

Terraprobe

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

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

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**FOUNDATION INVESTIGATION REPORT
WATER MAINS INSTALLATION BELOW THE QEW
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PROCUREMENT No. PR-2588**

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.

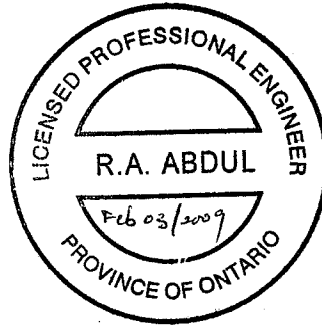
The rock cores were examined by geologist Mr. Bradford Ripley, B.Sc.

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



R. Abdul

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



Michael Tanos

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



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

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical design recommendations for the proposed water main installations in the vicinity of the QEW/Walkers Line interchange. The water mains are to be installed under the proposed eight-lanes of the QEW.

Alignment 1 crosses the QEW at Sta. 15+340 west of the Walkers Line underpass. The water main will be installed below the QEW in a 69 m long and 600 mm diameter steel casing. The approximate invert and obvert elevations of the steel casing are Elev. 109.4 m and Elev. 110.1 m respectively.

Alignment 2 crosses the QEW at Sta. 15+535 east of the Walkers Line underpass. The water main will be installed below the QEW in a 66 m long and 750 mm diameter steel casing. The approximate invert and obvert elevations of the steel casing are Elev. 110.1 m and Elev. 110.9 m respectively. At Sta. 0+060 in the vicinity of the Walkers Line Ramp N-E the existing water main will be lowered to about Elev. 111.2 m.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

7 OPEN EXCAVATIONS

7.1 General

Discussions and recommendations related to general open cut installation are presented in this section of the report. Recommendations related to tunnelling below the QEW are presented in Section 8.



7.2 Alignment 1 – Sta. 15+340

7.2.1 Vertical Alignment

Based on the proposed invert elevations along the alignment and the data from the Record of Borehole Logs the trench bottom will lie in firm the very stiff silty clay fill, hard silty clay till and shale bedrock. These soils will generally provide good to excellent support to the water main. Soft/loose soils that are encountered in the trench bottom will have to be sub-excavated and replaced with compacted granular fill in order to ensure reliable pipe support.

The borehole data indicates that the groundwater table ranges from Elev. 110.4± m to Elev. 113± m. Therefore, the groundwater table will generally be above the depth of excavation. This aspect must be taken into consideration when undertaking excavations at this site.

7.2.2 Excavation

The soils described at this site are considered to be suitable for excavation using trenching and excavating equipment, such as backhoes normally used by contractors for this type of utility installation. Excavations should be undertaken in accordance with OPSS 514 and OPSS 515.

Excavations at some sections along the alignment may encounter shale bedrock that may require excavation. The shale bedrock is of the Queenston Formation and is a rippable rock that can be removed with large conventional excavating equipment once it has been displaced by a ripper tooth. Harder layers (e.g. limestone) within the shale matrix that are not feasible or practical to map are normally broken with hoe mounted hydraulic rams prior to excavation.

Till soils inherently contain cobbles and boulders and the contract documents must identify this fact to bidders. The frequency of boulders is unlikely to be high enough to prevent the use of suitable trenching and excavating equipment. However, the contract documents should include a NSSP alerting bidders to the fact that cobbles and boulders and shale bedrock may be encountered. Suggested wording for this NSSP is included in Appendix E.

7.2.3 OHSA Soil Classification

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native soils at this site may be classified as Type 1 soils. The silty clay fill may be classified as a Type 3 soil.

Excavations above and below the water table in the overburden soils may be sloped at 1.5H:1V provided unwatering is carried out as described below. The rock when excavated



is nominally self supporting in a vertical face provided the rock bedding is horizontally oriented.

7.2.4 Groundwater Control

The groundwater table at this site is estimated to range from Elev. 110.4± m to Elev. 113± m. Groundwater will be encountered in the excavations.

The Contractor must implement suitable groundwater control and ground support systems as required to install the water mains in a safe, stable, unwatered excavation. The design of the unwatering system should be the responsibility of the Contractor.

Groundwater seepage into excavations made through the silty clay fill, silty clay till and the shale bedrock, should be minimal due to the relatively low permeability of these soils and the rock. It is believed that this seepage can be controlled by gravity drainage and pumping from strategically located filtered sumps as and where required.

7.2.5 Bedding & Backfill

The bedding for the water main must conform to the requirements of OPSD 802.030 802.031 and 802.033 as appropriate (rigid pipe) or OPSD 802.010 and OPSD 8-2.013 (flexible pipe) as appropriate.

It is recommended that the bedding material consist of OPSS Granular "A". Additional bedding requirements that may be imposed by the supplier must also be followed.

Any accumulation of water at the base of the excavation and any soft/loose soils should be removed prior to placing and compacting the pipe bedding. Placement of the pipe bedding must be done in the dry.

The backfill may consist of the excavated soil compacted to 95% SPMDD at a moisture content within ±2% of the optimum value. Shale bedrock is not recommended for use as backfill material. Trenching, backfilling and compaction operations should be in accordance with OPSS 514.

7.3 Alignment 2 – Sta. 15+535

7.3.1 Vertical Alignment

Based on the proposed invert elevations along the alignment and the data from the Record of Borehole Logs the trench bottom will lie in hard silty clay till and shale bedrock. These soils will provide excellent support to the water main. Soft/loose soils that are encountered in the trench bottom will have to be sub-excavated and replaced with compacted granular fill in order to ensure reliable pipe support.

The borehole data indicates that the groundwater table ranges from Elev. 111.1± m to Elev. 113.2± m. Therefore, the groundwater table will generally be above the depth of



excavation. This aspect must be taken into consideration when undertaking excavations at this site.

7.3.2 Excavation

The soils described at this site are considered to be suitable for excavation using trenching and excavating equipment, such as backhoes normally used by contractors for this type of utility installation. Excavations should be undertaken in accordance with OPSS 514 and OPSS 515.

Excavations at some sections along the alignment may encounter shale bedrock that may require excavation. The shale bedrock is of the Queenston Formation and is a rippable rock that can be removed with large conventional excavating equipment once it has been displaced by a ripper tooth. Harder layers (e.g. limestone) within the shale matrix that are not feasible or practical to map are normally broken with hoe mounted hydraulic rams prior to excavation.

Till soils inherently contain cobbles and boulders and the contract documents must identify this fact to bidders. The frequency of boulders is unlikely to be high enough to prevent the use of suitable trenching and excavating equipment. However, the contract documents should include a NSSP alerting bidders to the fact that cobbles and boulders and shale bedrock may be encountered. Suggested wording for this NSSP is included in Appendix E.

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Excavations above and below the water table in the overburden soils may be sloped at 1.5H:1V provided unwatering is carried out as described below. The rock excavations is nominally self supporting in a vertical face provided the rock bedding is horizontally oriented.

7.3.4 Groundwater Control

The groundwater table at this site is estimated to range from Elev. 111.1± m to Elev. 113.2± m. Groundwater will be encountered in the excavations.

The Contractor must implement suitable groundwater control and ground support systems as required to install the water mains in a safe, stable, unwatered excavation. The design of the unwatering system should be the responsibility of the Contractor.

Groundwater seepage into excavations made through the silty clay fill, silty clay till and the shale bedrock, should be minimal due to the relatively low permeability of these soils



and the rock. It is believed that this seepage can be controlled by gravity drainage and pumping from strategically located filtered sumps as and where required.

7.3.5 Bedding & Backfill

The bedding for the water main must conform to the requirements of OPSD 802.030 802.031 and 802.033 as appropriate (rigid pipe) or OPSD 802.010 and OPSD 8-2.013 (flexible pipe) as appropriate.

It is recommended that the bedding material consist of OPSS Granular "A". Additional bedding requirements that may be imposed by the supplier must also be followed.

Any accumulation of water at the base of the excavation and any soft/loose soils should be removed prior to placing and compacting the pipe bedding. Placement of the pipe bedding must be done in the dry.

The backfill may consist of the excavated soil compacted to 95% SPMDD at a moisture content within $\pm 2\%$ of the optimum value. Shale bedrock is not recommended for use as backfill material. Trenching, backfilling and compaction operations should be in accordance with OPSS 514.

8 WATER MAIN CROSSINGS BELOW QEW (ALIGNMENTS 1 AND 2)

8.1 Alignment 1- Sta. 15+340

A 600 mm diameter steel casing will be installed below the QEW. The length of the crossing is approximately 69 m extending from Sta. 0+026 and Sta. 0+095. The casing will be installed primarily in shale bedrock, but mixed face conditions are expected at the south section of the alignment where it is envisaged that the trenchless excavation will be made in hard silty clay till (till-shale complex) overlying the bedrock.

The diameter, length and anticipated subsurface conditions limit the range of trenchless installation techniques that would be economically viable at this site. Each method considered has advantages; disadvantages or limitations and these are discussed. The methods that are considered viable are:

1. Pipe Jacking and Horizontal Auger Boring
2. Micro Tunnelling

Tunnelling shall be undertaken in accordance with OPSS 415 and 416. The choice of equipment and the method of tunnelling is the Contractor's responsibility.



8.1.1 Pipe Jacking & Horizontal Auger Boring

A pipe jacking operation involves pushing an oversized liner pipe horizontally into the ground by jacking. A range of excavation methods are available for removing the soil from inside the pipe as it is advanced. Augering is one common excavation method. Precision is normally $\pm 1\%$ of the driven length.

Horizontal auger boring requires an auger boring machine that is used to bore horizontally through soil or rock with a cutting head and auger. The cutting head can be located either inside or outside of the casing pipe that is being jacked forward. The auger boring machine can accept many types of cutting attachments ranging from backhoe teeth cutters for excavating soil to small boring units equipped with mini disc cutters for excavating rock. Small boring units can be steered to maintain line and grade.

