

**DRAFT
FOUNDATION INVESTIGATION AND DESIGN
REPORT**

**PROPOSED WATERMAIN ALONG BROOKDALE AVENUE
PART "A"
INTERSECTION OF BROOKDALE AVENUE
AND HIGHWAY 401
CORNWALL, ONTARIO**

QUOTATION No. 09-Q77

Submitted to:

**The Corporation of The City of Cornwall
Department of Infrastructure & Municipal Works
Engineering Division
1246 Ontario Street
Cornwall, Ontario K6H 4C8
Canada**

Submitted by:

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18 February 2010

TT95009

Distribution:

- The Corporation of The City of Cornwall – 2 bound copies and 1 electronic copy
- AMEC Earth & Environmental – 1 copy



18 February 2010

TT95009

The Corporation of The City of Cornwall
Department of Infrastructure & Municipal Works
Engineering Division
1246 Ontario Street
Cornwall, Ontario K6H 4C8

Attention: Mr. Jean Lemire, P. Eng.

Dear Mr. Lemire:

Re: Draft Report
Foundation Investigation & Design - Proposed Watermain along Brookdale Avenue
Part "A" - Intersection of Brookdale Avenue and Highway 401
Cornwall, Ontario
Quotation No. 09-Q77

We take pleasure in enclosing two hard copies and one digital copy of our Draft Foundation Investigation and Design Report carried out for the above-mentioned project and we will be glad to discuss any questions arising from this work.

Soil samples will be retained for a period of twelve months, and will thereafter be disposed of unless we are otherwise instructed.

We thank you for giving us this opportunity to be of service to you.

Sincerely,

**AMEC Earth & Environmental,
a division of AMEC Americas Limited**

Wissam Farah, MSc., MEng., P.Eng., PMP
Geotechnical and Materials Engineering Group Leader

Encl.

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1.0 INTRODUCTION

AMEC Earth & Environmental, a division of AMEC Americas Limited (AMEC), Consulting Geotechnical, Construction Quality Control and Environmental Engineers, was retained by The Corporation of The City of Cornwall to conduct a geotechnical investigation for installing a new watermain along Brookdale Avenue in Cornwall, Ontario. A key plan showing the location of the proposed watermain alignment is presented on Drawing No. 1 in Appendix A of this report.

The purpose of this investigation is to determine the subsurface conditions along the proposed watermain alignment. Authorization to proceed with this investigation was provided by The Corporation of The City of Cornwall on 20 November 2009. The work was carried out by AMEC according to The Corporation of The City of Cornwall Terms of Reference under Quotation No. 09-Q77 dated 10 November 2009 and AMEC's proposal submission dated 11 November 2009.

The investigation was carried out by means of a limited number of boreholes, in-situ tests and laboratory tests on selected samples. Based on AMEC's interpretation of the data obtained, recommendations for the watermain installation are provided.

2.0 SITE AND PROJECT DESCRIPTIONS

It is proposed to install a new 300 mm diameter watermain along the east side of Brookdale Avenue's right of way in Cornwall, Ontario. The watermain will extend from the intersection of the south side of Tollgate Road and Brookdale Avenue to approximately 225 m south of Cornwall Centre Road. The watermain will have an approximate total length of 2000 m.

The proposed watermain alignment will be located at approximately 5 m west of the Brookdale Avenue's east right of way property line and will cross under the existing CN railway track, Cardinal Drain and MTO Highway 401.

The length of this project has been divided into two parts by The Corporation of The City of Cornwall as follows:

- Part "A": This part of the project covers the section of the proposed watermain that runs within the Ministry of Transportation of Ontario (MTO) property and under Highway 401 corridor and its ramps.
- Part "B": This part of the project covers the remainder length of the proposed watermain as defined above and located to the north and south of the Ministry of Transportation of Ontario (MTO) property limits.

This report is prepared specifically for Part "A" of the project.

3.0 SCOPE OF WORK

The scope of work for this geotechnical investigation was conducted in accordance with the requirements detailed in the Terms of Reference published by The Corporation of The City of Cornwall for Part "A" of this project and it included the following requirements:

- Six - 4.5 m deep foundation boreholes, numbered BH 11 through BH 16, are to be advanced along the alignment of the new watermain. The boreholes are to be placed at the indicated locations by The Corporation of The City of Cornwall. Should bedrock be encountered, rock cores will be acquired to a maximum of 3 m depth.
- Perform laboratory tests, including moisture content, Atterberg limits and soil grain size distribution analyses on selected samples, if warranted.
- Document the results of the field and laboratory programmes in a Foundation Investigation and Design Report complete with geotechnical recommendations concerning the following.
 - Subgrade preparations.
 - Foundation design and construction.
 - Soil Parameters.
 - Pavement structure design for re-instatement.
 - Watermain installation.
 - Construction staging and considerations.
 - Permanent and temporary excavation side slopes.
 - Excavation conditions.
 - Corrosion potential.

