

Terraprobe

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

**FOUNDATION INVESTIGATION REPORT
STORM SEWER INSTALLATIONS
QUEEN ELIZABETH HIGHWAY
FROM BRANT STREET TO BURLOAK DRIVE
AGREEMENT No. 2006-E-0026, W.P. 2831-02-01
MINISTRY OF TRANSPORTATION, ONTARIO
CENTRAL REGION**

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PART 1: FACTUAL INFORMATION**

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted along storm sewer alignments crossing the QEW at Sta. 15+425 (Walkers Line) and Sta. 17+609 (Appleby Line). This project is the Ministry of Transportation of Ontario undertaking to rehabilitate and widen the QEW from Brant Street to Burloak Drive.

The purpose of this investigation was to explore the subsurface conditions along the alignments and, based on the data obtained, to provide borehole location plans, records of boreholes, stratigraphic profiles, laboratory test results and descriptions 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 (Giffels), under the Ministry of Transportation Ontario (MTO) Agreement Number 2006-E-0026.

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

- Terraprobe Limited, "Foundation Investigation and Design Report, High Mast Lighting, Queen Elizabeth Highway, From Brant Street to Burloak Drive", W.P. 2831-02-01, MTO Central Region, dated August 29 2008.

For reporting purposes the investigated sections are designated as Walkers Line Crossing and Appleby Line Crossing. Further details are outlined below.

Walkers Line Crossing: A 750 mm to 825 mm diameter storm sewer crossing the East Bound and West Bound lanes of the QEW at Sta. 15+425.

Appleby Line Crossing: A 525 mm diameter storm sewer crossing the East Bound lanes of the QEW at Sta. 17+609.

2 SITE DESCRIPTION & PHYSIOGRAPHY

This project is located in the Regional Municipality of Halton, City of Burlington, Ontario, and extends a distance of approximately 8.2 km from Sta.11+700 to Sta.10+330. Within the project limits, this divided highway comprises of six lanes and fully paved shoulders. There is an existing storm sewer located close to the median centreline of the highway. There are four interchanges within the project limits: Guelph Line, Walkers Line, Appleby Line and Burloak Drive.



A significant feature at Walkers Line is Tuck Creek, which crosses the QEW at Sta. 15+370. When the QEW was constructed provisions were made to cross this watercourse by constructing a concrete culvert. Fill was placed in the creek valley to achieve the current grade profile of the QEW.

The site is located in the physiographic region of Southern Ontario referred to as the Iroquois Plain¹. This strip of land is approximately 3 km wide and is located between the shoreline of the former glacial lake, Lake Iroquois and Lake Ontario. The topography is flat to moderately rolling and the terrain slopes gently towards Lake Ontario.

The soils generally consist of fine grained silts and clays, underlain by silty clay glacial till. The overburden soils are further underlain by bedrock of the Queenston Formation, which is predominantly shale and is known to exist at relatively shallow depths within the project limits. Very often the basal portion of this till is distinctly red in colour from large amounts of incorporated Queenston shale.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out during the period January 25 to 27, 2009 and consisted of drilling and sampling four boreholes each to a depth of 7.8 m below ground surface. Borehole HML-3/3A from Terraprobe's previous work was drilled on August 01, 2007 and October 04, 2007 to a depth of 9.2 m below ground surface. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix C.

Solid stem auger drilling techniques were used to advance the boreholes. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils and the bedrock. The boreholes were also advanced approximately 3.1 m to 4.9 m into bedrock by NQ size diamond coring techniques.

Borehole S3 was drilled through the paved left shoulder of the QEW EBL. This borehole was sealed using bentonite and the pavement structure was reinstated by backfilling with granular material and patching with cold mix asphalt.

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

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers consisting of 19 mm PVC pipe with a slotted screen enclosed in sand were installed in selected boreholes to permit longer term groundwater level monitoring. The locations and completion details of the piezometers are shown in Table 3.1.

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



Table 3.1 – Piezometer Installation Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation (m)	Completion Details
Walkers Line Crossing (Sta. 15+425)		
S1 - P1	7.8/107.0	Piezometer with 1.5 m slotted screen installed with filter sand to 5.9 m, bentonite seal from 5.9 m to 3.7 m, filter sand from 3.7 m to 1.8 m and bentonite seal from 1.8 m to ground surface.
S1 - P2	3.7/111.1	Piezometer with 1.5 m slotted screen installed with filter sand to 1.8 m and bentonite seal from 1.8 m to ground surface.
S2 - P1	7.8/107.2	Piezometer with 1.5 m slotted screen installed with filter sand to 5.9 m, bentonite seal from 5.9 m to 3.0 m, filter sand from 3.0 m to 1.2 m and bentonite seal from 1.2 m to ground surface.
S2 - P2	3.0/111.9	Piezometer with 1.5 m slotted screen installed with filter sand to 1.2 m and bentonite seal from 1.2 m to ground surface.
Appleby Line Crossing (Sta. 17+609)		
S4 - P1	7.6/110.2	Piezometer with 1.5 m slotted screen installed with filter sand to 5.8 m, bentonite seal from 5.8 m to 4.6 m, filter sand from 4.6 m to 2.4 m, bentonite seal from 2.4 m to 0.3 m and a flush mounted casing installation from 0.3 m to ground surface.
S4 - P2	4.3/113.5	Piezometer with 1.5 m slotted screen installed with filter sand to 2.4 m, bentonite seal from 2.4 m to 0.3 m and a flush mounted casing installation from 0.3 m to ground surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Selected samples were also subjected to gradation analysis and Atterberg Limits tests. Rock core samples were subjected to unconfined compressive strength tests and unit weight tests. The results of the laboratory testing program are shown on the Record of Borehole sheets and Core Logs in Appendix A. The grain size distribution curves and plasticity charts are illustrated in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A and the Core Logs. 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 at each site is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets and Core Logs governs any interpretation of the site conditions.



5.1 Walkers Line Crossing (Sta. 15+425)

In general, the site is underlain by surficial layers of topsoil and a flexible pavement followed by firm to stiff silty clay fill, stiff to hard silty clay till and hard till/shale complex. These overburden soils are further underlain by shale bedrock of the Queenston Formation.

5.1.1 Topsoil

Topsoil ranging from 230 mm to 280 mm was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.1.2 Flexible Pavement

Borehole HML 3/3A indicates that the inner shoulder of the QEW WBL consists of 280 mm of asphalt concrete underlain by a 720 mm thick layer of gravelly sand fill that extends to a depth of 1.0 m (Elev. 114.7 m) below ground surface.

Standard Penetration tests conducted in the granular fill gave SPT "N" values ranging from 23 blows to 29 blows for 0.3 m penetration indicating a compact relative density. The moisture content (by weight) of samples of the granular fill was 1%.

5.1.3 Fill – Silty Clay

Silty clay fill was encountered at the site extending to depths ranging from 3.7 m (Elev. 111.1 m) to 4.9 m (Elev. 110.8 m) below ground surface.

The grain size distribution curves of samples of this fill are shown in Figure B1. The results show a grain size distribution consisting of 1% to 20% gravel, 21% to 34% sand, 34% to 50% silt and 15% to 33% clay size particles.

Samples of the silty clay fill were also subjected to Atterberg Limits tests and the results are illustrated in Figure B2. The summarized index values from these tests are presented herein.

Liquid Limit:	31 to 36%
Plastic Limit:	19 to 22%
Plasticity Index:	12 to 15%
Natural Moisture Content:	8 to 19%

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

Standard Penetration tests conducted in the silty clay fill gave SPT "N" values ranging from 6 blows to 10 blows for 0.3 m penetration indicating a firm to stiff consistency. The moisture content of samples of the silty clay fill ranged from 8% to 27% by weight.



5.1.4 Silty Clay Till

Silty clay glacial till was encountered at the site extending to a depth of 1.0 m (Elev. 113.9 m) below ground surface. Till soils can also be expected to contain random cobble and boulder inclusions.

The grain size distribution curve of a sample of the silty clay till is illustrated in Figure B3. These results show a grain size distribution consisting of 3% gravel, 32% sand, 42% silt and 23% clay size particles.

A sample of the silty clay till was also subjected to an Atterberg Limits test and the results are illustrated in Figure B4. The summarized index values from this test are presented herein.

Liquid Limit:	26%
Plastic Limit:	18%
Plasticity Index:	8%
Natural Moisture Content:	15%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the silty clay till gave "N" values ranging from 12 to 34 blows for 0.3 m. 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 ranged from 13% to 15% by weight.

5.1.5 Silty Clay Till - Till/Shale Complex

The lower portions of the glacial till above the shale bedrock are difficult to distinguish from the upper, highly weathered shale. This transition zone of material is sometimes referred to as till/shale complex. The unit may often be described as residual soil or completely weathered shale bedrock. Shale and limestone slabs may occur within this deposit.

The till/shale complex extends to depths ranging from 1.8 (Elev. 113.1 m) to 4.1 m (Elev. 110.7 m) below ground surface.

The results of a grain size distribution test conducted on a sample obtained from this deposit are shown in Figure B5. These results show a grain size distribution consisting of 14% gravel, 21% sand, 52% silt and 13% clay size particles.

A sample of the till/shale complex was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart in Figure B6.



The index values from these tests are summarized below:

Liquid Limit:	20%
Plastic Limit:	15%
Plasticity Index:	5%
Natural Moisture Content:	8%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the till/shale complex gave "N" values ranging from 34 blows to more than 100 blows for 0.3 m penetration. Based on these results the till/shale complex is considered to have a hard consistency.

The moisture content of samples from this deposit ranged from 6% to 8% by weight.

5.1.6 Bedrock

The bedrock beneath the site is of the Queenston Formation, a deposit predominantly comprised of thickly bedded to massive reddish brown shale of Ordovician age. The rock contains within the shale matrix occasional layers of limestone, sandstone and siltstone, and occasionally green calcareous shale layers. There is typically a horizontal zone of weathering at the contact between the weak rock of the Queenston Formation and the glacial soil overburden. In the Ontario Ministry of Transportation and Communications document RR229, *Evaluation of Shales for Construction Projects*, there is reproduced from Skempton, Davis and Chandler, *a typical weathering profile of a low durability shale*, that characterizes the shale surface into three grades of weathering and four zones described and interpreted as follows:

	Zone	Description	Notes
Fully Weathered	IVb	soil like matrix only	indistinguishable from glacial drift deposits, slightly clayey, may be fissured
Partially Weathered	IVa	soil like matrix with occasional pellets of shale less than 3 mm diameter	little or no trace of rock structure, although matrix may contain relic fissures
	III	soil like matrix with frequent angular shale particles up to 25 mm diameter	moisture content of matrix greater than the shale particles
	II	angular blocks of unweathered shale with virtually no matrix separated by weaker chemically weathered but intact shale	spheroidal chemical weathering of shale pieces emanating from relic joints and fissures, and bedding planes
Unweathered (sound)	I	shale	regular fissuring

At the base of the glacial till deposit there is sometimes found a zone of silty clay and fragmented shale that can be interpreted as the lowest portion of the till or as partially weathered rock of Zone III. The distinction is subjective and depends on the investigator.



The surface of the bedrock as indicated on the Borehole Logs from this investigation is to be consistently interpreted as the surface of Zone II in the profile.

Shale bedrock was encountered within the depth of investigation. The bedrock was penetrated by solid stem augering and samples were obtained by split spoon sampling. The bedrock was also cored approximately 3.3 m to 4.9 m using NQ-sized diamond drilling techniques.

Tabulated below are the bedrock depth and elevation at the borehole locations.

BH No.	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
S1	4.1	110.7
HML3/3A	4.9	110.8
S2	1.8	113.1

The bedrock is described as slightly to highly weathered to depths ranging from 4.1 m to 7.3 m and is unweathered below. It is generally thinly to medium bedded shale, occasionally laminated with interbeds of greenish grey to light grey limestone and dolostone. Total core recovery ranged from 98% to 100% and the RQD values generally ranged from 39% to 82% indicating poor to good quality rock. In Borehole HML3/3A an RQD value of 15% was obtained in the first run, indicating very poor rock quality.

Three unconfined compressive strength tests were conducted on core samples of the shale bedrock retrieved between Elev. 109.3 m and Elev. 111.3 m. The unconfined compressive strengths ranged between 8.3 MPa and 44.1 MPa indicating low to medium strength rock. The unit weight of the rock ranged from 21.3 kN/m³ to 27.6 kN/m³.

5.2 Appleby Line Crossing (Sta. 17+609)

In general, the site is underlain by a flexible pavement followed by stiff to hard silty clay fill, very stiff to hard silty clay till and hard till/shale complex. These overburden soils are further underlain by shale bedrock of the Queenston Formation.