The borehole data indicates that the tunnelling operation will be made in shale bedrock below the QEW West Bound Lanes. Below the QEW East Bound Lanes the bedrock surface is sloping and the subsurface conditions within the design profile of the tunnel will change from shale bedrock to silty clay till/till-shale complex.

Since mixed face conditions will be encountered at this site the tunnelling contractor must ensure that the tunnelling equipment is suitably designed to deal with these varying conditions while ensuring that proper alignment is maintained during the tunnelling operation.

To minimize the risk of uncontrollable and/or unpredictable settlements as well as to ensure that accurate alignment is maintained it would be necessary to shore the overburden soils along the south section of the QEW by installing a larger diameter casing in the overburden soils. This oversize casing can be installed either by pipe jacking or by horizontal auger boring and the casing should be seated as much as practical in the weathered shale bedrock. With the oversize casing in place provisions can then be made to undertake the tunnelling operation through the rock for the remainder of the alignment either by horizontal auger boring or microtunnelling.

The silty clay till (till-shale complex) possesses sufficient cohesion and/or cementation and is expected to have a stand-up time of several hours depending on the composition of the soil matrix. Nevertheless, the casing should follow closely behind the advancing cutting head to minimize settlements.

When excavation is halted, the casing should be in close contact with the cutting head in order to maintain stability. Ground closure around the liner is expected to be minimal. The application of bentonite slurry under pressure may be required to reduce frictional resistance.

Settlement at the ground surface is estimated to be negligible when tunnelling within the hard silty clay till (till-shale complex) and the shale bedrock. This estimate is based on the assumption that the work will be carried out by experienced tunnellers with great care and



good workmanship. Under "normal" tunnelling operations, ground loss can be limited to acceptable levels. However, excessive ground loss, and settlement can occur when unusual conditions (such as boulder removal and water-bearing sand lenses) are encountered. A great deal of care is required under these conditions.

Possible problems when tunnelling within the silty clay till include boulders and water-bearing sand lenses, which are common in glacial deposits.

The silty clay till has a relatively low permeability and groundwater seepage is expected to be in small quantities at a slow rate. This seepage can be handled by gravity drainage into the entry shaft from where it could be removed by pumping from filtered sumps.

8.1.2 Microtunnelling

This technique is similar to horizontal auger boring where a liner pipe is jacked horizontally into the ground. The liner follows closely behind a remote controlled cutting head that can be designed to excavate soil and rock.

Microtunnelling is a very precise method of tunnelling and with the suitable choice of cutting tools a wide soil spectrum as well as rock can be excavated. Additionally, there is relatively little settlement with this method if handled properly.

This method is feasible for consideration at this site. However, due to the specialized type of machinery required it might be prohibitively expensive for this relatively short run.

8.2 Alignment 2- Sta. 15+535

A 750 mm diameter steel casing will be installed below the QEW. The length of the crossing is approximately 66 m extending from Sta. 0+031 and Sta. 0+097. The casing will be installed in shale bedrock.

The diameter, length and anticipated subsurface conditions limit the range of trenchless installation techniques that would be economically viable at this site. Each method considered has advantages; disadvantages or limitations and these are discussed. The methods that are considered viable are:

1. Horizontal Auger Boring
2. Micro Tunnelling

Tunnelling shall be undertaken in accordance with OPSS 415 and 416. The choice of equipment and the method of tunnelling is the Contractor's responsibility.



8.2.1 Horizontal Auger Boring

Horizontal auger boring requires the use of an auger boring machine that is used to bore horizontally through soil or rock with a cutting head and auger. The auger boring machine can accept many types of cutting attachments ranging from backhoe teeth cutters for excavating soil to small boring units equipped with mini disc cutters for excavating rock. Small boring units can be steered to maintain line and grade.

The borehole data indicates that the tunnelling operation will be made in shale bedrock. The rock excavation is nominally self supporting in a vertical face; provided the rock bedding is horizontally oriented. Nevertheless, to minimize the potential for rock loss the casing should follow closely behind the advancing the cutting head.

When excavation is halted, the casing should be in close contact with the cutting head in order to maintain stability. Ground closure around the casing is expected to be minimal. The application of bentonite slurry under pressure may be required to reduce frictional resistance.

Settlement at the ground surface is estimated to be negligible when tunnelling within the shale bedrock. This estimate is based on the assumption that the work will be carried out by experienced tunnellers with great care and good workmanship. Under "normal" tunnelling operations, ground loss can be limited to acceptable levels. However, excessive ground loss, and settlement can occur when unusual conditions are encountered.

Typical unusual conditions than can be encountered in the bedrock include vertical and subvertical joints which can cause rock instability and rock loss from the tunnel face and periphery. A great deal of care is required under these conditions.

The rock will yield limited quantities of groundwater seepage at a slow rate. This seepage can be handled by gravity drainage into the entry shaft from where it could be removed by pumping from filtered sumps.

8.2.2 Microtunnelling

This technique is similar to horizontal auger boring where a liner pipe is jacked horizontally into the ground. The liner follows closely behind a remote controlled cutting head that can be designed to excavate soil and rock.

Microtunnelling is a very precise method of tunnelling and with the suitable choice of cutting tools a wide soil spectrum and rock can be excavated. Additionally, there is relatively little settlement with this method if handled properly.

This method is feasible for consideration at this site. However, due to the specialized type of machinery required it might be prohibitively expensive for this relatively short run.



9 TUNNEL SUPPORT

In the completed tunnel the maximum residual stress would be expressed in the spring-line of the tunnel diameter where the unbalanced horizontal stress is a maximum. The horizontal and tangential pressure on the permanent tunnel lining is a function of the vertical in situ pressure, which is given by:

$$P_h = \gamma (h - h_w) + \gamma' h_w + h_w \gamma_w$$

γ = bulk unit weight of soil

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

h = depth below surface (m)

h_w = depth below the groundwater level (m)

For design purposes assume a unit weight of 21 kN/m³ for the soil and rock overlying the springline of the tunnel.

10 EARTH PRESSURE

The entry and exit shafts will have to be supported by a shoring system. The shape of the soil pressure distribution diagram behind the shoring system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The sequence of work may also alter the shape of the pressure diagram during the various construction phases.

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

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

The appropriate values of the parameters for use in the design of structures subject to unbalanced earth pressures are given in Table 10.1 and Table 10.2.

Table 10.1 – Earth Pressure Coefficients (Alignment 1 Sta 15+340)

| Stratum | ϕ | γ | K_a | K_o | K_p |
|--------------------------------------|--------|----------|-------|-------|-------|
| Fill – Silty Clay | 25 | 18 | 0.40 | 0.58 | 2.46 |
| Fill – Sand and Gravel | 32 | 21 | 0.31 | 0.47 | 3.25 |
| Silty Clay Till | 30 | 20 | 0.33 | 0.50 | 3.00 |
| Silty Clay Till (Till-Shale Complex) | 35 | 21 | 0.27 | 0.43 | 3.70 |



Table 10.2 – Earth Pressure Coefficients (Alignment 2 Sta 15+535)

| Stratum | ϕ | γ | K_a | K_o | K_p |
|--------------------------------------|--------|----------|-------|-------|-------|
| Fill – Silty Clay | 25 | 18 | 0.40 | 0.58 | 2.46 |
| Silty Clay Till | 30 | 20 | 0.33 | 0.50 | 3.00 |
| Silty Clay Till (Till-Shale Complex) | 35 | 21 | 0.27 | 0.43 | 3.70 |

The factors in the table above are “ultimate” values and require certain movements for the active and passive conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the CHBDC, 2000.

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

Where the excavation penetrates the bedrock, the rock excavation is nominally self supporting in a vertical face, provided the rock bedding is horizontally oriented. The rock induces no pressure on shoring systems that require structural support. The requirement for lagging support of partially weathered rock depends on the cleanliness of the excavation break.

Where shoring systems are made perched in the rock above the excavation base, great care and consideration must be given to providing protection and support for the rock in the area of influence directly beneath the base of the soldier pile toe as appropriate. It has become accepted practice in the shoring design community to leave a minimum metre wide shelf to carry soldier pile toes perched above the level of the excavation base.

Soldier piles socketted into the sound bedrock can be designed based on a lateral resistance of 1 MPa.

11 BASAL STABILITY

Tunnelling will require the construction of entry and exit shafts on both alignments. The borehole data shows that the excavation bases will be made in hard silty clay till (till-shale complex) and shale bedrock. The base of the excavations will be stable with respect to bottom heave.

12 MONITORING

The contract documents should require the contractor to monitor the roadway surface before, during and after the trenchless installation. A precondition survey is also required prior to tunnelling. A recommended settlement monitoring guideline is included in Appendix F.

It is also necessary to check the amount of spoil removal to determine if there is over excavation and if there are any possible voids outside of the casing. Voids must be grouted with approved grouting materials using approved methods.



13 CONSTRUCTION CONCERNS

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

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

- the possibility of encountering boulders or other obstructions in the overburden soils when tunnelling along Alignment 1 on the south side of the QEW.
- the possibility of encountering vertical and subvertical joints in the rock and the potential for rock instability and rock loss when tunnelling across these joints.
- the potential for groundwater levels to be higher at the time of construction than those recorded in this report.





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Engineering Analysis and Report Preparation by:
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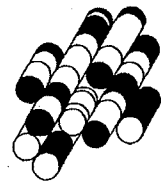
Michael Tanos

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.