4.0 INVESTIGATION PROCEDURES

In accordance with the Terms of Reference and AMEC's proposal for this investigation six – 4.5 m deep foundation boreholes numbered BH 11 through BH 16 were advanced along the proposed alignment of the watermain within Part "A" (i.e. within MTO property limits) and at the locations indicated by The Corporation of The City of Cornwall. Drawing No. 2 in Appendix A shows the locations of the drilled boreholes.

The boreholes were drilled between 20th January and 22nd January, 2010. Some of the borehole locations had to be moved slightly in order to avoid existing underground service lines.

Most of the boreholes were advanced to beyond the indicated depths shown in the Terms of Reference of 4.5 m. Soil samples were normally taken at 1.5 m intervals to a depth of 4.6 m to 4.9 m during the performance of Standard Penetration Test (SPT) in hollow stem augers and in accordance with ASTM D1586. This consisted of freely dropping a 63.5 kg (140 lbs.) hammer for a vertical distance of 0.76 m (30 inches) to drive a 51 mm (2 inches) diameter O.D. split-barrel (split spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m (12 inches) was recorded as SPT 'N' value of the soil which indicated the consistency of cohesive soils or the

relative density of non-cohesive soils. Bedrock was not encountered in any of the boreholes, hence, no coring activities took place. Groundwater, where encountered, was measured in the open boreholes upon their completion. Two stand pipes were installed for future monitoring of groundwater. In situ field vane testing was carried out in cohesive soils to determine their undrained shear strength.

The borehole locations were established by The Corporation of the City of Cornwall. The ground surface elevations at these locations were surveyed in the field by AMEC's survey crew. The established borehole locations are presented in Drawing No. 2 in Appendix A of this report. The Corporation of the City of Cornwall provided AMEC with a number of existing geodetic benchmarks that were located within or close to the borehole locations for reference in surveying the borehole elevations. The geodetic ground surface elevations at the specified borehole locations are presented on the borehole logs in Appendix B of this report.

Upon completion of drilling, the boreholes were backfilled with bentonite. The soil samples were transported to AMEC's Soil Laboratory for further examination and laboratory soil testing. The programme of laboratory testing included, where applicable, in-situ water content determination on more than 25% of the retrieved samples and Atterberg limit.

The encountered soil strata and the results of the field and laboratory tests are presented on the Borehole Records in Appendix B.

5.0 INVESTIGATION RESULTS

This section of the report summarizes the encountered surface and subsurface conditions at Part "A" of the site that is located within the MTO property limits. The field and laboratory test results along with the encountered soil conditions are detailed below.

5.1 Surface Conditions

This section of the site is located along the eastern side of Brookdale Avenue's right-of-way. The proposed watermain will run under Highway 401 right-of-way, the 401 south east ramp, the 401 south west ramp and the 401 east north/south ramp.

The ground surface at the borehole locations placed along the subject site was covered with vegetation underlain by rootmat, silty clay and glacial till deposits.

The ground surface along this stretch of the site was relatively flat. A maximum ground surface elevation difference of 1.2 m was recorded at the borehole locations placed within this section.

5.2 Subsurface Conditions

The following soils were encountered at this site:

5.2.1 Rootmat

A surficial 300 mm to 600 mm thick black to dark brown sandy silt with organics rootmat was encountered at all of the borehole locations at this site.

Laboratory testing conducted on two of the rootmat samples revealed moisture contents ranging between 38% and 100%.

5.2.2 Silty Clay

A brown to grey silty clay deposit was encountered underlying the rootmat in all of the boreholes. This deposit extended to maximum depths between 4.0 m to 4.9 m below ground surface. This deposit consisted of two zones.

The upper zone of the clay deposit, crust, was brown in colour and, generally, stiff to firm as denoted by the recorded SPT 'N'-values and as indicated by the measured in situ shear strength which ranged from 27 kPa to 59 kPa. The crust was 1.7 m to 2.7 m thick, approximately. The crust was not clearly defined in BH 13. Laboratory testing conducted on a few of the silty clay samples retrieved from the crust zone revealed moisture contents ranging between 40% and 54%.

Atterberg limits test conducted on one crust sample returned a liquid limit of 47 a plastic limit of 19 with plasticity index of 28. The silty clay crust can be classified as Lean Clay "CL".

