The grain size distribution curves of tested samples of the silty clay are presented in Figures B1-4 and B1-5. These results show a grain size distribution consisting of 0% gravel, 1-3% sand, 52-69% silt and 29-47% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B1-6 and B1-7. The index values from these tests are summarized below:

Liquid Limit:	28-45%
Plastic Limit:	18-21%
Plasticity Index:	9-25%
Natural Moisture Content:	16-32%

These values indicate that the silty clay has a generally low to intermediate plasticity.

Standard Penetration tests in this stratum gave 'N' values that ranged from 5 to 42 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 64 kPa to in excess of 120 kPa. These results indicate that the consistency of the silty clay is generally stiff to very stiff with occasional firm and hard zones. The moisture content of samples of the silty clay range from 16% to 32% by weight.

5.1.5 Silty Clay Till

A silty clay till deposit was encountered across this site extending to borehole termination depths ranging from 12.7 m (Elev. ± 169.0 m) to 19.1 m (Elev. ± 164.2 m) below ground surface.

The grain size distribution plot of a tested sample from this unit is depicted in Figure B1-8. The results show a grain size distribution consisting of 3% gravel, 18% sand, 54% silt and 25% clay size particles. Till soils will also contain random cobble and boulder inclusions and it is noted that auger refusal was encountered (probably on a boulder in this deposit) in Borehole C2-2 at depths of 10.5 m, 10.7 m and 10.8 m.

A sample was also subjected to Atterberg Limits tests and the results are plotted on the plasticity chart, Figure B1-9. The index values from these tests are summarized below:

Liquid Limit:	25%
Plastic Limit:	13%
Plasticity Index:	12%
Natural Moisture Content:	25%

These values are typical of clayey soils of low plasticity.

Standard Penetration tests in this stratum yielded 'N' values ranging widely from 1 to in excess of 100 blows per 0.3 m penetration and field vane tests performed in this deposit gave undrained shear strength ranging from 80 kPa to in excess of 120 kPa. Based on these results, the silty clay till is



considered to have a generally stiff to hard consistency with occasional soft zones. The moisture content of samples from this deposit varies from 13% to 25% by weight.

5.1.6 Water Levels

Standpipe piezometers were installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.1.1.

Table 5.1.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C2-1	July 08, 2010	4.0	179.3
	July 13, 2010	3.7	179.6
	July 20, 2010	3.6	179.7
C2-3	July 28, 2010	5.9	175.7
	August 06, 2010	7.1	174.5
	August 13, 2010	6.5	175.1
	August 23, 2010	4.6	177.0
	September 25, 2010	7.4	174.2
	October 03, 2010	6.2	175.4
	October 14, 2010	6.6	175.0

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at about Elev. ± 180.0 m. Perched water can also be expected to occur where permeable layers of sand and gravel are underlain by more impermeable silty clay soils.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.2 Culvert #5 (Hwy 406 Sta. 10+777)

In general, the site is underlain by topsoil, fill material (sand and gravel and silty clay) and native overburden deposits of silty clay and silty clay till.

5.2.1 Topsoil

A 100 mm thick layer of topsoil was encountered in Borehole C3-2 and Test Pit TP 3-1. Topsoil thickness may vary between and beyond the boreholes.

5.2.2 Fill – Sand and Gravel

Sand and gravel fill material was encountered in Borehole C3-1 which was drilled through the existing shoulder of Highway 406. This fill material extends to a depth of 1.4 m (Elev. ± 181.8 m) below ground surface.

The grain size distribution curve of a tested sample of this fill is presented in Figure B2-1. The results show a grain size distribution consisting of 37% gravel, 46% sand, 13% silt and 4% clay size particles.



Standard Penetration tests in this fill gave 'N' values ranging from 27 to 33 blows for 0.3 m penetration, indicating a compact to dense relative density. The moisture content of samples of this fill was 5% by weight.

5.2.3 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths of 2.1 m below ground surface or to elevations ranging from ± 181.7 m to ± 181.1 m.

Samples of the silty clay fill were subjected to grain size distribution tests and the results are presented in Figure B2-2. These results show grain size distributions consisting of 0-7% gravel, 5-13% sand, 40-46% silt and 40-49% clay size particles.

Samples of the fill were also subjected to Atterberg Limits tests and the results are presented in Figure B2-3. The index values from these tests are summarized below:

Liquid Limit:	42-49%
Plastic Limit:	20-24%
Plasticity Index:	22-25%
Natural Moisture Content:	17-24%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values that ranged from 13 to 26 blows for 0.3 m penetration. Based on these results the fill is considered to have a stiff to very stiff consistency. The moisture content of samples of this fill ranged from 16% to 24% by weight.

5.2.4 Silty Clay

A silty clay deposit was encountered at this site extending to depths ranging from 9.4 m (Elev. ± 173.8 m) to 10.1 m (Elev. ± 173.7 m) below ground surface.

The grain size distribution plots of tested samples of the silty clay are presented in Figure B2-4. These results show a grain size distribution consisting of 0% gravel, 1-3% sand, 46-72% silt and 25-52% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity chart, Figure B2-5. The index values from these tests are summarized below:

Liquid Limit:	28-49%
Plastic Limit:	16-23%
Plasticity Index:	12-26%
Natural Moisture Content:	17-24%

These values indicate that the silty clay has a generally low to intermediate plasticity.



Standard Penetration tests in this stratum gave 'N' values that ranged from 11 to 28 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 100 kPa to in excess of 120 kPa. These values indicate that the consistency of the silty clay is generally stiff to very stiff. Moisture content of samples of the silty clay ranged from 16% to 24% by weight.

5.2.5 Silty Clay Till

A deposit of silty clay till was encountered across this site extending to borehole termination depths ranging from 13.6 m (Elev. ± 169.6 m) to 14.1 m (± 169.7 m) below ground surface.

The results of a grain size distribution test conducted on a sample of silty clay till are shown in Figure B2-6. The curve shows a grain size distribution consisting of 6% gravel, 18% sand, 56% silt and 20% clay size particles. Till soils will also contain random cobble and boulder inclusions.

A sample of the silty clay till was also subjected to Atterberg Limits tests and the results are plotted on the plasticity chart, Figure B2-7. The summarized index values from these tests are presented herein.

Liquid Limit:	23%
Plastic Limit:	14%
Plasticity Index:	9%
Natural Moisture Content:	14%

These values are typical of clayey soils of low plasticity.

Standard Penetration tests in this stratum yielded 'N' values ranging from 11 to more than 100 blows for 0.3 m penetration and field vane tests performed in this deposit gave undrained shear strengths in excess of 120 kPa. Based on these results, the silty clay till is considered to have a stiff to hard consistency. The moisture content of samples from this deposit varies from 11% to 19% by weight.

5.2.6 Water Levels

The boreholes were instrumented with a standpipe piezometer. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.2.1.

Table 5.2.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C3-1	July 08, 2010	2.0	181.2
	July 14, 2010	1.9	181.3
	July 20, 2010	2.0	181.2
C3-2	July 28, 2010	5.6	178.2
	August 06, 2010	5.8	178.0

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at about Elev. ± 181.0 m. Perched water can



also be expected to occur where relatively permeable soils are underlain by more impermeable silty clay soils.

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.3 Culvert #6 (Highway 406 Sta. 11+499)

In general, the site is underlain by topsoil, fill material (sand and gravel and silty clay) and native overburden deposits of silty clay and silty clay till.

Stereoscopic interpretations of 1970 air photos indicate that this section of Highway 406 was not yet constructed. The 1970 aerial photography show significant construction activity in this area and it appears that large quantities of excavated soil from the Welland Canal construction were being stockpiled at this site. The 1998 air photos show the current Highway 406 crossing this site and it would be reasonable to assume that the highway and culvert at this site are founded on fill material.

5.3.1 Topsoil

A 100 mm to 130 mm thick layer of topsoil was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.3.2 Fill – Sand and Gravel

Borehole C5-1 was extended through the existing shoulder of Highway 406 where it encountered a 610 mm thick layer of sand and gravel fill that extends to a depth of 0.6 m (Elev. ± 189.8 m) below ground surface.

The grain size distribution plot of a tested sample of this granular fill is depicted in Figure B3-1. The results show a grain size distribution consisting of 40% gravel, 41% sand, 14% silt and 5% clay size particles.

A Standard Penetration test in the granular fill gave an 'N' value of 22 blows for 0.3 m penetration indicating that the fill has a compact relative density. The moisture content of a sample of the fill was 6% by weight.

5.3.3 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 4.4 m (Elev. ± 182.8 m) to 7.1 m (Elev. ± 183.3 m) below ground surface.

The grain size distribution curve of a sample of this fill is shown in Figure B3-2. The results show a grain size distribution consisting of 0% gravel, 2% sand, 41% silt and 57% clay size particles.



A sample of the silty clay fill was also subjected to Atterberg Limits tests and the results are plotted on the plasticity chart in Figure B3-3. The summarized index values from these tests are presented below.

Liquid Limit:	50%
Plastic Limit:	24%
Plasticity Index:	26%
Natural Moisture Content:	21%

These values are characteristic of clayey soils of intermediate to high plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values ranging from 9 to 45 blows for 0.3 m penetration. Based on these results the fill is considered to have a stiff to hard consistency. The moisture content of samples of this fill ranged from 10% to 32% by weight.

5.3.4 Silty Clay

A native silty clay stratum was encountered in both boreholes at this site. This deposit was fully penetrated in Borehole C5-2 where it extends to a depth of 16.8 m (Elev. ± 170.4 m) below ground surface. Borehole C5-1 was terminated in this deposit at a depth of 18.8 m (Elev. ± 171.6 m) below ground surface.

The grain size distribution curves of tested samples of the silty clay are presented in Figures B3-4 and B3-5. These results show a grain size distribution consisting of 0-3% gravel, 2-6% sand, 44-69% silt and 28-40% clay size particles. One tested sample from Borehole C5-2 at approximately 4.7 m depth (Elev. ± 182.5 m) contained 21% sand and was described as sandy.

Samples were also subjected to Atterberg Limits tests and the results are shown on the plasticity charts, Figures B3-6 and B3-7. The index values from these tests are summarized below:

Liquid Limit:	28-40%
Plastic Limit:	15-20%
Plasticity Index:	11-20%
Natural Moisture Content:	14-24%

These values indicate that the silty clay has a generally low to intermediate plasticity.

Standard Penetration tests in this deposit gave 'N' values that ranged from 2 to more than excess of 100 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 20 kPa to in excess of 100 kPa. These results indicate that the consistency of the silty clay is generally firm to hard with occasional soft zones. The moisture content of samples from this deposit ranged from 14% to 24% by weight.



5.3.5 Silty Clay Till

Borehole C5-2 encountered a silty clay till deposit that extends to a borehole termination depth of 18.8 m (Elev. ± 168.4 m) below ground surface.

The grain size distribution plot of a tested sample of the silty clay till is shown in Figure B3-8. The results show a grain size distribution consisting of 3% gravel, 16% sand, 49% silt and 32% clay size particles. Till soils will also contain random cobble and boulder inclusions.

One sample was also subjected to Atterberg Limits tests and the results are illustrated on the plasticity chart, Figure B3-9. The index values from these tests are presented herein.

Liquid Limit:	28%
Plastic Limit:	14%
Plasticity Index:	14%
Natural Moisture Content:	16%

These results are typical for low plasticity silty clay soils.

Standard Penetration tests in the silty clay till yielded 'N' values ranging from 50 to 52 blows for 0.3 m penetration indicating that the silty clay till has a hard consistency. Moisture contents of samples from this deposit ranged from 11% to 16% by weight.

5.3.6 Water Levels

Both boreholes were instrumented with a standpipe piezometer. The water level readings measured on separate visits made after drilling was complete are presented in Table 5.3.1.

Table 5.3.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C5-1	July 05, 2010	9.0	181.4
	July 14, 2010	4.9	185.5
	July 21, 2010	8.3	182.1
	July 28, 2010	8.6	181.8
C5-2	July 14, 2010	6.7	180.5
	July 21, 2010	6.3	180.9
	July 28, 2010	6.4	180.8

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at Elev. ± 181.8 m. Perched water can also be expected to occur where relatively permeable soils are underlain by more impermeable silty clay soils.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.



5.4 Culvert #8 (Highway 406 Sta. 12+338)

In general, the site is underlain by topsoil, silty clay fill, and native overburden deposits of silty clay and silty clay to clayey silt till.

5.4.1 Topsoil

Topsoil ranging from 50 mm to 200 mm in thickness was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.4.2 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 1.4 m (Elev. ± 182.1 m) to 4.4 m (Elev. ± 179.2 m) below ground surface.

Samples of the silty clay fill were subjected to grain size distribution tests and the results are presented in Figure B4-1. These results show a grain size distribution consisting of 0% gravel, 3-11% sand, 38-59% silt and 30-59% clay size particles.

Samples of the fill were also subjected to Atterberg Limits tests and the results are presented in Figure B4-2. The index values from these tests are summarized below:

Liquid Limit:	26-57%
Plastic Limit:	14-26%
Plasticity Index:	12-31%
Natural Moisture Content:	9-20%

These values indicate a silty clay fill with low to high plasticity.

Standard Penetration tests in the fill gave 'N' values ranging from 8 to 93 blows for 0.3 m penetration. Based on these results the fill is considered to have a stiff to hard consistency. The moisture content of samples of this fill ranged from 8% to 26% by weight.

5.4.3 Silty Clay

A major silty clay deposit was encountered across the site extending to depths ranging from 10.1 m (Elev. ± 169.1 m) to 16.2 m (Elev. ± 167.3 m) below ground surface.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B4-3 to B4-5 inclusive. These results show a grain size distribution consisting of 0-2% gravel, 0-4% sand, 59-87% silt and 13-38% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B4-6 to B4-8 inclusive. The index values from these tests are summarized below:

Liquid Limit:	24-37%
Plastic Limit:	16-20%
Plasticity Index:	6-17%
Natural Moisture Content:	17-22%



These values indicate that the silty clay has a generally low to intermediate plasticity with infrequent zones of low plasticity clayey silt.

The Atterberg Limits test results are plotted against elevation, Figure B4-11. These results illustrate that the natural moisture contents are generally at or below the plastic limit down to about Elev. ± 177.5 m. Below Elev. ± 177.5 m the data indicates that the moisture content values generally exist between the plastic and liquid limits.

Standard Penetration tests in this stratum gave 'N' values that ranged from 8 to 36 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 72 kPa to in excess of 120 kPa and a laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 78 kPa. These values indicate that the consistency of the silty clay is generally stiff to hard. The moisture content of samples of the silty clay ranged from 11% to 23% by weight and the unit weight of a tested sample was 21.0 kN/m^3 .

The variation of undrained shear strength with elevation is depicted in Figure B4-12. The plot illustrates a wide scatter in the data with no obvious trend with depth and an interpreted dashed line is shown representing a lower bound trend with depth for the data. The upper portion of this deposit down to about Elev. ± 178.0 m is estimated to have relatively high shear strength i.e. in excess of 100 kPa. Below Elev. ± 178.0 m the undrained shear strength decreases with depth and is about 75 kPa from Elev. ± 173.0 m to Elev. ± 171.0 m. Below Elev. ± 171.0 m the trend indicates increasing undrained shear strength with depth.

Consolidation tests were also performed on Shelby tube samples retrieved from Boreholes SEW 10+025Rt and WES 10+360Lt and the results are presented in Figures B4-13 to B4-18 inclusive. Preconsolidation pressures were estimated from the e-log p curves. Due to the rounded nature of the curves the preconsolidation pressures were also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.

Borehole/Sample No.	Sample Depth/Elevation (m)	P_c (kPa)	C_c	C_r	e_o
S-EW 10+025Rt TW12	12.2/171.4	310 – 400	0.119	0.013	0.47
WE-S 10+360Lt TW11	12.2/171.2	220 – 260	0.157	0.029	0.59

Where: P_c = Preconsolidation pressure
 C_c = Compression index
 C_r = Recompression index
 e_o = Initial void ratio

5.4.4 Silty Clay to Clayey Silt Till

A deposit of silty clay to clayey silt till was encountered across this site. All of the boreholes were terminated within this deposit at depths ranging from 12.7 m to 20.3 m below ground surface or to elevations ranging from ± 167.8 m to ± 163.1 m.

The grain size distribution curves of samples of the silty clay to clayey silt till are presented in Figure B4-9. These results show grain size distributions consisting of 2-15% gravel, 13-34% sand, 38-58% silt and 13-27% clay size particles.



Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity chart, Figure B4-10. The index values from these tests are summarized below:

Liquid Limit:	17-25%
Plastic Limit:	11-14%
Plasticity Index:	5-11%
Natural Moisture Content:	7-18%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in this stratum gave 'N' values that ranged from 37 to in excess of 100 blows for 0.3 m penetration and a field vane test gave an in-situ undrained shear strength of 104 kPa. Based on these values the silty clay to clayey silt till is considered to have a very stiff to hard consistency. The moisture content of samples from this deposit ranged from 7% to 18% by weight.

5.4.5 Water Levels

A standpipe piezometer was installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.4.1.

Table 5.4.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C6-1	July 28, 2010	Dry	Dry
	August 06, 2010	4.7	174.5
	August 13, 2010	2.5	176.7
	August 23, 2010	2.0	177.2
	September 25, 2010	2.0	177.2
C6-2	July 28, 2010	4.1	179.4
	August 06, 2010	1.8	181.7
	August 13, 2010	3.6	179.9
	August 23, 2010	4.1	179.4
	September 25, 2010	4.1	179.4
S-EW 10+025Rt	December 08, 2009	17.7	165.9
	December 15, 2009	16.1	167.5
	January 04, 2010	5.0	178.6
	January 11, 2010	3.9	179.7
	January 19, 2010	4.0	179.6
WE-S 10+360Lt	November 20, 2009	6.3	177.1
	November 30, 2009	7.7	175.7
	December 15, 2009	5.9	177.5
	January 04, 2010	5.7	177.7
	January 11, 2010	5.5	177.9

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at Elev. ± 179.5 m. Perched water can also be expected to occur where permeable layers of sand and gravel and sand and silts are underlain by more impermeable silty clay soils.



All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.5 Culvert #9 (Highway 406 Sta. 12+476)

In general, the site is underlain by topsoil and peat, silty clay fill, and native overburden deposits of silty clay and clayey silt to silty clay till.

5.5.1 Topsoil & Peat

Topsoil ranging from 80 mm to 130 mm in thickness was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

A surficial peat deposit ranging from 200 mm to 230 mm in thickness was encountered in Borehole C7-4 and in Test Pit TP 7-1. This material will be encountered at the east end of the proposed culvert alignment (below the culvert footprint), a horizontal distance of about ± 32.0 m extending westerly from the culvert outlet.

5.5.2 Fill – Silty Clay

Silty clay fill material was encountered in Borehole C7-2 extending to a depth of 0.7 m (Elev. ± 180.8 m) below ground surface.

A sample of this fill material was subjected to a grain size distribution test and the results are presented in Figure B5-1. These results show a grain size distribution consisting of 0% gravel, 6% sand, 57% silt and 37% clay size particles. An Atterberg Limits test was not performed on this sample because of limited sample recovery.

A Standard Penetration test in the silty clay fill gave an 'N' value of 11 blows for 0.3 m penetration. Based on this result the fill is considered to have a stiff consistency. The moisture content of a sample of this fill was 15% by weight.

5.5.3 Silty Clay

A silty clay deposit was encountered across the site extending to depths ranging from 12.3 m (Elev. ± 169.7 m) to 14.0 m (Elev. ± 167.0 m) below ground surface.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B5-2 and B5-3. These results show a grain size distribution consisting of 0-1% gravel, 1-3% sand, 42-79% silt and 20-57% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B5-4 and B5-5. The index values from these tests are summarized below:

Liquid Limit:	26-50%
Plastic Limit:	17-23%
Plasticity Index:	8-27%
Natural Moisture Content:	16-24%



These values indicate that the silty clay has a generally low to intermediate plasticity.

The Atterberg Limits test results are plotted against elevation, Figure B5-8. These results illustrate that the natural moisture contents are generally at or below the plastic limit down to about Elev. ± 177.0 m. Below Elev. ± 177.0 m the data indicates that the moisture contents generally exist between the plastic and liquid limits.

Standard Penetration tests in this stratum gave 'N' values that ranged from 10 to 71 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 64 kPa to in excess of 120 kPa. A laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 103 kPa. These values indicate that the consistency of the silty clay is generally stiff to hard. The moisture content of samples of the silty clay ranged from 14% to 44% by weight and the unit weight of a tested sample was 21.0 kN/m^3 .

The variation of undrained shear strength with elevation is depicted in Figure B5-9. The plot illustrates a wide scatter in the data with no obvious trend with depth and an interpreted dashed line is shown representing a lower bound trend with depth for the data. The upper portion of this deposit down to about Elev. ± 177.0 m is estimated to have relatively high shear strength i.e. in excess of 100 kPa. Below Elev. ± 177.0 m the undrained shear strength decreases with depth and is about 60 kPa from Elev. ± 172.0 m to Elev. ± 171.0 m. Below Elev. ± 171.0 m the trend indicates increasing undrained shear strength with depth.

Consolidation tests were also performed on a Shelby tube sample retrieved from Borehole C7-2 and the results are presented in Figures B5-10 to B5-12 inclusive. The preconsolidation pressure was estimated from the e-log p curve. Due to the rounded nature of the curve the preconsolidation pressure was also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.

Borehole/Sample No.	Sample Depth/Elevation (m)	P_c (kPa)	C_c	C_r	e_o
C7-2 TW8	6.1/175.4	310 – 600	0.291	0.030	0.52

Where: P_c = Preconsolidation pressure
 C_c = Compression index
 C_r = Recompression index
 e_o = Initial void ratio

5.5.4 Clayey Silt to Silty Clay Till

Clayey silt to silty clay till was encountered across this site extending to borehole termination depths ranging from 12.6 m (Elev. ± 169.4 m) to 17.0 m (Elev. ± 164.0 m) below ground surface.

The grain size distribution plots of tested samples of the clayey silt to silty clay till are presented in Figure B5-6. These results show grain size distributions consisting of 0-8% gravel, 2-26% sand, 49-78% silt and 17-20% clay size particles.



Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity chart, Figure B5-7. The index values from these tests are summarized below:

Liquid Limit:	20-26%
Plastic Limit:	12-18%
Plasticity Index:	7-8%
Natural Moisture Content:	10-18%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in this stratum gave 'N' values that ranged from 17 to in excess of 100 blows for 0.3 m penetration. Based on these results the till is considered to have a very stiff to hard consistency. The moisture content of samples from this deposit ranged from 7% to 18% by weight.

5.5.5 Water Levels

A standpipe piezometer was installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.5.1.

Table 5.5.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C7-1	July 05, 2010	5.5	175.5
	July 13, 2010	4.2	176.8
	July 19, 2010	4.1	176.9
C7-2	July 05, 2010	6.4	175.1
	July 13, 2010	2.5	179.0
	July 19, 2010	3.0	178.5
	July 28, 2010	2.8	178.7
C7-4	July 12, 2010	3.6	178.4
	July 19, 2010	2.3	179.7
	July 27, 2010	2.3	179.7

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a phreatic surface that is estimated exist at about Elev. ± 179.7 m at the east end of the site falling gradually to Elev. ± 176.9 m at the west end of the site. Perched water can also be expected to occur where permeable layers of sand and gravel and sand and silts are underlain by more impermeable silty clay soils.

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.



5.6 Culvert #24 (Highway 406 Sta. 14+152)

In general, the site is underlain by native overburden deposits of silty clay and silt.

5.6.1 Silty Clay

A silty clay deposit was encountered across this site. Both boreholes were terminated within this stratum at depths of 12.7 m (Elev. ± 162.2 m) and 13.6 m (Elev. ± 162.4 m) below ground surface.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B6-1 and B6-2. These results show a grain size distribution consisting of 0-1% gravel, 0-5% sand, 43-76% silt and 22-56% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B6-3 and B6-4. The index values from these tests are summarized below:

Liquid Limit:	25-52%
Plastic Limit:	16-24%
Plasticity Index:	7-28%
Natural Moisture Content:	19-24%

These values indicate that the silty clay has a generally low plasticity with occasional intermediate and highly plastic clayey inclusions.

The Atterberg Limits test results are plotted against elevation, Figure B6-6. These results illustrate that the natural moisture contents are generally at or below the plastic limit down to about Elev. ± 170.0 m. Below Elev. ± 170.0 m the data indicates that the moisture contents generally exist between the plastic and liquid limits.

Standard Penetration tests in this stratum gave 'N' values that ranged from 2 to 22 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 36 kPa to in excess of 120 kPa and a laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 52 kPa. These values indicate that the consistency of the silty clay is generally firm to very stiff. The moisture content of samples from this stratum ranged from 16% to 26% by weight and the unit weight of a tested sample was 20.6 kN/m³.

The variation of undrained shear strength with elevation is depicted in Figure B6-7. The plot shows an interpreted dashed line that represents a lower bound trend with depth for the data. At Elev. ± 171.0 m the estimated shear strength is about 30 kPa and the trend indicates increasing shear strength with depth.

A consolidation test was performed on a Shelby tube sample retrieved from Borehole C9-1 and the results are presented in Figures B6-8 to B6-10 inclusive. The preconsolidation pressure was estimated from the e-log p curve. Due to the rounded nature of the curve the preconsolidation pressure was also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.



Borehole/Sample No.	Sample Depth/Elevation (m)	P _c (kPa)	C _c	C _r	e _o
C9-1 TW7	6.1/168.8	170 – 280	0.158	0.027	0.58

Where:
P_c = Preconsolidation pressure
C_c = Compression index
C_r = Recompression index
e_o = Initial void ratio

5.6.2 Silt

The silty clay stratum is divided by a 0.4 m to 2.0 m thick layer of silt that extends to depths ranging from 2.1 m (Elev. ±172.8 m) to 4.1 m (Elev. ±171.9 m) below ground surface.

The grain size distribution plot of a tested sample of the silt is presented in Figure B6-5. The result shows a grain size distribution consisting of 0% gravel, 3% sand, 82% silt and 15% clay size particles.

Standard Penetration tests in this deposit gave 'N' values that ranged from 7 to 20 blows per 0.3 m penetration. Based on these results the deposit is considered to have a loose to compact relative density. The moisture content of samples from this soil ranged from 16% to 23% by weight.

5.6.3 Water Levels

Standpipe piezometers were installed in both of the boreholes at this site and water level readings were taken on separate visits made after the completion of drilling. The water level records are presented in Table 5.6.1.

Table 5.6.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C9-1	November 30, 2009	3.0	171.9
	December 08, 2009	2.1	172.8
	January 04, 2010	0.4	174.5
	January 11, 2010	0.6	174.3
	January 14, 2010	0.5	174.4
C9-2	November 30, 2009	3.9	172.1
	December 08, 2009	3.4	172.6
	January 04, 2010	1.7	174.3
	January 11, 2010	1.7	174.3
	January 14, 2010	1.5	174.5

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates that the local ground water level at this site exists at Elev. ±174.5 m. Perched water can also be expected to occur where relatively permeable soils are underlain by more impermeable soils.



All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.7 Culvert #48 (Highway 406 Sta. 15+712)

In general, the site is underlain by topsoil, fill material (gravelly sand, silt and silty clay), and native overburden deposits of silty clay and silt.

5.7.1 Topsoil

An approximately 230 mm thick layer of topsoil was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.7.2 Fill – Gravelly Sand

Borehole C10-2 was advanced through the existing shoulder of Highway 406 where granular fill material consisting of gravelly sand was encountered. This fill extends to a depth of 0.7 m (Elev. ± 181.0 m) below ground surface.

The grain size distribution plot of a tested sample of this granular fill is depicted in Figure B7-1. These results show a grain size distribution consisting of 26% gravel, 56% sand, 14% silt and 4% clay size particles.

A Standard Penetration test in the granular fill gave an 'N' value of 17 blows for 0.3 m penetration. Based on this result the fill is considered to have a compact relative density. The moisture content of a sample of this fill was 6% by weight.

5.7.3 Fill – Silt

Test Pits TP 10-1 and TP 10-2 encountered a surficial layer of fill material consisting of a mixture of silt with some organics. This fill is approximately 200 mm to 300 mm thick.

5.7.4 Fill – Silty Clay

Silty clay fill was encountered extending to depths ranging from 2.1 m to 5.6 m below ground surface or to elevations ranging from ± 176.4 m to ± 176.1 m.

A sample of the silty clay fill was subjected to a grain size distribution test and the results are presented in Figure B7-2. These results show a grain size distribution consisting of 0% gravel, 3% sand, 57% silt and 40% clay size particles.

A sample of this fill was also subjected to Atterberg Limits tests and the results are presented in Figure B7-3. The index values from these tests are summarized below:

Liquid Limit:	37%
Plastic Limit:	20%
Plasticity Index:	17%
Natural Moisture Content:	28%



These values indicate that the silty clay fill is of intermediate plasticity.

Standard Penetration tests in this layer gave 'N' values ranging from 3 to 14 blows for 0.3 m penetration. Based on these results the fill is considered to have a soft to stiff consistency. The moisture content of samples of this fill ranged from 18% to 38% by weight.

5.7.5 Silty Clay

Discontinuous deposits of native silty clay were encountered across this site. An upper silty clay stratum was fully explored in all of the boreholes where it was found to extend to depths ranging from 10.5 m to 16.2 m below ground surface or to elevations ranging from ± 166.6 m to ± 165.3 m. A lower silty clay deposit was encountered in Boreholes C10-2 and C10-3 extending to borehole termination depths of 17.3 m (Elev. ± 161.2 m) and 23.4 m (Elev. ± 158.3 m) below ground surface. The upper and lower silty clay deposits are divided by layers of silt.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B7-4 and B7-5. These results show a grain size distribution consisting of 0% gravel, 0-8% sand, 30-82% silt and 18-42% clay size particles. One tested sample from Borehole C10-1 contained 41% sand and was described as sandy.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B7-6 and B7-7. The index values from these tests are summarized below:

Liquid Limit:	22-42%
Plastic Limit:	15-20%
Plasticity Index:	7-23%
Natural Moisture Content:	17-30%

These values indicate that the silty clay has a generally low to intermediate plasticity.

The Atterberg Limits test results (upper silty clay deposit) are plotted against elevation, Figure B7-9. These results illustrate that the natural moisture contents are generally at or close to the plastic limit down to about Elev. ± 175.0 m. Below Elev. ± 175.0 m the data generally indicates a trend of increasing moisture content with depth with values plotting between the plastic and liquid limits.

Standard Penetration tests in the upper silty clay gave 'N' values that ranged widely from 0 to 31 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 32 kPa to in excess of 100 kPa. A laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 32 kPa. These values indicate that the consistency of the upper silty clay is generally firm to hard. The moisture content of samples of the upper silty clay ranged from 19% to 39% by weight and the unit weight of a tested sample was 20.7 kN/m^3 .

The variation of undrained shear strength with elevation (upper silty clay) is depicted in Figure B7-10. The plot illustrates a wide scatter in the data with no obvious trend with depth and an interpreted dashed line is shown representing a lower bound trend with depth for the data. The upper portion of this deposit down to about Elev. ± 171.0 m is estimated to have relatively high



shear strength i.e. in excess of 100 kPa. Below Elev. ± 171.0 m the undrained shear strength decreases with depth and is about 30 kPa from Elev. ± 169.5 m to Elev. ± 168.5 m. Below Elev. ± 168.5 m the trend indicates increasing undrained shear strength with depth.

Standard Penetration tests in the lower silty clay gave 'N' values that ranged from 8 to 33 blows for 0.3 m penetration indicating a stiff to hard consistency. The moisture content of samples of the lower silty clay ranged from 17% to 22% by weight.

A consolidation test was also performed on a Shelby tube sample retrieved from Borehole C10-1 and the results are presented in Figures B7-11 to B7-13 inclusive. The preconsolidation pressure was estimated from the e-log p curve and due to the rounded nature of the curve the preconsolidation pressure was also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.

Borehole/Sample No.	Sample Depth/Elevation (m)	P _c (kPa)	C _c	C _r	e _o
C10-1 TW10	9.1/168.0	210 – 300	0.323	0.034	0.84

Where: P_c = Preconsolidation pressure
C_c = Compression index
C_r = Recompression index
e_o = Initial void ratio

5.7.6 Silt

Discontinuous silt deposits were encountered across this site. In Boreholes C10-2 and C10-3 a ± 3.0 m thick layer of silt was encountered extending to depths of 16.2 m (Elev. ± 162.3 m) and 19.2 m (Elev. ± 162.5 m) below ground surface. Borehole C10-1 was terminated within this silt layer at a depth of 12.7 m (Elev. ± 164.4 m) below ground surface. A ± 1.2 m thick silt layer was also encountered in Borehole C10-1 extending to a depth of 5.6 m (Elev. ± 171.5 m).

The grain size distribution plots of tested samples from these silt deposits are presented in Figure B7-8. The results show a grain size distribution consisting of 0% gravel, 0-3% sand, 78-89% silt and 11-19% clay size particles. Based on visual and tactile examinations of the retrieved samples, the units are essentially cohesionless silts with frequent cohesive silty clay seams and partings.

Standard Penetration tests in these deposits gave 'N' values that ranged from 0 to 37 blows for 0.3 m penetration. Based on these results the deposit is considered to have a very loose to dense relative density. The moisture content of samples from this soil ranged from 19% to 26% by weight.



5.7.7 Water Levels

A standpipe piezometer was installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.7.1.

Table 5.7.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C10-1	July 19, 2010	0.1	177.0
	August 06, 2010	0.0	177.1
	August 13, 2010	0.0	177.1
	August 23, 2010	0.0	177.1
C10-3	July 20, 2010	1.5	177.0
	July 27, 2010	1.1	177.4
	August 06, 2010	1.1	177.4

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at an elevation of ± 177.4 m. Perched water can also be expected to occur where permeable layers of gravelly sand and sand and silts are underlain by more impermeable silty clay soils.

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.8 Culvert #35 (Port Robinson Road Sta. 9+704)

In general, the site is underlain by topsoil, a flexible pavement, fill material (sandy gravel, silty sand and silty clay) and native overburden deposits of silty clay, silt and clayey silt.

5.8.1 Topsoil

Topsoil ranging in thickness from 150 mm to 180 mm was encountered. Topsoil thickness may vary between and beyond the boreholes.

5.8.2 Flexible Pavement

A flexible pavement structure consisting of 110 mm of asphalt and 410 mm of gravelly sand was encountered in Borehole C11-2.

The grain size distribution plot of a tested sample of the granular fill is depicted in Figure B8-1. The result shows a grain size distribution consisting of 26% gravel, 58% sand, and 16% silt and clay size particles.

A Standard Penetration test in this fill gave an 'N' value of 83 blows for 0.3 m penetration indicating a very dense relative density. The moisture content of a sample of this fill was 5% by weight.



5.8.3 Fill – Sandy Gravel

A layer of sandy gravel fill was encountered in Borehole C11-1 extending to a depth of 2.1 m (Elev. ± 175.8 m) below ground surface.

A Standard Penetration test in this fill gave an 'N' value of 100 blows for less than 0.3 m penetration. Based on this result the fill is considered to have a very dense relative density. The moisture content of a sample of this fill was 10% by weight.

5.8.4 Fill – Silty Sand

Fill material consisting of silty sand with some organics was encountered in Test Pit TP 11-1 dug near the outlet of the existing culvert. This fill material is approximately 180 mm thick.

5.8.5 Fill – Silty Clay

Silty clay fill was encountered in all of the boreholes extending to depths ranging from 0.7 m to 2.1 m below ground surface or to elevations ranging from ± 178.4 m to ± 176.7 m.

The grain size distribution curves of two representative samples from this fill are shown in Figure B8-2. The results show grain size distributions consisting of 4-28% gravel, 6-21% sand, 25-44% silt and 26-46% clay size particles.

Samples of the silty clay fill were also subjected to Atterberg Limits testing and the results are plotted on the plasticity chart in Figure B8-3. The summarized index values from these tests are presented below.

Liquid Limit:	37-47%
Plastic Limit:	18-23%
Plasticity Index:	19-24%
Natural Moisture Content:	15-18%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in this fill gave 'N' values ranging from 5 to in excess of 100 blows for 0.3 m penetration. Based on these results the fill is considered to have a firm to hard consistency. The moisture content of samples of this fill ranged from 15% to 27% by weight.

5.8.6 Silty Clay

A silty clay stratum was encountered across the site. This deposit extends to depths ranging from 14.0 m to 15.5 m below ground surface or to elevations ranging from ± 164.3 m to ± 163.6 m.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B8-4 and B8-5. These results show a grain size distribution consisting of 0% gravel, 0-5% sand, 49-68% silt and 31-50% clay size particles.



Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B8-6 and B8-7. The index values from these tests are summarized below:

Liquid Limit:	29-42%
Plastic Limit:	15-22%
Plasticity Index:	13-23%
Natural Moisture Content:	19-32%

These values indicate that the silty clay has a generally low to intermediate plasticity.

The Atterberg Limits test results are plotted against elevation, Figure B8-11. These results illustrate that the natural moisture contents are generally at or close to the plastic limit down to about Elev. ± 175.0 m. Below Elev. ± 175.0 m the data generally indicates a trend of increasing moisture content with depth with values generally plotting between the plastic and liquid limits.

Standard Penetration tests in this stratum gave 'N' values that ranged widely from 0 to 55 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 28 kPa to in excess of 120 kPa and a laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 42 kPa. These values indicate that the consistency of the silty clay is generally firm to hard. The moisture content of samples from this stratum ranged from 19% to 46% by weight and the unit weight of a tested sample was 20.8 kN/m³.

The variation of undrained shear strength with elevation is depicted in Figure B8-12. An interpreted dashed line representing a lower bound trend with depth for the data is shown on this plot. The upper portion of this deposit down to about Elev. ± 171.0 m is estimated to have relatively high shear strength i.e. in excess of 100 kPa. Below Elev. ± 171.0 m the undrained shear strength decreases with depth and is about 35 kPa from Elev. ± 168.0 m to Elev. ± 167.0 m. Below Elev. ± 167.0 m the trend indicates increasing undrained shear strength with depth.

A consolidation test was also performed on a Shelby tube sample retrieved from Borehole C11-3 and the results are presented in Figures B8-13 to B8-15 inclusive. The preconsolidation pressure was estimated from the e-log p curve. Due to the rounded nature of the curve the preconsolidation pressure was also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.

Borehole/Sample No.	Sample Depth/Elevation (m)	P _c (kPa)	C _c	C _r	e _o
C11-3 TW11	10.7/168.4	270 – 390	0.309	0.033	0.77

Where: P_c = Preconsolidation pressure
C_c = Compression index
C_r = Recompression index
e_o = Initial void ratio



5.8.7 Silt

Silt approximately 1.5 m to 4.2 m thick was encountered in all of the boreholes extending to depths ranging from 17.0 m (Elev. ± 162.1 m) to 18.9 m (Elev. ± 160.1 m) below ground surface.

The grain size distribution plot of a tested sample of the silt is presented in Figure B8-8. The result shows a grain size distribution consisting of 1% gravel, 5% sand, 77% silt and 17% clay size particles. Based on visual and tactile examinations of the retrieved samples, the unit is essentially a cohesionless silt with frequent cohesive silty clay seams and partings.

Standard Penetration tests in this deposit gave 'N' values that ranged from 0 to 16 blows per 0.3 m penetration. Based on these results the deposit is considered to have a very loose to compact relative density. The moisture content of samples from this soil ranged from 18% to 27% by weight.

5.8.8 Clayey Silt

All of the boreholes were terminated in a clayey silt deposit at depths ranging from 18.8 m (Elev. ± 159.1 m) to 23.4 m (Elev. ± 155.6 m) below ground surface.

The grain size distribution plots of samples retrieved from this deposit are presented in Figure B8-9. These results show a grain size distribution consisting of 0% gravel, 0-1% sand, 83-86% silt and 14-16% clay size particles.

Samples from this stratum were also subjected to Atterberg Limits tests and the results are presented in Figure B8-10. The index values from these tests are summarized below:

Liquid Limit:	23%
Plastic Limit:	17%
Plasticity Index:	6%
Natural Moisture Content:	18-20%

These values are characteristic of clayey silt soils of low plasticity.

Standard Penetration tests in this deposit yielded 'N' values ranging from 6 to 59 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 96 kPa to in excess of 100 kPa. Based on these results, the clayey silt is considered to have a generally stiff to hard consistency with occasional firm zones. The moisture content of samples from this deposit ranged from 13% to 25% by weight.

5.8.9 Water Levels

Standpipe piezometers were installed in selected boreholes and water level readings were taken on separate visits made after the completion of drilling. The water level records are presented in Table 5.8.1.



Table 5.8.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C11-1	July 12, 2010	4.5	173.4
	July 19, 2010	4.4	173.5
C11-3	July 19, 2010	5.1	174.0
	July 26, 2010	3.5	175.6
	August 06, 2010	2.0	177.1
	August 13, 2010	1.9	177.2

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at Elev. ± 177.0 m. Perched water can also be expected to occur where relatively permeable soils are underlain by more impermeable silty clay soils.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.9 Culvert #49 (Highway 406 NBL Sta. 5+839)

In general, the site is underlain by topsoil, a flexible pavement, silty clay fill and native overburden deposits of silty clay, silt and clayey silt.

5.9.1 Topsoil

A layer of topsoil approximately 200 mm to 330 mm thick was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.9.2 Flexible Pavement

Borehole C12-1 was drilled through the partially paved shoulder of Highway 406 and encountered 130 mm of asphalt underlain by 180 mm of sandy gravel. The sandy gravel fill extends to a depth of 0.3 m (Elev. ± 181.0 m) below ground surface. The moisture content of a sample of this fill was 3% by weight.

5.9.3 Fill – Silty Clay

Silty clay fill was encountered at this site extending to depths of 1.4 m (Elev. ± 178.4 m) and 2.1 m (Elev. ± 179.2 m) below ground surface.

The grain size distribution curves of two samples of this fill are shown in Figure B9-1. The results show grain size distributions consisting of 2-28% gravel, 8-16% sand, 28-41% silt and 28-49% clay size particles.

Samples of the silty clay fill were also subjected to Atterberg Limits testing and the results are plotted on the plasticity chart in Figure B9-2. The summarized index values from these tests are presented below.



Liquid Limit:	39-53%
Plastic Limit:	20-24%
Plasticity Index:	19-29%
Natural Moisture Content:	17-19%

These values are characteristic of clayey soils of intermediate to high plasticity.

Standard Penetration tests in this fill gave 'N' values ranging from 3 to 22 blows for 0.3 m penetration. Based on these results the fill is considered to have a soft to very stiff consistency. The moisture content of samples of this fill ranged from 17% to 34% by weight.

5.9.4 Silty Clay

Silty clay deposits were encountered in all of the boreholes. An upper silty clay stratum was encountered extending to depths ranging from 15.2 m to 16.2 m below ground surface or to elevations ranging from ± 165.1 m to ± 163.6 m. A lower silty clay deposit was encountered across the site extending at least to borehole termination depths ranging from 20.3 m to 21.8 m below ground surface corresponding to elevations of ± 159.5 m.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B9-3 and B9-4. These results show a grain size distribution consisting of 0-4% gravel, 0-4% sand, 19-77% silt and 22-80% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B9-5 and B9-6. The index values from these tests are summarized below:

Liquid Limit:	25-61%
Plastic Limit:	14-26%
Plasticity Index:	9-35%
Natural Moisture Content:	17-47%

These values indicate that the silty clay has a generally low to intermediate plasticity with infrequent zones of high plasticity clay inclusions.

Standard Penetration tests in these deposits gave 'N' values that ranged widely from 0 to 52 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths ranging from 48 kPa to in excess of 100 kPa. A laboratory vane test on a relatively undisturbed Shelby tube sample gave an undrained shear strength of 99 kPa. These values indicate that the consistency of the silty clay is generally firm to hard. The moisture content of samples of the silty clay ranged from 17% to 47% by weight and the unit weight of a tested sample was 21.1 kN/m³.

Consolidation tests were also performed on a Shelby tube sample retrieved from Borehole C12-3 and the results are presented in Figures B9-10 to B9-12 inclusive. The preconsolidation pressure was estimated from the e-log p curves. Due to the rounded nature of the curve the preconsolidation pressure was also assessed based on the 'Work' – method proposed by Becker et al. (1987). The details of the test results are summarized below.



Borehole/Sample No.	Sample Depth/Elevation (m)	P _c (kPa)	C _c	C _r	e _o
C12-3 TW7	4.6/175.2	250 – 430	0.255	0.049	0.66

Where: P_c = Preconsolidation pressure
C_c = Compression index
C_r = Recompression index
e_o = Initial void ratio

5.9.5 Silt

Silt approximately 1.6 m to 4.1 m thick was encountered at this site extending to depths ranging from 17.8 m (Elev. ±162.0 m) to 20.3 m (Elev. ±161.0 m) below ground surface.

The grain size distribution plot of a tested sample of the silt is presented in Figure B9-7. The result shows a grain size distribution consisting of 0% gravel, 0% sand, 93% silt and 7% clay size particles. Based on visual and tactile examinations of the retrieved samples, the unit is essentially a cohesionless silt with frequent cohesive silty clay seams and partings.

Standard Penetration tests in this deposit gave 'N' values that ranged from 0 to 16 blows per 0.3 m penetration indicating a very loose to compact relative density. The moisture content of samples of this soil ranged from 21% to 28% by weight.

5.9.6 Clayey Silt

A 1.5 m thick deposit of clayey silt was encountered in Borehole C12-3 where it extends to a depth of 13.2 m (Elev. ±166.6 m) below ground surface.

The grain size distribution plot of a sample retrieved from this deposit is presented in Figure B9-8. The results show a grain size distribution consisting of 0% gravel, 0% sand, 87% silt and 13% clay size particles.

A sample from this stratum was also subjected to Atterberg Limits tests and the results are presented in Figure B9-9. The index values from these tests are summarized below:

Liquid Limit:	22%
Plastic Limit:	18%
Plasticity Index:	4%
Natural Moisture Content:	24%

These values are characteristic of clayey silt soils of low plasticity.

A Standard Penetration test in this deposit yielded an 'N' value of 17 blows for 0.3 m penetration and a field vane test performed in this deposit gave in-situ undrained shear strength of 104 kPa. Based on these results, the clayey silt is considered to have a generally very stiff consistency. The moisture content of a sample of the clayey silt was 24% by weight.



5.9.7 Water Levels

Standpipe piezometers were installed in selected boreholes and water level readings were measured on separate visits made after the completion of drilling. The water level records are presented in Table 5.9.1.

Table 5.9.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
C12-2	July 20, 2010	4.5	175.3
	July 26, 2010	3.7	176.1
	August 06, 2010	2.7	177.1
	August 13, 2010	2.7	177.1
C12-3	July 20, 2010	2.8	177.0
	July 28, 2010	2.8	177.0

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to exist at about Elev. ± 177.0 m. Perched water can also be expected to occur where relatively permeable soils are underlain by more impermeable silty clay soils.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level will also be controlled by the free water level in the existing water course.

5.10 Miscellaneous

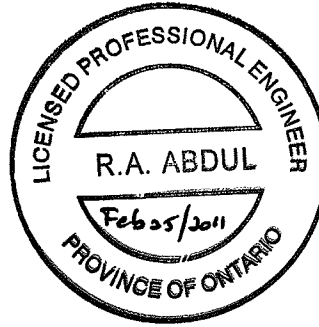
The drilling, sampling and in-situ testing operations were conducted with track and truck mounted drill rigs owned and operated by Groundworks Drilling Limited of Toronto, Ontario, DBW Drilling Limited of Ajax, Ontario, Determination Drilling & Soil Investigations of Hamilton, Ontario, Strong Soil Search Inc. of Claremont, Ontario, and Kodiak Drilling of Oakville, Ontario. The boreholes were advanced using both solid stem and hollow-stem auger drilling techniques.

Messrs. Phil Khuu, B.A.T., Alexander Winkelmann, E.I.T., Lucas Yu, E.I.T., and Brady Lin, P.Eng. observed and recorded the field work. The laboratory testing was performed at Terraprobe's Brampton laboratory and the Mississauga laboratory of Golder Associates. The report was written by Rehman Abdul, P.Eng. and reviewed by Michael Tanos, P.Eng.



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Review Principal



FOUNDATION DESIGN REPORT
CULVERTS & CULVERT EXTENSIONS
HIGHWAY 406 TWINNING
ONTARIO
AGREEMENT No. 2008-E-0016, W.P. 280-99-00, SITE:
GEOCRES No. 30M3-269
PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 DISCUSSION AND RECOMMENDATIONS

6.1 General

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to design suitable culvert extensions and culvert replacements as appropriate. The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

For the design of new culverts and culvert extensions, an economic analysis usually includes factors such as construction cost, estimated service life, maintenance cost, replacement cost, risk of failure and risk of property damage. Fish passage is also an important factor that affects the choice of culvert type.

The most economical culvert is neither the one with the lowest initial cost nor the culvert with the longest service life. Short and long term costs should be considered in both original designs and in repairs or replacements. In the case of culvert extensions the existing structure to be extended usually influences the type of extension culvert that is selected. Normally where weak foundation soils and/or settlement sensitive soils exist (as encountered on this project) closed bottom concrete culverts or pipe culverts provide better solutions. A comparison of the foundation alternatives is presented in Appendix E.

The material choice includes steel, concrete, high density polyethylene and polyvinyl chloride. Some of the factors to consider when choosing the material type include:

- Steel and plastic have the advantage of simpler and quicker construction, especially in remote areas. Steel also has the added advantage of often being at least partly salvageable.
- A well designed concrete culvert is extremely durable under a wide range of conditions.
- Precast concrete and smooth walled plastic pipes provide more efficient inlets than sharp edged inlets on metal culverts.
- The greater roughness of corrugated interiors may be an advantage for fish passage and for other situations where barrel or outlet velocities must be reduced.



- Flexible pipe culverts may have an advantage over concrete box culverts in certain unfavourable foundation soil conditions.

The design details at each site are outlined below.

Culvert #2: Sta. 10+307 (Highway 406). A new 1800 x900 culvert measuring approximately 29 m in length is proposed. Based on a design culvert invert of Elev. 180.9 the maximum height of the embankment fill above the culvert invert will be about ± 3 m. The current ground surface is above the culvert invert requiring up to ± 3 m of excavations below existing ground surface.

Culvert #5: Sta. 10+777 (Highway 406). An existing 1,850x1,250 concrete culvert that will be extended easterly below Highway 406 NBL a distance of about 11.5 m. Based on a design culvert invert of Elev. 180.5 m the maximum height of the embankment fill above the culvert invert will be about ± 2.5 m. The current ground surface is above the culvert invert requiring up to ± 3.5 m of excavations below existing ground surface.

Culvert #6: Sta. 11+499 (Highway 406). An existing 2,450 x 1,250 concrete culvert that will be extended easterly below Highway 406 NBL a distance of about 34 m. Based on a design culvert invert of Elev. 186.6 m the maximum height of the embankment fill above the culvert invert will be about ± 4.5 m.

Culvert #8: Sta. 12+338 (Highway 406). A new 3,000 x 1,800 culvert measuring approximately 139 m in length is proposed at this site. The culvert will be located below the Ramp Woodlawn EW-406S, Highway 406 NBL and SBL and Ramp 406S – Woodlawn EW. Based on a design culvert invert of Elev. 179 m the maximum height of the embankment fill above the culvert invert will be about ± 13 m. Since the current ground surface is above the culvert invert, excavations below the existing Highway 406 will be about ± 5.5 m deep. Excavations outside of the footprint area of the existing highway will be about ± 1.5 m deep.

Culvert #9: Sta. 12+476 (Highway 406). A new 1,800 x 900 culvert measuring approximately 160 m in length is proposed at this site. The culvert will be located below the Ramp Woodlawn EW-406S, Highway 406 NBL and SBL and Ramp 406S – Woodlawn EW. Based on a design culvert invert of about Elev. 181.5 m the maximum height of the embankment fill above the culvert invert will be about ± 11.5 m. Since the current ground surface is above the culvert invert, excavations below the existing Highway 406 will be about ± 2.5 m deep. Excavation depths outside of the footprint area of the existing highway will range from about ± 0.5 m to ± 1 m.

Culvert #24: Sta. 14+152 (Highway 406). An existing 2,000 x 1,250 concrete culvert that will be extended easterly below Highway 406 NBL a distance of about 26 m. Based on a design culvert invert of Elev. 172.3 m the maximum height of the embankment fill above the culvert invert will be about ± 6.5 m. The current ground surface is above the culvert invert requiring up to ± 1.5 m of excavations below existing ground surface.



Culvert #48: Sta. 15+712 on Highway 406 alignment. An existing 3,650 x 2,520 concrete culvert that will be extended westerly below Highway 406 SBL a distance of about 35 m. Based on a design culvert invert of Elev. 176.4 m the maximum height of the embankment fill above the culvert invert will be about ± 5.5 m.

Culvert #35: Sta. 9+710 (Port Robinson Road). A new 3,000 x 4,000 culvert measuring approximately 33 m in length is proposed at this site. The culvert will be located below Port Robinson Road and based on a design culvert invert of Elev. 175.5 m the maximum height of the embankment fill above the culvert invert will be about 5.0 m. Since the current ground surface is above the culvert invert, excavations below Port Robinson Road will be about ± 3.5 m deep. Twin 2,500 mm diameter CSP culverts currently exist at this site and will be extended.

Culvert #49: Sta. 5+839 (Highway 406). A new 1800 x 1,200 culvert measuring approximately 33 m in length is proposed at this site. The culvert will be located below Highway 406 NBL and based on a design culvert invert of Elev. 179.7 m the maximum height of the embankment fill above the culvert invert will be about ± 2.0 m.

7 STRUCTURE FOUNDATIONS

Based on the subsurface stratigraphy encountered at the sites and the proposed design culvert inverts, the recommended founding depths and geotechnical resistances for a structure (culvert replacements and extensions) founded on undisturbed competent natural soils are tabulated below.

Table 7.1 – Geotechnical Resistances (Culvert # 2)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC2 – 1	183.3 \pm	± 2.1 to ± 4.3	181.2 – 179.0	180*	100	Silty Clay
BHC2 – 2	181.7 \pm	± 0.7 to ± 4.2	181.0 – 177.5	180*	100	Silty Clay
BHC2 – 3	181.6 \pm	± 0.7 to ± 3.6	180.9 – 178.0	180*	100	Fill - Silty Clay
Assumes a minimum footing width of 1.8 m and a ground water table at the footing level. Silty Clay fill material may be encountered at culvert invert. Soft/weak soils if encountered must be removed and replaced with Granular "A" compacted to 95% SPMD.						

Table 7.2 – Geotechnical Resistances (Culvert # 5)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC3 – 1	183.2 \pm	± 2.1 to ± 9.5	181.1 – 173.7	180	125	Silty Clay
BHC3 – 2	183.8 \pm	± 2.1 to ± 10.1	181.7 – 173.7	180	125	Silty Clay
Assumes a minimum footing width of 1 m and a ground water table at the footing level.						



Table 7.3 – Geotechnical Resistances (Culvert # 6)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC5 – 1	190.4±	Below ±3.8	Below 186.6	150	N/A*	Fill – Silty Clay
BHC5 – 2	187.2±	Below ±0.6	Below 186.6	150	N/A*	Fill – Silty Clay

Assumes a minimum footing width of 1 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.
 Soft/weak soils if encountered must be removed and replaced with Granular "A" compacted to 95% SPMDD.

Table 7.4 – Geotechnical Resistances (Culvert # 8)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC6 – 1	179.2±	Below ±0.2	Below 179.0	300	N/A*	Silty Clay
BH S-EW 10+025Rt.	183.6±	Below ±4.6	Below 179.0	300	N/A*	Silty Clay
BH WE-S 10+360Lt.	183.4±	Below ±4.4	Below 179.0	300	N/A*	Silty Clay
BHC6 – 2	183.5±	Below ±4.5	Below 179.0	300	N/A*	Silty Clay

Assumes a minimum footing width of 1 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.

Table 7.5 – Geotechnical Resistances (Culvert # 9)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC7 – 1	181.0±	Below ±0.1	Below 180.9	300	N/A*	Silty Clay
BHC7 – 2	181.5±	Below ±0.7	Below 180.8	300	N/A*	Silty Clay
BHC7 – 3	182.4±	Below ±0.9	Below 181.5	300	N/A*	Silty Clay
BHC7 – 4	182.0±	Below ±0.5	Below 181.5	300	N/A*	Silty Clay

Assumes a minimum footing width of 1.8 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.
 Weak silty clay fill may be encountered in the excavations. We recommend removing these soils (approximately 600 mm thick) and replacing with Granular "A" compacted to 95% SPMDD.



Table 7.6 – Geotechnical Resistances (Culvert # 24)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC9 – 1	174.9±	Below ±2.6	Below 172.3	175	N/A*	Silty Clay
BHC9 – 2	176.0±	Below ±3.7	Below 172.3	175	N/A*	Silt some Clay

Assumes a minimum footing width of 2 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.
 Silt soils will be easily disturbed if encountered in the excavations. We recommend removing these soils (approximately 400 mm thick) and replacing with Granular "A" compacted to 95% SPMDD.

Table 7.7 – Geotechnical Resistances (Culvert # 48)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC10 – 1	177.1±	Below ±0.7	Below 176.4	250	N/A*	Silty Clay
BHC10 – 2	181.7±	Below ±5.6	Below 176.1	250	N/A*	Silty Clay
BHC10 – 3	178.5±	Below ±2.1	Below 176.4	250	N/A*	Silty Clay

Assumes a minimum footing width of 3.6 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.
 Weak silty clay fill may be encountered in the excavations. We recommend removing these soils (approximately 300 mm thick) and replacing with Granular "A" compacted to 95% SPMDD.

Table 7.8 – Geotechnical Resistances (Culvert # 35)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC11 – 1	177.9±	±2.4	175.5	225	150	Silty Clay
BHC11 – 2	179.0±	±3.5	175.5	225	150	Silty Clay
BHC11 – 3	179.1±	±3.6	175.5	225	150	Silty Clay

Assumes a minimum footing width of 3.6 m and a ground water table at the footing level.



Table 7.9 – Geotechnical Resistances (Culvert # 49)

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
BHC12 – 1	181.3±	±2.1	Below 179.2	225	N/A*	Silty Clay
BHC12 – 2	179.8±	±0.8	Below 179.0	225	N/A*	Fill – Silty Clay
BHC12 – 3	179.8±	±0.2	Below 179.6	225	N/A*	Silty Clay

Assumes a minimum footing width of 1.0 m and a ground water table at the footing level.
 * Settlement will be greater than 25 mm and a geotechnical resistance for 25 mm settlement is not provided. Culvert to be designed with camber to accommodate settlement.
 Weak silty clay fill may be encountered in the excavations. We recommend removing these soils (approximately 500 mm thick) and replacing with Granular "A" compacted to 95% SPMDD.

These values are for vertical, concentric loads only. Effects of load inclination and eccentricity should be taken into account as illustrated in CHBDC 2006, Clause 6.7.3 and Clause 6.7.4. Where SLS values are provided, they correspond to a settlement of up to 25 mm and therefore a culvert camber is not required at these sites.

It is recommended that the bedding material be placed expeditiously to avoid disturbance of the foundation bearing surfaces. If this cannot be accomplished then we recommend an allowance be made to pour a 150 mm thick layer of lean concrete (mud mat) on the foundation bearing surfaces as soon as possible after excavation and approval.

Resistance to lateral forces/sliding resistance between the concrete footing and the subgrade soils should be evaluated in accordance with the CHBDC 2006. Assume an ultimate coefficient of friction of 0.5 for the stiff silty clay and 0.7 for Granular 'A'.

The design frost depth at this site is a minimum of 1.2 m of earth cover.

8 LATERAL EARTH PRESSURE

Earth pressures acting on the structure should be computed in accordance with Clause 6.9 of the CHBDC but generally are given by the expression:

$$P_h = K(\gamma h + q)$$

P_h = horizontal pressure on the wall (kPa)

K = earth pressure coefficient (see Table 11.1)

γ = unit weight of retained soil (see Table 11.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I or at a depth of 2.0 m for Granular A or Granular B Type II.



Earth pressure coefficients for backfill to the culvert and wing walls are dependent on the material used as backfill. Typical values are given in Table 8.1.

Table 8.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40*	0.30	0.48*
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.70	-	3.30	-

* For wing walls.

The factors in the table above are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the CHBDC, 2006.

9 EXCAVATION

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the soil classifications for various sites are provided in the following table. Excavations above the ground water table may be sloped at 2H:1V. Below the ground water table excavations may be sloped at 3H:1V or flatter. Excavations should be undertaken in accordance with OPSS 902.

Stratum	OHSa Soil Classification
Culvert 2	
Fill – Sandy Gravel	Type 3 soils above the water table.
Fill – Silty Clay	Type 3 soils above the water table and Type 4 soils below the water table.
Silty Clay	Type 3 soils above and below the water table.
Silty Clay Till	Type 4 soils below the water table.
Culvert 5	
Fill – Sand and Gravel	Type 2 soils above the water table.
Fill – Silty Clay	Type 3 soils above the water table and Type 4 soils below the water table.
Silty Clay	Type 3 soils above and below the water table.
Silty Clay Till	Type 3 soils below the water table.
Culvert 6	
Fill – Sand and Gravel	Type 3 soils above the water table.
Fill – Silty Clay	Type 2 soils above the water table and Type 4 soils below the water table.
Silty Clay	Type 3 soils above and below the water table.
Silty Clay Till	Type 1 soil below the water table.
Culvert 8	
Fill – Silty Clay	Type 2 soils above the water table and Type 3 soils below the water table.
Silty Clay	Type 3 soils above and below the water table.
Silty Clay to Clayey Silt Till	Type 1 soils below the water table.
Culvert 9	
Fill – Silty Clay	Type 3 soils above and below the water table.
Silty Clay	Type 3 soils above and below the water table.
Clayey Silt to Silty Clay Till	Type 2 soils below the water table.



Stratum	OHSO Soil Classification
Culvert 24	
Silty Clay	Type 3 soils above and below the water table.
Silt	Type 3 soils below the water table.
Culvert 48	
Fill – Gravelly Sand	Type 3 soils above the water table.
Fill – Silty Clay	Type 4 soils above and below the water table.
Silty Clay	Type 3 soils above and below the water table.
Silt	Type 4 soils below the water table.
Culvert 35	
Fill – Silty Clay	Type 3 soils above the water table.
Fill – Sandy Gravel to Gravelly Sand	Type 1 soils above the water table.
Silty Clay	Type 3 soils above and below the water table.
Silt	Type 4 soils below the water table.
Clayey Silt	Type 3 soils above and below the water table.
Culvert 49	
Fill – Sandy Gravel	Type 3 soils above the water table.
Fill – Silty Clay	Type 3 soils above the water table and Type 4 soils below the water table.
Silty Clay	Type 3 soils below the water table.
Silt	Type 4 soils below the water table.
Clayey Silt	Type 2 soils below the water table.

Where workers must enter excavations extending deeper than 1.2 m, the trench walls must be suitably sloped and/or braced in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects.

10 GROUND WATER CONTROL

The ground water level is at or just below ground surface at the sites. We recommend temporarily diverting the flow of water away from the construction area as per OPSD 221.010 or OPSD 221.030 as appropriate so that construction will proceed in sufficiently dry conditions. An interceptor perimeter trench is also recommended to prevent water from entering the excavations.

The design of the unwatering system should be the responsibility of the Contractor. However, a suitable system that might be employed would be gravity drainage and pumping from strategically placed filtered sumps.

A Permit to Take Water (PTTW) for ground water control will most likely not be required in areas where the excavations are either above the water table or are made within the low permeability silty clay soils. However, a PTTW is required for any water taking if the volume exceeds 50,000 L/day. The rate and volume required for dewatering will be dependent on the construction methods and staging chosen by the contractor.

Any accumulation of water from the base of the excavation should be removed prior to culvert installation or compacting granular fill. Culvert installation or compacting engineered fill must be done in the dry.



The estimated range of hydraulic conductivities³ of the various soil types are provided below.

- Fill – Sandy Gravel to Gravelly Sand 10^{-2} to 10^{-3} m/s
- Fill – Silty Clay 10^{-8} to 10^{-9} m/s
- Silty Clay to Clayey Silt 10^{-9} to 10^{-11} m/s
- Silt 10^{-7} to 10^{-8} m/s
- Till – Silty Clay to Clayey Silt 10^{-10} to 10^{-11} m/s

11 EMBANKMENT STABILITY

In the Niagara area embankments constructed with cohesive earth fill at conventional 2H:1V slopes have historically performed below par. Shallow surficial failures usually occur on the face of these slopes thereby requiring frequent maintenance in order to prevent more significant deep-seated failures.

Recent studies conducted by the Ministry of Transport indicate that these shallow surficial failures occur because of the mineralogy of the local soils and its inherent effect on the effective shear strength of the local clay fill. Poor performance was also attributed to climatic effects including precipitation, wetting and drying cycles, snow melt and freezing and thawing cycles.

The historical performance of existing embankments in the area was considered when selecting embankment design side slopes for this project. The global, internal and surficial stability of the embankments will depend on their slope geometries and also to a large degree on the material used to construct the embankment. For the purpose of embankment stability analyses, the commercially available slope stability program Slide 5.0 developed by Rocscience Inc. was used.

The Spencer, Janbu and Bishop's simplified method for stability analysis were employed and a minimum target factor of safety of 1.3 was established. Stability analyses were conducted at sites where the embankment height exceeds 4 m. Tabulated below are the soil parameters used for the slope stability analyses and the factors of safety that were obtained. Within the footprint area of the culvert the factors of safety will be higher since the analyses neglected the culvert's existence.

Culvert 6						
Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ' (degrees)	c' (kPa)	γ (kN/m ³)
Embankment Fill	31	0	19	31	0	19
Fill – Silty Clay	0	60	19	28	0	19
Upper Silty Clay	0	100	20	28	5	20
Lower Silty Clay	0	30	20	28	5	20
Silty Clay Till	0	200	21	28	5	21
Design Factors of Safety	1.8 to 1.9			1.6 to 1.7		

³ Freeze, R, & Cherry, J. (1979) "Groundwater", (pp 29), Prentice-Hall, Inc.



Culvert 8						
Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ' (degrees)	c' (kPa)	γ (kN/m ³)
Embankment Fill (SSM)	32	0	20	32	0	20
Fill – Silty Clay	0	80	19	28	0	19
Silty Clay	0	80	20	28	5	20
Silty Clay Till	0	200	21	28	5	21
Design Factors of Safety	1.5 to 1.7			1.5 to 1.7		

Culvert 9						
Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ' (degrees)	c' (kPa)	γ (kN/m ³)
Embankment Fill	31	0	19	31	0	19
Upper Silty Clay	0	150	20	28	5	20
Lower Silty Clay	0	70	20	28	5	20
Silty Clay Till	0	150	21	28	5	21
Design Factors of Safety	1.7 to 2.0			1.7 to 2.0		

Culvert 24						
Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ' (degrees)	c' (kPa)	γ (kN/m ³)
Embankment Fill	31	0	19	31	0	19
Upper Silty Clay	0	30	20	28	5	20
Silt	30	0	19	30	0	19
Lower Silty Clay	0	40	20	28	5	20
Design Factors of Safety	1.6 to 1.7			1.5 to 1.7		

Culvert 48						
Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ' (degrees)	c' (kPa)	γ (kN/m ³)
Embankment Fill	31	0	19	31	0	19
Upper Silty Clay	0	100	20	28	5	20
Middle Silty Clay	0	30	20	28	5	20
Silt	30	0	19	30	0	19
Lower Silty Clay	0	75	20	28	5	20
Design Factors of Safety	2.0 to 2.1			2.0 to 2.3		

For the undrained (short-term) analyses, the measured field vane results were corrected by applying a vane shear correction factor intended to compensate for pore-pressure and shearing-rate effects during field testing. The correction factor was derived in accordance with Morris and Williams (1994).

In our analysis we incorporated a 2 m wide mid-height berm for earth fill embankment heights equal to or greater than 8 m. Where earth fill embankments are higher than 8 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive drainage to shed run-off water.



Our analyses indicate that the factors of safety will be greater than the target factor of safety of 1.3. The slope stability models depicting the corresponding factors of safety are provided in Appendix D.

Since the culvert sites are classified as Seismic Performance Zone 1, seismic stability analysis is not required as per Clause 4.6 of the CHBDC 2006.

12 SETTLEMENT

To predict the magnitude and time rate of settlement of the underlying silty clay soils the commercially available program Settle 3D developed by Rocscience Inc. was used. The deformation parameters used for the analyses were established from data obtained from consolidation tests as well as from predictions/empirical correlations using undrained shear strengths, laboratory index tests and soil moisture contents.

Settlement analyses were carried out at selected culvert sites where the embankment loads will trigger more than 25 mm settlement in the underlying soils. Because of the trapezoidal embankment geometry, settlement will be highest where the embankment fill attains its maximum height and will be lower where the fill heights are minimal and therefore culvert cambers will be required at these locations.

At some sites the overburden soils in the footprint area of the culvert will be excavated. Hence, the net applied load (due to the additional fill height above existing grade) was considered when predicting settlements at these sites.

The parameters used for the settlement calculations are provided in the following tables. There is a wide scatter in the data and a slight variation of P_c with depth. Therefore the tabulated data represents the range of values for the upper and lower silty clay strata. The settlements at selected locations along the culvert alignment are also provided.

Culvert 6 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	600 to 450 500 to 350	450 to 350
Coefficient of Compressibility - C_c	0.20 to 0.25	0.20 to 0.25
Recompression Index - C_r	0.03 to 0.037	0.03 to 0.037
Initial Void Ratio - e_o	0.75 to 0.60	0.75 to 0.60
Coefficient of Consolidation - C_v (m^2/s)	4.0x10 ⁻⁷ to 8.0x10 ⁻⁷	

Culvert 8 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	500 to 450 435 to 400	450 to 300 400 to 300
Coefficient of Compressibility - C_c	0.20 to 0.22	0.15 to 0.18
Recompression Index - C_r	0.030	0.02 to 0.025
Initial Void Ratio - e_o	0.9	0.7
Coefficient of Consolidation - C_v (m^2/s)	2.8x10 ⁻⁶ to 1.1x10 ⁻⁶	



Culvert 9 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	575 to 450 480 to 400	450 to 300 400 to 300
Coefficient of Compressibility - C_c	0.22	0.16 to 0.19
Recompression Index - C_r	0.030	0.025 to 0.03
Initial Void Ratio - e_o	0.8	0.7 to 0.58
Coefficient of Consolidation - C_v (m^2/s)	8.0×10^{-7} to 4.0×10^{-7}	

Culvert 24 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	600 to 280	280
Coefficient of Compressibility - C_c	0.25	0.16
Recompression Index - C_r	0.040	0.027
Initial Void Ratio - e_o	0.85	0.58
Coefficient of Consolidation - C_v (m^2/s)	8.0×10^{-7} to 4.0×10^{-7}	

Culvert 48 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	600 to 300	300
Coefficient of Compressibility - C_c	0.25	0.18
Recompression Index - C_r	0.030	0.030
Initial Void Ratio - e_o	0.80	0.80
Coefficient of Consolidation - C_v (m^2/s)	8.0×10^{-7} to 4.0×10^{-7}	

Culvert 49 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure Range - P_c (kPa)	570 to 400 470 to 300	400 300
Coefficient of Compressibility - C_c	0.22 to 0.26	0.22 to 0.26
Recompression Index - C_r	0.030 to 0.040	0.030 to 0.040
Initial Void Ratio - e_o	0.85	0.80 to 0.65
Coefficient of Consolidation - C_v (m^2/s)	8.0×10^{-7} to 4.0×10^{-7}	

Total Estimated Settlement Along Culvert Alignment – Culvert 6

Culvert 6						
Offset Distance (m)	0	5	10	15	20	30
Estimated Settlement (mm)	50	80	90	90	85	55

Total Estimated Settlement Along Culvert Alignment – Culvert 8

Culvert 8									
Offset Distance (m)	-60	-50	-40	-20	0	20	40	50	60
Estimated Settlement (mm)	40	75	105	110	100	65	75	65	30



Total Estimated Settlement Along Culvert Alignment – Culvert 9

Culvert 9														
Offset Distance (m)	-70	-60	-47	-40	-25	-15	0	15	25	40	50	57	65	75
Estimated Settlement (mm)	45	95	135	140	150	150	145	110	110	130	120	120	90	50

Total Estimated Settlement Along Culvert Alignment – Culvert 24

Culvert 24					
Offset Distance (m)	10	15	20	25	30
Estimated Settlement (mm)	25	35	45	50	40

Total Estimated Settlement Along Culvert Alignment – Culvert 48

Culvert 48					
Offset Distance (m)	-10	-20	-30	-35	-40
Estimated Settlement (mm)	30	90	85	75	55

Total Estimated Settlement Along Culvert Alignment – Culvert 49

Culvert 49							
Offset Distance (m)	-13	-10	-5	0	5	10	13
Estimated Settlement (mm)	45	60	70	70	70	60	45

It needs to be emphasized that where culvert extensions are proposed the settlement at the interface between the existing culvert and the proposed extension will translate into differential settlement. It is therefore imperative that this joint be designed to accommodate this settlement.

Alternatively, it may be preferable to install a temporary culvert extension (such as a CSP), preload the existing site by constructing the embankment around the temporary extension, wait for most of the settlement to be complete before returning to install the permanent culvert. The preloading periods for the various sites where this arrangement would be applicable are:

- Culvert 6 – approximately 50 mm of settlement at connection. Remaining post construction settlement after 3 months will be less than 25 mm.
- Culvert 24 – approximately 35 mm of settlement at connection. Remaining post construction settlement after 3 months will be less than 25 mm.
- Culvert 48 – approximately 30 mm of settlement at connection. Remaining post construction settlement after 3 months will be less than 25 mm.

Embankments comprised of local earth fill will also settle during construction (fill compression) and this settlement is expected to be about 1% of the fill height. The settlement of non-cohesive fill should be immediate in nature and essentially be complete shortly after construction is complete.



13 CULVERT BEDDING & BACKFILL

Backfill around the culvert should be carried out as per OPSD 803.010 (concrete culvert), OPSD 802.032 (Rigid Pipe) and OPSD 802.010 (Flexible Pipe) as appropriate and the backfill should consist of free-draining, non-frost susceptible granular materials in accordance with OPSS 1010. The excavated silty clay soils at these sites can be used for backfilling purposes provided they are free of organics and other deleterious material. These soils will also require moisture conditioning prior to their placement. All granular fill (meeting OPSS 1010 specifications) should be placed in loose lifts not exceeding 200 mm thick and be compacted to at least 95% of its SPMDD.

For fills below the ground water level or immediately below the roadway, it is recommended that Granular A material be used. Where necessary, proper tapering should be provided and the design should also incorporate a subdrain as shown in OPSD 3101.150.

Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. The height of the backfill to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with Special Provision 105S10 "Amendment to OPSS 501, February 1996". Backfilling operations should be undertaken in accordance with OPSS 902.

All disturbed or softened soils and deleterious material must be removed from the base of the excavation before bedding material is placed. At some sites it is anticipated that either the grade will be raised marginally or excavations will be required to remove poor/unsuitable soils. We recommend that the fill material in these areas consist of OPSS Granular "A" material.

Bedding material should consist of OPSS Granular "A" material. Additional bedding requirements that may be imposed by the supplier must also be followed. The bedding shall also be cambered (where required) to allow for settlement and in this regard the surface prepared to support the box units shall have a minimum 75 mm thick top levelling course consisting of either uncompacted Granular "A" or fine aggregate.

14 EMBANKMENT CONSTRUCTION

Materials used for embankment construction should be placed in lifts not exceeding 300 mm before compaction and each lift should be uniformly compacted to at least 95 % of the material's Standard Proctor Maximum Dry Density (SPMDD).

Borrow material must meet the requirements of OPSS 212, (2008). Embankment construction should be in accordance with OPSS 501 and OPSS 206. Benching between existing fill and new fill should be established by benching in accordance with OPSD 208.010

Proper erosion control measures should be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS 577 and



embankment slopes must be reinstated with permanent erosion protection in accordance with OPSS 511.

It is also imperative that the designs include provisions for preventing the flow of surface water down the face of slopes. Surface water must be directed to armoured outfalls/outlets designed to drain into roadside ditches.

Where earth fill embankments are higher than 8 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive drainage to shed run-off water.

15 EROSION PROTECTION

Erosion protection should be provided at the culvert inlets and outlets (including the slopes and sides). At the inlet area this could consist of a clay seal. The purpose of the clay seal is to ensure that water flow is channelled through the culvert and does not seep through the backfill around and underneath the structure. It should be ensured that the clay seal extends to cover all the granular backfill materials to prevent seepage through them. The clay seal should therefore be continuous around the culvert and have a minimum compacted thickness of 0.6 m and should extend at least 1 m above the high water level. The clay seal should be protected by a layer of rip-rap. The material used for the clay seal should conform to the requirements stipulated in OPSS 1205.

Alternatively, concrete cut-off and head walls can be constructed to protect the granular backfill and prevent seepage around the culvert.

Concrete cut-off and head walls can also be used to protect the granular fill around the culvert outlet against erosion. In this case, however, filtered erosion protection such as rip-rap should be provided along the channel and the sides beyond the concrete cut-off and head walls at the outlet.

Design of erosion protection schemes for the stream bed in the inlet and outlet areas will depend on hydrologic, hydraulic and/or other concerns. Typically, rip-rap protection should be provided to these areas. The rip-rap layer should cover all surfaces on the embankment slopes with which creek water is likely to be in contact.

The above recommendations are suggestions only. We recommend that a qualified Hydraulics Engineer be consulted to design the specifics of the channel, culvert outlet and inlet (i.e. thickness and extent of protection) and scour depth. Footings must also be placed below the scour depth.



16 TEMPORARY SHORING

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary shoring should be designed by a licensed Professional Engineer experienced in shoring design and should be in accordance with OPSS 539.

Earth pressure computations must also take into account the ground water level. Above the ground water level, earth pressure is computed using the bulk unit weight of the retained soil. Below the ground water level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

Earth pressures acting on the structure should be computed in accordance with Clause 6.9 of the CHBDC. The appropriate pressures can be computed from the expression:

$$P_h = K[\gamma(h - h_w) + (\gamma' h_w) + q] + h_w \gamma_w$$

P_h = horizontal pressure on the wall (kPa)

K = earth pressure coefficient (see Table 16.1)

γ = bulk unit weight of retained soil (see Table 16.1)

γ' = submerged unit weight of soil ($\gamma - \gamma_w$)

γ_w = unit weight of water (9.81 kN/m³)

h = depth below surface (m)

h_w = depth below the ground water level (m)

q = value of any surcharge (kPa)

If the shoring is internally braced at more than one level, then it is recommended that the design of the system be undertaken based on an earth pressure distribution consisting of a uniformly distributed pressure defined by the expression:

$$P = 0.65 K[\gamma h + q] + h_w \gamma_w$$

K = earth pressure coefficient (see Table 16.1)

γ = bulk unit weight of retained soil (see Table 16.1)

γ_w = unit weight of water (9.81 kN/m³)

h = depth below surface (m)

h_w = depth below the ground water level (m)

q = value of any surcharge (kPa)

The appropriate values of the parameters for use in the design of structures subject to unbalanced earth pressures are given in Table 16.1.