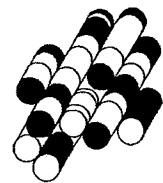
The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional 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

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APPENDIX A

Record of Borehole Sheets

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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 \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_e | 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_r | 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 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_c | 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 | | | | | | | | WATER CONTENT (%) | | | |
| | | | | | | | | ○ UNCONFINED | | + FIELD VANE | | | | | | | ● QUICK TRIAXIAL | | × LAB VANE |
| 113.8 | Ground Surface | | | | | | 20 | 40 | 60 | 80 | 100 | | | | GR | SA | SI | CL | |
| 0.0 113.5 | 330mm TOPSOIL - dark brown | | 1 | SS | 4 | | | | | | | | | | 20 | 21 | 43 | 16 | |
| 0.3 112.9 | FILL - Silty Clay, sandy, gravelly, firm, reddish brown, damp to moist | | 2 | SS | 50/ 10cm | | | | | | | | | | | | | | |
| 0.9 112.9 | SILTY CLAY TILL- with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX) | | 3 | SS | 50/ 8cm | | | | | | | | | | | | | | |
| 111.4 2.4 | | | 4 | SS | 50/ 8cm | | | | | | | | | | | | | | |
| | | | 5 | SS | 50/ 8cm | | | | | | | | | | | | | | |
| | 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) | | 1 | RUN | NQ | | | | | | | | | | | | | RUN#1 TCR=100% RQD=69% | |
| | | | 2 | RUN | NQ | | | | | | | | | | | | | | RUN#2 TCR=100% RQD=56% |
| | | | 3 | RUN | NQ | | | | | | | | | | | | | | RUN#3 TCR=100% RQD=61% |
| 106.1 7.7 | End of Borehole | | | | | | | | | | | | | | | | | | |
| | 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 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

CORE LOG



Terraprobe

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|----------|-------------------------|-----------------|-------------------|------------------|-------------------|--------------------------|-----------|--------------|-----------|
| 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 3.1 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 7.7 8.0 8.5 9.0 9.5 10.0 | | | See Borehole Log WM1 | | | | | | | | | | | | | | | | | |
| | | | QUEENSTON FORMATION | | | | | | | | | | | | | | | | | |
| | | | <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. | 1 | B | F | C | RP | T | O | | | | | 1 | 100% | 69% | NQ | 19.1 | 24.6 |
| | | | <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. | | | | | | | | | | | | | | | | | |
| | | | | 1 | B | F | C | RP | T | O | | | | | 2 | 100% | 56% | NQ | | |
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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 | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|---|------------|---------|------|-------------|----------------------------|-----------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| 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 | | 115 | | | | | | o | | | | |
| 0.4 | brown to 1.4m | | 2 | SS | 10 | | | | | | | | | | | | 2 19 47 32 |
| | ---- | | | | | | 114 | | | | | | | | | | |
| | 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 | | 113 | | | | | | | | | | 2 18 47 33 |
| 112.1 | | | 5 | SS | 7 | | | | | | | | | | | | |
| 3.4 | SILTY CLAY - trace sand, reddish brown, damp (GLACIAL TILL) | | | | | | 112 | | | | | | | | | | |
| 111.8 | | | 6 | SS | 97/ 28cm | | | | | | | | | | | | 7 14 65 14 |
| 3.7 | SILTY CLAY TILL- with shale, hard, reddish brown, damp (TILL-SHALE COMPLEX) | | 7 | SS | 50/ 10cm | | 111 | | | | | | | | | | |
| 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 | | 110 | | | | | | | | | | RUN#1 TCR=100% RQD=72% |
| | | | 2 | RUN | NQ | | 109 | | | | | | | | | | RUN#2 TCR=100% RQD=62% |
| 107.8 | End of Borehole | | | | | | 108 | | | | | | | | | | |
| 7.7 | Commence rock coring at 4.5m See CORE LOG2 for detailed information | | | | | | | | | | | | | | | | |

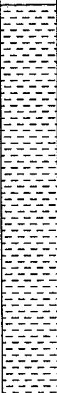
ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

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 | Halton 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 | | | | | | | | 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 | | |
| 110.9 | 4.0 |  | See Borehole Log WM2 | | | | | | | | | | | | | | | | | |
| | 4.5 | | | | | | | | | | | | | | | | | | | |
| | 4.6 | | | | | | | | | | | | | | | | | | | |
| | 5.0 | | QUEENSTON FORMATION | | | | | | | | | | | | | | | | | |
| | 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 | | | | | 1 | 100% | 72% | NQ | 25.2 | |
| | 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 | 100% | 62% | NQ | | |
| | 7.0 | | | 1 | B | F | C | RP | T | O | | | | | | | | | | |
| | 7.5 | | | | | | | | | | | | | | | | | | | |
| | 7.72 | | | | | | | | | | | | | | | | | | | |
| 107.78 | 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 | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|-----------------------|---|------------|---------|------|-------------|----------------------------|-----------------|---|----|----|----|-----|---|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 | 40 | 60 | 80 | 100 | | |
| 114.3 | Ground Surface | | | | | | | | | | | | | |
| 0.0 114.0 | 300mm TOPSOIL | | 1 | SS | 27 | | 114 | | | | | | | 27 33 27 13 |
| 0.3 113.6 | FILL - Sand, Gravelly, Silty, with asphalt and clay inclusions, compact, grey / brown, dry | | 2 | SS | 11 | | 113 | | | | | | | |
| 0.7 | FILL - Silty Clay, sandy, trace to some gravel, occasional asphalt inclusions, trace organics, stiff to very stiff, brown, damp to moist | | 3 | SS | 20 | | 112 | | | | | | | 13 32 35 20 |
| | | | 4 | SS | 11 | | 111 | | | | | | | Sampler Wet |
| | | | 5 | SS | 14 | | 110 | | | | | | | |
| 110.6 3.7 110.2 | SILTY CLAY - trace sand, trace gravel, hard, reddish brown, damp (GLACIAL TILL) | | 6 | SS | 32 | | 109 | | | | | | | |
| 4.1 | SILTY CLAY TILL - with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX) | | 7 | SS | 37 | | 108 | | | | | | | |
| | | | 8 | SS | 50/ 10cm | | 107 | | | | | | | |
| 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 | | 107 | | | | | | | 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.06.09 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 | Halton 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 WM3 | | | | | | | | | | | | | | | |
| 108.5 | 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 | |
| 106.99 | 7.31 | | | 1 | B | F | C | RP | T | O | | | | 2 | 25% | 0% | NQ | |
| | 7.5 | | Limestone/Dolostone (INTERBEDS)(9%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength. | | | | | | | | | | | | | | | |
| | 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 | | | SHEAR STRENGTH kPa | | | | | | |
| 114.6 | Ground Surface | | | | | P2 P1 | | 20 40 60 80 100 | 20 40 60 80 100 | 10 20 30 | | | | |
| 114.4 | 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 | | | | | | | | | 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 | | 113 | | | | | | | |
| 112.5 | | | | | | | | | | | | | | |
| 2.1 | SHALE BEDROCK | | 4 | SS | 50/ 8cm | | 112 | | | | | | | |
| | 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 | | | | | | | | | |
| | Shale = 92% Limestone = 8% (Queenston Formation) | | 1 | RUN | NQ | | 111 | | | | | | | RUN#1 TCR=100% RQD=46% |
| | | | | | | | 110 | | | | | | | |
| | | | 2 | RUN | NQ | | 109 | | | | | | | RUN#2 TCR=100% RQD=78% |
| | | | | | | | 108 | | | | | | | |
| | | | 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 | | | | | | | | | | | | | |

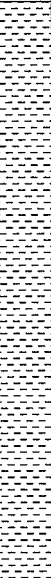
ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

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 | | <u>Shale (92%)</u> : 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 | | <u>Limestone/Dolostone (INTERBEDS)(8%)</u> : Light to medium grey, 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 | | | | | | | | | | | | | | 3 | | | | |
| | 7.0 | | | | | | | | | | | | | | 100% | 97% | NQ | | |
| 106.78 | 7.2 | | | | | | | | | | | | | | | | | | |
| | 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 kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|---|------------|---------|------|-------------|----------------------------|-----------------|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| 115.9 | Ground Surface | | | | | | | | | | | | | |
| 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 | | | 2 | SS | 55 | | | | | | | | | 2 20 49 29 |
| 0.5 | | | | | | | | | | | | | | |
| 115.2 | FILL - Silty Clay, trace sand, trace gravel, stiff, brown, damp to moist | | | | | | | | | | | | | |
| 0.7 | SILTY CLAY some sand, trace gravel, hard, brown, damp (GLACIAL TILL) | | 3 | SS | 64 | | | | | | | | | |
| 113.8 | SILTY CLAY TILL- with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX) | | 4 | SS | 50/ 15cm | | | | | | | | | |
| 2.1 | 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 | | | | | | | | | |
| 113.2 | | | 1 | RUN | NQ | | | | | | | | | RUN#1 TCR=96% RQD=28% |
| 2.7 | | | 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

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

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. | | | | | | | | | | | 2 | | | | | |
| | 5.0 | | | | 1 | B | F | C | RP | T | O | | | | 99% | 52% | NQ | 31.1 | | |
| | 5.5 | | | Limestone/Dolostone (INTERBEDS)(12%): Light to medium grey, laminated to thinly bedded. Bedding planes are tight, planar, rough, medium to high strength. | | | | | | | | | | | | | | | | |
| | 6.0 | | | | | | | | | | | | | | 3 | | | | | |
| | 6.5 | | | | 1 | B | F | C | RP | T | O | | | | 100% | 52% | NQ | | | |
| | 7.0 | | | | | | | | | | | | | | | | | | | |
| 7.5 | | | | 1 | B | F | C | RP | T | O | | | | 4 | | NQ | | | | |
| 108.26 | 7.64 | | | | | | | | | | | | | 100% | 100% | | | | | |
| | 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 | | | | |
| 115.0 | Ground Surface | | | | | | | | | | | | | | | |
| 0.0 114.8 | 250mm TOPSOIL | | | | | | | | | | | | | | | |
| 0.3 | FILL - Silty Clay, sandy, trace gravel, trace rootlets, very stiff to hard, brown, damp to moist | | 1 | SS | 16 | | | | | | | | | | | |
| | | | 2 | SS | 30 | | | | | | | | | | | 2 23 49 26 |
| 113.6 | SILTY CLAY sandy, trace gravel, hard, brown, damp (GLACIAL TILL) | | 3 | SS | 41 | | | | | | | | | | | 2 24 47 27 |
| 1.4 | | | 4 | SS | 76/ 23cm | | | | | | | | | | | |
| 112.4 | SILTY CLAY TILL - with shale, hard, reddish brown, dry to damp (TILL-SHALE COMPLEX) | | 5 | SS | 85 | | | | | | | | | | | |
| 2.6 | | | 6 | SS | 50/ 0cm | | | | | | | | | | | |
| 111.5 | 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, grey limestone. Shale = 85% Limestone = 15% (Queenston Formation) | | 7 | SS | 50/ 0cm | | | | | | | | | | | |
| 3.5 | | | 1 | SS RUN | 50/ 0cm NQ | | | | | | | | | | | RUN#1 TCR=100% RQD=52% |
| | | | 2 | RUN | NQ | | | | | | | | | | | RUN#2 TCR=100% RQD=79% |
| | | | 3 | RUN | NQ | | | | | | | | | | | RUN#3 TCR=100% RQD=96% |
| | | | | | | | | | | | | | | | | |
| 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 | | | | | | | | | | | | | | | |

