2 March 2010

**AMEC Reference TT93061**

City of Kitchener
Engineering Services
9th Floor, Berlin Tower
City Hall, P.O. Box 1118
200 King Street West
Kitchener, Ontario
N2G 4G7

**Attn.: Mr. Shailesh Shah, BASc.**
**Design Engineer**

**Re: FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT**
**TUNNELING FOR PROPOSED SANITARY SEWER UNDER HIGHWAY 8**
**(APPROXIMATELY BETWEEN STATION 11+865 TO STATION 11+875)**
**CITY OF KITCHENER, ONTARIO**

Please find enclosed two (2) copies of for the Final Foundation Investigation and Design Report for the above-mentioned project, incorporating revisions as per Ministry of Transportation (MTO) comments dated 23 February 2010. The following comments, received from MTO, were addressed in the Final Report, as per AMEC's responses below:

PART A – FOUNDATION INVESTIGATION REPORT – Sections 1 to 4

1. MTO GEOCRES No. **40P8-179** has been assigned to the Final Report and Foundation Drawing (BH Locations and Soil Strata).

   *Duly Noted.*

2. Section 4.2.2 (page 4) – AMEC states that "Some cobbles/boulders were noted in BH 2". According to the Record of BH 2, only cobbles were noted in the Sand and Gravel Fill.

   *Statement revised as per borehole log.*

3. Section 4.3 (page 5) – The paragraph on DCPT should be relocated after the moisture content and grain size distribution results for Silt.

   *Revised as requested.*

4. Drawing 2 – BH Locations and Soil Profile – Plan View – Why is the location of BH 103 shown (no reference in report text)?

   *Borehole information was not available to AMEC at the time of the report. Reference to the borehole has been included in the Final report.*

5. Record of BH 2 – Sand Fill – Based on SPT 'N' = 34, "very dense" should be "dense".

   *Borehole log revised.*

PART B – FOUNDATION DESIGN REPORT – Sections 5 to 6

6. Section 5.1 (page 6) – **Was consideration given to lowering the grade of the sewer to below the various fills and above the groundwater levels encountered in the 3 BHs?**

   *The City of Kitchener is aware of and has considered this comment. Final alignment of the proposed sewer depends on the design by the City of Kitchener.*

7. Section 5.2.1 (page 7-8):
   a. AMEC states that "Cobbles and boulders should be expected, particularly within the fill soils". The Contract should contain an NSSP to warn the Contractor of the presence of cobbles/boulders for tunneling.

      *A red flag statement regarding the NSSP has been included in revised report.*

   b. During the pipe jacking operation, a plug of soil should be left inside the front end of the casing at all times to maintain stability and to prevent a potential flowing or running condition to develop.

      *Statement included in revised report.*

8. Section 5.4 (page 11-12) – Per the MTO Guidelines (page 4 of 8), **estimated settlements should be provided**

   *Included in the revised report.*

Please do not hesitate to contact AMEC if there is any questions.

Sincerely,

AMEC Earth & Environmental,
a Division of AMEC Americas Limited

George SW Chow, P.Eng.
Senior Vice President

Distribution:

| | |
|---|---|
| 2 copies | City of Kitchener |
| 1 copy | AMEC |

**FINAL**
**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**TUNNELING FOR PROPOSED SANITARY SEWER UNDER HIGHWAY 8**
**(APPROXIMATELY BETWEEN STATION 11+865 TO STATION 11+875)**

**CITY OF KITCHENER**
**ONTARIO**

**(MTO GEOCRES No. 40P8-179)**

*Submitted to:*

**City of Kitchener**
**Engineering Services**

9th Floor, Berlin Tower
City Hall, P.O. Box 1118
200 King Street West
Kitchener, Ontario
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*Submitted by:*


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2 March 2010

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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 City of Kitchener ("the City") to conduct a foundation investigation for installation of a 80.1 m long, 350 mm diameter sanitary sewer (750 mm diameter with casing) under Highway 8 (King Street Bypass), approximately between Station 11+865 to Station 11+875, in Kitchener, Ontario. The project site location is shown in Drawing No. 1.

As per the information provided by the City, the new sewer pipe is to be installed parallel to the existing 250 mm diameter sewer using the Jacking and Boring method. A drawing indicating the planned tunnel for the new sanitary sewer and the profile at the proposed tunnel location was provided to AMEC (Appendix C). A foundation investigation and design report was required by the Ministry Transportation (MTO) for the City's Encroachment Permit Application for this installation. A copy of MTO's "*Guidelines for Foundation Engineering – Tunneling Specialty – for Corridor Encroachment Permit Application*" ("Guideline") was provided to AMEC (refer to Appendix D).

This work was carried out by AMEC according to the requirements set out in the City's email (*dated 5 November 2009*), MTO's above noted Guidelines and AMEC's Proposal No. P29264 (*dated 17 November 2009*). AMEC's proposal included settlement monitoring during construction of the tunnel, submitted as per the City's request. Authorization to proceed with the foundation investigation was received from the City via Purchase Order dated 1 December 2009, authorized by Mr. Larry Gordon. A total of three (3) boreholes were drilled to depths ranging from about 5.2 m to 10.8 m below existing ground surface. Subsequent to drilling, Dynamic Cone Penetration Tests (DCPT) were carried out in all boreholes to depths of ranging from about 10.8 m to 13.3 m. Borehole locations are shown in Drawing No. 2. The number, depths and locations of the boreholes were based on the requirements of the MTO Guideline (Appendix D).

A copy of the borehole log for Borehole No. 103, drilled near the proposed tunnel location by Golder Associates on 8 April 2003, was provided to AMEC by the City of Kitchener. The borehole location is shown in Drawing No. 2 and a copy of the log is attached in Appendix E for information.

This report contains the findings of the foundation investigation, together with recommendations and comments. These recommendations and comments are based on the factual information and are intended only for use of the design engineers. The number of boreholes may not be sufficient to determine all the factors that may affect construction methods and costs. Subsurface and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The anticipated construction conditions are also discussed, but only to the extent that they may influence design decisions. Construction methods discussed, however, express AMEC's opinion only and are not intended to direct the contractors on how to carry out the construction. Contractors should also be aware that the data and their interpretation presented in this report may not be sufficient to assess all the factors that may have an effect upon the construction.

The report was prepared with the condition that the design would be in accordance with all applicable standards and codes, regulations or authorities having jurisdiction, and good engineering practice. Further, the recommendations and opinions in this report are applicable only to the proposed projects as described above.

On-going liaison with AMEC during final design and construction phase of the project is recommended to confirm that the recommendations in this report are applicable and/or correctly interpreted and implemented. Also, any queries concerning the geotechnical aspects of the proposed project should be directed to AMEC for further elaboration and/or clarification.

## 2.0 SITE DESCRIPTION

The project site is located at Highway 8 (King Street Bypass), approximate Station 11+865 to 11+875, in the City of Kitchener, as shown in Drawing No. 1. The new sanitary sewer is to be constructed parallel and adjacent to an existing 250 mm sanitary sewer. The new sewer is approximately 4.2 m south of existing sewer, as per the drawing provided by the City. The proposed sewer is to extend from east of Highway 8 (at the end of Kingsbury Drive) to west of Highway 8 (near Kingsway Drive) (refer to Drawing No. 2 and Appendix C). The new sanitary sewer is to be connected to the existing manholes on both ends as indicated in Appendix C.

The areas on both sides of the highway are used for commercial purposes. Highway 8 at the project location is a divided paved freeway, with 3 lanes in each direction (northbound and southbound). The proposed sewer is to be located just south of the exit ramp from northbound lanes to Fairway Road/Weber Street.

## 3.0 INVESTIGATION PROCEDURES

Field investigations were conducted on 23 and 28 December 2009 and consisted of drilling and sampling of three (3) boreholes (BH 1 to BH 3). Dynamic Cone Penetration Test (DCPT) was also carried out in each borehole. The boreholes were advanced to depths ranging from about 5.2 m to 10.8 m below existing ground surface, with DCPT extended, after borehole drilling, to depths ranging from about 10.8 m to 13.3 m. The borehole locations were staked out on site by AMEC's field personnel, under the direction of City of Kitchener representatives, approximately along the alignment of the proposed sanitary sewer, with regard to accessibility, minimum disturbance to traffic and existing utility lines. The borehole locations are shown in Drawing No. 2.

Boreholes BH 1 and BH 3, which were located to the east and west of Highway 8 respectively, were drilled using a track-mounted drill rig with solid-stem continuous-flight augers. A truck-mounted drill rig was utilized for BH 2, which was located on the highway. The drilling work was carried out by Determinations Drilling & Soil Investigation (321 Guyatt Road East, Hamilton, Ontario L0R 1C0). Traffic protection during the drilling on the highway was provided by On Track Safety Ltd. (190A Doughton Road, Concord, Ontario L4K 1R4) and was carried out as per the requirements of the Ontario Traffic Manual – Temporary Conditions (Book 7). The drilling work was conducted under the full-time supervision of an experienced AMEC geotechnical supervisor, Mr. Javad Farhoodi, B.Eng.

