

Terraprobe

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

**FOUNDATION INVESTIGATION REPORT
WATER MAINS INSTALLATION BELOW THE QEW
WALKERS LINE INTERCHANGE
THE REGIONAL MUNICIPALITY OF HALTON
PROCUREMENT No. PR-2588**

PREPARED FOR: Giffels Associates Limited/IBI Group
30 International Boulevard
Toronto, Ontario

Attention: Mr. Stephen Chiu, P.Eng.
Manager, Roads and Highways Engineering

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Terraprobe Limited.
10 Bram Court
Brampton, Ontario
L6W 3R6
Phone: (905) 796 2650
Fax: (905) 796 2250

Distribution:

1 Copy - MTO Central Region
1 Copy - Giffels Associates Limited/IBI Group
1 Copy - Terraprobe Limited, Brampton

Terraprobe Limited

10 Bram Court
Brampton, Ontario L6W 3R6
(905) 796-2650 Fax 796-2250

220 Bayview Drive, Unit 25
Barrie, Ontario L4N 4Y8
(705) 739-8355 Fax 739-8369

1012 Kelly Lake Road, Unit 1
Sudbury, Ontario P3E 5P4
(705) 670-0460 Fax 670-0558

903 Barton Street, Unit 22
Stoney Creek, Ontario L8E 5P5
(905) 643-7560 Fax 643-7559

www.terraprobe.ca

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted along two water main alignments crossing the QEW in the vicinity of the Walkers Line interchange, in the Regional Municipality of Halton, Ontario. One alignment (Alignment 1) crosses the QEW at Sta. 15+340 west of the Walkers Line underpass. The second alignment (Alignment 2) crosses the QEW at Sta. 15+535 east of the Walkers Line underpass. The water mains are to be installed under the proposed eight-lanes of the QEW in steel casings ranging from 600 mm to 750 mm in diameter.

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 Limited (Terraprobe) conducted the investigation as a sub-consultant to Giffels Associates Limited/IBI Group (Giffels), under The Halton Region Procurement Number PR-2588.

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. 2831-20-01, MTO Central Region, dated August 29 2008.

2 SITE DESCRIPTION & PHYSIOGRAPHY

The site is located at the Walkers Line interchange in the Regional Municipality of Halton, City of Burlington, Ontario. Within the project limits, this divided highway comprises of six lanes, and fully paved inner and outer shoulders. There is an existing storm sewer located close to the median centreline of the highway.

A significant feature at this site 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. Very often the basal portion of this till is distinctly red in colour from large amounts of incorporated Queenston shale. The overburden soils are further underlain by bedrock of the Queenston Formation, which is predominantly shale.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out during the period December 17 to December 29, 2008 and consisted of drilling and sampling six boreholes to depths ranging from 7.3 m to 7.9 m below ground surface. Borehole HML-13 from Terraprobe's previous work was drilled on January 23, 2008 to a depth of 6.2 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. The boreholes were also advanced approximately 1.5 m to 4.6 m into bedrock by NQ size diamond coring techniques.

Boreholes WM2 and WM5 were drilled through the paved left shoulder of the QEW WBL. These boreholes were sealed using bentonite and the pavement structure was reinstated by backfilling with granular material and patching with cold mix asphalt.

Members of Terraprobe's engineering staff observed the drilling and recorded the sampling, in-situ testing and rock coring operations on a full time basis. 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.

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
Alignment 1 – Sta. 15+340		
WM1 - P1	7.6/106.2	Piezometer with 1.5 m slotted screen installed with filter sand to 5.8 m, bentonite seal from 5.8 m to 2.9 m, filter sand from 2.9 m to 1.1 m and bentonite seal from 1.1 m to ground surface.
WM1 - P2	2.9/110.9	Piezometer with 1.5 m slotted screen installed with filter sand to 1.1 m and bentonite seal from 1.1 m to ground surface.
WM3	4.5/109.8	Hole backfilled with bentonite to 4.5 m, piezometer with 1.5 m slotted screen installed with filter sand to 2.7 m and bentonite seal from 2.7 m to ground surface.
Alignment 2 – Sta. 15+535		
WM4 - P1	7.3/107.2	Piezometer with 1.5 m slotted screen installed with filter sand to 5.5 m, bentonite seal from 5.5 m to 3.0 m, filter sand from 3.0 m to 1.1 m and bentonite seal from 1.1 m to ground surface.
WM4 - P2	3.0/111.6	Piezometer with 1.5 m slotted screen installed with filter sand to 1.1 m and bentonite seal from 1.1 m to ground surface.
WM6 - P1	7.6/107.4	Piezometer with 1.5 m slotted screen installed with filter sand to 5.8 m, bentonite seal from 5.8 m to 4.7 m, filter sand from 4.7 m to 2.9 m and bentonite seal from 2.9 m to ground surface.
WM6 - P2	4.7/110.3	Piezometer with 1.5 m slotted screen installed with filter sand to 2.9 m and bentonite seal from 2.9 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 cores were selected from within the depth of the proposed tunnel and these cores were subjected to unconfined compressive strength tests and unit weight tests. The results of the soils testing program are shown on the Record of Borehole sheets 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 along each alignment is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.



5.1 Alignment 1 – Sta. 15+340

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

5.1.1 Topsoil and Asphalt

Topsoil ranging from 300 mm to 330 mm was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

At Borehole WM2 130 mm thick asphalt concrete was encountered.

5.1.2 Fill – Sand and Gravel

Sand and gravel and gravelly sand fill were encountered at the site. This granular material extends to depths ranging from 0.4 m to 0.7 m below ground surface or to elevations ranging from Elev. 113.6 m to Elev. 115.1 m.

The grain size distribution curve of a sample of this fill is shown in Figure B1. The results show a grain size distribution consisting of 27% gravel, 33% sand, 27% silt and 13% clay size particles.

Standard Penetration tests conducted in the granular fill gave SPT "N" values ranging from 18 blows to 27 blows for 0.3 m penetration indicating a compact relative density. The moisture content of samples of the granular fill ranged from 1% to 5% by weight.

5.1.3 Fill – Silty Clay

Silty clay fill was encountered across the site. The fill extends to depths ranging from 0.9 m (Elev. 112.9 m) to 3.7 m (Elev. 110.6 m).

Grain size distribution curves of samples of this fill material are presented in Figures B2. These results show grain size distributions consisting of 2 to 20% gravel, 18 to 32% sand, 35 to 47% silt and 16 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 B3. The summarized index values from these tests are presented herein.

Liquid Limit:	24 to 33%
Plastic Limit:	17 to 20%
Plasticity Index:	7 to 13%
Natural Moisture Content:	11 to 23%

These values are characteristic of clayey soils of low plasticity.



Standard Penetration tests in the silty clay fill material yielded 'N' values ranging from 4 blows to 20 blows for 0.3 m penetration. Based on these results the fill is considered to have a firm to very stiff consistency.

The moisture content of samples of this fill ranged from 11% to 25% by weight.

5.1.4 Silty Clay Till

Silty clay glacial till was encountered at the site extending to depths ranging from 3.7 m (Elev. 111.8 m) to 4.1 m (Elev. 110.2 m) below ground surface. Till soils can also be expected to contain random cobble and boulder inclusions.

A Standard Penetration test in the silty clay till gave an 'N' value of 32 blows for 0.3 m. Based on this result the silty clay till is considered to have a hard consistency.

The moisture content of samples from this deposit ranged from 9% to 19% 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 2.4 (Elev. 111.4 m) to 5.8 m (Elev. 108.5 m) below ground surface.

The results of a grain size distribution test conducted on a sample obtained from this deposit is shown in Figure B4. These results show a grain size distribution consisting of 7% gravel, 14% sand, 65% silt and 14% 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 B5. The index values from these tests are summarized below:

Liquid Limit:	24%
Plastic Limit:	17%
Plasticity Index:	7%
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 37 blows to more than 50 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 5% to 10% 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 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 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 1.5 m to 4.6 m metres 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)
WM1	2.4	111.4
WM2	4.4	111.1
WM3	5.8	108.5



The bedrock is described as weathered generally in the top ± 3 m, and moderately weathered below. It is medium to thickly bedded shale with occasional interbeds of grey limestone. Total core recovery was generally 100% and the RQD values generally ranged from 56% to 72% indicating fair quality rock. In Borehole WM3 total core recovery was 0% and the RQD values were 0%, indicating very poor rock quality at this location. The retrieved rock core from Borehole WM3 was highly weathered.

Two unconfined compressive strength tests were conducted on the shale bedrock at elevations of 109.7 m. The results ranged between 19.1 MPa and 25.2 MPa indicating medium strength rock. The unit weight of the rock ranged from 23.7 kN/m³ to 24.6 kN/m³.

5.2 Alignment 2 – Sta. 15+535

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

5.2.1 Topsoil and Asphalt

Topsoil ranging from 130 mm to 250 mm was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

At Borehole WM5 160 mm thick asphalt concrete was encountered.

5.2.2 Fill – Sand

Sand and silt some gravel was encountered below the asphalt concrete in Borehole WM5 extending to a depth of 0.5 m (Elev. 115.4 m) below ground surface.

The grain size distribution curve of a sample of this fill is shown in Figure B6. The results show a grain size distribution consisting of 18% gravel, 36% sand, 30% silt and 16% clay size particles.

A Standard Penetration Test conducted in the granular fill gave an SPT "N" value of 14 blows for 0.3 m penetration indicating a compact relative density. The moisture content of a sample of the granular fill was 11% by weight.

5.2.3 Fill – Silty Clay

Silty clay fill was encountered across the site. The fill extends to depths ranging from 0.7 m (Elev. 115.2 m) to 1.4 m (Elev. 113.6 m).

The grain size distribution curve of a sample of this fill material is presented in Figure B7. These results show a grain size distribution consisting of 2% gravel, 23% sand, 49% silt and 26% clay size particles.

A sample of the silty clay fill was also subjected to an Atterberg Limits test and the results are illustrated in Figure B8. The summarized index values from these tests are presented herein.



Liquid Limit:	27%
Plastic Limit:	18%
Plasticity Index:	9%
Natural Moisture Content:	12%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the silty clay fill material yielded 'N' values ranging from 4 blows to 30 blows for 0.3 m penetration. Based on these results the fill is considered to have a firm to hard consistency.

The moisture content of samples of this fill ranged from 9% to 17% by weight.