Table 16.1 – Earth Pressure Coefficients

Stratum	C_u	ϕ	γ	K_a	K_o	K_p
Culvert 2						
Fill – Sandy Gravel	N/A	30	19	0.33	0.50	3.00
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	75	28	20	0.36	0.53	2.77
Silty Clay Till	100	28	21	0.36	0.53	2.77



Stratum	C_u	ϕ	γ	K_a	K_o	K_p
Culvert 5						
Fill – Sand and Gravel	N/A	33	19	0.29	0.46	3.39
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	75	28	20	0.36	0.53	2.77
Silty Clay Till	100	28	21	0.36	0.53	2.77
Culvert 6						
Fill – Sand and Gravel	N/A	33	19	0.29	0.46	3.39
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	30	28	20	0.36	0.53	2.77
Silty Clay Till	200	28	21	0.36	0.53	2.77
Culvert 8						
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	80	28	20	0.36	0.53	2.77
Silty Clay to Clayey Silt Till	200	28	21	0.36	0.53	2.77
Culvert 9						
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	70	28	20	0.36	0.53	2.77
Clayey Silt to Silty Clay Till	150	28	21	0.36	0.53	2.77
Culvert 24						
Silty Clay	30	28	20	0.36	0.53	2.77
Silt	N/A	30	19	0.33	0.50	3.00
Culvert 48						
Fill – Gravelly Sand	N/A	32	19	0.31	0.47	3.25
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay	30	28	20	0.36	0.53	2.77
Silt	N/A	29	19	0.35	0.52	2.88
Culvert 35						
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Fill – Sandy Gravel to Gravelly Sand	N/A	35	19	0.27	0.43	3.69
Silty Clay	30	28	20	0.36	0.53	2.77
Silt	N/A	29	19	0.35	0.52	2.88
Clayey Silt	90	28	20	0.36	0.53	2.77
Culvert 49						
Fill – Sandy Gravel	N/A	30	19	0.33	0.50	3.00
Fill – Silty Clay	N/A	28	19	0.36	0.53	2.77
Silty Clay		28	20	0.36	0.53	2.77
Silt	N/A	29	19	0.35	0.52	2.88
Clayey Silt	100	28	20	0.36	0.53	2.77

The factors in the table above are “ultimate” values and require certain movements for the active and passive conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the CHBDC, 2006.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). In this case, the performance level should be Level 2 – Angular Distortion 1:200 but shall not be more than 25 mm. Where limited shoring movement (less than performance Level 1) is required, the design should be based on the at rest earth pressure coefficient (K_o). For “kick out” design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p).

For the design of temporary shoring in cohesive silty clay soils, the ultimate horizontal resistance can be estimated as $4c_u$, where c_u is the undrained shear strength of the silty clay in this zone. The undrained shear strength values to be used are provided in Table 16.1.



17 SEISMIC REQUIREMENTS

The site is treated as lying in Seismic Zone 0. Reference to Annex A3.1 of the CHBDC indicates that the following seismic parameters (Welland) should be used for design:

- | | |
|-------------------------------------|--------------------------|
| • Velocity Related Seismic Zone | 0 |
| • Zonal Velocity Ratio | 0 |
| • Acceleration Related Seismic Zone | 1 |
| • Zonal Acceleration Ratio | 0.05 |
| • Peak Horizontal Acceleration | 0.08 g (10% in 50 years) |

The soil profile types at these sites are classified as Type I. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

Culverts should be designed in accordance with Clause 7.5.5 of the CHBDC for a seismic event having a 10% probability of being exceed in 50 years. The vertical component of the earthquake acceleration ratio (A_v) shall be two-thirds of the horizontal ground acceleration ratio (A_h) and A_h shall be set equal to the zonal acceleration ratio.

18 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

Potential construction concerns include, but are not necessarily limited to:

- the potential for encountering soft/weak soils at the design culvert inverts that would necessitate sub-excavation and replacement with Granular “A” material.
- The potential for easily disturbing the foundation bearing surface during construction operations.
- the nature and geotechnical properties of the local earth fill used in the embankment fill.
- stream channel disturbance during construction.



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TABLES

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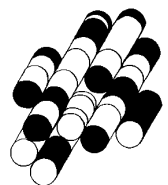


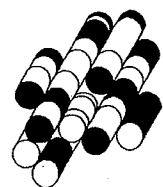
TABLE 1

DOCUMENT	TITLE
OPSS 206	Construction Specification for Grading.
OPSS 212	Construction Specification of Borrow.
OPSS 501	Construction Specification for Compacting.
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheetting.
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 577	Construction Specification for Temporary Erosion and Sediment Control Measures.
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1205	Material Specification for Clay Seal
SP 105 S10	Amendment to OPSS 501, February 1996
OPSD 208.010	Benching of Earth Slopes.
OPSD 221.010	Temporary Water Passage System, Culvert in Watercourse
OPSD 221.030	Temporary Water Passage System, Temporary Channel or Culvert Outside watercourse
OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation.
OPSD 802.032	Rigid Pipe Bedding, Cover and Backfill, Type 4 Soil – Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement.



APPENDICES

TERRAPROBE INC.



LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole and test pit locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report

This report was prepared for the express use of the Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group. It is not for use by others. This report is copyright of Terraprobe Inc. and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Inc. The Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group, are authorized users.

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg. FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0-12	12-25	25-50	50-100	100-200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0-5	5-10	10-30	30-50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0-25	25-50	50-75	75-90	90-100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50-300mm	0.3m-1m	1m-3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

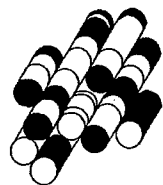
m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_{α}	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_r	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1%	VOID RATIO	e_{min}	1%	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_u	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ² /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $(w_L - w_p)$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_p) / I_p$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_c	1	CONSISTENCY INDEX = $(w_L - w) / I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1%	VOID RATIO IN LOOSEST STATE	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

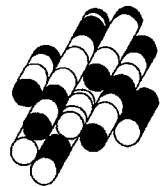
CULVERT #2

TERRAPROBE INC.



A1

TERRAPROBE INC.



RECORD OF BOREHOLE No C2-1

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761869.4 E:327476.3
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T.
 DATUM Geodetic DATE 06.21.10
 ORIGINATED BY BL
 COMPILED BY DB
 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL												
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	w _p	w	w _L														
			15	SS	1		168																			
							167		2.2																	
							166																			
							165																			
164.2	very stiff		16	SS	15																					
19.1	End of Borehole																									
	<p>Dynamic Cone Penetration Test performed from 16.2 to 18.6m.</p> <p>Borehole was dry (not stabilized) and hole open to 13.7m on completion.</p> <p>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>Water Level Readings:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elevation(m)</th> </tr> </thead> <tbody> <tr> <td>Jul. 08. 10</td> <td>4.0</td> <td>179.3</td> </tr> <tr> <td>Jul. 13. 10</td> <td>3.7</td> <td>179.6</td> </tr> <tr> <td>Jul. 20. 10</td> <td>3.6</td> <td>179.7</td> </tr> </tbody> </table>														Date	Depth(m)	Elevation(m)	Jul. 08. 10	4.0	179.3	Jul. 13. 10	3.7	179.6	Jul. 20. 10	3.6	179.7
Date	Depth(m)	Elevation(m)																								
Jul. 08. 10	4.0	179.3																								
Jul. 13. 10	3.7	179.6																								
Jul. 20. 10	3.6	179.7																								

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

RECORD OF BOREHOLE No C2-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761866.4 E:327497.5 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.20.10 - 07.21.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100	○ UNCONFINED + FIELD VANE		w _p — w — w _L			
								20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%)			
181.7	Ground Surface													
0.0 181.4	300mm TOPSOIL		1	SS	13		181							
0.3 181.0	FILL - Silty Clay, trace sand, some organics, stiff, dark brown, moist													
0.7	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		2	SS	27									
	—		3	SS	29		180							
	hard		4	SS	42		179					45		0 1 52 47
	—		5	SS	27									
			6	SS	24		178							
			7	SS	13		177							0 1 61 38
							176							
			8	SS	9		175							0 2 69 29
			9	TW	PH		174							
173.1 8.6	SILTY CLAY some sand to sandy, trace to some gravel, hard, brown, damp to moist (GLACIAL TILL)		10	SS	31		173							
			11	SS	100/ 10cm		172							
			12	SS	100/ 13cm		171							
			13	SS	100/ 10cm		170							
169.0 12.7	End of Borehole		14	SS	68		169							
	Obstruction to augering at 10.5m. Probably on a boulder. Borehole moved 1.5m south and 1.5m east and redrilled. Obstruction to augering at 10.8m. Probably on a boulder. Borehole moved 3.5m south and 0.5m east and redrilled. Obstruction to augering at 10.7m. Probably on a													

ONTARIO MOT 1-09-4135 CULVERTS2.GPJ ONTARIO MOT.GDT 10/01/10

Continued Next Page

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

RECORD OF BOREHOLE No C2-2

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761866.4 E:327497.5 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.20.10 - 07.21.10 CHECKED BY RA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
							20	40	60	80	100	W _p	W	W _L		
	boulder. Borehole moved 5.0m south and 6.0m east and redrilled. Borehole was dry (not stabilized) and hole open to 10.4m on completion.															

ONTARIO MOT 1-09-4135 CULVERTS2.GPJ ONTARIO MOT.GDT 10/01/10

RECORD OF BOREHOLE No C2-3

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761859.0 E:327522.2 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.20.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
181.6	Ground Surface							20 40 60 80 100	10 20 30						
0.0	300mm TOPSOIL														
181.3			1	SS	12		181							0 1 60 39	
0.3	FILL - Silty Clay, trace sand, trace organics, stiff to very stiff, brown, damp to moist		2	SS	19										
180.2			3	SS	22		180								
1.4	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		4	SS	32		179							0 3 58 39	
	hard		5	SS	31		178								
			6	SS	17		177							0 3 60 37	
			7	SS	12		176								
			8	SS	9		175								
			9	SS	10		174							0 2 63 35	
			10	SS	7		173							0 1 55 44	
171.0			11	SS	13		171								
10.6	SILTY CLAY trace to some sand, trace gravel, very stiff, brown, damp to moist (GLACIAL TILL)		12	SS	28		170								
			13	SS	25		169								
167.4	End of Borehole						168								
14.2	Sampler wet at 10.7m														

ONTARIO MOT. 1-09-4135 CULVERTS2.GPJ ONTARIO MOT.GDT 10/01/10

Continued Next Page

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

RECORD OF BOREHOLE No C2-3

2 OF 2

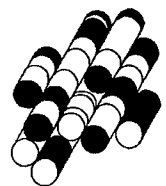
METRIC

W.P. 280-99-00 LOCATION Coords: N:4761859.0 E:327522.2 ORIGINATED BY BL
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 07.20.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	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) Jul. 28. 10 5.9 175.7 Aug. 06. 10 7.1 174.5 Aug. 13. 10 6.5 175.1 Aug. 23. 10 4.6 177.0 Sept. 25. 10 7.4 174.2 Oct. 03. 10 6.2 175.4 Oct. 14. 10 6.6 175.0																

B1

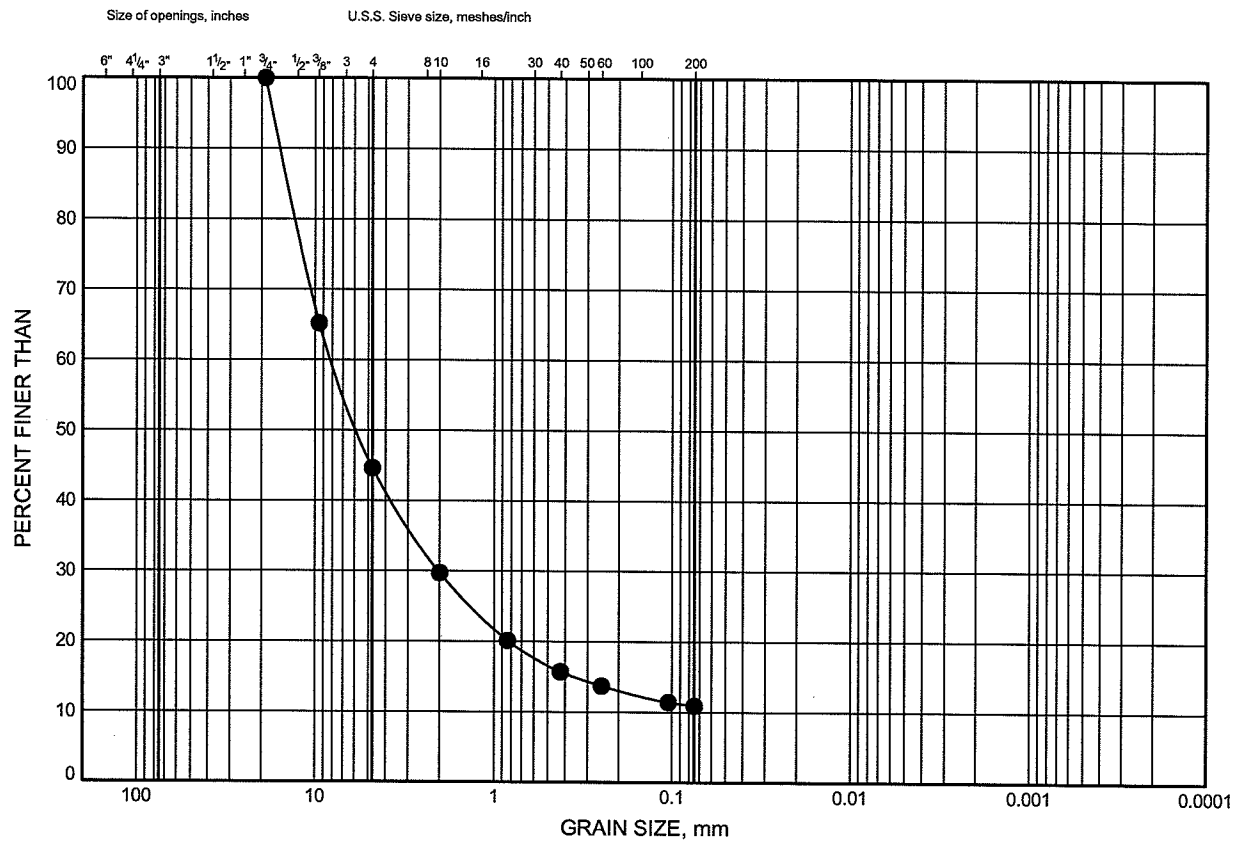
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B1-1

FILL - SANDY GRAVEL

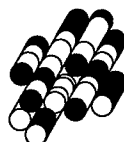


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-1	0.3	183.0

Date November 2010

Project 1-09-4135



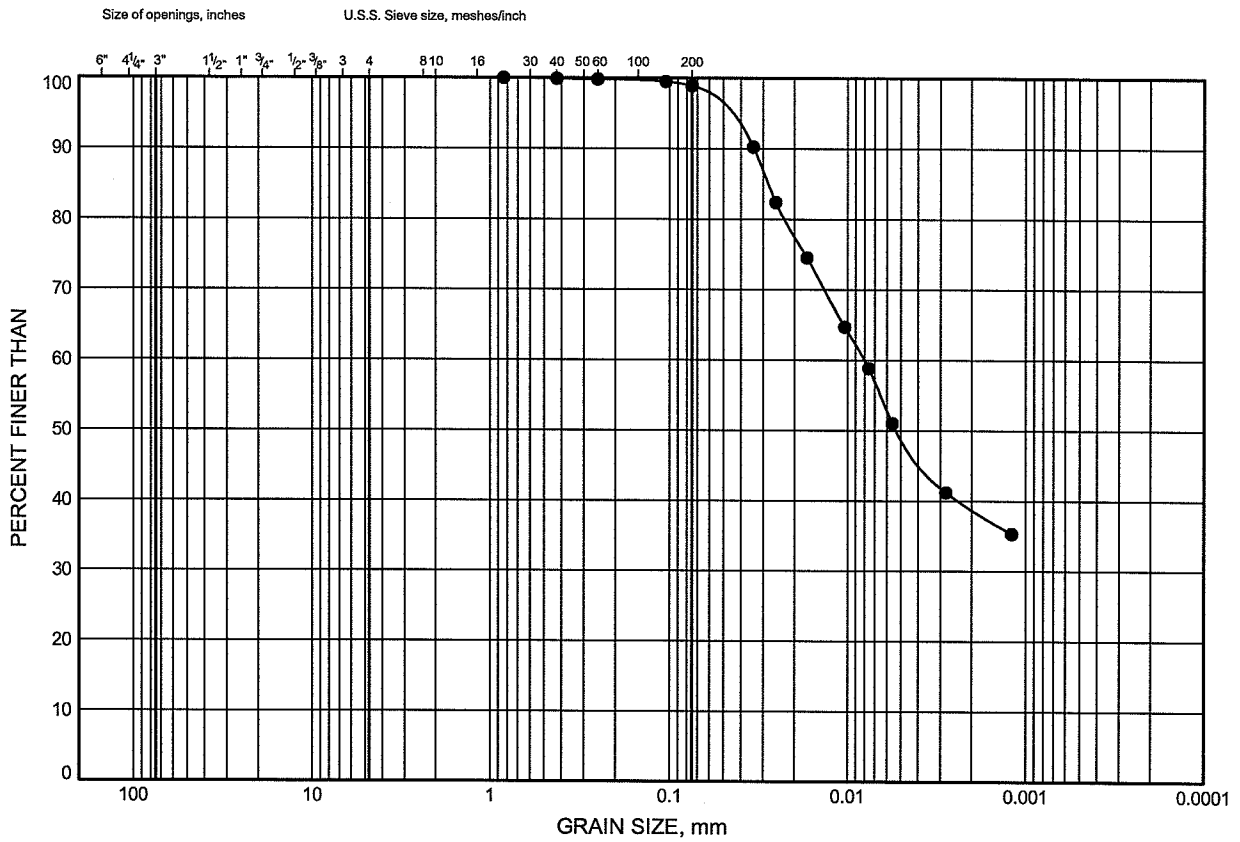
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B1-2

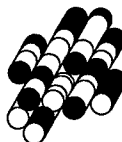
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-3	0.4	181.2

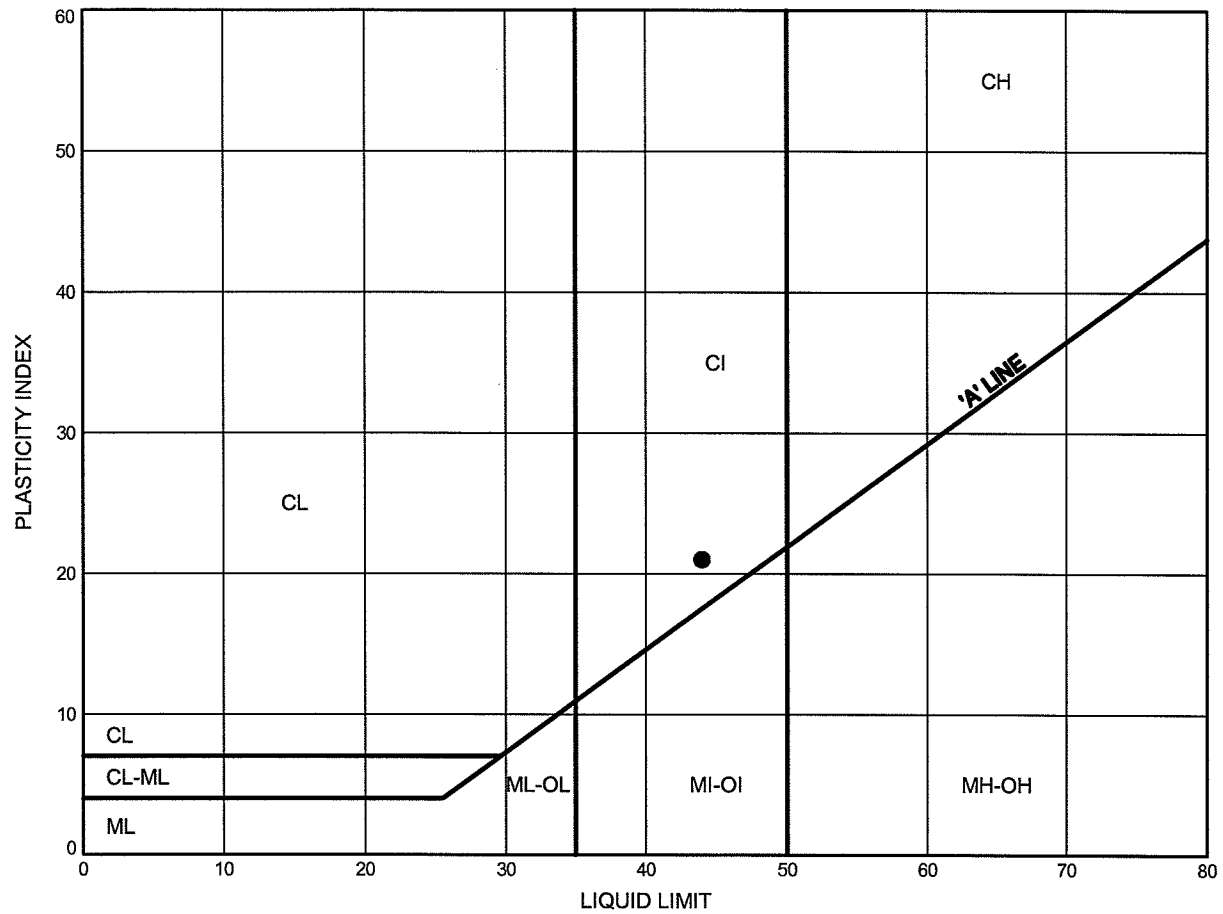
Date November 2010
Project 1-09-4135



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

FIGURE B1-3

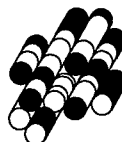
FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-3	0.4	181.2

Date November 2010

Project 1-09-4135.....



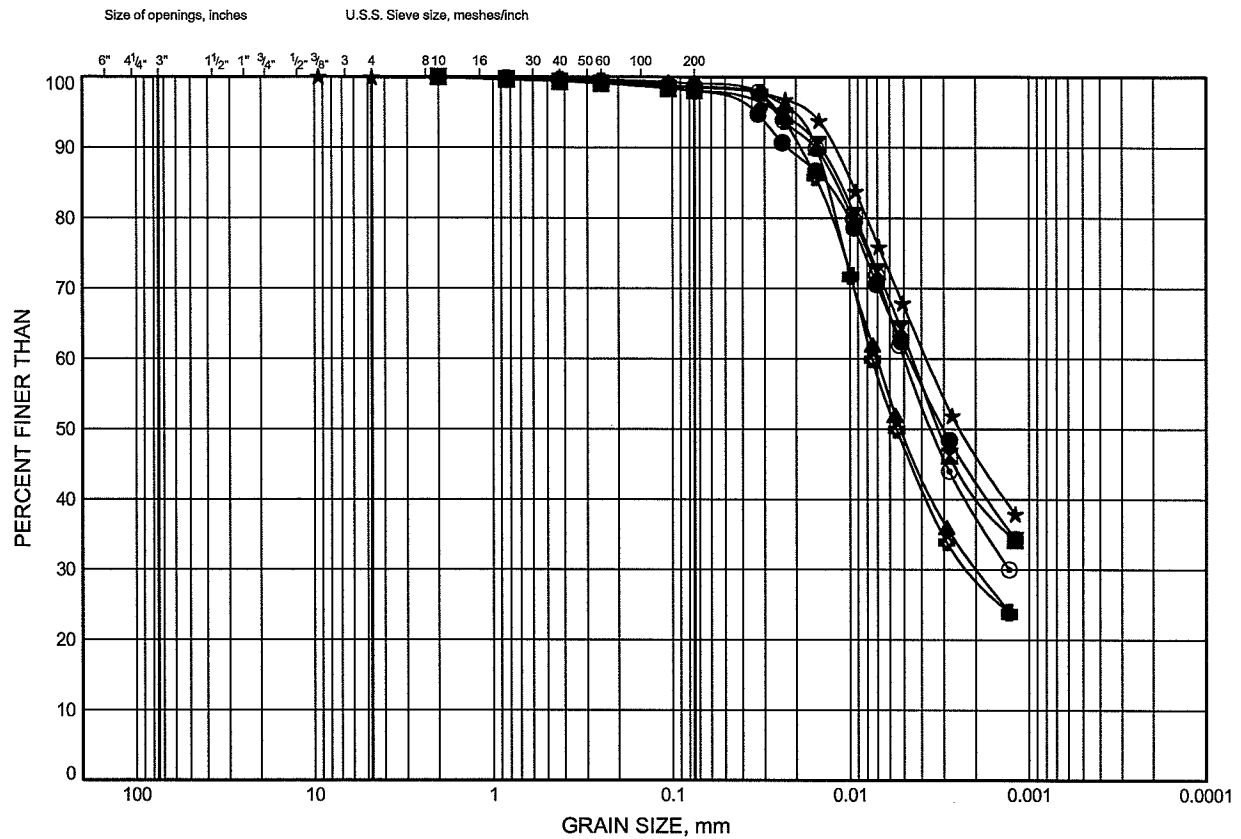
Prep'dK.L.....

Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B1-4

SILTY CLAY



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

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C2-1	3.2	180.1
■	C2-1	4.7	178.6
▲	C2-1	7.8	175.5
★	C2-2	2.5	179.2
⊙	C2-2	4.7	177.0
⊕	C2-2	6.3	175.4

Date November 2010

Project 1-09-4135



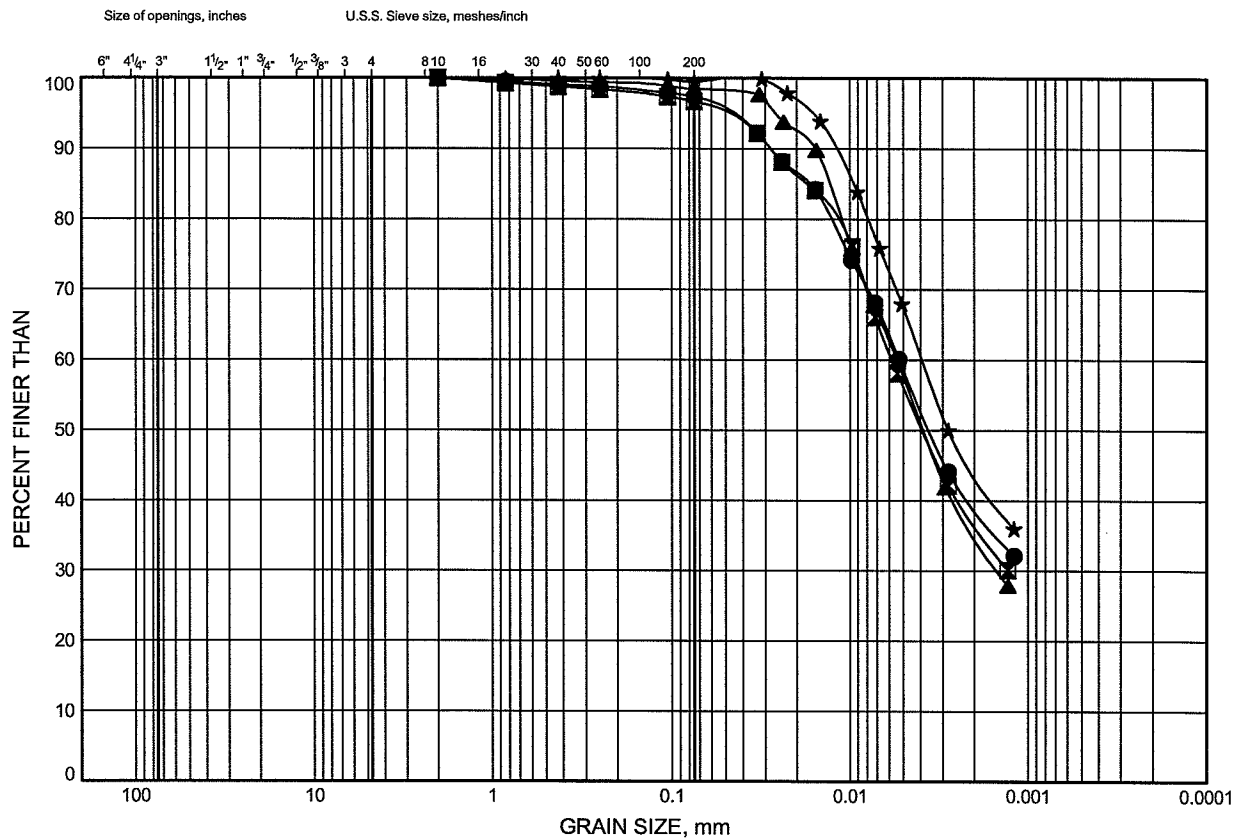
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B1-5

SILTY CLAY

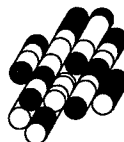


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-3	2.5	179.1
⊠	C2-3	4.0	177.6
▲	C2-3	7.8	173.8
★	C2-3	9.3	172.3

Date November 2010

Project 1-09-4135



Prep'd JS

Chkd. MP

FIGURE B1-6

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-1	3.2	180.1
☒	C2-1	4.7	178.6
▲	C2-1	7.8	175.5
★	C2-2	2.5	179.2
⊙	C2-2	4.7	177.0
⊕	C2-2	6.3	175.4

Date ..November 2010....
Project ...1-09-4135...

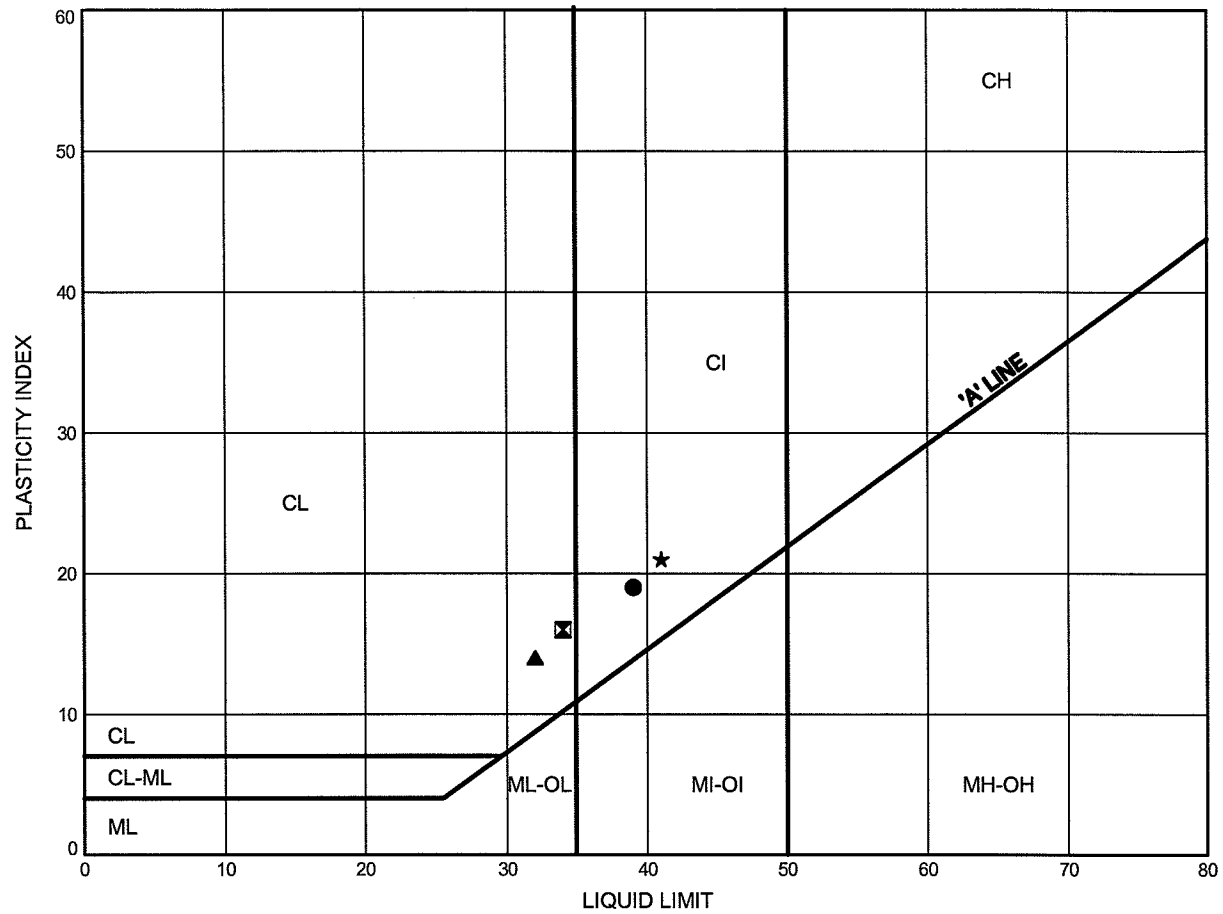


Prep'd JS
Chkd. MP

ATTERBERG LIMITS TEST RESULTS

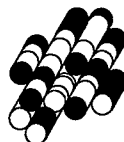
FIGURE B1-7

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-3	2.5	179.1
⊠	C2-3	4.0	177.6
▲	C2-3	7.8	173.8
★	C2-3	9.3	172.3

Date November 2010
Project 1-09-4135

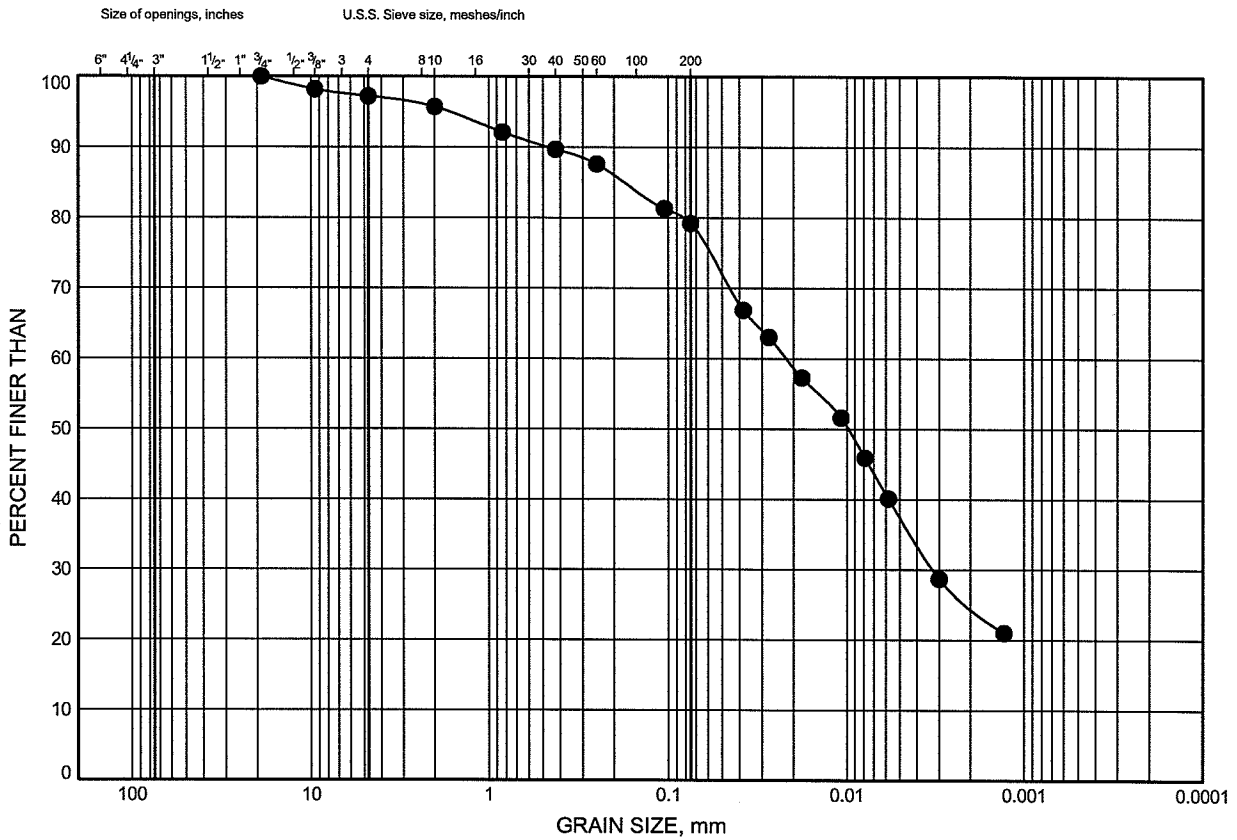


Prep'd JS
Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B1-8

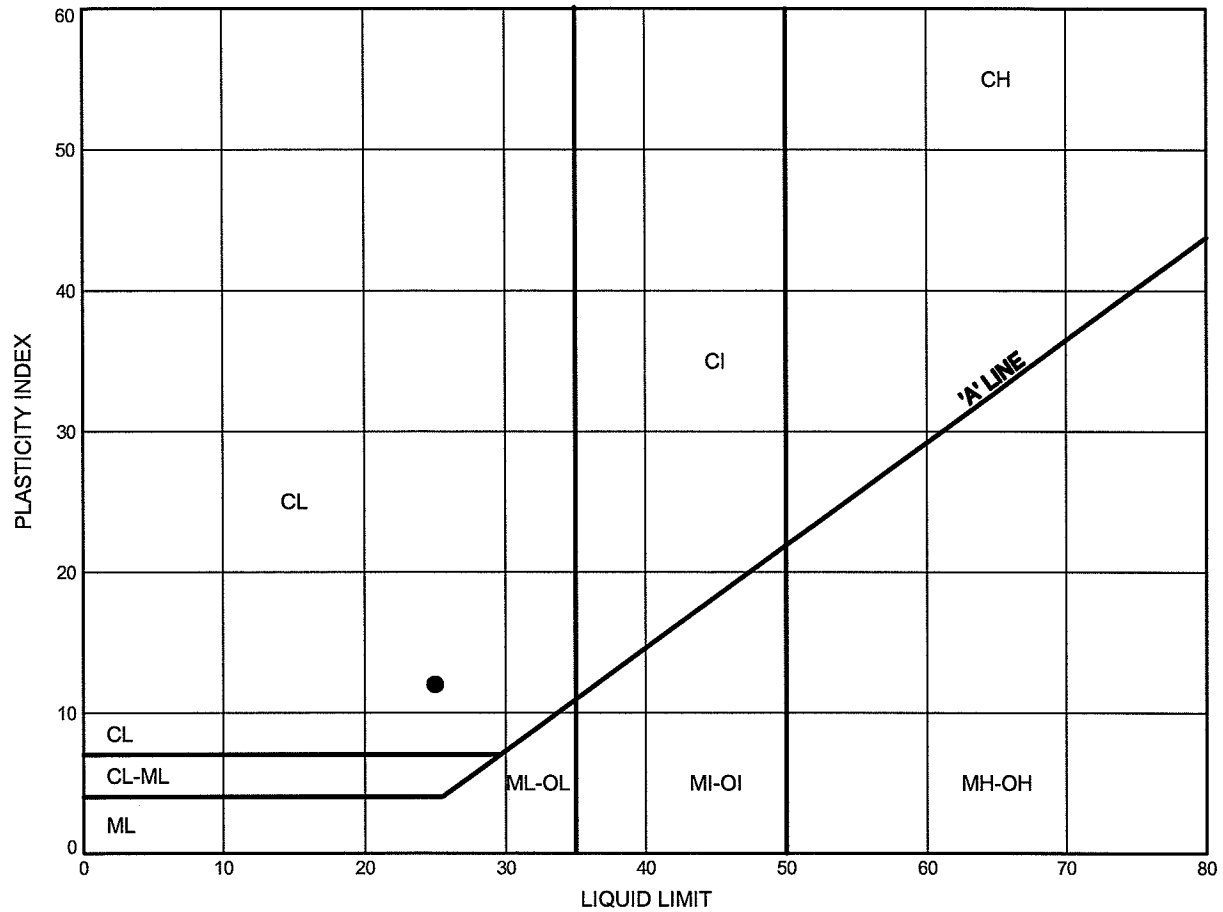
SILTY CLAY TILL



ATTERBERG LIMITS TEST RESULTS

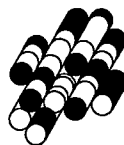
FIGURE B1-9

SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C2-1	10.9	172.4

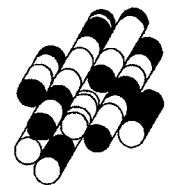
Date November 2010
Project 1-09-4135



Prep'd JS
Chkd. MP

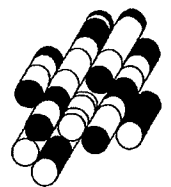
C1

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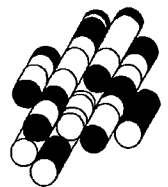
CULVERT #5

TERRAPROBE INC.



A2

TERRAPROBE INC.



RECORD OF BOREHOLE No C3-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4762329.4 E:327576.6 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 6.17.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
183.2	Ground Surface						20 40 60 80 100								
0.0	1420mm FILL - Sand and Gravel, some silt, trace clay, compact to dense, brown/grey, damp to moist		1	SS	27		183			○				37 46 13 4	
			2	SS	33		182			○					
181.8	FILL - Silty Clay, some sand, trace gravel, trace organics, very stiff, brown, damp to moist		3	SS	26		181					42		7 13 40 40	
181.1	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		4	SS	15		180								
2.1			5	SS	17		179								
			6	SS	15		178								
			7	SS	11		177								
			8	SS	11		176								
			9	TW	PH		175								
173.8	SILTY CLAY some sand, trace gravel, stiff to very stiff, brown, damp to moist (GLACIAL TILL)		10	SS	16		174								
9.4			11	SS	11		173								
			12	SS	17		172								
169.6	End of Borehole						171							6 18 56 20	
13.6	Resistance to augering at 2.3m Sampler wet at 7.6m Unable to push vane beyond 11.1m						170								

ON MOT 1-09-4135 CULVERTS2.GPJ ON MOT.GDT 9/8/10

Continued Next Page

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

RECORD OF BOREHOLE No C3-1

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4762329.4 E:327576.6 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 6.17.10 CHECKED BY RA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	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) Jul. 08. 10 2.0 181.2 Jul. 14. 10 1.9 181.3 Jul. 20. 10 2.0 181.2																

RECORD OF BOREHOLE No C3-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4762327.3 E:327602.0 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / Hollow Stem Augers COMPILED BY DB
DATUM Geodetic DATE 7.8.10 - 7.20.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa														
								○ UNCONFINED + FIELD VANE														
								● QUICK TRIAXIAL x LAB VANE														
							20	40	60	80	100	WATER CONTENT (%)		10	20	30	kN/m ³	GR	SA	SI	CL	
183.8	Ground Surface																					
0.1	100mm TOPSOIL		1	SS	14		183															
	FILL - Silty Clay, trace sand, trace organics, stiff, brown, damp to moist		2	SS	14																	
			3	SS	13		182															
181.7			4	SS	21																	
2.1	SILTY CLAY trace sand, very stiff, brown, damp to moist		5	SS	19																	
			6	SS	28		180															
			7	SS	21		179															
			8	SS	20		178															
			9	SS	23		177															
			10	SS	17		176															
			11	SS	62/ 20cm		175															
			12	SS	27		174															
			13	SS	100/ 25cm		173															
173.7							172															
10.1	SILTY CLAY trace to some sand, trace gravel, very stiff to hard, brown, damp to moist (GLACIAL TILL)						171															
							170															
169.7																						
14.1	End of Borehole																					
	Borehole was dry (not stabilized) and hole open to full depth on completion.																					

Continued Next Page

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

ON MOT 1-09-4135 CULVERTS2.GPJ ON MOT.GDT 9/8/10

2 OF 2

METRIC

ELEV. DEPTH	SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES			WATER CONTENT (%)				
										10	20			30
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100							

Date	Depth(m)	Elevation(m)
Jul. 28. 10	5.6	178.2
Aug. 06. 10	5.8	178.0

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

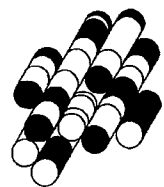
Test Pit Logs
Culvert #3 (Highway 406 Sta. 10+782)

Test Pit# TP 3-1

0	-	100	Tps
100	-	300	Fill, Br Si(y) Cl, Tr Sa, Tr Gr, Damp

B2

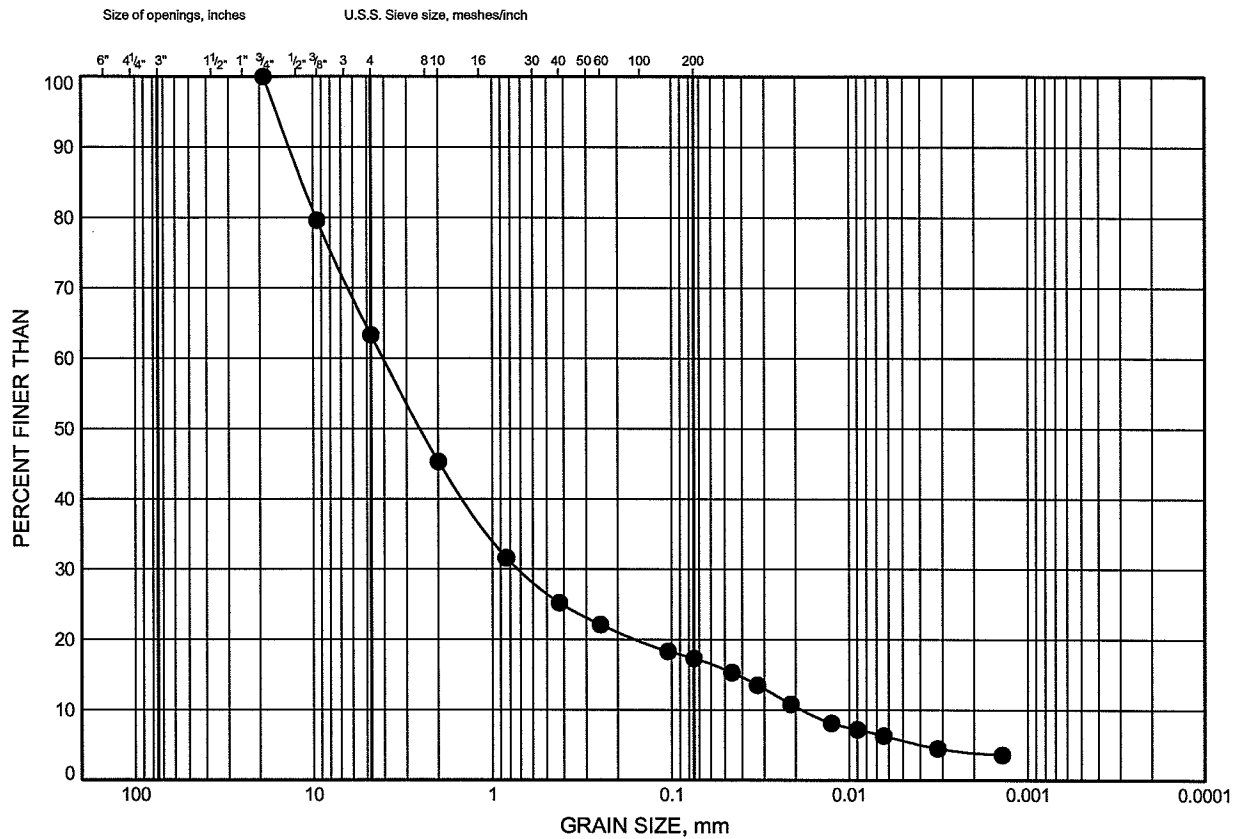
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B2-1

FILL - Sand and Gravel

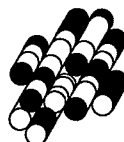


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C3-1	0.3	182.9

Date November 2010

Project 1-09-4135



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FIGURE B2-2

Size of openings, inches

U.S.S. Sieve size, meshes/inch

PERCENT FINER THAN

GRAIN SIZE, mm

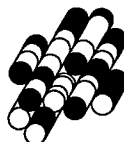
Grain Size (mm)	Percent Finer Than (Solid Circles)	Percent Finer Than (Squares)
100	100	100
4.75	100	100
2.0	95	100
0.85	93	100
0.425	91	100
0.25	87	99
0.15	85	98
0.075	83	97
0.0425	80	95
0.025	77	92
0.015	73	90
0.0075	69	88
0.00425	64	80
0.0025	60	76
0.0015	55	68
0.00075	44	54
0.000425	33	40

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C3-1	1.7	181.5
⊠	C3-2	1.1	182.7

Date November 2010

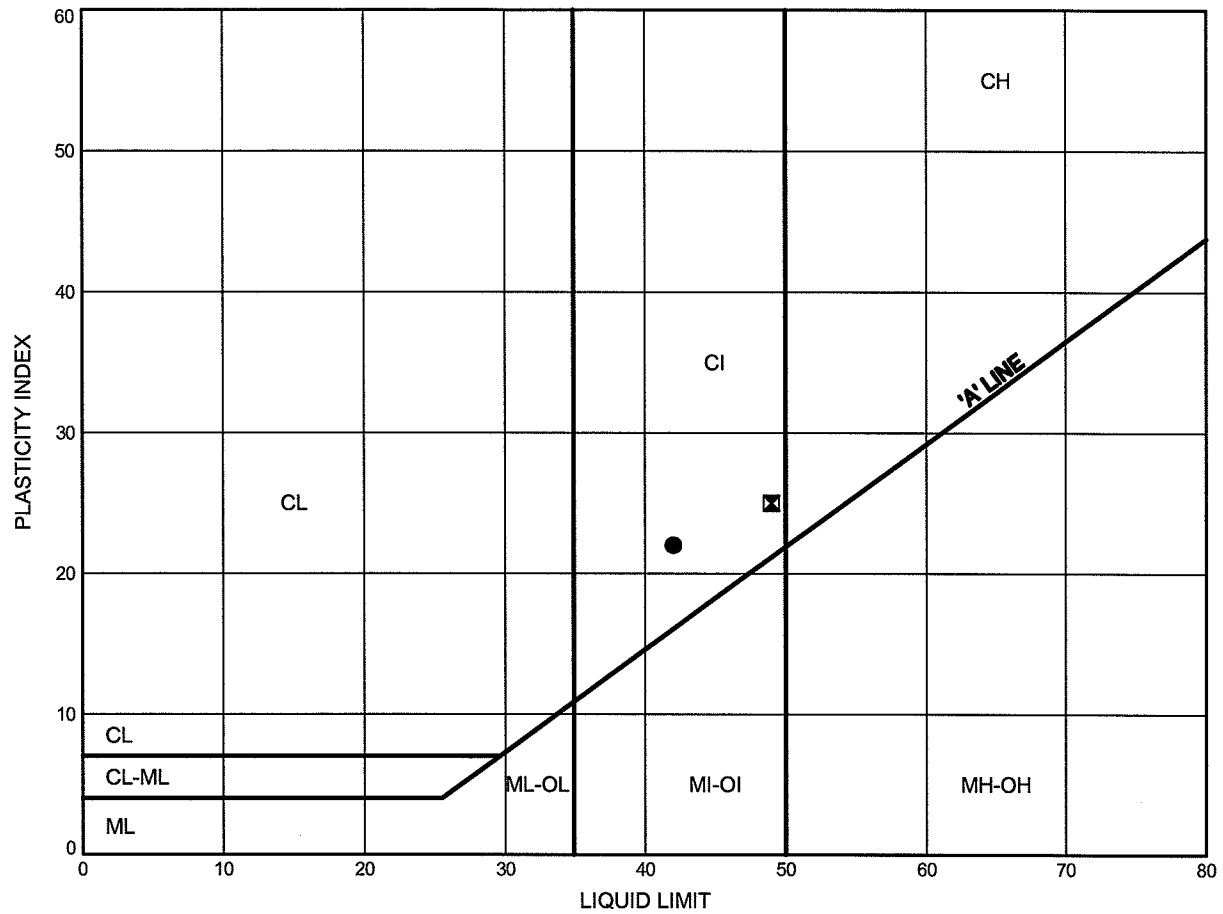
Project ...1-09-4135...



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Chkd.MP.....

FIGURE B2-3



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C3-1	1.7	181.5
⊠	C3-2	1.1	182.7

Date November 2010

Project 1-09-4135



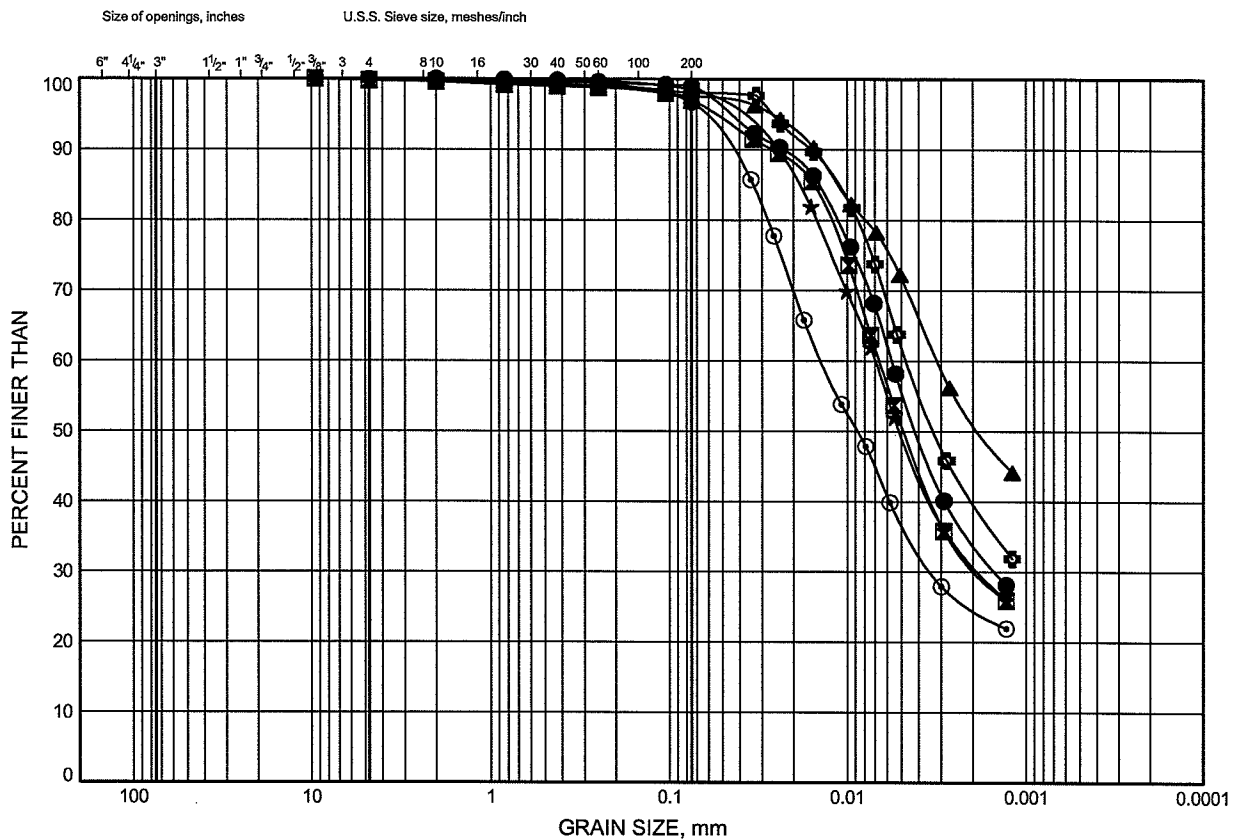
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B2-4

SILTY CLAY

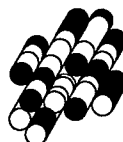


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C3-1	4.0	179.2
⊠	C3-1	6.3	176.9
▲	C3-2	3.3	180.6
★	C3-2	6.4	177.5
⊙	C3-2	7.9	175.9
⊕	C3-2	9.4	174.5

Date November 2010

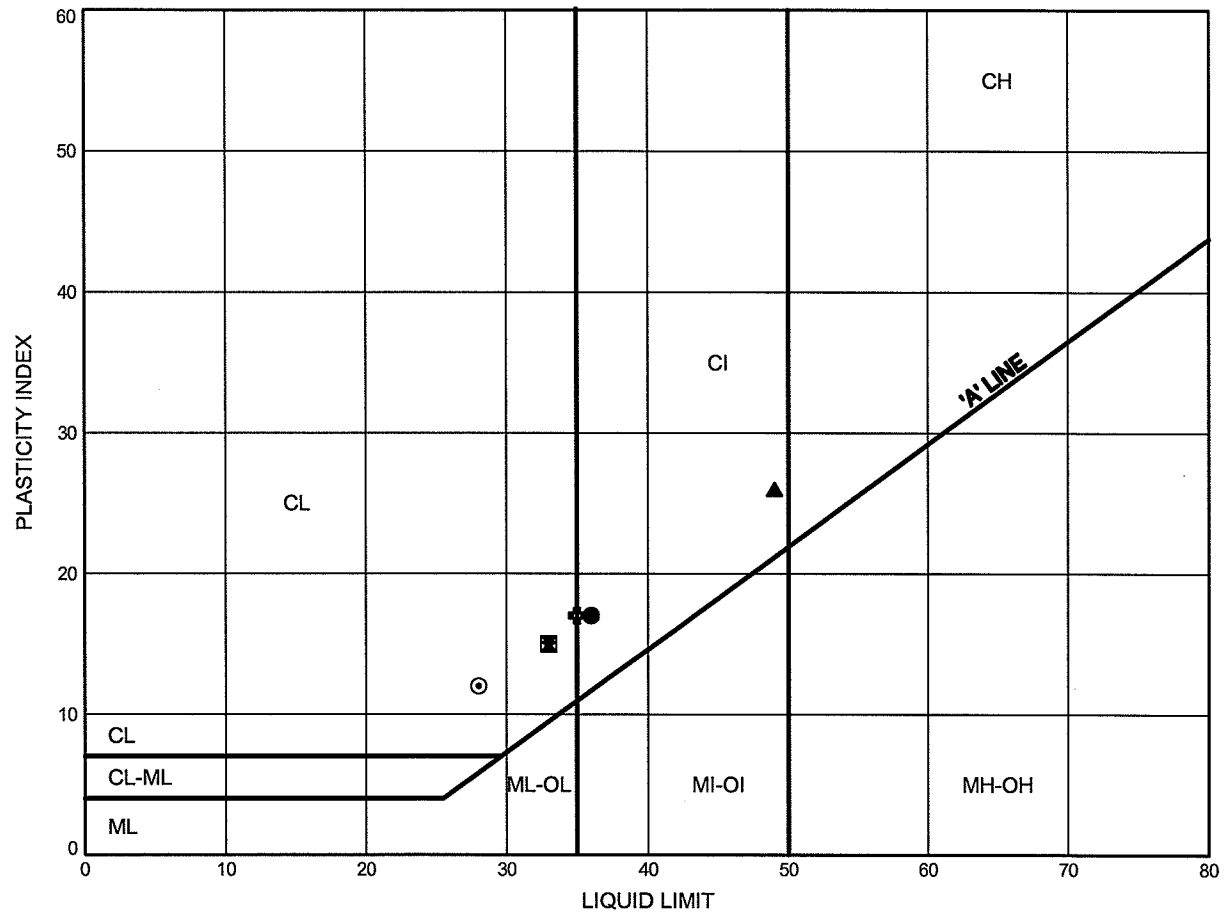
Project 1-09-4135



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FIGURE B2-5

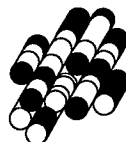


SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C3-1	4.0	179.2
⊠	C3-1	6.3	176.9
▲	C3-2	3.3	180.6
★	C3-2	6.4	177.5
⊙	C3-2	7.9	175.9
⊕	C3-2	9.4	174.5

Date September 2010

Project 1-09-4135



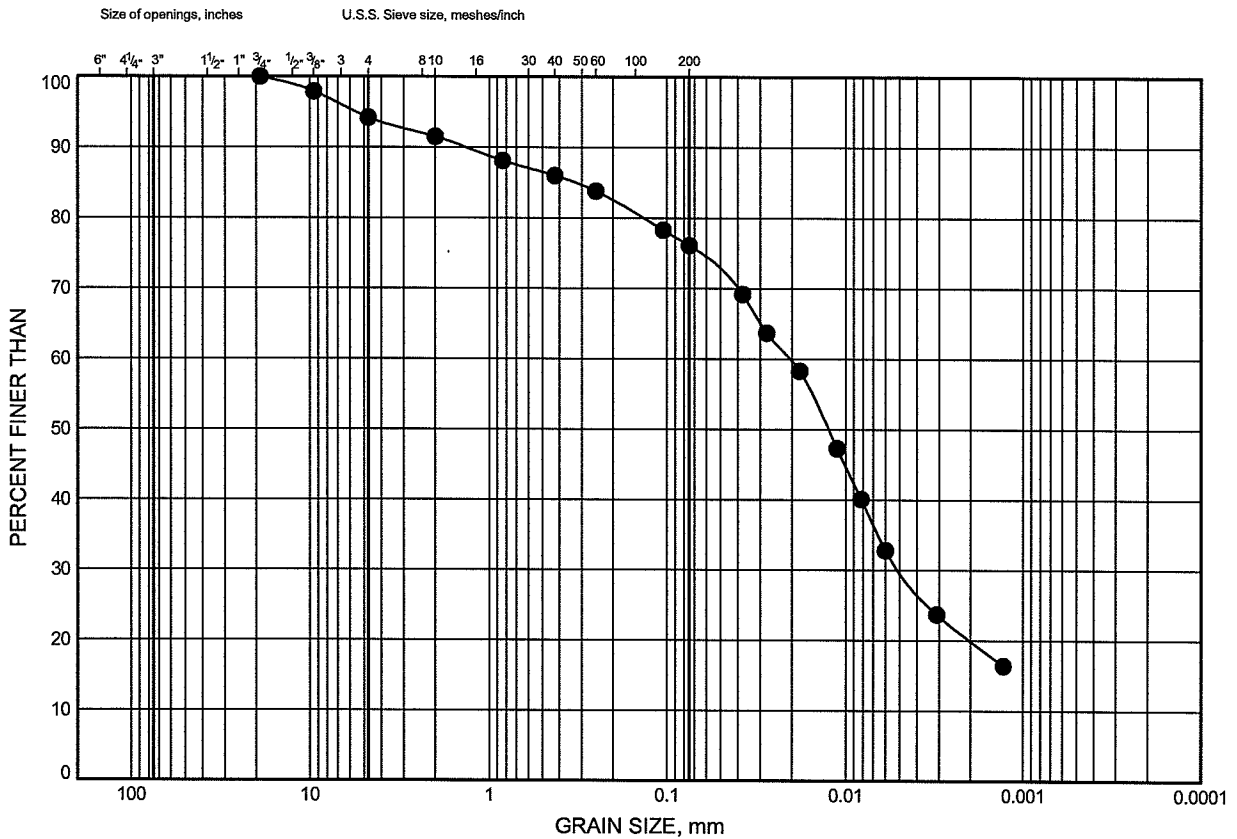
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B2-6

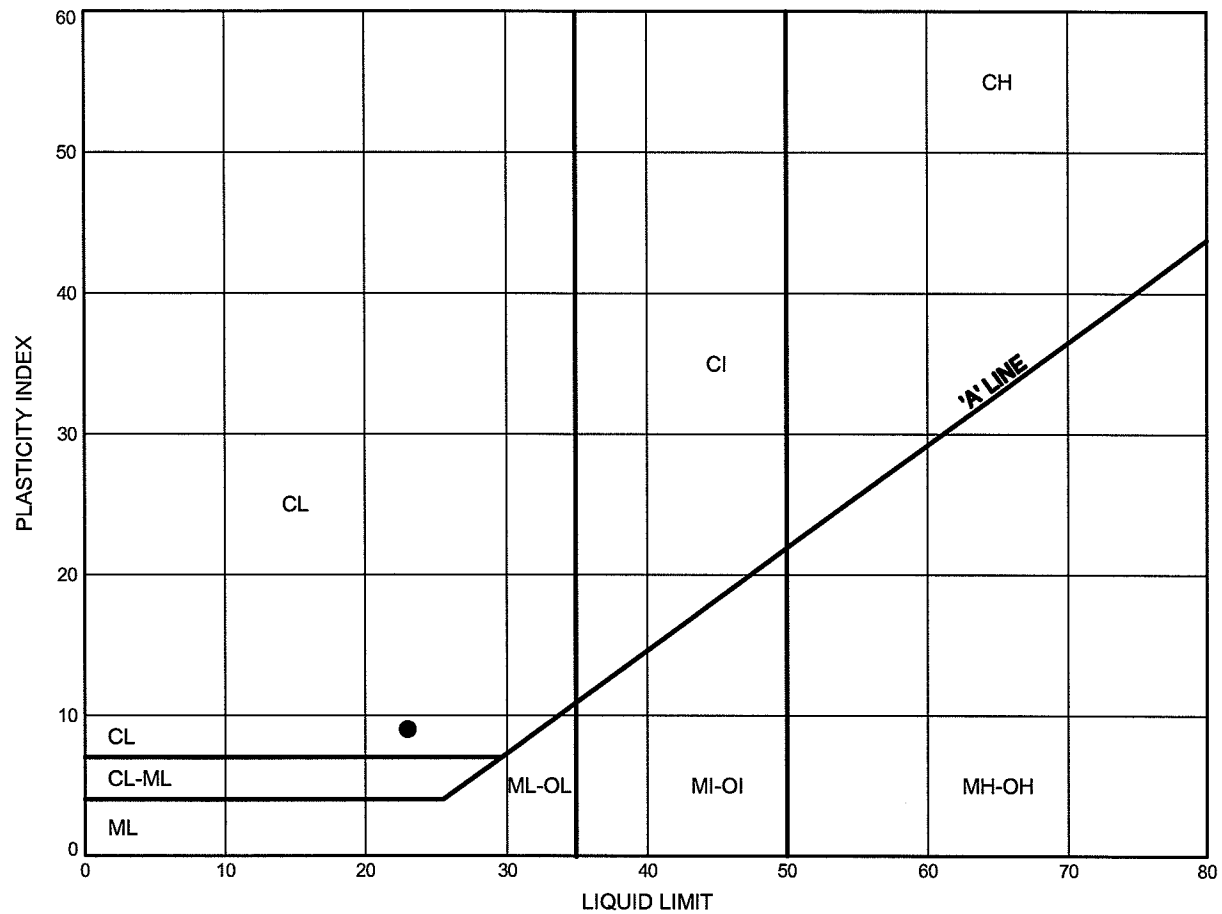
SILTY CLAY TILL



ATTERBERG LIMITS TEST RESULTS

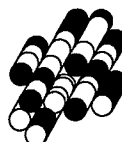
FIGURE B2-7

SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C3-1	12.4	170.8

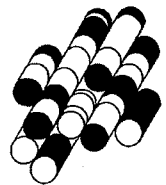
Date November 2010
Project 1-09-4135

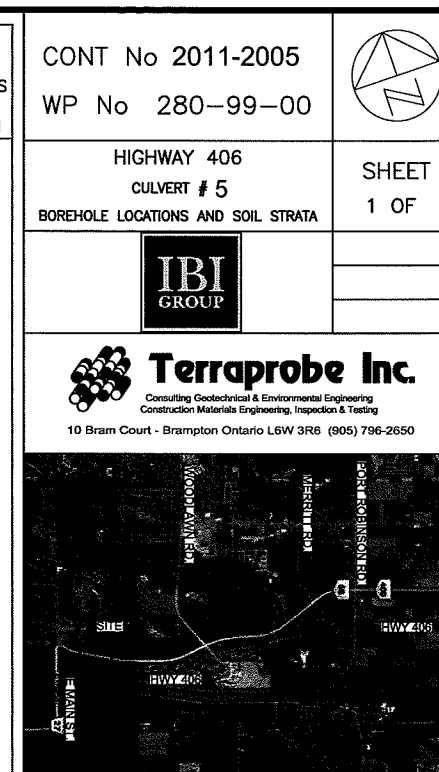
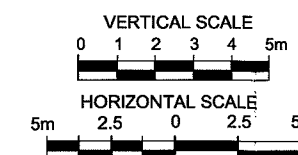
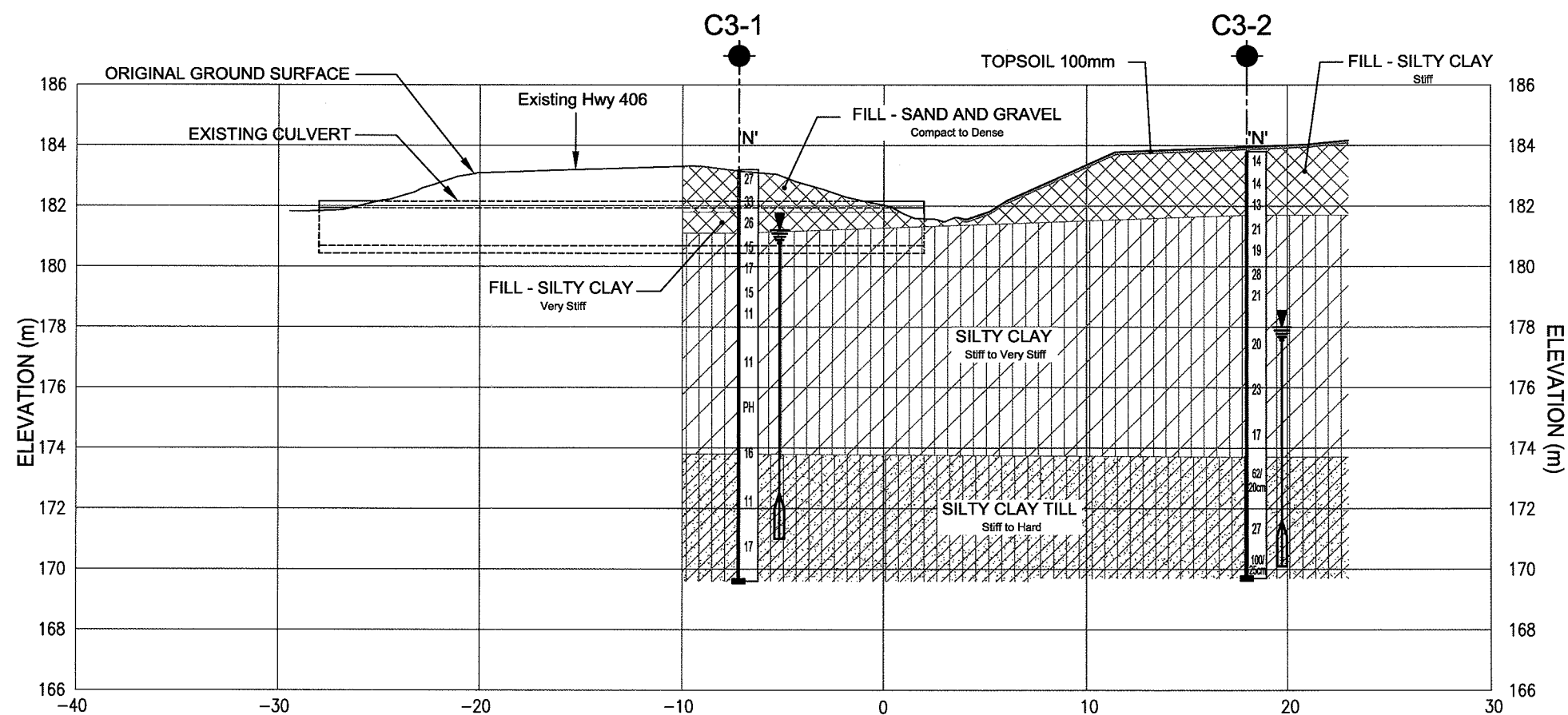
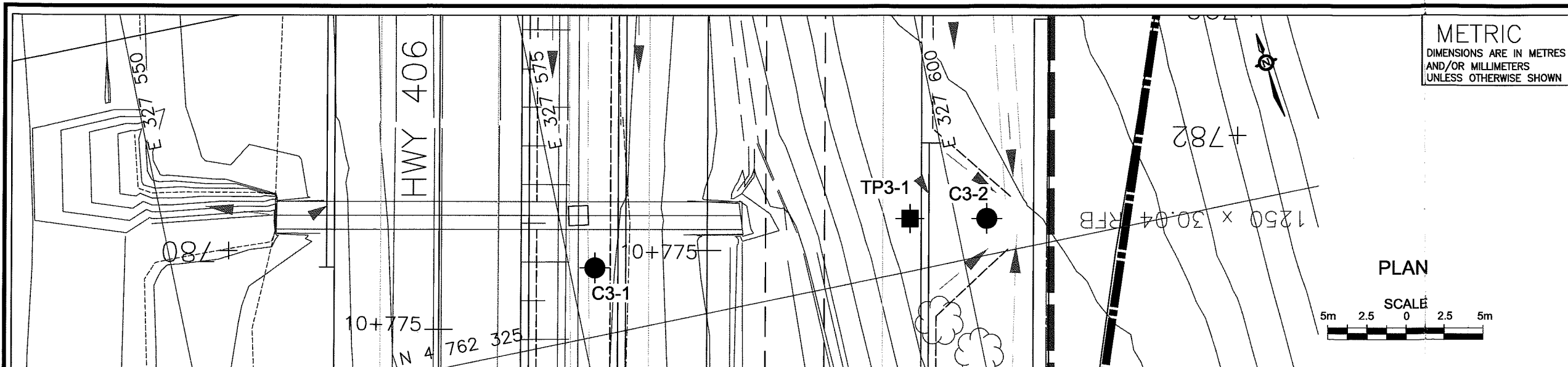









Prep'd JS
Chkd. MP

C2

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KEY PLAN	
LEGEND	
	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
	Test Pit
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer (AUG. 2010)
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

[illegible]

NOTE

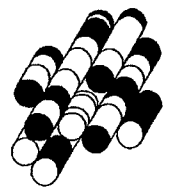
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVIEWS					
	DATE	BY	DESCRIPTION		
DESIGN	R.A.	CODE	CHBDC2008	LOAD	DATE FEB. 2011
DRAWN	K.C.	CHK	R.A.	STRUCT	GEOCRETS 30Mx3-

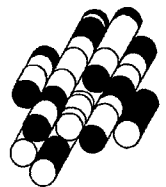
CULVERT #6

TERRAPROBE INC.



A3

TERRAPROBE INC.



RECORD OF BOREHOLE No C5-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763047.5 E:327637.7
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T.
 DATUM Geodetic DATE 06.18.10
 ORIGINATED BY PK
 COMPILED BY DB
 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
190.4	Ground Surface							20 40 60 80 100						
0.0	610mm FILL - Sand and Gravel, some silt, trace clay, compact, brown/grey, damp		1	SS	22		190	○ UNCONFINED + FIELD VANE		○				40 41 14 5
189.8								● QUICK TRIAXIAL × LAB VANE						
0.6	FILL - Silty Clay, trace sand, stiff to very stiff, brown, damp to moist		2	SS	20		189			○				
			3	SS	21		188			○				
			4	SS	14		187			○				
			5	SS	11		186			○				
			6	SS	20		185			○				
			7	SS	16		184			○				
	trace to some organics, black		8	SS	9		183			○				
183.3							182							
7.1	SILTY CLAY trace sand, occasional gravel inclusions, very stiff to hard, brown, damp to moist		9	SS	27		181			○				1 6 62 31
			10	SS	51		180			○				
			11	SS	25		179			○				
	firm to stiff		12	SS	2		178			○				
			13	TW	PH		177							
							176							

Continued Next Page

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

RECORD OF BOREHOLE No C5-1

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763047.5 E:327637.7
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T.
 DATUM Geodetic DATE 06.18.10
 ORIGINATED BY PK
 COMPILED BY DB
 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
171.6	inferred hard		14	SS	5	175				0 3 67 30 Sampler refusal probably on a cobble	
174			15	SS	100/ 5cm	173					
173			16	SS	6	172					
172			171	171	171	171					
171.0	End of Borehole										
19.4	End of Dynamic Cone Penetration Test										
Dynamic Cone Penetration Test performed from 18.8m to 19.4m. Resistance to augering at 2.0m. 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) Jul. 05. 10 9.0 181.4 Jul. 14. 10 4.9 185.5 Jul. 21. 10 8.3 182.1 Jul. 28. 10 8.6 181.8											

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

RECORD OF BOREHOLE No C5-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763044.7 E:327676.8
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 6.30.10 - 7.5.10
 ORIGINATED BY BL
 COMPILED BY DB
 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
187.2	Ground Surface						20 40 60 80 100	20 40 60 80 100	10 20 30					GR SA SI CL	
0.1	100mm TOPSOIL		1	SS	11										
	FILL - Silty Clay, trace to some sand, trace gravel, stiff to hard, brown, damp to moist		2	SS	45										
			3	SS	13										
			4	SS	11										
	trace organics		5	SS	10										
			6	SS	18										
182.8			7	SS	18									3 21 44 32	
4.4	weathered, sandy, trace gravel														
	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist		8	SS	35										
			9	SS	27									0 3 57 40	
			10	SS	15										
			11	SS	15										
	firm to stiff		12	SS	13									0 3 63 34	
			13	SS	14									June 30 July 05 0 3 69 28	

Continued Next Page

+³, X³: Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C5-2

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763044.7 E:327676.8
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 6.30.10 - 7.5.10
 ORIGINATED BY BL
 COMPILED BY DB
 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
							20 40 60 80 100	20 40 60 80 100	10 20 30						
170.4			14	TW	PH		172	1.3							
16.8							171	1.6							
	SILTY CLAY some sand, trace gravel, hard, brown, damp (GLACIAL TILL)		15	SS	50			1.3							
168.4							170								
18.8			16	SS	52		169								
	End of Borehole													3 16 49 32	
	Sampler wet at 13.7m. 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) Jul. 14. 10 6.7 180.5 Jul. 21. 10 6.3 180.9 Jul. 28. 10 6.4 180.8														

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

Test Pit Logs
Culvert #5 (Highway 406 Sta. 11+499)

Test Pit# TP 5-1

0	-	100	Tps
100	-	300	Fill, Br Si(y) Cl, Moist

Test Pit# TP 5-2

0	-	130	Tps
130	-	300	Fill, Br Si(y) Cl, Moist

Test Pit# TP 5-3

0	-	100	Tps
100	-	300	Fill, Br Si(y) Cl, Damp

B3

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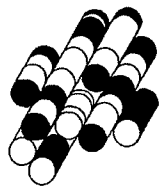


FIGURE B3-1

The graph displays the grain size distribution of a soil sample. The y-axis represents the percentage of soil finer than a given grain size, ranging from 0 to 100. The x-axis represents the grain size in millimeters on a logarithmic scale, ranging from 100 mm down to 0.0001 mm. A smooth curve is drawn through the data points, indicating the distribution of particle sizes. The soil is predominantly fine-grained, with over 95% of the material passing through a No. 20 sieve (0.075 mm).

