**FOUNDATION INVESTIGATION AND DESIGN REPORTS**
**PROPOSED KEMP CREEK CULVERT (C11)**
**REPLACEMENT AT STATION 11+737 ON**
**HIGHWAY 6 SOUTH OF DURHAM**
**SOUTH OF TOWN LIMITS AND**
**NORTH OF GREY COUNTY ROAD 9, ONTARIO**
**G.W.P. 338-97-00**
**SITE NO. 8-450/C**

**GEOCRES NO. 41A-196**

**Prepared For:**

**UMA/AECOM ENGINEERING LIMITED**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1174E**
**January 15, 2008**


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# Table of Contents

**FOUNDATION INVESTIGATION REPORT**
**PROPOSED KEMP CREEK CULVERT (C11) REPLACEMENT**
**AT STATION 11+737 ON HIGHWAY 6**
**SOUTH OF DURHAM SOUTH TOWN LIMITS AND**
**NORTH OF GREY COUNTY ROAD 9, ONTARIO**
**G.W.P. 338-97-00; SITE NO. 8-450/C**

## 1. INTRODUCTION

Shaheen & Peaker Limited (S&P) was retained by UMA/AECOM Engineering Limited (UMA) to conduct a foundation investigation for detail design of the proposed culvert replacements on Highway 6 from 1.1 km south of Grey County Road 9 (North Junction) at Station 21+100 northerly through the Village of Varney to Township of Durham South Limits at Station 11+887 in Grey County, Ontario.

As part of the detail design for the proposed improvements on Highway 6, a foundation investigation was required for the detail design of Kemp Creek concrete culvert structure and the associated retaining/wing walls and possible construction of a detour lane during construction.

The Terms of Reference (TOR) for this investigation was outlined in the Request for Proposals (RFP) by the Ministry of Transportation (MTO) under Purchase Order Number 3004-E-0042 dated January 2005 and subsequent S&P proposal P07413. The work was performed in accordance with Consultant Agreement No. 3004-E-0042.

The purpose of this investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the geotechnical investigation at this site, as well as general comments and recommendations for design and construction of the proposed replacement of Kemp Creek culvert with a larger open bottom concrete culvert and construction of new retaining/wing walls and possible construction of a detour embankment.

## 2. PHYSIOGRAPHY

According to the Physiography of Southern Ontario (by Putnam & Chapman) and the Ontario Geological Survey Map P.2715, the study area lies in the area known as the Horseshoe Moraines. The Horseshoe Moraines has two main distinguishing features; i.e., irregular sand and gravel knobs and ridges (sand plain and kame moraine), and gravel or swamp-covered valleys. These granular deposits constitute aquifers associated primarily with kame deposits at or near the ground surface within a larger more extensive regional till plain. The existing gravel pit in Durham is part of the moraine spillway.

Existing subsurface information from Geocres database indicates that the overburden in this area primarily consisted of sand and gravel. However, south of the CPR Railway (which runs east-west) and east of CNR Railway limestone bedrock was encountered at about El. 1127 ft (343.7 m) during earlier geotechnical investigations.

According to Ontario Department of Mines Map 2039, entitled distribution of Limestone, Dolomite and Precambrian Pebbles in Gravels of Southern Ontario, the overburden (glacial drift), in this general area, is underlain by bedrock of predominately Guelph-Lockport-Amabel Formations with occasional Ancaster Chert beds. The bedrock composition generally consists of 90% dolomite, 3% limestone and 6% Pre-Cambrian rock. However, some shale and occasional gypsum and salt inclusions may also be found in the surrounding area.

Within the project limits, the grade of Highway 6 generally rises from about El. 377.4 m at Station 21+100 to about El. 386.2 m at Station 24+175, then it drops down to El. 383.7 m at Station 24+440 and generally rolls up to about El. 390.2 m at Station 24+700 and down to about El. 348.6 m at Station 10+700, and up to about El. 353.0 m at Station 10+870 (northern limit of contract), and up to El. 356.2 m at Station 11+175.

## 3. INVESTIGATION PROCEDURES

Based on the scope of work outlined in RFP document and our proposal, the foundation field investigation for Kemp Creek culvert (C11) consisted of a total of 11 boreholes to evaluate the subsurface conditions in the areas of the proposed culvert replacement, retaining/wing walls and a detour construction.

The field investigation at this site was carried out during several periods from August 21 to December 6, 2006. The field investigation consisted of drilling and sampling of 3 boreholes (Boreholes C11-1, C11-2 and C11-3) for the culvert replacement, 4 boreholes (Boreholes C11-RW1, C11-RW2, C11-RW3 and C11-RW4) for the associated retaining/wing walls, and 4 boreholes (Boreholes C11-D1, C11,-D2, C11-D3 and C11-D4) for possible highway detour (around the culvert as discussed in the following sections of this report). As mentioned before, for the proposed culvert replacement, 3 boreholes (Boreholes C11-1, C11-2 and C11-3) were drilled, one at each end of the culvert and one at the crest of the embankment for culvert replacement to a maximum of 10.2 m below the ground surface.

Based on the information provided to us by UMA, four new wing walls are proposed, at the location of culvert C11, on both sides and both ends of the new culvert. The proposed retaining/wing walls will have individual lengths much less than 50 m. Therefore, four boreholes (C11-RW1 through C11-RW4) were put down. Boreholes were generally drilled on the flatter part of the slope or toe of the embankment near the ends of the retaining/wing walls to different depths ranging from 4.7 m to a maximum of 6.6 m, or refusal.

In addition, four boreholes were put down along the proposed detour near Kemp Creek culvert (C11-D1 through C11-D4) to a maximum of 5.5 m depth below the ground surface.

The majority of the boreholes were advanced using solid stem, or hollow stem augers run by truck and track mounted drill rigs owned and operated by Walker Drilling Limited. However, at some borehole locations (e.g., C11-D1 and C11-D2), where steep slopes and difficult access did not allow utilization of a track mounted drilling rig, the boreholes were advanced by manual soil sampling methods using a standard split spoon and a tripod operated by K. J. Beamish Construction Co. Limited. All the boreholes were drilled under the full time supervision of geotechnical engineers from S&P.

Sampling in the boreholes was conducted at frequent intervals of depth by the Standard Penetration Test (SPT) method, as specified in ASTM D1586. This consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm 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 is recorded as the Standard Penetration Resistance or the N-value of the soil and this gives an indication of the consistency or the compactness condition of the soil deposit. Refusal was generally defined by reaching competent material for which the resistance measured by the Standard Penetration Test exceeds 100 blows per 0.3 m of penetration.

At Boreholes C11-D1, C11-D2 locations, the boreholes were advanced by manual methods, using light portable equipment. Sampling was effected using a standard split-spoon sampler driven by 31.8 kg hammer (rather than a 63.5 kg hammer, as required by the SPT method). The number of blows of the hammer to drive the sampler was divided by two to obtain equivalent N-values.

At the completion of drilling, all boreholes drilled were grouted and sealed using a cement/bentonite mixture. The boreholes installed with piezometer were sealed with bentonite seal and grout above the slotted portion of the pipes and at ground surface.

Water level observations in the open boreholes were made during drilling and at the completion of each borehole. In addition, piezometers were installed in selected boreholes. These piezometers allow monitoring of groundwater levels over time without undue interference/impact from surface water.

The borehole locations were measured approximately by S&P field staff with reference to the local features, which were converted to station and offset measurements. The corresponding geodetic elevations and coordinates for all the borehole were provided to us by UMA.

A laboratory testing program, consisting of natural moisture content, Atterberg Limits tests, grain-size analyses (sieve and hydrometer), was performed on selected soil samples.

The results of drilling, in-situ testing and water level measurements, as well as laboratory soil testing are summarized on the Record of Borehole Sheets in Appendix A.

The results of the laboratory tests are also presented separately in Appendix B.

## 4. SUBSURFACE CONDITIONS

The soil conditions at the location of the culvert are discussed in the following sections. Details of the stratigraphy encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A and on the soil strata drawings in Drawing No. 11B. The following paragraphs are only meant to complement and amplify these data.

From the information provided to us by UMA, the existing Kemp Creek culvert (C11) is located at Sta. 11+736 and it is a 20.6 m long open bottom concrete structure, about 3.5 m wide and 1.2 m high. The invert elevation of the existing culvert is at 334.95 m (upstream) to 334.77 m (downstream).

Based on the design drawing (Sheet S 03 dated December 2006) provided by UMA, a new larger open bottom concrete culvert is proposed at Sta. 11+736. The proposed highway realignment in this area include a maximum grade raise of 0.5 m.

Three boreholes were drilled for this culvert replacement. Borehole C11-1 was advanced on the west (left) side of Highway 6 near the downstream-end of the existing culvert. Boreholes C11-2 and C11-3 were put down on the east (right) side of Highway 6 on the gravel shoulder and adjacent to the east-end (upstream-end) of the existing culvert, respectively, as shown on the Site Plan and Profile Drawings 11A and 11B.

In general below some fill and original topsoil, all three boreholes contacted a major deposit of sand and gravel, with occasional cobbles and possible boulders, to the termination of the boreholes (to a maximum depth of 10.2 m, or about El. 324.7 m in Borehole C11-3).

### 4.1 KEMP CREEK CULVERT (CULVERT C11)

#### 4.1.1 GRANULAR FILL

Boreholes C11-1 and C11-2 (on the left and right shoulders of the highway) contacted gravelly sand fill extending to a depth of about 2.2 and 1.5 m below the ground surface, or to El 334.3 m and 335.4 m, respectively.

The grain-size distribution of a sample of this deposit (C11-2/AS2) is presented in Figure B11-1 in Appendix B. The following grain-size distribution is indicated:

| | |
|---|---|
| Gravel: | 48% |
| Sand: | 49% |
| Silt and Clay: | 3% |

It is noted that the grain size distribution of the sample tested meets that of a Granular 'B' material.

The measured natural moisture contents of the granular fill range from 5 to 11%.

Standard Penetration tests performed in the granular fill yielded N-values ranging from 14 to 6 blows/0.3 m, indicating compact to loose condition.

#### 4.1.2 SANDY SILT FILL

The gravelly sand fill in Borehole C11-2 and the surficial topsoil layer in Borehole C11-3 are underlain by another fill deposit which consists of sandy silt. At Borehole C11-2 and C11-3 locations, this fill deposit was found to extend to a depth of about 2.2 and 1.2 m, or El. 334.7 and 333.7 m, respectively. This deposit is basically a fine-grained granular (i.e. non-cohesive) material.

The measured natural moisture contents of the sandy silt fill material range from 14 to 16%.

Standard Penetration tests performed in this fill deposit yielded N-values ranging from 4 to 12 blows/0.3 m, indicating loose to compact condition.

#### 4.1.3 TOPSOIL AND ORGANIC SILT

Borehole C11-3, which was put down beyond the bottom of the existing highway embankment on the right side, contacted topsoil layer at ground surface to about 0.3 m below grade, or to El. 334.6 m.

In Boreholes C11-2 and C11-3, the fill is underlain by a 0.5 to 0.3 m thick topsoil and peaty organic silt (floodplain deposit) layer to a depth of 2.7 m (El. 334.2 m) and 1.5 m (El. 333.4 m), respectively.

Standard Penetration tests performed in these organic deposits yielded N-values of 8 and 4 blows/0.3 m, respectively, indicating loose to very loose conditions.

#### 4.1.4 SILTY FINE SAND

In Borehole C11-2, the topsoil and organic silt layer is underlain by a 0.3 m thick native silty fine sand deposit.

This fine-grained cohesionless deposit is grey, wet and from the Standard Penetration test results, it is inferred to be loose.

#### 4.1.5 GRAVELLY SAND

Underlying the surficial soils described in the preceding paragraphs, all three boreholes contacted a coarse granular deposit consisting of gravelly sand with traces of silt and occasional cobbles and boulders. The presence of more silty seams is also noted in the deposit (e.g., Borehole C11-3 between 3 and 7 m depths). This deposit was contacted at the borehole locations at depths ranging from 1.5 to 3.0 m below the ground surface or at El. 334.3 to 333.4 m and extended to the termination depths of all three boreholes or 4.6 to 10.2 m or to El. 332.0 to 324.7 m and possibly beyond.

The grain-size distribution of a sample of this deposit (C11-1/SS6) is presented in Figure B11-2 in Appendix B. The following grain-size distribution is indicated:

| | |
|---|---|
| Gravel: | 39% |
| Sand: | 56% |
| Silt and Clay: | 5% |

It is of interest to note that the grain-size distribution of the sample tested meets that of a Granular 'B' material, OPSD Form 1010.

The measured N-values in the gravelly sand range from 21 to 74 blows/0.3 m, indicating a compact to very dense but generally dense to very dense condition. The measured natural moisture contents range from 7 to 22% but generally between 7 and 16%. Higher range of moisture contents up to 22% generally correspond to more silty seams.

From the grain-size distribution curve, the deposit is considered to be a relatively pervious deposit.

#### 4.1.6 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, piezometers were installed in Boreholes C11-1 and C11-3 to allow ground monitoring over a prolonged period of time. The observations and recorded values are shown on the individual Record of Borehole sheets.

The results indicate that at the time of our investigation, in Borehole C11-1 the soil became wet at about 1.1 m (El. 335.5 m) during drilling, where free-standing water was subsequently recorded in the piezometer (one week later) at the same El. 335.5 m. In the piezometer installed in Borehole C11-3, water level was recorded at a depth of 0.3 m below the ground surface or at El. 334.6 m. From these observations, the groundwater level at the time of our investigation ranged between El. 335.5 and 334.6 m. Slightly lower water level at El. 333.8 m was encountered in C11-2 during field drilling, but this may not represent the stabilized water level and the stabilized water level could be at higher elevation.

