FOUNDATION INVESTIGATION REPORT
HIGHWAY 11
FREDERICKHOUSE RIVER BRIDGE
STRUCTURE REHABILITATION
W.P. 647-90-01

GEOCRES NO. 42H-32

Prepared For:

LEA CONSULTING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

Project: SPT1142A
February 1, 2006

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1. INTRODUCTION

The abutments of the Highway 11 Bridge over the Frederickhouse River near Cochrane, Ontario are experiencing excessive deformations and will be rehabilitated.

Shaheen & Peaker Limited (S&P) was retained by Lea Consulting Limited (LEA) to conduct a foundation investigation at the abutment locations of the bridge. The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes.

The findings of the investigation are presented in this report.

2. SITE DESCRIPTION AND GEOLOGY

The site of this investigation is located approximately 11 km west of the Town of Cochrane. At the site, Highway 11 crosses Fredrickhouse River via a five span steel girder bridge, about 10 m in width and 135 m in length. Approximately 1 km east of the bridge, Highway 636 intersects Highway 11 and continues toward the north.

In general, terrain in the areas adjacent to the river falls gently from about El. 272 m at a distance of 2 to 3 km from the river, to about El. 258 m on top of the river valley. At the existing bridge location, the River cuts a deep valley and the elevation of the river bed is approximately 238 m.

Below the existing bridge, boulders are exposed along the east bank of the river and the presence of some lumber crib remains was noted, probably parts of an old bridge.

Available geological information show that within the project area, the overburden is an extensive drift cover consisting of glaciolacustrine deposits (clay and silt), glacial till (silty sand till) and glaciofluvial (sand, gravel, cobbles and boulders). The depth of the overburden in the general area can be expected to be more than 30 m. Published geological information indicates that the bedrock in the area is generally metasedimentary rocks composed of wacke, argillite, marble and iron. Metavolcanic rocks are also common in this formation, which belongs to the Neo to Mesoarchean in age and is more than two billion years old.

3. METHOD OF INVESTIGATION

Fieldwork for this investigation was carried out during the period of August 22-31, 2005 and consisted of drilling and sampling a total of five boreholes. The plan locations of the boreholes along with stratigraphic profiles are shown on Drawing Nos. 1 and 2.

The boreholes were extended using a truck-mounted drilling rig owned and operated by Landcore Drilling of Chelmsford, Ontario, under the full-time supervision of a Geotechnical Engineer from S&P.

The depths of the boreholes ranged from 14.2 to 31.7 m. The boreholes were extended using hollow-stem augers. However, below the groundwater table, uplift of the granular soils was experienced in Boreholes 1, 2 and 4 and therefore, utilizing casing and washboring methods became necessary. Rock coring was also resorted to advance Boreholes 1 and 4 through cobbles and boulders.

Samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The test 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 (SS-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 which is indicative of the compactness condition of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils).

In cohesive (clayey) deposits, where the consistency of the soil permitted, relatively undisturbed samples (TW) were taken with 50 and 70 mm diameter thin-walled (Shelby) tube samplers. As well, the undrained shear in-situ strength of the soil was measured by means of MTO-type field vane, as well as a smaller diameter vane where the soil was found too stiff to turn the standard MTO vane.

Dynamic Cone Penetration Tests (DCPT) was performed from the bottom of Boreholes 2 and 5. In Dynamic Cone Penetration Test, a 51 mm diameter, 60 degree apex cone point, attached to the tip of A-size rods, is driven into the ground using the same driving energy as in the SPT method. By recording the number of blows to drive the cone/rod assembly into the soil every 0.3 m, a qualitative record of relative density/consistency is obtained. Although the interpretation of the test results is difficult because no samples are obtained by the DCPT method and the penetration resistances are not necessarily equal to the N-values, useful information is gained by the continuity of the results and by the elimination of unbalanced hydrostatic effects which in many cases affect the SPT values, especially in the fine-grained granular soils. The DCPT was generally terminated when the number of blows to drive the cone/rod assembly 0.3 m exceeded 100.

In Borehole 1, a deep piezometer was installed at a depth of 16.8 m, as well as a second, shallow piezometer at 3.6 m, below the ground surface to enable us to monitor the groundwater table over a prolonged period of time without interference from surface water.

After completion, the boreholes were grouted using a cement/bentonite mixture as per MTO standards and MOE Regulations.

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

A laboratory testing programme, consisting of natural moisture content, bulk unit weight, Atterberg limits, grain-size analysis and one-dimensional consolidation (oedometer) tests, was performed on selected soil samples. The results of the laboratory tests are given on the appropriate Record of Borehole Sheets and also in Appendix B.

4. SUBSURFACE CONDITIONS

The boreholes were drilled near the abutments at elevations very close to the top of the bridge. The ground elevations at the borehole locations range from 258.1 (BH5) to 257.5 m (BH2).

The water level in the river was at the time of our investigation measured at a depth of 17.4 m below the top of the bridge or at about El. 240.6 m. High water level in September 1994 is shown as El. 244.5 m on one of the drawings supplied to us. The bottom of creek near the middle of the River bed appears to be about 6 m below this elevation (El. 238.5± m).

In general, the boreholes revealed, beneath a layer of asphalt (Boreholes 2, 3 and 5), topsoil (BH1) and at ground surface (BH4), the presence of a granular fill extending to depths ranging from 0.7 to 2.9 m below the ground surface. Underlying the granular fill, all boreholes contacted a silty clay fill which extends to depths of between 3.8 m (BH1) and 12.7 m (BH5) below the ground surface. The silty clay fill is in turn underlain by a silty clay deposit which extends to a depth of 12.0 m (about El. 244.5 m) at Boreholes 1, 2 and 3 locations at the east abutment area and to 14.5 and 15.3 m below the ground surface at Boreholes 4 and 5, respectively (or at about El. 243 m) at the west abutment area. The thickness of the silty clay ranges from 2.6 m at Borehole 5 to 7.5 m at Borehole 1.

Underlying the silty clay, all boreholes contacted, at depths ranging from 12 to 15 m below the ground surface, a deposit of silt. At the east abutment location at Boreholes 1 and 2, the silt extends to a depth of 16.2 m and 16.5 m or to about El. 241 m, while at the west abutment area the silt was found to extend considerably deeper to a depth of 26.0 m or to about El. 232 m at Borehole 4.

The silt is underlain by coarse granular soils ranging from silty sand till to cobbles and boulders in a sand and gravel matrix.

In the shallow piezometer installed in BH1 a perched water table was recorded at 2.4 m below the ground surface (i.e. in the clayey fill) while in the deep piezometer the groundwater table was recorded at a depth of about 13 m or at about El. 245 m (i.e. about 4 m above the water level in the river, at the time of our investigation). The groundwater table can be expected to be subject to fluctuations.

Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. Stratigraphic profiles, along with borehole locations are given in Drawing Nos. 1 and 2. The individual soil strata encountered in the boreholes are described briefly in the following paragraphs.

4.1 ASPHALT

Boreholes 2, 3 and 5 were drilled from the paved portion of the Highway and contacted a layer of asphaltic concrete which ranged in thickness from 0.17 m (BH5) and 0.30 m (BH2).

4.2 TOPSOIL

A 0.1 m thick topsoil layer was contacted in BH1 at ground surface level.

4.3 GRANULAR FILL

Underlying the asphaltic concrete (Boreholes 2, 3 and 5), topsoil at Borehole 1 and immediately at ground surface in BH4, all boreholes contacted a granular fill, which extended to depths ranging from 0.7 m (BH4) to 2.9 m (BH2). In Boreholes 2, 3 and 5, the upper zones of the pavement fill under the paved roadway appeared to be slightly better graded with crushed gravel and appeared to be of Granular ‘A’ quality material.

Grain-size distribution of samples from the granular fill is given in Figure B-1 in Appendix B.

Standard Penetration tests performed in the granular fill soils yielded N-values which range from 3 to 7 blows/0.3 m in Boreholes 1 and 4, indicating that these soils did not receive a systematic compaction under the unpaved portion of the roadway while in the remaining boreholes drilled from the paved portion of the road the recorded N-values range from 12 to 22 blows/0.3 m which indicate some degree of systematic compaction, especially in the upper zones.

4.4 SILTY CLAY FILL

Underlying the granular fill, all boreholes contacted a cohesive fill deposit which consists of mainly silty clay with some topsoil and occasional organic soil inclusions (such as peat pockets) and traces of gravel and sand. The presence of decomposed lumber was also noted in several of the samples from Boreholes 2 and 3.

The grain-size distribution curve of a typical sample from the fill is given in Figure B-2 in Appendix B. These indicate the following grain-size distribution:

Gravel:	2%
Sand:	17%
Silt:	47%
Clay:	34%

Atterberg Limits tests performed in the laboratory yielded the following index values, as shown in Figure B-3 in Appendix B.

Liquid Limit:	23-30%
Plastic Limit:	12-17%
Plasticity Index:	10-14%

These values are characteristic of clayey soils of low plasticity. The measured natural moisture contents range from 15 to 38% but typically about 20%.

Standard Penetration tests performed in the silty clay fill gave N-values which typically range from 2 to 9 blows/0.3 m with some values between 10 and 23 m the lower zones. These values indicate that the fill was placed without any systematic compaction. Based on the recorded N-values and field vane test results which range from 60 to in excess of 100 kPa the consistency of the deposit can be described as generally firm to stiff.

4.5 SILTY CLAY

Underlying the fill deposits the boreholes contacted a silty clay deposit at depths ranging from 3.8 m (El. 253.8 m) BH1 to 12.7 m (El. 245.4 m) at BH5. This cohesive deposit was found to extend to a depth of 12.0 m below the ground surface or to about El. 245.6 m at Boreholes 1, 2 and 3 located on the east side and to depths of 14.5 and 15.3 m at Boreholes 4 and 5 or to El. 243.1 and 242.8 m, respectively on the west.

The silty clay is an irregularly layered material with the thickness of individual layer generally ranging from 1 to 4 cm. The material is generally of low to medium plasticity with some highly plastic seams typically about 1 to 2 cm thick.

The grain-size distribution of samples (five samples) from the deposit is given in an envelope form in Figure B-4 in Appendix B. These show the following grain-size distribution:

Gravel:	0%
Sand:	0-1%
Silt:	17-54%
Clay:	45-83%

Atterberg limits tests performed in the laboratory on selected samples (ten samples) gave the following values, as shown in Figure B-5, Appendix B.

Liquid Limit:	24-59%
Plastic Limit:	16-23%
Plasticity Index:	8-36%
Natural Moisture Content:	29-54%

These results are characteristic of clayey soils of low to high plasticity but generally low to medium plasticity. The measured moisture contents in relation to the measured liquid and plastic limits are generally in the mid range indicating a possible moderate pre-consolidation, but some are in excess of measured liquid limit values.

When examining the grain-size and Atterberg limits tests results, the layered nature of the soil should be kept in mind.

Standard Penetration tests gave N-values which range from 1 to 6 blows/0.3 m in Boreholes 1, 2 and 3 drilled on the east side and between 5 and 16 blows/0.3 m in Boreholes 4 and 5, located on the west side of the bridge.

