FOUNDATION INVESTIGATION & DESIGN REPORTS
PROPOSED CAMP CREEK CULVERT (C10)
REPLACEMENT AT STATION 28+050 ON HIGHWAY 6
SOUTH OF DURHAM SOUTH TOWN LIMITS AND
NORTH OF GREY COUNTY ROAD 9, ONTARIO
G.W.P. 338-97-00

GEOCRES NO. 41A-195

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

Project: SPT1174D
February 8, 2008

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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.

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

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

The purpose of this investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the geotechnical investigation at this site, as well as general comments and recommendations for design and construction of the proposed replacement of Camp Creek culvert and possible construction of a detour embankment.

2. PHYSIOGRAPHY

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

Geological information indicates that the overburden (glacial drift), in this general area, may be underlain by bedrock at relatively shallow depths (i.e. less than 10 m). The culvert site is 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.

Within the project limits, the grade of Highway 6 generally rises from about El. 377 m at Station 21+100 to about El. 386 m at Station 24+175, then it drops down to El. 384 m at Station 24+440 and generally rolls up to about El. 390 m at Station 24+700 and down to about El. 349 m at Station 10+700, and up to about El. 353 m at Station 10+870 (northern limit of contract), and up to El. 356 m at Station 11+175.

3. INVESTIGATION PROCEDURES

Based on the scope of work outlined in RFP document and our proposal, the foundation field investigation for Camp Creek culvert (C10) consisted of a total of 7 boreholes to evaluate the subsurface conditions in the areas of the proposed culvert replacement and a possible detour construction.

The field investigation at this site was carried out during several periods from August 21 to November 20, 2006. The field investigation consisted of drilling and sampling of 3 boreholes for the culvert replacement and 4 boreholes for possible highway detour (around culvert C10 as discussed in the following sections of this report). For the proposed culvert replacement, three boreholes were drilled (C10-1, C10-2 and C10-3), one at each end of the culvert and one at the crest of the embankment for culvert replacement to a maximum depth of 6.0 m below the existing ground surface.

In addition, four boreholes were put down along a possible detour near Camp Creek culvert (C10-D1 through C10-D4) to a maximum of 6.2 m depth below the ground surface.

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. All the boreholes were drilled under the full time supervision of geotechnical engineers from S&P.

Sampling in the boreholes was conducted at frequent intervals of depth by the Standard Penetration Test (SPT) method, as specified in ASTM D1586. This consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split-barrel (split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance or the N-value of the soil and this gives an indication of the consistency or the compactness condition of the soil deposit.

Water level observations in the open boreholes were made during drilling and at the completion of each borehole. In addition, two 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 A.

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

4. SUBSURFACE CONDITIONS

The soil conditions are discussed in the following sections. Details of the stratigraphy encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. The locations of the boreholes at the site are shown on the Borehole Location Plan Drawing No. 1. Stratigraphy along the culvert is given in Drawing No. 2 while Drawing No. 3 shows the soil profile along proposed detour.

4.1 CAMP CREEK CULVERT (CULVERT C10)

The existing structure at Camp Creek crossing at Station 28+050 is a 6.1 m wide x 1.52 high x 26.8 m long open bottom concrete culvert with an invert elevation of 336.33 to 336.06 m.

At this location three boreholes were drilled along the existing culvert. Borehole C10-1 was advanced on the west (left) side of Highway 6 near the downstream-end of the existing culvert. Boreholes C10-2 and C10-3 were put down on the east (right) side of Highway 6 on the gravel shoulder and adjacent to the east-end (upstream-end) of the existing culvert, respectively, as shown on Drawing No. 1 and Drawing No. 2.

Borehole C10-2, drilled from the shoulder of the highway, encountered a pavement and embankment fill to a depth of about 2.6 m or to El. 336.0 m. Boreholes C10-1 and C10-3, put down from the o.g. level contacted a 0.2 to 0.3 m thick topsoil layer. Underlying the topsoil (Boreholes C10-1 and C10-3) and pavement fill (Borehole C10-2), the boreholes contacted a glacial deposit consisting of sandy silt to silty sand till with silty sand/sandy silt layers.

4.1.1 EMBANKMENT FILL

Borehole C10-2 contacted a 0.3 m thick granular road shoulder fill, consisting of sand & gravel. Underlying this and to a depth of 2.6 m (El. 336.0 m), the embankment fill consists of sand to sandy silt with traces of gravel and topsoil. The presence of occasional shale fragments was noted. As well, the presence of cobbles was inferred during drilling.