It should also be pointed out that the groundwater is subject to seasonal fluctuations and fluctuations in response to major weather events. In addition, the water table at the site will be influenced by the water level in the water course.

## 4.2 RETAINING WALLS/WING WALLS AT BOTH ENDS OF CULVERT C11

In addition to the culvert Boreholes C11-1 through C11-3 (described above), four boreholes (C11-RW1 through C11-RW4) were drilled near the existing Kemp Creek floodplain at the locations shown on the Site Plan Drawing 11A. These boreholes were extended to a maximum of 6.6 m depth to evaluate the subsurface conditions in the area of the proposed retaining/wing walls. It is our understanding that these walls are expected to be less than 3 m high.

These boreholes primarily encountered surficial topsoil and granular fill underlain by some fine sand/silty sand and sand & gravel deposit extending to the termination of the boreholes.

### 4.2.1 TOPSOIL

A topsoil layer was encountered in all four boreholes near the existing floodplain at ground surface ranging in thickness from about 0.1 to 0.3 m. The insitu moisture content for this material was measured at about 9%.

### 4.2.2 GRANULAR FILL AND POSSIBLE FILL

At the location of Boreholes C11-RW1 and C11-RW4 on the west side of the existing Culvert C11 (near the existing snowmobile trail), sand and gravel fill and similar material identified as possible fill were encountered extending to about 2.0 and 1.5 m depth (or to El. 335.0 m and 335.4 m) in Boreholes C11-RWI and C11-RW4, respectively. The natural moisture contents of this granular fill were measured at about 4%. Standard Penetration tests performed in these granular fill and suggested fill materials yielded N-values ranging from 9 to 47 blows/0.3 m, indicating variable, loose to dense, condition.

### 4.2.3 SILTY SAND/FINE SAND/GRAVELLY SAND FILL (POSSIBLE FILL)

The sand and gravel fill in Borehole C11-RW4 on the left side of the highway was underlain by silt sand to fine sand (possible fill) to about 2.1 m depth (El. 334.7 m). Similarly, at the location of Boreholes C11-RW2 and C11-RW3 on the right side of the highway, silty sand to fine sand and gravelly sand fill/possible fill was encountered extending to about 2.2 and 2.4 m depth (to El. 334.3 m). The measured natural moisture contents of this material range from

7 to 18%. Standard Penetration tests performed in this material yielded N-values ranging from 10 to 23 blows/0.3 m, indicating a compact condition. This is a basically granular (i.e. non-cohesive) material.

#### 4.2.4 FINE SAND TO SILTY SAND

In Borehole C11-RW2 at 2.2 m depth, the silty sand to gravelly sand (possible fill) is underlain by a 1.5 m thick layer of native fine sand to silty sand extending to about El. 332.8 m. Standard penetration tests performed in these basically granular (cohesionless) material yielded N-values of 4 and 24 blows/0.3 m, indicating loose to compact condition.

The measured natural moisture contents of this deposit range from 9 to 15%.

#### 4.2.5 SAND AND GRAVEL

Below the granular fill materials in most boreholes (C11-RW1, C11-RW3, C11-RW4, C11-1 and C11-3) and/or native sand to silty sand in C11-RW2, a coarse granular deposit of sand and gravel was contacted with traces of silt and occasional cobbles and boulders. This deposit was found at depths ranging from 2.0 m (El. 335.0 m in Borehole C11-RW1) on the left side of the highway to 3.7 m (El. 332.8 in Borehole C11-RW2) on the right side of the highway. This deposit extended to the termination of all the boreholes or up to about 10.2 m depth (El. 324.7 m) in Borehole C11-3.

Grain-size analysis tests were performed on three representative samples of this deposit. The results are presented in the following table and in an envelope form in Figure B11-3, in Appendix B.

Table 4.2.5
Results of Grain Size Analyses

| Borehole/Sample | Depth (m) | Mid-El. (m) | Gravel % | Sand % | Silt & Clay % |
|---|---|---|---|---|---|
| C11-RW1/SS4 & SS5 | 3.0 | 334.0 | 55 | 40 | 5 |
| C11-RW3/SS5 & SS6 | 3.7 | 333.0 | 59 | 35 | 6 |
| C11-RW4/SS6 | 4.1 | 332.8 | 45 | 49 | 6 |

The measured N-values in this deposit range from 15 blows/0.3 m to 50 blows/0.08 m, indicating a compact to very dense but generally dense to very dense condition.

The measured natural moisture contents range from 7 to 22% but generally between 8 and 13%.

#### 4.2.6 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, as noted earlier, piezometers were installed in the culvert Boreholes C11-1 and C11-3 to allow ground monitoring over time. The observations and recorded values are shown on the individual Record of Borehole sheets.

The results indicate that at the time of our investigation, the soil became wet a depths ranging from about 1.5 m (El. 335.5 m) in Borehole C11-RW1 to about 2.0 m (El. 334.5 m) in Borehole C11-RW2 during drilling. In addition, water level in the piezometer installed in Borehole C11-3 was reported earlier at a depth of 0.3 m below the ground surface or at El. 334.6 m, which is close to the observed water level in Borehole C11-RW2. From these observations, the groundwater level at the time of our investigation generally ranged between El. 335.5 and 334.5 m.

It should also be pointed out that the groundwater is subject to seasonal fluctuations and fluctuations in response to major weather events. In addition, the water table at the site will be influenced by the water level in the water course.

### 4.3 PROPOSED DETOUR IN THE VICINITY OF CULVERT C11

In addition to the culvert and retaining wall boreholes (described in Sections 4.1 and 4.2), four detour boreholes C11-D1, C11-D2, C11-D3 and C11-D4 were drilled on the right side of the highway beyond the toe of the existing embankment at the locations shown on Drawing 11A. These boreholes, in addition to Borehole C11-3, put down between Sta 11+625 and Sta 11+825 to evaluate the subsurface conditions along the proposed detour. Based on the base drawing provided by UMA, Boreholes C11-D1, C11-D2 and C11-D3 appear to be located in the Kemp Creek floodplain and near existing wetlands. In particular, Borehole C11-D3 is located between the existing creek and the highway embankment.

Boreholes C11-D3 and C11-D4 were drilled using a regular drilling machine mounted on a truck (Bombardier) type vehicle. These boreholes were extended to depths of 5.5 and 4.6 m. Boreholes C11-D1 and C11-D2, however, had to be advanced using manual methods, due to limited access with a vehicle, as noted earlier in Section 3 of this report. These boreholes were put down by driving a conventional 51 mm O.D., split-spoon sampler into the ground using a 31.8 kg, however, instead of the conventional 63.6 kg hammer. The number of blows of the hammer required to drive the sampler into the undisturbed ground was recorded. After 0.6 m penetration, the sampler was withdrawn and the soil sample inside the sampler was visually examined and logged. The sampler was then put back into the hole and driven in the same manner another 0.6 m. This was continued until 2.4 m depth below the ground surface when the hole was terminated. The number of blows to drive the sampler by 0.3 m into the ground was divided by two to obtain a resistance value which is approximately equivalent to the value which would be obtained by the Standard Penetration test. Dividing by two was implemented because the weight of the hammer was half of the standard one while the fall was same as in Standard Penetration test.

In general, these boreholes encountered surficial peaty topsoil, some granular fill and organic silt underlain by alluvial silt and fine sand, followed by sand & gravel deposit extending to the termination of all the boreholes.

#### 4.3.1 TOPSOIL/PEATY TOPSOIL

A layer of topsoil/peaty topsoil was found at ground surface in Boreholes C11-D1 through C11-D4 drilled near the toe of the existing highway embankment. The thickness of this material ranges from about 0.15 m in Borehole C11-D4 to 0.8 m in Borehole C11-D1.

#### 4.3.2 SURFICIAL SAND & GRAVEL (POSSIBLE FILL)

Below topsoil, a 0.3 to 0.5 m thick sand and gravel layer was contacted in Boreholes C11-D3 and C11-D4 extending to depths of about 0.6 and 0.7 m (El. 336.1 and 337.0 m), respectively. This material was identified as ‘possible fill.’

Standard Penetration tests performed in this surficial granular soil encountered in Boreholes C11-D3 and C11-D4 yielded N-values ranging of 8 and 18 blows/0.3 m, indicating a loose to compact condition, respectively.

#### 4.3.3 PEATY ORGANIC SILT

Below topsoil and some granular fill in C11-D3, a peaty organic silt deposit was found extending to about 2.2 m depth (El. 334.5 m).

Standard Penetration tests performed in this organic deposit yielded N-values of 5 and 8 blows/0.3 m, indicating a loose condition.

#### 4.3.4 ALLUVIAL SILT & FINE SAND

Below surficial soils described above, a 0.4 to 1.0 m thick alluvial silt and fine sand deposit was contacted in Boreholes C11-D1 through C11-D3 extending to about 1.2 m depth in Boreholes C11-D1 and C11-D2 (El. 335.2 m and El. 334.7 m, respectively) and 3.0 m depth in Borehole C11-D3 (El. 333.7 m). This fine-grained, generally cohesionless deposit contains trace organics and rootlets. It is brown to grey and wet.

Standard Penetration tests performed in this deposit yielded N-values ranging from 2 to 17 blows/0.3 m, indicating a very loose to compact condition.

The measured moisture content for this material ranges from 16 to 36%.

#### 4.3.5 SAND & GRAVEL

Underlying the surficial soils described in the preceding paragraphs, all four detour boreholes contacted a coarse granular deposit consisting of sand & gravel with traces to some silt and occasional cobbles and boulders.

This deposit was contacted in all borehole locations at depths ranging from 0.7 to 3.0 m below the ground surface or at El. 337.0 to 333.7 m and extended to the termination of all the four boreholes at depths ranging from 2.4 to 5.5 m below the ground surface or to El. 333.9 to 331.2 m and likely beyond. The refusal of sampling spoon in Borehole C11-D4, at about 4.6 m depth which led to the termination of this borehole at El. 333.1 m, indicates possible presence of cobbles/boulders in this deposit.

Grain-size analysis tests were performed on two representative samples of this deposit. The results are presented in the following table and in Figures B11-4 in Appendix B.

Table 4.3.5
Results of Grain Size Analyses

| Borehole/Sample | Depth (m) | Mid-El. (m) | Gravel % | Sand % | Silt & Clay % |
|---|---|---|---|---|---|
| C11-D1/SS3 | 1.5 | 334.9 | 29 | 51 | 20 |
| C11-D4/SS2 | 3.7 | 333.0 | 57 | 34 | 9 |

Therefore, the tested materials can be described as gravely sand to sandy gravel, (or in general sand & gravel) with traces to some silt.

The measured N-values in the deposit range from 17 blows/0.3 m to 50 blows/0.13 m, indicating a compact to very dense but generally dense to very dense condition.

The measured natural moisture contents range from 5 to 16 but generally between 5 and 12%. A higher range of moisture contents in this deposit from 12 to 16% generally correspond to more silty seams below the groundwater table. This cohesionless (granular) deposit is generally considered to be a relatively pervious material.

#### 4.3.6 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, as noted in Sections 4.1.6 and 4.2.6, a piezometer was installed in Borehole C11-3 (on the right side of the highway and between Boreholes C11-D2 and C11-D3) to allow ground monitoring over time. The observations and recorded values are shown on the individual Record of Borehole sheets.

The results indicate that at the time of our investigation, water was found in open boreholes at different depths ranging from a depth of about 0.2 m (El. 336.2 m) in Borehole C11-D1 to about 2.2 m (El. 334.5 m) in Borehole C11-D3. In the piezometer installed in Borehole C11-3, water level was recorded at a depth of 0.3 m below the ground surface or at El. 334.6 m, which is very close to the water level observed in Borehole C11-D3 during drilling. From these observations, the groundwater level at the time of our investigation generally ranged between El. 336 and 335 m.

It should also be pointed out that the groundwater is subject to seasonal fluctuations and fluctuations in response to major weather events. In addition, the water table at the site will be influenced by the water level in the water course.

**SHAHEEN & PEAKER LIMITED**

LICENSED PROFESSIONAL ENGINEER
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Ramon Miranda, P.Eng.

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
PROVINCE OF ONTARIO

ZO:tr/idrive

Z.S. Ozden, P.Eng.