5.2.1 Flexible Pavement

Borehole S3 indicates that the inner shoulder of the QEW EBL consists of 130 mm of asphalt concrete underlain by a 270 mm thick layer of sand and gravel fill that extends to a depth of 0.4 m (Elev. 118.4 m) below ground surface.

A Standard Penetration test conducted in the granular fill gave an SPT "N" value of 86 blows for 0.3 m penetration indicating a very dense relative density. The moisture content (by weight) of a sample of the granular fill was 6%.



5.2.2 Fill – Silty Clay

Silty clay fill was encountered at this site extending to depths ranging from 0.7 m (Elev. 117.1 m) to 1.8 m (Elev. 117.0 m).

Grain size distribution curves of samples of this fill material are presented in Figure B7. These results show grain size distributions consisting of 1% to 15% gravel, 7% to 23% sand, 46% to 72% silt and 16% to 20% clay size particles.

Samples of the silty clay fill were also subjected to Atterberg Limits tests and the results are illustrated in Figure B8. The summarized index values from these tests are presented herein.

Liquid Limit:	24 to 32%
Plastic Limit:	18 to 21%
Plasticity Index:	6 to 11%
Natural Moisture Content:	10 to 15%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the silty clay fill material yielded "N" values ranging from 12 blows to 69 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 15% by weight.

5.2.3 Silty Clay Till

Silty clay glacial till was encountered at the site extending to depths ranging from 1.4 m to 2.4 m below ground surface or to Elev. 116.4 m.

The grain size distribution curve of a sample of the silty clay till is illustrated in Figure B9. These results show a grain size distribution consisting of 8% gravel, 12% sand, 57% silt and 23% clay size particles. Till soils can also be expected to contain random cobble and boulder inclusions.

A sample of the silty clay till was also subjected to an Atterberg Limits test and the results are illustrated in Figure B10. The summarized index values from these tests are presented herein.

Liquid Limit:	36%
Plastic Limit:	23%
Plasticity Index:	13%
Natural Moisture Content:	14%



These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in this deposit gave "N" values ranging from 24 blows to more than 100 blows for 0.3 m. Based on these results the silty clay till is considered to have a very stiff to hard consistency.

The moisture content of samples from this deposit ranged from 11% to 14% by weight.

5.2.4 Silty Clay Till - Till/Shale Complex

The lower portions of the glacial till above the shale bedrock are difficult to distinguish from the upper, highly weathered shale. This transition zone of material is sometimes referred to as till/shale complex. The unit may often be described as residual soil or completely weathered shale bedrock. Shale and limestone slabs may occur within this deposit.

The till/shale complex extends to depths ranging from 2.3 m (Elev. 115.5 m) to 4.2 m (Elev. 114.6 m) below ground surface.

The results of a grain size distribution test conducted on a sample obtained from this deposit are shown in Figure B11. These results show a grain size distribution consisting of 1% gravel, 16% sand, 66% silt and 17% clay size particles.

A sample of the till/shale complex was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart in Figure B12.

The index values from these tests are summarized below:

Liquid Limit:	25%
Plastic Limit:	17%
Plasticity Index:	8%
Natural Moisture Content:	6%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the till/shale complex gave "N" values ranging from 30 blows to more than 100 blows for 0.3 m penetration. Based on these results the till/shale complex is considered to have a hard consistency.

The moisture content of samples from this deposit ranged from 6% to 12% by weight.

5.2.5 Bedrock

The bedrock beneath the site is of the Queenston Formation, a deposit predominantly comprised of thickly bedded to massive brick red shale of Ordovician age. The rock contains within the shale matrix occasional layers of limestone, sandstone and siltstone, and occasionally green calcareous shale layers. There is typically a horizontal zone of weathering at the contact between the weak rock of the Queenston Formation and the



glacial soil overburden. In the Ontario Ministry of Transportation and Communications document RR229, *Evaluation of Shales for Construction Projects*, there is reproduced from Skempton, Davis and Chandler, *a typical weathering profile of a low durability shale*, that characterizes the shale surface into three grades of weathering and four zones described and interpreted as follows:

	Zone	Description	Notes
Fully Weathered	IVb	soil like matrix only	indistinguishable from glacial drift deposits, slightly clayey, may be fissured
Partially Weathered	IVa	soil like matrix with occasional pellets of shale less than 3 mm diameter	little or no trace of rock structure, although matrix may contain relic fissures
	III	soil like matrix with frequent angular shale particles up to 25 mm diameter	moisture content of matrix greater than the shale particles
	II	angular blocks of unweathered shale with virtually no matrix separated by weaker chemically weathered but intact shale	spheroidal chemical weathering of shale pieces emanating from relic joints and fissures, and bedding planes
Unweathered (sound)	I	shale	regular fissuring

At the base of the glacial till deposit there is sometimes found a zone of silty clay and fragmented shale that can be interpreted as the lowest portion of the till or as partially weathered rock of Zone III. The distinction is subjective and depends on the investigator. The surface of the bedrock as indicated on the Borehole Logs from this investigation is to be consistently interpreted as the surface of Zone II in the profile.

Shale bedrock was encountered within the depth of investigation. The bedrock was penetrated by solid stem augering and samples were obtained by split spoon sampling. The bedrock was also cored approximately 3.1 m using NQ-sized diamond drilling techniques.

Tabulated below are the bedrock depth and elevation at the borehole locations.

BH No.	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
S3	4.2	114.6
S4	2.3	115.5

The bedrock is described as moderately weathered to depths ranging from 4.7 m to 5.0 m and is unweathered below. It is generally thinly bedded to medium bedded shale that is occasionally laminated with interbeds of light greenish grey to light grey limestone and dolostone. Total core recovery ranged from 99% to 100% and the RQD values ranged from 46% to 93% indicating poor to excellent quality rock.



Two unconfined compressive strength tests were conducted on the shale bedrock at elevations ranging between 112.2 m and 113 m. The results ranged between 21.4 MPa and 22.7 MPa indicating medium strength rock. The unit weight of the rock ranged from 26.4 kN/m³ to 27.9 kN/m³.

5.3 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 5.3.

Table 5.3 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
Walkers Line Crossing (Sta. 15+425)			
S1-P1*	January 30, 2009	4.3	110.5
	February 03, 2009	4.3	110.5
S1-P2**	January 30, 2009	3.4	111.4
	February 03, 2009	3.6	111.2
S2-P1*	January 30, 2009	3.9	111.0
	February 03, 2009	4.3	110.6
S2-P2**	January 30, 2009	2.1	112.8
	February 03, 2009	2.0	112.9
Appleby Line Crossing (Sta. 17+609)			
S4-P1*	January 30, 2009	3.2	114.6
	February 03, 2009	3.1	114.7
S4-P2	January 30, 2009	2.6	115.2
	February 03, 2009	3.1	114.7

* Standpipe piezometer installed and sealed in the bedrock

** Standpipe piezometer installed in the overburden soils

At the Walkers Line Crossing the recorded water levels in the bedrock range between Elev. 110.5 m and Elev. 111.0 m. The water level readings in the overburden soils indicate that the groundwater level is likely to exist at elevations ranging between ±111.2 m and ±112.9 m.

At the Appleby Line Crossing the recorded water level in the bedrock ranges between Elev. 114.6 m and Elev. 114.7 m. The estimated groundwater level in the overburden is Elev. ±117 m.

All groundwater observations at the two sites are short term and the levels are expected to fluctuate seasonally and after severe weather events. The ground water level at the Walkers Line Crossing will also be controlled by the free water level in Tuck Creek.



5.4 Miscellaneous

The borehole locations, their coordinates and geodetic elevations, were established in the field by surveyors from Strada Survey Inc. of Vaughan, Ontario based on drawings provided by Giffels,

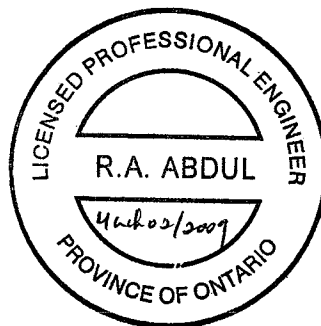
The drilling, sampling and in-situ testing operations were conducted using both truck-mounted and track-mounted drill rigs owned and operated Geo-Environmental Drilling Inc. of Milton, Ontario.

The utility locates, fieldwork planning and its coordination were undertaken by Mr. H. Ahmed, P.Eng. Drilling and sampling operations were observed and recorded on a full time basis by Mr. K. Singh, P.Eng., Mr. B. Racher, C.E.T, and Mr. P. Khuu. The supervisors logged the boreholes and processed the recovered soil samples and rock cores for transport to Terraprobe's Brampton laboratory for further examination and testing.

The report was written by Mr. Rehman Abdul, P.Eng. and reviewed by Mr. Michael Tanos, P.Eng.



Rehman Abdul



Prepared by:
R. Abdul, P.Eng.,
Senior Geotechnical Engineer

Michael Tanos

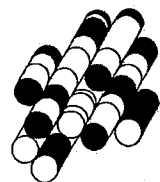


Report Reviewed by:
Michael Tanos, P.Eng.,
Review Principal



APPENDICES

Terraprobe Limited



LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole 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 is 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

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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 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_p	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_t	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 ³ /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						

Column Number

- ### Joint (discontinuity) Characteristics

- | | | | | | |
|---------|-----------|-----------|-------------|----------------|------------|
| 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 |

- ### Approximate ϕ

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	RESEMBLES A SOIL: ROCK STRUCTURE - USUALLY PRESERVED			

- | | | 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 | | | |

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

- ### Rock Mass Classification (after Deere)

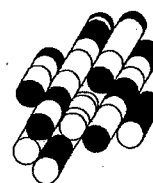
RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
DESCRIPTION	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

- (i) percentage drill water recovery
- (ii) water level depth
- (iii) positions and results of tests, e.g., permeability and packer tests

APPENDIX A

Record of Borehole Sheets, Core Logs and Core Photos

Terraprobe Limited



RECORD OF BOREHOLE No S1

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4802943.9 E:281382.9 ORIGINATED BY PK
 DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 25.01.09 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS P1	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												
114.8	Ground Surface							20	40	60	80	100					GR	SA	SI	CL
0.0	280mm TOPSOIL		1	SS	6		114													
0.3	FILL - Silty Clay, trace sand to sandy, trace to some gravel, trace rootlets, occasional cobbles, occasional shale inclusions, firm to stiff, brown, damp to moist		2	SS	10		113													
	---		3	SS	9		112													
	topsoil stained		4	SS	10		111													
	---		5	SS	8		110													
111.1							109													
3.7	SILTY CLAY TILL - with shale, hard, reddish brown, dry (TILL-SHALE COMPLEX)		6	SS	147/ 20cm		108													
110.7																				
4.1	SHALE BEDROCK		1	RUN	NQ															
	Dark reddish brown, slightly to moderately weathered to 7.0m, then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength, with interbeds of light greenish grey to light grey, medium to high strength limestone / dolostone.		2	RUN	NQ															
	(Queenston Formation)																			
			3	RUN	NQ															
107.0	End of Borehole																			
7.8	Commence rock coring at 4.4m. See Core Log S1 for detailed information.																			
	Piezometer Installation consists of 19mm diameter, schedule 40 PVC pipe with a 1.52m slotted screen.																			
	Water Level Readings (P1):																			
	Date Depth(m) Elevation(m)																			
	Jan.30.09 4.3 110.5																			
	Feb.03.09 4.3 110.5																			
	Water Level Readings (P2):																			
	Date Depth(m) Elevation(m)																			
	Jan.30.09 3.4 111.4																			
	Feb.03.09 3.6 111.2																			

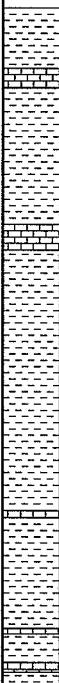
ONTARIO MOT 1-09-4007 QEW SANITARY SEWER.GPJ ONTARIO MOT.GDT 11/02/09

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

CORE LOG



Project	QEW Sanitary Sewer	Orientation Vertical	Ground Elevation 114.8m	Datum Geodetic	Borehole No. S1
Location	Burlington, Ontario	Date Started January 26, 2009	Completed January 26, 2009	Logged By P.K.	Sheet 1 of 1
Client	Ministry of Transportation, Ontario	Drilling Agency GeoEnvironmental	Drill Type Bombardier	Core Barrel & Bit Design NQ	Project No. 1-09-4007

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		
4.0			Overburden, see Borehole Log S1																	
110.4	4.4		QUEENSTON FORMATION – Shale with interbedded limestone.	2	BC	FD	VC	SP	NC	0 to 1				#1	100%	39%	NQ			
110.3	4.5		Shale Reddish brown, slightly to moderately weathered to 7.0m (Elev. 107.8m), then unweatherd, thinly to medium bedded, occasionally laminated, low to medium strength.	2	BC	FV	VC	SP	T					#2	100%	74%				
109.8	5.0		Vertical joint occurs at: 4.7m (Elev. 110.1m).	2	BC	FV	VC	SP	NC											
109.3	5.5		High frequency fractures occur at: 6.5–7.0m (Elev. 108.3–107.8m) 7.2–7.4m (Elev. 107.6–107.4m)	2	BC	FVD	VC	SP	T	0 to 1							NQ	44.1	21.3	
				1	B	F	VC	SP	T											
108.8	6.0			2	BC	FV	VC	SP	NC											
				Limestone/Dolostone Light greenish grey to light grey, laminated to thinly bedded, medium to high strength.																
108.3	6.5			Run 1 Shale = 100%	2	BC	FV	VC	SP	NC					#3	100%	39%			
107.8	7.0			Run 2 Shale = 85% Limestone = 15%	2 2	BC BC	FVD FVD	VC VC	RP SP	T NC	0 to 1							NQ		
				Run 3 Shale = 92% Limestone = 8%	2	BC	FVD	VC	SP	T										
107.3	7.5			1	B	F	VC	SP	T											
107.0	7.8		End of Core Log																	
106.8	8.0																			
106.3	8.5																			
105.8	9.0																			
105.3	9.5																			
104.8	10.0																			

Remarks:

Only limestone layers thicker than 25mm are reported in column 3.