5.2.4 Silty Clay Till

Silty clay glacial till was encountered at the site extending to depths ranging from 1.3 m to 2.6 m below ground surface or to elevations ranging from 113.8 m to 112.4 m.

Grain size distribution curves of samples of the silty clay till are illustrated in Figure B9. These results show grain size distributions consisting of 2 to 8% gravel, 20 to 24% sand, 42 to 49% silt and 25 to 29% clay size particles. Till soils can also be expected to contain random cobble and boulder inclusions.

Samples of the silty clay till were also subjected to Atterberg Limits tests and the results are illustrated in Figure B10. The summarized index values from these tests are presented herein.

Liquid Limit:	26 to 29%
Plastic Limit:	16 to 19%
Plasticity Index:	9 to 13%
Natural Moisture Content:	11 to 13%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in this deposit gave a 'N' values ranging from 13 blows to more than 50 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 10% to 13% by weight.

5.2.5 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 2.1 m to 3.5 m below ground surface or to elevations ranging from 113.2 m to 111.5 m.

Standard Penetration tests in the till/shale complex gave 'N' values ranging from 85 blows to more than 50 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 5% to 8% by weight.

5.2.6 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 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 3.4 m to 4.6 m metres 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)
WM4	2.1	112.5
WM5	2.7	113.2
WM6	3.5	111.5

The bedrock is described as weathered generally in the top ± 3 m to ± 4.5 m, and slight to moderately weathered below. It is medium to thickly bedded shale with occasional interbeds of grey limestone. Total core recovery was generally 86% to 100% and the RQD values generally ranged from 28% to 100% indicating poor to excellent quality rock.

Three unconfined compressive strength tests were conducted on the shale bedrock at elevations ranging between 110.3 m and 110.9 m. The results ranged between 18.7 MPa and 38.9 MPa indicating medium strength rock. The unit weight of the rock ranged from 25.2 kN/m³ to 25.9 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 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
Alignment 1 – Sta. 15+340			
WM1-P1*	December 24, 2008	3.6	110.2
	January 06, 2009	3.4	110.4
	January 09, 2009	3.5	110.3
WM1-P2**	December 24, 2008	2.8	111.0
	January 06, 2009	2.6	111.2
	January 09, 2009	2.7	111.1
WM3**	January 06, 2009	1.5	112.8
	January 09, 2009	1.3	113.0
Alignment 2 – Sta. 15+535			
WM4-P1*	January 06, 2009	2.1	112.5
	January 09, 2009	2.3	112.3
WM6-P1*	January 06, 2009	3.8	111.2
	January 09, 2009	3.9	111.1
WM4-P2**	January 06, 2009	1.4	113.2
	January 09, 2009	1.6	113.0
WM6-P2**	January 06, 2009	3.6	111.4
	January 09, 2009	3.7	111.3

* Standpipe piezometer installed and sealed in the bedrock

** Standpipe piezometer installed in the overburden soils



At Alignment 1 the recorded water levels in the bedrock range between Elev. 110.2 m and Elev. 110.4 m. The water level readings in the overburden soils indicate that the groundwater level is likely to exist at elevations ranging between ± 111 m and ± 113 m.

Along Alignment 2 the recorded water levels in the bedrock range between Elev. 111.1 m and Elev. 112.5 m. The water level readings in the overburden soils indicate that the groundwater level is likely to exist at elevations ranging between ± 111.3 m and ± 113.2 m.

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

5.4 Miscellaneous

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

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

The utility locates, fieldwork planning and its coordination were undertaken by Mr. H. Ahmed, P.Eng. Ms. J. Solop, E.I.T, Mr. S. Shah, E.I.T, and Mr. P. Khuu observed and recorded the drilling and sampling operations on a full time basis under the direction of Mr. H. Ahmed, P.Eng. 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 rock cores were examined by geologist Mr. Bradford Ripley, B.Sc.

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





Rahman Abdul

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



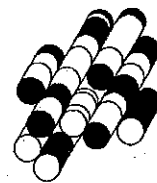
Michael Tanos

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.

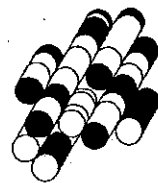
The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional 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 Halton Region, the Ministry of Transportation, their retained design consultants and Giffels Associates Limited/IBI Group. It is not for use by others. This report is copyright of Terraprobe Limited and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Limited. Halton Region, Ministry of Transportation, their retained design consultants and Giffels Associates Limited/IBI Group, are authorized users.

APPENDIX A

Record of Borehole Sheets

Terraprobe Limited



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_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_{vm}	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_a	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No WM1

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4802881.3 E:281326.5 ORIGINATED BY PK
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 17.12.08 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						
113.8	Ground Surface													
0.0	330mm TOPSOIL - dark brown		1	SS	4									GR SA SI CL
113.5														
0.3	FILL - Silty Clay, sandy, gravelly, firm, reddish brown, damp to moist		2	SS	50/ 10cm									20 21 43 16
112.9														
0.9	SILTY CLAY TILL- with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		3	SS	50/ 8cm									
111.4			4	SS	50/ 8cm									
2.4	SHALE BEDROCK Reddish brown, weathered to 3.1m, then moderately weathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, grey limestone. Shale = 93% Limestone = 7% (Queenston Formation)		5	SS	50/ 8cm									
			1	RUN	NQ									RUN#1 TCR=100% RQD=89%
			2	RUN	NQ									RUN#2 TCR=100% RQD=56%
			3	RUN	NQ									RUN#3 TCR=100% RQD=61%
106.1	End of Borehole													
7.7	Commence rock coring at 3.1m See CORE LOG1 for detailed information Water Level Readings P1: Date Depth(m) Elevation(m) Dec.24.08 3.6 110.2 Jan.06.09 3.4 110.4 Jan.09.09 3.5 110.3 Water Level Readings P2: Date Depth(m) Elevation(m) Dec.24.08 2.8 111.0 Jan.06.09 2.6 111.2 Jan.09.09 2.7 111.1													

ONTARIO MOT 1-08-3350 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	113.8m	Datum	Geodetic	Borehole No.	WM1
Location	Burlington, Ontario	Date Started	December 17, 2008	Completed	December 17, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Halton Region	Drilling Agency	Geoenvironmental	Drill Type	Bombardier	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								WEATHERING	STRENGTH	FRACTURE FREQUENCY	RUN NO.	CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m ³
				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		
110.8 110.7	3.0		See Borehole Log WM1																	
	3.1																			
	3.5																			
	4.0																			
	4.5																			
	5.0																			
	5.5																			
	6.0																			
	6.5																			
	7.0																			
106.1	7.5		<p>QUEENSTON FORMATION</p> <p><u>Shale (93%):</u> Reddish brown, slight to moderately weathered, medium to thickly bedded, low to medium strength, breaks easily along bedding planes upon drying.</p> <p><u>Limestone/Dolostone (INTERBEDS)(7%):</u> Light to medium grey, laminated to thinly bedded, fresh. Bedding planes are tight, planar, rough, medium to high strength.</p>	1	B	F	C	RP	T	O					1	100%	69%	NQ	19.1	24.6
	7.7																			
	8.0																			
	8.5																			
	9.0																			
	9.5																			
	10.0																			

Remarks

RECORD OF BOREHOLE No WM2

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4802857.5 E:281351.7 ORIGINATED BY SS
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 29.12.08 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE	×						
								QUICK TRIAXIAL LAB VANE								
						WATER CONTENT (%)										
115.5	Ground Surface						20	40	60	80	100					
0.0	130mm ASPHALT															
0.1	FILL - Sand and Gravel, silty, compact, brown, moist		1	SS	18											
0.4	brown to 1.4m		2	SS	10											

	FILL - Silty Clay, some sand, trace gravel, occasional wood pieces below 2.9m, firm to stiff, grey, damp to moist		3	SS	6											
			4	SS	5											
			5	SS	7											
112.1																
3.4	SILTY CLAY - trace sand, reddish brown, damp (GLACIAL TILL)		6	SS	97/ 28cm											
111.8	SILTY CLAY TILL - with shale, hard, reddish brown, damp (TILL-SHALE COMPLEX)		7	SS	50/ 10cm											
3.7																
111.1	SHALE BEDROCK															
4.4	Reddish brown, weathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, grey limestone. Shale = 88% Limestone = 12% (Queenston Formation)		1	RUN	NQ											
			2	RUN	NQ											
107.8	End of Borehole															
7.7	Commence rock coring at 4.5m See CORE LOG2 for detailed information															

ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	115.5m	Datum	Geodetic	Borehole No.	WM2
Location	Burlington, Ontario	Date Started	December 29, 2008	Completed	December 29, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Hallon Region	Drilling Agency	DBW Drilling	Drill Type	Bombardier	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								STRENGTH	FRACTURE FREQUENCY	RUN NO. CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m
				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
			See Borehole Log WM2															
110.9	4.0																	
	4.5																	
	4.6																	
	5.0		QUEENSTON FORMATION											1				
	5.5		Shale (88%): Reddish brown, weathered, medium to thickly bedded, low to medium strength, breaks easily along bedding planes upon drying.	1	B	F	C	RP	T	O				100%	72%	NQ	25.2	23.7
	6.0																	
	6.5		Limestone/Dolostone (INTERBEDS) (12%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength.											2				
	7.0			1	B	F	C	RP	T	O				100%	62%	NQ		
107.78	7.72																	
	8.0																	
	8.5																	
	9.0																	
	9.5																	
	10.0																	

Remarks

RECORD OF BOREHOLE No WM3

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4802838.9 E:281378.6 ORIGINATED BY PK
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 15.12.08 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
114.3	Ground Surface																	
0.0 114.0	300mm TOPSOIL																	
0.3 113.6	FILL - Sand, Gravelly, Silty, with asphalt and clay inclusions, compact, grey / brown, dry		1	SS	27									27 33 27 13				
0.7																		
	FILL - Silty Clay, sandy, trace to some gravel, occasional asphalt inclusions, trace organics, stiff to very stiff, brown, damp to moist		2	SS	11													
			3	SS	20									13 32 35 20				
			4	SS	11									Sampler Wet				
			5	SS	14													
110.6 3.7	SILTY CLAY - trace sand, trace gravel, hard, reddish brown, damp (GLACIAL TILL)		6	SS	32													
110.2 4.1																		
	SILTY CLAY TILL - with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		7	SS	37													
			8	SS	50/ 10cm													
108.5 5.8	SHALE BEDROCK - Reddish brown, weathered to 7m, then moderately weathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, grey limestone. Shale = 91% Limestone = 9% (Queenston Formation)		1	RUN	NQ									RUN#1 TCR=7% RQD=0%				
107.0 7.3	End of Borehole		2	RUN	NQ									RUN#2 TCR=25% RQD=0%				
	Commence rock coring at 5.8m See CORE LOG3 for detailed information																	
	Water Level Readings:																	
	Date Depth(m) Elevation(m)																	
	Jan.05.09 1.5 112.8																	
	Jan.09.09 1.3 113.0																	

ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	114.3m	Datum	Geodetic	Borehole No.	WM3
Location	Burlington, Ontario	Date Started	December 15, 2008	Completed	December 15, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Haltom Region	Drilling Agency	DBW Drilling	Drill Type	Bombardier	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								STRENGTH	FRACTURE FREQUENCY	RUN NO. CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m
				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
108.5	5.0		See Borehole Log WM3															
	5.5																	
	5.8		QUEENSTON FORMATION															
	6.0		Shale (91%): Reddish brown, moderately weathered, medium to thickly bedded, low to medium strength, breaks easily along bedding planes upon drying.	1	B	F	C	RP	T	O				1	7%	0%	NQ	
	6.5																	
	7.0																	
106.99	7.31		Limestone/Dolostone (INTERBEDS)(9%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength.	1	B	F	C	RP	T	O				2	25%	0%	NQ	
	7.5																	
	8.0																	
	8.5																	
	9.0																	
	9.5																	
	10.0																	

Remarks

RECORD OF BOREHOLE No WM4

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4803046.7 E:281465.5 ORIGINATED BY PK
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 18.12.08 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					
114.6	Ground Surface																
114.0	250mm TOPSOIL																
0.3	FILL - Silty Clay, trace sand, trace gravel, firm, brown, damp to moist		1	SS	4		114							○			
113.9																	
0.7	SILTY CLAY - some sand, trace gravel, hard, brown, damp (GLACIAL TILL)		2	SS	74/ 28cm		113							○			8 20 47 25
113.3																	
1.3	SILTY CLAY TILL - with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		3	SS	50/ 10cm		112							○			
112.5																	
2.1	SHALE BEDROCK		4	SS	50/ 8cm		111							○			
	Reddish brown, weathered to 3.2m, then slight to moderately weathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, grey limestone.		5	SS	50/ 10cm		110							○			
	Shale = 92% Limestone = 8% (Queenston Formation)		1	RUN	NQ		109										RUN#1 TCR=100% RQD=46%
			2	RUN	NQ		108										RUN#2 TCR=100% RQD=78%
			3	RUN	NQ		107										RUN#3 TCR=100% RQD=97%
106.8	End of Borehole																
7.8	Commence rock coring at 3.2m See CORE LOG4 for detailed information																
	Water Level Readings P1:																
	Date Depth(m) Elevation(m)																
	Jan.06.09 2.1 112.5																
	Jan.09.09 2.3 112.3																
	Water Level Readings P2:																
	Date Depth(m) Elevation(m)																
	Jan.06.09 1.4 113.2																
	Jan.09.09 1.6 113.0																

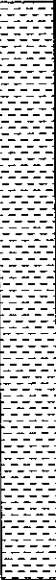
ONTARIO MOT 1-08-3360 QEW WATERMAIN GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	114.6m	Datum	Geodetic	Borehole No.	WM4
Location	Burlington, Ontario	Date Started	December 18, 2008	Completed	December 18, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Halton Region	Drilling Agency	Geoenvironmental	Drill Type	Bombardier	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								WEATHERING	STRENGTH	FRACTURE FREQUENCY	RUN NO.	CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m
				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		
111.4	3.0		See Borehole Log WM4																	
	3.2																			
	3.5		QUEENSTON FORMATION												1					
	4.0		Shale (92%): Reddish brown, slight to moderately weathered, medium to thickly bedded, low to medium strength, breaks easily along bedding planes upon drying.	1	B	F	C	RP	T	O					100%	46%	NQ	18.7	25.2	
	4.5																			
	5.0		Limestone/Dolostone (INTERBEDS)(8%): Light to medium gray, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength.												2					
	5.5			1	B	F	C	RP	T	O					100%	78%	NQ			
	6.0																			
	6.5																			
	7.0				1	B	F	C	RP	T	O					3				
106.78	7.5																			
	7.82																			
	8.0																			
	8.5																			
	9.0																			
	9.5																			
	10.0																			

Remarks

RECORD OF BOREHOLE No WM5

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4803021.7 E:281485.5 ORIGINATED BY JS
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 28.12.08 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						
115.9	Ground Surface						20	40	60	80	100					
0.0	160mm ASPHALT															
0.2	FILL - Sand and Silt, some gravel, occasional clayey inclusions, compact, brown, damp to moist		1	SS	14										18 36 30 16	
115.4																
0.3	FILL - Silty Clay, trace sand, trace gravel, stiff, brown, damp to moist		2	SS	55										2 20 49 29	
115.2																
0.7	SILTY CLAY some sand, trace gravel, hard, brown, damp (GLACIAL TILL)		3	SS	64											
113.8																
2.1	SILTY CLAY TILL- with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		4	SS	50/ 15cm											
113.2																
2.7	SHALE BEDROCK Reddish brown, weathered to 3.8m, slight to moderately weathered below, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, grey limestone. Shale = 88% Limestone = 12% (Queenston Formation)		5	SS	50/ 10cm											
			1	RUN	NQ										RUN#1 TCR=96% RQD=28%	
			2	RUN	NQ										RUN#2 TCR=99% RQD=52%	
			3	RUN	NQ										RUN#3 TCR=100% RQD=52%	
			4	RUN	NQ										RUN#4 TCR=100% RQD=100%	
108.3	End of Borehole															
7.6	Commence rock coring at 3.8m See CORE LOG5 for detailed information															

ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	115.9m	Datum	Geodetic	Borehole No.	WM5
Location	Burlington, Ontario	Date Started	December 28, 2008	Completed	December 28, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Halton Region	Drilling Agency	DBW Drilling	Drill Type	Truck-Mounted	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								WEATHERING	STRENGTH	FRACTURE FREQUENCY	RUN NO. CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m
				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	
112.1	3.0		See Borehole Log WM5																
	3.5																		
	3.8																		
	4.0			QUEENSTON FORMATION	1	B	F	C	RP	T	O				1		NQ		
	4.5		Shale (88%): Reddish brown, slight to moderately weathered, medium to thickly bedded, low to medium strength, breaks easily along bedding planes upon drying. Limestone/Dolostone (INTERBEDS)(12%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength.											96%	28%				
	5.0			1	B	F	C	RP	T	O				2	99%	52%	NQ	31.1	25.9
	5.5																		
	6.0														3	100%	52%	NQ	
	6.5			1	B	F	C	RP	T	O									
	7.0																		
7.5														4	100%	100%	NQ		
7.64																			
108.26	8.0																		
	8.5																		
	9.0																		
	9.5																		
	10.0																		

Remarks

RECORD OF BOREHOLE No WM6

1 OF 1

METRIC

W.P. _____ LOCATION _____ Coords: N:4802995.8 E:281508.7 ORIGINATED BY PK
 DIST _____ HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
 DATUM Geodetic DATE 22.12.08 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	20	40	60	80	100	10
115.0	Ground Surface																						
0.0	250mm TOPSOIL																						
114.8			1	SS	16																		
0.3	FILL - Silty Clay, sandy, trace gravel, trace rootlets, very stiff to hard, brown, damp to moist		2	SS	30															2	23	49	26
113.6																							
1.4	SILTY CLAY sandy, trace gravel, hard, brown, damp (GLACIAL TILL)		3	SS	41															2	24	47	27
112.4			4	SS	76/ 23cm																		
2.6	SILTY CLAY TILL- with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX)		5	SS	85																		
111.5																							
3.5	SHALE BEDROCK Reddish brown, weathered to 4.5m, slight to moderately weathered below, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium strength, gray limestone. Shale = 85% Limestone = 15% (Queenston Formation)		6	SS	50/ 0cm																		
			7	SS	50/ 0cm																		
			1	RUN	NQ																		
			2	RUN	NQ																		
			3	RUN	NQ																		
107.1	End of Borehole																						
7.9	Commence rock coring at 4.5m See CORE LOG6 for detailed information Water Level Readings P1: Date Depth(m) Elevation(m) Jan.06.09 3.8 111.2 Jan.09.09 3.9 111.1 Water Level Readings P2: Date Depth(m) Elevation(m) Jan.06.09 3.6 111.4 Jan.09.09 3.7 111.3																						

ONTARIO MOT. 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

Project	Watermains Installation	Orientation	Vertical	Ground Elevation	115.0m	Datum	Geodetic	Borehole No.	WM6
Location	Burlington, Ontario	Date Started	December 22, 2008	Completed	December 22, 2008	Logged By	B. Ripley	Sheet	1 of 1
Client	Halton Region	Drilling Agency	Geoenvironmental	Drill Type	Bombardier	Core Barrel & Bit Design	NQ	Project No.	1-08-3360

ELEVATION (m)	DEPTH (m)	SYMBOL	GENERAL DESCRIPTION	Joint Characteristics								STRENGTH	FRACTURE FREQUENCY	RUN NO. CORE RECOVERY %	R Q D %	CORE SIZE/CASING	UNCONFINED COMPRESSIVE STRENGTH TESTS (MPa)	UNIT WEIGHT KN/m ³
				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
			See Borehole Log WM6															
110.5	4.5		QUEENSTON FORMATION	1	B	F	C	RP	T	O				1	100%	52%	NQ	38.9
	5.0		Shale (85%): Reddish brown, slight to moderately weathered, medium to thickly bedded, low to medium strength shale, breaks easily along bedding planes upon drying.											2	100%	79%		
	5.5			1	B	F	C	RP	T	O							NQ	
	6.0																	
	6.5		Limestone/Dolostone (INTERBEDS)(15%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength.											3	100%	96%		
	7.0			1	B	F	C	RP	T	O							NQ	
	7.5																	
107.1	7.9																	
	8.0																	
	8.5																	
	9.0																	
	9.5																	
	10.0																	

Remarks

RECORD OF BOREHOLE No HML-13

1 OF 1

METRIC

W.P. 2831-02-01 LOCATION Coords: N:4802849.4 E:281478.8 ORIGINATED BY JS
DIST HWY QEW BOREHOLE TYPE Solid Stem Augers & NQ Coring COMPILED BY DB
DATUM Geodetic DATE 23.01.08 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
114.5	Ground Surface							20 40 60 80 100						
114.3	130mm TOPSOIL													
0.1	trace organics, stiff		1	SS	13		114			>>	o			
	SILTY CLAY		2	SS	38		113			>>	o			6 24 42 28
	sandy, trace gravel, hard, brown, moist (GLACIAL TILL)		3	SS	68		112			>>	o			
	trace shale fragments, reddish brown		4	SS	100/ 5cm		111				o			
112.4	SHALE BEDROCK		1	RUN	NQ		110							RUN#1 TCR=86% SCR=88% RQD=30%
2.1	Reddish brown, partially weathered to 4.8m, then unweathered, medium to thickly bedded, low to medium strength shale with occasional interbeds of medium to high strength greenish grey limestone. Smooth, stained subvertical joints at 2.9m and 3.7m.		2	RUN	NQ		109							RUN#2 TCR=100% SCR=98% RQD=29%
	Shale = 80% Limestone = 20% (Queenston Formation)		3	RUN	NQ									RUN#3 TCR=100% SCR=100% RQD=60%
108.3	End of Borehole													
6.2	Borehole filled with drill water upon completion of drilling.													

