

**FOUNDATION INVESTIGATION AND DESIGN REPORTS
PROPOSED CULVERT REPLACEMENTS
(C1, C2, C3, C4, C7 & C8)
HIGHWAY 6 FROM 1.1 KM SOUTH OF
GREY COUNTY ROAD 9 NORTHERLY TO
DURHAM SOUTH LIMITS, ONTARIO
G.W.P. 338-97-00**

GEOCRES NO. 41A-193

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174A
January 24, 2008**



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**FOUNDATION INVESTIGATION REPORT
PROPOSED CULVERT REPLACEMENTS (C1, C2, C3, C4, C7 & C8)
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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.

The Highway 6 project includes pavement rehabilitation throughout, vertical grade revisions in some areas, construction of a new northbound (NB) passing lane and replacement extension of several culverts (C1 through C11) within the project limits. 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.

This report presents the findings of the geotechnical investigation for the proposed replacement of six non-structural culverts (C1 through C4, C7 and C8) at the following locations:

Culvert No	Station
C1	21+204
C2	21+809
C3	23+793
C4	24+482
C7	27+065
C8	28+299

The geotechnical investigation results for the replacement of three structural culverts were presented in separate reports under SPT1174C (for Culvert C9), 1174D (for Culvert C10) and 1174E (for culvert C11). The findings of the geotechnical investigation for replacement of the other non-structural culverts (C2A, C3A, C5, C6) will be presented under a separate report (SPT1174B).

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 Physiographic Region known as the Horseshoe Moraines. The Horseshoe Moraines Physiographic Region 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.

Geological information indicates that the overburden (glacial drift), in this general area, may be underlain by bedrock at relatively shallow depths. Some areas may be located near the interface of Upper Silurian Salina and Middle Silurian Guelph Formations, which are approximately 420 million years old. The Salina Formation (the younger of the two) consists of dolostone, shale, gypsum and salt while the Guelph Formation consists of dolostone.

3. INVESTIGATION PROCEDURES

In the current geotechnical report, the subsurface conditions for the proposed culvert replacement at six sites (C1 through C4, C7 and C8) were investigated for replacements, as per the original TOR in the RFP document and the S&P proposal.

At each culvert site, three boreholes were drilled, one at each end of the culvert and one at the crest of the embankment for culvert replacement. Therefore, a total of eighteen boreholes were drilled for the replacement of six culverts to different depths (typically a minimum of 6 m below the culvert invert).

The fieldwork was carried out during several periods from August 10 to 22, 2006, September 21-29, 2006, October 2 to 16, 2006, Oct. 16 to 19, 2006, November 8 to 14, and December 5 to 8, 2006

All 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, except for Borehole C2-1 which had to be put down using manual methods (due to inaccessibility with a conventional drill rig). All the boreholes were drilled under the full time supervision of geotechnical engineers from S&P.

Sampling in the boreholes (except Borehole C2-1) 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.

Manual drilling (in Borehole C2-1) consisted of driving a conventional 51 mm O.D. split-spoon sampler into the ground using a 31.8 kg hammer (instead of the conventional 63.6 kg hammer). The number of blows required to advance the sampler into the undisturbed ground was counted and recorded. After 0.6 m penetration, the sampler was withdrawn and sample which was retrieved was examined and logged. The sampler was then put back into the hole and driven another 0.6 m. This was continued until the termination of the borehole or refusal to penetration at 3.0 m below the ground surface. The number of blows of the hammer to drive the sampler by 0.3 m into the ground was divided by two (since the weight of the hammer is one-half of the conventional hammer) in order to obtain a resistance value approximately equivalent to the N-value obtained in the Standard Penetration test. These values are shown on the Record of Borehole as "equivalent" N-values.

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.

At the completion of drilling, all boreholes drilled were grouted and sealed using a cement/bentonite mixture. The boreholes with piezometers were sealed with bentonite 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 A1 through A6. The locations of the boreholes and the inferred subsurface stratigraphy are also shown in the same Appendices (i.e. Appendix A1 through A6).

The results of the laboratory tests are also presented in Appendices B1 through B6.

4. SUBSURFACE CONDITIONS

The soil conditions at the location of each individual culvert are discussed in the following sections. Details of the stratigraphy encountered in the boreholes are presented on the Record of Borehole Sheets and on the soil strata drawings in Appendix A1 through A6. The following paragraphs are only meant to complement and amplify these data.

4.1 CULVERT REPLACEMENT AT STATION 21+204 (C1)

At this location, the existing culvert is a corrugated steel pipe (CSP) about 0.76 m in diameter and approximately 22 m in length with the culvert invert elevation at 375.99 to 376.16 m.

Three boreholes were drilled for this culvert replacement. Boreholes C1-1 and C1-3 were put down near the existing culvert ends on the left (west) and right (east) sides of highway, respectively, while Borehole C1-2 was advanced on the left shoulder of the highway, as shown on Drawings No. 1A and 1B.

Borehole C1-2 was located on the shoulder of the highway and contacted fill materials which extend to a depth of about 1.5 m below the ground surface, underlain by a 0.3 m thick topsoil layer to El. 376.0 m. Boreholes C1-1 and C1-3, which were put down beyond the bottom of the existing highway embankment, contacted topsoil and organic silt to 0.7 m below the ground surface or to El. 375.4 and 375.8 m, respectively.

In general below the fill and organic soils, the boreholes contacted, a major deposit of sand and gravel, changing to relatively finer granular soils below about 5 m depth or below El. 371-370 m.

4.1.1 GRANULAR FILL

Borehole C1-2, drilled from the left shoulder of the highway, contacted a 0.8 m thick granular shoulder fill which consisted of sand and gravel to a depth of 0.25 m, changing to sand with some gravel below this depth.

4.1.2 SILT AND CLAYEY SILT FILL

The granular shoulder fill in Borehole C1-2 is underlain by a 0.7 m thick fill layer which consists of silt with some sand and traces of gravel. This basically fine-grained granular (i.e. non-cohesive) soil extends to 1.5 m below the ground surface or to El. 376.3 m and is underlain by a 0.3 m thick organic topsoil layer to a depth of 1.8 m (El. 376.0 m). The topsoil is in turn underlain by a 0.4 m cohesive deposit (clayey silt with traces of gravel and organics) which was identified as possible fill.

4.1.3 TOPSOIL AND ORGANIC SILT

In Borehole C1-2, the embankment fill is underlain at 1.5 m depth by a 0.3 m thick topsoil layer.

Boreholes C1-1 and C1-3, which were drilled from the bottom (i.e. beyond the toe) of the highway embankments, contacted a topsoil layer extending to about 0.5 m and 0.2 m, respectively. In these two boreholes, the topsoil is underlain by organic silt (floodplain deposit) to a depth of 0.7 m below the ground surface, or to El. 375.4 m and 375.8 m, respectively.

Standard Penetration tests performed in these organic deposits yielded N-values which are 6 and 7 blows/0.3 m, respectively, indicating a loose condition of this basically granular (non-cohesive) soil.

It should be pointed out that the thickness of topsoil and organic soils can be expected to be variable in between and beyond borehole locations, especially near water courses.

4.1.4 SAND & GRAVEL

Underlying the surficial soils described in the preceding paragraphs, all three boreholes contacted a coarse granular deposit consisting of sand & gravel with some silt and occasional cobbles and boulders. This deposit was contacted at depths 0.7 to 2.2 m below the ground surface or at El. 375.8 to 375.4 m and extended to depths ranging between 5.0 m (El. 371.0 m) in Borehole C1-1 and 6.0 m (El. 370.6 m) in Borehole C1-3. Borehole C1-2 was terminated in this deposit at 6.9 m or at El. 371.0 m. In Borehole C1-3, it attained at El. 370.6 m a somewhat finer texture, changing to sand to sand with some gravel.

The grain-size distribution of three samples from the sand & gravel is presented in Figure B1-1 in Appendix B1. The following grain-size distribution is indicated:

Gravel:	31 – 48%
Sand:	36 - 57%
Silt and clay:	11 - 20%

The measured N-values in the sand & gravel and in the underlying sand deposit range from 28 to in excess of 100 blows/0.3 m, indicating a compact but generally dense to very dense condition. The measured natural moisture contents range from 6 to 17% but generally between 5 and 11%.

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

4.1.5 SILTY SAND TO SANDY SILT TILL

Borehole C1-1 contacted underlying the sand & gravel at 5.2 m depth (El. 371.0 m) relatively finer granular soils ranging from silty sand to sandy silt till to the full depth of the borehole at 7.9 m depth or El. 368.1 m.

N-values recorded in these basically granular soil deposit range from 51 blows/0.3 m to 50 blows/0.08 m which indicate a very dense condition.

4.1.6 SILT TILL

Underlying the sand & gravel and sand in Borehole C1-3, a glacial till deposit was contacted at a depth of 6.8 m (El. 369.7 m). The deposit consists of mainly silt size particles with some sand and clay content. The borehole was terminated at 7.3 m (El. 369.2 m) after penetrating this basically granular soil by a vertical distance of 0.5 m.

The natural moisture content of the sample recovered from this deposit was measured to 9% and based on a recorded N-value of 50 blows/0.15 m, its relative density is described as very dense.

4.1.7 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, a piezometer was installed in Borehole C1-3 to allow ground monitoring over a prolonged period of time, without interference from surface water. 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 C1-1 the soil became wet at 1.1 m and on completion free-standing water was recorded at about 1.2 m or at about El. 374.9 m. In the piezometer installed in Borehole C1-3, water level was recorded at a depth of 0.9 m below the ground surface or at El. 375.6 m. From these observations, the groundwater level at the time of our investigation was at about 1 m below the ground surface or between Elevations 375.6 and 375.0 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.

4.2 CULVERT REPLACEMENT AT STATION 21+809 (C2)

The existing culvert at Station 21+807 is a 0.914 m diameter, 25 m long CSP (corrugated steel pipe) culvert, with an invert at El. 382.0 m (on the east side) to 379.7 m (on the west side). The new culvert will be located at Station 21+809.5 m (immediately adjacent to the existing culvert).

The field investigation for the new culvert consisted of three sampled boreholes put down at the locations shown on the Borehole Location Plan, Drawing Nos. 2A and 2B in Appendix A2. Borehole C2-2 was drilled from the left shoulder of the highway, while Boreholes C2-1 and C2-3 were put down from the bottom of the highway embankment immediately adjacent to the toe, from the original ground (o.g.) levels on the left and right sides, respectively. Records of Borehole Sheets are presented in Appendix A2.

Boreholes C2-2 and C2-3 were advanced using truck-mounted and track-mounted drilling rigs, respectively while Borehole C2-1 had to be put down using manual drilling methods due to inaccessibility with a conventional drill rig. Manual drilling consisted of driving a conventional 51 mm O.D. split-spoon sampler into the ground using a 31.8 kg hammer (instead of the conventional 63.56 kg hammer). The number of blows required to advance the sampler into the undisturbed ground was counted and recorded. After 0.6 m penetration, the sampler was withdrawn and sample which was retrieved was examined and logged. The sampler was then put back into the hole and driven another 0.6 m. This was continued until refusal to penetration at 3.0 m below the ground surface. The number of blows of the hammer to drive the sampler by 0.3 m into the ground was divided by two (since the weight of the hammer is one-half of the conventional hammer) in order to obtain a resistance value approximately equivalent to the N-value obtained in the Standard Penetration test. These values are shown on the Record of Borehole C2-1, as equivalent N-values.

Borehole C2-2 which was put down from the shoulder of the highway, contacted a granular embankment fill to a depth of 3.4 m. Between 3.4 and 4.3 m, the material changed to silty sand to sandy silt with clayey silt zones. Due to the presence of some topsoil and wood below about 4.0 m depth, this material was identified as probable fill.

Underlying the fill and material identified as possible fill in Borehole C2-2 and surficial topsoil in Boreholes C2-1 and C2-3, the boreholes contacted glacial till deposits with some silt and gravelly sand layers.

4.2.1 EMBANKMENT FILL

Borehole C2-2 was drilled from the shoulder of the highway from near the existing culvert and this borehole encountered a granular fill to a depth of 3.4 m. The granular fill consists of sand & gravel at top and primarily sand with some gravel below. A 0.1 m thick asphaltic

concrete layer/slab was contacted at 0.45 m depth. The presence of occasional topsoil inclusions was also noted below about 3.0 m depth.

Standard Penetration tests, performed in the granular fill deposit below 1.5 m depth, yielded N-values of between 21 and 64 blows for 0.3 m penetration and based on this, the fill appears to have received systematic compaction when it was first placed. The N-values indicate a compact to very dense density.

Underlying the granular fill, in Borehole C2-2, mixed soil conditions were encountered from 3.4 to 4.3 m below the ground surface or between El. 381.1 and 380.2 m, where the soil consists of primarily silty sand to sandy silt with traces of gravel and some clayey silt zones. In addition a topsoil layer/pocket was contacted at 4.0 m depth. From this and from its dark brown to brown colour, the soil in this zone is described as probable fill material. The deposit is considered to be a basically granular soil with cohesive zones. Based on an N-value of 8 blows/0.3 m, it is described as loose to firm. The grain-size distribution of a sample from this deposit is given in Figure B2-1 of Appendix B2.

4.2.2 TOPSOIL

Boreholes C2-1 and C2-3, drilled from the o.g. levels near the toe of the highway embankment, contacted a 0.1 m to 0.3 m thick topsoil layer.

It should be pointed out that in our experience the thickness of topsoil and organic rich soils can be variable in between and beyond the borehole locations, especially near water courses and low-lying areas.

4.2.3 CLAYEY SILT TO SILTY CLAY TILL

In Borehole C2-3, the topsoil is underlain by a 1.6 m thick layer of cohesive glacial deposit, consisting of clayey silt to silty clay till. This deposit was found to extend to 1.7 m depth or to El. 381.3 m. The material consists of a heterogeneous mixture of clayey silt to silty clay with traces to some sand and gravel. The grain-size distribution of a sample from this deposit was determined in the laboratory and the resulting curve is given in Figure B2-2 in Appendix B2. The following grain-size distribution is indicated.

Gravel:	2%
Sand:	12%
Silt:	49%
Clay:	37%

Based on this and a visual examination of the soil samples, the deposit can be expected to be practically impervious. Due to their mode of deposition the presence of cobbles and

boulders can be expected in the glacial deposits. From the recorded N-values of 9 and 14 blows/0.3 m, the consistency of this cohesive soil is described as stiff.

4.2.4 SILT

The cohesive till contacted in Borehole C2-3, described the preceding section of this report, is underlain by a 1.3 m thick silt layer. The silt was encountered at a depth of 1.7 m (El. 381.3 m) and was found to extend to 3.0 m or El. 380.0 m. This deposit is a borderline material between a fine-grained granular soil and a cohesive soil, but more akin to a cohesive material. In addition, it contains occasional very thin clay interbeds. N-values of 10 and 47 blows/0.3 m were recorded and from this the consistency of deposit is described as stiff near the top, changing to hard with increased depth.

4.2.5 SILTY SAND TO SANDY SILT TILL

Underlying the topsoil in Borehole C2-1, embankment fill in C2-2 and clayey till and silt deposits in Borehole C2-3, all three boreholes contacted a glacial deposit consisting of silty sand to sandy silt till, at depths 0.3 m to 4.3 m below the ground surface or below Elevations ranging from 380.2 m to 379.4 m. This deposit extends to the full depth of all three boreholes. The till consists of a heterogeneous mixture of silty sand to sandy silt with some gravel and traces of clay size particles. The presence of cobbles and boulders was also inferred during drilling. In any event, the presence of cobbles and boulders should always be anticipated in the glacial till deposits due to their mode of deposition. The presence of gravelly sand and sand seams/layers was noted. The grain-size distribution of a sample is given in Figure No. B2-3 and B2-4 in Appendix B2.

The deposit is a basically granular (non-cohesive) material. Natural moisture contents measured on samples from the deposit typically range from 6 to 12%.

Standard Penetration tests performed in this deposit in Boreholes C2-2 and C2-3 yielded N-values which ranged from 30 blows/0.3 m to typically in excess of 50 blows/0.15 m penetration. These results indicate a dense to very dense but generally very dense relative density.

In Borehole C2-1 in the upper 2± metres of the deposit the recorded equivalent N-values range from 8 to 28 blows/0.3 m. These values indicate a loose to compact relative density. Below about 2.3 m depth, however, an equivalent N-value of 110 blows/0.3 m was recorded which indicates a very dense condition near the bottom of borehole (i.e. from a depth of about 2.5 m to 3.0 m or between El. 377.2 and 376.7 m). This manually drilled borehole was terminated at 3.0 m depth due to spoon refusal, probably on a cobble or boulder.

4.2.6 GROUNDWATER CONDITIONS

A free-standing water level was recorded in Borehole C2-1 at a depth of 0.8 m (El. 378.9 m) upon completion. In Borehole C2-2 which was drilled from the shoulder of the highway, no free standing water was recorded upon its completion. However, this is a short-term condition and does not represent stabilized conditions. A piezometer was installed in Borehole C2-3 and in this borehole the groundwater was recorded at a depth of 2.4 m below the ground surface or at El. 380.9 m, about six weeks after completion.

Based on these observations, the groundwater level at the site is likely to range from about El. 381. m on the east side to about 379 m on the west side of the road and would be influenced by the level of water in the water course. As well, seasonal fluctuations in the groundwater level can be anticipated, including fluctuations in response to major weather events.

4.3 CULVERT REPLACEMENT AT STATION 23+793 (C3)

Based on the information provided to us by UMA, the existing culvert is a corrugated steel pipe arch (CSPA), approximately 1.5 m wide, 1.2 m high (inside dimensions) and 22.8 m long. The existing culvert invert is at El. 373.41 m (upstream) and at El. 373.32 m (downstream).

The original TOR in the RFP contemplated the replacement of the existing CSPA culvert at Sta. 23+793 with a new culvert. Based on the latest UMA 30% Design Drawings, the new culvert will be significantly larger, 3.0 m wide and 1.8 m high. It will be installed at approximately the same invert elevations as the existing culvert.

For design of the proposed culvert replacement, three boreholes (C3-1, C3-2 and C3-3) were drilled at this site along the existing culvert. Borehole C3-1 was advanced on the left (west) side of Highway 6 near the downstream-end of the existing culvert, as shown on the Site Plan and profile (Drawing Nos. 3A and 3B in Appendix A3). Boreholes C3-2 and C3-3 were drilled on the right (east) side of the highway, on the east shoulder and close to the upstream end of the culvert, respectively.

Details of the subsurface conditions encountered in the boreholes are shown on the Record of Borehole Sheets presented in Appendix A3. The following paragraphs are only meant to complement and amplify these data.

Below the embankment fill and topsoil/organic silt, these boreholes encountered native gravelly sand to silty sand and/or silty sand to sandy silt till with intermittent sand & gravel seam extending to the termination of the boreholes (up to a maximum depth of 9.2 m or El. 366.1 m in Borehole C 3-2).

4.3.1 TOPSOIL/PEATY ORGANIC SILT

At the locations of Borehole C3-1 and C3-3 near downstream and upstream ends of the existing culvert, a topsoil/peaty organic silt layer was contacted at the ground surface. The thickness of this organic layer was about 0.3 and 0.15 m, respectively. In addition, an organic silt layer (about 0.2 m in thickness) was contacted below the embankment fill in Borehole C 3-2.

The natural moisture content of a surficial sample of topsoil/organic silt was measured at 38%.

4.3.2 EMBANKMENT GRANULAR FILL

Borehole C3-2, drilled on the right shoulder of the highway, contacted 2.1 m granular fill material extending to about El. 373.2 m. The embankment fill primarily consist of sand and gravel.

Standard Penetration test performed in the fill material below 1.5 m depth yielded a N-value of 15 blows/0.3 m, indicating compact condition.

The measured moisture contents of the embankment fill material range from 2 to 6%.

4.3.3 GRAVELLY SAND TO SILTY SAND

Underlying the surficial soils (topsoil or embankment fill and organic silt materials) described in the preceding paragraphs, Boreholes C3-2 and C3-3 contacted a granular deposit consisting of gravelly sand to silty sand. This deposit was found to extend to depths of about 2.1 m (El. 371.5 m) and 5.2 m (El. 370.1 m), in Boreholes C3-3 and C3-2, respectively. This deposit was generally grey and moist to wet.

Grain size analysis tests performed on two samples of the upper portion of this deposit (C3-2/SS4 and C3-3/SS2) yielded the following grain-size distribution, as shown in Figure B3-1 in Appendix B3.

Gravel:	28 and 32%
Sand:	70 and 55%
Silt and Clay:	2 and 13%;

Therefore, the tested material is described as gravelly sand, a coarse-grained granular (i.e. non-cohesive) deposit. It may be of interest that the tested sample from Borehole C3-3/SS2 meets the gradation requirements for Granular 'B'.

The measured natural moisture contents of this granular deposit range from 12 to 13%.

Standard Penetration tests performed in this granular deposit yielded N-values ranging from 11 to 34 blows/0.3 m, indicating a compact to dense but generally compact condition.

4.3.4 SILTY SAND TO SANDY SILT TILL

Below surficial topsoil in Borehole C 3-1 and embankment fill and gravelly sand to silty sand deposit in Boreholes C 3-2 and C3-3, a glacial silty sand to sandy silt till deposit with occasional cobbles/boulders was encountered extending to the termination of all three boreholes (i.e., to 7.8 to 9.2 m depth or El. 366.1 to 365.4 m and possibly beyond). The presence of some clayey or silty seams was noted in the upper part of this deposit (e.g., in Borehole C 3-2 and C 3-3 up to about El. 369.5 m).

In addition, occasional wet sand/sand & gravel seams were found in this glacial till deposit in the boreholes. For example, a significant water bearing sand and gravel layer (about 1.9 m in thickness) was found in Borehole C3-1, as described in Section 4.3.5.

Standard penetration tests performed in this granular deposit yielded N-values ranging from 16 blows/0.3 m to 80 blows/0.25 m, indicating a compact to very dense but a typically dense to very dense condition.

The measured natural moisture contents of soil samples recovered from this deposit range from 8 to 21% but generally from 8 to 14%. It should be noted that higher measured natural moisture contents ranging from 17 to 21% generally correspond to more silty/clayey seams.

4.3.5 SAND & GRAVEL

At the location of Borehole C3-1, a water bearing (wet) sand and gravel layer was encountered within the glacial till deposit at about 5.2 m depth (El. 368.3 m) extending to about 7.1 m depth (El. 366.4 m).

Standard penetration tests performed in this deposit yielded N-values of 42 blows/0.3 m and 50 blows/0.14 m, indicating dense to very dense condition.

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, piezometers were installed in Boreholes C3-1 and C3-3 to allow ground monitoring over prolonged period of time. The groundwater observations during our investigation are presented on the individual Record of Borehole sheets in Appendix A3.

The results indicate that at the time of our investigation the groundwater level in sealed piezometers in Boreholes C3-1 and C3-3 (adjacent to the existing culvert) was recorded at 0.4 and 0.5 m below the ground surface, or at El. 373.6 and 373.2 m, respectively. The observed water level during drilling in Borehole C3-2 (through the highway embankment) was found to be lower at about El. 371.6 m. However, this water level does not represent a stabilized condition.

Based on these observations at the time of our investigation, the groundwater level at the site was at about 0.4 to 0.5 m below o.g. levels or at about El. 373.6 to 373.2 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.

4.4 CULVERT REPLACEMENT AT STATION 24+482 (C4)

The existing CSP culvert at Station 24+482 is 914 mm in diameter and about 23 m in length with the culvert invert elevation at 381.86 to 381.90 m.

At this location, three boreholes were drilled for the proposed culvert replacement. Borehole C4-1 was put down near the west-end (downstream) of the existing culvert, while Boreholes C4-2 and C 4-3 were drilled on the west shoulder of the highway and near the east-end (upstream) of the existing culvert, respectively, as shown on Drawing Nos. 4A and 4B in Appendix A4.

Below some granular embankment fill (Borehole C4-2) and surficial topsoil and slightly organic silt, the boreholes show, in general, the presence of sandy silt to silty sand glacial till with some sand layers.

Details of the stratigraphy encountered in the boreholes are given on the Record of Boreholes in Appendix A4. The following paragraphs are only meant to amplify and complement these data.

4.4.1 GRANULAR FILL

Borehole C4-2, which was put down on the left shoulder of Highway 6, contacted a 0.4 m thick layer of sand & gravel pavement fill underlain by sand fill with some gravel to a depth of 2.2 m.

A Standard Penetration test, performed at a depth of 1.5 m below the ground surface, yielded an N-value of 23 blows/0.3 m. Based on this, the relative density of the lower portion of the granular embankment fill is described as compact.

4.4.2 TOPSOIL

Boreholes C4-1 and C4-3, drilled from beyond the toe of the highway embankment (i.e. from the o.g. level), contacted a 0.2 m to 0.13 m thick topsoil layer, respectively.

It should be pointed out that, in our experience, the thickness of topsoil and other organic soils can be expected to be variable, especially in low-lying areas and near water courses.

An approximately 0.2 to 0.3 m thick organic rich layer of soil (possibly original topsoil) was also encountered in Borehole C4-2 below the granular embankment fill at depth of 2.2 m (El. 381.9 m).

4.4.3 SILT

Underneath the topsoil described in the preceding paragraph, Boreholes C4-1 and C4-3 contacted a surficial alluvial silt layer which extended to a depth of 0.7 m below the ground surface at both borehole locations (El. 382.2 and 381.7 m, respectively). From its darkish colour, relatively high natural moisture contents of 22 to 32%, this surficial fine-grained granular deposit is believed to have a slight organic content.

N-values recorded in this surficial unit are 7 and 13 blows/0.3 m which indicates a loose to compact condition.

4.4.4 SAND

Underlying the granular pavement fill and a possible original organic rich soil layer, Borehole C4-2 contacted a sand to silty sand deposit at a depth of about 2.2 m below the ground surface or at about El. 381.9 m. This is a granular soil and was identified as a possible till deposit. Based on the recorded N-values its relative density is described as compact to dense.

In Borehole C4-3, sand with some gravel and traces of silt was encountered underlying glacial till at 7.1 m below the ground surface or below El. 375.3 m. This borehole was terminated in this sand deposit after penetrating it a vertical distance of 0.8 m. An N-value of 50 blows per 8 cm penetration was recorded on this granular (non-cohesive) deposit, indicating a very dense condition.