# Drawings

# METRIC

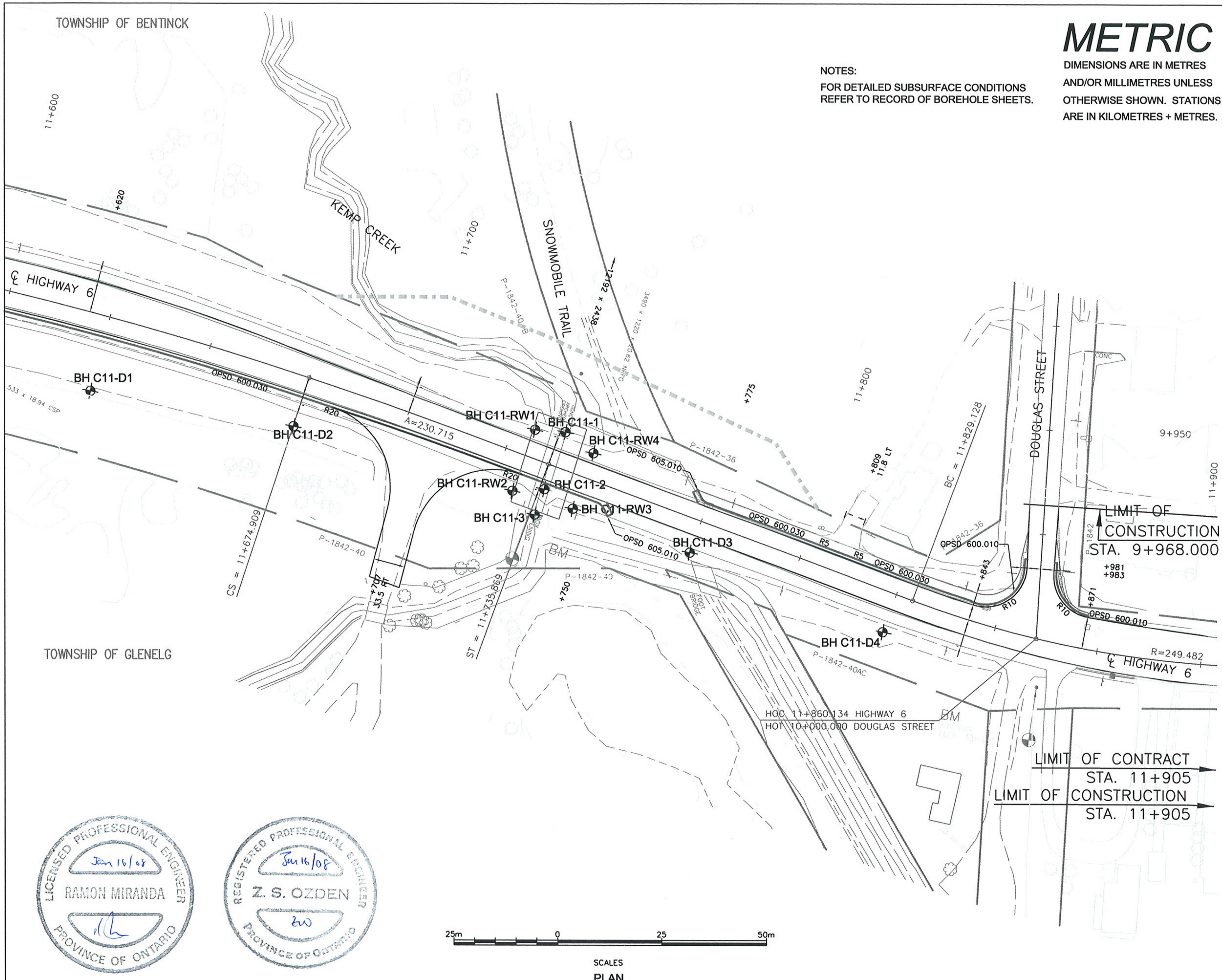
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES + METRES.

NOTES:
FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

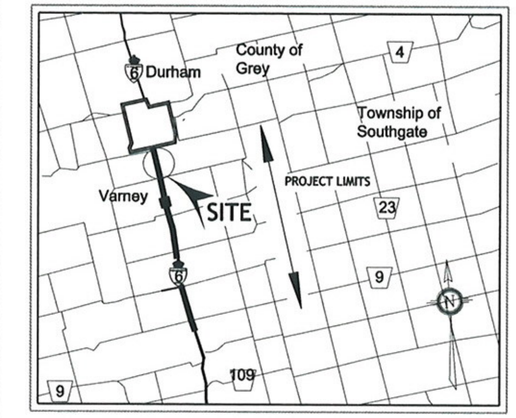
CONT No.
GWP: 338-97-00

Highway 6, Durham
Kemp Creek Culvert (C11) @ Sta. 11+736
BORE HOLE LOCATIONS

## SHAHEEN & PEAKER LIMITED




SCALES
PLAN




KEY PLAN
N.T.S

## LEGEND

- Borehole
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation Aug./ Nov., 2006 (Not Stabilized)
- Water Level in Piezometer
- Piezometer

| No. | ELEV. | CO-ORDINATES | |
|---|---|---|---|
| | | NORTH | EAST |
| C11-1 | 336.6 | 4,892,473.2 | 199,439.8 |
| C11-2 | 336.9 | 4,892,470.7 | 199,454.2 |
| C11-3 | 334.9 | 4,892,469.6 | 199,460.6 |
| C11-D1 | 336.4 | 4,892,359.4 | 199,451.4 |
| C11-D2 | 335.9 | 4,892,408.9 | 199,450.6 |
| C11-D3 | 336.7 | 4,892,507.8 | 199,462.6 |
| C11-D4 | 337.7 | 4,892,556.8 | 199,472.7 |
| C11-RW1 | 337.0 | 4,892,465.9 | 199,440.6 |
| C11-RW2 | 336.5 | 4,892,463.3 | 199,456.0 |
| C11-RW3 | 336.7 | 4,892,478.3 | 199,457.5 |
| C11-RW4 | 336.9 | 4,892,480.7 | 199,443.6 |

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

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office,Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

| REV. | DATE | BY | DESCRIPTION |
|---|---|---|---|

Geocres No. 41A-196

| SPT 1174, CURVERT C11 | | | DIST |
|---|---|---|---|
| SUBM'D ZO | CHECKED RM | DATE Jan 07, 08 | SITE 8-450/C |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 11 A |

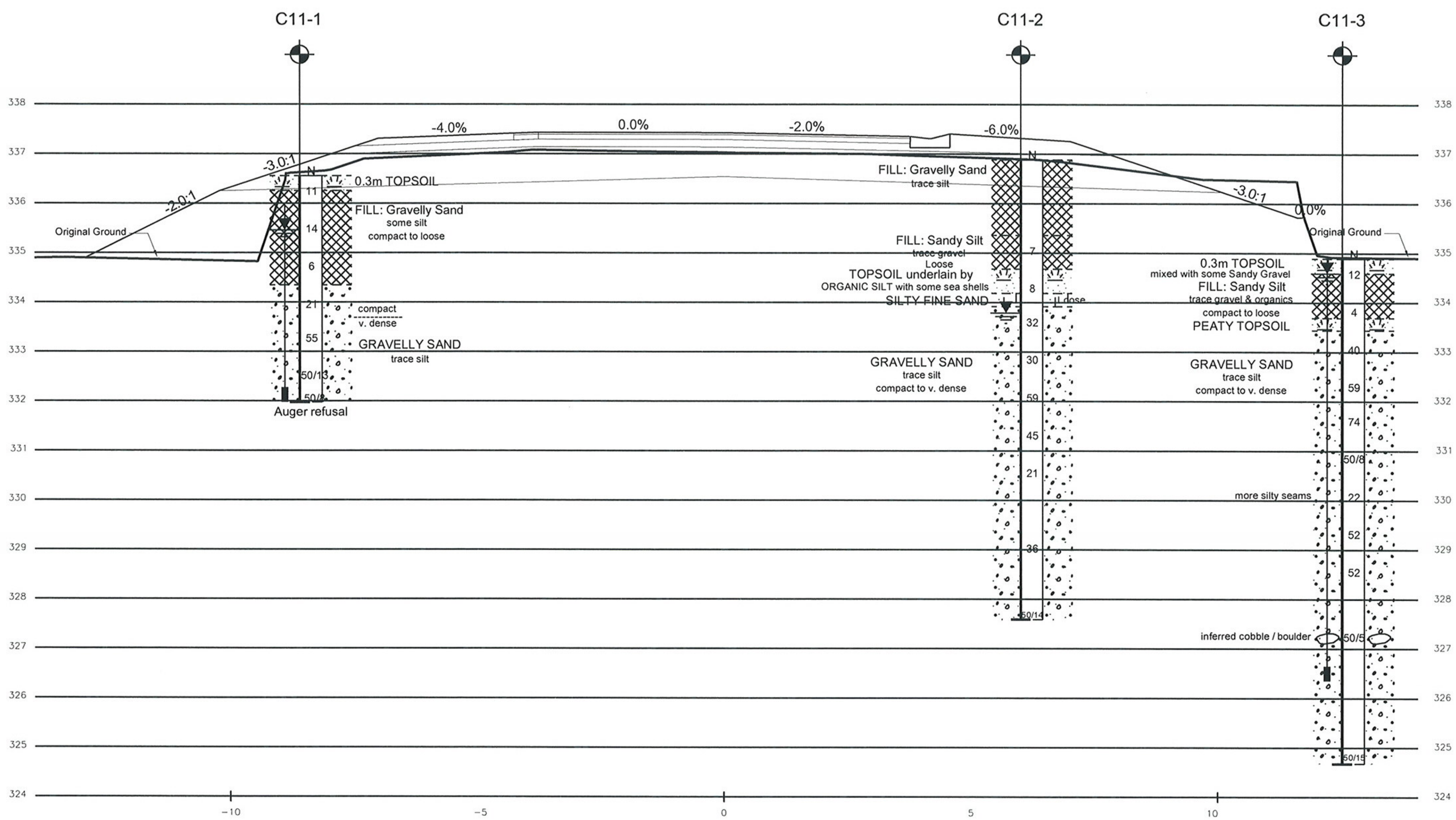
LICENSED PROFESSIONAL ENGINEER
Jan 16/08
RAMON MIRANDA
PROVINCE OF ONTARIO

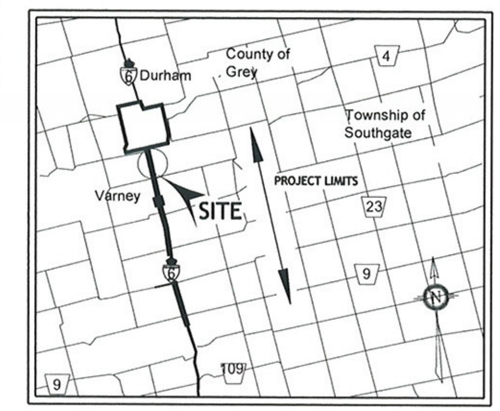
REGISTERED PROFESSIONAL ENGINEER
Jan 16/08
Z. S. OZDEN
ZO
PROVINCE OF ONTARIO

CONT No.
GWP: 338-97-00

Highway 6, Durham
Kemp Creek Culvert (C11) @ Sta. 11+736
PROFILE & SOIL STRATIGRAPHY

## SHAHEEN & PEAKER LIMITED




KEY PLAN
N.T.S

### LEGEND

Borehole

N Blows/0.3m (Std. Pen. Test, 475 J/blow)

Water Level at Time of Investigation
( W. L. NOT STABILIZED)

Water Level in Piezometer

Piezometer

| No. | ELEV. | CO-ORDINATES NORTH | CO-ORDINATES EAST |
|---|---|---|---|
| C11-1 | 336.6 | 4 892 465.3 | 199 438.5 |
| C11-2 | 336.9 | 4 892 470.7 | 199 454.2 |
| C11-3 | 334.9 | 4 892 469.6 | 199 460.6 |

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

NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office,Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

| REV. | DATE | BY | DESCRIPTION |
|---|---|---|---|

Geocres No. 41A-196

SCALES
1m 0 1 2m VERT
1m 0 1 2m HOR

## PROFILE ALONG C11 @ STA. 11+736

LICENSED PROFESSIONAL ENGINEER
Jan 16/08
RAMON MIRANDA
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
Jan 16/08
Z. S. OZDEN
PROVINCE OF ONTARIO

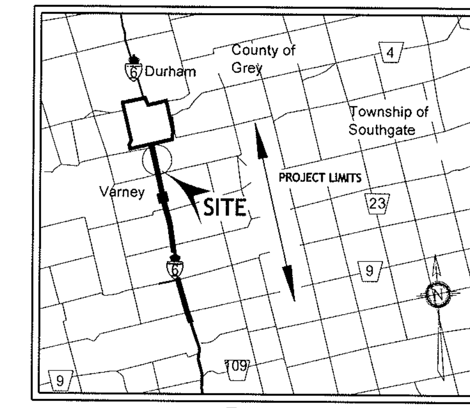
| SPT 1174 | | | DIST |
|---|---|---|---|
| SUBM'D | CHECKED | DATE Jan., 2008 | SITE 8-450/C |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 11B |

CONT No.

