

**FOUNDATION INVESTIGATION & DESIGN REPORTS  
PROPOSED CULVERT (C9)  
AT STATION 28+374 ON HIGHWAY 6  
SOUTH OF DURHAM SOUTH TOWN LIMITS AND  
NORTH OF GREY COUNTY ROAD 9, ONTARIO  
G.W.P. 338-97-00  
SITE 8-616/C**

**GEOCRES NO. 41A-194**

**Prepared For:**

**UMA/AECOM ENGINEERING LIMITED**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1174C  
January 15, 2008**



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SOUTH OF DURHAM SOUTH TOWN LIMITS AND  
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G.W.P. 338-97-00  
SITE 8-616/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 the proposed replacement of Culvert C9 at Station 28+374 with a new culvert and new retaining/wing walls.

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.

## **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 (343.7m) 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 the proposed culvert replacement at Station 28+374 (C9) consisted of a total of 3 boreholes to evaluate the subsurface conditions in the areas of the proposed culvert replacement and the associated retaining/wing walls construction.

The field investigation at this site was carried out during several periods from August 16 to November 14, 2006. The field investigation consisted of drilling and sampling of 3 boreholes along the proposed culvert replacement; one at each end of the culvert and one at the crest of the embankment for culvert replacement to a maximum of 6.3 m below the ground surface.

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. 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.

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

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

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, 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. 9B in Appendix B. The following paragraphs are only meant to complement and amplify these data.

##### **4.1 CULVERT C9**

The existing culvert at Station 28+375 is a 2134 x 1524 x 24.7 m CSPA culvert with an invert at about El. 334.1 to 334.5 m.

For the proposed culvert replacement at this location, three boreholes were drilled. Boreholes C9-1 and C9-3 were put down on the west (left) and east (right) sides of the highway close to the ends of the existing culvert, respectively. Borehole C9-2 was placed on the west side (left) shoulder of the highway, as shown on Site Plan and Soil Profile on Drawing Nos. 9A and 9B.

Borehole C9-2 which was drilled from the shoulder of the highway, immediately adjacent to the existing culvert location showed the presence of a silty sand fill with traces to some gravel, to a depth of 2.2 m or El. 334.3 m.

Borehole C9-1 which was put down beyond the toe of the embankment, contacted topsoil and organic silt to a depth of 0.7 m below the ground surface or to El. 333.5 m. Similarly, Borehole C9-3, which was located beyond the toe of the embankment contacted a 0.3 m thick topsoil layer, underlain by alluvial sand and gravel to 0.7 m or El. 333.9 m.

These surficial soils in all three boreholes are underlain, below El. 334.2 to 333.5 m, by a major deposit of silty sand to sandy silt till with sand & gravel layers.

Details of the stratigraphy encountered in the boreholes are given on the individual Record of Borehole Sheets in Appendix A. Engineering properties of the soil strata and the groundwater conditions are discussed in the following paragraphs.

#### 4.1.1 FILL

Borehole C9-2 which was drilled from the top of the embankment immediately adjacent to the existing culvert contacted a basically granular (non-cohesive) fill deposit consisting of silty sand with traces to some gravel. This deposit was found to extend to a depth of 2.3 m below the shoulder of the road or to El. 334.1 m and based on N-values which range from 13 to 27 blows/0.3 m, the material appears to have received systematic compaction when it was first placed. From the N-values, the relative density of the deposit at the borehole location can be described as compact.

#### 4.1.2 TOPSOIL/ORGANIC CLAYEY SILT

Borehole C9-1 contacted a 0.7 m thick layer of alluvium consisting of topsoil and organic clayey silt. Borehole C9-3 contacted 0.3 m thick topsoil. Some organic mixture was found in Borehole C9-2 immediately below the embankment fill. The thickness of the organic soils at or near courses can however be expected to be variable.

#### 4.1.3 SILTY SAND TO SANDY SILT TILL

At depths between 0.3 m and 2.3 m the boreholes contacted (below Elevations 334.2 and 333.5 m) a relatively fine-grained glacial till deposit. The deposit consists of a heterogeneous mixture of sand and silt size particles with some gravel and traces of clay size particles. The presence of cobbles and boulders was also noted during drilling and testing of the soil. The till, which is the predominant soil type underlying the site within the depths explored, also contains some sand or sand & gravel interbeds. In Borehole C9-3, the till was found to extend to the fill depth of the boreholes at 4.6 m (El. 330.0 m) while in the other two

boreholes, it was found to be underlain by a sand & gravel deposit at depths of 3.7 m (El. 330.5 m) and 4.4 m (El. 332.0 m).