The lower zone of the clay deposit was encountered at 2.7 m and 3.0 m depths below ground surface and extended to 4.0 m to 4.9 m depths. This grey silty clay zone was encountered immediately below the rootmat at 0.3 m depth in BH 13 and extended to 4.6 m depth. The lower clay zone was grey in colour and, generally, firm to soft as indicated by the measured in situ shear strength which ranged from 6 kPa to 25 kPa. Laboratory testing conducted on a few of the silty clay samples from this zone revealed moisture contents ranging between 68% and 80%.

Atterberg limits test conducted on one sample returned a liquid limit of 51, plastic limit of 20.7 and a plasticity index of 30.4. The silty clay in the lower zone can be classified as Heavy Clay "CH".

5.2.3 Till

A glacial till deposit was encountered underlying the silty clay deposit in BH 15 and BH 16 only at 4.0 m depth below ground surface. The till extended to the maximum depth of exploration. The till consisted mainly of sandy silt and clay with some gravel. The till was found to be generally loose to compact as indicated by the recorded SPT 'N' values which ranged between 5 and 25 blows per 300 mm of penetration.

Laboratory testing on one till sample indicated a moisture content of 35%.

5.3 Groundwater

The groundwater was encountered in all of the six boreholes as shown in the table below:

Borehole No.	Groundwater Depth, m	Groundwater Geodetic Elevation, m
BH 11	3.8	55.4
BH 12	2.4	56.5
BH 13	2.1	56.6
BH 14	1.4	58.0
BH 15	2.4	57.6
BH 16	3.1	56.8

Two standpipes were installed in BH 11 and BH 14 for future groundwater level observation. The groundwater table was observed one week after drilling in the installed stand pipes in BH 11 and BH 14 at depths of 3.1 m and 1.0 m, respectively.

Fluctuations in the groundwater level due to seasonal variations or in response to a particular precipitation event should be anticipated.

6.0 DISCUSSIONS AND RECOMMENDATIONS

AMEC understands that The Corporation of The City of Cornwall intends to install a 300 mm diameter watermain along the east side of Brookdale Avenue from Tollgate Road north to approximately 225 m south of Cornwall Centre Road. The watermain will have an approximate total length of 2000 m.

The proposed watermain alignment will be located at approximately 5 m west of the Brookdale Avenue's east right of way property line and will cross under the existing CN railway track, Cardinal Drain and MTO Highway 401.

This section of the report provides recommendations for the installation of the proposed watermain for the part that crosses MTO property and runs under Highway 401 right of way and its eastern ramps. It is noted that the watermain will be placed at below the frost line of 1.8 m depth. At the assumed 2.0 m cover pipe depth, a brown silty clay deposit was encountered which is suitable for the installation of the watermain.

For the purpose of this report, AMEC assumes that the watermain will be installed utilizing open cut trench excavation in the areas where no pavement is present and between the Highway 401 main corridor and its ramps. Trenchless methods such as "Jack and Bore", "Pipe Rimming" or "Horizontal Directional Drilling" shall be utilized to install the watermain under the pavement and embankments for the main corridor of Highway 401 and possibly its associated eastern ramps. If open cutting excavation through the eastern ramps is carried out, reinstatement of the subgrade fill and pavement structure will need to match existing conditions.

6.1 Open Cut Trench

6.1.1 Excavations and Dewatering

It is anticipated that open cut trench excavations for the watermain, where possible will extend to as much as 2.5 m below ground surface. Based on the 2.5 m depth, silty clay soil conditions should be anticipated during construction.

As defined by the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects, the overburden soils should be classified as follows:

Stiff to firm, brown silty clay crust as Type 3
Soft to firm grey silty clay as Type 4

Within Type 3 soils, open cut excavations must be sloped no steeper than one horizontal to one vertical from the bottom of the trench. Within Type 4 soils, open cut excavations must be sloped

no steeper than three horizontal to one vertical from the bottom of the trench. Alternatively, a trench box or sheet piling or other support methods will be required for protection of the workers and the works.

Groundwater was observed in all of the boreholes between 55.4 m and 58.0 m geodetic elevations while the ground surface geodetic elevations were between 60.0 m and 58.8 m. Groundwater and any surface water in the trench may be controlled by sump and pumping methods. To prevent disturbance of the soil at the bedding level, the groundwater table should be lowered to at least 0.8 m below the invert of the trench. In no case should the watermain be placed on dilated or disturbed subsoils. It is also anticipated that geotextiles (e.g., Terrafix 270R or equivalent) will be required to stabilize wet soil subgrade or excavation surfaces in wet areas by filtering the water and preventing the migration of fines.

Stockpiles of excavated materials should be kept at least 2 m from the edge of the excavation to avoid slope instability, subject to confirmation by a geotechnical engineer. Care should also be taken to avoid overloading of any underground services / structures by stockpiles.