Soil samples were generally taken at 0.76 m and 1.5 m intervals while performing the Standard Penetration Test (SPT) in accordance with ASTM D1586. Continuous samples, including SPT, were taken from about 1 m above the proposed tunnel crown to about 1 m below proposed tunnel invert. The SPT 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 provided an indication of the consistency of cohesive soils or the compactness of non-cohesive soils.

DCPT was carried out in all boreholes below the augered depth by advancing a steel cone into the ground with a 63.5 kg (140 lbs.) hammer and a drop height of 0.76 m. The number of blows per 0.3 m required to advance the cone was recorded and are presented in the Record of Boreholes (Appendix A).

The ground surface elevations at the borehole locations were surveyed by AMEC with reference to a temporary benchmark provided by the City of Kitchener. The temporary benchmark (Elevation 326.441 m) consisted of a survey nail set on the east sidewalk of Kingsway Drive, across the street from Borehole BH 3.

Groundwater was measured during and upon completion of the boreholes, where encountered. Upon completion of drilling, the boreholes were backfilled in accordance with the general requirements of Ministry of the Environment Regulation 903. The borehole areas were cleaned upon completion of the drill work.

The soil samples were transported to AMEC's Advanced Soil Laboratory in Scarborough (Toronto) for further examination and laboratory soil testing. The program of laboratory testing included grain size analyses and natural water content determination.

The results of the in-situ and laboratory tests are presented on the corresponding Record of Boreholes (Appendix A) and Laboratory Test Results (Appendix B).

## 4.0 SUB-SURFACE CONDITIONS

The soil profile generally consisted of surficial material, consisting of asphaltic concrete, concrete and topsoil, underlain by fill material (sandy silt/sand/silt/sand and gravel) which in turn was underlain by native silt deposit. The native silt deposit extended to the termination depth of all three boreholes.

### 4.1 Asphaltic Concrete and Concrete

An approximately 100 mm thick surficial asphaltic concrete pavement was encountered in Borehole BH 1. Surficial asphaltic concrete underlain by concrete pavement was noted in Borehole BH 2. The combined thickness of the concrete/asphalt pavement in BH 2 was about 300 mm.

### 4.2 Fill Soils

#### 4.2.1 Topsoil

Topsoil was encountered in Borehole BH 3 at the ground surface. The topsoil extended to about 0.3 m below ground surface (to Elevation 325.3 m).

#### 4.2.2 Sand and Gravel Fill

Sand and gravel fill was noted underlying the asphaltic concrete/concrete pavement in Boreholes BH 1 and BH 2. Some cobbles were noted in BH 2. The sand and gravel fill extended to depths of approximately 0.6 m (Elevation 326.7 m) and 1.4 m (Elevation 326.6 m) below the ground surface (paved surface) in BH 1 and BH 2 respectively. The SPT ‘N’ values in this fill were 9 blows per 0.3 m (loose)in BH 1 and 45 and 81 blows per 0.3 m (dense to very dense) in BH 2.

The natural moisture content of the fill was about 3%.

#### 4.2.3 Sand Fill

Sand fill was encountered underlying the sand and gravel fill in Borehole BH 2 to a depth of approximately 2.4 m below ground surface (Elevation 325.6 m). The sand fill included some gravel, with some cobbles/boulders. The SPT ‘N’ value in this fill was 34 blows per 0.3 m (dense) to 4 blows per 0.3 m (loose).

The natural moisture content of the fill was about 4%.

#### 4.2.4 Sandy Silt Fill

Sandy silt fill, with trace to some clay and trace gravel, was encountered in all three boreholes underlying the sand and gravel fill in BH 1, the sand fill in BH 2 and the topsoil in BH 3. Organic matters and some rootlets were also noted in this fill. The sandy silt fill extended to depths ranging from approximately 1.1 m (Elevation 326.2 m) in BH 1 to 5.3 m (Elevation 322.7 m) in BH 2. The SPT ‘N’ values ranged from 4 to 11 blows per 0.3 m, indicating loose to compact compactness.

Natural moisture content (%): 8 to 24

| Grain size distribution: (2 samples) | | BH 2/BH 3 |
|---|---|---|
| | Gravel (%): | 5 / 0 |
| | Sand (%): | 36 / 38 |
| | Silt (%): | 49 / 48 |
| | Clay (%): | 10 / 14 |

The grain size distribution curves (Figure No. B1) are presented in Appendix B.

### 4.2.5 Silt Fill

Silt fill, with sand, some clay and trace gravel, was noted underlying the sandy silt fill in Borehole BH 3 to a depth of about 2.7 m below the ground surface (Elevations 322.8 m). The SPT 'N' value in the silt fill was 6 blows per 0.3 m, indicating a loose compactness.

Natural moisture content (%): 14

| | | |
|---|---|---|
| Grain size distribution (1 sample): | Gravel (%): | 6 |
| | Sand (%): | 27 |
| | Silt (%): | 55 |
| | Clay (%): | 12 |

The grain size distribution curve (Figure No. B1) is presented in Appendix B.

## 4.3 Silt

Native silt deposit was encountered in all three boreholes underlying the fill soils and extended to the borehole termination depths about 5.2 m (Elevation 320.4 m) to 10.4 m (Elevation 317.6 m) below ground surface. The silt deposit included trace clay and gravel and trace to with sand. The SPT 'N' values of the silt generally ranged from 5 to 32 blows per 0.3 m, indicating loose to dense compactness.

Natural moisture content (%): 8 to 23

| | | |
|---|---|---|
| Grain size distribution (3 samples): | Gravel (%): | 0 |
| | Sand (%): | 9 to 23 |
| | Silt (%): | 73 to 86 |
| | Clay (%): | 4 to 5 |

The grain size distribution curves (Figure No. B2) are presented in Appendix B.

DCPT was carried out in all boreholes below the drilled depths. The depth of DCPT ranged from about 10.8 m in BH 1 to 13.3 m in BH 2. The DCPT results indicated that the compactness of the soil generally increased with depth. Cone penetration refusal was noted in BH 1 and BH 2 at about

10.8 m (Elevation 316.5m) and 13.3 m (Elevation 314.7m) respectively. The DCPT results are shown in the Record of Boreholes.

### 4.4 Groundwater

Free groundwater was encountered boreholes at depths ranging from approximately 4.4 m to 7.2 m below ground surface (Elevations 321.6 to 320.8 m).

It should be noted that the groundwater at the site would fluctuate seasonally and can be expected to be somewhat higher during the spring thaw and in response to major weather events.

## 5.0 DISCUSSIONS AND RECOMMENDATIONS

The project involves installation of an approximately 80 m long, 350 mm diameter sanitary sewer by trenchless method (tunneling) under Highway 8 (King Street Bypass) in Kitchener, Ontario. The size of the sewer installation is expected to be 750 mm diameter with steel casing. The new sewer is to be installed parallel and adjacent to an existing 250 mm diameter gravity sanitary sewer. As per the drawing provided by the City, the new manholes (MH 1A and MH 2A) at the two ends of the new sewer are to be connected to the existing manholes (MH 6A and MH 8A) by the open cut method. A drawing with the plan and cross-section of the project site, including existing and proposed sanitary sewer, was provided to AMEC by the City (Appendix C).

Based on the drawing provided, the depth of the tunnel invert would be about 3.4 m, 4.6 m and 2.8 m (Elevations 323.9 m, 323.4 m and 322.8 m) below existing ground surface at borehole locations of BH 1, BH 2 and BH 3 respectively. Based on the borehole information, the subsurface condition at the tunnel (new sanitary sewer) alignment would consist of sandy silt/silt fill and native silt deposit.

As per the log for Borehole No. 103, which was drilled in 2003 by Golder Associates south of the location of BH 2 on Highway 8, the fill soils (sand and gravel; sand; and sandy silt) extended to about 3.7 m (Elevation 324.5) below the road surface and were underlain by native silt and sand. This is in general agreement with the soils encountered in BH 2 drilled during this investigation. A copy of the borehole log for Borehole No. 103 is attached in Appendix E.

Details for tunneling, excavation, dewatering and settlement monitoring during construction are discussed in the following sections.

### 5.1 Soil/Groundwater Conditions at Tunnel Location

The subsurface soil and groundwater conditions encountered in the boreholes are discussed in detail in Section 4. A stratigraphic longitudinal cross-section at the tunnel location, based on the drawing provided by the City and showing the soil conditions, is shown in Drawing No. 2. In general, the tunnel will likely pass through the native silt deposit in the east portion of the tunnel (near Borehole BH 1) and through the various fill soils (sandy silt fill and silt fill) as it progress westward (refer to Drawing No. 2). As per observation made during the field investigation, groundwater will likely not be encountered during the tunneling. However, it should be cautioned that the soil/groundwater conditions between and beyond the borehole locations may be different and that cobbles and or boulder may be encountered, especially in the fill soils. The groundwater level may also vary seasonally and perched groundwater may be present.

## 5.2 Tunneling Methods

Tunneling depends upon a number of factors, of which the important ones are the groundwater conditions and the soil types through which the tunnel must pass. The following geotechnical factors should be considered for the selection of tunneling method:

1. The proposed tunneling method should cause minimal disturbance to the existing highway and its usage.
2. The proposed tunneling method would not cause instability of the existing highway embankments.
3. Although groundwater will likely not be encountered, the proposed tunneling method should consider suitable means of groundwater dewatering during the tunneling work, if it is encountered.