4.4.5 SANDY SILT TO SILTY SAND TILL

At a depth of 0.7 m in Boreholes C4-1 and C4-3 (at Elevations 382.2 and 381.7 m, respectively) and at 4.0 m depth (El. 380.1 m) all three boreholes contacted a relatively fine-grained granular till deposit which consists of a heterogeneous mixture of sandy silt to silty sand with traces of gravel and clay size particles. This is the predominant soil unit underlying the site and extends to the full depth of Boreholes C4-2 and C4-1 (i.e. to depths of 6.3 and 7.8 m or El. 377.9 and 375.1 m, respectively). In Borehole C4-3, the glacial till extends to 7.1 m depth (El. 375.3 m) and is underlain by a relatively coarser sand deposit to the full depth of the borehole.

The grain-size distribution of two samples from the glacial till deposit is given in Figure B4-1, in Appendix B4. These show the following grain-size distribution:

Gravel:	5 – 12%
Sand:	41-46%
Silt:	34-53%
Clay:	1 – 8%

Due to their mode of deposition, the presence of cobbles and boulders should always be anticipated in the glacial till deposits.

The measured natural moisture contents of the deposit range from 7 to 24% indicating a damp to wet condition. Standard Penetration tests performed in the deposit yielded N-values which range from 7 blows/0.3 m to in excess of 50 blows/0.15 m. These results indicate a loose to very dense material. The relatively low N-values were generally recorded in the upper portions of the deposit, while the lower portions appear to be typically very dense.

4.4.6 GROUNDWATER CONDITIONS

The groundwater level observations and recorded water levels in the open boreholes as well as in the piezometers installed in Boreholes C4-1 and C4-3 are given on the individual Record of Borehole sheets in Appendix A4.

Upon its completion in Borehole C4-3, no free-standing water was recorded in the open hole. Subsequent observations showed no groundwater in the piezometer installed. This shows that the groundwater level in this borehole was below a depth of 7.9 m or below El. 374.4 m. In Borehole C4-1, a water level was recorded at 7.3 m (El. 375.5 m) and water level remained at approximately this level in the piezometer installed. In Borehole C4-2 a free-standing water level was recorded at 4.1 m below the road shoulder level or at El. 380.1 m upon the completion of the borehole.

From these observations, it is our opinion that the groundwater level at the time of our investigation was at between El. 375 and 376 m, but from the short-term observations made in Borehole C4-2 and the moisture contents of the samples, it is our opinion that a perched groundwater level existed due to the accumulation of surface water in the relatively more pervious embankment fill and the underlying sandy deposit in Borehole C4-2. Relatively higher natural moisture contents of the near surface samples in the other two boreholes lead us to believe that perched water conditions are likely to have existed in the past at the other borehole locations, as well.

In summary, therefore, in our opinion that at the time of our investigation the groundwater level at the site was between El. 374 and 376 m, but perched water conditions can be expected. In addition, the groundwater table would be subject to seasonal fluctuations and variations in response to major weather events as well as the water levels in the water course.

4.5 CULVERT REPLACEMENT AT STATION 27+065 (C7)

At Station 27+065, the existing culvert is a corrugated steel pipe (CSP) about 1.5 m in diameter and approximately 22 m in length. Its invert is at El. 357.46m at its east end and 357.55 m at its west end.

Three boreholes were drilled for this culvert replacement. Boreholes C7-1 and C7-3 were put down near the existing culvert ends on the left (west) and right (east) sides of highway respectively, while Borehole C7-2 was advanced on the left shoulder of the highway, as shown on Drawing Nos. 7A and 7B, in Appendix A5.

Borehole C7-2 was located on the shoulder of the highway and contacted fill material which extends to a depth of approximately 2.8 m below the ground surface to El. 356.4 m. Boreholes C7-1 and C7-3, which were put down beyond the bottom of the existing highway embankment at the o.g. levels, contacted topsoil which extended 0.3 m and 0.6 m respectively below the ground surface.

In general below the fill and topsoil, the boreholes contacted silty sand to sandy silt till and silty sand to sandy silt deposits.

4.5.1 GRANULAR EMBANKMENT FILL

Borehole C7-2, which was drilled from the left shoulder of the highway, contacted embankment fill which extended to 2.2 m below the top of the shoulder or to El. 357.0 m. The embankment fill at this location was found to consist of sand and gravel with traces to some silt near the top and bottom of the embankment and sand with some gravel and silt within the middle portion.

The grain-size distribution of a sample obtained from the bottom portion of the fill is presented in Figure B7-1, in Appendix B5. The following grain-size distribution is indicated.

Gravel	43%
Sand	40%
Silt and Clay	17%

This particular sample was found to emit a hydrocarbon odour. A Standard Penetration test performed on this bottom section of the embankment fill, yielded an N-value of 9 blows /0.3 m which indicates that the embankment fill at this depth at the borehole location is in a loose condition.

The measured natural moisture contents of the removed samples ranged from 4% near the top and middle to 11% in the lower portion.

From 2.2 m to 2.8 m below the ground surface (i.e. from El. 357.0 to 356.4 m) the soil encountered in Borehole C7-2 was identified as a granular material (i.e. primarily a gravelly sand soil) and as a probable fill.

4.5.2 TOPSOIL

Boreholes C7-1 and C7-3, which were put down from the bottom of the highway embankment, contacted a topsoil layer of a depth approximately 0.3 m and 0.6 m respectively below the ground surface or to El. 357.9 and 357.3m. The topsoil layer in Borehole C7-3 was found to be a peaty material.

4.5.3 SURFICIAL SILTY SAND TO SANDY SILT

The topsoil in Borehole C7-1 is underlain by a 1.2 m thick layer of fine-grained granular soil which consists of fine sand and silt with traces of gravel and organics. Because of its organic content and relatively disturbed condition it was identified as possible fill or an alluvial soil. This layer extends to 1.5 m below the ground surface or to El. 356.7 m.

N-values recorded in this unit are 7 and 9 blows /0.3 m which indicate a loose condition.

4.5.4 SILTY SAND TO SANDY SILT TILL

Underlying the surficial soils encountered in the preceding paragraphs, all three boreholes contacted a glacial deposit which consists of a heterogeneous mixture of sand and silt with some gravel and traces of clay size particles. This deposit was contacted at depths of 0.6 m (Borehole C7-3) to 2.8 m (Borehole C7-2) below the ground surface or at El. 357.3 to 356.4 m and extended to depths of 3.0 to 5.5 m or to El. 354.9 m (Borehole C7-3) to 353.7 m (Boreholes C7-1 and C7-2), where it is underlain an interglacial deposit of silty sand to sandy silt. A lower till layer was contacted in Borehole C7-3 at 6.9 m (El. 351.0 m) and extended to the termination of the borehole at 8.1 m depth.

The grain-size distribution of a sample from the upper zones of this basically granular glacial deposit is given in Figure B7-2 in Appendix B5. The curve indicates the following grain-size distribution.

Gravel	36%
Sand	40%
Silt	20%
Clay	5%

N-values recorded in the deposit range from 4 blows/0.3 m to 50 blows/0.14 m. These results indicate a very loose to very dense but generally compact to dense relative density.

4.5.5 SILTY SAND TO SANDY SILT

Underlying the upper glacial till deposit all three boreholes contacted a fine grained granular interglacial deposit which consists of silty sand to sandy silt. This deposit was contacted at depths ranging from 3.0 to 5.5 m below the ground surface or at El. 354.9 to 353.7 m and extended to the full depth of Boreholes C7-1 and C7-2 (i.e. 8.1 and 9.6 m respectively) and to a depth of 6.9 m (El. 351.0 m in Borehole C7-2, where it is underlain by glacial till).

The grain-size distribution curve for a sample from the deposit is given in Figure B7-3 in Appendix B5, which shows the following particle sizes.

Gravel	2%
Sand	35%
Silt	57%
Clay	6%

The natural moisture contents of the samples from the deposits are typically 15-18% as opposed to the overlying glacial till which are typically 8-10%.

From the recorded N-values which range from 28 blows for 0.3 m penetration to 50 blows for 0.15 m penetration, the relative density of the deposit is described as compact to very dense but generally dense to very dense.

4.5.6 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 C7-1 and C7-3 to allow ground monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Boreholes sheets presented in Appendix A5.

The observations indicate that at the completion of Boreholes C7-1 and C7-3 the water level was recorded at 0.5m below the ground surface. Approximately five weeks thereafter the water levels in the piezometers rose to 0.2 m below the ground surface or El. 358.0 m and 357.7m respectively. From these observations, the groundwater level at the time of our investigation was at approximately 0.2 m below the ground surface or between El. 358.0 and 357.7 m.

It should however 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.

4.6 CULVERT REPLACEMENT AT STATION 28+299 (C8)

At this location, the existing culvert is a corrugated steel pipe (CSP) about 0.9 m in diameter and approximately 40 m in length. The invert elevation of the existing culvert is at El. 334.14 m (upstream) and El. 334.13 m (downstream).

For this culvert replacement, three boreholes (C8-1, C8-2 and C8-3) were drilled through the existing embankment. The boreholes were put down on or near the shoulder of the highway both on the left (west) and right (east) sides of highway, as shown on Drawings No. 8A and 8B. Boreholes C8-1 and C8-3 could not be located closer to the inlet and outlet of the existing culvert due to access restrictions.

As shown on the Record of Borehole Sheets in Appendix A6, all three boreholes contacted embankment fill materials extending to depths ranging from about 2.1 to 2.9 m below the ground surface (down to El. 333.4 m in Borehole C8-3). Below the embankment fill, the boreholes contacted native granular deposits consisting of primarily sand and gravel (except for the upper 1.8 m of silty sand in Borehole C8-3) to the termination of all the boreholes.

4.6.1 TOPSOIL

Borehole C8-3 put down beyond the gravel shoulder of the existing highway contacted 0.3 m topsoil at the ground surface to El. 336.0 m.

It should be pointed out that the thickness of topsoil and organic soils can be expected to be variable in between and beyond borehole locations, especially near water courses.

4.6.2 EMBANKMENT FILL

All three boreholes contacted embankment fill materials extending to depths ranging from about 2.1 to 2.9 m below the ground surface or to El. 334.1 and 334.2 m in Boreholes C8-2 and C8-1 and to El. 333.4 m in Borehole C8-3. The fill is essentially granular and its composition at the borehole locations ranges from silty sand to sandy silt with traces of gravel and topsoil inclusions (Borehole C8-3 from 0.3 to 1.4 m), silty sand to sand with traces of gravel, clay and topsoil (BH C8-1 from 1.4 to 2.6 m and BH C8-2 from 0.3 to 2.1 m depth) to sand & gravel (BH C8-1 from ground surface to 1.4 m below and BH C8-3 from 1.4 to 2.9 m). The presence of occasional asphalt inclusions was also noted in the sand & gravel fill in BH C8-3. As well, the material in this borehole was found to have some organic soil mixture.

The grain-size distribution curves for two tested samples of the sand & gravel fill are presented in Figure B8-1 in Appendix B6. The following grain-size distribution is indicated:

Gravel:	47 – 54%
Sand:	45 - 53%
Silt and Clay:	0 – 1%

From the grain-size distribution curves, the sand & gravel fill is considered a relatively pervious material.

Standard Penetration tests performed in the fill materials yielded N-values ranging from 5 to 36 blows/0.3 m, indicating loose to dense but generally loose to compact condition.

4.6.3 SILTY SAND

Borehole C8-3 contacted underlying the sand & gravel fill at 2.9 depth (El. 333.4 m), a natural soil deposit consisting of silty sand with traces of gravel and occasional silt pockets extending to 4.7 m depth or El. 331.6 m.

Standard Penetration tests, performed in this basically granular deposit, yielded N-values of 21 and 35 blows/0.3 m, indicating compact to dense condition.

The measured natural moisture contents of the recovered samples from this deposit were 18 and 21%.

4.6.4 SAND & GRAVEL

Underlying the embankment fill and silty sand (in Borehole C8-3 only) described in the preceding paragraphs, all three boreholes contacted a coarse granular deposit consisting of sand & gravel with occasional cobbles and boulders. This deposit was contacted at depths of 2.1 to 4.7 m below the ground surface or at El. 334.2 to 331.6 m and extended to the termination of all boreholes at depths of 5.0 to 7.9 m or to El. 331.3 to 328.4 m.

The measured N-values in this deposit range from 32 blows/0.3m to 100 blows/0.1 m, indicating a dense to very dense but generally very dense condition.

The measured natural moisture contents of samples from the deposit range from 8 to 18% but generally between 8 and 14%.

This deposit was in a wet condition (i.e. water-bearing) and based on a visual examination of the soil samples, it is considered to be a relatively pervious soil. Boreholes C8-1 and C8-2 were terminated in this deposit at depths/elevation of 5.0 m/331.3 m and 6.3 m/330.5 m due to auger refusal possibly owing to the presence of boulders, while Borehole C8-3 was extended to fill borehole depth of 7.9 m (El. 328.4 m) without encountering refusal to augering.

4.6.5 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, a piezometer was installed in Borehole C8-3 to allow ground monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Borehole sheets in Appendix A6.

The results indicate that at the time of our investigation, the soil in the boreholes became wet at about 2 m depth or at about El. 334.0 to 334.5 m. Upon completion of drilling, free-standing water was recorded in the sealed piezometer in Borehole C8-3 at 1.8 m or at El. 334.6 m. Subsequent readings in this piezometer over the following two weeks recorded a water level of 1.7 m below the ground surface, or at El. 334.7 m. From these observations, the groundwater level at the time of our investigation was about 1.7 to 2.0 m below the ground surface, or at about El. 334.5 to El. 334.7 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


Ramon Miranda, P.Eng.




Z.S. Ozden, P.Eng.



ZO:tr/hd

Appendix A1

Drawings & Record of Borehole Sheets for Culvert C1

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.

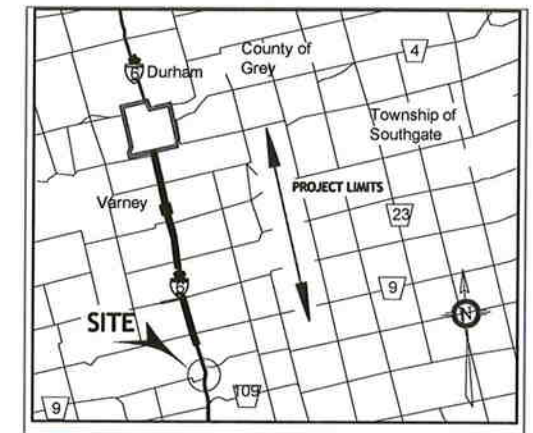
CONT No.

GWP: 338-97-00

Highway 6, Durham
Culvert C1 @ Sta. 21+204
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C1-1	376.1	4 882 440.1	200 946.4
C1-2	377.8	4 882 441.1	200 953.1
C1-3	376.5	4 882 450.8	200 969.0

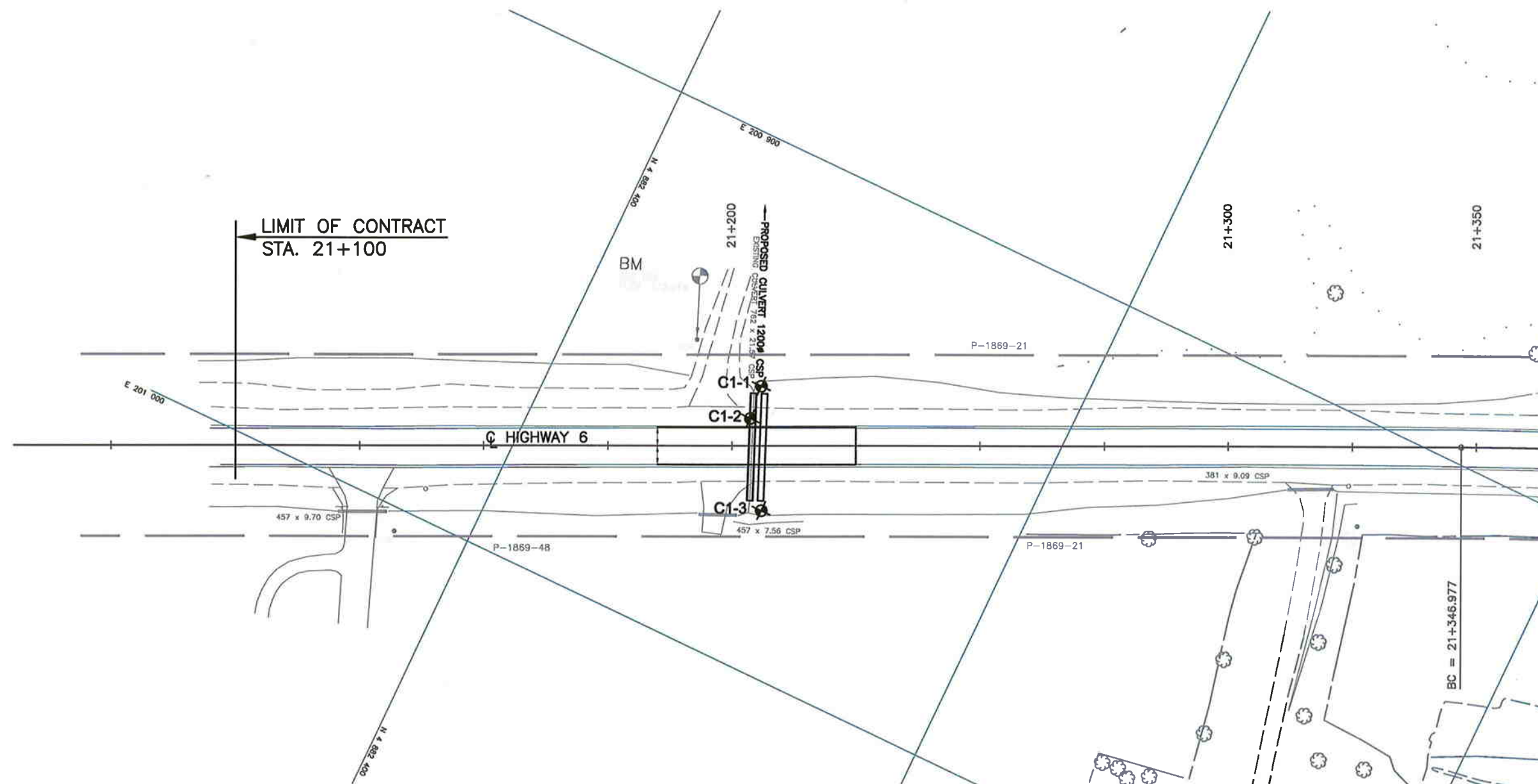
NOTE

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-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 1A



SCALE
10m 0 10 20m

PLAN



METRIC

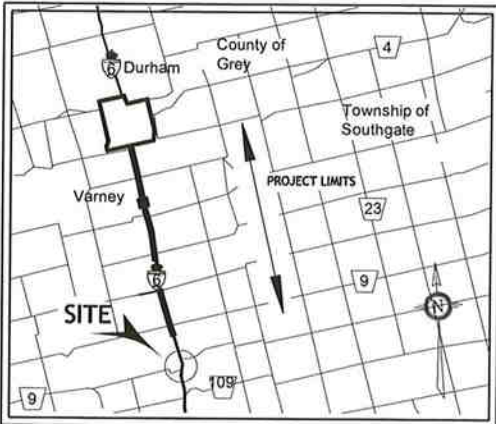
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
ARE IN KILOMETRES + METRES.

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

CONT No.
GWP: 338-97-00
Highway 6, Durham
Culvert C1 @ Sta. 21+204
SOIL STRATA



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 (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C1-1	376.1	4 882 440.1	200 946.4
C1-2	377.8	4 882 441.1	200 953.1
C1-3	376.5	4 882 450.8	200 969.0

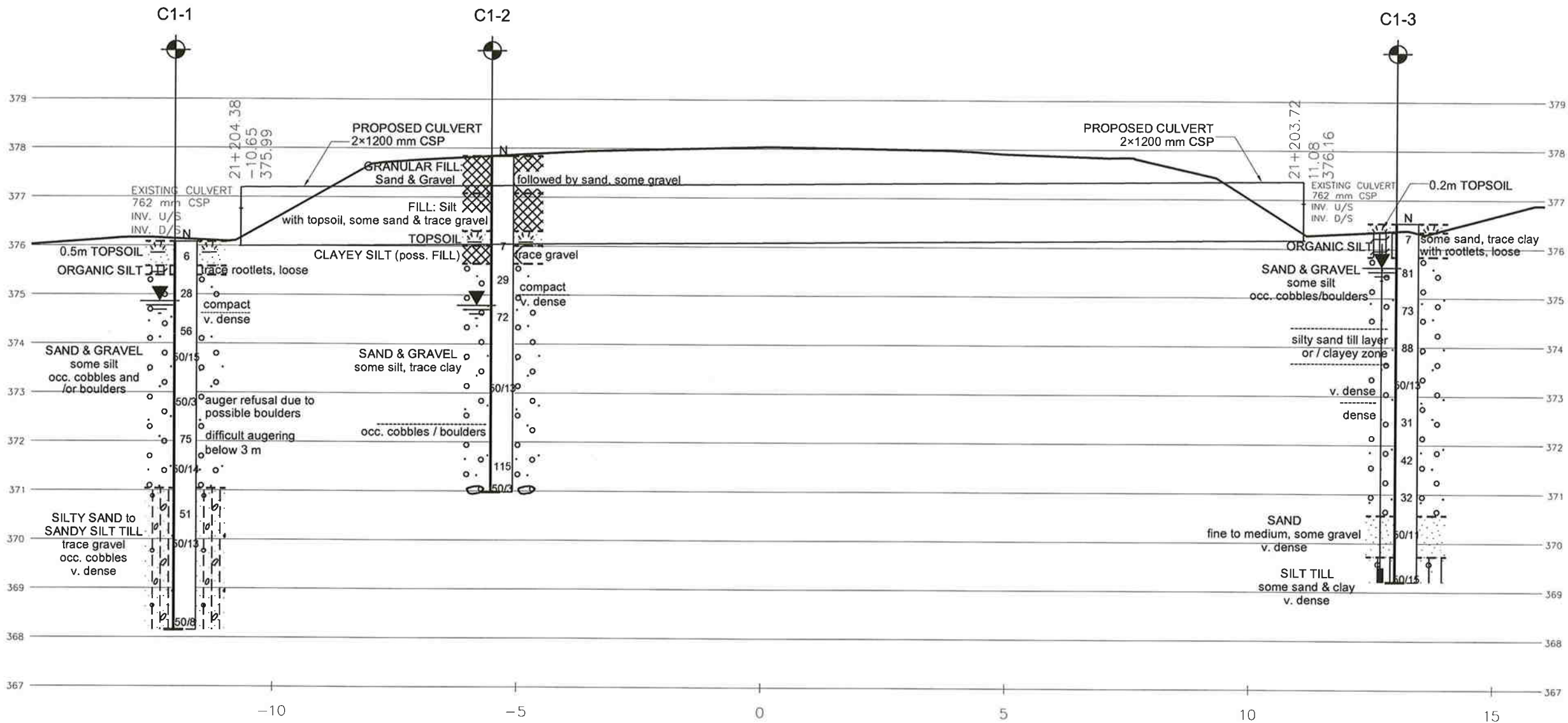
NOTE

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-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 1B



STRATIGRAPHIC SECTION ALONG CULVERT C1 @ STA. 21+204



SPT1174

RECORD OF BOREHOLE No C1-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 21+206, 12m Lt. C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY HL
DATUM Geodetic DATE 10/2/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								20	40	60	80						100	20	40
376.1	GROUND SURFACE																		
0.0	0.5 m TOPSOIL		1	SS	6		376												
375.6	ORGANIC SILT																		
0.5	trace rootlets, brown, wet to moist, loose		2	SS	28		375												
375.4																			
0.7	compact		3	SS	56		374												
	very dense		4	SS	50/15		373												
	SAND & GRAVEL																		
	some silt		5	SS	50/3		372												
	occasional cobbles and/or boulders		6	SS	75		371												
	brown, moist to wet		7	SS	50/14		370												
371.0																			
5.0	SILTY SAND to SANDY SILT TILL		8	SS	51		369												
	trace gravel		9	SS	50/13														
	occasional cobbles																		
	brown, moist to wet																		
	very dense																		
368.1			10	SS	50/8														
7.9	End of borehole.																		
	* Water level in open borehole at 1.2 m (El. 374.8 m) upon completion (not stabilized).																		
	Borehole was relocated by 1m north and redrilled due to possible boulder refusal at 3 m depth.																		

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C1-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 21+204, 5.5m Lt C/L
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers ORIGINATED BY JL
 DATUM Geodetic DATE 8/22/2006 COMPILED BY XS
 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE				
377.8 0.0	GROUND SURFACE		1	AS				20 40 60 80 100				
377.1 0.8	GRANULAR FILL: Sand & Gravel followed by sand, some gravel brown, damp		2	AS								
376.3 1.5	FILL: Silt with topsoil some sand, trace gravel dark brown, damp		3	AS			377					
376.0 1.8	TOPSOIL, black, moist		4	SS	7		376					
375.6 2.2	CLAYEY SILT (possible FILL) trace gravel & organics, dark brown, moist		5	SS	29		375					
	compact very dense		6	SS	72		374					
	SAND & GRAVEL some silt, trace clay brown, moist to wet		7	SS	50/13		373					
	occasional cobbles /boulders		8	SS	115		372					
371.0 6.9	End of borehole. Auger refusal @ 6.9 m possibly on a boulder. * Water level in open borehole at 3.1 m (El. 374.7 m) upon completion (not stabilised).		9	SS	50/3		371					

+ 3, x 3: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C1-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 21+206, 13m Rt. C/L ORIGINATED BY NH
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY HL
DATUM Geodetic DATE 10/10/2006 CHECKED BY FS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100					
376.5	GROUND SURFACE												
376.0	0.2 m TOPSOIL		1	SS	7								
375.8	ORGANIC SILT some sand, trace clay, with rootlets dark brown, loose		2	SS	81								
375.0	SAND & GRAVEL some silt occasional cobbles/boulders brown, wet very dense		3	SS	73								
374.0	silty sand till layer or / clayey zone		4	SS	88								
373.0	dense		5	SS	50/13								
372.0			6	SS	31								
371.0			7	SS	42								
370.6	SAND fine to medium, some gravel brown, wet, very dense		8	SS	32								
369.7			9	SS	50/11								
369.2	SILT TILL some sand & clay, brown, moist, very dense		10	SS	50/15								
7.3	End of borehole. Piezometer installed to depth of 7.3 m. Water level in piezometer: Oct. 10, 2006 ---1.4 m (El. 375.2 m) Nov. 22, 2006 ---0.9 m (El. 375.6 m)												

Appendix A2

Drawings & Record of Borehole Sheets for Culvert C2

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.

