

**SUPPLEMENTARY PRELIMINARY  
FOUNDATION INVESTIGATION REPORT  
FOR RE-ALIGNMENT OF  
HIGHWAY 11 AT ROBINS CREEK  
SUDBURY AREA  
AGREEMENT NO. 5004-E-0058  
(ASSIGNMENT #7)**

**Prepared For:**

**MINISTRY OF TRANSPORTATION  
NORTHEASTERN REGION GEOTECHNICAL SECTION**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1151G  
April 26, 2006**



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**SUPPLEMENTARY PRELIMINARY FOUNDATION INVESTIGATION REPORT  
FOR RE-ALIGNMENT OF HWY11 AT ROBINS CREEK, SUDBURY AREA.  
AGREEMENT NO. 5004-E-0058 (ASSIGNMENT #7)**

**1. INTRODUCTION**

Shaheen and Peaker (S&P) Limited, under Consultant Agreement No. 5004-E-0058 (Assignment No 7), was retained by MTO Northeastern Region to conduct a supplementary preliminary foundation investigation for the re-alignment of Highway 11 at Robins Creek (Site 1), Sudbury Area, Ontario.

The purpose of this investigation was to obtain additional information on the subsurface conditions at the site. A portion of this site (Site 1) was previously investigated as part of Assignment No. 3; however, swamp and/or standing water prevented access to some sections of the site. The current foundation investigation was carried out during winter condition (ice and/or frozen ground) to supplement the initial investigation.

The findings of the investigation are presented in this report, which should be read in conjunction with the previous Foundation Investigation Report for Site 1 of Assignment No. 3, dated December 12, 2005 (Reference No. SPT1151C).

**2. SITE DESCRIPTION AND PHYSIOGRAPHY**

The site is located about 9.9 km north of the intersection of Highway 11 and Highway 64, and is generally swampy between high ground areas. Drainage was provided by a concrete culvert under the embankment at Station 15+225. The height of the embankment at the east side of the highway in this section is typically less than 2 m south of the culvert, but increasing to about 6 to 8 m near Station 15+400. At this section, the highway is proposed to be re-aligned towards east to reduce the curvature of the road. Site photographs are presented in Appendix A of this report.

Throughout the project site, the topography is characterized by swampy areas in between rock outcrops. Through a series of rock cuts and relatively shallow embankments, the highway traverses undulating topographical features consisting of knolls of gneissic bedrock, separated by low swampy or wooded areas. The subsurface soils in the swampy areas were found to consist typically of peat or organic silt/clayey silt underlain by basal granular soil (i.e. primarily silt and sand) or glacial till which extends to bedrock or probable bedrock at the borehole locations.

The bedrock at the site consists mainly of gneiss of metasediment origin and metamorphic rocks with felsic intrusive, which were formed in the early to middle Precambrian Periods. At some locations, unsubdivided granitic and migmatitic rocks are also presented in this formation.

### **3. INVESTIGATION PROCEDURES**

The fieldwork for this investigation was performed on March 16 and 17, 2006. Four boreholes were drilled and they are numbered R3, R4, R5 and R6 to be consistent with the previous boreholes (R1 and R2) drilled at this site. The location plan of the boreholes is shown in Drawing No. 1-1

Due to unusually mild winter and to avoid the risk of inadequate support for a heavy track - mounted rig, the boreholes were advanced using a light tripod drill rig owned and operated by Landcore Drilling Limited. The drilling was carried out by wash boring method with steel casing.

The depths of the boreholes ranged from 0.6 to 9.8 m. The 0.6 m depth occurred in Boreholes R5 and R6 which were probably located on shallow bedrock below ice and water. 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. Where the consistency of the soil permitted in the cohesive deposits, the undrained shear strength of the soil was measured in-situ by means of field vane tests using an MTO-Type Field Vane.

At the completion of drilling, all boreholes drilled were grouted and sealed using a cement/bentonite mixture.

Water level observations in the open boreholes were made during drilling and at the completion of each borehole.

The borehole locations were established in the field by our engineering staff, referring from the chainage stations provided by MTO on site and the existing road centerline. The elevation of each borehole top of packed snow/ice was surveyed with respect to the top of existing road centerline at the corresponding chainage station. Geodetic elevations of the road centerline grades at each respective borehole station were provided to us by MTO and these elevations were used to determine the ground elevations at the borehole locations. Due to its variability, the elevation of the top of packed snow/ice should be considered approximate.

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

A laboratory testing programme, consisting of natural moisture content, Atterberg limits and grain-size analyses, was performed on selected soil samples. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets and also in Appendix C.

#### **4. SUBSURFACE CONDITIONS**

A total of 4 (four) boreholes were drilled at the site. Boreholes R3 and R4 were advanced to a depth of 9.8 m and 6.0 m below packed snow/ice respectively. Boreholes R5 and R6 were terminated at a depth of 0.6 m below packed snow/ice on possible bedrock. All the boreholes encountered packed snow/ice (0.3 to 0.4m thick) and water with depths ranging from 0.6 m to 1.5 m. Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix B. The individual strata are briefly described in the following paragraphs.