From a recorded N-value of 9 blows/0.3 m and the observations made during drilling the compactness condition of this basically granular fill is described as loose to compact

4.1.2 TOPSOIL

Boreholes, which were located within the Creek's floodplain, contacted a 0.2 to 0.3 m thick topsoil layer. In addition, some organic staining was noted (immediately below the topsoil) in the upper 0.2 m of the underlying inorganic soil.

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

4.1.3 SILTY SAND TO SANDY SILT TILL

Underlying the topsoil and embankment fill all three boreholes contacted (below elevations ranging from 336.9 to 336.0 m) a glacial till deposit consisting of a heterogeneous mixture of sandy silt to silty sand with some gravel and traces of clay size particles. The presence of silty sand to sandy silt layers/seams, as well as cobbles, was also noted. In particular, in Borehole C10-1, augering below 2.5 m became very difficult and refusal was encountered at 3.1 m (El. 333.1 m). Refusal to augering was also contacted in Boreholes C10-2 and C10-3 at depths of 6.0 m and 4.6 m or at El. 332.6 m and 331.8 m, respectively. From this it appears that a zone of frequent cobbles and boulders exist below about El. 333.1 m, or possibly bedrock surface.

The grain-size distribution of a sample from the deposit is given in Figure B10-1. The following grain-size distribution is indicated from the curve presented.

Gravel:	26%
Sand:	28%
Silt:	41%
Clay:	5%

The measured natural moisture contents of the basically granular (i.e. non-cohesive) deposit range from 7 to 19%, but are typically 9 to 11%. The higher moisture contents can be attributed to the silty sand and sandy silt layers.

Standard Penetration tests performed in this unit yielded N-values which ranged from 15 blows/0.3 m to 150 blows/0.08 m. These results indicate a compact to very dense relative density.

4.1.4 GROUNDWATER CONDITIONS

Groundwater conditions were observed during the drilling and upon completion of each open borehole. In addition, piezometers were installed in Boreholes C10-1 and C10-3.

Upon completion of the boreholes water levels were recorded at depths ranging from 0.6 to 0.8 m below o.g. or between Elevations 335.8 and 335.3 m. In the piezometer installed in Borehole C10-1 the water level in about a month later rose to 0.2 m or El. 335.9 m.

4.2 PROPOSED DETOUR LANE

Boreholes C10-D1, C10-D2, C10-D3 and C10-D4 were put down along the east side of the existing Highway 6 embankment between Stations 27+950 and 28+150 to investigate the subsurface conditions for a possible detour lane embankment which would be used during the construction of the culvert. The borehole locations are shown on Drawing No. 1 and a stratigraphic profile on Drawing No. 3.

The boreholes put down for the investigation were extended to depths ranging between 4.3 and 6.2 m below the ground surface adjacent to the highway embankment. A track mounted drilling rig equipped with standard soil testing and rock coring equipment was used to advance the boreholes. As shown on Drawing No. 1, Boreholes C10-2 and C10-3, drilled at the culvert location also provide subsurface information along the proposed detour lane route.

In the boreholes, Standard Penetration testing (SPT) was utilized to obtain soil samples and to obtain ‘N’-values of the soil.

In general, the boreholes show, below some topsoil, the presence of a sandy silt to silty sand till deposit with some sandy gravel to sandy silt layers/lenses.

Details of the subsurface conditions encountered in the boreholes are given on the Record of Borehole Sheets and the individual strata are briefly described in the following paragraphs.

4.2.1 TOPSOIL

The boreholes show the presence of a surficial topsoil layer with a recorded thickness of 0.15 to 0.3 m at the borehole locations (generally 0.3 m).

It should be pointed out that the thickness of topsoil and other organic soils can be expected to be variable in between and beyond borehole locations, especially near watercourses and in low-lying areas.

4.2.2 SANDY SILT TO SILTY SAND TILL

The site is underlain, within the depths investigated, by a major glacial deposit consisting of silty sand to sandy silt till.

The deposit was encountered in the majority of the boreholes (except for Boreholes C10-D1 and C10-D3) immediately underlying the surficial topsoil layer. In Borehole C10-D1, the topsoil is underlain by a 0.2 m thick sand layer and the till was encountered at 0.5 m below the ground surface underlying this surficial sand layer. Similarly, in Borehole C10-D3, the topsoil is underlain by a 2.1 m thick gravel layer (consisting of angular dolostone fragments) with some sand and silt, below which the glacial till was contacted at 2.4 m depth.