LEGEND:	
	Shale
	Limestone

RECORD OF BOREHOLE No S2

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4802901.9 E:281438.7 ORIGINATED BY PK
 DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 27.01.09 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 (%)
								20 40 60 80 100										
114.9	Ground Surface																	
114.7	230mm TOPSOIL																	
0.2	SILTY CLAY sandy, trace gravel, stiff to hard, brown, damp to moist (GLACIAL TILL)		1	SS	12												3 32 42 23	
113.9			2	SS	34		114											
1.0	SILTY CLAY TILL - with shale and limestone inclusions, hard, reddish brown, dry (TILL-SHALE COMPLEX)		3	SS	117		113										14 21 52 13	
113.1			4	SS	100/ 13cm		112											
1.8	SHALE BEDROCK Dark reddish brown, moderately to highly weathered to 4.1m, then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength, with interbeds of light greenish grey, medium to high strength limestone / dolostone. (Queenston Formation)		1	RUN	NQ		111										RUN#1 TCR=100% RQD=51%	
			2	RUN	NQ		110										RUN#2 TCR=100% RQD=82%	
			3	RUN	NQ		109										RUN#3 TCR=100% RQD=69%	
			4	RUN	NQ		108										RUN#4 TCR=100% RQD=68%	
107.2	End of Borehole																	
7.8	Commence rock coring at 2.9m. See Core Log S2 for detailed information. Piezometer Installation consists of 19mm diameter, schedule 40 PVC pipe with a 1.52m slotted screen. Water Level Readings (P1): Date Depth(m) Elevation(m) Jan.30.09 3.9 111.0 Feb.03.09 4.3 110.6 Water Level Readings (P2): Date Depth(m) Elevation(m) Jan.30.09 2.1 112.8 Feb.03.09 2.0 112.9																	

ONTARIO MOT 1-09-4007 QEW SANITARY SEWER.GPJ ONTARIO MOT.GDT 11/02/09

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

CORE LOG



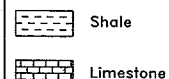
Project	QEW Sanitary Sewer	Orientation Vertical	Ground Elevation 114.9m	Datum Geodetic	Borehole No. S2
Location	Burlington, Ontario	Date Started January 27, 2009	Completed January 27, 2009	Logged By P.K.	Sheet 1 of 1
Client	Ministry of Transportation, Ontario	Drilling Agency GeoEnvironmental	Drill Type Bombardier	Core Barrel & Bit Design NQ	Project No. 1-09-4007

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		
	2.5		Overburden, see Borehole Log S2																	
112.0	2.9		QUEENSTON FORMATION – Shale with interbedded limestone. <u>Shale</u> Reddish brown, moderately to highly weathered to 4.1m (Elev. 110.8m), then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength. High frequency fractures occur at: 3.5–3.9m (Elev. 111.4–111.0m) <u>Limestone/Dolostone</u> Light greenish grey to light grey, laminated to thinly bedded, medium to high strength. <u>Run 1</u> Shale = 85% Limestone = 15% <u>Run 2</u> Shale = 98% Limestone = 2% <u>Run 3</u> Shale = 65% Limestone = 35% <u>Run 4</u> Shale = 80% Limestone = 20%	1	B	F	C	SP	NC	0 to 1				#1	100%	51%	NQ			
111.9	3.0			1	B	F	VC	SP	NC											
				2	BC	FV	VC	SP	NC						#2	100%	82%		8.3	23.0
111.4	3.5			1	B	F	VC	SP	NC	0 to 1								NQ		
				2	BC	FV	VC	SP	NC											
110.9	4.0			1	B	F	VC	SP	NC	0 to 1										
				2	BC	FV	VC	SP	NC											
110.4	4.5			1	B	F	VC	SP	T											
109.9	5.0														#3	100%	69%			
109.4	5.5			1	B	F	VC	SP	T	0 to 1							NQ			
108.9	6.0																			
108.4	6.5													#4	100%	68%				
107.9	7.0			1	B	F	VC	SP	T	0 to 1							NQ			
107.4	7.5																			
107.1	7.8																			
106.9	8.0		End of Core Log																	
106.4	8.5																			

Remarks:

Only limestone layers thicker than 25mm are reported in column 3.

LEGEND:

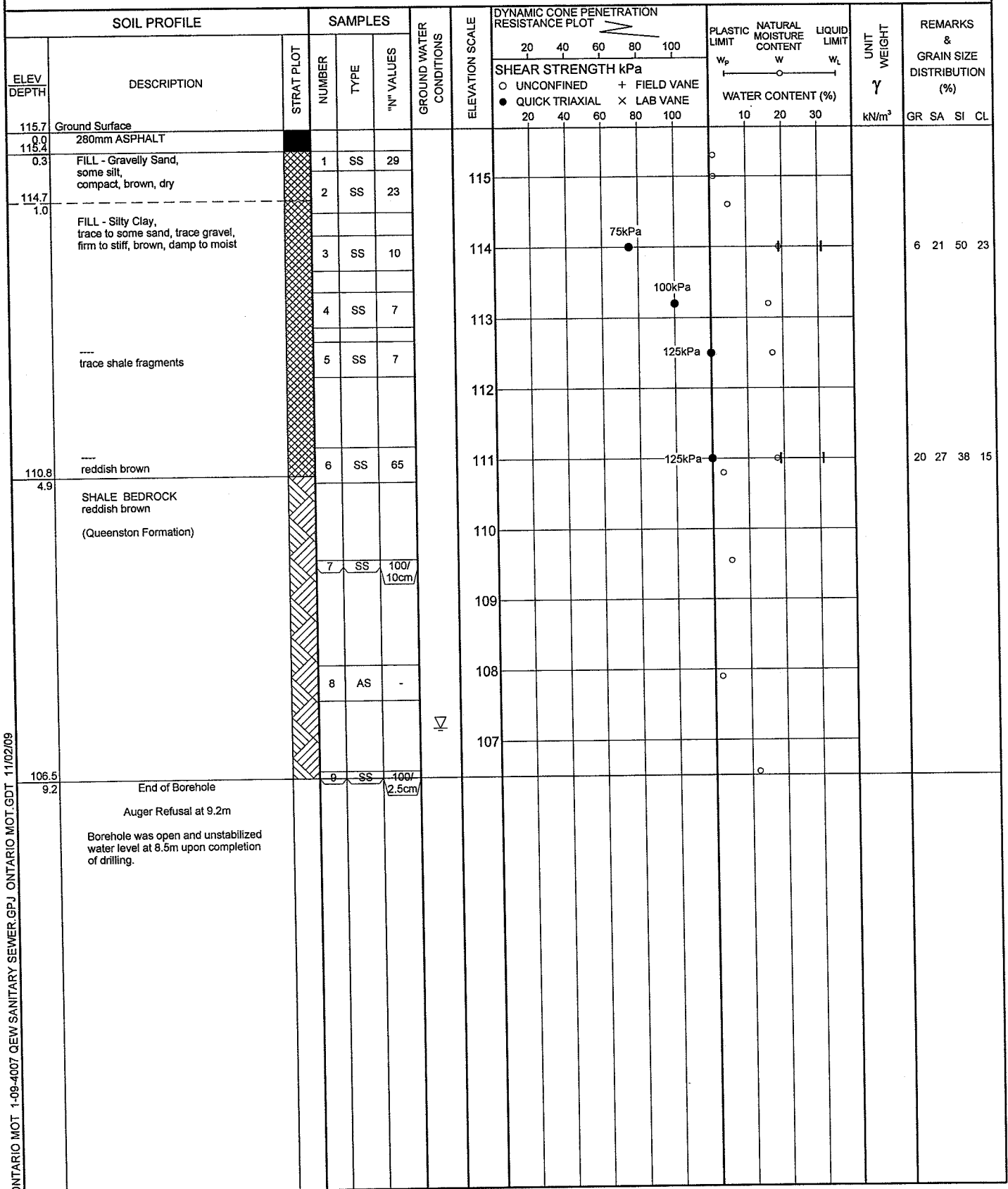


RECORD OF BOREHOLE No HML-3

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4802915.0 E:281399.1 ORIGINATED BY SK
DIST HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY DB
DATUM Geodetic DATE 01.08.07 - 02.08.07 CHECKED BY RA



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


ONTARIO MOT 1-09-4007 QEW SANITARY SEWER.GPJ ONTARIO MOT.GDT 11/02/09

RECORD OF BOREHOLE No HML-3A

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4802915.0 E:281399.1 ORIGINATED BY HA
DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
DATUM Geodetic DATE 04.10.07 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	"N" VALUES			SHEAR STRENGTH kPa								
115.7 0.0	Ground Surface						20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	GR SA SI CL
110.1 5.6	SHALE BEDROCK Reddish brown, slightly weathered to 7.3m, then unweathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium to high strength greenish grey limestone. Irregular, stained subvertical joints at 7.3, 8.2m. Shale = 80% Limestone = 20% (Queenston Formation)		1	RUN	NQ		20 40 60 80 100	WATER CONTENT (%)					10 20 30	27.6	RUN#1 TCR=98% SCR=90% RQD=15%	
106.8 8.9	End of Borehole		2	RUN	NQ		20 40 60 80 100								RUN#2 TCR=100% SCR=100% RQD=49%	

ONTARIO MOT. 1-09-4007 QEW SANITARY SEWER.GPJ ONTARIO MOT.GDT 11/02/09

CORE LOG



Terraprobe

Project QEW - Bront Street to Burlock Drive Agreement No. 2006-E-0026: W.P. 2831-02-01	Orientation Vertical	Ground Elevation 115.7m	Datum Geodetic	Borehole No. HML-3A
Location Burlington, Ontario	Date Started October 4, 2007	Completed October 4, 2007	Logged By H.A.	Sheet 1 of 1
Client Ministry of Transportation, Ontario	Drilling Agency DBW	Drill Type Truck-Mount	Core Barrel & Bit Design NQ	Project No. 1-09-4007

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
110.7	5.0		Overburden, see Borehole Log HML-3A															
110.2	5.5																	
110.1	5.6																	
			QUEENSTON FORMATION – Shale with interbedded limestone.	2	BC	FVD	VC	RP	NC					#1				
108.7	6.0		Shale Reddish brown, slightly weathered to 7.3m (Elev. 108.4m), then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength.	2	BC	FV	VC	RP	T					98%	15%		17.8	27.6
			Multiple vertical and subvertical joints occur at: 7.8–8.4m (Elev. 107.9–107.3m).	1	B	F	VC	RP	T	0 to 1						NQ		
109.2	6.5		High frequency fractures occur at: 6.2m (Elev. 109.5m)	2	BC	FV	VC	RP	NC									
				2	BC	FV	VC	RP	T									
108.7	7.0			1	B	F	VC	SP	T									
				2	BC	FV	VC	RP	NC									
			Limestone/Dolostone Light greenish grey to light grey, laminated to thinly bedded, medium to high strength.															
108.2	7.5			2	BC	FV	VC	RP	T					#2				
														100%	49%			
107.7	8.0		Run 1 Shale = 73% Limestone = 27%							0 to 1						NQ		
			Run 2 Shale = 92% Limestone = 8%	2	BC	FVD	VC	SP	T									
107.2	8.5																	
106.8	8.9			1	B	F	VC	SP	T									
106.7	9.0		End of Core Log															
106.2	9.5																	
105.7	10.0																	
105.2	10.5																	
104.7	11.0																	

Remarks:

Only limestone layers thicker than 25mm are reported in column 3.