##### **4.1 ORGANIC SILT/PEAT**

Underlying the snow/ice and water in Borehole R3, an organic silt/peat deposit was encountered which extended to a depth of 3.2 below packed snow/ice surface. The peat deposit was found to contain some silty sand seams pockets, and traces of gravel. The measured natural moisture contents of the samples retrieved from this organic deposit range from 54 to 162%.

Based on the Standard Penetration test results of 1 to 2 blows/0.3 m, the consistency of these deposits is described as very soft. Owing to their organic nature, these soils can be expected to be highly compressible.

##### **4.2 SILTY CLAY**

Underlying the snow/ice and water in Borehole R4, a silty clay deposit with peat inclusions was encountered which extended to a depth of 2.3 below packed snow/ice surface. The measured natural moisture content of the sample retrieved from the silty clay with peat inclusion is 25%.

Based on the Standard Penetration test results of 2 blows/0.3 m, the consistency of this deposit is described as very soft.

##### **4.3 SILT TO CLAYEY SILT**

Underlying the organic silt/peat deposit in Borehole R3, a silt to clayey silt deposit was encountered at a depth of 3.2 m and extended to a depth of 4.6 m and at a depth of 5.3 m extending to 7.6 m below packed snow/ice surface. In Borehole R4, this deposit was

encountered at a depth of 2.3 m underlying silty clay with peat deposit and extended to a depth of 3.8 m. The clayey silt deposit was found to contain occasional silty clay seams with peat inclusions, traces of gravel, and occasional cobbles.

The results of grain-size analyses performed on selected samples are presented in Figures C1, C3, C6 and C7 in Appendix C. These indicate the following particle size distribution:

Gravel:	0-12%
Sand:	2-12%
Silt:	53-79%
Clay:	19-32%

Atterberg limits tests carried out in the laboratory on selected samples from this deposit yielded the following index values:

Liquid Limit:	21-29%
Plastic Limit:	12-20%
Plasticity Index:	6-12%

As presented in Figures C-11 and C-12 in Appendix C, these values are characteristic of clayey soils of low plasticity. The measured natural moisture contents of the silt to clayey silt deposit range from 14 to 31%.

In Borehole R3, Standard Penetration tests results gave N-values of 1 to 11 blows/0.3 m. A field vane test yielded undrained shear strength value of 68 kPa at a depth of 4.6 m. Based on these values, the consistency of the silt to clayey silt deposit in Borehole R3 can be described as very soft to stiff. In Borehole R4, Standard Penetration tests results yielded N-values of 2 and 6 blows/0.3 m, and based on this, the silt to clayey silt deposit can be described as very soft to firm at this location.

#### 4.4 SANDY SILT

Underlying the clayey silt deposit in Boreholes R3 and R4, both boreholes encountered a sandy silt deposit at depths of 4.6 m in Borehole R3 and of 3.8 m in Borehole R4.

This sandy silt deposit was found to extend to a depth of 5.3 m and 6.0 m (wash boring refusal) at Boreholes R3 and R4, respectively. Occasional clay seams were also recorded in this deposit. Based on the Standard Penetration tests results with N-values of 9 to 23 blows/0.3 m, the relative density of the sandy silt deposit can be described as loose to compact.

The results of grain-size analyses performed on selected samples are presented in Figures C2, C8, C9 and C10 in Appendix C. These indicate the following particle size distribution.

Gravel:	0-18%
Sand:	12-25%
Silt:	48-72%
Clay:	9-17%

The measured natural moisture contents of sandy silt deposit ranged from 14 to 21%.

#### 4.5 SANDY SILT TO SILTY SAND

Underlying the silt to clayey silt deposit in Borehole R3, a relatively coarser sandy silt to silty sand deposit was encountered at a depth of 7.6 m.

The sandy silt to silty sand deposit was found to extend to the terminated depth of 9.8 m, where refusal by wash boring was encountered. Based on the Standard Penetration tests results with N-values of 13 and 15 blows/0.3 m, the relative density of the sandy silt to silty sand deposit can be described as compact.

The results of grain-size analyses performed on selected samples are presented in Figures C4 and C5 in Appendix C. These indicate the following particle size distribution.

Gravel:	0%
Sand:	50-65%
Silt :	22-36%
Clay:	13-14 %

The measured natural moisture contents of silty sand/sandy silt deposit ranged from 19 to 20% indicating moist to wet condition.

#### 4.6 INFERRED BEDROCK

Below depths of 9.8 m in Borehole R3 and 6.0 m in Borehole R4, below top of packed snow/ice, wash boring refusal was encountered probably on the surface of the bedrock. At and in the vicinity of Boreholes R5 and R6, probably shallow bedrock was contacted at a depth of about 0.6 m below packed snow/ice. The bedrock was not proven by rock coring as this was not within the scope of work. The bedrock in this area is known to consist of gneiss. It should be noted that to the west of Boreholes R5 and R6 and on the left side of Highway 11, rock cuts are present.

#### 4.7 GROUNDWATER CONDITIONS

Groundwater levels in the boreholes were observed in the open boreholes during the drilling and at the completion of each borehole. The recorded values are detailed on the individual Record of Borehole Sheets presented in Appendix B.