The grain-size distribution of two samples from the deposit was determined in the laboratory. As shown in Figure B9-1, the following grain-size distribution is indicated:

|         |        |
|---------|--------|
| Gravel: | 12-26% |
| Sand:   | 36-54% |
| Silt:   | 20-43% |
| Clay:   | 0- 9%  |

As was mentioned before, the presence of cobbles and boulders was inferred in the deposit.

The measured natural moisture contents of samples from the material ranged from typically 10 to 15%.

N-values recorded in the deposit ranged from 6 blows/0.3 m to in excess of 50 blows/0.15 m. From the test results, the deposit is considered to be compact to very dense with possible occasional loose zones (i.e. the recorded low N-value= 6 may be due to disturbance during drilling).

#### 4.1.4 SAND & GRAVEL

A sand & gravel deposit with some cobbles and occasional boulders was contacted underlying the glacial till in Boreholes C9-1 and C9-2 at depths/elevations of 3.7 m/330.5 and 4.4 m/332.0 m, respectively. The boreholes were terminated in this coarse grained granular deposit after penetrating it for a vertical distance of about 2 m at elevations 328.2 m and 330.2 m, respectively.

Standard Penetration tests performed in this deposit encountered refusal after little penetration (N-values of 50 blows/0.13 m to 100 blows/0.03 m) due to the presence of frequent cobbles and boulders. Based on these results and on the observations made during drilling, the relative density of the granular deposit is described as very dense.

The deposit was wet and water-bearing and based on a visual examination of the soil samples it is considered to be considerably more pervious than the overlying glacial till deposit.

#### 4.1.5 GROUNDWATER CONDITIONS

The groundwater conditions were observed during the drilling, upon completion of each borehole and in the piezometer installed in Borehole C9-1. The observations are given on the Record of Borehole Sheets.



During drilling the samples became wet at 0.8 to 1.5 m depth in Boreholes C9-1 and C9-3, respectively and upon completion of the boreholes, free-standing water was recorded in the boreholes at the following depths/elevations BH C9-1 at 0.6 m/333.5 m, BH C9-2 at 2.1 m/334.3 m and BH C9-3 at 1.5 m/333.0 m. In the piezometer installed in Borehole C9-1 the recorded water level rose from an initial reading of 1.4 m six days after completion to 0.2 m (El. 333.9 m) seven days thereafter. From these observations and the moisture contents of the recovered soil samples, the groundwater level at the time of our investigation was close to the o.g. level (i.e. typically within 1 m). The groundwater level would, however, be subject to seasonal fluctuations and in response to major weather events as well as the water level in the watercourse.

**SHAHEEN & PEAKER LIMITED**

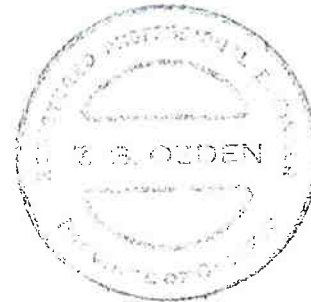
  
Ramon Miranda, P.Eng.



ZO:tr/idrive



Z.S. Ozden, P.Eng.



# Drawings

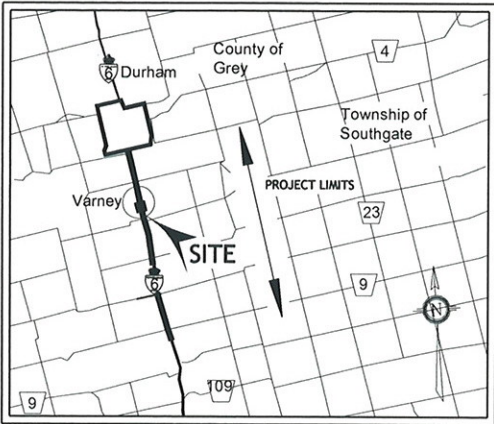
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
ARE IN KILOMETRES + METRES.