A general description of some of the tunneling methods and their applicability to the site conditions are presented below. Other tunneling methods may also be considered, if required.

### 5.2.1 Jacking and Boring

This technique forms a horizontal borehole from a drive shaft to a reception shaft by means of a rotating cutting head. Spoil 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 augering operation. After the installation of the steel casing, the sanitary sewer pipe is installed inside the casing and the gap between the casing and the pipe is grouted. Steel casing is typically used due to high strength, good flexibility and good workability. Other casing material (e.g. concrete) may be used, depending on the design against surrounding pressure, workability, cost etc. It should be noted that this method of tunneling does not allow significant change in direction between the drive shaft and the reception shaft.

The compact silt deposit and the loose to compact sandy silt/silt fills expected to be encountered during tunneling may not be stable at the tunnel face, particularly if groundwater seepage occurs. However, as per the borehole information, groundwater is not expected to be encountered. Since the size of the tunnel (750 mm diameter) and the length of the tunnel (80 m) are relatively small, the jacking and boring method of tunneling is feasible. Provisions for handling groundwater seepage during tunneling should be discussed and a contingency plan should be in place prior to start of tunneling. Groundwater seepage, if any, during tunneling may be handled by gravity drainage and pumping from open sumps. The tunnel alignment should be provided with a gentle gradient so that water seepage into the opening can be directed away from the tunnel face. If there is a possibility of loss of soils due to high groundwater seepage into the tunnel, proper measure(s) should be implemented (e.g., installing a shield at the tunnel face, grouting the soils around the tunnel prior to excavation, etc). **As a minimum and as a preventative measure against development of potential flowing or running condition and to maintain stability of the tunnel face, a plug of soil should be left inside the front end of the tunnel casing at all times. The size of the plug depends on the soil and groundwater conditions encountered at the time of the tunneling.** If unexpected high groundwater flow is encountered and/or loss of soil through the tunnel is excessive, the tunneling operation should be stopped immediately and remedial measures should be taken to stabilize the tunnel face. Potential gap between the tunnel casing and the soil, after the completion of tunneling, should be grouted to reduce settlements.

**Cobbles and boulders should be expected, particularly within the fill soils. The Construction Contract should include a Non Standard Special Provision (NSSP) to warn the Contractor of the possible presence of cobbles/boulders.**

For general design purposes, following parameters may be used:

- The friction between the steel casing and the sandy/silty soils should be calculated by using a friction angle of $33^o$.
- The bulk unit weight of the overburden above the tunnel crown should be considered as 20 $kN/m^3$.
- For the soils surrounding the tunnel, the estimated Soil Modulus of Elasticity, E, should be in the order of 15 MPa.
- Estimated coefficient of lateral earth pressure at rest, $K_o$, should be taken as 0.45

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).

### 5.2.2 Horizontal Directional Drilling

An alternative method that may be utilized is the horizontal direction drilling. 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 ground surface and proceeds downwards at an angle (typically from 8 to 18 degrees) from the horizontal until the target depth is achieved. At the target depth, the path of the bore is approximately leveled, and the bore is steered to the designated exit point where it is brought to the surface at an angle (typically similar to the entry side). Drilling fluid, typically a mix of bentonite or polymer and water, is pumped, during drilling, under pressure 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.

Horizontal directional drilling should be carried out by a contractor who should be able to select the drilling equipment that is capable of pulling a 750 mm steel pipe through the sandy silt/silt fill and silt deposit using appropriate drilling fluid composition. It should be noted that the suitability of type of materials (synthetic or steel) of the pipe for pulling should also be evaluated.

If the fluid pressure of the bentonite/drilling fluid slurry is sufficiently high and the surrounding soil is quite pervious, it is possible that this fluid may flow into the surrounding soil and, subsequently, to the ground surface (i.e., frac-out). The environmental aspects with respect to the possible frac-out should be considered in planning and implementing the horizontal directional drilling technique.

During drilling, the site should be monitored by geotechnical and environmental personnel in order to observe any frac-out and / or impact from the drilling to the surrounding environment. A mitigation plan for potential frac-out should be developed prior to drilling. The specialist contractor should develop such a plan for approval.

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).

### 5.2.3 Comparison of Tunneling Methods

The following Table 5.1 provides a comparison of the tunneling methods.

**Table 5.1 – Comparison of various Tunneling Methods**

| Tunneling Method | Advantages | Disadvantages |
|---|---|---|
| Jacking and boring | - Good for short length of tunnel (<100 m)<br>- Good control of gradient<br>- Boulder, if encountered, may be removed by hand digging | - Does not allow significant change of direction<br>- Not preferred if installation is under groundwater table.<br>- Requires tunnel shafts |
| Horizontal Directional Drilling | - Good control over change in direction<br>- Suitable even under groundwater level<br>- Does not require tunnel shaft | - Risk of frac-out<br>- Problem, if boulders are encountered in the alignment<br>- Requires drilling fluid<br>- Requires larger working platform from the sewer location |

Based on the requirements of the project and the soil condition, any of the tunneling methods may be used. The relative cost for the two alternatives may not be significantly different. It is recommended that practical aspects for the best suited/economical method of installation be discussed with experienced tunnel contractors. As per the information provided by the City, the preferred method is jacking and boring, which is feasible for this site.

### 5.3 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 loose to compact sandy silt/silt fill and/or compact to dense silt with possible cobbles/boulders. As per the construction plan, the sewer pipe between the existing manholes and proposed manholes at both sides of the tunnel are to be installed by open cut excavation. The groundwater levels at these excavation locations 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 follows:

| | |
|---|---|
| Loose to compact sandy silt/silt fill | - Type 3 |
| Compact to dense silt deposit | - Type 3 |

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).

#### 5.3.1 Temporary Shoring

If the space available for excavation is limited, vertical excavation may be required. This can be accomplished by a sheeting and bracing system or by using a trench box in order to support the sides of the excavation. The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressures which could occur during construction. Bracings should also be installed within the shoring system to minimize movements of the soils. The temporary shoring system should be designed and provided in accordance with the Ontario Health and Safety Regulations.

For temporary shoring design, the following soil parameters may be adopted:

| | | |
|---|---|---|
| Coefficient of Lateral Earth Pressure | = | 0.45 |
| Bulk Unit Weight of Retained Soils | = | 20 kN/$m^3$ |

The temporary shoring analysis and design should be carried out in accordance with the Canadian Foundation Engineering Manual, 4th Edition.

Excavated material from the tunnel and from the shaft should be stockpiled at least 5 m from the edge of the shaft excavation. The excavated material could be temporarily stockpiled not higher than 3 m, with side slopes not steeper than 2H:1V.

The temporary shoring of excavation should conform to Ontario Provincial Standard Specification (OPSS) – "*Construction Specification for Temporary Protection Systems*" (OPSS 539).

### 5.3.2 Bedding

For open cut, the boreholes (BH 1 and BH 3) show that in their undisturbed state, the compact silt deposit would provide adequate support for the sewers and manholes. The embedment and excavation for the sewer pipeline in Type 3 soil 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 rigid pipe is used, OPSD 802.031 should be followed. Some fill material may be encountered in the vicinity of BH 3. If any fill material or soft 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 should be placed between the granular material and the silt subgrade in order to prevent migration of sandy/silty soil. The geotextile should be selected accordingly.

### 5.3.3 Backfill

Based on the visual and tactile examination of the soil samples, the on-site excavated sandy silt/silt/sand fill and silt deposit may be re-used as backfill in sewer trenches provided their moisture contents at the time of construction are at or near the optimum.

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.

## 5.4 Settlement

Settlement caused by tunneling is the aggregate of two basic types of settlement, which consist of ground loss or 'immediate' settlement, and consolidation settlement.

The 'immediate' settlement is the direct result of the movement of ground into the tunnel heading. The factors which influence the magnitude of immediate settlement due to tunneling include soil strength and stiffness, the method of tunneling and the quality of tunnel operations. Even when tunneling is carried out apparently through homogeneous soils with the same equipment and crew, ground settlements typically vary by a factor of 2 or 3. This variation can be ascribed to items such as use of overcutters and localized variations in soil type, strength or stiffness etc.

Based the size of the proposed tunnel and its depth from the ground surface, the method of construction and the soil type, the settlement at the surface, over the tunnel axis, is likely to be less than 5 mm. Such settlement is likely to be experienced up to a horizontal distance of about 2.6 m on either side of the tunnel axis.

Good workmanship and site control is the most effective way to reduce immediate settlements to practical minimum. Factors to consider in the specification and review of tenders include grouting behind the temporary support system as quickly as possible and minimizing the use of overcutters.

Consolidation settlement is the settlement caused by pore-pressure changes in compressible deposits as related to dissipation of excess pore pressures induced by tunneling and also from long term seepage effects into the tunnel. Consolidation settlement is not expected to be significant at this site.

Excavation from the tunnel and from the shaft should be stockpiled at least 3 m from the edge of the shaft excavation. The excavated material could be temporarily stockpiled not higher than 3 m, with side slopes not steeper than 2H to 1V.