LEGEND:



Shale



Limestone

RECORD OF BOREHOLE No S3

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4804619.9 E:282779.9 ORIGINATED BY KS
 DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 25.01.09 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						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
118.8	Ground Surface													
0.0	130mm ASPHALT													
0.1	FILL - Sand and Gravel, silty,		1	SS	86									
118.4	very dense, brown, moist													
0.4	FILL - Silty Clay, trace sand,		2	SS	69									
	trace gravel, with shale inclusions,													
	very stiff to hard,													
	brown, damp to moist													
117.0	topsoil stained		3	SS	24									
1.8	SILTY CLAY - trace sand, trace													
	gravel, very stiff to hard, brown, damp													
	(GLACIAL TILL)													
116.4			4	SS	118/ 22cm									
2.4	SILTY CLAY TILL													
	with shale, some sand,													
	hard, reddish brown, dry to damp		5	SS	100/ 14cm									
	(TILL-SHALE COMPLEX)													
			6	SS	30									
114.6														
4.2	SHALE BEDROCK		7	SS	100/ 11cm									
	Dark reddish brown, unweathered,													
	thinly to medium bedded,													
	occasionally laminated, low to		1	RUN	NQ									
	medium strength, with interbeds of													
	light greenish grey, medium to high													
	strength limestone / dolostone.													
	(Queenston Formation)													
			2	RUN	NQ									
111.0	End of Borehole													
7.8	Borehole was open and dry upon completion of drilling.													
	Commence rock coring at 4.7m. See Core Log S3 for detailed information.													

ONTARIO MOT 1-09-4007 QEW SANITARY SEWER.GPJ ONTARIO MOT.GDT 11/02/09

CORE LOG



Terraprobe

Project	QEW Sanitary Sewer	Orientation Vertical	Ground Elevation 118.8m	Datum Geodetic	Borehole No. S3
Location	Burlington, Ontario	Date Started January 26, 2009	Completed January 26, 2009	Logged By K.S.	Sheet 1 of 1
Client	Ministry of Transportation, Ontario	Drilling Agency GeoEnvironmental	Drill Type Bombardier	Core Barrel & Bit Design NQ	Project No. 1-09-4007

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	
114.8	4.0																		
114.3	4.5		Overburden, see Borehole Log S3																
114.0	4.8																		
113.8	5.0		QUEENSTON FORMATION – Shale with interbedded limestone.	2	BC	FVD	VC	SP	T					#1					
				1	B	F	VC	SP	T					99%	77%				
113.3	5.5		Shale Reddish brown, unweatherd, thinly to medium bedded, occasionally laminated, medium strength.							0 to 1									
			Multiple vertical and subvertical joints occur at: 4.8–6.0m (Elev. 114.0–112.8m). 6.3–6.5m (Elev. 112.5–112.3m).	2	BC	FVD	VC	SP	T								NQ		
112.8	6.0			1	B	F	VC	SP	T								21.4	27.9	
				2	BC	FVD	VC	SP	T										
112.3	6.5		Limestone/Dolostone Light greenish grey to light grey, laminated to thinly bedded, high strength.											#2					
														100%	80%				
111.8	7.0		Run 1 Shale = 93% Limestone = 7%	1	B	F	VC	SP	T	0 to 1							NQ		
111.3	7.5		Run 2 Shale = 79% Limestone = 21%																
111.0	7.8																		
110.8	8.0		End of Core Log																
110.3	8.5																		
109.8	9.0																		
109.3	9.5																		
108.8	10.0																		

Remarks:

Only limestone layers thicker than 25mm are reported in column 3.

LEGEND:

	Shale
	Limestone
	Alternating Shale and Limestone Layers

RECORD OF BOREHOLE No S4

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4804600.0 E:282809.0 ORIGINATED BY BR
DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
DATUM Geodetic DATE 27.01.09 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 (%)
								20 40 60 80 100									
								20 40 60 80 100									
117.8	Ground Surface																
0.0	FILL - Silty Clay, sandy, some gravel, topsoil stained, stiff, moist		1	SS	12											15 23 46 16	
117.1																	
0.7	SILTY CLAY - some sand, trace gravel, occasional shale inclusions, hard, brown, damp to moist (GLACIAL TILL)		2	SS	43											8 12 57 23	
116.4																	
1.4	SILTY CLAY TILL - with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		3	SS	58												
115.5																	
2.3	SHALE BEDROCK Dark reddish brown, moderately weathered to 5.0m, then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength, with interbeds of light greenish grey to light grey, medium to high strength limestone / dolostone. (Queenston Formation)		4	SS	100/ 15cm												
			5	SS	100/ 15cm												
			6	SS	100/ 15cm												
			7	SS	100/ 10cm												
			1	RUN	NQ											RUN#1 TCR=100% RQD=46%	
			2	RUN	NQ											RUN#2 TCR=100% RQD=93%	
110.1	End of Borehole																
7.8	Commence rock coring at 4.7m. See Core Log S4 for detailed information. Piezometer Installation consists of 19mm diameter, schedule 40 PVC pipe with a 1.52m slotted screen. Water Level Readings (P1): Date Depth(m) Elevation(m) Jan.30.09 3.2 114.6 Feb.03.09 3.1 114.7 Water Level Readings (P2): Date Depth(m) Elevation(m) Jan.30.09 2.6 115.2 Feb.03.09 3.1 114.7																

ONTARIO MOT 1-09-4007 QEW SANITARY SEWER GPJ ONTARIO MOT GDT 11/02/09

CORE LOG



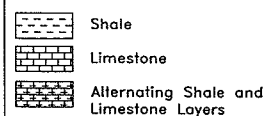
Project	QEW Sanitary Sewer	Orientation Vertical	Ground Elevation 117.8m	Datum Geodetic	Borehole No. S4
Location	Burlington, Ontario	Date Started January 26, 2009	Completed January 26, 2009	Logged By K.S.	Sheet 1 of 1
Client	Ministry of Transportation, Ontario	Drilling Agency GeoEnvironmental	Drill Type Bombardier	Core Barrel & Bit Design NQ	Project No. 1-09-4007

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								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	WEATHERING							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
113.8	4.0																	
113.3	4.5		Overburden, see Borehole Log S4															
113.1	4.7																	
112.8	5.0		QUEENSTON FORMATION - Shale with interbedded limestone.	2	BC	FVD	VC	RP	T					#1				
			Shale Reddish brown, moderately weathered to 5.0m (Elev. 112.8m), then unweathered, thinly to medium bedded, occasionally laminated, low to medium strength.	1	B	F	VC	SP	T					100%	46%			
112.3	5.5		High frequency fractures occur at: 4.8m (Elev. 113.0m) 5.8m (Elev. 112.0m)	2	BC	FVD	VC	RP	T	0 to 1						NQ	22.7	26.4
111.8	6.0		Limestone/Dolostone Light greenish grey to light grey, laminated to thinly bedded, medium to high strength.	2	BC	FV	VC	RP	T									
			Run 1 Shale = 86% Limestone = 14%	1	B	F	VC	SP	T	0 to 1				#2				
111.3	6.5													100%	93%			
110.8	7.0															NQ		
110.3	7.5																	
110.0	7.8																	
109.8	8.0		End of Core Log															
109.3	8.5																	
108.8	9.0																	
108.3	9.5																	
107.8	10.0																	

Remarks:

Only limestone layers thicker than 25mm are reported in column 3.

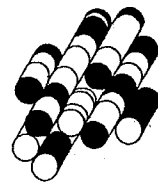
LEGEND:



APPENDIX B

Laboratory Test Results

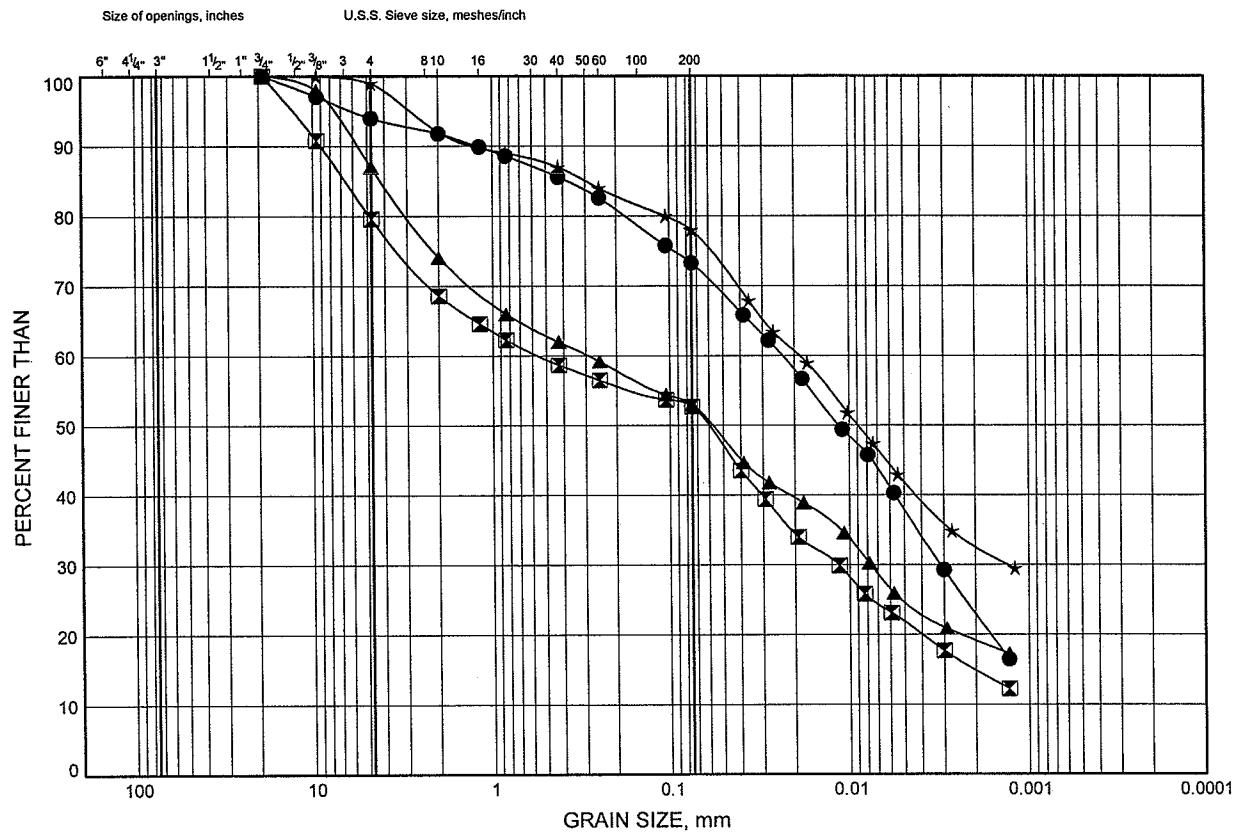
Terraprobe Limited



GRAIN SIZE DISTRIBUTION

FIGURE B1

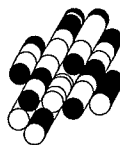
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	HML-3	1.7	114.0
⊠	HML-3	4.7	111.0
▲	S1	1.0	113.8
★	S1	3.2	111.6

