



Terraprobe

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

**FOUNDATION INVESTIGATION REPORT
PORT ROBINSON ROAD UNDERPASS
HIGHWAY 406 TWINNING
PORT ROBINSON ROAD TO EAST MAIN STREET
AGREEMENT No. 2008-E-0016, W.P. 280-99-00, SITE: 34-462
GEOCRES No. 30M3-262**

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**FOUNDATION INVESTIGATION REPORT
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ONTARIO**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the Port Robinson Road Underpass bridge site in the City of Thorold, Ontario.

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

The following documents are referenced in the preparation of this report:

- Peto MacCallum Ltd., "Preliminary Foundation Investigation and Design Report for Port Robinson Road Underpass", Highway 406 Four-Laning, G.W.P. 280-99-00, City of Thorold, Ontario, GEOCRES 30M03-237, dated January 20, 2009.

2 SITE DESCRIPTION & PHYSIOGRAPHY

The site is located approximately 25 m south of the existing at grade intersection of Highway 406 and Port Robinson Road in the City of Thorold, Regional Municipality of Niagara, Ontario. At this location Highway 406 is a two-lane highway with gravel shoulders carrying both north and south bound traffic.

The topography is flat and vegetation at this site consists primarily of deciduous trees and wild bush. Areas of groomed grass can be found at some locations along the existing roadways.

The site 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 unit at this site is the Guelph Formation of Upper Silurian Age². This unit consists essentially of unweathered, grey, laminated argillaceous dolostone.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between December 21, 2009 and February 3, 2010 and consisted of drilling and sampling five boreholes to depths ranging from 30.5 m to 38.0 m. The boreholes were numbered PR1, PR2, PR3, PR4, and PR5 and their approximate locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix C.

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 Borehole PR3 was difficult due to locally steep slopes and this borehole was relocated to be as close as feasible to the staked out location while allowing safe operation of the drill rig. Terraprobe obtained utility clearances and permits 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. The boreholes at the abutments were also advanced into bedrock by NQ size diamond coring techniques.

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 bentonite slurry mixture after drilling was complete.

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.



The locations and completion details of the piezometers are shown in Table 3.1.

Table 3.1 – Piezometer Installation Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation (m)	Completion Details
PR1	32.0/149.7	Piezometer with 1.5 m slotted screen installed with filter sand to 29.9 m, bentonite seal from 29.9 m to 29.0 m, drill cuttings from 29.0 m to 1.5 m, bentonite seal from 1.5 m to ground surface.
PR3	32.0/149.3	Hole sealed to 32.0 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 29.9 m, bentonite seal from 29.9 m to ground surface.
PR4	14.6/167.6	Hole sealed to 14.8 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 12.8 m, bentonite seal from 12.8 m to ground surface.
PR5	30.5/150.7	Piezometer with 1.5 m slotted screen installed with filter sand to 28.3 m, bentonite seal from 28.3 m to 27.1 m, drill cuttings from 27.1 m to 0.6 m, bentonite seal from 0.6 m to ground surface.

The drilling, sampling and coring operations were observed on a full time basis by members of Terraprobe's technical staff who logged the boreholes and rock cores 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, 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 A and the figures in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil and rock stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawings in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the site is underlain by topsoil, gravelly sand fill, silty sand fill, silty clay fill and native overburden deposits of silty clay, silt, silty clay to clayey silt, and clayey silt till. These soils are underlain by bedrock consisting primarily of dolostone of the Guelph formation.



5.1 Topsoil

Topsoil ranging from 180 mm to 300 mm thick was encountered on the site. Topsoil thickness may vary between and beyond the boreholes.

5.2 Fill – Gravelly Sand

Borehole PR4 was drilled on the median between the existing Highway 406 NBL and the dedicated right turn lane that conveys Highway 406 northbound traffic to Port Robinson Road east. This borehole encountered a layer of gravelly sand fill (approximately 500 mm thick) that extends to a depth of 0.7 m (Elev. 181.5 m) below ground surface.

A sample of this fill material was subjected to grain size analysis and the results are presented in Figure B1. These results show a grain size distribution consisting of 22% gravel, 50% sand, 20% silt and 8% clay size particles.

A Standard Penetration test in the gravelly sand fill gave an 'N' value of 12 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 8% by weight.

5.3 Fill – Silty Sand

Borehole PR3 was drilled near to the west shoulder of the existing Highway 406. This borehole encountered a discontinuous layer of silty sand fill (approximately 1.1 m thick) that extends to a depth of 1.4 m (Elev. 179.9 m) below ground surface. Based on visual and tactile examinations of the retrieved samples, the fill is essentially a cohesionless soil with frequent cohesive silty clay inclusions.

A sample of this fill material was subjected to a grain size analysis and the results are presented in Figure B2. These results show a grain size distribution consisting of 0% gravel, 48% sand, 34% silt and 18% clay size particles.

Standard Penetration tests in the fill gave 'N' values that ranged from 4 to 8 blows for 0.3 m penetration. Based on these results the fill is considered to have a loose relative density. The moisture content of samples of this fill ranged from 15% to 20% by weight.

5.4 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 0.7 m (Elev. 180.5 m) to 2.1 m (Elev. 180.1 m) below ground surface.

Samples of this fill were subjected to grain size analysis and the results are presented in Figure B3. These results show a grain size distribution consisting of 0% gravel, 8-12% sand, 35-44% silt and 44-57% clay size particles.



The fill material was also subjected to an Atterberg Limits test and the results are presented in Figure B4. The index values from these tests are summarized below:

Liquid Limit:	40%
Plastic Limit:	20%
Plasticity Index:	20%
Natural Moisture Content:	19%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values that ranged from 4 to 22 blows for 0.3 m penetration but generally the recorded 'N' values ranged from 4 to 11 blows for 0.3 m penetration. Based on these results the fill is considered to have a generally firm to stiff consistency with occasional very stiff zones. The moisture content of samples of this fill ranged from 17% to 26% by weight.

5.5 Silty Clay

A major silty clay deposit exists at this site. This deposit was fully penetrated in all of the boreholes where it was found to extend to depths ranging from 14.7 m (Elev. 167.5 m) to 15.7 m (Elev. 166.0 m) below ground surface.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B5 to B9 inclusive. These results show a grain size distribution consisting of 0-7% gravel, 0-4% sand, 16-77% silt and 23-83% clay size particles.

Samples of the silty clay were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B10 to B14 inclusive. The index values from these tests are summarized below:

Liquid Limit:	25-61%
Plastic Limit:	16-27%
Plasticity Index:	8-34%
Natural Moisture Content:	19-47%

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

Standard Penetration tests in this stratum gave 'N' values that ranged from 0 to 27 blows for 0.3 m penetration but generally the recorded 'N' values ranged from 3 to 14 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 24 kPa to in excess of 100 kPa and laboratory vane tests on relatively undisturbed Shelby tube samples gave undrained shear strengths ranging from 38 kPa to 78 kPa. These values indicate that the consistency of the silty clay is generally firm to very stiff with infrequent soft zones. Moisture content of samples of the silty clay range from 19% to 47% by weight and the unit weight of selected samples ranged from 17.4 to 20.3 kN/m³.



The variation of undrained shear strength with elevation is depicted in Figure B22 (Elev. 178 m to Elev. 166 m). The plot generally illustrates a trend of decreasing shear strength with depth within this deposit. The upper portion of this deposit up to about Elev. 177.5 m is estimated to have relatively high undrained shear strength i.e. in excess of 100 kPa. Below Elev. 177.5 m the undrained shear strength decreases with depth and is about 25 kPa between Elev. 171.0 m and Elev. 170.0 m. Below Elev. 170.0 m the trend indicates increasing undrained shear strength with depth.

The Atterberg Limits tests results are also plotted against elevation, Figure B23 (Elev. 180 m to Elev. 167 m). These results illustrate that the natural moisture contents of this deposit are generally at or below the plastic limit up to about Elev. 177.5 m. Below Elev. 177.5 m the natural moisture content increases and is between the plastic and liquid limits.

Consolidation tests were also performed on Shelby tube samples retrieved from Boreholes PR1 and PR5 and the results are presented in Figures B24 to B29 inclusive. These results indicate estimated preconsolidation pressures ranging between 200 kPa and 360 kPa.

5.6 Silt

A native silt deposit was encountered at this site in all of the boreholes. The deposit is approximately 2.1 m to 3.1 m thick and extends to depths ranging from 16.8 m (Elev. 164.5 m) to 17.8 m (Elev. 163.9 m) below ground surface. 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.

The grain size distribution plots of tested samples of this silt deposit are presented in Figure B15. These results show a grain size distribution consisting of 0% gravel, 0-1% sand, 75-96% silt and 3-24% clay size particles.

The deposit is considered to have a very loose to compact relative density based on SPT 'N' values that ranged from 0 to 26 blows for 0.3 m penetration. SPT 'N' values of 0 are likely attributed to sample disturbance. The moisture content of samples from this deposit ranged from 16% to 29% by weight.

5.7 Silty Clay to Clayey Silt

A native deposit of silty clay to clayey silt was encountered across this site. This stratum extends to depths ranging from 26.9 m (Elev. 154.8 m) to 29.9 m (Elev. 152.3 m) below ground surface.

The grain size distribution plots of tested samples from this stratum are depicted in Figure B16 and B17. These results show a grain size distribution consisting of 0-3% gravel, 0-11% sand, 63-81% silt and 16-37% clay size particles.



Samples were also subjected to Atterberg Limits tests and the results are plotted on the plasticity charts, Figure B18 and B19. The index values from these tests are summarized below:

Liquid Limit:	23-39%
Plastic Limit:	16-20%
Plasticity Index:	4-19%
Natural Moisture Content:	16-31%

These values indicate that the silty clay to clayey silt is of low to intermediate plasticity.

Standard Penetration tests in this deposit yielded 'N' values ranging from 6 to 43 blows for 0.3 m penetration. Field vane tests were also performed in this deposit and the results indicate undrained shear strengths ranging from 80 kPa to in excess of 100 kPa. Based on these results the silty clay to clayey silt is considered to have a stiff to hard consistency with occasional firm zones. The moisture content of samples from these deposits varies from 9% to 34% by weight.

The variation of undrained shear strength with elevation is depicted in Figure B22 (Elev. 164 m to Elev. 153 m). The plot illustrates a slight decrease in shear strength with depth. The undrained shear strength decreases from about 100 kPa at Elev. 164.0 m to about 75 kPa at Elev. 157.0 m. Below Elev. 157.0 m the trend indicates increasing undrained shear strength with depth.

The Atterberg Limits tests results are also plotted against elevation, Figure B23 (Elev. 164 m to Elev. 153 m). These results illustrate that the natural moisture content of the upper portion of this deposit is generally at or below the plastic limit up to about Elev. 158.0 m. Below Elev. 158.0 m the natural moisture content increases and is generally between the plastic and liquid limits up to about Elev. 154.0 m. Below Elev. 154.0 m the natural moisture content is below the plastic limit.

5.8 Clayey Silt Till

A native deposit of clayey silt till was encountered across the site extending to depths ranging from 30.5 m to 34.3 m below ground surface or to elevations ranging from 150.7 m to 147.7 m. Boreholes PR1 and PR5 were terminated in this deposit at depths of 32.0 m (Elev. 149.7 m) and 30.5 m (Elev. 150.7 m) respectively. The lower 1.5 m to 1.8 m of this stratum overlying bedrock contains frequent cobbles and in Borehole PR3 a boulder was encountered above the bedrock.

The grain size distribution plot of a tested sample from this till deposit is depicted in Figure B20. These result shows a grain size distribution consisting of 3% gravel, 18% sand, 64% silt and 15% clay size particles.

A sample was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart, Figure B21. The index values from these tests are summarized below:

Liquid Limit:	20%
Plastic Limit:	14%
Plasticity Index:	6%
Natural Moisture Content:	11%

This value is typical of a low plasticity clayey silt soil.



Standard Penetration tests in this stratum deposits yielded 'N' values ranging from 16 to more than 100 blows per 0.3 m penetration but generally the recorded 'N' values ranged from 30 to more than 100 blows for 0.3 m penetration. Based on these results the clayey silt till is considered to have a hard consistency with occasional very stiff zones. The moisture content of samples from this deposit varies from 3% to 23% by weight.

5.9 Bedrock (Guelph Formation)

The overburden soils described above are underlain by the Guelph Formation. Bedrock was proved by coring at the abutment and pier locations. Table 5.1 summarizes the bedrock depth and the elevations to the top of bedrock.

Table 5.1 – Depth to Bedrock

Location	BH Number	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
West Abutment	PR2	33.5	148.2
Pier	PR3	33.6	147.7
East Abutment	PR4	34.3	147.9

The bedrock is described as unweathered dolostone and its colour is light to medium brownish grey. Total core recovery in the bedrock generally ranged from 52% to 100%. The RQD values ranged widely from 0% to 76%, but generally most of the RQD values were between 24% and 69%. The core data also reveals that there is no trend of improving rock quality with depth. Based on these results the rock quality is considered to be very poor to fair with infrequent zones of good quality rock.

5.10 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 5.2.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
PR1	January 11, 2010	7.0	174.7
	January 19, 2010	7.2	174.5
	January 27, 2010	7.1	174.6
	February 08, 2010	7.2	174.5
	February 19, 2010	7.1	174.6
PR3	January 19, 2010	8.2	173.1
	January 27, 2010	6.6	174.7
	February 08, 2010	0.6	180.7
	February 19, 2010	0.5	180.8
PR4	February 08, 2010	5.0	177.2
	February 19, 2010	4.5	177.7
	April 16, 2010	4.3	177.9
PR5	January 19, 2010	6.4	174.8
	January 27, 2010	6.2	175.0
	February 08, 2010	6.3	174.9
	February 19, 2010	6.2	175.0



The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of the moisture contents of the retrieved samples. Based on these observations, the local ground water level is estimated to be about Elev. ± 179.5 m. At Borehole PR3, perched water exists in the silty sand fill at Elev. ± 180.8 m.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events.

5.11 Miscellaneous

The drilling, sampling and in-situ testing operations were conducted with track mounted drill rigs owned and operated by Determination Drilling & Soil Investigations of Hamilton, Ontario.

The boreholes were advanced using hollow-stem augers and rock cores were retrieved by NQ size diamond coring techniques.

Messrs. Alexander Winkelmann, E.I.T., and Phil Khuu, B.A.T carried out the field work and 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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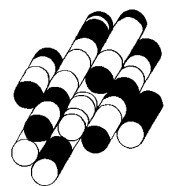
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APPENDICES

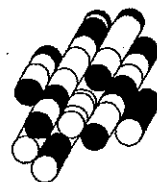
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APPENDIX A

Record of Borehole Sheets, Core Logs and Core Photos

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	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_n	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 ²	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

EXPLANATORY SHEET FOR CORE LOG

Column Number

1. Elevation of borehole collar.
2. Depth of geotechnical boundary in borehole
3. Geologic symbol for rock or soil material
4. General description of geotechnical unit - qualitative description, including rock type(s), percentage rock types, frequency and sizes of interbeds, colour, texture.

Joint (discontinuity) Characteristics

5. Number of joint sets: a rock mass can be intersected by a number of joint sets of varying orientations.
6. Joint type: B = Bedding joint C = Cross joint
7. Orientation: only variations in dip can be identified in core; dip direction is from field mapping or oriented core:
F = Flat = 0 - 20° D = Dipping = 20 - 50° V = Vertical = 50 - 90°
8. Joint spacing: this is an approximate measure of spacing between joints in specific joint sets.

SPACING	> 3 m	1 m - 3 m	0.3 m - 1 m	50 mm - 300 mm	< 50 mm
	VERY WIDE	WIDE	MODERATE	CLOSE	VERY CLOSE

9. Roughness:

RU = Rough Undulating
SU = Smooth Undulating
LU = Slickensided Undulating

RP = Rough Planar
SP = Smooth Planar
LP = Slickensided Planar

10. Filling:

T = Tight, hard, non-softened
O = Oxidation surface staining only
SA = Slightly altered; clay-free
S = Sandy particles; clay-free
Si = Sandy and silty, minor clay
NC = Non-softening Clays; 5mm
SC = Swelling Clay fillings; 5mm

Approximate ϕ

25 - 35
25 - 30
25 - 30
20 - 25
16 - 24
6 - 12

11. Aperture: estimated size of joint opening.

12. Degree of weathered rock material:

DEGREE	DESCRIPTION	
UNWEATHERED	NO SIGNS OF DISCOLOURATION OR OXIDIZATION	
SLIGHTLY WEATHERED	PARTIAL DISCOLOURATION; FRACTURES (JOINTS), TYPICALLY OXIDIZED	
MODERATELY WEATHERED	TOTAL DISCOLOURATION	
HIGHLY WEATHERED	TOTAL DISCOLOURATION; TYPICALLY FRIABLE AND PITTED	
COMPLETELY WEATHERED	RESEMBLE A SOIL; ROCK STRUCTURE - USUALLY PRESERVED	

13. Strength of rock material:

		MPa	
VERY HIGH STRENGTH	SPECIMEN CAN ONLY BE CHIPPED BY GEOLOGICAL HAMMER	> 200	
HIGH STRENGTH	SPECIMEN REQUIRES A NUMBER OF BLOWS OF A GEOLOGICAL HAMMER TO FRACTURE IT; CANNOT BE SCRAPPED WITH POCKET KNIFE	50 - 200	
MEDIUM STRENGTH	SPECIMEN CANNOT BE FRACTURED BY A SINGLE, FIRM BLOW OF GEOLOGICAL HAMMER; CAN BE SCRAPPED WITH POCKET KNIFE, NOT PEELED	15 - 50	
LOW STRENGTH	SHALLOW INDENTATIONS MADE BY FIRM BLOW WITH POINT OF GEOLOGICAL HAMMER; CAN BE PEELED WITH POCKET KNIFE WITH DIFFICULTY	4 - 15	
VERY LOW STRENGTH	CRUMBLES UNDER FIRM BLOW WITH POINT OF GEOLOGICAL HAMMER; CAN BE PEELED	1 - 4	

14. Fracture frequency: number of natural joints occurring over a meter length of core. All natural joints are counted irrespective of the number of joint sets.

FRACTURE FREQUENCY	JOINT SPACING	LENGTH	
0.3 m	VERY WIDE	> 3 m	
0.3 - 1 m	WIDE	1 m - 3 m	
1 - 3 m	MODERATE	0.03 m - 1 m	
3 - 20 m	CLOSE	0.005 m - 0.03 m	
20 m	VERY CLOSE	< 0.005 m	

15. Run number and Core Recovery

- (i) Drill run number

- (ii) Total Core Recovery is the total length of core pieces, irrespective of their individual lengths obtained in a core run, and expressed as a percentage of the length of that core run.

16. Rock Quantity Designation (RQD): The total length of those pieces of sound core which are 0.01 metres or greater in length in a core run, expressed as a percentage of the total length of that core run. Sound pieces of rock are those pieces separated by natural breaks and not machine breaks or subsequent artificial breaks.