The glacial till consists of a heterogeneous mixture of sandy silt to silty sand with some gravel. The grain-size distribution of a typical sample from the till is presented in Figure B10-1 in Appendix B. Visual examination of the soil samples showed that the till attains with increasing depth a typically somewhat coarser (sillty sand till) nature with increased dolostone fragment (gravel) content. The presence of cobbles was also noted. The boreholes were typically terminated at 4.3 to 6.2 m below the ground surface upon encountering refusal to further augering probably on boulders or possibly on bedrock (hence the increase dolostone fragments with increased depth).

N-values recorded in the till ranges from 10 blows/0.3 m to 50 blows/0.08 m. These results indicate that the compactness condition of the soil deposit ranges from compact to very dense.

4.2.3 SANDY SILT

In addition to occasional thin interbeds/lenses of silt/silty sand in the glacial till, a 1.6 m thick layer/lense of sandy silt was contacted in Borehole C10-D4 from 1.4 m below the ground surface to 3.0 m below the ground surface.

Standard Penetration tests in the sandy silt yielded N-values of 7 and 10 blows/0.3 m, which indicate a loose condition. A visual examination of the soil samples recovered from the deposit indicated that it is a dilatent material and it was in a wet condition.

4.2.4 GROUNDWATER CONDITIONS

Groundwater conditions were observed in the open boreholes during drilling and upon completion of each borehole. The recorded levels, shown on the individual Record of Borehole Sheets, are not believed to represent the stabilized groundwater levels due to insufficient time available for the observations. In the piezometer installed in Borehole C10-3 (located immediately adjacent to the creek), the stabilized groundwater level was recorded at 0.6 m below the ground surface. Based on this, along with observations made during drilling of the boreholes, it is our opinion that at the time of our investigation the groundwater level was generally 0.6 to 1.5 m below the ground surface.

It should be pointed out that the groundwater level would be subject to seasonal fluctuations and variations in response to major weather events. It would also be controlled by the water level in the Creek.

SHAHEEN & PEAKER LIMITED

Ramon Miranda, P.Eng.

Z.S. Ozden, P.Eng.

ZO:tr/idrive

Drawings

METRIC

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

NOTES:

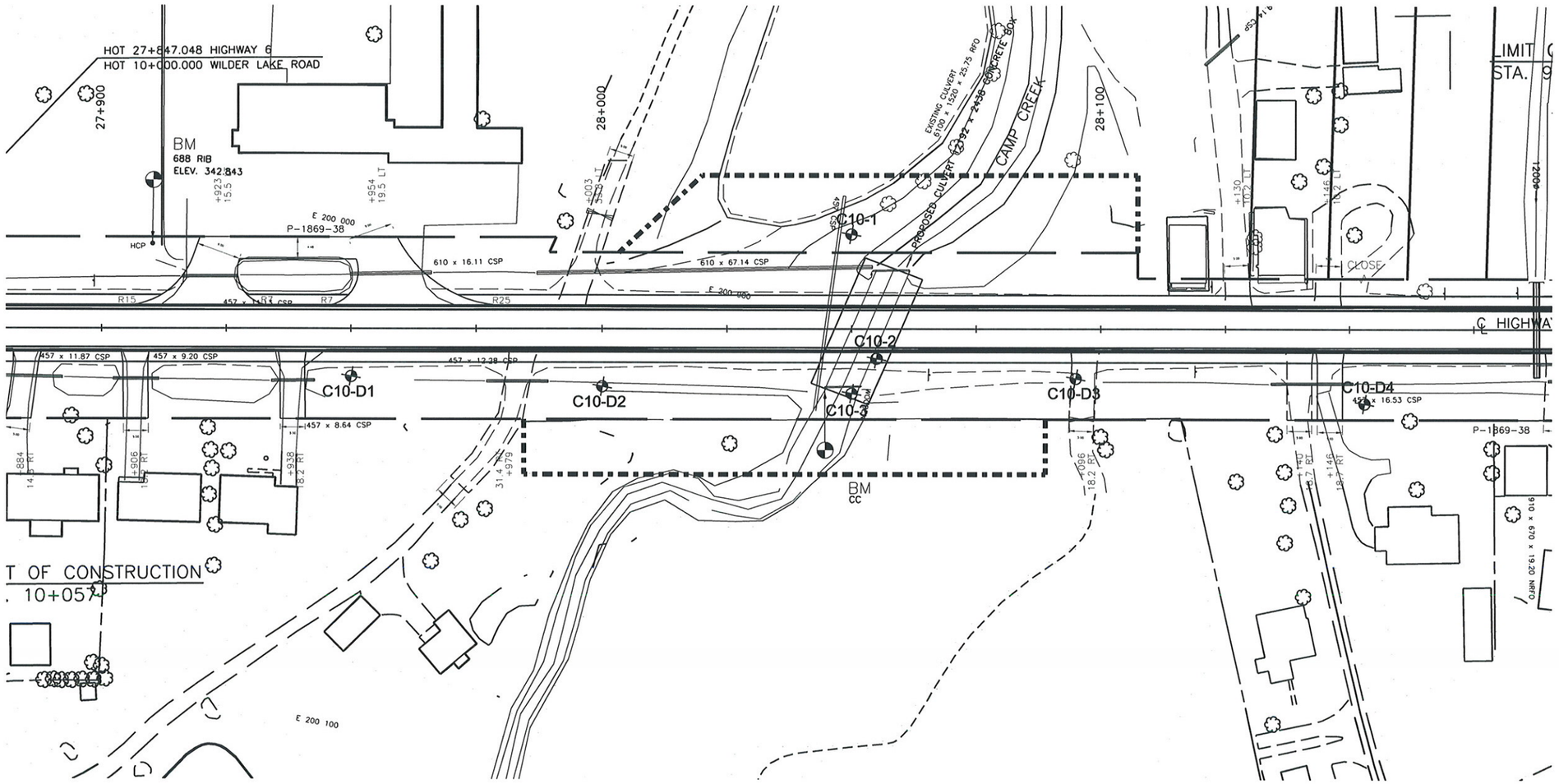
FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.