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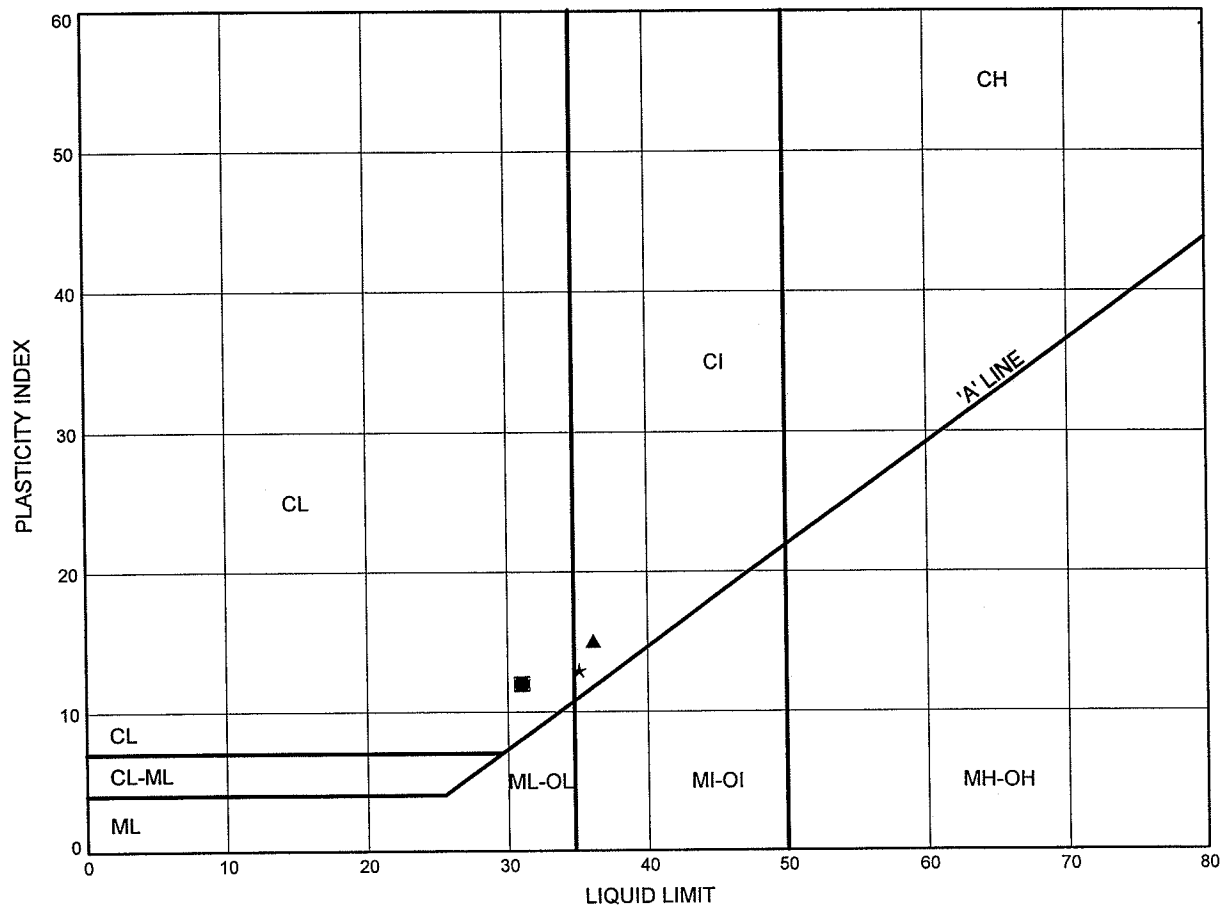


Prep'd DB
Chkd. RA

ATTERBERG LIMITS TEST RESULTS

FIGURE B2

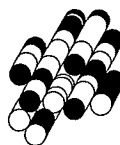
FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	HML-3	1.7	114.0
⊠	HML-3	4.7	111.0
▲	S1	1.0	113.8
★	S1	3.2	111.6

Date February 2009

Project 2831-02-01



Prep'd DB

Chkd. RA

FIGURE B3

Size of openings, inches

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

PERCENT FINER THAN

GRAIN SIZE, mm

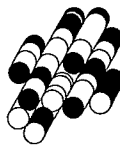
Grain Size (mm)	Percent Finer (%)
75	100
42.5	100
25	98
150	89
300	83
600	78
1250	75
2500	68
5000	65
10000	61
20000	58
40000	54
80000	46
160000	42
320000	35
640000	27
1280000	20

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S2	0.3	114.6

Prep'dDB.....