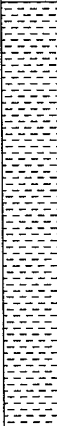
ONTARIO MOT 1-08-3360 QEW WATERMAIN.GPJ ONTARIO MOT.GDT 15/01/09

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 | | | | | | | | 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 | | |
| 110.5 | 4.0 |  | See Borehole Log WM6 | | | | | | | | | | | | | | | | | |
| | 4.5 | | QUEENSTON FORMATION | 1 | B | F | C | RP | T | O | | | | 1 | 100% | 52% | NQ | 38.9 | 25.5 | |
| | 5.0 | | <u>Shale (85%)</u> : 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 | | <u>Limestone/Dolostone (INTERBEDS)(15%)</u> : 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 | | | | | | | | | | | | | | | | | | | |
| | 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

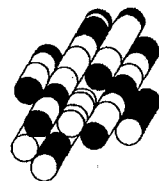
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|-------------|----------------------------|-----------------|---|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | |
| 114.5 | Ground Surface | | | | | | | 20 40 60 80 100 | | | | | | | |
| 113.8 | 130mm TOPSOIL | | 1 | SS | 13 | | 114 | | | | | | | | |
| 0.1 | trace organics, stiff | | | | | | | | | | | | | | |
| | SILTY CLAY | | 2 | SS | 38 | | 113 | | | | | | | | |
| | sandy, trace gravel, hard, brown, moist (GLACIAL TILL) | | | | | | | | | | | | | | |
| | trace shale fragments, reddish brown | | 3 | SS | 68 | | | | | | | | | | |
| 112.4 | | | | | | | | | | | | | | | |
| 2.1 | SHALE BEDROCK | | 4 | SS | 100/ 5cm | | 112 | | | | | | | | |
| | 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. | | 1 | RUN | NQ | | 111 | | | | | | | | |
| | Shale = 80% Limestone = 20% (Queenston Formation) | | 2 | RUN | NQ | | 110 | | | | | | | | |
| | | | 3 | RUN | NQ | | 109 | | | | | | | | |
| 108.3 | | | | | | | | | | | | | | | |
| 6.2 | End of Borehole | | | | | | | | | | | | | | |
| | Borehole filled with drill water upon completion of drilling. | | | | | | | | | | | | | | |

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

APPENDIX B

Laboratory Test Results

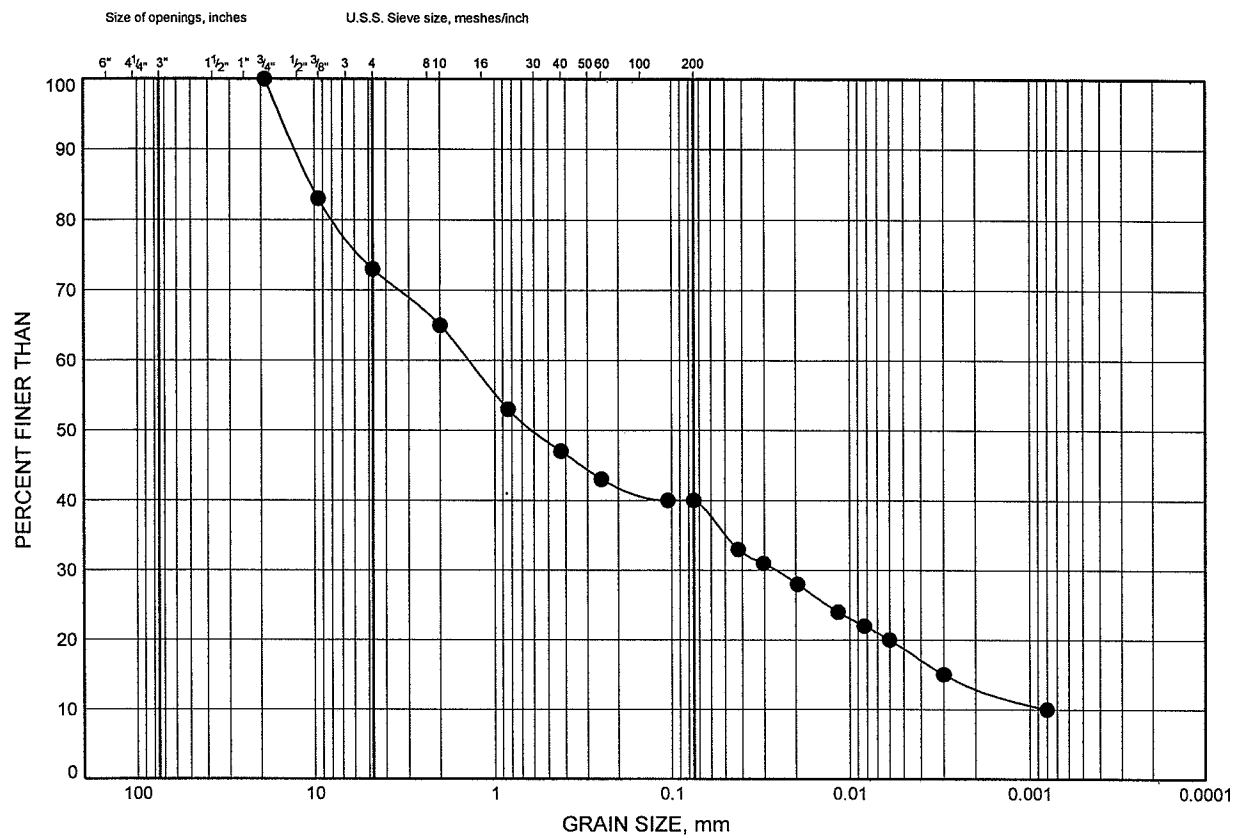
Terraprobe Limited



GRAIN SIZE DISTRIBUTION

FIGURE B1

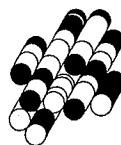
FILL - Gravelly Sand



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

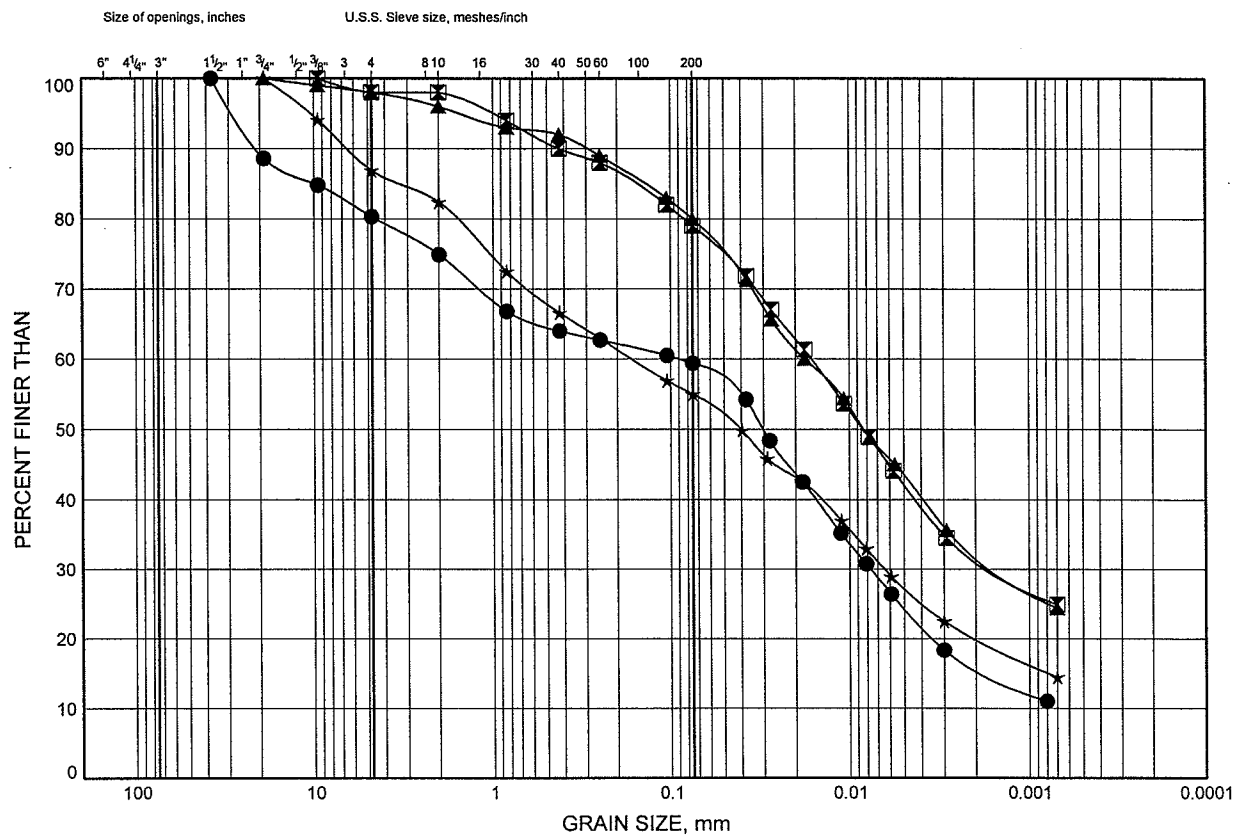


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B2

FILL - Silty Clay



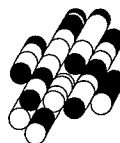
| | | | | | | |
|----------------|--------|------|--------|--------|------|---------------|
| COBBLE SIZE | COARSE | FINE | COARSE | MEDIUM | FINE | SILT and CLAY |
| | GRAVEL | | SAND | | | FINE GRAINED |