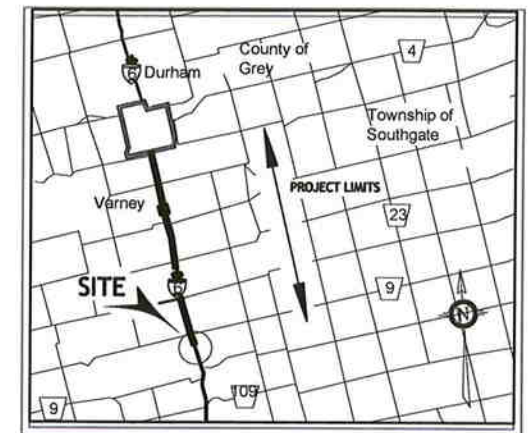
CONT No.

GWP: 338-97-00

Highway 6, Durham
Culvert C2 @ Sta. 21+807
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C2-1	379.7	4 883 014.5	200 770.2
C2-2	384.5	4 883 016.5	200 781.6
C2-3	383.0	4 883 018.4	200 797.6

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-193

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 2A

SCALE
10m 0 10 20m

PLAN



METRIC

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

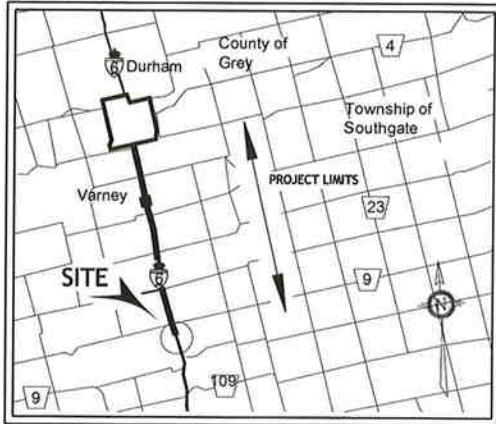
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C2 @ Sta. 21+807
SOIL STRATA



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	EAST
C2-1	379.7	4 883 014.5	200 770.2
C2-2	384.5	4 883 016.5	200 781.6
C2-3	383.0	4 883 018.4	200 797.6

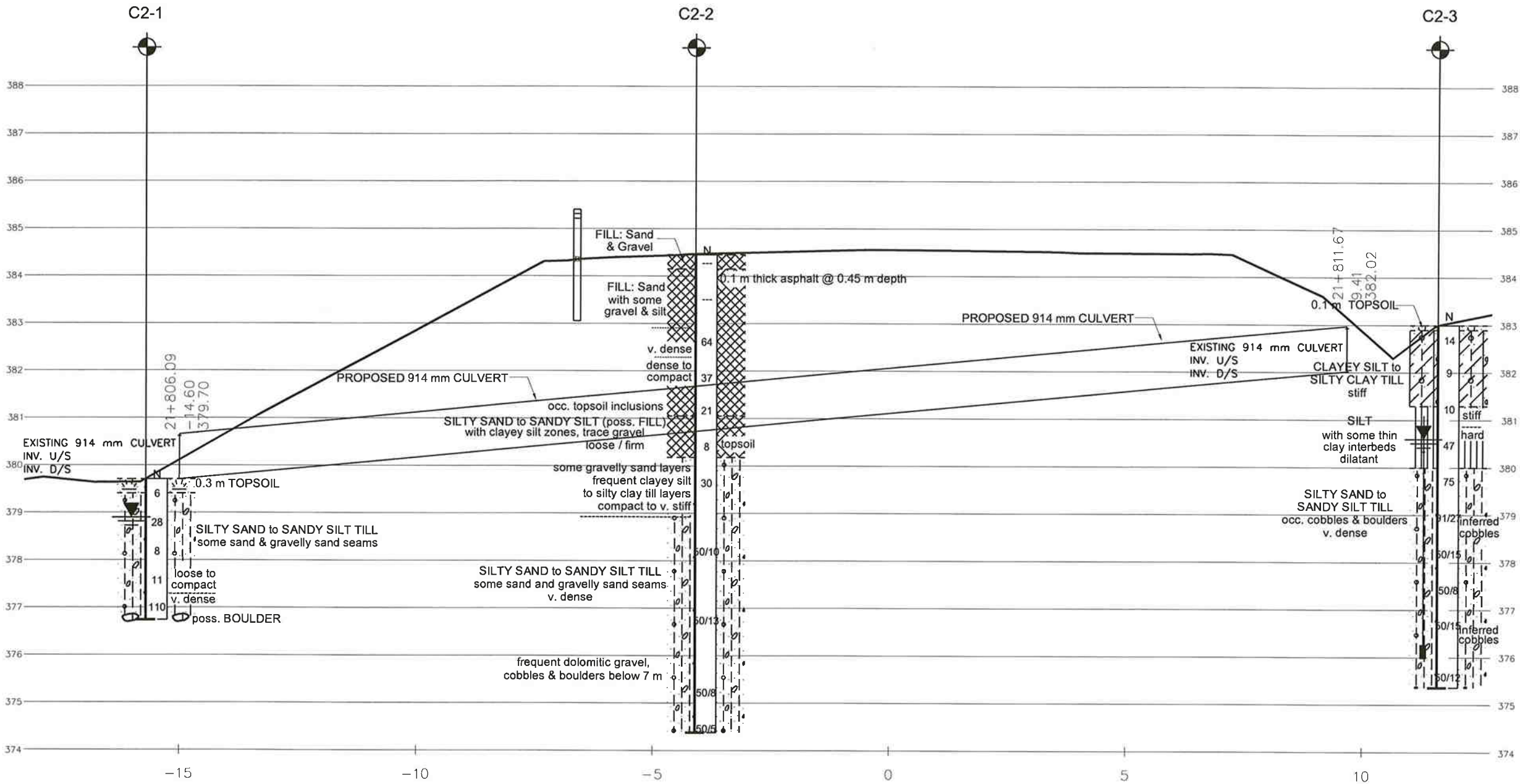
=NOTE=

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-193	
				SPT 1174	DIST
				SUBM'D	CHECKED
				DATE Jan., 2008	SITE
				DRAWN SM	CHECKED RM
				APPROVED ZO	DWG 2B



SCALE
1m 0 1 2m VERT
1m 0 1 2m HOR

STRATIGRAPHIC SECTION ALONG CULVERT C2 @ STA. 21+810



SPT1174

RECORD OF BOREHOLE No C2-1

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 21+807, 15.7m Lt, C/L

ORIGINATED BY ZI

DIST HWY 6

BOREHOLE TYPE Manual (Hand) Drilling Using 31.8 kg Hammer

COMPILED BY XS

DATUM Geodetic

DATE 12/7/2006

CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
379.7	GROUND SURFACE													
379.2	0.3 m TOPSOIL		1	SS	6									
0.3	SILTY SAND to SANDY SILT TILL some sand and gravelly sand seams brown, moist to wet		2	SS	28									
			3	SS	8									
			4	SS	11									
376.7			5	SS	110									
3.0	End of borehole. * Water level in open borehole at 0.8 m (El. 378.9 m) upon completion (not stabilized). Borehole caved at 2.3 m depth. ** Note: A 31.8 kg hammer was used to obtain N- values. Blow counts were divided by two to obtain an equivalent N- value.													spoon refusal @ 3.0 m, probably on a boulder.

+ 3, x 3: Numbers refer to
Sensitivity

20
15 10 5
(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C2-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 21+807, 4.1m LI, C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 8/24/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100						
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT							
							W P W L							
							20 40 60 80 100							
384.5	GROUND SURFACE													
384.2	FILL: Sand & Gravel		1	AS	---									
0.3	0.1 m thick asphalt @ 0.45 m depth						384							
	FILL: Sand with some gravel & silt brown, damp		2	AS	---									
	very dense		3	SS	64		383							
	dense to compact		4	SS	37		382							
381.1	occasional topsoil inclusions		5	SS	21		381					8 42 37 13		
3.4	SILTY SAND to SANDY SILT (possible FILL) with clayey silt zones, trace gravel brown to dark brown, moist loose / firm		6	SS	8							topsoil @ 4.0 m		
380.2							380							
4.3	some gravelly sand layers frequent clayey silt to silty clay till layers compact to very stiff		7	SS	30		379					23 63 (14)		
			8	SS	50/10		378							
	SILTY SAND to SANDY SILT TILL some sand and gravelly sand seams brown, moist to damp very dense		9	SS	50/13		377							
	frequent dolomitic gravel, cobbles & boulders below 7 m		10	SS	50/8		376							
374.4							375							
10.1	End of borehole. Borehole dry upon completion.		11	SS	50/5									

+³ ×³: Numbers refer to
Sensitivity 15 10 5 10 (%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C2-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 21+806, 9.5m Rt, C/L
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 10/11/2006
 ORIGINATED BY NH
 COMPILED BY HL
 CHECKED BY FS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100					
383.0	GROUND SURFACE												
382.8	0.1 m TOPSOIL		1	SS	14								
381.3	CLAYEY SILT to SILTY CLAY TILL brown, stiff		2	SS	9								
381.3	SILT		3	SS	10								
380.0	with some thin clay interbeds brown, wet, dilatant		4	SS	47								
380.0	SILTY SAND to SANDY SILT TILL occasional cobbles & boulders brown, damp, very dense		5	SS	75								
379.4			6	SS	91/27								
378.9			7	SS	50/15								
378.4			8	SS	50/8								
377.9			9	SS	50/15								
377.4													
376.9													
376.4			10	SS	50/12								
375.4	End of borehole.												
375.4	Piezometer installed to depth of 7.0 m. Water level in piezometer: Oct. 11, 2006 ---4.0 m (El. 379.4 m) Nov. 22, 2006 ---2.4 m (El. 380.9 m)												

Appendix A3

Drawings & Record of Borehole Sheets for Culvert C3

METRIC

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

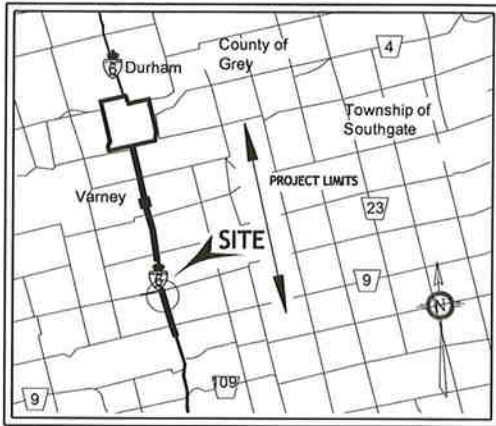
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C3 @ Sta. 23+793
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C3-1	373.5	4 884 976.8	200 426.0
C3-2	375.3	4 884 971.9	200 444.1
C3-3	373.7	4 884 971.3	200 451.8

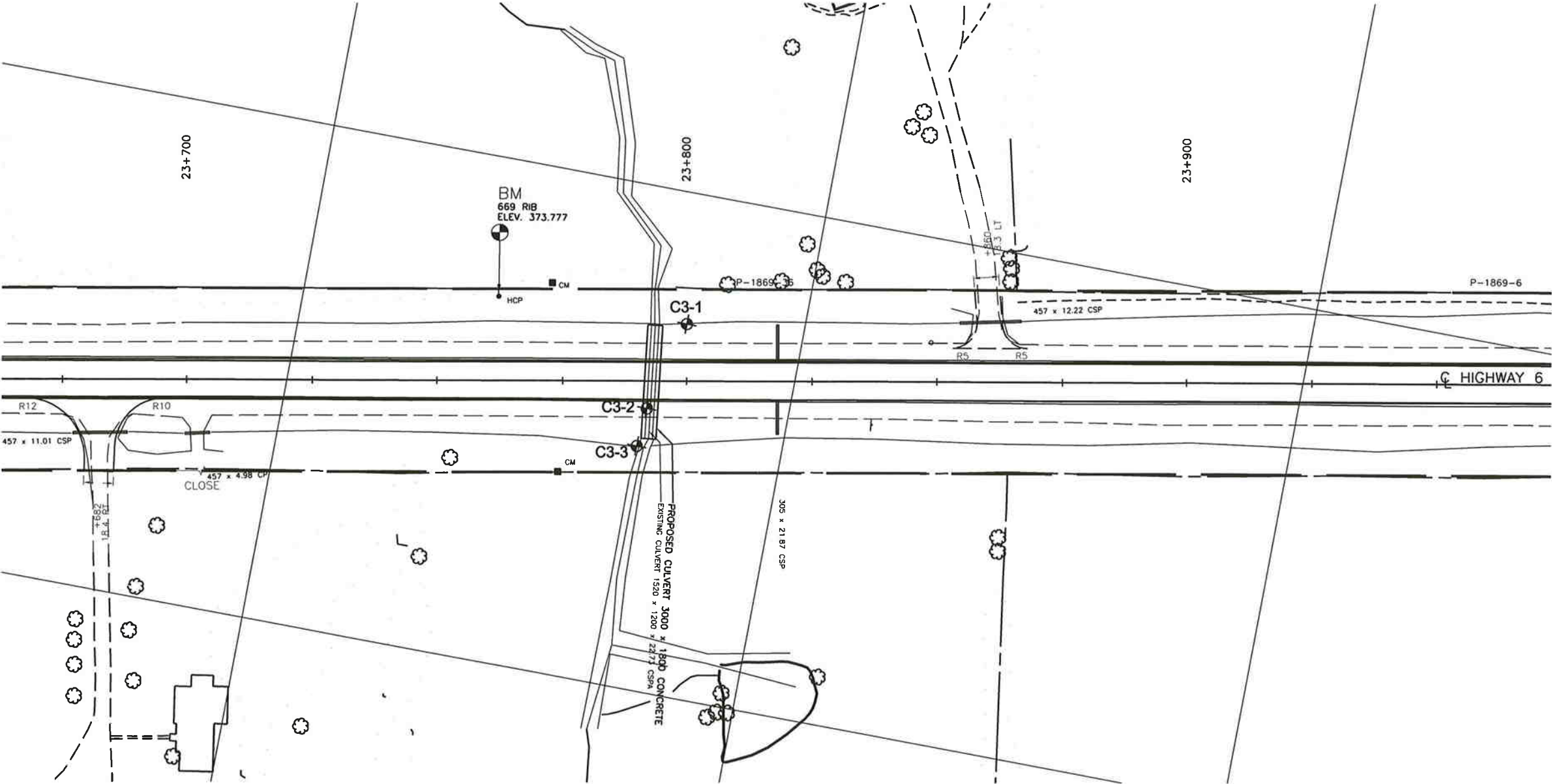
NOTE

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-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 3A



PLAN



METRIC

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

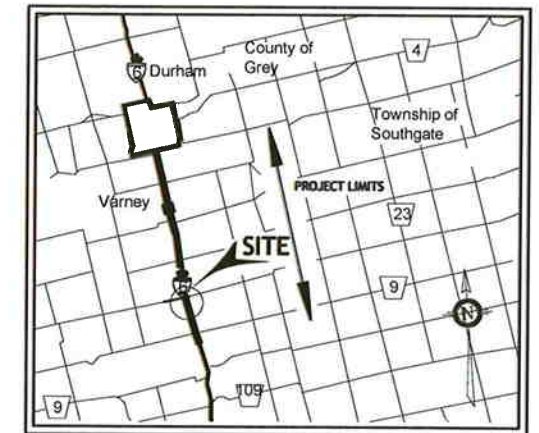
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C3 @ Sta. 23+793
SOIL STRATA



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 (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C3-1	373.5	4 884 976.8	200 426.0
C3-2	375.3	4 884 971.9	200 444.1
C3-3	373.7	4 884 971.3	200 451.8

NOTE

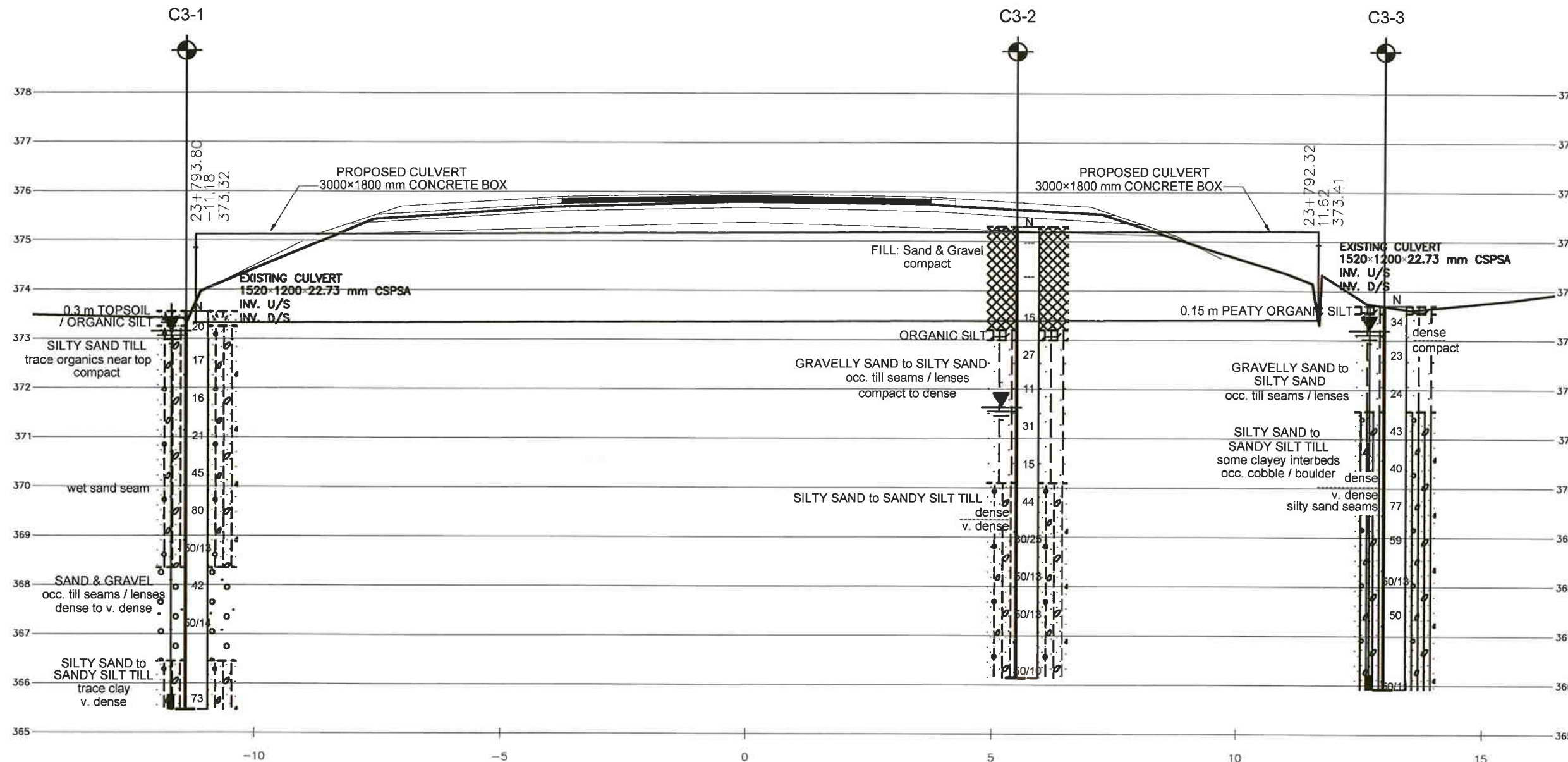
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

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

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REV.			
	DATE	BY	DESCRIPTION

Geocres No. 41A-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 3B



STRATIGRAPHIC SECTION ALONG CULVERT C3 @ STA. 23+793



SPT1174

RECORD OF BOREHOLE No C3-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 23+800, 11.4m Lt, C/L
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
DATUM Geodetic DATE 10/12/2006
ORIGINATED BY JL
COMPILED BY HL
CHECKED BY FS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100				
373.5	GROUND SURFACE														
373.2	0.3 m TOPSOIL / ORGANIC SILT		1	SS	20										
0.3	SILTY SAND to SANDY SILT TILL trace organics near top dark brown to brown compact		2	SS	17										
			3	SS	16										
			4	SS	21										
			5	SS	45										
			6	SS	80										
			7	SS	50/13										
368.3	SAND & GRAVEL occasional till seams / lenses brown, wet dense to very dense		8	SS	42										
5.2			9	SS	50/14										
366.4	SILTY SAND to SANDY SILT TILL trace clay brown, wet very dense														
7.1			10	SS	73										
365.5	End of borehole. Piezometer installed to depth of 7.0 m. Water level in piezometer: Oct. 12, 2006 --6.7 m (El. 367.3 m) Nov. 22, 2006 --0.4 m (El. 373.6 m)														
8.1															

+ 3, X 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C3-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 23+792, 5.5m Rt, C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 10/8/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
375.3	GROUND SURFACE													
0.0	FILL: Sand & Gravel brown, damp to moist compact		1	AS	--		375							
			2	AS	--									
							374							
373.2			3	SS	15									
2.1	ORGANIC SILT trace rootlets, black, moist						373							
373.0			4	SS	27									
2.3	GRAVELLY SAND to SILTY SAND occasional till seams / lenses grey, compact to dense													
			5	SS	11		372							
			6	SS	31		371							
			7	SS	15									
370.1							370							
5.2			8	SS	44									
			9	SS	80/25		369							
			10	SS	50/13		368							
			11	SS	50/13		367							
366.1			12	SS	50/10									
9.2	End of borehole.													
	* Water level in open borehole at 3.7 m (El. 371.6 m) upon completion (not stabilized).													

SPT1174

RECORD OF BOREHOLE No C3-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 23+790, 13m Rt. C/L
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 10/12/2006
 ORIGINATED BY NH
 COMPILED BY HL
 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● POCKET PENETR. X LAB VANE						
								20 40 60 80 100						
373.7	GROUND SURFACE													
378.5	0.15 m PEATY ORGANIC SILT													
0.2			1	SS	34									
			2	SS	23		373							wet spoon
			3	SS	24		372							
371.6														
2.1			4	SS	43		371							
			5	SS	40		370							
			6	SS	77		369							
			7	SS	59		368							
			8	SS	50/13		367							
			9	SS	50		366							
365.9			10	SS	50/11									
7.8														
	End of borehole.													
	Piezometer installed to depth of 7.6m. Water level in piezometer: Nov. 10, 2006 ---3.4m (El. 370.3m) Nov. 22, 2006 ---0.5m (El. 373.2m)													

Appendix A4

Drawings & Record of Borehole Sheets for Culvert C4

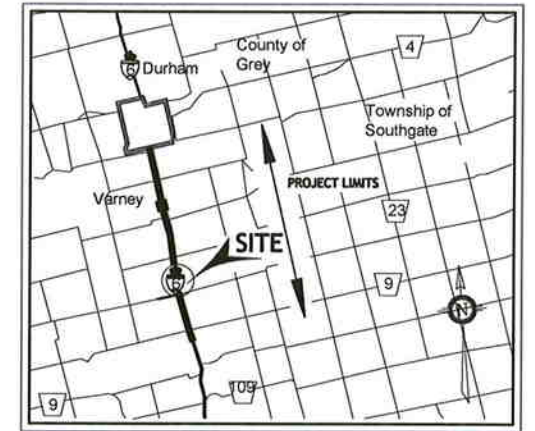
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
ARE IN KILOMETRES + METRES.

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

CONT No.
GWP: 338-97-00
Highway 6, Durham
Culvert C4 @ Sta. 24+482
BOREHOLE LOCATIONS




SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

 Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C4-1	382.9	4 885 655.7	200 318.1
C4-2	384.2	4 885 651.4	200 323.9
C4-3	382.4	4 885 651.7	200 341.9

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.