Grain Size (mm)	Percent Finer (%)
100	100
4.75	77
2.0	60
0.85	49
0.425	35
0.25	28
0.15	25
0.075	21
0.06	20
0.0425	16
0.03	14
0.025	12
0.015	10
0.01	9
0.0075	8
0.006	6
0.00425	5

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-1	0.3	190.1

Date November 2010
Project 1-09-4135

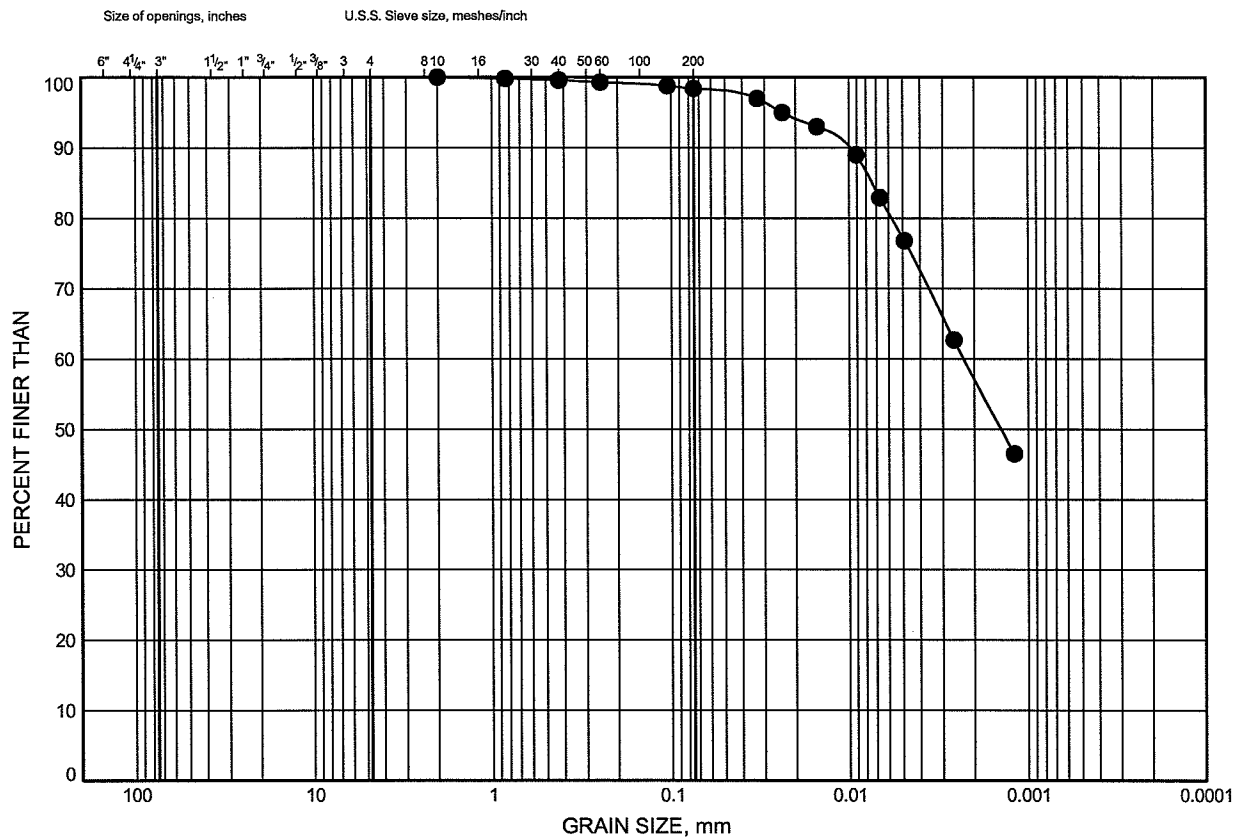


Prep'd JS
Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B3-2

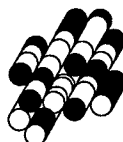
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-1	2.5	187.9

Date November 2010
Project 1-09-4135

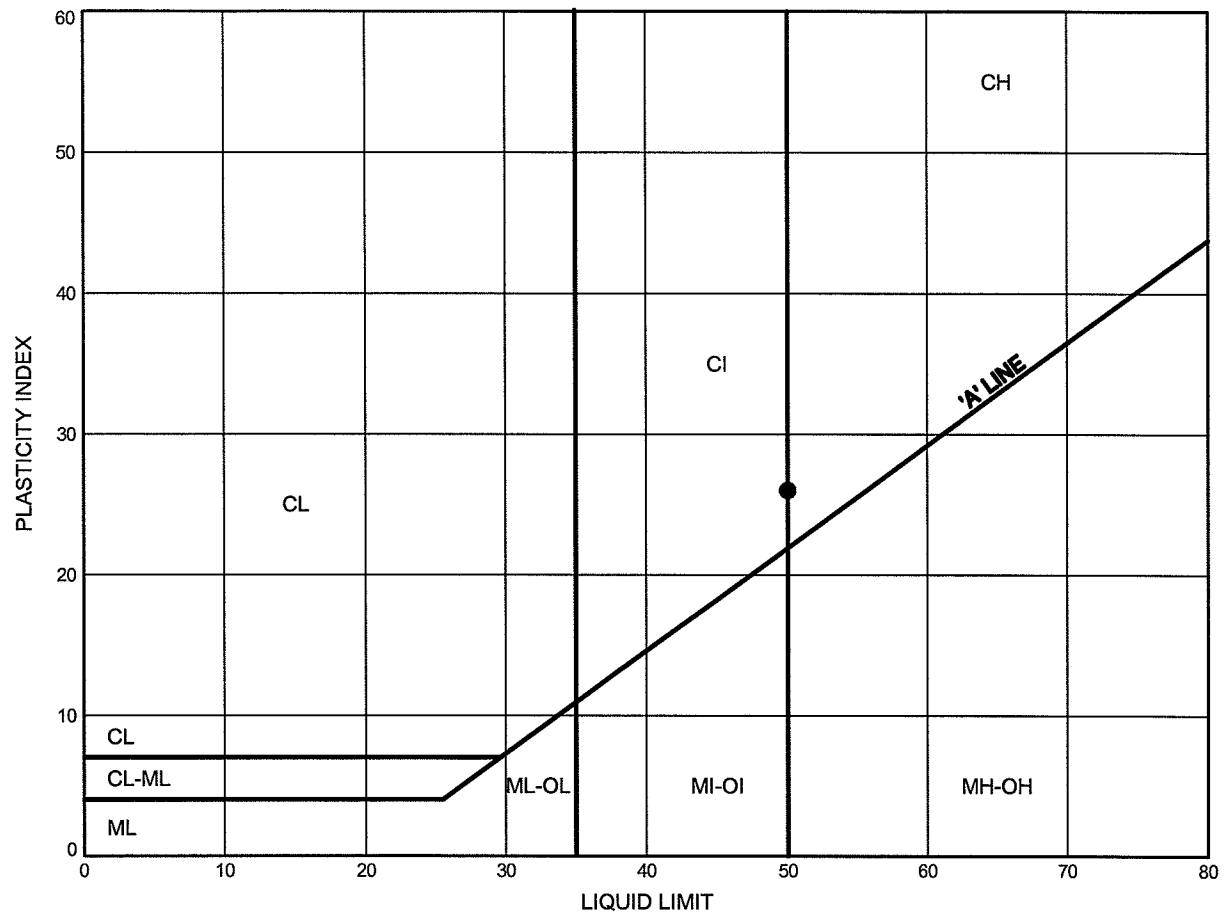


Prep'd JS
Chkd. MP

ATTERBERG LIMITS TEST RESULTS

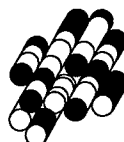
FIGURE B3-3

FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-1	2.5	187.9

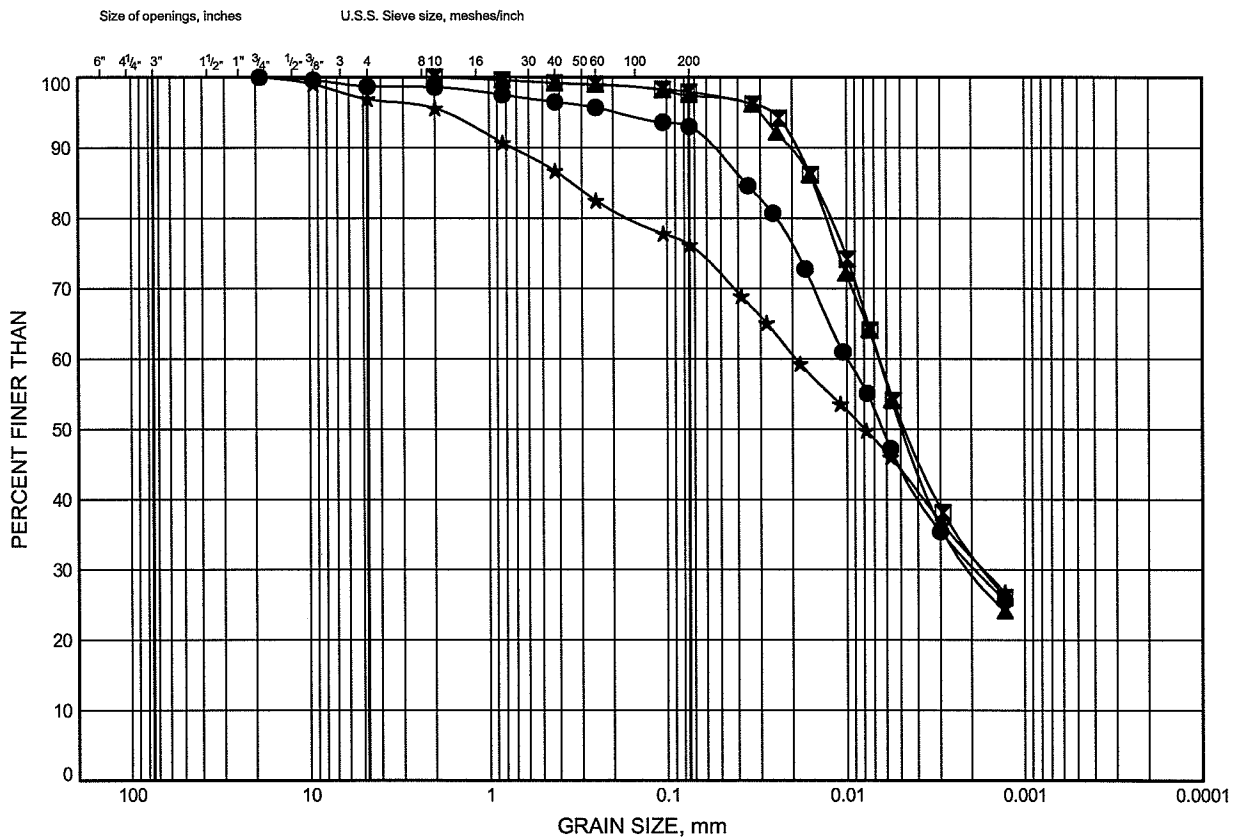
Date November 2010
Project 1-09-4135



Prep'd JS
Chkd. MP

FIGURE B3-4

SILTY CLAY

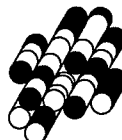


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-1	7.8	182.6
☒	C5-1	10.9	179.5
▲	C5-1	15.7	174.7
★	C5-2	4.7	182.5

Date November 2010

Project 1-09-4135...



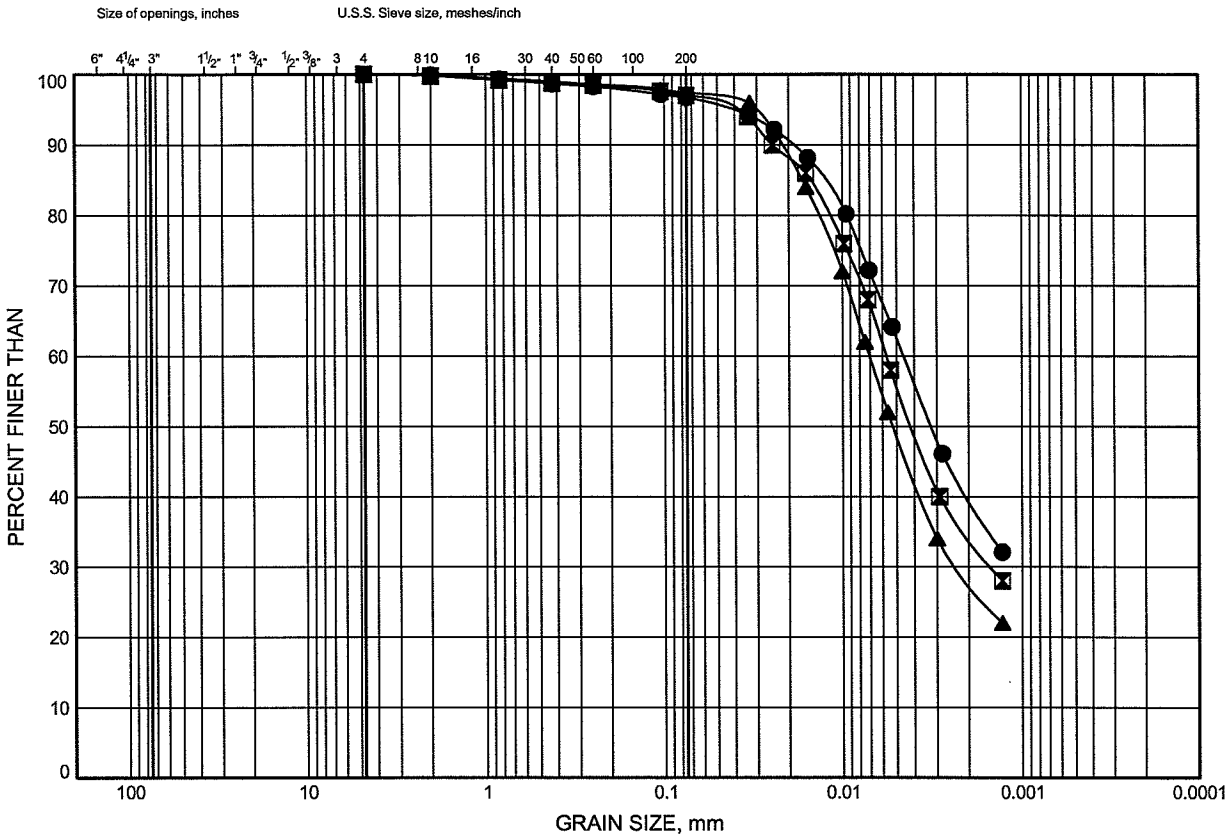
Prep'dJS.....

Chkd.MP.....

GRAIN SIZE DISTRIBUTION

FIGURE B3-5

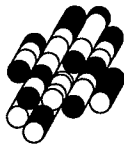
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-2	7.8	179.4
■	C5-2	12.4	174.8
▲	C5-2	13.9	173.3

Date November 2010
 Project 1-09-4135...

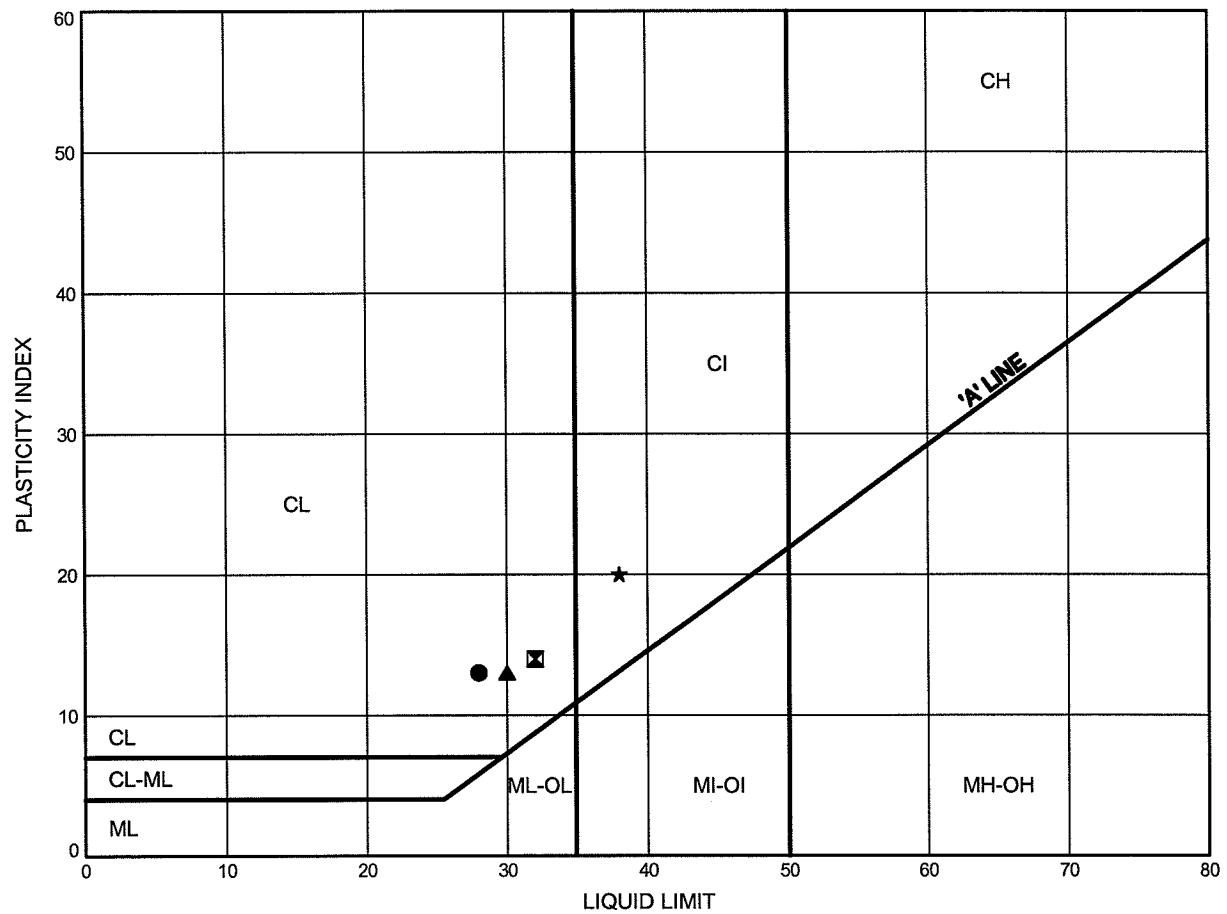


Prep'd JS
 Chkd. MP

ATTERBERG LIMITS TEST RESULTS

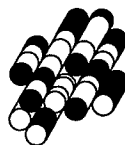
FIGURE B3-6

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-1	7.8	182.6
⊠	C5-1	10.9	179.5
▲	C5-1	15.7	174.7
★	C5-2	4.7	182.5

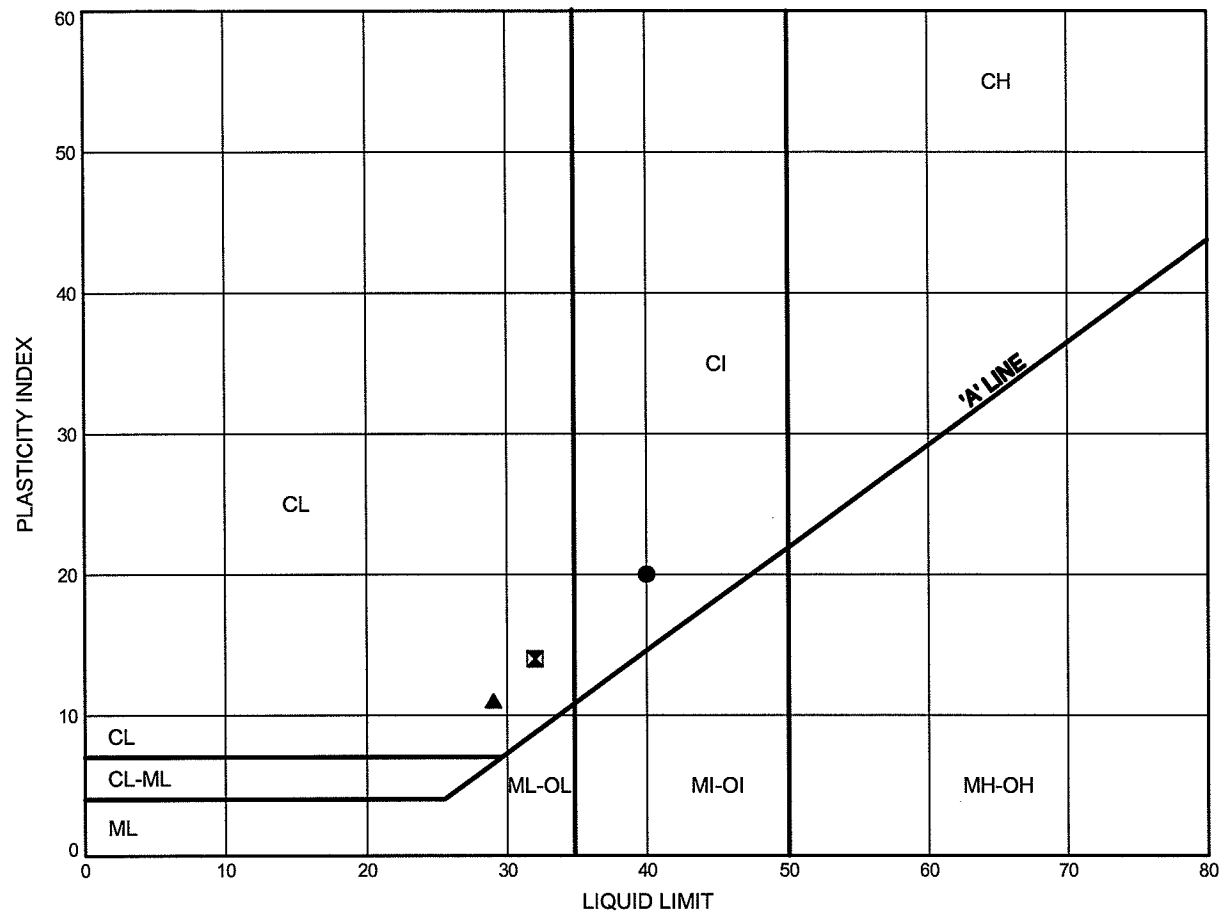
Date November 2010
Project 1-09-4135



Prep'd JS
Chkd. MP

FIGURE B3-7

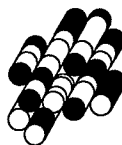
SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-2	7.8	179.4
⊠	C5-2	12.4	174.8
▲	C5-2	13.9	173.3

Date November 2010

Project 1-09-4135...



Prep'dJS.....

Chkd.MP.....

FIGURE B3-8

Size of openings, inches

U.S.S. Sieve size, meshes/inch

6" 4 1/4" 3" 1 1/2" 1" 3/4" 1/2" 3/8" 3/16" 3 4 8 10 16 30 40 50 60 100 200

PERCENT FINER THAN

100 90 80 70 60 50 40 30 20 10 0

100 10 1 0.1 0.01 0.001 0.0001

GRAIN SIZE, mm

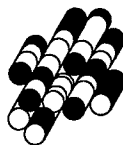
Grain Size (mm)	Percent Finer (%)
100	100
75	100
60	100
48	100
40	100
30	100
25	100
20	100
16	100
12	100
10	100
8	100
6	100
4.75	98
4	97
3	96
2.5	95
2	93
1.5	91
1.18	89
0.85	87
0.75	82
0.6	73
0.5	69
0.425	63
0.354	58
0.25	52
0.18	46
0.15	37
0.106	27

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-2	18.5	168.7

Date ..November 2010...

Project ..1-09-4135...

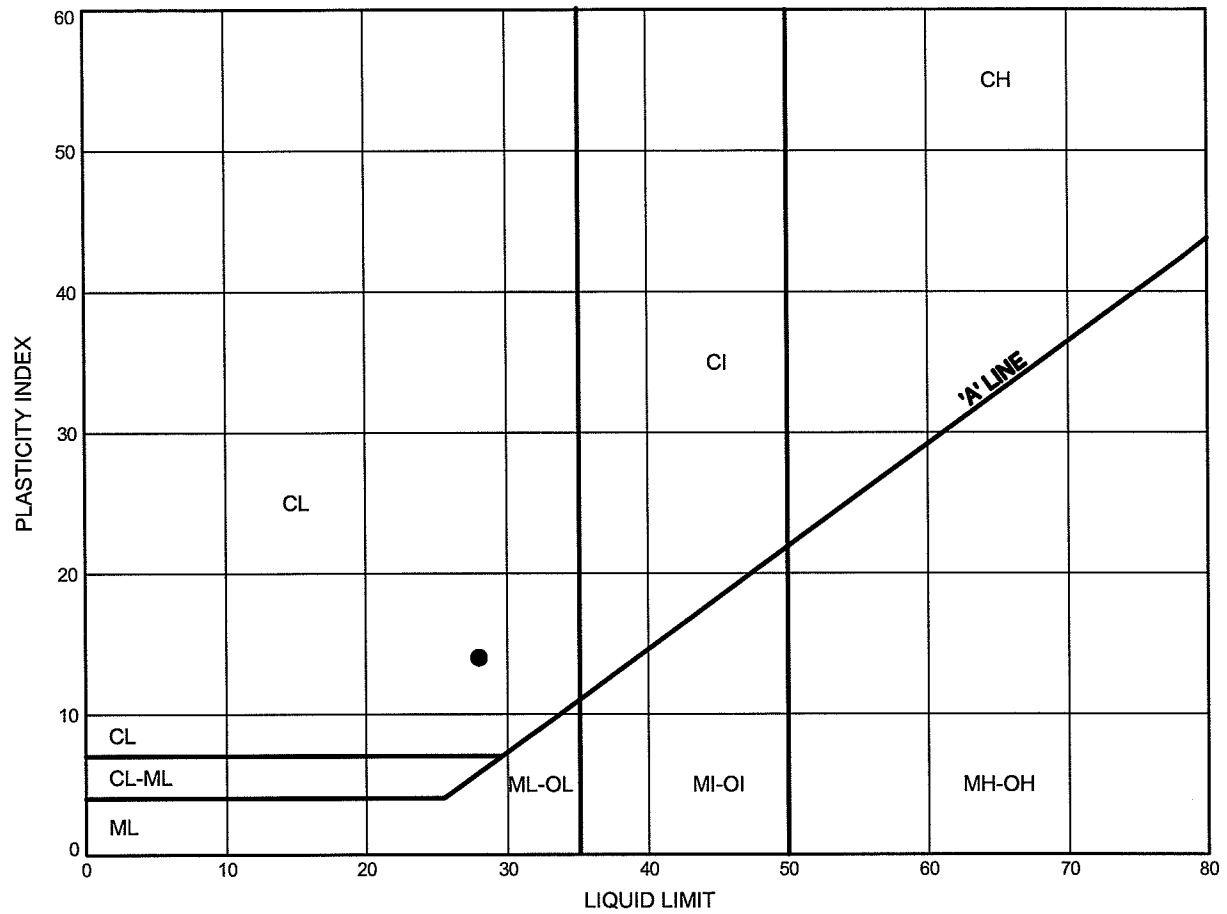


Prep'd JS
Chkd. MP

ATTERBERG LIMITS TEST RESULTS

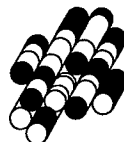
FIGURE B3-9

SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C5-2	18.5	168.7

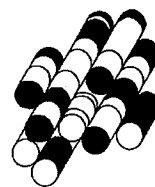
Date November 2010
Project 1-09-4135...



Prep'd JS
Chkd. MP

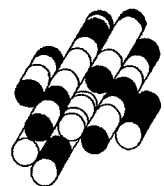
C3

TERRAPROBE INC.



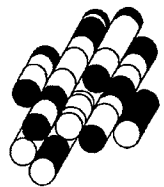
CULVERT #8

TERRAPROBE INC.



A4

TERRAPROBE INC.



RECORD OF BOREHOLE No C6-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763918.4 E:327528.0 ORIGINATED BY JS
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY JS
 DATUM Geodetic DATE 7.26.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
						20 40 60 80 100	20 40 60 80 100	10 20 30							
179.2	Ground Surface						179								
179.0	200mm TOPSOIL														
0.2	SILTY CLAY trace sand, stiff to hard, brown, damp to moist		1	SS	10									0 3 59 38	
			2	SS	15		178								
	frequent silt seams		3	SS	36									0 0 87 13	
			4	SS	23		177								
			5	SS	18		176							0 3 69 28	
			6	SS	28		175								
			7	SS	17									0 3 68 29	
							174								
			8	SS	21		173								
							172								
			9	TW	PH										
							171								
			10	SS	36		170								
169.1							169								
10.1	SILTY CLAY TO CLAYEY SILT sandy, trace gravel, hard, brown, damp (GLACIAL TILL)		11	SS	48		168							4 25 53 18	
			12	SS	86		167								
166.5															
12.7	End of Borehole														
	Borehole was dry (not stabilized) and hole open to full depth on completion.														

Continued Next Page

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

ON MOT 1-09-4135 CULVERTS2.GPJ ON MOT.GDT 9/9/10

RECORD OF BOREHOLE No C6-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763794.6 E:327454.9 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 7.21.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
183.5	Ground Surface							20 40 60 80 100	20 40 60 80 100					
0.1	80mm TOPSOIL		1	SS	16		183							
	FILL - Silty Clay, trace sand, trace organics, very stiff to hard, brown, damp to moist		2	SS	34		182						57	0 3 38 59
182.1			3	SS	27		182							
1.4	SILTY CLAY trace sand, occasional gravel inclusions, very stiff to hard, brown, damp to moist		4	SS	31		181							
			5	SS	20		180							
			6	SS	21		179							
	frequent silt seams		7	SS	19		178							
			8	SS	27		177							0 2 66 32
			9	SS	18		176							
			10	SS	17		174							1 3 67 29
			11	SS	21		173							
			12	SS	19		171							2 2 70 26
			13	SS	24		170							
168.5							169							

Continued Next Page


+³, x³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C6-2

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763794.6 E:327454.9 ORIGINATED BY BL
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 7.21.10 CHECKED BY RA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
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									
							20	40	60	80	100					
15.0	SILTY CLAY TO CLAYEY SILT some sand, trace gravel, hard, brown, damp (GLACIAL TILL)		14	SS	37											GR SA SI CL
167.8						168										2 13 58 27
15.7	End of Borehole															
	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)															
	Jul. 28. 10 4.1 179.4															
	Aug. 06. 10 1.8 181.7															
	Aug. 13. 10 3.6 179.9															
	Aug. 23. 10 4.1 179.4															
	Sept. 25. 10 4.1 179.4															

ON MOT 1-09-4135 CULVERTS2.GPJ ON MOT.GDT 9/9/10

RECORD OF BOREHOLE No WE-S 10+360Lt

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763814.3 E:327476.6 ORIGINATED BY AW
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB
DATUM Geodetic DATE 11.12.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
183.4	Ground Surface							20 40 60 80 100						
0.1	50mm TOPSOIL		1	SS	8		183							
	FILL - Silty Clay, trace sand, stiff, brown, damp to moist		2	SS	15		182							
182.0			3	SS	21		181							
1.4	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist		4	SS	30		180							
			5	SS	32		179							
			6	SS	10		178							
			7	SS	8		177							
			8	SS	10		176							
			9	SS	10		175							
			10	SS	26		174							
			11	TW	PH		173							
			12	SS	10		172							
							171							
							170							
							169							

Continued Next Page

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

2 OF 2

METRIC

LOCATION

Coords: N:4763814.3 E:327476.6

ORIGINATED BY AW

DIST _____ HWY 406

BOREHOLE TYPE

Hollow Stem Augers

COMPILED BY DB

DATUM Geodetic

DATE _____

11.12.09

CHECKED BY RA

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

RECORD OF BOREHOLE No S-EW 10+025Rt

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763892.5 E:327500.9 ORIGINATED BY AW
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY KL
DATUM Geodetic DATE 12.03.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
183.6	Ground Surface						20 40 60 80 100	20 40 60 80 100	10 20 30						
0.1	70mm TOPSOIL		1	SS	13										
	FILL - Silty Clay, trace to some sand, trace organics, occasional gravel inclusions, occasional concrete debris, stiff to hard, brown, damp to moist		2	SS	93										
			3	SS	50									0 11 59 30	
			4	SS	15										
			5	SS	12										
			6	SS	14										
179.2			7	SS	25										
4.4	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		8	SS	17									0 2 67 31	
			9	SS	21										
			10	SS	11									0 2 68 30	
			11	SS	15										
			12	TW	PH								21.0	0 4 75 21	
			13	SS	28									0 2 66 32	

Continued Next Page

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

RECORD OF BOREHOLE No S-EW 10+025Rt

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763892.5 E:327500.9 ORIGINATED BY AW
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY KL
DATUM Geodetic DATE 12.03.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE						
								20 40 60 80 100							
167.4			14	SS	26		168								
16.2	CLAYEY SILT TO SILTY CLAY sandy, some gravel, hard, brown, damp (GLACIAL TILL)		15	SS	81		167							15 34 38 13	
164.8			16	SS	125		165								
18.8	End of Borehole														
	Unable to push vane beyond 15.7m. 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 3.0m slotted screen. Water Level Readings: Date Depth(m) Elevation(m) Dec. 08.09 17.7 165.9 Dec. 15.09 16.1 167.5 Jan. 04.10 5.0 178.6 Jan. 11.10 3.9 179.7 Jan. 19.10 4.0 179.6 Consolidation Test performed on TW12														

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

Test Pit Logs
Culvert #6 (Highway 406 Sta. 12+354)

Test Pit# TP 6-1

0	-	200	Dk Br Si(y) Cl, Some Org, Some Rootlets, Moist
200	-	1.22	Br Si(y) Cl, Tr Sa, Damp to Moist

Test Pit# TP 6-2

0	-	610	Br Si(y) Cl, Some Org, Some Rootlets, Moist
610	-	910	Br Si(y) Cl, Tr Sa, Tr Rootlets, Moist
910	-	1.22	Br Si(y) Cl, Damp to Moist

Test Pit# TP 6-3

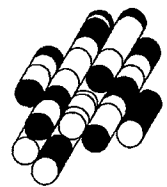
0	-	610	Br Si(y) Cl, Tr Sa, Some Org, Some Rootlets, Moist
610	-	1.83	Br Si(y) Cl, Occ Sa Lense, Damp to Moist

Test Pit# TP 6-4

0	-	300	Br Si(y) Cl, Tr Sa, Some Org, Some Rootlets, Moist
300	-	1.83	Br Si(y) Cl, Tr Sa, Damp to Moist

B4

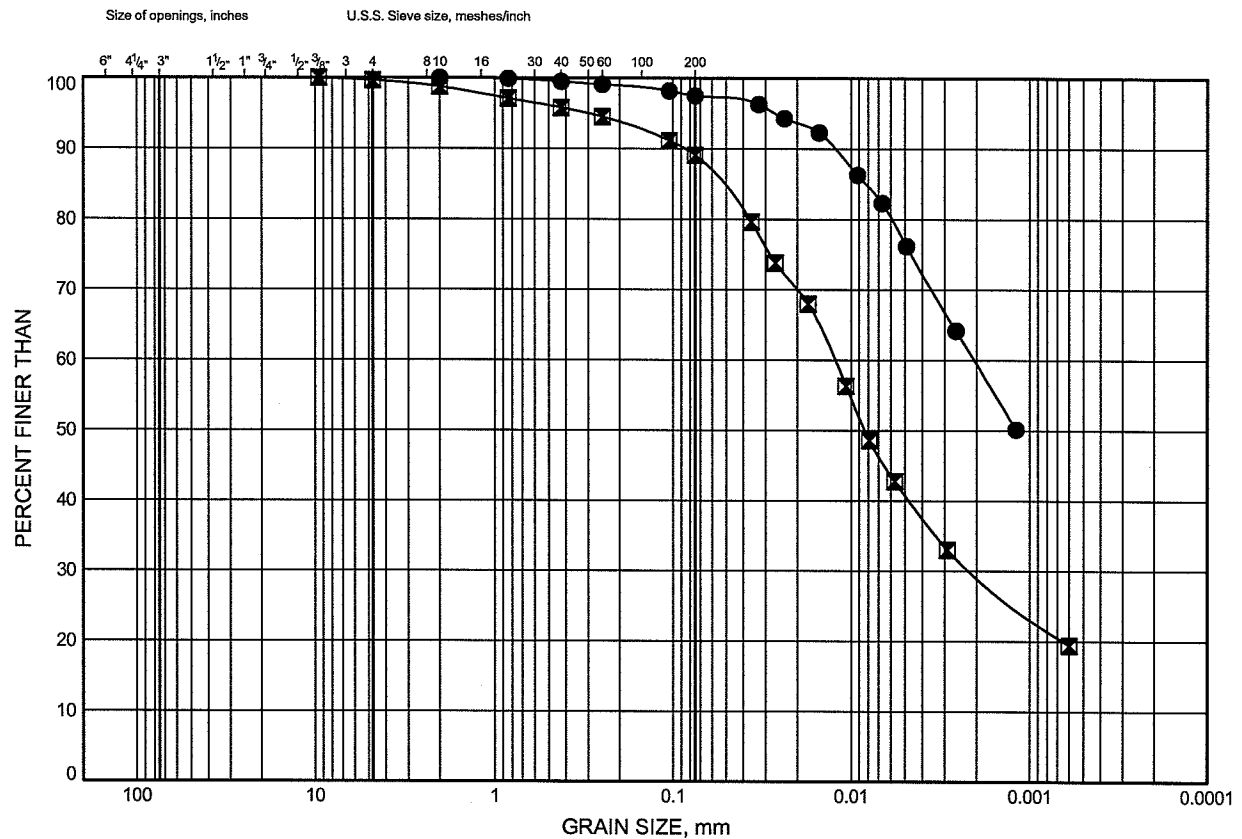
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B4-1

FILL - Silty Clay



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

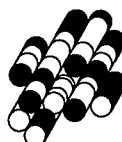
SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

● C6-2 1.0 182.5

■ S-EW 10+025Rt 1.7 181.9

Date November 2010

Project 1-09-4135



Prep'd JS

Chkd. MP

FIGURE B4-2

The Plasticity Chart (Figure 2) is a graph of Plasticity Index (PI) on the y-axis (0 to 60) versus Liquid Limit (LL) on the x-axis (0 to 80). The chart is divided into several regions by horizontal and diagonal lines. The regions are labeled as follows:

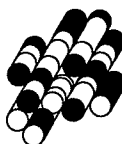
- CL** (Clay of Low Plasticity): LL < 40, PI < 7
- CH** (Clay of High Plasticity): LL > 40, PI > 7
- CI** (Clay of Intermediate Plasticity): LL > 40, PI < 7
- MI-OI** (Silt of Medium to High Plasticity): LL > 40, PI < 7
- MH-OH** (Silt of High Plasticity): LL > 40, PI < 7
- ML** (Silt of Low Plasticity): LL < 40, PI < 4
- CL-ML** (Clay of Low to Medium Plasticity): LL < 40, 4 < PI < 7
- ML-OL** (Silt of Low to High Plasticity): LL < 40, PI < 4

A diagonal line labeled **'A' LINE** is plotted, representing the boundary between the CL and CH regions. A data point is plotted at approximately (57, 31), which falls within the CH region. Another point is marked with a cross at approximately (26, 12), which falls within the CL region.

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C6-2	1.0	182.5
☒	S-EW 10+025Rt	1.7	181.9

Date November 2010

Project 1-09-4135.....



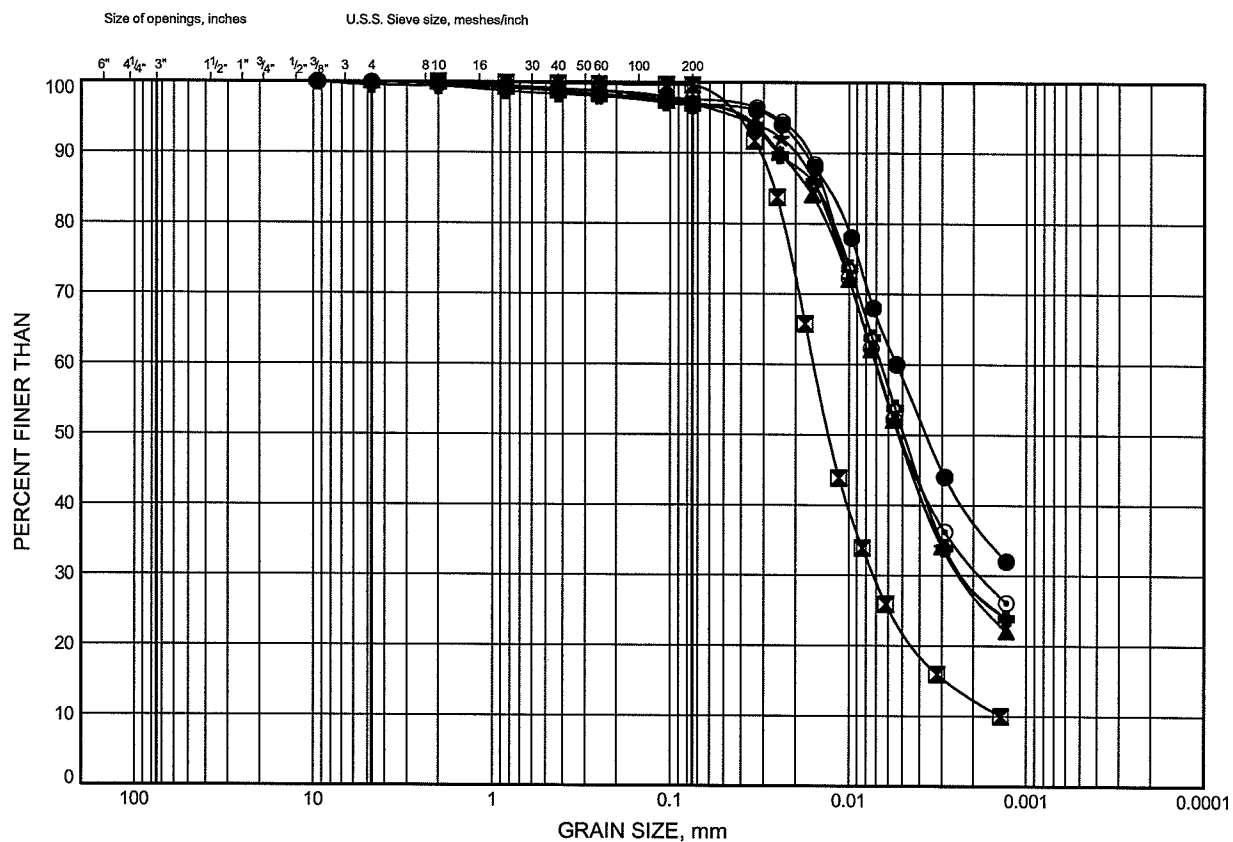
Prep'dK.L.

Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B4-3

SILTY CLAY



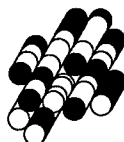
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C6-1	0.4	178.8
⊠	C6-1	1.7	177.5
▲	C6-1	3.2	176.0
★	C6-1	4.7	174.5
⊙	C6-2	6.3	177.2
⊕	C6-2	9.3	174.2

Date November 2010

Project 1-09-4135



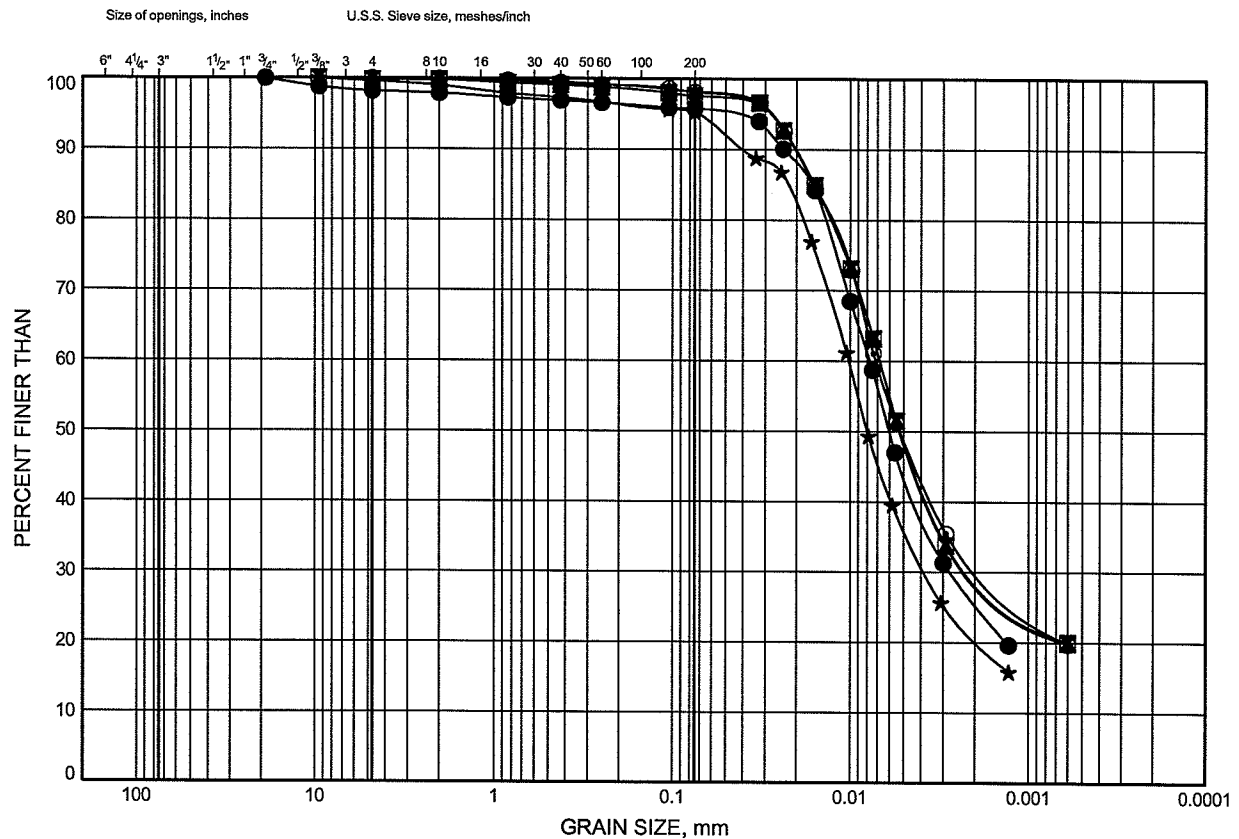
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B4-4

SILTY CLAY



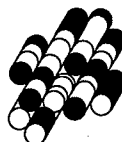
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C6-2	12.4	171.1
■	S-EW 10+025Rt	6.3	177.3
▲	S-EW 10+025Rt	9.3	174.3
★	S-EW 10+025Rt	12.4	171.2
⊙	S-EW 10+025Rt	13.9	169.7

Date November 2010

Project 1-09-4135



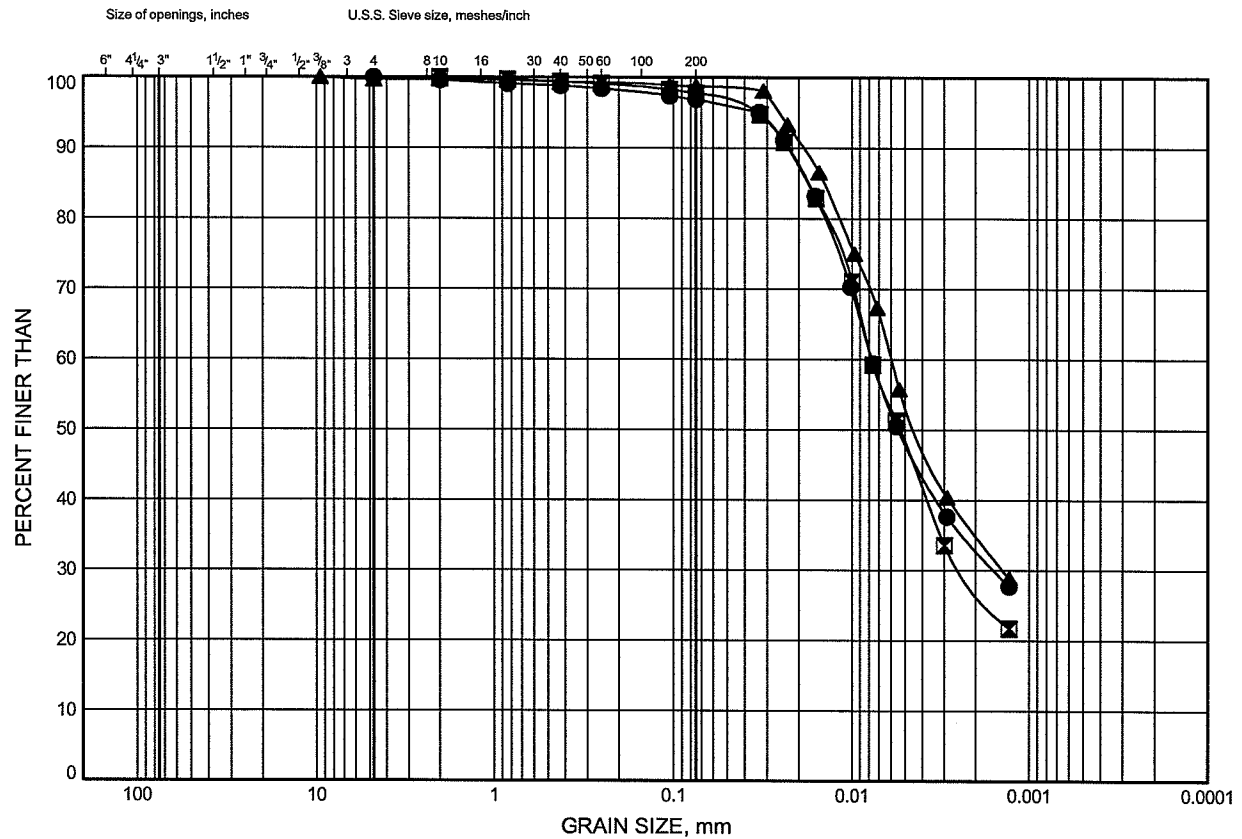
Prep'd JS

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B4-5

SILTY CLAY



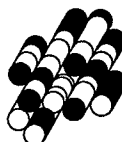
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	WE-S 10+360Lt	3.2	180.2
■	WE-S 10+360Lt	6.3	177.1
▲	WE-S 10+360Lt	13.9	169.5

Date November 2010

Project 1-09-4135

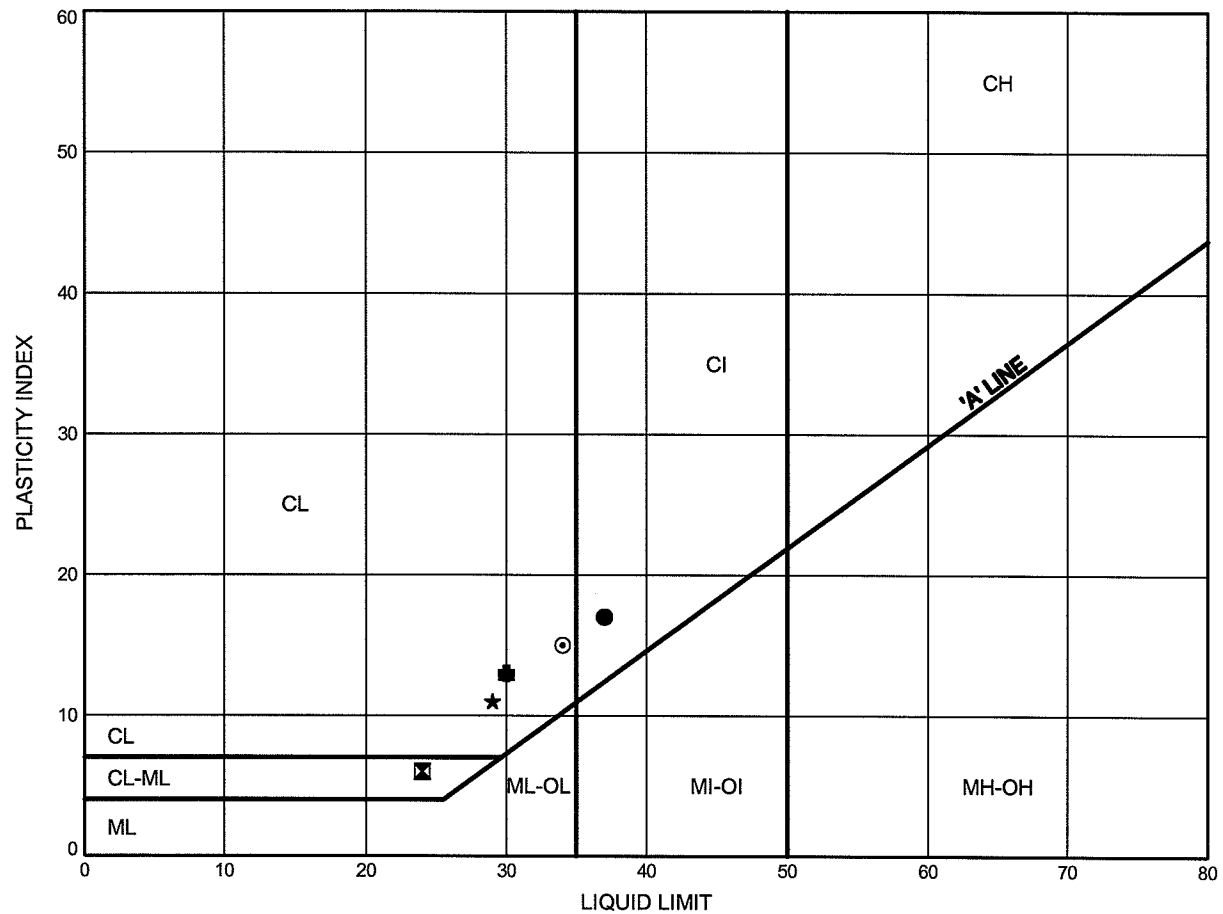


Prep'd JS

Chkd. MP

FIGURE B4-6

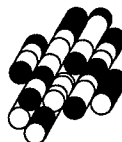
SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C6-1	0.4	178.8
⊠	C6-1	1.7	177.5
▲	C6-1	3.2	176.0
★	C6-1	4.7	174.5
⊙	C6-2	6.3	177.2
⊕	C6-2	9.3	174.2

Date November 2010

Project 1-09-4135.....



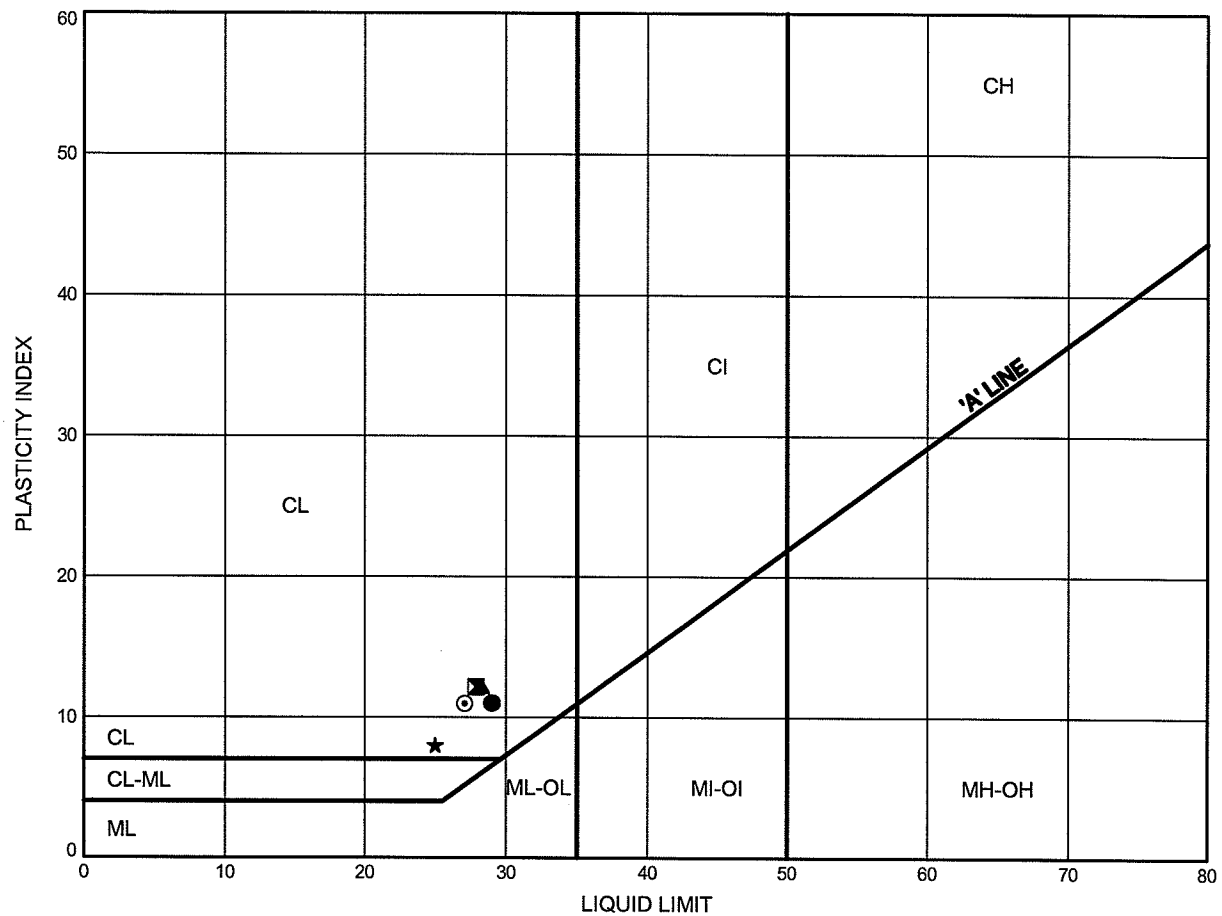
Prep'dK.L.

Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

FIGURE 4-7

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C6-2	12.4	171.2
⊠	S-EW 10+025Rt	6.3	177.3
▲	S-EW 10+025Rt	9.3	174.3
★	S-EW 10+025Rt	12.4	171.2
⊙	S-EW 10+025Rt	13.9	169.7

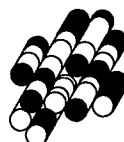
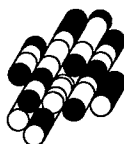


FIGURE B4-8

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WE-S 10+360Lt	3.2	180.2
☒	WE-S 10+360Lt	6.3	177.1
▲	WE-S 10+360Lt	12.4	171.0
★	WE-S 10+360Lt	13.9	169.5

Project 1-09-4135

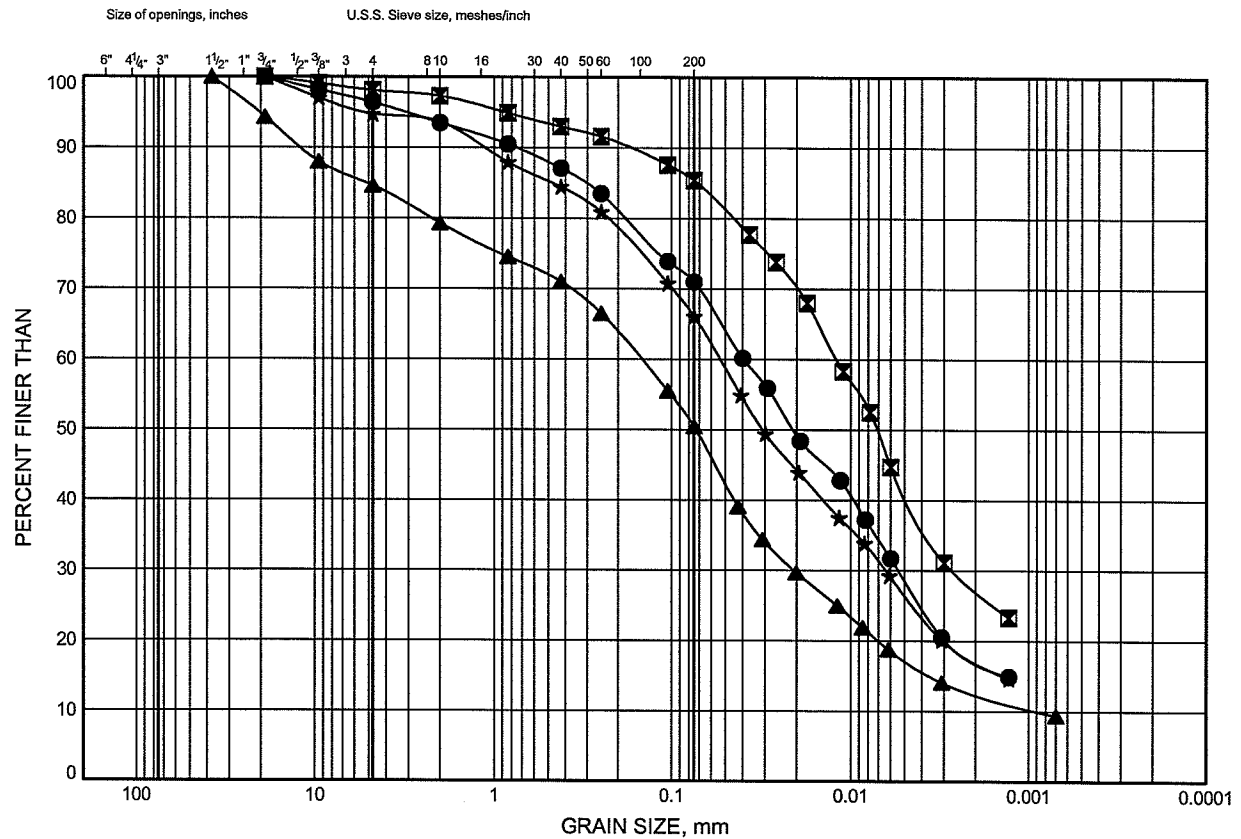


Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B4-9

SILTY CLAY TO CLAYEY SILT TILL



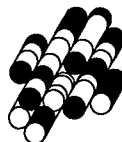
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C6-1	10.9	168.3
⊠	C6-2	15.4	168.1
▲	S-EW 10+025Rt	17.0	166.6
★	WE-S 10+360Lt	18.5	164.9

Date November 2010

Project 1-09-4135



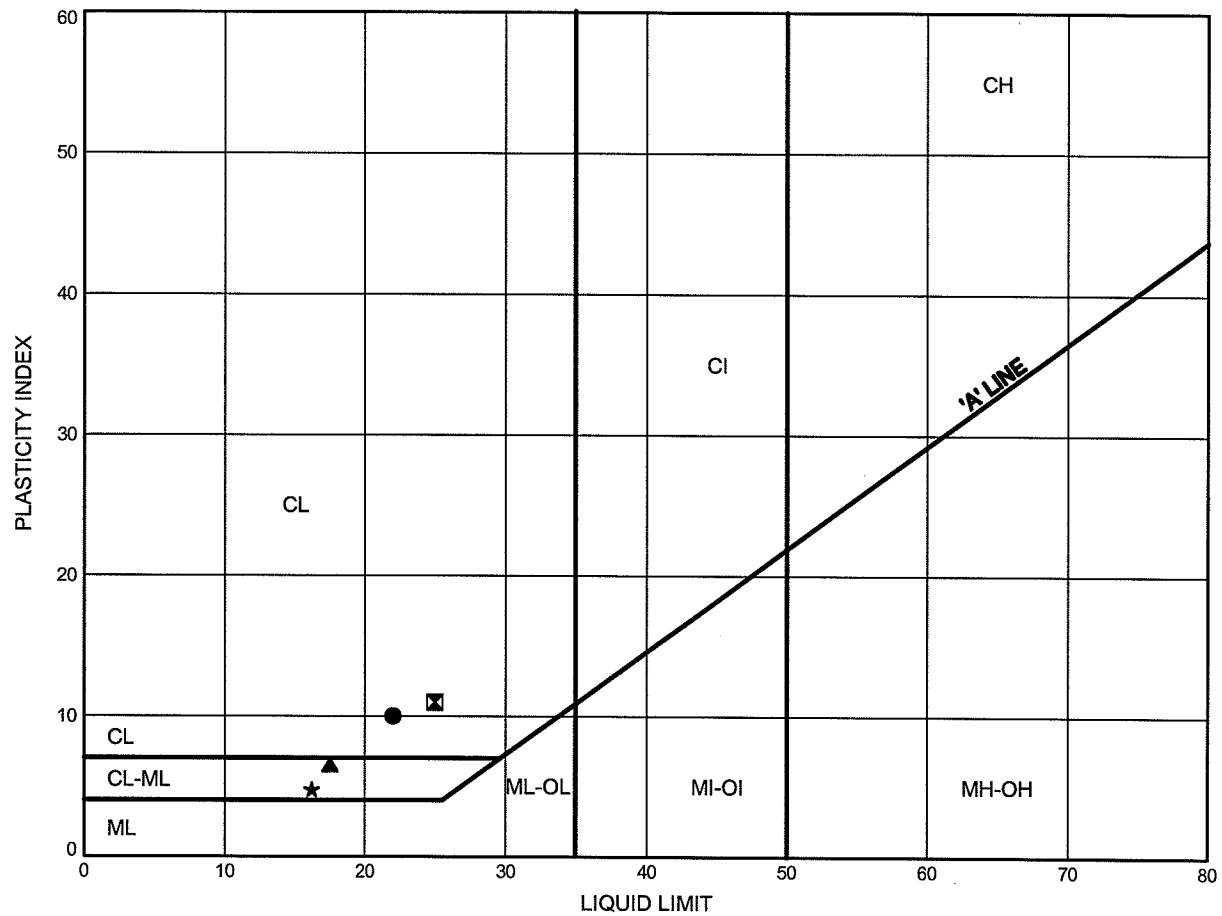
Prep'd JS

Chkd. MP

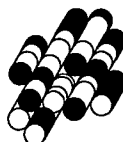
ATTERBERG LIMITS TEST RESULTS

FIGURE B4-10

SILTY CLAY TO CLAYEY SILT TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C6-1	10.9	168.3
⊠	C6-2	15.4	168.1
▲	WE-S 10+025Lt	17.0	166.6
★	WE-S 10+360Lt	18.5	164.9



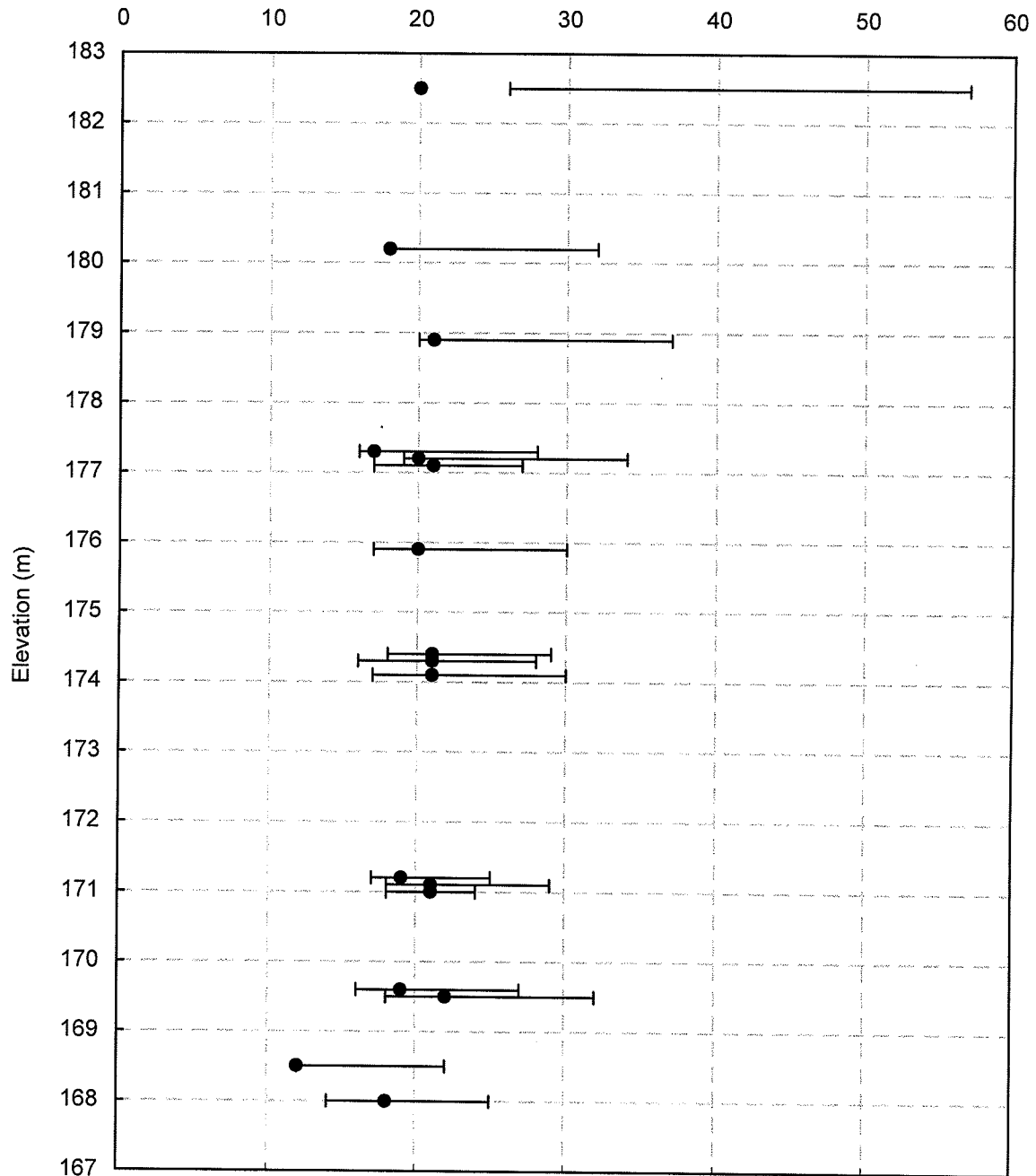
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B4-11

HWY 406 TWINNING - CULVERT #6

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

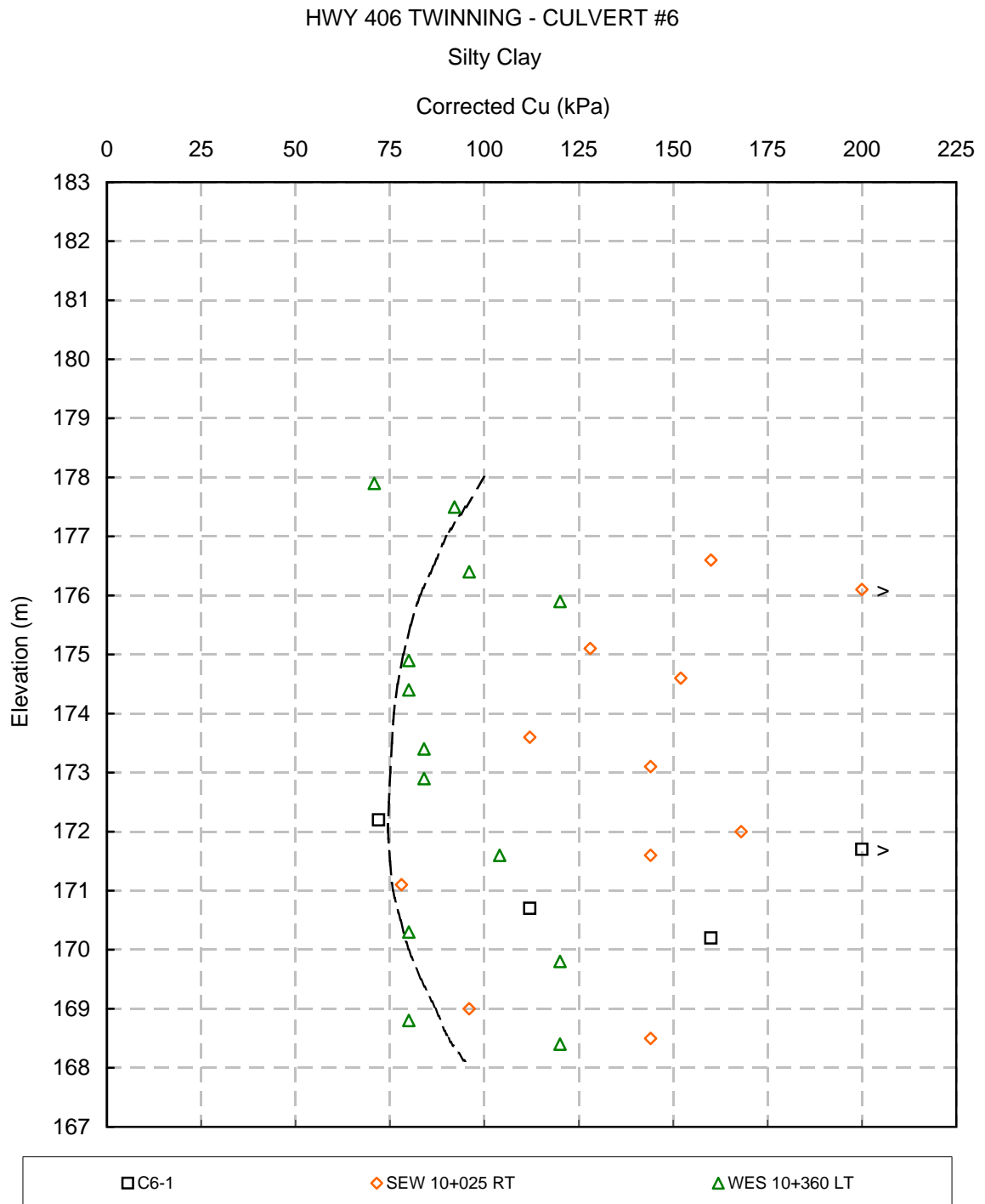
Prepared By : HW

Checked By : RA

CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B4-12

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\1-09-4135C6 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

0.89 (Elev.>177m) 1.00 (Elev.<177m)

Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

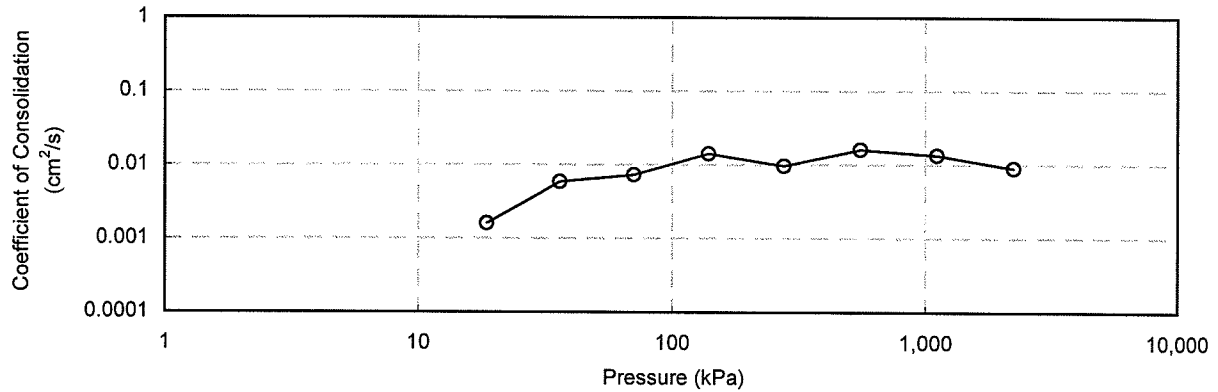
Prepared By : HW

Checked By : RA

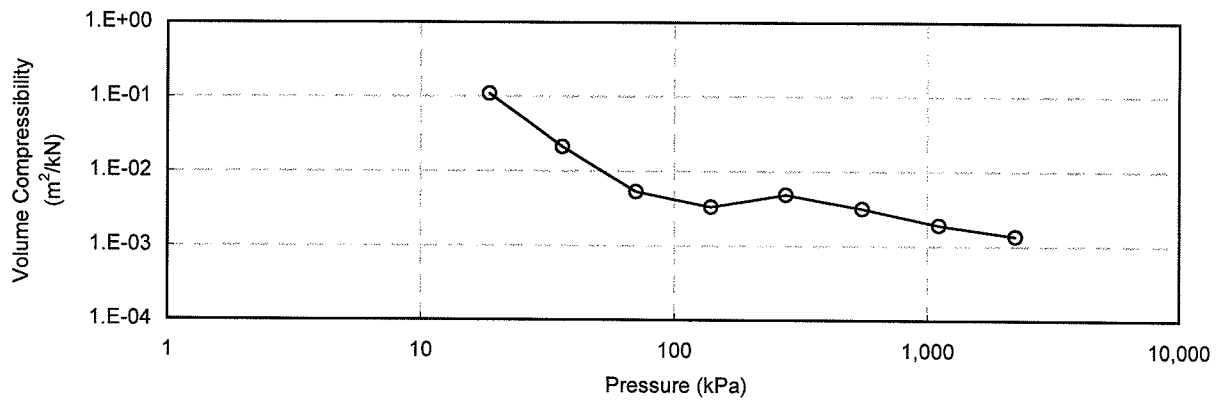
HWY 406 TWINNING - CULVERT#6

FIGURE B4-13

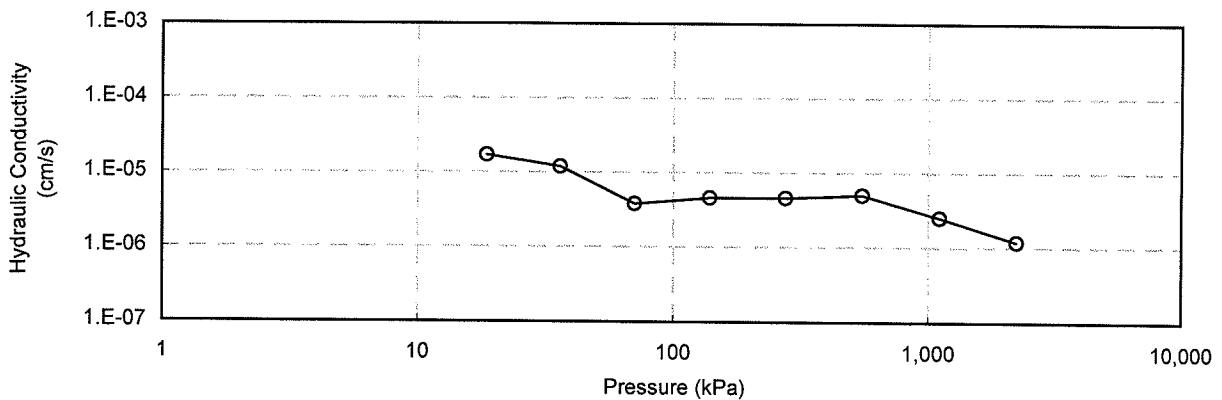
CONSOLIDATION TEST
Cv vs Pressure
SEW 10+025, TW12



CONSOLIDATION TEST
mv vs Pressure
SEW 10+025, TW12



CONSOLIDATION TEST
k vs Pressure
SEW 10+025, TW12



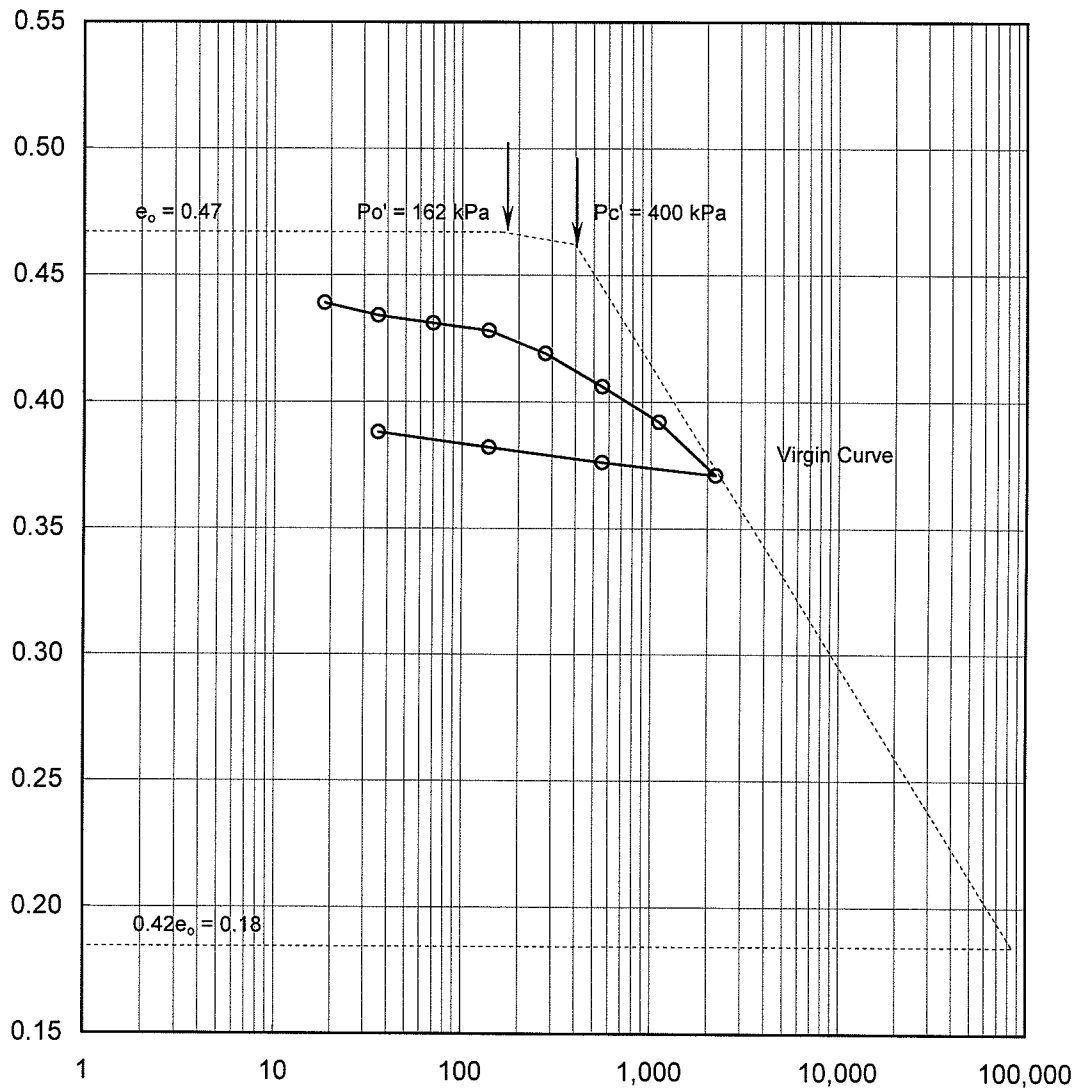
Project No. : 1-09-4135
Date : November 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
e vs Pressure
SEW 10+025, TW12



Soil Type : Silty Clay

$e_o =$	0.47	$\omega_L =$	25%	$P_o' =$	162 kPa
$\omega =$	19%	$\omega_p =$	17%	$P_c' =$	400 kPa
$\gamma =$	21.8 kN/m ³	PI =	8%	Cc =	0.119
Gs =	2.73			Cr =	0.013

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



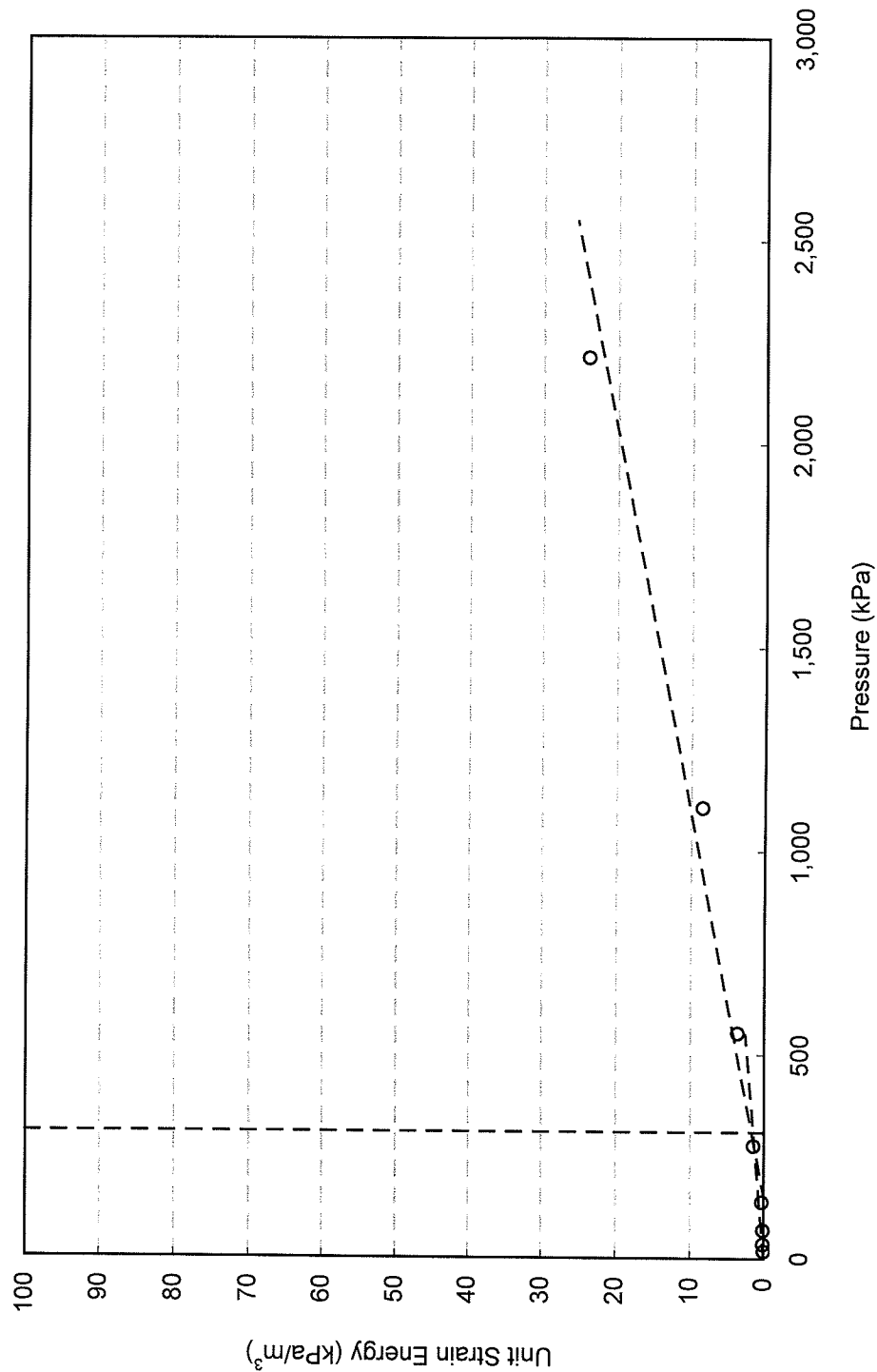
Terraprobe Inc.