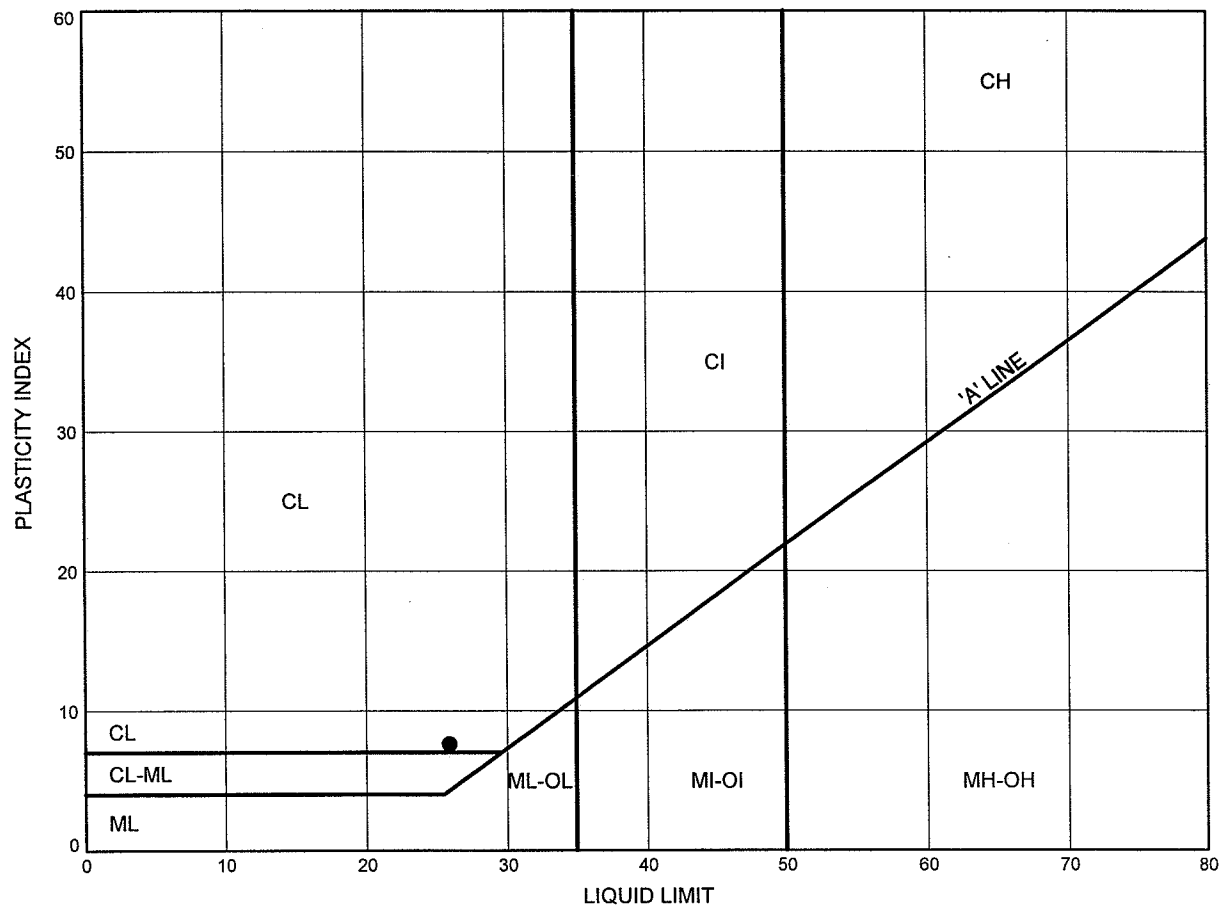
Chkd. RA



ATTERBERG LIMITS TEST RESULTS

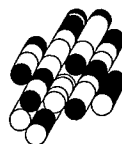
FIGURE B4

SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S2	0.3	114.6

Date February 2009
Project 2831-02-01

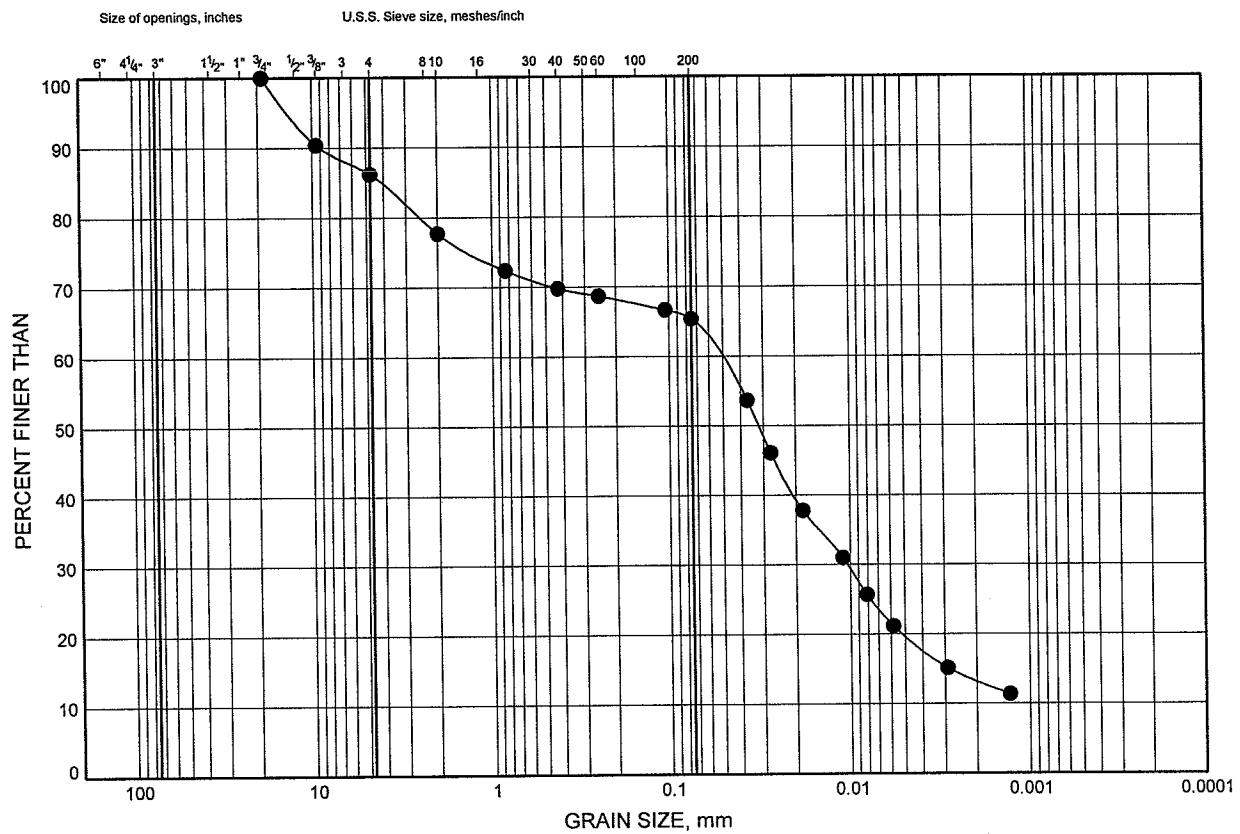


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B5

TILL SHALE COMPLEX

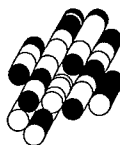


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S2	1.6	113.3

Date February 2009

Project 2831-02-01



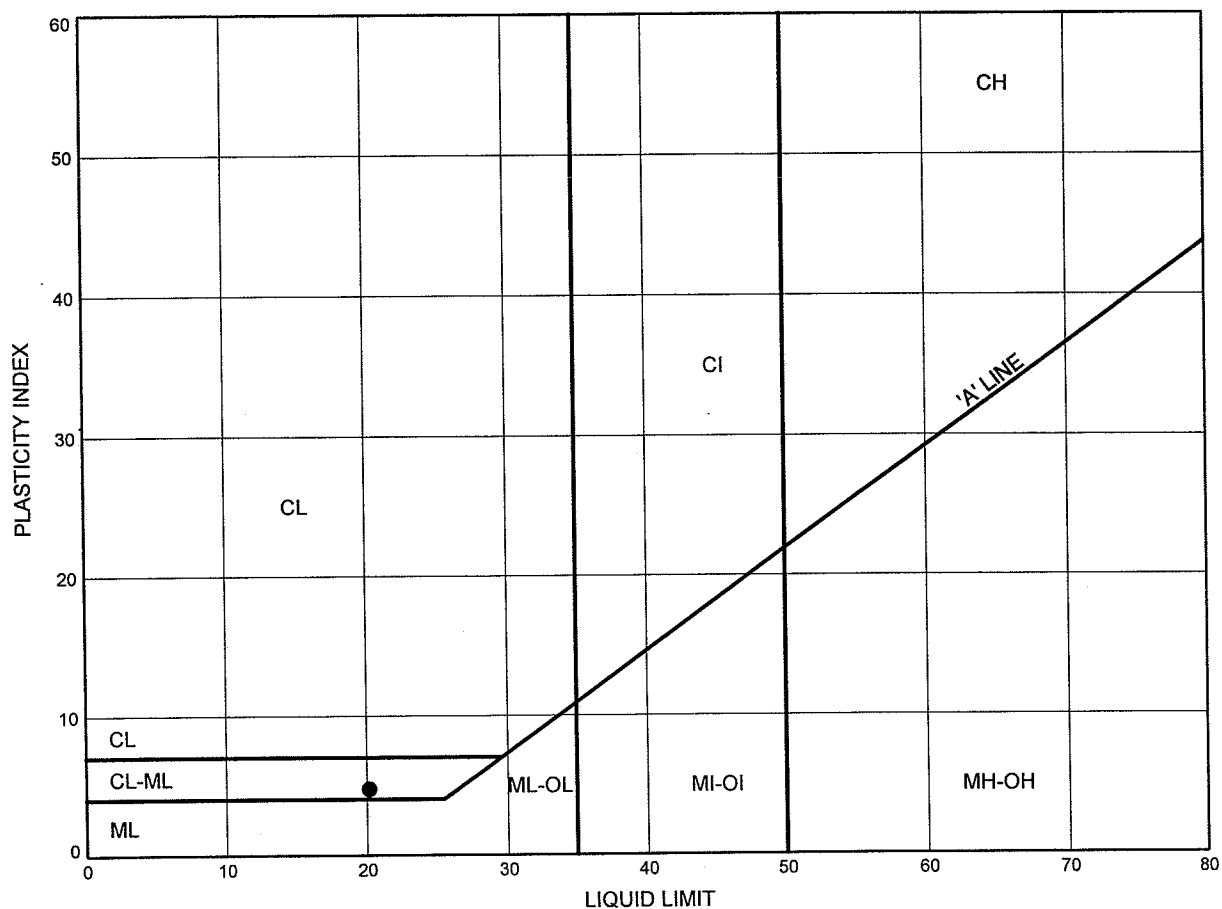
Prep'd DB

Chkd. RA

ATTERBERG LIMITS TEST RESULTS

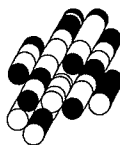
FIGURE B6

TILL SHALE COMPLEX



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S2	1.6	113.3

Date February 2009
Project 2831-02-01

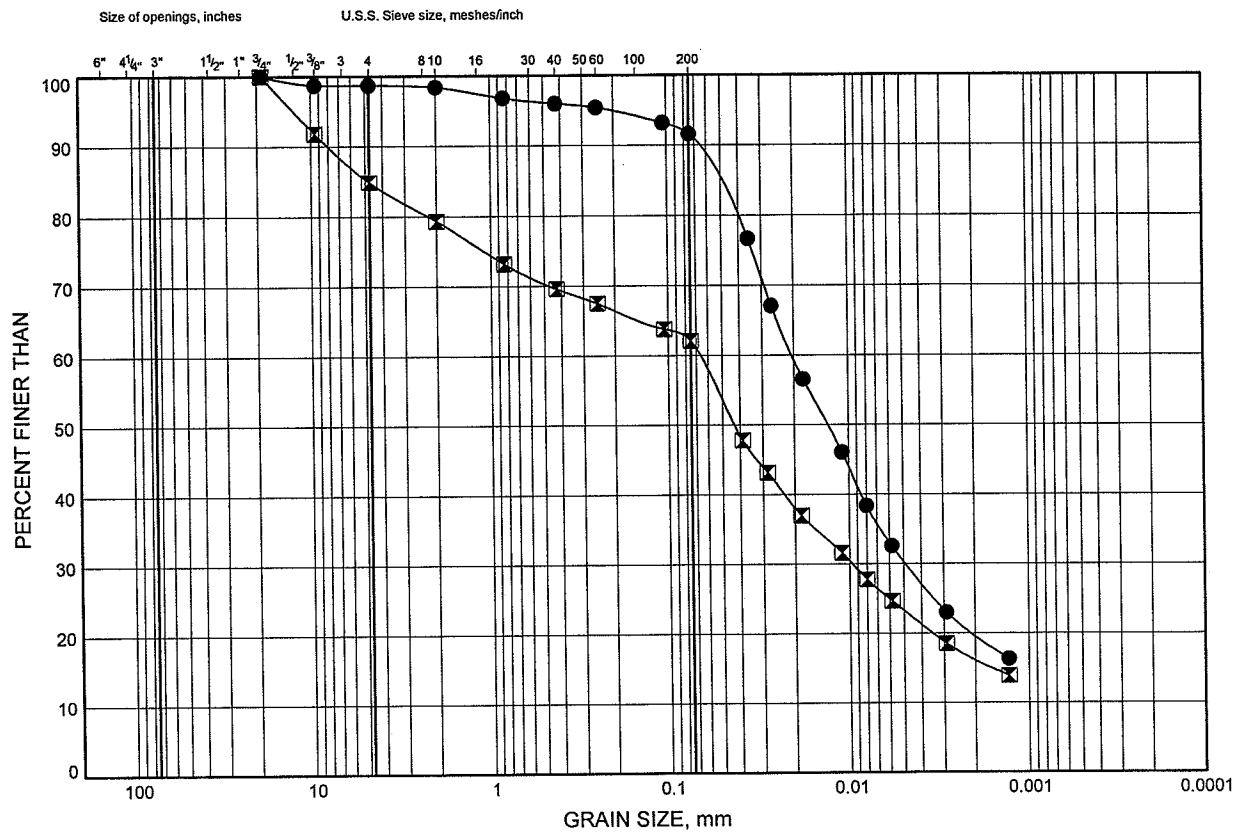


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B7

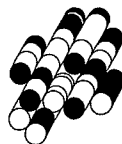
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S3	1.0	117.8
⊠	S4	0.3	117.5

Date February 2009
Project 2831-02-01

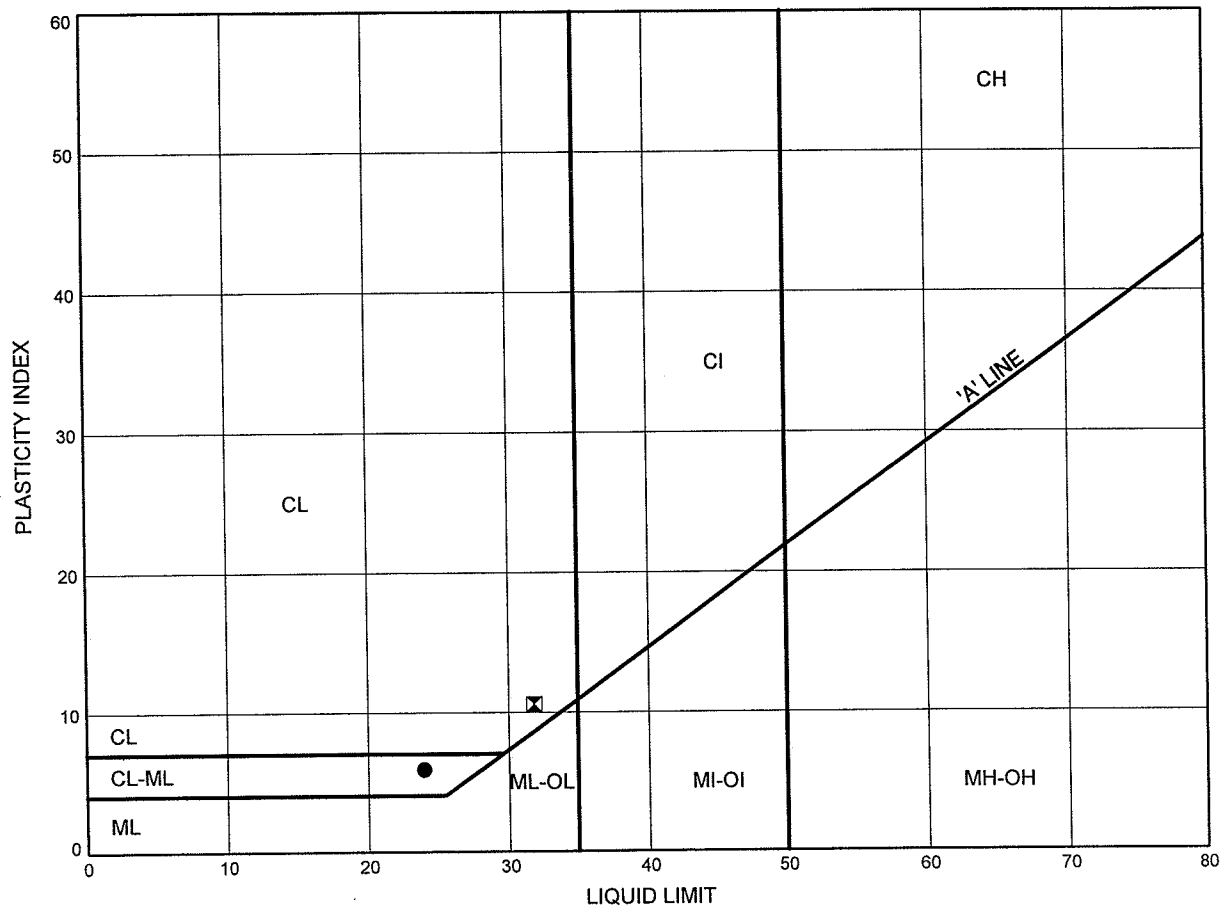


Prep'd DB
Chkd. RA

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

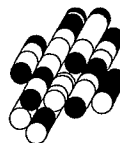
FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S3	1.0	117.8
⊠	S4	0.3	117.5

Date February 2009.....

Project 2831-02-01.....



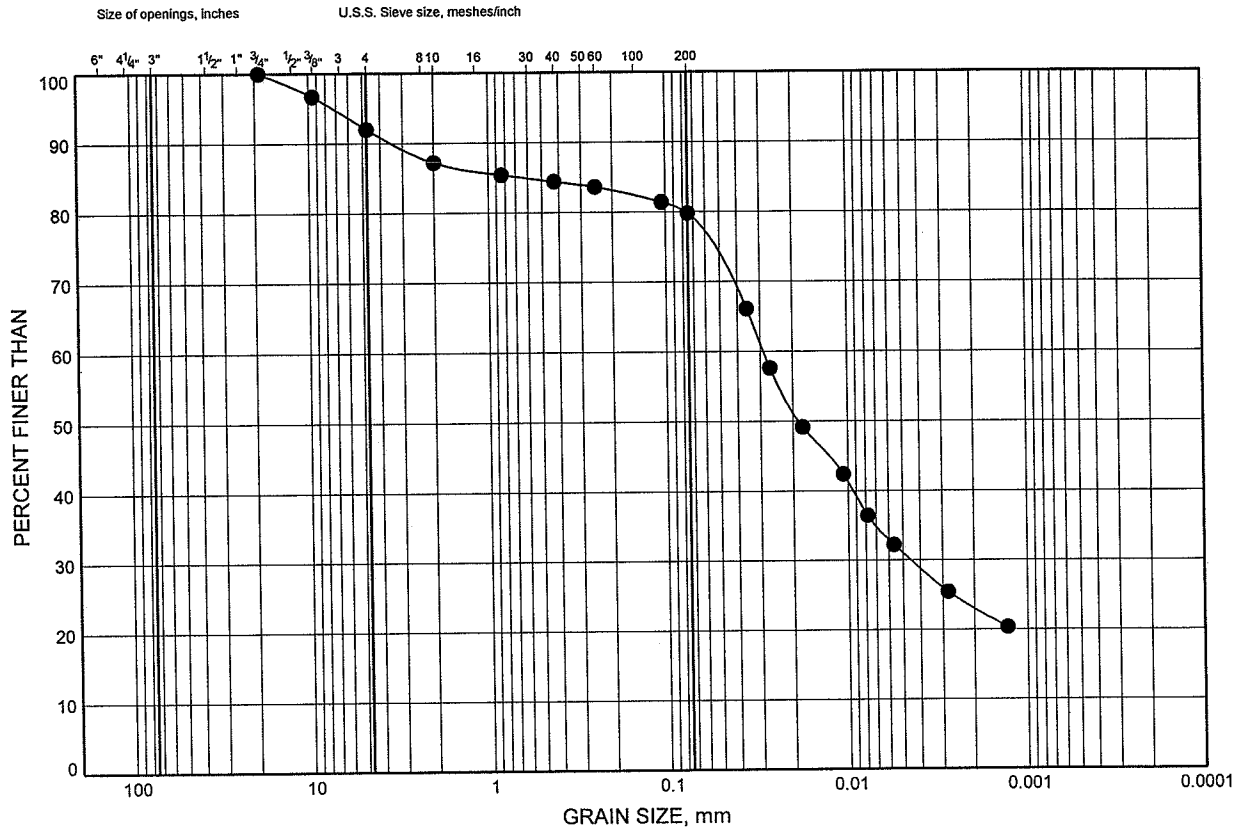
Prep'd DB.....