Excavations deeper than 2.5 m that are within 5 m of adjacent structures could require a temporary shoring system and should be reviewed by a geotechnical engineer. For shoring systems that are designed to allow rotation, active earth pressure may be used for design. For rigidly tied structures, the at-rest pressure should be used for design, unless the wall can deflect enough (approximately 0.05% of the retained height) to establish the active pressure. Lateral earth pressures may be calculated using the parameters listed in the table below.

Parameters	OPSS Granular A	OPSS Granular B Type I	Native Silty Clay Crust	Native Soft Silty Clay
Unit Weight (kN/m ³)	22.8	21	18	16.5
Angle of Internal Friction, ϕ	35°	32°	22° (Undrained Conditions)	0° (Undrained Conditions)
Coeff. of Active Earth Pressure, K_a	0.27	0.31	0.38	1
Coeff. of Passive Earth Pressure, K_p	1.85	1.65	1.3	1
Coeff. of Earth Pressure at Rest, K_o	0.43	0.47	0.55	1

6.1.2 Pipe Bedding and Backfill

The embedment and excavation for the watermain in Type 3 and Type 4 soils should be done according to Ontario Provincial Standard Drawing, OPSD 802.010 for flexible pipe, as the PVC pipe is expected to be used. If a rigid pipe is used in Type 3 soil, OPSD 802.031 should be followed. The embedment and excavation for the watermain in Type 4 soil should be done according to Ontario Provincial Standard Drawing, OPSD 802.032 for a rigid pipe. The subsoil

conditions should be considered as Class B for bedding purposes as per OPSD. Should soft and wet subgrade conditions be encountered in the open trench, concrete bedding may be necessary to provide stability for the working surface.

If any fill material or disturbed material is encountered at founding level, it should be sub-excavated and backfilled with clean fill material and compacted (minimum 95 % of Standard Proctor Maximum Density) in maximum 200 mm thick layers. The recommended minimum thickness of granular bedding below the invert is 150 mm. The thickness of the bedding may, however, have to be increased depending on the pipe diameter or if wet or weak subgrade conditions are encountered.

A layer of geotextile (e.g., Terrafix 270R or equivalent) should be placed between the granular material and the silty subgrade in order to prevent migration of fine soil. The geotextile should be selected accordingly.

The native soils have a high silt and clay content and are very susceptible to disturbance due to moisture or traffic. The base of the excavation should not be exposed for extended periods of time.

It should be noted that reuse of the site excavated soil will be highly dependent on the moisture content of the soil at the time of placement. The backfill should be placed in maximum 200 mm thick layers at or near (± 2 %) optimum moisture content, and each layer should be compacted to at least 95 % Standard Proctor Maximum Dry Density (SPMDD).

Unsuitable material such as organic soils, boulders, cobbles, frozen soils, etc., should not be used for backfilling.

6.2 Trenchless Methods

Trenchless technologies may be considered to be used to install the 300 mm diameter watermain under paved areas such as the main corridor for Highway 401 and its eastern ramps.

Tunnelling procedures depend upon a number of factors, the most important of which are the groundwater conditions and the soil type through which the tunnel must pass. It is recommended

that practical aspects for the best suited/economical method(s) of installation be discussed with experienced tunnel contractors.

It should be noted that jacking and boring method is more applicable to steel or rigid pipes. Directional drilling method would be more applicable to flexible (e.g., PVC) pipes. In view of the soil conditions encountered at the site, three tunnelling methods are feasible as follows:

6.2.1 Jacking and Boring – (Steel or Rigid Pipes)

The watermain might be jacked and bored beneath the pavement and highway embankments, if permissible. Based on the borehole data and assumed depth of watermain, it is anticipated that jacking reaction blocks will be founded within the existing silty clay at approximate elevations of 57.0 m to 58.0 m or at approximately 2 m to 2.5 m depth below the ground surface.

This technique forms a horizontal borehole from a drive shaft to a reception shaft by means of rotating cutting head. Soil is transported back to the drive shaft by helical auger flights rotating inside a steel casing. The casing is jacked in place simultaneously with the auguring operation. After the installation of the steel casing, the watermain will be installed inside the casing and the gap between the casing and the pipe will be grouted.

The underlying native soil consists of stiff to firm silty clay crust overlying softer silty clay. The depth of proposed pipe is unknown at this time; however it will be about 2.0 m below existing grades. The approximate soil cover above the tunnel pipe is approximately 2 m and the pipe should go through silty clay crust deposit although the soils between borehole locations may be different from those encountered in the boreholes.