### 5.5 Instrumentation and Settlement Monitoring during Tunneling

During tunneling, the ground over and in the vicinity of the tunnel alignment may experience settlement. Good workmanship and site control is the most effective way to reduce settlements to practical minimum. It is recommended that ground movement during tunneling be monitored together with the monitoring of 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 steel pipe casing/pipe is properly installed. If any adverse effect of tunneling is identified by the monitoring program, the tunneling process can be modified accordingly.

Additionally, MTO's *Guidelines for Foundation Engineering – Tunneling Specialty, for Corridor Encroachment Permit Application* requires settlement monitoring during tunneling to prevent damage to existing utilities and highway structures along the tunnel alignment. The appendix – "*Settlement Monitoring Guidelines – Tunneling*" - to the Guideline (refer to Appendix D) details MTO's requirements for the tunneling, including instrumentation, monitoring requirements and monitoring frequency. As the tunnel is being constructed within MTO's right-of-way (ROW), the Guideline should be strictly followed.

The instrumentation plan should be designed, as per the Guideline, when the Contractor's proposed construction method is available and prior to beginning the installation of the tunnel. The proposed method should be reviewed by the foundation/tunnel engineer. As per the Guideline, a qualified geotechnical consultant should supervise the installation of surface settlement points on site and provide directions, technical input and field inspection on this project.

## 5.6 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 may be classified as Site Class "E-Soft Soil", based on the soil encountered in the boreholes at the project location.

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.

## 6.0 CLOSURE

The sub-soil information and recommendations contained in this report should be used solely for the purpose of geotechnical assessment of the subsurface conditions at the proposed tunnel site. Subject to the selected method for tunneling and other requirements, additional geotechnical investigation may be required.

It is recommended that AMEC be retained to review the recommendations for this specific applicability, once the details of the development are finalized and prior to the final design/construction stage of the project.

The attached Report Limitations is an integral part of this report.

Yours truly,

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

LICENSED PROFESSIONAL ENGINEER
S. MALLA
PROVINCE OF ONTARIO

Shami Malla, P.Eng.
Geotechnical Engineer

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Senior Vice President
Designated Principal Contact for MTO

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G. S. W. CHOW
PROVINCE OF ONTARIO

**AMEC Earth & Environmental**
**a Division of AMEC Americas Limited**

## 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, a Division of AMEC Americas Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

**DRAWINGS**

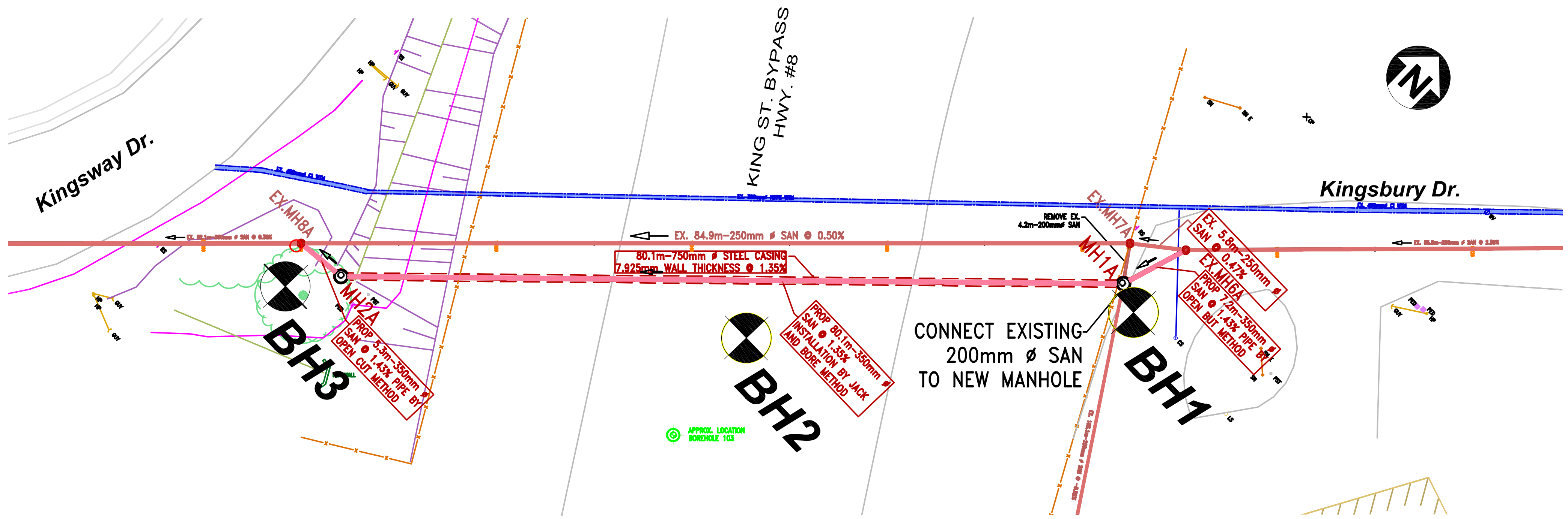

# KEY PLAN

250 0 250 500 750 1000m

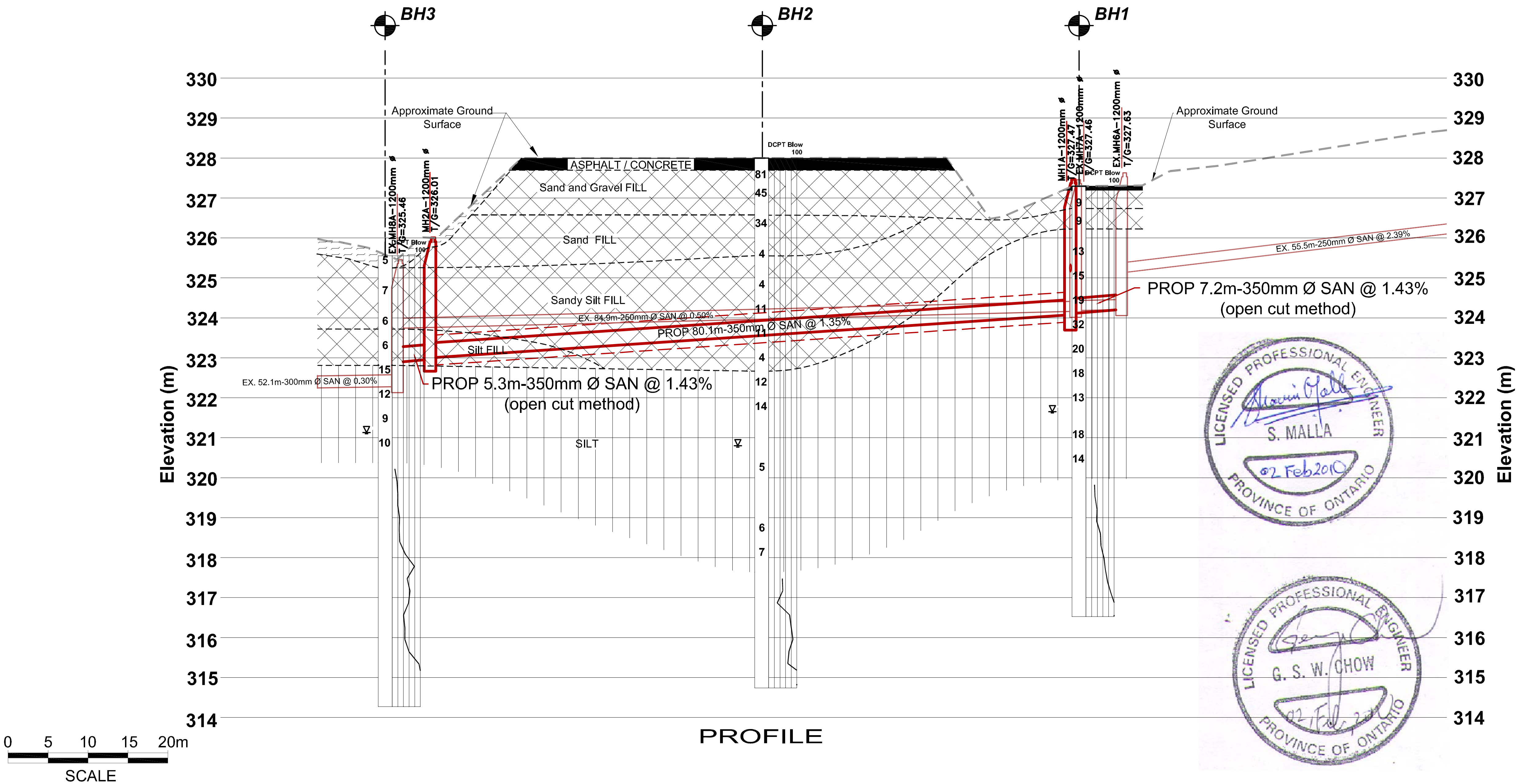
Approximate Scale

| | | | |
|---|---|---|---|
| AMEC Earth & Environmental, a Division of AMEC Americas Limited | amec | CLIENT LOGO KITCHENER | CLIENT The Corporation Of The CITY OF KITCHENER |

| | | | |
|---|---|---|---|
| TITLE SITE MAP | DWN BY: KW | DATUM: - | DATE: JANUARY 2010 |
| PROJECT FOUNDATION INVESTIGATION AND DESIGN REPORT TUNNELING FOR PROPOSED SANITARY SEWER UNDER HIGHWAY 8 (KING ST. BYPASS) APPROXIMATE STATION 11+865 to 11+875 Kitchener, Ontario | CHK'D BY: SM | REV. NO.: A | PROJECT NO: TT93061 |
| | PROJECTION: - | SCALE: AS SHOWN | DRAWING No. 1 |