Field vane tests yielded undrained shear strengths which range from 36 to in excess of 100 kPa. In Boreholes 1, 2 and 3 (east side of the bridge) the recorded values are between 36 and 86 kPa, while in Boreholes 4 and 5 the measured undrained in-situ shear strengths range from 56 to in excess of 100 kPa. Based on these values, the consistency of the silty clay is described as firm to stiff on the east side and firm to very stiff on the west side of the bridge.

Bulk unit weights measured in the laboratory on three samples range from 18.3 to 19.2 kN/m^3.

The results of two oedometer (i.e. one-dimensional consolidation) tests performed in the laboratory on relatively undisturbed Shelby tube (TW) samples are given in Figures B-6 and B-7 in Appendix B. The test results indicate probable P_c-P_o values ranging from about 100 to 180 kPa (i.e. pre-consolidation pressure in excess of the existing effective vertical stress).

4.6 SILT

Underlying the silty clay at a depth of 12.0 m or at about El. 245.6 m in Boreholes 1, 2 and 3 on the east side and below 14.5 and 15.3 m at Boreholes 4 and 5 or El. 243.1 and 242.8 m, on the west side, a silt deposit was contacted. On the east side of the bridge, Borehole 3 was terminated in this deposit at a depth of 14.2 m while in Boreholes 1 and 2 the silt deposit extended to a depth of 16.2 to 16.5 m or to El. 241.1 to 241.3 m. On the west side, Borehole 5 was terminated in this deposit at a depth of about 20 m, while in Borehole 4 which was extended deeper the silt extended to 26.0 m or to El. 231.6 m.

The silt is a basically fine-grained granular deposit with some clayey silt and occasional thin clay seam within the upper 1 m. Below this upper zone, some sandy silt layers/zones are also present, and the material attains a sandy silt character. The grain-size distribution of selected samples from this unit is given in Figure B-8 in Appendix B.

The silt was wet and it is a dilatant material. N-values recorded in the deposit in Boreholes 1, 2 and 3 (i.e. on the east side of the bridge) ranged from 4 to 9 blows/0.3 m indicating a generally loose relative density (some of the N-values may be on the low side due to disturbance of the fine-grained granular soil below the groundwater table). On the west side in Boreholes 4 and 5 the recorded N-values range from 3 to 11 blows/0.3 m to depth of about 20 m. The recorded N-value of 3 blows/0.3 m is likely to be disturbed due to hydrostatic uplift and can be discarded. Based on these values, the relative density of the soil within the upper zones is described as loose to compact. Below about 20 to 22 m, the recorded N-values and DCPT results show a relatively more competent material (N-values of 19 to 34 blows/0.3 m) indicating a generally compact soil, changing to dense near the bottom of the deposit.

4.7 COARSE-GRAINED GRANULAR SOILS

Underlying the silt deposit, the deeper boreholes (i.e. Boreholes 1, 2 and 4) contacted coarse-grained granular soils which generally consist of sand and gravel with some cobbles and boulders alternating with cobbles and boulders in a sand and gravel matrix. Near the upper zones the material was identified as glacial till or probable glacial till. The grain-size distribution of samples from the glacial till is given in Figure B-9, Appendix B.

Because of the presence of cobbles and boulders, it was difficult to determine the relative density of the deposit by means of Standard Penetration tests. The recorded N-values range from 9 to generally in excess of 100 blows/0.3 m. Based on these, it is surmised that the material is generally compact to dense in the upper zones becoming dense to very dense below.

Because of its coarse nature, it was necessary to advance the boreholes by coring in the lower zones of the material. From an examination of the cores, the material cored from 30.8 m to 31.7 m (i.e. below El. 226.8 m) in Borehole 4 may represent the bedrock underlying the site.

4.8 GROUNDWATER CONDITIONS

During drilling, the silt deposit underlying the silty clay was found to be wet. In the piezometer installed in Borehole 1, the groundwater table at the time of our investigation was recorded at a depth of about 12.8 m below the ground surface or at El. 244.8 m or immediately below the silty clay deposit and in the underlying silt.

In addition, a perched water table was recorded at 2.4 m in the shallow piezometer installed in Borehole 1 due to the accumulation of surface water in the fill overlying the practically impervious silty clay deposit.

It should be pointed out that the groundwater at the site would be subject to seasonal fluctuations and in response to major weather events.

In addition, the groundwater table at the site would be largely controlled by the water level in the river. At the time of our investigation, the groundwater level recorded in the piezometer (i.e. El. 244.8 m) was about 4 m above the water level in the river.

SHAHEEN & PEAKER LIMITED

Z. S. Ozden, P.Eng.

ZO:tr/idrive

for K. R. Peaker, Ph.D., P.Eng.

Drawings

METRIC

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

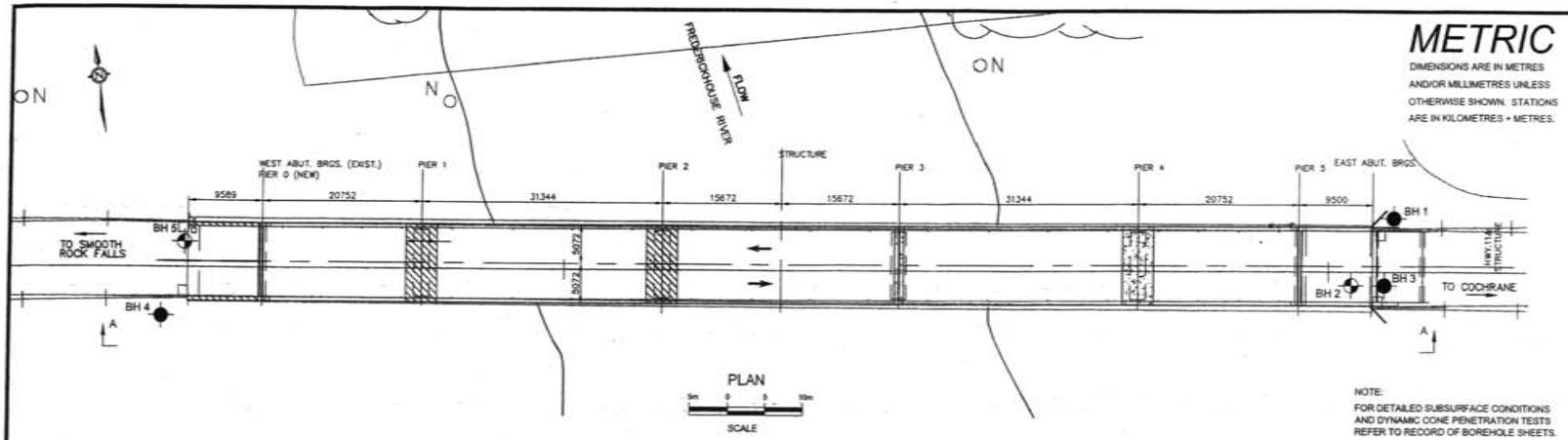
CONT No.

WP: 647-90-01

HIGHWAY 11
FREDERICKHOUSE RIVER BRIDGE
BORE HOLE LOCATIONS & SOIL STRATA

SHAHEEN & PEAKER LIMITED

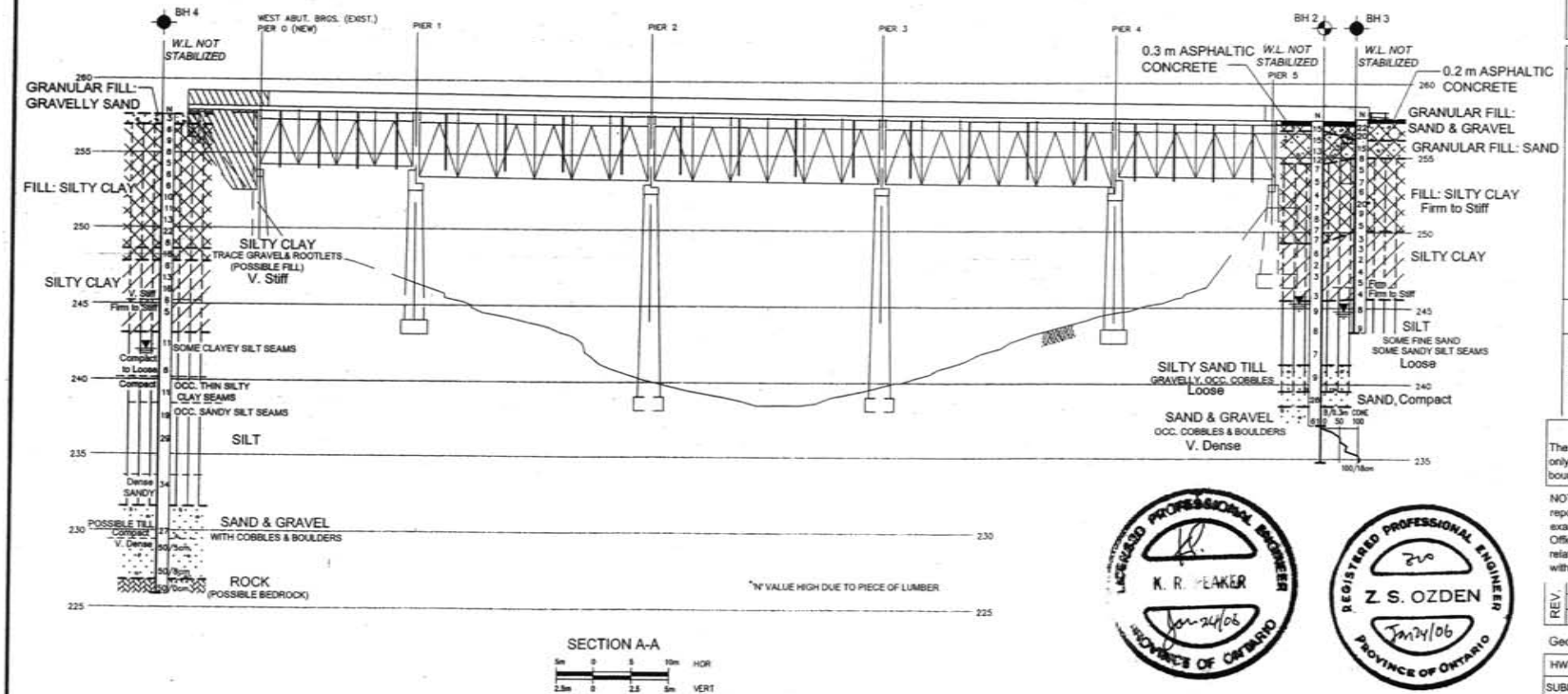
KEY PLAN
N.T.S



PLAN

SCALE

NOTE:
FOR DETAILED SUBSURFACE CONDITIONS AND DYNAMIC CONE PENETRATION TESTS REFER TO RECORD OF BOREHOLE SHEETS.



"N" VALUE HIGH DUE TO PIECE OF LUMBER

SECTION A-A

SCALES

LEGEND

- Bore Hole
- Bore Hole & Cone
- Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation August, 2005

No.	ELEV.	CO-ORDINATES NORTH	EAST
BH1	257.6	5000.7	4999.6
BH2	257.5	4992.3	4993.7
BH3	257.6	4992.1	4998.0
BH4	257.6	4994.8	4838.4
BH5	258.1	5004.1	4841.8

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: 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.