It is recommended that the bulk unit weight of the silty clay crust be 18 kN/m^3 and the coefficient of friction between the steel pipe and silty clay crust be 0.25. A unit weight of 16.5 kN/m^3 and a coefficient of friction of 0.20 can be used for the soft and grey silty clay. The gap between the pipe and the soil, after the completion of the tunnelling, should be grouted to reduce settlements.

The construction of the tunnel by this method should conform to Ontario Provincial Standard Specification (OPSS) – *“Construction Specification for Pipeline and Utility Installation by Jacking and Boring”* (OPSS 416).

It should be noted that the stability of the face of the tunnel is to be maintained at all times. A significant amount of soil should be left in the tunnel behind the tunnel face and/or a shield is installed in order to prevent instability. Drainage within the tunnel due to inflowing groundwater should be provided. It is imperative to monitor any ground surface movement during tunnelling, particularly in the vicinity of the highway embankments.

6.2.2 Pipe Ramming

For the highway embankments, the tunnel could be jacked and/or rammed with vibrator through the silty clay deposit with an open ended pipe. This method is feasible for cohesionless and cohesive soils.

It is recommended that at least 2 m of soil cover below the existing ground surface be provided on top of the pipe to minimize disturbance. Once the pipe has crossed under the highway embankments, the soil inside the pipe could be mined or augured out from the shaft location.

For design purposes, the estimated coefficient of friction between the steel liner and the silty clay crust is 0.25. A bulk unit weight of 18 kN/m^3 can be used for the silty clay crust. A unit weight of 16.5 kN/m^3 and a coefficient of friction of 0.20 can be used for the soft and grey silty clay.

The required construction activities will generate some vibrations that will be perceptible to the nearby residences and structures. The vibrations are expected to be greatest during pipe ramming.

It is recommended that construction vibrations generally be limited to a maximum peak particle velocity of 25 mm/sec at the nearest structure. Should there be structures in the area sensitive to vibrations more stringent specifications should be developed by a vibration specialist. Vibration monitoring should be carried out prior to and throughout the construction period.

6.2.3 Horizontal Directional Drilling - (PVC or Flexible Pipe)

Horizontal direction drilling is another feasible technique for the pipe installation under the highway and its ramps. This technique is a well-accepted method for installing pipes underground. A typical horizontal directional drilling operation begins with a small diameter pilot hole at the entry side of the site.

The bore starts from the surface and proceeds downwards at an angle (from 8 to 18 degrees) from the horizontal until the target depth is achieved. At the target depth the path of the bore is levelled, and the bore is steered to the designated exit point where it is brought to the surface. Drilling fluid, typically a mix of bentonite or polymer and water, is pumped under pressure (up to 20 MPa) through the hollow drill string.

Subsequent to completing the pilot bore, the new water pipe is normally pulled back by a reamer, with a diameter larger than that of the pilot hole, through the pilot hole bore path. Drilling fluid is also used during the pulling of the pipe.

Generally, the entry/exit points for the horizontal directional drilling are located away from the target entry/exit point (e.g. manhole location) at a distance governed by the angle of entry/exit.

Therefore, the feasibility of the use of horizontal directional drilling may be governed by availability of such space at project location.

The success of directional drilling is mainly controlled by the capability and experience of a specialist contractor. The construction of the tunnel by this method should conform to OPSS – “Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling” (OPSS 450).

6.2.4 Monitoring during Tunnelling

During tunnelling, the ground in the vicinity of the tunnel alignment and the existing roads/ramps may undergo settlement. It is recommended that ground movement during tunnelling be monitored together with the monitoring of the tunnel activity. This is to confirm that the tunnelling process does not cause any significant impact on the existing soil and groundwater conditions and the watermain is properly installed. If any adverse effect of tunnelling is identified by the monitoring program, the tunnelling process can be modified accordingly.

6.3 Tunnel Shaft, Excavation and Dewatering

In constructing the tunnel, shafts will be constructed on both sides of the proposed tunnel. The anticipated soils to be excavated consist of stiff to firm silty clay. The groundwater levels at pavement crossing are expected to be below bottom of the excavation. Therefore, a significant dewatering may not be required, although a sump and pump system may be required, if groundwater is encountered.

The excavations should be carried out as per the Safety Regulations of the Province of Ontario. Based on the borehole information, the soils to be excavated can be classified as Type 3 soils. Accordingly, a minimum bank slope of 1H:1V should be provided from the bottom of the excavation. A flatter slope may be required based on the site condition.

The excavation, backfilling and compacting for the sewer pipe by open cut method should conform to Ontario Provincial Standard Specification (OPSS) – “*Construction Specification for Trenching, Backfilling and Compacting*” (OPSS 514).