Rock Mass Classification (after Deare)					
RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
DESCRIPTION	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

17. Core and Casing sizes: changes of core and casing sizes are indicated.

18. Water recovery, level and tests:

- (i) percentage drill water recovery

- (ii) water level depth

- (iii) positions and results of tests, e.g., permeability and packer tests

METRIC

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

RECORD OF BOREHOLE No PR1

3 OF 3

METRIC

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

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																				
149.7	frequent cobbles.		24	SS	182/ 28cm		151																												
32.0			25	SS	100/ 2.5cm		150																												
	<p>End of Borehole</p> <p>Resistance to augering at 10.5m, 12.8m, 31.4m, and 31.7m.</p> <p>Borehole was dry (not stabilized) and hole open to full depth on completion.</p> <p>Consolidation test performed on TW 8.</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>Jan.11.10</td> <td>7.0</td> <td>174.7</td> </tr> <tr> <td>Jan.19.10</td> <td>7.2</td> <td>174.5</td> </tr> <tr> <td>Jan.27.10</td> <td>7.1</td> <td>174.6</td> </tr> <tr> <td>Feb.08.10</td> <td>7.2</td> <td>174.5</td> </tr> <tr> <td>Feb.19.10</td> <td>7.1</td> <td>174.6</td> </tr> </tbody> </table>																	Date	Depth(m)	Elevation(m)	Jan.11.10	7.0	174.7	Jan.19.10	7.2	174.5	Jan.27.10	7.1	174.6	Feb.08.10	7.2	174.5	Feb.19.10	7.1	174.6
Date	Depth(m)	Elevation(m)																																	
Jan.11.10	7.0	174.7																																	
Jan.19.10	7.2	174.5																																	
Jan.27.10	7.1	174.6																																	
Feb.08.10	7.2	174.5																																	
Feb.19.10	7.1	174.6																																	

METRIC

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

Continued Next Page

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

3 OF 3

METRIC

[illegible]

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

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

CORE LOG



Terraprobe

Project Highway 406 Twinning				Orientation Vertical		Ground Elevation 181.7m		Datum Geodetic		Borehole No. PR2	
Location Welland, Ontario				Date Started December 30, 2009		Completed December 30, 2009		Logged By AW		Sheet 1 of 1	
W.P.: 280-99-00				Drilling Agency DDSI		Drill Type Track-Mount		Core Barrel & Bit Design NQ		Project No. 1-09-4135	

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								WEATHERING	STRENGTH	FRACTURE FREQUENCY	RUN NO.	CORE RECOVERY %	R Q D %	CORE SIZE/CASING	MPa	UNIT WEIGHT (kN/m³)
				No. OF SETS	JOINT TYPE	ORIENTATION	SPACING	ROUGHNESS	FILLING	APERTURE										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
149.7	32.0		Overburden, refer to Borehole Log PR2																	
149.2	32.5		Clayey Silt TILL, refer to Borehole Log PR2																	
148.7	33.0																			
148.2	33.5																			
147.7	34.0		GUELPH FORMATION BEDROCK																	
147.2	34.5		DOLOSTONE Unweathered, thinly laminated, light to medium brownish-grey, medium strength, argillaceous.	1	B	F	C	SP	T	0 to 1										
146.7	35.0																			
146.2	35.5																			
145.7	36.0																			
145.2	36.5																			
144.7	37.0																			
144.2	37.5																			
143.7	38.0		End of Core Log																	

Remarks:

LEGEND:

 Dolostone
 Clayey Silt TILL

RECORD OF BOREHOLE No PR3

1 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766747.0 E:326343.5 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB
 DATUM Geodetic DATE 01.07.10 - 01.08.10 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						
181.3	Ground Surface							20 40 60 80 100							
0.0 181.0	280mm TOPSOIL							20 40 60 80 100							
0.3	FILL - Silty Sand, frequent clayey inclusions, loose, grey, wet		1	SS	8									0 48 34 18	
			2	SS	4										
179.9			3	SS	6										
1.4	SILTY CLAY trace sand, occasional gravel inclusions, firm to stiff, grey / brown, moist		4	SS	12									0 1 39 60	
			5	SS	14										
			6	SS	9									1 1 65 33	
	soft		7	SS	4										
			8	SS	4									0 4 55 41	
			9	SS	7									0 3 54 43	
			10	SS	4									0 1 57 42	
			11	TW	PH								18.3		
			12	SS	1									0 0 65 35	
			13	SS	3										
166.6															
14.7															

Continued Next Page

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

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

METRIC

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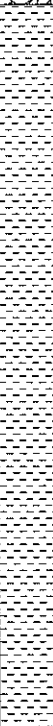
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

CORE LOG



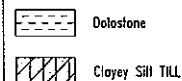
Terraprobe

Project	Highway 406 Twinning	Orientation	Vertical	Ground Elevation	181.3m	Datum	Geodetic	Borehole No.	PR3
Location	Welland, Ontario	Date Started	January 8, 2010	Completed	January 8, 2010	Logged By	AW	Sheet	1 of 1
W.P.:	280-99-00	Drilling Agency	DDSI	Drill Type	Track-Mount	Core Barrel & Bit Design	NQ	Project No.	1-09-4135

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics							WEATHERING	STRENGTH	FRACTURE FREQUENCY	RUN NO.	CORE RECOVERY %	R Q D %	CORE SIZE/CASING	MPa UNCONFINED COMPRESSIVE STRENGTH	UNIT WEIGHT (kN/m³)
				No. OF SETS	JOINT TYPE	ORIENTATION	SPACING	ROUGHNESS	FILLING	APERTURE									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
149.3	32.0		Overburden, refer to Borehole Log PR3																
148.8	32.5		Clayey Silt TILL, (Boulder 32.90m to 33.60m), refer to Borehole Log PR3												#1 TCR 0 SCR 0	0	NQ		
148.3	33.0																		
147.8	33.5			GUELPH FORMATION BEDROCK											#2 TCR 71 SCR 69	29	NQ		
147.3	34.0		DOLOSTONE Unweathered, thinly laminated, light to medium brownish grey, medium strength, argillaceous.	1	B	F	C	SP	T	0 to 1									
146.8	34.5																		
146.3	35.0			1	B	F	C	SP	T	0 to 2					#3 TCR 100 SCR 100	76	NQ		
145.8	35.5																		
145.3	36.0																		
144.8	36.5																		
144.3	37.0																		
143.8	37.5																		
143.3	38.0																		
			End of Core Log																

Remarks:

LEGEND:



RECORD OF BOREHOLE No PR4

1 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4768752.2 E:326382.2 ORIGINATED BY PK
 DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB
 DATUM Geodetic DATE 01.28.10 - 02.03.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	T _N VALUES			20	40	60	80	100		
182.2	Ground Surface													
182.0	180mm TOPSOIL													
0.2	FILL - Sand, gravelly, some silt, trace clay, trace organics, compact, brown, moist		1	SS	12		182							22 50 20 8
181.5														
0.7	FILL - Silty Clay, some sand, trace gravel, stiff to very stiff, brown, moist		2	SS	10		181							
			3	SS	22									0 12 44 44
180.1							180						56	0 1 35 64
2.1	SILTY CLAY trace sand, firm to very stiff, brown, damp to moist		4	SS	12									
			5	SS	12		179							
			6	SS	13								44	0 0 47 53
			7	SS	4		178							
							177							
								1.2						
			8	TW	PH		176							
									2.0					
							175							
										1.4				
			9	SS	7		174							0 2 59 39
							173							
			10	SS	8									
							172							
							171							
							170							
			12	SS	4									
							169							
							168							
167.5														
14.7														

Continued Next Page

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

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

RECORD OF BOREHOLE No PR4

2 OF 3

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766752.2 E:326382.2 ORIGINATED BY PK
DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB
DATUM Geodetic DATE 01.28.10 - 02.03.10 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					GR SA SI CL		
	SILT trace sand, frequent silty clay seams and partings, very loose to compact, brown, wet		14	SS	1		167							0 1 75 24		
							166									
			15	SS	15		165									
164.5 17.7	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel, stiff to very stiff, brown, damp to moist		16	SS	12		164									
							163									
			17	SS	12		162									
							161									
			18	SS	19		160							0 2 80 18		
							159									
			19	SS	21		158									
			20	SS	6		157							0 0 63 37		
							156									
			21	SS	10		155									
							154									
			22	SS	13		153							3 11 63 23		
152.3			23	SS	19											

Continued Next Page

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

METRIC

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

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ONTARIO MOT 1-09-4135 PORT ROBINSON,GPJ ONTARIO MOT.GDT 06/08/10


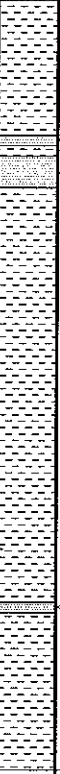
+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

CORE LOG



Terraprobe

Project	Highway 406 Twinning	Orientation	Vertical	Ground Elevation	182.2m	Datum	Geodetic	Borehole No.	PR4
Location	Welland, Ontario	Date Started	February 3, 2010	Completed	February 3, 2010	Logged By	AW	Sheet	1 of 1
W.P.:	280-99-00	Drilling Agency	DDSI	Drill Type	Truck Mount	Core Barrel & Bit Design	NQ	Project No.	1-09-4135

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								WEATHERING	STRENGTH	FRACTURE FREQUENCY	CORE RECOVERY %		CORE SIZE/CASING	MPa UNCONFINED COMPRESSIVE STRENGTH	UNIT WEIGHT (KN/m³)	
				NO. OF SETS	JOINT TYPE	ORIENTATION	SPACING	ROUGHNESS	FILLING	APERTURE	R				Q D %					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
149.7	32.5		Overburden, refer to Borehole Log PR4																	
			Clayey Silt Till, refer to Borehole Log PR4																	
149.2	33.0														#1 TCR 23 SCR 18	0	NQ			
148.7	33.5																			
148.2	34.0		GUELPH FORMATION BEDROCK												#2 TCR 54 SCR 40	0	NQ			
147.7	34.5		DOLOSTONE Unweathered, thinly laminated, light to medium brownish grey, medium strength, argillaceous.	2	BC	FV	VC	SP	T	0 to 1										
147.2	35.0			1 1 1	B B B	F F F	C VC VC	SP SP SU	T T T	0 to 1					#3 TCR 100 SCR 100	41	NQ			
				2	BC	FV	VC	SU	T	0 to 1						#4 TCR 56 SCR 34	0	NQ		
146.7	35.5			1	B	F	C	SP	T	0 to 1										
146.2	36.0																			
145.7	36.5				1	B	F	C	SP	T	0 to 1					#5 TCR 100 SCR 100	62	NQ		
145.2	37.0																			
144.7	37.5			<u>Rubblelized zones at:</u> 34.95-35.00m; 35.05-35.20m; 37.20-37.25m. Rubble indicated by 'c'. <u>Highly fractured zone at:</u> 34.30-34.80m.	1	B	F	VC	SP	T										
					1	B	F	C	SP	T	0 to 1					#6 TCR 100 SCR 100	14	NQ		
144.2	38.0		End of Core Log																	
143.7	38.5																			

Remarks:

LEGEND:

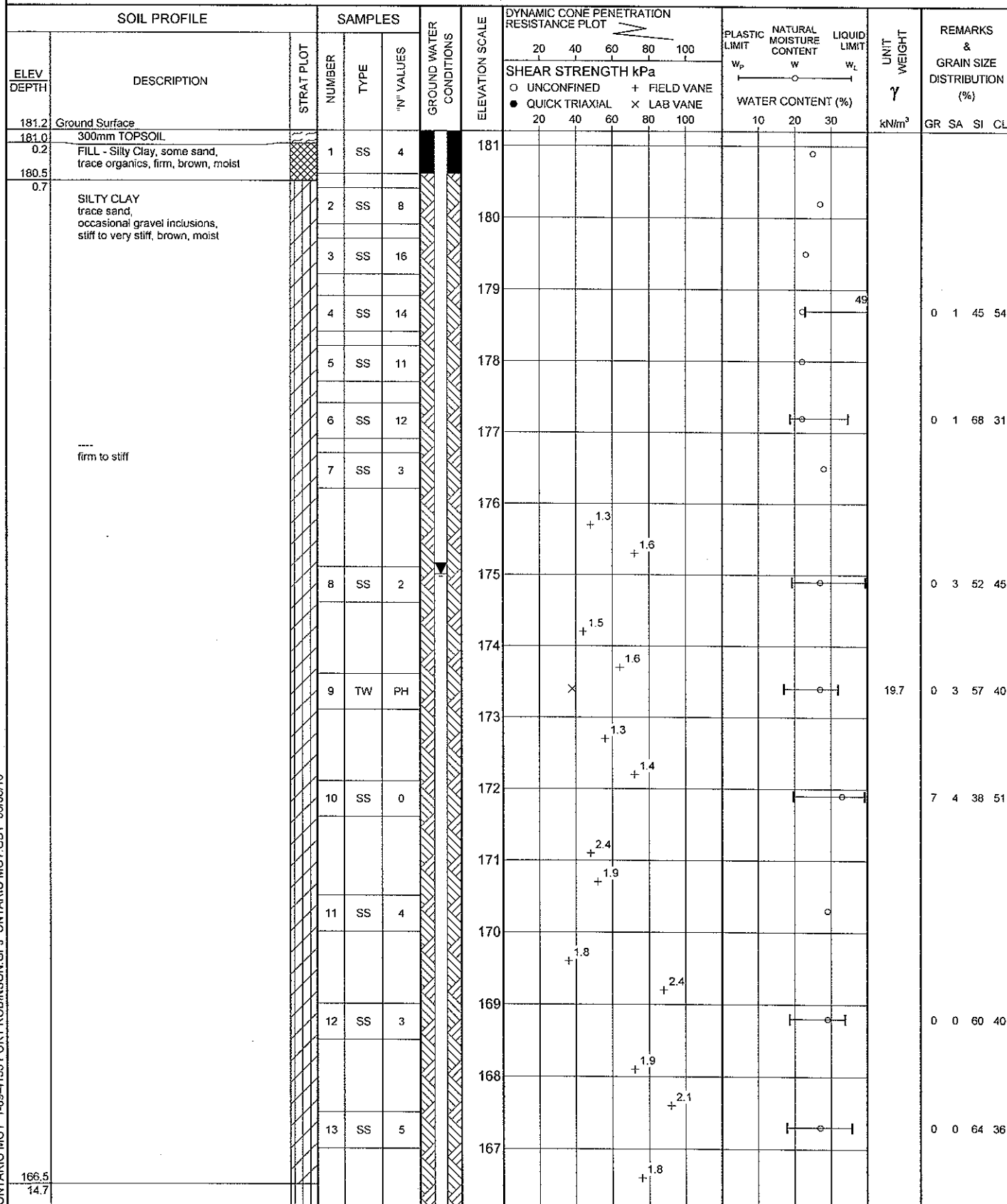
	Dolostone
	Rubble
	Clayey Silt TILL

RECORD OF BOREHOLE No PR5

1 OF 3

METRIC

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



ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

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

METRIC

[illegible]

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

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

RECORD OF BOREHOLE No PR5

3 OF 3

METRIC

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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _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			20	40	60	80	100					
150.7			24	SS	92		151										
30.5	End of Borehole																
	Unable to push vane beyond 19.2m.																
	Resistance to augering at 28.9m.																
	No sample recovery at SS5 and SS23. Sampler redriven and disturbed sample collected.																
	Sampler wet at 6.1m.																
	Borehole was dry (not stabilized) and hole open to full depth on completion.																
	Consolidation test performed on TW 9.																
	Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.																
	Water Level Readings:																
	Date Depth(m) Elevation(m)																
	Jan.19.10 6.4 174.8																
	Jan.27.10 6.2 175.0																
	Feb.08.10 6.3 174.9																
	Feb.19.10 6.2 175.0																

ONTARIO MOT 1-09-4135 PORT ROBINSON.GPJ ONTARIO MOT.GDT 06/08/10

+ 3, X 3. Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

Foundation Investigation Report
Highway 406 Twinning - Port Robinson Road to East Main Street
Agreement No.: 2008-E-0016; W.P. 280-99-00



Bedrock Core Sample

Borehole: PR2

Runs: 1, 2, 3 & 4

Depth: 32.0m – 37.3m



Foundation Investigation Report
Highway 406 Twinning - Port Robinson Road to East Main Street
Agreement No.: 2008-E-0016; W.P. 280-99-00



Bedrock Core Sample

Borehole: PR3

Runs 1, 2, 3 & 4

Depth: 32.0m – 37.1m



Foundation Investigation Report
Highway 406 Twinning - Port Robinson Road to East Main Street
Agreement No.: 2008-E-0016; W.P. 280-99-00



Bedrock Core Sample

Borehole: PR4

Runs: 1, 2, 3, 4, 5 & 6

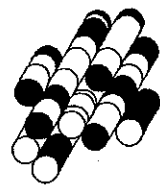
Depth: 32.5m – 38.0m



APPENDIX B

Laboratory Test Results

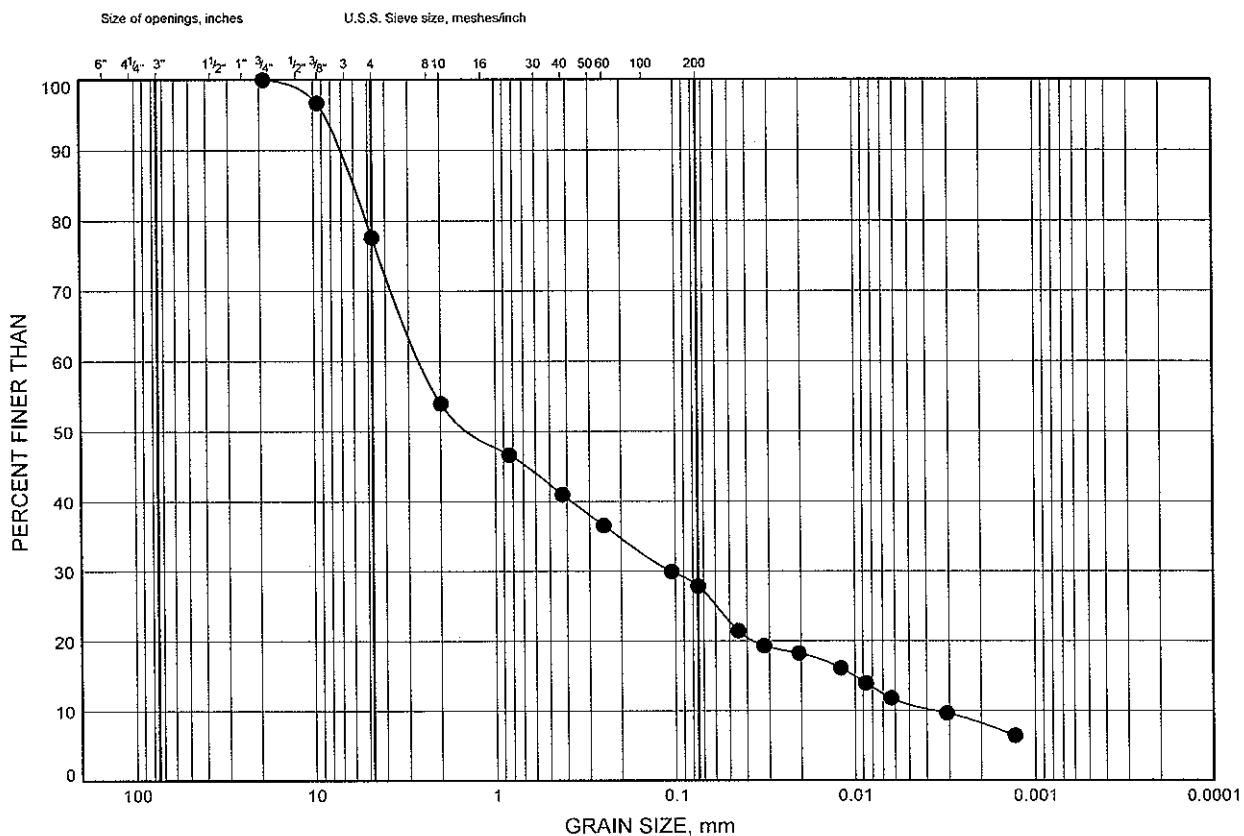
Terraprobe Inc.