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

CONT No.  
GWP: 338-97-00

Highway 6, Durham  
Culvert C9 @ Sta. 28+375  
BOREHOLE LOCATIONS

SHAHEEN & PEAKER LIMITED



KEY PLAN  
N.T.S

LEGEND

Borehole

| No.  | ELEV. | CO-ORDINATES |           |
|------|-------|--------------|-----------|
|      |       | NORTH        | EAST      |
| C9-1 | 334.1 | 4,889,464.8  | 199,928.9 |
| C9-2 | 336.4 | 4,889,466.4  | 199,937.3 |
| C9-3 | 334.5 | 4,889,470.0  | 199,956.6 |

NOTE

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

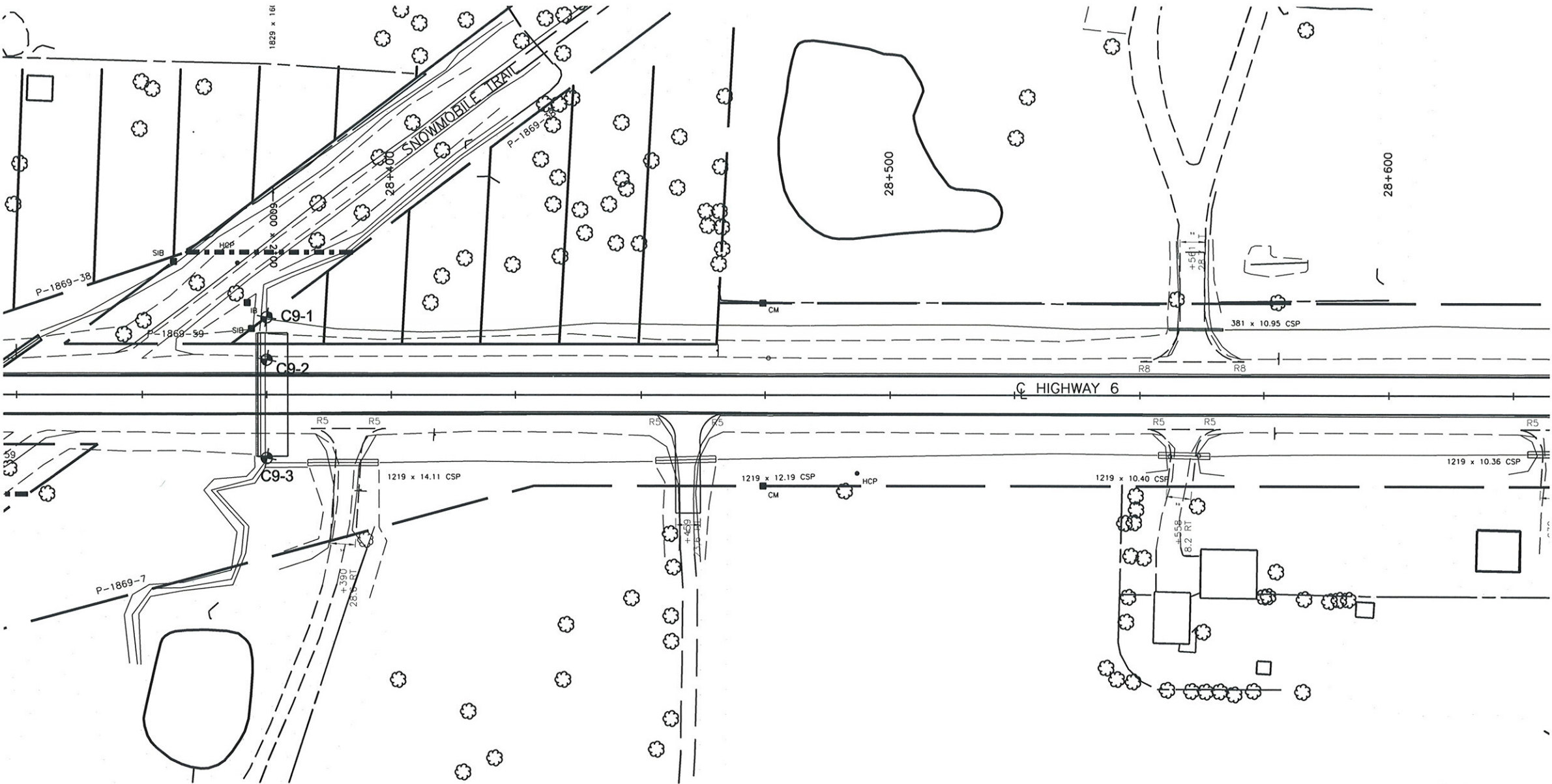
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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-194