Prepared By : HW
Checked By : RA

HWY 406 TWINNING - CULVERT#6

FIGURE B4-15

CONSOLIDATION TEST Unit Strain Energy vs Pressure SEW 10+025, TW12



$P_c = 310 \text{ kPa}$

Project No. : 1-09-4135

Date : November 2010

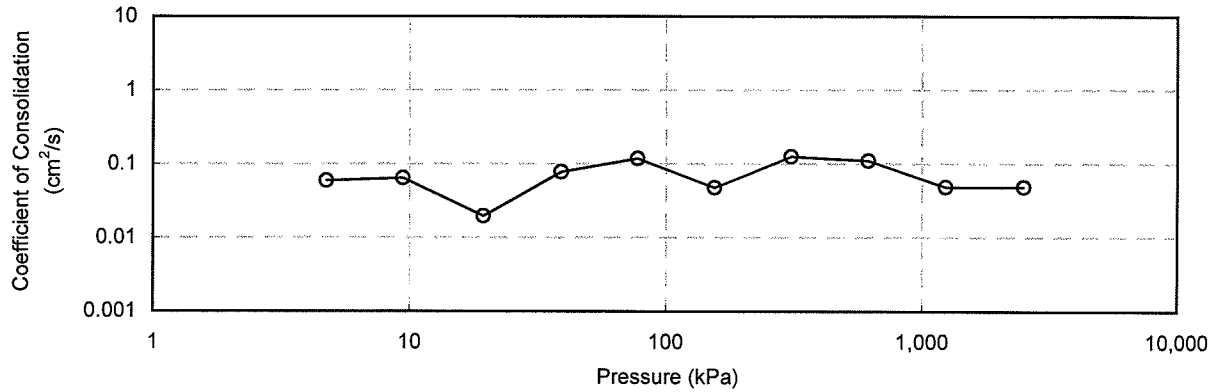


Terraprobe Inc.

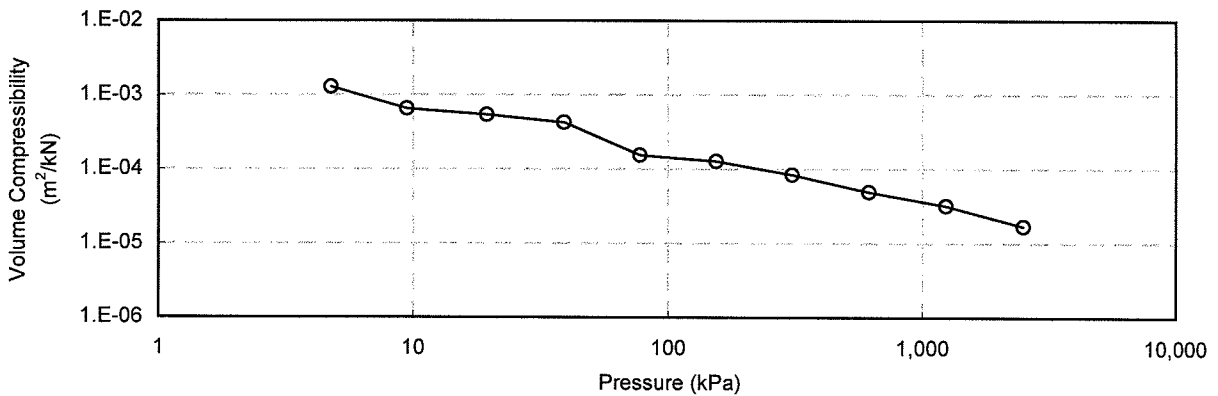
Prepared By : HW

Checked By : RA

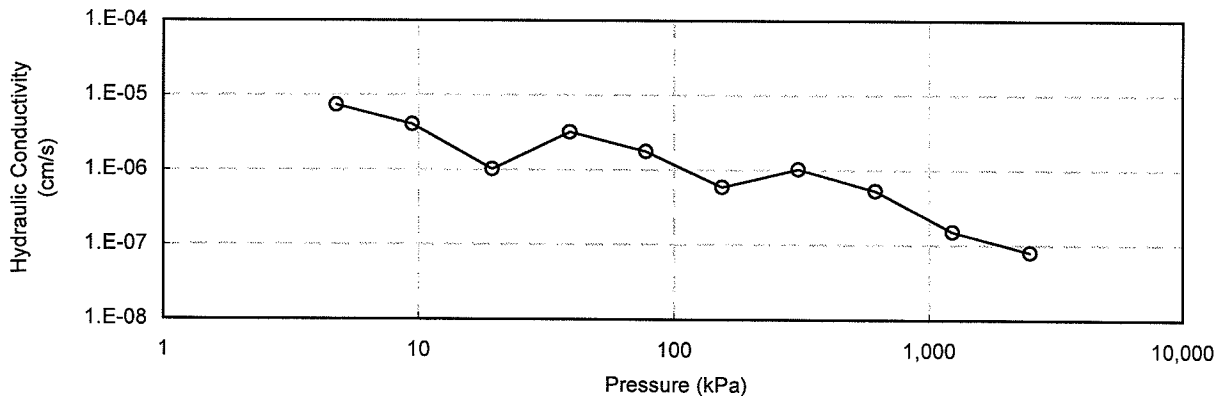
CONSOLIDATION TEST
Cv vs Pressure
WES 10+360 LT, TW11



CONSOLIDATION TEST
mv vs Pressure
WES 10+360 LT, TW11



CONSOLIDATION TEST
k vs Pressure
WES 10+360 LT, TW11



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

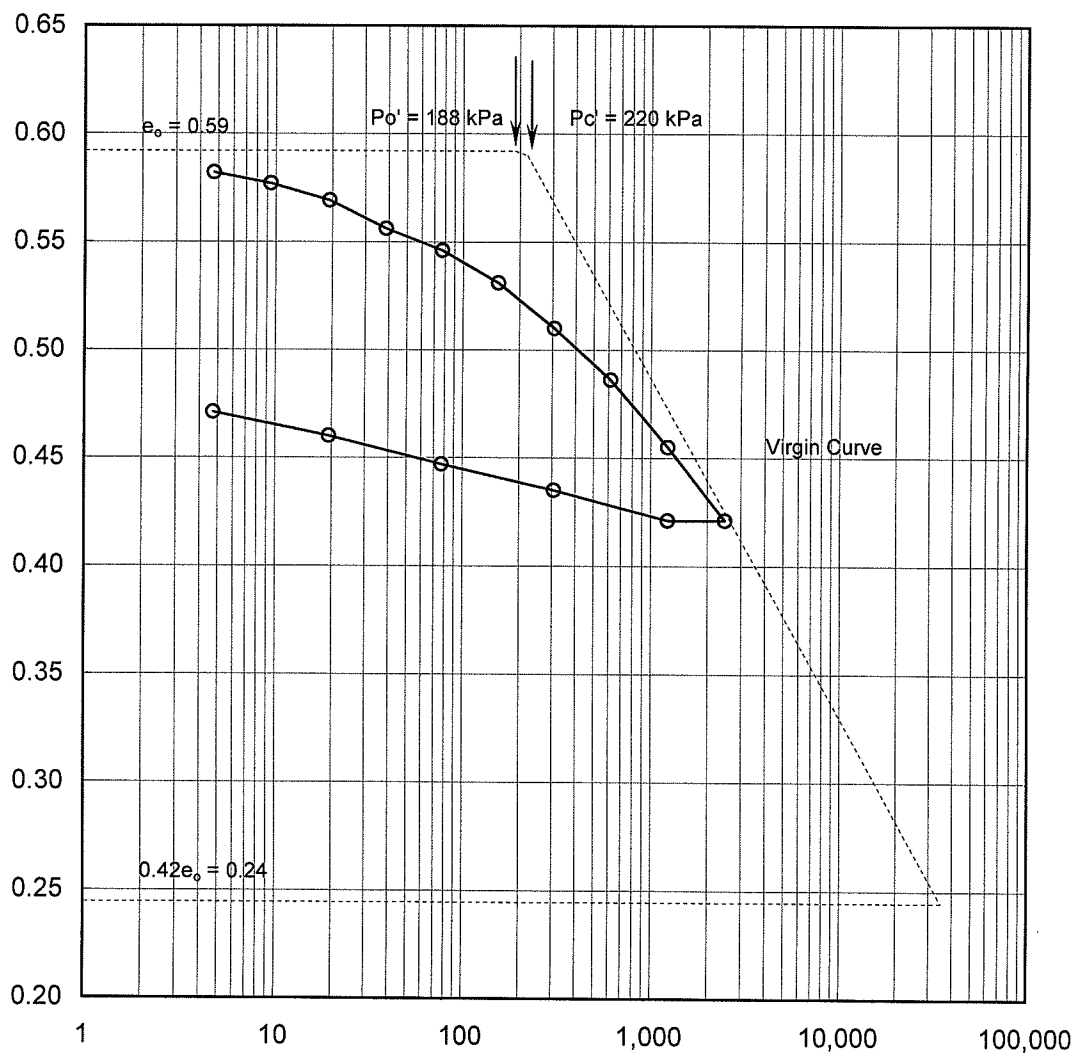
Project No. : 1-09-4135
Date : November 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
e vs Pressure
WES 10+360 LT, TW11



Soil Type : Silty Clay

$e_o =$	0.59	$\omega_L =$	24%	$P_o' =$	188 kPa
$\omega =$	21%	$\omega_p =$	18%	$P_c' =$	220 kPa
$\gamma =$	20.5 kN/m ³	PI =	6%	Cc =	0.157
Gs =	2.75			Cr =	0.029

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



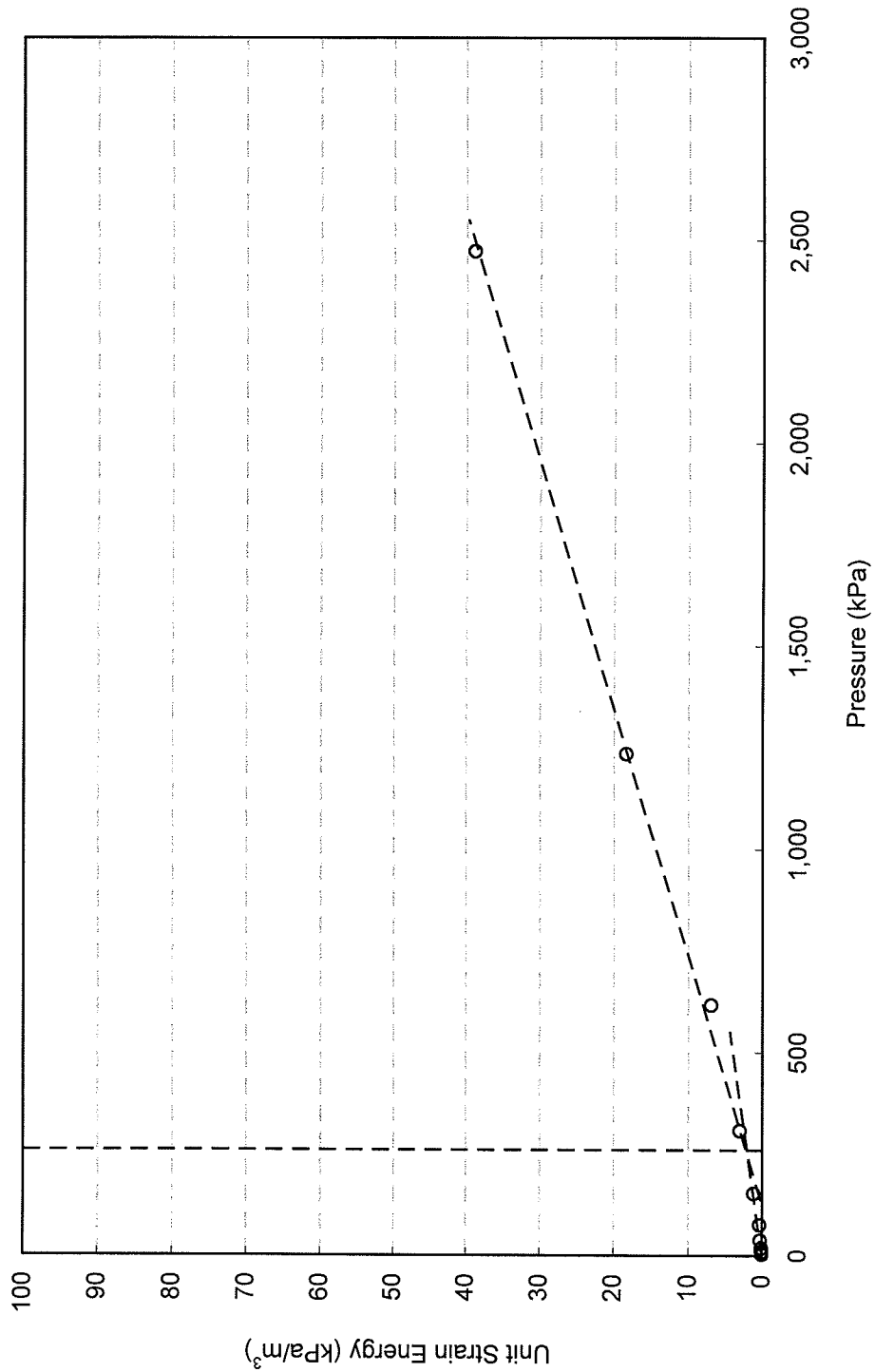
Terraprobe Inc.

Prepared By : HW
Checked By : RA

HWY 406 TWINNING - CULVERT#6

FIGURE B4-18

CONSOLIDATION TEST Unit Strain Energy vs Pressure WES 10+360 LT, TW11



Pc = 260 kPa

Project No. : 1-09-4135

Date : November 2010



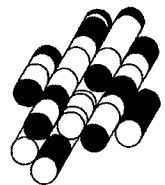
Terraprobe Inc.

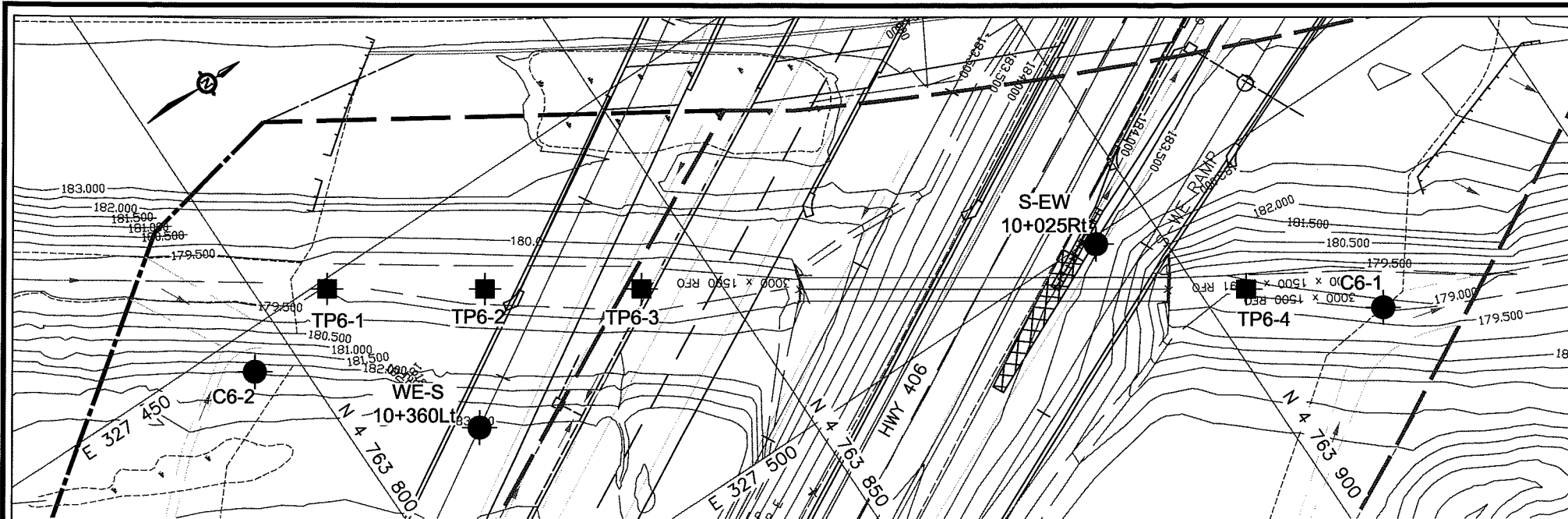
Prepared By : HW

Checked By : RA

C4

TERRAPROBE INC.





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

CONT No 2011-2005
WP No 280-99-00

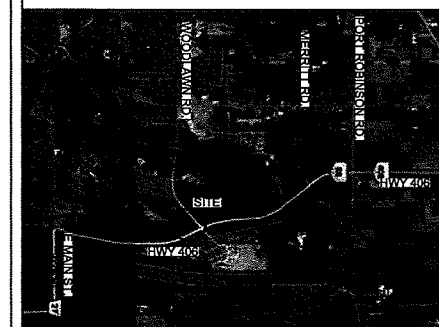
HIGHWAY 406
CULVERT # 8
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET
1 OF



Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650



KEY PLAN

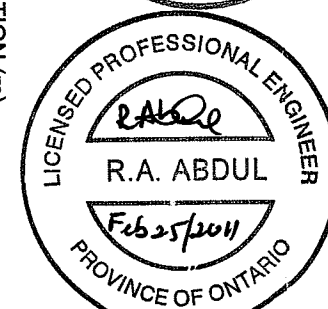
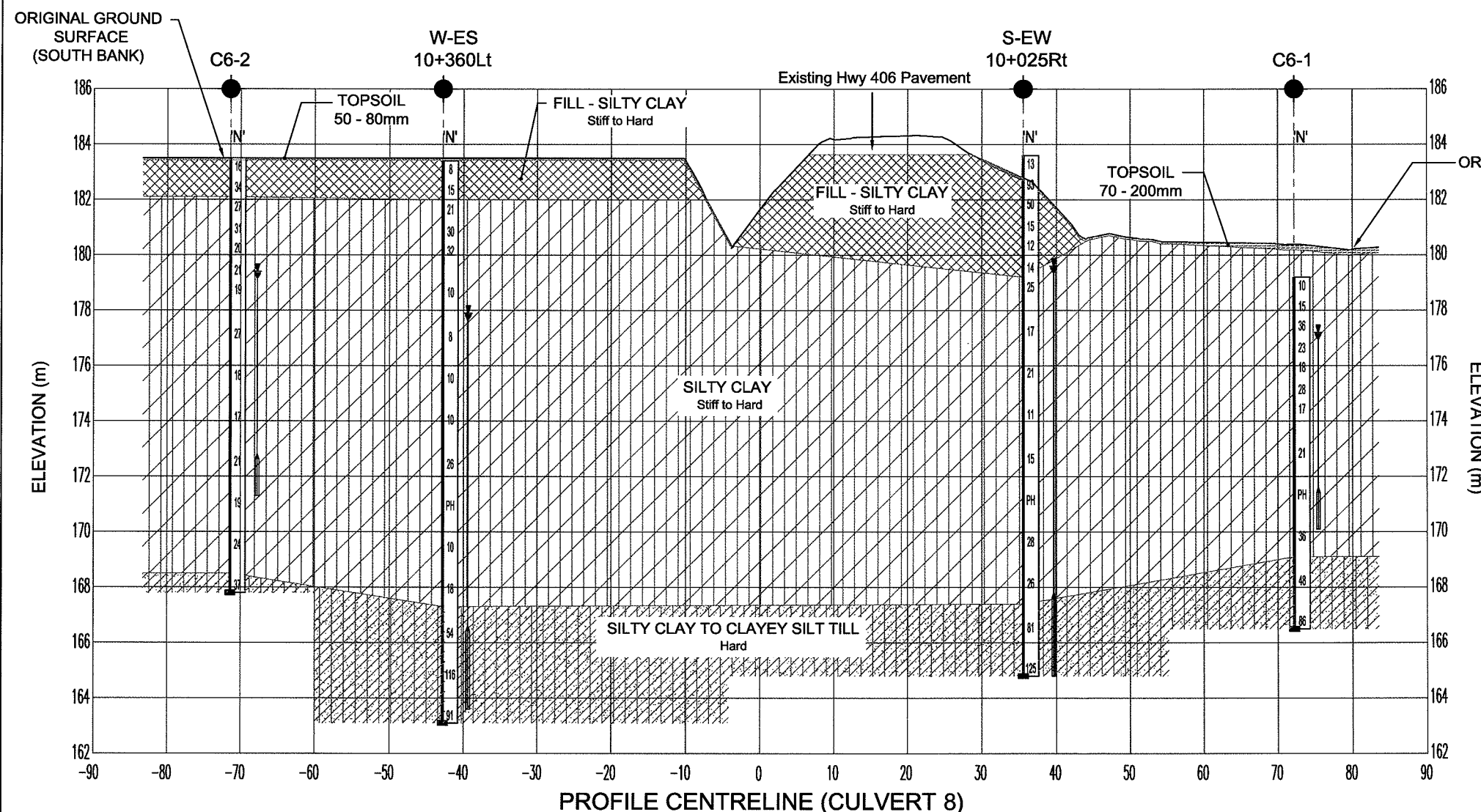
LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test
- Bore Hole And Cone
- Test Pit
- N' Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer (SEPT. 2010)
- Piezometer
- 90% Rock Quality Designation
- A/R Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
C6-1	179.2	4 763 918.4	327 528.0
C6-2	183.5	4 763 794.6	327 454.9
SEW 10+025Rt	183.6	4 763 892.5	327 500.9
W-ES 10+360Lt	183.4	4 763 814.3	327 476.6

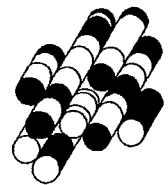
NOTE
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS		DATE		BY	DESCRIPTION
DESIGN	R.A.	CODE	CHBDC2006	LOAD	DATE FEB. 2011
DRAWN	K.C.	CHK	R.A.	STRUCT	GEORES 30M3-269



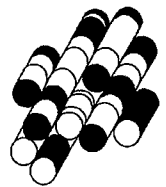
CULVERT #9

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A5

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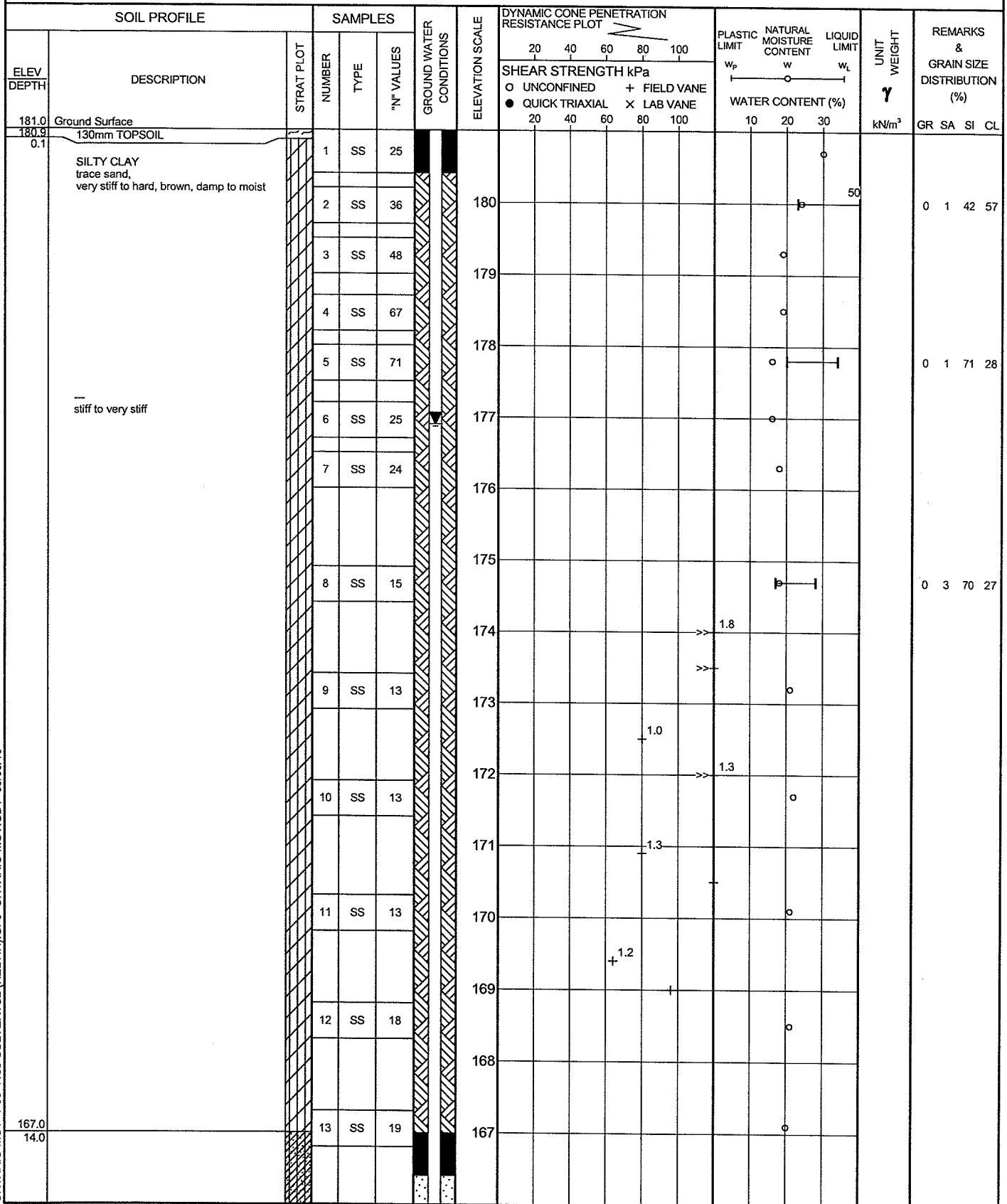


RECORD OF BOREHOLE No C7-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763942.5 E:327381.6
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers
 DATUM Geodetic DATE 06.29.10
 ORIGINATED BY PK
 COMPILED BY DB
 CHECKED BY RA

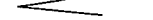




Continued Next Page

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

2 OF 2

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60 80 100				
164.0	CLAYEY SILT TO SILTY CLAY sandy, trace gravel, very stiff to hard, brown, damp to moist (GLACIAL TILL)		14	SS	17		165						GR SA SI C
17.0			15	SS	100/10cm		164						

No sample recovery at SS7. Sampler redriven and disturbed sample collected.

Resistance to augering at 15.8m and 16.6m.

Borehole was dry (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Scheduled 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
July.05.10	5.5	175.5
July.13.10	4.2	176.8
July.19.10	4.1	176.9

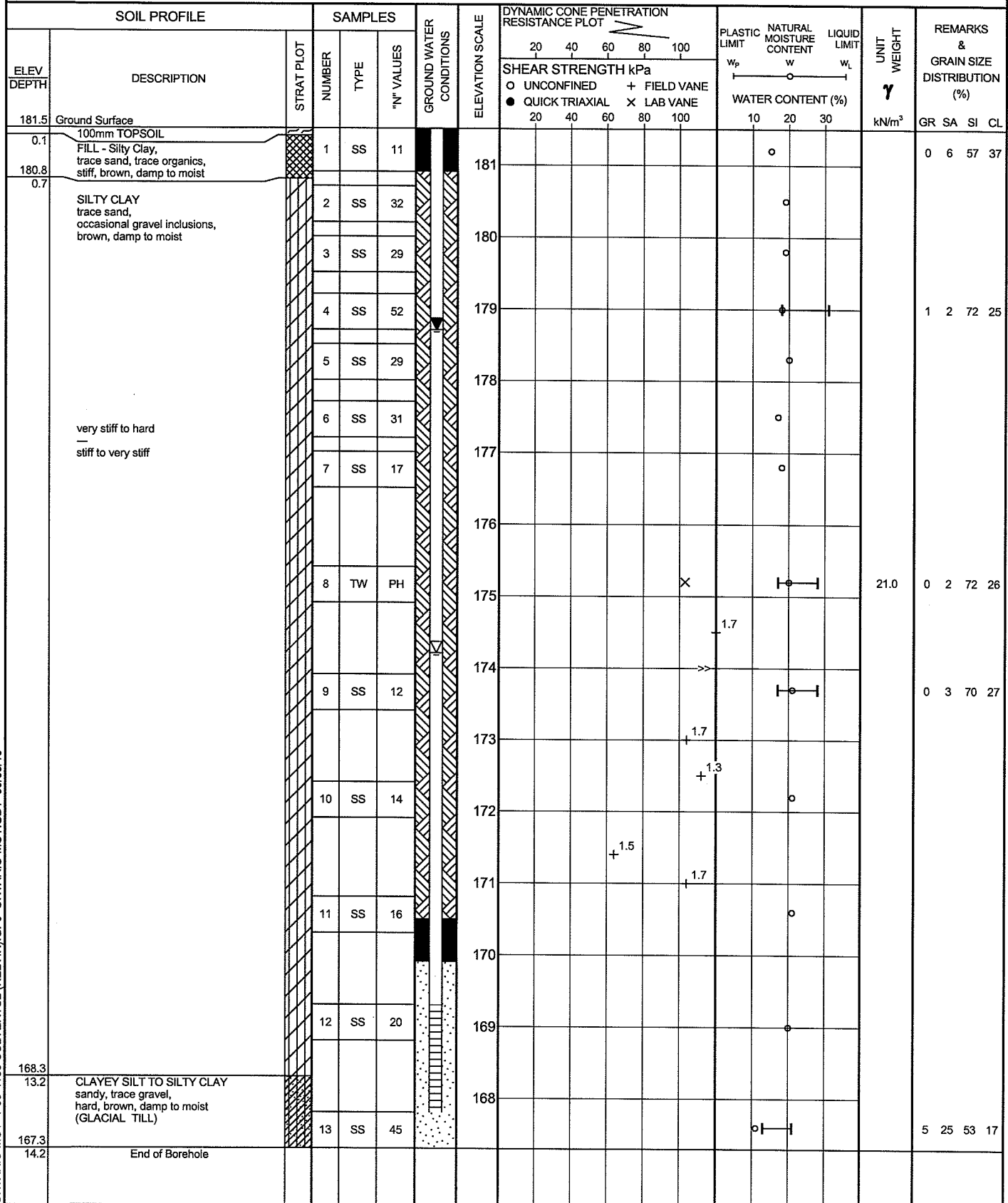
+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C7-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4763976.6 E:327417.4 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 06.28.10 CHECKED BY RA



Continued Next Page

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

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

RECORD OF BOREHOLE No C7-3

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4764008.4 E:327455.7 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 06.25.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
182.4	Ground Surface							20 40 60 80 100		10 20 30				GR SA SI CL
0.1	80mm TOPSOIL		1	SS	23		182				○			
	SILTY CLAY trace sand, brown, damp to moist very stiff to hard — stiff to very stiff		2	SS	45		181				○			
			3	SS	43		180				○			
			4	SS	39		179				○			
			5	SS	48		178				○			
			6	SS	15		177		1.6		○			0 1 79 20
			7	SS	14		176				○			
			8	SS	11		175		1.4		○			
			9	SS	14		174				○			
			10	SS	16		173		1.3		○			0 2 70 28
			11	SS	22		172				○			
			12	SS	20		171				○			
169.2	CLAYEY SILT TO SILTY CLAY sandy, trace gravel, hard, brown, damp (GLACIAL TILL)		13	SS	41		170			○				
13.2							169			○			4 25 53 18	
							168							

Continued Next Page

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

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

RECORD OF BOREHOLE No C7-3

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4764008.4 E:327455.7 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 06.25.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
166.8			14	SS	160/ 20cm		167										
15.6	End of Borehole Borehole was dry (not stabilized) and hole open to full depth on completion.																

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

RECORD OF BOREHOLE No C7-4

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4764040.4 E:327486.8 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.07.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
182.0	Ground Surface							20 40 60 80 100							
181.8	200mm PEAT							20 40 60 80 100							
0.2	stiff		1	SS	10										
	—		2	SS	21		181							0 1 47 52	
	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist		3	SS	32		180								
			4	SS	29		179								
			5	SS	18		178							0 1 56 43	
	—		6	SS	34		177								
	frequent sandy silt seams		7	SS	37		176								
	—		8	SS	18		175							0 3 69 28	
			9	SS	16		174								
			10	SS	17		173								
			11	SS	14		172								
			12	SS	27		171								
169.7	CLAYEY SILT to SILTY CLAY, trace sand, very stiff, brown, damp (GLACIAL TILL)						170							0 2 78 20	
12.3	End of Borehole														
169.4	No sample recovery in SS8 and SS10. Sampler redriven and disturbed sample collected.														
12.6	Borehole was dry (not stabilized) and hole open to full depth on completion.														

Continued Next Page

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

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

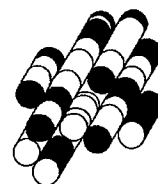
Test Pit Logs
Culvert #7 (Highway 406 Sta. 12+525)

Test Pit# TP 7-1

0	-	230	Dk Br/Blk Amor Peat, Some Rootlets, Moist
230	-	610	Br Si(y) Cl, Tr to Some Org, Tr Rootlets, Moist
610	-	1.22	Br Si(y) Cl, Tr Sa, Damp to Moist

B5

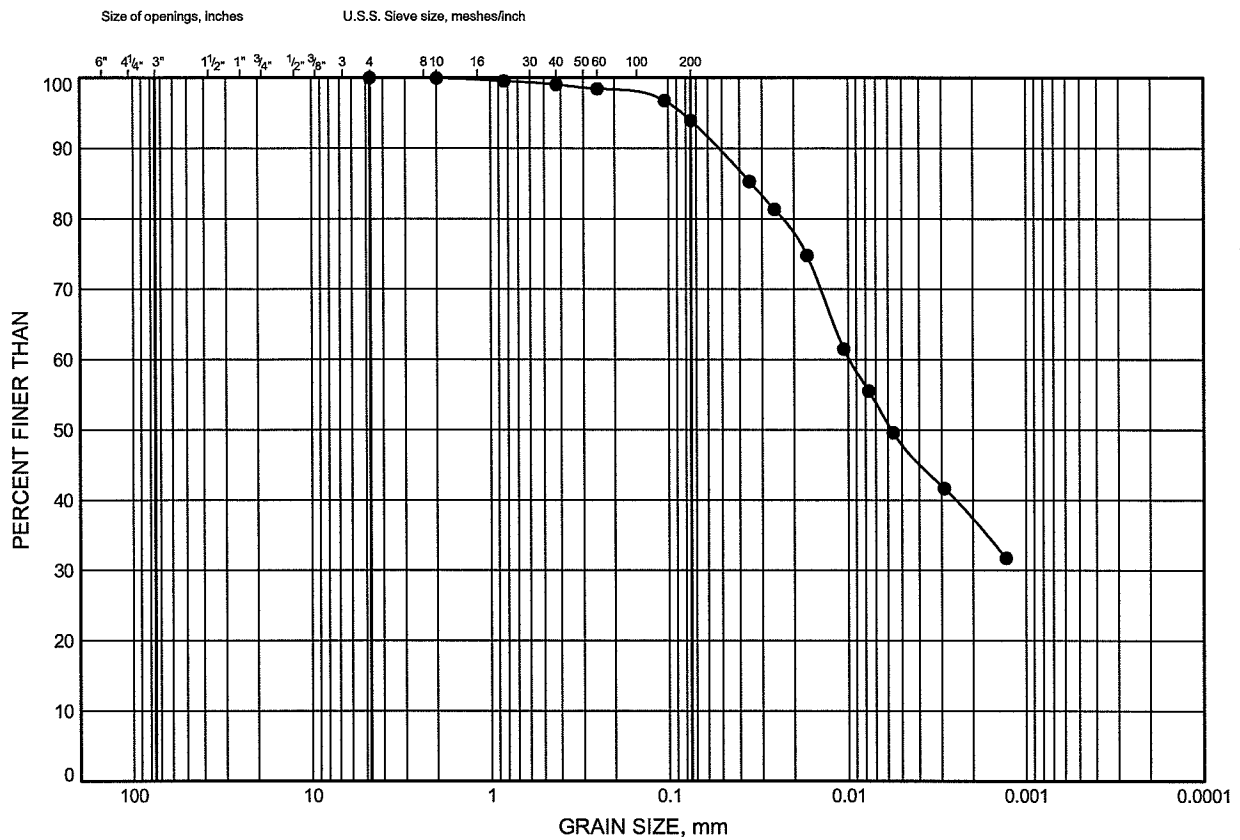
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B5-1

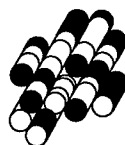
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-2	0.3	181.2

Date November 2010
Project 1-09-4135

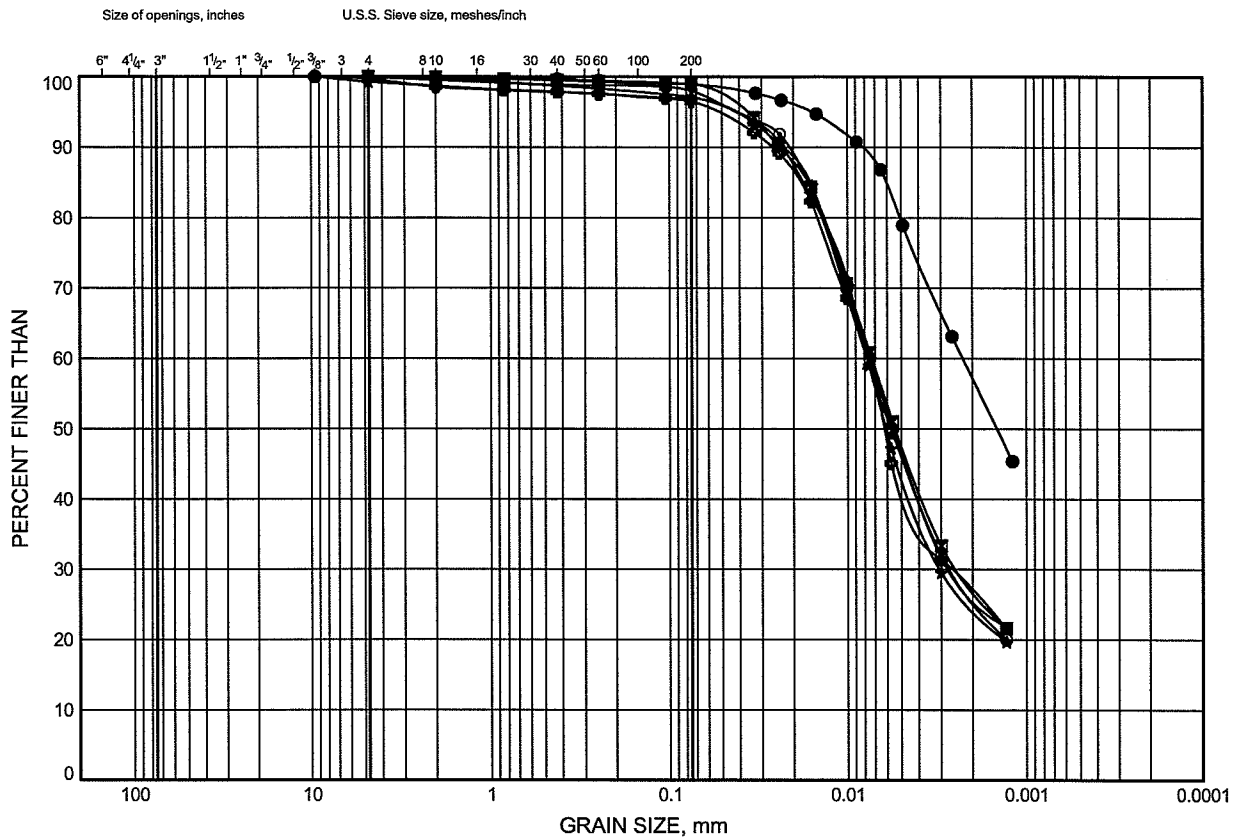


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B5-2

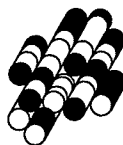
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-1	1.0	180.0
■	C7-1	3.2	177.8
▲	C7-1	6.3	174.7
★	C7-2	2.5	179.0
⊙	C7-2	6.3	175.2
⊕	C7-2	7.8	173.7

Date November 2010
Project 1-09-4135

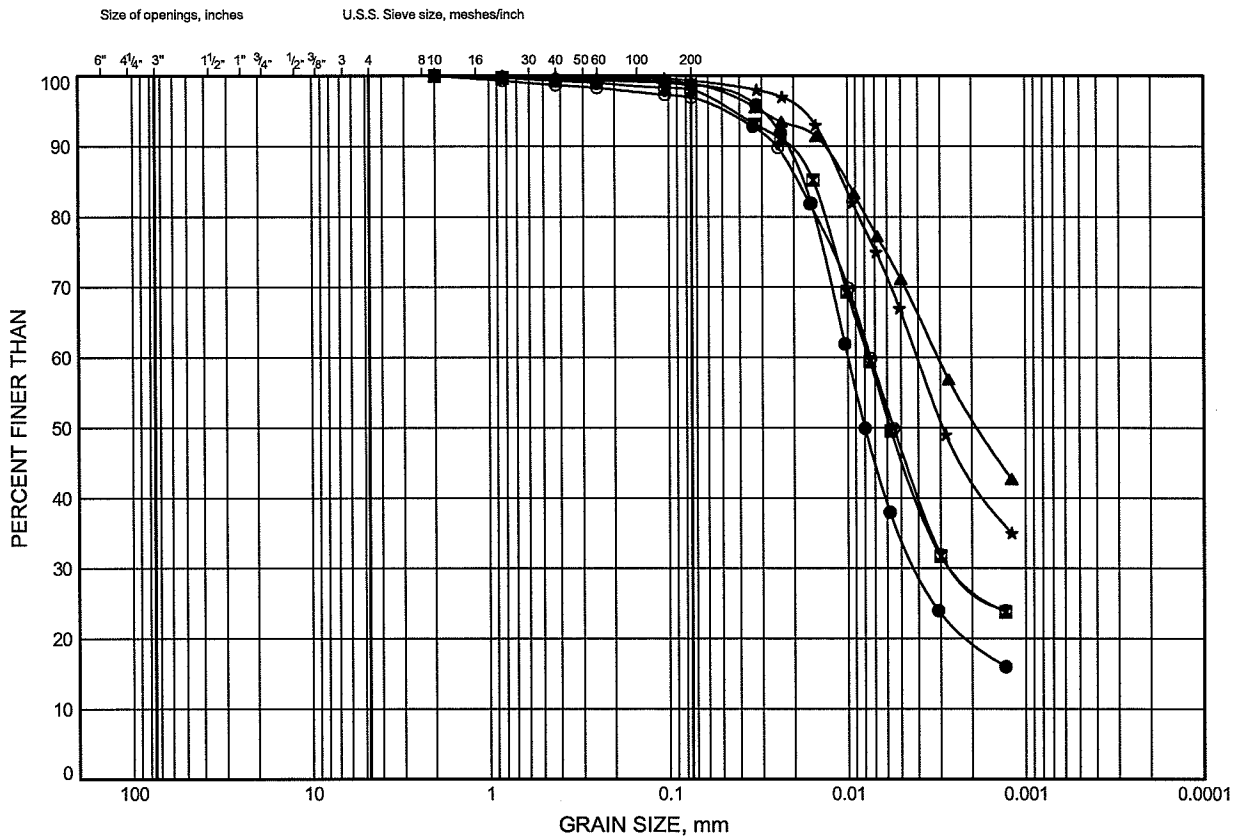


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B5-3

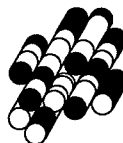
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-3	4.0	178.4
■	C7-3	9.3	173.1
▲	C7-4	1.0	181.0
★	C7-4	3.2	178.8
⊙	C7-4	6.3	175.7

Date November 2010
Project 1-09-4135

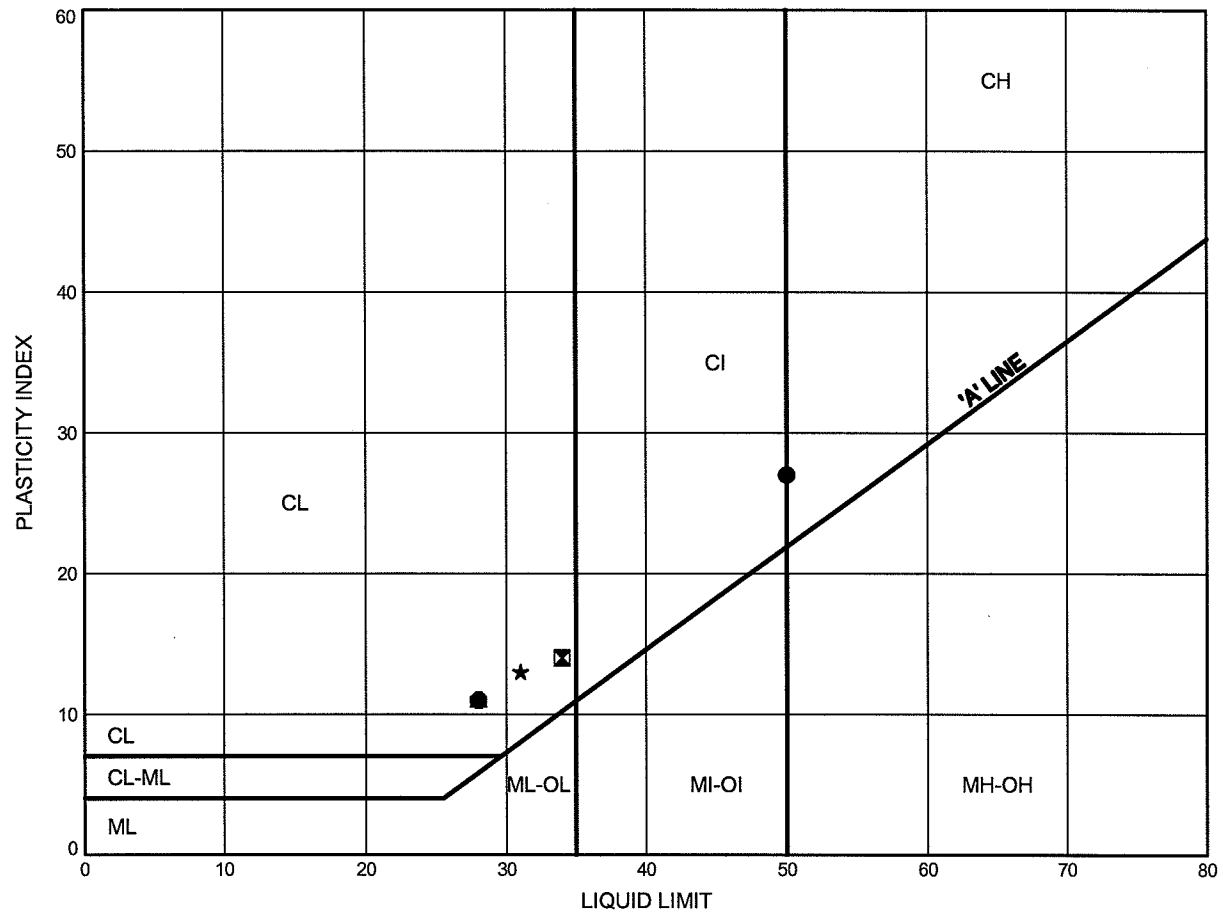


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

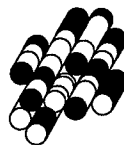
FIGURE B5-4

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-1	1.0	180.0
⊠	C7-1	3.2	177.8
▲	C7-1	6.3	174.7
★	C7-2	2.5	179.0
⊙	C7-2	6.3	175.2
⊕	C7-2	7.8	173.7

Date November 2010
Project 1-09-4135

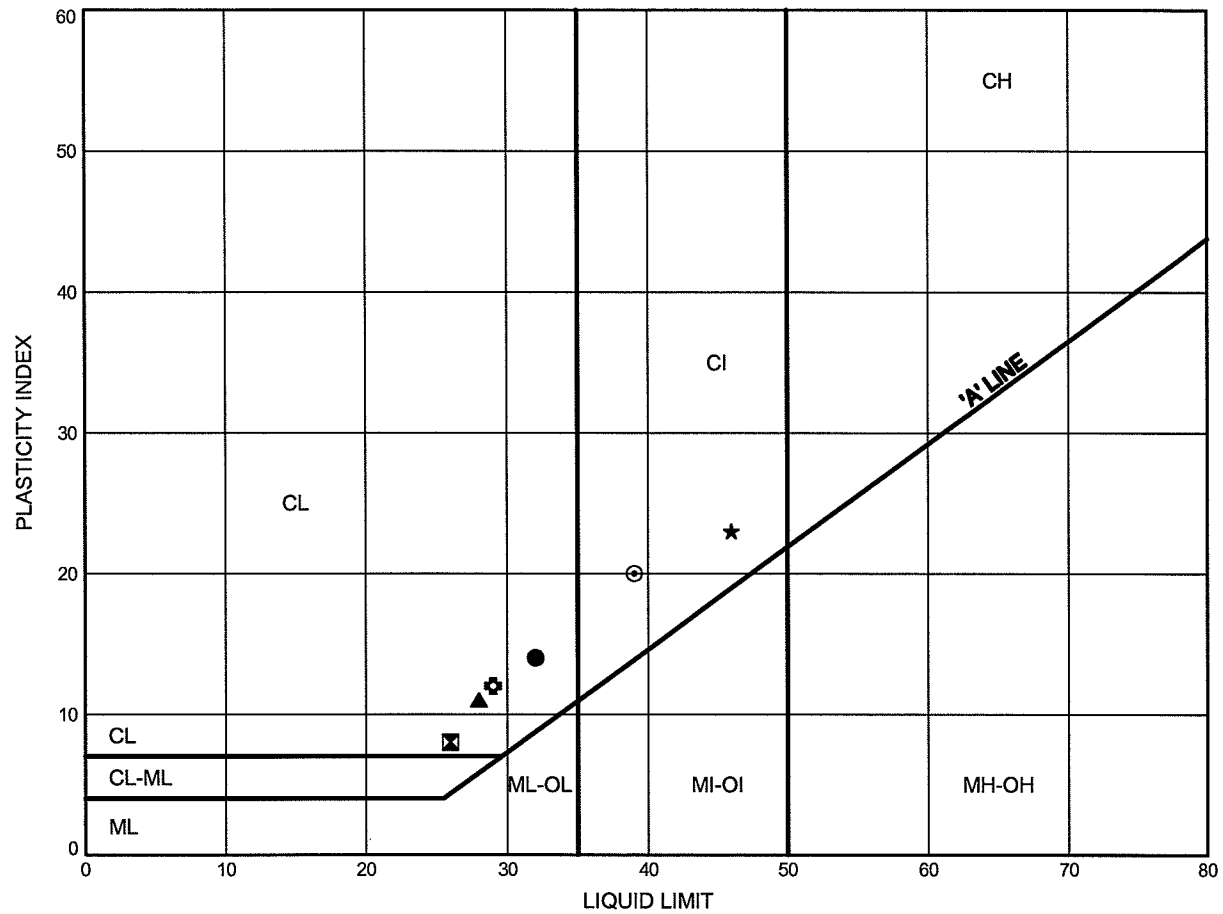


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

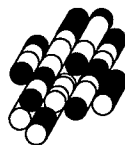
FIGURE B5-5

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-3	1.7	180.7
⊠	C7-3	4.0	178.4
▲	C7-3	9.3	173.1
★	C7-4	1.0	181.0
⊙	C7-4	3.2	178.8
⊕	C7-4	6.3	175.7

Date November 2010
Project 1-09-4135

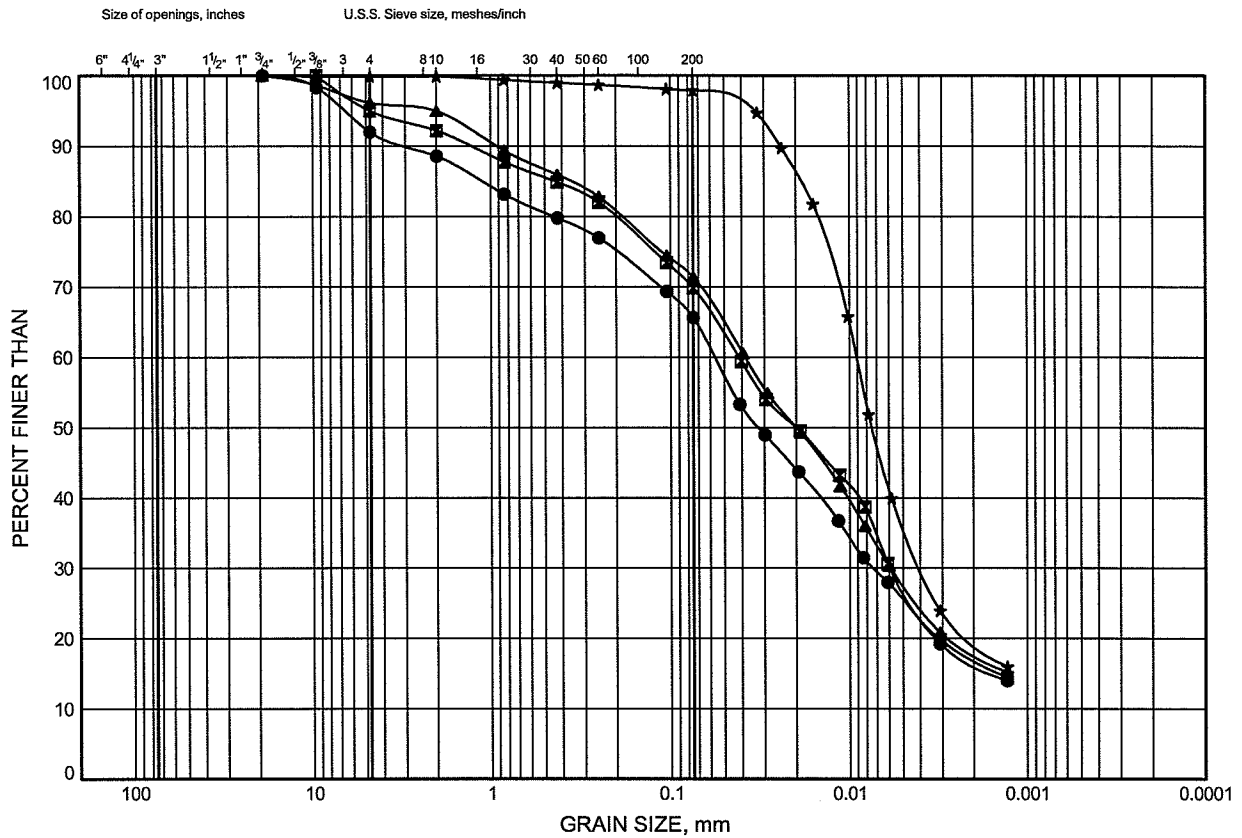


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

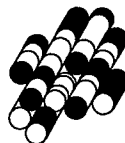
FIGURE B5-6

CLAYEY SILT TO SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-1	15.4	165.6
■	C7-2	13.9	167.6
▲	C7-3	13.9	168.5
★	C7-4	12.5	169.5

Date November 2010
Project 1-09-4135

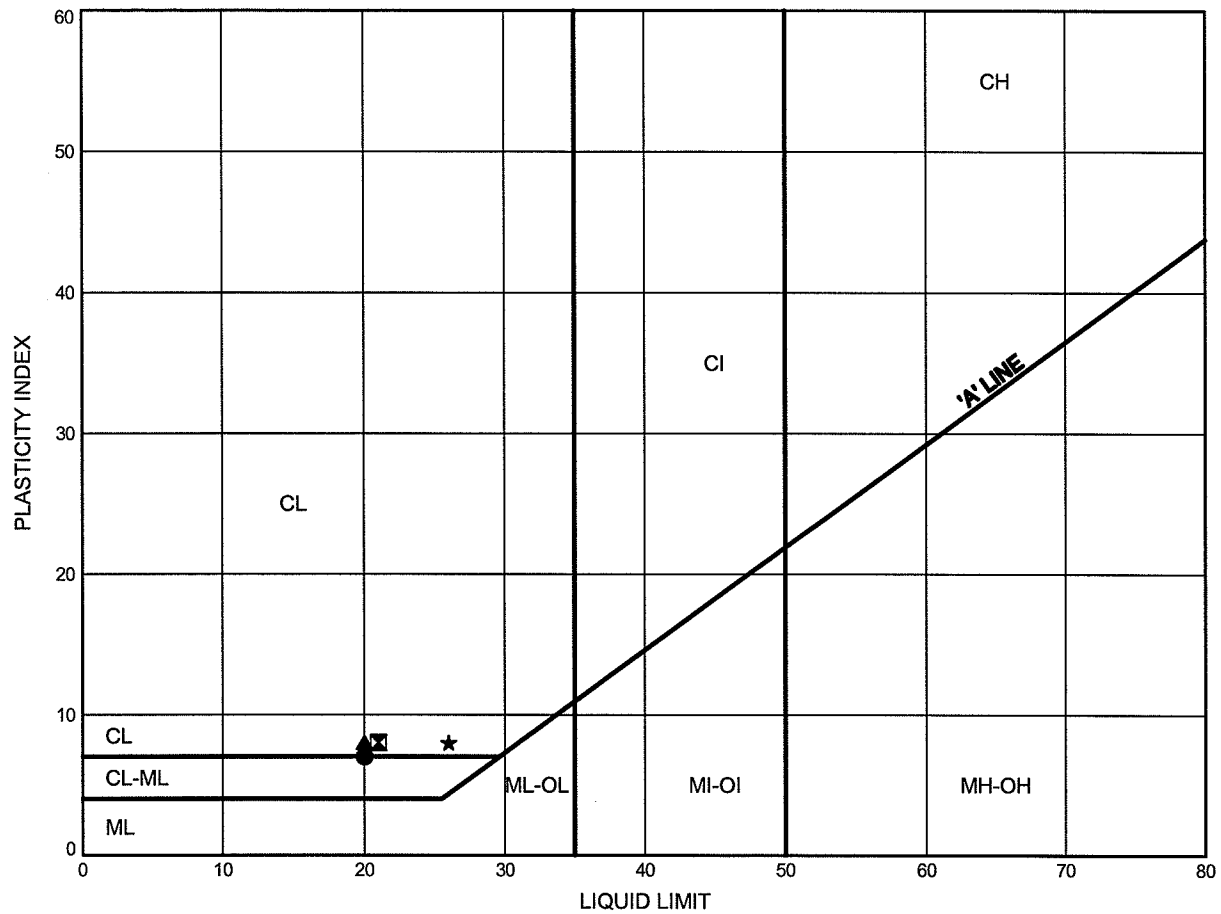


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

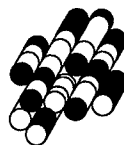
FIGURE B5-7

CLAYEY SILT TO SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C7-1	15.4	165.6
■	C7-2	13.9	167.6
▲	C7-3	13.9	168.5
★	C7-4	12.5	169.5

Date November 2010
Project 1-09-4135



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

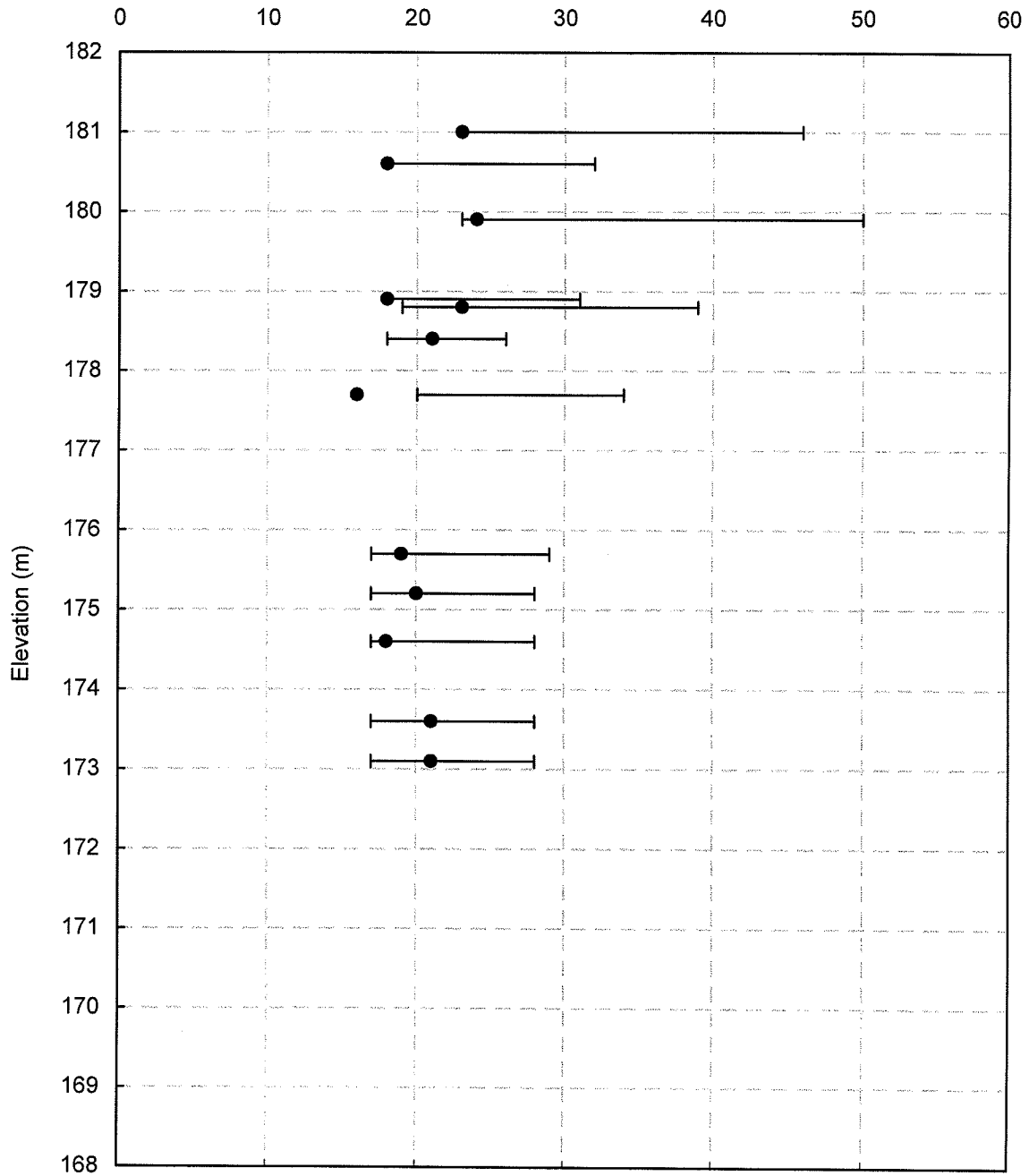
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B5-8

HWY 406 TWINNING - CULVERT #7

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

Prepared By : HW

Checked By : RA

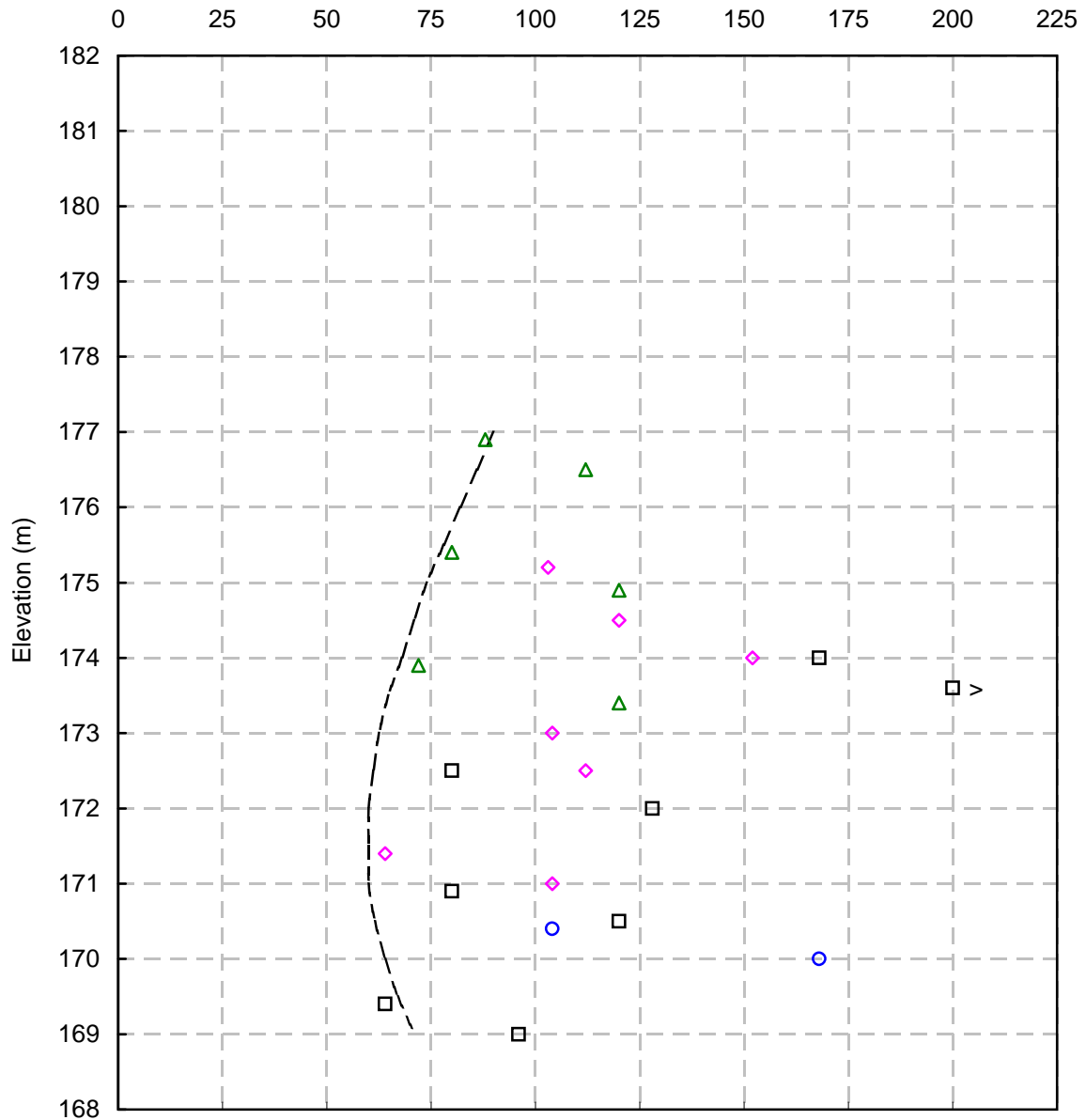
CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B5-9

HWY 406 TWINNING - CULVERT #7

Silty Clay

Corrected Cu (kPa)



□ C7-1

◇ C7-2

△ C7-3

○ C7-4

Field Shear Vane Correction

Morris & Williams (1994)

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

Applied Correction Factors

0.78 (Elev. > 179 m)

1.00 (Elev. < 179 m)

Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

Prepared By : HW

Checked By : RA

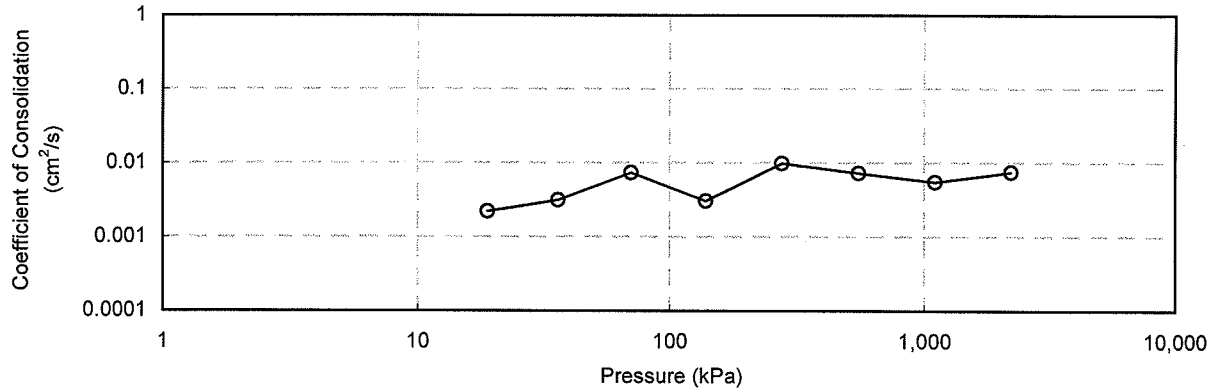
HWY 406 TWINNING - CULVERT#7

FIGURE B5-10

CONSOLIDATION TEST

Cv vs Pressure

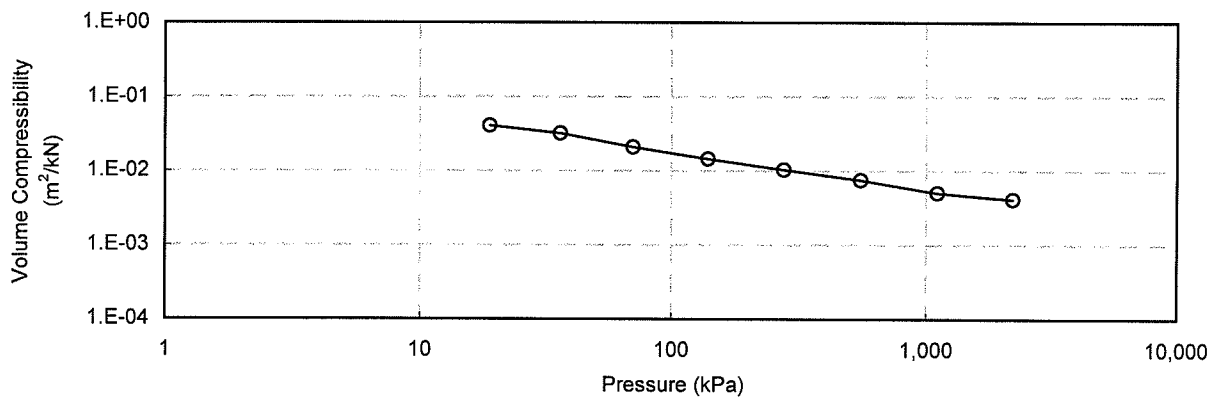
C7-2, TW8



CONSOLIDATION TEST

mv vs Pressure

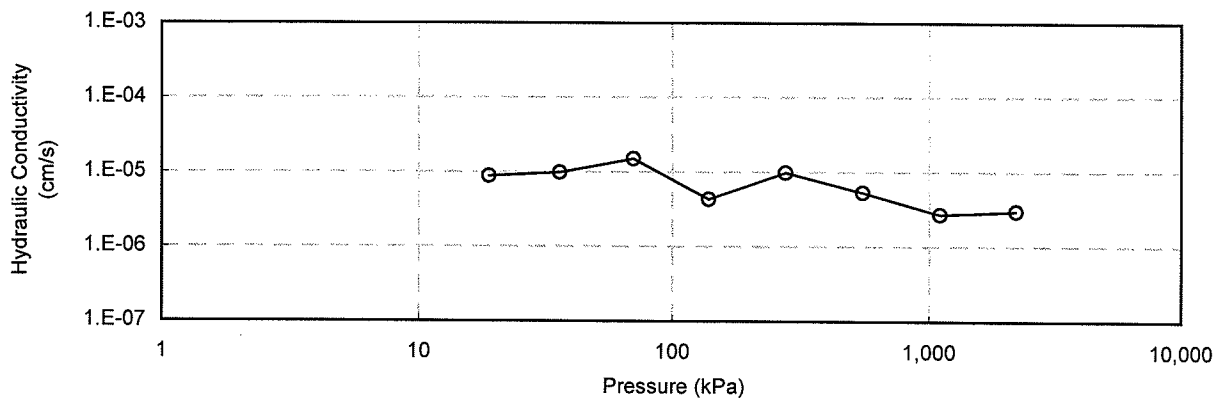
C7-2, TW8



CONSOLIDATION TEST

k vs Pressure

C7-2, TW8



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

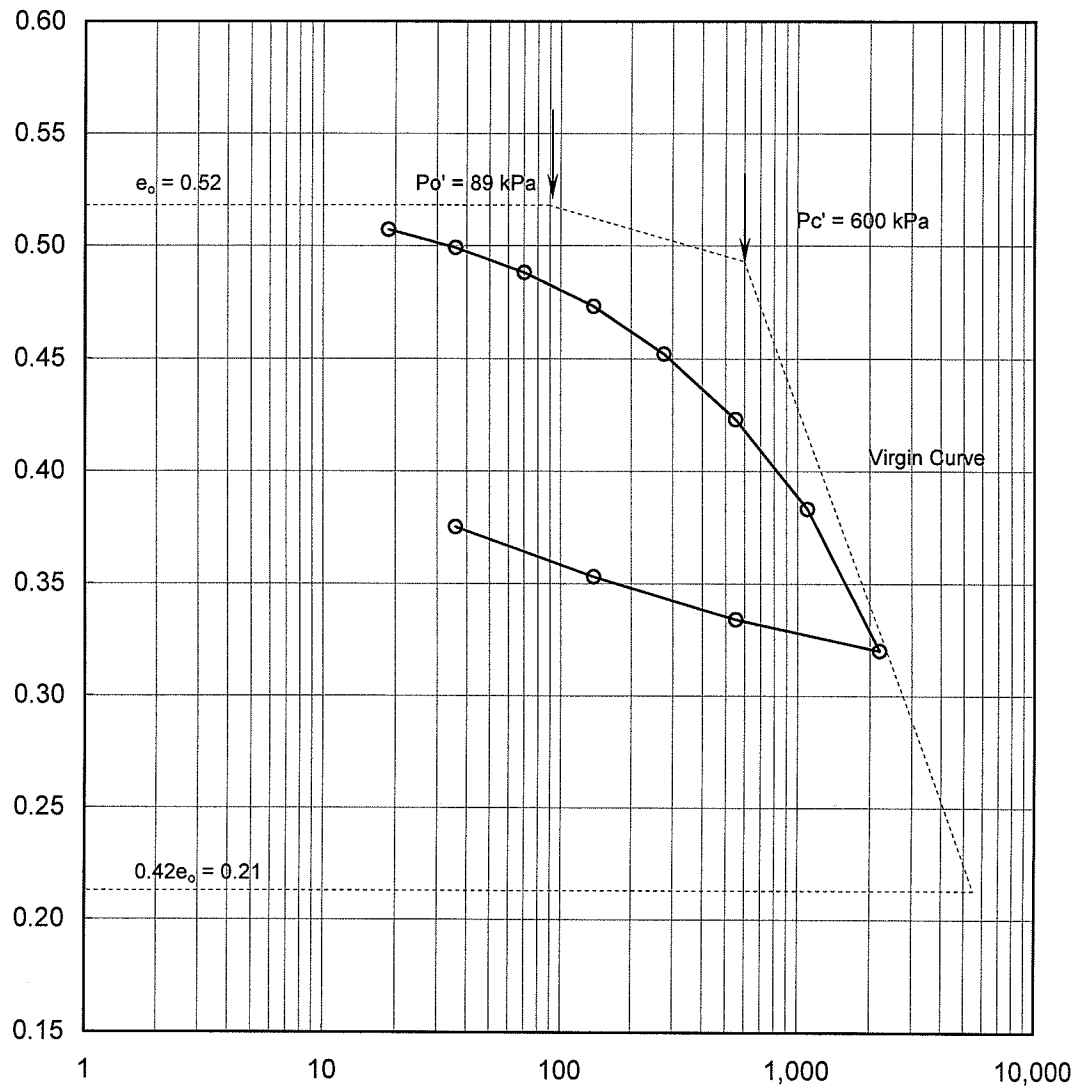
Project No. : 1-09-4135
Date : November 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
e vs Pressure
C7-2, TW8



Soil Type : Silty Clay

$e_o =$	0.52	$\omega_L =$	28%	$Po' =$	89 kPa
$\omega =$	19%	$\omega_P =$	17%	$Pc' =$	600 kPa
$\gamma =$	21.0 kN/m ³	PI =	11%	Cc =	0.291
Gs =	2.73			Cr =	0.030

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



Terraprobe Inc.