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



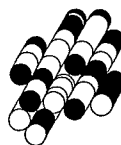
Prep'd DB

Chkd. RA

FIGURE B3

| 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

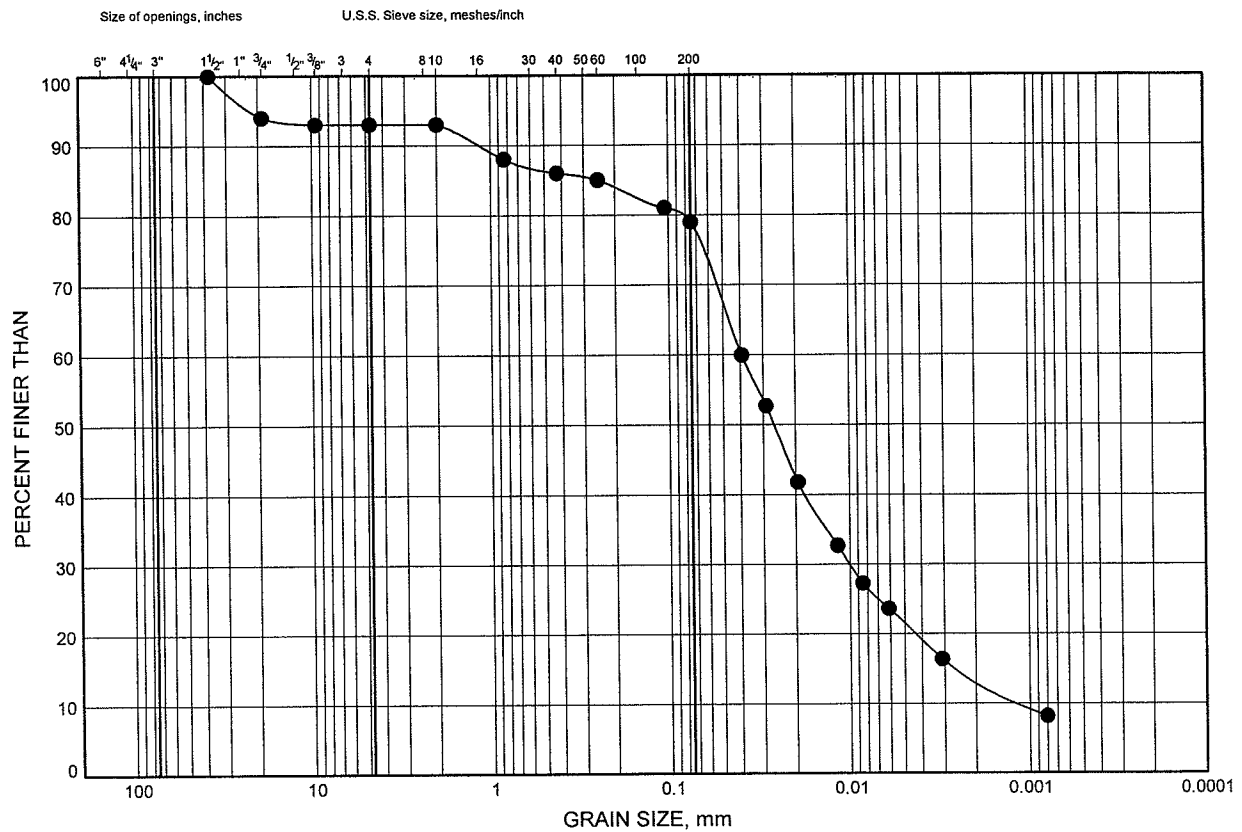


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B4

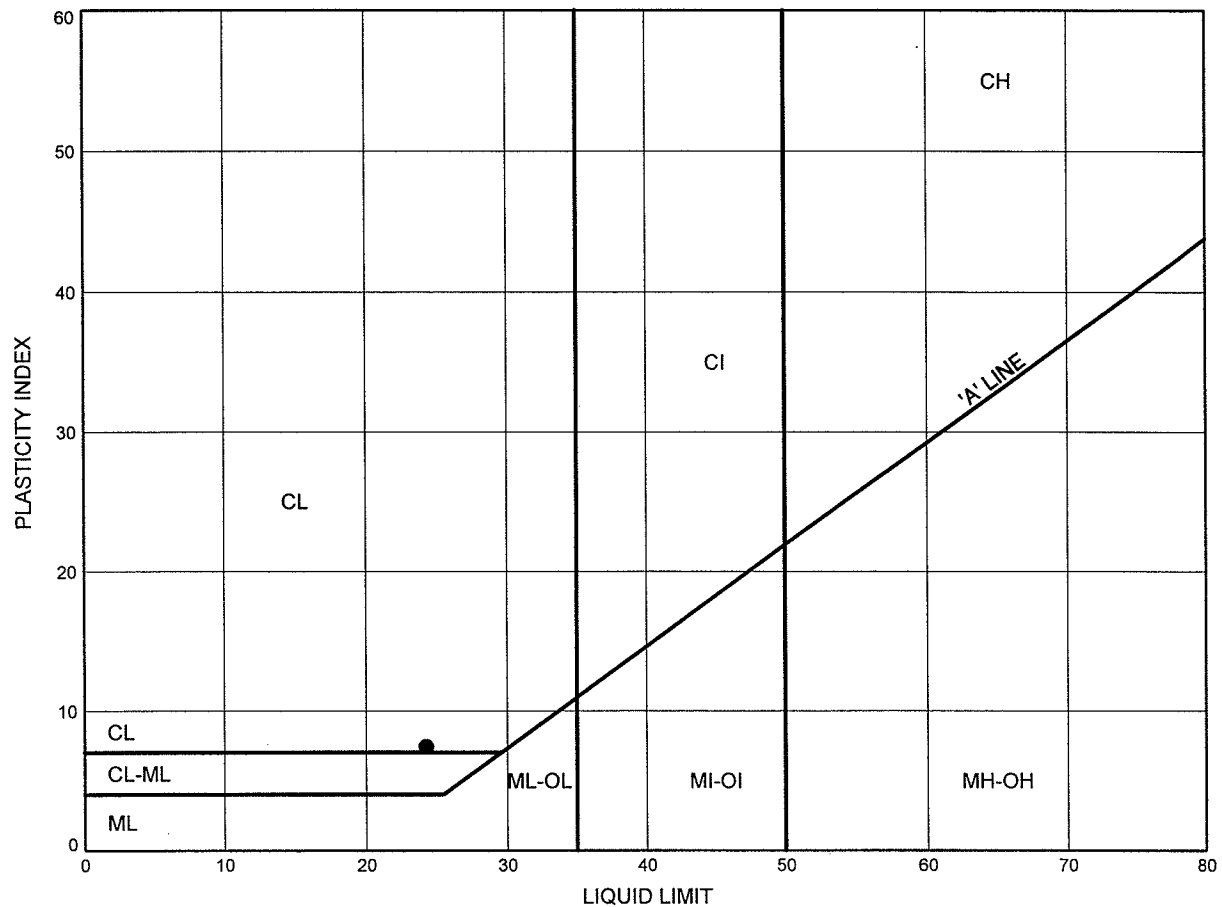
SILTY CLAY TILL / TILL - SHALE COMPLEX



ATTERBERG LIMITS TEST RESULTS

FIGURE B5

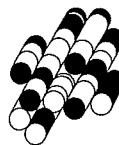
SILTY CLAY TILL / TILL - SHALE COMPLEX



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

Date January 2009

Project 1-08-3360



Prep'd DB

Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B6

FILL - Sand and Silt

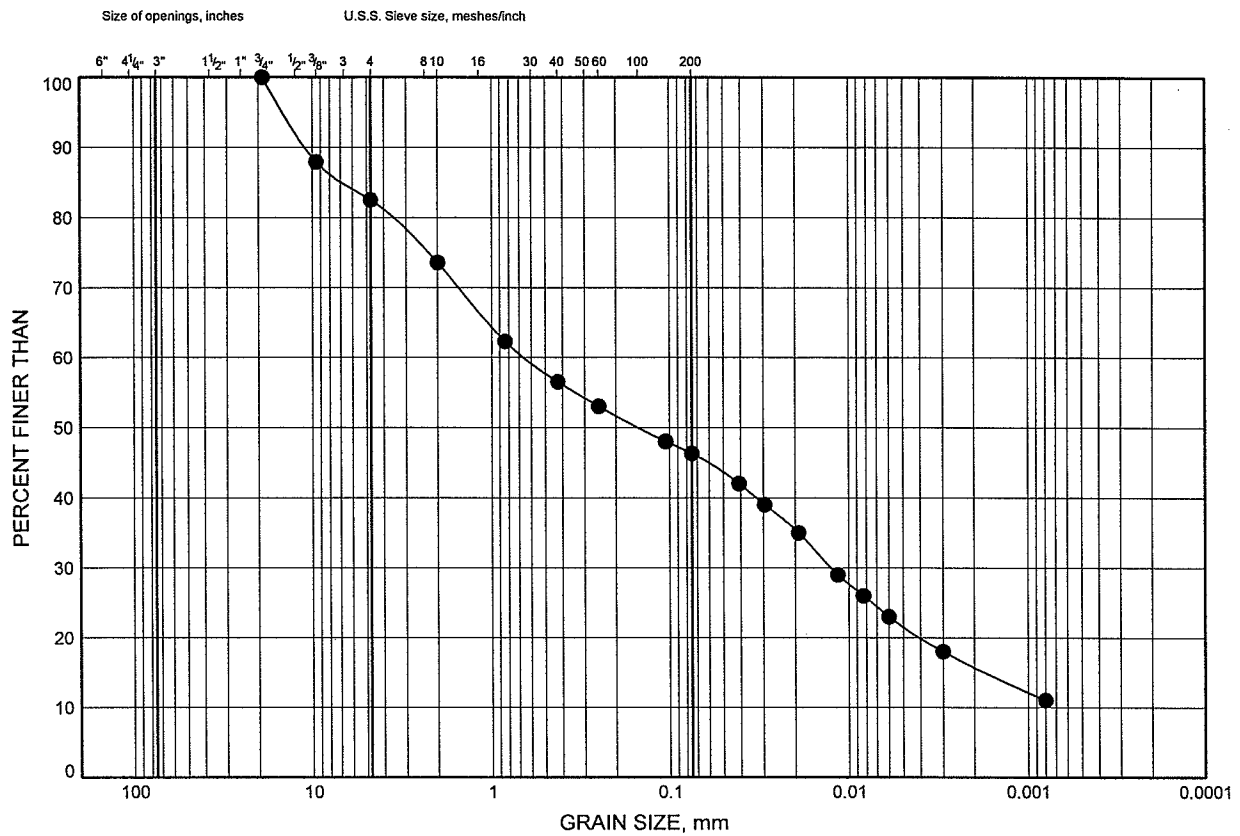


FIGURE B7

Size of openings, inches

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

PERCENT FINER THAN

GRAIN SIZE, mm

| Grain Size (mm) | Percent Finer (%) |
|-----------------|-------------------|
| 100 | 100 |
| 75 | 100 |
| 60 | 100 |
| 40 | 100 |
| 30 | 100 |
| 25 | 100 |
| 20 | 100 |
| 15 | 100 |
| 12.5 | 100 |
| 10 | 100 |
| 7.5 | 100 |
| 6 | 100 |
| 4.75 | 100 |
| 4 | 100 |
| 3.75 | 100 |
| 3 | 100 |
| 2.5 | 100 |
| 2 | 100 |
| 1.5 | 100 |
| 1.18 | 100 |
| 1 | 100 |
| 0.85 | 100 |