LICENSED PROFESSIONAL ENGINEER
K. R. PEAKER
Jan-24/06
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
Jan24/06
PROVINCE OF ONTARIO

REV.	DATE	BY	DESCRIPTION

Geocres No. 42H-32

HWY No. 11			DIST
SUBM'D ZO	CHECKED RM	DATE Sep, 2005	SITE
DRAWN JZ	CHECKED	APPROVED	DWG 1

METRIC

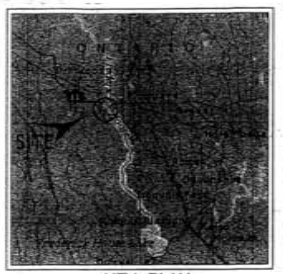
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES + METRES.

CONT No.

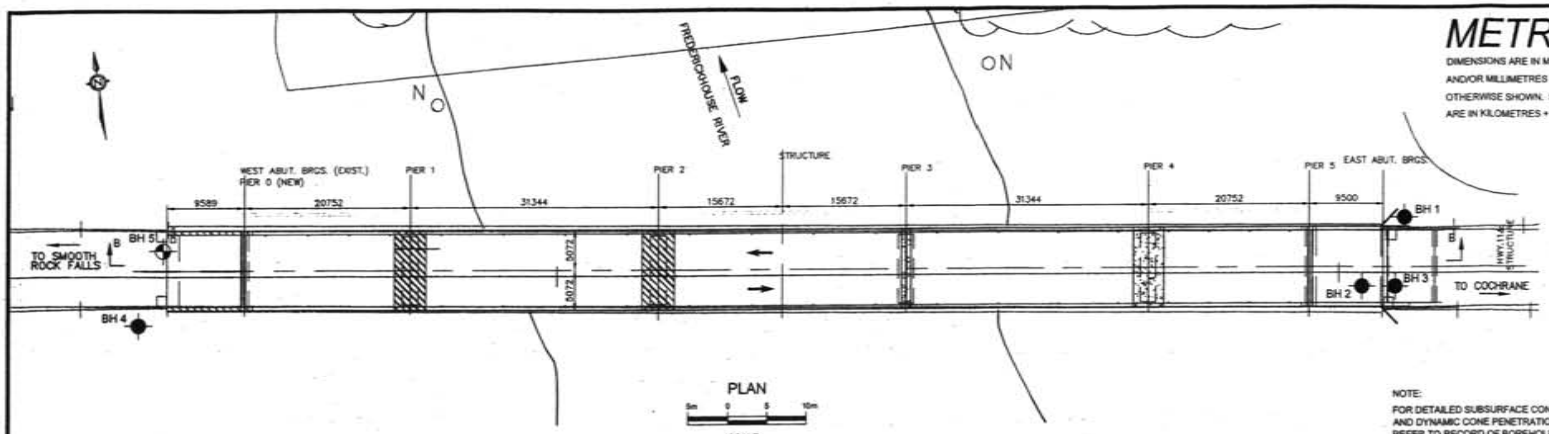
WP: 647-90-01

HIGHWAY 11
FREDERICKHOUSE RIVER BRIDGE
BORE HOLE LOCATIONS & SOIL STRATA

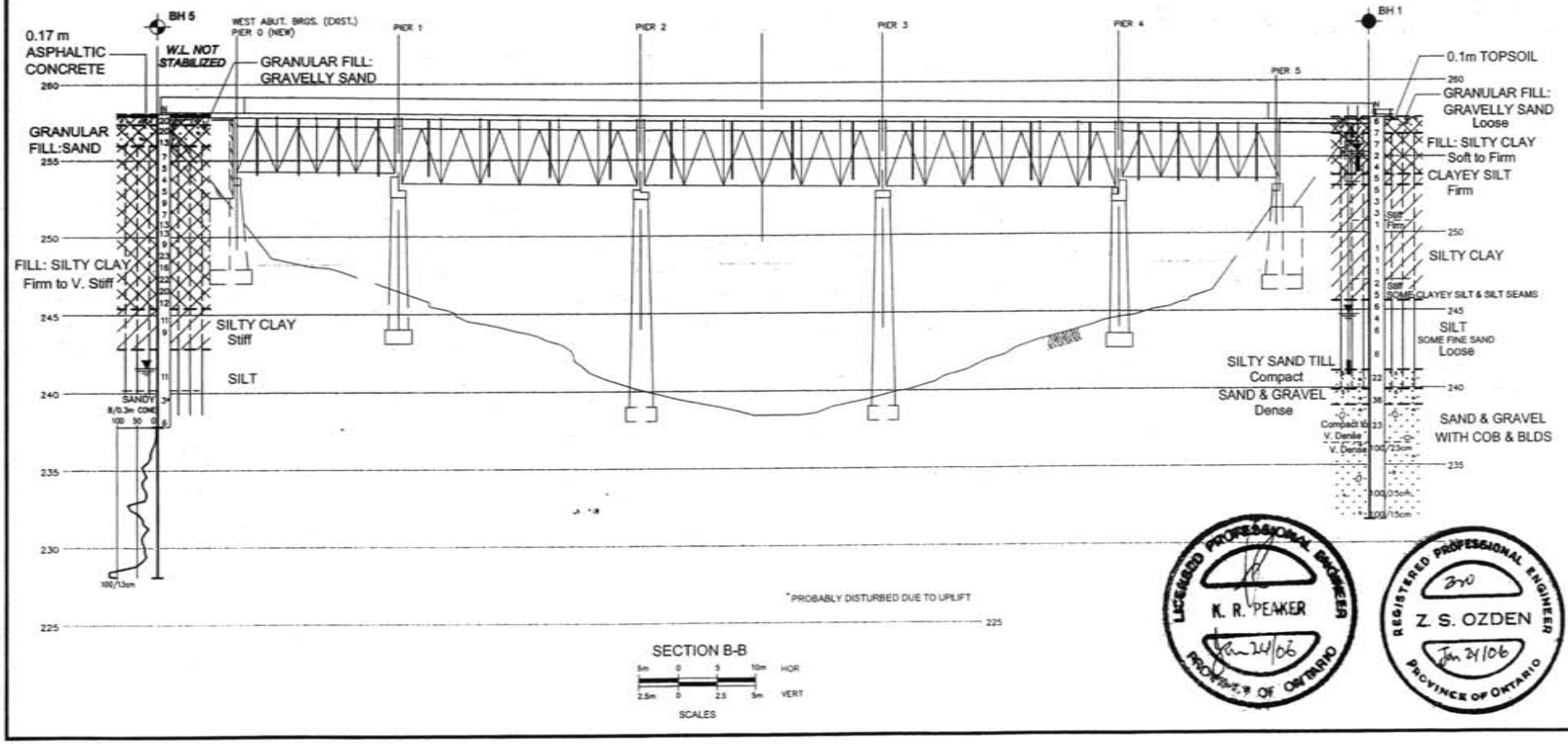
SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S



NOTE:
FOR DETAILED SUBSURFACE CONDITIONS AND DYNAMIC CONE PENETRATION TESTS REFER TO RECORD OF BOREHOLE SHEETS.



LEGEND

- Bore Hole
- Bore Hole & Cone
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation August, 2005
- Water Level in Piezometer
- Piezometer

No.	ELEV.	CO-ORDINATES NORTH	EAST
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BH2	257.5	4992.3	4993.7
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REV.	DATE	BY	DESCRIPTION

Geocres No. 42H-32

HWY No. 11			DIST
SUBM'D ZO	CHECKED RM	DATE Sep, 2005	SITE
DRAWN JZ	CHECKED	APPROVED	DWG 2

LICENSED PROFESSIONAL ENGINEER — K. R. PEAKER — Jan 24/06 — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER — Z. S. OZDEN — Jan 24/06 — PROVINCE OF ONTARIO

Appendix A

Records of Borehole Sheets

RECORD OF BOREHOLE No 1

1 OF 2

METRIC

WP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 5000.7; E 4999.6 ORIGINATED BY G.I.

DIST _____ HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & Coring COMPILED BY J.Z.

DATUM Geodetic DATE 8/22/2005 to 8/23/2005 CHECKED BY Z.O.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.6	Ground Surface								
0.0	0.1 m **TOPSOIL**		1	SS	6		257		
	GRANULAR FILL: Gravelly Sand brown, loose, damp								
256.5			2	SS	7				34 62 (4)
1.1	**FILL: Silty Clay** traces of gravel & topsoil brown, soft to firm		3	SS	7		256		
			4	SS	2		255		
			5	SS	4		254		
253.8									
3.8	**CLAYEY SILT** some organic seams, grey/dark grey, firm peat seam at 3.8 m		6	SS	5		253		
253.1									
4.5	**SILTY CLAY** brown to 6 m grey below		7	SS	5				
			8	SS	3		252		0 0 17 83
		stiff	9	SS	3		251		
		firm	10	SS	1				
			11	TW	PH		250	19.2	
			12	SS	1		249		
			13	SS	1		248		
			14	SS	1				
		stiff	15	SS	2		247		
	some clayey silt & silt seams		16	SS	5		246		
245.6									
12.0	some clayey silt & occ. thin clay seams		17	SS	6		245		
	SILT some fine sand grey, loose, wet, dilatant		18	SS	4		244		
			19	SS	6		243		

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 (%) 20 40 60

Continued Next Page

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

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 1 2 OF 2 METRIC

WP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 5000.7; E 4999.6 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & Coring COMPILED BY J.Z.

DATUM Geodetic DATE 8/22/2005 to 8/23/2005 CHECKED BY Z.O.

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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.6											
15.0 / 241.1	**SILT** some find sand grey, loose, wet, dilatant		20	SS	6		242		○		
16.5 / 239.9	**SILTY SAND TILL** gravelly, occ. cobbles grey, compact, wet		21	SS	22		241		○		20 55 17 8
17.7 / 238.9	**SAND & GRAVEL** traces of silt, occ. cobbles grey, wet, dense		22	SS	36		240		○		Back-up due to hydrostatic uplift @ 17.7 m, change to casing and wash boring.
18.7	**SAND & GRAVEL with COBBLES & BOULDERS** grey, wet		23	RC			239				
	compact to very dense		24	SS	23		238				
			25	RC			237				
	very dense		26	SS	100/23		236		○		
			27	RC			235				
			28	SS	100/15		234				
			29	RC			233		○		
231.5			30	SS	100/15		232		○		
26.1	End of Borehole.										

Borehole open to 16.8 m and water level at 16.8 m (not stablized) on completion.

Install piezometers @ 16.8 m and @ 3.6 m.

*Water level in deep piezometer:
Aug. 25, 2005 - 12.8 m (El. 244.8 m)
Aug. 26, 2005 - 12.9 m (El. 244.7 m)
Aug. 27, 2005 - 12.95 m (El. 244.65 m)
Aug. 28, 2005 - 13.05 m (El. 244.55 m)
Aug. 29, 2005 - 12.9 m (El. 244.7 m)
Aug. 30, 2005 - 12.85 m (El. 244.75 m)

*Water level in shallow piezometer:
Aug. 25, 2005 - 2.4 m (El. 255.2 m)
Aug. 26, 2005 - 2.3 m (El. 255.3 m)
Aug. 27, 2005 - 2.4 m (El. 255.2 m)
Aug. 28, 2005 - 2.5 m (El. 255.1 m)
Aug. 29, 2005 - 2.3 m (El. 255.3 m)
Aug. 30, 2005 - 2.3 m (El. 255.3 m)

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

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

1 OF 2

METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4992.3; E 4993.7 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & D.C.P.T. COMPILED BY J.Z.