GRAIN SIZE DISTRIBUTION

FIGURE B1

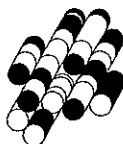
FILL - Gravelly Sand



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	0.3	181.9

Date June 2010
Project 1-09-4135

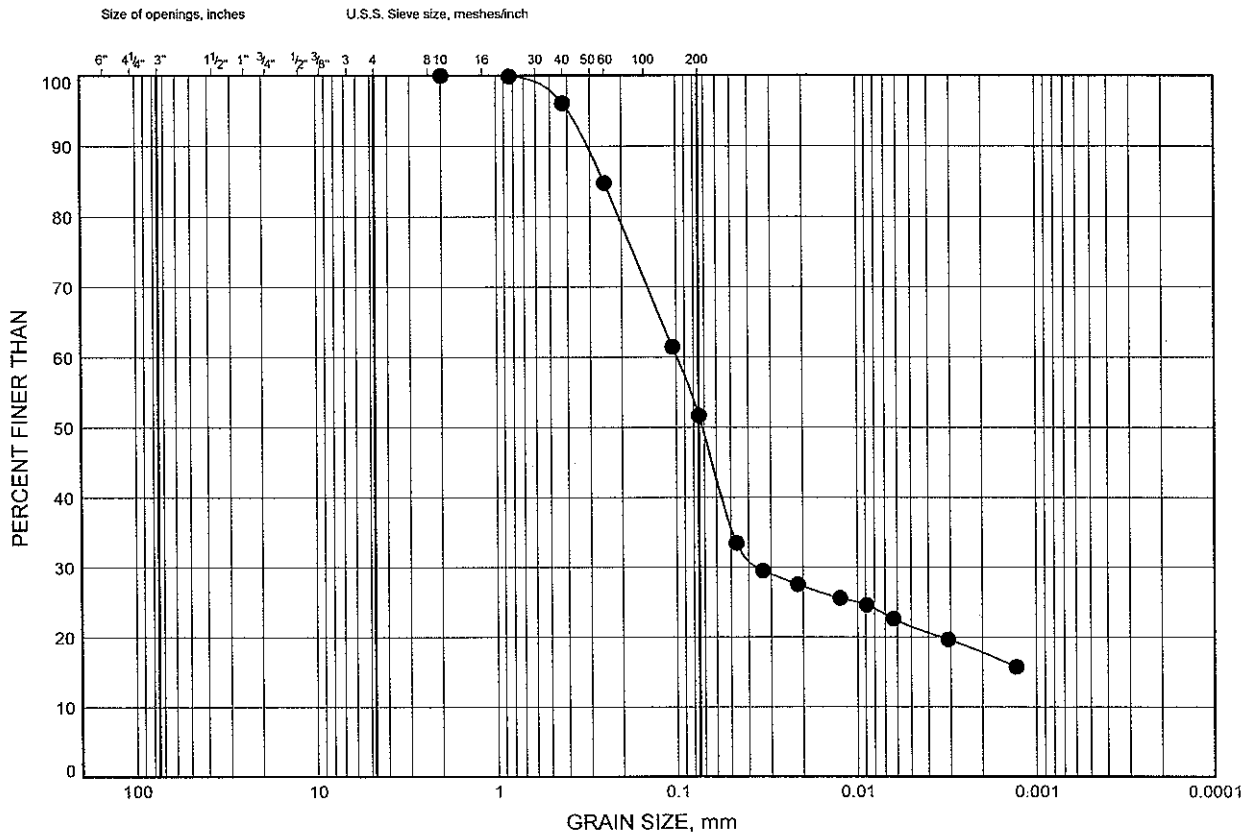


Prep'd DB
Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B2

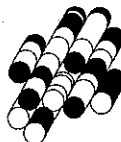
FILL - Silty Sand



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	0.3	181.0

Date June 2010
Project 1-09-4135

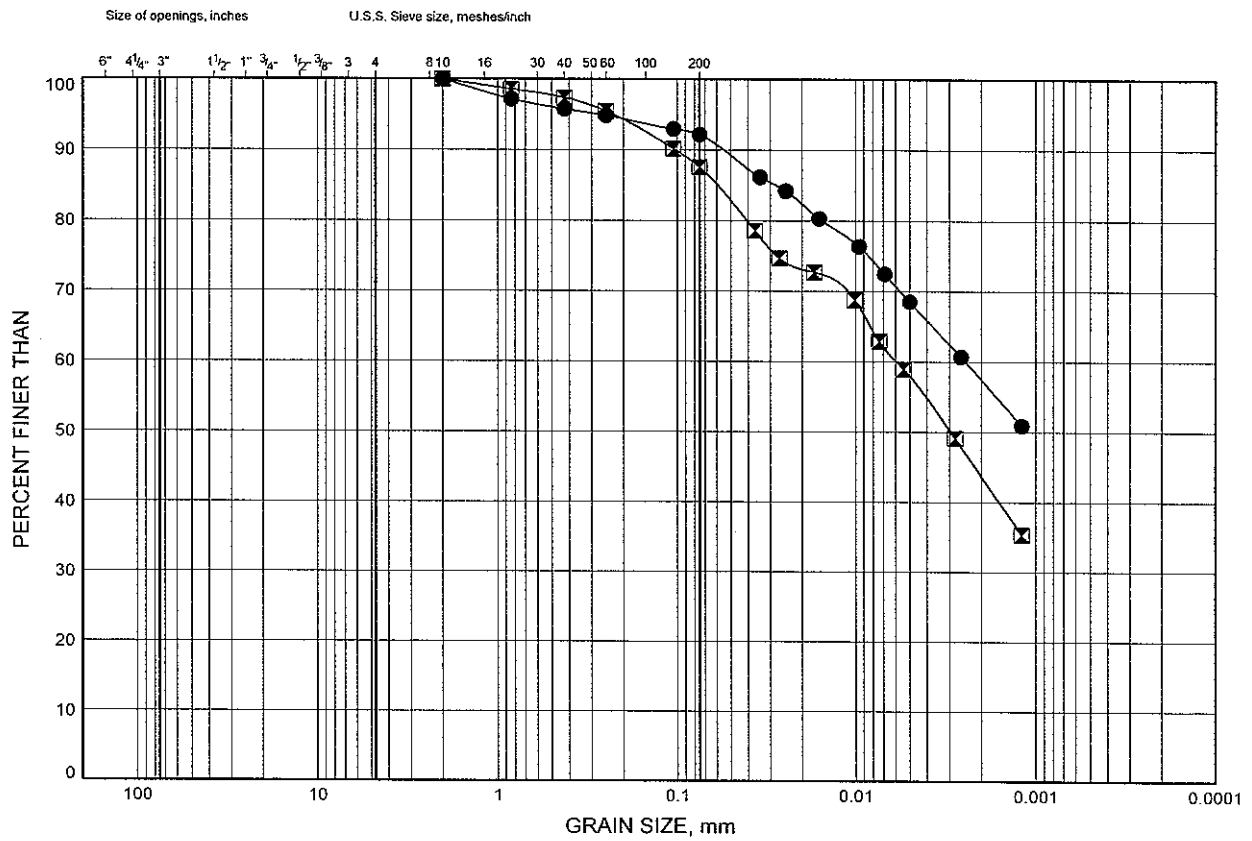


Prep'd DB
Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B3

FILL - Silty Clay

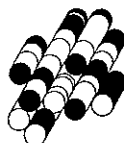


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.0	180.7
☒	PR4	1.7	180.5

Date June 2010

Project 1-09-4135



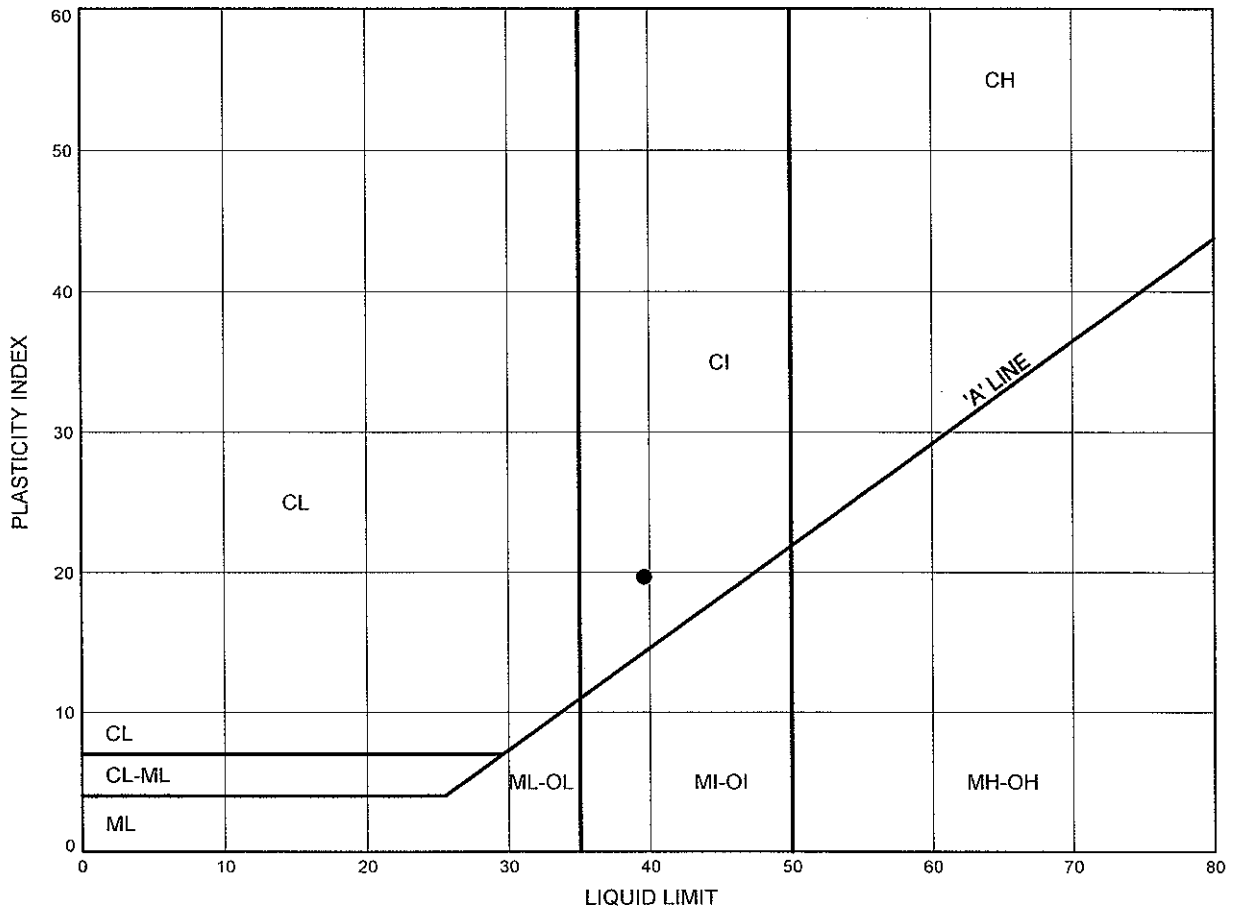
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

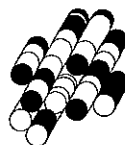
FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	1.7	180.5

Date June 2010

Project 1-09-4135



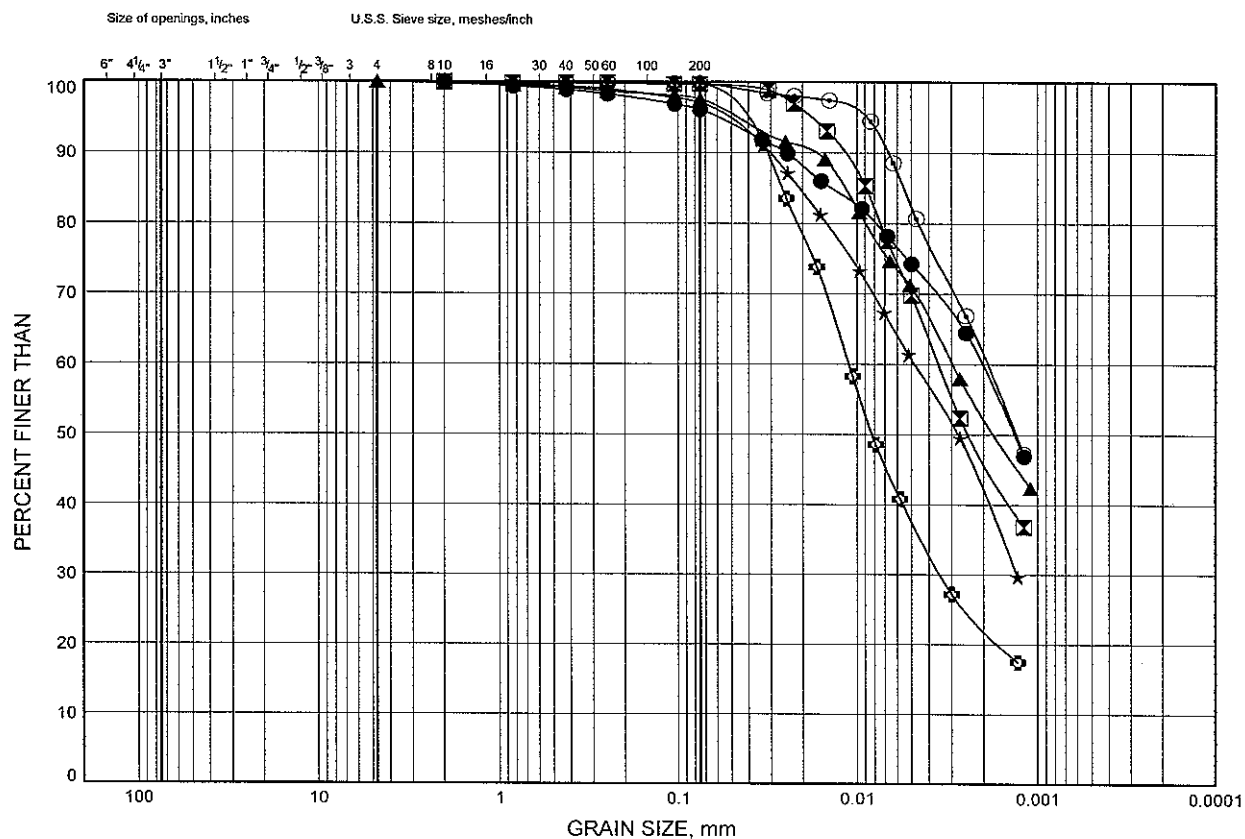
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY CLAY



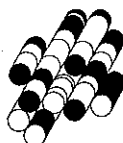
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	PR1	2.5	179.2
⊠	PR1	4.0	177.7
▲	PR1	6.3	175.4
★	PR1	7.8	173.9
⊙	PR1	10.9	170.8
⊛	PR1	13.9	167.8

Date June 2010

Project 1-09-4135



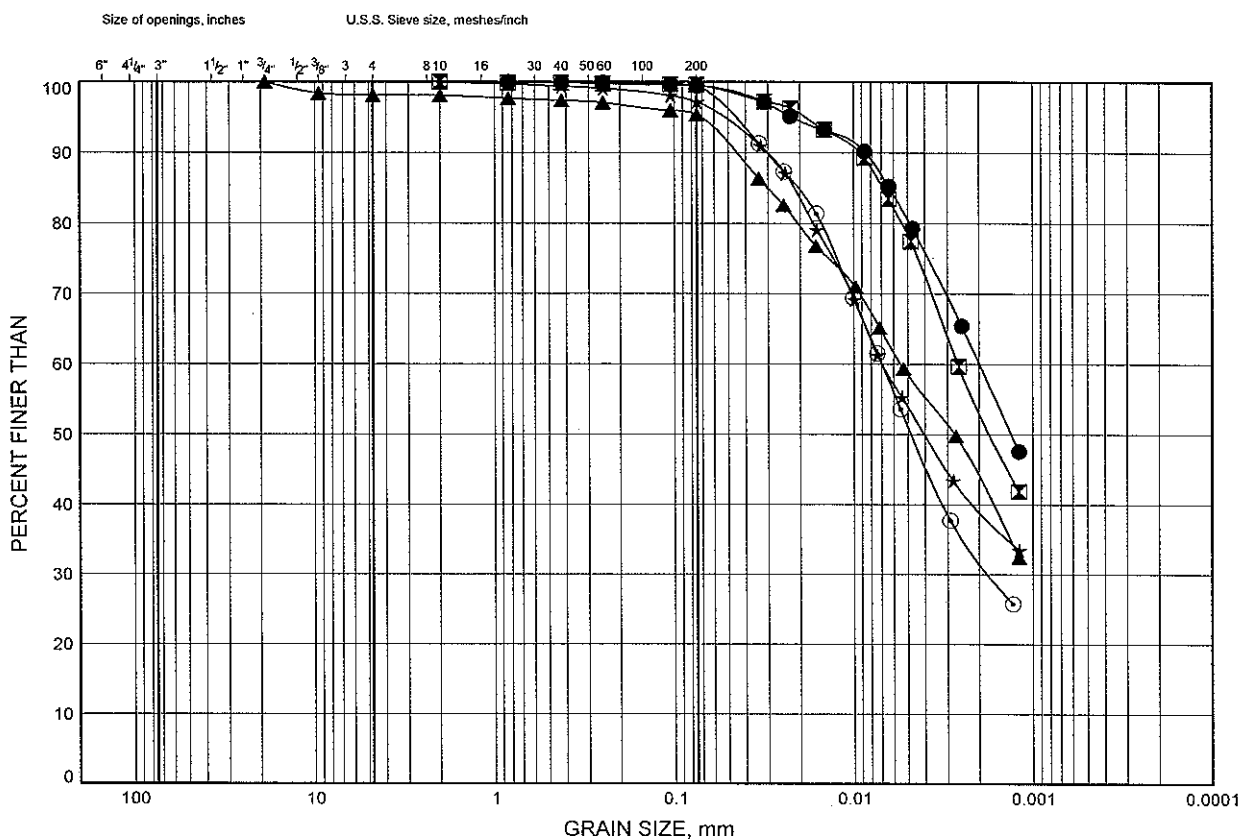
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY CLAY

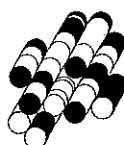


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.7	180.0
⊠	PR2	3.2	178.5
▲	PR2	6.3	175.4
★	PR2	9.3	172.4
⊙	PR2	13.9	167.8