| SPT 1174 |            |                 | DIST         |
|----------|------------|-----------------|--------------|
| SUBM'D   | CHECKED    | DATE Jan., 2008 | SITE 8-616/C |
| DRAWN SM | CHECKED RM | APPROVED ZO     | DWG 9A       |



PLAN





METRIC

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

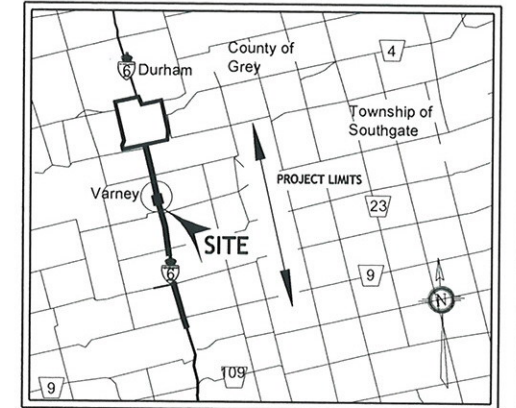
NOTES:  
FOR DETAILED SUBSURFACE CONDITIONS  
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.  
GWP: 338-97-00

Highway 6, Durham  
Culvert C9 @ Sta. 28+375  
PROFILE & SOIL STRATIGRAPHY



SHAHEEN & PEAKER LIMITED



KEY PLAN  
N.T.S

LEGEND

- Borehole
- 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      |
| C9-1 | 334.1 | 4 889 464.8  | 199 928.9 |
| C9-2 | 336.4 | 4 889 466.4  | 199 937.3 |
| C9-3 | 334.5 | 4 889 470.0  | 199 956.6 |

NOTE

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

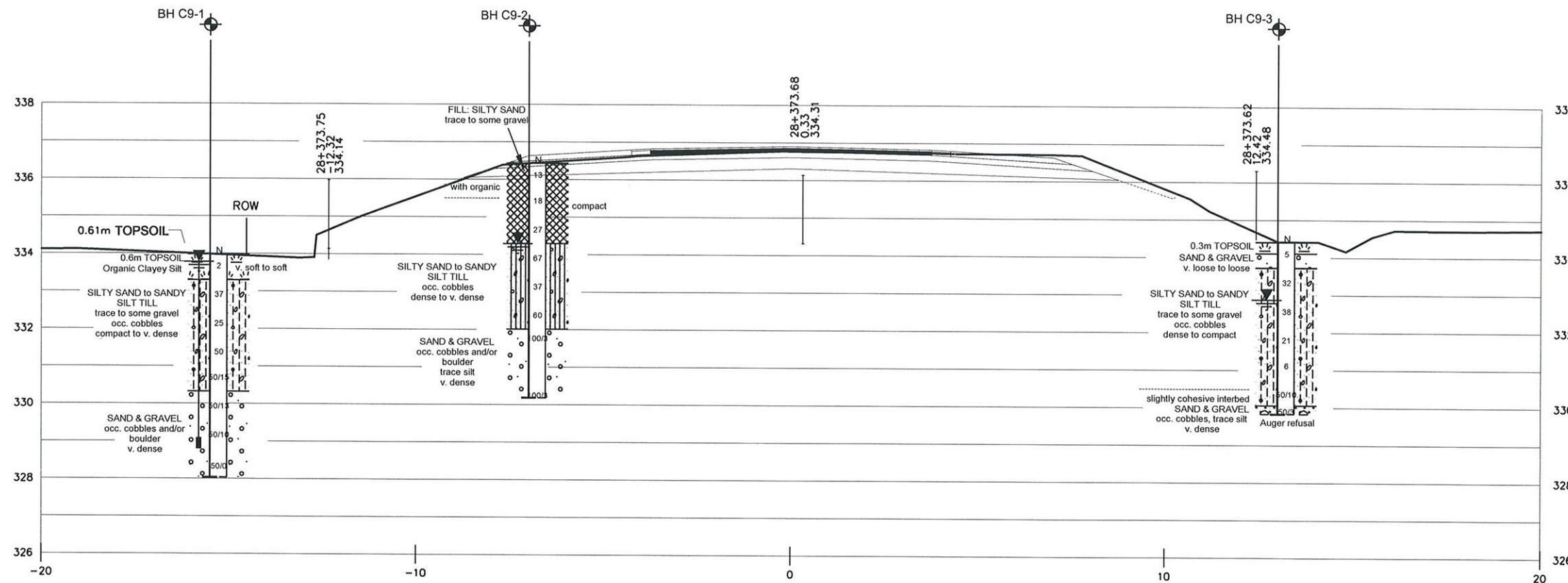
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| REV. | DATE | BY | DESCRIPTION |
|------|------|----|-------------|
|      |      |    |             |