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REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-193

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 4A

SCALE
10m 0 10 20m

PLAN



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

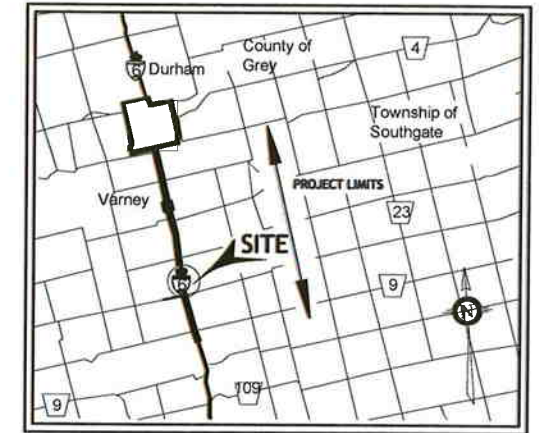
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C4 @ Sta. 24+482
SOIL STRATA



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
(W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C4-1	382.9	4 885 655.7	200 318.1
C4-2	384.2	4 885 651.4	200 323.9
C4-3	382.4	4 885 651.7	200 341.9

NOTE

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

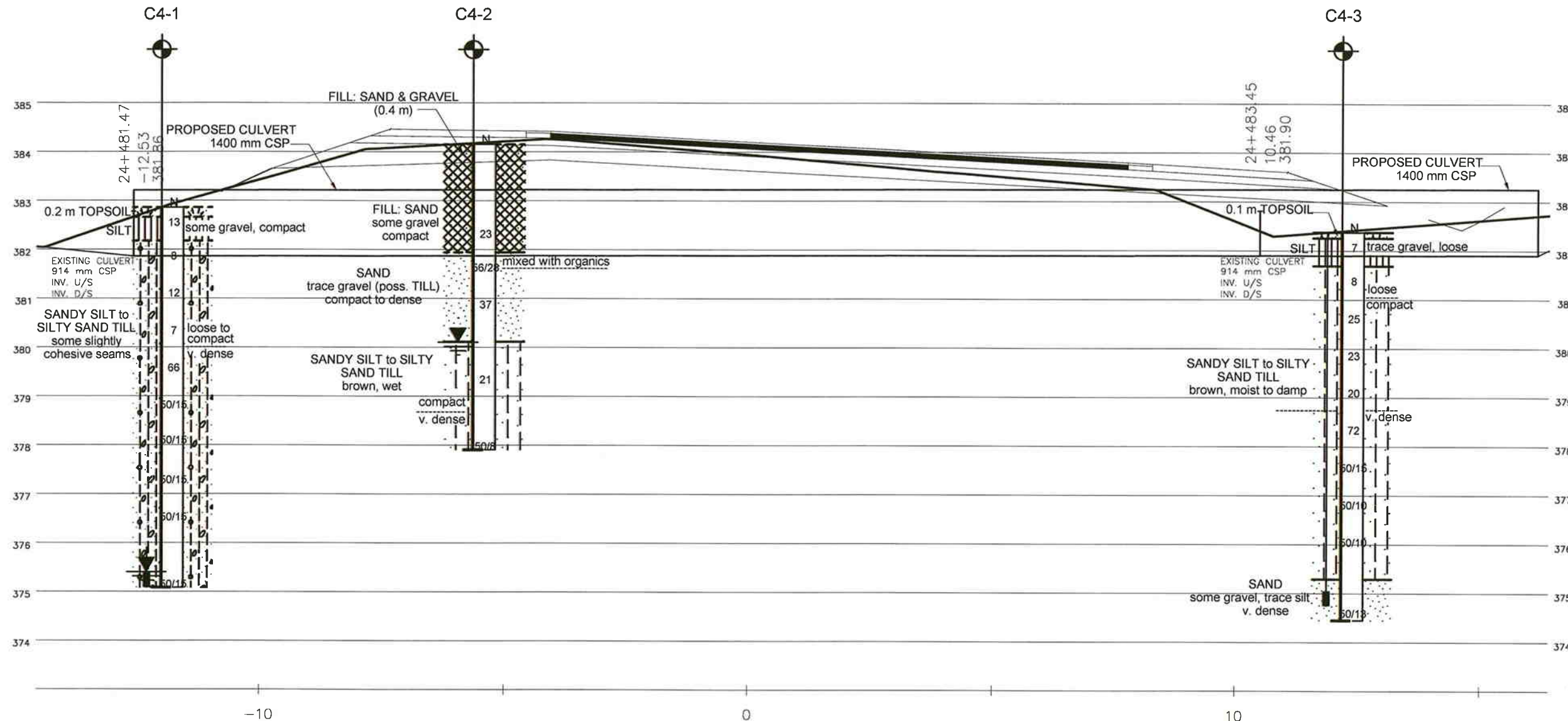
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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-193

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 4B



STRATIGRAPHIC SECTION ALONG CULVERT C4 @ STA. 24+482



RECORD OF BOREHOLE No C4-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 24+486, 12m Lt C/L
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
DATUM Geodetic DATE 10/13/2006
ORIGINATED BY NE
COMPILED BY XS
CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
382.9	GROUND SURFACE						20	40	60	80	100				
382.0	0.2 m TOPSOIL		1	SS	13										
382.2	SILT some gravel, dark brown, damp, compact		2	SS	8										
0.7	SANDY SILT to SILTY SAND TILL some slightly cohesive seams brown, moist to damp		3	SS	12										
			4	SS	7										
			5	SS	66										
			6	SS	50/15										
			7	SS	50/15										
			8	SS	50/15										
			9	SS	50/15										
			10	SS	50/15										
375.1	End of borehole.														
7.8	Water level @ 7.3 m and hole caved-in @ 7.4 m upon completion. Piezometer installed to depth of 7.8 m. Water level in piezometer: Oct. 13, 2006 ---7.3 m (El. 375.5 m) Nov. 22, 2006 ---7.4 m (El. 375.4 m)														

+ 3, x 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C4-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 24+482, 6m LI, C/L ORIGINATED BY JL
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
 DATUM Geodetic DATE 8/22/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE							● POCKET PENETR. x LAB VANE	
								20	40	60								80
384.2 0.0	GROUND SURFACE																	
	FILL: Sand & Gravel (0.4 m)		1	AS														
	FILL: Sand some gravel brown, damp compact		2	AS														
			3	SS	23													
381.9 2.2	mixed with organics		4	SS	56/28													
	SAND trace gravel (possible TILL) brown, moist to wet compact to dense		5	SS	37													
380.1 4.0	SANDY SILT to SILTY SAND TILL brown, wet		6	SS	21													
	compact very dense																	
377.9 6.3	End of borehole.		7	SS	50/8													
	* Water level in open borehole at 4.1 m (El. 380.1 m) upon completion (not stabilized).																	

RECORD OF BOREHOLE No C4-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 24+483, 12m RI, C/L
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers ORIGINATED BY NH
DATUM Geodetic DATE 10/13/2006 COMPILED BY HL
CHECKED BY FS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
382.4	GROUND SURFACE												
382.3	0.1 m TOPSOIL												
381.7	SILT trace gravel, dark brown, damp, loose		1	SS	7								
381.7			2	SS	8								
381.7			3	SS	25								
381.7			4	SS	23								
381.7			5	SS	20								
381.7			6	SS	72								
381.7			7	SS	50/15								
381.7			8	SS	50/10								
381.7			9	SS	50/10								
375.3	SAND some gravel, trace silt brown, damp very dense		10	SS	50/13								
374.4	End of borehole.												
374.4	Borehole dry upon completion.												
374.4	Piezometer installed to depth of 7.6 m. Water level in piezometer: Oct. 13, 2006 ---dry. Oct. 18, 2006 ---dry. Nov. 22, 2006 ---dry												

Appendix A5

Drawings & Record of Borehole Sheets for Culvert C7

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.

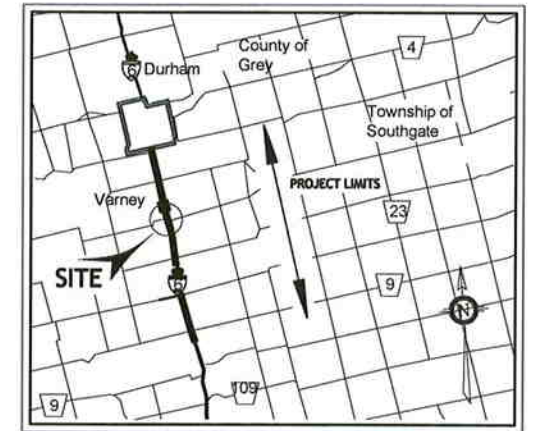
CONT No.

GWP: 338-97-00

Highway 6, Durham
Culvert C7 @ Sta. 27+065
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

 Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C7-1	358.2	4 888 178.8	200 167.8
C7-2	359.2	4 888 180.6	200 177.7
C7-3	357.9	4 888 184.1	200 196.3

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-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 7A

SCALE
10m 0 10 20m

PLAN



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

GWP: 338-97-00

Highway 6, Durham
Culvert C7 @ Sta. 27+065
SOIL STRATA



A map of the project area. A thick black line represents the project route, running north-south. At the top, it is labeled 'Durham' with a small circle. Below it, a rectangular area is outlined. Further down, a circle is labeled 'Varney'. A double-headed arrow labeled 'PROJECT LIMITS' points to the right, indicating the extent of the project. To the right of the route, a road is labeled 'Township of Southgate'. A north arrow is located in the bottom right corner. Road shields for 4, 23, 9, and 109 are visible. A label 'SITE' with an arrow points to a specific location on the route.

KEY PLAN
N.T.S

Borehole

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	EAST
C7-1	358.2	4 888 178.8	200 167.8
C7-2	359.2	4 888 180.6	200 177.7
C7-3	357.9	4 888 184.1	200 196.3

==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-193

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 7B

The diagram illustrates a geotechnical cross-section of a road project, showing three boreholes (C7-1, C7-2, C7-3) and a proposed culvert. The vertical axis represents elevation in meters, ranging from 350 to 361. The horizontal axis represents distance in meters, ranging from -15 to 10.

Proposed Culvert: 1800x1200 mm CONCRETE, located between C7-1 and C7-3.

Existing Culvert: 1520x1200 mm CSP, located between C7-2 and C7-3.

Soil Profiles and Labels:

- C7-1:**
 - 0.3m TOPSOIL
 - SILTY SAND to SANDY SILT (poss. FILL) trace to some gravel, trace organic loose
 - SILTY SAND to SANDY SILT TILL with some silty sand layers
 - SILTY SAND to SANDY SILT
- C7-2:**
 - FILL: Sand & Gravel (0.25m)
 - FILL: Sand some gravel & silt
 - FILL: Sand & Gravel some silt & odorous near top
 - GRAVELLY SAND (poss. FILL) some silt
 - SILTY SAND to SANDY SILT TILL with some silty sand layers
 - SILTY SAND to SANDY SILT v. dense to dense
- C7-3:**
 - 0.6m PEATY TOPSOIL trace gravel
 - SILTY SAND to SANDY SILT TILL dense to v. dense
 - SILTY SAND to SANDY SILT dense to v. dense
 - occ. thin clayey silt interbeds
 - SILTY SAND to SANDY SILT TILL v. dense

Elevations and Distances:

- C7-1:** 358.38, 357.31, 357.55, 356.26, 355.29, 354.36, 353.28, 352.77/29, 351.60, 350.73
- C7-2:** 358.38, 357.31, 357.55, 356.26, 355.29, 354.36, 353.28, 352.77/29, 351.60, 350.73
- C7-3:** 358.82, 357.97, 357.46, 356.26, 355.29, 354.36, 353.28, 352.77/29, 351.60, 350.73

SCALE

1m 0 1 2m

1m 0 1 2m

VERT

HOR

STRATIGRAPHIC SECTION ALONG CULVERT C7 @ STA. 27+065



SPT1174

RECORD OF BOREHOLE No C7-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 27+067, 16m Lt C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 10/16/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80
358.2	GROUND SURFACE															
357.9	0.3 m TOPSOIL, with rootlets		1	SS	7											
356.7	SILTY SAND to SANDY SILT (possible FILL) trace to some gravel trace organic light brown to grey, moist loose		2	SS	9											
353.7	SILTY SAND to SANDY SILT TILL with some silty sand layers greyish brown	very loose	3	SS	4											
		compact to dense	4	SS	26											
			5	SS	29											
			6	SS	36											
			7	SS	28											
			8	SS	77/29											
350.1	SILTY SAND to SANDY SILT greyish brown, wet, dilatant	compact	9	SS	60											
		very dense	10	SS	73											
			11	SS	50/15											
8.1	End of borehole. Piezometer installed to depth of 7.6 m. Water level in piezometer: Oct. 16, 2006 ---0.5 m (El. 357.7 m) Nov. 22, 2006 ---0.2 m (El. 358.0 m)															

+ 3, x 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C7-2

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 27+067.6m Lt 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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								WATER CONTENT (%)					
359.2	GROUND SURFACE												
0.0	FILL: Sand & Gravel (0.25 m)		1	AS									
	FILL: Sand some gravel & silt brown, moist		2	AS									
357.7			3	SS	9								
1.5	FILL: Sand & Gravel some silt & odorous near top dark brown to black, wet, loose												
357.0	GRAVELLY SAND (possible FILL.) some silt grey, wet		4	SS	24								
2.2			5	SS	13								
356.4	SILTY SAND to SANDY SILT TILL with some silty sand layers greyish brown, wet												
2.8			6	SS	73								
353.7			7	SS	77								
5.5	SILTY SAND to SANDY SILT greyish brown very dense to dense, wet, dilatant												
			8	SS	37								
349.6			9	SS	76								
9.6	End of borehole.												
	* Water level in open borehole at 3.0 m (El. 356.2 m) upon completion (not stabilized).												

+³, ×³: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C7-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 27+067, 13m Rt C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 10/16/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
357.9 0.0	GROUND SURFACE													
357.3 0.6	0.6 m PEATY TOPSOIL black, trace gravel, wet to moist		1	SS	3									
	SILTY SAND to SANDY SILT TILL greyish brown dense to very dense, wet, dilatant		2	SS	33		357							
			3	SS	68		356							35 40 20 5
			4	SS	38		355							
354.9 3.0	SILTY SAND to SANDY SILT greyish brown, wet dilatant dense to very dense		5	SS	33		354							
			6	SS	58		353							
			7	SS	66		352							
			8	SS	55		351							
	occasional thin clayey silt interbeds		9	SS	50/15		350							2 35 57 6
351.0 6.9	SILTY SAND to SANDY SILT TILL greyish brown, very dense													
349.8 8.1	End of borehole. Piezometer installed to depth of 7.0 m. Water level in piezometer: Oct. 16, 2006 ---0.5 m (El. 357.4 m) Nov. 22, 2006 ---0.2 m (El. 357.7 m)		10	SS	50/14									

+ 3, x 3: Numbers refer to
Sensitivity 20
15 5
10 (%) STRAIN AT FAILURE

Appendix A6

Drawings & Record of Borehole Sheets for Culvert C8

METRIC

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

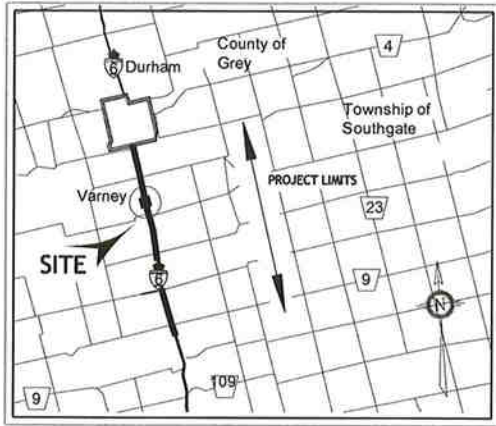
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C8 @ Sta. 28+299
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C8-1	336.3	4 889 391.5	199 950.2
C8-2	336.4	4 889 393.9	199 963.5
C8-3	336.3	4 889 401.2	199 964.2

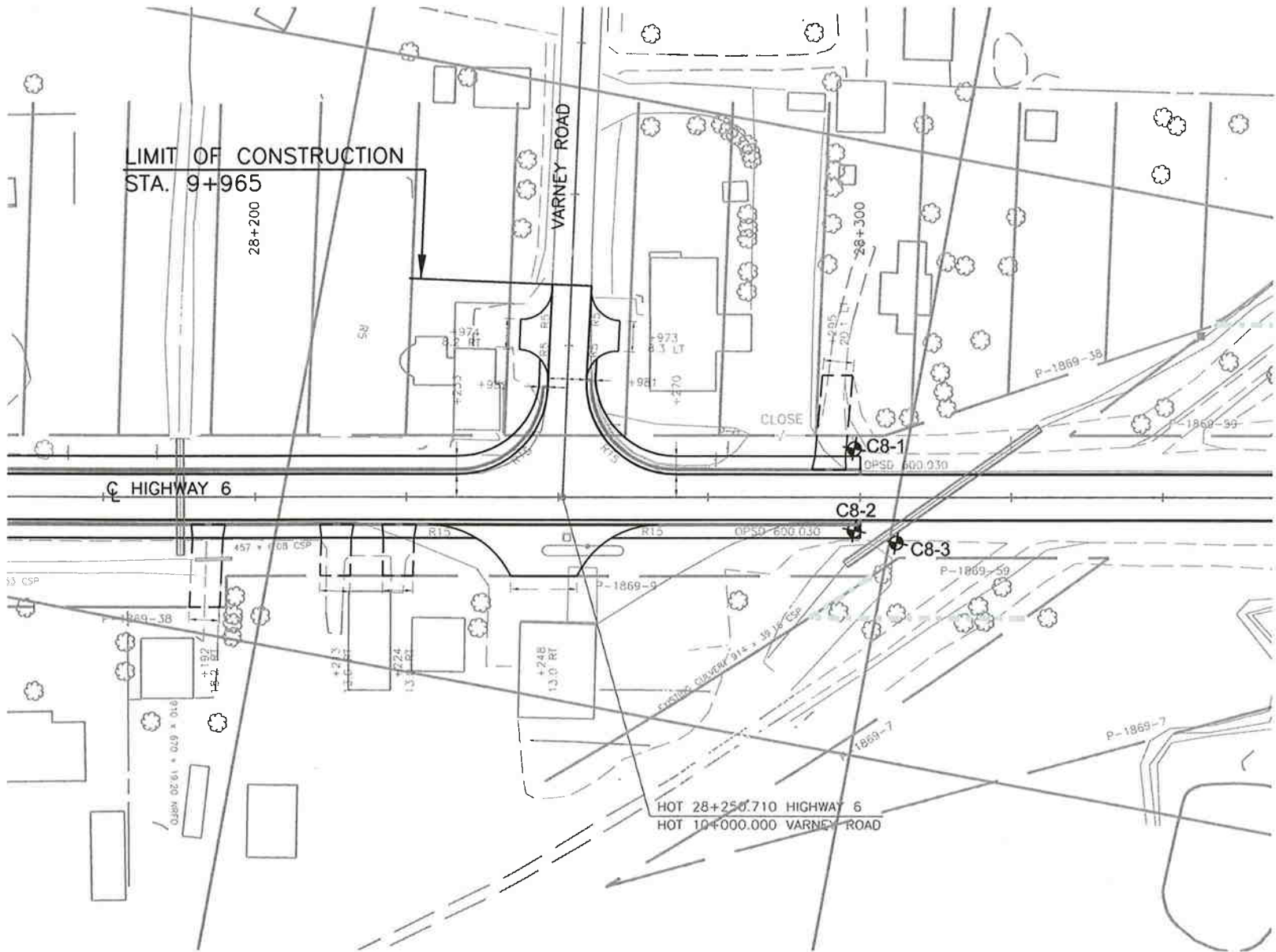
NOTE

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.

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REV.	DATE	BY	DESCRIPTION
Geocres No. 41A-193			
SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 8A



PLAN



METRIC

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

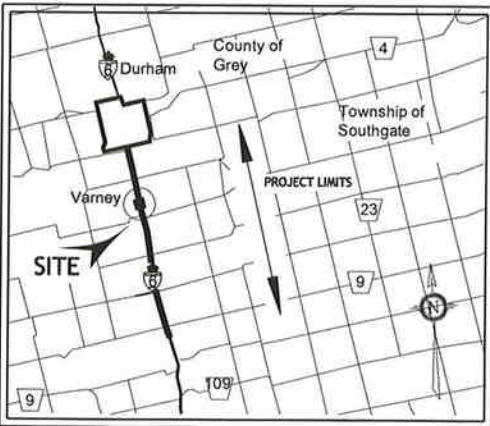
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C8 @ Sta. 28+299
SOIL STRATA



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	EAST
C8-1	336.3	4 889 391.5	199 950.2
C8-2	336.4	4 889 393.9	199 963.5
C8-3	336.3	4 889 401.2	199 964.2

NOTE

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

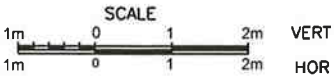
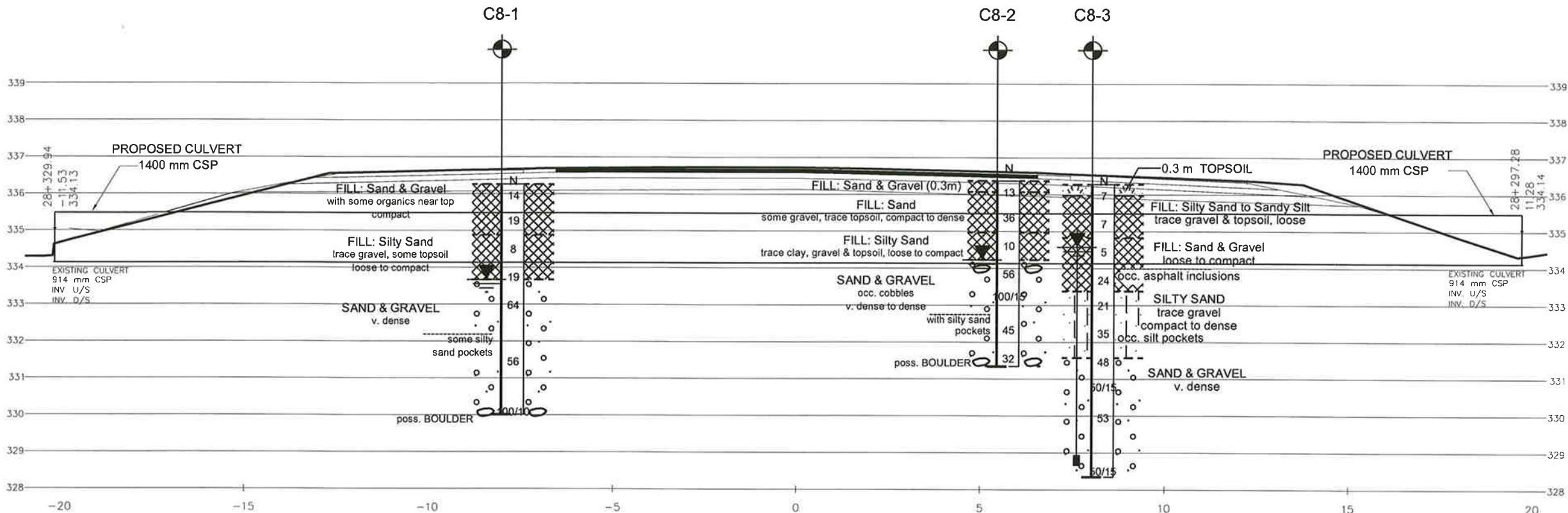
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-193

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 8B



STRATIGRAPHIC SECTION ALONG CULVERT C8 @ STA. 28+299



SPT1174

RECORD OF BOREHOLE No C8-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+299, 12m Lt, C/L
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
 DATUM Geodetic DATE 8/16/2006
 ORIGINATED BY NH
 COMPILED BY XS
 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
336.7	GROUND SURFACE												
0.0	FILL: Sand & Gravel with some organics near top brown, moist compact		1	SS	14		336						
335.3			2	SS	19								
1.4	FILL: Silty Sand trace gravel, some topsoil brown to dark brown, moist to wet loose to compact		3	SS	8		335						
334.1			4	SS	19		334						
2.6	compact		5	SS	64		333						
	SAND & GRAVEL greyish brown to brown, wet very dense		6	SS	56		332						
	some silty sand pockets						331						
330.5			7	SS	100/10								
6.3	End of borehole. Auger refusal on a possible boulder or bedrock at 6.3 m. * Water level in open borehole at 2.6 m (El. 332.9 m) upon completion (not stabilized).												possible boulder.

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C8-2

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 28+299, 5.5m Rt C/L

ORIGINATED BY ZI

DIST HWY 6

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY XS

DATUM Geodetic

DATE 8/17/2006

CHECKED BY FS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100	20 40 60 80 100	W _p W W _L	10 20 30		
336.4	GROUND SURFACE												
336.1	FILL: Sand & Gravel (0.3 m)		1	SS	13								
335.0	FILL: Sand some gravel, trace topsoil brown, dry to moist compact to dense		2	SS	36								
334.2	FILL: Silty Sand trace clay, gravel & topsoil brown, moist loose to compact		3	SS	10								
331.3	SAND & GRAVEL occasional cobbles brown, wet very dense to dense		4	SS	56								split spoon bounced on possible cobble
	with silty sand pockets		5	SS	100/15								
			6	SS	45								
			7	SS	32								
331.3	End of borehole. Auger refusal at 5.0 m on possible boulder or bedrock. * Water level in open borehole at 2.1 m (El. 334.3 m) upon completion (not stabilized). Hole caved at 2.3 m.												possible boulder.