Chkd. RA.....

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILTY CLAY TILL

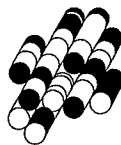


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S4	1.0	116.8

Date February 2009

Project 2831-02-01



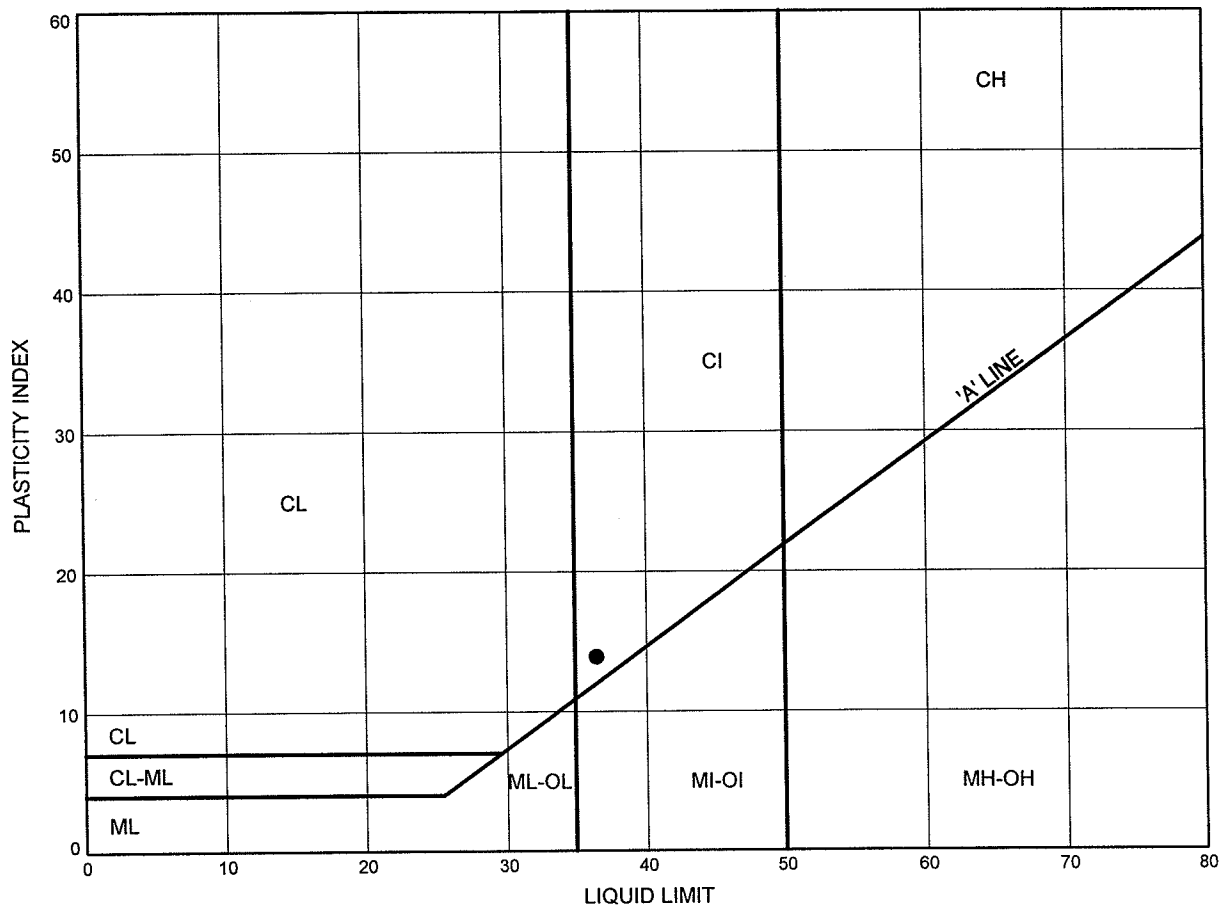
Prep'd DB

Chkd. RA

ATTERBERG LIMITS TEST RESULTS

FIGURE B10

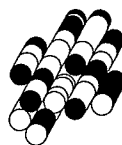
SILTY CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
•	S4	1.0	116.8

Date February 2009.....

Project 2831-02-01...



Prep'd DB.....

Chkd. RA.....

FIGURE B11

Size of openings, inches

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

PERCENT FINER THAN

GRAIN SIZE, mm

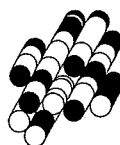
Grain Size (mm)	Percent Finer (%)
20	100
10	100
4.75	100
2.0	98
0.85	91
0.425	88
0.25	87
0.15	85
0.075	83
0.0425	72
0.025	63
0.015	51
0.0075	42
0.00425	36
0.0025	29
0.0015	21
0.00075	14

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S3	3.2	115.6

Prep'dDB.....

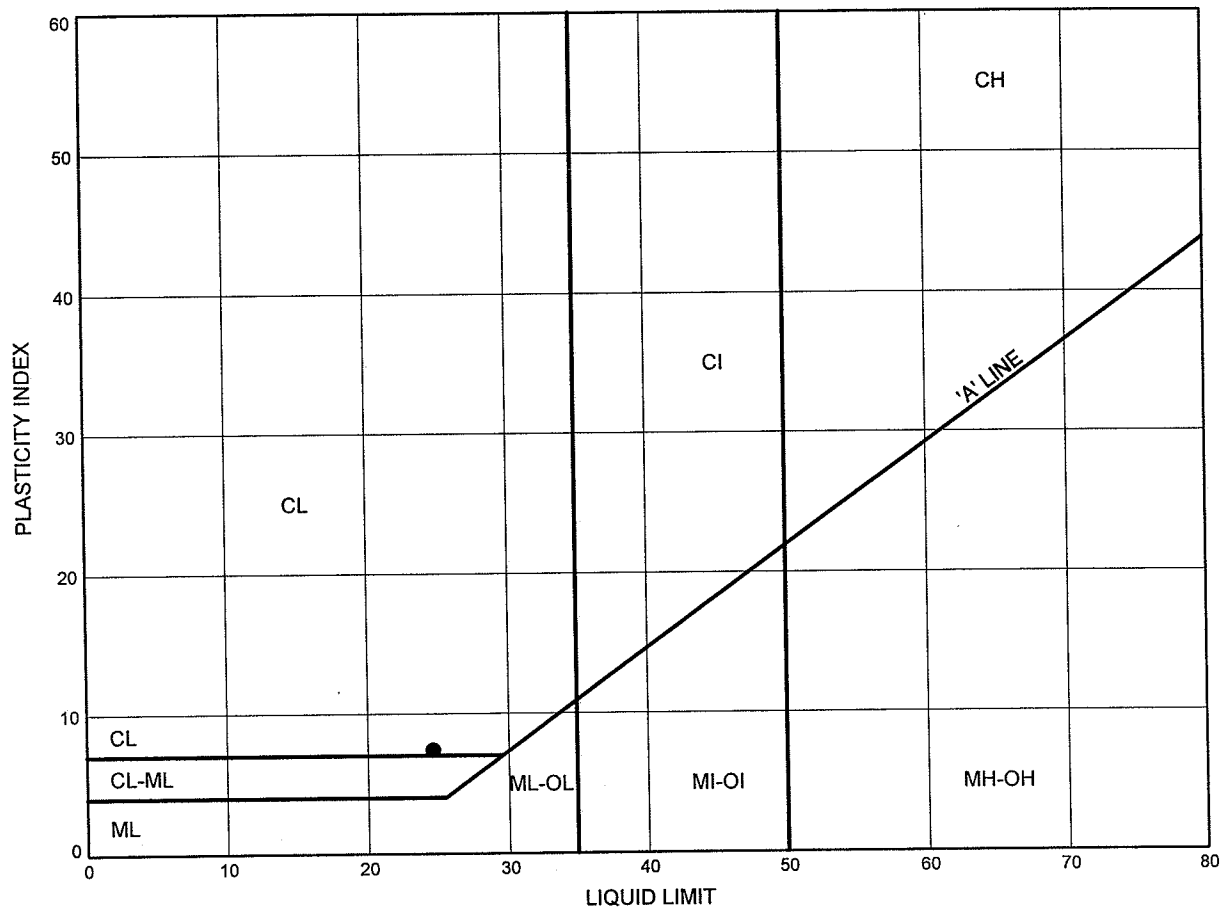
Chkd. RA



ATTERBERG LIMITS TEST RESULTS

FIGURE B12

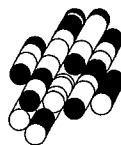
TILL SHALE COMPLEX



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	S3	3.2	115.6

Date February 2009

Project 2831-02-01



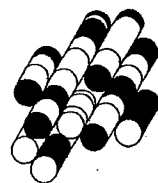
Prep'd DB

Chkd. RA

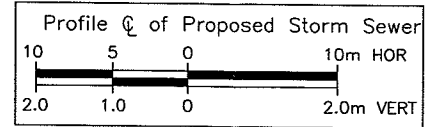
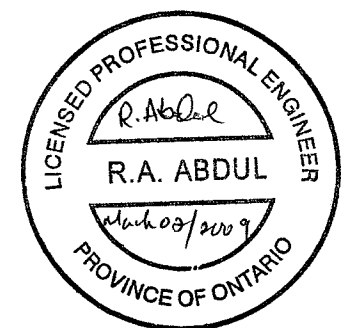
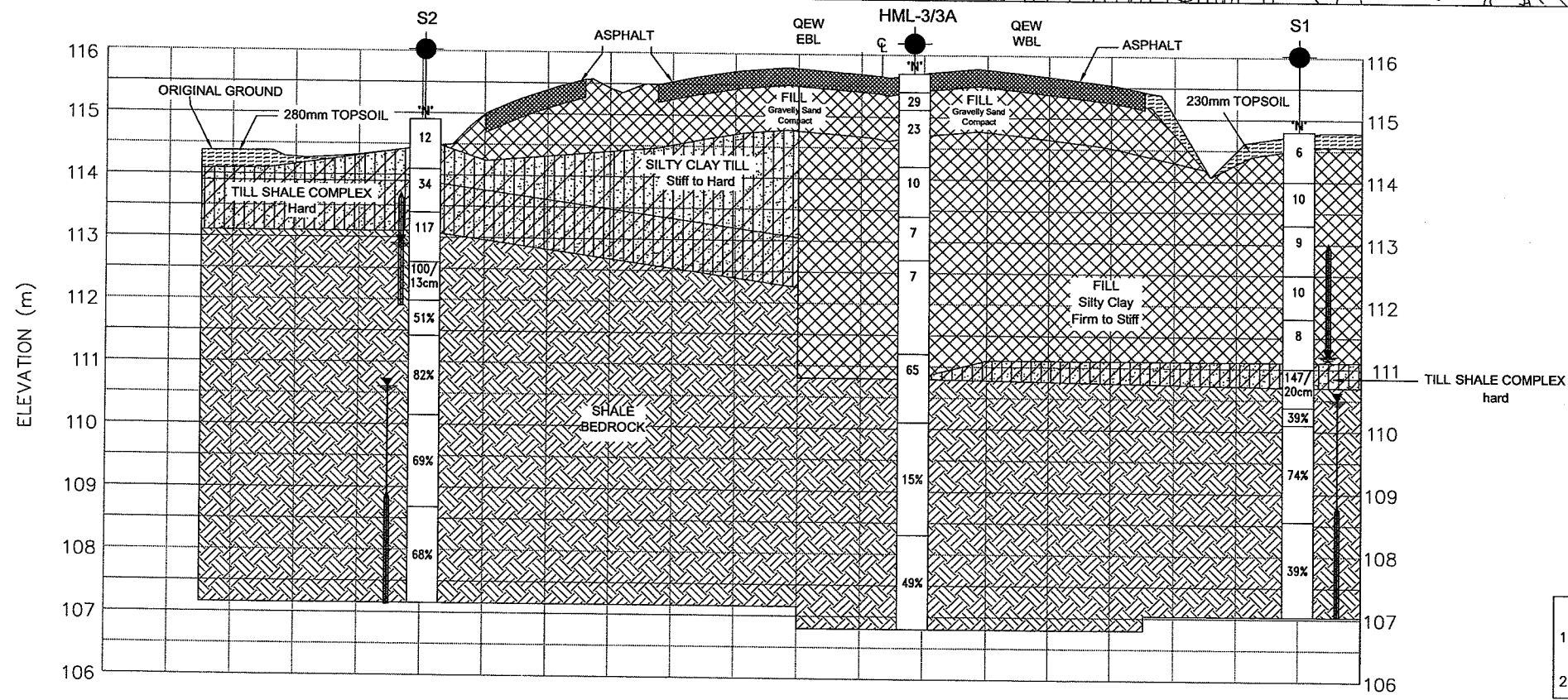
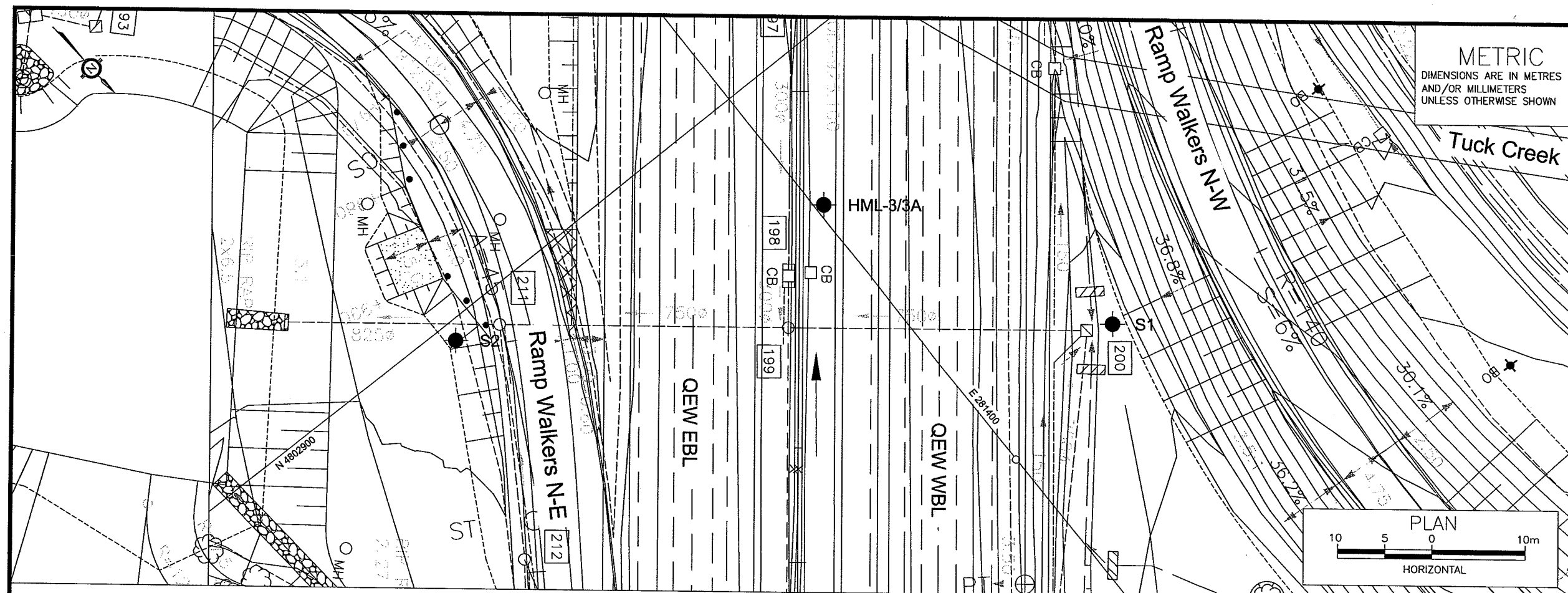
APPENDIX C