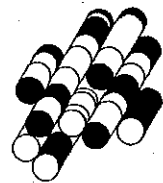
ONTARIO MOT 1-07-2145 SIGNS AND LIGHTS.GPJ ONTARIO MOT.GDT 16/01/09

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

APPENDIX B

Laboratory Test Results

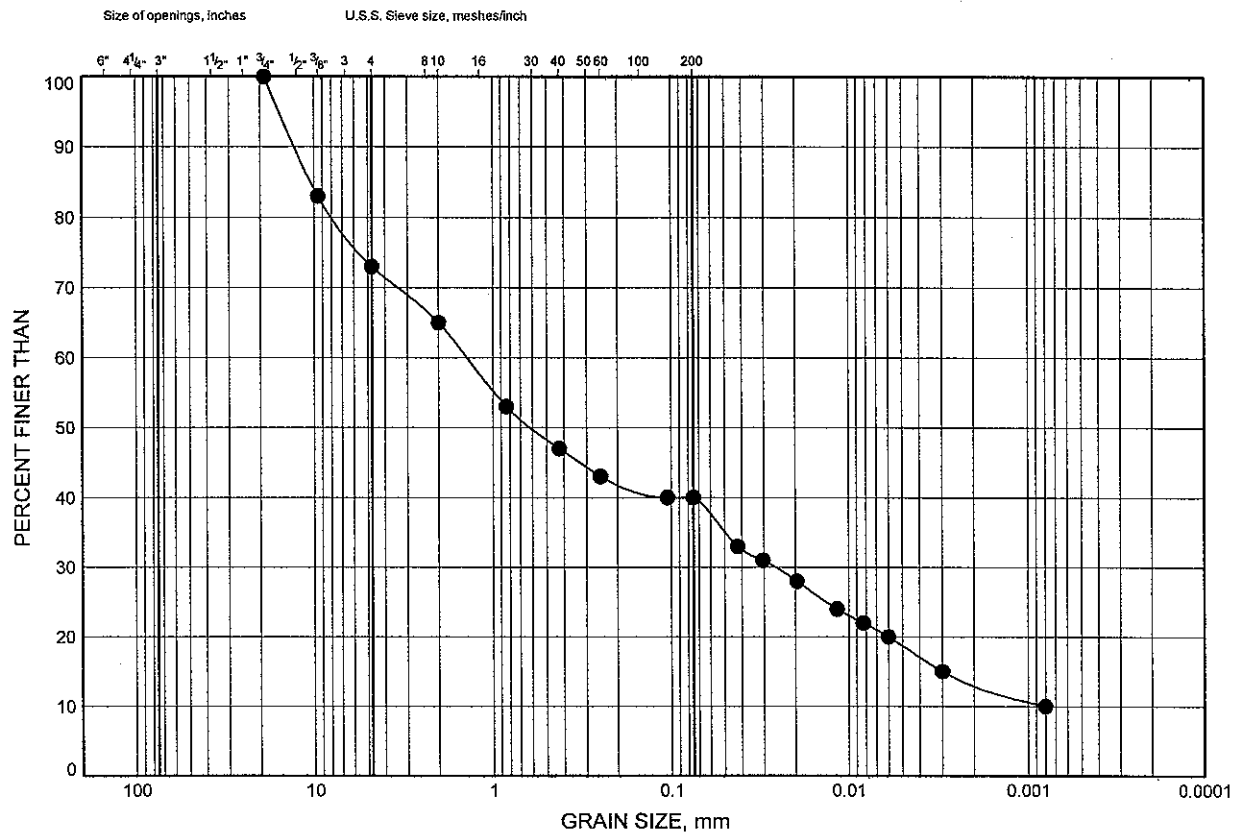
Terraprobe Limited



GRAIN SIZE DISTRIBUTION

FIGURE B1

FILL - Gravelly Sand

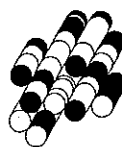


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM3	0.3	114.0

Date January 2009

Project 1-08-3360



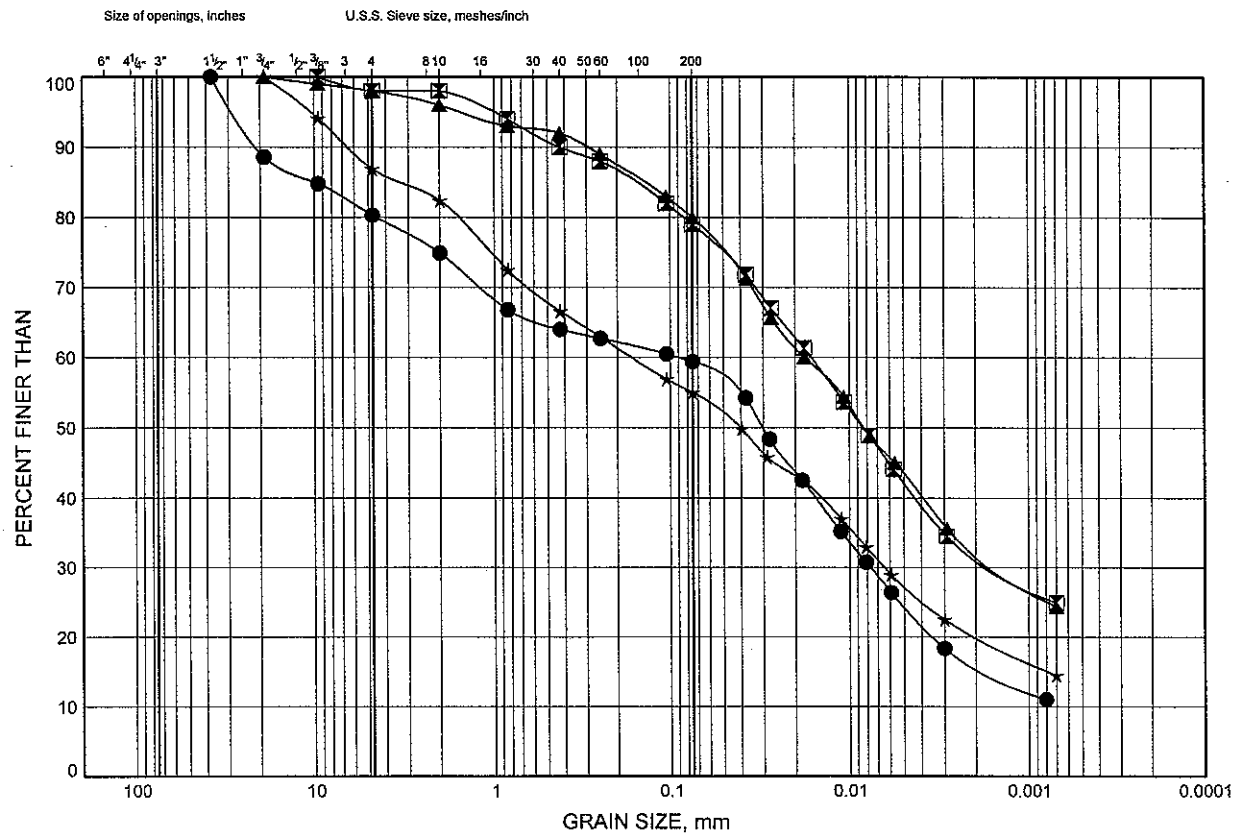
Prep'd DB

Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B2

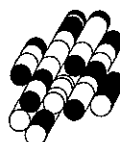
FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM1	0.3	113.5
⊠	WM2	1.0	114.5
▲	WM2	2.5	113.0
★	WM3	1.7	112.6