Date June 2010

Project 1-09-4135



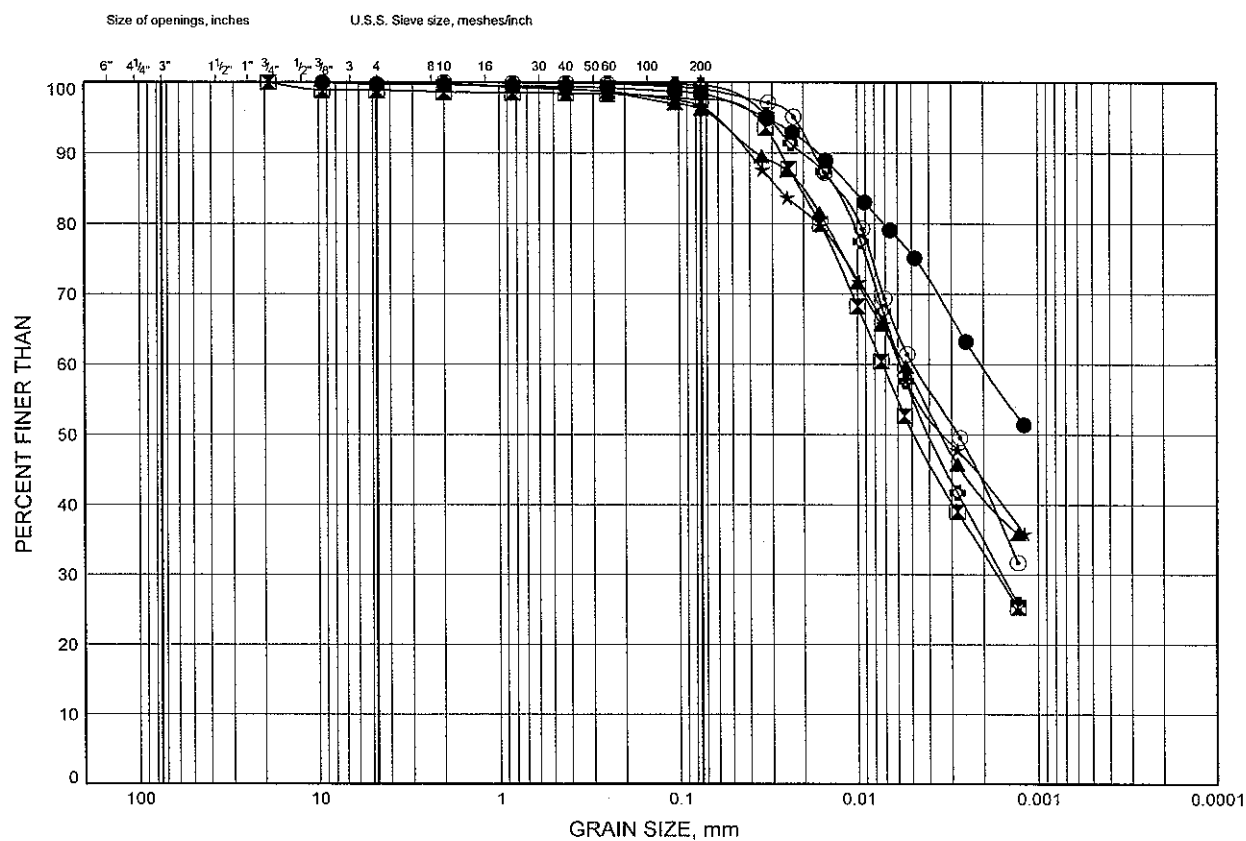
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B7

SILTY CLAY



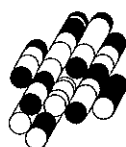
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	PR3	2.5	178.8
⊠	PR3	4.0	177.3
▲	PR3	6.3	175.0
★	PR3	7.8	173.5
⊙	PR3	9.3	172.0
⊛	PR3	12.4	168.9

Date June 2010

Project 1-09-4135



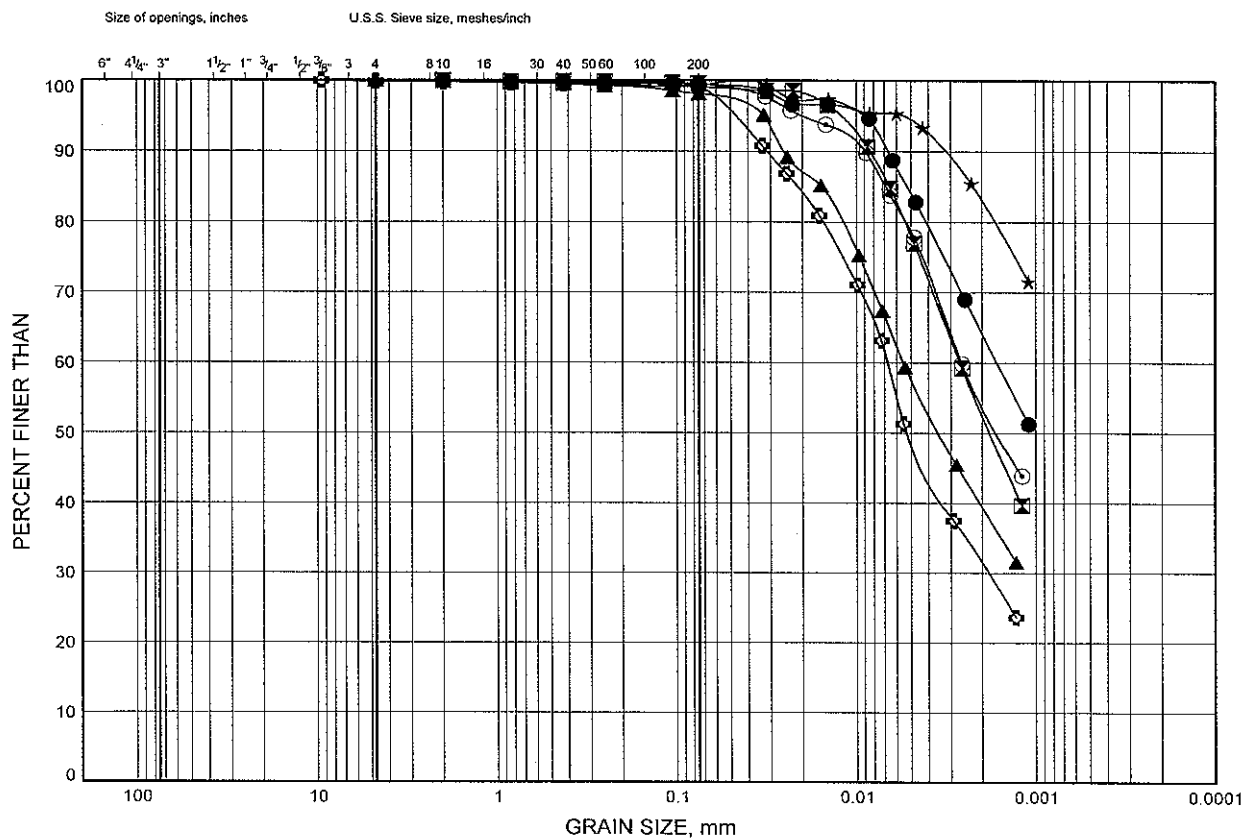
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B8

SILTY CLAY

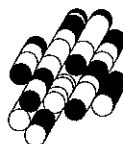


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	2.5	179.7
⊠	PR4	4.0	178.2
▲	PR4	7.8	174.4
★	PR4	10.9	171.3
⊙	PR5	2.5	178.7
⊗	PR5	4.0	177.2

Date June 2010

Project 1-09-4135



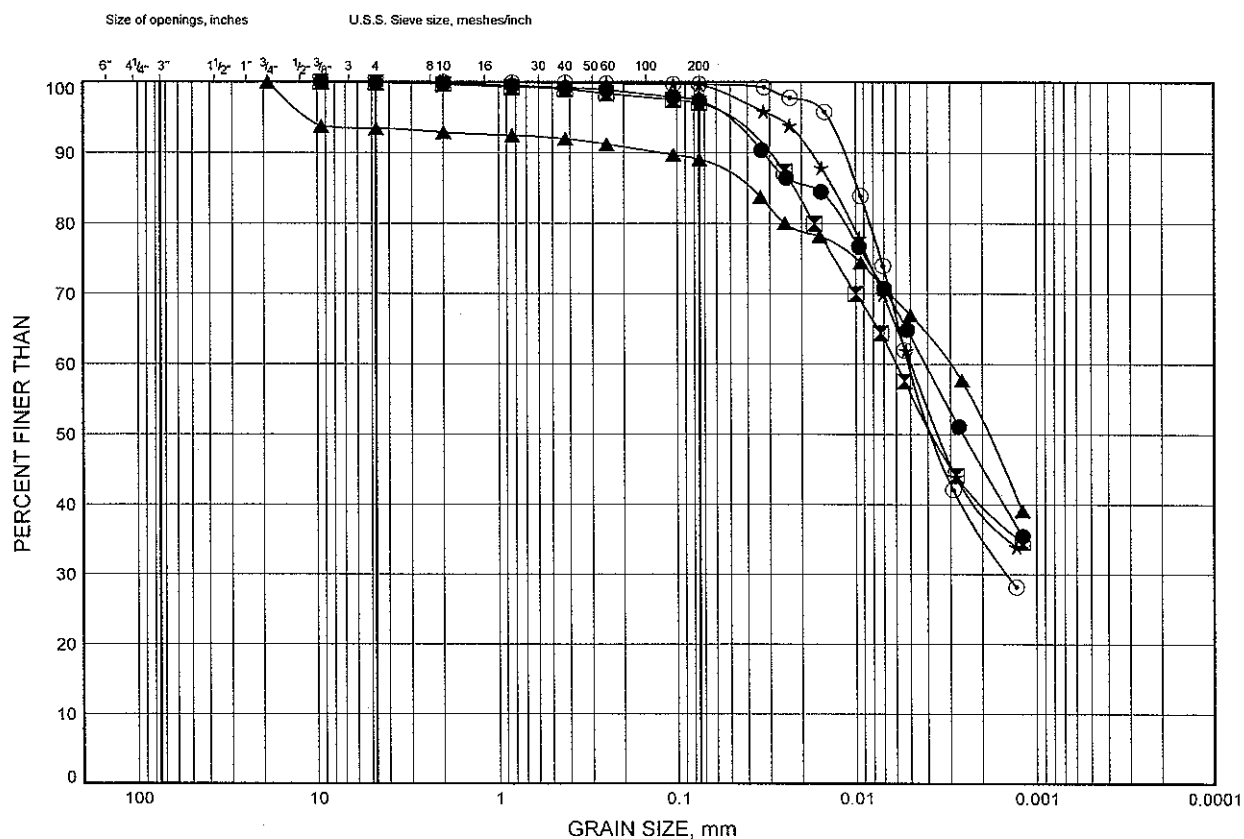
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILTY CLAY



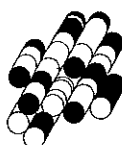
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	PR5	6.3	174.9
⊠	PR5	7.8	173.4
▲	PR5	9.3	171.9
★	PR5	12.4	168.8
⊙	PR5	13.9	167.3

Date June 2010

Project 1-09-4135



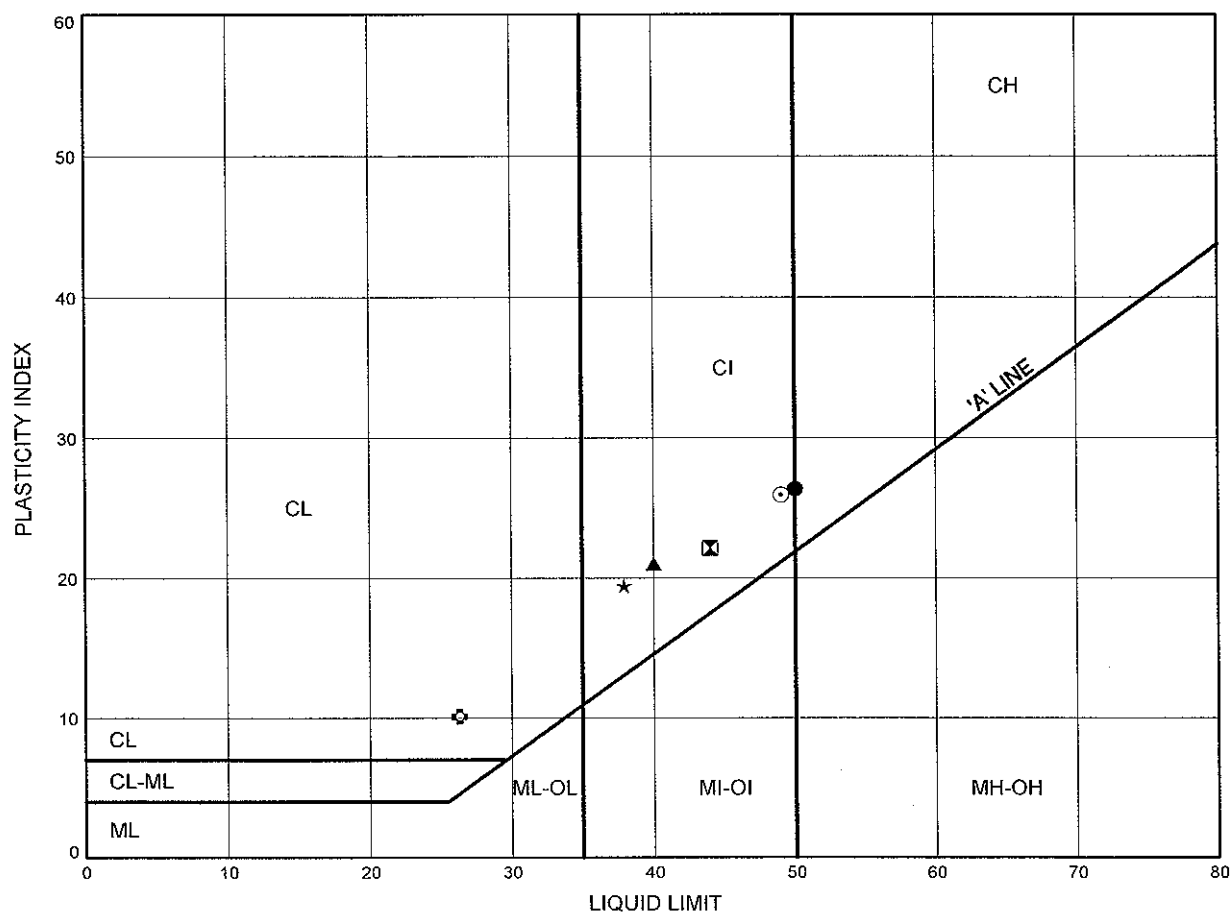
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B10

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR1	2.5	179.2
⊠	PR1	4.0	177.7
▲	PR1	6.3	175.4
★	PR1	7.8	173.9
⊙	PR1	10.9	170.8
⊛	PR1	13.9	167.8

Date June 2010
Project 1-09-4135

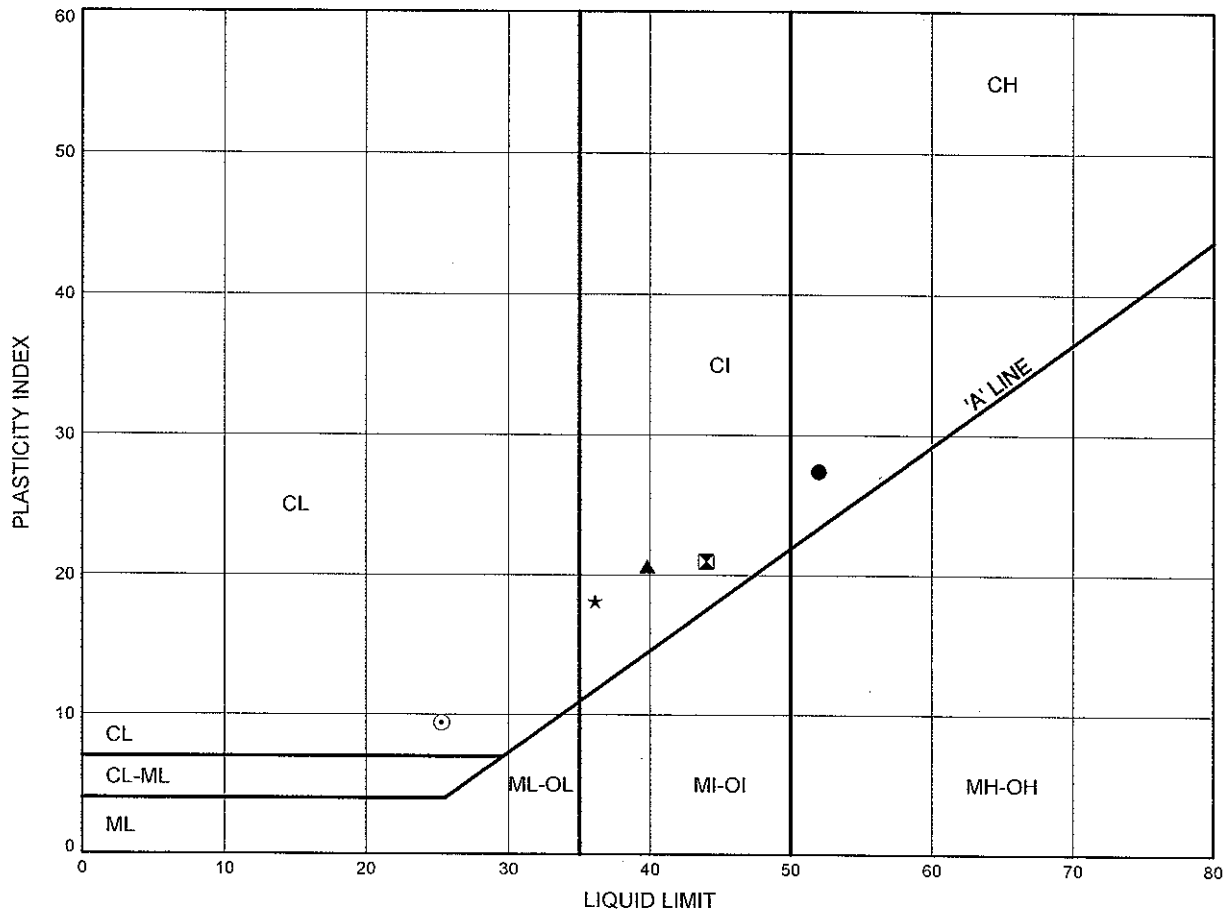


Prep'd DB
Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B11

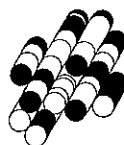
SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.7	180.0
⊠	PR2	3.2	178.5
▲	PR2	6.3	175.4
★	PR2	9.3	172.4
⊙	PR2	13.9	167.8