6.4 Thrust Blocks

The unbalanced horizontal thrust (if any) could be resisted by using thrust blocks. As these rely on the passive earth pressure of the soil in front of the blocks, they should be used only where there is assurance that the ground in front of the thrust will not be disturbed. Please refer to table in Section 6.1.1 above for Kp values.

6.5 Earthquake Considerations

In conformance with the criteria in Table 4.1.8.4A, Part 4, Division B of the National Building Code (NBC 2005), the project site is classified as Site Class "E - Soft Soil". The four values of the spectral response acceleration, $S_a(T)$, for different periods and the Peak Ground Acceleration (PGA) can be obtained from Table C-2 in Appendix C, Division B of the NBC (2005). The design values of F_a and F_v for the project site should be determined in accordance with Table 4.1.8.4 B and C.

6.6 Reinstatement of Pavement

It is assumed that the installation of the watermain under Highway 401 corridor will be completed utilizing tunnelling or directional drilling as described above, hence no pavement reinstatement will be anticipated for the highway main corridor. Where open cutting of Highway 401 ramps is permitted, pavement reinstatement shall match existing subgrade fill and pavement structure thicknesses and conditions to the satisfaction of the MTO.

It is anticipated that most of the construction activities will not be close to the road embankment of Brookdale Avenue, hence it may not influence the right of way for Brookdale Avenue nor its associated slopes. However, should the roadway embankment be affected, it should be reinstated with select subgrade material.

6.7 Cement Type and Corrosion Potential

One selected soil sample from this site was sent to Exova Accutest Environmental Laboratories in Ottawa to test for pH, sulphate, chloride concentrations and resistivity. The results are summarized in the table below. The presented results should be considered while selecting the type of concrete and the requirement for coating of any buried steel.

Borehole/ Sample #	pH	Sulphate, %	Chloride, %	Electrical Resistivity Ohm-cm
BH 11 - SS3	7.3	0.02	0.169	382

Generally, the soluble sulphate results indicated that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type 10 Portland Cement should therefore be suitable for use in concrete at this site.

The results for the samples tested for this project indicate a resistivity of 382 Ohm-cm for the tested sample. The indicated resistivity results reflect that severe corrosion activity may occur for steel placed within this soil. Therefore, protective coatings may be required for steel protection against corrosion. The corrosion potential should be evaluated by a corrosion expert.

7.0 CLOSURE

The sub-soil information and recommendations contained in this report should be used solely for the purpose of foundation assessment of this site and installation of the proposed watermain. AMEC should be retained to review the recommendations provided in this report, once the details of the development are finalized and prior to the final design stage of the project. The attached Report Limitations, in Appendix C, are an integral part of this report. Should there be any questions, please contact the undersigned.

Sincerely,

**AMEC Earth & Environmental,
a division of AMEC Americas Limited**

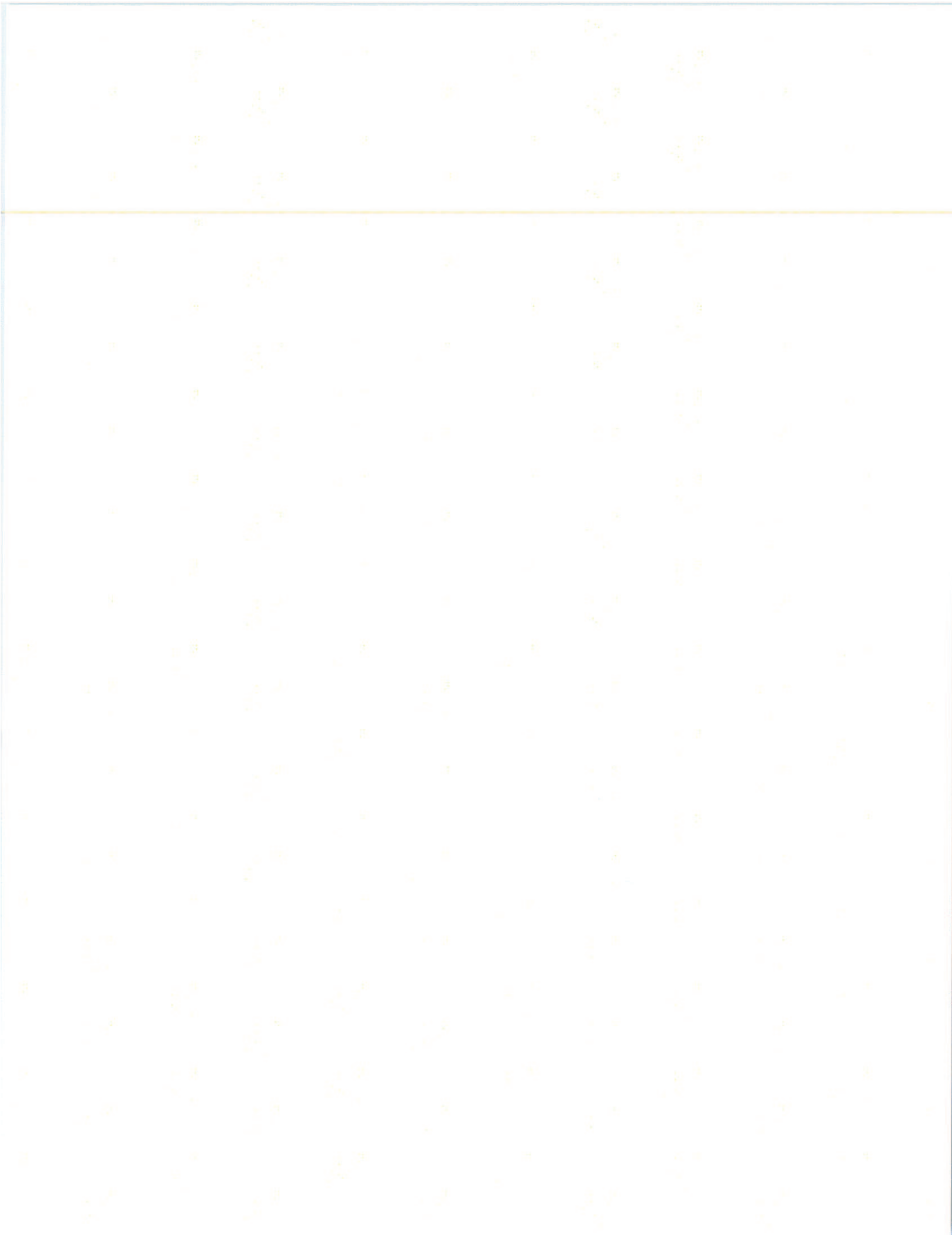
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APPENDIX A