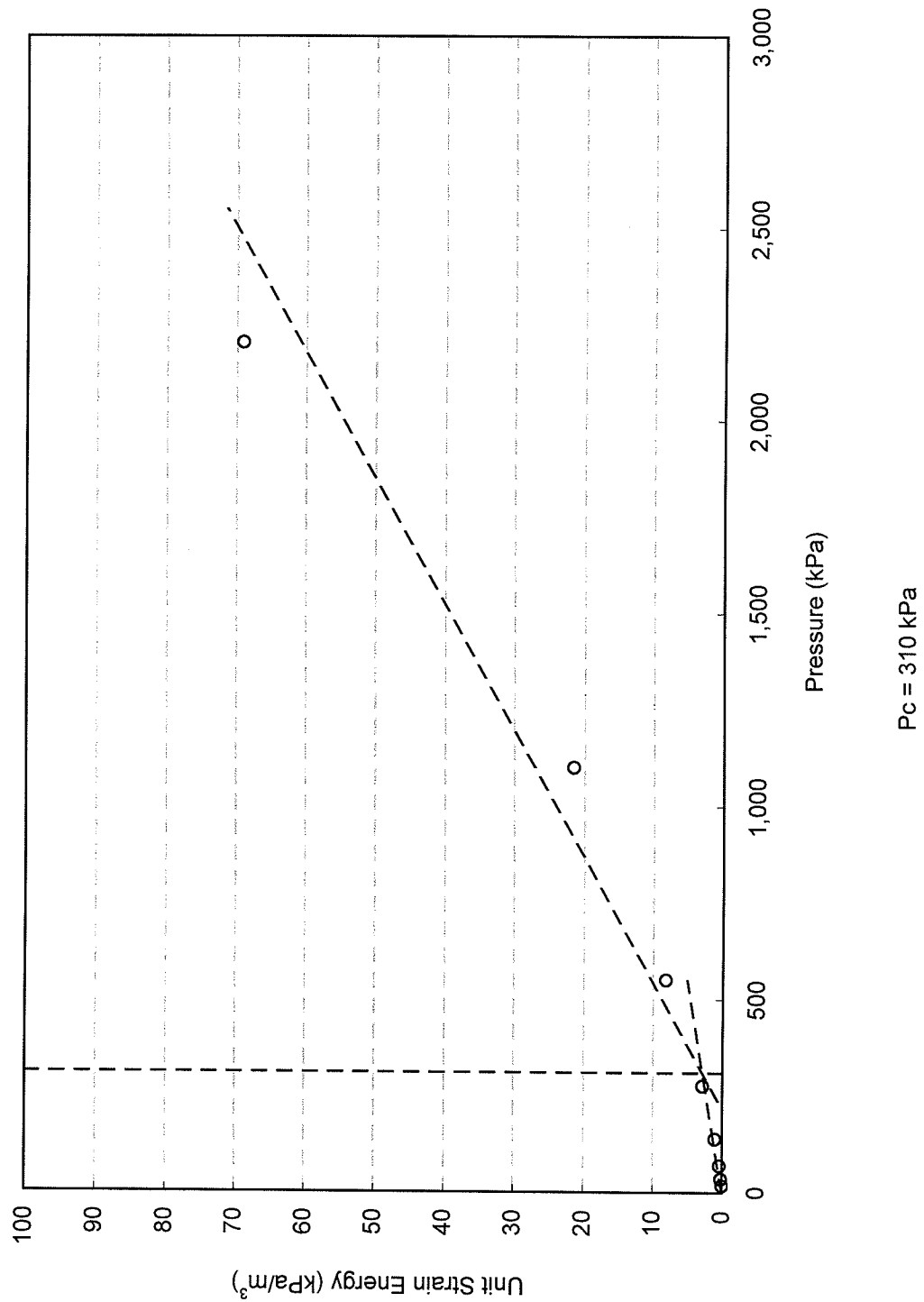
Prepared By : HW
Checked By : RA

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

HWY 406 TWINNING - CULVERT#7

FIGURE B5-12

CONSOLIDATION TEST Unit Strain Energy vs Pressure C7-2, TW8



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

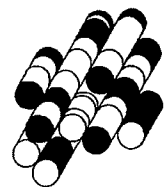


Terraprobe Inc.

Prepared By : HW
Checked By : RA

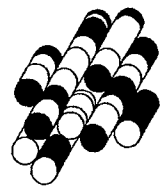
C5

TERRAPROBE INC.



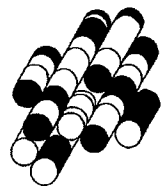
CULVERT #24

TERRAPROBE INC.



A6

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RECORD OF BOREHOLE No C9-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4765568.5 E:326999.7 ORIGINATED BY LY
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 11.18.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
174.9	Ground Surface							20 40 60 80 100	10 20 30					GR SA SI CL	
0.0	SILTY CLAY trace sand, trace rootlets, occasional sand pockets, firm, brown, moist		1	SS	5		174							0 5 56 39	
			2	SS	7										
173.2			3	SS	7		173								
1.7	SILTY CLAY trace sand, firm to stiff, brown, damp to moist		4	SS	2		172								
172.8			5	SS	5		171	1.7 1.3							
2.1			6	SS	5		170	1.4 1.9							
			7	TW	PH		169	1.4 3.5					20.6	0 2 76 22	
			8	SS	8		168	1.4 1.8						0 1 72 27	
			9	SS	9		167	1.3 1.7							
			10	SS	13		166	2.1 1.8						0 0 71 29	
			11	SS	15		165	>>						0 0 67 33	
162.2		End of Borehole													
12.7		Consolidation test performed on TW 7. Borehole was dry (not stabilized) and hole open to full depth on completion.													

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/02/10

Continued Next Page

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

RECORD OF BOREHOLE No C9-1

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4765566.5 E:326999.7
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 11.18.09

ORIGINATED BY LY
 COMPILED BY DB
 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	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) Nov.30.09 3.0 171.9 Dec.08.09 2.1 172.8 Jan.04.10 0.4 174.5 Jan.11.10 0.6 174.3 Jan.14.10 0.5 174.4																

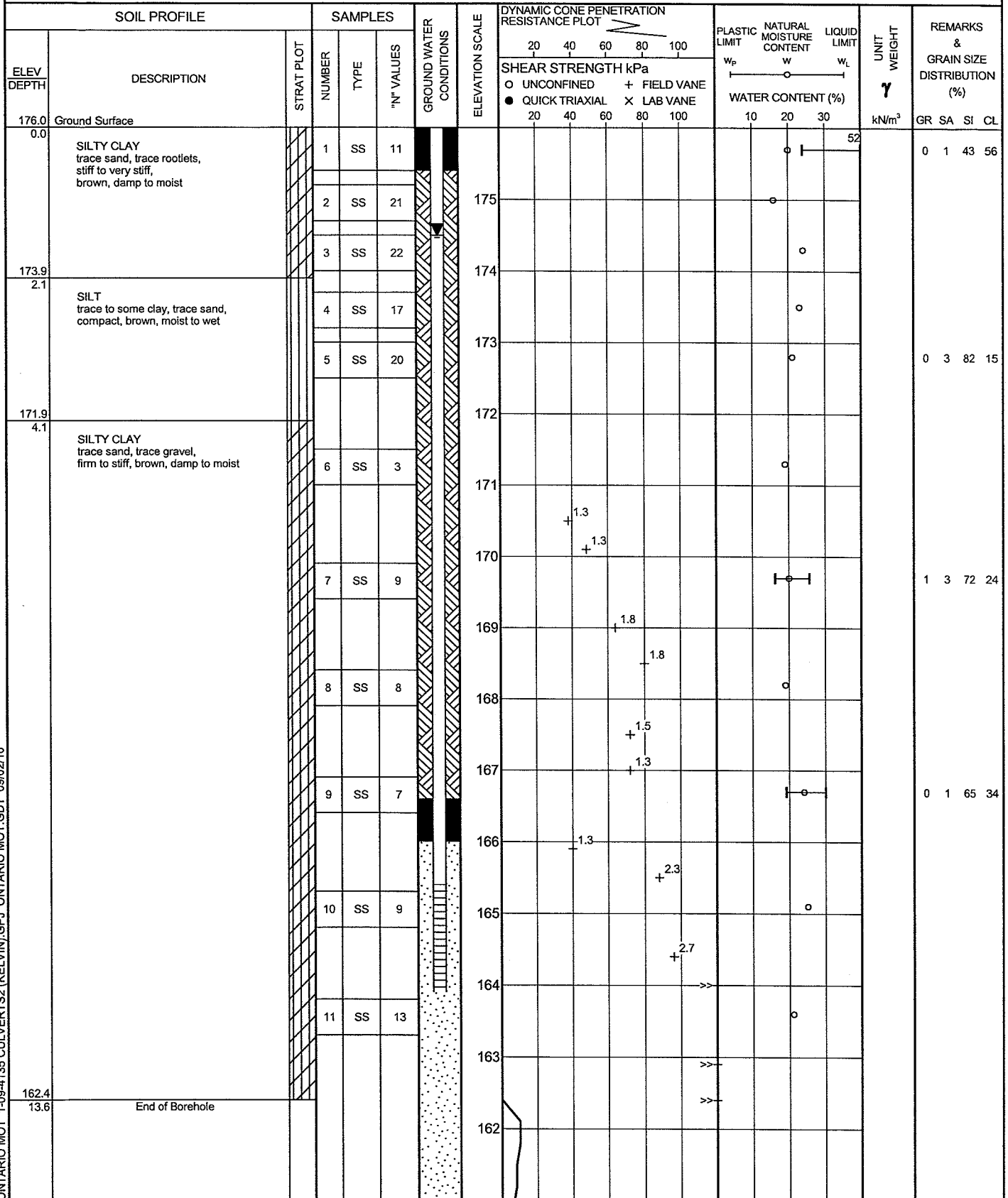
ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN) GPJ ONTARIO MOT.GDT 09/02/10

RECORD OF BOREHOLE No C9-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4765579.6 E:327009.4 ORIGINATED BY LY
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T. COMPILED BY DB
DATUM Geodetic DATE 11.17.09 CHECKED BY RA



Continued Next Page

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

ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/02/10

RECORD OF BOREHOLE No C9-2

2 OF 2

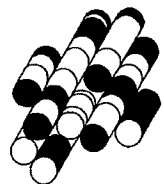
METRIC

W.P. 280-99-00 LOCATION Coords: N:4765579.6 E:327009.4 ORIGINATED BY LY
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T. COMPILED BY DB
DATUM Geodetic DATE 11.17.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL																		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)																						
							20	40	60	80	100	W _p	W	W _L																				
158.9																																		
17.1	<p>End of Dynamic Cone Penetration Test</p> <p>Dynamic Cone Penetration Test performed from 13.6m to 17.1m.</p> <p>Borehole was dry (not stabilized) and hole open to full depth on completion.</p> <p>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>Water Level Readings:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elevation(m)</th> </tr> </thead> <tbody> <tr> <td>Nov.30.09</td> <td>3.9</td> <td>172.1</td> </tr> <tr> <td>Dec.08.09</td> <td>3.4</td> <td>172.6</td> </tr> <tr> <td>Jan.04.10</td> <td>1.7</td> <td>174.3</td> </tr> <tr> <td>Jan.11.10</td> <td>1.7</td> <td>174.3</td> </tr> <tr> <td>Jan.14.10</td> <td>1.5</td> <td>174.5</td> </tr> </tbody> </table>	Date	Depth(m)	Elevation(m)	Nov.30.09	3.9	172.1	Dec.08.09	3.4	172.6	Jan.04.10	1.7	174.3	Jan.11.10	1.7	174.3	Jan.14.10	1.5	174.5															
Date	Depth(m)	Elevation(m)																																
Nov.30.09	3.9	172.1																																
Dec.08.09	3.4	172.6																																
Jan.04.10	1.7	174.3																																
Jan.11.10	1.7	174.3																																
Jan.14.10	1.5	174.5																																

B6

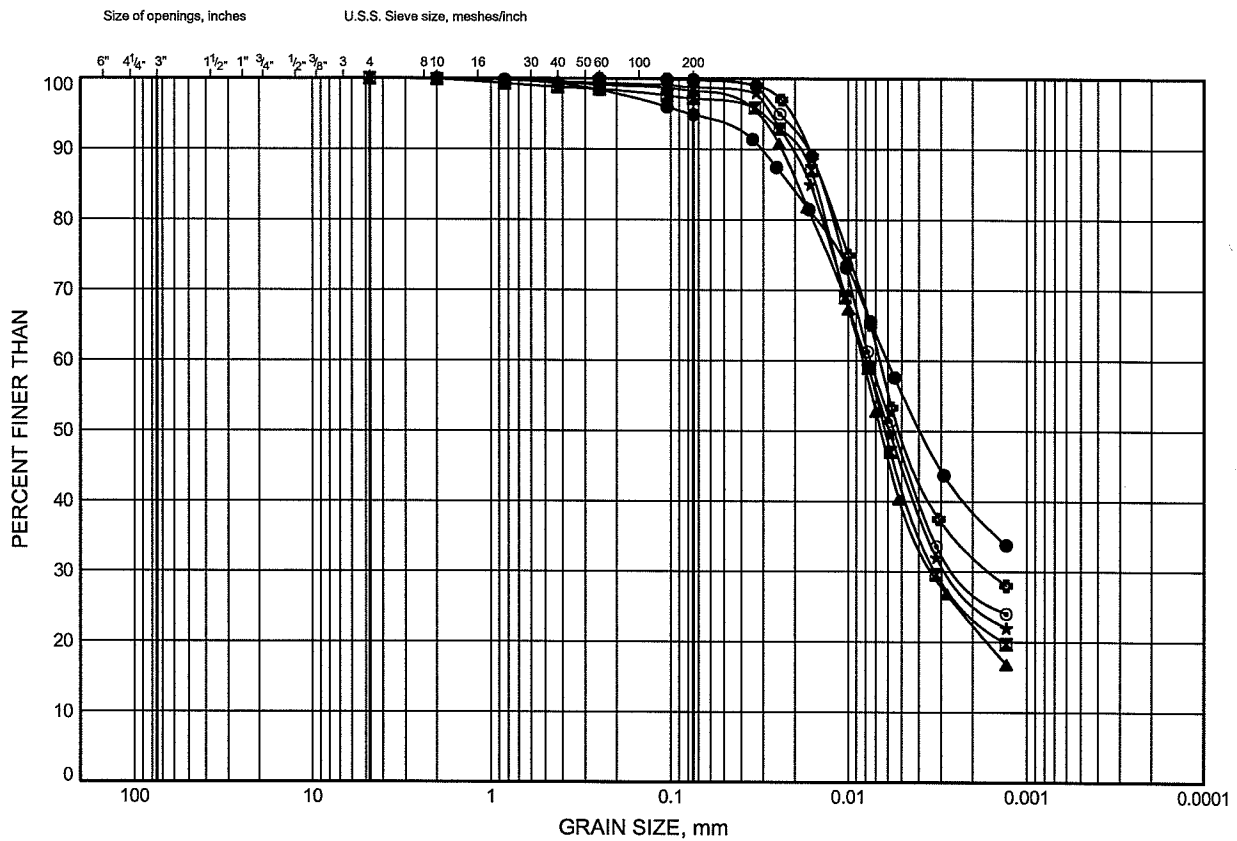
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B6-1

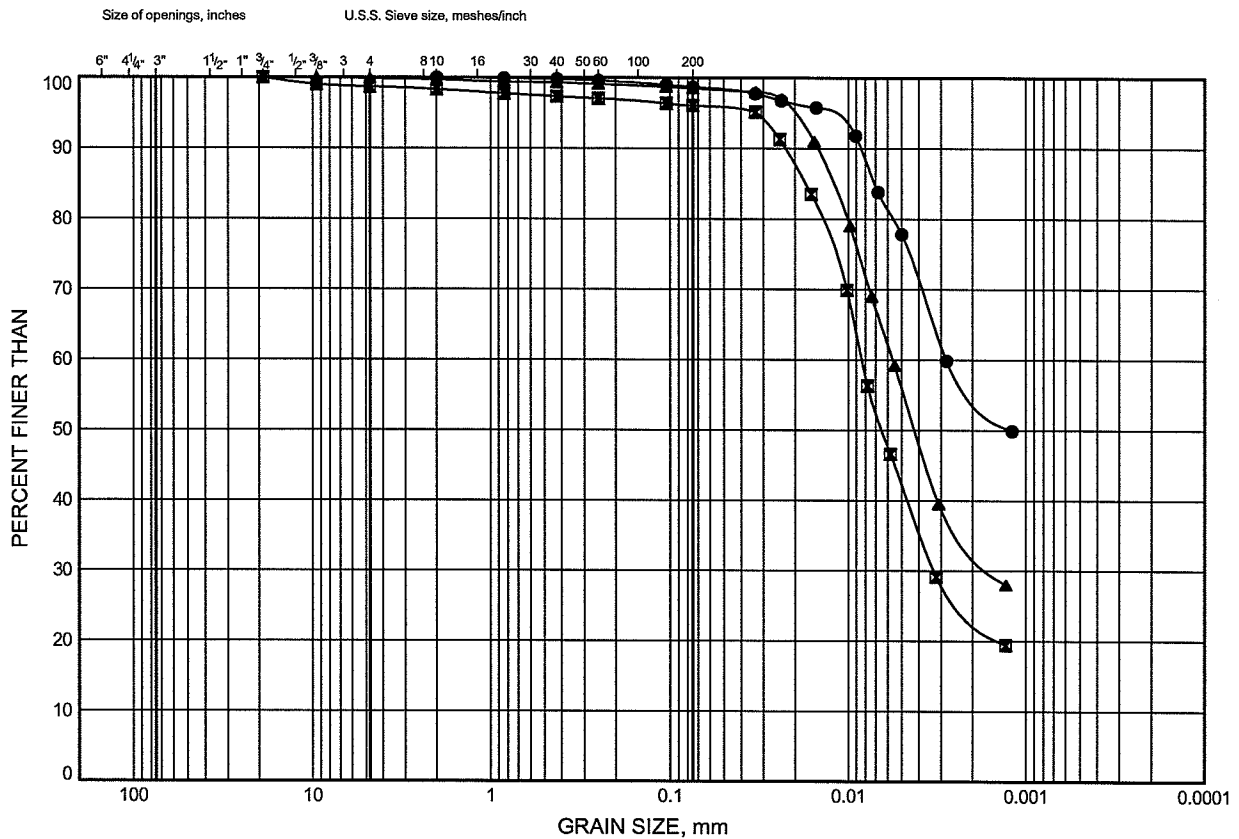
SILTY CLAY



GRAIN SIZE DISTRIBUTION

FIGURE B6-2

SILTY CLAY



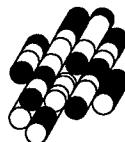
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C9-2	0.3	175.7
■	C9-2	6.3	169.7
▲	C9-2	9.3	166.7

Date November 2010

Project 1-09-4135



Prep'd K.L.

Chkd. M.P.

FIGURE B6-3

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C9-1	1.0	173.9
⊠	C9-1	4.7	170.2
▲	C9-1	6.3	168.6
★	C9-1	7.8	167.1
⊙	C9-1	10.9	164.0
⊕	C9-1	12.4	162.5

Prep'dK.L.....

Chkd. M.P.

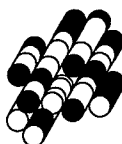
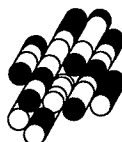


FIGURE B6-4

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C9-2	0.3	175.7
☒	C9-2	6.3	169.7
▲	C9-2	9.3	166.7

Date November 2010

Project 1-09-4135.....



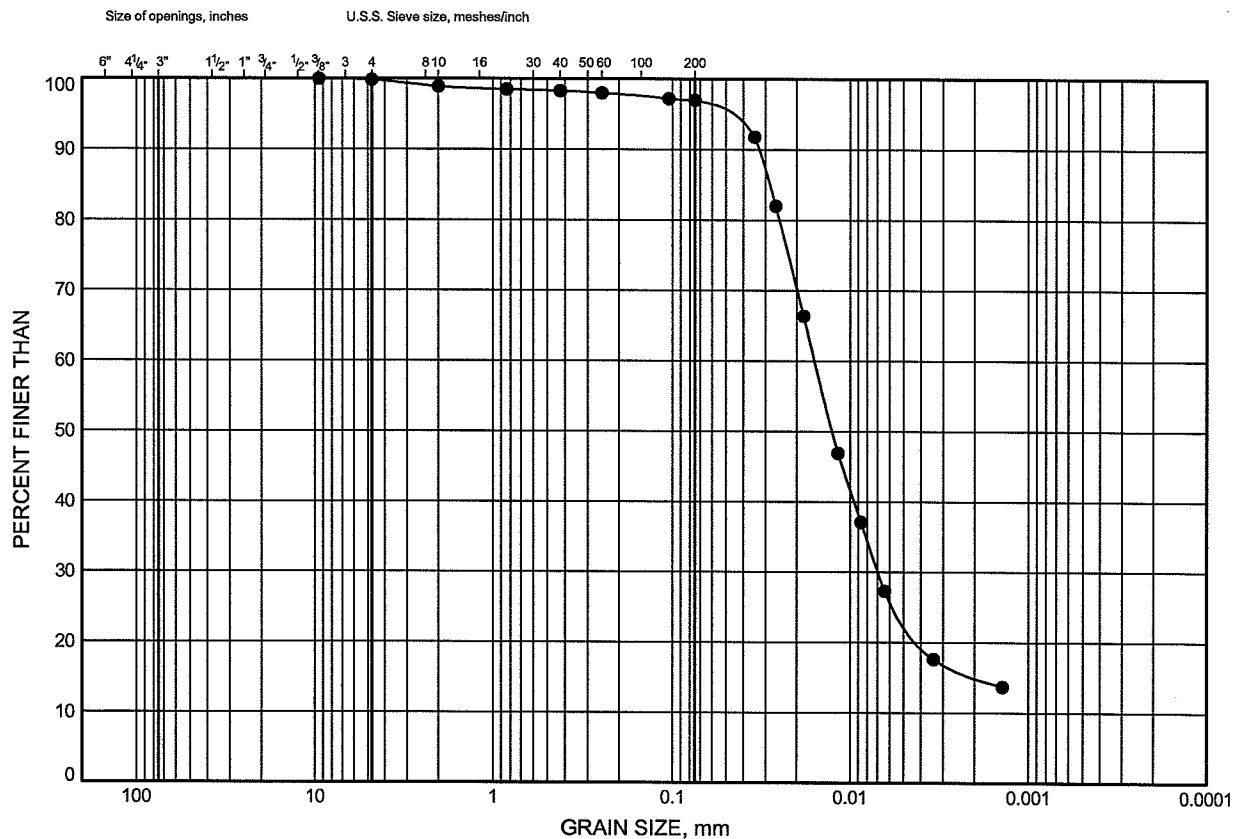
Prep'dK.L.....

Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B6-5

SILT

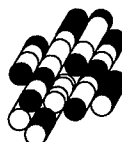


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C9-2	3.2	172.8

Date November 2010

Project 1-09-4135



Prep'd K.L.

Chkd. M.P.

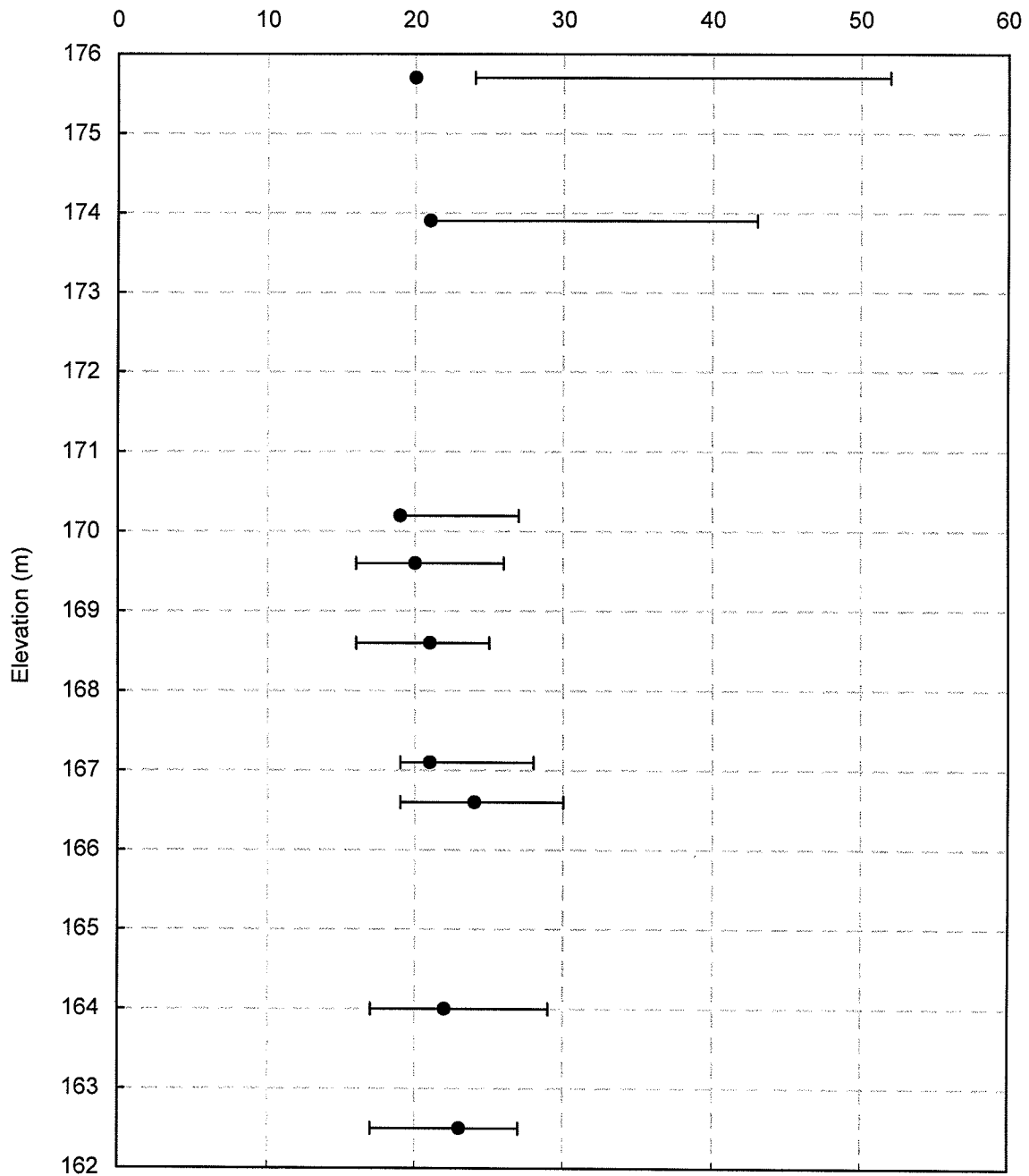
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B6-6

HWY 406 TWINNING - CULVERT #9

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



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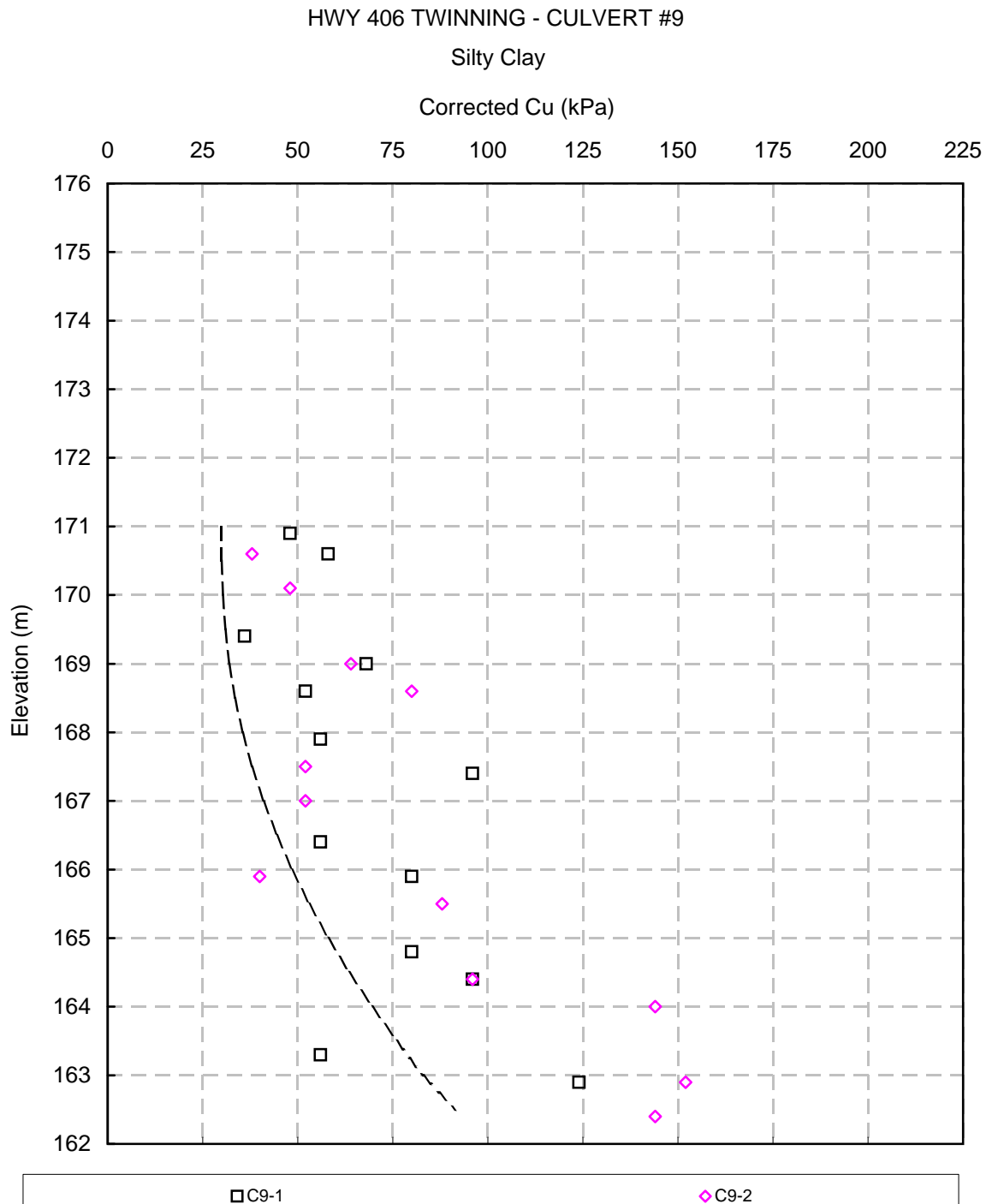
Prepared By : HW

Checked By : RA

CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B6-7

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\1-09-4135C9 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

0.73 (Elev. > 173 m) 1.00 (Elev. < 173 m)

Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

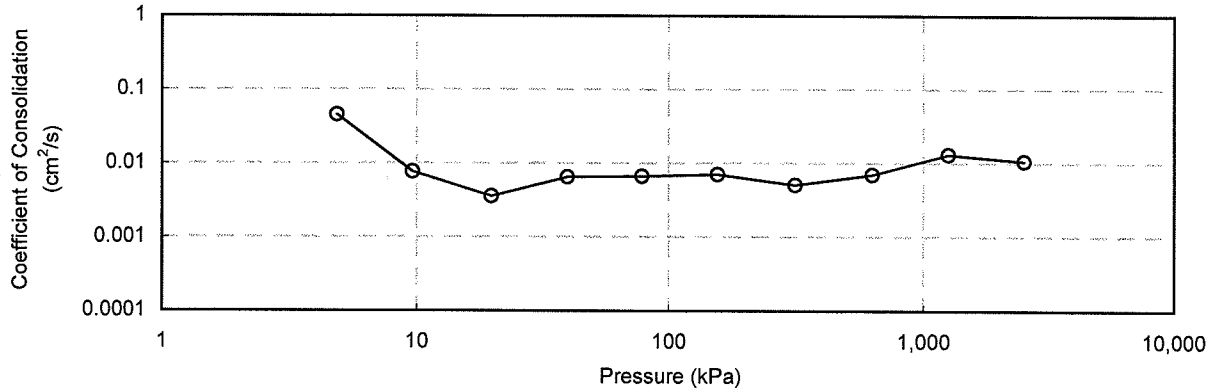
Prepared By : HW

Checked By : RA

CONSOLIDATION TEST

Cv vs Pressure

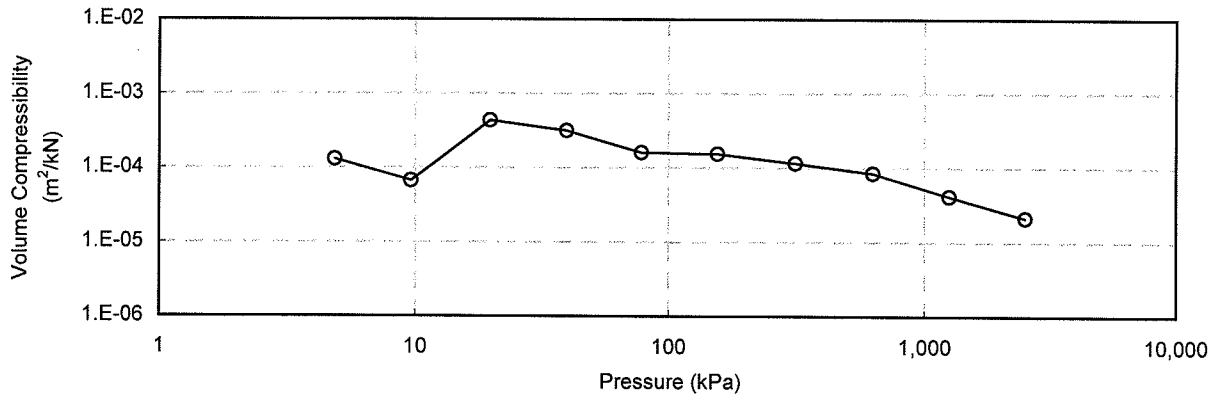
C9-1, TW 7



CONSOLIDATION TEST

mv vs Pressure

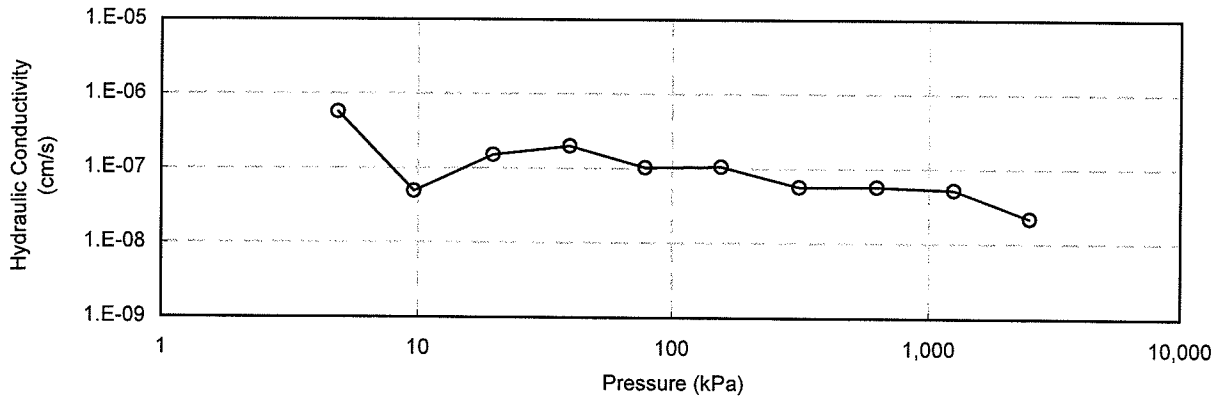
C9-1, TW 7



CONSOLIDATION TEST

k vs Pressure

C9-1, TW 7



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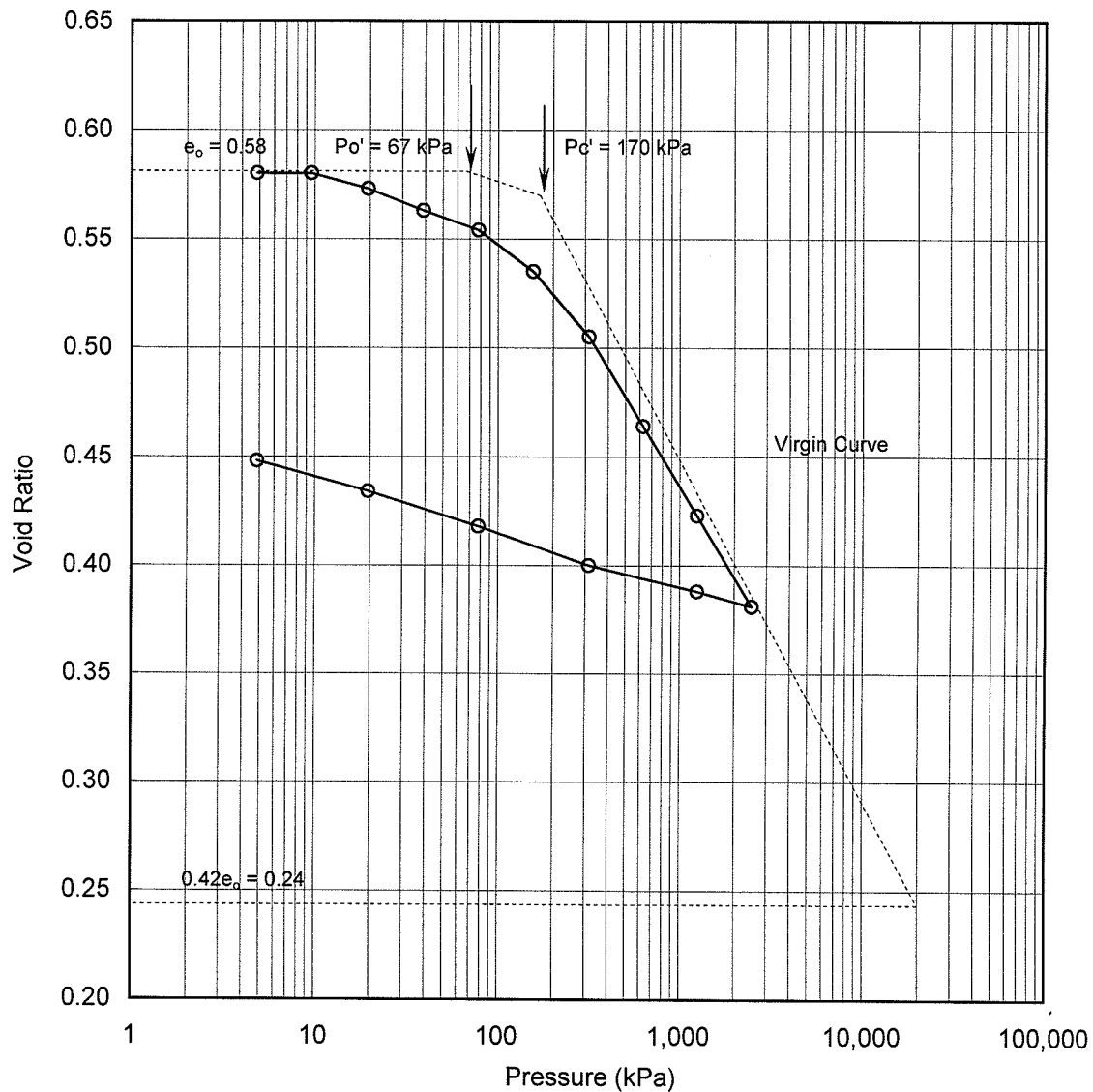
Project No. : 1-09-4135
Date : November 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
e vs Pressure
C9-1, TW 7



Soil Type : Silty Clay

$e_o =$	0.58	$\omega_L =$	25%	$P_o' =$	67 kPa
$\omega =$	21%	$\omega_p =$	16%	$P_c' =$	170 kPa
$\gamma =$	20.6 kN/m ³	PI =	9%	$C_c =$	0.158
$G_s =$	2.74			$C_r =$	0.027

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



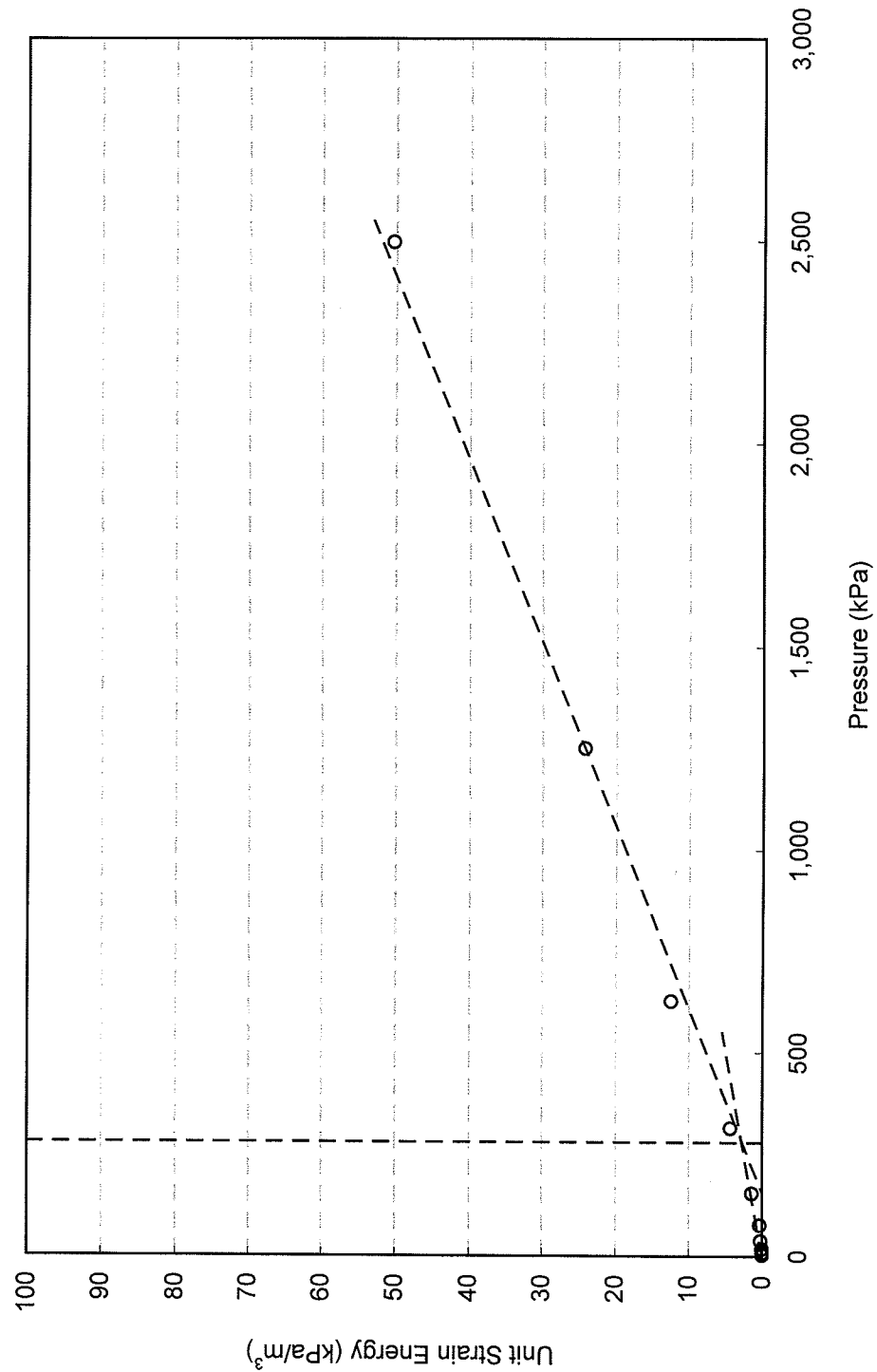
Terraprobe Inc.

Prepared By : HW
Checked By : RA

HWY 406 TWINNING - CULVERT#9

FIGURE B6-10

CONSOLIDATION TEST Unit Strain Energy vs Pressure C9-1, TW 7



Pc = 280 kPa

Project No. : 1-09-4135

Date : November 2010



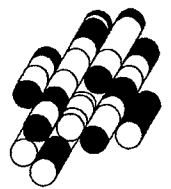
Terraprobe Inc.

Prepared By : HW

Checked By : RA

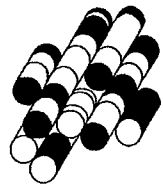
C6

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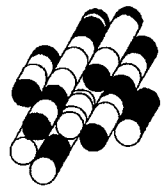
CULVERT #48

TERRAPROBE INC.



A7

TERRAPROBE INC.



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			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						× LAB VANE		
177.1	Ground Surface						20	40	60	80	100							
176.9	230mm TOPSOIL																	
0.2	sandy SILTY CLAY trace sand, firm to very stiff, brown, damp to moist		1	SS	7													
			2	SS	17													
			3	SS	21													
			4	SS	22													
			5	SS	16													
			6	SS	10													
172.7	SILT trace clay, compact, brown, wet		7	SS	11													
171.5	SILTY CLAY trace sand, firm to stiff, brown, moist		8	SS	6													
5.6																		
			9	SS	5													
			10	TW	PH													
166.6	SILT trace to some clay, very loose to dense, brown, wet		11	SS	2													
10.5																		
164.4	End of Borehole		12	SS	37													
12.7																		
	Sampler wet at 6.1m. Water level at 7.3m (not stabilized) and hole open to 10.7m on completion. Consolidation test performed on TW 10.																	

Continued Next Page

+³, X³: 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 NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
	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 _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	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														
0.7	FILL - Silty Clay, trace sand, soft to stiff, brown, damp to moist		2	SS	5									
			3	SS	4		180							
			4	SS	12									
			5	SS	4		179							
			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							
			10	SS	3		172							
			11	SS	WOH		171							
			12	SS	WOH		170							
							169							
			13	SS	4		168							
							167							

Continued Next Page

+³, X³: 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 C10-3

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 _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
							20 40 60 80 100	20 40 60 80 100						
178.5	Ground Surface													
178.3	230mm TOPSOIL													
0.2	FILL - Silty Clay, trace sand to sandy, trace organics, firm to stiff, brown, moist		1	SS	7									
			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									
			11	SS	16								0 0 82 18	
			12	SS	8									
165.3	SILT trace clay, loose to compact, brown, wet		13	SS	9									
13.2														

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

Continued Next Page

+³, X³: 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 NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL												
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)																
							20	40	60	80	100	W _p	W	W _L															
162.3			14	SS	21																								
16.2	SILTY CLAY trace sand, hard, brown, damp to moist																												
161.2			15	SS	33																								
17.3	End of Borehole																												
	<p>Sampler wet at 9.1m.</p> <p>Water level at 8.5m (not stabilized) and hole open to 15.2m on completion.</p> <p>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>Water Level Readings:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elevation(m)</th> </tr> </thead> <tbody> <tr> <td>July.20.10</td> <td>1.5</td> <td>177.0</td> </tr> <tr> <td>July.27.10</td> <td>1.1</td> <td>177.4</td> </tr> <tr> <td>Aug.06.10</td> <td>1.1</td> <td>177.4</td> </tr> </tbody> </table>	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																
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																											

Test Pit Logs
Culvert #10 (Highway 406 Sta. 15+723)

Test Pit# TP 10-1

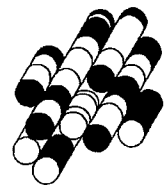
0	-	200	Fill, Br Si, Some Org, Wet
NFP			

Test Pit# TP 10-2

0	-	300	Fill, Br Si, Some Org, Wet
300	-	610	Br Si(y) Cl, Tr Sa, Damp to Moist

B7

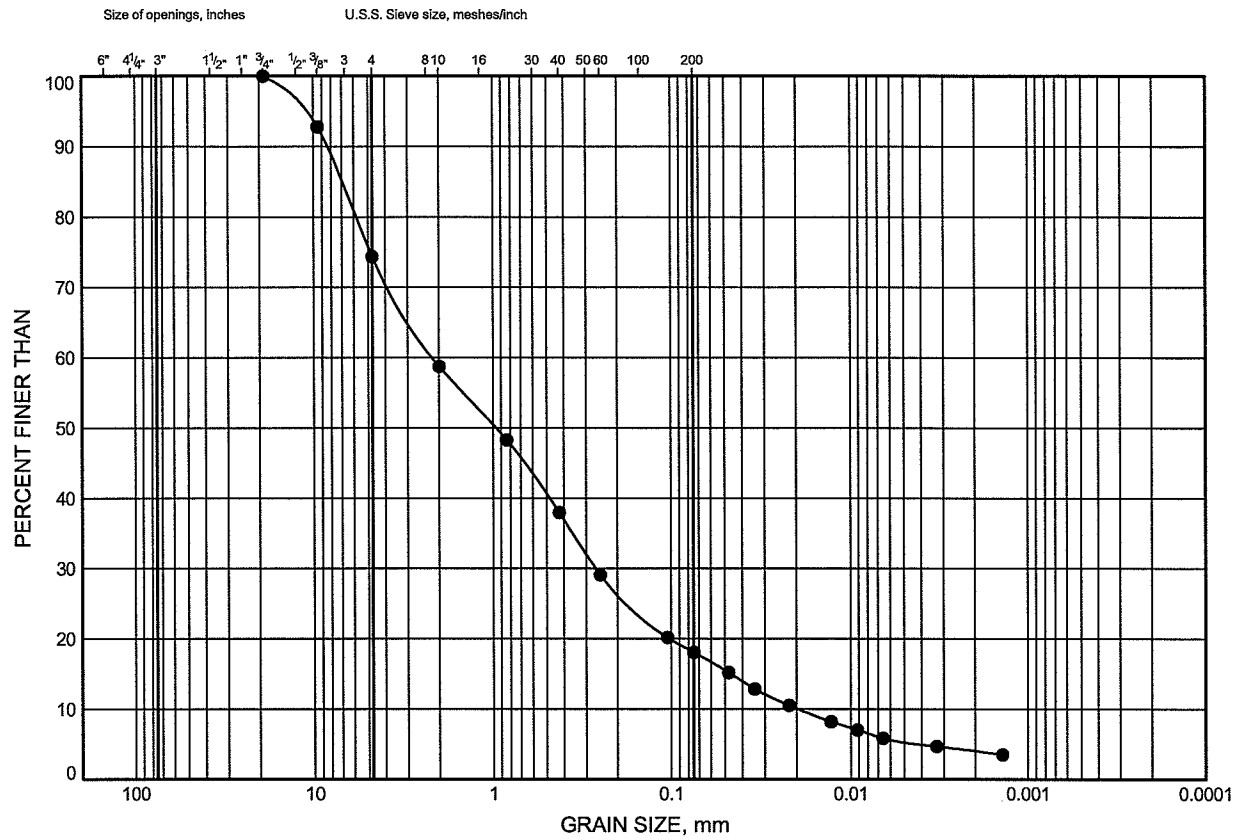
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B7-1

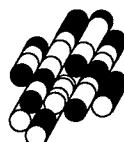
FILL - Gravelly Sand



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

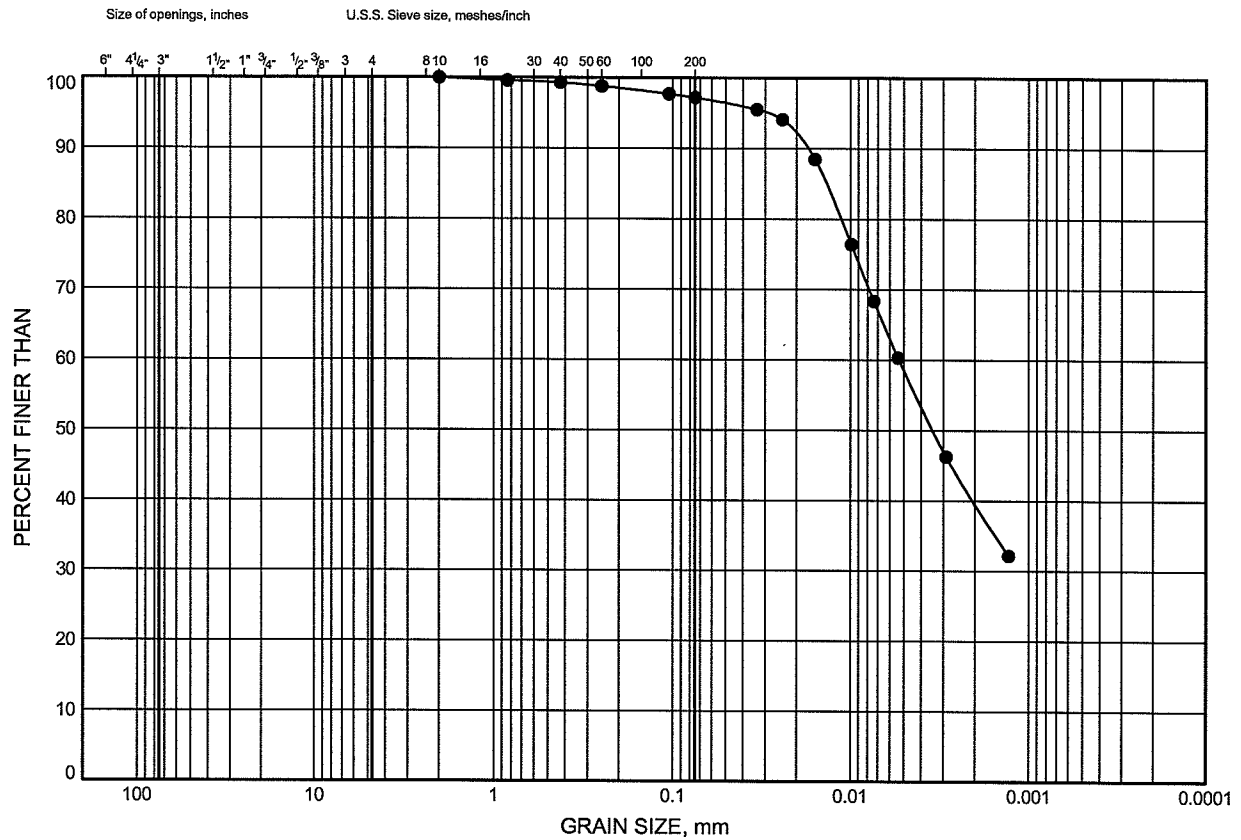


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B7-2

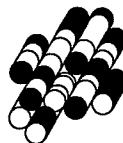
FILL - Silty Clay



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

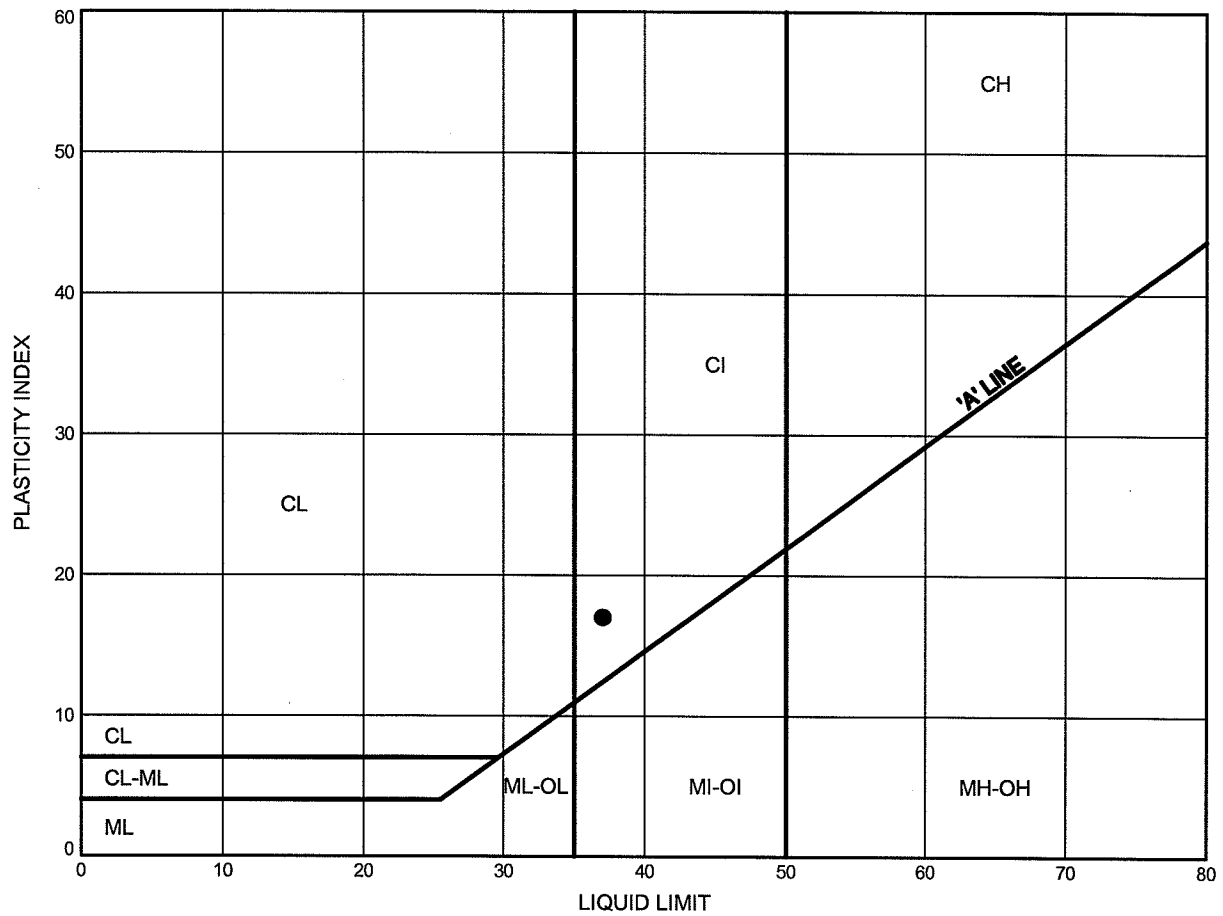


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

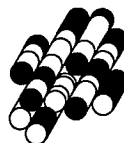
FIGURE B7-3

FILL - Silty Clay



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

Date November 2010
 Project 1-09-4135

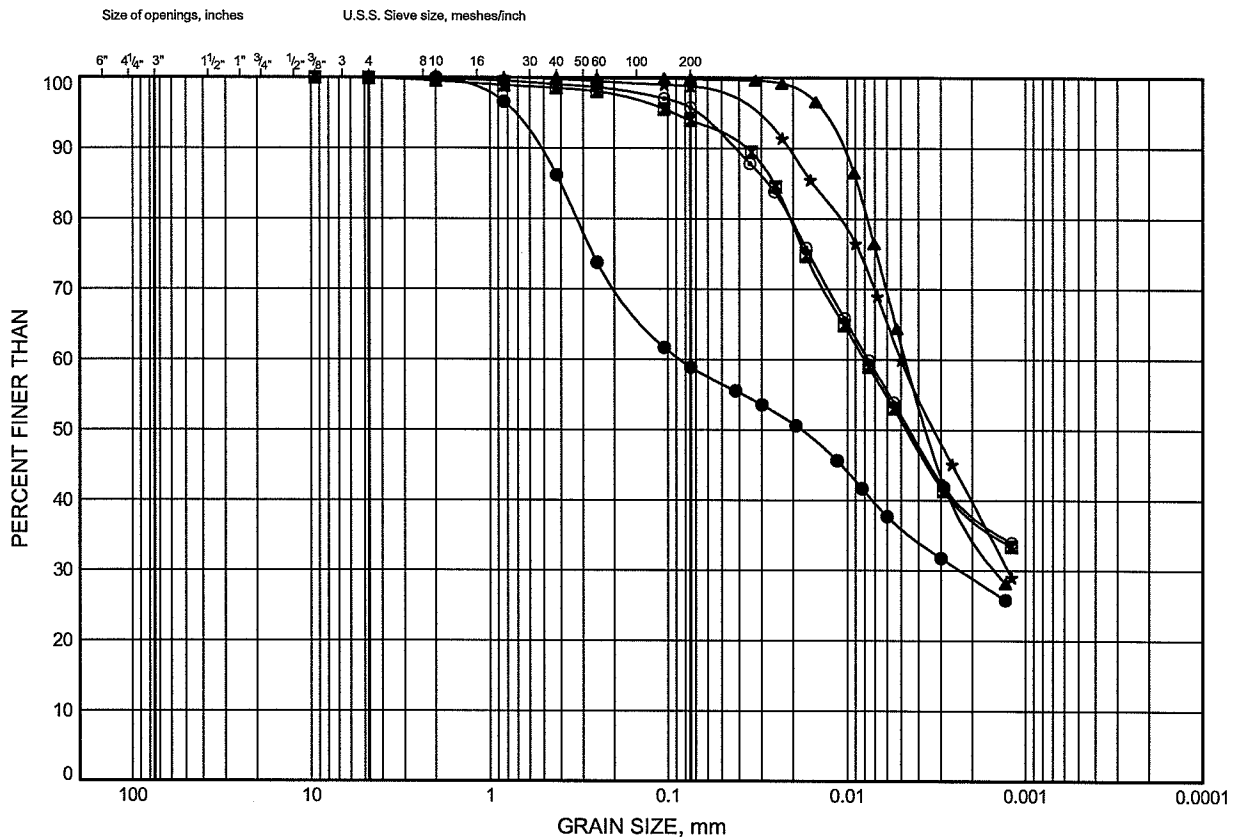


Prep'd K.L.
 Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B7-4

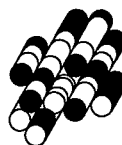
SILTY CLAY



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

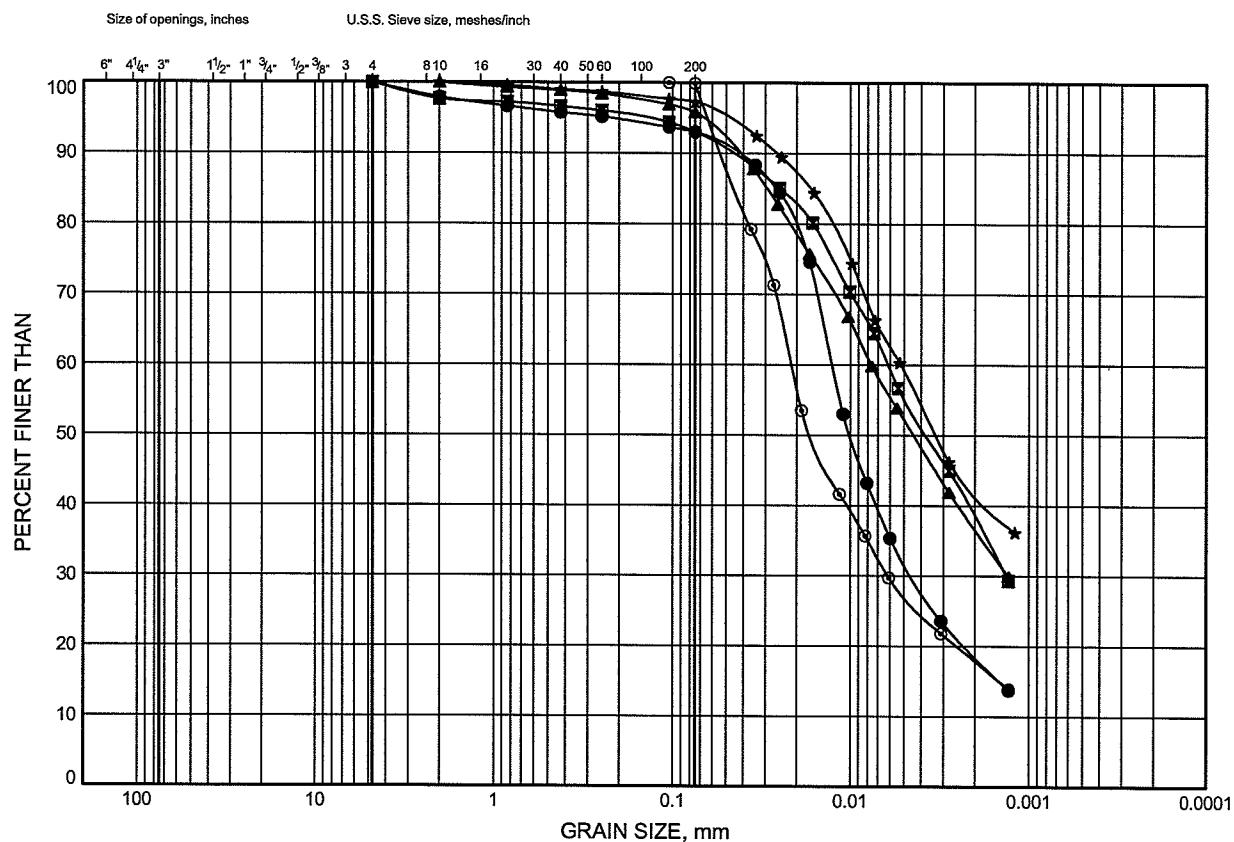


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B7-5

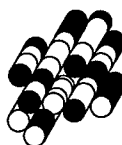
SILTY CLAY



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

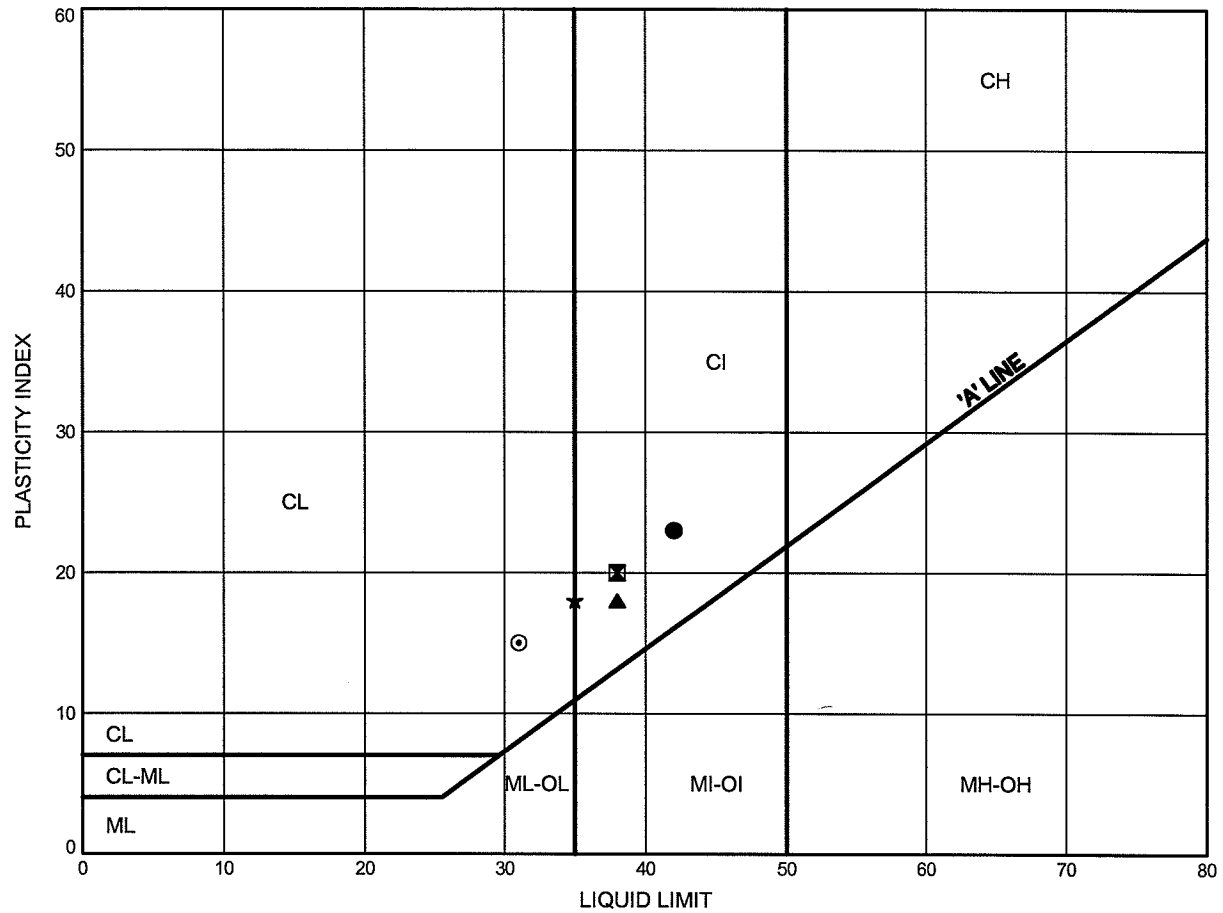
SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C10-2	21.5	160.2
■	C10-3	3.2	175.3
▲	C10-3	4.0	174.5
★	C10-3	6.3	172.2
⊙	C10-3	10.9	167.6

Date November 2010
Project 1-09-4135



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

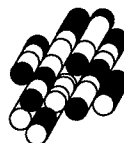
FIGURE B7-6



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



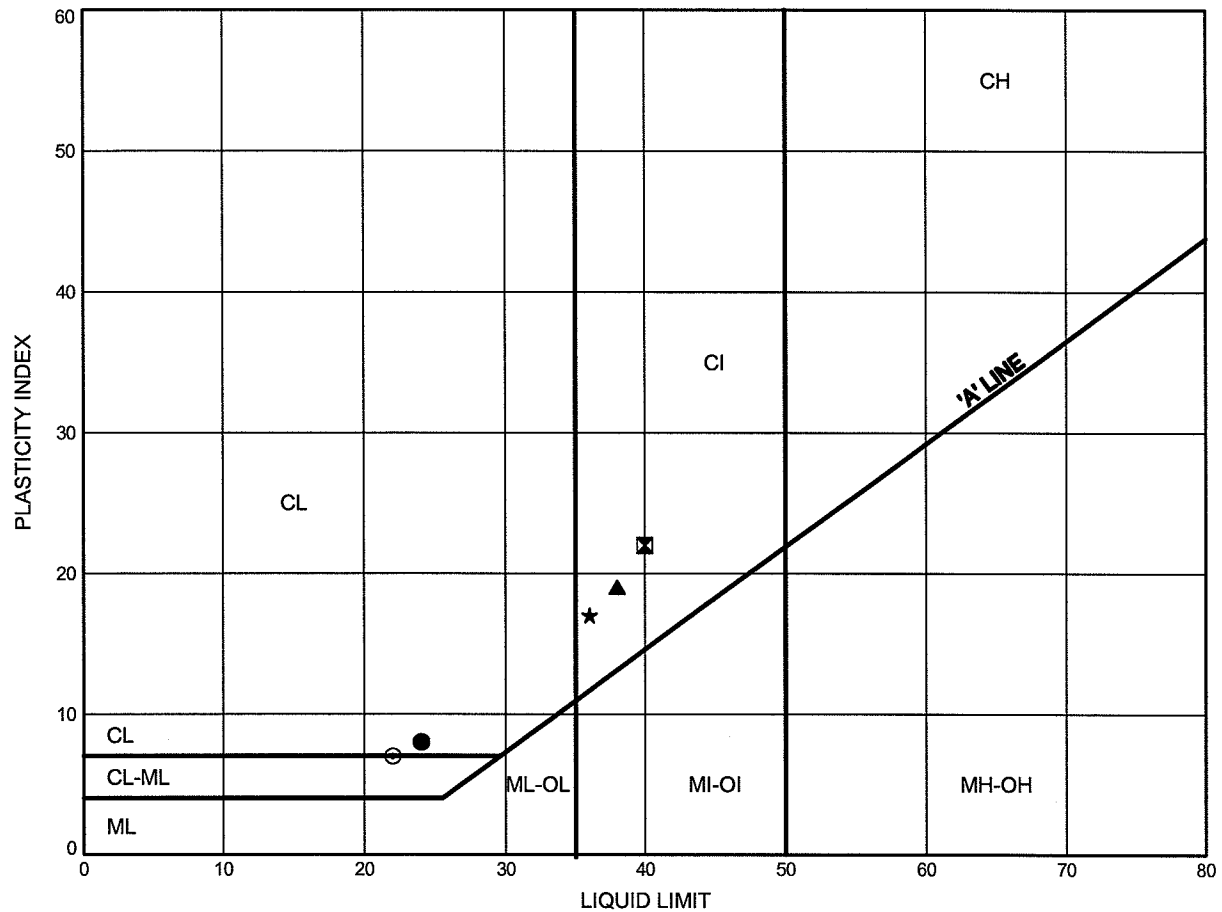
Prep'd K.L.

Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

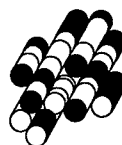
FIGURE B7-7

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

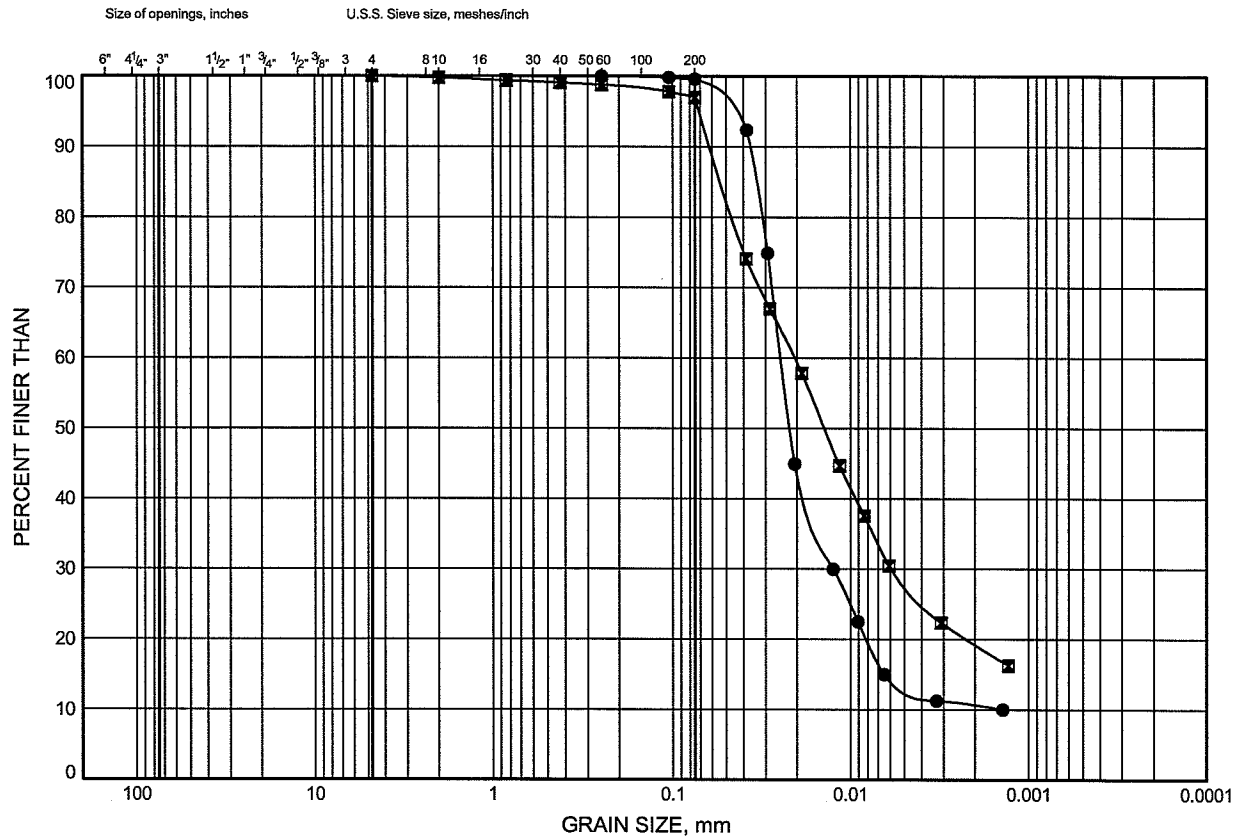


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B7-8

SILT



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

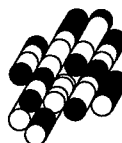
SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

● 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.

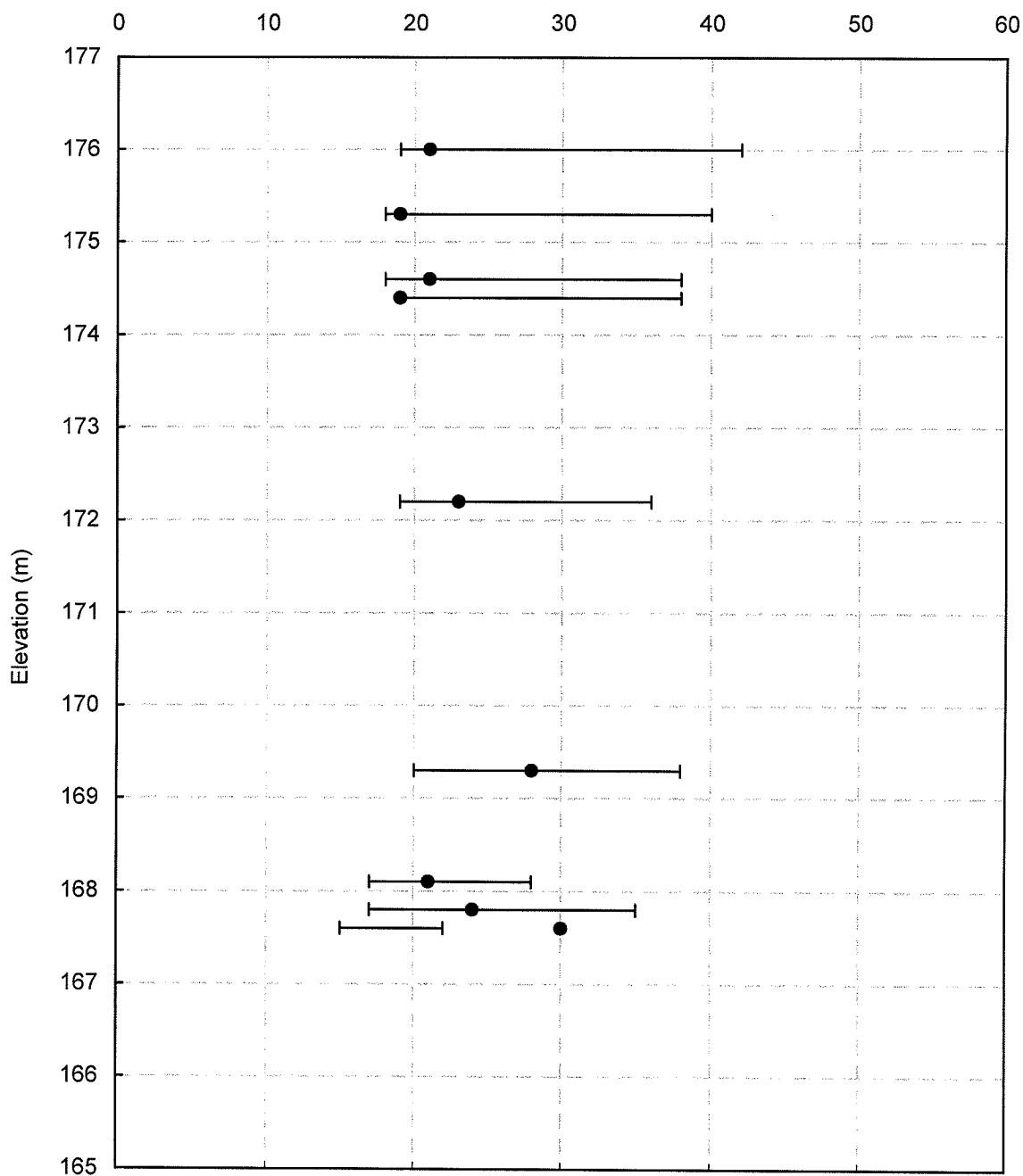
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B7-9

HWY 406 TWINNING - CULVERT #10

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : November, 2010



Terraprobe Inc.