DATUM Geodetic DATE 8/25/2005 CHECKED BY Z.O.

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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.5	Ground Surface										
0.0 / 256.8	0.3 m **Asphaltic Concrete** **GRANULAR FILL: Sand & Gravel** brown, compact, damp		1	SS	15		257				
0.7	**GRANULAR FILL: Sand, some Gravel** brown, compact, damp		2	SS	15						
			3	SS	13		256				
254.6			4	SS	12		255				20 78 (2)
2.9	**FILL: Silty Clay** traces of gravel & topsoil brown to 7 m, grey below, firm		5	SS	7		254				
			6	SS	5						2 17 47 34
			7	SS	4		253				
			8	SS	7		252				
	occ. wood pieces		9	SS	8						
	some topsoil dark grey		10	SS	7		251				
	occ. wood pieces		11	SS	7		250				
249.3											
8.2	brown / grey **SILTY CLAY**		12	SS	6		249				
			13	SS	2		248				
			14	SS	3		247				0 1 42 57
	firm / stiff		15	TW	PH					18.4	0 1 54 45 consolidation test
			16	SS	3		246				
245.5											
12.0	some clayey silt & occ. thin clay seams **SILT** some fine sand, some sandy silt seams grey, loose, wet, dilatant		17	SS	9	▼	245				
			18	SS	8		244				0 29 59 12
							243				

Continued Next Page

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

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

RECORD OF BOREHOLE No 2 2 OF 2 METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4992.3; E 4993.7 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & D.C.P.T. COMPILED BY J.Z.

DATUM Geodetic DATE 8/25/2005 CHECKED BY Z.O.

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
242.5											
15.0 241.3	**SILT** some fine sand, and sandy silt seams grey, loose, wet, dilatant		19	SS	7		242		○		
16.2 239.5	**SILTY SAND TILL** gravelly, occ. cobbles, grey, loose		20	SS	9		241		○		
18.0 238.5	**SAND** some silt, trace of clay & gravel (possible till) grey, compact, wet		21	SS	28		240		○		excessive back-up in hollow stem augers, switch to casing & wash boring.
19.0 237.2	**SAND & GRAVEL** occ. cobbles & boulders grey, very dense, wet		22	SS	61		239		○		
20.3 234.8	End of Borehole. *Water level at 12.2 m (not stabilized) and hole open to 14.6 m on completion.						238		○		
22.7	End of Dynamic Cone Penetration Test. Dynamic Cone Penetration Test (D.C.P.T.) performed from 20.4 m to 22.7 m						237	100/18			
							236				
							235				

SHEAR STRENGTH kPa: 20 40 60 80 100 — WATER CONTENT (%): 20 40 60

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

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

1 OF 1

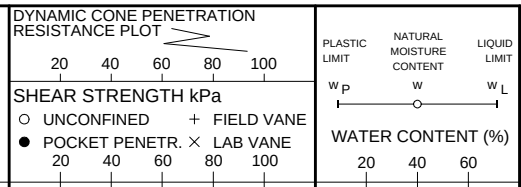
METRIC

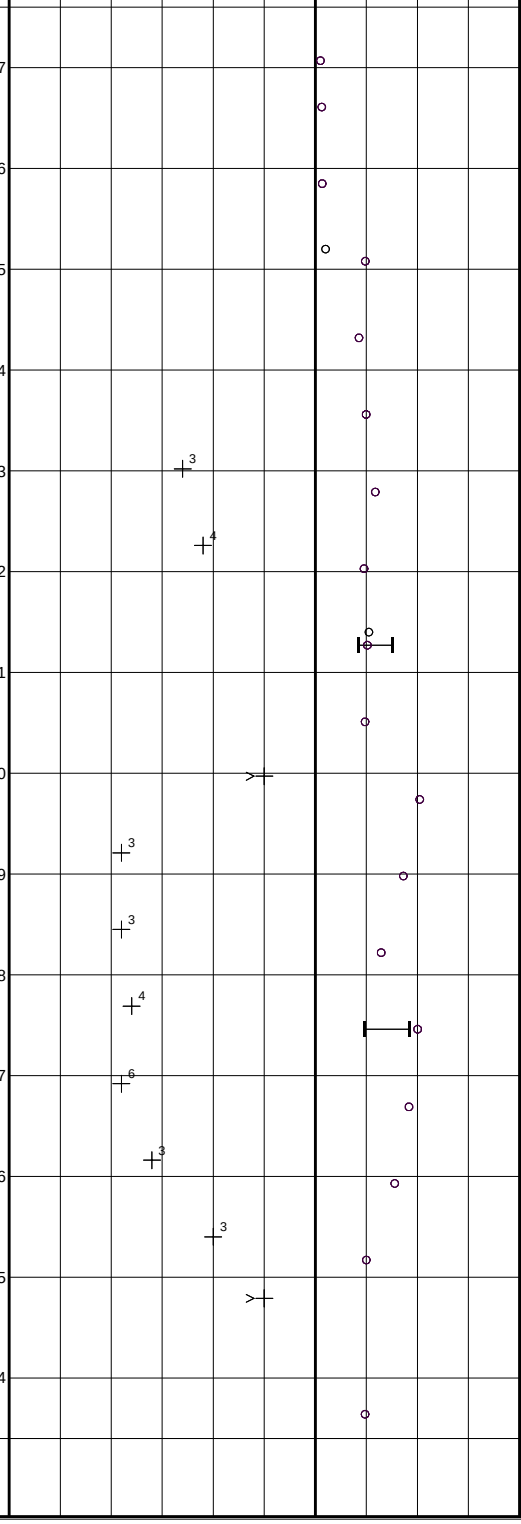
GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4992.1; E 4998.0 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY J.Z.

DATUM Geodetic DATE 8/26/2005 CHECKED BY Z.O.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.6	Ground Surface								
0.0	0.2 m **Asphaltic Concrete**								
	GRANULAR FILL: Sand & Gravel brown, compact, damp		1	SS	22		257		
			2	SS	20				
256.2									
1.4	**GRANULAR FILL: Sand, some Gravel** brown, compact, damp		3	SS	15		256		piece of asphalt @ 1.8 m.
			4	SS	8		255		
255.0									
2.6	**FILL: Silty Clay** occ. topsoil & somewhat organic soil inclusions trace gravel & sand, occ. wood pieces brown, some grey & darkish brown zones firm to stiff		5	SS	5		254		
			6	SS	7				
			7	SS	6		253		
			8	SS	20**		252		**N-value high due to piece of lumber
			9	SS	9				
			10	SS	5		251		
250.1									
7.5	**SILTY CLAY** grey		11	SS	3		250		
			12	SS	3		249		
			13	SS	2				
			14	SS	4		248		
			15	SS	5		247		
	firm								
	firm to stiff		16	SS	4		246		
245.6	occ. silt seams								
12.0	some clay silt & occ. thin clay seams		17	SS	8	▼	245		
	SILT some fine sand, some sandy silt seams grey, loose, wet, dilatant						244		
243.4			18	SS	9				
14.2	End of Borehole.								
	*Water level at 12.8 m (not stabilized) and hole open to 12.8 m on completion.								





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

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

RECORD OF BOREHOLE No 4

1 OF 3

METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4994.8; E 4838.4 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & Coring COMPILED BY J.Z.

DATUM Geodetic DATE 8/27/2005 to 8/29/2005 CHECKED BY Z.O.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	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 (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.6	Ground Surface										
0.0 / 256.9	**GRANULAR FILL: Gravelly Sand** some clayey silt seams brown, very loose, moist		1	SS	3		257				
0.7	**FILL: Silty Clay** some topsoil & somewhat organic soil inclusions, trace gravel & sand brown		2	SS	6		256				
			3	SS	9						
			4	SS	8		255				
			5	SS	5						
			6	SS	6		254				
			7	SS	6		253				
			8	SS	10		252				
			9	SS	11						
			10	SS	13		251				
			11	SS	22		250				
	somewhat organic some peat inclusions dark grey to black		12	SS	8		249				
9.0 / 248.6	**SILTY CLAY** trace gravel & rootlets (possible fill) brown, very stiff		13	SS	18		248				
9.8 / 247.8	**SILTY CLAY**		14	SS	6		247				
			15	SS	13						
			16	SS	16		246				
	brown very stiff		17	SS	6		245				
	firm to stiff grey		18	SS	5						0 1 51 48
			19	TW	PH		244			18.3	0 0 53 47 consolidation test
14.5 / 243.1	**SILT** grey, compact, wet, dilatant						243				

Continued Next Page

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

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

RECORD OF BOREHOLE No 4 2 OF 3 METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4994.8; E 4838.4 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & Coring COMPILED BY J.Z.

DATUM Geodetic DATE 8/27/2005 to 8/29/2005 CHECKED BY Z.O.

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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.6										
15.0	some clayey silt seams		20	SS	11	▼	242			
			21	SS	8		241			
	compact to loose compact		22	SS	11		240			
	occ. thin silty clay seams occ. sandy silt seams						239			
	SILT grey, wet, dilatant		23	SS	19		238			excessive back up in hollow stem auger, change to casing and wash boring
			24	SS	29		237			
	dense sandy		25	SS	34		236			
231.6							235			
26.0							234			
	possible till compact very dense		26	NQ RC	Rec.50%		233			
			27	SS	27		232			
	SAND & GRAVEL with cobbles & boulders grey, wet		28	NQ RC	Rec.30%		231			
			29	SS	50/5		230			
			30	NQ RC	Rec.30%		229			
							228			

Continued Next Page

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

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 4

3 OF 3

METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 4994.8; E 4838.4 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers & Wash Boring & Coring COMPILED BY J.Z.

DATUM Geodetic DATE 8/27/2005 to 8/29/2005 CHECKED BY Z.O.

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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.6											
30.0 / 226.8	**SAND & GRAVEL** with cobbles & boulders grey, dense, wet		31	SS	50/8		227		○		
30.8 / 225.9	**ROCK (possible bedrock)** grey		32	NQ RC	Rec.75%		226				RQD=53%
31.7	End of Borehole. Borehole open to 23.8 m on completion. *Water level on: Aug. 29, 2005 - 22.9 m (El. 234.7 m) Aug. 30, 2005 - 15.6 m (El. 242.0 m)		33	SS	50/0						

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

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

RECORD OF BOREHOLE No 5

1 OF 3

METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 5004.1; E 4841.8 ORIGINATED BY G.I.

DIST _____ HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY J.Z.

DATUM Geodetic DATE 8/30/2005 CHECKED BY Z.O.

SOIL PROFILE			SAMPLES							
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
258.1	Ground Surface								
0.0	0.17 m **Asphaltic Concrete**						258		
	GRANULAR FILL: Gravelly Sand brown, compact, damp		1	SS	20				
257.4							257		
0.7			2	SS	20				28 67 (5)
	GRANULAR FILL: Sand some gravel brown, compact, damp								
			3	SS	13				
256.0							256		
2.1			4	SS	7				
	FILL: Silty Clay occ. topsoil & somewhat organic soil inclusions trace gravel brown, some grey & darkish brown/grey zones firm to very stiff								
			5	SS	5		255		
			6	SS	4		254		
			7	SS	5		253		
			8	SS	9				
			9	SS	7		252		
			10	SS	13		251		
			11	SS	13		250		
			12	SS	9				
			13	SS	23		249		
			14	SS	16		248		
			15	SS	22		247		
			16	SS	20				
			17	SS	12		246		
245.4									
12.7	**SILTY CLAY** brown, stiff		18	SS	11		245		
			19	SS	9		244		

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 (%) — 20 40 60

Continued Next Page

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

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 5 2 OF 3 METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 5004.1; E 4841.8 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY J.Z.