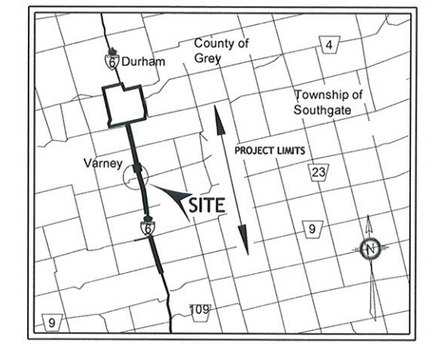
GWP: 338-97-00

Highway 6, Durham
Camp Creek Culvert (C10) @ Sta. 28+050
BOREHOLE LOCATIONS

SHAHEEN & PEAKER LIMITED



PLAN



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES NORTH	CO-ORDINATES EAST
C10-1	336.1	4 889 144.6	199 985.0
C10-2	338.6	4 889 154.1	200 008.6
C10-3	336.4	4 889 150.5	200 016.4
C10-D1	341.2	4 889 051.6	200 031.4
C10-D2	338.5	4 889 101.1	200 024.2
C10-D3	337.9	4 889 194.2	200 005.2
C10-D4	336.2	4 889 252.1	199 999.5

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.

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RAMON MIRANDA
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
PROVINCE OF ONTARIO

REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-195

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 1

METRIC

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

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

CONT No.

GWP: 338-97-00

Highway 6, Durham
Camp Creek Culvert (C10) @ Sta. 28+050
SOIL STRATA

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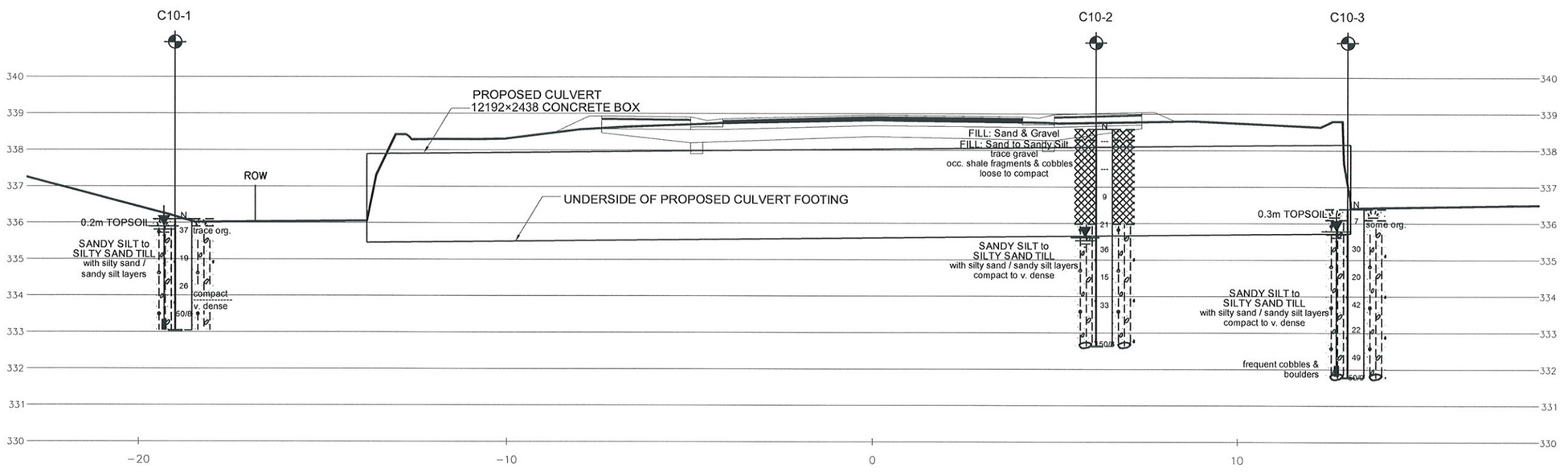