Geocres No. 41A-194

| SPT 1174  |            |                 | DIST         |
|-----------|------------|-----------------|--------------|
| SUBM'D ZO | CHECKED RM | DATE Jan., 2008 | SITE 8-616/C |
| DRAWN SM  | CHECKED RM | APPROVED ZO     | DWG 9B       |



2m 1 0 2 4m HOR  
2m 1 0 2 4m VERT  
SCALES

STRATIGRAPHY ALONG CULVERT C9 @STA. 28+373.68



# Appendix A

## Record of Borehole Sheets



SPT1174

# RECORD OF BOREHOLE No C9-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+375, 15.5m Lt C/L ORIGINATED BY ZI  
DIST          HWY 6 BOREHOLE TYPE Solid Stem Augers COMPILED BY XS  
DATUM Geodetic DATE 11/8/2006 CHECKED BY FS

| SOIL PROFILE  |  | SAMPLES    |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |    | PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT |                |   | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
|---------------|--|------------|--------|------|----------------------------|-----------------|---|----|----|----|----|---|----------------|---|--|--|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER | TYPE |                            |                 | "N" VALUES                                  | 20 | 40 | 60 | 80 | 100   | w <sub>p</sub> | w |  |  |
| 334.1         |  |            |        |      |                            |                 |   |    |    |    |    |   |                |   |  |  |
| 0.0           | 0.6 m <b>TOPSOIL</b><br>Organic Clayey Silt with rootlets<br>dark brown, moist<br>very soft to soft  |            | 1      | SS   | 2                          |                 |   |    |    |    |    |   |                |   |  |  |
| 333.5         |  |            |        |      |                            |                 |   |    |    |    |    |   |                |   |  |  |
| 0.7           | <b>SILTY SAND to SANDY SILT TILL</b><br>trace to some gravel<br>occasional cobbles<br>greyish brown to grey, wet<br>compact to very dense  |            | 2      | SS   | 37                         |                 |   |    |    |    |    |   |                |   |  |  |
|               |  |            | 3      | SS   | 25                         |                 |   |    |    |    |    |   |                |   |  |  |
|               |  |            | 4      | SS   | 50                         |                 |   |    |    |    |    |   |                |   |  |  |
|               |  |            | 5      | SS   | 50/15                      |                 |   |    |    |    |    |   |                |   |  |  |
| 330.5         |  |            |        |      |                            |                 |   |    |    |    |    |   |                |   |  |  |
| 3.7           | <b>SAND &amp; GRAVEL</b><br>some cobbles and/or boulders<br>grey, wet<br>very dense  |            | 6      | SS   | 50/13                      |                 |   |    |    |    |    |   |                |   |  |  |
|               |  |            | 7      | SS   | 50/10                      |                 |   |    |    |    |    |   |                |   |  |  |
|               |  |            | 8      | SS   | 50/0                       |                 |   |    |    |    |    |   |                |   |  |  |
| 328.2         |  |            |        |      |                            |                 |   |    |    |    |    |   |                |   |  |  |
| 6.0           | End of borehole.<br><br>Water level at 0.6 m upon completion, cave<br>at 4.9 m.<br>Piezometer installed to depth of 5.2 m.<br><br>Water level in piezometer:<br>Nov. 14, 2006 ---1.4 m (El. 332.7 m)<br>Nov. 21, 2006 ---0.2 m (El. 333.9 m) |            |        |      |                            |                 |   |    |    |    |    |   |                |   |  |  |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      20 15 10 5 0 (%) STRAIN AT FAILURE