Upon completion, water was observed at the ice surface in the boreholes as controlled by the water level in the swamp. It should be pointed out that the water level (elevation) is subject to seasonal fluctuations and in response to major weather events.

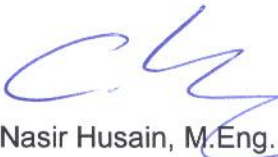
#### 5. CLOSURE

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at specific boreholes and can only be extrapolated to an undefined limited area around the locations. The extent of the limited area depends on the variability of the soil and ground water conditions as influenced by geological process, as well as the history of the site reflecting natural condition, construction activities, and site use.

We trust the above information meets with your present requirements. Should you have any question or require further information, please do not hesitate to contact us at your convenience.

Yours very truly,

**SHAHEEN & PEAKER LIMITED**

*for*  Nasir Husain, M.Eng.



 Ramon Miranda, P.Eng.  
Manager, Transportation Division



# Drawings

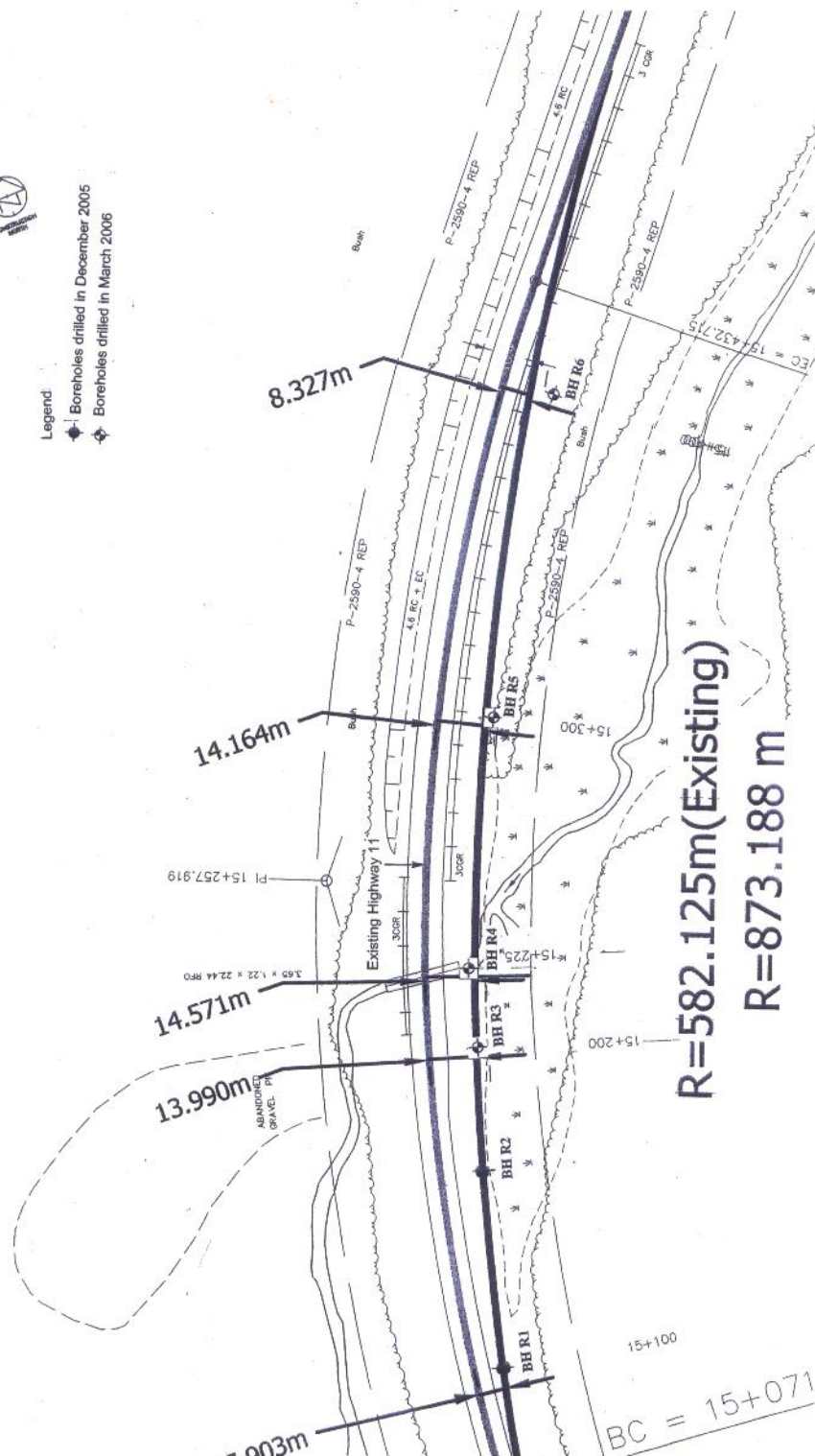
# METRIC

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



## Legend

- ◆ Boreholes drilled in December 2005
- ◆ Boreholes drilled in March 2006



NO.	DESCRIPTION	DATE

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SUPPLEMENTARY PRELIMINARY  
 FOUNDATION INVESTIGATION  
 FOR RE-ALIGNMENT OF HWY 11  
 AT ROBINS CREEK  
 SUDBURY AREA, ONTARIO