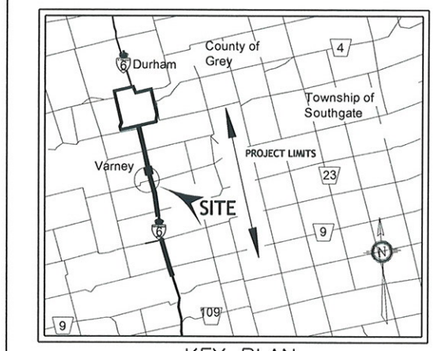

KEY PLAN
N.T.S

LEGEND

- Borehole
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES NORTH	CO-ORDINATES EAST
C10-1	336.1	4 889 144.6	199 985.0
C10-2	338.6	4 889 154.1	200 008.6
C10-3	336.4	4 889 150.5	200 016.4

NOTE

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

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REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-195

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

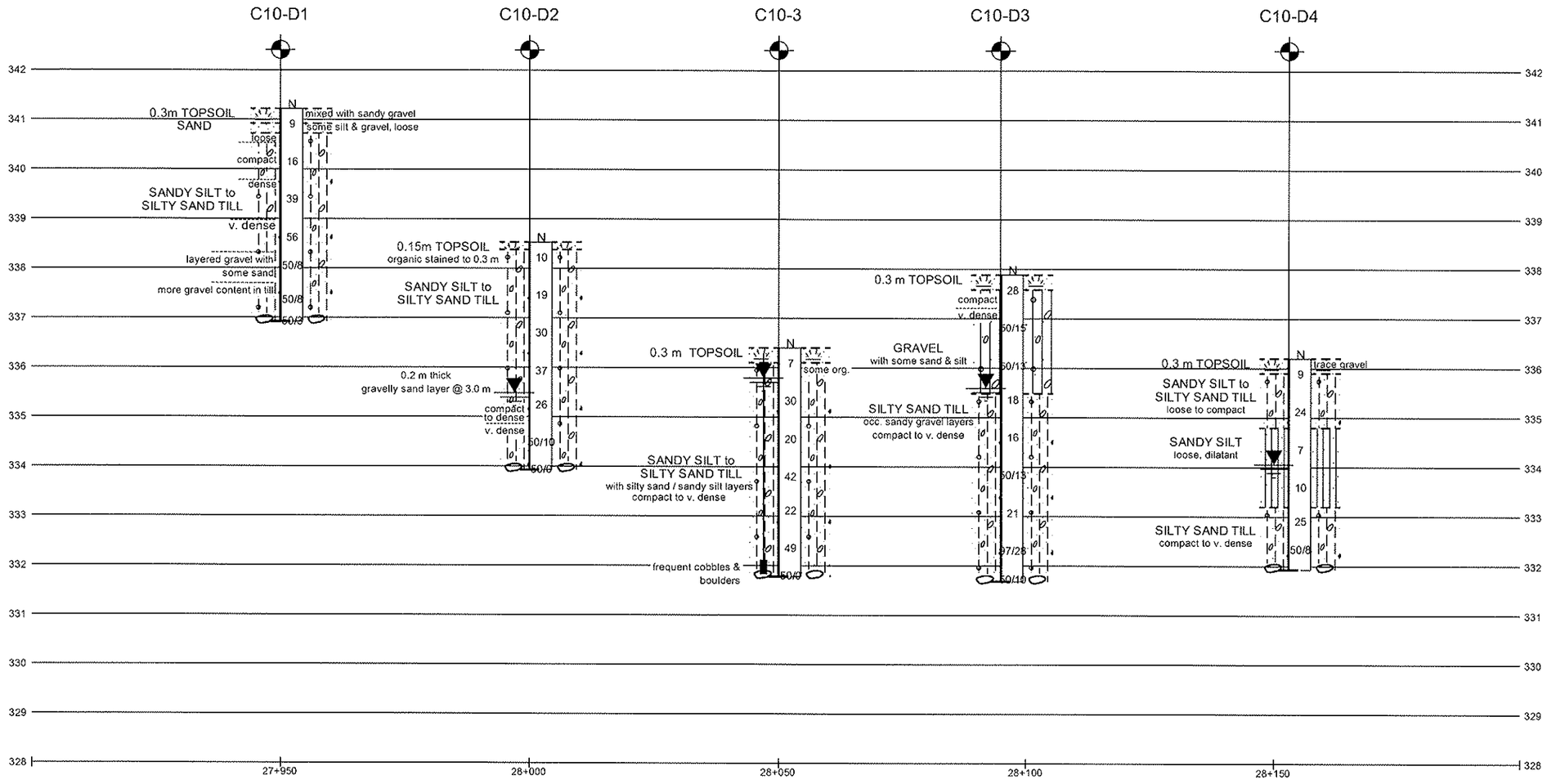
STRATIGRAPHIC SECTION ALONG CULVERT C10 @ STA. 28+053

CONT No.

GWP: 338-97-00

Highway 6, Durham
Camp Creek Culvert (C10) @ Sta. 28+050
SOIL STRATA

SHAHEEN & PEAKER LIMITED



SCALE
1m 0 1 2m VERT
10m 0 10 20m HOR

SOIL PROFILE ALONG PROPOSED DETOUR

KEY PLAN
N.T.S

LEGEND

- Borehole
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES NORTH	CO-ORDINATES EAST
C10-D1	341.2	4 889 051.6	200 031.4
C10-D2	338.5	4 889 101.1	200 024.2
C10-3	336.4	4 889 150.5	200 016.4
C10-D3	337.9	4 889 194.2	200 005.2
C10-D4	336.2	4 889 252.1	199 999.5

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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Z. S. OZDEN
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REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-195

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 3

Appendix A

Record of Borehole Sheets

RECORD OF BOREHOLE No C10-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+050, 19m Lt C/L ORIGINATED BY JL

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

DATUM Geodetic DATE 10/19/2006 CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
336.1											
336.0	0.2 m **TOPSOIL**										
0.2	trace org.		1	SS	37		336		○		
	SANDY SILT to SILTY SAND TILL with silty sand / sandy silt layers brown to grey, moist to wet		2	SS	19		335		○		
	compact		3	SS	26		334		○		
	very dense		4	SS	50/8				○		
333.1											
3.1	End of borehole.										

Very difficult augering below 2.5 m. Auger refusal at 3.1 m. Equipment damaged, probably due to cobbles and boulders.