Date June 2010

Project 1-09-4135



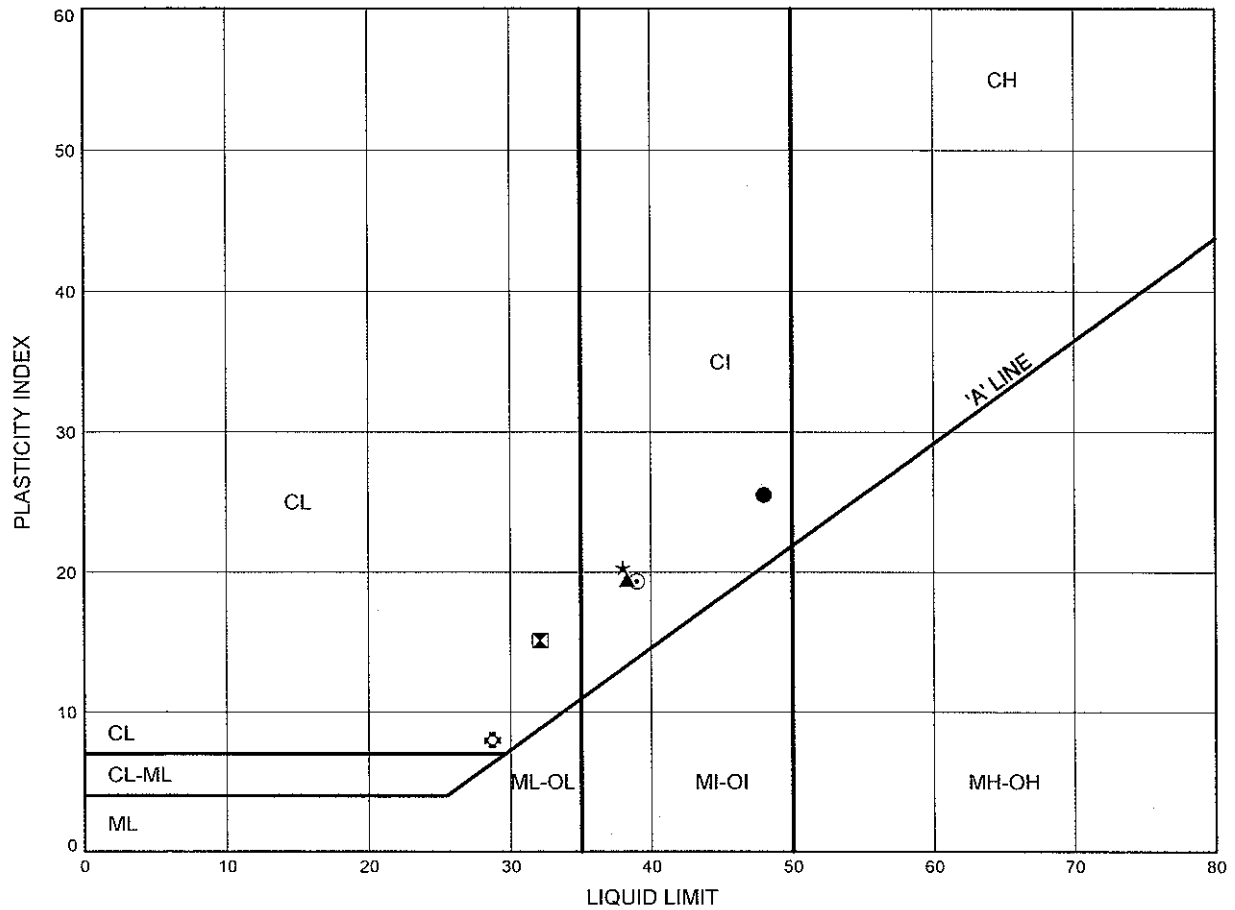
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

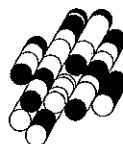
FIGURE B12

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	2.5	178.8
⊠	PR3	4.0	177.3
▲	PR3	6.3	175.0
★	PR3	7.8	173.5
⊙	PR3	9.3	172.0
⊛	PR3	12.4	168.9

Date June 2010
Project 1-09-4135

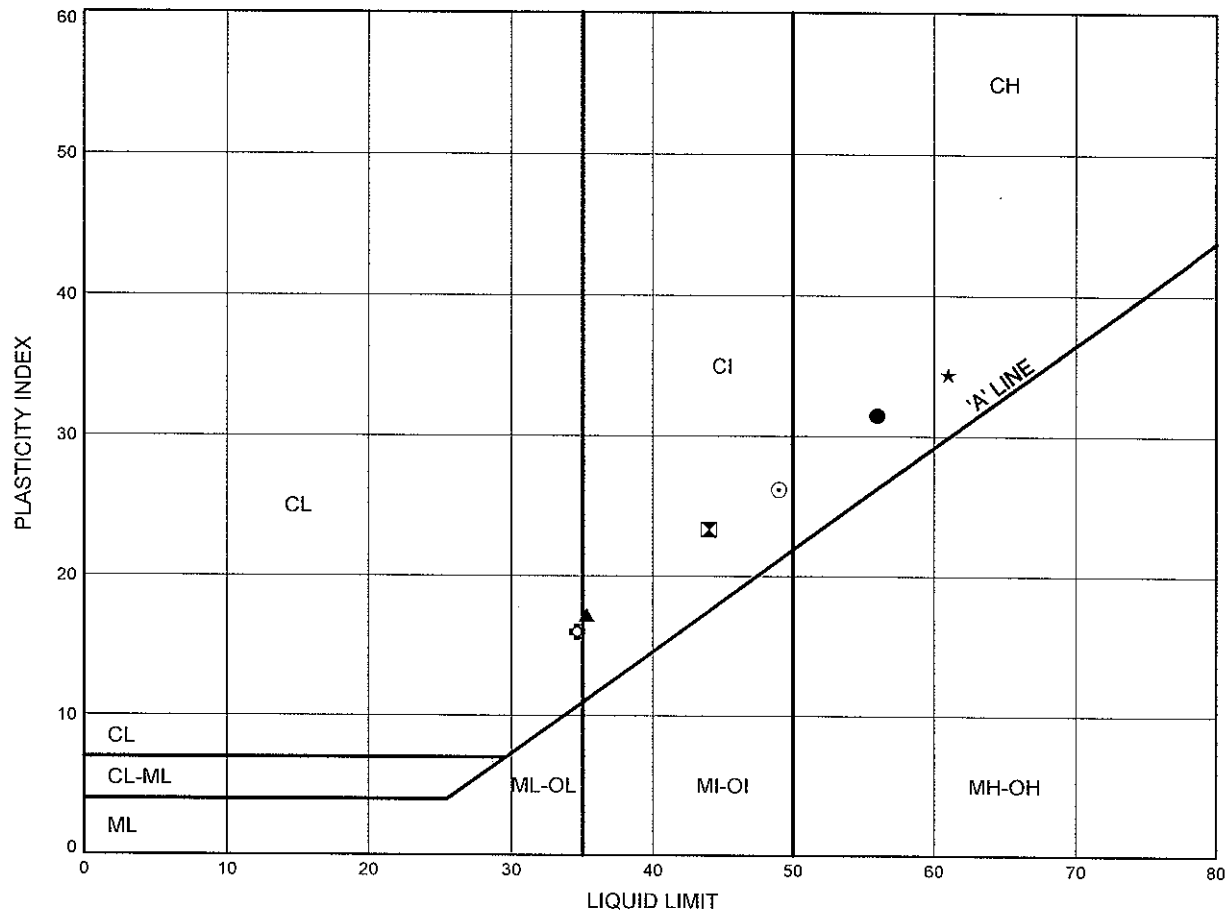


Prep'd DB
Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B13

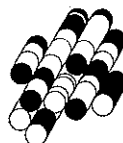
SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	2.5	179.7
⊠	PR4	4.0	178.2
▲	PR4	7.8	174.4
★	PR4	10.9	171.3
⊙	PR5	2.5	178.7
⊛	PR5	4.0	177.2

Date June 2010

Project 1-09-4135



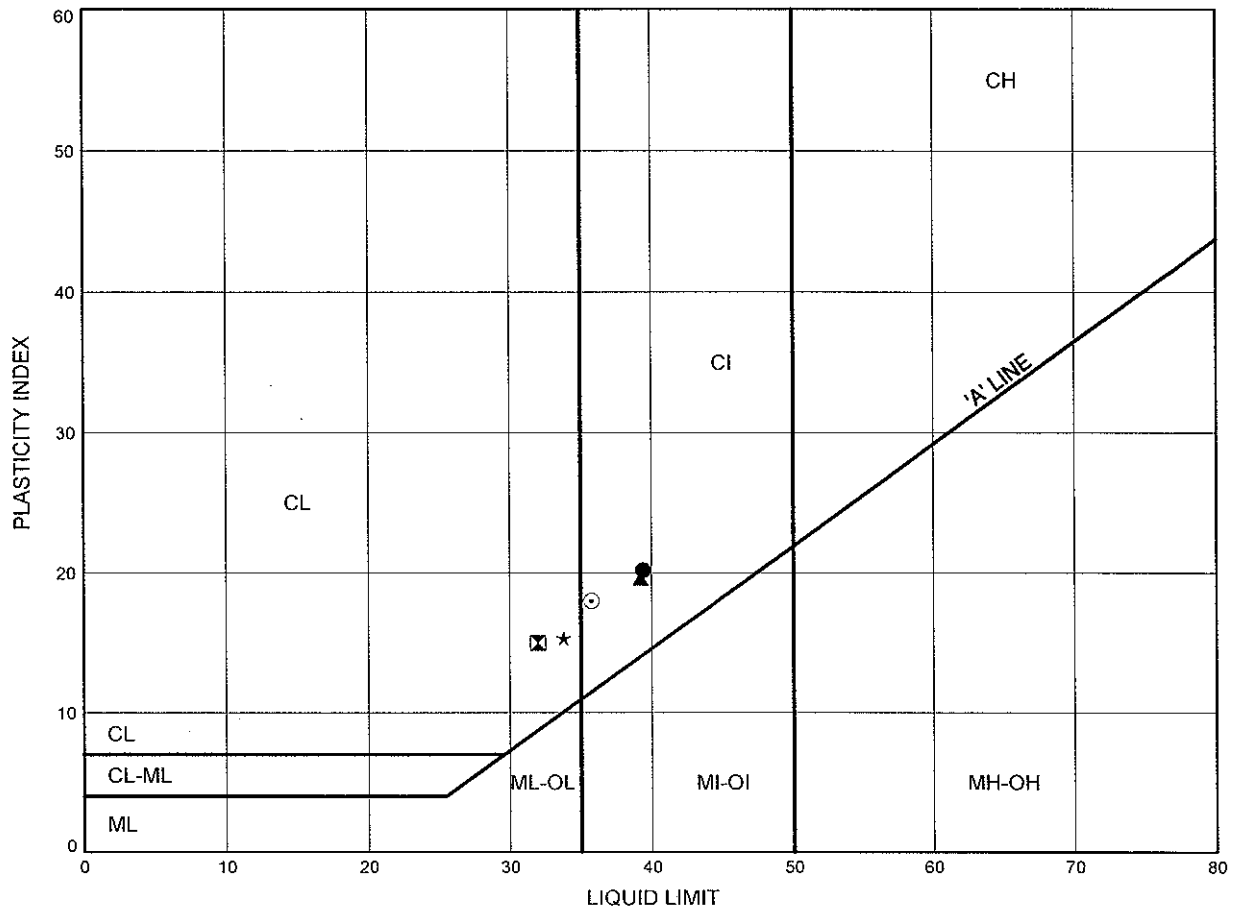
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B14

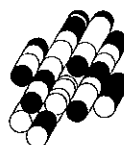
SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR5	6.3	174.9
⊠	PR5	7.8	173.4
▲	PR5	9.3	171.9
★	PR5	12.4	168.8
⊙	PR5	13.9	167.3

Date June 2010

Project 1-09-4135



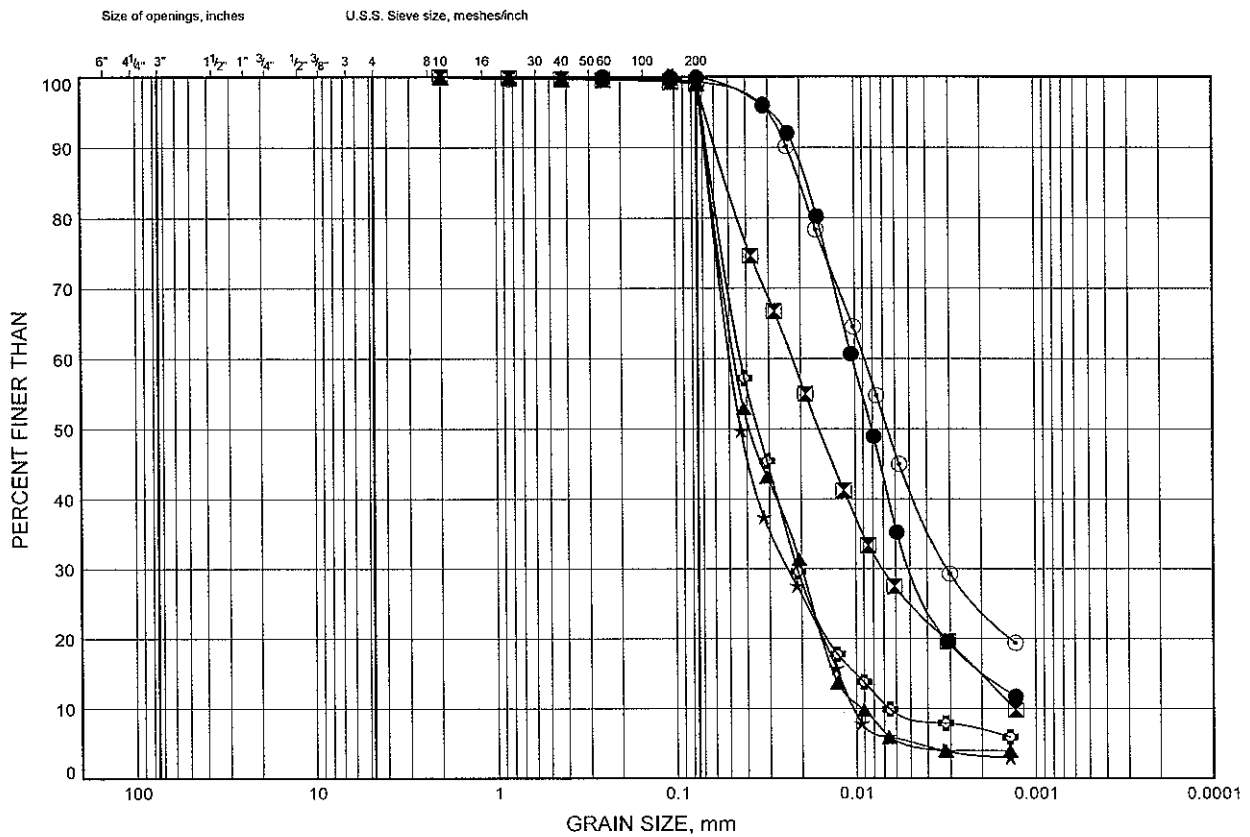
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B15

SILT



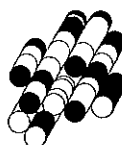
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	PR1	15.4	166.3
⊠	PR1	17.0	164.7
▲	PR2	17.0	164.7
★	PR3	15.4	165.9
⊙	PR4	15.4	166.8
⊠	PR5	15.4	165.8

Date June 2010

Project 1-09-4135



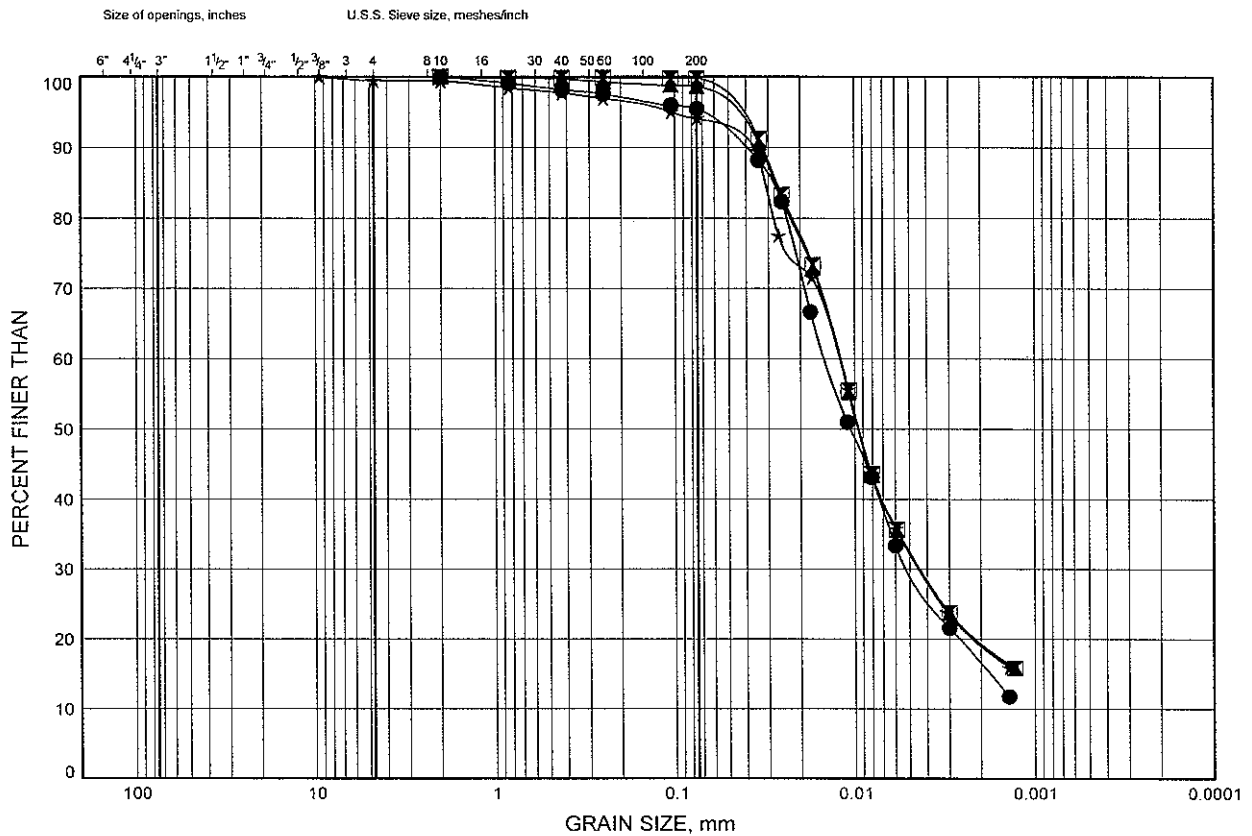
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B16

SILTY CLAY TO CLAYEY SILT

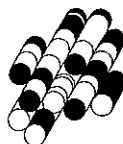


SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
--------	----------	-----------	---------------