DATUM Geodetic DATE 8/30/2005 CHECKED BY Z.O.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
243.1							243		
15.0 / 242.8	**SILTY CLAY**, grey, stiff								
15.3	occ. clayey silt & thin clay seams		20	TW	PH				
	occ. thin clayey silt seams						242		
	SILT grey, compact to loose wet, dilatant					▼*			
			21	SS	11		241		0 19 70 11
	sandy						240		
			22	SS	3**				**probably disturbed due to uplift
237.8							239		
			23	SS	6		238		0 28 63 9
20.3	End of Borehole.								
	*Water level at 16.5 m (not stabilized) and hole open to 17.1 m on completion.						237		
							236		
							235		
							234		
							233		
							232		
							231		
							230		
							229		
228.1									

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 (%) 20 40 60

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 5 3 OF 3 METRIC

GWP 647-90-01 LOCATION Frederickhouse River Bridge, Cochrane, Ontario - Coords: N 5004.1; E 4841.8 ORIGINATED BY G.I.

DIST HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY J.Z.

DATUM Geodetic DATE 8/30/2005 CHECKED BY Z.O.

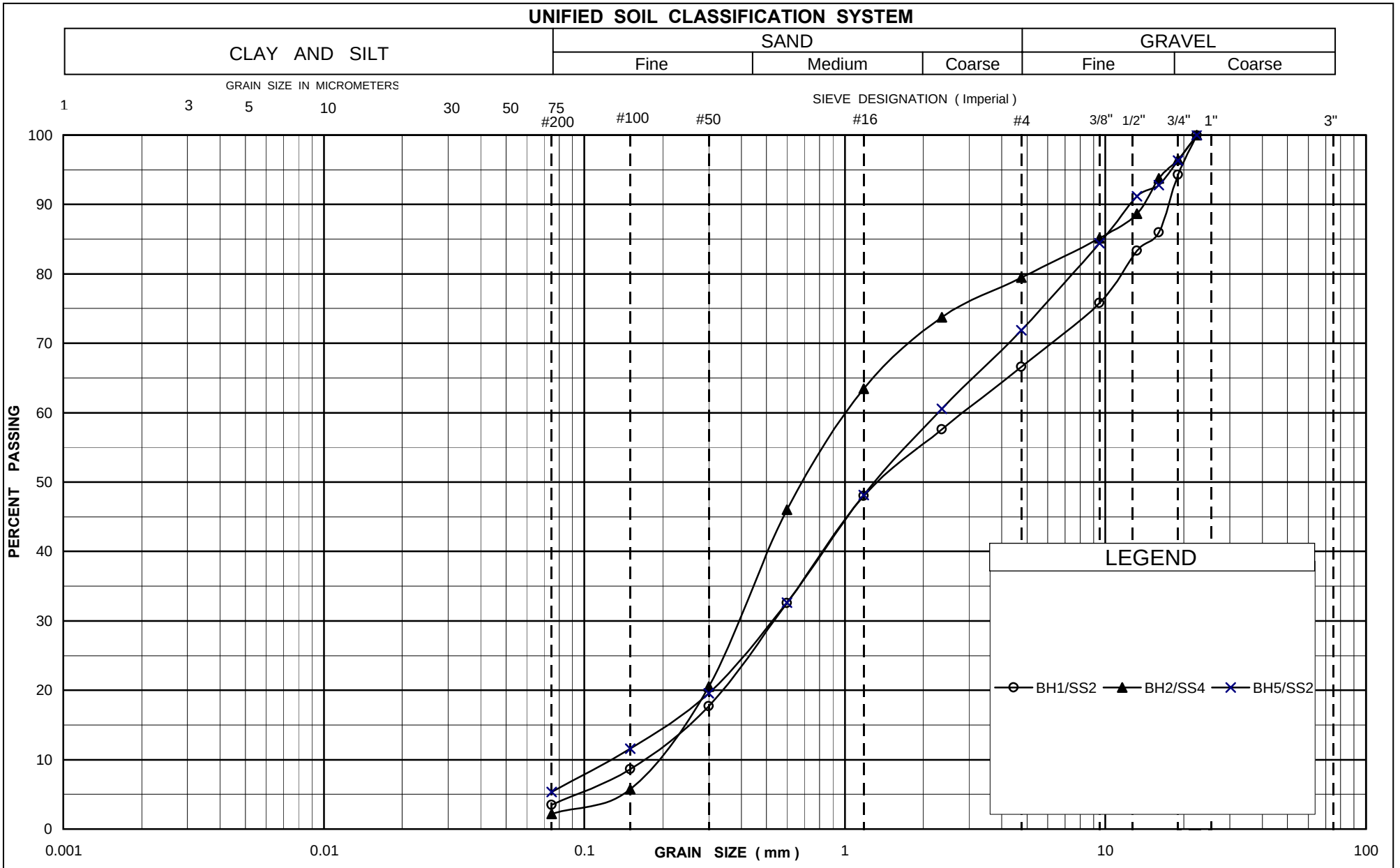
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
228.1 **30.0**	End of Dynamic Cone Penetration Test. Dynamic Cone Penetration Test (D.C.P.T.) performed from 20.3 m to 30.0 m.										