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

SPT1174

RECORD OF BOREHOLE No C8-3

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 28+306, 7.5m Rt C/L

ORIGINATED BY ZI

DIST HWY 6

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY XS

DATUM Geodetic

DATE 11/8/2006

CHECKED BY FS

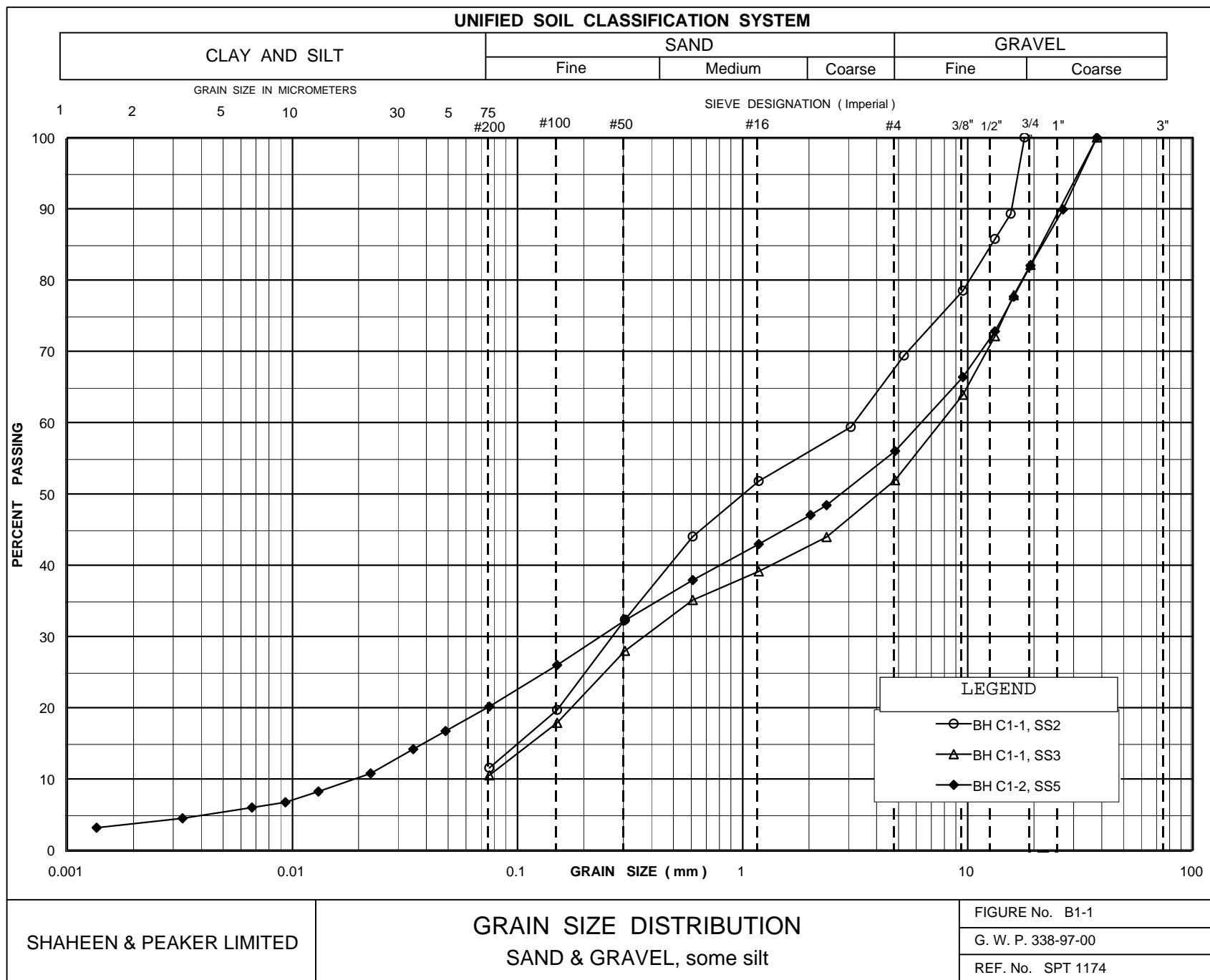
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80
336.3	GROUND SURFACE															
336.0	0.3 m TOPSOIL, with rootlets		1	SS	7											
334.8	FILL: Silty Sand to Sandy Silt trace gravel & topsoil brown, moist, loose		2	SS	7											
333.4	FILL: Sand & Gravel some organic soil black to dark grey, wet loose to compact occasional asphalt inclusions		3	SS	5											
333.4			4	SS	24											
331.6	SILTY SAND trace gravel brown, wet compact to dense occasional silt pockets		5	SS	21											
331.6			6	SS	35											
328.4			7	SS	48											
328.4			8	SS	50/15											
328.4			9	SS	53											
328.4			10	SS	50/15											
328.4	End of borehole. Piezometer installed to depth of 7.6 m. Water level in piezometer: Nov. 8, 2006 ---1.8 m (El. 334.6 m) Nov. 14, 2006 ---1.7 m (El. 334.7 m) Nov. 22, 2006 ---1.7 m (El. 334.7 m)															

+ 3, X 3: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

Appendix B1

Laboratory Test Results for Culvert C1



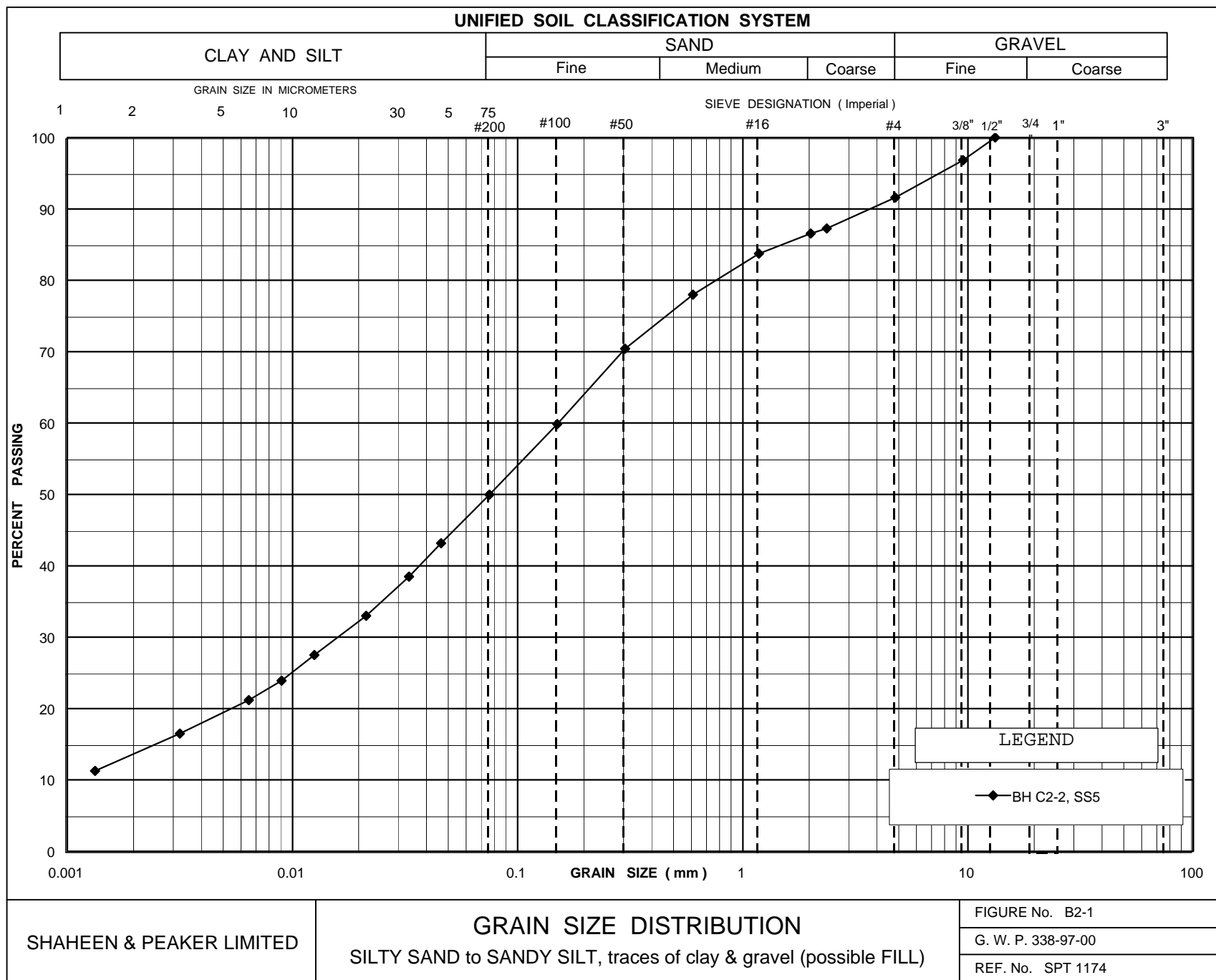
SHAHEEN & PEAKER LIMITED

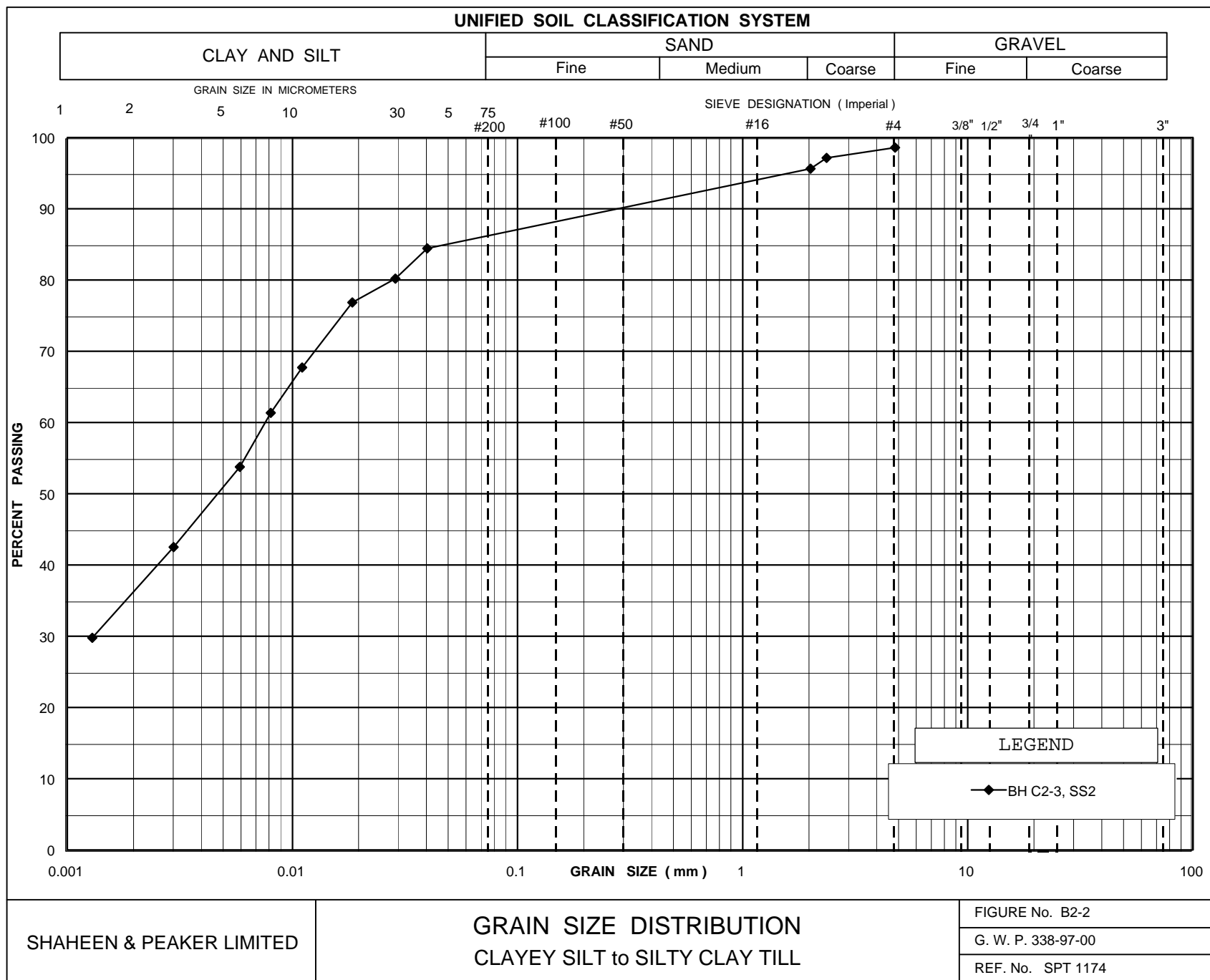
GRAIN SIZE DISTRIBUTION
SAND & GRAVEL, some silt

FIGURE No. B1-1
G. W. P. 338-97-00
REF. No. SPT 1174

Appendix B2

Laboratory Test Results for Culvert C2





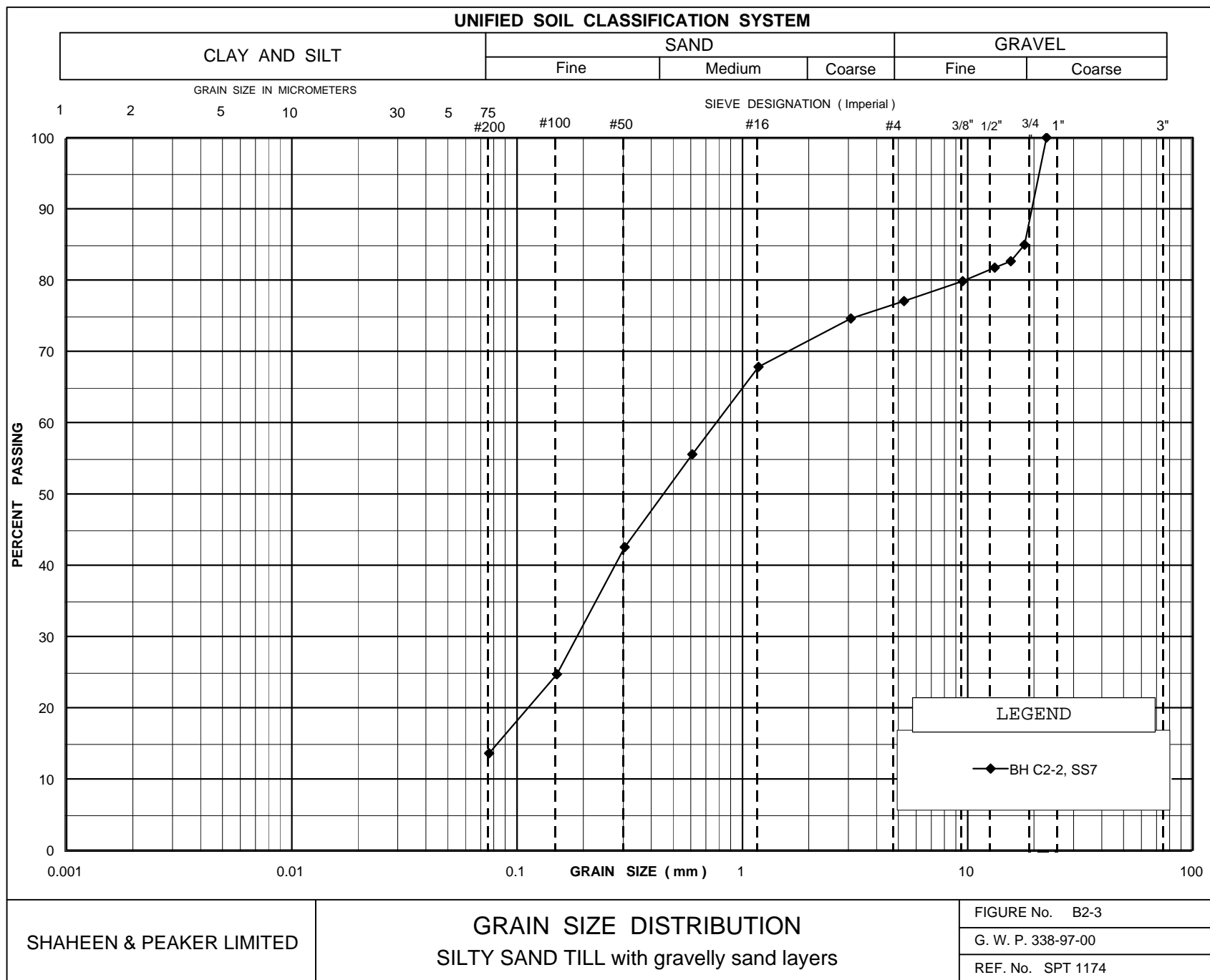
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
CLAYEY SILT to SILTY CLAY TILL

FIGURE No. B2-2

G. W. P. 338-97-00

REF. No. SPT 1174



0.001 0.01 0.1 1 10 100

GRAIN SIZE (mm)

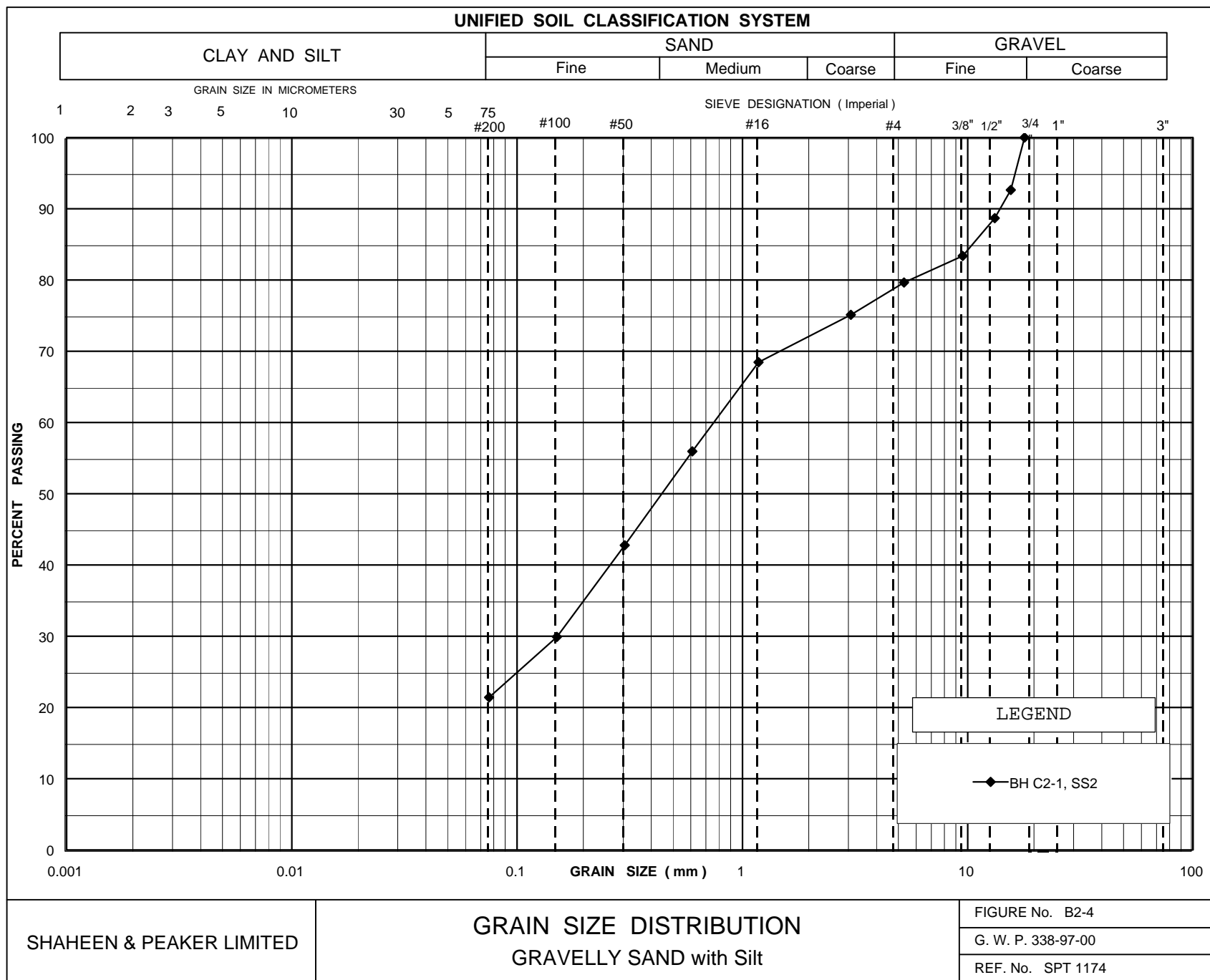
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
SILTY SAND TILL with gravelly sand layers

FIGURE No. B2-3

G. W. P. 338-97-00

REF. No. SPT 1174



0.001 0.01 0.1 1 10 100

GRAIN SIZE (mm)

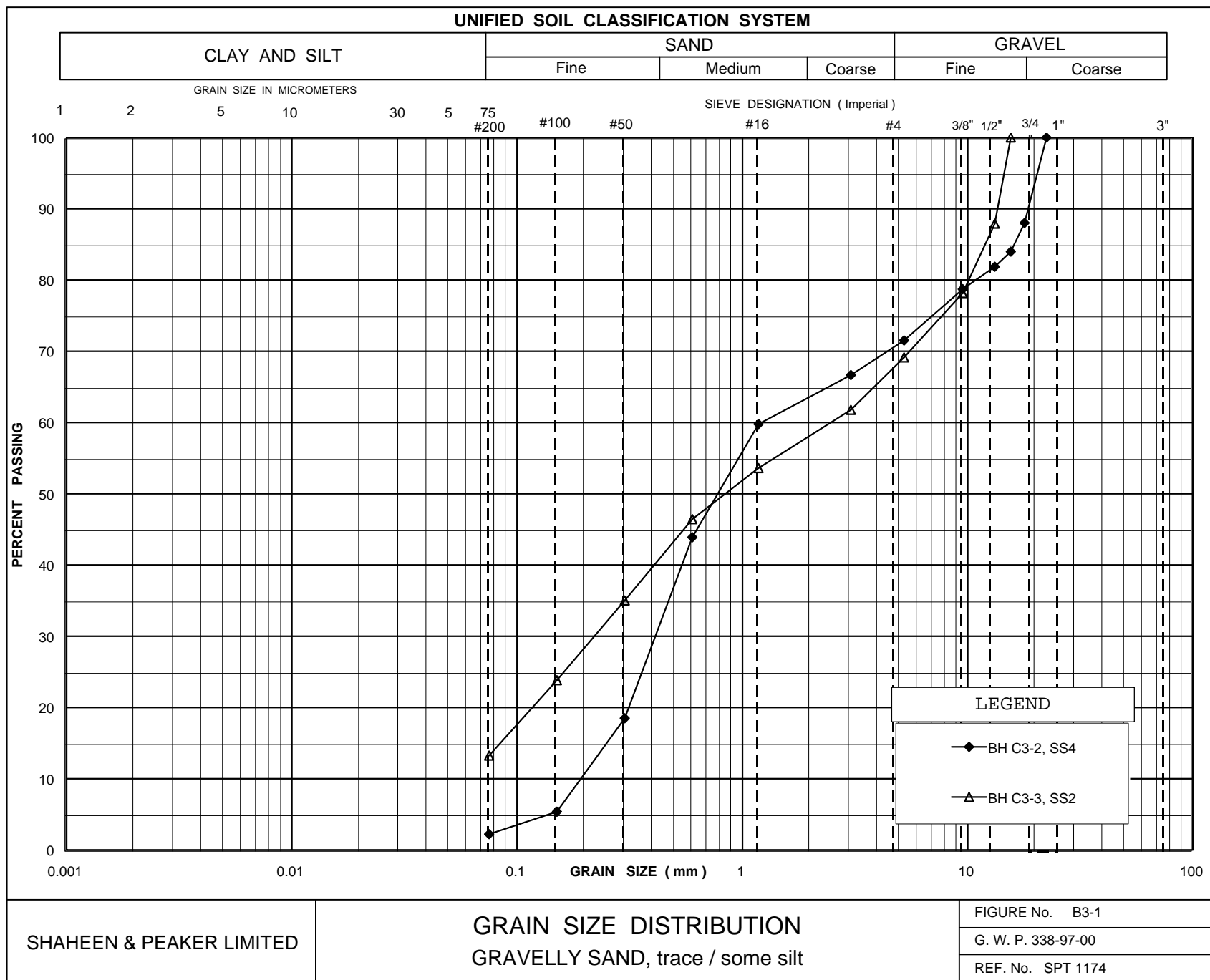
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
GRAVELLY SAND with Silt