SPT1174

# RECORD OF BOREHOLE No C9-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+375, 7m Lt C/L ORIGINATED BY NH  
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS  
 DATUM Geodetic DATE 8/16/2006 CHECKED BY FS

| SOIL PROFILE  |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|--|---|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | 20  | 40 | 60 | 80 | 100 |  |   |
| 336.4         |   |            |         |      |            |                            |                 |   |    |    |    |     |  |   |
| 0.0           | <b>FILL: Silty Sand</b><br>trace to some gravel<br>with organic<br>brown, moist<br>compact                            |            | 1       | SS   | 13         |                            | 336             |   |    |    |    |     |  |   |
|               |   |            | 2       | SS   | 18         |                            |                 |   |    |    |    |     |  |   |
|               |   |            | 3       | SS   | 27         |                            | 335             |   |    |    |    |     |  |   |
| 334.1         |   |            | 4       | SS   | 67         |                            | 334             |   |    |    |    |     |  |   |
| 2.3           | <b>SILTY SAND to SANDY SILT TILL</b><br>occasional cobbles<br>greyish brown to grey, wet<br>dense to very dense       |            | 5       | SS   | 37         |                            | 333             |   |    |    |    |     |  |   |
|               |   |            | 6       | SS   | 60         |                            |                 |   |    |    |    |     |  |   |
| 332.0         | <b>SAND &amp; GRAVEL</b><br>trace silt<br>some cobbles and / or boulders<br>brown, wet<br>very dense                  |            | 7       | SS   | 100/3**    |                            | 332             |   |    |    |    |     |  |   |
| 4.4           |   |            | 8       | SS   | 100/3**    |                            | 331             |   |    |    |    |     |  |   |
| 330.2         | End of borehole.<br><br>* Water level in open borehole at 2.1 m<br>(El. 334.3 m) upon completion<br>(not stabilized). |            |         |      |            |                            |                 |   |    |    |    |     |  |   |
| 6.3           |   |            |         |      |            |                            |                 |   |    |    |    |     |  |   |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE




SPT1174

# RECORD OF BOREHOLE No C9-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+375, 12.7m Rt. C/L ORIGINATED BY ZI  
DIST            HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS  
DATUM Geodetic DATE 11/14/2006 CHECKED BY FS