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

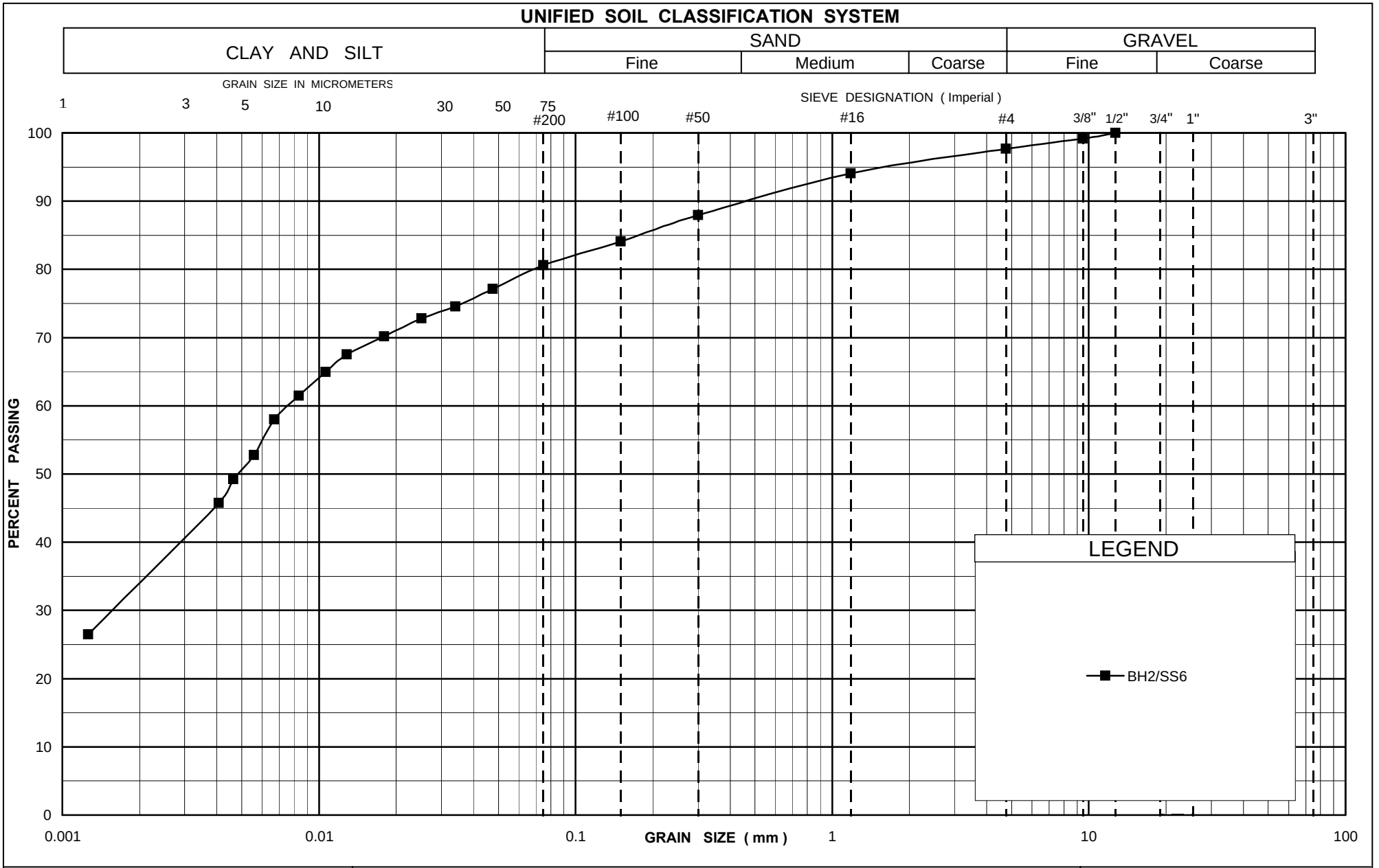
15 20 10 5 (%) STRAIN AT FAILURE

Appendix B

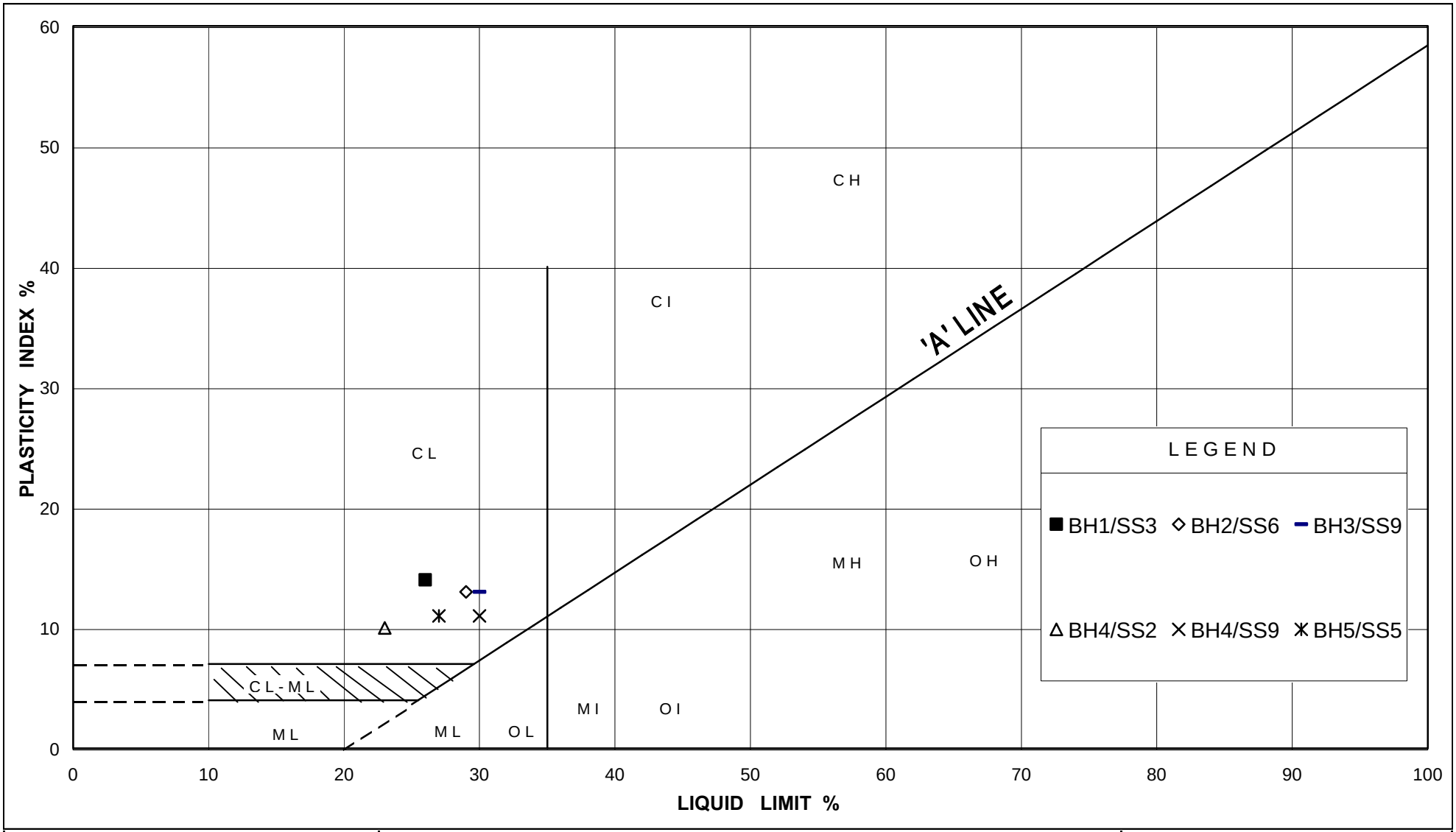
Laboratory Test Results



SHAHEEN & PEAKER LIMITED	GRAIN SIZE DISTRIBUTION GRANULAR FILL	FIGURE No. B-1 REF. No. SPT 1142A W.P. 647-90-01



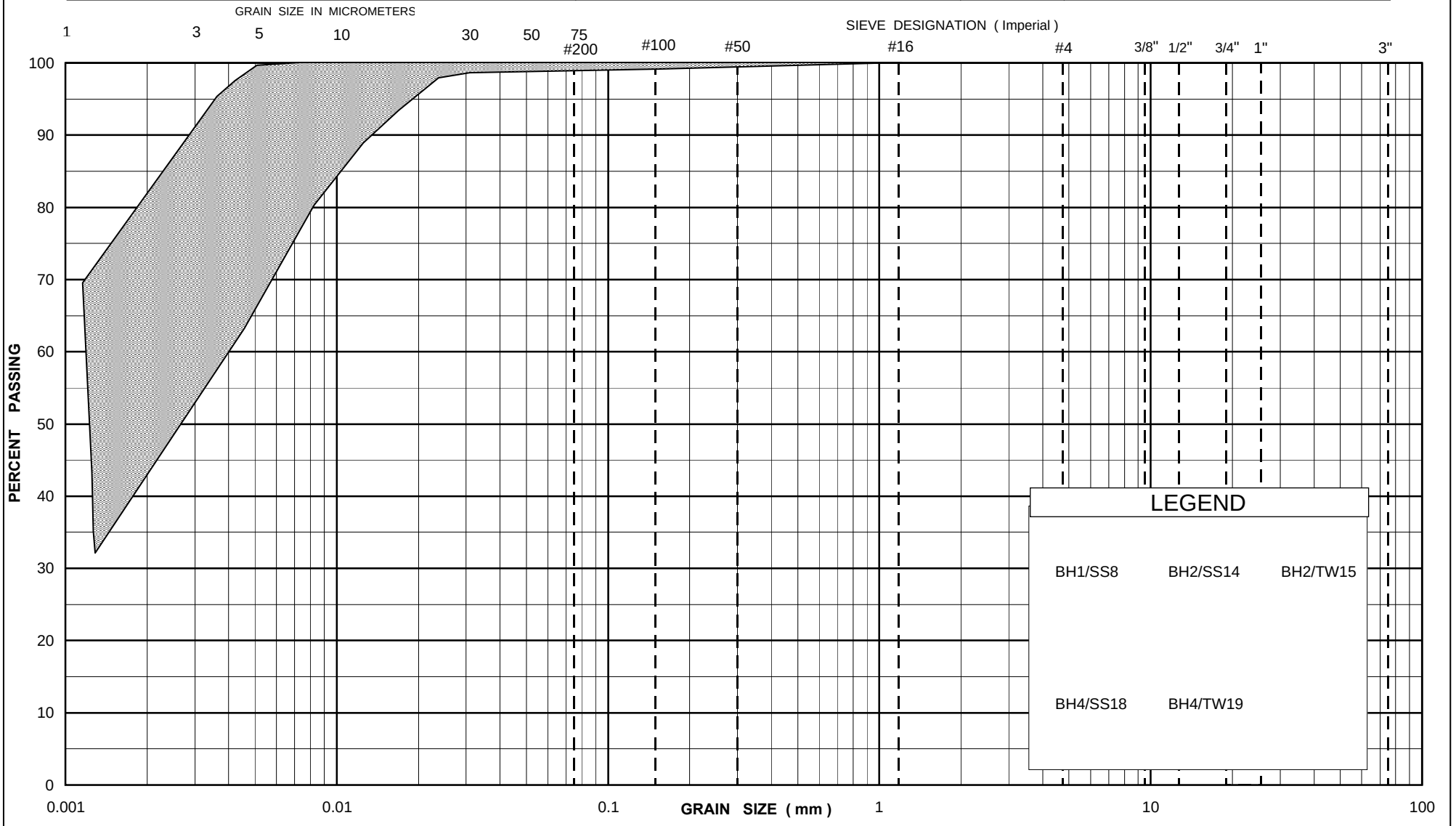
SHAHEEN & PEAKER LIMITED	GRAIN SIZE DISTRIBUTION SILTY CLAY FILL	FIGURE No. B-2 REF. No. SPT 1142A W.P. 647-90-01



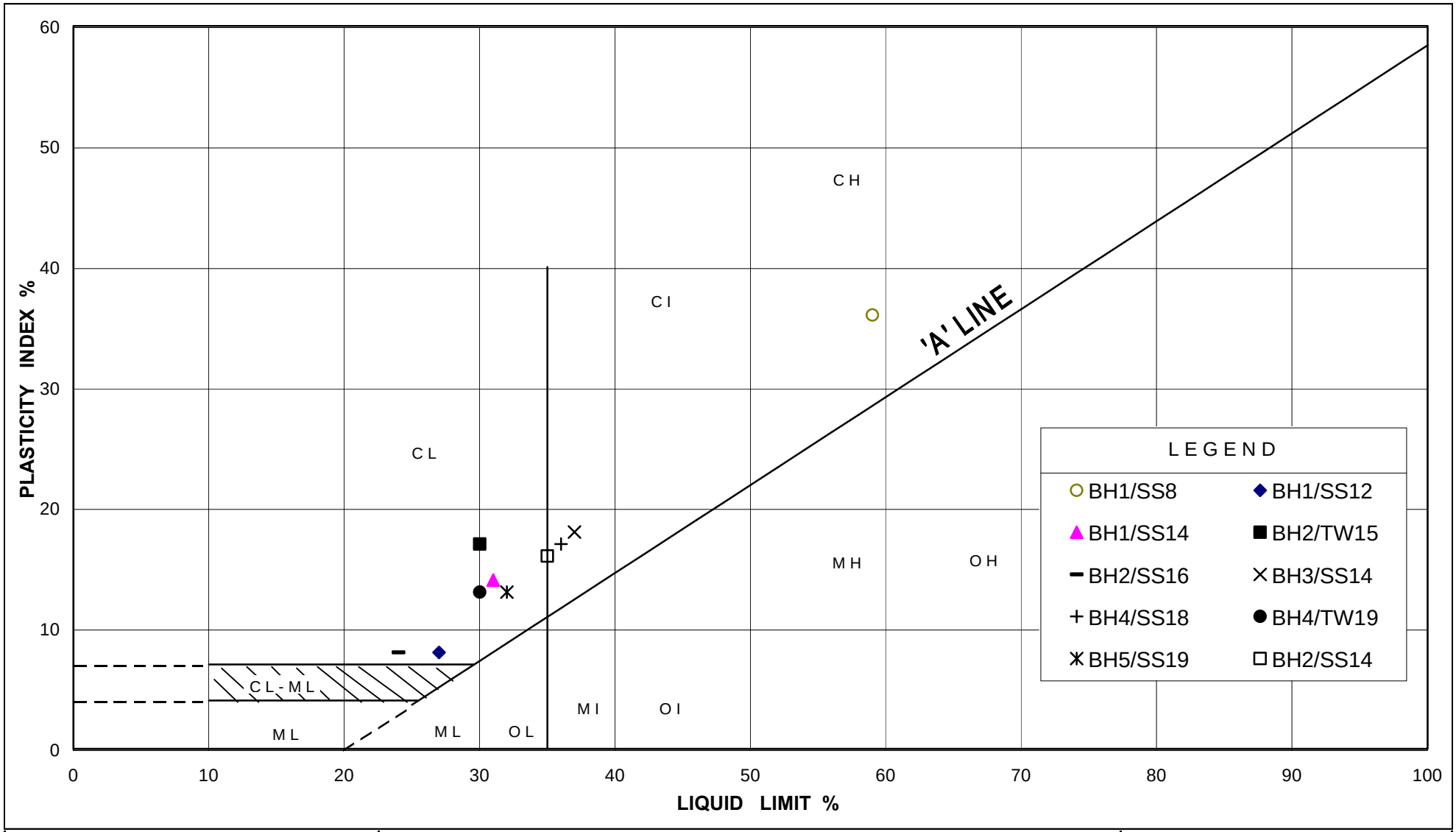
SHAHEEN & PEAKER LIMITED	PLASTICITY CHART SILTY CLAY FILL	FIG No B-3 REF No SPT 1142 A W.P. 647-90-01