KEY AND BOREHOLE LOCATION PLANS
(DRAWINGS 1 AND 2)







KEY PLAN



Approximate Scale

AMEC Earth & Environmental, a Division of AMEC Americas Limited			CLIENT LOGO 	CLIENT MINISTRY OF TRANSPORTATION ONTARIO	
TITLE SITE MAP			DWN BY: KW	DATUM: -	DATE: FEBRUARY 2010
PROJECT FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED WATERMAIN ON BROOKDALE AVE. (FROM TOLLGATE RD. TO NORTH OF HWY 401) Cornwall, Ontario			CHK'D BY: WF	REV. NO.: A	PROJECT NO.: TT95009
			PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 1

APPENDIX B

**BOREHOLE RECORDS
(BH 11 THROUGH BH 16)**

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil strata, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *Modified Unified Soil Classification System*.

The compactness condition of cohesionless soils (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows (Ref. *Canadian Foundation Engineering Manual*):

Compactness of	
<u>Cohesionless</u>	<u>SPT N-Value*</u>
<u>Soils</u>	
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

<u>Consistency of</u>	<u>Undrained Shear Strength</u>	
	<u>kPa</u>	<u>psf</u>
<u>Cohesive Soils</u>		
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	Over 200	Over 4000

* For penetration of less than 0.3 m, N-values are indicated as the number of blows for the penetration achieved (e.g. 50/25: 50 blows for 25 centimeter penetration).

Soil Sampling

Sample types are abbreviated as follows:

SS	Split Spoon	TW	Thin Wall Open (Pushed)	RC	Rock Core	GS	Grab Sample
AS	Auger Sample	TP	Thin Wall Piston (Pushed)	WS	Washed Sample	AR	Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Instrumentation Installation

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section. Water levels, if measured during fieldwork, are also plotted. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors.

Comments

This column is used to describe non-standard situations or notes of interest.

MODIFIED * UNIFIED CLASSIFICATION SYSTEM FOR SOILS						
*The soil of each stratum is described using the Unified Soil Classification System (Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S Army, Vol. 1 March 1953.) modified slightly so that an inorganic clay of "medium plasticity" is recognized.						
MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (TRACE OR NO FINES)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4; C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME OR MORE FINES)	GM	SILTY GRAVELS, GRAVEL-SAND- SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4	
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7	
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (TRACE OR NO FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6; C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			SP	POORLY GRADED GRAVELS, GRAVEL- SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME OR MORE FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4	
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7	
FINE GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)	
		$W_L < 50\%$	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L < 50\%$	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE	$W_L < 50\%$	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F". E.G SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L < 50\%$	OH	ORGANIC CLAYS OF HIGH PLASTICITY		
	HIGH ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE

SOIL COMPONENTS					
FRACTION	U.S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS		
GRAVEL	COARSE	PASSING	RETAINED	PERCENT	DESCRIPTOR
		76 mm	19 mm	35-50	AND
	FINE	19 mm	4.75 mm	20-35	Y/EY
		4.75 mm	2.00 mm	10-20	SOME
SAND	COARSE	4.75 mm	2.00 mm	1-10	TRACE
	MEDIUM	2.00 mm	425 µm		
	FINE	425 µm	75 µm		
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm			
OVERSIZED MATERIAL					
ROUNDED OR SUBROUNDED: COBBLES 76 mm TO 200 mm BOULDERS > 200 mm				NOT ROUNDED: ROCK FRAGMENTS > 76 mm ROCKS > 0.76 CUBIC METRE IN VOLUME	

Plasticity Chart for Soil Passing 425 Micron Sieve

AMEC Earth & Environmental 104 Crockford Boulevard Scarborough, ON M1R 3C3 Ph: (416) 751-6565 Fax: (416) 751-7592 www.amec.com		Note 1: Soils are classified and described according to their engineering properties and behaviour. Note 2: The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual (4th Edition, Canadian Geotechnical Society, 2006.)
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RECORD OF BOREHOLE No BH 11

1 OF 1

G.W.P. _____ LOCATION Brockdale Avenue, Cornwall ORIGINATED BY CE
 DIST _____ HWY _____ BOREHOLE TYPE Hollow Stem Augering COMPILED BY CE
 DATUM _____ DATE 21 January 2010 - 21 January 2010 CHECKED BY WF
 PROJECT Watermain, Brockdale Avenue, Cornwall JOB NO. TT95C09

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa						
59.2									20 40 60 80 100	20 40 60 80 100					
0.0	Black sandy silt with organics, trace roots: ROOTMAT							59							
58.9			1	SS	7										
0.3	Stiff to firm, brown SILTY CLAY														
			2	SS	5		1								
								58							
			3	SS	2		2								
								57							
							3								
	Becoming gray and soft		4	SS	1			56							
							4								
								55							
			5	SS	0										
54.3															
4.9	End of Borehole														

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

[illegible]

1 OF 1

G.W.P. _____	LOCATION <u>Brockdale Avenue, Cornwall</u>	1 OF 1	ORIGINATED BY <u>CE</u>
DIST _____ HWY _____	BOREHOLE TYPE <u>Hollow Stem Augering</u>		COMPILED BY <u>CE</u>
DATUM _____	DATE <u>20 January 2010 - 20 January 2010</u>		CHECKED BY <u>WF</u>
PROJECT <u>Watermain, Brockdale Avenue, Cornwall</u>		JOB NO. <u>TT95C09</u>	

[illegible]

+³, ×³: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH 15

1 OF 1

G.W.P. _____ LOCATION Brookdale Avenue, Cornwall ORIGINATED BY CE
 DIST _____ HWY _____ BOREHOLE TYPE Hollow Stem Augering COMPILED BY CE
 DATUM _____ DATE 20 January 2010 - 20 January 2010 CHECKED BY WF
 PROJECT Watermain, Brookdale Avenue, Cornwall JOB NO. TT95009

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	SOIL VAPOUR READING PPM	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa						
60.0	Dark brown sandy silt with organics; ROOTMAT		1	SS	6										
59.4															
0.6	Stiff to firm, brown SILTY CLAY		2	SS	5		1	59			19	47			
			3	SS	5		2	58				54			
	----- Becoming grey and soft		4	SS	2		3	57			21	51	70		
56.1															
4.0	Loose, grey sandy silt and clay, some gravel: TILL		5	SS	5		4	56				38			
55.5															
4.6	End of Borehole														

G.W.P.	LOCATION	Brookdale Avenue, Cornwall	1 OF 1	ORIGINATED BY	CE
DIST	HWY	BOREHOLE TYPE	Hollow Stem Augering	COMPILED BY	CE
DATUM	DATE	22 January 2010 - 22 January 2010		CHECKED BY	WF
PROJECT	Watermain, Brookdale Avenue, Cornwall			JOB NO.	TT95009

[illegible]

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

APPENDIX C
REPORT LIMITATIONS

REPORT LIMITATIONS

The conclusions and recommendations given in this report are based on information determined at the testhole locations. The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. It is recommended practice that the Geotechnical Engineer be retained during the construction to confirm that the subsurface conditions across the site do not deviate materially from those encountered in the testholes.

The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final design stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

The comments made in this report relating to potential construction problems and possible methods of construction are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices. No other warranty is expressed or implied.

The benchmark and elevations mentioned in this report were obtained strictly for use by this office in the geotechnical design of the project. They should not be used by any other party for any other purpose.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC Earth & Environmental accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