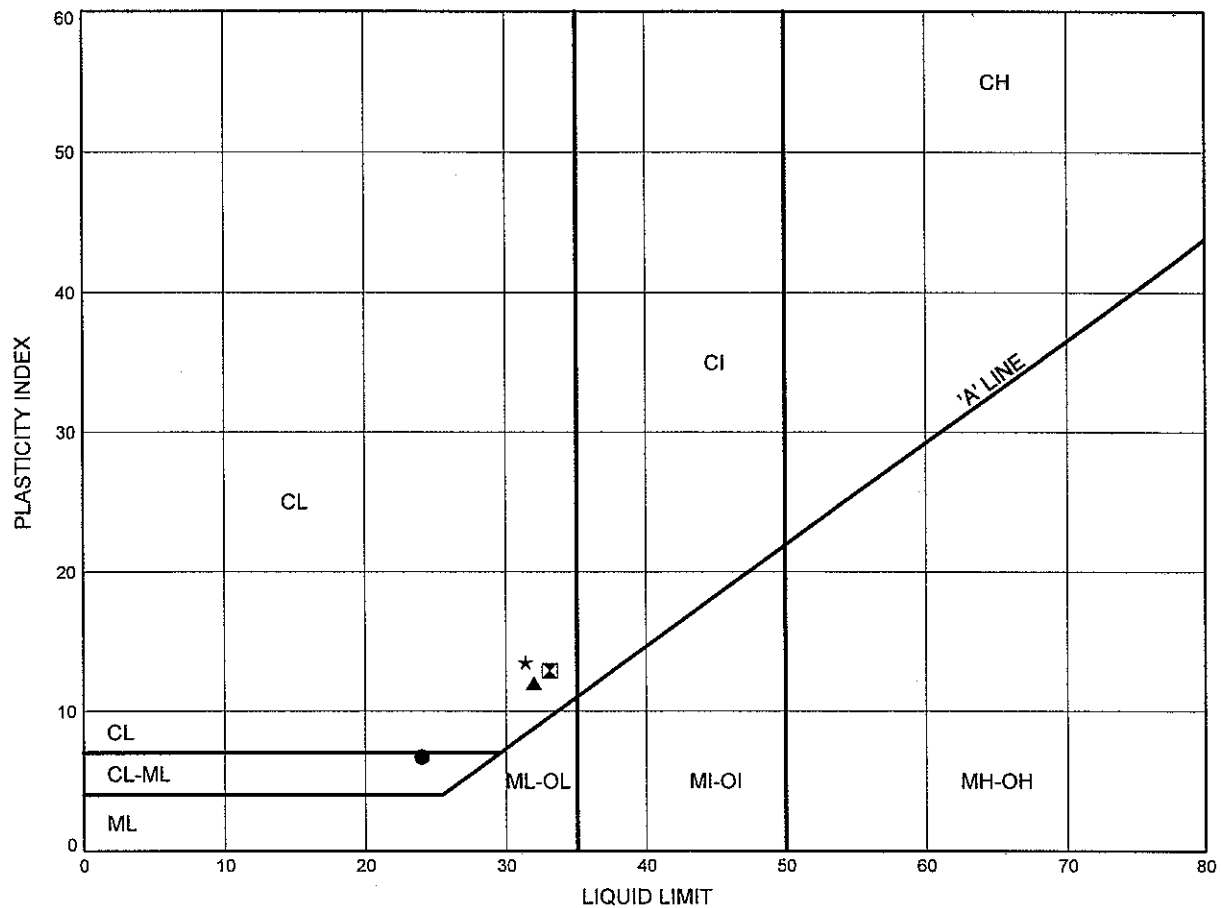
Date January 2009
Project 1-08-3360



Prep'd DB
Chkd. RA

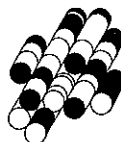
FIGURE B3

FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM1	0.3	113.5
⊠	WM2	1.0	114.5
▲	WM2	2.5	113.0
★	WM3	1.7	112.6

Date January 2009
Project 1-08-3360

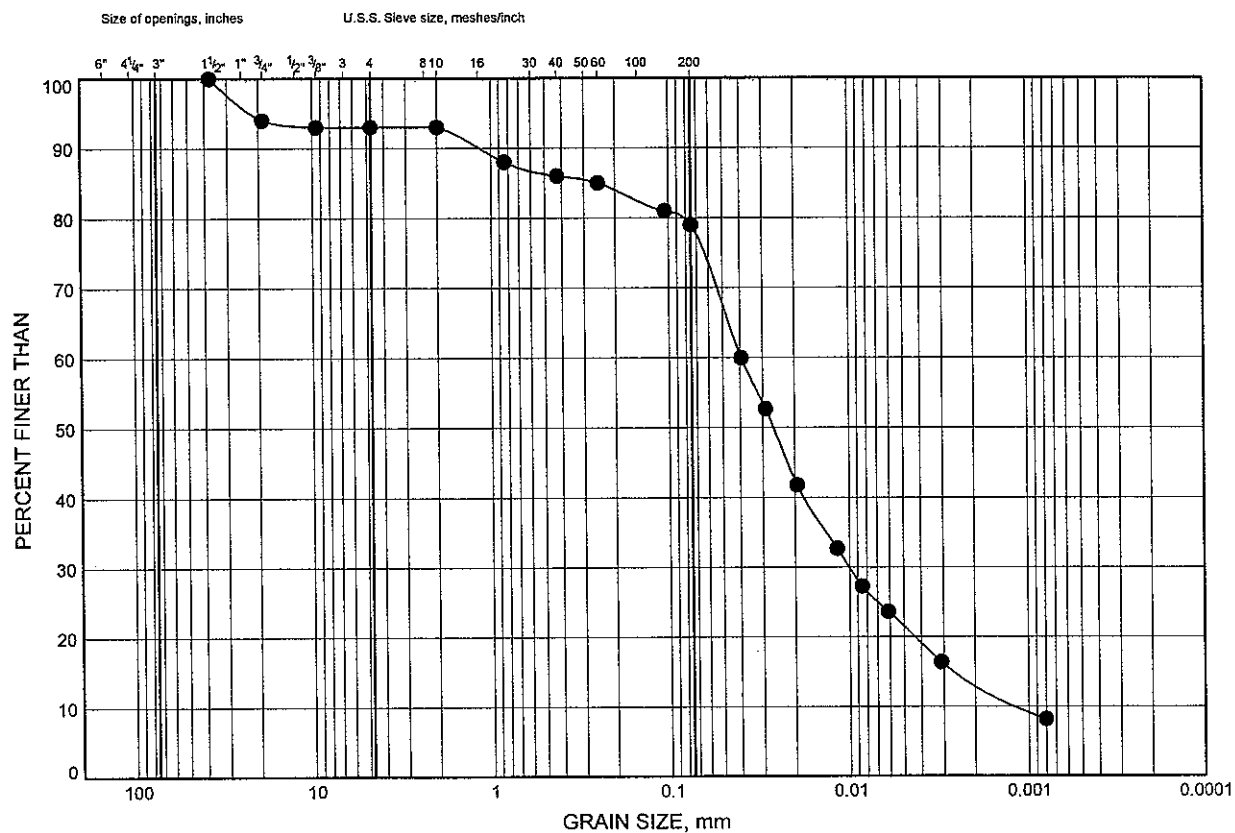


Prep'dDB.....
Chkd.RA.....

GRAIN SIZE DISTRIBUTION

FIGURE B4

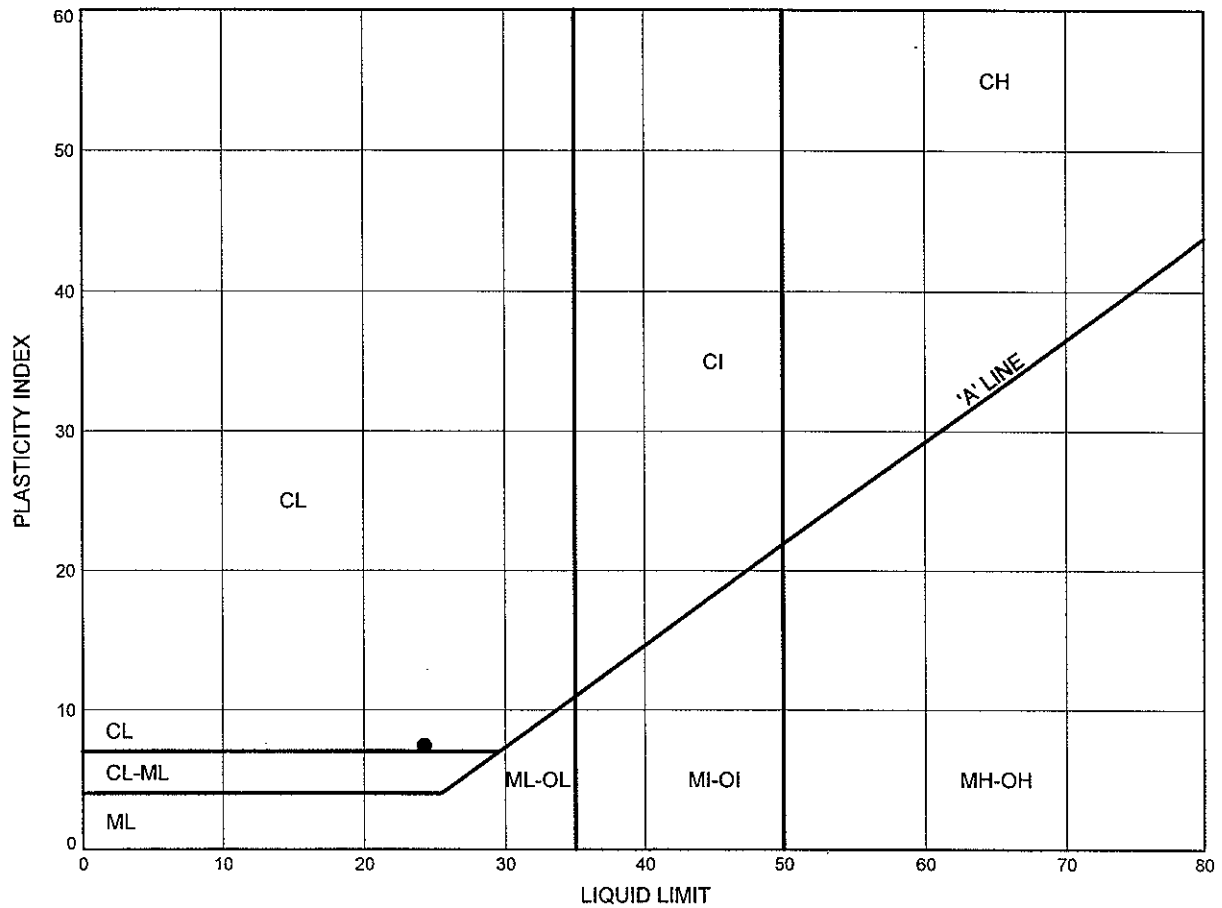
SILTY CLAY TILL / TILL - SHALE COMPLEX



ATTERBERG LIMITS TEST RESULTS

FIGURE B5

SILTY CLAY TILL / TILL - SHALE COMPLEX



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM2	4.0	111.5

Date January 2009
Project 1-08-3360



Prep'd DB
Chkd. RA

FIGURE B6

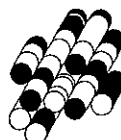
The graph displays the grain size distribution of a soil sample. The y-axis represents the percentage of soil finer than a given grain size, ranging from 0 to 100. The x-axis represents the grain size in millimeters on a logarithmic scale, ranging from 100 mm to 0.0001 mm. Vertical lines indicate standard sieve sizes. The data curve shows that approximately 100% of the soil is finer than 100 mm, and about 11% is finer than 0.075 mm.

Grain Size (mm)	Percent Finer (%)
100	100
75	100
60	100
47.5	100
37.5	100
30	100
25	100
20	100
15	100
12.5	100
10	100
7.5	88
6	83
4.75	74
3.75	63
3	57
2.5	53
2	48
1.5	46
1.18	42
0.85	39
0.75	35
0.6	29
0.5	26
0.425	23
0.35	18
0.25	11

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM5	0.3	115.6

Date January 2009.....
Project 1-08-3360.....