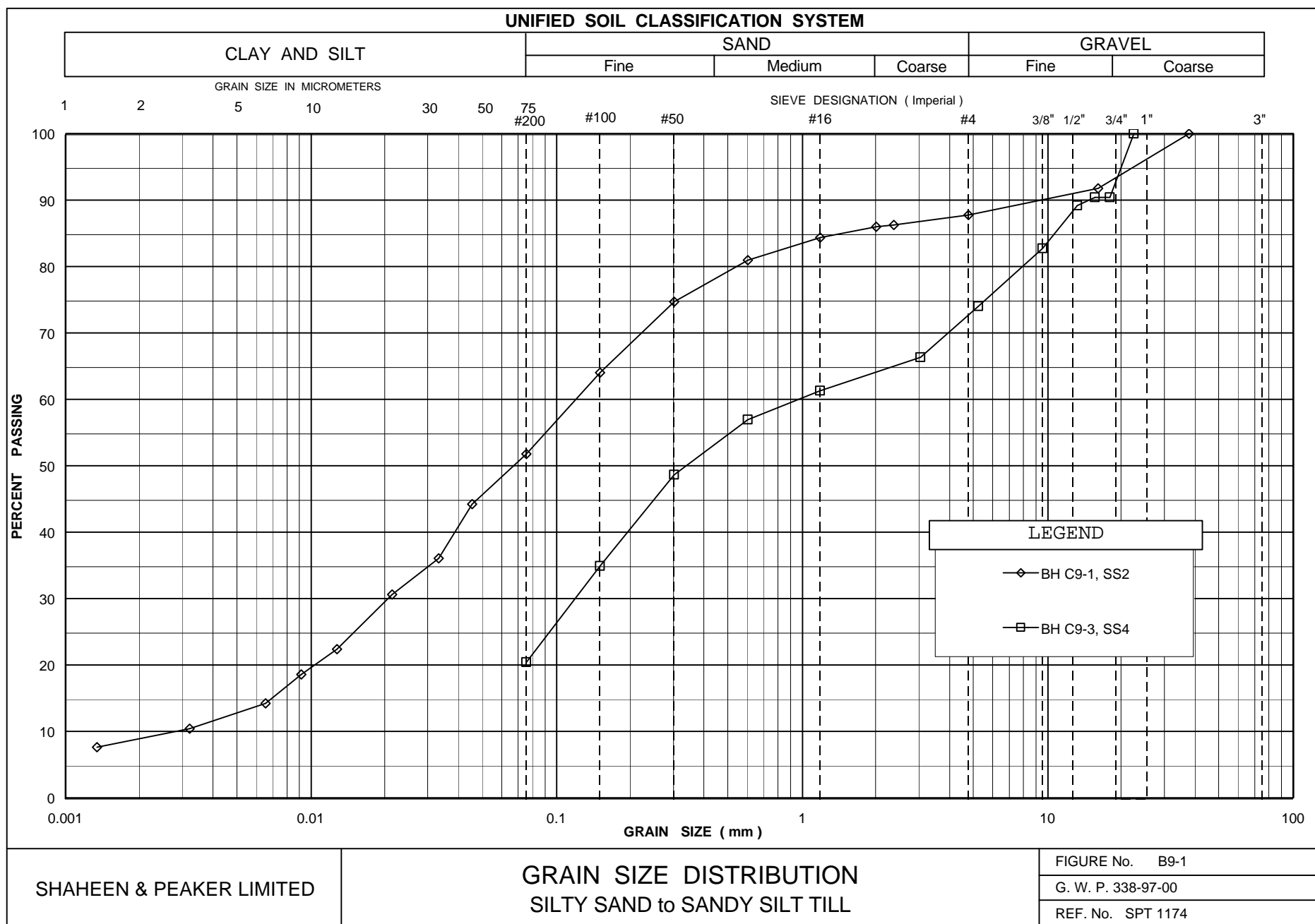
| SOIL PROFILE   |   |             | SAMPLES |      |            | GROUND WATER<br>CONDITIONS  | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |    |    |    | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |   |  |  |  |  |  |  |
|----------------|---|-------------|---------|------|------------|---|-----------------|--|----|----|----|--|--|---|--|--|--|--|--|--|
| ELEV.<br>DEPTH | DESCRIPTION   | STRAT. PLOT | NUMBER  | TYPE | "N" VALUES |   |                 | SHEAR STRENGTH kPa<br>○ UNCONFINED    + FIELD VANE<br>● POCKET PENETR.    × LAB VANE |    |    |    |  |  | WATER CONTENT (%)<br>w <sub>p</sub> w                      w <sub>L</sub> |  |  |  |  |  |  |
| 334.5          |   |             |         |      |            |   |                 | 20   | 40 | 60 | 80 | 100  |  |   |  |  |  |  |  |  |
| 0.0<br>334.2   | <del>SILTY SAND to SANDY SILT</del>   |             | 1       | SS   | 5          |  | 334             |  |    |    |    |  |  |   |  |  |  |  |  |  |
| 0.3            | some organics   |             |         |      |            |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                | <b>SILTY SAND to SANDY SILT TILL</b><br>trace to some gravel<br>with frequent cobbles<br>grey, wet  |             | 2       | SS   | 32         |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                |   |             |         |      |            |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                |   |             | 3       | SS   | 38         |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                |   |             |         |      |            |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                |   |             | 4       | SS   | 21         |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                | dense to compact  |             |         |      |            |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                | loose   |             | 5       | SS   | 6          |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |
|                | very dense & bouldery   |             | 6       | SS   | 50/10      |   | 331             |  |    |    |    |  |  |   |  |  |  |  |  |  |
| 330.0          |   |             | 7       | SS   | 50/3**     |   | 330             |  |    |    |    |  |  |   |  |  |  |  |  |  |
| 4.6            | End of borehole.<br><br>Auger refusal at 4.4 m, hole caved-in @ 4.3 m upon completion.<br><br>* Water level in open borehole at 1.5 m (El. 333.0 m) upon completion (not stabilized). |             |         |      |            |   |                 |  |    |    |    |  |  |   |  |  |  |  |  |  |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 5 10 15 20 (%) STRAIN AT FAILURE