TITLE:	BOREHOLE LOCATION PLAN
SCALE:	DATE: April 2006
DRAWN BY:	PROJECT NO.: SPT 1151G
APPROVED BY:	DRAWING NO.: 1-1

# Appendix A

## Site Photographs



Photograph A-1: Sta. 15+300 Looking Southeast





Photograph A-2: around Sta. 15+225 Looking North

## Appendix B

# Records of Boreholes for Site 1 (Boreholes R3, R4, R5 and R6)

SPT 1151G

# RECORD OF BOREHOLE No R3

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Robins Creek, Station 15+200; 14 m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Wash boring/Tripod COMPILED BY JZ  
 DATUM Geodetic DATE 3/16/2006 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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 x LAB VANE		W P	W	W L		
291.2 0.0	Ground Surface							20 40 60 80 100		20 40 60				
	<b>SNOW &amp; ICE (0.4 m) and WATER</b>						291							
289.7 1.5	<b>ORGANIC SILT and PEAT</b> some rootlets, trace gravel dark brown, moist to wet, very soft with silty sand seams		1	SS	2		290							
			2	SS	1		289						91	
288.0 3.2	<b>CLAYEY SILT</b> with peat inclusions, occ. silty clay seams dark brown to grey, wet very soft stiff		3	SS	1		288						162	0 2 79 19
			4	SS	11		287							
286.6 4.6	<b>SANDY SILT</b> some gravel, trace clay grey, wet, compact		5	SS	15		286							18 25 48 9
285.9 5.3	<b>SILT to CLAYEY SILT</b> trace gravel, occ. cobbles grey, wet stiff very stiff		6	SS	9		285							12 4 59 25
			7	SS	18		284							
283.6 7.6	<b>SANDY SILT to SILTY SAND</b> trace to occasional gravel, trace clay grey, wet, compact		8	SS	13		283							0 50 36 14
			9	SS	15		282							0 65 22 13
281.4 9.8	End of borehole. Wash boring refusal at 9.8 m. Water level at surface (not stabilized) and hole open to 6.7 m on completion.		10	SS	100/5									

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

SPT 1151G

# RECORD OF BOREHOLE No R4

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Robins Creek, Station 15+223; 12 m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Wash boring/Tripod COMPILED BY JZ  
 DATUM Geodetic DATE 3/17/2006 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
291.2 0.0	Ground Surface													GR SA SI CL
289.8 1.4	SNOW & ICE (0.4 m) and WATER						291							
288.9 2.3	SILT CLAY with peat inclusions grey, wet, very soft		1	SS	2		290							
287.4 3.8	SILT to CLAYEY SILT occ. silty clay seams & peat inclusions trace gravel grey, wet		2	SS	2		289							0 2 74 24
285.2 6.0	SANDY SILT with silt layer occ. clay seams, grey, wet		3	SS	6		288							9 6 53 32
			4	SS	9		287							0 21 63 16
			5	SS	9		286							0 12 72 17
			6	SS	23									0 25 58 17
			7	SS	100/0									
	End of borehole. Wash boring refusal at 5.9 m. Water level at surface (not stabilized) and hole open to full depth on completion.													



SPT 1151G

RECORD OF BOREHOLE No R5

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Robins Creek, Station 15+300; 15 m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Wash boring/Tripod COMPILED BY JZ  
 DATUM Geodetic DATE 3/16/2006 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  W <sub>P</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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							
291.5	Ground Surface							20 40 60 80 100							
0.0	<b>SNOW &amp; ICE (0.3 m) and WATER</b>														
290.9							291								
0.6	Rod refusal (probably bedrock).  Move 1.5 m Rt. Rod refusal at 0.6 m.  Move 2.5 m south to 15+297.5. Rod refusal at 0.5 m.  Move 10 m north to 15+310; 15.5 m Rt C/L. Rod refusal at 0.75 m.														

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1151G

# RECORD OF BOREHOLE No R6


1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Robins Creek, Station 15+400; 13 m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Wash boring/Tripod COMPILED BY JZ  
 DATUM Geodetic DATE 3/16/2006 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
291.5	Ground Surface																
0.0	<b>SNOW &amp; ICE (0.3 m) and WATER</b>																
290.9																	
0.6	Rod refusal (probably bedrock).  Move 1.5 m Rt. Rod refusal at 0.6 m.  Move 2 m south to 15+398. Rod refusal at 0.6 m.  Move 2 m north to 15+402; 13 m Rt C/L. Rod refusal at 0.6 m.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity


 20  
15  
10  
(%) STRAIN AT FAILURE

## Appendix C

### Laboratory Test Results for Site 1 (Boreholes R3, R4, R5 and R6)

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

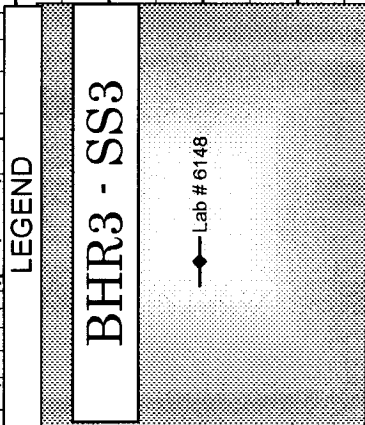


FIGURE No.:	C-1
PROJECT No:	SPT - 1151G
Date:	April 10, 2006

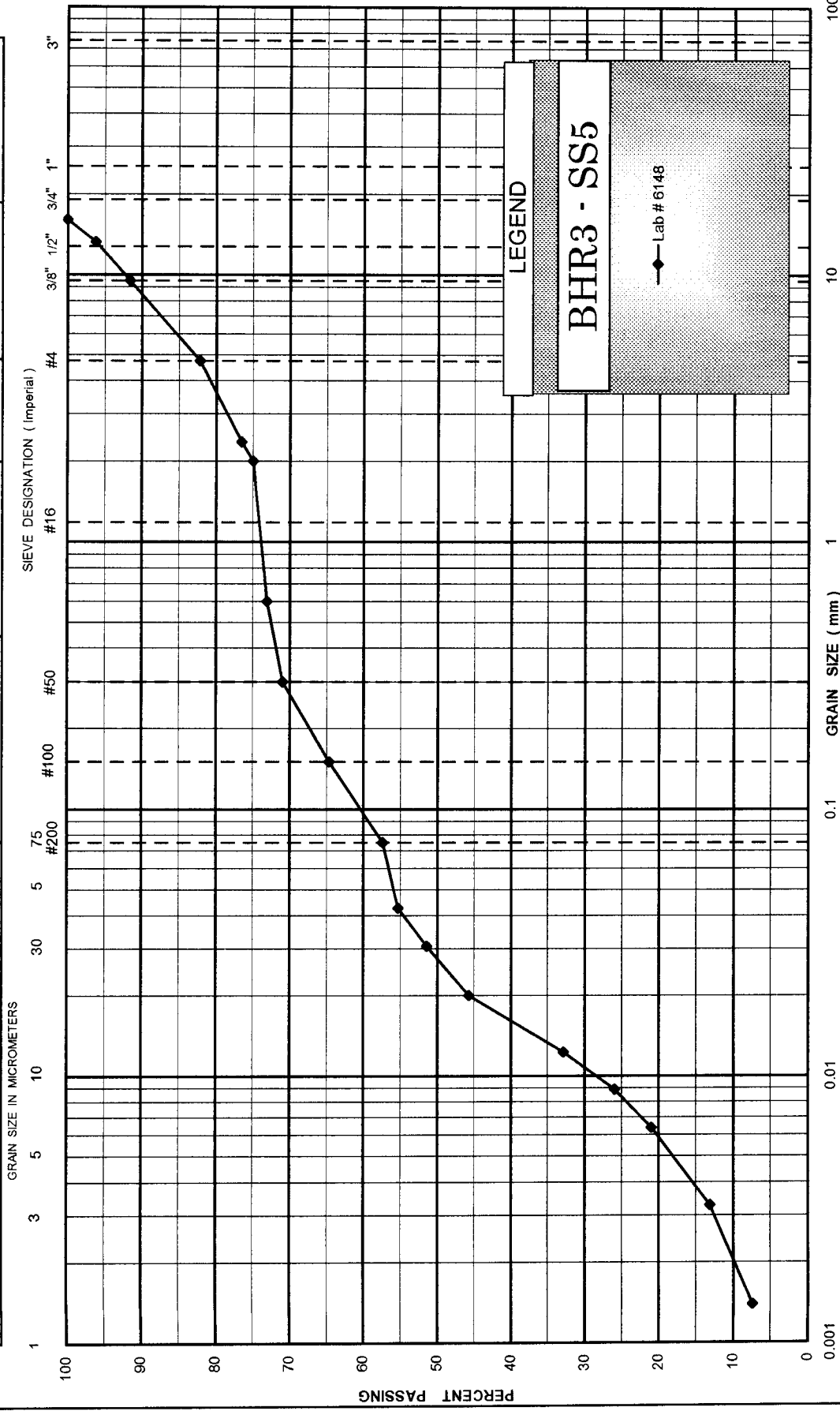
## GRAIN SIZE DISTRIBUTION

### CLAYEY SILT

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# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	