PLAN




PROFILE

**METRIC**

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

| | |
|---|---|
| AGREEMENT No. | |
| G.W.P. No. | |
| FOUNDATION INVESTIGATION AND DESIGN REPORT TUNNELING FOR PROPOSED SANITARY SEWER UNDER HIGHWAY 8 (KING ST. BYPASS) APPROXIMATE STATION 11+865 to 11+875 | SHEET |

amec

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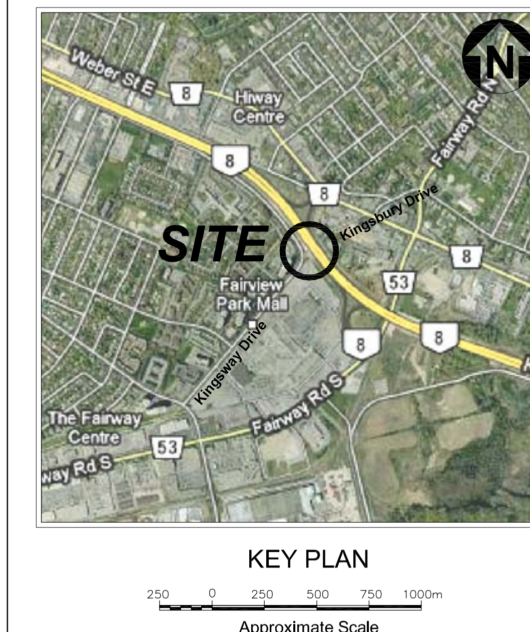


KEY PLAN

## LEGEND

- BOREHOLE LOCATION
- GROUNDWATER LEVEL IN BOREHOLE AT TIME OF INVESTIGATION

**NOTES:**

The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are assumed from geological evidence and may be subject to considerable error.

SOIL STRATIGRAPHY

- ASPHALTIC CONCRETE / CONCRETE
- TOPSOIL
- FILL
- SILT

REVISIONS

| | | | | |
|---|---|---|---|---|
| DESIGN | CHK PB | CODE | CL | DATE JAN. 2010 |
| DRAWN KW | CHK GC | SITE | | DWG 2 |

P:\GEO\Projects\2009\TT93061 - City of Kitchener - King St. Bypass (HWY 8)\Drawings - AMEC\TT93061 - Jan27_CityofKitchener_PlanAndProf_Fig2.DWG

# APPENDIX A

# RECORD OF BOREHOLES

# 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 stratums, 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 Cohesionless Soils | SPT N-Value* |
|---|---|
| Very loose | 0 to 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | > 50 |

| Consistency of Cohesive Soils | Undrained Shear Strength kPa | psf |
|---|---|---|
| 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.

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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 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 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 SLITS & 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 |

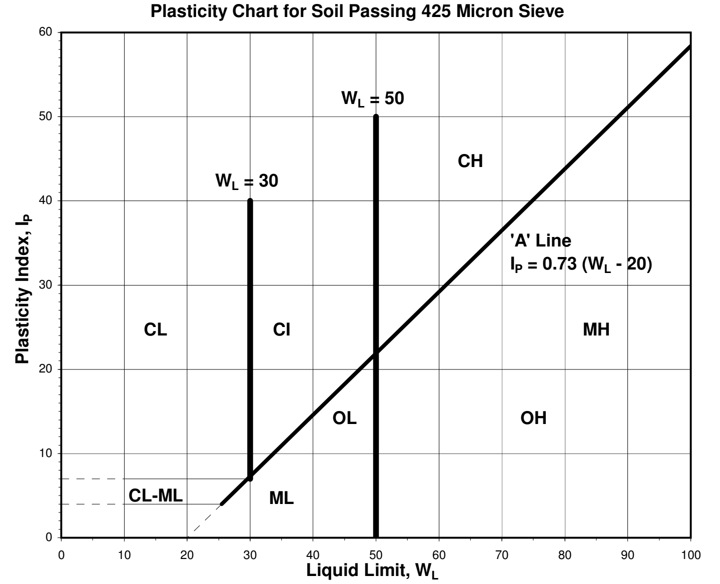
SOIL COMPONENTS

| FRACTION | | U.S STANDARD SIEVE SIZE | | DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS | |
|---|---|---|---|---|---|
| | | PASSING | RETAINED | PERCENT | DESCRIPTOR |
| GRAVEL | COARSE | 76 mm | 19 mm | 35-50 | AND |
| | | | | 20-35 | Y/EY |
| | FINE | 19 mm | 4.75 mm | 10-20 | SOME |
| | | | | 1-10 | TRACE |
| SAND | COARSE | 4.75 mm | 2.00 mm | | |
| | 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**





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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.)

# RECORD OF BOREHOLE No BH 1



G.W.P. - LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875 ORIGINATED BY JF

DIST Kitchener HWY 8 BOREHOLE TYPE Solid Stem Augering COMPILED BY SN

DATUM Geodetic DATE 28 December 2009 - 28 December 2009 CHECKED BY PB

PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8 JOB NO. TT93061

| ELEV / DEPTH (m) | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 327.3 | | | | | | | |
| 327.2 / 0.0 | **about 100 mm ASPHALT** | | | | | | |
| 0.1 | brown **Sand and Gravel FILL** moist | | | | | | |
| 326.7 / 0.6 | brown **Sandy Silt FILL** trace clay, trace gravel, trace clayey silt loose moist | 1 | SS | 9 | | 3 | |
| 326.2 / 1.1 | brown **SILT** trace to with sand, trace clay and gravel loose to dense moist | 2 | SS | 9 | | 13 | |
| | | 3 | SS | 13 | | 11 | |
| | | 4 | SS | 15 | | 8 | 23 73 4 |
| | | 5 | SS | 19 | | 16 | |
| | | 6 | SS | 32 | | 14 | |
| | | 7 | SS | 20 | | 19 | |
| | --------- wet | 8 | SS | 18 | | 19 | 9 86 5 |
| | | 9 | SS | 13 | ∇ | 23 | |
| | | 10 | SS | 18 | | 20 | |

Column headings: SOIL PROFILE; SAMPLES; DEPTH (m); ELEVATION SCALE (m); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$, WATER CONTENT (%) 10 20 30; SOIL VAPOUR READING PPM.

Continued Next Page

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

# RECORD OF BOREHOLE No BH 1



| | | | |
|---|---|---|---|
| G.W.P. - | LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875 | ORIGINATED BY | JF |
| DIST Kitchener HWY 8 | BOREHOLE TYPE Solid Stem Augering | COMPILED BY | SN |
| DATUM Geodetic | DATE 28 December 2009 - 28 December 2009 | CHECKED BY | PB |
| PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8 | | JOB NO. | TT93061 |

| ELEV DEPTH (m) | DESCRIPTION (SOIL PROFILE) | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | DEPTH m | ELEVATION SCALE m | DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa | WATER CONTENT (%) | SOIL VAPOUR READING PPM | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | brown **SILT** trace to with sand, trace clay and gravel compact moist | | 11 | SS | 14 | | | 320 | | 20 | | |
| 320.0<br>7.3 | **End of Borehole**<br>Cave-in depth recorded on completion of borehole: 6.1 m<br><br>Dynamic Cone Penetration Test (DCPT) carried out from 7.3 m depth. | | | | | | 8<br>9<br>10 | 319<br>318<br>317 | | | | |
| 316.5<br>10.8 | **End of DCPT**<br><br>Cone refusal on possible boulder / bedrock at about 11 m depth. | | | | | | | | | | | DCPT = 100 blows/100 mm<br>Cone bouncing |

Legend: SHEAR STRENGTH kPa — O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Scale: 20 40 60 80 100. PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$. WATER CONTENT (%) 10 20 30.