Water level at 0.8 m upon completion, cave at 3.1 m.

Piezometer installed to depth of 3.0 m.
Water level in piezometer:
Oct. 19, 2006 ---0.8 m (El. 337.4 m)
Nov. 21, 2006 ---0.2 m (El. 337.9 m)

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

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

SPT1174

RECORD OF BOREHOLE No C10-2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+055, 6m Rt C/L ORIGINATED BY JL

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 8/21/2006 CHECKED BY FS

ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
338.6								20 40 60 80 100	10 20 30		
0.0 / 338.3	**FILL: Sand & Gravel**										
0.3	**FILL: Sand to Sandy Silt** trace gravel occasional shale fragments & cobbles brown, moist loose to compact		1	AS	---		338				
			2	AS	---						
			3	SS	9		337		○		
336.0											
2.6	**SANDY SILT to SILTY SAND TILL** with silty sand / sandy silt layers brown, moist compact to very dense		4	SS	21	▼*	336		○		
			5	SS	36		335		○		26 28 41 5
			6	SS	15						
			7	SS	33		334		○		
332.6							333				
6.0	End of borehole. Auger refusal at 5.9 m, probably on a boulder. * Water level in open borehole at 3.0 m (El. 335.6 m) upon completion (not stabilized).		8	SS	150/8						possible boulder

+^{3}, ×^{3}: Numbers refer to Sensitivity

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

SPT1174

RECORD OF BOREHOLE No C10-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+050, 13m Rt C/L ORIGINATED BY JL

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

DATUM Geodetic DATE 10/18/2006 CHECKED BY FS

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
336.4										
0.0 338.1	0.3 m **TOPSOIL**		1	SS	7		336			
0.3	some organics		2	SS	30					
	SANDY SILT to SILTY SAND TILL with silty sand / sandy silt layers grey, wet compact to very dense		3	SS	20		335			sampler wet @ 1.5 m
			4	SS	42		334			
			5	SS	22		333			
			6	SS	49					
331.8	frequent cobbles & boulders		7	SS	50/0		332			
4.6	End of borehole.									