**Drawing titled “Borehole
Locations and Soil Strata”**

Terraprobe Limited



C:\Documents and Settings\Admin\My Documents\1 AUTOCAD 2008 FILES\1 Projects 2008 Lx\1-09-4007 GEOWORKING\1-09-4007 Working.dwg, Lx 9



CONT No 2008-XXXX
WP No 2831-02-01

QUEEN ELIZABETH HIGHWAY
BRANT STREET TO BURLOAK DRIVE
WALKERS LINE STORM SEWER

SHEET

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

Terraprobe
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing

WALKERS LINE
APPLEBY LINE

KEY PLAN

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- Blows/0.3m (Std Pen Test, 475 J/blow)
- 'N'
- Blows/0.3m (60" Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer (FEB 2009)
- Piezometer
- 90% Rock Quality Designation
- A/R Auger Refusal

No	ELEVATION	COORDINATES	
		NORTHING	EASTING
S1	114.8m	4 802 943.9	281 382.9
S2	114.9m	4 802 901.9	281 438.7
HML-3	115.7m	4 802 915.0	281 399.1

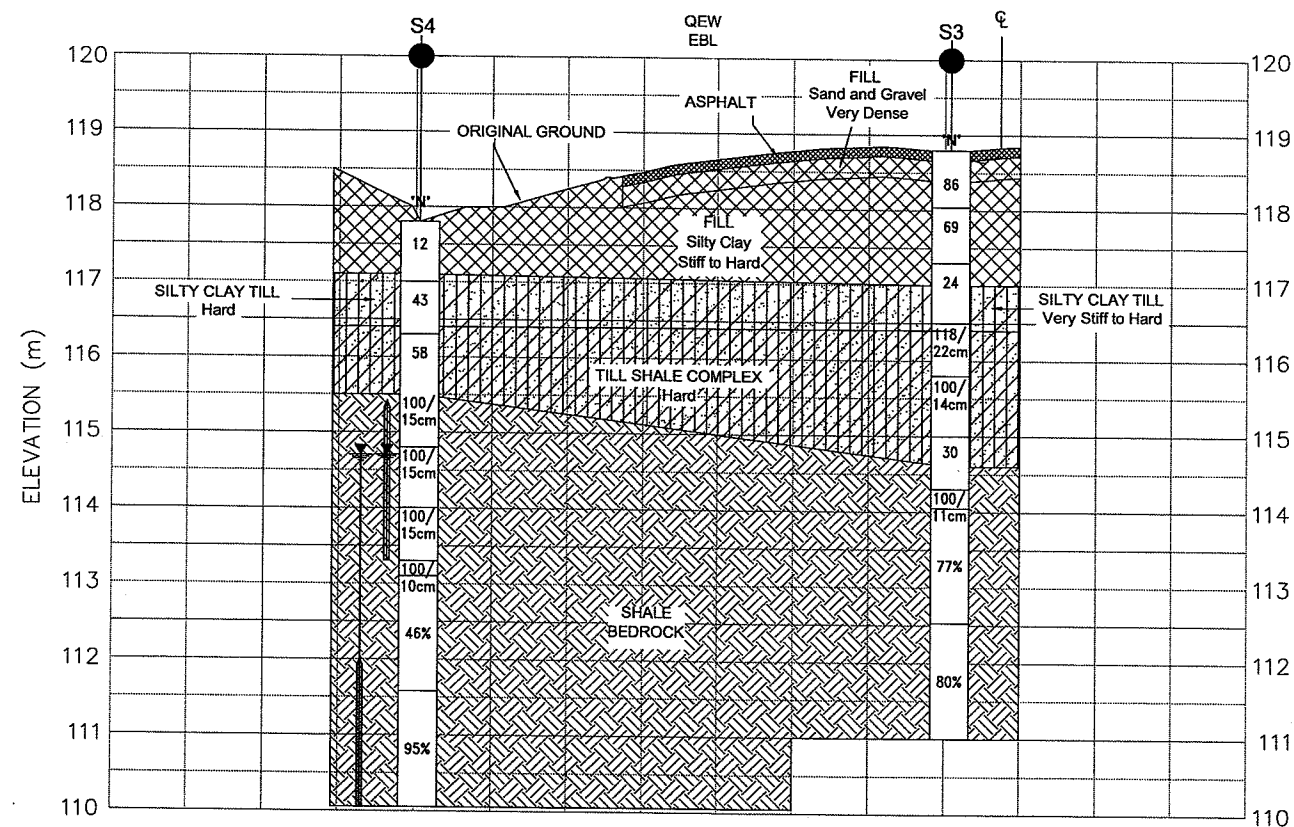
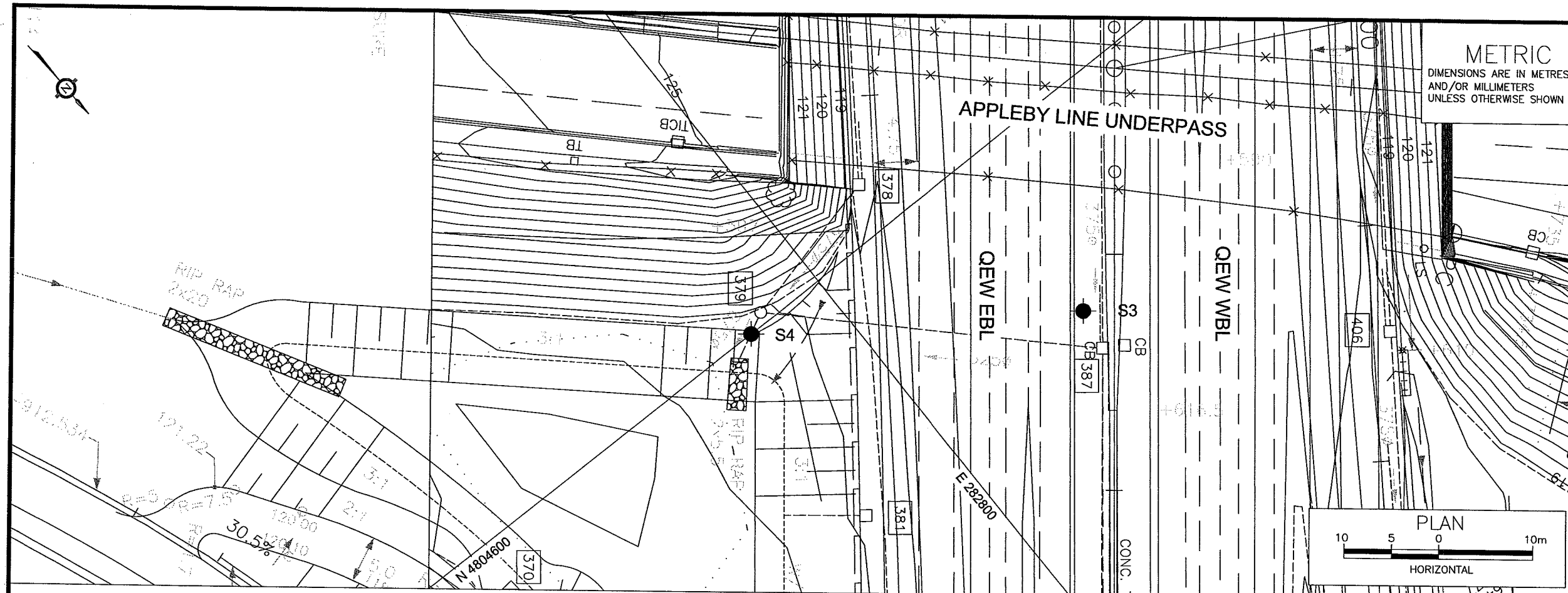
NOTE
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

REVISIONS

DATE	BY	DESCRIPTION

DESIGN R.A. CODE LOAD DATE FEB 2009
DRAWN L.B. CHK R.A. STRUCT

DRAWING NOT TO BE SCALED



PROFILE FOR SEWER
CROSSING QEW AT STA 17+609

DRAWING NOT TO BE SCALED

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

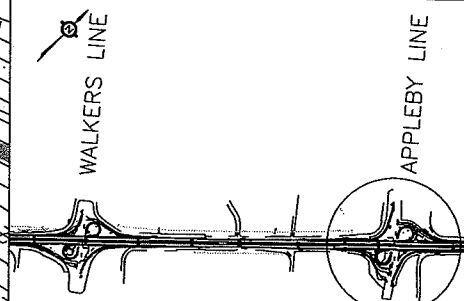
CONT No 2008-XXXX
WP No 2831-02-01



QUEEN ELIZABETH HIGHWAY
BRANT STREET TO BURLOAK DRIVE
APPLEBY LINE STORM SEWER







SHEET

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company



KEY PLAN

LEGEND

- | | |
|---|---------------------------------------|
|  | Bore Hole |
|  | Dynamic Cone Penetration Test (Cone) |
|  | Bore Hole & Cone |
| '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 (FEB 2009) |
|  | Piezometer |
| 90% | Rock Quality Designation |
| A/R | Auger Refusal |

No	ELEVATION	COORDINATES	
		NORTHING	EASTING
S3	118.8m	4 804 619.9	282 779.9
S4	117.8m	4 804 600.0	282 809.0

NOTE

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

REVIEWS				
	DATE	BY	DESCRIPTION	
DESIGN	R.A.	CODE	LOAD	DATE FEB 2009
DRAWN	L.B.	CHK R.A.		STRUCT