GWP: 338-97-00

Highway 6, Durham
Kemp Creek Culvert (C11) @ Sta. 11+736
PROFILE & SOIL STRATIGRAPHY

# SHAHEEN & PEAKER LIMITED




KEY PLAN
N.T.S

## LEGEND

Borehole

N Blows/0.3m (Std. Pen. Test, 475 J/blow)

Water Level at Time of Investigation
( W. L. NOT STABILIZED)

Water Level in Piezometer

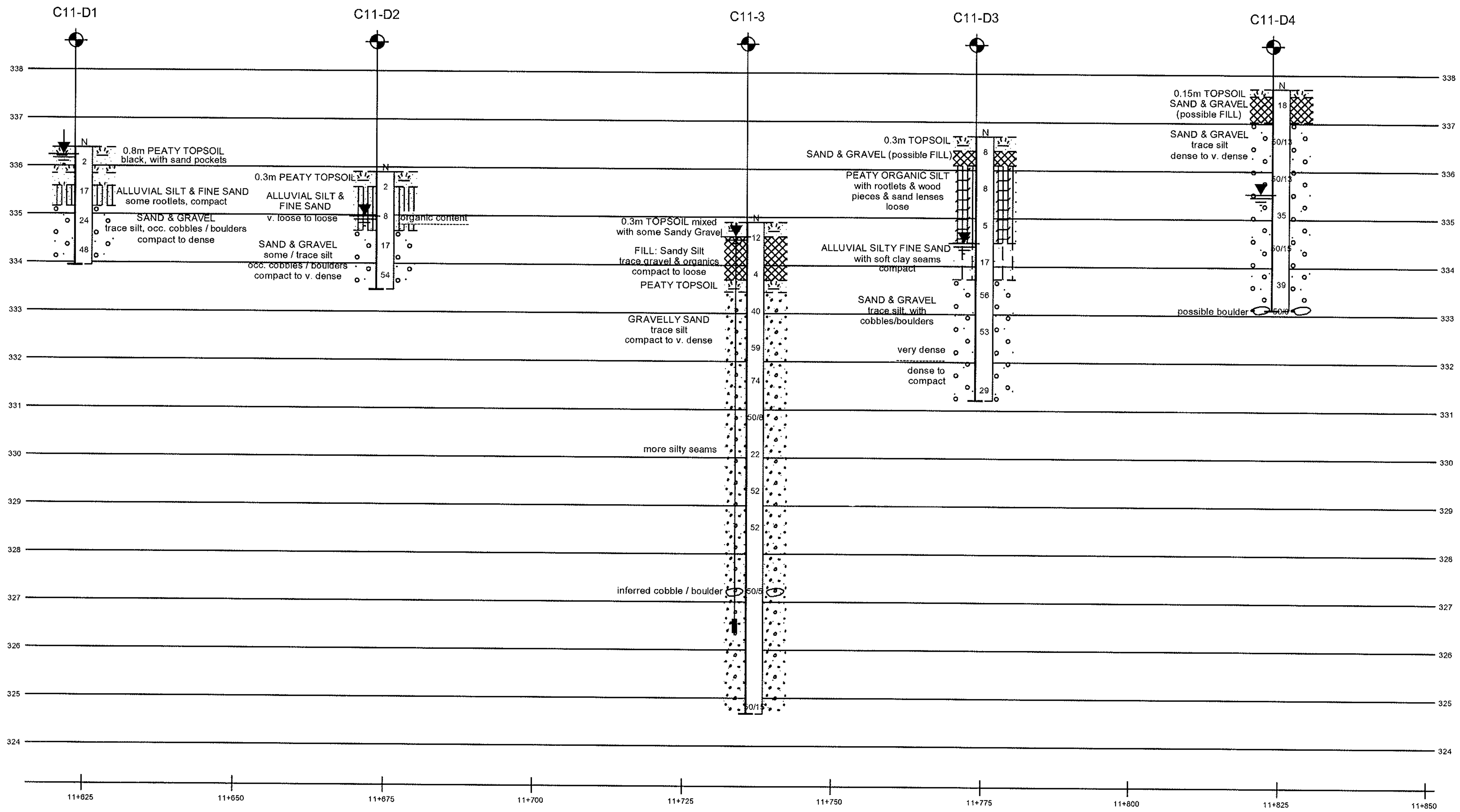
Piezometer

| No. | ELEV. | CO-ORDINATES NORTH | CO-ORDINATES EAST |
|---|---|---|---|
| C11-D1 | 336.4 | 4 892 359.4 | 199 451.4 |
| C11-D2 | 335.9 | 4 892 408.9 | 199 450.6 |
| C11-3 | 334.9 | 4 892 469.6 | 199 460.6 |
| C11-D3 | 336.7 | 4 892 507.8 | 199 462.6 |
| C11-D4 | 337.7 | 4 892 556.8 | 199 472.7 |

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

NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.




SCALES
1m 0 1 2m VERT
8m 0 8 16m HOR

PROFILE ALONG PROPOSED DETOUR

Jan 16/08

Jan 16/08
Z. S. OZDEN

| REV. | DATE | BY | DESCRIPTION |
|---|---|---|---|
| | | | |

Geocres No. 41A-196

| SPT 1174 | | | DIST |
|---|---|---|---|
| SUBM'D | CHECKED | DATE Jan 07, 2008 | SITE 8-450/C |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 11C |

# Appendix A

# Record of Borehole Sheets

# RECORD OF BOREHOLE No C11-1

1 OF 1 METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 11+737, 8.6m Lt, C/L ORIGINATED BY NH

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/13/2006 CHECKED BY FS

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 336.6 | | | | | | | |
| 0.0 336.3 | 0.3 m TOPSOIL | 1 | SS | 11 | | | |
| 0.3 | FILL: Gravelly Sand some silt brownish grey compact to loose damp -------- wet | 2 | SS | 14 | 336 | | wet spoon |
| | | 3 | SS | 6 | 335 | | |
| 334.3 2.2 | GRAVELLY SAND compact ----------- very dense trace silt greyish brown to brownish grey, wet | 4 | SS | 21 | 334 | | |
| | | 5 | SS | 55 | 333 | | |
| | | 6 | SS | 50/13 | | | 39 56 (5) |
| 332.0 4.6 | | 7 | SS | 50/8 | 332 | | auger refusal |

End of borehole.

Piezometer installed to depth of 13.8 m.
Water level in piezometer:
Nov. 14, 2006 ---2.9 m (El. 333.7 m)
Nov. 21, 2006 ---1.1 m (El. 335.5 m)

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100
PLASTIC LIMIT $w_P$ NATURAL MOISTURE CONTENT $w$ LIQUID LIMIT $w_L$ WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m$^3$

$+^3$, $\times^3$: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-2



**METRIC**

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+737, 6m Rt, C/L | ORIGINATED BY JL

DIST | HWY 6 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY XS

DATUM Geodetic | DATE 8/21/2006 | CHECKED BY FS

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 336.9 / 0.0 | **FILL: Gravelly Sand** trace silt brown / dark brown, moist | 1 | AS | | | |
| | | 2 | AS | | 336 | 48 49 (3) |
| 335.4 / 1.5 | **FILL: Sandy Silt** trace gravel brown to dark brown, moist, loose | 3 | SS | 7 | 335 | |
| 334.7 / 2.2 | **TOPSOIL** underlain by **ORGANIC SILT** with some sea shells black to dark grey, moist to wet | 4 | SS | 8 | | |
| 334.2 / 2.7 | **SILTY FINE SAND** grey, wet, loose | | | | 334 | |
| 333.9 / 3.0 | **GRAVELLY SAND** trace silt brown to greyish brown, wet compact to very dense | 5 | SS | 32 | | |
| | | 6 | SS | 30 | 333 | |
| | | 7 | SS | 59 | 332 | |
| | | 8 | SS | 45 | 331 | |
| | | 9 | SS | 21 | 330 | |
| | | 10 | SS | 36 | 329 | |
| | | | | | 328 | |
| 327.6 / 9.3 | End of borehole. | 11 | SS | 50/14 | | |

Groundwater conditions: water level symbol * at approx. El. 333.8

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT $w_P$ NATURAL MOISTURE CONTENT $w$ LIQUID LIMIT $w_L$

WATER CONTENT (%) 10 20 30

UNIT WEIGHT $\gamma$ kN/m$^3$

End of borehole.

* Water level at 3.1 m (El. 333.8 m) and hole open to full depth upon completion (not stabilized).

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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# RECORD OF BOREHOLE No C11-3



**METRIC**

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+737, 12.5m Rt, C/L | ORIGINATED BY ZI

DIST | HWY 6 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY HL

DATUM Geodetic | DATE 11/9/2006 | CHECKED BY RM

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---|---|---|---|---|---|---|
| 334.9 | | | | | | |
| 334.6 / 0.0 | 0.3m **TOPSOIL** mixed with some Sandy Gravel | 1 | SS | 12 | | |
| 0.3 | **FILL: Sandy Silt** trace gravel & organics brown to grey, wet compact to loose | | | | 334 | |
| 333.7 / 1.2 | | 2 | SS | 4 | | |
| 333.4 / 1.5 | **PEATY TOPSOIL** dark grey, wet | | | | | |
| | **GRAVELLY SAND** trace silt brownish grey, wet compact to very dense | 3 | SS | 40 | 333 | |
| | | 4 | SS | 59 | 332 | |
| | | 5 | SS | 74 | | |
| | | 6 | SS | 50/8 | 331 | |
| | more silty seams | 7 | SS | 22 | 330 | |
| | | 8 | SS | 52 | 329 | |
| | | 9 | SS | 52 | 328 | |
| | | ~~10~~ | ~~SS~~ | ~~50/5~~ | 327 | boulder |
| | | | | | 326 | |
| 324.7 / 10.2 | | 11 | SS | 50/15 | 325 | |

End of borehole.

Piezometer installed to depth of 8.5 m. Water level in piezometer:
Nov. 14, 2006 ---0.4 m (El. 334.5 m)
Nov. 21, 2006 ---0.3 m (El. 334.6 m)

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100; PLASTIC LIMIT $w_P$ NATURAL MOISTURE CONTENT $w$ LIQUID LIMIT $w_L$; WATER CONTENT (%) 10 20 30; UNIT WEIGHT $\gamma$ kN/m$^3$; GR SA SI CL

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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# RECORD OF BOREHOLE No C11-RW1 1 OF 1 METRIC

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+730, 6.6m Lt, C/L | ORIGINATED BY NH

DIST | HWY 6 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY XS

DATUM Geodetic | DATE 11/10/2006 | CHECKED BY FS

| ELEV DEPTH | SOIL PROFILE DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 337.0 | | | | | | 337 | |
| 336.8 0.2 | 0.15 m **TOPSOIL** | | | | | | |
| | **SAND & GRAVEL (possible FILL)** trace silt occasional rootlets near top and bottom brown to dark brown and grey, damp compact to dense | 1 | SS | 13 | | | |
| | | 2 | SS | 47 | ▼* | 336 | |
| 335.0 2.0 | | 3 | SS | 29 | | 335 | wet spoon |
| | **SAND & GRAVEL** trace silt grey to greyish brown, wet dense to very dense | 4 | SS | 59 | | | combined SS4 + SS5 55 40 (5) |
| | | 5 | SS | 34 | | 334 | |
| | | 6 | SS | 79 | | 333 | |
| 332.0 5.0 | some silt | 7 | SS | 42 | | 332 | |

End of borehole.

* Water level in open borehole at 1.5 m (El. 335.5 m) upon completion (not stabilized).

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT $w_P$ — NATURAL MOISTURE CONTENT $w$ — LIQUID LIMIT $w_L$

WATER CONTENT (%) 10 20 30

UNIT WEIGHT $\gamma$ kN/m$^3$

+ 3, × 3 : Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-RW2 1 OF 1 METRIC

| | | | |
|---|---|---|---|
| GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+730, 9m Rt C/L | ORIGINATED BY NH |
| DIST HWY 6 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY XS |
| DATUM Geodetic | DATE 11/10/2006 | CHECKED BY FS |

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE |
|---|---|---|---|---|---|---|
| 336.5 | | | | | | |
| 336.2<br>0.0 | 0.3 m **TOPSOIL** | 1 | SS | 7 | | |
| 0.3 | **FILL: Silty Sand to Fine Sand**<br>trace to some gravel<br>dark brown to grey<br>loose | 2 | SS | 10 | | 336 |
| 335.1<br>1.4 | **SILTY SAND to GRAVELLY SAND (possible FILL)**<br>brown, moist, compact | 3 | SS | 10 | ▼* | 335 |
| 334.3<br>2.2 | **FINE SAND to SILTY SAND**<br>some gravel, grey, wet<br>loose<br>------------<br>compact | 4 | SS | 4 | | 334 |
| | | 5 | SS | 24 | | 333 |
| 332.8<br>3.7 | **SAND & GRAVEL**<br>trace silt, wet<br>compact<br>--------------<br>very dense | 6 | SS | 29 | | 332 |
| 331.8<br>4.7 | | 7 | SS | 50/15 | | |

End of borehole.

* Water level in open borehole at 2.0 m (El. 334.5m) upon completion (not stabilized).

Borehole caved at 4.3 m upon completion.

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT $w$, LIQUID LIMIT $w_L$; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

# RECORD OF BOREHOLE No C11-RW3



**METRIC**

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+745, 8m Rt C/L | ORIGINATED BY NH

DIST | HWY 6 | BOREHOLE TYPE Solid Stem Augers & Hollow Stem Augers | COMPILED BY XS

DATUM Geodetic | DATE 11/10/2006 | CHECKED BY FS

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 336.7 | | | | | | |
| 336.4 / 0.0 | 0.3 m **TOPSOIL** | 1 | SS | 12 | | |
| 0.3 | **FILL: Silty Sand to Fine Sand** some gravel, trace clay, dark brown to greyish brown, compact; moist ------- wet | 2 | SS | 21 | ▼* | |
| | | 3 | SS | 14 | | wet spoon |
| 334.3 / 2.4 | trace topsoil; **SAND & GRAVEL** some to trace silt, greyish brown, wet, compact to very dense | 4 | SS | 15 | | |
| | | 5 | SS | 26 | | combined SS5 + SS6: 59 35 (6) |
| | | 6 | SS | 34 | | |
| | | 7 | SS | 23 | | |
| | | 8 | SS | 84 | | borehole caved-in; hollow stem auger used |
| 330.2 | | 9 | SS | 40 | | |
| 6.6 | End of borehole. | | | | | |

Elevation scale: 336, 335, 334, 333, 332, 331

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● POCKET PENETR., × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT $w_P$ — NATURAL MOISTURE CONTENT $w$ — LIQUID LIMIT $w_L$

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

* Water level in open borehole at 1.5 m (El. 335.2 m) upon completion (not stabilized).