●	PR2	20.0	161.7
⊠	PR2	23.1	158.6
▲	PR2	26.1	155.6
★	PR3	18.5	162.8

Date June 2010

Project 1-09-4135



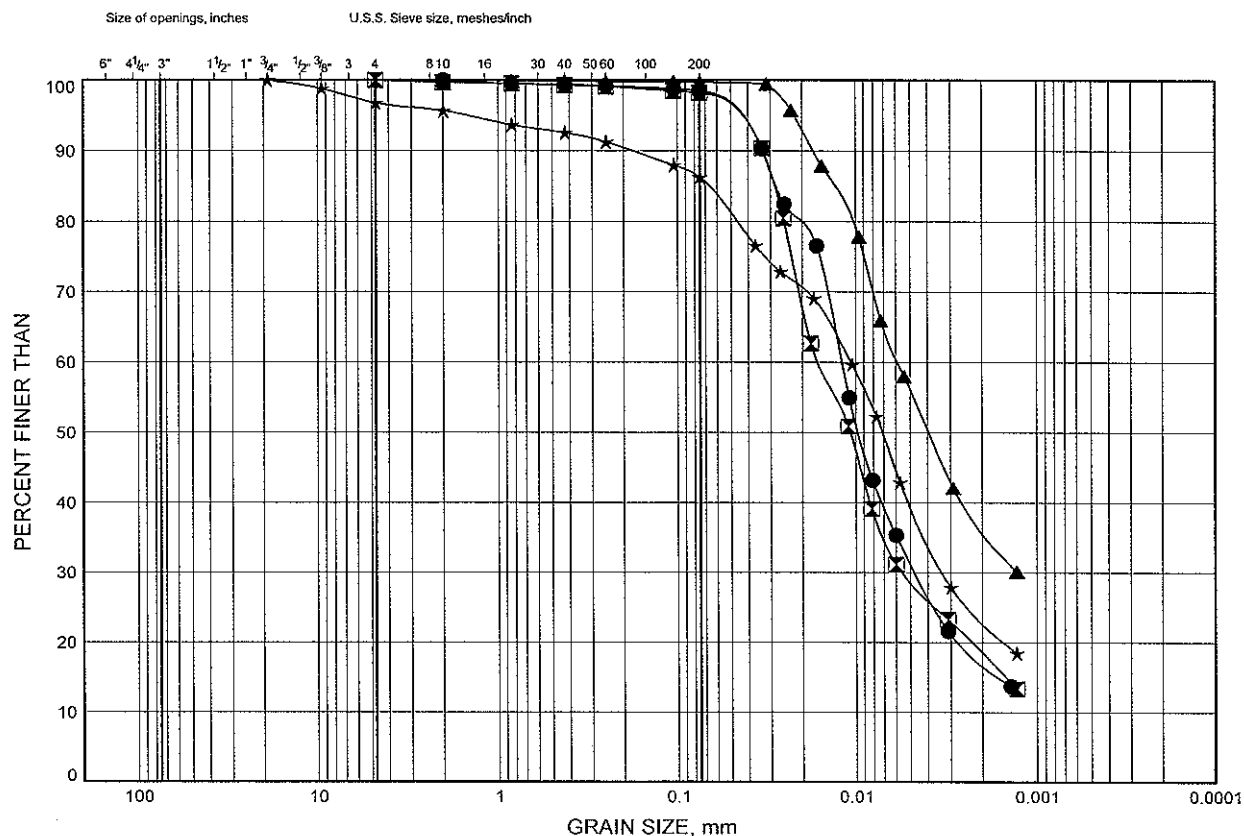
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B17

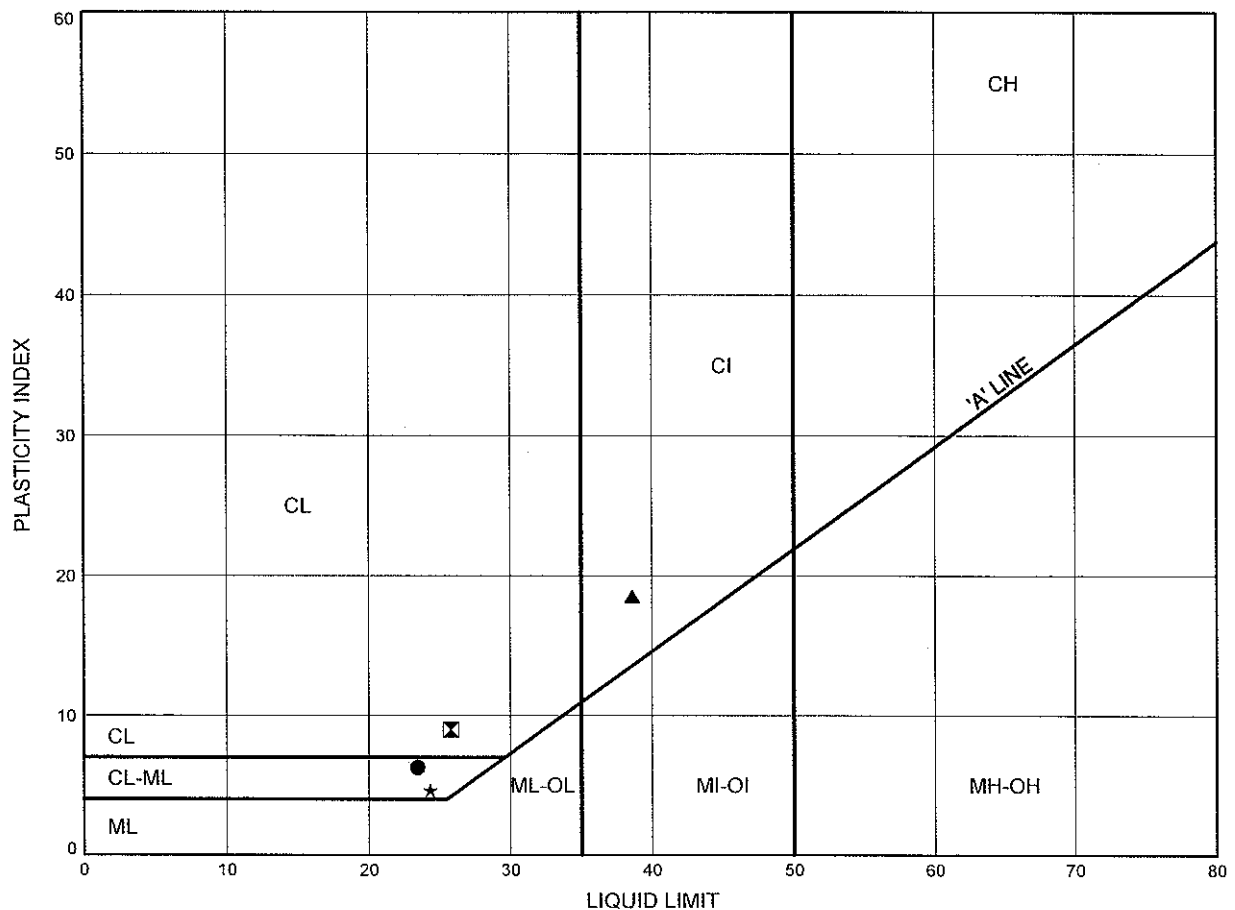
SILTY CLAY TO CLAYEY SILT



ATTERBERG LIMITS TEST RESULTS

FIGURE B18

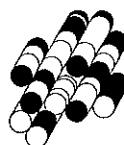
SILTY CLAY TO CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	20.0	161.7
⊠	PR2	23.1	158.6
▲	PR2	26.1	155.6
★	PR3	18.5	162.8

Date June 2010

Project 1-09-4135



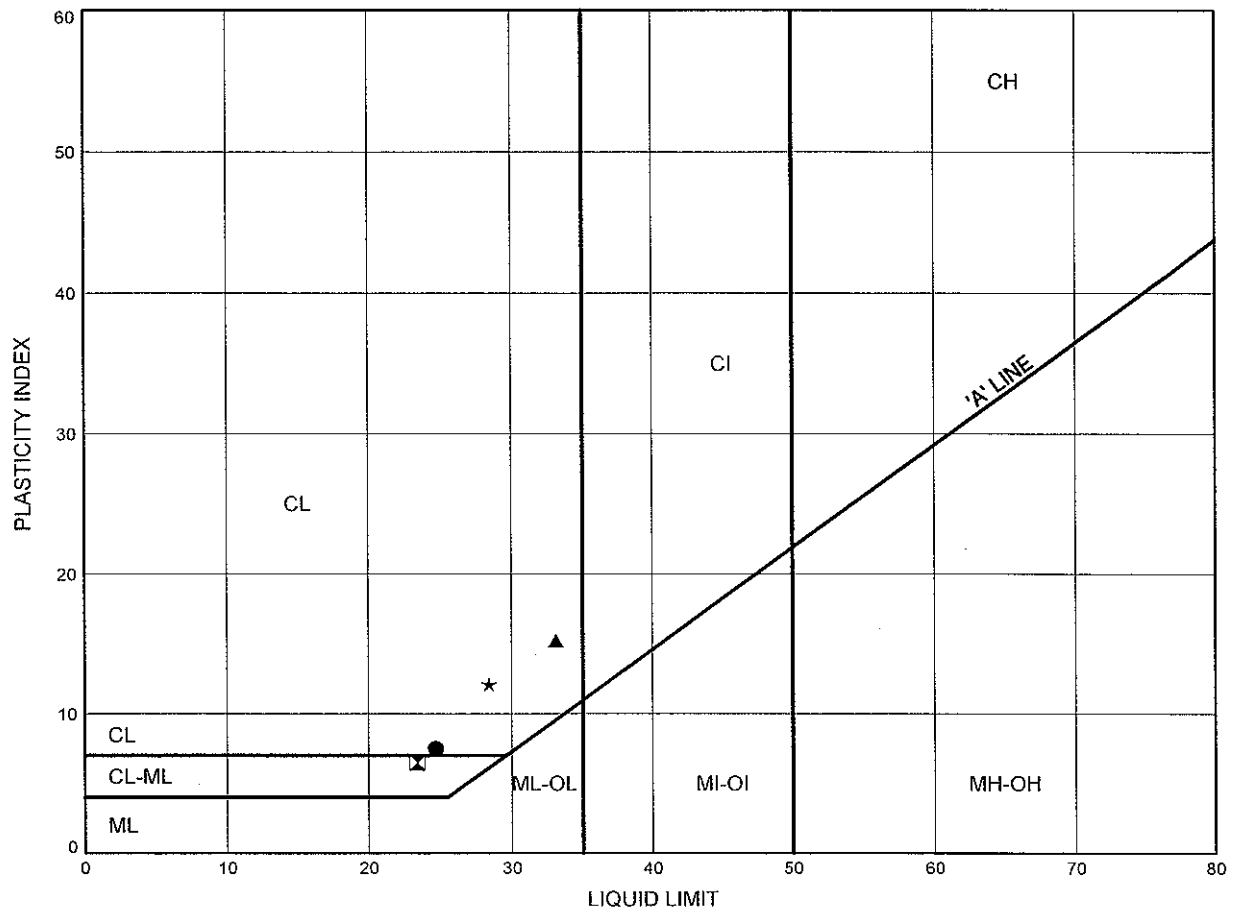
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B19

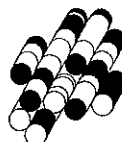
SILTY CLAY TO CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	23.1	158.2
⊠	PR4	21.5	160.7
▲	PR4	24.6	157.6
★	PR4	27.6	154.6

Date June 2010

Project 1-09-4135



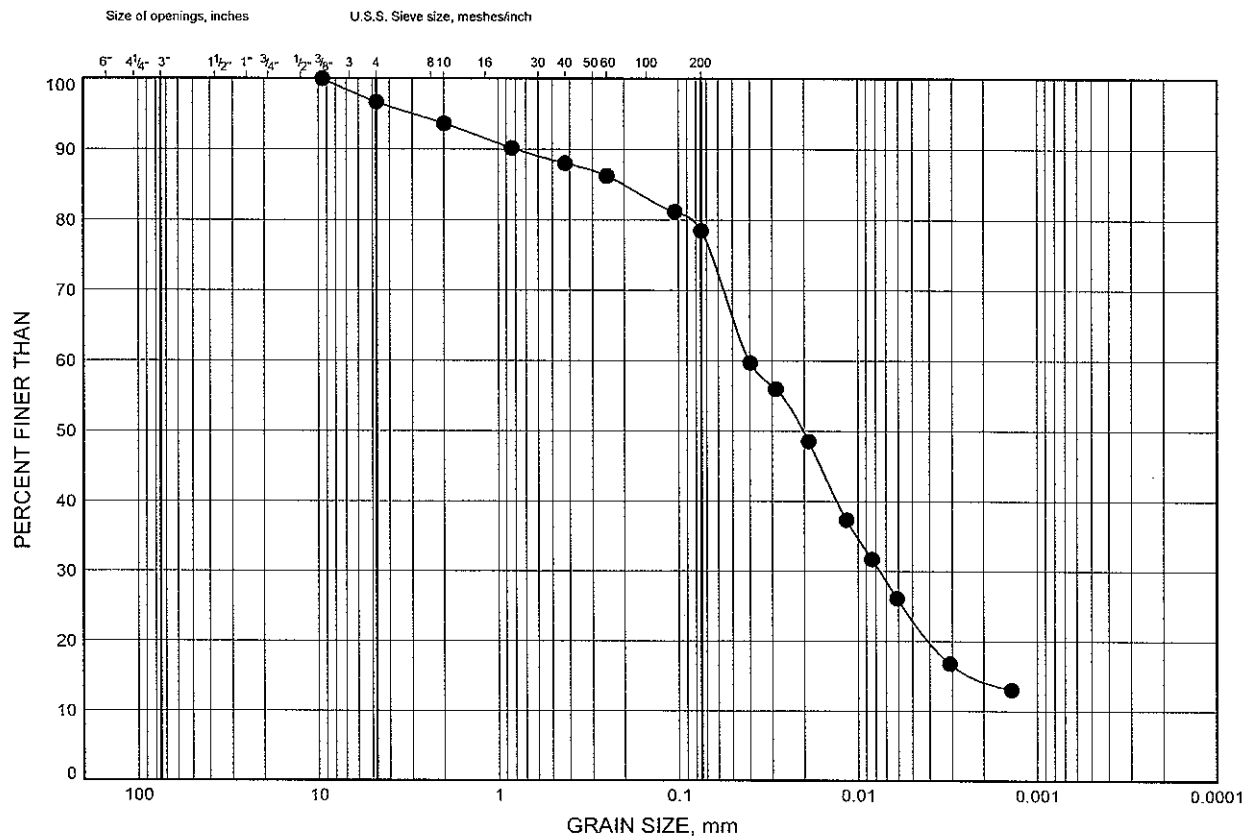
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B20

CLAYEY SILT TILL

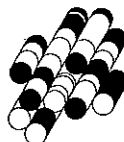


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	27.6	153.7

Date June 2010

Project 1-09-4135



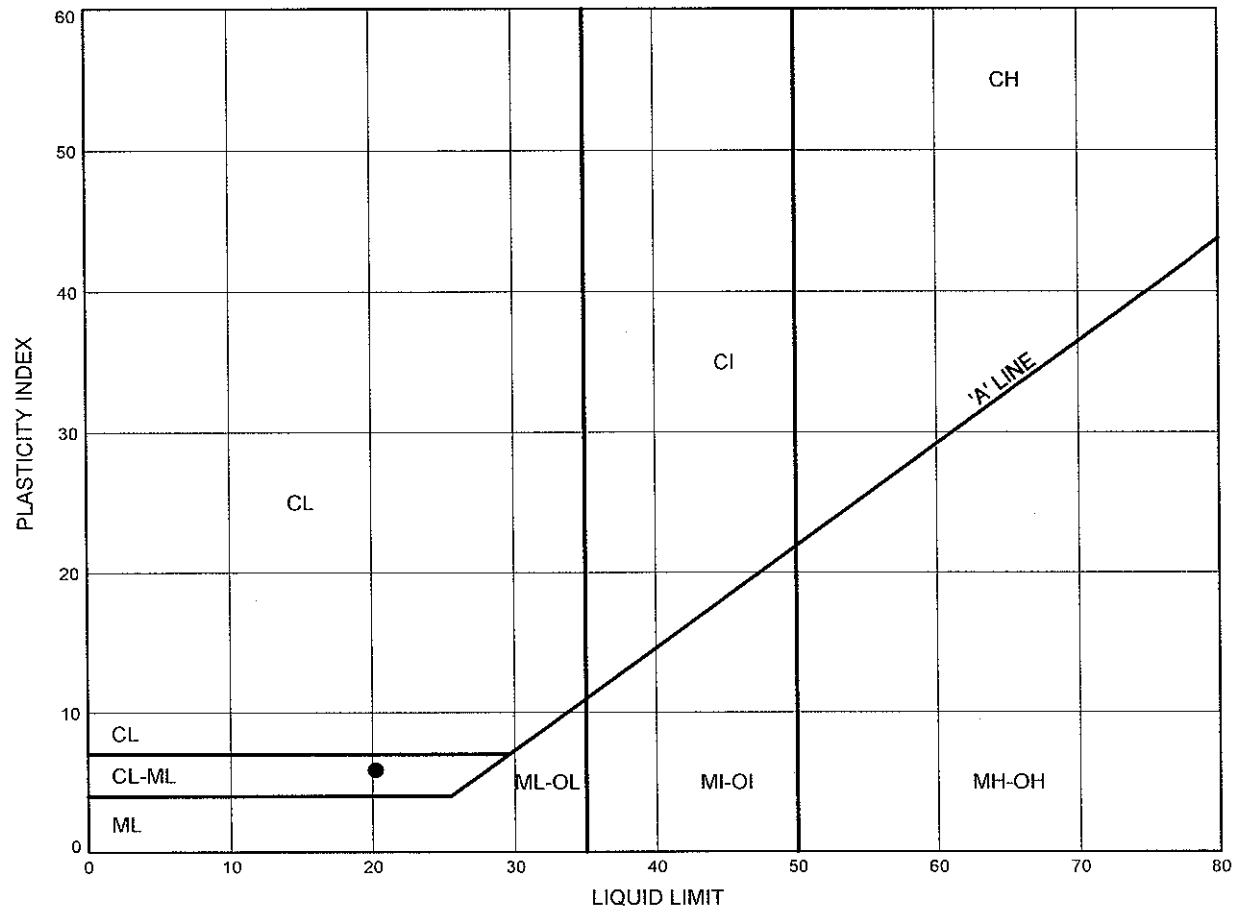
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B21

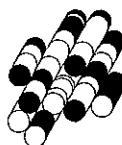
CLAYEY SILT TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	27.6	153.7