Auger refusal @ 4.6 m. Borehole relocated 1.5 m south and redrilled but auger refusal encountered again @ 4.6 m, possible boulder or bedrock.

Water level at 0.6m upon completion.
Piezometer installed to depth of 4.6 m.
Water level in piezometer:
Oct. 18, 2006 --- 0.6 m (El. 335.8 m)

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

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C10-D1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 27+950, 9.6m Rt C/L ORIGINATED BY ZI

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/14/2006 CHECKED BY FS

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
341.2	GROUND SURFACE										
0.0 / 340.9	0.3 m **TOPSOIL** mixed with sand & gravel										
0.3	**SAND**, some silt & gravel, brown, loose		1	SS	9		341				
340.7 / 0.5	loose										
	compact		2	SS	16		340				
	dense										
	SANDY SILT to SILTY SAND TILL brown, moist to wet		3	SS	39						
	very dense						339				
			4	SS	56						
	layer of gravel with some sand		5	SS	50/8		338				
	more gravel content in till		6	SS	50/8						
336.9											
4.3	End of borehole.		7	SS	50/3		337				

Auger refusal @ 4.3 m possibly on a boulder.

No free-standing water in open borehole upon completion.

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No C10-D2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+000, 11.6m Rt C/L ORIGINATED BY JL

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/14/2006 CHECKED BY FS

ELEV. DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
338.5	GROUND SURFACE										
338.0 / 0.2	0.15 m TOPSOIL organic stained to 0.3 m		1	SS	10		338		○		
			2	SS	19				○		
	SANDY SILT to SILTY SAND TILL		3	SS	30		337		○		
			4	SS	37	▼*	336		○		
	0.2 m thick gravelly sand layer @ 3.0 m										spoon wet @ 3.1 m
	compact to dense		5	SS	26		335		○		
	very dense		6	SS	50/10				○		
333.9 / 4.6	End of borehole. Auger refusal @ 4.6 m possibly on a boulder. Borehole caved-in @ 4.3 m. * Water level at 3.1 m (El. 335.4 m) in the open borehole upon completion (not stabilized).		7	SS	50/0		334				

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C10-D3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+095, 10m Rt C/L ORIGINATED BY JL

DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/20/2006 CHECKED BY FS

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
337.9 / 0.0	GROUND SURFACE							20 40 60 80 100	10 20 30		
337.6 / 0.3	0.3 m **TOPSOIL**										
	compact very dense **GRAVEL** with some sand & silt, greyish moist wet		1	SS	28		337				
			2	SS	50/15						
			3	SS	50/13	▼*	336				
335.5 / 2.4			4	SS	18						spoon wet @ 2.4 m
			5	SS	16		335				
	SILTY SAND TILL occasional sandy gravel layers brown, compact to very dense		6	SS	50/13		334				
			7	SS	21		333				
			8	SS	97/28						
331.7 / 6.2			9	SS	50/10		332				
	End of borehole. Auger refusal @ 6.2 m. Borehole caved-in @ 6.1 m upon completion. * Water level at 2.3 m (El. 335.6 m) in the open borehole upon completion (not stabilized).										

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

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

SPT1174

RECORD OF BOREHOLE No C10-D4

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+153, 15m Rt C/L ORIGINATED BY JL