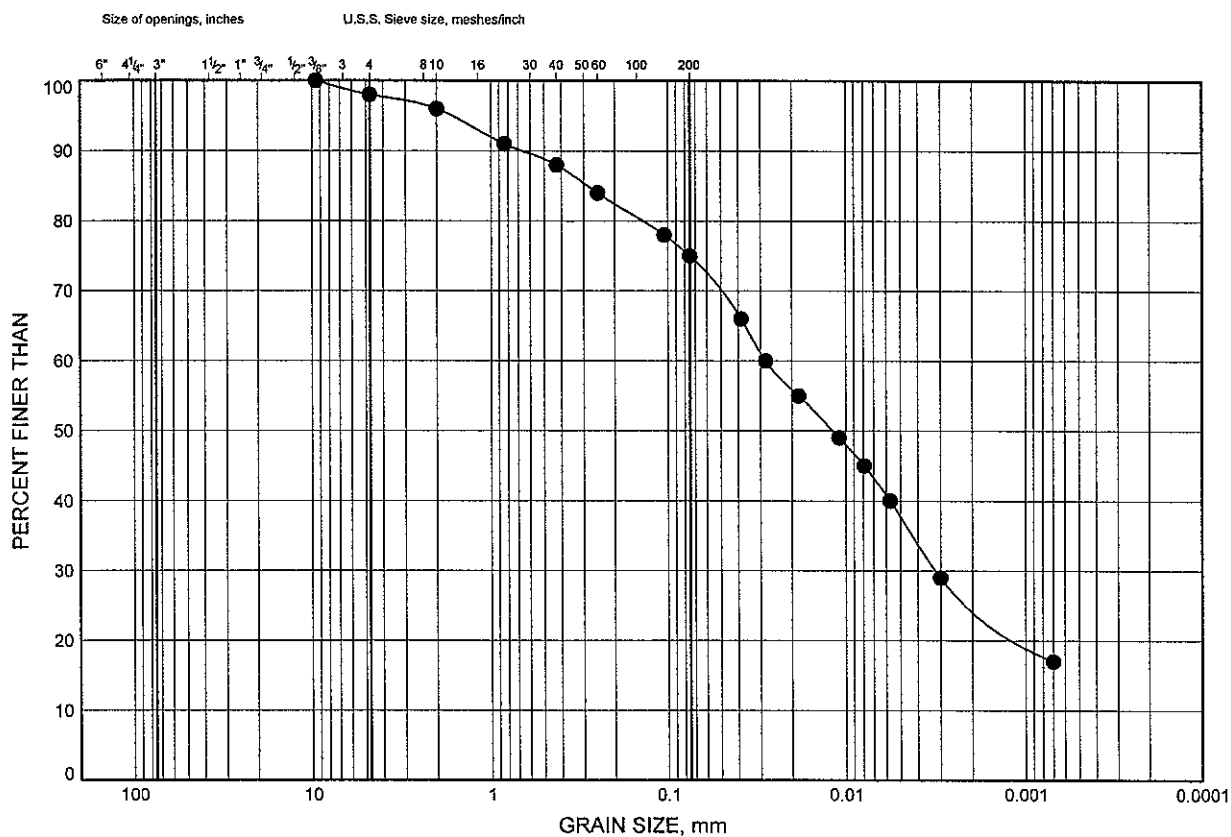


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B7

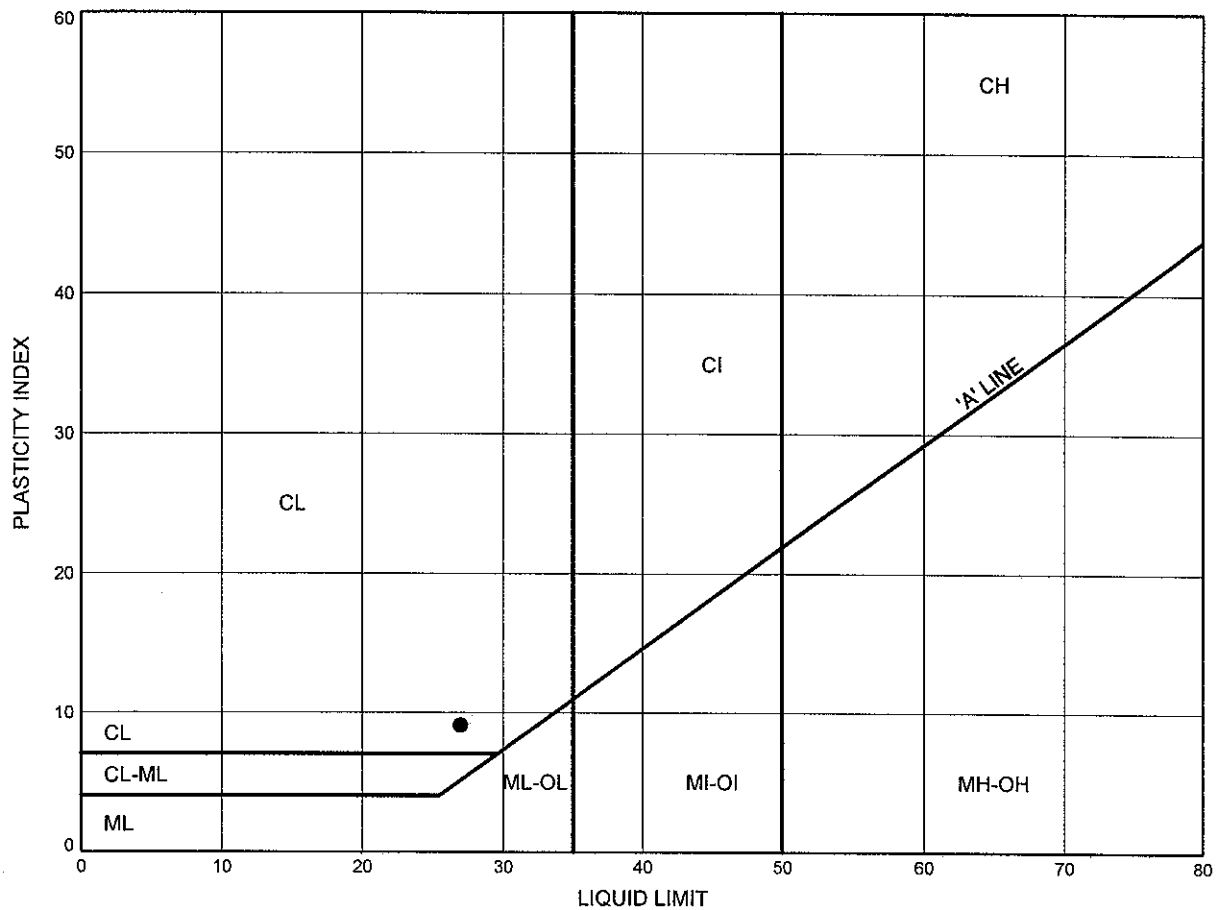
FILL - Silty Clay



ATTERBERG LIMITS TEST RESULTS

FIGURE B8

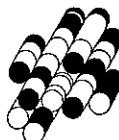
FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	WM6	1.0	114.0

ALTR 1-08-3360 OE W WATERMAIN GP J 19/01/09

Date January 2009
Project 1-08-3360

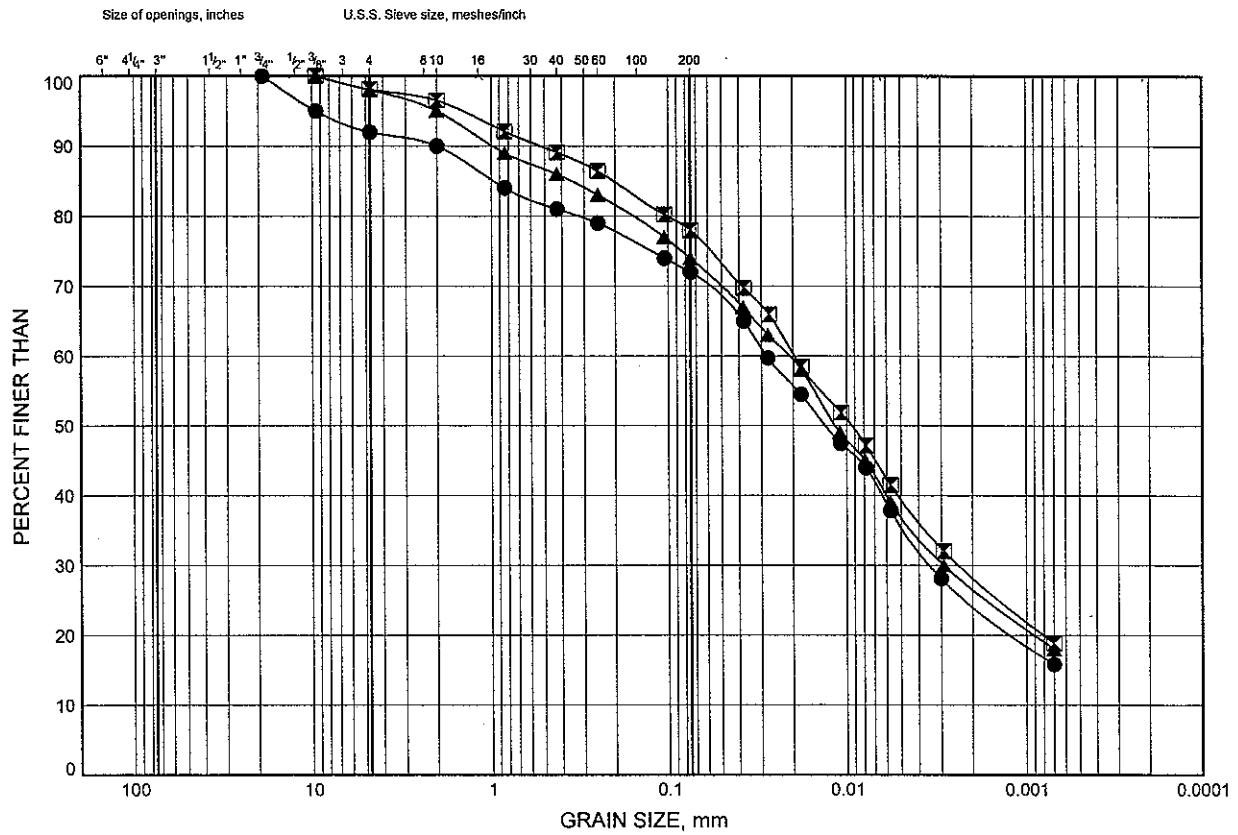


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILTY CLAY TILL



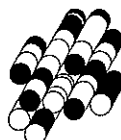
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL BOREHOLE DEPTH (m) ELEVATION (m)