| 0.75 | 100 |
| 0.6 | 100 |
| 0.5 | 100 |
| 0.425 | 100 |
| 0.375 | 100 |
| 0.3 | 100 |
| 0.25 | 100 |
| 0.2 | 100 |
| 0.18 | 100 |
| 0.15 | 100 |
| 0.125 | 100 |
| 0.118 | 100 |
| 0.106 | 100 |
| 0.095 | 100 |
| 0.085 | 100 |
| 0.075 | 100 |
| 0.075 | 92 |
| 0.06 | 88 |
| 0.05 | 84 |
| 0.0425 | 78 |
| 0.0375 | 75 |
| 0.03 | 66 |
| 0.025 | 60 |
| 0.02 | 55 |
| 0.018 | 49 |
| 0.015 | 45 |
| 0.0125 | 40 |
| 0.0106 | 29 |
| 0.0095 | 17 |

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

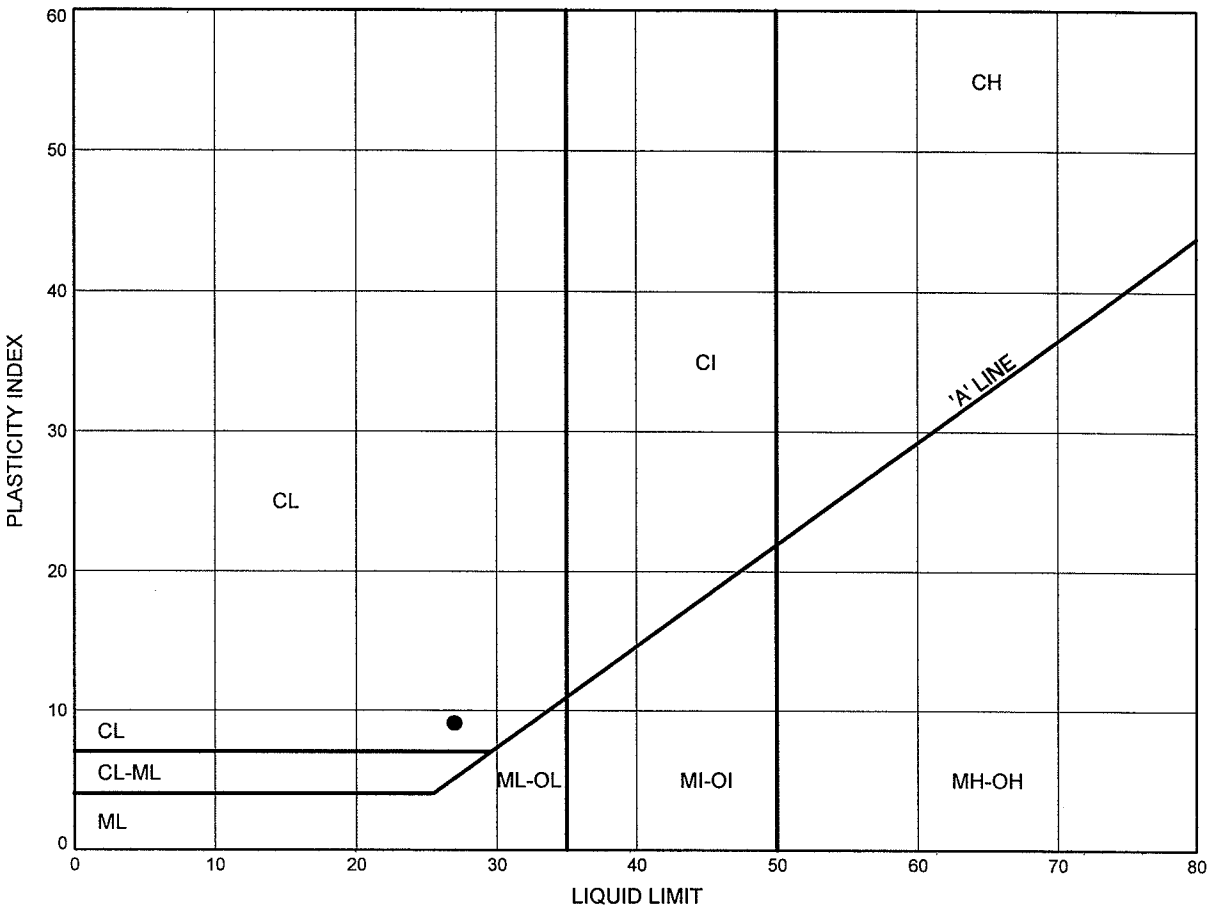
| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|--------|----------|-----------|---------------|
| ● | WM6 | 1.0 | 114.0 |

Chkd. RA

ATTERBERG LIMITS TEST RESULTS

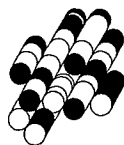
FIGURE B8

FILL - Silty Clay



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

Date January 2009
Project 1-08-3360

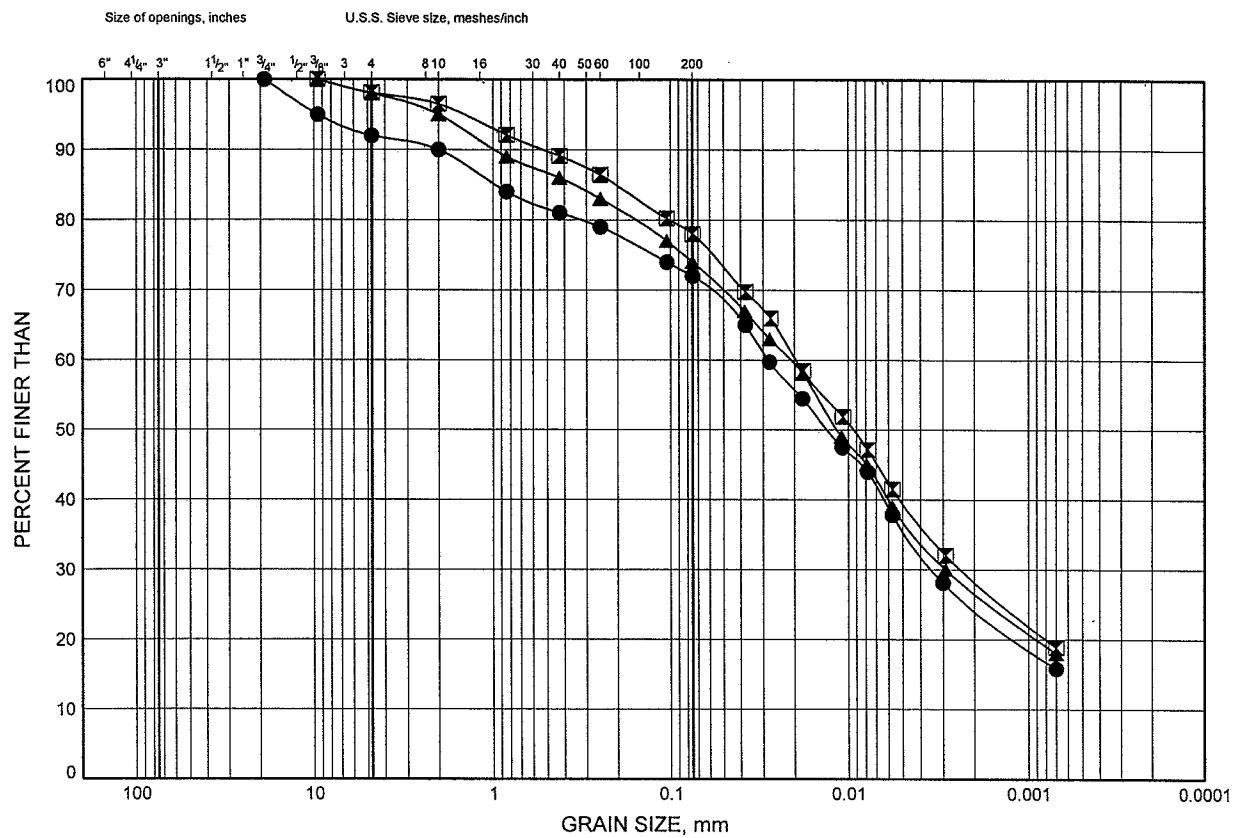


Prep'd DB
Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILTY CLAY TILL



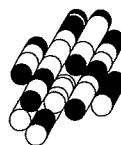
| COBBLE SIZE | COARSE | FINE | COARSE | MEDIUM | FINE | SILT and CLAY |
|----------------|--------|------|--------|--------|------|---------------|
| | GRAVEL | | SAND | | | FINE GRAINED |