DIST HWY 6 BOREHOLE TYPE Solid Stem Augers COMPILED BY XS

DATUM Geodetic DATE 11/20/2006 CHECKED BY FS

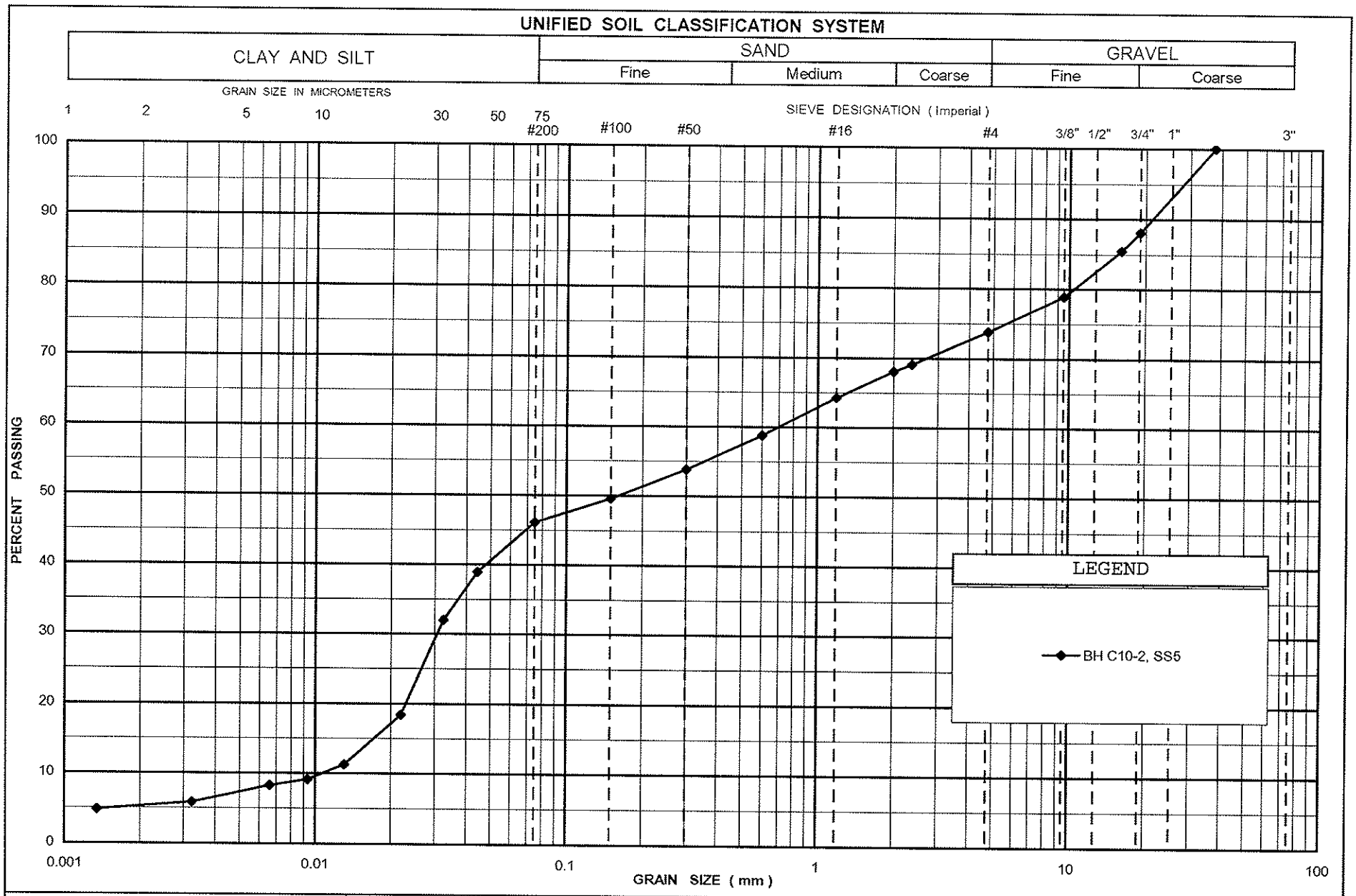
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
336.2	GROUND SURFACE										
0.0 / 335.9	0.3 m **TOPSOIL** trace gravel		1	SS	9		336				
0.3 / 334.8	**SANDY SILT to SILTY SAND TILL** brown, loose to compact		2	SS	24		335				
1.4 / 333.2	**SANDY SILT** brown, loose, wet, dilatant		3	SS	7	▼*	334				
			4	SS	10						spoon wet @ 2.3 m no recovery
3.0 / 331.9	**SILTY SAND TILL** brown, moist to wet compact to very dense		5	SS	25		333				
			6	SS	50/8		332				difficult augering
4.3	End of borehole. Auger refusal @ 4.3 m. Borehole caved-in @ 4.0 m upon completion. * Water level at 2.1 m (El. 334.1 m) in the open borehole upon completion (not stabilized).										

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

{%} STRAIN AT FAILURE

Appendix B

Laboratory Test Results



SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION

SANDY SILT to SILTY SAND TILL

FIGURE No. B10-1

G. W. P. 338-97-00

REF. No. SPT 1174

Appendix C

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

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

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 COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

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

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

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

JOINT AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
σ_1, σ_2, σ_3	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
ε_1, ε_2, ε_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'	$-^o$	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	$-^o$	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
γ_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
γ_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
γ	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
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = $(W_L - W_L)$	v	m/s	DISCHARGE VELOCITY
P_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(W - W_P)/ I_P$	i	1	HYDAULIC GRADIENT
γ_{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
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

Appendix D

Site Photographs

Photo (1): Culvert C10 at Station 28+050 on Highway 6, West end view

Photo (2): Culvert C10 at Station 28+050 on Highway 6, East end view