Borehole caved at 4.7 m.

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-RW4 1 OF 1 METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 11+745, 6.2m Lt C/L ORIGINATED BY JL

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/13/2006 CHECKED BY FS

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 336.9 | | | | | | | |
| 336.8<br>0.1 | 0.1 m **TOPSOIL** | | | | | | |
| | **FILL: Sand & Gravel**<br>compact<br>------------<br>loose<br>greyish brown, damp | 1 | SS | 25 | | | |
| | | 2 | SS | 9 | | 336 | |
| 335.4<br>1.5 | **SILTY SAND to FINE SAND (possible FILL)**<br>some gravel, grey, wet, compact | 3 | SS | 23 | ▼* | 335 | |
| 334.7<br>2.1 | **SAND & GRAVEL**<br>trace silt<br>greyish brown, wet | 4 | SS | 31 | | 334 | |
| | | 5 | SS | 40 | | 333 | |
| | medium sand interlayer<br>dense<br>-------- | 6 | SS | 42 | | | 45 49 (6) |
| | compact<br>------------ | 7 | SS | 21 | | 332 | |
| | very dense | 8 | SS | 50/10 | | 331 | |
| 330.8<br>6.0 | | 9 | SS | 50/8 | | | |
| | End of borehole.<br><br>* Water level in open borehole at 1.7 m (El. 335.2 m) upon completion (not stabilized). | | | | | | |

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE; 20 40 60 80 100

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

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-D1



**METRIC**

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+625, 18.3m Rt, C/L | ORIGINATED BY ZI
DIST | HWY 6 | BOREHOLE TYPE Hand Drilling | COMPILED BY XS
DATUM Geodetic | DATE 12/6/2006 | CHECKED BY FS

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES** | GROUND WATER CONDITIONS | ELEVATION SCALE | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|
| 336.4 | | | | | | | | | |
| 0.0 | 0.8 m **PEATY TOPSOIL** black, with sand pockets | 1 | SS | 2 | ▼* | 336 | | | spoon wet |
| 335.6 / 0.8 | **ALLUVIAL SILT & FINE SAND** some rootlets brown to grey, wet, compact | 2 | SS | 17 | | | | | |
| 335.2 / 1.2 | **SAND & GRAVEL** trace to some silt occasional cobbles / boulders brown, oxidised, wet, compact to dense | 3 | SS | 24 | | 335 | | | 29 51 (20) |
| | | 4 | SS | 48 | | 334 | | | |
| 333.9 / 2.4 | End of Borehole. | | | | | | | | |

*Water level at 0.2 m (El. 336.2 m, not stabilized) and hole open to full depth upon completion.

**Equivalent N- value

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE
PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT $w$, LIQUID LIMIT $w_L$

+ ³, × ³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

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# RECORD OF BOREHOLE No C11-D2



**METRIC**

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 11+675, 14.5m Rt, C/L ORIGINATED BY ZI

DIST HWY 6 BOREHOLE TYPE Hand Drilling COMPILED BY XS

DATUM Geodetic DATE 12/5/2006 CHECKED BY FS

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES** | GROUND WATER CONDITIONS | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---|---|---|---|---|---|---|---|---|
| 335.9 | | | | | | | | |
| 335.6 / 0.0 | 0.3 m **PEATY TOPSOIL** | 1 | SS | 2 | | | | |
| 0.3 | **ALLUVIAL SILT & FINE SAND** organic content --------------------- brown to grey, wet, very loose to loose | 2 | SS | 8 | ▼* | 335 | | spoon wet |
| 334.7 / 1.2 | **SAND & GRAVEL** some / trace silt occasional cobbles / boulders oxidised brown, wet compact to very dense | 3 | SS | 17 | | | | |
| | | 4 | SS | 54 | | 334 | | |
| 333.5 / 2.4 | End of Borehole. | | | | | | | |

*Water level at 0.9 m (El. 335.0 m, not stabilized) and hole open to full depth upon completion.

**Equivalent N- value

Dynamic cone penetration resistance plot: 20 40 60 80 100. Shear strength kPa: ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE; 20 40 60 80 100. Plastic limit $w_P$, natural moisture content $w$, liquid limit $w_L$; water content (%) 10 20 30. Unit weight $\gamma$ kN/m$^3$. GR SA SI CL.

+ 3, × 3: Numbers refer to Sensitivity; 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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Ontario



SPT1174

# RECORD OF BOREHOLE No C11-D3



**METRIC**

GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+775, 8m Rt, C/L | ORIGINATED BY ZI

DIST | HWY 6 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY HL

DATUM Geodetic | DATE 11/9/2006 | CHECKED BY FS

| ELEV DEPTH | DESCRIPTION (SOIL PROFILE) | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 336.7 | | | | | | | |
| 336.4 / 0.0 | 0.3 m **TOPSOIL** | | | | | | |
| 0.3 | **SAND & GRAVEL (possible FILL)** | 1 | SS | 8 | | | |
| 336.1 / 0.6 | **PEATY ORGANIC SILT** with rootlets, wood pieces & sand lenses black to greyish brown, wet loose | | | | | 336 | |
| | | 2 | SS | 8 | | | |
| | | 3 | SS | 5 | | 335 | |
| 334.5 / 2.2 | **ALLUVIAL SILTY FINE SAND** with soft clay seams greyish brown, wet compact | | | | ▼* | | spoon wet |
| | | 4 | SS | 17 | | 334 | |
| 333.7 / 3.0 | **SAND & GRAVEL** trace silt, with cobbles/boulders brown, wet | 5 | SS | 56 | | | |
| | | | | | | 333 | |
| | | 6 | SS | 53 | | | |
| | very dense | | | | | 332 | |
| | dense to compact | | | | | | |
| 331.2 | | 7 | SS | 29 | | | |
| 5.5 | End of Borehole. | | | | | | |

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT $w_P$ — NATURAL MOISTURE CONTENT $w$ — LIQUID LIMIT $w_L$

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

End of Borehole.

* Water level at 2.2 m (El. 334.5 m) and hole open to full depth upon completion (not stabilized).

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C11-D4



**METRIC**

| | | | |
|---|---|---|---|
| GWP 338-97-00 | LOCATION Hwy 6, Durham - Sta. 11+825, 9.6m Rt, C/L | ORIGINATED BY ZI |
| DIST | HWY 6 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY XS |
| DATUM Geodetic | | DATE 11/13/2006 | CHECKED BY FS |

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|
| 337.7 | | | | | | | | |
| 337.6 / 0.0 | 0.15 m **TOPSOIL** | | | | | | | |
| 0.2 | **SAND & GRAVEL (possible FILL)** | 1 | SS | 18 | | | | |
| 337.0 / 0.7 | **SAND & GRAVEL** trace silt brown to greyish brown, wet dense to very dense | 2 | SS | 50/13 | | 337 | | 57 34 (9) |
| | | 3 | SS | 50/13 | ▼* | 336 | | |
| | | 4 | SS | 35 | | 335 | | |
| | | 5 | SS | 50/15 | | | | |
| | | 6 | SS | 39 | | 334 | | |
| 333.1 / 4.6 | | ~~7~~ | ~~SS~~ | ~~50/0~~ | | | | spoon bouncing on a possible boulder (no sample recovery) |

End of Borehole.

* Water level at 2.2 m (El. 335.5 m, not stabilized) and hole open to full depth upon completion.

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT $w_P$ — NATURAL MOISTURE CONTENT $w$ — LIQUID LIMIT $w_L$; WATER CONTENT (%) 10 20 30