UNIFIED SOIL CLASSIFICATION SYSTEM

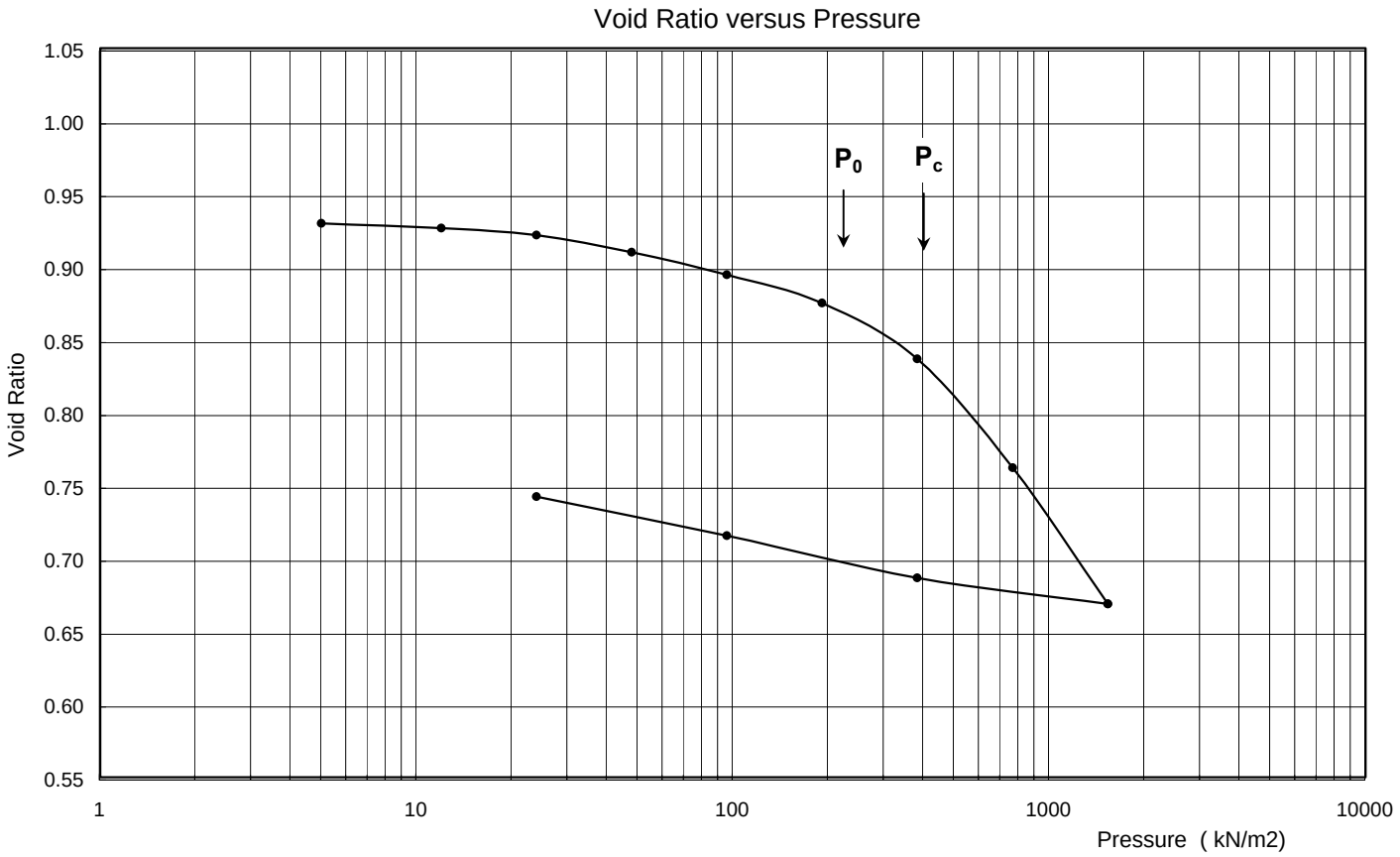
CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

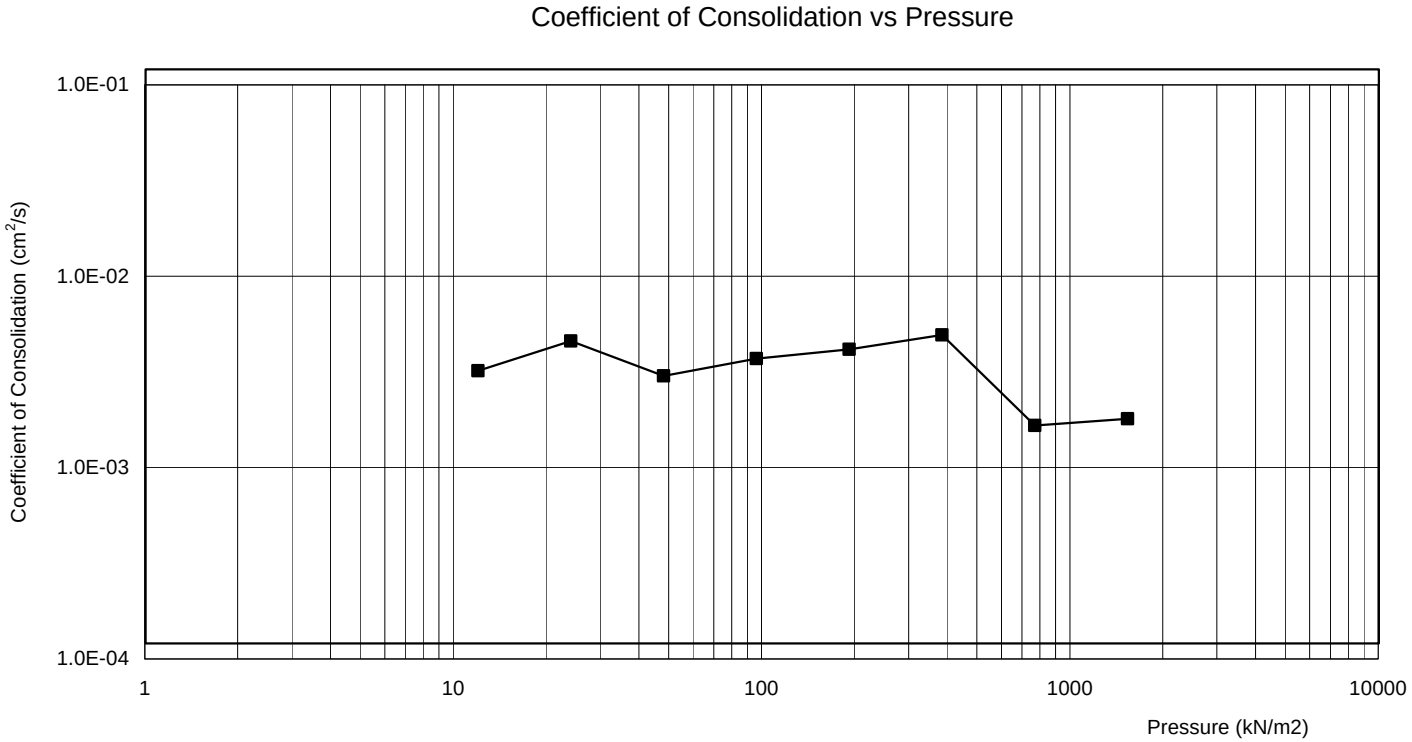


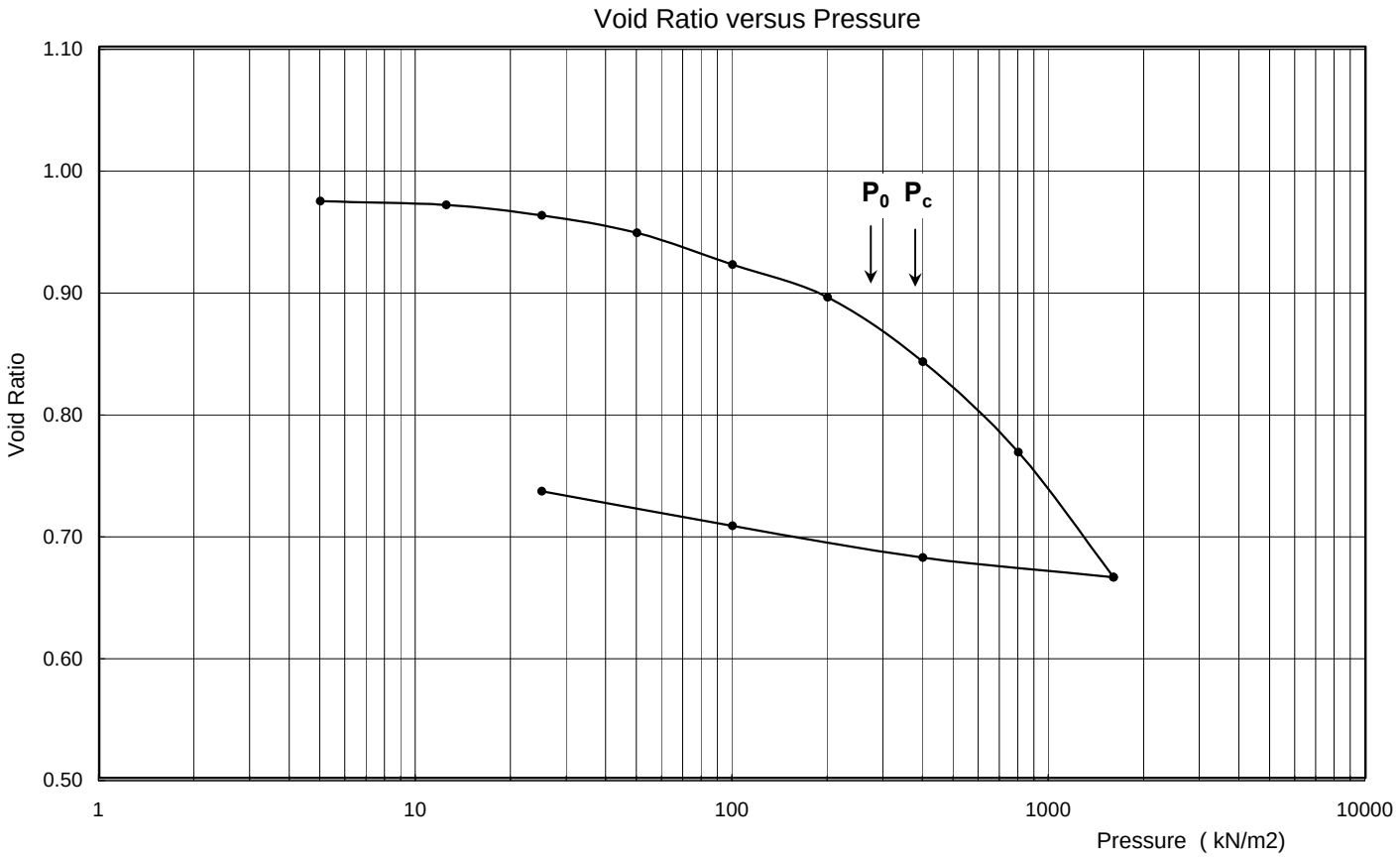
SHAHEEN & PEAKER LIMITED	GRAIN SIZE DISTRIBUTION SILTY CLAY	FIGURE No. B-4 REF. No. SPT 1142A W.P. 647-90-01