| 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



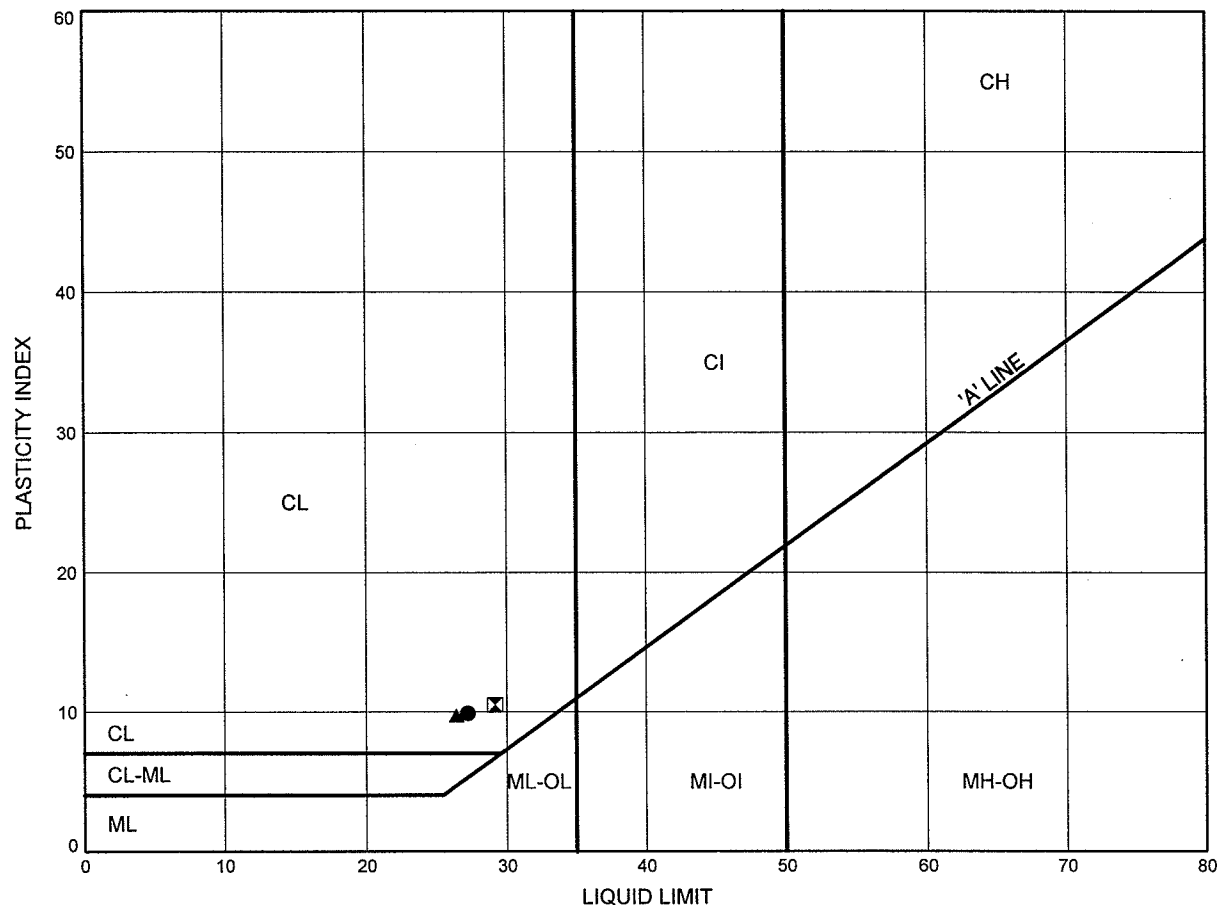
Prep'd DB

Chkd. RA

ATTERBERG LIMITS TEST RESULTS

FIGURE B10

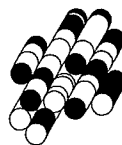
SILTY CLAY TILL



| 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



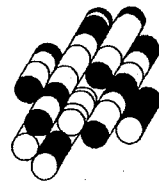
Prep'd DB

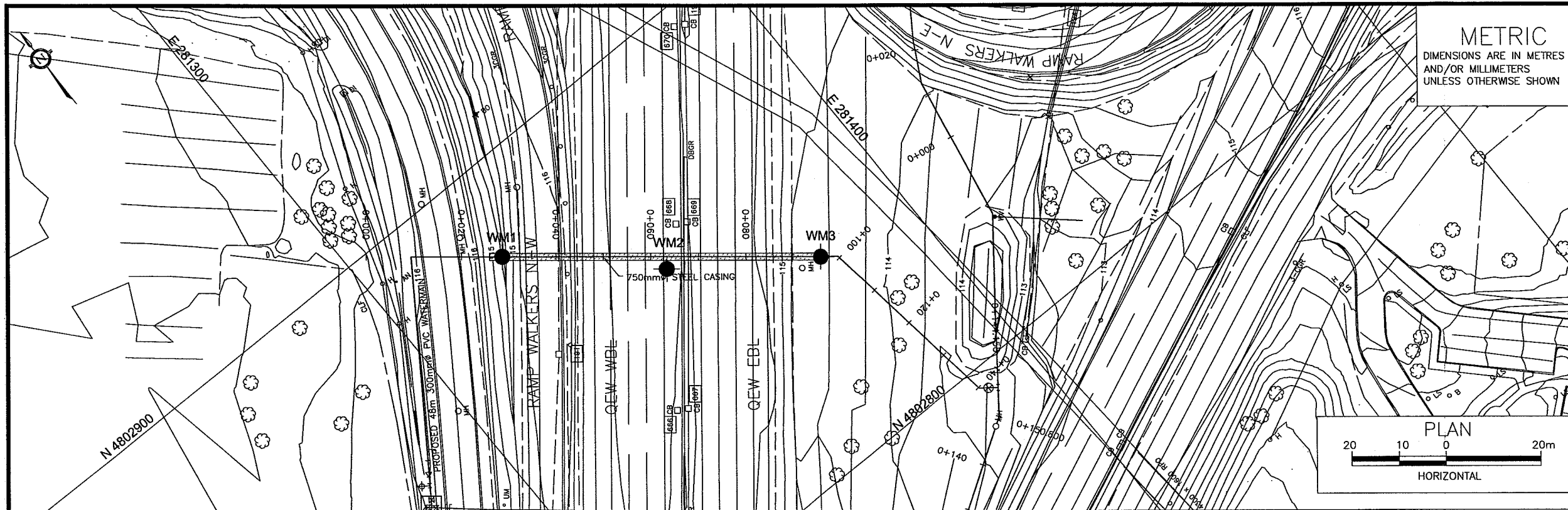
Chkd. RA

APPENDIX C

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

Terraprobe Limited



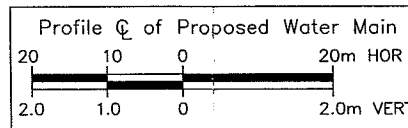
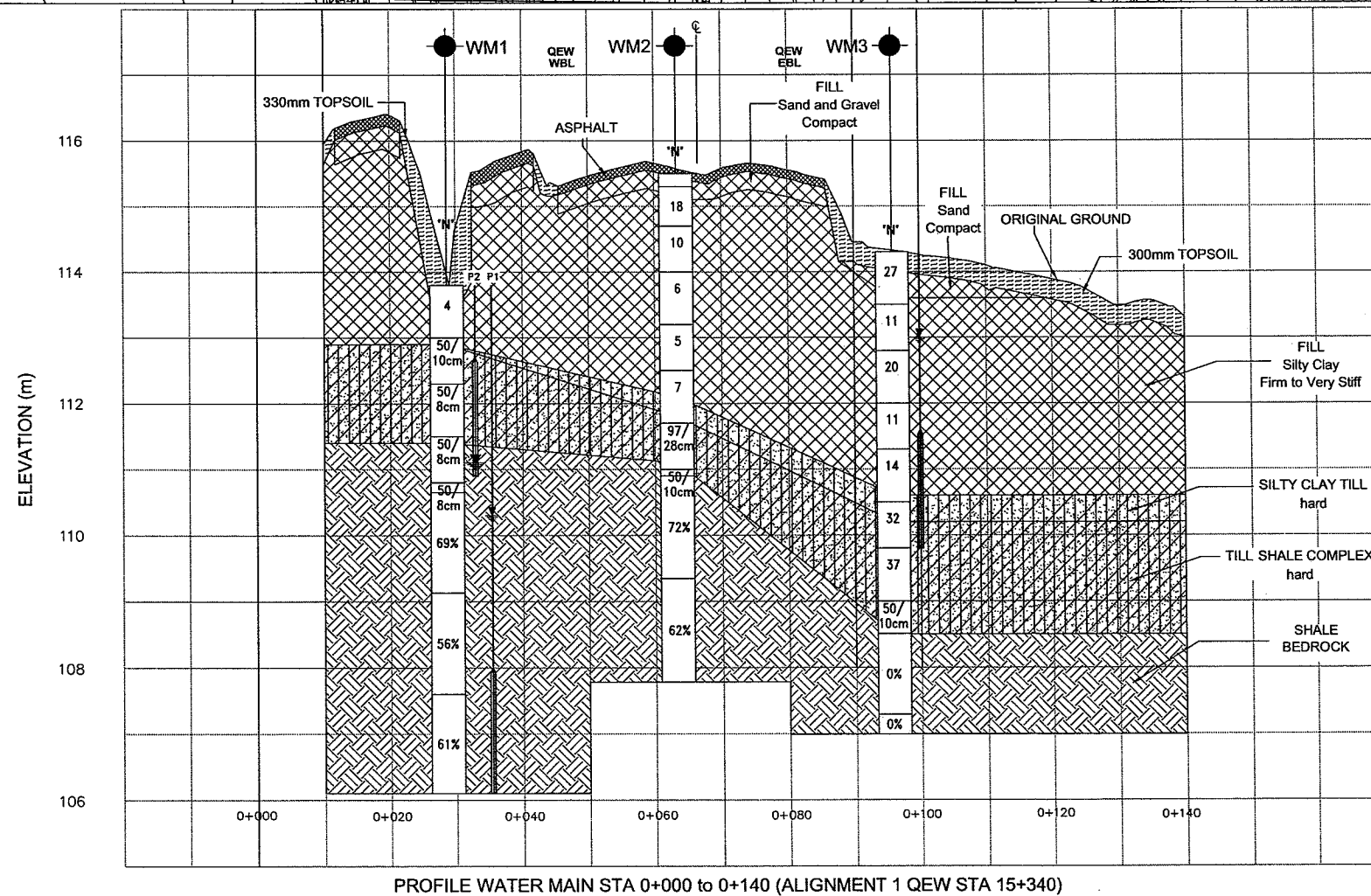
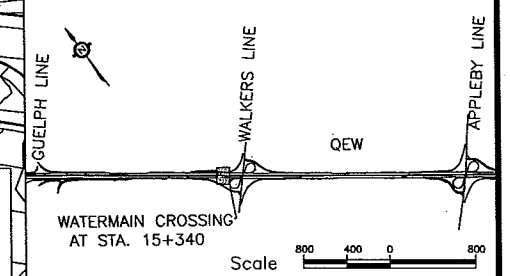


CONT No
WP No

WATERMAIN INSTALLATION
BELOW THE QEW
WALKERS LINE INTERCHANGE

SHEET
1 OF 3

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company



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 |
| | Rock Quality Designation |
| | 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.

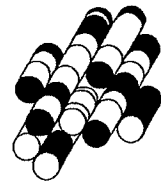
| REVISIONS | DATE | BY | DESCRIPTION |
|---------------------|------|----|-------------|
| DESIGN R.A. CODE | | | LOAD |
| DRAWN L.B. CHK R.A. | | | STRUCT |

DRAWING NOT TO BE SCALED

APPENDIX D

Comparison of Installation Methods

Terraprobe Limited



COMPARISON OF TRENCHLESS INSTALLATION METHODS

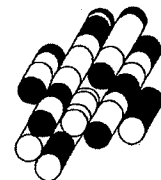
| Pipe Jacking | Microtunnelling | Horizontal Auger Boring |
|--|---|---|
| <p>Advantages:</p> <ul style="list-style-type: none"> i. Avoids open cut excavation, highway closure and traffic diversion. ii. Readily available equipment/technology. iii. More economical than Microtunnelling. iv. Accuracy/Tolerance ± 25 mm. v. Relatively good control of potential settlement. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. More expensive than open cut excavation. ii. Requires constructing special jacking and receiving pits. iii. Requires good care and workmanship by experienced tunnellers in order to reduce ground settlement above the existing freeway. iv. Potential problems such as boulders and water bearing sand lenses can cause ground loss during tunnelling which can result in excessive ground settlement. v. Not practical in rock and would only be suitable for partial tunnelling operations on Alignment 1. | <p>Advantages:</p> <ul style="list-style-type: none"> i. Avoids open cut excavation, highway closure and traffic diversion. ii. Well tested technology. iii. Smaller jacking and receiving pits compared to Pipe Jacking and Horizontal Auger Boring. iv. Accuracy/Tolerance ± 25 mm. v. Relatively good control of potential settlement. vi. Can be used for tunnelling in both rock and soil and would therefore be suitable for both alignments. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Equipment may not be readily available. ii. More expensive than Jack & Bore and Horizontal Auger Boring. | <p>Advantages:</p> <ul style="list-style-type: none"> i. Avoids open cut excavation, highway closure and traffic diversion. ii. Readily available equipment/technology. iii. More economical than microtunnelling. iv. Relatively good control of potential settlement. v. Can be used for tunnelling in both rock and soil and would therefore be suitable for both alignments. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. More expensive than open cut excavation. ii. Requires good care and workmanship by experienced tunnellers in order to reduce ground settlement above the existing freeway. iii. Potential problems such as boulders and water bearing sand lenses as well as rock loss due to vertical and subvertical joints can cause ground loss during tunnelling which can result in excessive ground settlement. iv. Accuracy/Tolerance ± 25 mm v. Relatively large area required to accommodate bore pit and to lay out pipe. vi. Requires a small boring unit for rock excavation. |



APPENDIX E

Suggested NSSP Wording

Terraprobe Limited



In this report reference is made to the following Provincial Standards

- OPSS 514, November 2005.
- OPSS 515, November 2005

The contract documents should contain a NSSP containing the following wording:

Cobbles and Boulders

“The Contractor is informed that the soils at this site may contain cobbles and boulders that may impede the progress of trenching and trenchless installation. The soil conditions are described in the Foundation Investigation Report prepared for this site. Reference should be made to this report for a description of the soil conditions.”

Shale Bedrock

“The Contractor is informed that shale bedrock of the Queenston Formation will be encountered at this site. The rock conditions are described in the Foundation Investigation Report prepared for this site. Reference should be made to this report for a description of the rock conditions. Appropriate equipment should be selected to deal with the shale excavation as well as the harder limestone layers that are likely to be encountered when excavating the rock.”

Mixed Face Conditions