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

Ontario

# RECORD OF BOREHOLE No BH 2



amec

G.W.P. -

LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875

ORIGINATED BY JF

DIST Kitchener HWY 8

BOREHOLE TYPE Solid Stem Augering

COMPILED BY SN

DATUM Geodetic

DATE 23 December 2009 - 23 December 2009

CHECKED BY PB

PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8

JOB NO. TT93061

## SOIL PROFILE

| ELEV (m) | DEPTH (m) | DESCRIPTION |
|---|---|---|
| 328.0 | 0.0 | **about 300 mm ASPHALT and CONCRETE** |
| 327.7 | 0.3 | brown **Sand and Gravel FILL** some cobbles very dense to dense moist |
| 326.6 | 1.4 | brown **Sand FILL** some gravel and cobbles/boulders dense to loose moist |
| 325.6 | 2.4 | brown to dark brown **Sandy Silt FILL** trace clay and gravel, rootlets, trace organics in SS4 loose to compact moist to wet; some rootlets; some cobbles/boulders, organic stains |
| 322.7 | 5.3 | brown **SILT** trace to with sand, trace clay and gravel loose to compact wet |

## SAMPLES

| NUMBER | TYPE | "N" VALUES | WATER CONTENT (%) | GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|
| 1 | SS | 81 | 3 | |
| 2 | SS | 45 | 3 | |
| 3 | SS | 34 | 4 | |
| 4 | SS | 4 | 10 | |
| 5 | SS | 4 | 17 | |
| 6 | SS | 11 | 13 | 5 36 49 10 |
| 7 | SS | 11 | 14 | |
| 8 | SS | 4 | 8 | |
| 9 | SS | 12 | 12 | |
| 10 | SS | 14 | 21 | |

DEPTH scale (m): 1, 2, 3, 4, 5, 6 — ELEVATION SCALE (m): 327, 326, 325, 324, 323, 322

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT $W_P$ — NATURAL MOISTURE CONTENT W — LIQUID LIMIT $W_L$; WATER CONTENT (%) 10 20 30

SOIL VAPOUR READING PPM — REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

Ontario

amec

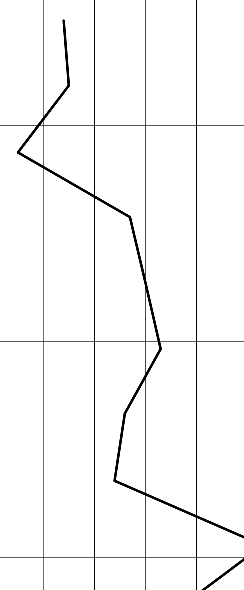
# RECORD OF BOREHOLE No BH 2



| | | | |
|---|---|---|---|
| G.W.P. - | LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875 | | ORIGINATED BY JF |
| DIST Kitchener HWY 8 | BOREHOLE TYPE Solid Stem Augering | | COMPILED BY SN |
| DATUM Geodetic | DATE 23 December 2009 - 23 December 2009 | | CHECKED BY PB |
| PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8 | | | JOB NO. TT93061 |

| ELEV DEPTH (m) | SOIL PROFILE – DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | DEPTH (m) | ELEVATION SCALE (m) | WATER CONTENT (%) | SOIL VAPOUR READING (PPM) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | brown **SILT** trace to with sand, trace clay and gravel loose wet | | | | | ▽ | | | | | |
| | | | 11 | SS | 5 | | 8 | 320 | 20 | | |
| | | | | | | | 9 | 319 | | | |
| | | | 12 | SS | 6 | | | | 18 | | 15 81 4 |
| | | | 13 | SS | 7 | | 10 | 318 | 17 | | |
| 317.6<br>10.4 | **End of Borehole**<br>Cave-in depth recorded on completion of borehole: 7.2 m<br>Top of cave-in soil was wet.<br><br>Dynamic Cone Penetration Test (DCPT) carried out from 10.4 m depth. | | | | | | 11<br>12<br>13 | 317<br>316<br>315 | | | DCPT = 100 blows/130 mm |
| 314.7<br>13.3 | **End of DCPT**<br><br>Cone refusal on possible boulder / bedrock at 13.3 m depth. | | | | | | | | | | Cone bouncing |

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100



SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT $W_P$ — NATURAL MOISTURE CONTENT W — LIQUID LIMIT $W_L$; WATER CONTENT (%) 10 20 30

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

# RECORD OF BOREHOLE No BH 3



G.W.P. - | LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875 | ORIGINATED BY JF

DIST Kitchener HWY 8 | BOREHOLE TYPE Solid Stem Augering | COMPILED BY SN

DATUM Geodetic | DATE 28 December 2009 - 28 December 2009 | CHECKED BY PB

PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8 | JOB NO. TT93061

## Soil Profile

| ELEV DEPTH (m) | DESCRIPTION |
|---|---|
| 325.6 / 0.0 | **about 300 mm TOPSOIL** |
| 325.3 / 0.3 | dark brown **Sandy Silt FILL** some clay, trace gravel, trace organics, loose, moist; trace rootlets |
| 323.7 / 1.8 | brown **Silt FILL** with sand, some clay, trace gravel, loose, moist; some cobbles/boulders |
| 322.8 / 2.7 | brown **SILT** trace to with sand, trace clay and gravel, compact to loose, wet |
| 320.4 / 5.2 | **End of Borehole** Cave-in depth recorded on completion of borehole: 4.7 m. Top of cave-in soil was wet. Dynamic Cone Penetration Test (DCPT) carried out from 5.2 m depth. |

## Samples

| NUMBER | TYPE | "N" VALUES | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|
| 1 | SS | 5 | 9 | | | | |
| 2 | SS | 7 | 24 | | 38 | 48 | 14 |
| 3 | SS | 6 | 15 | 6 | 27 | 55 | 12 |
| 4 | SS | 6 | 14 | | | | |
| 5 | SS | 15 | 14 | | | | |
| 6 | SS | 12 | 19 | | | | |
| 7 | SS | 9 | 22 | | | | |
| 8 | SS | 10 | 23 | | | | |

Ground water level symbol shown at approximately 4.3 m depth (sample 7).

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DEPTH m; ELEVATION SCALE m; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; WATER CONTENT (%) 10 20 30; SOIL VAPOUR READING PPM; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Elevation scale: 325, 324, 323, 322, 321, 320, 319. Depth scale: 1, 2, 3, 4, 5, 6.

Continued Next Page

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

# RECORD OF BOREHOLE No BH 3



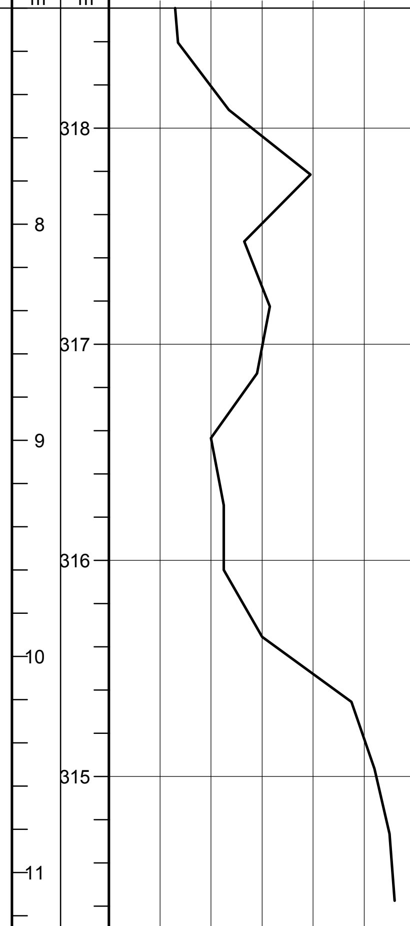
G.W.P. - | LOCATION HWY 8 Bypass, Kitchener, Ontario, Sta. 11+865 to 11+875 | ORIGINATED BY JF

DIST Kitchener HWY 8 | BOREHOLE TYPE Solid Stem Augering | COMPILED BY SN

DATUM Geodetic | DATE 28 December 2009 - 28 December 2009 | CHECKED BY PB

PROJECT Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8 | JOB NO. TT93061

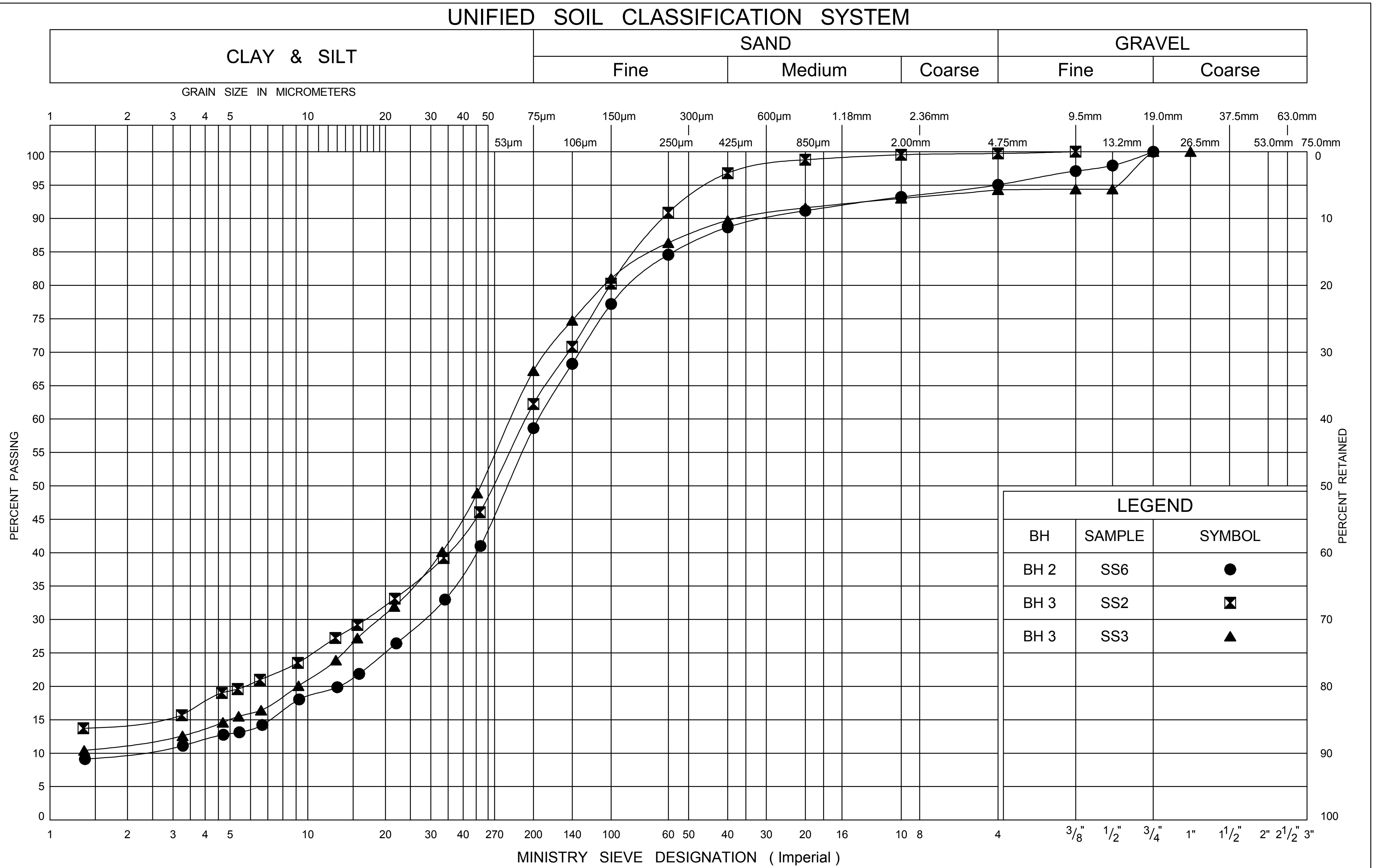
| SOIL PROFILE | | | SAMPLES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEV DEPTH (m) | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | DEPTH m | ELEVATION SCALE m | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 | PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $W_L$; WATER CONTENT (%) 10 20 30 | SOIL VAPOUR READING PPM | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| 314.3<br>11.3 | **End of DCPT** | | | | | | | | | | | |