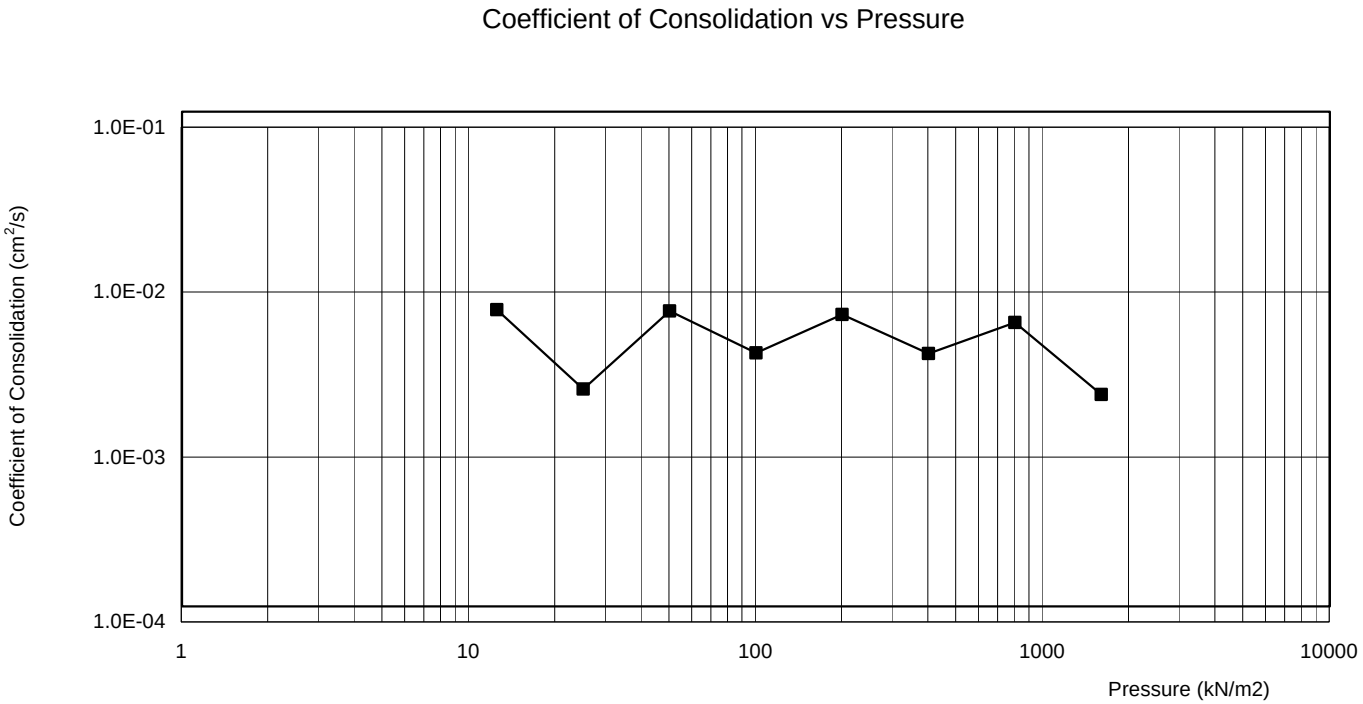


SHAHEEN & PEAKER LIMITED	PLASTICITY CHART SILTY CLAY	FIG No B-5 REF No SPT 1142 A W.P. 647-90-01


Void Ratio versus Pressure
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
Void Ratio
P_0
P_c
1
10
100
1000
10000
Pressure (kN/m2)

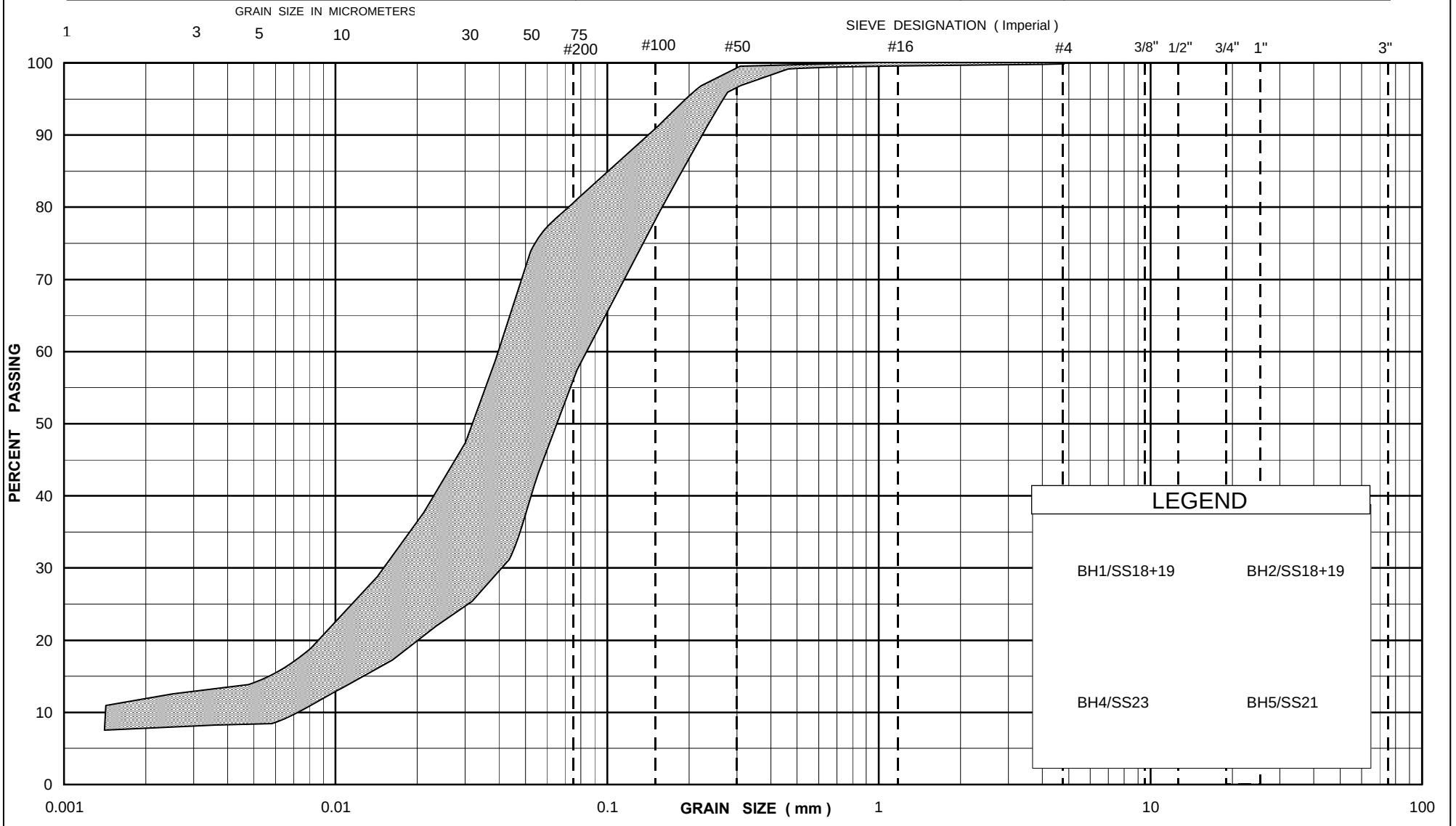

Coefficient of Consolidation vs Pressure
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Coefficient of Consolidation (cm^2/s)
1
10
100
1000
10000
Pressure (kN/m2)


Void Ratio versus Pressure
1.10
1.00
0.90
0.80
0.70
0.60
0.50
Void Ratio
P0
Pc
1
10
100
1000
10000
Pressure (kN/m2)

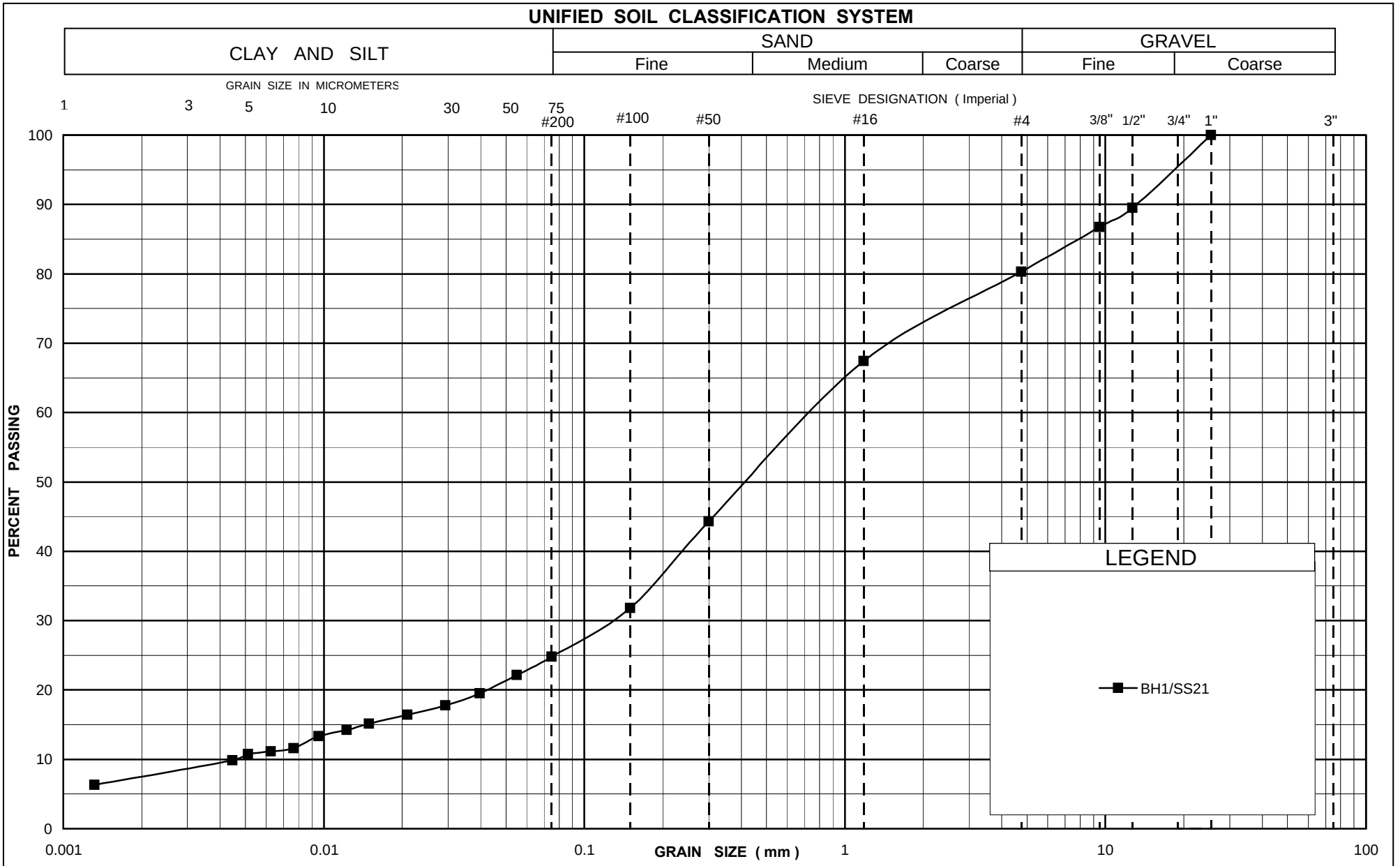

Coefficient of Consolidation vs Pressure
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Coefficient of Consolidation (cm2/s)
1
10
100
1000
10000
Pressure (kN/m2)

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



SHAHEEN & PEAKER LIMITED	GRAIN SIZE DISTRIBUTION SILT	FIGURE No. B-8 REF. No. SPT 1142A W.P. 647-90-01



SHAHEEN & PEAKER LIMITED	GRAIN SIZE DISTRIBUTION SILTY SAND TILL	FIGURE No. B-9 REF. No. SPT 1142A W.P. 647-90-01

Appendix C

Photographs of Bridge Site

Figure C-1 Crib Remains (probably representing old bridge remains), August 2005

Figure C-2 Boulders on the East Shore (next to the bridge) , August 2005

Figure C-3 South Elevation, July 2005

Figure C-4 North Elevation, July 2005

Appendix D

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						