FIGURE No. B2-4
G. W. P. 338-97-00
REF. No. SPT 1174

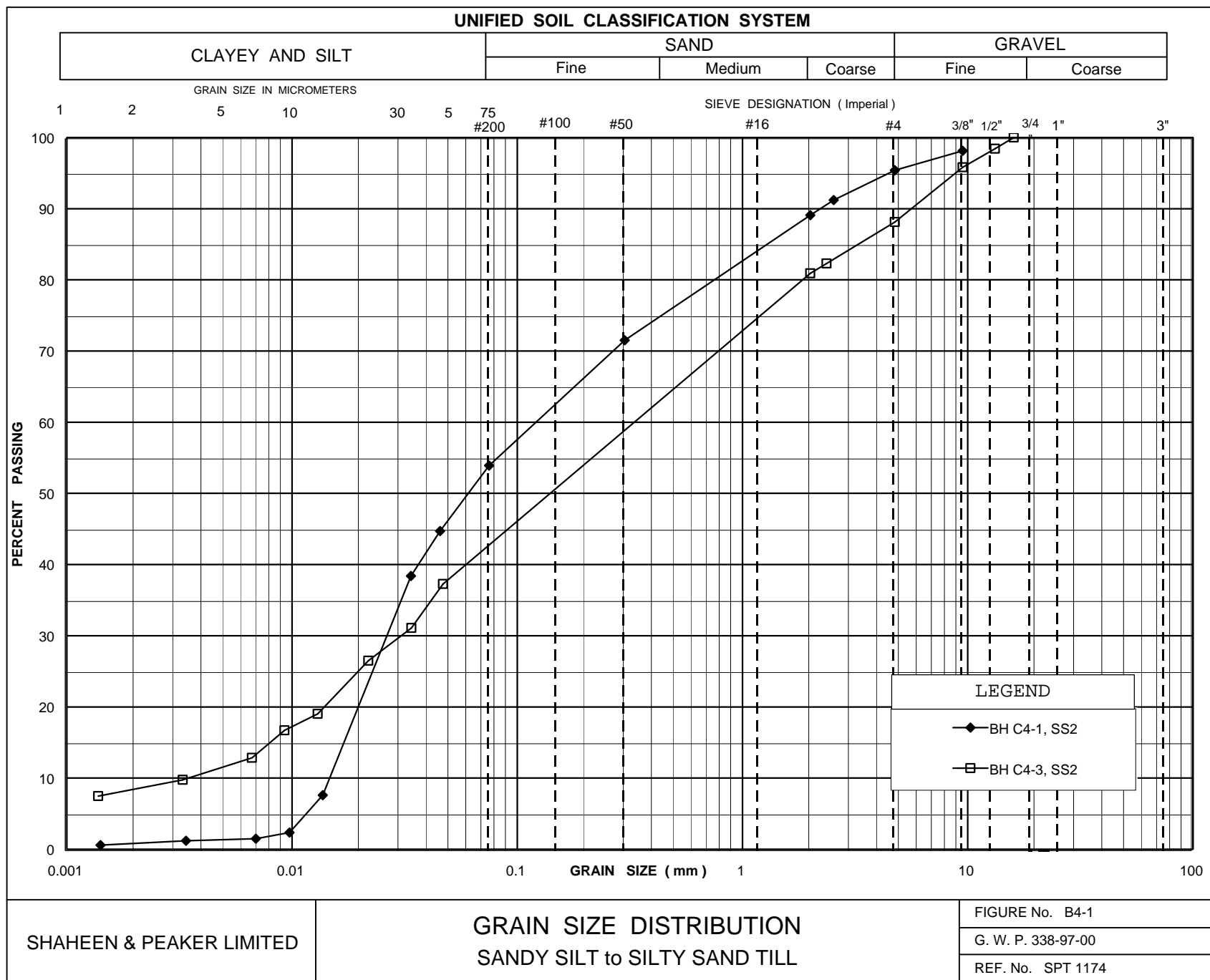
Appendix B3

Laboratory Test Results for Culvert C3



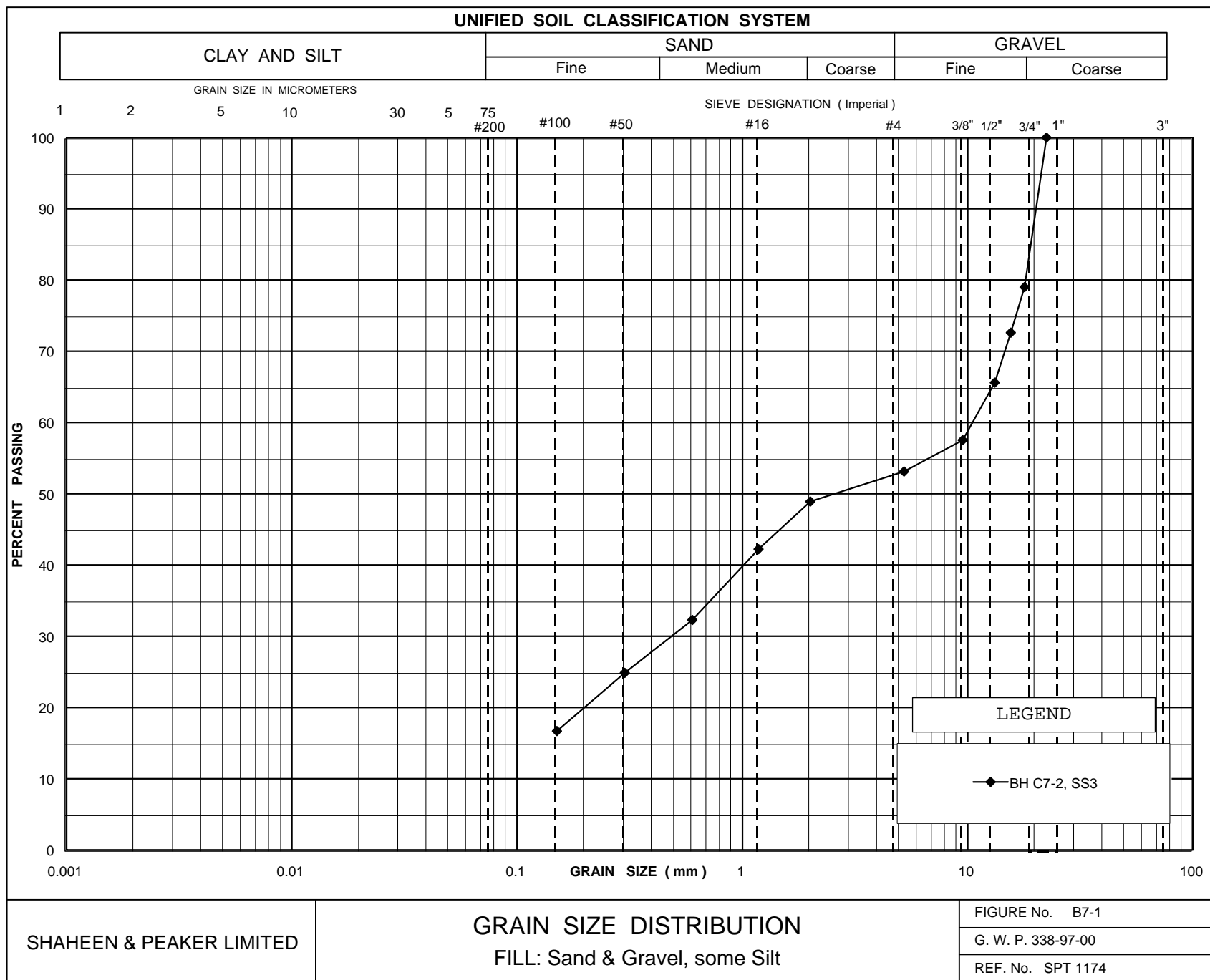
Appendix B4

Laboratory Test Results for Culvert C4



Appendix B5

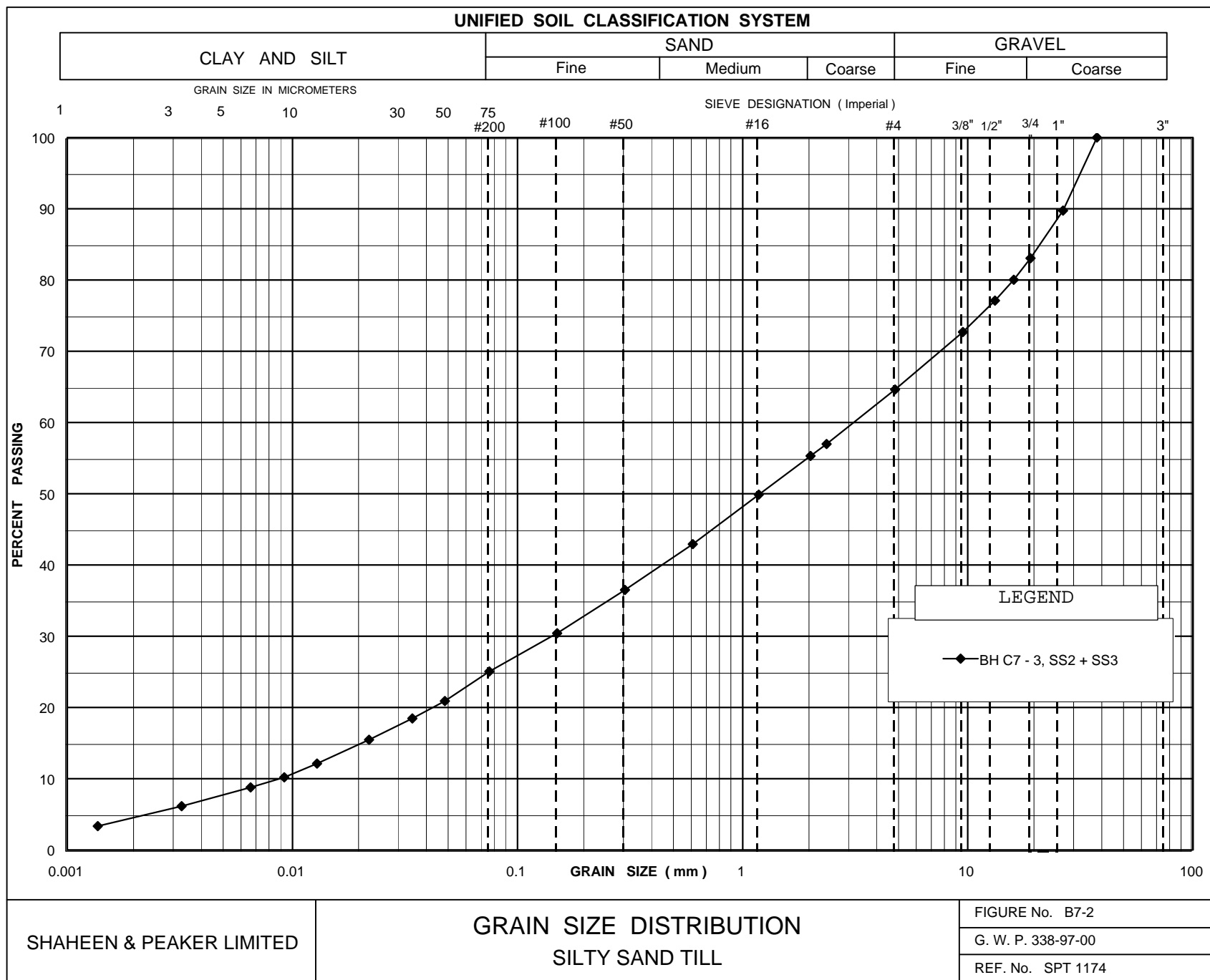
Laboratory Test Results for Culvert C7

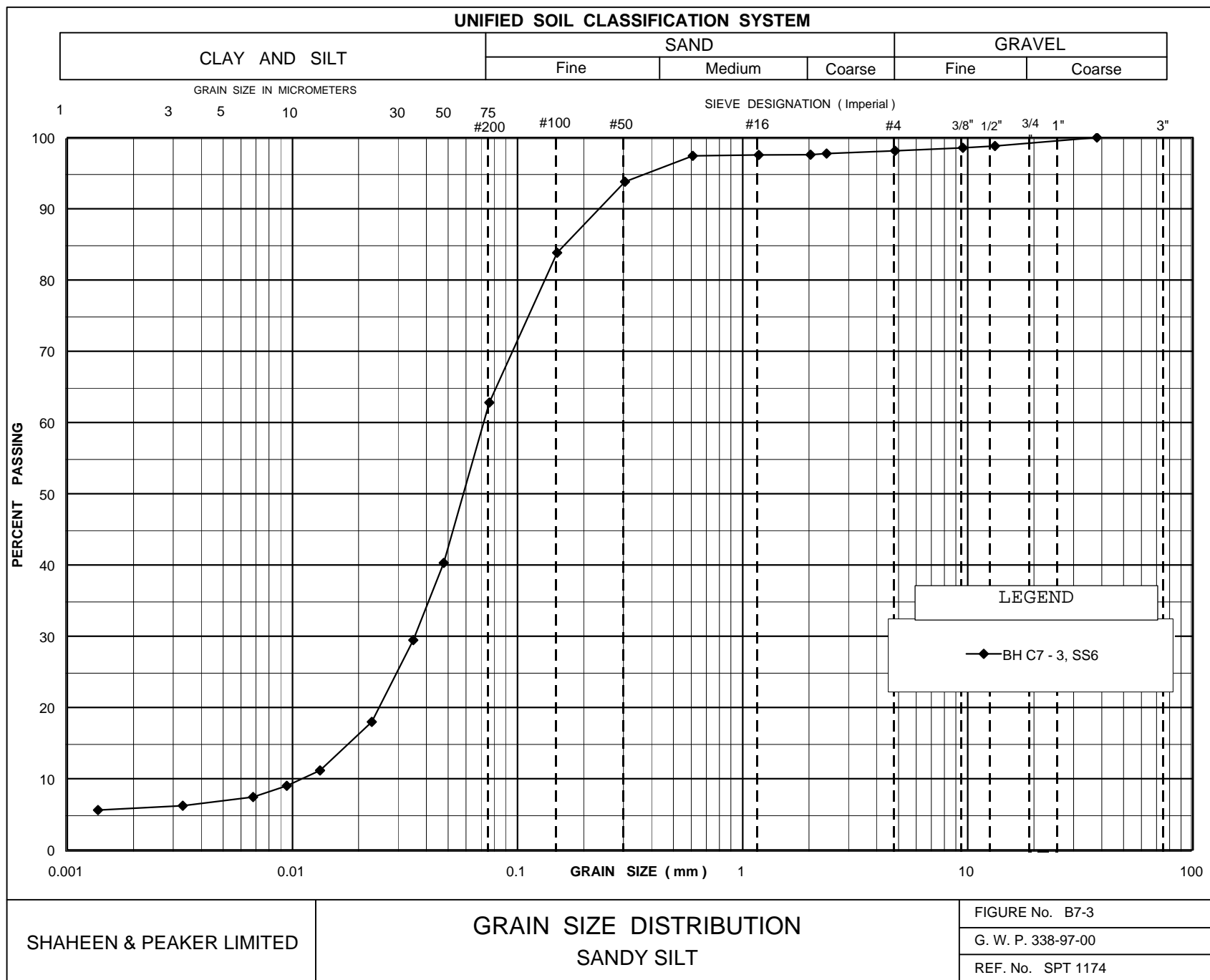


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GRAIN SIZE DISTRIBUTION
FILL: Sand & Gravel, some Silt

FIGURE No. B7-1
G. W. P. 338-97-00
REF. No. SPT 1174





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GRAIN SIZE DISTRIBUTION
SANDY SILT

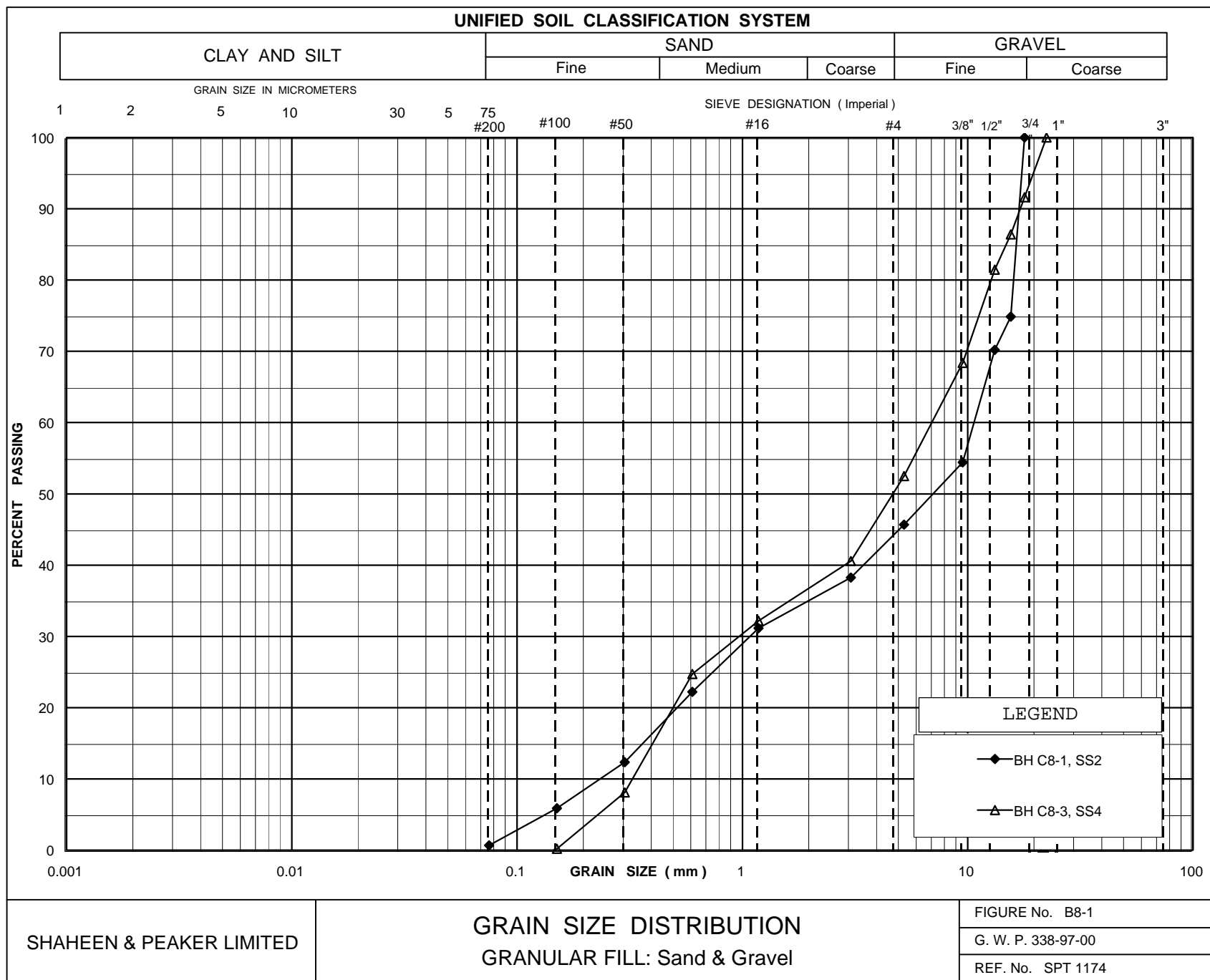
FIGURE No. B7-3

G. W. P. 338-97-00

REF. No. SPT 1174

Appendix B6

Laboratory Test Results for Culvert C8



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
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

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
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
j_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
j_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
j	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
j_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $(W_L - W_p) / I_p$	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
j_{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
j'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

**FOUNDATION DESIGN REPORT
PROPOSED CULVERT REPLACEMENTS
(C1, C2, C3, C4, C7 & C8)
HIGHWAY 6 FROM 1.1 KM SOUTH OF
GREY COUNTY ROAD 9 NORTHERLY TO
DURHAM SOUTH LIMITS, ONTARIO
G.W.P. 338-97-00**

GEOCRES NO. 41A-193

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174A
January 24, 2008**



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APPENDIX E: LIMITATION OF REPORT

**FOUNDATION DESIGN REPORT
PROPOSED CULVERT REPLACEMENTS (C1, C2, C3, C4, C7 & C8)
HIGHWAY 6 FROM 1.1 KM SOUTH OF GREY COUNTY ROAD 9
NORTHERLY TO DURHAM SOUTH LIMITS, ONTARIO
G.W.P. 338-97-00**

5.0 DISCUSSION AND RECOMMENDATIONS

This report includes the replacement of six existing culverts as follows:

Culvert No	Station
C1	21+204
C2	21+807
C3	23+793
C4	24+482
C7	27+065
C8	28+299

The Foundation Investigation and Design reports for the replacement of three structural culverts were presented in separate reports under SPT1174C (for Culvert C9), 1174D (for Culvert C10) and 1174E (for culvert C11). The findings of the geotechnical investigation for replacement of three other non-structural culverts (C3A, C5, C6) will be presented under a separate report (SPT1174B).

The current report involves the replacement of six existing culverts (as detailed above) in a section of the highway where little or no vertical grade revisions are proposed. However, some embankment widening for construction of Northbound (NB) passing lane around culvert C4 north of Station 24+200 is also proposed. The purpose of the foundation investigation was to obtain subsurface information at these sites by means of exploratory boreholes. The design report will provide general comments and recommendations for design of the proposed culvert replacements as well as embankment widening along the proposed NB passing lane.

5.1 CULVERT REPLACEMENT AT STATION 21+204 (C1)

From the information provided to us by UMA, the existing culvert is a 22 m long and 0.76 m diameter, corrugated steel pipe (CSP). The invert of the pipe is at about El. 376.99 to 376.16 m.

The new culvert will be located adjacent to the present culvert. It will provide drainage during the construction after which it will be removed and backfilled. It is proposed to replace the existing culvert with twin 1.22 m CSP's with a similar invert elevation and length as the existing. No grade changes are anticipated in the roadway over the culvert.

Three boreholes were put down for this culvert replacement. Boreholes C1-1 and C1-3 were drilled near the existing culvert inlet and outlet, while Borehole C1-2 was advanced from the left shoulder of the highway, as shown on Drawing Nos. 1A and 1B in Appendix A1.

In general, below an approximately 1.5 m of embankment fill, a 0.3 m thick topsoil layer (beneath the embankment fill) and a 0.4 m of clayey silt material (identified as possible fill) to a depth of 2.2 m below the left shoulder of the highway, Borehole C1-2 contacted a sand & gravel deposit at El. 375.6 m. Boreholes C1-1 and C1-3, which were drilled from the original ground (o.g.) level, near the toe of the highway embankment, contacted topsoil and organic silt to a depth of 0.7 m, underlain by the sand & gravel deposit at El. 375.4 m and 375.8 m, respectively.

In Boreholes C1-1 and C1-3, the sand and gravel extends to a depth of about 5 to 6 m below o.g. and is underlain by somewhat finer grained granular deposits to the full investigation depth. Borehole C1-2 was terminated in the sand & gravel deposit, upon encountering auger refusal at 6.9 m depth or El. 371.0 m. From the Standard Penetration test results, the sand and gravel and the underlying granular soils are assessed to be compact to very dense, but generally dense to very dense.

The groundwater level at the time of our investigation was recorded at about 1 m below the o.g. or El. 375.0 m and 375.6 m in Boreholes C1-1 and C1-3, respectively, but may be subject to fluctuations due to major weather events and seasonal variations.

The boreholes show that the site is suitable for the use of open or closed bottom concrete or CSP type culverts. CSP would be the preferred type of culvert at this site due to the high water level recorded, since it would be easier to construct the culvert under the highway with the prevailing subsurface conditions.

As the design has already been prepared as CSP type culverts, this option will be discussed in the ensuing paragraphs.

5.1.1 CULVERT FOUNDATION SUPPORT

In its undisturbed state, the compact to very dense natural sand & gravel deposit, underlying the fill and the organic soils, is suitable to support the proposed CSPs. Geotechnical resistances of the order of Factored Bearing Resistance at ULS of 400 to 700 kPa and Bearing Resistance at SLS equal to 200 to 400 kPa are available, depending on the structure details. However, for the presently proposed CSPs, the required resistances will be significantly less. From the information provided to us, the cover above the pipes will be 1 m and will cause insignificant stresses. In fact, the stresses would theoretically be less than the existing stresses (i.e. a hollow pipe will replace heavier soil within the embankment). Therefore, no problems with bearing resistances are anticipated for CSPs supported on the undisturbed sand & gravel deposit and the settlements should be negligible, provided the sand & gravel subgrade soils are not unduly disturbed during the construction. The surface of the sand & gravel deposit was contacted at the following depths/elevations.

Table 5.1.1.1
Top of Suitable Bearing Stratum at
Borehole Locations

Borehole No./Elevation	Depth to the Surface of the Natural Sand & Gravel Deposit	Elevation	Soil Type
C1-1/376.1 m	0.7 m	375.4 m	sand & gravel
C1-2/377.8 m	2.2 m	375.6 m	sand & gravel
C1-3/376.5 m	0.7 m	375.8 m	sand & gravel

It is recommended that the twin culverts be founded at or below the elevations given in Table 5.1.1.1 on the natural, undisturbed native soil. The following minimum geotechnical resistances would be available at or below these elevations.

ULS = 400 kPa
SLS = 200 kPa

As the groundwater level can be expected to be close to the proposed culvert invert elevation of 376.2 to 376.0 m and the anticipated stripping Elevations of 375.8 to 375.4 m to reach the surface of the undisturbed, natural sand & gravel deposit, careful construction techniques will be required to facilitate the construction and to ensure that the bearing subsoil is undisturbed.

5.1.2 BEDDING

Under the existing road, the new culvert will essentially represent a net pressure relief, as the overall loads imposed by the culvert are expected to be less than the existing embankment loading. For this reason, there should be no concern regarding the geotechnical resistances. In order to provide a uniform support for the pipe, however, it is recommended that a Class B

type, 150 mm thick granular bedding be provided as per OPSD-802.010 and 802.014. We recommend that the bedding material consist of a well-graded granular soil, such as Granular 'A' material.

When the excavation is completed, the exposed subgrade should be inspected and approved. If unsuitable soils (i.e. organic, weak, loose, etc) are found, these should be removed and replaced with suitable, well-compacted soils. If feasible, the exposed subgrade should be compacted from the surface. If this is not possible due to prevailing site conditions (e.g. proximity to the groundwater), then compaction can be applied after the placement of the bedding material to the underside elevation of the pipe.

In any event, the granular fill should be placed in shallow lifts not exceeding 300 mm before compaction and each layer should be compacted to at least 98% of the material's Standard Proctor Maximum Dry Density (SPMDD). An ULS value of 400 kPa can be assigned to subgrade soils prepared in this manner and, as mentioned before, under the existing embankment the new culvert will present a net unload and total settlements should not exceed 15 mm, primarily due to recompression of the soil after the construction.

5.1.3 BACKFILLING

The bedding and backfill material should be extended along the sides to cover the pipe. The selection and placing of the backfill should be in accordance with OPSD-802.010 and OPSD-802.014. The backfill should consist of free-draining, non-frost susceptible granular materials such as Granular 'A' or 'B' (OPSS-1010). As mentioned before, on site, granular embankment materials, if selectively used, could be suitable for this purpose. All granular backfill materials should be placed in thin lifts (i.e. not exceeding 200 mm before compaction) and should be compacted to at least 98% of the material's SPMDD. The Granular 'A' and Granular 'B' sub-base courses should be compacted to 100% of the SPMDD.

We would like to point out that the performance of flexible pipe culverts is largely dependent on the side support provided by the backfill and the adjacent soils. The use of proper backfill material and especially good compaction are, therefore, necessary for proper side support. For the twin culverts greater care may be required when compacting the soils in between the two culverts, depending on the distance between the culverts. The use of heavy compaction equipment should, however, be avoided immediately adjacent and above the pipes, as per MTO practice. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the pipe, to avoid lateral displacement of the pipe.

Proper frost treatment is required in accordance with OPSD-803.030 or 803.031, whichever is applicable.

5.1.4 CONSTRUCTION

Depending on the conditions encountered during the construction problems due to groundwater may be encountered (i.e. if the groundwater level is within 0.4 m below the bottom of excavation). Recommended bedding procedures were discussed on Section 5.1.2 of this report. These include stripping soils beneath the culvert invert to a depth of 150 mm, or possibly more, if unsuitable soils are detected. There is possibility that dewatering may be required during this process should groundwater be encountered. If this happens, it may be possible to lower the groundwater level by about 0.6 m by pumping from strategically located filtered sumps. As the subsoils encountered (i.e. sand & gravel deposit) can be classified as a pervious soil, closely spaced sumps will be required and it may not be possible to lower the water table by more than about 0.6 m unless methods such as deep wells are used. For this reason, if possible, the construction should be done during a dry season. As well, care should be taken to minimize vibrations (e.g. during compaction process) to avoid disturbing the underlying soils.

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA), Reg 213/91, as well as the following specifications:

SP 105 S19 – Protection Systems

SP 902 S01 – Excavation and Backfilling to Structures

The results of Borehole C1-2 show that the excavation can be expected to extend through pavement fill to about El. 377.1 m or about 1 m below the pavement surface, underlain by a 0.7 m thick silt fill to El. 376.3 m, which is in turn underlain by topsoil and clayey silt to El. 375.6 m. Below this elevation, a compact to very dense sand & gravel deposit with some cobbles and boulders was contacted. In accordance with the Province's Safety Regulation, the following soil classification would be applicable.

Granular Pavement Fill	Type 3 Soil
Silt Fill	Type 3 Soil above water level Type 4 Soil below water level
Topsoil & Clayey Silt (possible fill)	Type 3 Soil above water level Type 4 Soil below water level
Natural sand & gravel deposit	Type 3 Soil above water level Type 4 Soil below water level

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.1.4.1 can be used for the design of the temporary shoring system, based primarily on Borehole C1-2 results.

Table 5.1.4.1
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	21.5
Silt Fill	0.36	0.53	2.8	18.5
Organic Topsoil	0.53	0.72	1.6	15.0
Sand & gravel deposit	0.27	0.43	3.7	21.5
Sand and silty sand	0.32	0.48	3.1	20.5

5.1.5 EROSION PROTECTION

Erosion and scour protection should be provided at the culvert inlet and outlet, including the side slopes. 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 sand & gravel deposit underlying some surficial alluvial and/or organic soils. While the surficial alluvial or recent organic deposits are considered highly erodible, the sand & gravel is not highly erodible. But this too depends on the anticipated water velocities, etc., as mentioned above. The sand & gravel is considered to be a relatively pervious soil type. Erosion and scour protection, provided at the culvert inlet and outlet (including the side slopes) can consist 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). In addition, an impervious seal may be provided at an immediate length around the culverts.

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 6 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. 6 m). The protection is generally extended to at least 0.3 m above the high water level in the creek.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.2 CULVERT AT STATION 21+807 (C2)

The existing 914 mm diameter CSP culvert at Station 21+807 will be replaced with a new culvert which will be located about 2.5 m away from the existing one, at about Station 21+809.5 m. It is proposed to install the new culvert by the jack and bore method. The existing culvert is approximately 25 m long and its invert at the right (east) side is at about El. 382.0 m and about 379.7 m on the left (west) side. The invert, diameter and the length of the new culvert will be similar to the existing culvert.

The boreholes show, below some fill and/or topsoil, the presence of glacial till deposits with some silt and/or gravelly sand layers. The groundwater level appears to be close to the existing ground surface but can be expected to experience seasonal fluctuations and as well in response to major weather events.