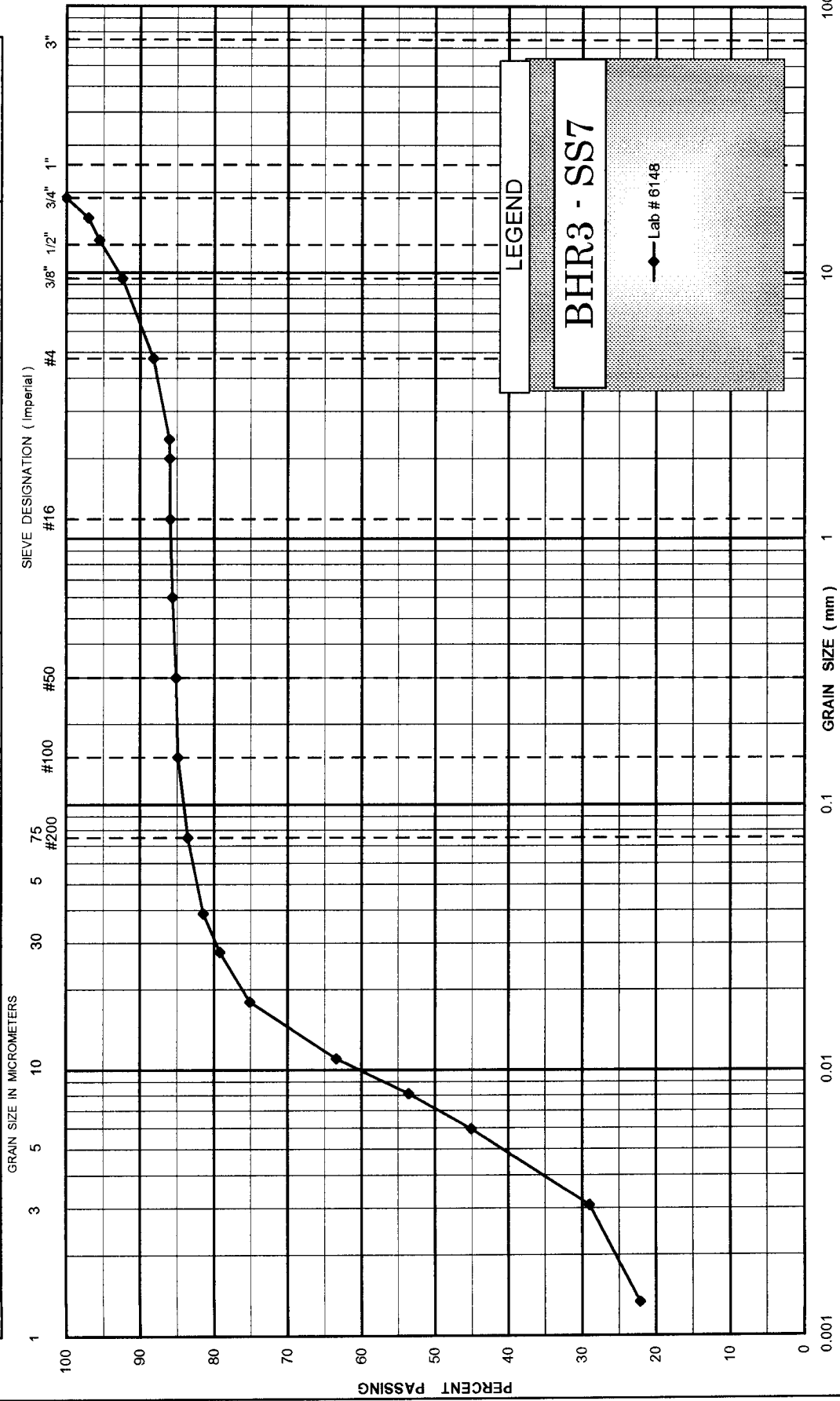
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION  
Sandy Silt, some gravel, trace clay

FIGURE No.: C-2  
PROJECT No: SPT - 1151G  
Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



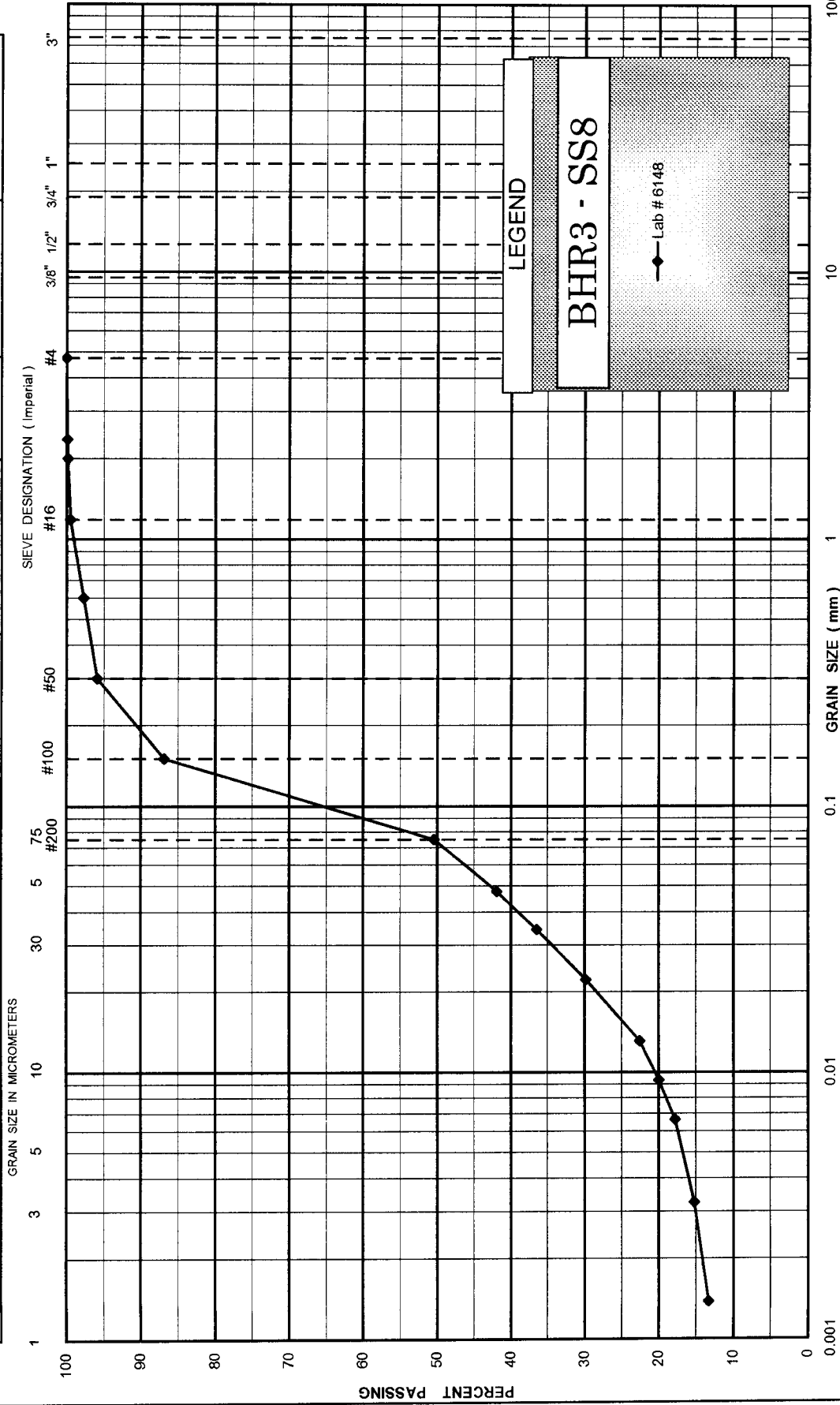
**GRAIN SIZE DISTRIBUTION**  
Clayey Silt trace gravel, some Sand