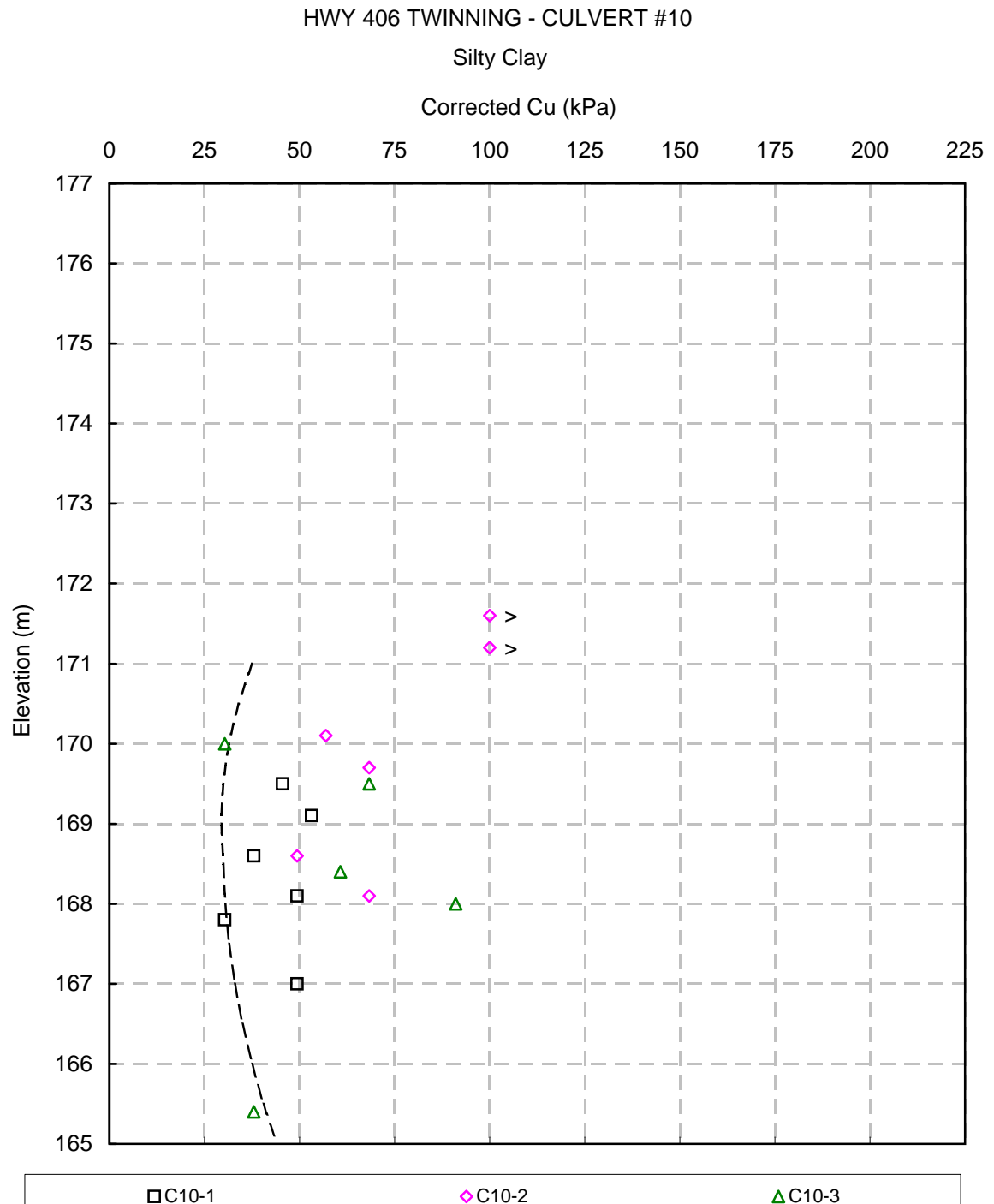
Prepared By : HW

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

Applied Correction Factors

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

Project No. : 1-09-4135

Date : November, 2010



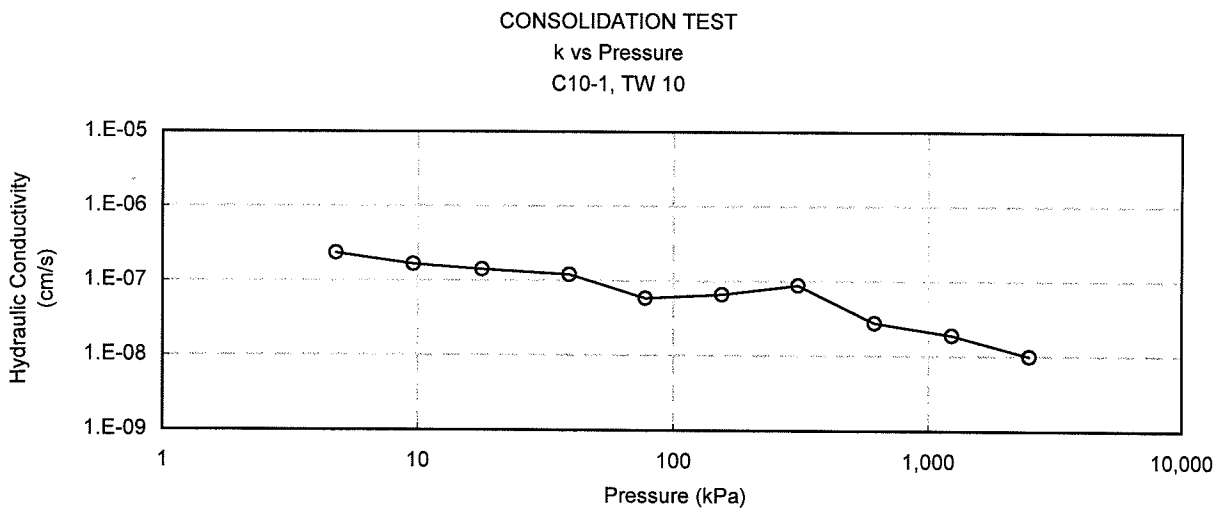
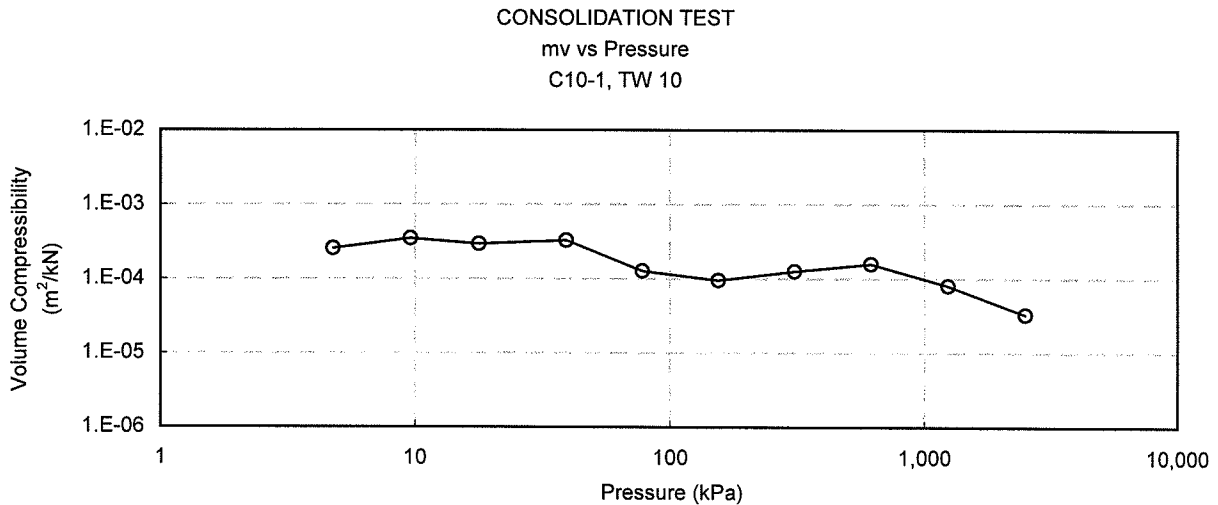
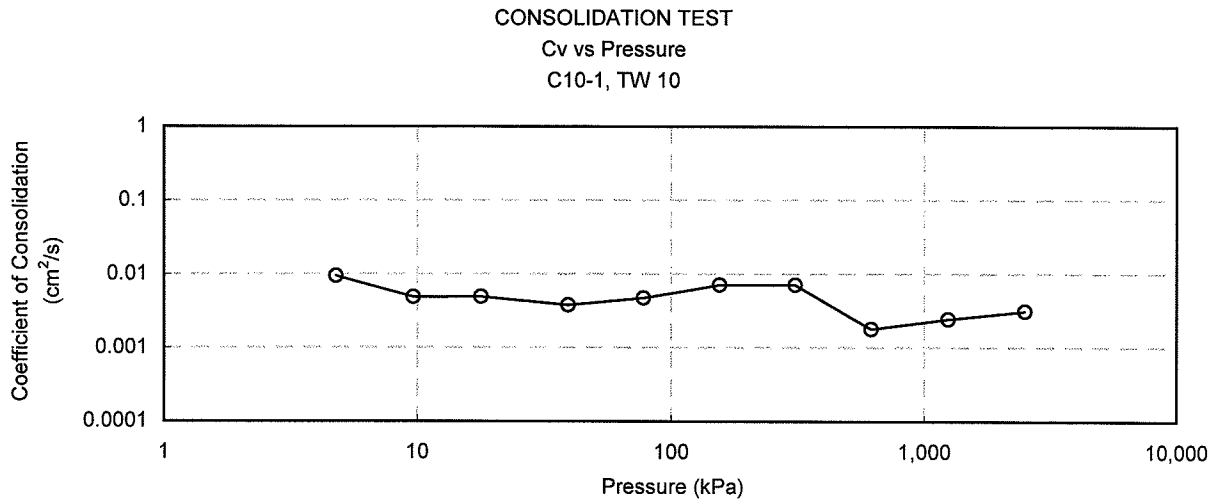
Terraprobe Inc.

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



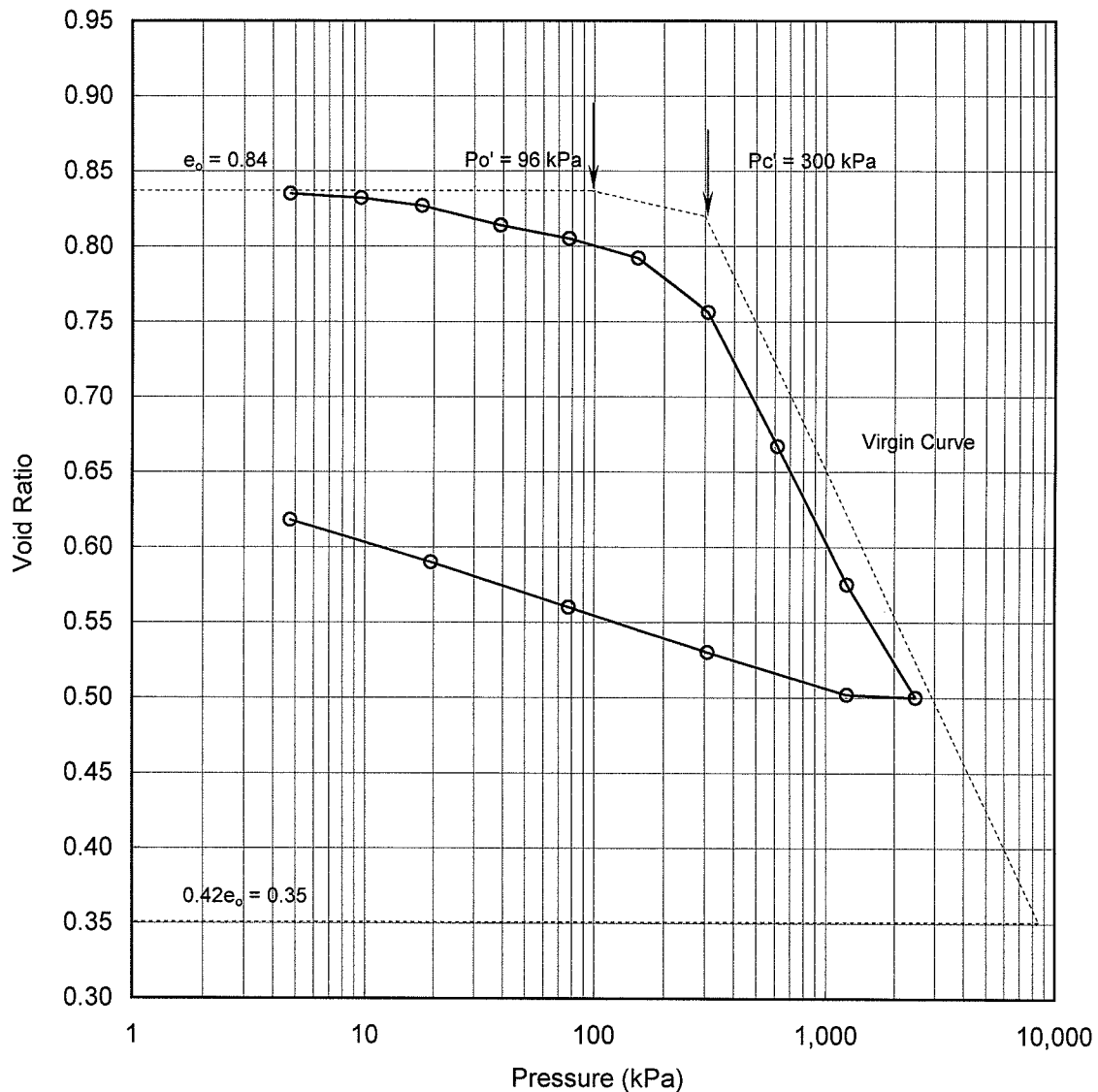
Terraprobe Inc.

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 ³	PI =	17%	Cc =	0.323
Gs =	2.81			Cr =	0.034

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



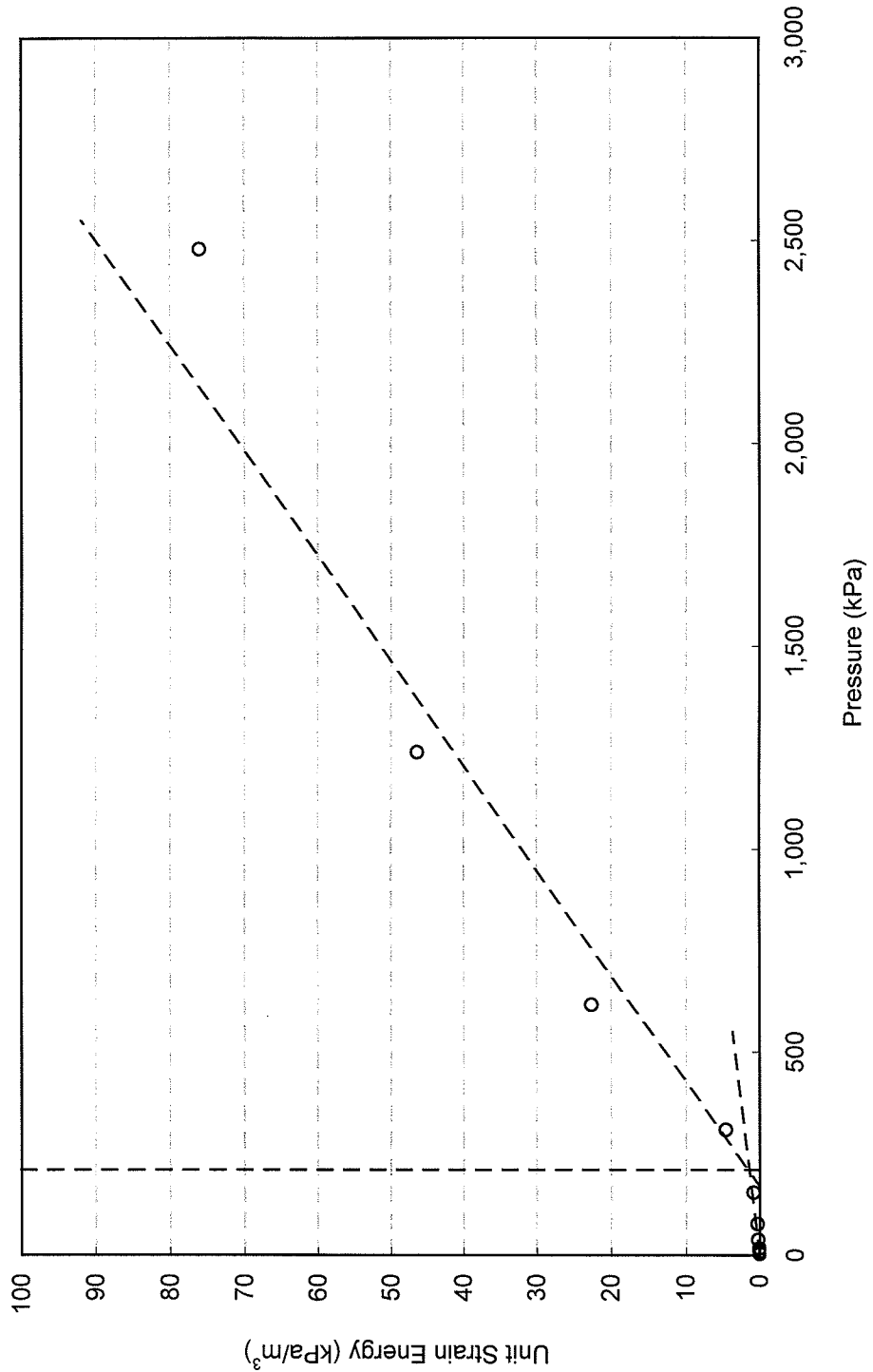
Terraprobe Inc.

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



$P_c = 210 \text{ kPa}$

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

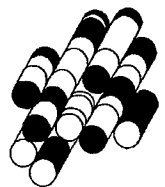


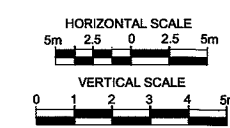
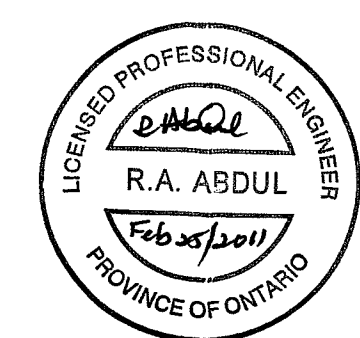
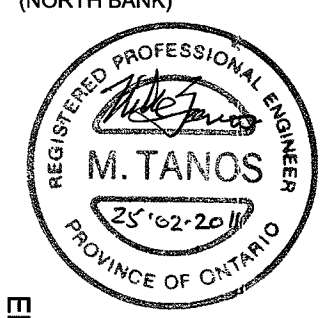
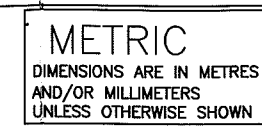
Terraprobe Inc.

Prepared By : HW
Checked By : RA

C7

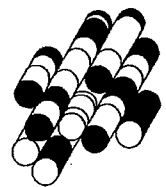
TERRAPROBE INC.



[illegible]

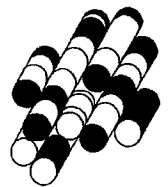
CULVERT #35

TERRAPROBE INC.



A8

TERRAPROBE INC.



METRIC

[illegible]

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

ONTARIO MOT 1-094135 CULVERTS2 (KELVIN).GPJ ONTARIO MOT.GDT 09/10/10

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)								
								○ UNCONFINED	+ FIELD VANE														
160.8	SILT trace sand, trace gravel, frequent silty clay seams and partings, loose to compact, brown, wet		14	SS	9		162							1 5 77 12									
17.1	CLAYEY SILT trace sand, very stiff to hard, brown, damp to moist		15	SS	16		161																
159.1			16	SS	55		160								0 1 83 16								
18.8	<p>End of Borehole</p> <p>Sampler wet at 3.8m.</p> <p>No sample recovery at SS3. Disturbed sample collected.</p> <p>No sample recovery at SS7. Sampler redriven and disturbed sample collected.</p> <p>Borehole was dry (not stabilized) and hole open to full depth on completion.</p> <p>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>Water Level Readings:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elevation(m)</th> </tr> </thead> <tbody> <tr> <td>July.12.10</td> <td>4.5</td> <td>173.4</td> </tr> <tr> <td>July.19.10</td> <td>4.4</td> <td>173.5</td> </tr> </tbody> </table>														Date	Depth(m)	Elevation(m)	July.12.10	4.5	173.4	July.19.10	4.4	173.5
Date	Depth(m)	Elevation(m)																					
July.12.10	4.5	173.4																					
July.19.10	4.4	173.5																					

+³, X³: Numbers refer to Sensitivity O^{3%} STRAIN AT FAILURE

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

RECORD OF BOREHOLE No C11-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766773.0 E:326047.9 ORIGINATED BY AW
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 07.16.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
179.0	Ground Surface														
0.1	110mm ASPHALT														
178.5	410mm FILL - Gravelly Sand, some silt, very dense, brown, damp		1	SS	83					○				26 58 (16)	
0.5															
	FILL - Silty Clay, sandy, gravelly, trace organics, firm, brown, damp to moist		2	SS	5					○				28 21 25 26	
			3	SS	6							○			
176.9															
2.1	SILTY CLAY trace sand, firm to stiff, brown, damp to moist		4	SS	13						○				
			5	SS	11						○		42	0 3 51 46	
			6	SS	12						○				
			7	SS	5						○				
			8	SS	6							○			
										>>	1.5				
										>>	1.5				
										>>					
			9	SS	3								○		0 1 53 46
							</								

Continued Next Page

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

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

2 OF 2

METRIC

[illegible]

160.1 18.9	<p>SILT trace to some clay, very loose to loose, brown, wet</p>	14	SS	WOH
		15	SS	5
155.6	<p>CLAYEY SILT trace sand, stiff to hard, brown, damp to moist</p>	16	SS	6
		17	SS	21
		18	SS	8
		19	SS	43

End of Borehole
Sampler wet at 12.2m.
Wet cave at 14.3m on completion.

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

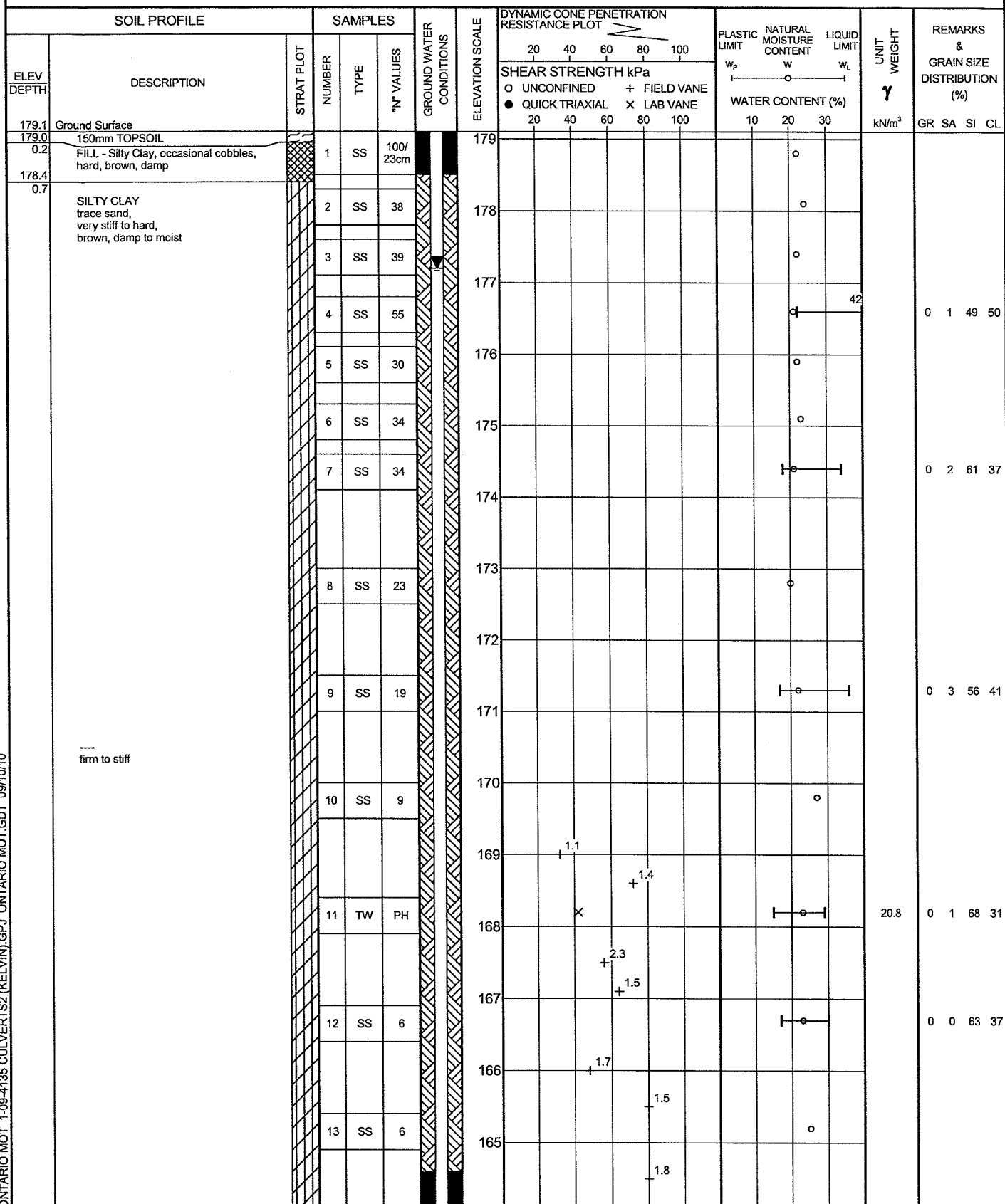
+³, X³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

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



Continued Next Page

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

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

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 _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL														
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																				
163.6	SILT trace clay, loose, brown, wet		14	SS	5		164						July 09 July 12															
15.5								163																				
162.1	CLAYEY SILT trace sand, trace gravel, firm to hard, brown, damp to moist		15	SS	6		162						0 0 86 14															
17.0								161																				
								160																				
								159																				
158.8			16	SS	11																							
20.3	End of Borehole		17	SS	59																							
<p>Consolidation test performed on TW 11.</p> <p>Water level at 17.4m (not stabilized) and hole open to 13.7m on completion.</p> <p>SS1 - Sampler bouncing, probably on a cobble.</p> <p>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>Water Level Readings:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elevation(m)</th> </tr> </thead> <tbody> <tr> <td>July.19.10</td> <td>5.1</td> <td>174.0</td> </tr> <tr> <td>July.26.10</td> <td>3.5</td> <td>175.6</td> </tr> <tr> <td>Aug.06.10</td> <td>2.0</td> <td>177.1</td> </tr> <tr> <td>Aug.13.10</td> <td>1.9</td> <td>177.2</td> </tr> </tbody> </table>														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
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																										

Hwy 406 Expansion -
Port Robinson Road to East Main Street

W.P 280-99-00
Project Number: 1-09-4135

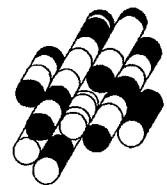
Test Pit Logs
Culvert #11 (Port Robinson Road Sta. 9+710)

Test Pit# TP 11-1

0	-	180	Fill, Br Si(y) Sa, Some Org, Some Rootlets, Wet
180	-	300	Br Si(y) Cl, Tr Sa, Damp to Moist

B8

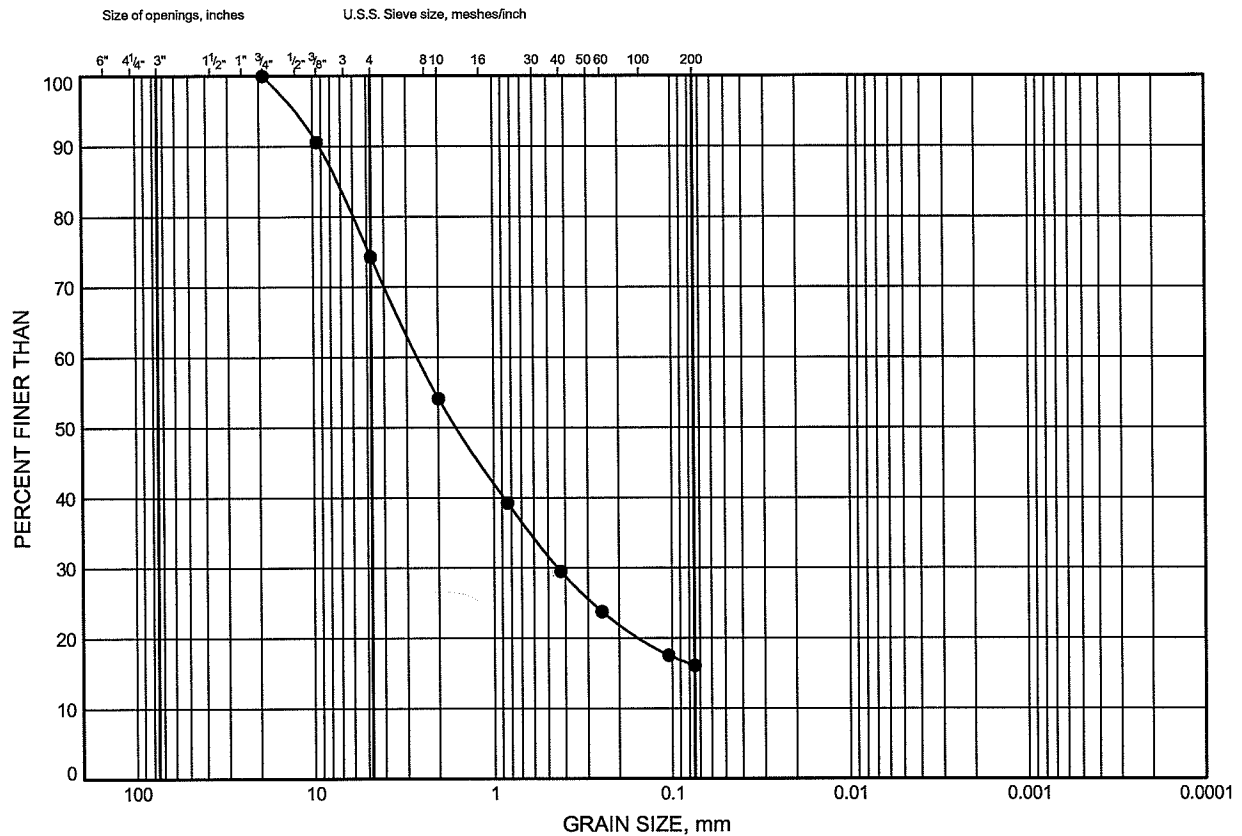
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B8-1

FILL - Gravelly Sand



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-2	0.3	178.7

Date November 2010
Project 1-09-4135



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

GRAIN SIZE DISTRIBUTION

FIGURE B8-2

FILL - Silty Clay

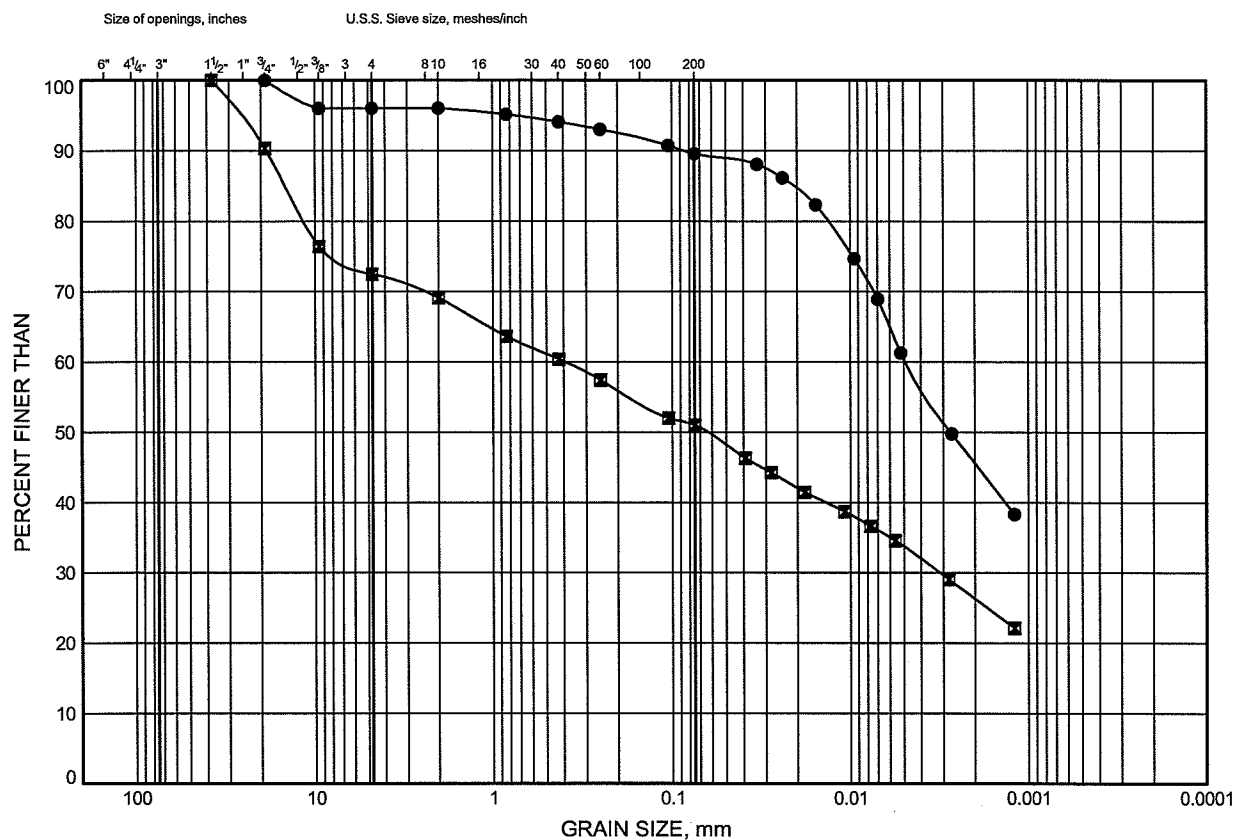
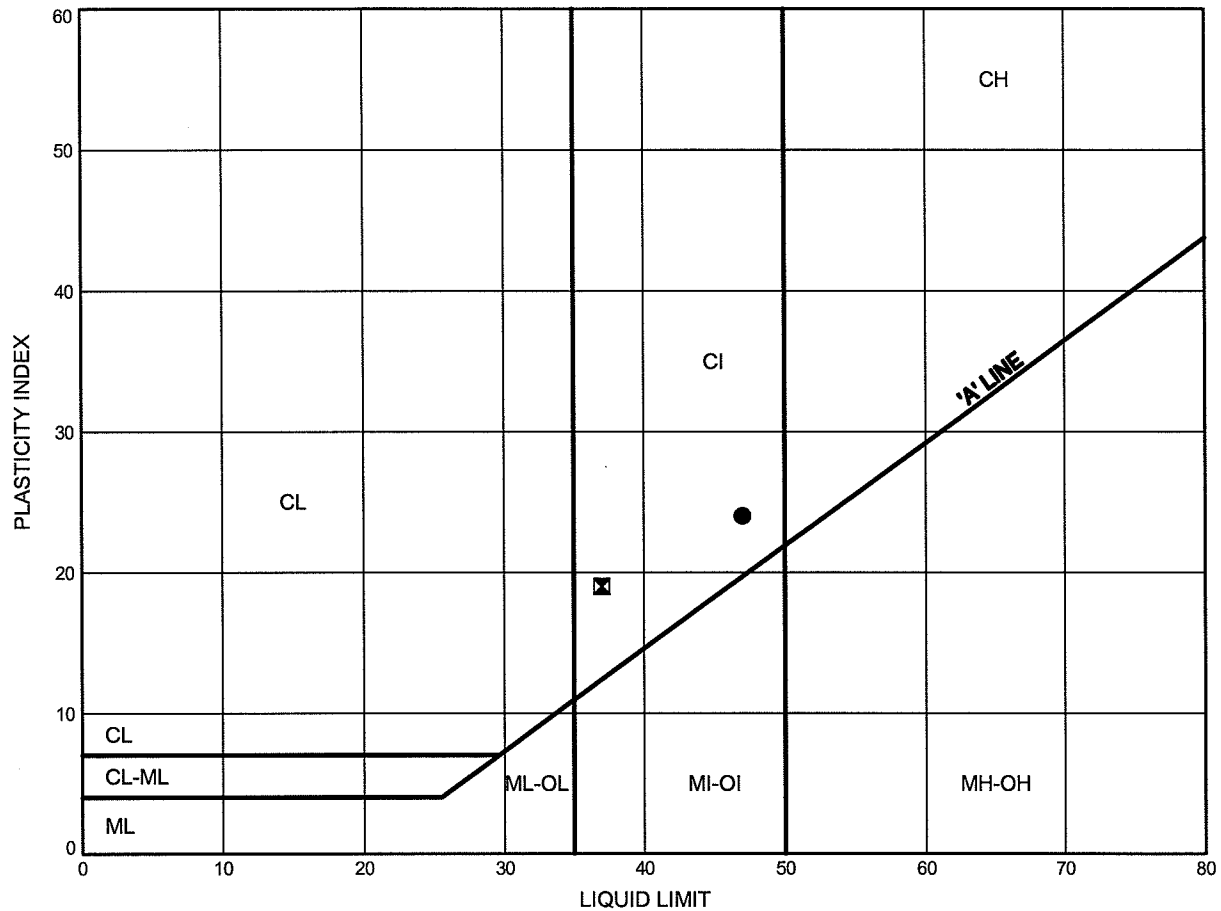


FIGURE B8-3



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-1	0.3	177.6
⊠	C11-2	1.0	178.0

Date November 2010
Project 1-09-4135

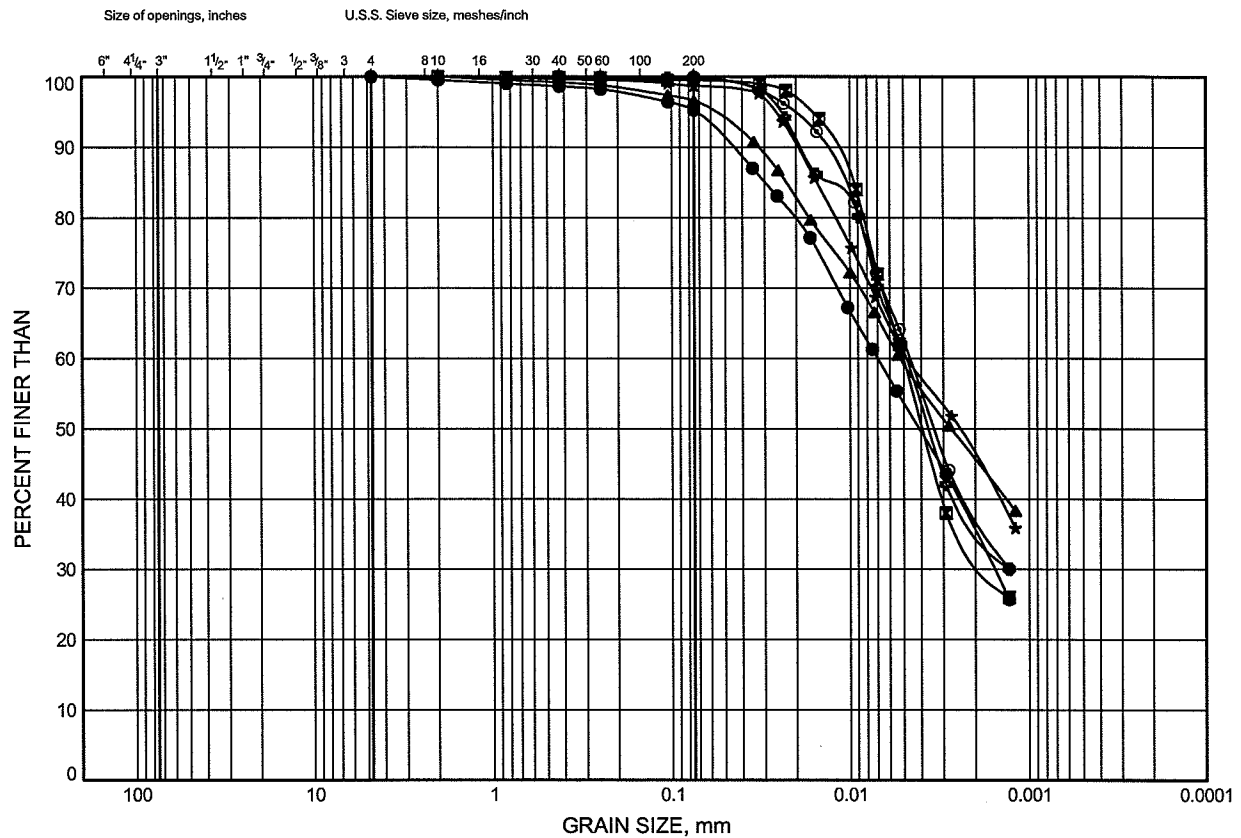


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B8-4

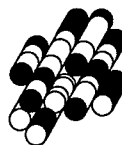
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-1	4.0	173.9
■	C11-1	9.3	168.6
▲	C11-2	3.2	175.8
★	C11-2	7.8	171.2
⊙	C11-2	10.9	168.1
⊕	C11-2	12.4	166.6

Date November 2010
Project 1-09-4135

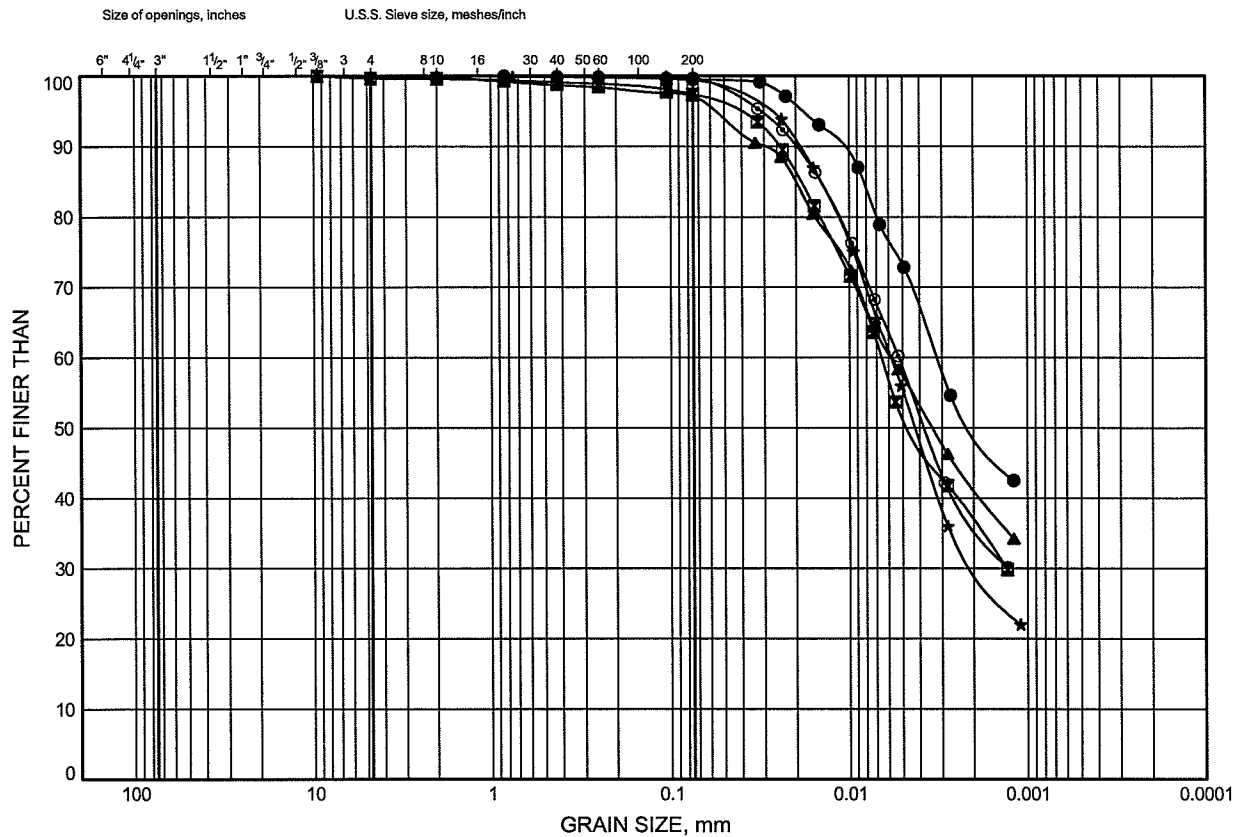


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B8-5

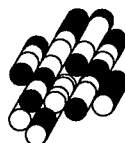
SILTY CLAY



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

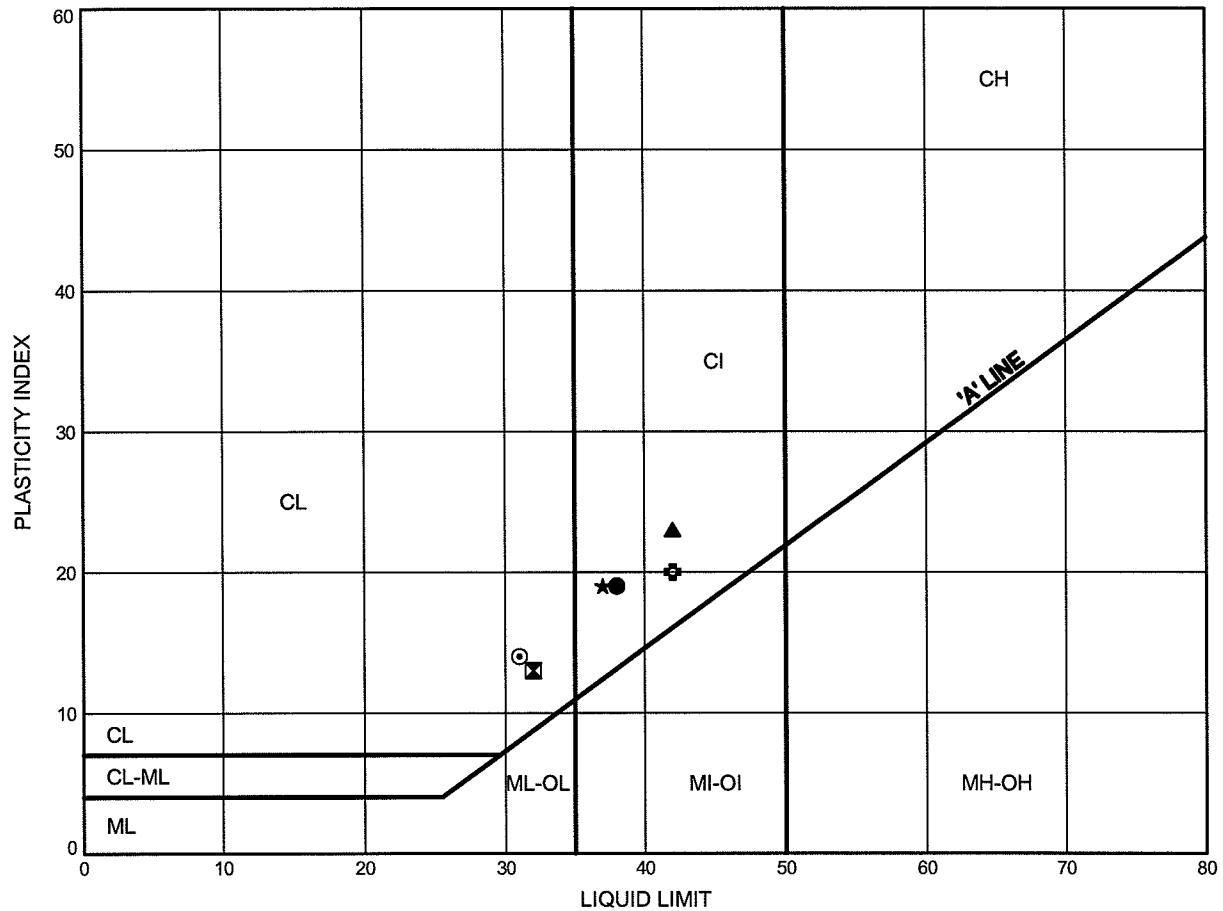
SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-3	2.5	176.6
⊠	C11-3	4.7	174.4
▲	C11-3	7.8	171.3
★	C11-3	10.9	168.2
⊙	C11-3	12.4	166.7

Date November 2010
Project 1-09-4135



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

FIGURE B8-6

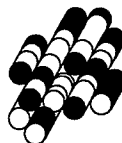


SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	C11-1	4.0	173.9
⊠	C11-1	9.3	168.6
▲	C11-2	3.2	175.8
★	C11-2	7.8	171.2
⊙	C11-2	12.4	166.6
⊕	C11-3	2.5	176.6

Date November 2010

Project 1-09-4135



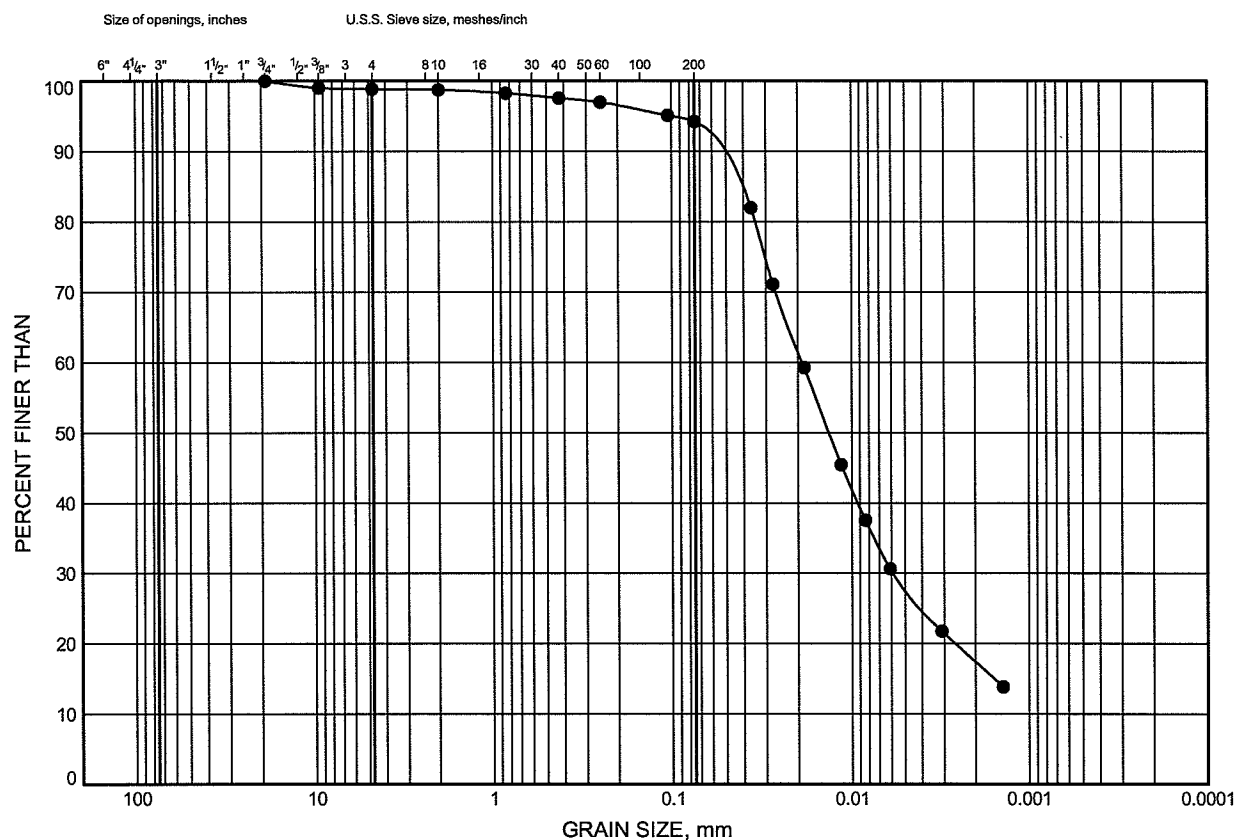
Prep'd K.L.

Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B8-8

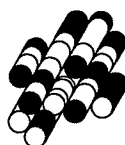
SILT



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-1	15.4	162.5

Date November 2010
Project 1-09-4135

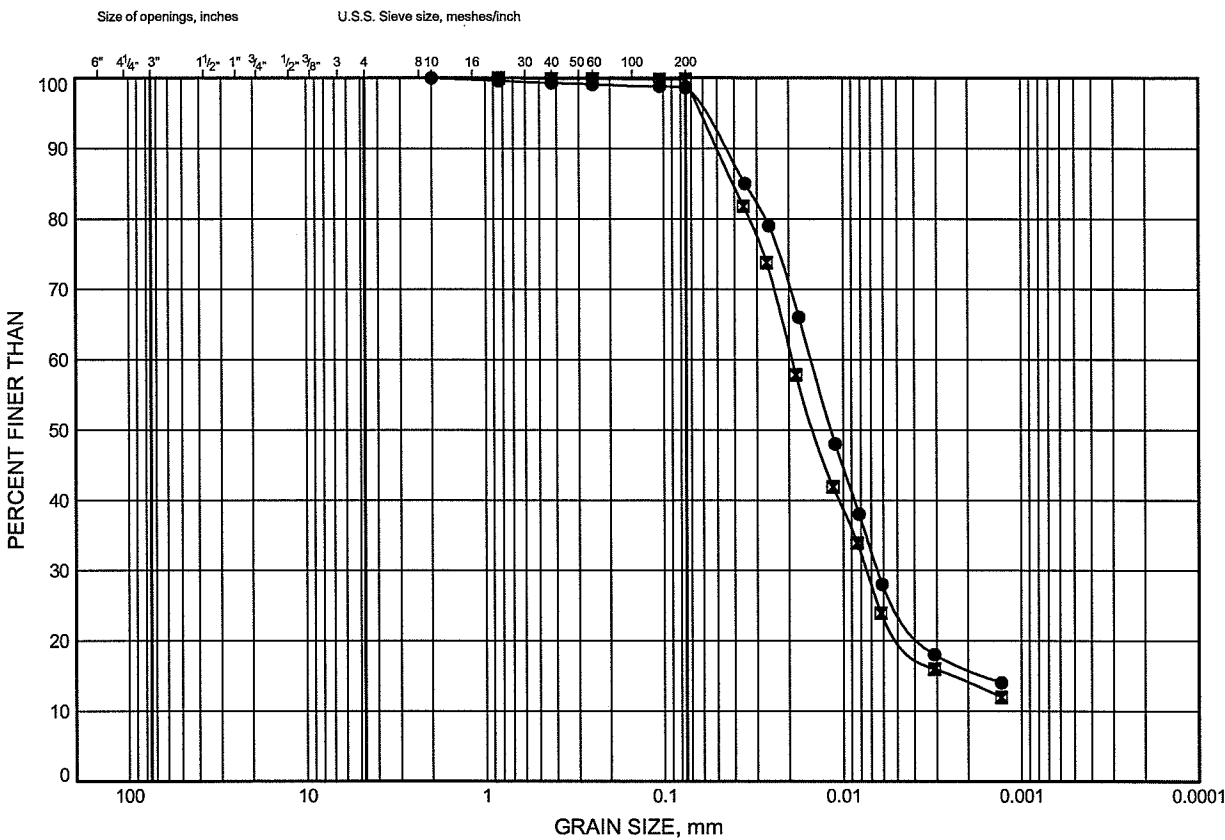


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B8-9

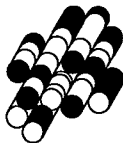
CLAYEY SILT



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-1	18.5	159.4
■	C11-3	20.0	159.1

Date November 2010
 Project 1-09-4135

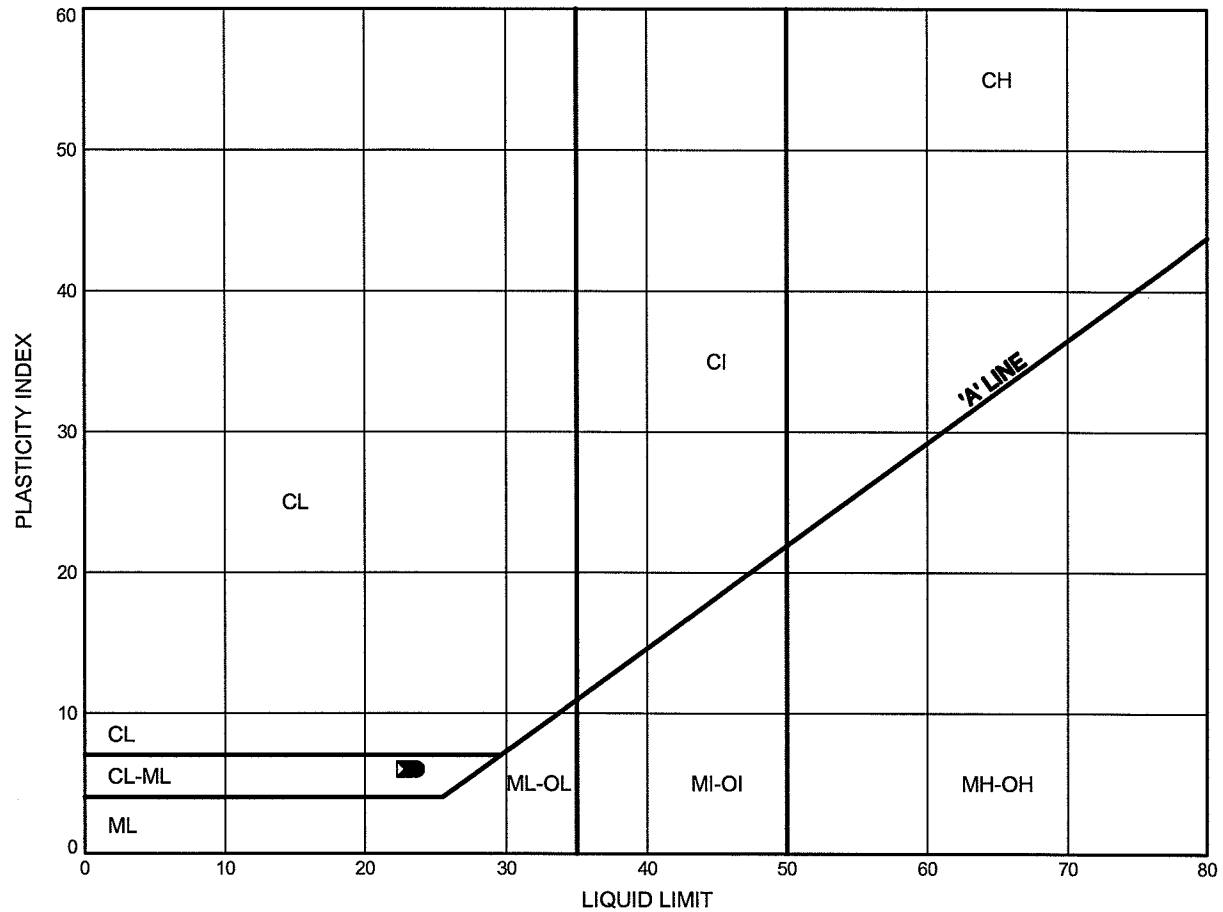


Prep'd K.L.
 Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

FIGURE B8-10

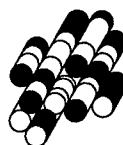
CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C11-1	18.5	159.4
⊠	C11-3	20.0	159.1

Date November 2010

Project 1-09-4135



Prep'd K.L.

Chkd. M.P.

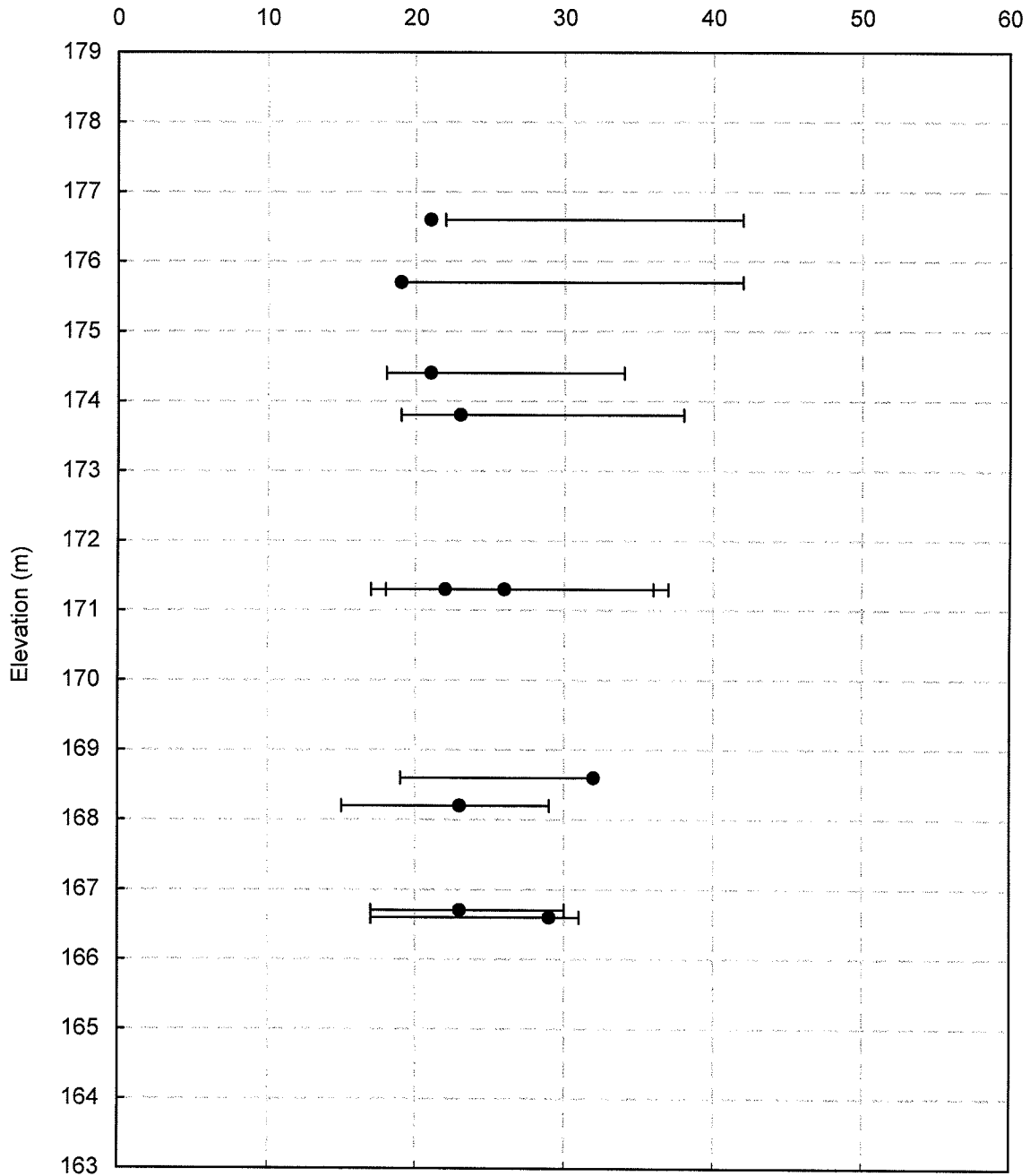
ATTERBERG LIMITS AND WATER CONTENTS

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

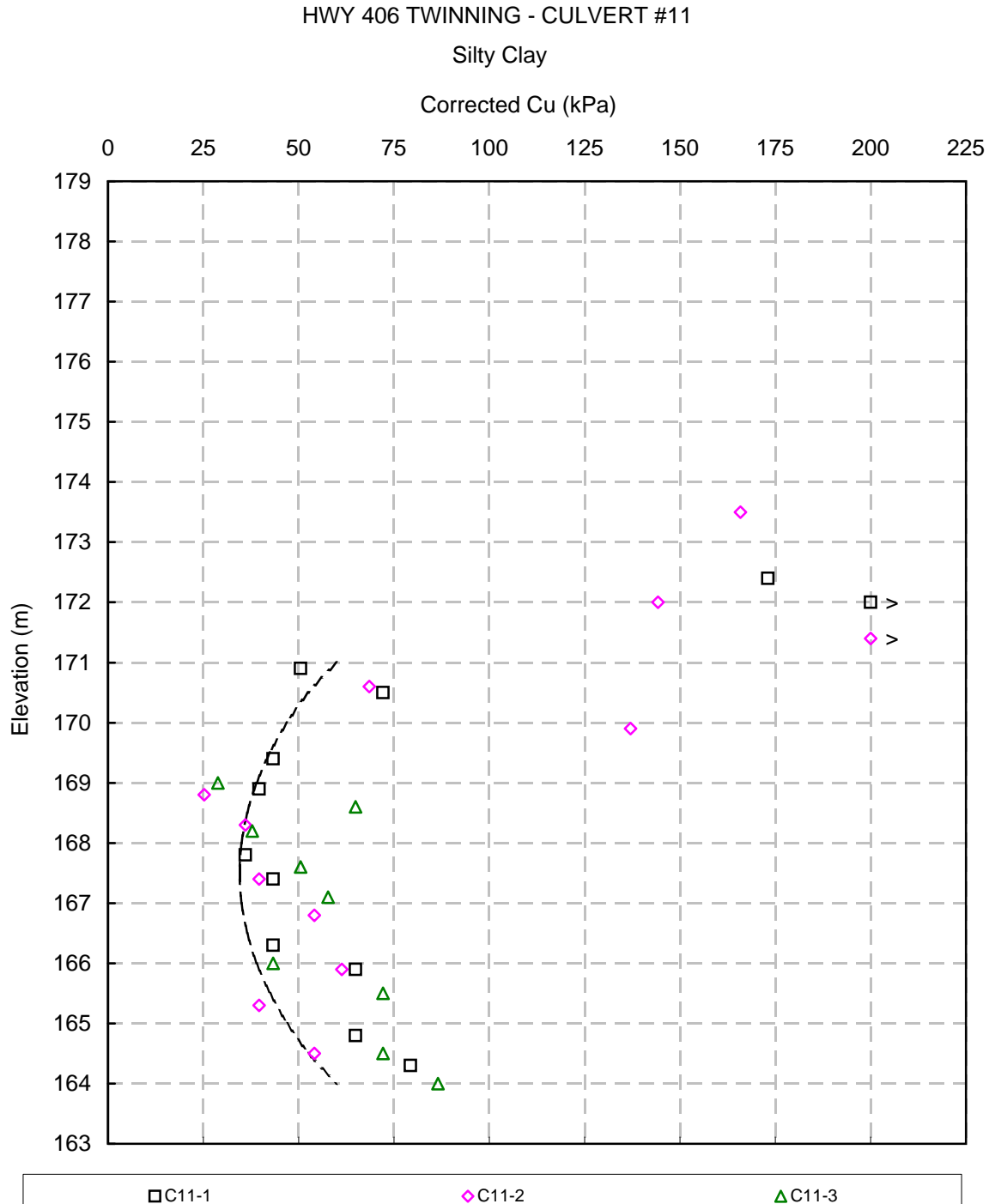
Checked By : RA

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

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

Applied Correction Factors

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

Project No. : 1-09-4135

Date : November, 2010



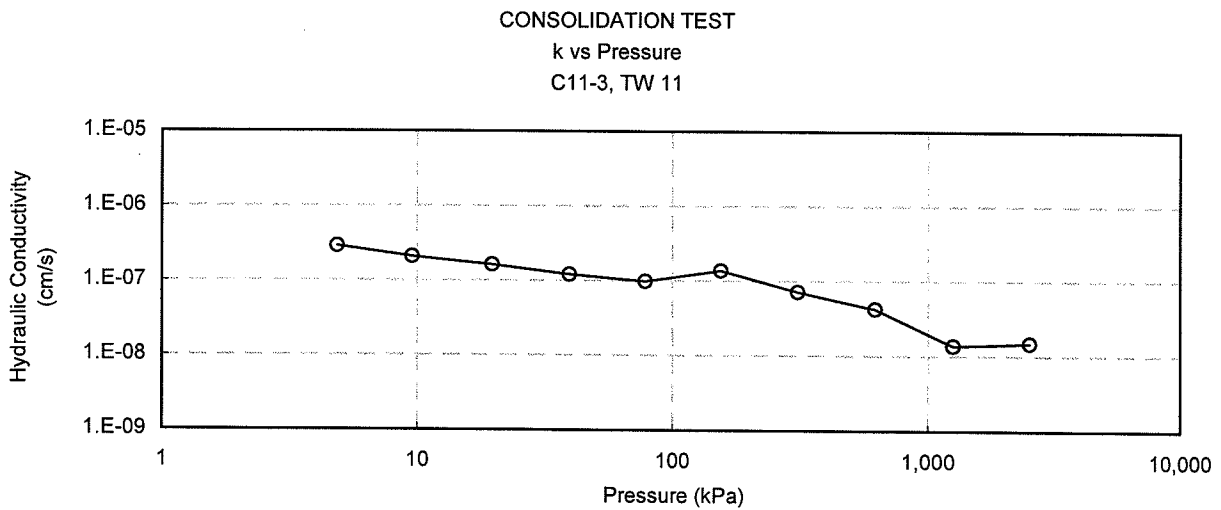
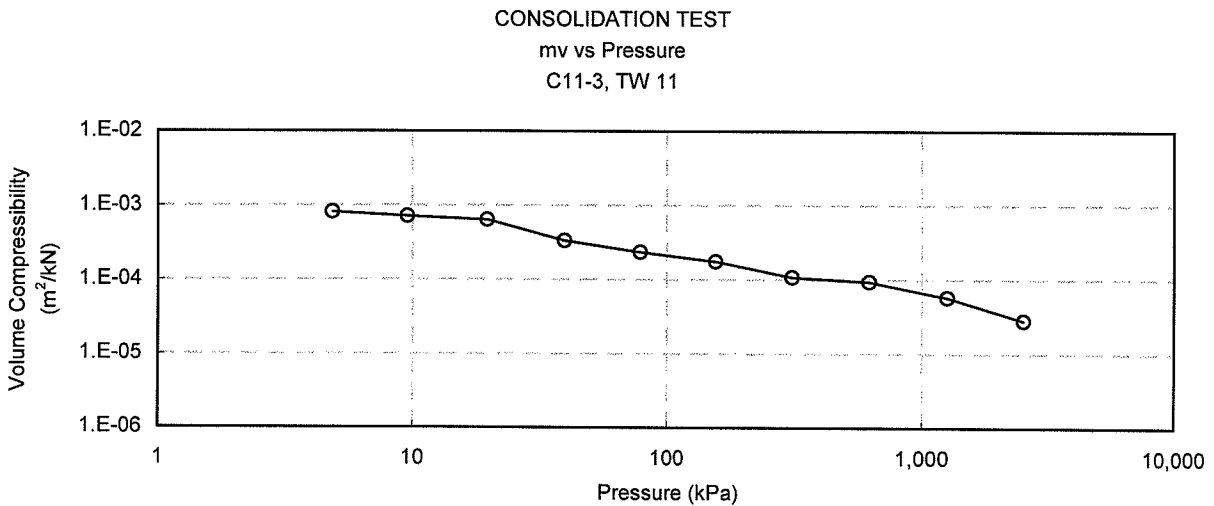
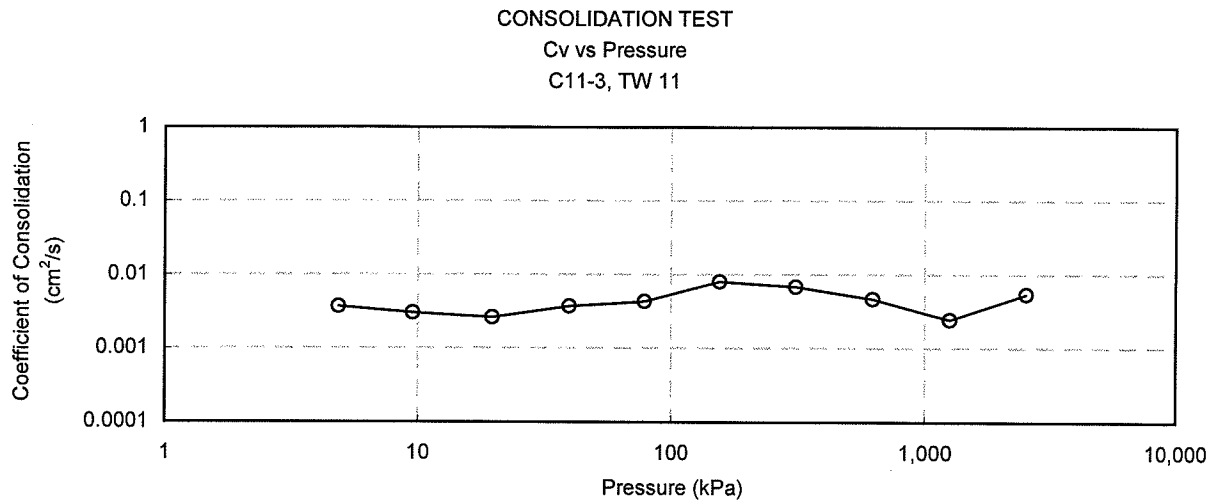
Terraprobe Inc.

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



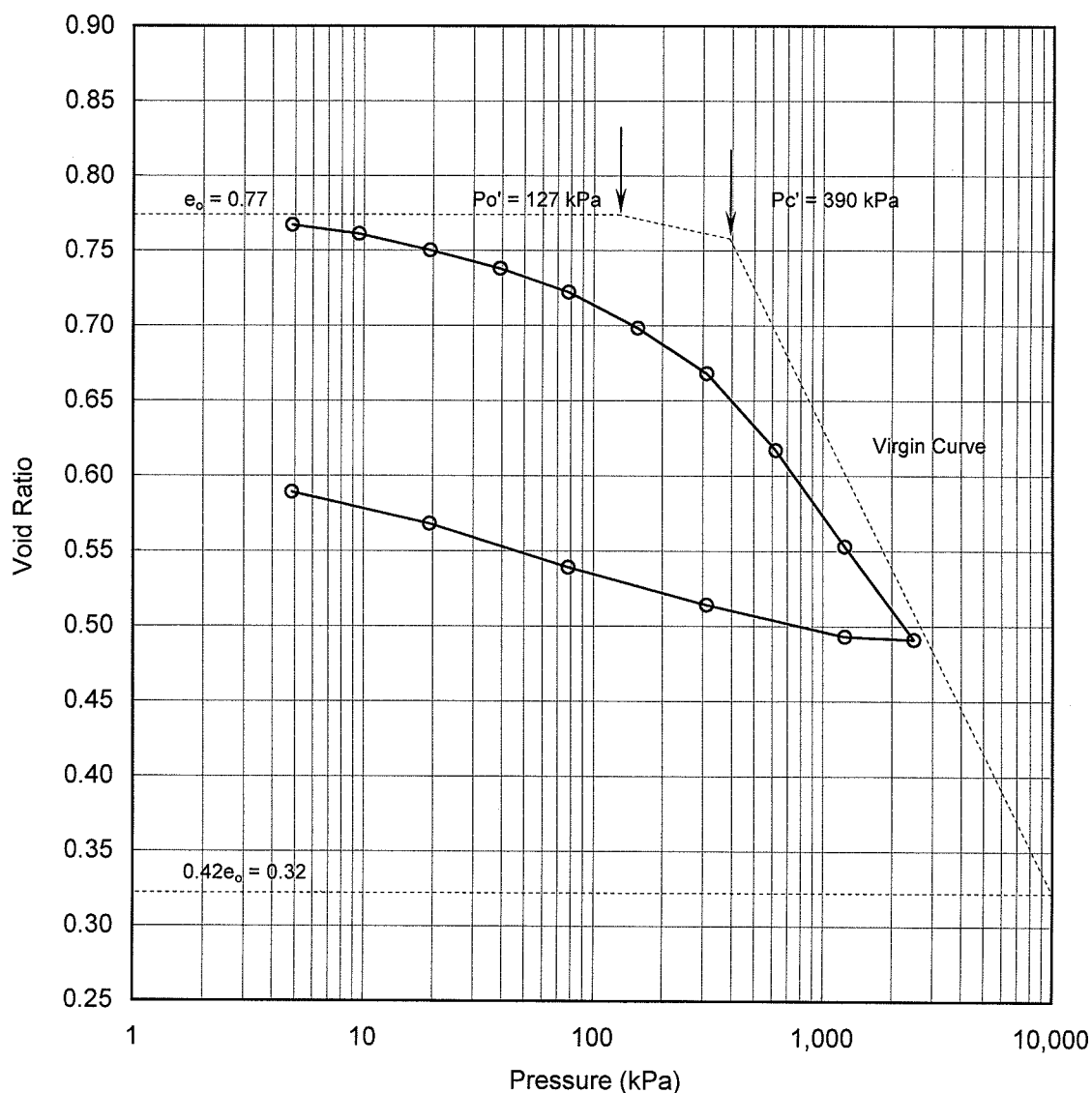
Terraprobe Inc.