5.2.1 JACK & BORE TUNNELLING

From the available borehole data tunneling (jack & bore) can be expected to advance through mix face and little cover (especially towards the inlet and outlet). The advancing face of the tunnel opening at Borehole C2-1 location can be expected to go through clayey silt to silty clay till which would provide favourable conditions for tunneling. This cohesive soil can be classified as a 'firm' soil in terms of Terzaghi's Classification for Soils in Tunnelling (see Appendix D). However, if the underlying silt is encountered, the silt, due to its wet condition, can cause problems, unless it is properly dewatered. Where it occurs below the water table and if not properly stabilized by dewatering, it can be classified as a 'flowing' soil.

At most instances, the top (crown) of the culvert can be expected to be tunneled through the embankment fill. Based on Borehole C2-2 findings, the fill can be expected to be granular and may contain cobbles or even boulders depending on the control that was exercised when the fill was first placed. Depending on the silt binder content and moisture, above the water table, running may occur in clean gravelly sand in which case the soil may be classified as 'running' soil, while below the water table it may flow into the face, in which case the soil can be classified as 'flowing' soil, unless it was properly dewatered. Borehole C2-2 also encountered immediately underlying the fill between El. 381.1 and 380.2 m, mixed soil

conditions consisting of silty sand to sandy silt with clayey silt zones. Topsoil was also contacted at about El. 380.5 m. These soils represent a transition zone from the embankment fill into the underlying natural soils. In our opinion, these transition zones will need to be dewatered to be stable, if they are encountered below the water table.

The underlying silty sand to sandy silt till can be classified as 'slow ravelling' below the water level. The presence of cobbles and boulders can always be in the glacial till deposits and their presence was inferred in at least in one borehole (Borehole C2-3) during drilling. In addition, the presence of water bearing gravelly sand seams/layers was also noted in Borehole C2-2, near the upper zone of the deposit.

From the available information, it is our opinion that a mixed face condition, as well as insufficient and somewhat variable cover materials (i.e. granular embankment fills) exist above the crown of the pipe. In addition, it is possible that cobbles and boulders may also be encountered. As well, dewatering will likely be required to stabilize the soils during the installation. Further more, the installation of launching pad (pit) can be expected to present some problems. Piles may need to be driven as a reaction board or concrete thrust block extending a sufficient distance into the subsoils. Tunnelling, as presently planned, is therefore considered costly as well as relatively unsafe since any loss of ground may translate into a settlement at road surface, due to lack of cover (i.e. little or no arching will occur, especially with the vibrations created due to highway traffic). As such tunneling methods, including jack and bore method, is not recommended due to lack of reliability and high cost factors. However, if it is necessary to utilize such methods, it is recommended that a specialist contractor be consulted to further look into their feasibility. The following are some suggestions.

Consideration may be given to the use of a drop structure to allow a lower grade, especially on the upstream side of the culvert, if possible, to increase the soil cover over the crown of the tunnel. However, MTO may not be in favor of utilization of such structures because it would require long term maintenance. Nevertheless, if a minimum of 3 m soil cover can be provided along the entire length of the proposed culvert, tunneling via jack & bore may become feasible subject to the following considerations:

- Adequate space can be provided for launching pit and provision of a thrust block for jacking operation.
- Any potential perched groundwater pressure is relieved prior to the proposed jack and bore operations.
- Provisions are made for potential removal of cobbles and boulders, if encountered.

Any such installation should be carried out according to OPSS 416, Construction Specification for Pipeline and Utility Installation by Jack and Boring, using a Smooth Walled

Steel Pipe as per OPSS 1802 or a Concrete Pipe as per OPSS 1820. In this case, consideration may be given to the installation of galvanized liner plates and grouting inside to provide permanent ground support.

An alternative installation method may be utilization of pipe ramming method. However, pipe ramming through compact to dense soil could potential result in heaving of the highway, as well, settlements may occur due to vibrations created during ramming of the pipe.

Consideration may also be given to the use of directional drilling method for installation of a 914 mm diameter (I.D.) steel culvert, however, this should be discussed with a specialist contractor for its feasibility for this project.

5.2.2 CSP OR CONCRETE BOX CULVERT

The construction of a CSP, using an open cut method would be the preferred option at this site considering the subsurface conditions. Concrete box culvert can also be considered, but CSP is a better choice. An open bottom box culvert can also be considered but is not as well-suited for the prevailing conditions.

In their undisturbed state, the inorganic soils (below the fill and organic soils) are considered to be suitable to support a CSP or a concrete box culvert. The top of the suitable bearing stratum at each borehole location for a CSP is given in the following table.

Table 5.2.2.1
Top of Suitable Bearing Stratum at
Borehole Locations

Borehole No./Elevation (m)	Depth to the Surface of Suitable Soil (m)	Elevation (m)	Soil Type
C2-1/374.7	0.7	379.0	silty sand to sandy silt till
C2-2/384.5	4.5	380.0	silty sand to sandy silt till with clayey silt and gravelly sand layers
C2-3/383.0	1.0	382.0	clayey silt to silty clay till

The groundwater table can be expected to be at or near the proposed culvert invert; therefore, careful construction techniques will be required to facilitate the construction and to avoid the excessive disturbance of the bearing subgrade.

5.2.2.1 BEDDING

Assuming that the new culvert will be built adjacent to the existing culvert under the existing road, the loading from the culvert (especially CSP) will represent a net pressure relief, as the overall loads after the culvert is built can be expected to be less than the existing, assuming the road grade will not be changed. For this reason, there should be no concern regarding the geotechnical resistances. To provide a uniform support, granular bedding should be provided as per applicable OPSD. We recommend that the bedding consist of a well-graded soil, such as Granular 'A' material and its thickness should be at least 200 mm.

If, for ease of construction, the use of well-graded soil is undesirable, then consideration may be given to the use of a 20 mm clear stone or preferably an HL4 type material. In this case (i.e. if a well-graded bedding material is not used) however, the bedding should be protected against the migration of the silt subgrade into the bedding material by placing a suitable geotextile against the subgrade soil. The geotextile (OPSS 1860) should be a Class II non woven type of filter cloth with Filtering Opening Size (F.O.S.) not larger than 115 micron (such as Terrafix 400R, or approved equivalent). We also recommend that the compatibility of the geotextile with the exposed silty subgrade be reviewed and approved during the construction.

When the excavation is completed, the exposed subgrade should be inspected and approved. If unsuitable soils (i.e. weak, loose, organic, etc.) are encountered these should be removed and replaced with suitable, well-compacted granular soils. Where feasible, the exposed subgrade should be compacted from the surface. This should, however, be done in a manner so as to prevent a dilation and disturbance of the underlying soil, especially if the subgrade is wet. In any event, the granular fill should be placed in shallow lifts and each lift should be compacted to at least 98% of the material's Standard Proctor Maximum Dry Density (SPMDD).

As mentioned before, provided that the subgrade is not unduly disturbed, under the existing embankment the new culvert should represent a net unload and therefore total settlements should not exceed 15 mm for a CSP and 25 mm for a concrete box culvert, primarily due to recompression of the soil after the construction.

Frost and scour depths may need to be considered when selecting concrete box culvert invert elevation.

The unfactored horizontal resistance against sliding between approved subgrade surface, and the bedding can be calculated using a friction angle of 25 degrees. The same value can be used if a geotextile is utilized in conjunction with the bedding (i.e. if a poorly graded material is used as a bedding material).

5.2.2.2 BACKFILLING

For backfilling recommendations reference can be made to Sections 5.1.3 and 5.3.3 of this report for CSP and concrete box culverts, respectively.

5.2.2.3 CONSTRUCTION

Dewatering will likely be required during the construction. Depending on the site conditions during the construction this may consist of gravity drainage and pumping from strategically placed sumps. The sumps will need to be filtered in the silty soils such as the silt deposit and the silty sand to sandy silt till. If this is not sufficient more sophisticated methods such as deep wells, etc. may need to be considered.

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA), Reg 213/91, as well as the following specifications:

SP105 S19 – Protection Systems

SP902 S01 – Excavation and Backfilling to Structures

In accordance with the Safety Regulations of the Province (i.e. Occupational Health and Safety Act O. Reg 213/91), the following classification would be applicable.

Granular pavement fill	Type 3 soil
Granular embankment fill	Type 3 soil above water level
	Type 4 soil below water level
Silty sand to sandy silt (possible fill in BH C2-2) and topsoil	Type 3 soil above water level
	Type 4 soil below water level
Clayey silt to silty clay till	Type 2 soil
Silt	Type 2 soil above water level
Silty sand to sandy silt	Type 2 soil above water level
	Type 3 soil below water level

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.2.2.3.1 can be utilized for the design of the temporary shoring system.

Table 5.2.2.3.1
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	21.5
Silty sand to sandy silt with a topsoil layer (BH C2-2, El. 381.1-380.2 m)	0.52	0.7	1.7	16.5
Clayey silt to Silty clay till	0.46	0.62	2.2	18.5
Silt	0.33	0.50	3.0	18.5
Silty sand to sandy silt till, loose to compact (BH C2-1 from 0.3 to 2.5 m below o.g.)	0.33	0.50	3.0	19.5
Silty sand to Sandy silt till, dense to very dense	0.3	0.45	3.3	21.5

5.2.2.4 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 structure. The erosion/scour protection should be designed by a specialist River Engineer/Scientist who is familiar with the findings of this investigation.

The boreholes indicate that below some fill and material identified as possible fill in Borehole C2-2, the predominant soil type at the site consists of clayey/sandy silt to silty sand till with some silt and gravelly sand layers. In addition to the soil types, the particular design depends on other considerations such as water velocity in the water course at the culvert locations, fisheries, etc. Typically, concrete cut-off (apron) walls and head walls or proper seals are constructed both at the inlet and the outlet and, if necessary, a seal at mid-length to prevent scour and to inhibit seepage around the culvert, particularly through the granular backfill.

Clay seal can be used at the inlet in lieu of or in addition to the concrete cut-off and head walls. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure or from beneath the structure. The clay material should comply with the material specifications given in OPSS 1205. It should be extended around the culvert from at least 0.5 m above the high water level in the watercourse, across the channel bed and up to the sides, in a continuous manner. It must be ensured that the seal extends to cover all the granular backfill to prevent seepage through these granular backfill materials. The clay seal is typically protected by laying a 0.6 m thick rock protection over it. The clay seal should be extended to a suitable distance beyond the inlet (typically 6 m).

At the outlet (and also if clay seal is not provided at the inlet), in addition to the concrete cut-off and head walls and/or impervious seals, rock protection may need to be considered. This is typically 0.6 m thick and consists of 300 mm diameter size rock (depending on the water velocity). This is normally underlain by a 0.3 m thick layer of granular filter material. The granular filter can consist of a suitable granular soil, such as Granular 'A' (OPSS Form 1010). Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter. The rock fill protection should extend a suitable distance from the outlet and the inlet (e.g. 6 m) and at least 0.3 m above the high water level.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.3 CULVERT REPLACEMENT AT STATION 23+793 (C3)

Based on the information provided to us, the existing culvert at Station 23+793 is a corrugated steel pipe arch (CSPA) which is approximately 1.5 m wide and 1.2 m high (inside dimensions). It is 22.8 m long and its invert is at El. 373.41 m upstream and 373.32 m downstream. The new structure will be a precast concrete box culvert and it will be installed at approximately the same invert elevations as the existing culvert. The structure will be 3.0 m (width) x 1.8 m (height) x 22.8 m (length).

No other details are available at the time of preparing this report.

Three boreholes were drilled, at the location of the existing C3, for this culvert replacement.

Borehole C3-1 was advanced on the left (west) side of Highway 6 near the downstream-end of the existing culvert. Boreholes C3-2 and C3-3 were drilled on the right (east) side of the highway close to the upstream end of the culvert, as shown on the Site Plan and profile (Drawing Nos. 3A and 3B).

In general, below topsoil, some fill and organic silt, all three boreholes encountered native gravelly sand to silty fine sand and/or silty sand to sandy silt till with some sand & gravel layers extending to the termination of the boreholes.

The groundwater table at the time of our investigation in sealed piezometers was recorded close to the existing ground surface (at about 0.4 to 0.5 m below the ground surface (i.e. o.g.)) up to about El. 373.6 m. However, the observed water level can be expected to experience seasonal fluctuations and as well in response to major weather events.

Based on the borehole data presented in Section 4.3, the undisturbed native gravelly sand to silty sand and the silty sand to sandy silt till encountered in the boreholes are considered suitable to support both concrete box, concrete open bottom and CSP type culverts. However, since the culvert crossing has been already designed as a precast concrete box culvert, this option will be discussed in the following sections.

5.3.1 CULVERT FOUNDATION SUPPORT

The proposed culvert can be supported on the native, undisturbed competent silty sand to sandy silty till, or native, undisturbed gravelly sand to silty sand deposit.

The recommended highest founding depths/elevations at each borehole location are tabulated below.

Table 5.3.1.1
Top of Suitable Bearing Stratum at
Borehole Locations

Borehole No.	Existing Ground Surface Elevation (m)	Recommended Highest* Founding Level (i.e. bottom of concrete slab) (m)	Elevation (m)	Subgrade Material
C3-1	373.5	0.4	373.1	Silty sand to sandy silt till
C3-2	375.3	2.3	373.0	Gravelly sand to silty sand
C3-3	373.7	0.3	373.4	Gravelly sand to silty sand

* Subject to provision of adequate frost and scour protection.

The following geotechnical resistances are available for the culvert to be placed on undisturbed competent silty sandy to silty sand till, or gravelly sand to silty sand deposit, for both concrete box or concrete open bottom culverts.

Factored Bearing Resistance at U.L.S. = 250 kPa
Geotechnical Resistance at S.L.S. = 150 kPa

Since the imposed loads due to the structure would be less than the existing, there should be no settlement problems. However, an allowance of 20 to 25 mm of possible total settlement should be made for possible rebound during construction due to stress relief, which would be followed by an approximately equivalent amount of settlement after the application of structural loads and backfilling. If this amount of total/differential settlement is acceptable between individual precast segments settlements it should not present problems, as well cambering should not be necessary.

Foundations should be kept as high as possible due to dewatering requirements, as discussed later in this report. Frost and scour depths may also need to be considered.

5.3.2 BEDDING

We recommend that a minimum 250 mm thick bedding material be placed beneath the concrete box culvert slab to provide uniform support. This can consist of a well-graded material such as Granular 'A'. For ease of construction, consideration may also be given to the use of 20 mm clear stone or preferably an HL4 type material. In this case (i.e. if a well-graded bedding material is not used) however, the bedding should be protected against the

migration of the silt subgrade into the bedding material by placing a suitable geotextile against the subgrade soil. The geotextile (OPSS 1860) should be a Class II non woven type of filter cloth with Filtering Opening Size (F.O.S.) not larger than 115 micron (such as Terrafix 400R, or approved equivalent). We also recommend that the compatibility of the geotextile with the exposed silty subgrade be reviewed and approved during the construction.

The unfactored horizontal resistance against sliding between approved till surface, or gravelly sand to silty sand and the bedding can be calculated using a friction angle of 27 degrees. The same value can be used if a geotextile is utilized in conjunction with the bedding (i.e. if a poorly graded material is used as a bedding material). It is, however, believed that sliding will not present a problem.

5.3.3 BACKFILLING

Backfilling for the culvert construction should consist of select, suitable materials, compacted in accordance with the MTO standards and conform to OPSD-803.01. Below the groundwater level or immediately below the roadway, it is recommended that Granular 'A' or 'B' aggregates be used. Where appropriate, proper tapering as per standards should be provided. Below a depth of about 1.6 from the finished road grade, approved compactable fill, such as select subgrade materials (SSM) can be used. It is recommended that in order to minimize damage to pavement due to frost heave, materials with similar frost heave characteristics with the existing adjacent soils be used for backfill in this intermediate zone. However, free-draining frost-free materials such as Granular 'B' Type II (OPSS 1010), with less than 5% silt content should be used immediately adjacent to the structure.

In any case, 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' base and sub-base course materials should be compacted to 100% of their SPMDD's. To avoid damaging or laterally dislocating it, care should be exercised when compacting fill adjacent to and immediately on top of the culvert structure and compaction equipment should be restricted in size as per MTO convention. The backfilling operation should be carried out simultaneously on both sides of the culvert as per MTO specifications.

Backfilling behind any retaining (wing) walls should consist of granular materials in accordance with the Ontario Ministry of Transportation Standards. Free draining backfill materials, weepholes, etc. should be provided in order to prevent hydrostatic pressure build-up.

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with the Canadian Highway Bridge Design Code, (CHBDC) 2006. For design purposes, the following properties can be assumed for backfill.

Compacted Granular 'A' and Granular 'B' Type II

Angle of Internal Friction $\phi=35^\circ$ (unfactored)

Unit weight = 22 kN/m³

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 $\phi=30^\circ$ (unfactored)

Unit Weight = 21 kN/m³

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.

5.3.4 CONSTRUCTION

The excavation should be carried out in accordance with the Occupational Health and Safety Act, Reg 213/91, as well as the following specifications:

SP105 S19 – Protection Systems

SP902 S01 – Excavation and Backfilling to Structures

The boreholes show that the excavations for the construction of the culvert can be expected to extend through basically granular embankment fill, underlying topsoil or other organic mixed layer into gravelly sand to silty sand and/or sandy silt to silty sand till layers. These soils can be classified as follows:

Granular Pavement Fill	Type 3 soil (above water level)
Gravelly Sand to Silty Sand	Type 3 above water level
	Type 3 below water level
Silty sand to sandy silt till	Type 2 above water level
	Type 3 below water level

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. Consideration can be given to using the existing culvert during the construction to facilitate the flow, while constructing the new culvert several meters away or if the new culvert has to be at the same place as the existing then the existing pipe can be relocated to provide temporary flow of water (during the construction).

Dewatering will be required during the construction to stabilize the soil and to prevent its dilatation. It is our opinion that the groundwater level can be lowered by up to about 0.6 m by means of gravity drainage and pumping from strategically located filtered sumps, depending on the site 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 1 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. As well, care should be taken to avoid disturbing the foundation soils by minimizing construction traffic (including foot traffic) and minimizing vibrations.

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.3.4.1 can be used for the design of the temporary shoring system.

Table 5.3.4.1
Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	K_a	K_o	K_p	Unit Weight (kN/m^3)
Granular Embankment Fill	0.31	0.47	3.2	21.0
Compact silty sand to sandy silt till	0.33	0.5	3.0	20.0
Dense to very dense silty sand to sandy silt till	0.30	0.45	3.3	21.0
compact to dense gravelly sand to silty sand	0.32	0.48	3.1	20.5

5.3.5 EROSION PROTECTION

Erosion and scour protection should be provided at the culvert inlet and outlet, including the side slopes. 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 gravelly sand to silty sand and silty sand to sandy silt till deposits underlying some surficial alluvial and/or organic soils. While the surficial alluvial or recent organic deposits are considered highly erodible, the erodibility of the gravelly sand to silty sand and the silty sand to sandy silt till depends largely on the anticipated water velocities. The gravelly sand to silty sand 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), according to MTO Concrete Culvert Design and Detailing Manual.

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. gravelly sand) around or underneath the structure. The clay seal must therefore be continuous and it should be sufficiently thick (generally 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 rock protection over it (typically 0.6 m). 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 6 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 typically consists of 0.6 m thick 300 mm rock placement. The rock is typically separated from the underlying natural soils by means of a filter. This could consist of a granular soil, such as Granular 'A' (OPSS Form 1010). Alternatively, a suitable geotextile can be used underneath the rock fill. The rock protection should extend a suitable distance from the outlet and the inlet (e.g. say 6 m) and at least 0.3 m above the high water level.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.4 CULVERT REPLACEMENT AT STATION 24+482 (C4)

The existing CPS culvert at Station 24+482 is 914 mm in diameter and about 23 m in length with the culvert invert elevation at 381.86 to 381.90 m. The new culvert will be a 1400 mm diameter CSP with its invert at the same level as the existing culvert.

At this location, three boreholes were drilled for the proposed culvert replacement. Borehole C 4-1 was put down near the west-end (downstream) of the existing culvert, while Boreholes C 4-2 and C 4-3 were drilled on the west shoulder of the highway and near the east-end (upstream) of the existing culvert, respectively, as shown on Drawing Nos. 4A and 4B in Appendix A.

In general, the boreholes show, below some pavement and embankment fill (to 2.2 m – El. 381.9 m in Borehole C4-2), and some surficial topsoil and silt to 0.7 m or El. 382.2-381.7 m in Boreholes C4-1 and C4-3, the presence of a sandy silt to silty sand till deposit with some sand layers. A significant sand layer (identified as possible till) was encountered in Borehole C4-2 underlying the fill and a thin layer of organic rich soil. At the time of our investigation, the groundwater level was recorded between 376 and 374.5 m but the presence of a perched water was noted in Borehole C4-2 and similar perched water condition is believed to have existed prior to our investigation in the remaining two boreholes.

The boreholes show that the compact to very dense inorganic natural soils (i.e. sandy silt to silty sand till and sand deposits) in their undisturbed state would be suitable to support open bottom or closed bottom concrete culverts or CSP's. However, CSP would be better suited for the prevailing subsurface conditions. This is because the upper zones of the soil in Boreholes C4-1 and C4-3 were found to be in a relatively loose state (i.e. N-values of 7 and 8 blows/0.3 m were recorded) to a depth of 3.0 m and 1.6 m below o.g. or to El. 379.9 m and

380.8 m, respectively. The foundations will, therefore, have to be extended to these elevations and this would require additional excavations at Borehole C4-1 area. While the groundwater levels in the piezometers were found below these elevations, depending on the site conditions and the water level in the existing water course, a perched water condition may be encountered. This may present some dewatering problems during construction, should it occur. Therefore, a CSP type culvert is considered to be a better choice from foundations point of view. For this reason and since the project has already been designed as a CSP type culvert, this type of culvert will be discussed in the following paragraphs.

5.4.1 CULVERT FOUNDATION SUPPORT

In their undisturbed state, the natural till and sand deposits would be capable of providing suitable support for the proposed CSP. It must, however, be ensured that all the fill, topsoil and otherwise organic soils as well as any weak and otherwise unsuitable materials are removed and replaced with well-compacted suitable soils prior to placing the pipe. At the borehole locations, the suitable soils were contacted at the following elevations:

Borehole C4-1	-	Elevation 381.8 m
Borehole C4-2	-	Elevation 381.5 m
Borehole C4-3	-	Elevation 381.5 m

These elevations can, however, be expected to be variable in between borehole locations and should be carefully identified in the field during construction prior to placing the bedding materials. As well, as will be discussed later the silty soils can be expected to be dilatent and should be prevented from being disturbed and dilating during the construction. This will necessitate careful construction techniques as well as any necessary dewatering procedures.

The geotechnical resistance of the foundation soil appears to be variable with depth but at the levels stated above the following geotechnical resistances are available.

Factored Bearing Resistance at ULS	=	200 kPa
Geotechnical Resistance at SLS	=	100 kPa

The required resistance at ULS will be less than the resistance given above since the cover above the pipe will only be about 1 m. As well, since the pipe will be located within the existing embankment, the stresses after the construction of the culvert should be less than the existing. Therefore, in theory, there should be no settlements in the founding soils, unless the subgrade is unduly disturbed during the construction. A settlement of about 20 to 25 mm should, however, be allowed for the possible rebound and recompression of the foundations soils, when excavated and subsequently backfilled.

5.4.2 BEDDING

When the excavation is completed, the founding subgrade should be inspected, evaluated and approved. Should weak, organic or otherwise unsuitable soils be encountered, they should be removed and replaced with Granular 'A' type granular material compacted in thin layers to not less than 95% of the material's Standard Proctor maximum dry density (SPMDD). The exposed approved subgrade should be compacted from the surface using a suitable compactor for the prevailing site conditions. It may be necessary to limit the intensity of vibrations or even a static roller may need to be used.

The bedding material should be placed as soon as practicable after exposing the foundation subgrade, inspection, approval and compaction. The bedding should be in accordance with the appropriate standards (e.g. OPSD-802.010 and 802.014) and should consist of not less than 350 mm thick layer (after compaction) of approved granular material, such as Granular 'A.' The bedding material should be compacted to at least 98% of the material's SPMDD. If the bedding is to consist of a poorly graded material such as clear crushed stone, a suitable geotextile should be placed as a separator at the bottom and sides of the excavation, as well as the top.

5.4.3 BACKFILLING

Backfilling was discussed in Section 5.1.3 and will not be repeated here for brevity.

5.4.4 CONSTRUCTION

As was mentioned before, a perched water condition is believed to exist at the site and, for this reason, depending on the site conditions at the time of construction, dewatering may be required to facilitate the construction and to prevent the disturbance and dilatancy of the founding soils. The silty soils (i.e. glacial till) encountered in the boreholes are dilatant soils which can be expected to dilate (i.e. expand) in the presence of water, a condition which can be recognized by the liverish, jelly-like appearance of the soil.

If the soil is allowed to dilate, settlements will occur after backfilling. In our opinion, dewatering of the site to prevent this from happening can be achieved by means of gravity drainage and pumping from strategically placed filtered sumps.

We recommend that, if at all possible, the construction should be carried out during a dry period. In addition, vibrations should be minimized during the construction to prevent the disturbance of the founding soils.

Excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA), Reg 213/91 and the following specifications.

SP105 S19 – Protection Systems

SP902 S01 – Excavation and Backfilling to Structures

Borehole C4-2 was put down from the shoulder of the highway and this borehole showed the presence of a granular pavement and an underlying organic mixed layer (probably original topsoil). The embankment fill and any previous organic rich soil left in place can be expected to be underlain by a sandy silt to silty sand till or sand, based on the borehole data. The following soil classification would be applicable.

Granular Pavement Fill	Type 3 soil
Topsoil or Organic Rich Soils	Type 3 soil above water level Type 4 soil below water level
Sand	Type 3 soil above water level Type 4 soil below bottom water
Sandy silt to silty sand till	Type 2 soil, if dense (above water level) Type 3 soil, if loose (above water level) Type 4 soil, below water level, if not dewatered

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.4.4.1 can be used for the design of the temporary shoring system.