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FIGURE No.: C-3  
PROJECT No: SPT - 1151G  
Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	Coarse



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GRAIN SIZE DISTRIBUTION  
Sandy Silt to Silty Sand, trace clay

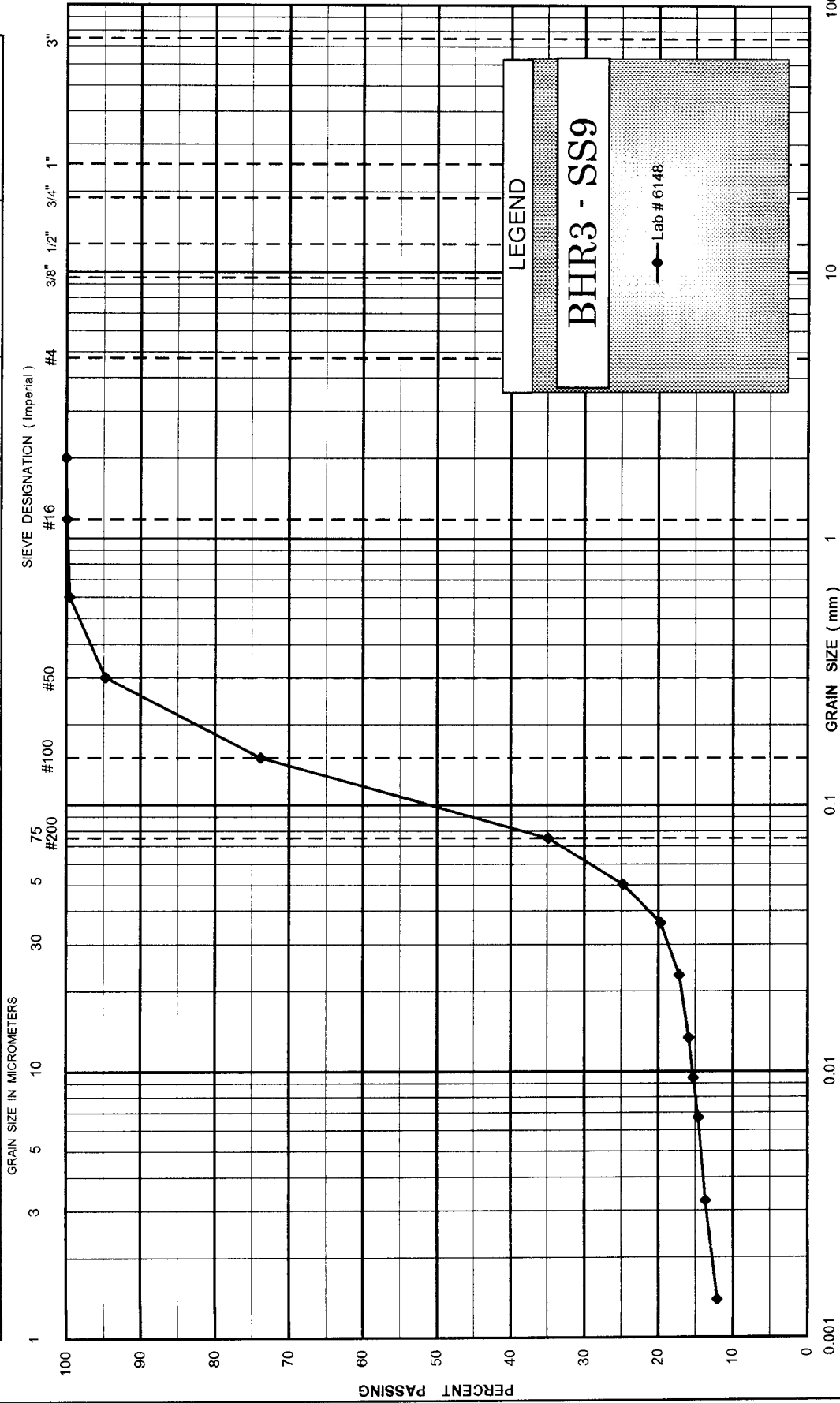
FIGURE No.: C-4

PROJECT No: SPT - 1151G

Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