Date June 2010

Project 1-09-4135



Prep'd DB

Chkd. MP

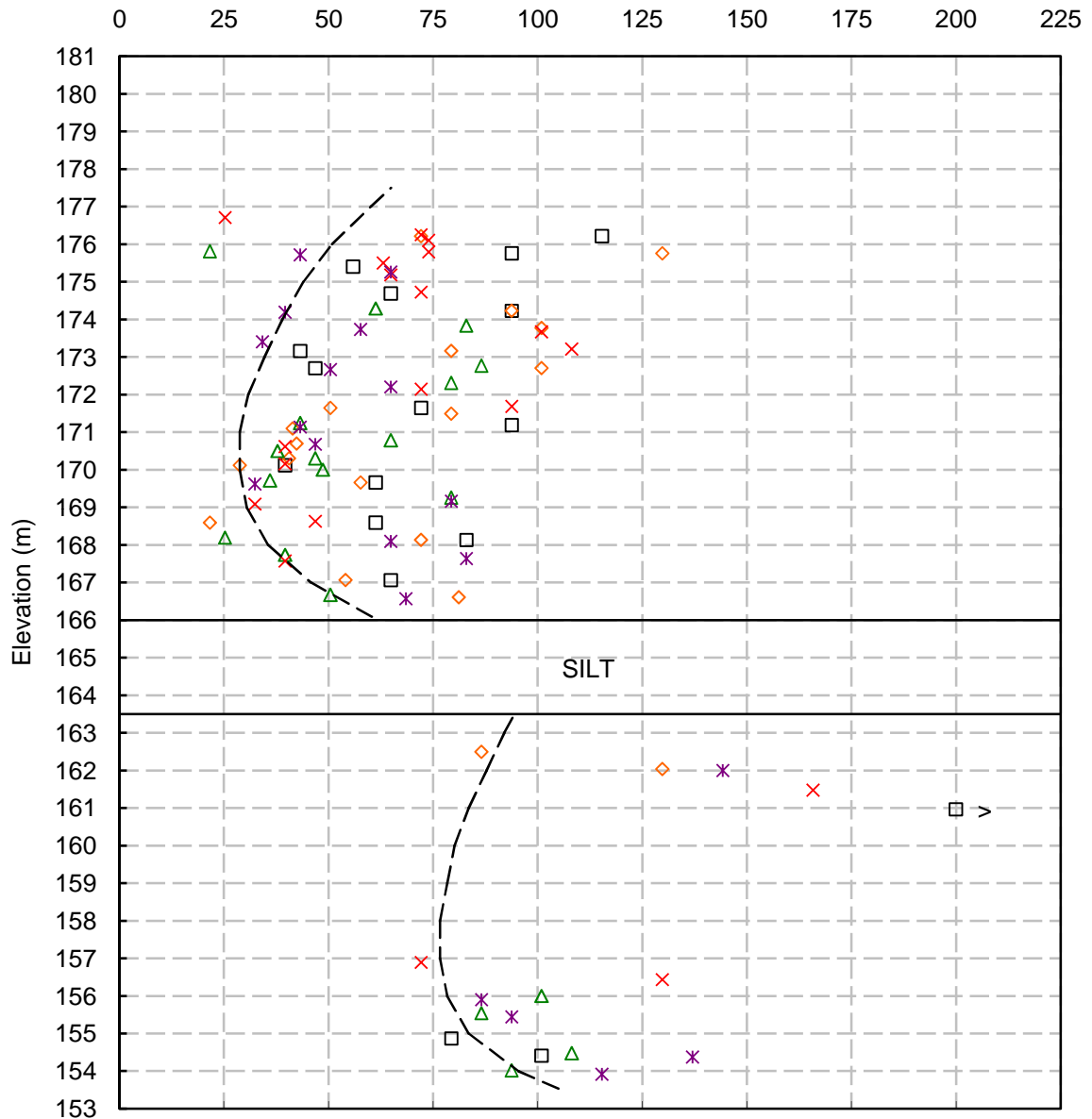
CORRECTED UNDRAINED SHEAR STRENGTH

FIGURE B22

HWY 406 TWINNING - PORT ROBINSON ROAD

Silty Clay

Corrected Cu (kPa)



□PR1

◇PR2

△PR3

×PR4

*PR5

Field Shear Vane Correction

Morris & Williams (1994)

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

Applied Correction Factors

0.72 (Elev.>177.5m)

0.90 (Elev.<177.5m)

Project No. : 1-09-4135

Date : September, 2010



Terraprobe Inc.

Prepared By : HW

Checked By : RA

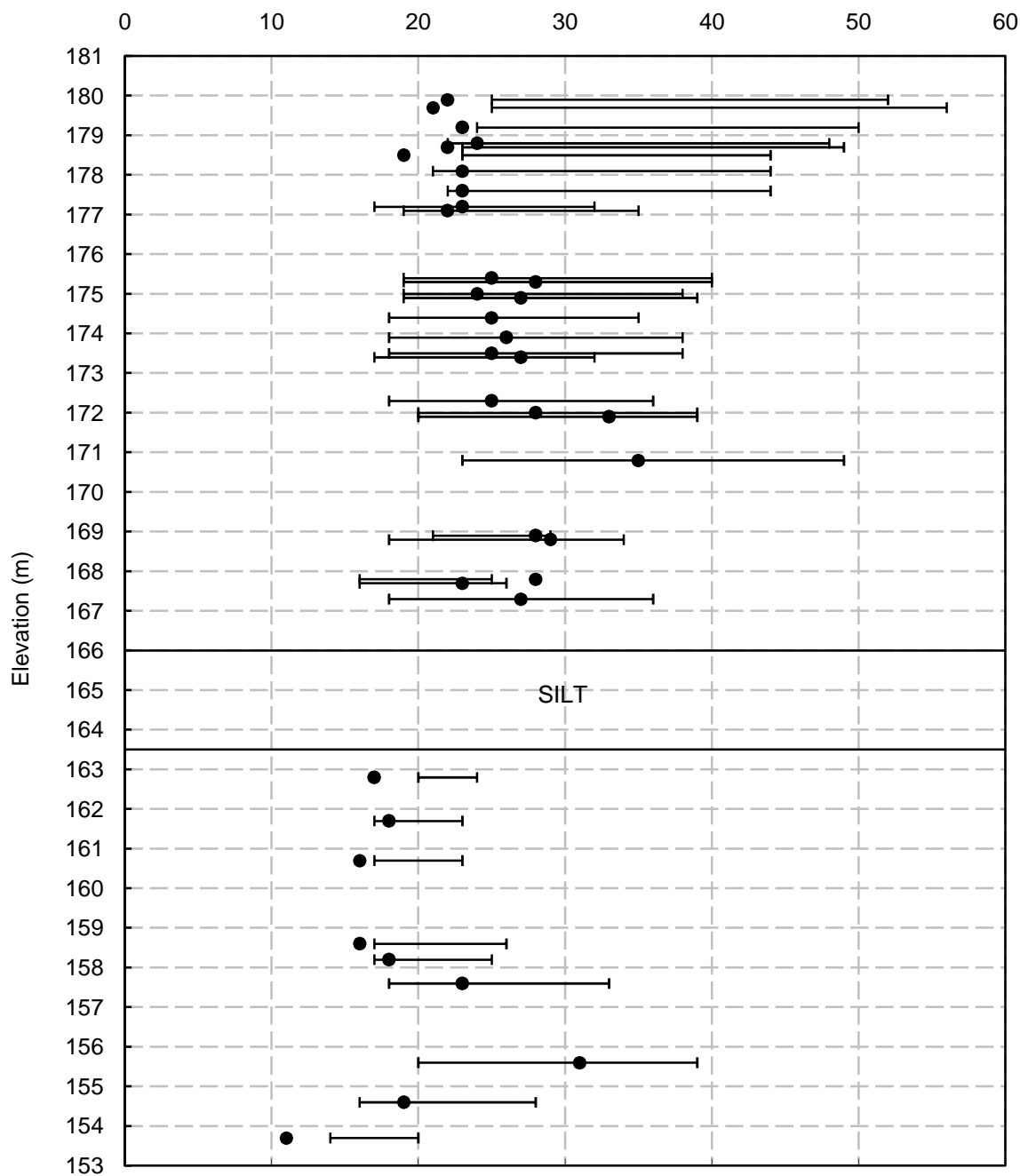
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B23

HWY 406 TWINNING - PORT ROBINSON ROAD

Silty Clay

Atterberg Limits & Water Contents (%)



Project No. : 1-09-4135

Date : September, 2010



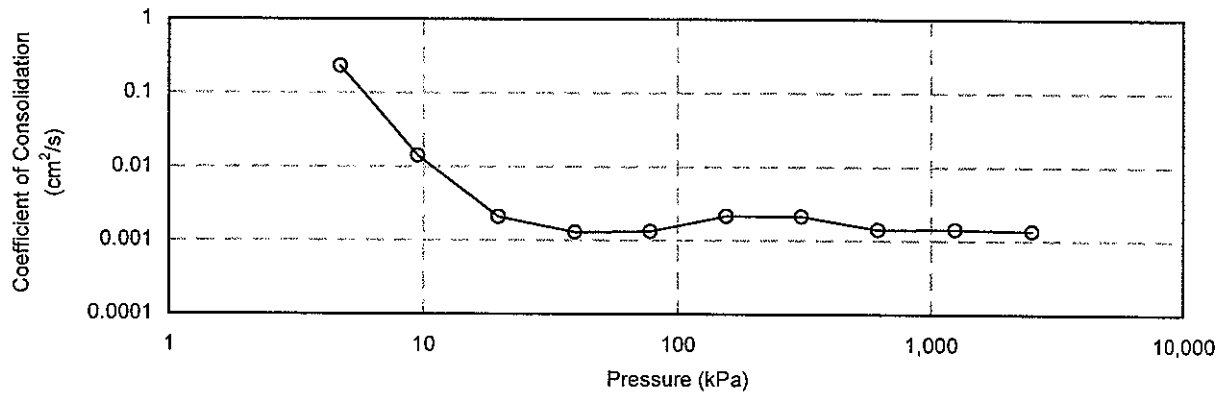
Prepared By : HW

Checked By : RA

CONSOLIDATION TEST

Cv vs Pressure

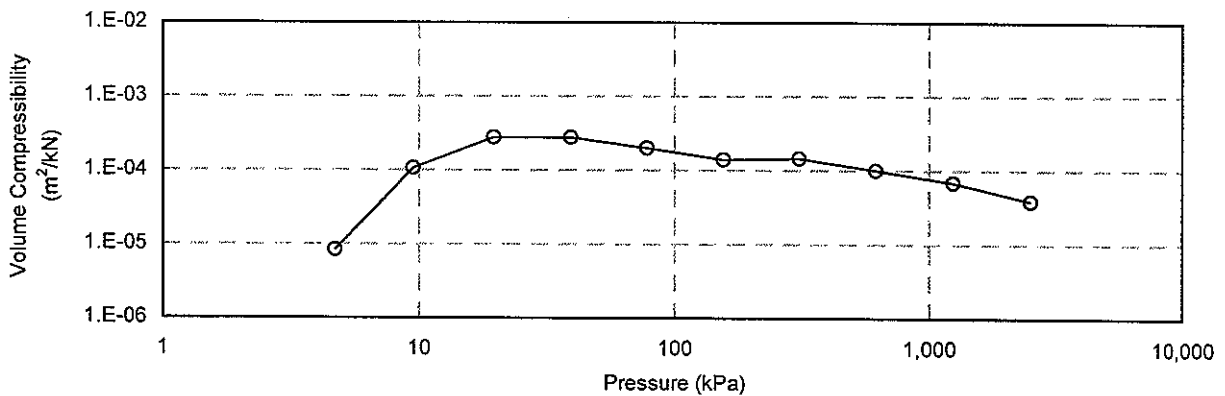
PR1, TW8



CONSOLIDATION TEST

mv vs Pressure

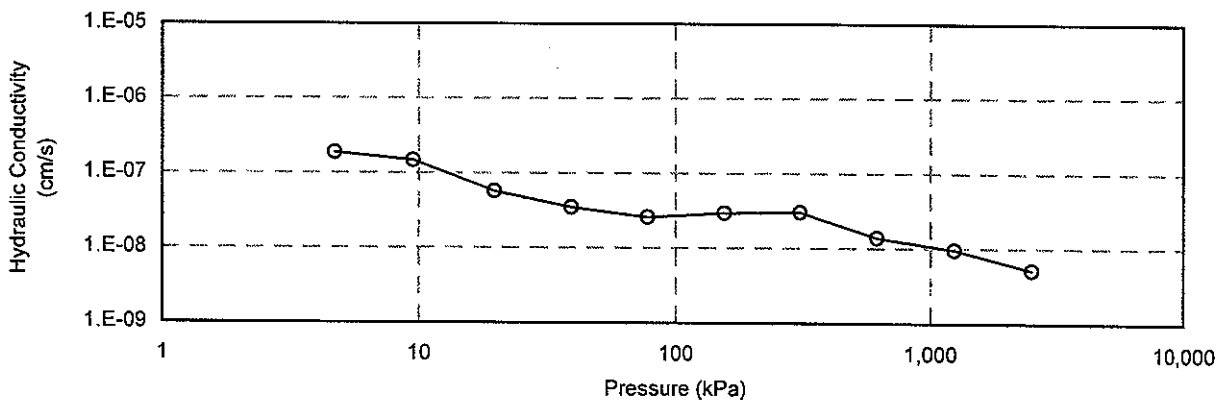
PR1, TW8



CONSOLIDATION TEST

k vs Pressure

PR1, TW8



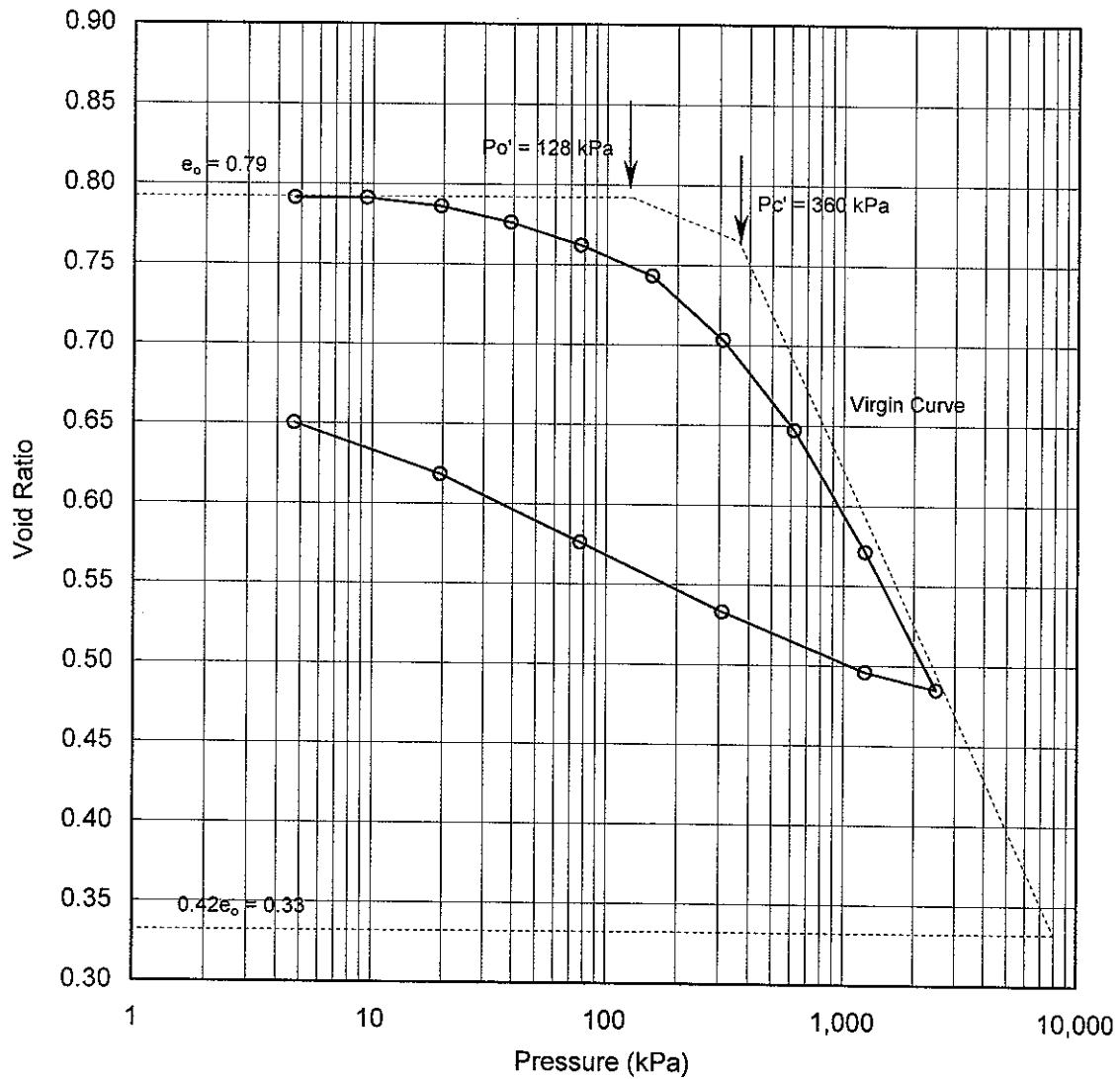
Project No. : 1-09-4135
Date : June 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
e vs Pressure
PR1, TW8



Soil Type : Silty Clay

$e_0 =$	0.79	$\omega_L =$	40%	$P_{o'} =$	128 kPa
$\omega =$	28%	$\omega_p =$	19%	$P_{c'} =$	360 kPa
$\gamma =$	19.5 kN/m ³	PI =	21%	Cc =	0.321
Gs =	2.78			Cr =	0.060

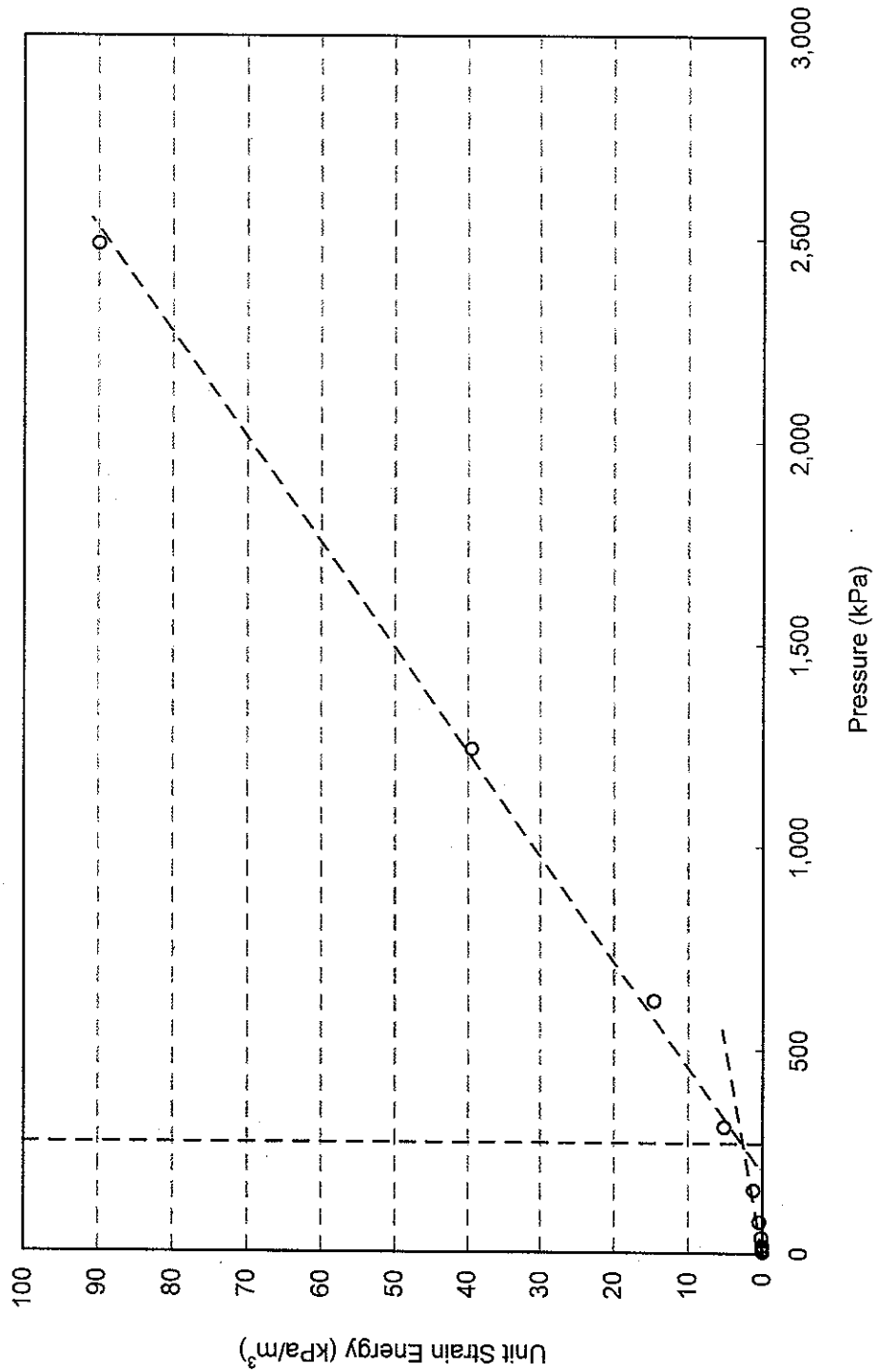
Project No. : 1-09-4135
Date : June 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
Unit Strain Energy vs Pressure
PR1, TW8