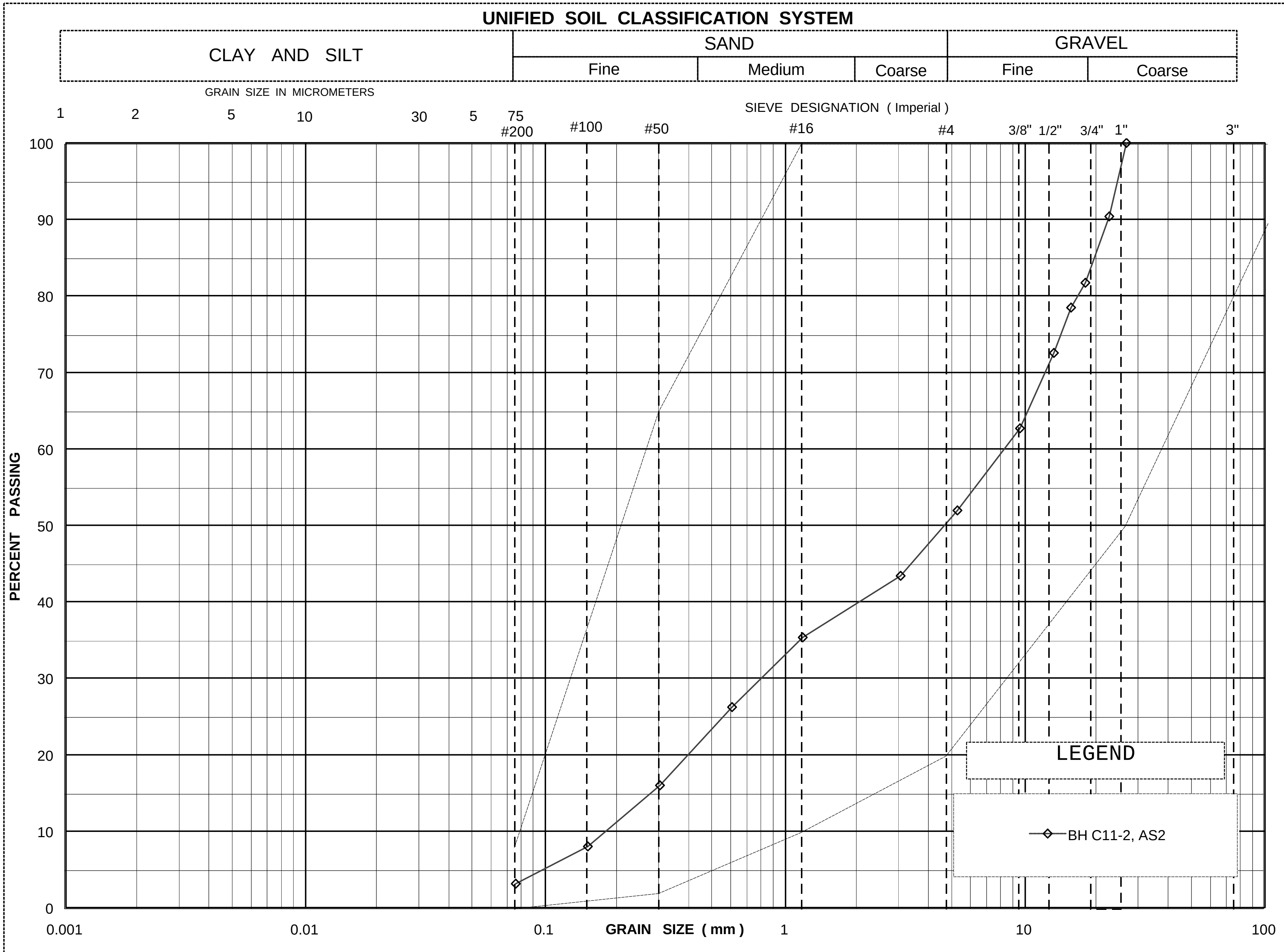
UNIT WEIGHT γ kN/m³

+ ³, × ³: Numbers refer to Sensitivity

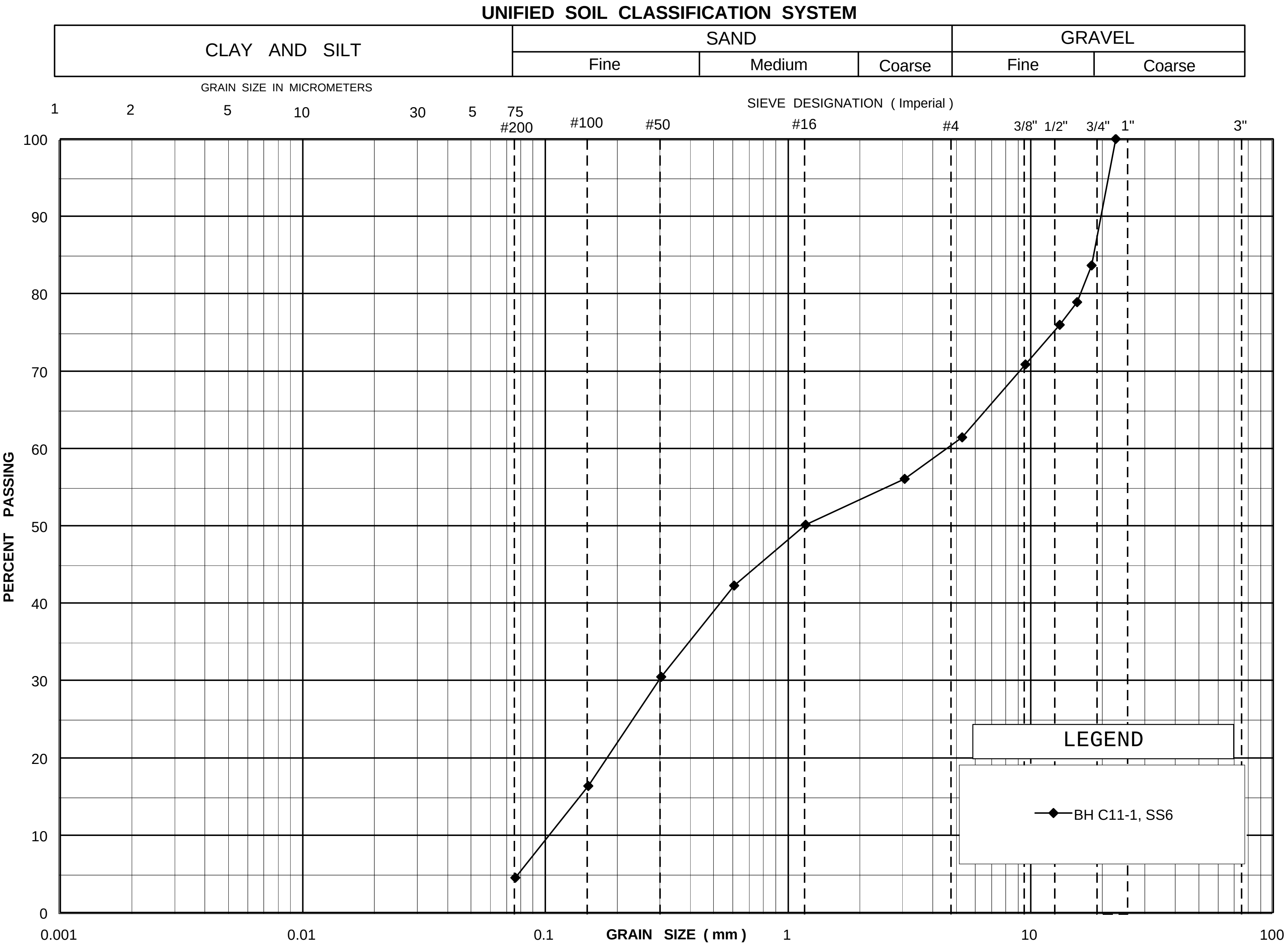
20 / 15 5 / 10 (%) STRAIN AT FAILURE

# Appendix B

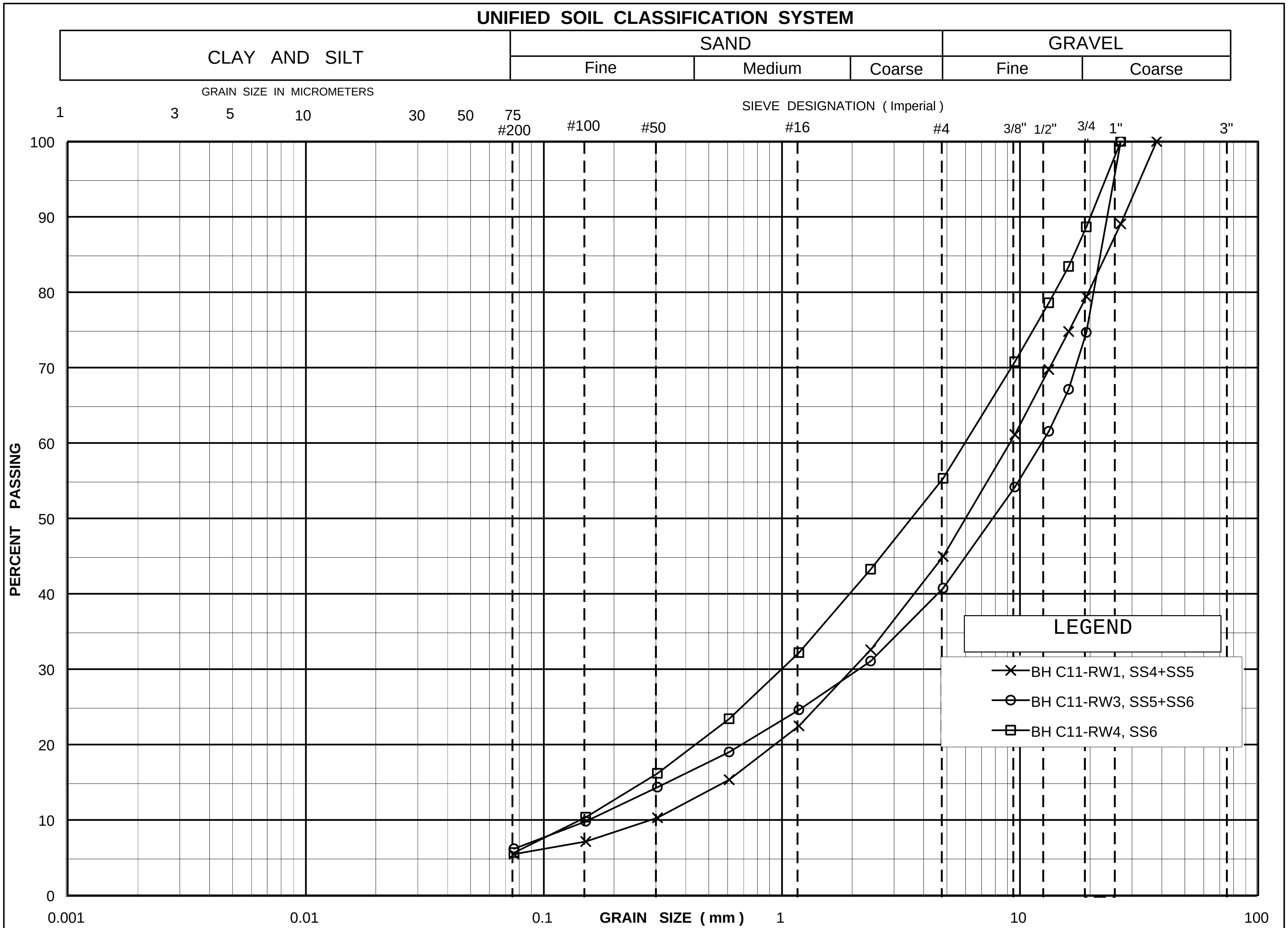
# Laboratory Test Results



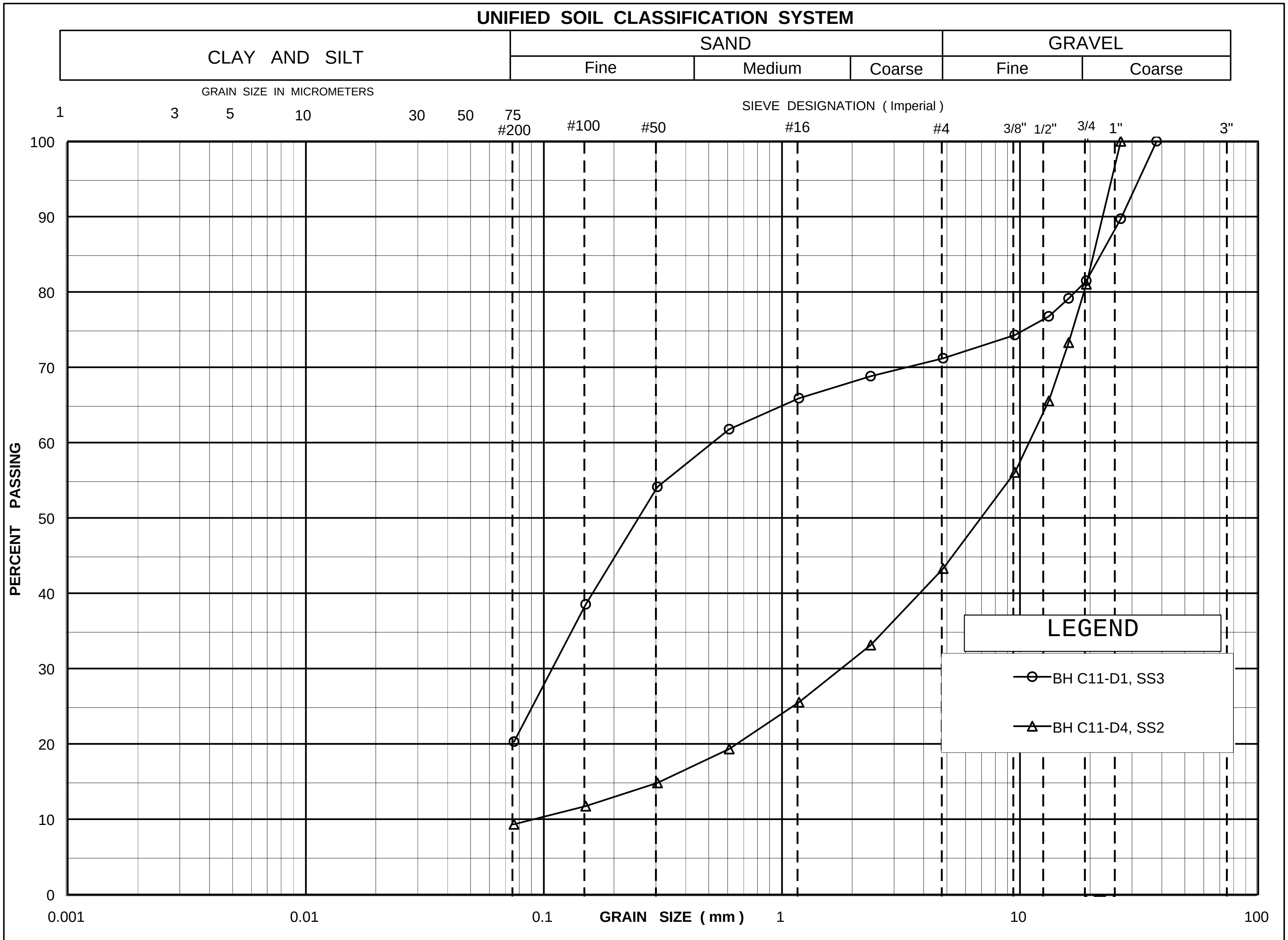

| | | |
|---|---|---|
| SHAHEEN & PEAKER LIMITED | GRAIN SIZE DISTRIBUTION<br>FILL: Gravelly Sand | FIGURE No. B11-1<br>G. W. P. 338-97-00<br>REF. No. SPT 1174 |




| | | |
|---|---|---|
| SHAHEEN & PEAKER LIMITED | GRAIN SIZE DISTRIBUTION<br>Gravelly Sand | FIGURE No. B11-2<br>G. W. P. 338-97-00<br>REF. No. SPT 1174 |




| | | |
|---|---|---|
| SHAHEEN & PEAKER LIMITED | GRAIN SIZE DISTRIBUTION<br>SAND & GRAVEL | FIGURE No. B11-3<br>G. W. P. 338-97-00<br>REF. No. SPT 1174 |




| | | |
|---|---|---|
| SHAHEEN & PEAKER LIMITED | GRAIN SIZE DISTRIBUTION<br>SAND & GRAVEL | FIGURE No. B11-4 |
| | | G. W. P. 338-97-00 |
| | | REF. No. SPT 1174 |

# Appendix C

# Explanation of Terms Used in Report

# EXPLANATION OF TERMS USED IN REPORT

N-VALUE: THE STANDARD PENETRATION TEST (SPT) N-VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N-VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N-VALUE IS DENOTED THUS $\overline{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ($c_u$) AS FOLLOWS:

| $C_u$ (kPa) | 0 – 12 | 12 – 25 | 25 – 50 | 50 – 100 | 100 – 200 | >200 |
|---|---|---|---|---|---|---|
| | *VERY SOFT* | *SOFT* | *FIRM* | *STIFF* | *VERY STIFF* | *HARD* |

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

| N (BLOWS/0.3m) | 0 – 5 | 5 – 10 | 10 – 30 | 30 – 50 | >50 |
|---|---|---|---|---|---|
| | *VERY LOOSE* | *LOOSE* | *COMPACT* | *DENSE* | *VERY DENSE* |

ROCKS ARE DESCRIBED BY THEIR COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

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

JOINT AND BEDDING:

| SPACING | 50mm | 50 – 300mm | 0.3m – 1m | 1m – 3m | >3m |
|---|---|---|---|---|---|
| JOINTING | *VERY CLOSE* | *CLOSE* | *MOD. CLOSE* | *WIDE* | *VERY WIDE* |
| BEDDING | *VERY THIN* | *THIN* | *MEDIUM* | *THICK* | *VERY THICK* |

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

| | | | |
|---|---|---|---|
| SS | SPLIT SPOON | TP | THINWALL PISTON |
| WS | WASH SAMPLE | OS | OSTERBERG SAMPLE |
| ST | SLOTTED TUBE SAMPLE | RC | ROCK CORE |
| BS | BLOCK SAMPLE | PH | TW ADVANCED HYDRAULICALLY |
| CS | CHUNK SAMPLE | PM | TW ADVANCED MANUALLY |
| TW | THINWALL OPEN | FS | FOIL SAMPLE |

### STRESS AND STRAIN

| | | |
|---|---|---|
| $u_w$ | kPa | PORE WATER PRESSURE |
| $r_u$ | 1 | PORE PRESSURE RATIO |
| $\sigma$ | kPa | TOTAL NORMAL STRESS |
| $\sigma'$ | kPa | EFFECTIVE NORMAL STRESS |
| $\tau$ | kPa | SHEAR STRESS |
| $\sigma_l, \sigma_2, \sigma_3$ | kPa | PRINCIPAL STRESSES |
| $\varepsilon$ | % | LINEAR STRAIN |
| $\varepsilon_1, \varepsilon_2, \varepsilon_3$ | % | PRINCIPAL STRAINS |
| E | kPa | MODULUS OF LINEAR DEFORMATION |
| G | kPa | MODULUS OF SHEAR DEFORMATION |
| $\mu$ | 1 | COEFFICIENT OF FRICTION |