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 ³	PI =	14%	Cc =	0.309
Gs =	2.76			Cr =	0.033

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



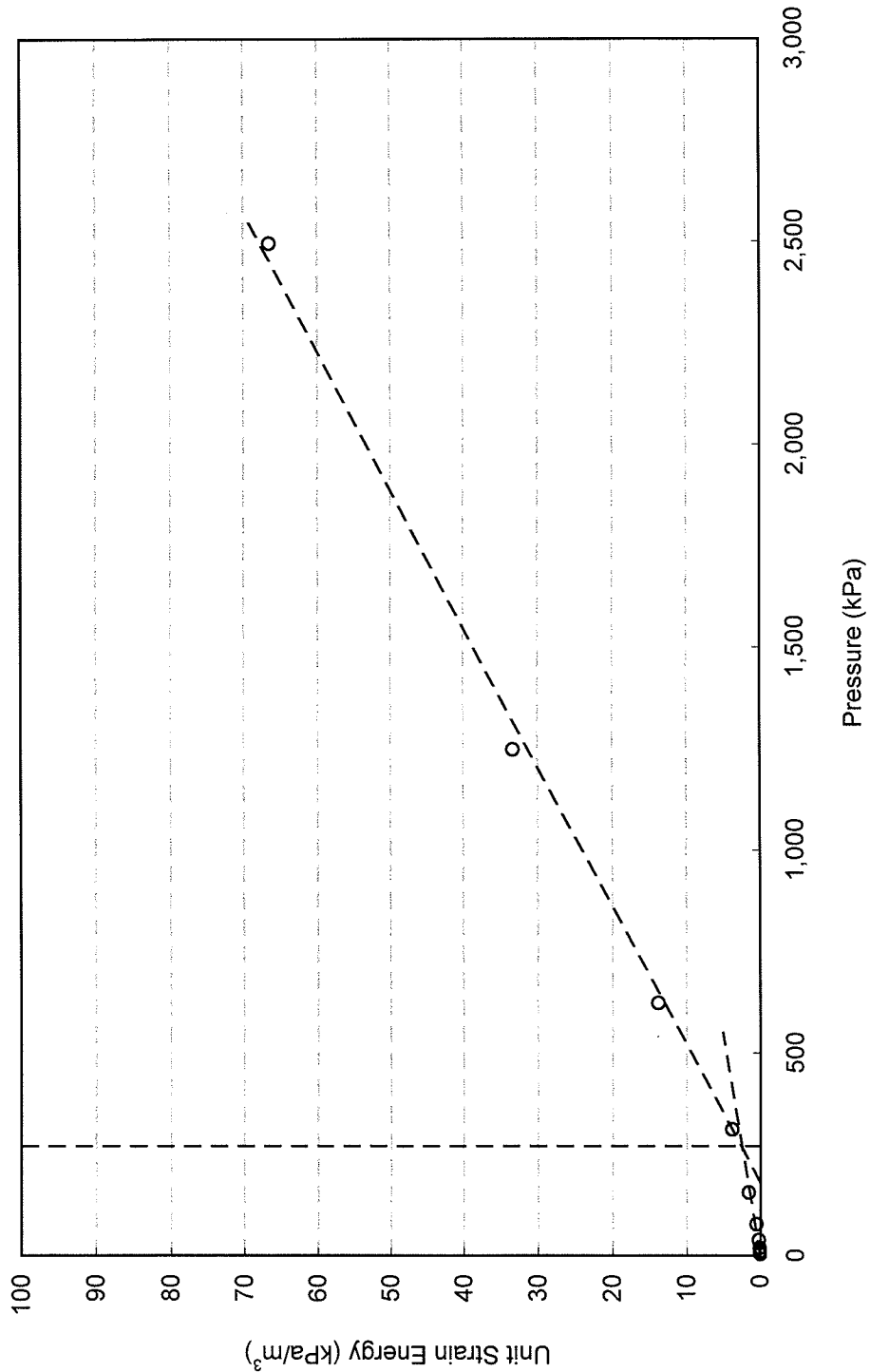
Terraprobe Inc.

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



Project No. : 1-09-4135

Date : November 2010



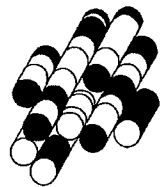
Terraprobe Inc.

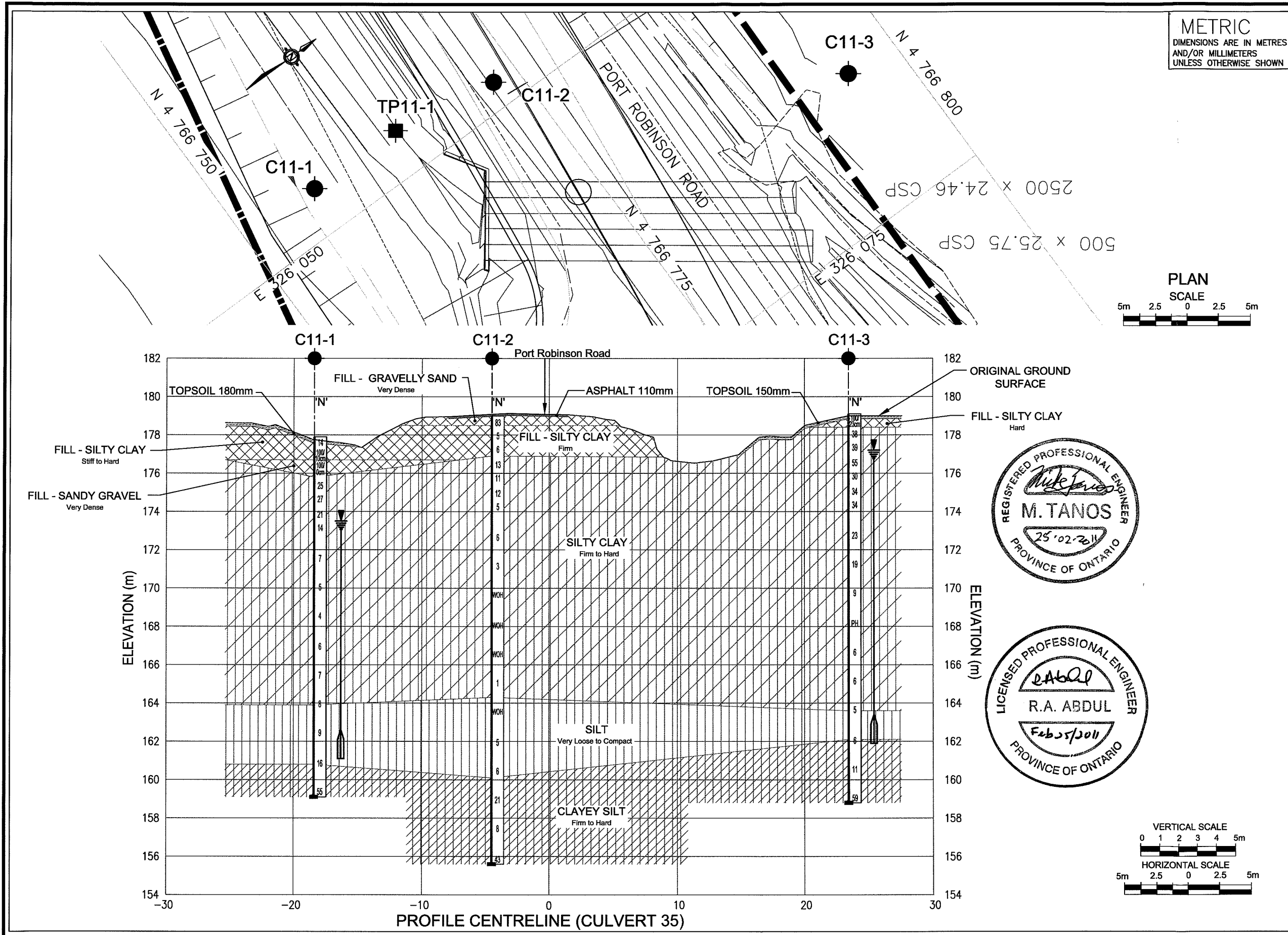
Prepared By : HW

Checked By : RA

C8

TERRAPROBE INC.





CONT No 2011-2005
WP No 280-99-00

HIGHWAY 406
CULVERT #35
BOREHOLE LOCATIONS AND SOIL STRATA

IBI GROUP

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650

SHEET
1 OF

KEY PLAN

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test
- Bore Hole And Cone
- Test Pit
- 'N' Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer (AUG. 2010)
- Piezometer
- 90% Rock Quality Designation
- A/R Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
C11-1	177.9	4 766 756.7	326 046.4
C11-2	179.0	4 766 773.0	326 047.9
C11-3	179.1	4 766 795.7	326 063.9

NOTE

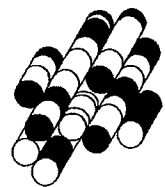
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

DESIGN		CODE		LOAD		DATE	
DESIGN	R.A.	CODE	CHBDC2006	LOAD		DATE	FEB. 2011
DRAWN	K.C.	CHK	R.A.	STRUCT			

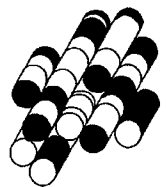
CULVERT #49

TERRAPROBE INC.



A9

TERRAPROBE INC.



RECORD OF BOREHOLE No C12-1

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4767228.9 E:326354.3 ORIGINATED BY BL
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers, D.C.P.T. COMPILED BY DB
 DATUM Geodetic DATE 06.25.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
181.3	Ground Surface							20 40 60 80 100							
181.2	130mm ASPHALT														
181.0	180mm FILL - Sandy Gravel, grey, damp		1	AS	-		181			○					
0.3															
	FILL - Silty Clay, some sand, gravelly, trace organics, soft to firm, brown, damp to moist		2	SS	6		180				○			28 16 28 28	
			3	SS	3							○			
179.2							179								
2.1	SILTY CLAY trace sand, firm to very stiff, brown, damp to moist		4	SS	12						○				
			5	SS	22		178				○		43	0 0 57 43	
			6	SS	16										
			7	SS	12		177				○				
							176								
			8	SS	6		175					○		0 4 60 36	
							174								
			9	TW	PH										
							173								
								1.4							
			10	SS	2		172								
								2.0							
							171								
								1.6							
			11	SS	1		170						61	0 1 19 80	
								1.4					47		
							169								
			12	SS	WOH			2.4							
								2.2					41		
							168								
								2.0							
							167								
			13	SS	6			2.4						0 1 77 22	

Continued Next Page

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

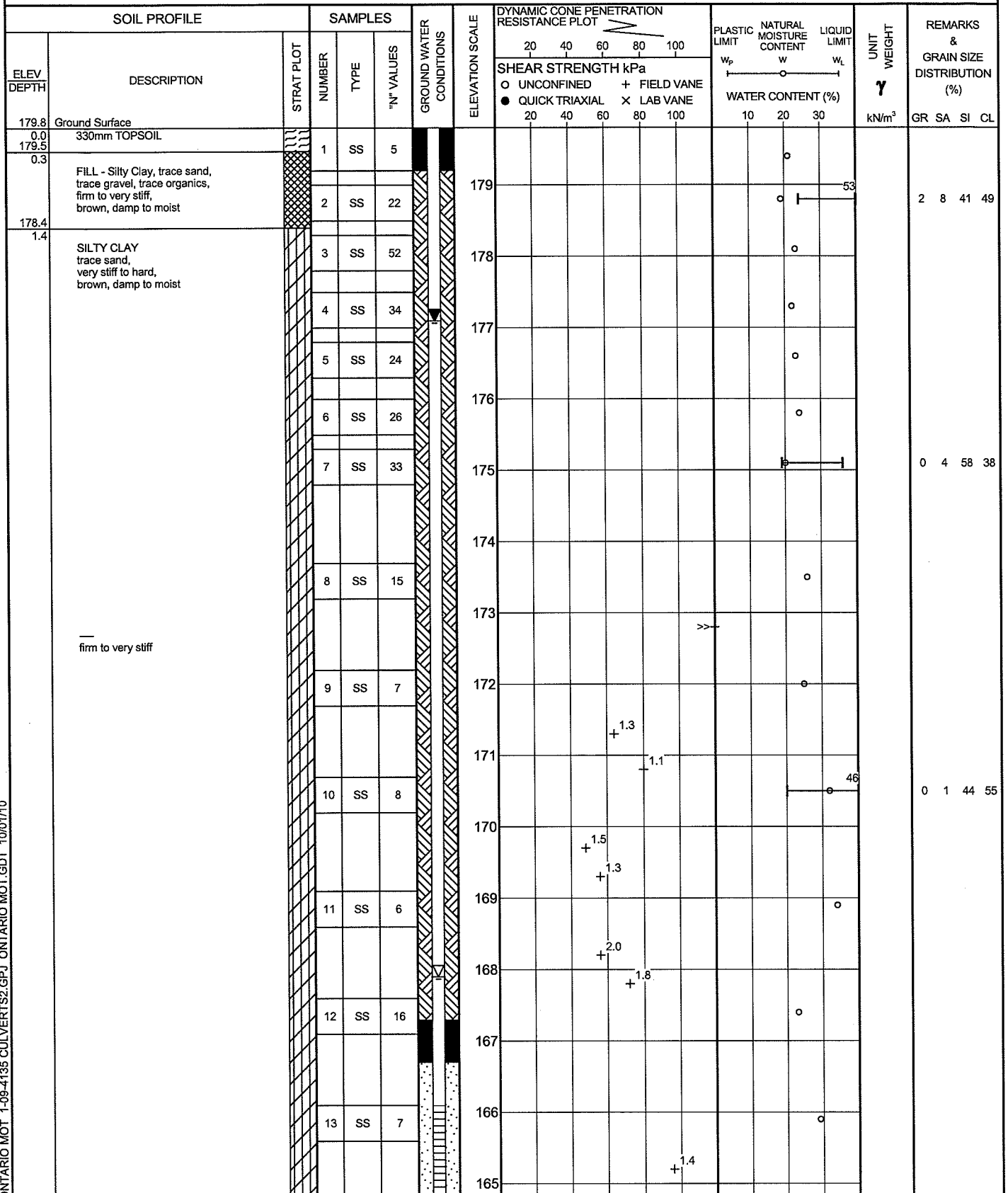
ONTARIO MOT 1-09-4135 CULVERTS2 (KELVIN) GPJ ONTARIO MOT.GDT 09/10/10

RECORD OF BOREHOLE No C12-2

1 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4767226.6 E:326344.2 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.15.10 CHECKED BY RA



ONTARIO MOT 1-09-4135 CULVERTS2.GPJ ONTARIO MOT.GDT 10/01/10

Continued Next Page

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

RECORD OF BOREHOLE No C12-2

2 OF 2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4767226.6 E:326344.2 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
 DATUM Geodetic DATE 07.15.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE						○ QUICK TRIAXIAL	
164.6 15.2	SILT trace sand, occasional silty clay seams and partings, loose to compact, brown, wet		14	SS	16		164							0 0 93 7		
			15	SS	8		163									
162.0 17.8	SILTY CLAY trace sand, very stiff, brown, damp to moist		16	SS	24		162							0 4 74 22		
			17	SS	29		160									
159.5 20.3	End of Borehole															
	Sampler wet at 9.1m. Water level at 11.9m (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 4.5 175.3 July.26.10 3.7 176.1 Aug.06.10 2.7 177.1 Aug.13.10 2.7 177.1															

1 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 _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
179.8	Ground Surface							○ UNCONFINED	+ FIELD VANE							
179.6	200mm TOPSOIL							● QUICK TRIAXIAL	x LAB VANE							
0.2																
179.8	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist		1	SS	16											
			2	SS	33											
			3	SS	32											
			4	SS	36								41	0 0 56 44		
			5	SS	23											
			6	SS	17											
			7	TW	PH			x					21.1	4 3 59 34		
								>>	2.0							
	firm to very stiff		8	SS	14			>>						0 3 64 33		
			9	SS	9				1.5							
									1.2							
			10	SS	8											
			11	SS	9											
168.1																
11.7	CLAYEY SILT very stiff, brown, moist		12	SS	17									0 0 87 13		
166.6																
13.2	SILTY CLAY trace sand, firm to stiff, brown, damp to moist		13	SS	6											

Continued Next Page

+³, X³: 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 C12-3

2 OF 2

METRIC

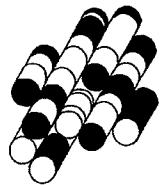
W.P. 280-99-00 LOCATION Coords: N:4767208.6 E:326322.1 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 07.14.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
								20 40 60 80 100							
163.6 16.2	SILT occasional silty clay seams and partings, compact, brown, wet		14	SS	7		164								
162.0 17.8			15	SS	12		163								
159.5 20.3	SILTY CLAY trace sand, trace gravel, very stiff to hard, brown, damp to moist		16	SS	24		162								
			17	SS	36		161								
	End of Borehole						160								
	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

B9

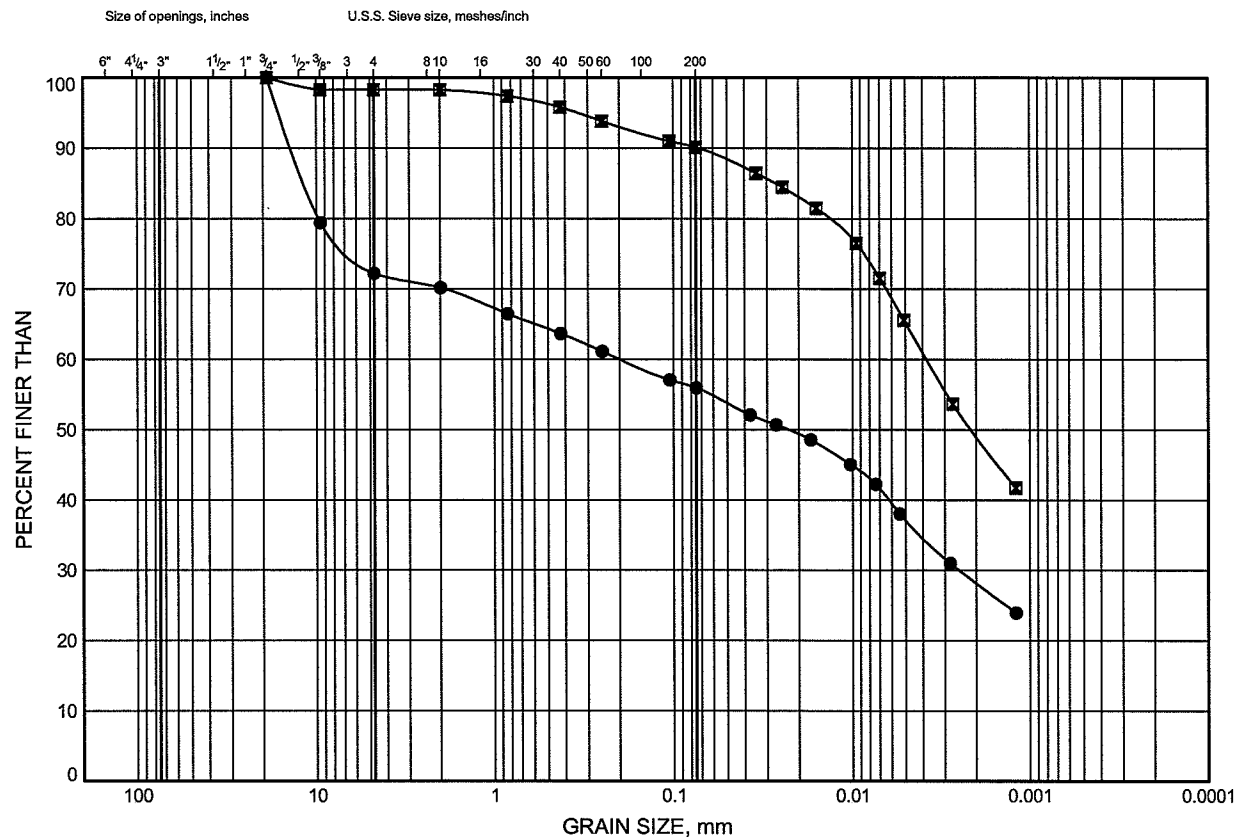
TERRAPROBE INC.



GRAIN SIZE DISTRIBUTION

FIGURE B9-1

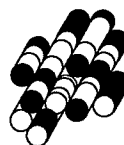
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-1	1.0	180.3
■	C12-2	1.0	178.8

Date November 2010
Project 1-09-4315

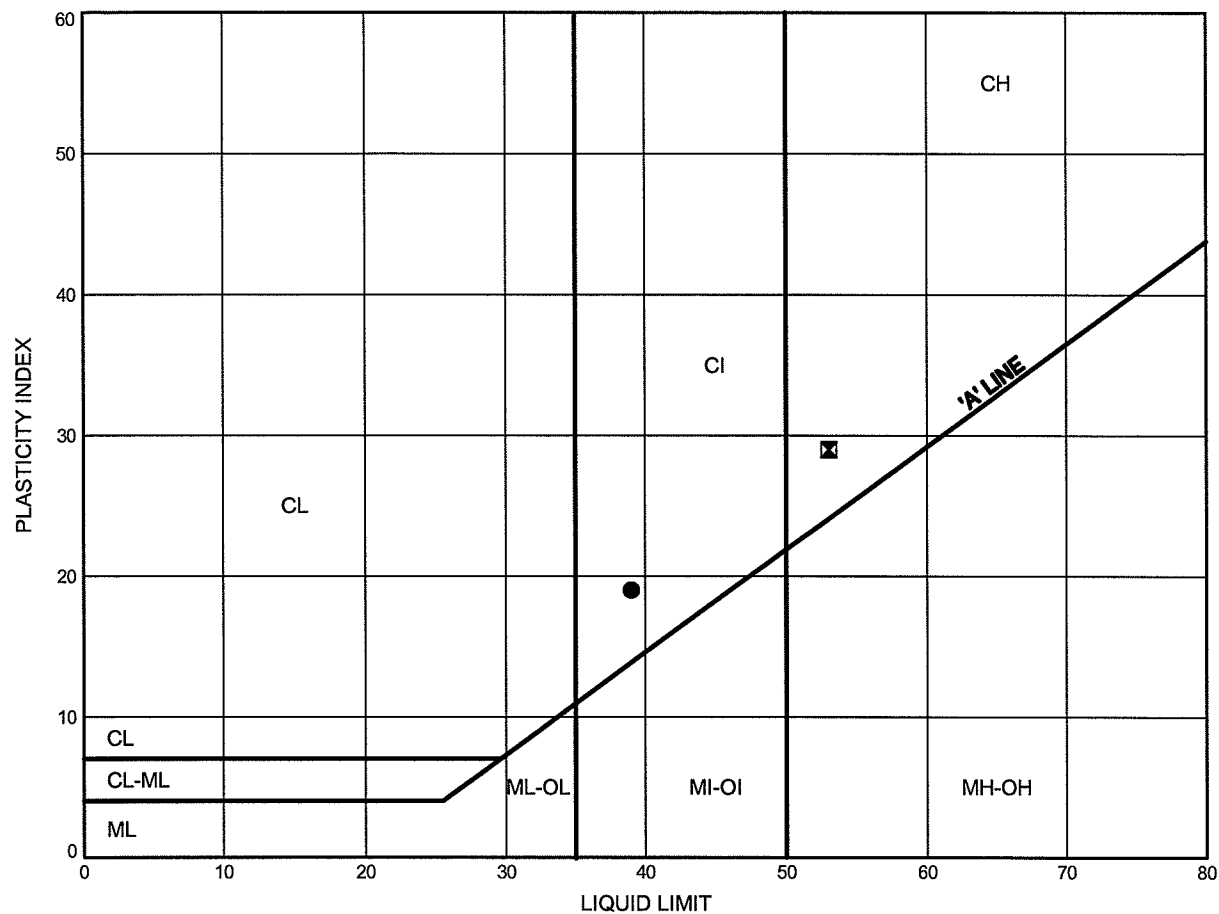


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

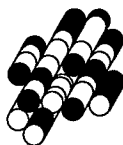
FIGURE B9-2

FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-1	1.0	180.3
⊠	C12-2	1.0	178.8

Date November 2010
Project 1-09-4135

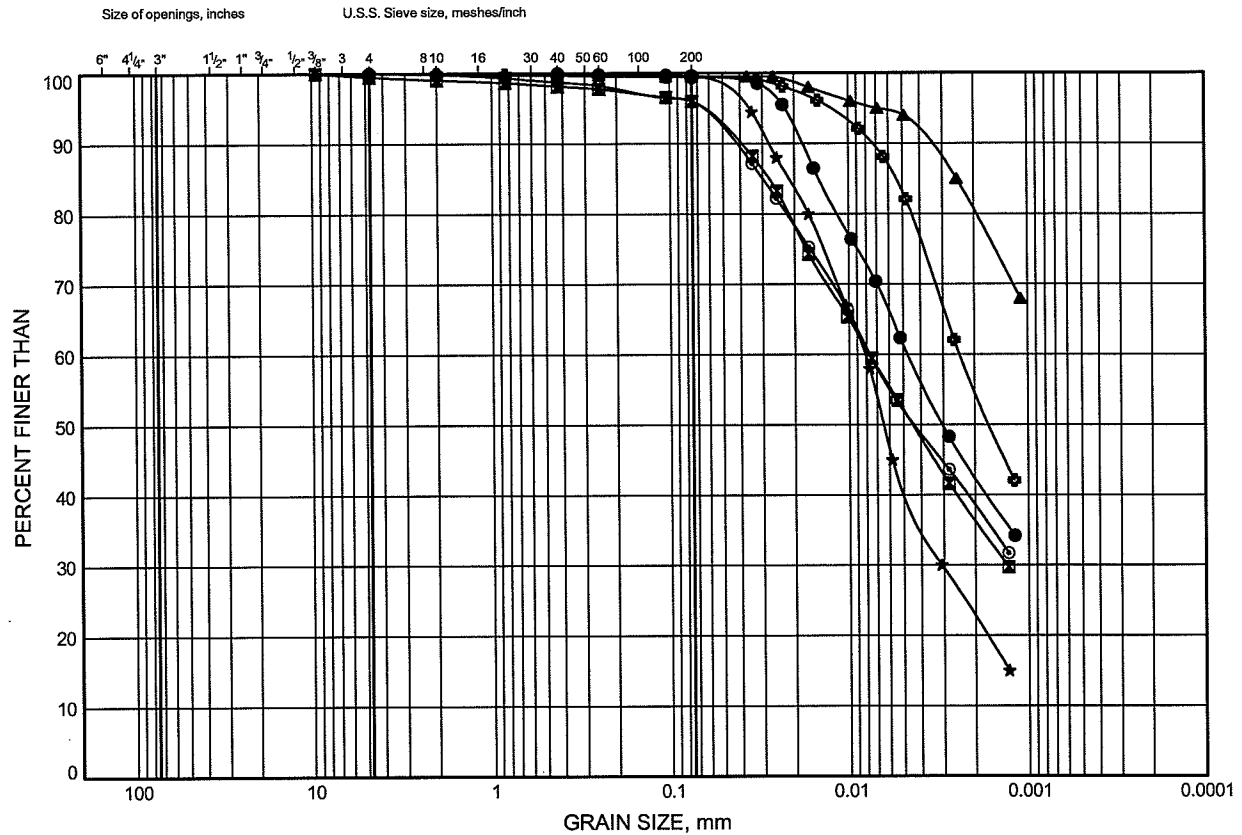


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B9-3

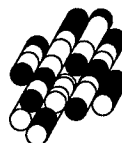
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-1	3.2	178.1
■	C12-1	6.3	175.0
▲	C12-1	10.9	170.4
★	C12-1	13.9	167.4
⊙	C12-2	4.7	175.1
⊕	C12-2	9.3	170.5

Date November 2010
Project 1-09-4135

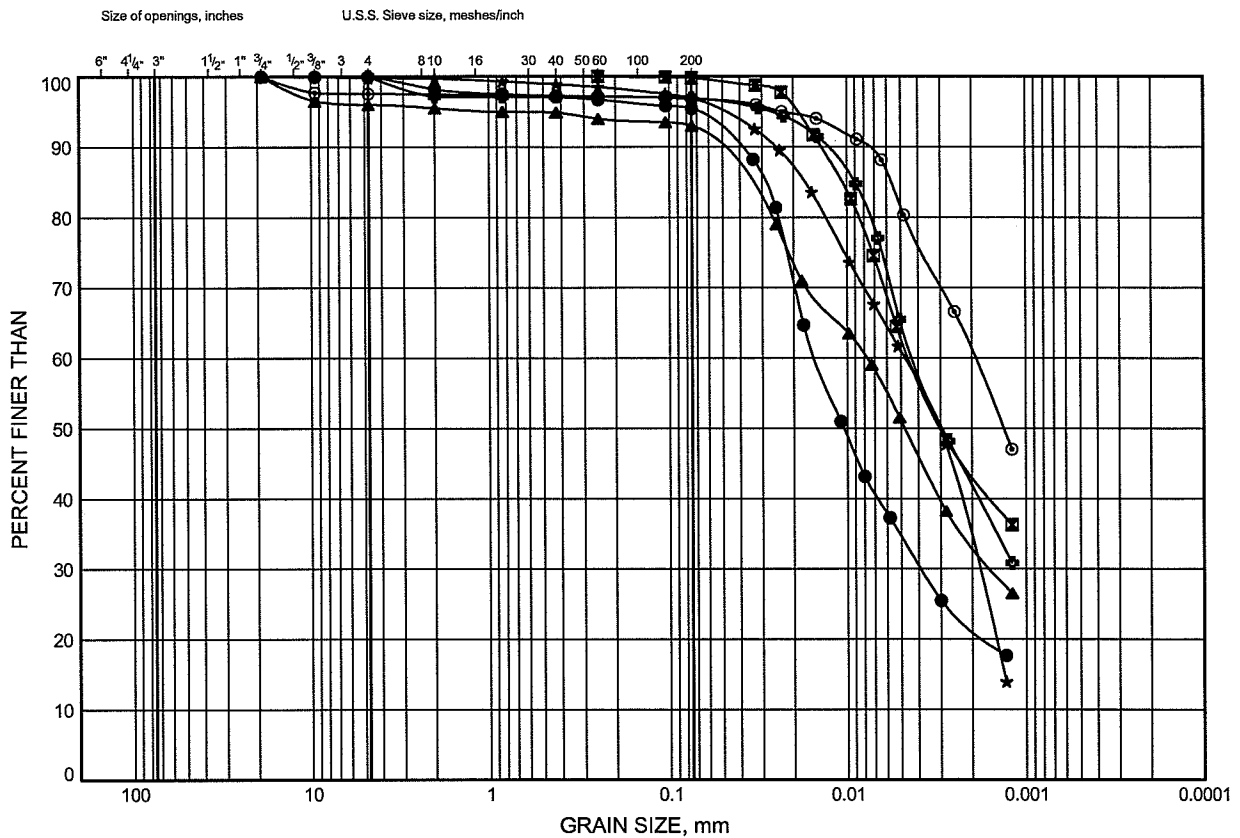


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B9-4

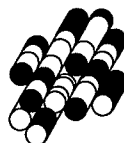
SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-2	20.0	159.8
⊠	C12-3	2.5	177.3
▲	C12-3	4.7	175.1
★	C12-3	6.3	173.5
⊙	C12-3	9.3	170.5
⊕	C12-3	10.9	168.9

Date November 2010
Project 1-09-4135

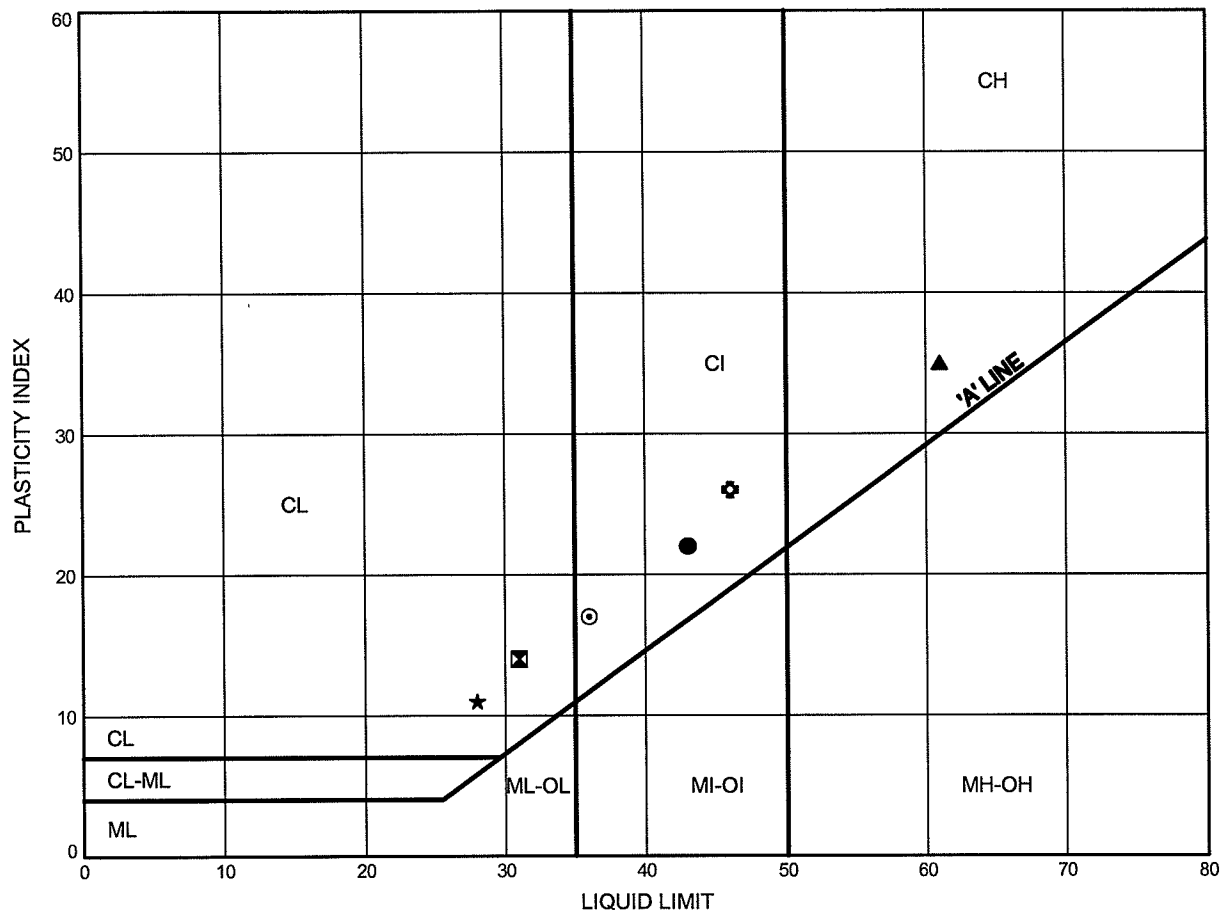


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

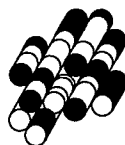
FIGURE B9-5

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-1	3.2	178.1
⊠	C12-1	6.3	175.0
▲	C12-1	10.9	170.4
★	C12-1	13.9	167.4
⊙	C12-2	4.7	175.1
⊕	C12-2	9.3	170.5

Date November 2010
Project 1-09-4135

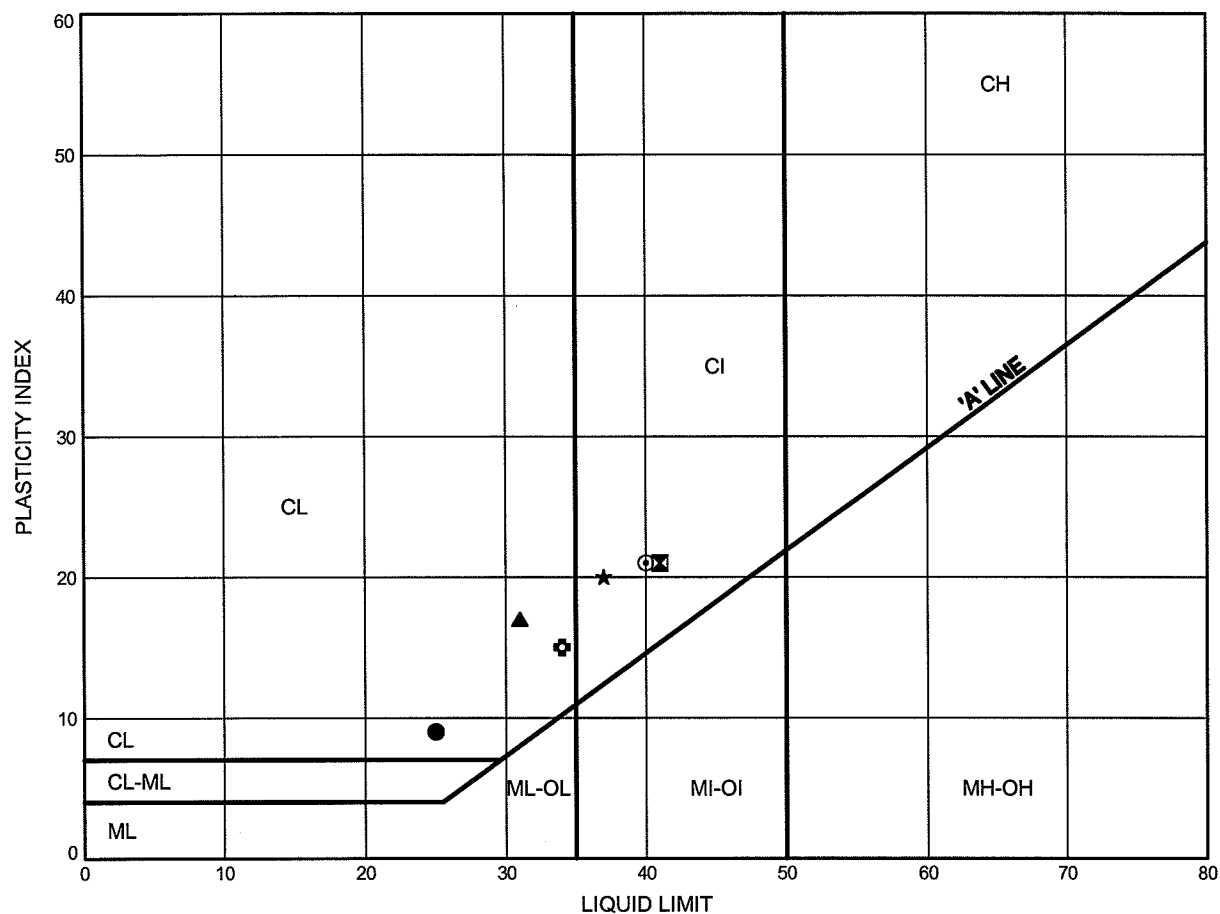


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

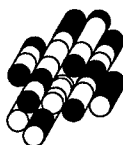
FIGURE B9-6

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-2	20.0	159.8
⊠	C12-3	2.5	177.3
▲	C12-3	4.7	175.1
★	C12-3	6.3	173.5
⊙	C12-3	9.3	170.5
⊕	C12-3	10.9	168.9

Date November 2010
 Project 1-09-4135

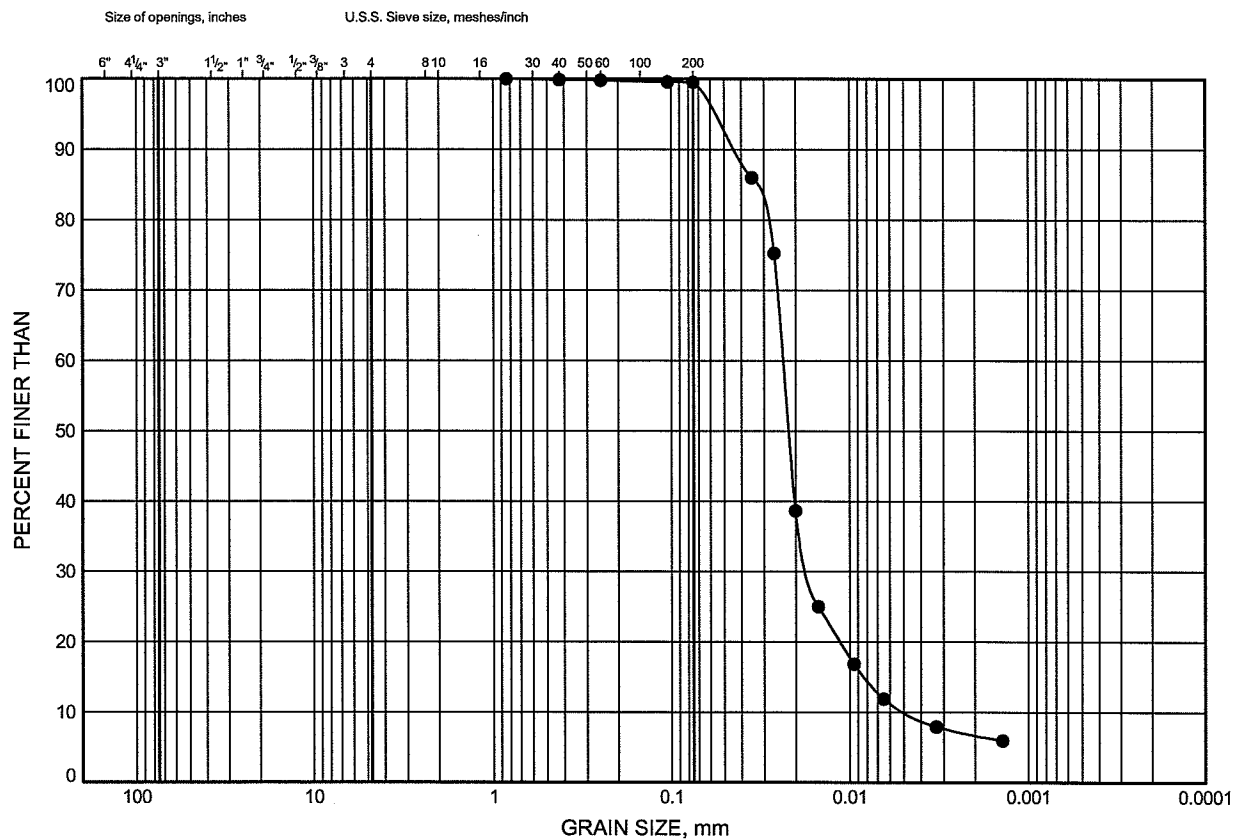


Prep'd K.L.
 Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B9-7

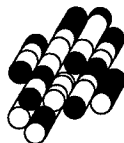
SILT



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-2	17.0	162.8

Date November 2010
Project 1-09-4135

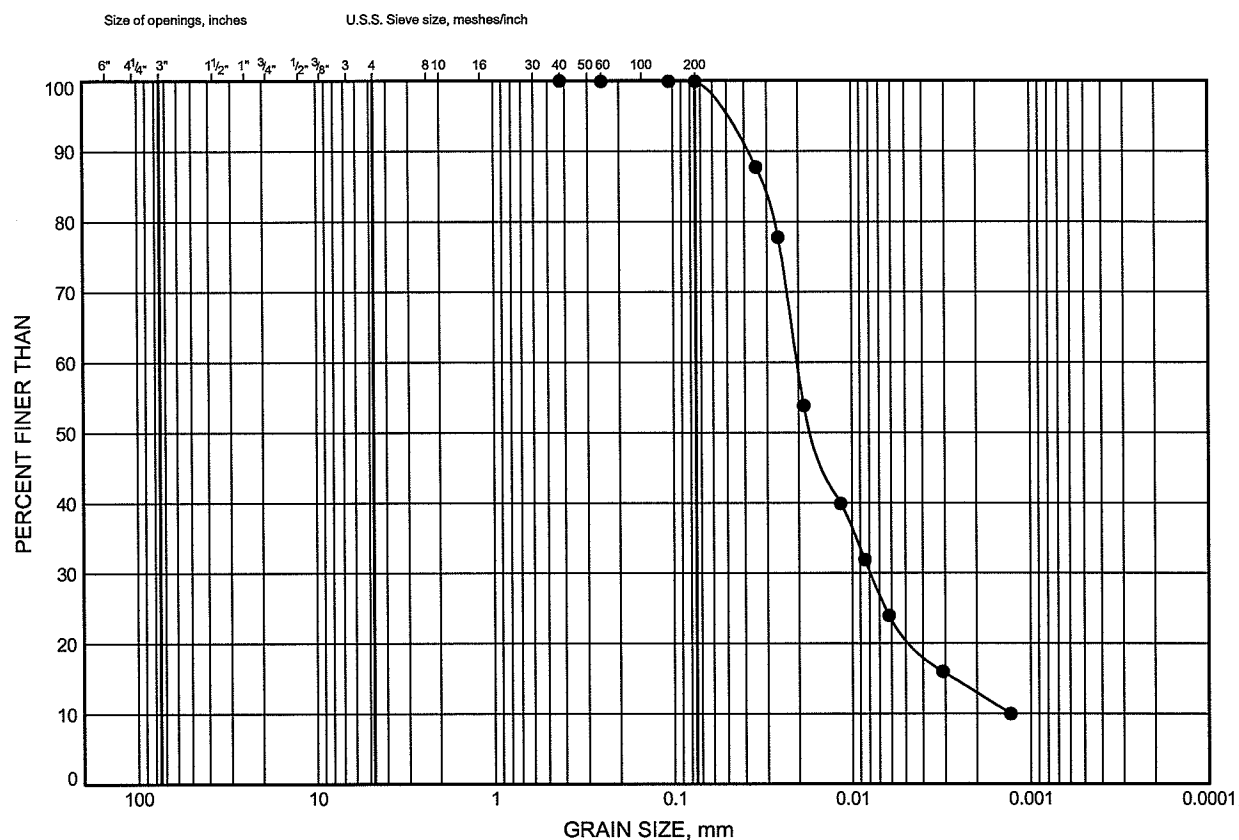


Prep'd K.L.
Chkd. M.P.

GRAIN SIZE DISTRIBUTION

FIGURE B9-8

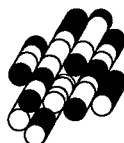
CLAYEY SILT



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-3	12.4	167.4

Date November 2010
Project 1-09-4135

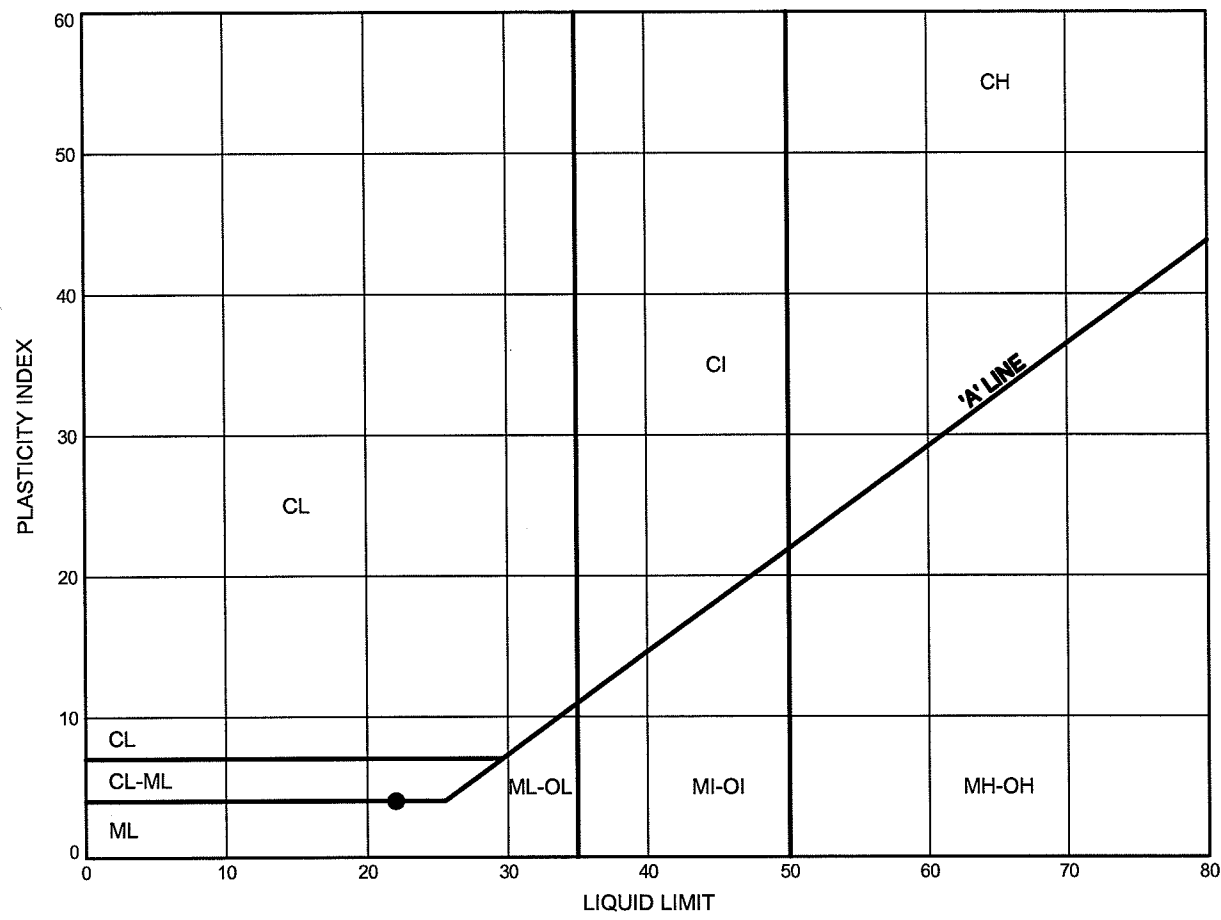


Prep'd K.L.
Chkd. M.P.

ATTERBERG LIMITS TEST RESULTS

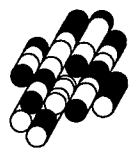
FIGURE B9-9

CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	C12-3	12.4	167.4

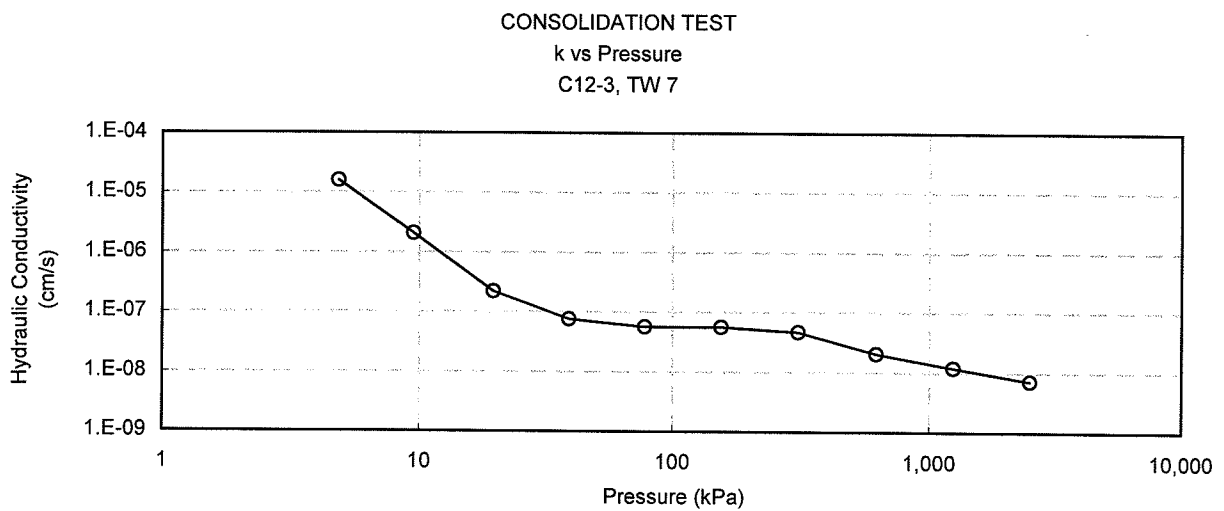
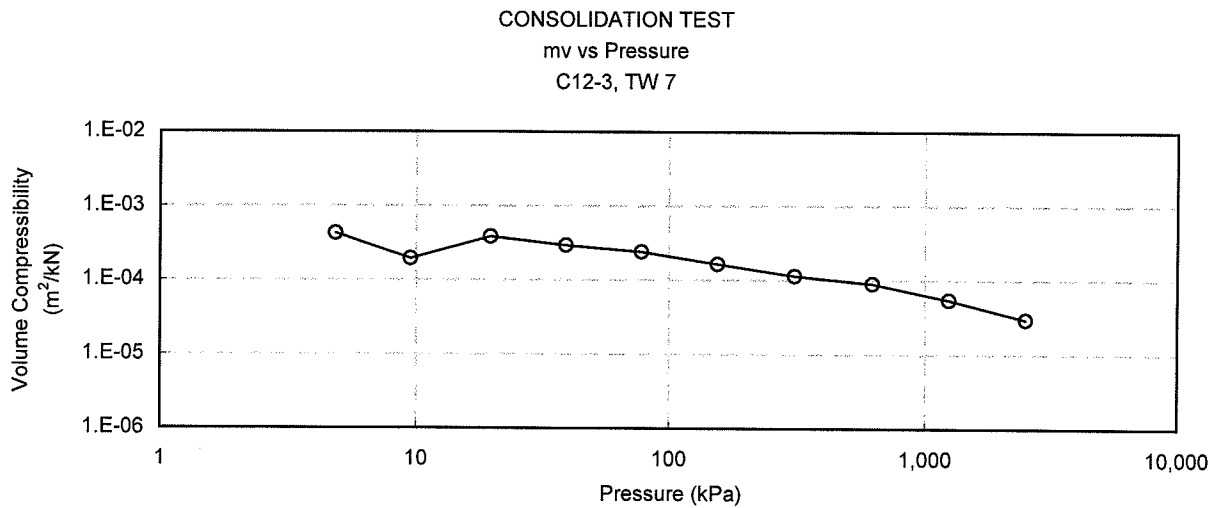
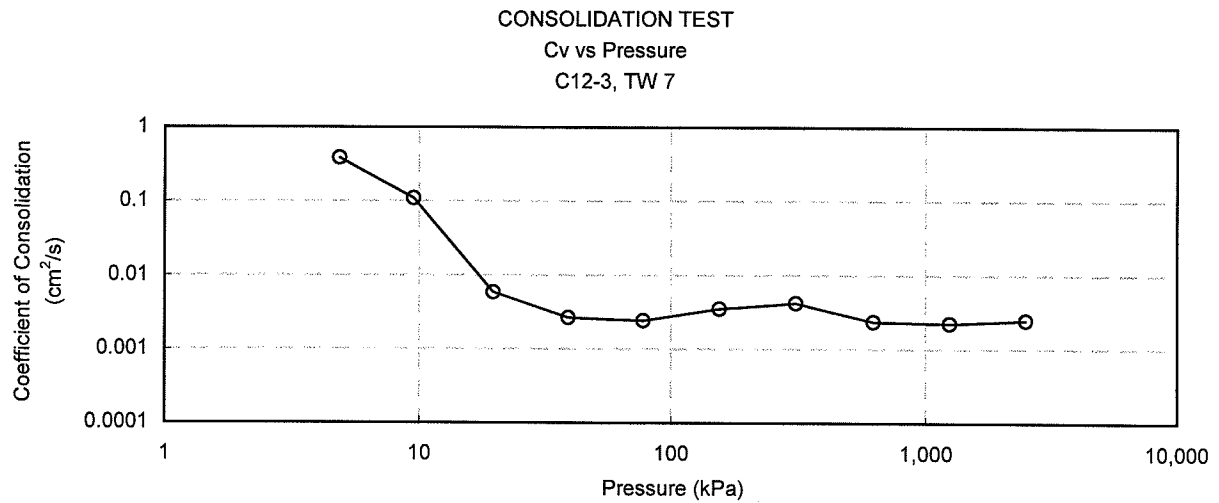
Date November 2010
Project 1-09-4135



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

HWY 406 TWINNING - CULVERT#12

FIGURE B9-10



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



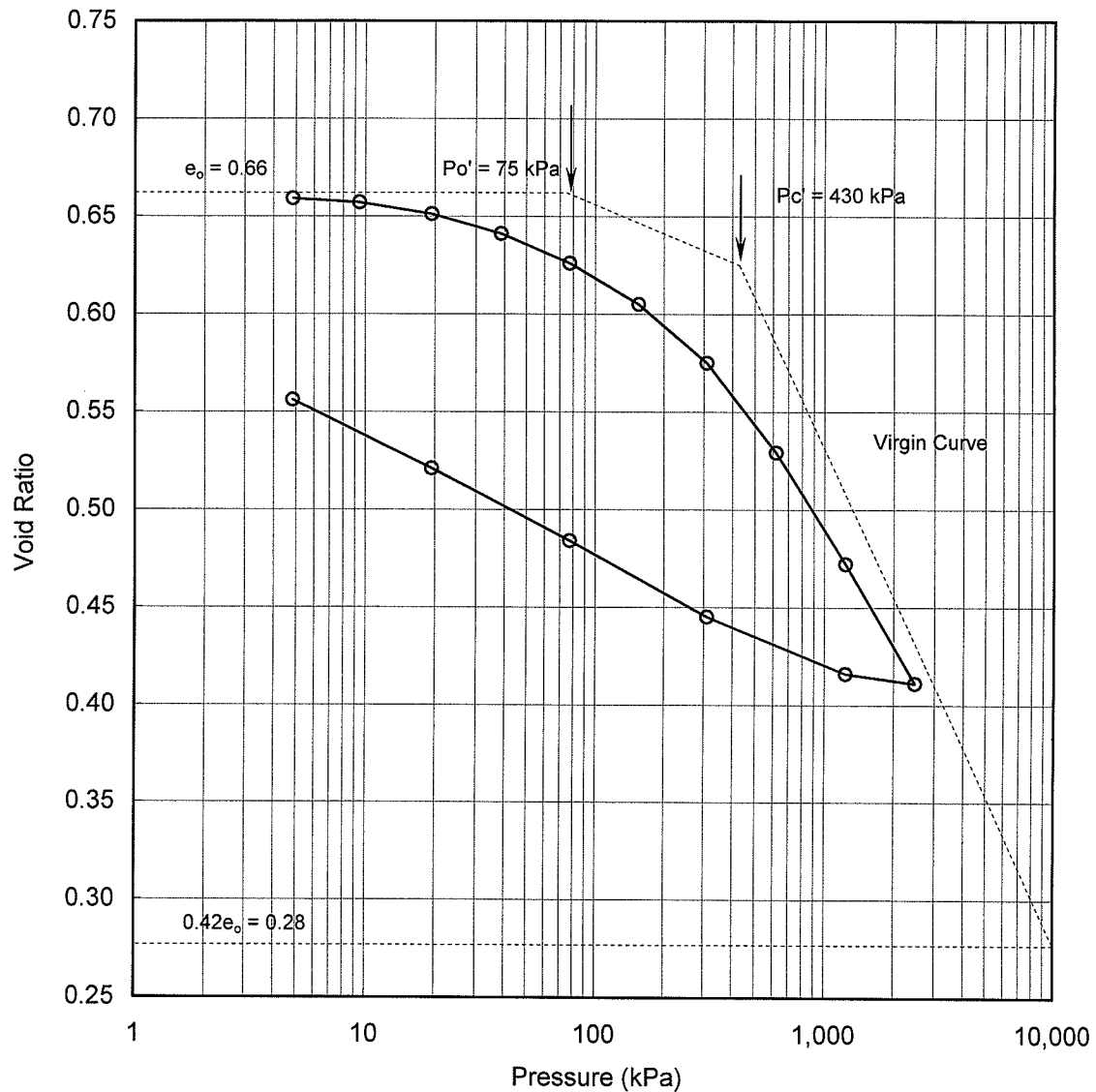
Terraprobe Inc.

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 ³	PI =	14%	Cc =	0.255
Gs =	2.78			Cr =	0.049

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



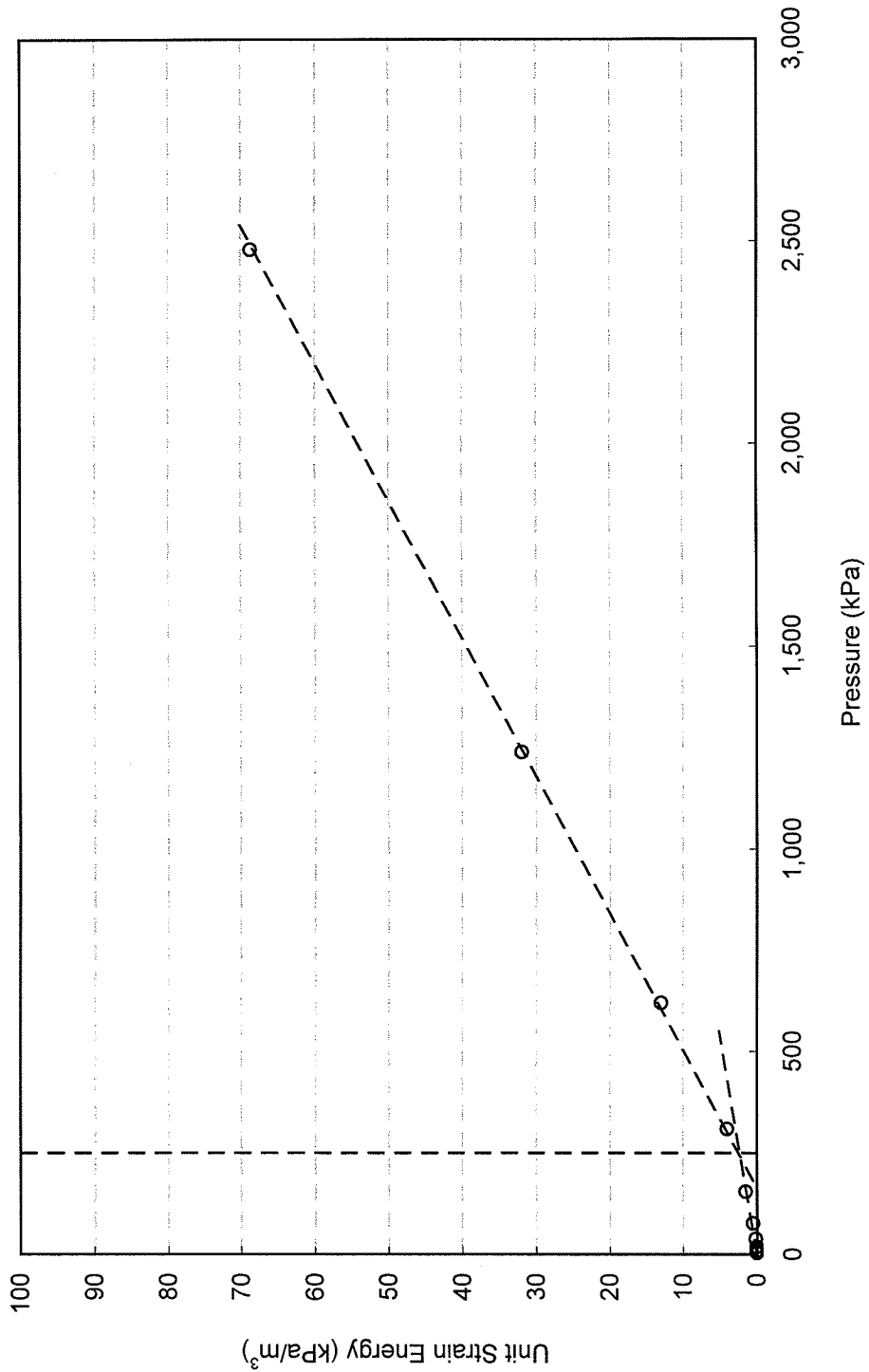
Terraprobe Inc.

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



$P_c = 250$ kPa

Project No. : 1-09-4135

Date : November 2010



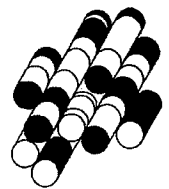
Terraprobe Inc.

Prepared By : HW

Checked By : RA

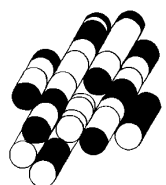
C9

TERRAPROBE INC.



APPENDIX D

TERRAPROBE INC.



Terraprobe

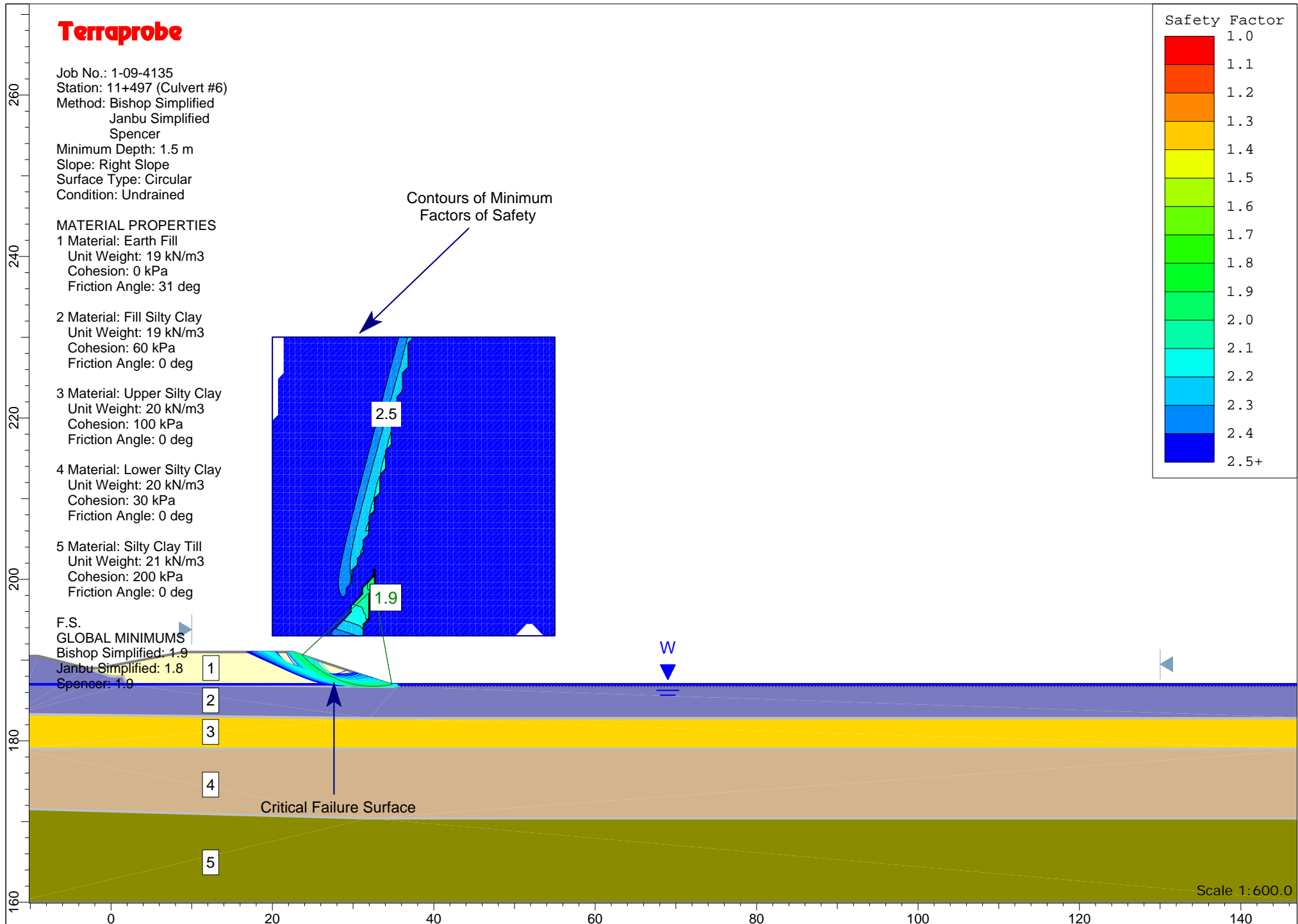
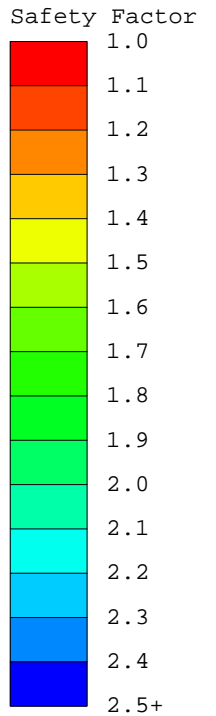
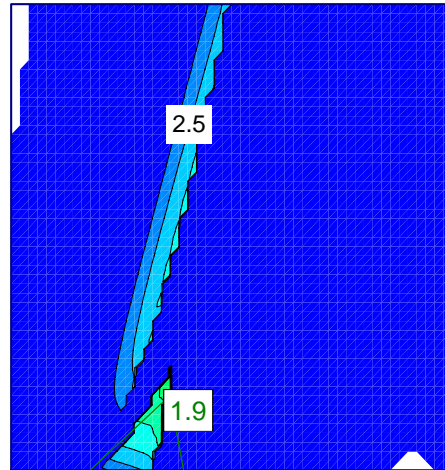
Job No.: 1-09-4135
Station: 11+497 (Culvert #6)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 1.5 m
Slope: Right Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 60 kPa
Friction Angle: 0 deg
- 3 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 100 kPa
Friction Angle: 0 deg
- 4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 30 kPa
Friction Angle: 0 deg
- 5 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 200 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.9
Janbu Simplified: 1.8
Spencer: 1.9

Contours of Minimum
Factors of Safety



Terraprobe

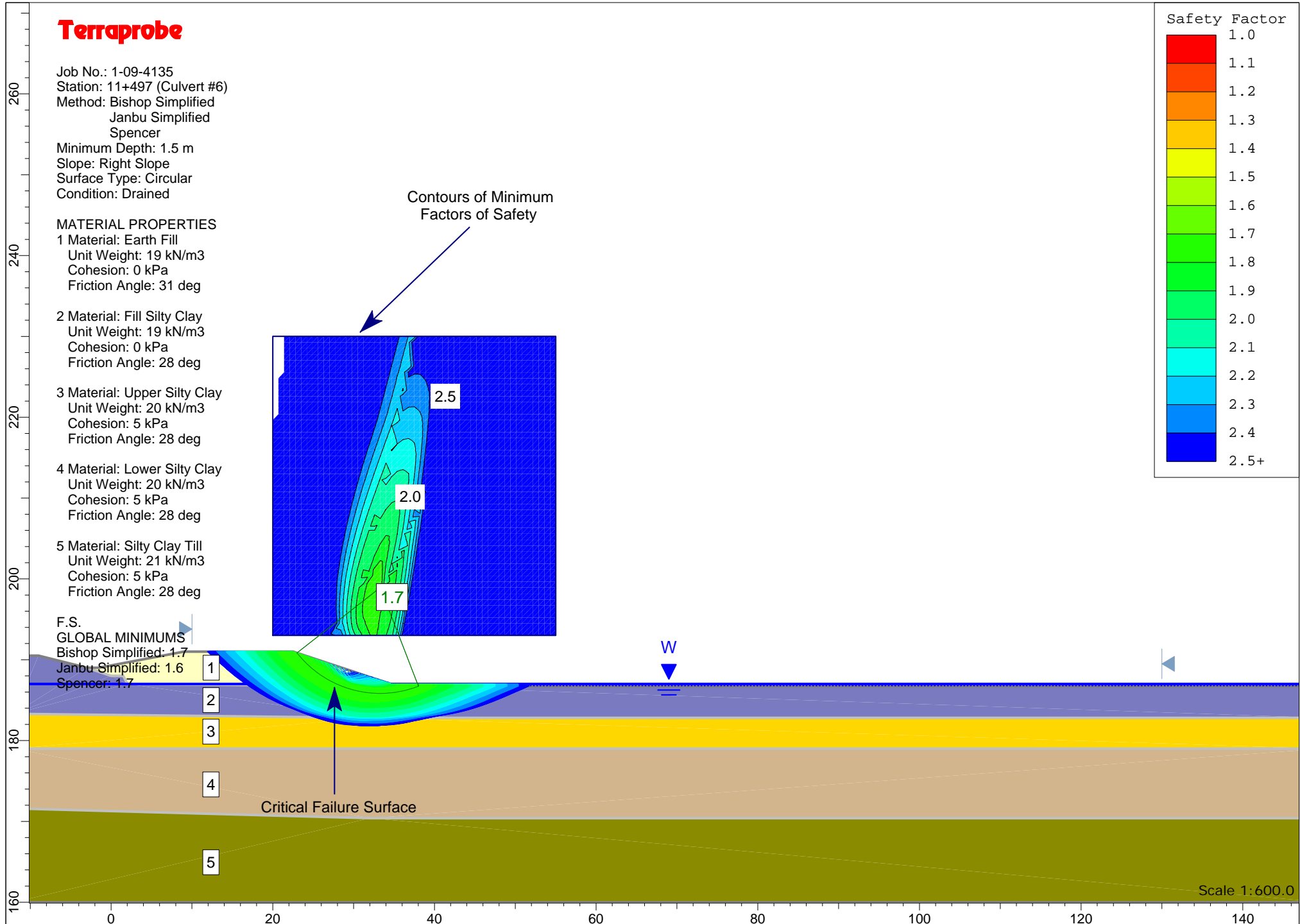
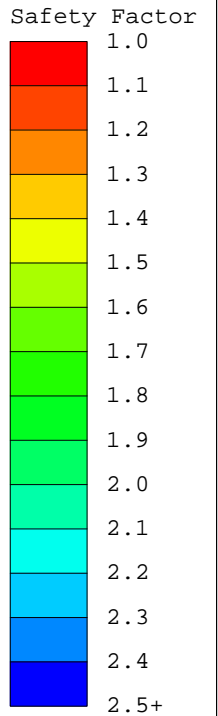
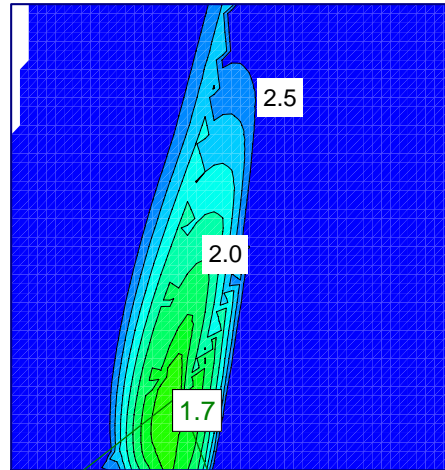
Job No.: 1-09-4135
Station: 11+497 (Culvert #6)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 1.5 m
Slope: Right Slope
Surface Type: Circular
Condition: Drained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 28 deg
- 3 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 5 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.6
Spencer: 1.7

Contours of Minimum
Factors of Safety



Terraprobe

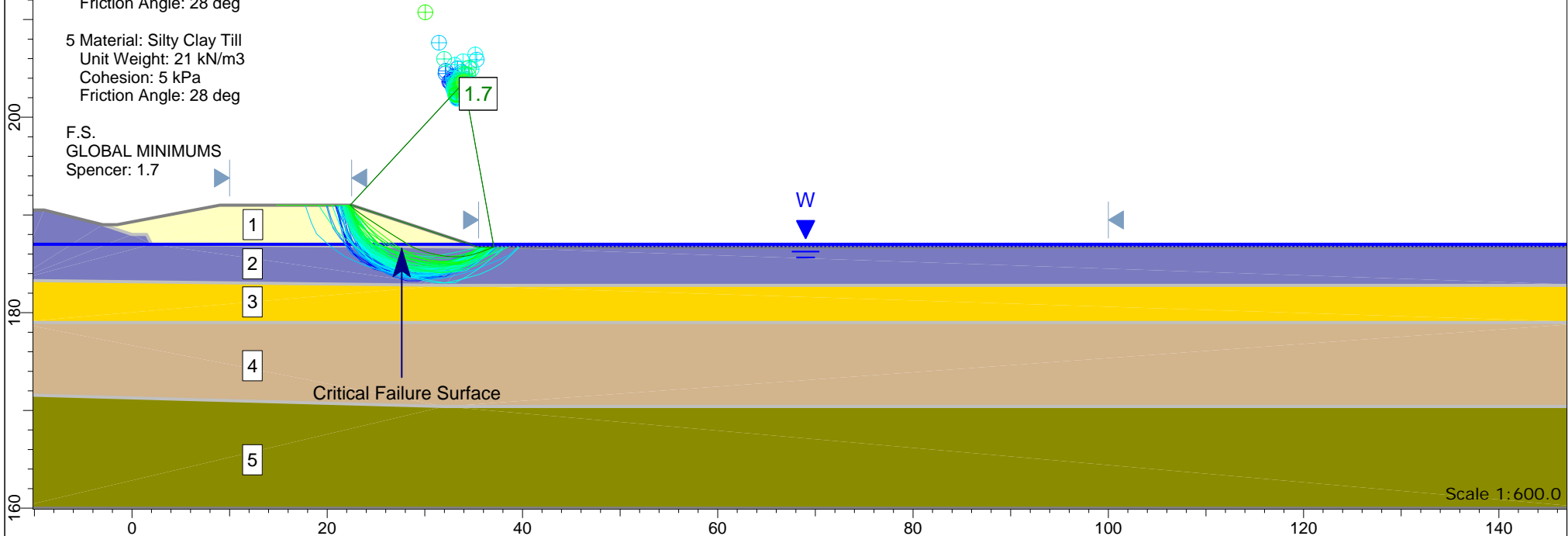
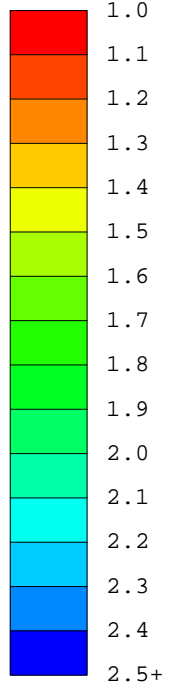
Job No.: 1-09-4135
Station: 11+497 (Culvert #6)
Method: Spencer
Minimum Depth: 1.5 m
Slope: Right Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 28 deg
- 3 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 5 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.7

Safety Factor



Terraprobe

Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2.5 m
Slope: Left Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

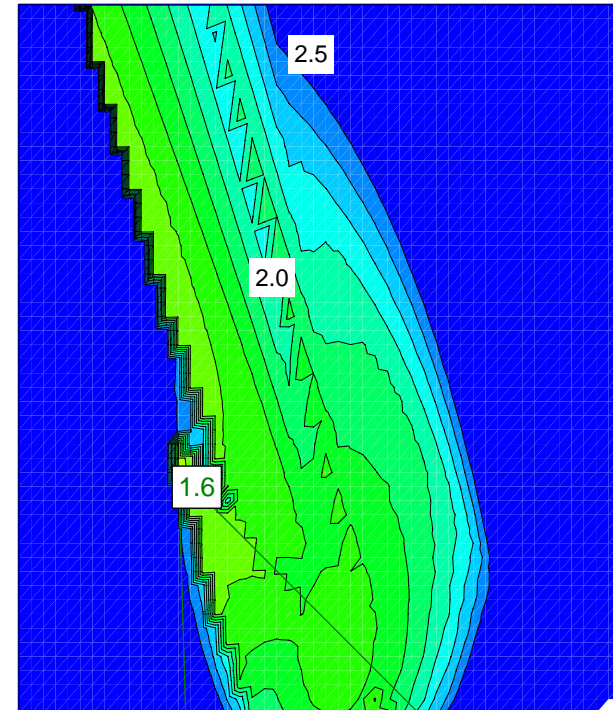
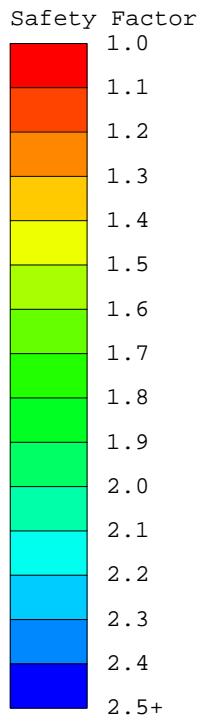
1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 80 kPa
Friction Angle: 0 deg

3 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 200 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.6
Janbu Simplified: 1.5
Spencer: 1.6

Contours of Minimum
Factors of Safety



Critical Failure Surface

1

2

3

W

Scale 1:800.0

Terraprobe

Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2.5 m
Slope: Left Slope
Surface Type: Circular
Condition: Drained