Project No. : 1-09-4135

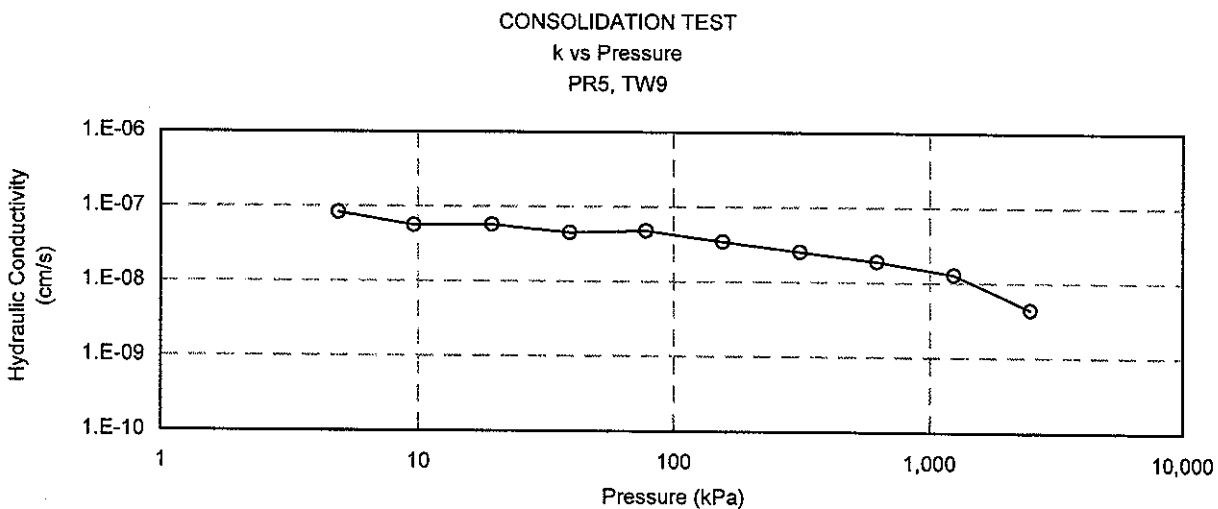
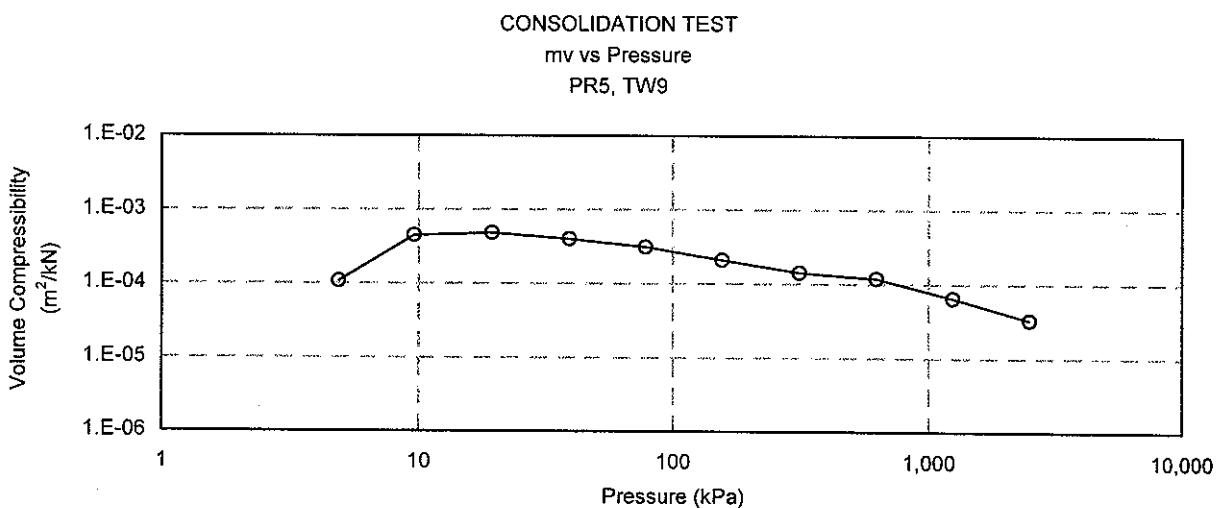
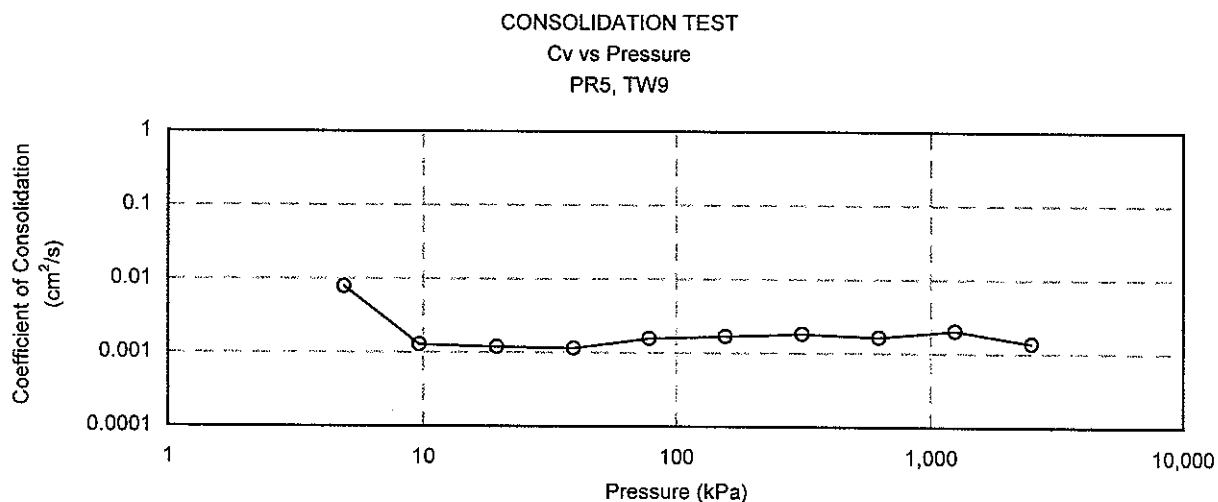
Date : June 2010



Terraprobe Inc.

Prepared By : HW

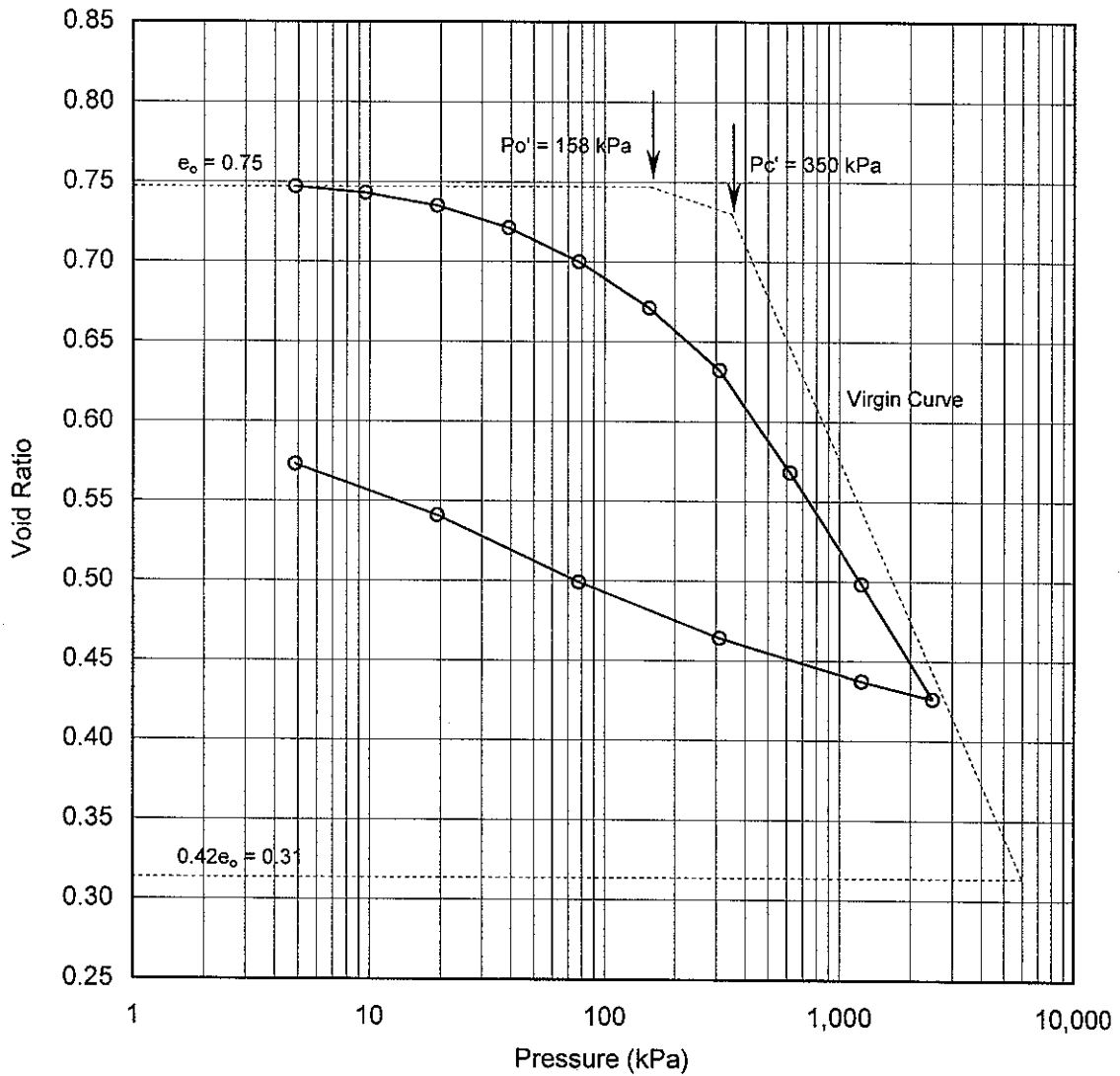
Checked By : RA



CONSOLIDATION TEST

e vs Pressure

PR5, TW9



Soil Type : Silty Clay

$e_o =$	0.75	$\omega_L =$	32%	$P_{o'} =$	158 kPa
$\omega =$	27%	$\omega_p =$	16%	$P_{c'} =$	350 kPa
$\gamma =$	19.7 kN/m ³	PI =	15%	Cc =	0.337
Gs =	2.76			Cr =	0.049

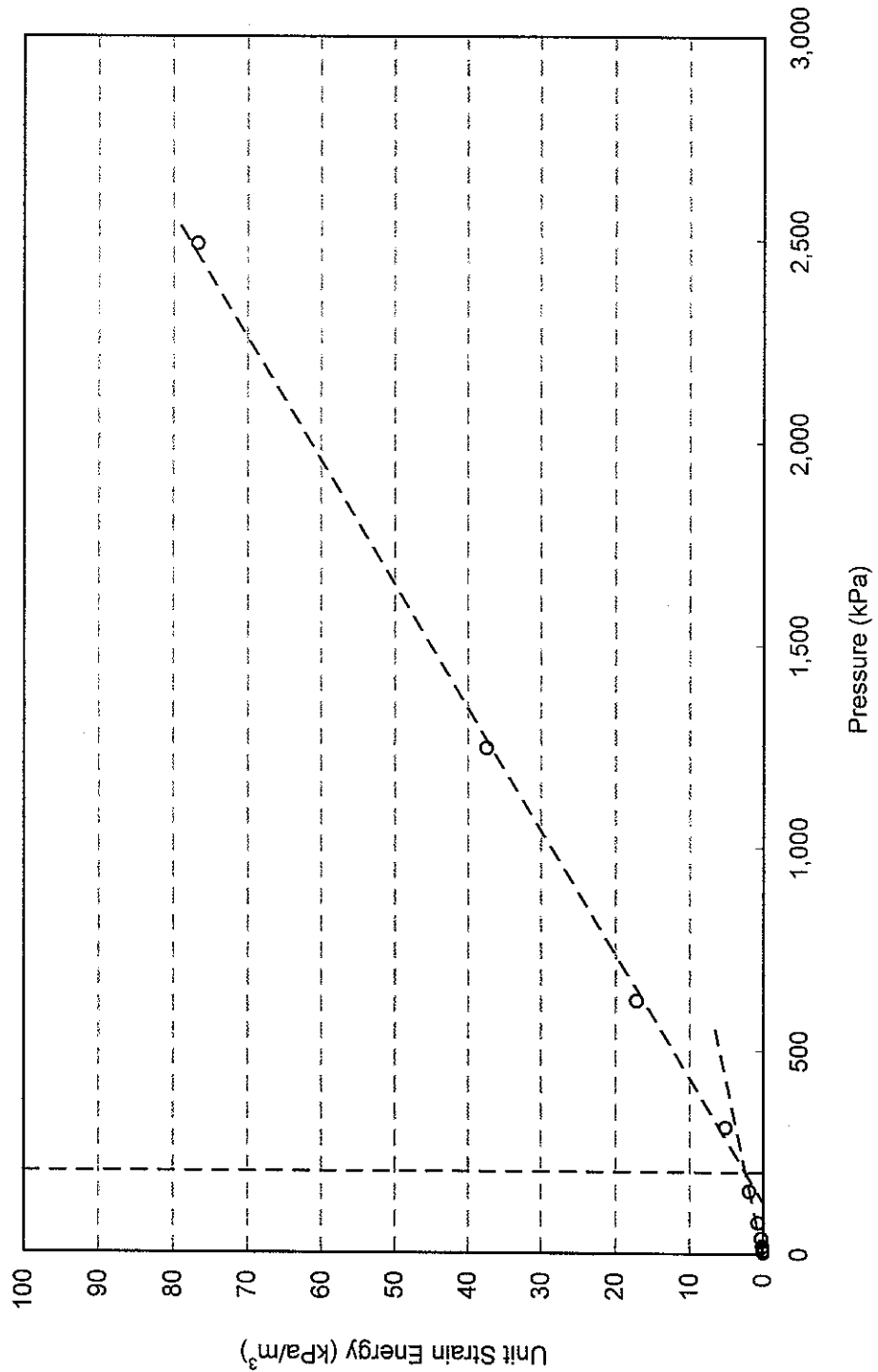
Project No. : 1-09-4135
Date : June 2010



Terraprobe Inc.

Prepared By : HW
Checked By : RA

CONSOLIDATION TEST
Unit Strain Energy vs Pressure
PR5, TW9



Project No. : 1-09-4135

Date : June 2010



Terraprobe Inc.

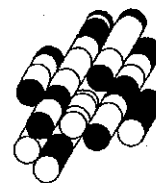
Prepared By : HW

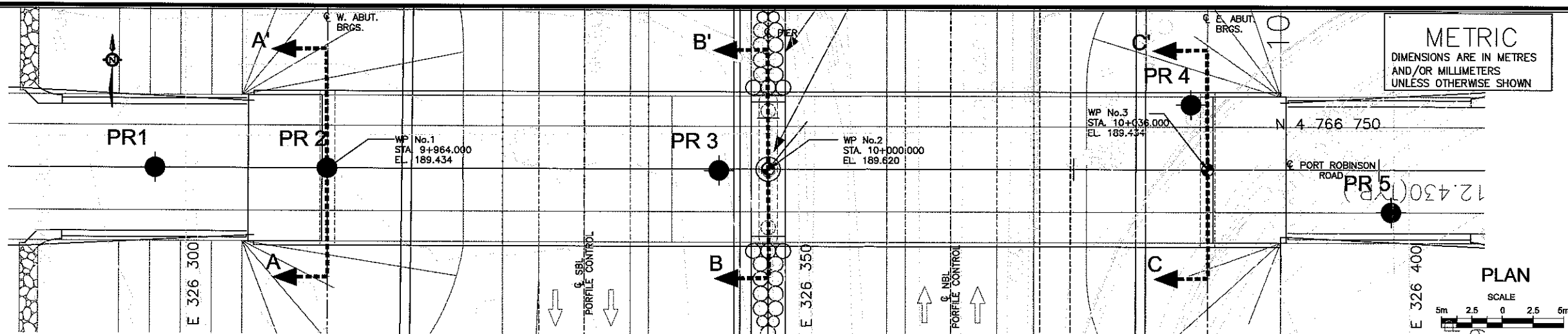
Checked By : RA

APPENDIX C

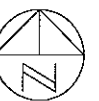
Drawings titled “Borehole Locations and Soil Strata”

Terraprobe Inc.





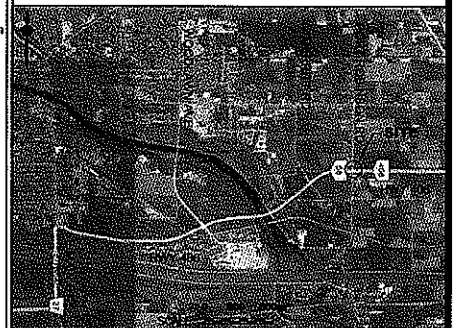
CONT No
WP No 280-99-00



HIGHWAY 406
PORT ROBINSON ROAD UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
1 OF

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company



KEY PLAN

LEGEND	
	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
	Blows/0.3m (Std Pen Test, 475 J/blow)
	Blows/0.3m (60° Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer (MAY 2010)
	Rock Quality Designation
	Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
PR1	181.7	4 766 747.4	326 297.5
PR2	181.7	4 766 747.3	326 311.5
PR3	181.3	4 766 747.0	326 343.5
PR4	182.2	4 766 752.2	326 362.2
PR5	181.2	4 766 743.3	326 398.5

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 SEPT. 2010
DRAWN K.C.	CHK R.A.	STRUCT 34-462	GEOCRES 30M3-262