### MECHANICALL PROPERTIES OF SOIL

| | | |
|---|---|---|
| $m_v$ | $kPa^{-1}$ | COEFFICIENT OF VOLUME CHANGE |
| $c_c$ | 1 | COMPRESSION INDEX |
| $c_s$ | 1 | SWELLING INDEX |
| $c_a$ | 1 | RATE OF SECONDARY CONSOLIDATION |
| $c_v$ | $m^2/s$ | COEFFICIENT OF CONSOLIDATION |
| H | m | DRAINAGE PATH |
| $T_v$ | 1 | TIME FACTOR |
| U | % | DEGREE OF CONSOLIDATION |
| $\sigma'_{vo}$ | kPa | EFFECTIVE OVERBURDEN PRESSURE |
| $\sigma'_p$ | kPa | PRECONSOLIDATION PRESSURE |
| $\tau_f$ | kPa | SHEAR STRENGTH |
| c' | kPa | EFFECTIVE COHESION INTERCEPT |
| $\phi'$ | $-^o$ | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| $c_u$ | kPa | APPARENT COHESION INTERCEPT |
| $\phi_u$ | $-^o$ | APPARENT ANGLE OF INTERNAL FRICTION |
| $\tau_R$ | kPa | RESIDUAL SHEAR STRENGTH |
| $\tau_r$ | kPa | REMOULDED SHEAR STRENGTH |
| $S_t$ | 1 | SENSITIVITY = $c_u / \tau_r$ |

## PHYSICAL PROPERTIES OF SOIL

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $P_s$ | $kg/m^3$ | DENSITY OF SOLID PARTICLES | e | 1,% | VOID RATIO | $e_{min}$ | 1,% | VOID RATIO IN DENSEST STATE |
| $i_s$ | $kN/m^3$ | UNIT WEIGHT OF SOLID PARTICLES | n | 1,% | POROSITY | $I_D$ | 1 | DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$ |
| $P_w$ | $kg/m^3$ | DENSITY OF WATER | w | 1,% | WATER CONTENT | D | mm | GRAIN DIAMETER |
| $i_w$ | $kN/m^3$ | UNIT WEIGHT OF WATER | $s_r$ | % | DEGREE OF SATURATION | $D_n$ | mm | N PERCENT – DIAMETER |
| $P$ | $kg/m^3$ | DENSITY OF SOIL | $w_L$ | % | LIQUID LIMIT | $C_u$ | 1 | UNIFORMITY COEFFICIENT |
| $i$ | $kN/m^3$ | UNIT WEIGHT OF SOIL | $w_P$ | % | PLASTIC LIMIT | h | m | HYDRAULIC HEAD OR POTENTIAL |
| $P_d$ | $kg/m^3$ | DENSITY OF DRY SOIL | $w_s$ | % | SHRINKAGE LIMIT | q | $m^3/s$ | RATE OF DISCHARGE |
| $i_d$ | $kN/m^3$ | UNIT WEIGHT OF DRY SOIL | $I_P$ | % | PLASTICITY INDEX = $(W_L - W_L)$ | v | m/s | DISCHARGE VELOCITY |
| $P_{sat}$ | $kg/m^3$ | DENSITY OF SATURATED SOIL | $I_L$ | 1 | LIQUIDITY INDEX = $(W - W_P)/ I_P$ | i | 1 | HYDAULIC GRADIENT |
| $i_{sat}$ | $kN/m^3$ | UNIT WEIGHT OF SATURATED SOIL | $I_C$ | 1 | CONSISTENCY INDEX = $(W_L - W) / 1_P$ | k | m/s | HYDRAULIC CONDUCTIVITY |
| $P'$ | $kg/m^3$ | DENSITY OF SUBMERED SOIL | $e_{max}$ | 1,% | VOID RATIO IN LOOSEST STATE | j | $kN/m^3$ | SEEPAGE FORCE |
| $i'$ | $kN/m^3$ | UNIT WEIGHT OF SUBMERGED SOIL | | | | | | |

# Appendix D

# Site Photographs

Photo (1): Culvert C11 at Station 11+736 on Highway 6, East End

Photo (2): Highway 6 at Station 11+736 (Culvert C11), Facing North

**FOUNDATIONS DESIGN REPORT**
**PROPOSED KEMP CREEK CULVERT (C11)**
**REPLACEMENT AT STATION 11+737 ON**
**HIGHWAY 6 SOUTH OF DURHAM**
**SOUTH OF TOWN LIMITS AND**
**NORTH OF GREY COUNTY ROAD 9, ONTARIO**
**G.W.P. 338-97-00**
**SITE NO. 8-450/C**

**GEOCRES NO. 41A-196**

**Prepared For:**

**UMA/AECOM ENGINEERING LIMITED**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1174E**
**January 15, 2008**

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**FOUNDATION DESIGN REPORT**
**PROPOSED KEMP CREEK CULVERT (C11) REPLACEMENT**
**AT STATION 11+737 ON HIGHWAY 6**
**SOUTH OF DURHAM SOUTH TOWN LIMITS AND**
**NORTH OF GREY COUNTY ROAD 9, ONTARIO**
**G.W.P. 338-97-00; SITE NO. 8-450/C**

## 5. DISCUSSION AND RECOMMENDATIONS

As part of the rehabilitation of Highway 6, Kemp Creek Culvert (C11) at Station 11+737 on Highway 6 is proposed to be replaced, which also involves the construction of retaining walls/wing walls and associated detour.

### 5.1 KEMP CREEK CULVERT REPLACEMENT

The existing open bottom concrete culvert at Sta 11+737 (Kemp Creek Culvert) is a 20.6 m long, 3.5 m wide and 1.2 m high structure. The invert elevation of the existing culvert is at 334.95 m (upstream) to 334.77 m (downstream). The existing structure will be replaced with a larger (wider and higher) pre-cast concrete (open bottom) structure with slightly higher crown. The new structure will measure about 12.2 m wide and 2.1 m high (inside dimensions) with cast-in-place concrete footings at about El. 333.6 (on the east side) and at about El. 333.5 m (on the west side). The existing culvert will provide drainage during the construction after which it will be removed.

Boreholes C11-1, C11-2 and C11-3 put down for this culvert replacement contacted, below some fill and topsoil/organic soils, a major deposit of gravelly sand with occasional cobbles and possible boulders to the termination of the boreholes. Standard penetration test results in this deposit indicated a generally dense to very dense condition. The measured groundwater level near the ends of the existing culvert at the time of our investigation ranged from about 0.3 to 1.1 m below the ground surface or between El. 335.5 and 334.6 m. The groundwater level is subject to seasonal fluctuations and fluctuations in response to major weather events.

The native undisturbed gravelly sand deposit encountered at the site is suitable to support any type of culvert desired (CSP, concrete box or open bottom culvert). Since the open bottom culvert has been selected in design, this option will be discussed in the following sections.

We recommend that all bearing surfaces should be inspected and approved by a qualified Geotechnical Engineer (QVE).

It is recommended that an allowance be made to pour, as directed by the Geotechnical Engineer (QVE), a 100 mm thick layer of lean concrete (mud mat) on foundation bearing surfaces as soon as possible after excavation and approval.

### 5.1.1 CULVERT FOUNDATIONS

The boreholes show that the gravely sand deposit in its undisturbed state is suitable to support the proposed open bottom structure.

The following table summarizes the recommended highest founding depths/elevations at the borehole locations.

Table 5.1.1

| Borehole No. | Existing Ground Surface Elevation (m) | Recommended Highest Founding Level (Bottom of Footing) m | Elevation * (m) | Subgrade Material |
|---|---|---|---|---|
| C11-1 | 336.6 | 2.6 | 334.0 | compact to very dense gravelly sand |
| C11-2 | 336.9 | 3.0 | 333.6 | compact to very dense gravelly sand |
| C11-3 | 334.9 | 1.7 | 333.2 | Dense to very dense gravelly sand |

* Frost and scour depths need to be considered when choosing the footing elevations.

The following geotechnical resistances can be used for footings to be placed on undisturbed, competent gravelly sand, placed at or below the depths detailed in Table 5.1.1.

Bearing Resistance at ULS: 360 kPa
Factored Geotechnical Resistance at SLS: 240 kPa

Provided that the bearing subgrade is not unduly disturbed during the construction, with the recommended serviceability resistance value, the total and differential settlements should be less than 25 mm and 20 mm, respectively. As will be discussed in Section 5.1.3 of this report, good construction techniques including dewatering will be required to achieve this. As the groundwater level can be expected to be up to 2 m above the proposed culvert footing at about El. 333.5 m, careful construction techniques will be required to facilitate the construction to ensure that the bearing subsoil is undisturbed.

It should also be pointed out that Boreholes RW2 and RW3 drilled close to Boreholes C11-2 and C11-3, on the east side of the highway, show relatively less favourable conditions (including a fine sand to silty sand deposit in Borehole RW2, which is very loose to an elevation of about 333.5 m). For this reason, the footing excavations and bearing surfaces must be checked, evaluated and approved by a Geotechnical Engineer who is familiar with the findings of this investigation.

Frost and scour depths need to be considered when choosing the footing elevations.

Under inclined loading conditions, the bearing resistance at ULS should be reduced in accordance with Clause 6.7.4 of the CHBDC (Canadian Highway Bridge Design Code – CAN/SCA-S6-06).

The unfactored horizontal resistance against sliding between poured concrete and approved gravelly sand surface can be calculated using a friction angle of 30 degrees, although lateral resistance is unlikely to be a problem for culvert foundation.

#### 5.1.2 BACKFILLING AND LATERAL EARTH PRESSURES

Backfilling for the culvert and retaining walls replacements should consist of suitable free-draining granular materials, compacted in accordance with the MTO standards and should conform to the applicable OPSD such as OPSD-803.01. For fills below the groundwater level or immediately below the roadway, it is recommended that Granular ‘A’ or ‘B’ materials be used. Where necessary, proper tapering as per MTO standards should be provided. The fill should be compacted in shallow lifts, not exceeding 200 mm loose thickness, to at least 98% of the material’s Standard Proctor Maximum Dry Density (SPMDD). The Granular ‘A’ or ‘B’ materials should be compacted to 100% of their SPMDD’s. To avoid damaging or laterally dislocating the structure, care should be exercised when compacting fill adjacent to and immediately on top of the culvert and retaining wall structures. Compaction equipment should be restricted in size as per Ontario Ministry of Transportation (MTO) convention to prevent structural damage to the culvert. The backfilling operation should be carried out simultaneously on both sides of the culvert as per MTO specifications.

Backfill behind any retaining (wing) walls should consist of Granular ‘B’ type materials in accordance with the MTO Standards. Free draining backfill materials, weepholes, etc. should be provided in order to prevent hydrostatic build-up, as shown on OPSD-3101.150.

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with CHDBC. For design purposes, the following properties can be assumed for backfill.

**Compacted Granular ‘A’ or Granular ‘B’ Type II**

Angle of Internal Friction $\phi$=35° (unfactored)
Unit weight = 22 kN/$m^3$
Coefficient of Lateral Earth Pressure:

| Level Backfill | Backfill Sloping at 3H:1V | Backfill Sloping at 2H:1V |
|---|---|---|
| $K_a$=0.27 | $K_a$=0.34 | $K_a$=0.40 |
| $K_b$=0.35 | $K_b$=0.44 | $K_b$=0.50 |
| $K_o$=0.43 | $K_o$=0.56 | $K_o$=0.62 |
| K*=0.45 | K*=0.60 | K*=0.66 |

**Compacted Granular 'B' Type I**

Angle of Internal Friction $\phi$=30° (unfactored)
Unit Weight = 21 kN/m$^3$
Coefficient of Lateral Earth Pressure:

| Level Backfill | Backfill Sloping at 3H:1V | Backfill Sloping at 2H:1V |
|---|---|---|
| $K_a$=0.33 | $K_a$=0.42 | $K_a$=0.54 |
| $K_b$=0.41 | $K_b$=0.52 | $K_b$=0.64 |
| $K_o$=0.50 | $K_o$=0.66 | $K_o$=0.76 |
| K*=0.57 | K*=0.74 | K*=0.86 |

Note: $K_a$ is the coefficient of active earth pressure
$K_b$ is the backfill earth pressure coefficient for an unrestrained structure including compaction efforts
$K_o$ is the coefficient of earth pressure at rest
K* is the earth pressure coefficient for a soil loading a fully restrained structure and includes compaction effects

These values are based on the assumption that the backfill behind the retaining structure is free-draining granular material and adequate drainage is provided.

The earth pressure coefficient adopted will depend on whether the retaining structure is restrained or some movement can occur such that the active state of earth pressure can develop. The effect of compaction should also be taken into account in the selection of the appropriate earth pressure coefficients. The use of vibratory compaction equipment behind the culvert and the retaining walls should be restricted in size as per current MTO practice.

As an alternative to conventional retaining walls, consideration could be given to MTO's Retained Soil System in which case the designer will have to include the geometric, performance and appearance requirements (i.e: medium performance and low to medium appearance).