$+^3, \times^3$: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

# APPENDIX B

# LABORATORY TEST RESULTS




AMEC MOT GRAIN SIZE TT93061-MOT.GPJ ONTARIO MOT.GDT 29/01/10

amec

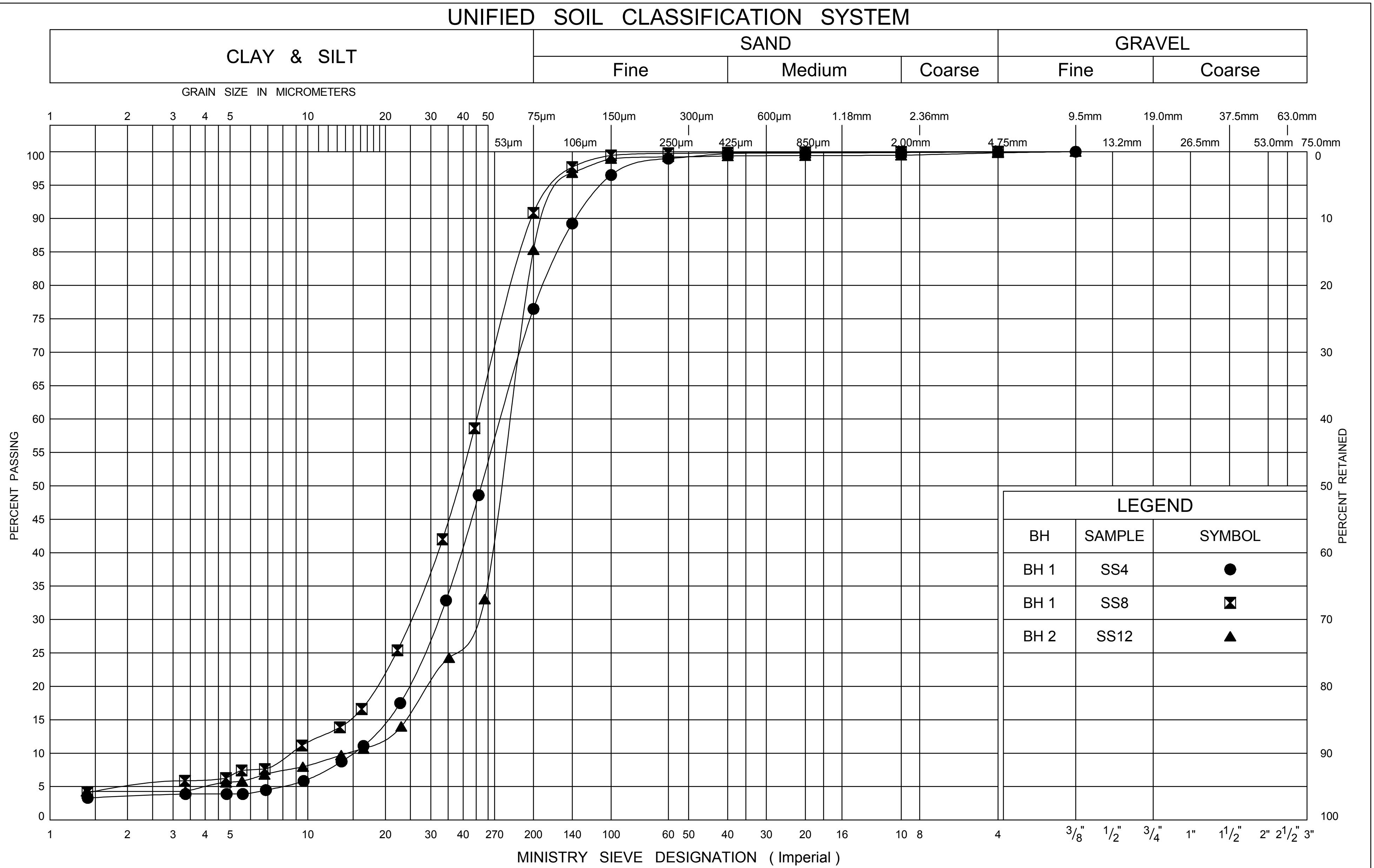
# GRAIN SIZE DISTRIBUTION

SANDY SILT / SILT
trace to some clay, trace gravel

Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8

Project No.: TT93061

Figure No. B1




LEGEND

| BH | SAMPLE | SYMBOL |
|---|---|---|
| BH 1 | SS4 | ● |
| BH 1 | SS8 | ⧗ |
| BH 2 | SS12 | ▲ |

amec

## GRAIN SIZE DISTRIBUTION

SILT

trace to with sand, trace clay

Foundation Investigation and Design Report- Tunneling for Proposed Sanitary Sewer under HWY 8