Table 5.4.4.1
Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	K_a	K_o	K_p	Unit Weight (kN/m^3)
Granular Embankment Fill	0.32	0.48	3.1	21.0
Organic Topsoil	0.41	0.58	2.4	15.0
Sand deposit	0.32	0.49	3.1	20.5
Loose to compact silty sand to sandy silt till	0.33	0.50	3.0	20.0
Dense to very dense silty sand to sandy silt till	0.31	0.47	3.3	21.0

5.4.5 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 structure. The erosion/scour protection should be designed by a specialist River Engineer/Scientist who is familiar with the findings of this investigation.

The boreholes indicate that below some surficial materials deposited by the Creek, the predominant soil type at the site consists of sandy silt to silty sand till and sand. In addition to the soil types, the particular design depends on other considerations such as water velocity in the water course at the culvert locations, fisheries, etc. Typically, concrete cut-off (apron) walls and head walls or proper impervious seals are constructed both at the inlet and the outlet and if necessary a seal at mid-length to prevent scour and to inhibit seepage around the culvert, particularly through the granular backfill.

Clay seal can be used at the inlet in lieu of or in addition to the concrete cut-off and head walls. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure or from beneath the structure. The clay material should comply with the material specifications given in OPSS 1205. It should be extended around the culvert from at least 0.5 m above the high water level in the watercourse, across the channel bed and up to the sides, in a continuous manner. It must be ensured that the seal extends to cover all the granular backfill to prevent seepage through these granular backfill materials. The clay seal is typically protected by laying a 0.6 m thick rock protection over it. The clay seal should be extended to a suitable distance beyond the inlet (typically 6 m).

At the outlet (and also if clay seal is not provided at the inlet), in addition to the concrete cut-off and head walls and/or impervious seals, a 0.6 m thick layer of rock protection, consisting of 300 mm diameter size rock (depending on the water velocity), can be considered. This should be underlain by a 0.3 m thick layer of granular filter material. The granular filter can consist of a suitable granular soil, such as Granular 'A' (OPSS Form 1010). Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter. The rock fill protection should extend a suitable distance from the outlet and the inlet (e.g. at least 6 m) and at least 0.3 m above the high water level.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.4A EMBANKMENT WIDENING

Based on the latest design information provided, a new Northbound (NB) passing lane (about 4 m wide) is to be constructed in the vicinity of the proposed Culvert C4 at Station 24+482. Therefore, tentative recommendations for the proposed embankment

widening are provided in this section, based on the findings of one borehole only (i.e. Borehole C4-3).

Borehole C4-3 drilled from beyond the toe of the existing embankment on the right side of the highway (near the east-end of the existing culvert) encountered surficial topsoil and alluvial silt deposits to a depth of 0.7 m below o.g. or to El. 381.7 m, underlain by native sandy silt to silty sand till, followed by a sand deposit at 7.1 m depth, extending to the termination of the borehole (7.9 m).

We understand that the proposed grade raise above the original grades (o.g.) for the new Northbound passing lane on the right side of the existing highway will generally be less than 2 m. Based on the conditions encountered in the exploratory boreholes around Culvert C4, no foundation failures are anticipated for the proposed embankment widening at the culvert location with normal (2H:1V) side slopes, provided that the all topsoil and organic silt or otherwise unsuitable materials are removed as per MTO standards and replaced with engineered fill prior to placing the new embankment fills.

The following table summarizes the stripping depth/elevation at the location of Borehole C4-3.

Table 5.4A.1
Anticipated Stripping Depth/Elevation

Borehole No./Elevation (m)	Anticipated Stripping Depth (m)	Elevation (m)
C4-3/El. 382.4 m	0.7	381.7

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 established 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. As well, the use of vibrations for compaction may not be suitable.

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, especially if the conditions beyond Borehole C4-3 warrant it.

The sides of the existing embankment should be properly benched prior to placing the fill for the widening of the approach embankments, as per the 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, 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 1.5 m above o.g., the anticipated foundation settlements should not exceed 20 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 15 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, toe wall and/or reinforced slopes, as appropriate. In that case, further consultations are recommended.

5.5 CULVERT REPLACEMENT AT STATION 27+065 (C7)

We understand that the existing culvert at Station 27+065 is a 22.20 m long and 1.52 m diameter, corrugated steel pipe (CSP). The elevation of the invert of the pipe ranges from El. 357.55 m to 357.46 m.

The new culvert will also be 22.2 m long and will at the same invert elevation as the existing culvert (i.e. El. 357.46 m at its east end and 357.55 m at its west end). It will however consist of a precast concrete box with inside dimensions of 1.80 m (width) by 1.20 m (height). The top of the culvert will be at about El. 358.7 m on the east side and El. 358.8 m

on the west side (see Drawing 7B in Appendix A5). There will be very little or no change in the road grade.

Three boreholes were drilled at the site, namely Boreholes C7-1 and C7-3 on the west and east ends (near the toe of the embankment), while the third borehole (Borehole C7-2) was put down from the top of the embankment on the west shoulder of the highway, immediately adjacent to the existing culvert. Below some embankment fill (Borehole C7-2) and topsoil and/or alluvial fill, the boreholes show the presence of a major glacial deposit consisting of silty sand to sandy silt till underlain by silty sand to sandy silt. The surface of the sufficiently competent till was contacted at about El. 356.0 m at Boreholes C7-1 and C7-2 and at about El. 357.0 m in Borehole C7-3. The groundwater table at the time of our investigation was recorded at about 0.2 m below the ground surface elevation at Boreholes C7-1 and C7-3 (i.e. about 0.2 m below o.g.).

The undisturbed till encountered in the boreholes is considered suitable to support both concrete box and CSP type culverts but since the crossing has been designed as a precast concrete box culvert, this option will be discussed in the following sections. Open bottom concrete culvert is considered a less suited option with the prevailing subsurface conditions (i.e. deeper excavations are required for the footings extending below the groundwater table, especially at Borehole C7-2 location).

5.5.1 CULVERT FOUNDATION SUPPORT

The proposed concrete box culvert can be supported on the undisturbed competent silty sand to sandy silty till.

The recommended highest founding depths/elevations at each borehole location is tabulated below.

Table 5.5.1.1
Top of Suitable Bearing Stratum at
Borehole Locations

Borehole No.	Existing Ground Surface Elevation (m)	Recommended Highest Founding Level (i.e. bottom of concrete slab) (m)	Elevation (m)	Subgrade Material
C7-1	358.2	2.3	355.9	Silty sand to sandy silt till
C7-2	359.2	3.2	356.0	Silty sand to sandy silt till
C7-3	357.9	0.9	357.0	Silty sand to sandy silt till

The following geotechnical resistances are available for the concrete box culvert to be placed on undisturbed competent silty sand to silty sand till.

Factored Bearing Resistance at U.L.S. = 260 kPa
Geotechnical Resistance at S.L.S. = 160 kPa

Since the imposed loads due to the structure would probably be less than the existing, there should be no settlement problems (since no grade raise is anticipated). However, an allowance of 25 mm of possible total settlement should be made for some rebound during construction due to stress relief, which would be followed by an approximately equivalent amount of settlement after the application of structural loads and backfilling. If this amount of differential settlement is acceptable between individual precast segments, settlements should not present problems, as well cambering should not be necessary.

Higher bearing resistance values are available at greater depths but are not believed to be necessary for the light structure proposed, as well as to keep the foundations as high as possible due to dewatering requirements, as discussed later in this report. Frost and scour depths may also need to be considered.

5.5.2 BEDDING

We recommend that a minimum 300 mm thick bedding material be placed beneath the concrete box culvert slab to provide uniform support. This can consist of a well-graded material such as Granular 'A'. For ease of construction, consideration may also be given to the use of 20 mm clear stone or preferably an HL4 type material. In this case (i.e. if a well-graded bedding material is not used) however, the bedding should be protected against the migration of the silt subgrade into the bedding material by placing a suitable geotextile against the subgrade soil. The geotextile (OPSS 1860) should be a Class II non woven type of filter cloth with Filtering Opening Size (F.O.S.) not larger than 115 micron (such as Terrafix 400R, or approved equivalent). We also recommend that the compatibility of the geotextile with the exposed silty subgrade be reviewed and approved during the construction.

The unfactored horizontal resistance against sliding between approved till surface and the granular bedding can be calculated using a friction angle of 27 degrees. The same friction angle value can be used if a geotextile is utilized in conjunction with the bedding (i.e. if a poorly graded material is used as a bedding material).

5.5.3 BACKFILLING

Backfilling for the culvert construction should consist of select, suitable materials, compacted in accordance with the MTO standards and conform to OPSD-803.01. For fills below the groundwater level or immediately below the roadway, it is recommended that Granular 'A' or 'B' aggregates be used. Where necessary, proper tapering as per standards should be provided. Below a depth of about 1.6 from the finished road grade, approved compactable fill, such as select subgrade materials (SSM) can be used. It is recommended that in order to minimize damage to pavement due to frost heave, materials with similar frost heave characteristics with the existing adjacent soils be used for backfill in this intermediate zone.

However, free draining, frost-free materials such as Granular 'B' Type II with less than 5% silt content would be used immediately adjacent to the structure.

In any case, 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' base and sub-base course materials should be compacted to not less than 100% of their SPMDD's. To avoid damaging or laterally dislocating it, care should be exercised when compacting fill adjacent to and immediately on top of the culvert structure and compaction equipment should be restricted in size as per MTO convention. The backfilling operation should be carried out simultaneously on both sides of the culvert as per MTO specifications.

Backfilling behind any retaining (wing) walls should consist of granular materials in accordance with the Ontario Ministry of Transportation Standards. Free draining backfill materials, weepholes, etc. should be provided in order to prevent hydrostatic pressure build-up.

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with the Canadian Highway Bridge Design Code, (CHBDC) 2006. For design purposes, the following properties can be assumed for backfill.

Compacted Granular 'A' and Granular 'B; Type II

Angle of Internal Friction $\phi=35^\circ$ (unfactored)

Unit weight = 22 kN/m³

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 $\phi=30^\circ$ (unfactored)

Unit Weight = 21 kN/m³

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).

5.5.4 CONSTRUCTION

The excavation should be carried out in accordance with the Occupational Health and Safety Act, Reg 213/91, as well as the following specifications:

SP105 S19 – Protection Systems

SP902 S01 – Excavation and Backfilling to Structures

The boreholes show that the excavations for the construction of the culvert can be expected to extend through basically granular embankment fill, underlying topsoil or other organic mixed layer or surficial alluvial soils and into the silty sand to sandy silt till and/or gravelly sand and silty sand to sandy silt layers. These soils can be classified as follows:

Granular Pavement Fill	Type 3 soil (above water level)
Topsoil and Organic Rich Soil, Alluvial Fill	Type 3 above water level Type 4 below water level
Silty sand to sandy silt till and gravelly sand	Type 2 above water level Type 3 below water level
Silty sand to sandy silt	Type 3 above water level Type 4 below water level

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. Consideration can therefore be given to using the existing culvert during the construction to facilitate the flow while constructing the new culvert a sufficient distance away. If, however, the new culvert has to be at the same place as the existing, then the existing pipe can be relocated to provide temporary flow of water (during the construction).

Dewatering will be required during the construction to stabilize the soil and to prevent its dilatation. It is our opinion that the groundwater level can be lowered by up to about 0.6 m by means of gravity drainage and pumping from strategically located filtered sumps, depending on the site 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 1 m groundwater 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. As well, care should be taken to avoid disturbing the foundation soils by minimizing construction traffic (including foot traffic) and minimizing vibrations.

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.5.4.1 can be used for the design of the temporary shoring system.

Table 5.5.4.1
Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	K_a	K_o	K_p	Unit Weight (kN/m ³)
Granular embankment fill	0.31	0.47	3.2	21.0
Organic topsoil/alluvial fill	0.53	0.72	1.6	15.0
Loose to compact silty sand to sandy silt till	0.33	0.5	3.0	20.0
Dense to very dense silty sand to sandy silt till	0.30	0.45	3.3	21.0
compact to very dense silty sand to sandy silt	0.32	0.48	3.1	20.5

5.5.5 EROSION PROTECTION

The boreholes indicate that below some surficial alluvial soils, the main soil strata at the site can be expected to be a silty sand to sandy silt till or gravelly sand soils.

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 structure. The erosion/scour protection should be designed by a specialist River Engineer/Scientist who is familiar with the findings of this investigation.

In addition to the soil types, the design to protect against erosion and scour depends on other considerations such as water velocity in the water course at the culvert location, fisheries aspects, etc. Typically, concrete cut-off (apron) walls and head walls are constructed both at the inlet and the outlet to prevent scour and to inhibit seepage beneath and around the culvert, particularly through the granular backfill, as per MTO Concrete Culvert Design & Detailing Manual. The depth of the concrete cut-off walls should be determined by the River Engineer.

Clay seal can be used at the inlet in lieu of or in addition to the concrete cut-off and head walls. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure or from beneath the structure. The clay material should comply with the material specifications given in OPSS 1205. It is extended around the culvert from at least 0.5 m above the high water level in the watercourse, across the channel bed and up to the side, in a continuous manner. It must be ensured that the seal extends to cover all the granular backfill to prevent seepage through these granular backfill materials. Typically, the clay seal is protected by laying a 0.6 m thick rock protection over it. As well, the clay seal and the overlying rock protection is extended generally about 6 m beyond the inlet.

At the outlet (and also if clay seal is not provided at the inlet), in addition to the concrete cut-off and head walls, rock protection can be considered. The rock protection is typically 0.6 m thick and consists of 300 mm nominal diameter size rock. It is generally underlain by a 0.3 m thick layer of granular filter material. The granular filter can consist of a suitable granular soil, such as Granular 'A' (OPSS Form 1010). Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter. The rock fill protection typically extends a suitable distance from the outlet and the inlet (e.g. about 6 m) and at least 0.3 m above the high water level.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.6 CULVERT REPLACEMENT AT STATION 28+299 (C8)

The existing culvert is a 40 m long and 0.9 m diameter corrugated steel pipe (CSP) with an invert elevation at El. 334.14 to 334.13 m.

The new culvert will be located adjacent to the existing culvert. As presently planned, the existing culvert will provide drainage during the construction after which it will be removed and backfilled. It is proposed to replace the existing culvert with a new 1.4 m CSP with a similar invert elevation and length as the existing. No major grade changes are anticipated in the roadway over the culvert.

As discussed in Section 4.6, three boreholes were put down for this culvert replacement, as shown on Drawing Nos. 8A and 8B. In general, below up to approximately 2.9 m of embankment fill, the boreholes contacted, at Elevations ranging between 334.1 and 333.4 m, native granular deposits consisting of primarily sand and gravel (except in Borehole C8-3 where a 1.8 m thick silty sand deposit was found sandwiched between the embankment fill and the sand & gravel deposit) to the termination of all the boreholes. Borehole C8-3 was extended to 7.9 m or to El. 328.4 m, while the other two boreholes had to be terminated at higher elevations due to auger refusal (possibly on boulders or bedrock).

From the Standard Penetration test results, the sand and gravel is assessed to be in a dense to very dense condition, while the silty sand layer encountered in Borehole C8-3 overlying the sand & gravel is considered compact to dense.

The groundwater level at the time of our investigation was recorded in Borehole C8-3 at 1.7 m below the ground surface, or El. 334.7 m, but may be subject to fluctuations due to major weather events and seasonal variations.

5.6.1 CULVERT FOUNDATION SUPPORT

In its undisturbed state, the native compact to very dense granular deposits (i.e., natural sand & gravel deposit in Boreholes C8-1 and C8-2 and the natural silty sand deposit in Borehole C8-3) are suitable to support corrugated steel pipe (CSP) or concrete box or open bottom culverts but since the project has already been designed for CSP, this type of culvert will be discussed in the following paragraphs. In fact, CSP is a good option for the site in view of the prevailing high water level and relative ease and speed of construction.

Geotechnical resistances of the order of Factored Bearing Resistance at ULS of 360 to 700 kPa and Bearing Resistance at SLS equal to 200 to 400 kPa are available, depending on the desired founding elevation and structure details including CSP and concrete type culverts. However, for the presently proposed CSP, the required resistances will be significantly less. From the information provided to us, the cover above the pipe will be about 1 m and will cause insignificant stresses due to embankment fill loading. In fact, the stresses

would theoretically be less than the existing stresses (i.e. a hollow pipe will replace heavier soil within the embankment). Therefore, no problems with geotechnical resistances are anticipated for a CSP supported on the undisturbed granular deposit of sand & gravel or silty sand and the settlements should be negligible, provided the granular subgrade soils are not unduly disturbed during the construction. The native granular deposit was contacted at the following depths/elevations.

Table 5.6.1.1
Top of Suitable Bearing Stratum at
Borehole Locations

Borehole No./Elevation	Depth to the Surface of the Natural Granular Deposits	Elevation	Soil Type
C8-1/336.7 m	2.6 m	334.1 m	sand & gravel
C8-2/336.4 m	2.1 m	334.2 m	sand & gravel
C8-3/336.3 m	2.9 m	333.4 m	silty sand

It is recommended that the culvert be placed at or below these elevations on the natural, undisturbed native soil. A Factored Bearing Resistance at Ultimate States (ULS) of 360 kPa and a Bearing Resistance at Serviceability Limit States (SLS) equal to 200 kPa can be assigned at the elevations given in Table 5.6.1.1.

Since the highest recorded groundwater level during the investigation is about 0.6 m above the proposed culvert invert elevation of 334.1 m, careful construction techniques will be required to facilitate the construction and to ensure that the bearing subsoil is properly dewatered (prior to excavation) and remains undisturbed throughout the construction and backfilling.

5.6.2 BEDDING

Under the existing road, the new culvert will essentially represent a net pressure relief, as the overall loads imposed by the culvert are expected to be less than the existing embankment loading. For this reason, there should be no concern regarding the geotechnical resistances. In order to provide a uniform support for the pipe, however, it is recommended that a Class B type, a minimum of 150 mm thick granular bedding be provided as per OPSD-802.010 and 802.014. This thickness may need to be increased due to site conditions and applicable specification. We recommend that the bedding material consist of a well-graded granular soil, such as Granular 'A' material.

When the excavation is completed, the exposed subgrade should be evaluated and approved. If unsuitable soils (i.e. organic, weak fill, loose, etc) are found, these should be removed to the surface of the natural suitable soil and replaced with suitable, well-compacted soils. If feasible, the exposed subgrade should be compacted from the surface. If this is not

possible due to prevailing site conditions (e.g. proximity to the groundwater), then compaction can be applied after the placement of the bedding material to the underside elevation of the pipe (provided the first lift is not thicker than 400 mm).

In any event, the granular fill should be placed in shallow lifts not exceeding 300 mm before compaction and each layer should be compacted to at least 98% of the material's Standard Proctor Maximum Dry Density (SPMDD). An ULS value of 360 kPa can be assigned to subgrade soils prepared in this manner and, as mentioned before, under the existing embankment the new culvert will present a net unload and total settlements should not exceed 15 mm, primarily due to recompression of the soil after the construction.

5.6.3 BACKFILLING

The bedding material should be extended along the sides to cover the pipe. The selection and placing of the backfill should be in accordance with OPSD-802.010, OPSD-802.014, OPSD-803.030 or OPSD-803.031 (whichever are applicable). The backfill should consist of free-draining, non-frost susceptible granular materials such as Granular 'A' or 'B' (OPSS-1010). All granular backfill materials should be placed in thin lifts (i.e. not exceeding 200 mm before compaction) and should be compacted to at least 98% of the material's SPMDD. Granular 'A' base and Granular 'B' sub-base courses should be compacted to 100% of the SPMDD.

We would like to point out that the performance of flexible pipe culverts is largely dependent on the side support provided by the backfill and the adjacent soils. The use of proper backfill material and especially good compaction are, therefore, necessary for proper side support. The use of heavy compaction equipment should, however, be avoided immediately adjacent and above the pipe, as per MTO practice. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the pipe, to avoid lateral displacement of the pipe.

Proper frost treatment is required in accordance with OPSD-803.030 or 803.031, whichever is applicable.

5.6.4 CONSTRUCTION

Depending on the conditions encountered during the construction, problems due to groundwater may be encountered (i.e. if the groundwater level is within 0.4 m below the bottom of excavation). Recommended bedding procedures were discussed on Section 5.6.2 of this report. These include stripping soils beneath the culvert invert to a depth of 150 mm, or possibly more, if unsuitable soils are detected. Depending on the site conditions during the construction, it is likely that dewatering will be required during this process. In this event, it may be possible to lower the groundwater level by about 0.6 m by pumping from

strategically located filtered sumps. As the subsoils encountered (i.e., silty sand or sand & gravel deposits) can be classified as a pervious soil, closely spaced relatively deep filtered sumps will be required and it may not be possible to lower the water table by more than say 0.6 m. For this reason, if possible, the construction should be carried out during a dry season. As well, care should be taken to minimize vibrations (e.g. during compaction process) to avoid disturbing the underlying soils.

All excavations should be carried out in accordance with the Occupational Health and Safety Act, Reg 213/91, as well as the following specifications:

SP 105 S19 – Protection Systems

SP 902 S01 – Excavation and Backfilling to Structures

The results of the boreholes show that the excavation can be expected to extend through embankment fill and top of native granular deposits at about Elevations 334.1 m (BH C8-1) to 333.4 m (BH C8-3). Below these elevations, a compact to very dense sand & gravel deposit with occasional cobbles and boulders (Boreholes C8-1 and C8-2) and a compact to dense silty sand deposit (BH C8-3) were contacted. In accordance with the Province's Safety Regulation, the following soil classification would be applicable.

Topsoil	Type 3 Soil above water level
Granular Pavement Fill	Type 3 Soil
Granular Embankment Fill	Type 3 Soil above water level
	Type 4 Soil below water level
Natural silty sand and sand & gravel deposits	Type 3 Soil above water level
	Type 4 Soil below water level

It is expected that temporary shoring will be required to support the excavations. 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, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.6.4.1 can be used for the design of the temporary shoring system, based primarily on existing borehole data.

Table 5.6.4.1
Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	K_a	K_o	K_p	Unit Weight (kN/m^3)
Topsoil	0.41	0.58	2.4	15.0
Granular Pavement Fill	0.30	0.45	3.3	21.0
Granular Embankment Fill	0.35	0.51	2.9	18.5
Native Silty Sand	0.32	0.48	3.1	20.5
Native Sand & Gravel	0.28	0.44	3.6	21.0

5.6.5 EROSION PROTECTION

Erosion and scour protection should be provided at the culvert inlet and outlet (including the slopes and sides). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime) who is familiar with the findings of this report. The following are some general suggestions, considering that below some organic and alluvial deposits at the watercourse level the boreholes indicate that the native soils can be expected to consist of sand & gravel and silty sand deposits.

We recommend that concrete cut-off (apron) be constructed both at the inlet and outlet to prevent seepage beneath and around the culvert, especially through the granular bedding and granular backfill around the culvert. Beneath the culvert, the concrete cut-off wall should extend to a suitable depth (e.g. below any possible scour depth). Consideration may also be given to an impervious seal at the inlet, outlet and at an intermediate location.

At the inlet, consideration may also be given to the use of a clay seal. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure and from beneath the structure. The clay seal should therefore be continuous and is typically 0.6 m thick. It should comply with the material specifications given in OPSS 1205. It should be extended around the culvert from at least 0.5 m above the high water level in the watercourse down to the channel bed and up the other side in a continuous manner. It should be ensured that it extends to cover all the granular backfill materials to prevent any seepage through them. Typically, the clay seal is protected by laying a 0.6 m thick rock protection over it. The clay seal would generally be extended at about 6 m beyond the inlet.

At the outlet as well as at the inlet (if clay seal is not used), in addition to the concrete cut-off and/or impervious seal or in conjunction with these a 0.6 m thick rock protection, consisting typically of 300 mm size rock can be considered, overlying a 200 mm thick layer of granular filter material. This would generally be extended about 6 m along the channel and the sides (to at least 0.3 m above the high water level). The granular filter material underlying the rock protection should consist of a suitable granular material such as Granular 'A'. Alternatively, a suitable geotextile can be used beneath the rock fill, in lieu of the granular filter material.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.7 BEARING SURFACES

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, where concrete foundations are involved.

5.8 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


Ramon Miranda, P.Eng.



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Appendix D

Tunnelman's Ground Classification and Probable Working Conditions

Tunnelman's Ground Classification And Probable Working Conditions

Soil Classification	Representative Soil Types	Tunnel Working Conditions
Hard	Very hard calcareous clay; Cemented sand and gravel	Tunnel heading may be advanced without roof support.
Firm	Loess above GWT; Various calcareous clay with low plasticity	Tunnel heading may be advanced without roof support. permanent support can be constructed before the ground will start to move.
Slow Ravelling and Fast Ravelling	Fast ravelling occurs in residual soils or in sand with clay binder below the GWT. Above the GWT, the same soils may be <u>Slow Ravelling</u> or even <u>Firm</u>	Chunks of material may drop out of the crown or the sides some time after the ground has been exposed. In <u>Fast Ravelling</u> ground, the process starts within a few minutes; otherwise; it is classed as <u>Slow Ravelling</u> .
Squeezing	Soft or medium-soft clay	Ground slowly advances into tunnel without fracturing and without perceptible increase of water content in ground surrounding the tunnel.
Swelling	Heavily pre-compressed clays with a plasticity index greater than 30. Sedimentary formations containing layers of anhydrite.	Like squeezing ground, moves slowly into tunnel, but the movement is associated with a very considerable volume increase in the ground surrounding the tunnel.
Cohesive Running and Running	Occurs in clean, fine moist sand Occurs in clean, coarse or medium sand above the GWT	Removal of the lateral support of any surface rising at an angle of more than about 34° to the horizontal is followed by a "run", whereby the material flows like granulated sugar until the slope angle is approx. 34°. If the "run" is preceded by a brief period of ravelling, the ground is called <u>Cohesive Running</u> .
Very Soft Squeezing	Clays and silts with high plasticity indices	Ground advances rapidly into the tunnel in a plastic flow
Flowing	Any ground below the GWT that has an effective grain size in excess of about 0.005 mm	Flowing ground moves like a viscous liquid. It can invade the tunnel not only through the roof and the sides, but also through the invert. If the flow is not stopped, it will eventually completely fill the tunnel.
Bouldery	Boulder glacial till; riprap fill; some land slide deposits, some residual soils. The matrix between boulders may be gravel, sand, silt, clay and in any combination	Problems incurred in advancing shield or in forepoling; blasting or hand mining ahead of machine may become necessary.

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.

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