#### 5.1.3 CONSTRUCTION

The excavation should be carried out in accordance with the Safety Regulations of the Province (i.e. Occupational Health and Safety Act O. Reg 213/91), as well as the following Ontario Provincial Standard Specifications (OPSS):

SP105 S19 – Construction Specification for Temporary Protection Systems
SP902 S01 – Construction Specification for Excavating and Backfilling - Structures

The boreholes show that the excavations for the construction of the culvert and retaining walls can be expected to extend through topsoil and basically granular embankment fill (gravelly sand and sandy silt, or silty sand to fine sand), and other underlying organic silts, into the native gravelly sand/sand & gravel deposit. These soils can be classified as follows:

| | |
|---|---|
| Granular Pavement Fill | Type 2 soil (above water level) |
| Sandy Silt/silty sand to fine sand Fill | Type 3 soil (above water level) |
| | Type 4 below water level |
| Topsoil and Organic Rich Soils | Type 3 above water level |
| | Type 4 below water level |
| Gravelly Sand/Sand & Gravel | Type 2 above water level |
| | Type 3 below water level |

Considering the proposed footing elevations, dewatering will likely be required to stabilize the soil and to prevent its disturbance due to excavation. It is our opinion that the groundwater level can be lowered by up to about 0.5 m by means of gravity drainage and pumping from strategically located filtered sumps. Depending on the groundwater conditions at the time of construction, closely spaced deep filtered sumps may be required if deeper water level lowering is required. For more than about 0.8 m water lowering well points or deep wells may be required. For this reason, we recommend that, if possible, the construction be carried out during a dry period. If deep wells and/or well points are required, the presence of cobbles or boulders (i.e. refusal to augering) encountered in all three boreholes should be taken into consideration. If necessary, this could consist, in addition to an above ground coffer dam, of an impervious clay trench barrier (i.e. similar to a slurry wall) or driven tight-interlocking steel sheet piling to reduce below ground water flow into the work area.

We recommend that the water flow in the existing watercourse be diverted away from the culvert so that the construction can be carried out in sufficiently dry conditions. Alternatively, the existing culvert can remain in place during the construction of the new culvert and be removed after the completion of the new culvert. As the soil types at the site are typically pervious soils (i.e. have relatively high coefficient of permeability) an underground impervious barrier(s) may need to be constructed to prevent flowing water from the water course from entering the excavation site, depending on the conditions at the time of the construction.

If weak, organic or otherwise unsuitable soils are encountered at the foundation subgrade level, they should be removed and replaced with lean concrete or Granular 'A' type material compacted to not less than 100% of the material's Standard Proctor Maximum Dry Density (SPMDD). In this instance, because of the high water table, the use of lean concrete is recommended to raise the foundation grades. All founding subgrades should be inspected and evaluated by the Quality Verification Engineer (QVE) at the time of construction. The dewatering should be continued until the footings are fully constructed and sufficiently backfilled to avoid an uplift condition. The contract documents should include adequate wording (NSSP) to warn/flag the contractor about the presence of cobbles and boulders encountered during the field investigation.

It is expected that temporary shoring will be required to support the excavations. Locally, temporary shoring systems generally consist of support provided by conventional soldier piles and timber lagging. Alternatively, sheet piling is normally considered to provide temporary support for the excavation and retard the potential ground water flow towards the base of the footings. However, considering the anticipated gravelly nature of the subgrade and potential presence of cobbles and boulders below the proposed footing levels at this site, this option may be difficult to implement.

Shoring system should be designed so that the lateral movement of any portion of the roadway protection system will not exceed the established criterion for the structural performance level. In this case, a performance level of 2 is deemed to be required. The coefficient of lateral earth pressures given in Table 5.1.3 can be used for the design of the temporary shoring system.

Table 5.1.3
Recommended Unfactored Parameters for Temporary Shoring Design

| **Soil Type** | **$K_a$** | **$K_o$** | **$K_p$** | **Unit Weight ($kN/m^3$)** |
|---|---|---|---|---|
| Granular Embankment Fill | 0.30 | 0.45 | 3.3 | 21.0 |
| Silt/Silty Sand to Fine Sand Fill | 0.36 | 0.53 | 2.8 | 18.5 |
| Organic Topsoil | 0.41 | 0.58 | 2.4 | 15.0 |
| Gravelly Sand/Sand & Gravel | 0.27 | 0.43 | 3.7 | 21.5 |

### 5.1.4 EROSION PROTECTION

Erosion and scour protection should be provided at the culvert inlet and outlet, including the side slopes, as well as inside the open bottom culvert. The design should be carried out by a specialist River Engineer/Scientist who is familiar with the findings of this investigation. The following are therefore some possible suggestions only and the actual design requirements will depend on such considerations as water velocity, creek regime, fish habitat, etc.

The boreholes show the presence of a gravelly sand to sand & gravel deposit underlying some surficial alluvial and/or organic soils. While the surficial alluvial or recent organic deposits are considered highly erodible, the gravelly sand to sand & gravel is not. But this too depends on the anticipated water velocities, etc., as mentioned above. The gravelly sand to sand & gravel is considered to be a relatively pervious soil type. Typically, erosion and scour protection, provided at the culvert inlet and outlet (including the side slopes), consists of concrete cut-off (apron walls) and head walls, to prevent seepage and scour beneath the culvert and around the culvert (including the granular backfill).

Consideration may be given to the use of clay seal at the inlet in lieu of or in addition to the concrete cut-off walls and head walls, to ensure that the flow in the channel is through the culvert itself and not around the structure through the granular backfill or through the relatively pervious soils (i.e. sand & gravel) around or underneath the structure. The clay seal must therefore be continuous and it should be at least 0.6 m thick. It should comply with the material specifications given in OPSS 1205. It should extend across the creek bed up to the side slopes in a continuous manner, a distance of at least 0.5 m above the high water level. It should be protected by providing a 0.6 m thick rock protection over it. This system must extend to cover all the granular backfill to prevent seepage through them. It should be extended a suitable distance beyond the culvert inlet (typically 9 m).

In addition to concrete cut-off and head walls, rock protection will likely be necessary at the outlet and also at the inlet (if clay seal is not used). The rock protection generally consists of 0.6 m thick 300 mm rock placement. The rock is typically separated from the underlying natural granular soil by a suitable geotextile. This extends a suitable distance beyond the inlet and the outlet (e.g. 9 m). The protection is generally extended to at least 0.3 m above the high water level in the creek. Similar protection scheme(s) will need to be considered inside the open bottom culvert. Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

## 5.2 RETAINING WALLS/WINGWALLS

### 5.2.1 FOUNDATIONS

The borehole data (i.e., C11-RW1, C11-1 and C11-RW4 on the left side of the highway; C11-RW2, C11-2, C11-3 and C11-RW3 on the right side of the highway) show that the native granular deposits (below some topsoil and fill) in their undisturbed conditions are suitable to support the proposed retaining walls/wingwalls on both ends of the new culvert.

Table 5.2.1.1 summarizes the recommended highest founding depths/elevations at the retaining wall/wingwalls borehole locations (C11-RW1 through C11-RW4). The recommended highest founding depths/elevations at the location of Boreholes C11-1 and C11-3 were presented earlier in Table 5.2.1.

Table 5.2.1.
Recommended Geotechnical Resistance Values

| Borehole No./Elevations (m) | Re-commended Highest Founding Level (Bottom of Footing) m | Elevation (m) | Re-commended Factored Geotechnical Resistance ULS (kPa) | Re-commended Bearing Resistance at SLS (kPa) | Subgrade Material |
|---|---|---|---|---|---|
| C11-RW1/<br>337.0 | 1.6*<br>2.0 | 335.4*<br>335.0 | 300<br>300 | 200<br>200 | compact to v. dense sand & gravel<br>compact to v. dense sand & gravel |
| C11-RW2/<br>336.5 | 3.0 | 333.5 | 300 | 200 | compact to v. dense fine sand to silty sand |
| C11-RW3/<br>336.7 | 2.4<br>2.9 | 334.3<br>333.8 | 240<br>300 | 150<br>200 | compact sand & gravel<br>compact to dense sand & gravel |
| C11-RW4/<br>336.9 | 1.7*<br>2.2 | 335.2*<br>334.7 | 300<br>300 | 200<br>200 | compact to dense silty sand to fine<br>dense sand & gravel |

*If the soil at this level is confirmed to be native in the field, otherwise the lower founding level is recommended.

The geotechnical resistances given are applicable to undisturbed, native soils. Provided the soil is undisturbed during the construction, the total and differential settlements should not exceed 25 mm and 20 mm, respectively.

### 5.2.2 BACKFILLING AND LATERAL EARTH PRESSURES

For comments and recommendations on backfilling, lateral earth pressure and construction and refer to Section 5.1.2.

### 5.2.3 CONSTRUCTION

For general comments and recommendations on construction considerations, refer to Section 5.1.3.

## 5.3 DETOUR DURING CULVERT REPLACEMENT

It is our understanding that the proposed highway realignment and culvert replacement will involve raising the existing grade by up to 0.5 m and may also involve embankment widening for the highway detour during construction from around Sta 11+587 to 11+887, as shown on Drawing No. 11A.

The borehole data (C11-D1, C11-D2, C11-RW2, C11-3, C11-RW3, C11-D3 and C11-D4) show that below some topsoil the existing subsoil along the proposed embankment widening generally consists of mostly granular fill underlain by alluvial silt and sand and native sand and gravel deposits. Buried organic soils were also contacted underlying the fill (e.g. BH C11-D3).

We understand that the grade raise above the original grades (o.g.) will generally be less than 2.5 m and will not exceed 4 m. Based on this, and the conditions encountered in the boreholes, no foundation failures are anticipated for the proposed embankment widening with normal (2H:1V) side slopes, assuming that all organic or otherwise unsuitable materials will be removed as per MTO standards prior to placing the embankment fills.

The following table summarizes the stripping depths/elevations at the borehole locations.

Table 5.3.1
Anticipated Stripping Depths/Elevations

| Borehole No./ Elevations (m) | Anticipated Stripping Depth (m) | Elevation (m) |
|---|---|---|
| C11-D1/El. 336.4 | 0.8 | 335.6 |
| C11-D2/El.335.9 | 0.8 | 335.1 |
| C11-RW2/El. 336.5 | 0.3* | 336.2* |
| C11-3/El. 334.9 | 1.5 | 333.4 |
| C11-RW3/El. 336.7 | 0.3* | 336.4* |
| C11-D3/El. 336.7 | 2.2 | 334.5 |
| C11-D4/El337.7 | 0.2 | 337.5 |

*Drilled from top of existing fill and as such topsoil/organic soils may have been stripped (i.e. may not represent overall surficial o.g. conditions).

It should be pointed out at that the above table is for preliminary estimating purposes only and actual stripping depths must be verified and approved in the field by proper inspection by a qualified Geotechnical Engineer (QVE).

All organic and other unsuitable soils should be removed within an envelope area given by an imaginary slope not steeper than 1:1 from the toe of the proposed embankment widening, as per normal MTO procedures.

After stripping and inspection, the approved subgrade should be proofrolled from the surface using a suitably heavy compactor. Application of compaction below the water table may be difficult and may require some dewatering.

Where deep excavations are required, stripping and backfilling may need to be performed in short sections in order not to cause instability of the existing embankment. This aspect should be looked into, after the details are known.

The sides of the existing embankment should be properly benched prior to placing the fill for the widening of the approach embankments, as per Ontario Provincial Standards Drawing OPSD 208.01.

The fills should be placed in lifts not exceeding 300 mm before compaction and each lift should be uniformly compacted to at least 95% of the material's Standard Proctor Maximum Dry Density. The selection, placement and compaction of the fill should be carried out under geotechnical supervision.

All borrow materials for proposed embankment widening should be approved by the geotechnical consultant from both geotechnical and environmental standpoints. The borrow materials should consist of select suitable inorganic earth borrow, free of objectionable inclusions such as cobbles and boulders, frozen materials, organic soils, etc., at or near the optimum moisture content. The on-site excavated granular soils may be suitable for this purpose.

Assuming that properly compacted, acceptable inorganic earth fill materials are used for the approach slopes, 2H:1V side slopes can be used for embankment widening. Based on the borehole information, the natural soils and properly compacted fill (as discussed above) is expected to be stable at 2H:1V side slopes, provided that they are properly protected from erosion during construction. Proper erosion control measures should be implemented by prompt seed and cover (OPSS 572) or sodding (OPSS 571). The anticipated settlements depend on the height of embankments. For a typical embankment of 2.5 m above o.g., the anticipated foundation settlements should not exceed 30 mm, most of which should take place within a period of about 6 weeks. In addition to this, the embankment will settle under its own weight. This would depend on the materials used and compaction achieved but should typically not exceed 20 mm. Settlements of this magnitude (provided the site is properly stripped to be free of organic soils) are normally considered to be within acceptable limits.

If and where the suggested side slopes can not be accommodated due to space limitations, consideration may be given to the use of temporary shoring (as per Section 5.1.2), toe wall and/or reinforced slopes, as appropriate. In that case, further consultations are recommended.

## 5.4 FROST PROTECTION

Design frost protection for the general area is 1.6 m. Therefore, a permanent soil cover of 1.6 m or its thermal equivalent of artificial insulation is required for frost protection of foundations. In case of riprap (rock fill), only one-half of the rock fill thickness should be assumed to be effective in providing frost protection.

# 6. CLOSURE

We recommend that once the details of the culverts and retaining walls are finalized, our recommendations be reviewed for their specific applicability. The Limitations of Report, as quoted in Appendix E, are an integral part of this report.

**SHAHEEN & PEAKER LIMITED**

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ZO:tr/idrive

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# Appendix E

# Limitations of Report

# LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to Shaheen & Peaker Limited at the time of preparation. Unless otherwise agreed in writing by Shaheen & Peaker Limited, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

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 environment 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. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

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.

The comments made in this report on potential construction problems and possible methods 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.

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