MATERIAL PROPERTIES

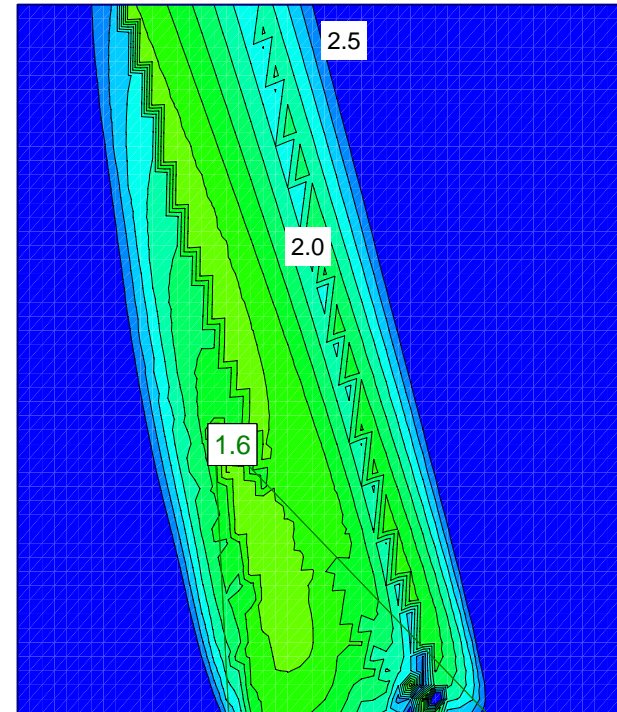
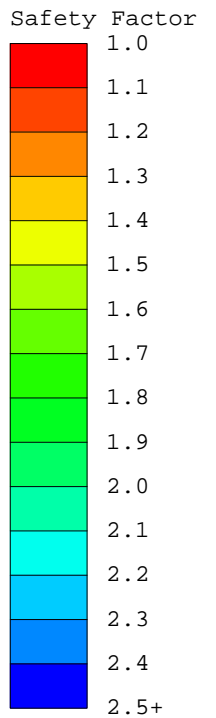
1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

3 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.6
Janbu Simplified: 1.5
Spencer: 1.6

Contours of Minimum
Factors of Safety



Critical Failure Surface

1

2

3

W

Scale 1:800.0

Terraprobe

Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Spencer
Minimum Depth: 2.5 m
Slope: Left Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

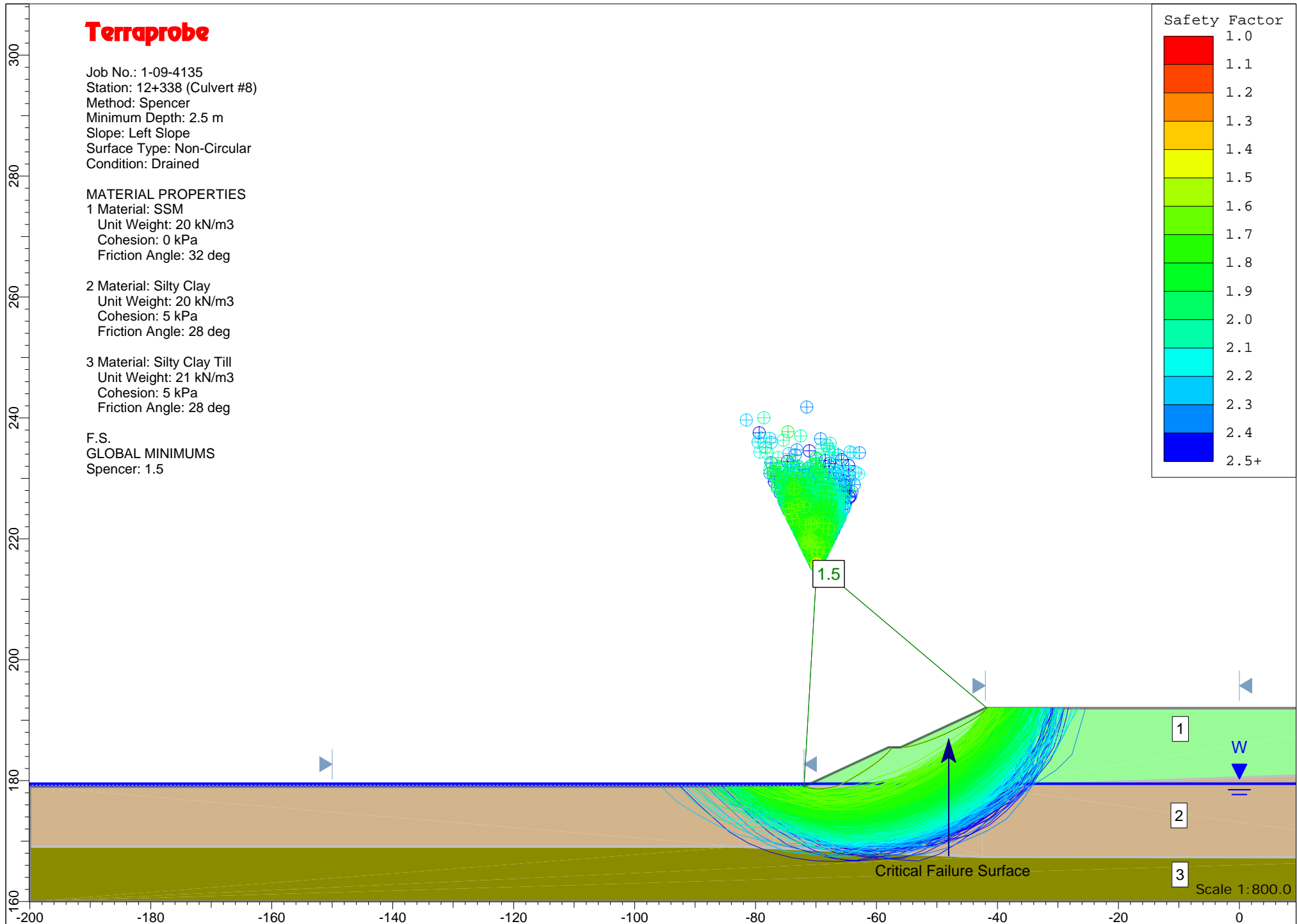
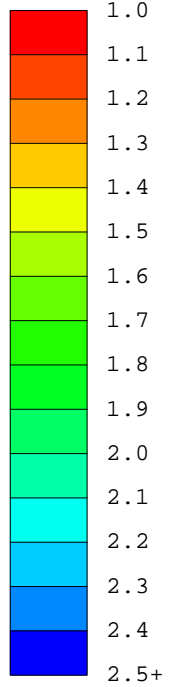
1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

3 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.5

Safety Factor



Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Undrained

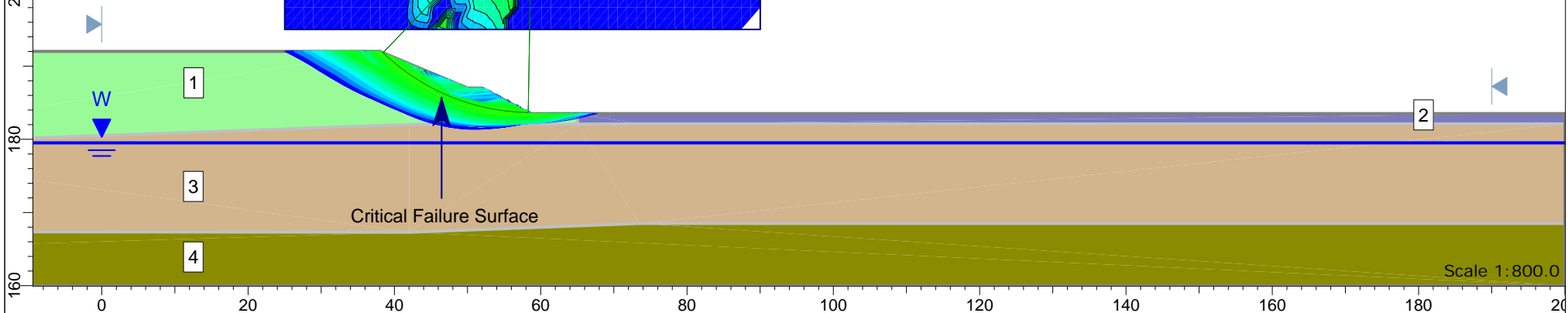
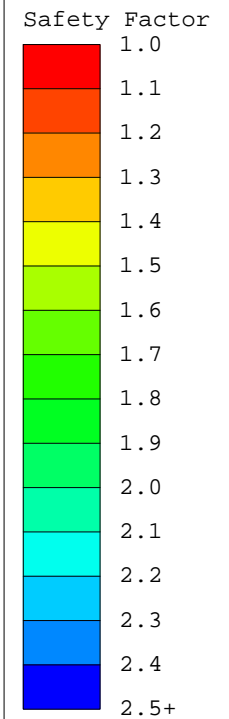
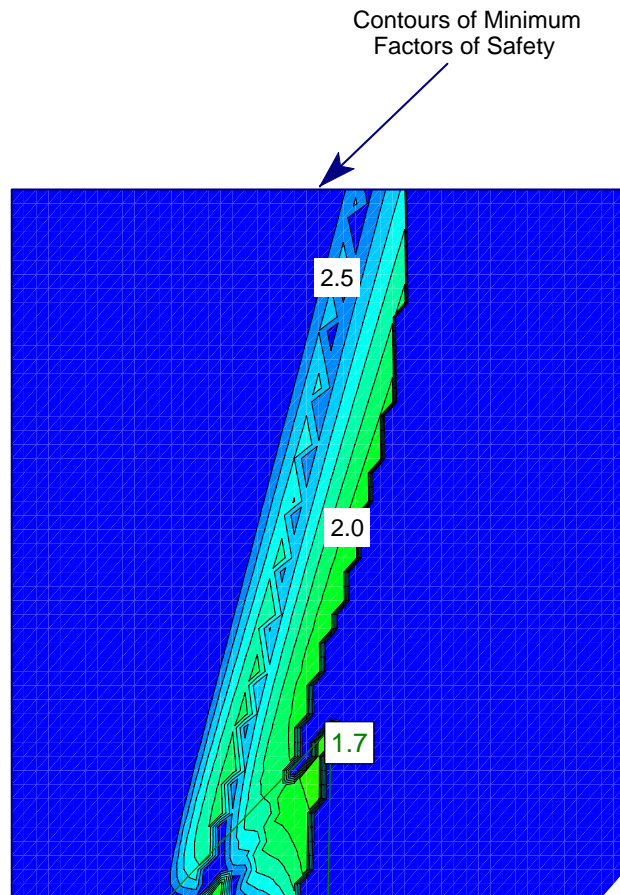
1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 80 kPa
Friction Angle: 0 deg

3 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 80 kPa
Friction Angle: 0 deg

4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 200 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.7
Spencer: 1.7



Terraprobe

Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Drained

MATERIAL PROPERTIES

1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 28 deg

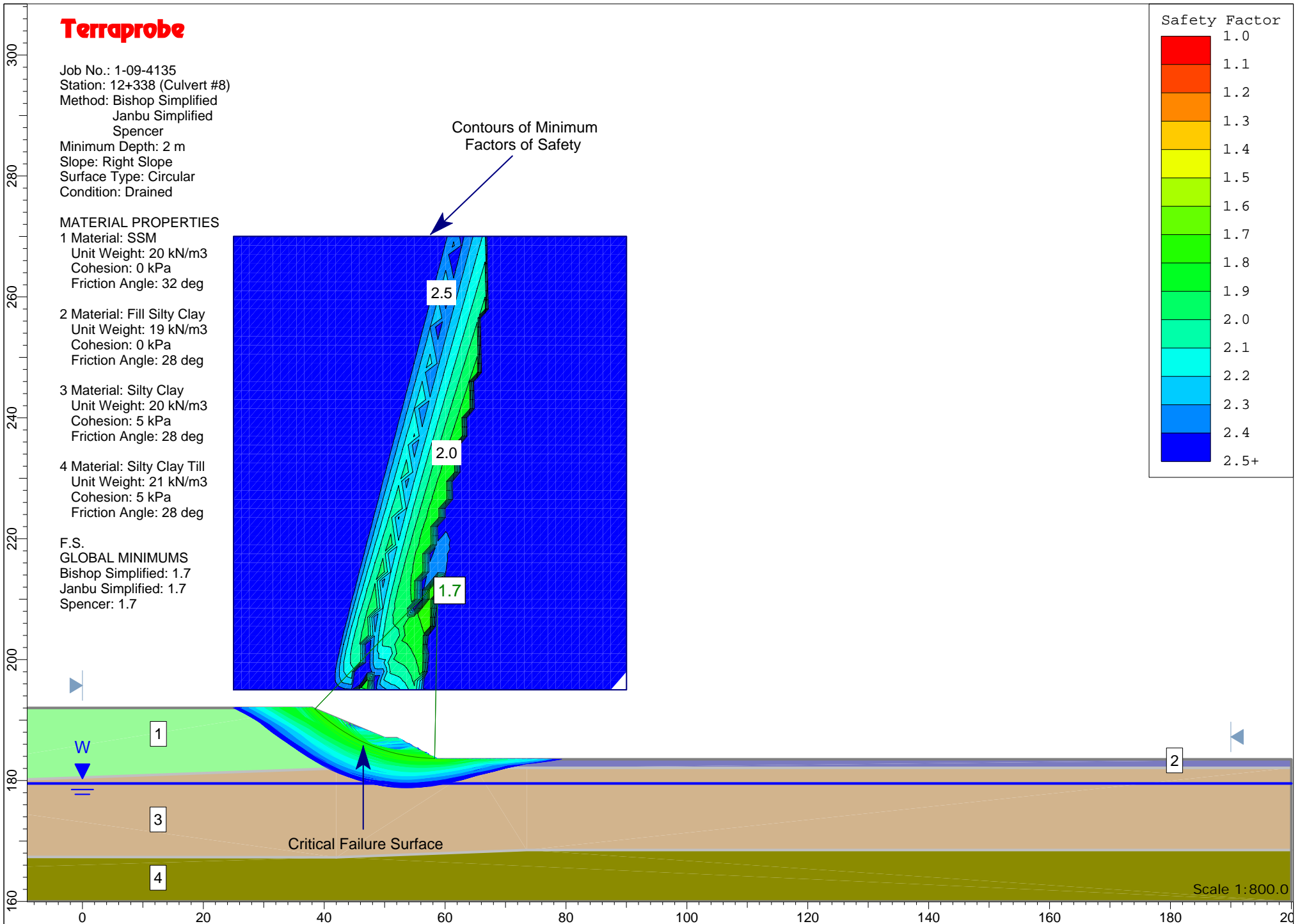
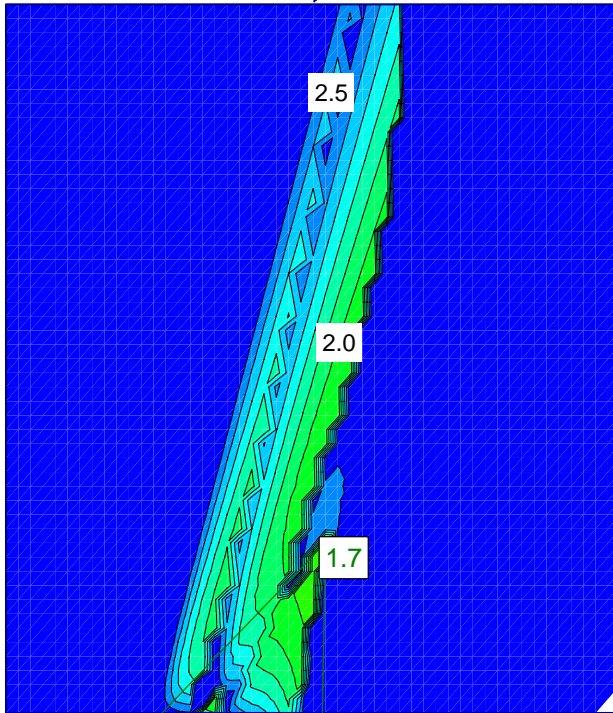
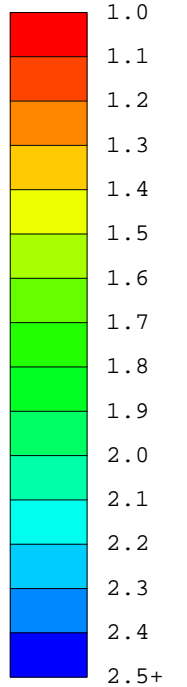
3 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.7
Spencer: 1.7

Contours of Minimum
Factors of Safety

Safety Factor



Terraprobe

Job No.: 1-09-4135
Station: 12+338 (Culvert #8)
Method: Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

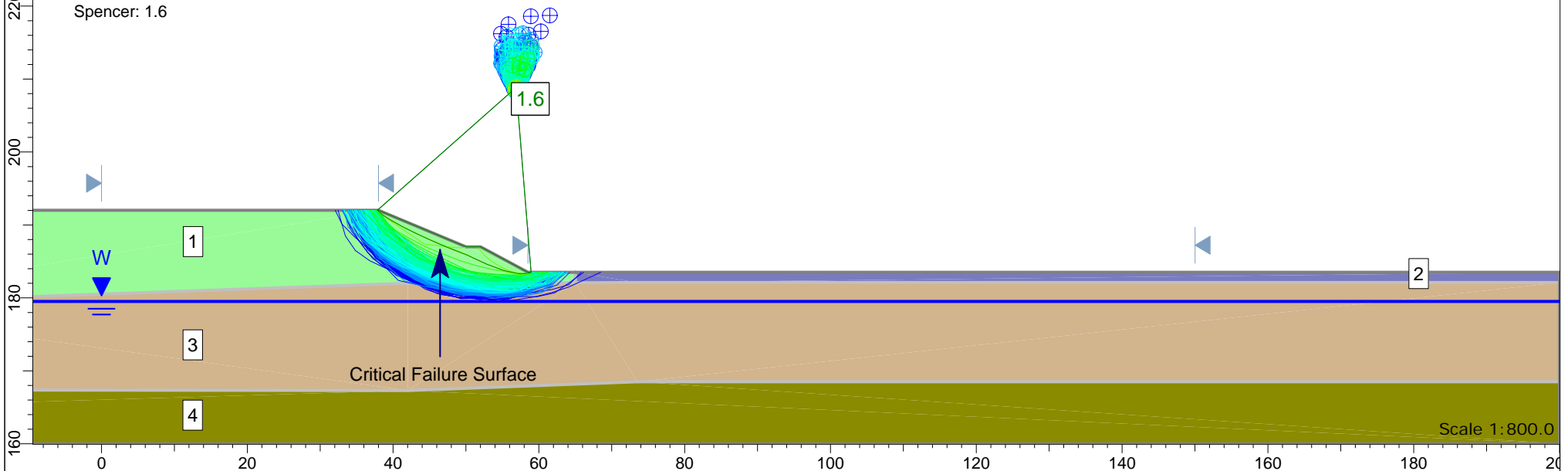
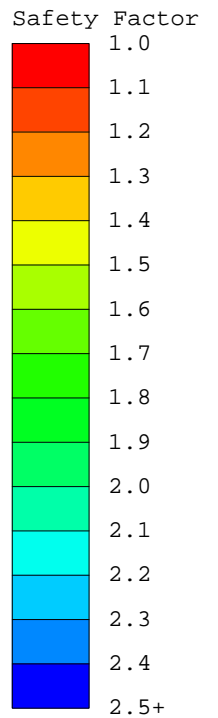
1 Material: SSM
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 32 deg

2 Material: Fill Silty Clay
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 28 deg

3 Material: Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.6



Terraprobe

Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Left Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg

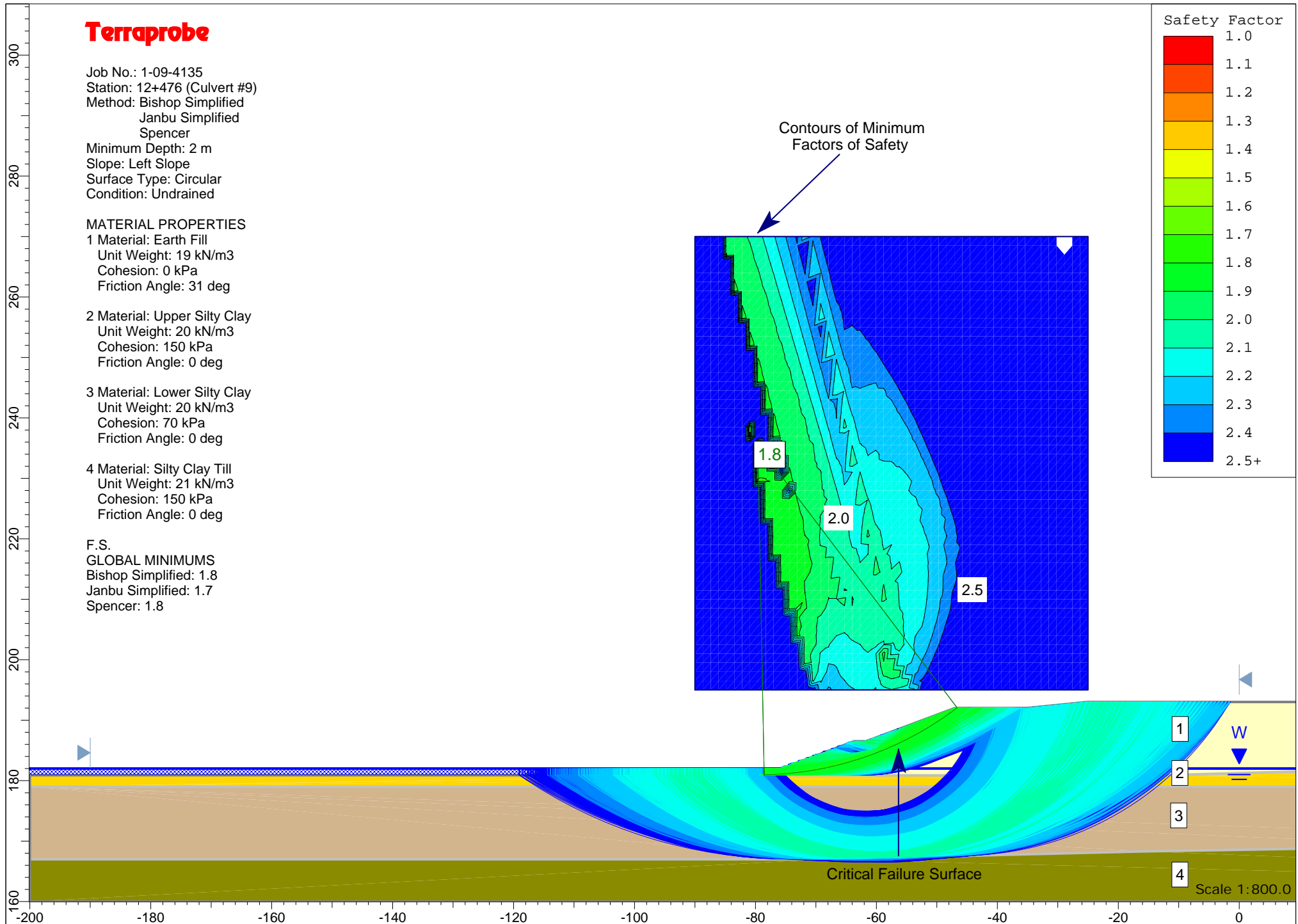
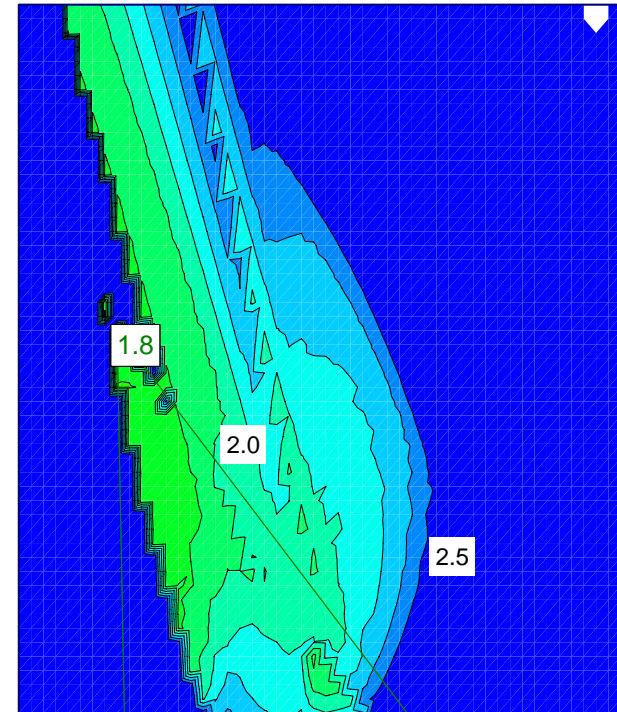
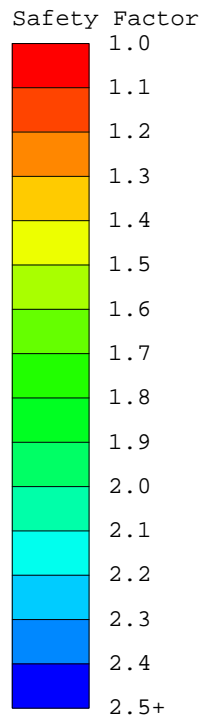
2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 150 kPa
Friction Angle: 0 deg

3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 70 kPa
Friction Angle: 0 deg

4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 150 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.8
Janbu Simplified: 1.7
Spencer: 1.8

Contours of Minimum
Factors of Safety



Critical Failure Surface

Scale 1:800.0

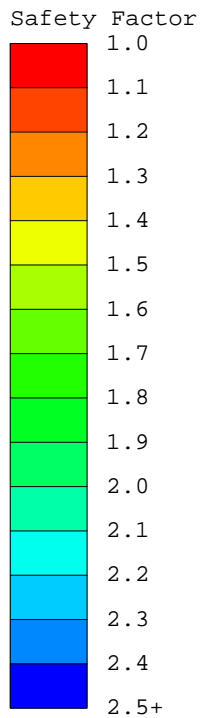
Terraprobe

Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Left Slope
Surface Type: Circular
Condition: Drained

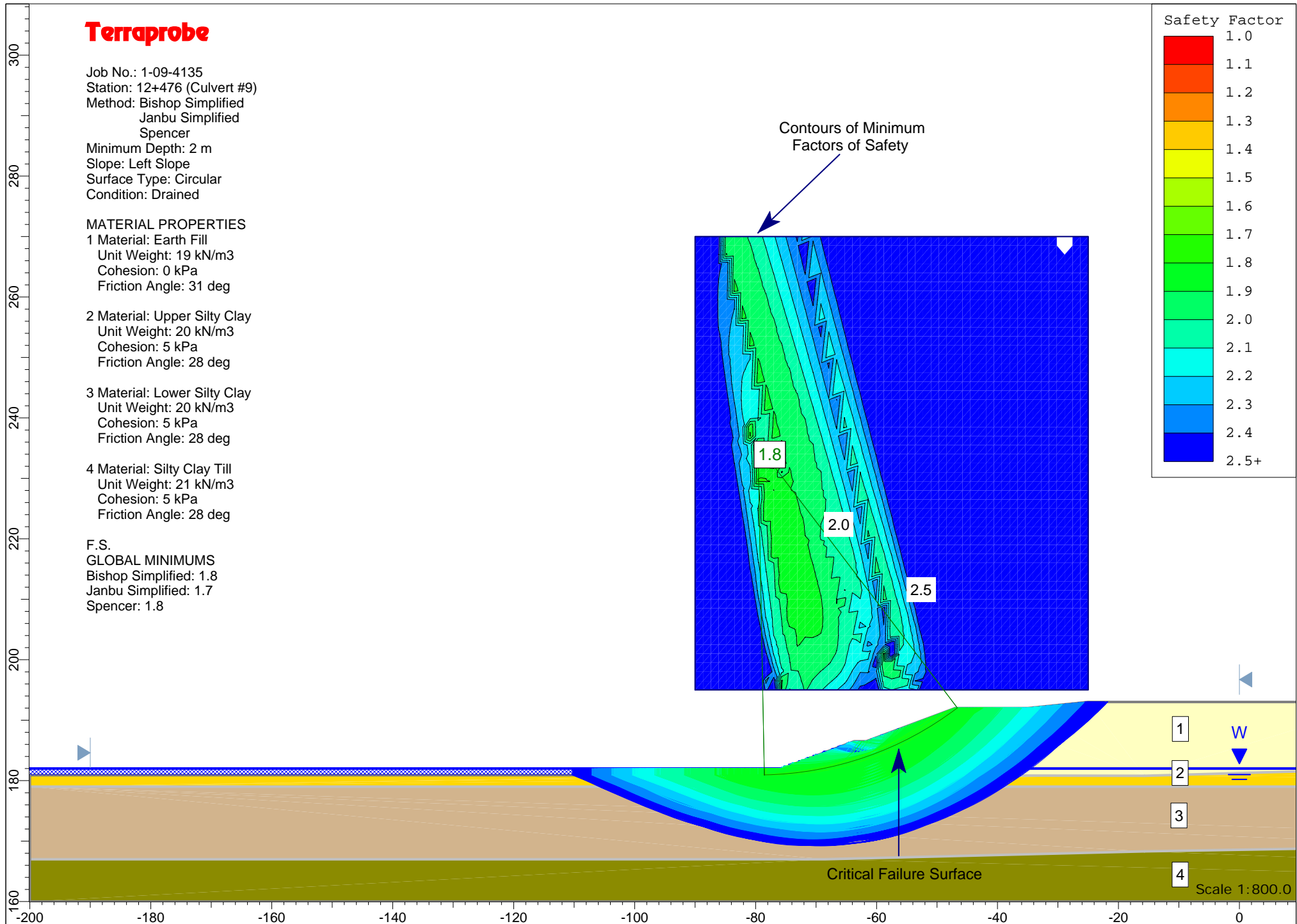
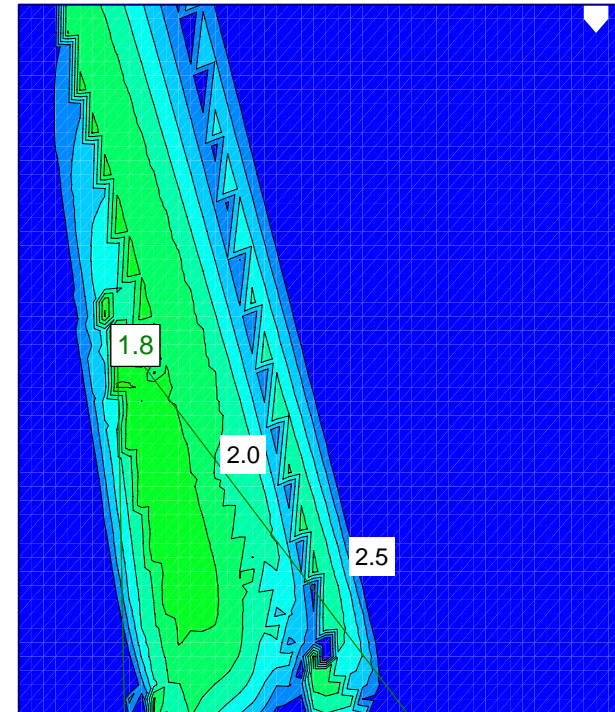
MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.8
Janbu Simplified: 1.7
Spencer: 1.8



Contours of Minimum
Factors of Safety



Terraprobe

Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Spencer
Minimum Depth: 2 m
Slope: Left Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg

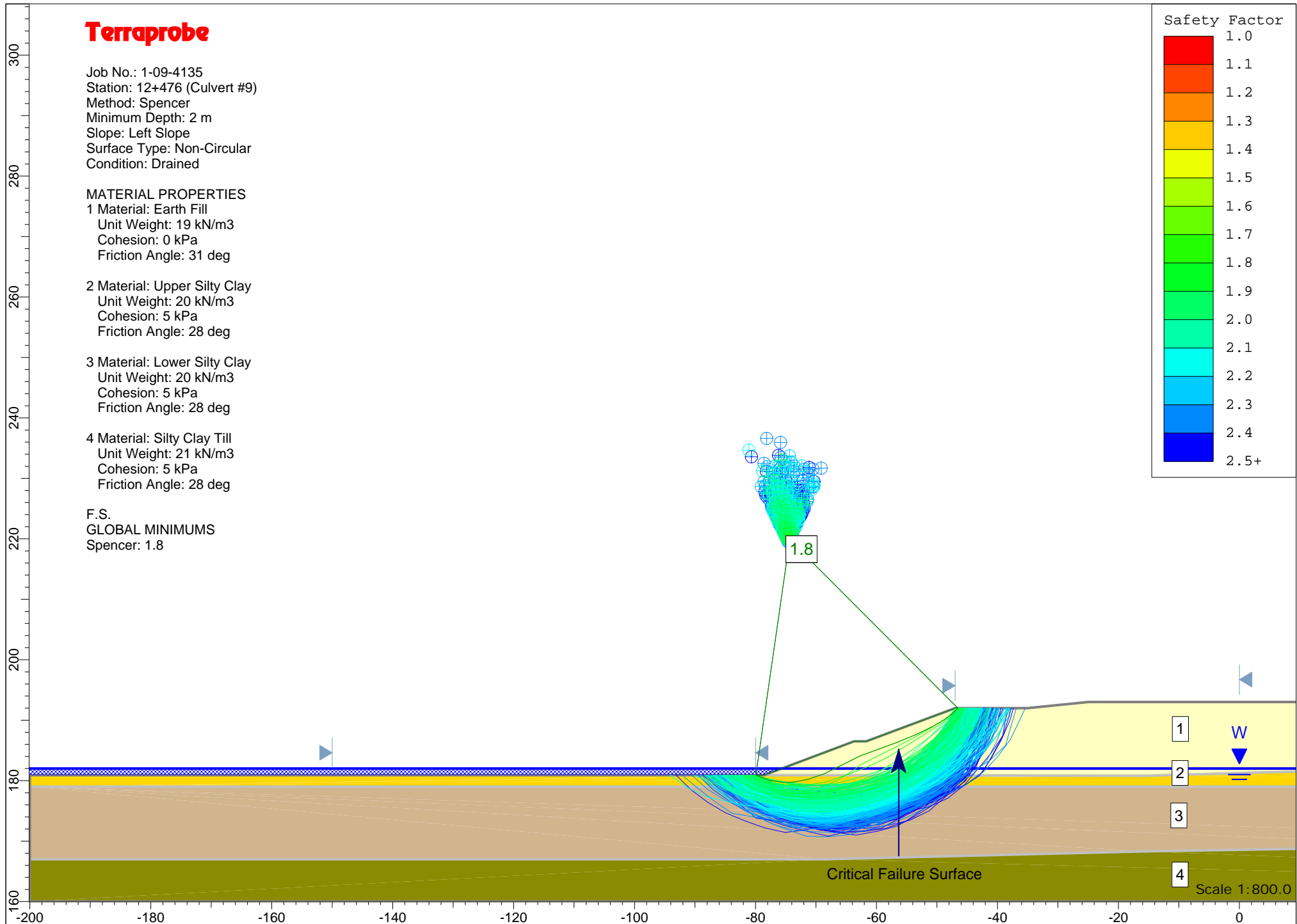
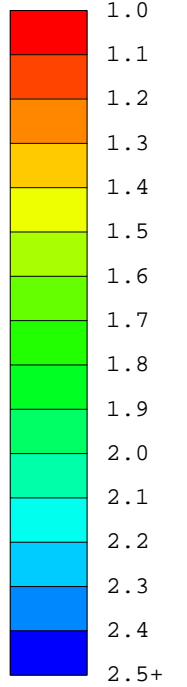
2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.8

Safety Factor



Terraprobe

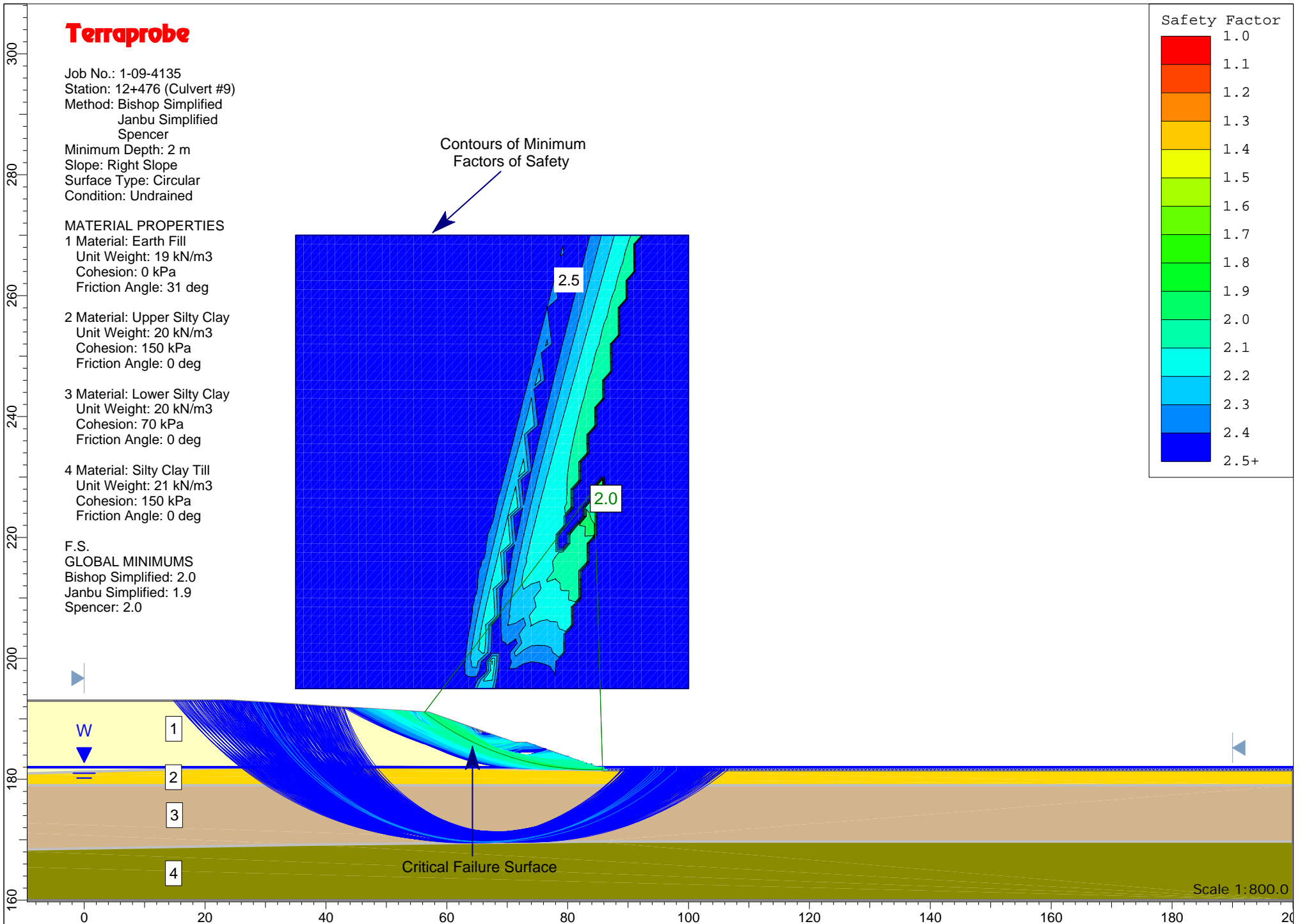
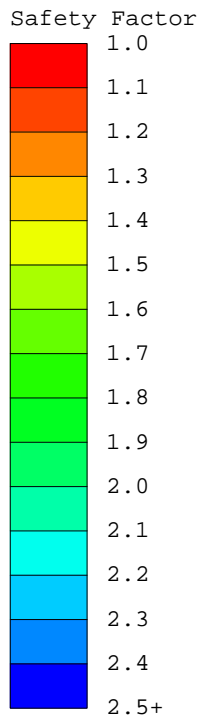
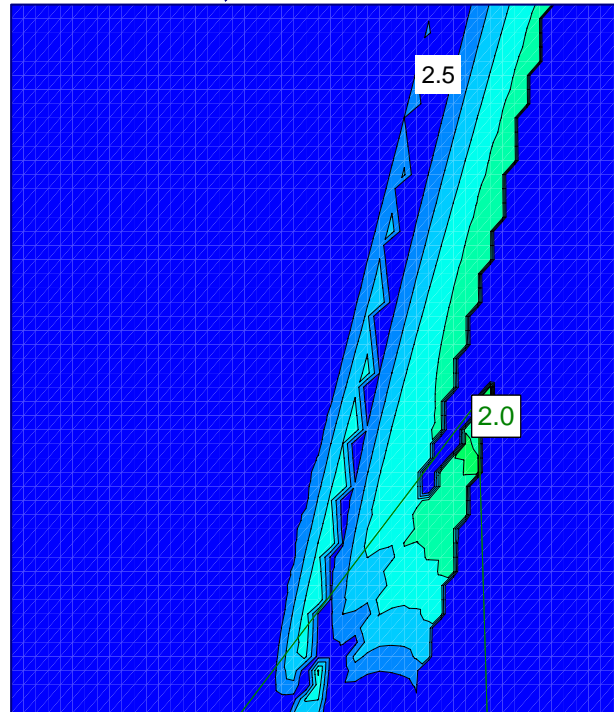
Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 150 kPa
Friction Angle: 0 deg
- 3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 70 kPa
Friction Angle: 0 deg
- 4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 150 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.0
Janbu Simplified: 1.9
Spencer: 2.0

Contours of Minimum
Factors of Safety



Terraprobe

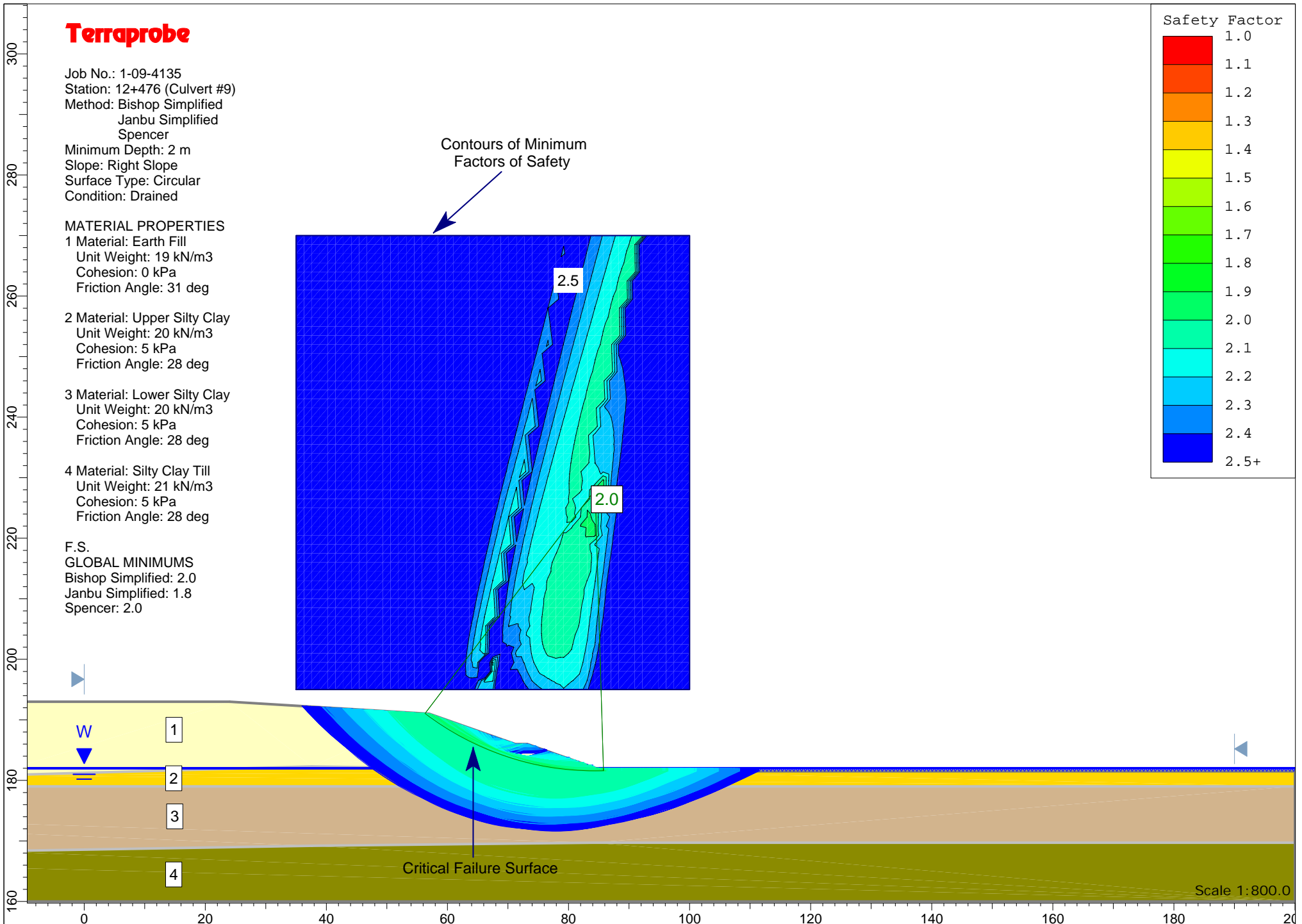
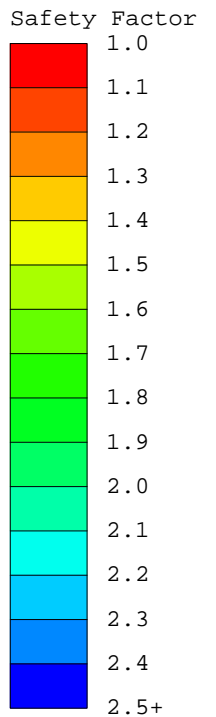
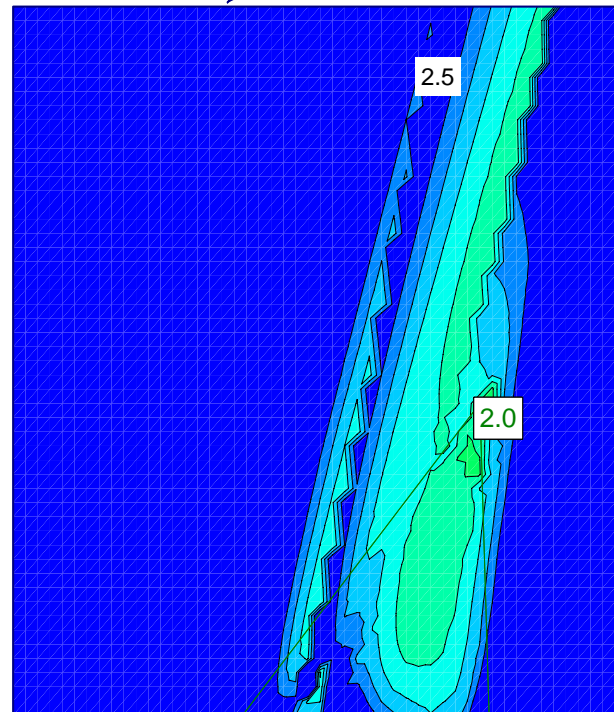
Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Drained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.0
Janbu Simplified: 1.8
Spencer: 2.0

Contours of Minimum
Factors of Safety



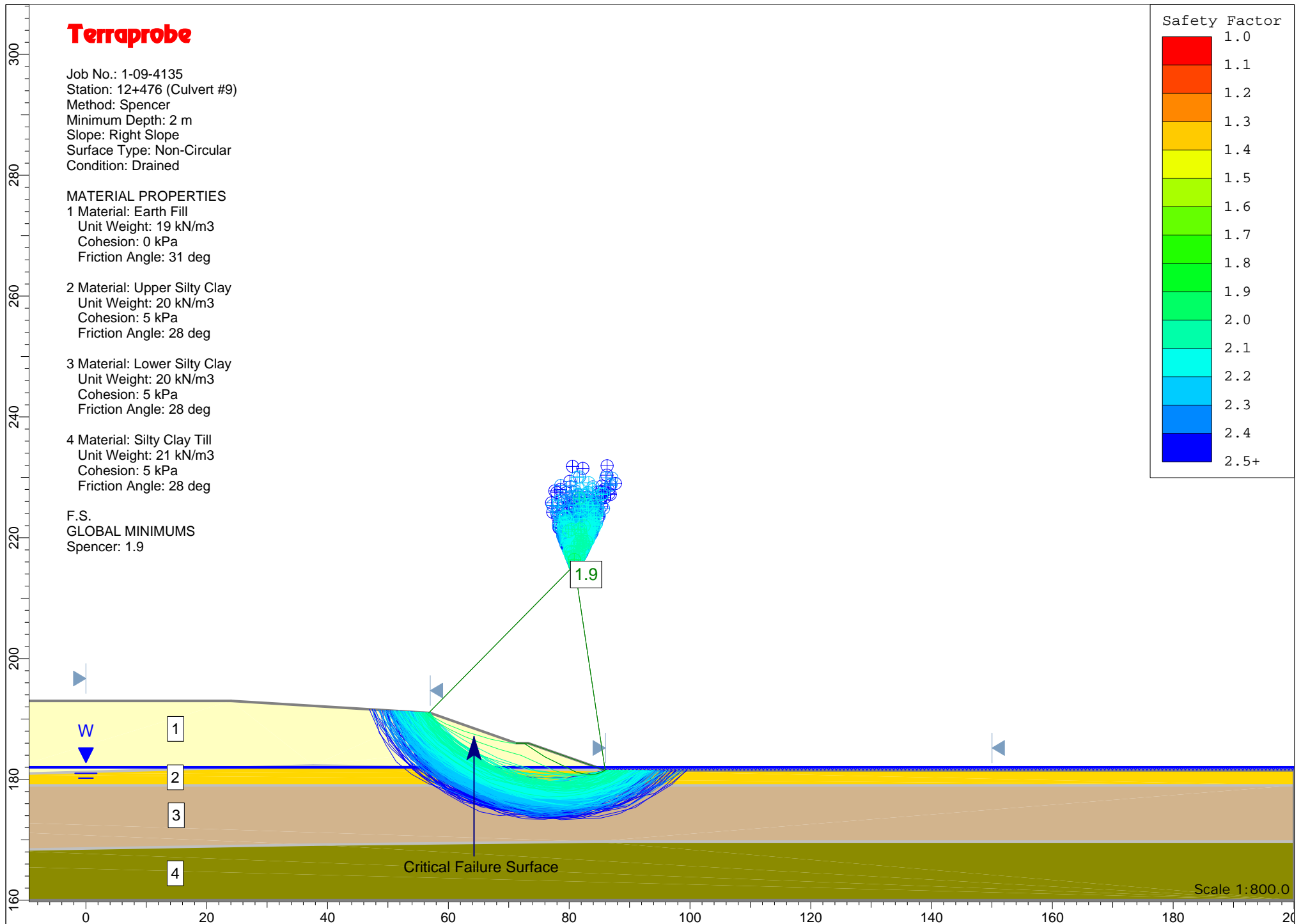
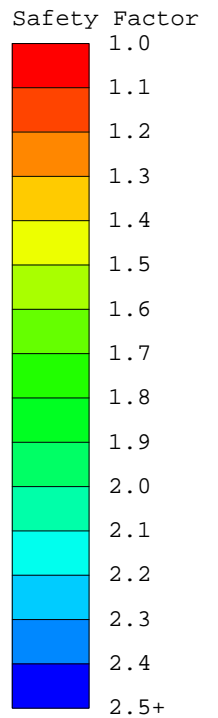
Terraprobe

Job No.: 1-09-4135
Station: 12+476 (Culvert #9)
Method: Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 4 Material: Silty Clay Till
Unit Weight: 21 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.9



Terraprobe

Job No.: 1-09-4135
Station: 14+152 (Culvert #24)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg

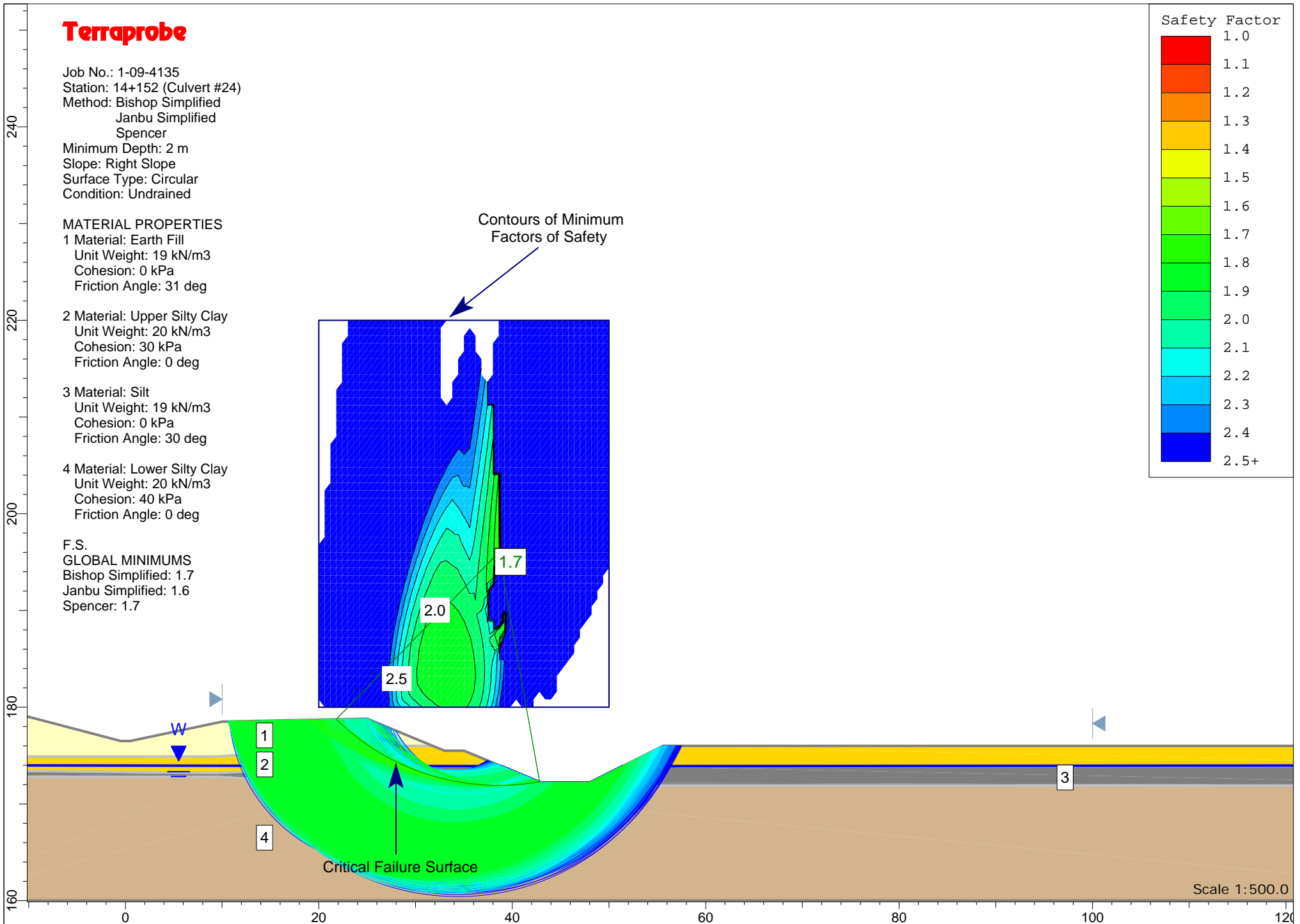
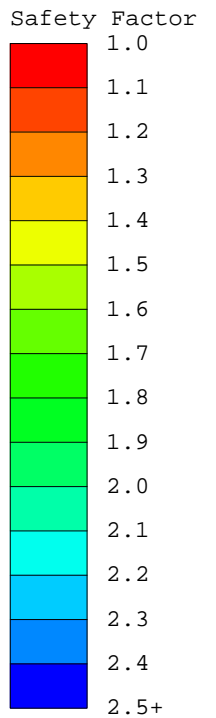
2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 30 kPa
Friction Angle: 0 deg

3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg

4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 40 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.6
Spencer: 1.7

Contours of Minimum
Factors of Safety



Terraprobe

Job No.: 1-09-4135
Station: 14+152 (Culvert #24)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Circular
Condition: Drained

MATERIAL PROPERTIES

1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg

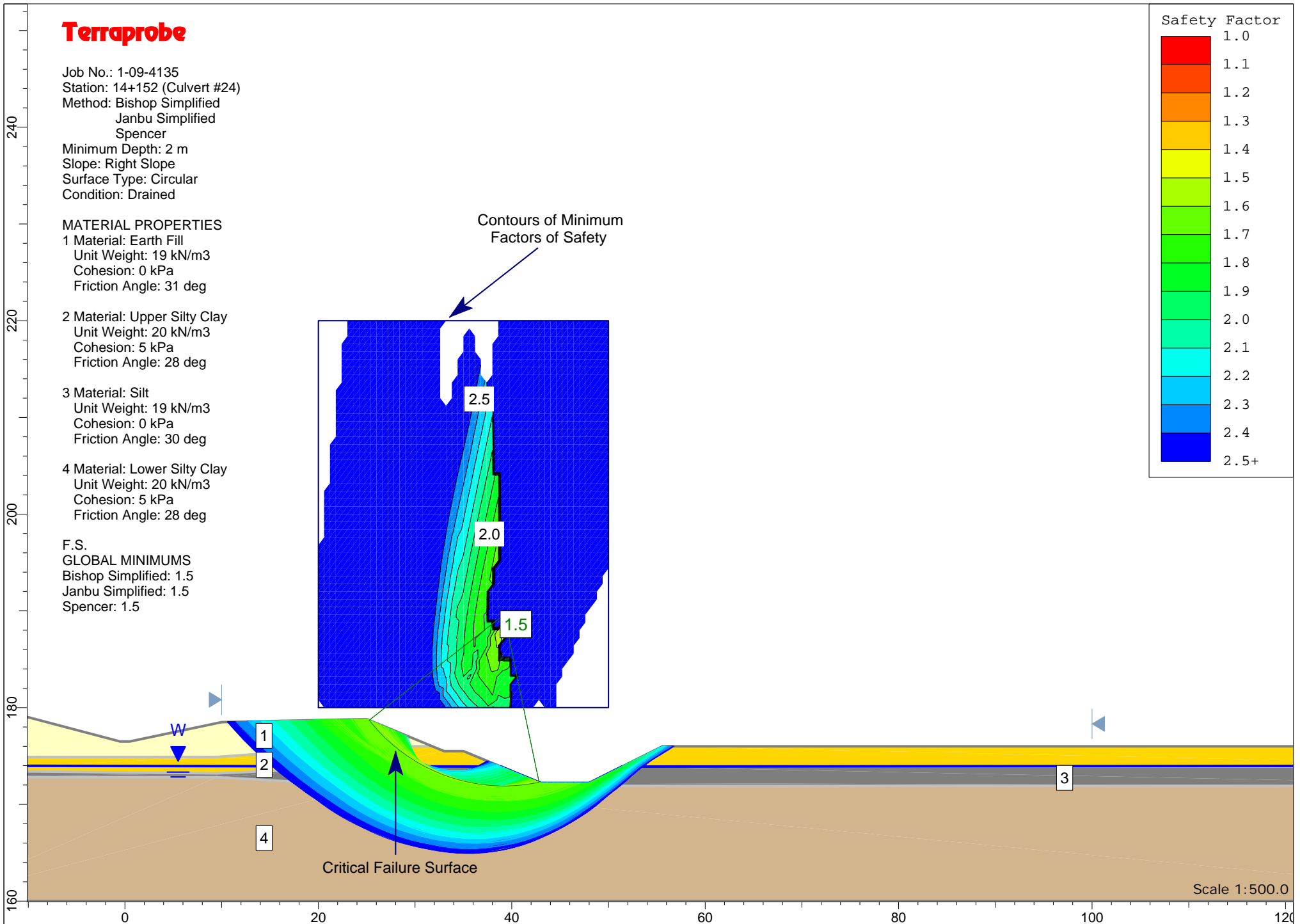
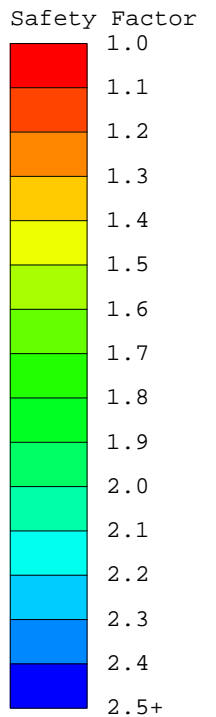
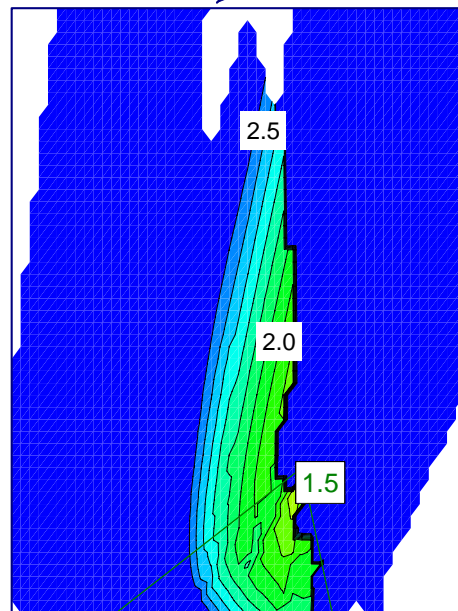
2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg

4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.5
Janbu Simplified: 1.5
Spencer: 1.5

Contours of Minimum
Factors of Safety



Scale 1:500.0

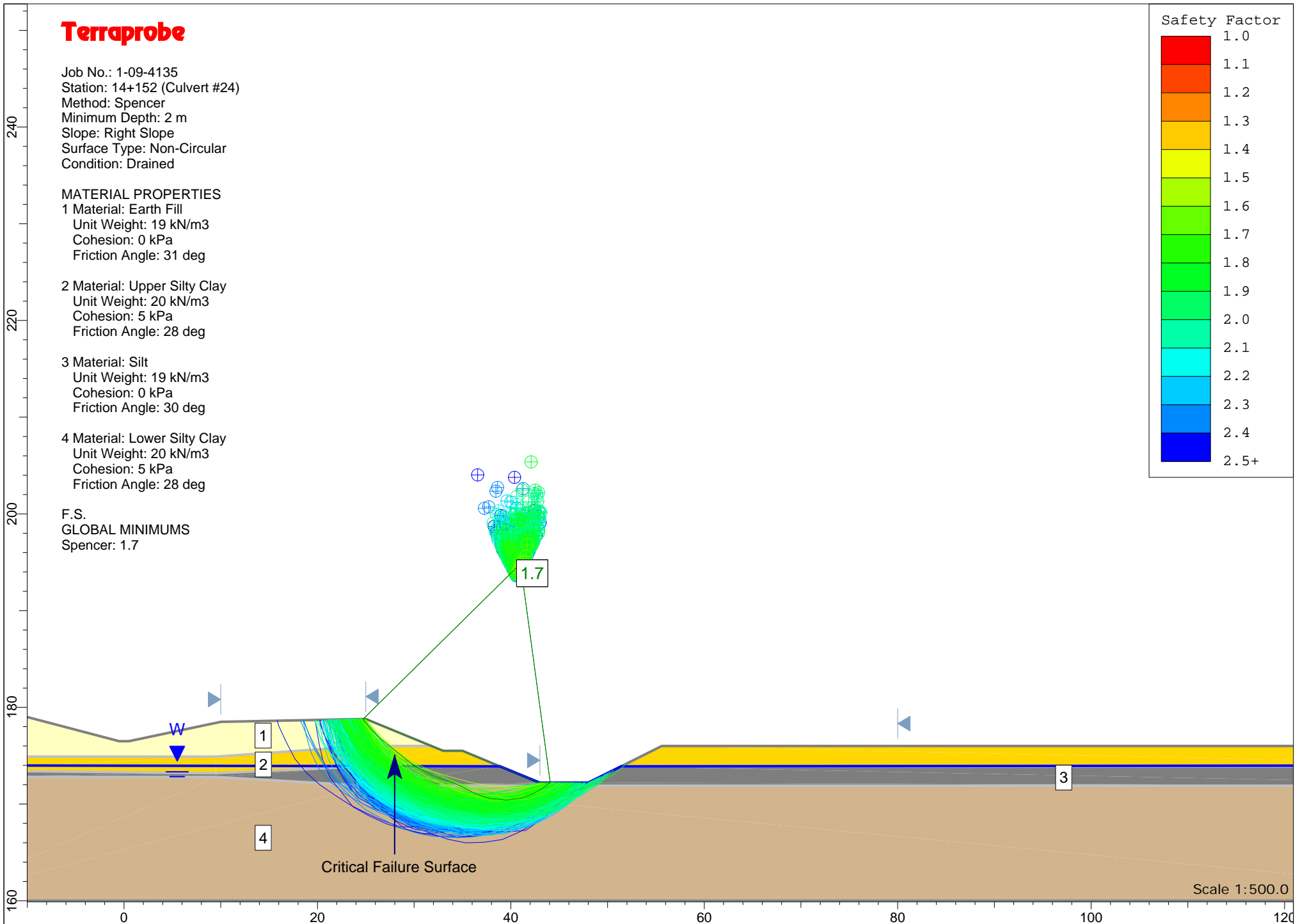
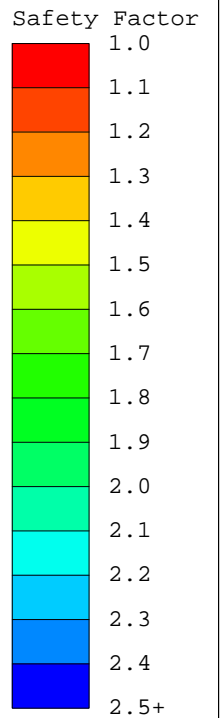
Terraprobe

Job No.: 1-09-4135
Station: 14+152 (Culvert #24)
Method: Spencer
Minimum Depth: 2 m
Slope: Right Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg
- 4 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 1.7



Terraprobe

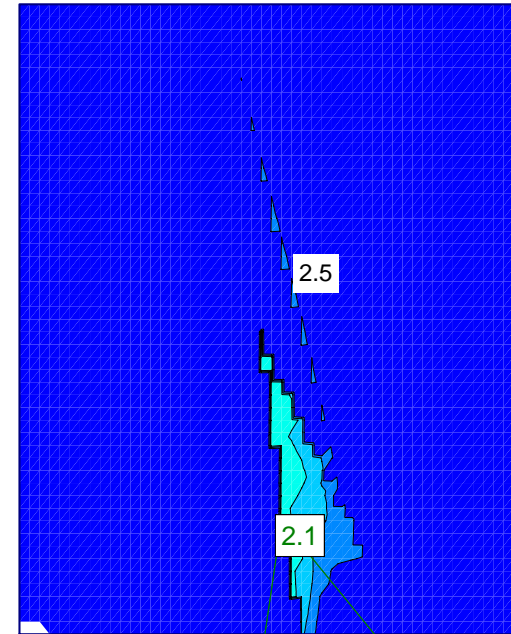
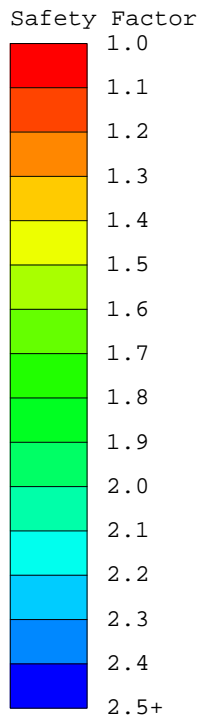
Job No.: 1-09-4135
Station: 15+712 (Culvert #48)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 1.5 m
Slope: Left Slope
Surface Type: Circular
Condition: Undrained

MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 100 kPa
Friction Angle: 0 deg
- 3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg
- 4 Material: Middle Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 30 kPa
Friction Angle: 0 deg
- 5 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 75 kPa
Friction Angle: 0 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.1
Janbu Simplified: 2.0
Spencer: 2.1

Contours of Minimum
Factors of Safety



W

Critical Failure Surface

Scale 1:600.0

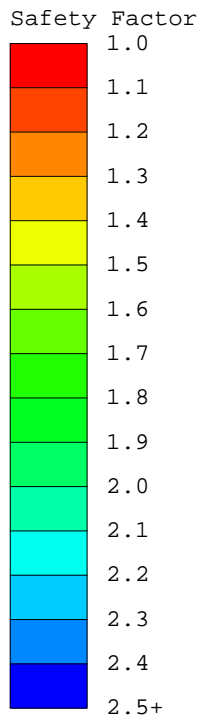
Terraprobe

Job No.: 1-09-4135
Station: 15+712 (Culvert #48)
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 1.5 m
Slope: Left Slope
Surface Type: Circular
Condition: Drained

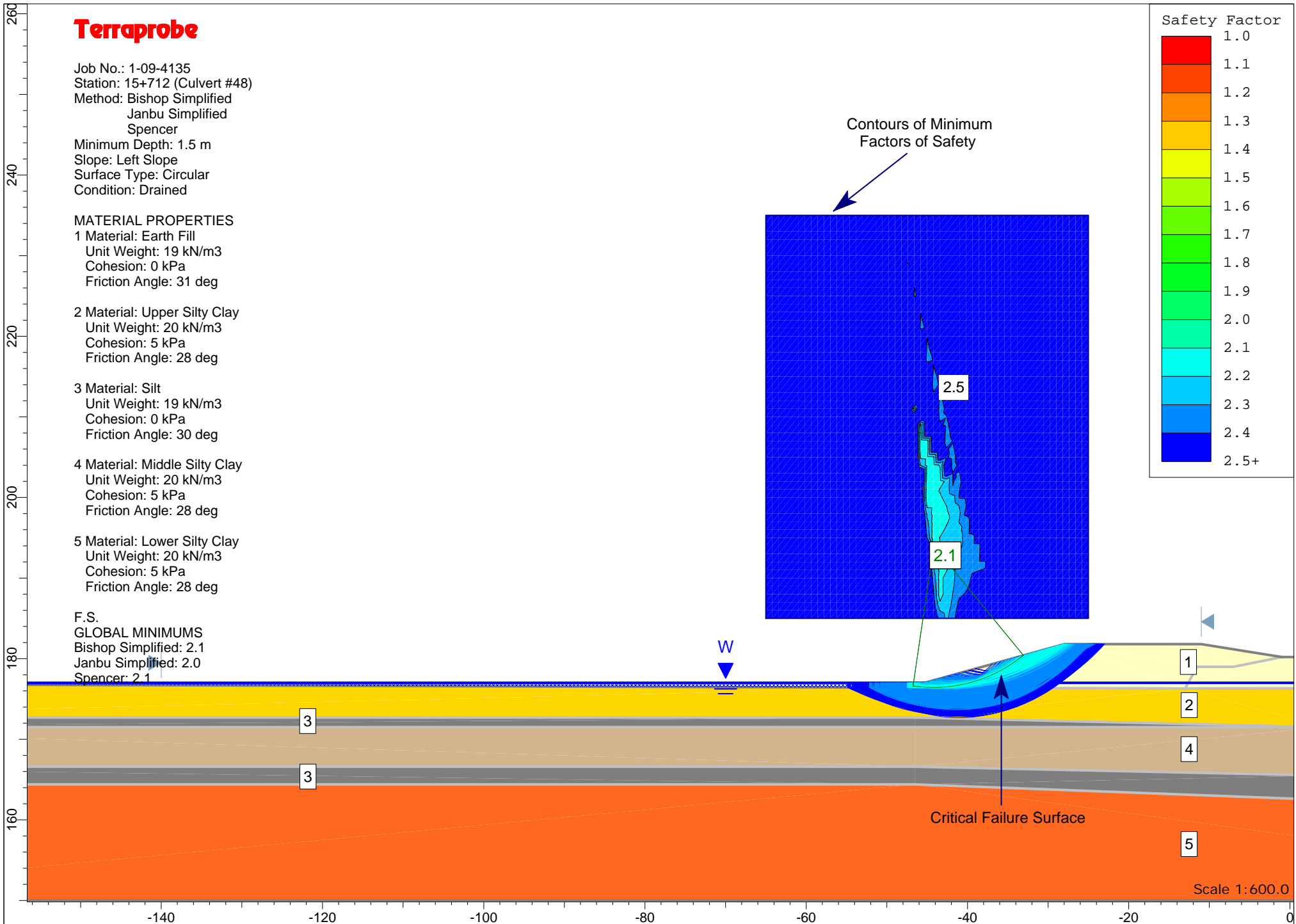
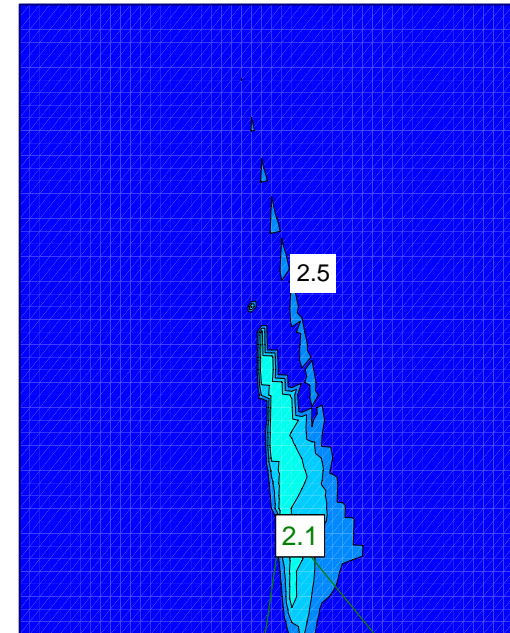
MATERIAL PROPERTIES

- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg
- 4 Material: Middle Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 5 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.1
Janbu Simplified: 2.0
Spencer: 2.1



Contours of Minimum Factors of Safety



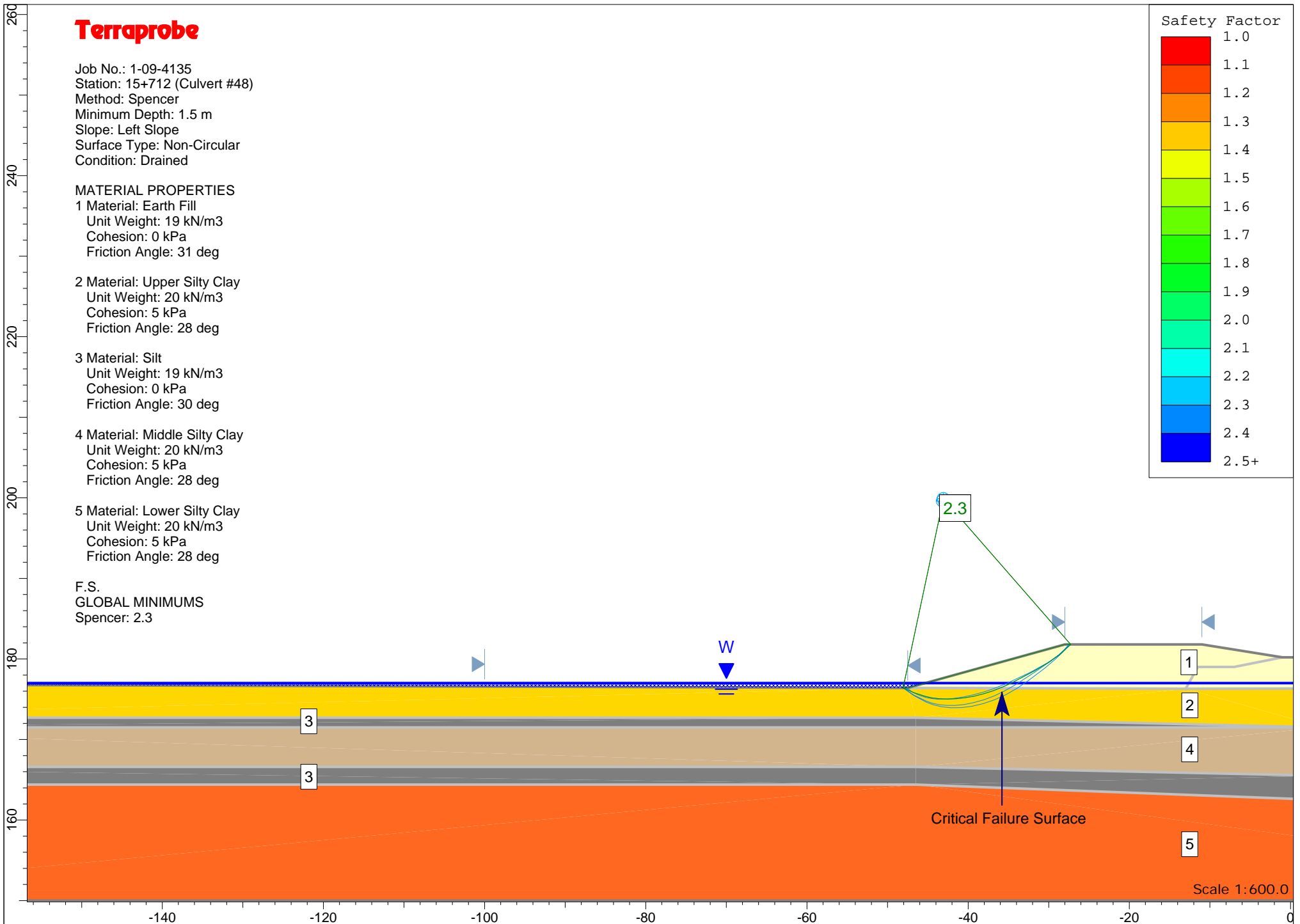
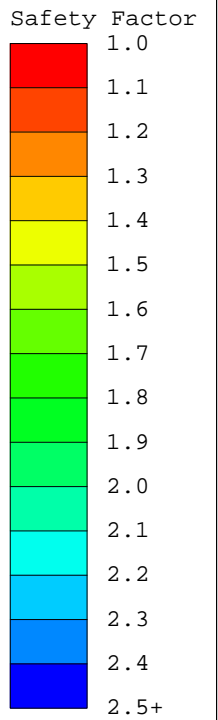
Terraprobe

Job No.: 1-09-4135
Station: 15+712 (Culvert #48)
Method: Spencer
Minimum Depth: 1.5 m
Slope: Left Slope
Surface Type: Non-Circular
Condition: Drained

MATERIAL PROPERTIES

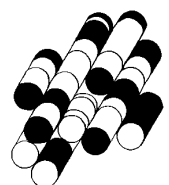
- 1 Material: Earth Fill
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 31 deg
- 2 Material: Upper Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 3 Material: Silt
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Friction Angle: 30 deg
- 4 Material: Middle Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg
- 5 Material: Lower Silty Clay
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Friction Angle: 28 deg

F.S.
GLOBAL MINIMUMS
Spencer: 2.3



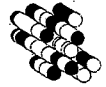
APPENDIX E

TERRAPROBE INC.



COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings	Closed Bottom Box Culvert	Pile Foundations
<p>Advantages:</p> <ul style="list-style-type: none"> i. None. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Not feasible due to very low shear strengths and compressible silty clay soils. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Reliable performance expected in areas where weak soils exist. ii. Available in precast units which facilitates ease in transportation, handling and placement. iii. Significant reduction in construction time. iv. More economical than other alternatives. v. Proven reliable performance on MTO projects. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Culverts have to be designed for camber where relatively large settlements are expected. ii. Good construction techniques required in order to ensure leak proof reliable joints between segments. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Reduces the amount of total and differential settlement. ii. Eliminates the need to camber culverts. iii. Proven reliable performance on MTO projects. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Very costly foundation scheme. ii. Relatively longer construction times required compared to other options. iii. Problems supporting pile driving equipment at some sites where weak soils exist.
<p>Risks/Consequences</p> <ul style="list-style-type: none"> i. High risk of failure due to settlement sensitive soils. ii. Not recommended. 	<p>Risks/Consequences</p> <ul style="list-style-type: none"> i. Represents the best alternative given the prevailing subsurface conditions. ii. Recommended. 	<p>Risks/Consequences</p> <ul style="list-style-type: none"> i. Very low risk of failure due to settlement. ii. Very high construction and material costs. iii. Not recommended based on economics.



Terraprobe Inc.