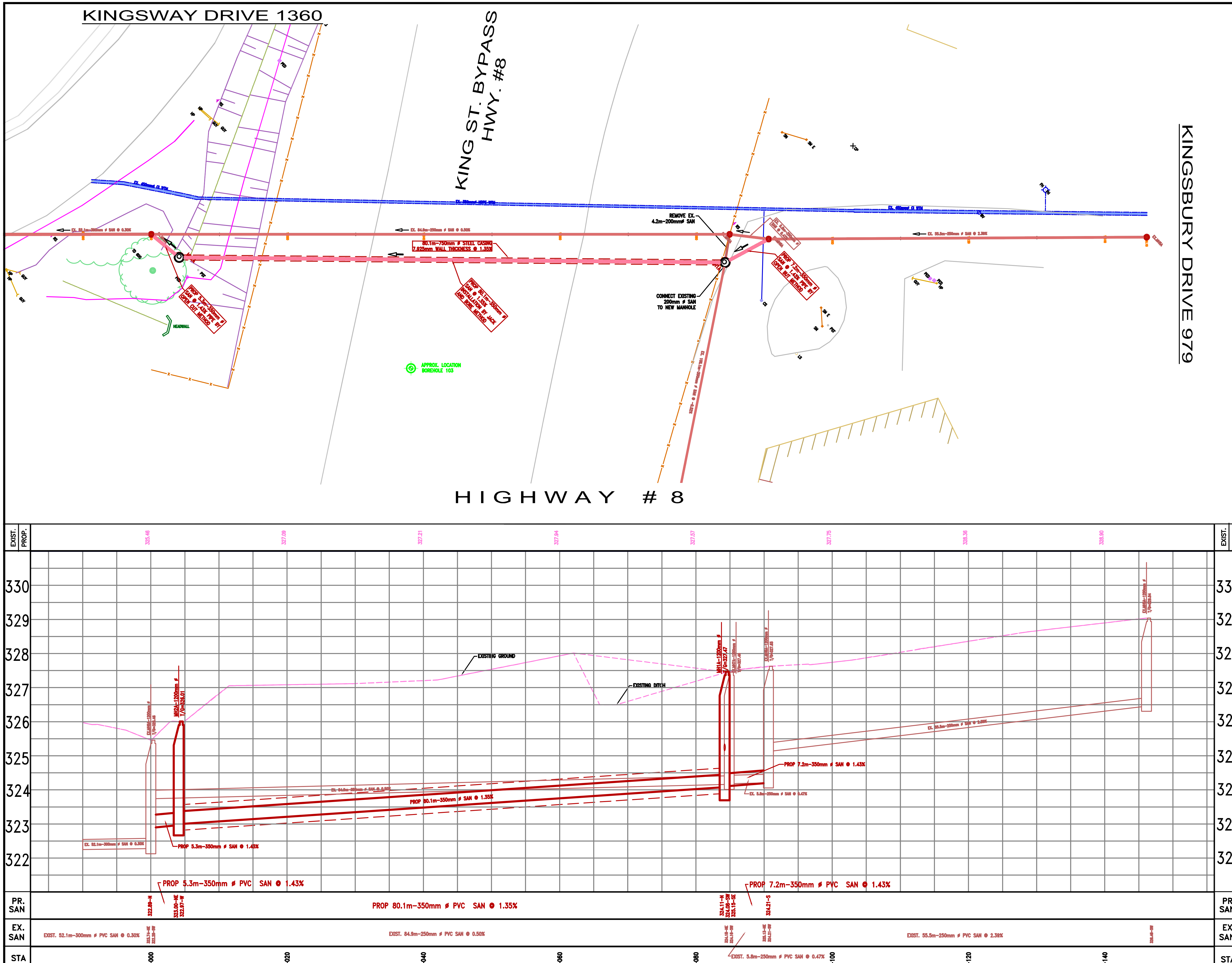
Project No.: TT93061

Figure No. B2

AMEC MOT GRAIN SIZE TT93061-MOT.GPJ ONTARIO MOT.GDT 29/01/10

# APPENDIX C

## COPY OF PLAN AND PROFILE PROVIDED BY THE CITY OF KITCHENER (DRAWING NO. G-271)




construction NORTH | true NORTH

THE POSITION OF THE POLE LINES, CONDUITS, WATERMAINS, SEWERS, AND OTHER UTILITIES AND STRUCTURES ARE N O T NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.

BEFORE STARTING WORK

THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

## NOTES:

SILT FENCING SHALL BE AS PER OPSD 219.130 AND INSTALLED PRIOR TO COMMENCEMENT OF ANY EXCAVATIONS AND LOCATED WHERE OFF-SITE FLOWS OCCUR.

OTHER UTILITIES

TEMPORARY SUPPORT OF EXISTING UTILITY POLES MUST BE APPROVED BY KITCHENER-WILMOT HYDRO. ALL ASSOCIATED COSTS WILL BE THE RESPONSIBILITY OF CONTRACTOR.

## SURVEY

EXISTING CONDITION SURVEY BY CITY OF KITCHENER JAN. 2010

## BENCHMARK

TOPOGRAPHICAL SURVEY TABLET IN SIDEWALK, OPPOSITE (DARE COOKIE FACTORY) NO NORTH SIDE OF KINGSWAY DR, 70 FEET NORTH FROM THE CENTRE OF INTERSECTION OF KINGSWAY DR AND NINTH AVE, 62.7 FEET NE FROM FIRE HYDRANT, 89.7 FEET NW FROM A LAMP POST AND 46 FEET SE OF ANOTHER LAP POST, 1.5 FEET SW FROM CONCRETE RETAINING WALL. APPROX UTM 544768.47, 4809032.57

ELEV. = 327.392m.

| No. | REVISION | By | MM/DD/YY |
|---|---|---|---|
| 6. | | | |
| 5. | | | |
| 4. | | | |
| 3. | | | |
| 2. | ISSUED FOR CONSTRUCTION | SA | 01/19/10 |
| 1. | ISSUED FOR TENDER | SA | 10/29/09 |

The Corporation Of The CITY OF KITCHENER

development and technical services department

engineering division

# EXISTING CONDITIONS HIGHWAY # 8 FROM STA. 1+000 TO STA. 1+160

DESIGNED BY: L. CHRISTENSEN

APPROVED BY: S. ALLEN

DRAWN BY: L.CHRISTENSEN

DATE: (MM.DD.YY) 01.19.10

SCALE: HOR.-1:250 / VER.-1:50

SHEET No. 1 of 1

DWG. No. G-271

**APPENDIX D**

**COPY OF MINISTRY OF TRANSPORTATION'S**
**"*GUIDELINES FOR FOUNDATION ENGINEERING – TUNNELING SPECIALTY – FOR CORRIDOR ENCROACHMENT PERMIT APPLICATION*"**

Guidelines For Foundation Engineering – Tunnelling Specialty
For Corridor Encroachment Permit Application

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

**Table 1: Complexity ratings for tunnelling specialty services**

| Highway Classification | Tunnel Excavation Diameter ($\phi$) | | | | | |
|---|---|---|---|---|---|---|
| | $\leq$ 1 m | | >1 m & $\leq$ 2 m | | >2 m | |
| | Minimum Overburden Cover * (m) | | | | | |
| | $\geq 3\phi$ (or 1.5 m whichever is greater) | $< 3\phi$ (or 1.5 m whichever is greater) | $\geq 3\phi$ | $< 3\phi$ (or 1.5 m whichever is greater) | $\geq 3\phi$ | $< 3\phi$ (or 1.5 m whichever is greater) |
| Kings Highway | **Low** | **Medium** | **Medium** | **High** | **High** | **High** |
| 400 Series Freeway | **Medium** | **High** | **High** | **High** | **High** | **High** |

*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

**Minimum requirements for Subsurface Investigation and Recommendations**

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

**Minimum Laboratory Testing Requirements:**

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

**Borehole Log Preparation and Foundation Drawing:**

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

**Minimum Requirements for the Foundation Investigation and Design Report:**

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD)and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative rosts; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments. .

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

## APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

**The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.**

### Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

*Surface Monitoring Points*

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

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

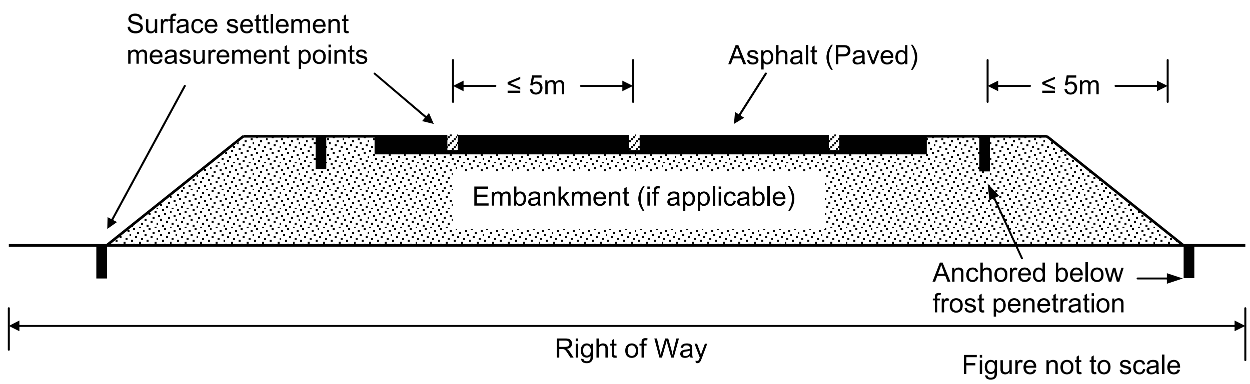



**Figure 1:** Typical configuration of surface settlement monitoring points along the tunnel alignment.

## Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

## Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, 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 non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

## 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 contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation 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 acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 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 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

### Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

### Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

### Construction Monitoring

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

## APPENDIX E

## COPY OF RECORD OF BOREHOLE NO. 103
## (BY *GOLDER ASSOCIATES, 3 APRIL 2003*)

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 103



**METRIC**

PROJECT 031-130087-2

G.W.P. 276-97-00 LOCATION N 4810194.4 ;E 228938.6 ORIGINATED BY MA

DIST ____ HWY 8 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY BG

DATUM GEODETIC DATE 8 April 2003 CHECKED BY MEB

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 328.12 | GROUND SURFACE | | | | | |
| 0.00 / 327.39 | FILL, sand and gravel, Brown | | | | | |
| 0.73 / 326.75 | FILL, sand, fine, some gravel, Compact, Brown | 1 | SS | 20 | | |
| 1.37 / 325.22 | FILL, sandy silt, trace clay, trace gravel, Loose to compact, Brown | 2 | SS | 5 | | |
| | | 3 | SS | 13 | | |
| 2.90 / 324.46 | FILL, sand, fine to coarse, with topsoil, trace gavel, Very loose, Brown | 4 | SS | 2 | | |
| 3.66 / 322.94 | SILTY FINE SAND, trace gravel, Loose to compact, Brown | 5 | SS | 9 | | |
| | | 6 | SS | 13 | | |
| 5.18 / 321.11 | SILT, some sand, Compact, Brown | 7 | SS | 12 | | |
| | | 8 | SS | 13 | | 0 15 78 7 |
| 7.01 / 319.59 | SANDY SILT, Loose, Brown | | | | ∇ | |
| | | 9 | SS | 8 | | |
| 8.53 / 318.07 | SILTY FINE SAND, Loose, Brown | 10 | SS | 9 | | |
| 10.05 / 316.84 | SAND, fine, trace to some silt, Compact, Brown | 11 | SS | 20 | | |
| 11.28 | End of Borehole | | | | | |

Note:
Water level encountered in borehole at elev. 320.80m during drilling Apr. 8, 2003.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
ELEVATION SCALE: 328 327 326 325 324 323 322 321 320 319 318 317
PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m³

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