# Appendix B

## Laboratory Test Results



# 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  $\bar{N}$ .

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND 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                  |
| $\sigma_1, \sigma_2, \sigma_3$       | kPa | PRINCIPAL STRESSES            |
| $\epsilon$                           | %   | LINEAR STRAIN                 |
| $\epsilon_1, \epsilon_2, \epsilon_3$ | %   | PRINCIPAL STRAINS             |
| E                                    | kPa | MODULUS OF LINEAR DEFORMATION |
| G                                    | kPa | MODULUS OF SHEAR DEFORMATION  |
| $\mu$                                | 1   | COEFFICIENT OF FRICTION       |

### MECHANICAL PROPERTIES OF SOIL

|                |                   |                                      |
|----------------|-------------------|--------------------------------------|
| $m_v$          | kPa <sup>-1</sup> | COEFFICIENT OF VOLUME CHANGE         |
| $c_c$          | 1                 | COMPRESSION INDEX                    |
| $c_s$          | 1                 | SWELLING INDEX                       |
| $c_a$          | 1                 | RATE OF SECONDARY CONSOLIDATION      |
| $c_v$          | m <sup>2</sup> /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         |
| $\phi'$        | -°                | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| $c_u$          | kPa               | APPARENT COHESION INTERCEPT          |
| $\phi_u$       | -°                | 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 <sup>3</sup> | DENSITY OF SOLID PARTICLES     | e         | 1, % | VOID RATIO                             | $e_{min}$ | 1, %              | VOID RATIO IN DENSEST STATE                             |
| $j_s$     | kN/m <sup>3</sup> | 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 <sup>3</sup> | DENSITY OF WATER               | w         | 1, % | WATER CONTENT                          | D         | mm                | GRAIN DIAMETER  |
| $j_w$     | kN/m <sup>3</sup> | UNIT WEIGHT OF WATER           | $s_r$     | %    | DEGREE OF SATURATION                   | $D_n$     | mm                | N PERCENT – DIAMETER                                    |
| $P$       | kg/m <sup>3</sup> | DENSITY OF SOIL                | $w_L$     | %    | LIQUID LIMIT                           | $C_u$     | 1                 | UNIFORMITY COEFFICIENT                                  |
| $j$       | kN/m <sup>3</sup> | UNIT WEIGHT OF SOIL            | $w_p$     | %    | PLASTIC LIMIT                          | h         | m                 | HYDRAULIC HEAD OR POTENTIAL                             |
| $P_d$     | kg/m <sup>3</sup> | DENSITY OF DRY SOIL            | $w_s$     | %    | SHRINKAGE LIMIT                        | q         | m <sup>3</sup> /s | RATE OF DISCHARGE                                       |
| $j_d$     | kN/m <sup>3</sup> | UNIT WEIGHT OF DRY SOIL        | $I_p$     | %    | PLASTICITY INDEX = $(W_L - W_p) / I_p$ | v         | m/s               | DISCHARGE VELOCITY                                      |
| $P_{sat}$ | kg/m <sup>3</sup> | DENSITY OF SATURATED SOIL      | $I_L$     | 1    | LIQUIDITY INDEX = $(W - W_p) / I_p$    | i         | 1                 | HYDAULIC GRADIENT                                       |
| $j_{sat}$ | kN/m <sup>3</sup> | UNIT WEIGHT OF SATURATED SOIL  | $I_c$     | 1    | CONSISTENCY INDEX = $(W_L - W) / 1_p$  | k         | m/s               | HYDRAULIC CONDUCTIVITY                                  |
| $P'$      | kg/m <sup>3</sup> | DENSITY OF SUBMERED SOIL       | $e_{max}$ | 1, % | VOID RATIO IN LOOSEST STATE            | j         | kN/m <sup>3</sup> | SEEPAGE FORCE   |
| $j'$      | kN/m <sup>3</sup> | UNIT WEIGHT OF SUBMERGED SOIL  |           |      |  |           |                   |   |

# Appendix D

## Site Photographs

**Foundation Investigation Report of Culvert C11 on Highway 6: GWP 338-97-00**



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