“The Contractor is informed that mixed face conditions will be encountered when tunnelling the alignment at QEW Station 15+340. The contractor must ensure that the selected equipment can deal with these varying conditions as well as maintain proper alignment during the tunnelling operation.”

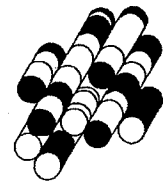
“The Contractor is required to submit a detailed work plan. The work plan must provide details on the proposed construction sequence and methodology and must also address how the Contractor intends to deal with any ground loss that may occur.”



APPENDIX F

Settlement Monitoring Guideline

Terraprobe Limited



SETTLEMENT MONITORING GUIDELINE

Instruments

Two types of settlement monitoring points are required:

- Surface points are placed within the asphalt portion of the highway
- In-ground points, approximately 2 m deep, are proposed next to the outer shoulders of the QEW EBL and WBL. The in-ground points are important for detecting settlements before they are transferred to the surface.

Instrumentation Arrays

In-Ground Monitoring Points

The lateral extent of the monitoring array shall cover a distance on both sides of the tunnel alignment as defined by a 45 degree line extending from one radius of the centerline at the invert level to the ground surface.

As a minimum, four (4) instrument arrays shall be utilized, two for each alignment. An array is to be installed next to the east bound and west bound shoulders perpendicular to the proposed water main alignment. At each location the array of in-ground monitoring points should consist of a minimum of five in-ground monitors, with one point directly over the centerline of the tunnel, and one point each at approximately 5 m and 10 m on either side of the tunnel.

Surface Monitoring Points

Surface monitoring points will be installed on the pavements.

Surface monitoring points will be located on each traveled lane as well as the paved inner and outer shoulder of the QEW EBL and WBL. The surface monitoring points will be identified using paint marks on the pavement.

The final instrumentation plan should be finalized when the Contractor's proposed construction method is available.

Condition Survey

A condition survey of the pavement will be carried out prior to commencement of construction and documented for the purpose of requiring restoration, if necessary. The condition survey will be carried out using the surface monitoring points installed on each travelled lane. This surface survey will be completed when the in-ground monitors and settlement points are installed and again when the tunnel has been completed. Interim surveys will be required should movement be detected in the in-ground monitoring points.



Reading Frequency

In-ground and surface monitoring points shall be read and the data recorded continually by the Contractor during the construction period. Readings shall continue to be made after construction to a time at which all parties agree that there is no further movement.

It is recommended that at least three (3) sets of readings be taken during each shift, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during a non-operation period (off-shifts) or weekends. At least three (3) sets of readings should be taken daily.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The responsible prime Consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Geotechnical Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The suggested acceptable surface settlement (or heave) is 12 mm, or at criteria specified by MTO. The baseline reading, alert level and review level should be established with input from MTO.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. All parties should recognize and accept the baseline level in writing.

Review Level – A maximum value of 6 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of the public and maintain uninterrupted traffic flow.

Review of Contractor's Proposed Method

The Contractor's proposed method of construction should be reviewed by MTO, the Proponent's prime consultant and Geotechnical Engineer. The proposed method should include a description of the potential loss of ground, calculation of the maximum settlement in relation to the Contractor's



procedure and equipment, alternative/remedial measures if the review level of measurement is reached; and contingency/remedial measures if the alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

Notwithstanding the monitoring program to assess the adequacy of the tunnelling construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distresses occur. The Contract is also required to provide a reasonable warranty period for the works acceptable to MTO.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface and subsurface settlement points on site and to provide direction, technical input and field inspection on this project.