●	WM4	1.0	113.6
◻	WM5	1.0	114.9
▲	WM6	1.7	113.3

Date January 2009

Project 1-08-3360



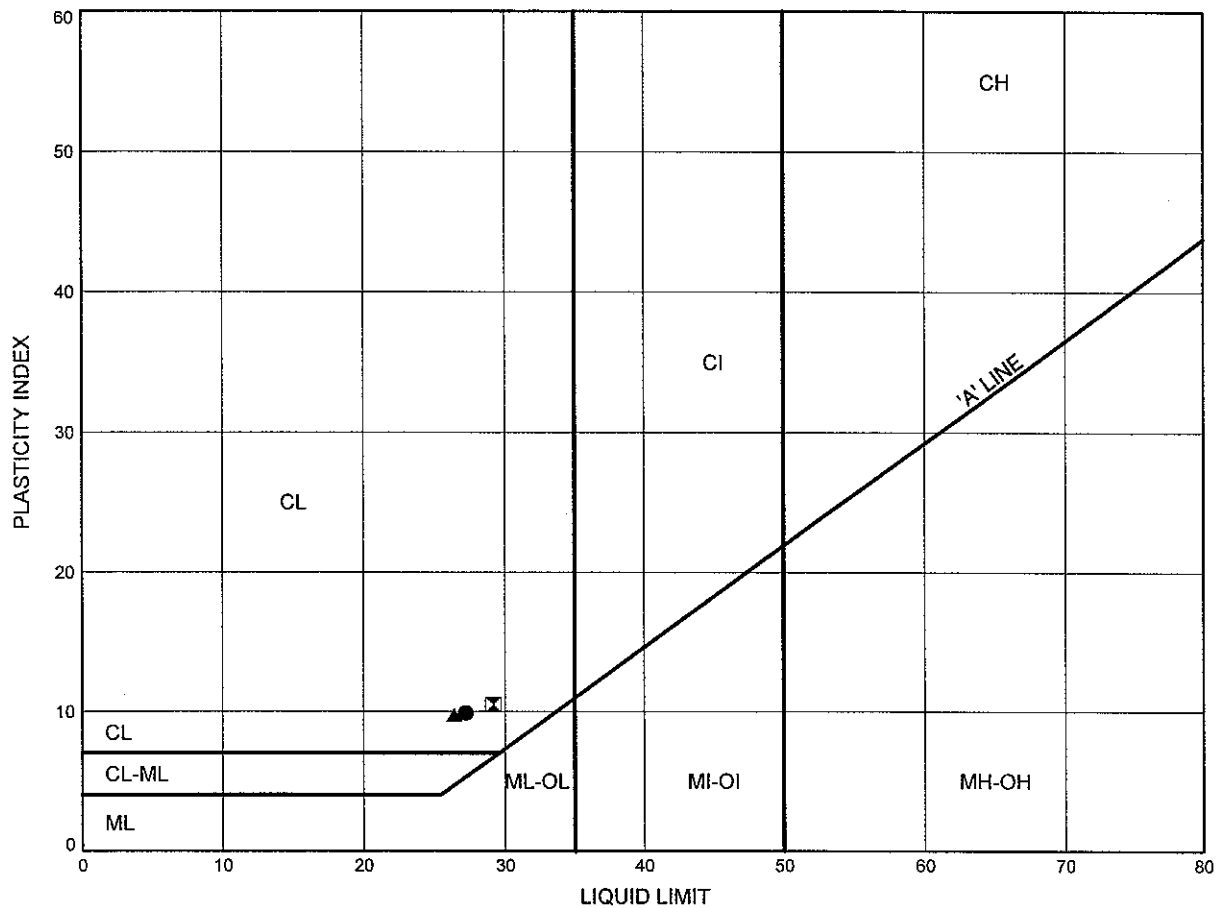
Prep'd DB

Chkd. RA

ATTERBERG LIMITS TEST RESULTS

FIGURE B10

SILTY CLAY TILL

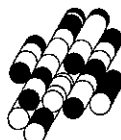


SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
--------	----------	-----------	---------------

●	WM4	1.0	113.6
⊠	WM5	1.0	114.9
▲	WM6	1.7	113.3

Date January 2009

Project 1-08-3360



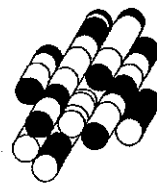
Prep'd DB

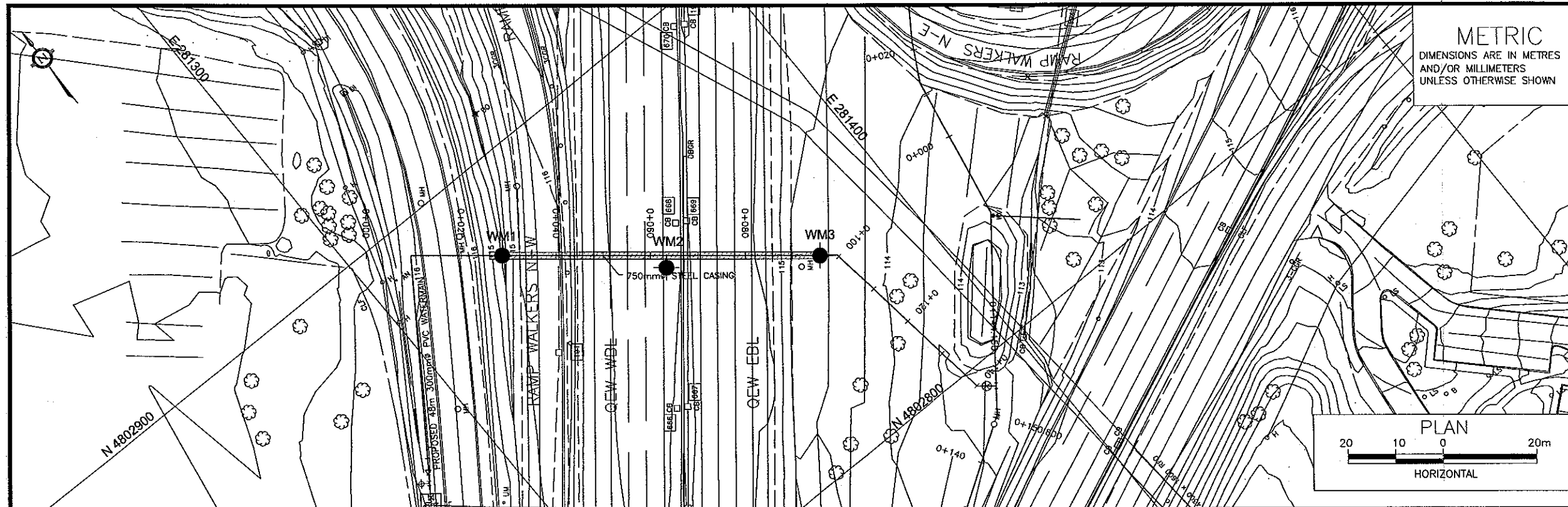
Chkd. RA

APPENDIX C

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

Terraprobe Limited





CONT No
WP No

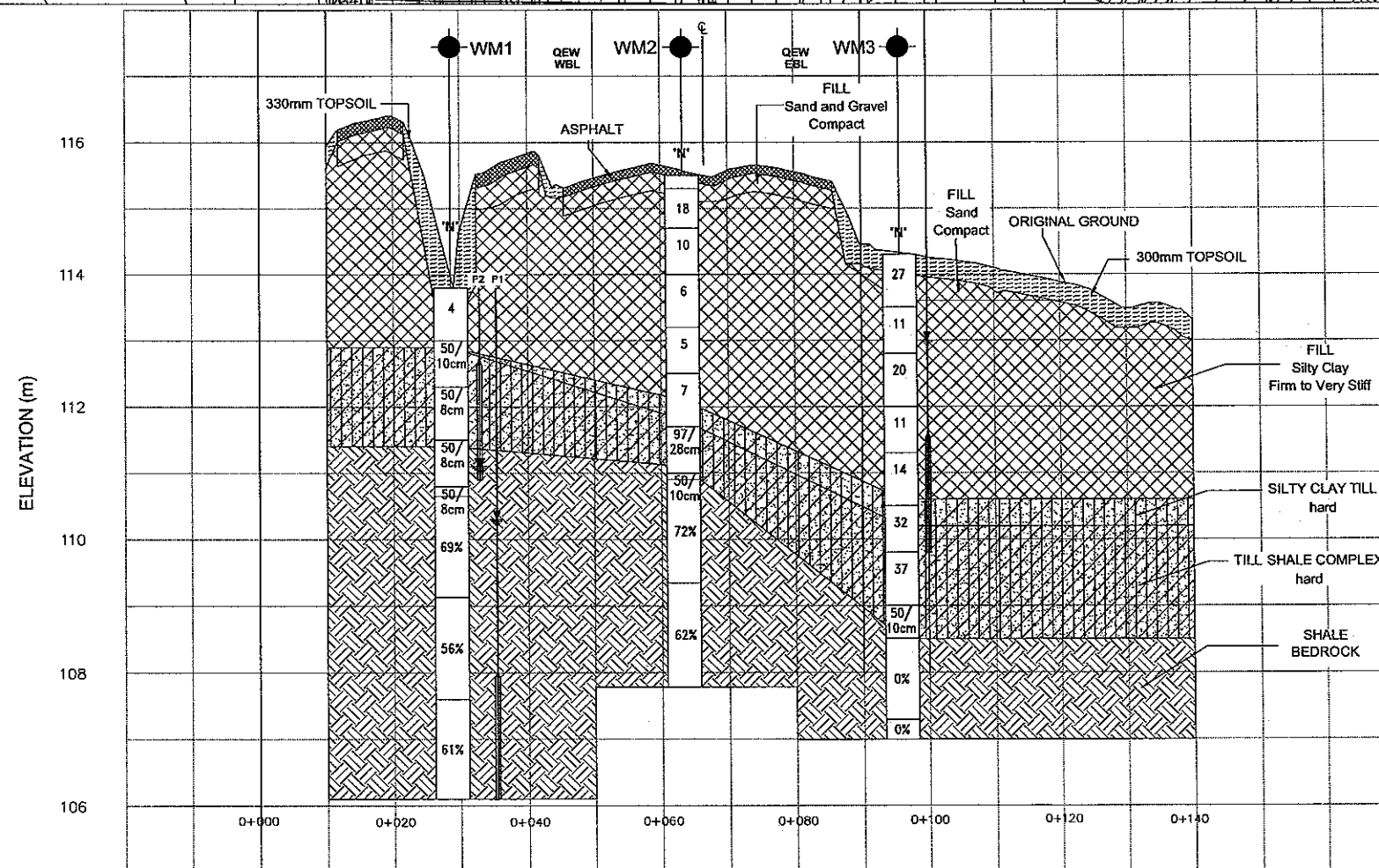
WATERMAIN INSTALLATION
BELOW THE QEW
WALKERS LINE INTERCHANGE

SHEET
1 OF 3

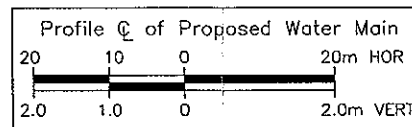
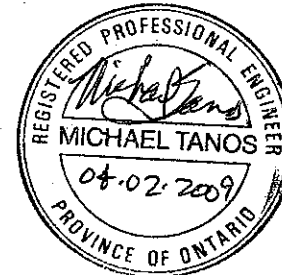
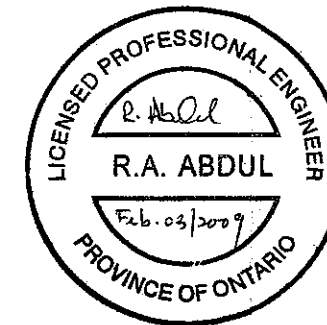
Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

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

KEY PLAN
WATERMAIN CROSSING
AT STA. 15+340
Scale 800 400 0 800



PROFILE WATER MAIN STA 0+000 to 0+140 (ALIGNMENT 1 QEW STA 15+340)



KEY PLAN

LEGEND

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

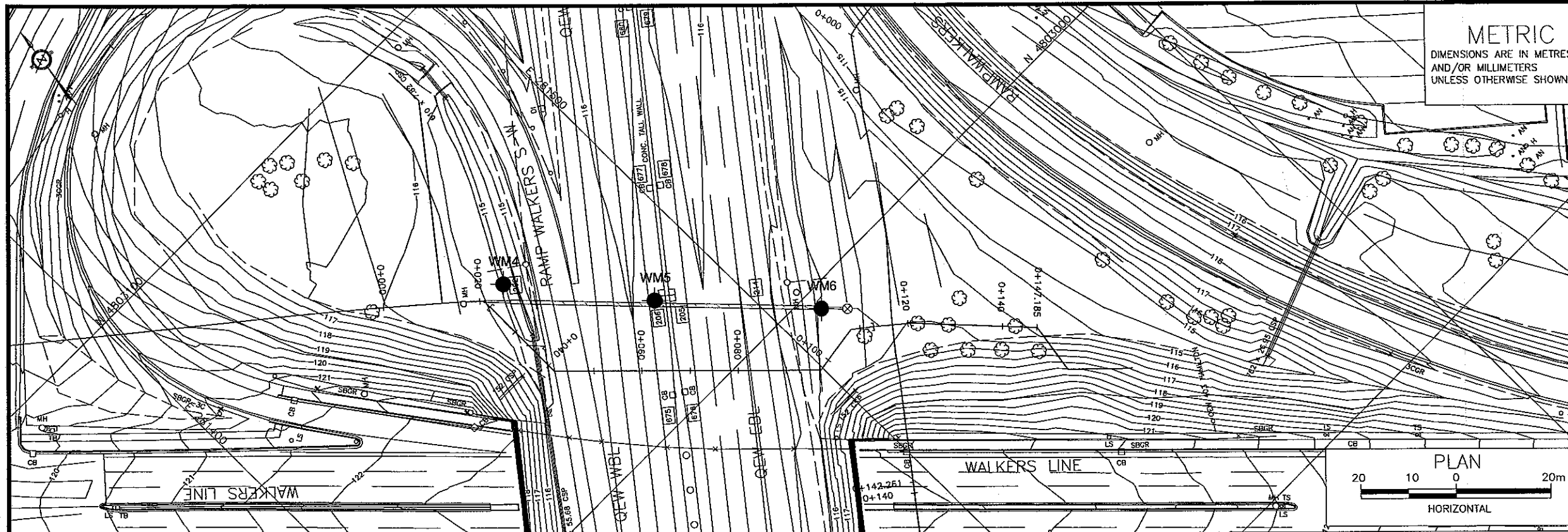
No	ELEVATION	COORDINATES	
		NORTHING	EASTING
WM1	113.8	4 802 881.3	281 326.5
WM2	115.5	4 802 857.5	281 351.7
WM3	114.3	4 802 838.9	281 378.6

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

REVISIONS

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

DRAWING NOT TO BE SCALED



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

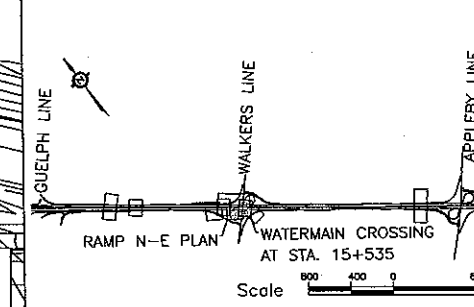
CONT No
WP No

WATERMAIN INSTALLATION
BELOW THE QEW
WALKERS LINE INTERCHANGE

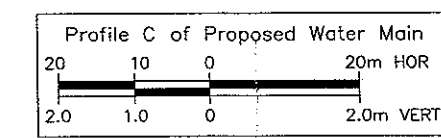
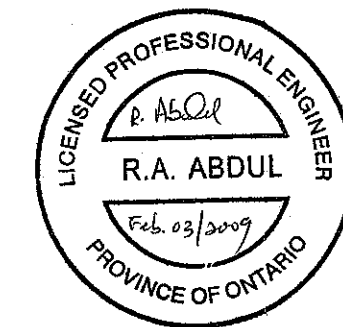
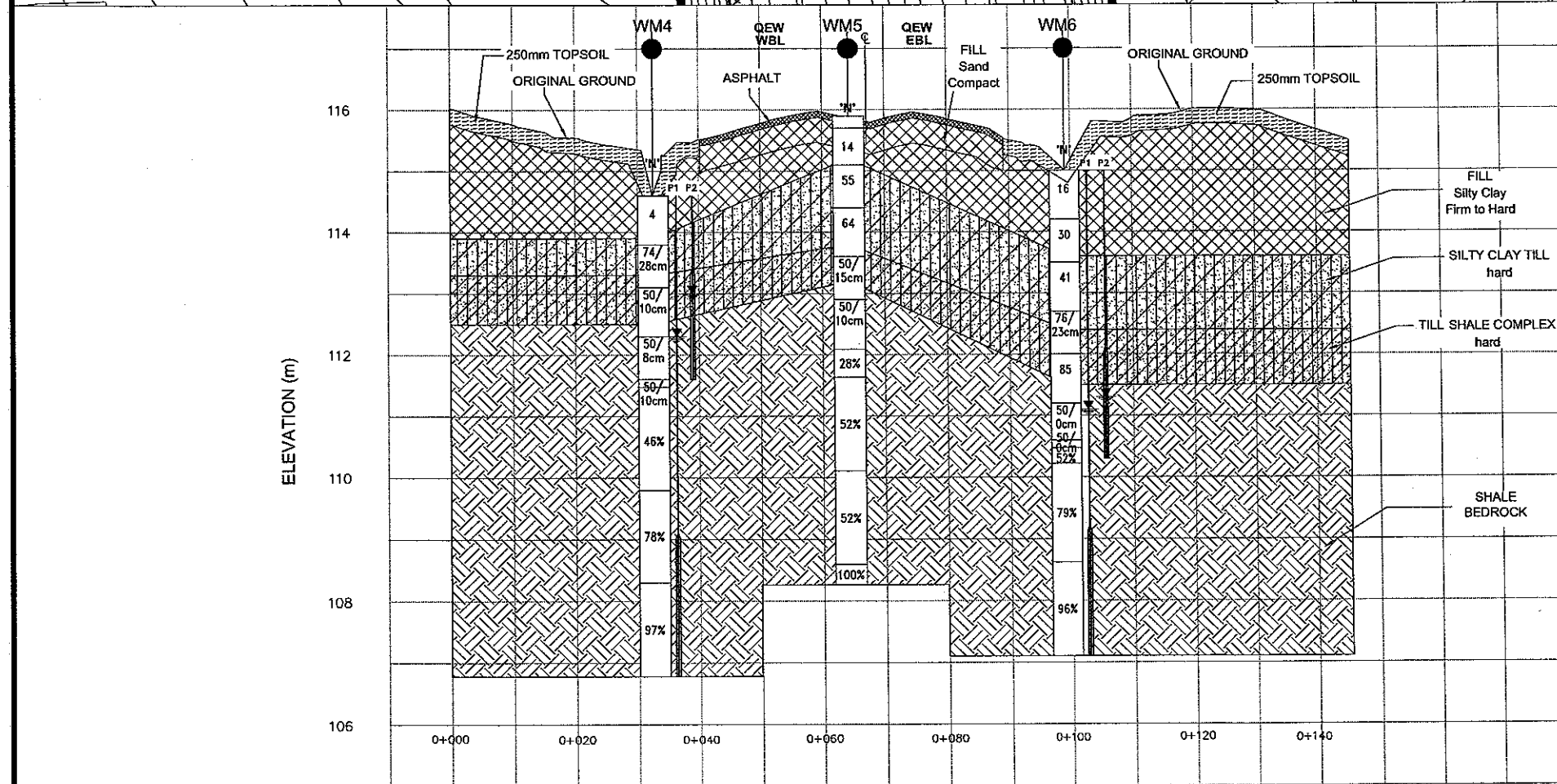
SHEET
2 OF 3

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



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
 - Piezometer
 - 90% Rock Quality Designation
 - A/R Auger Refusal

No	ELEVATION	COORDINATES	
		NORTHING	EASTING
WM4	114.6m	4803046.7	281465.5
WM5	115.9m	4803021.7	281485.5
WM6	115.0m	4802995.8	281508.7

REVISIONS	DATE	BY	DESCRIPTION

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

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

PROFILE WATER MAIN STA 0+000 to 0+140 (ALIGNMENT 2 QEW STA 15+535)

DRAWING NOT TO BE SCALED