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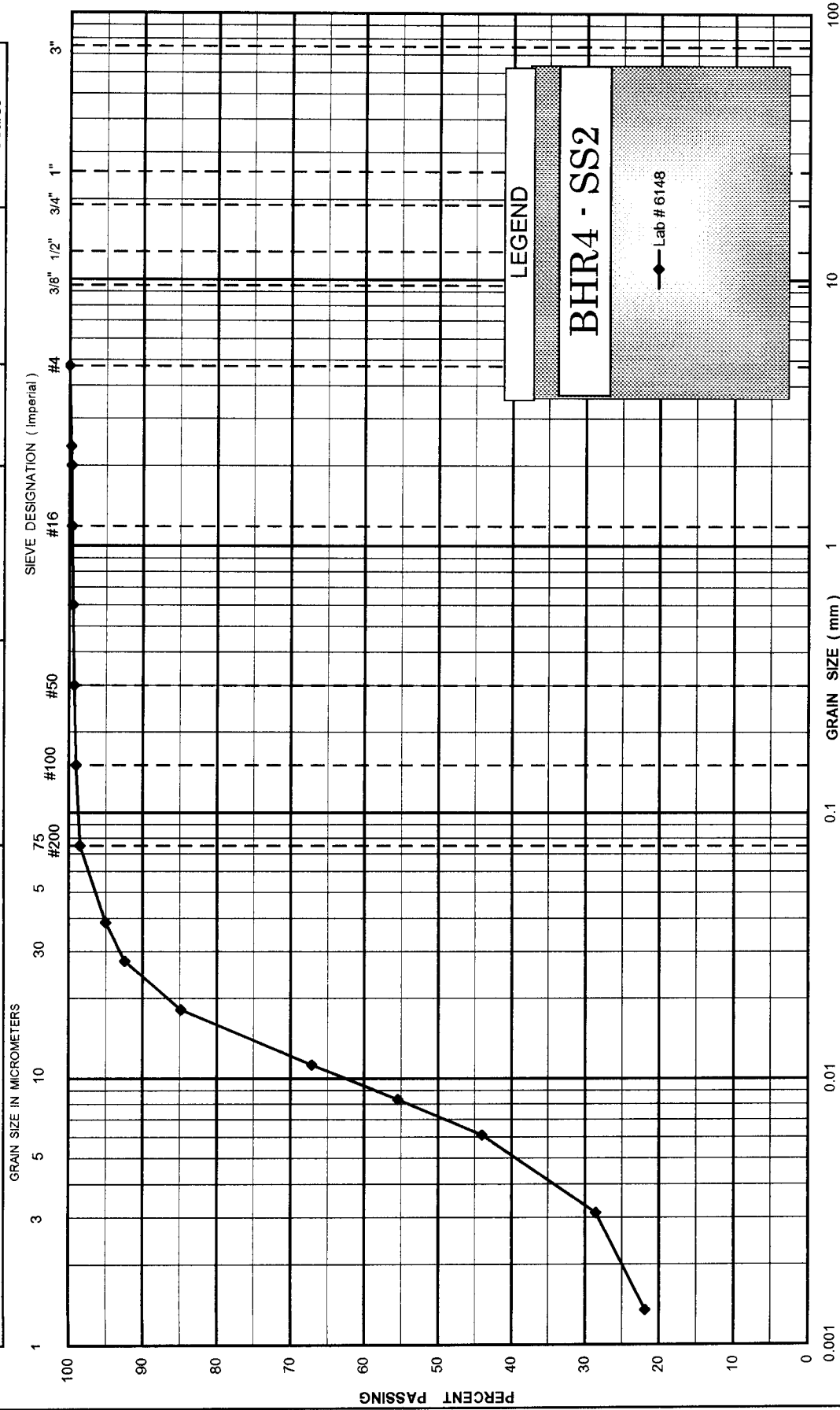
GRAIN SIZE DISTRIBUTION  
Silty Sand, trace clay

FIGURE No.: C-5  
PROJECT No: SPT - 1151G  
Date: April 10, 2006



# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



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GRAIN SIZE DISTRIBUTION  
Clayey Silt

FIGURE No.: C-6

PROJECT No: SPT - 1151G

Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	

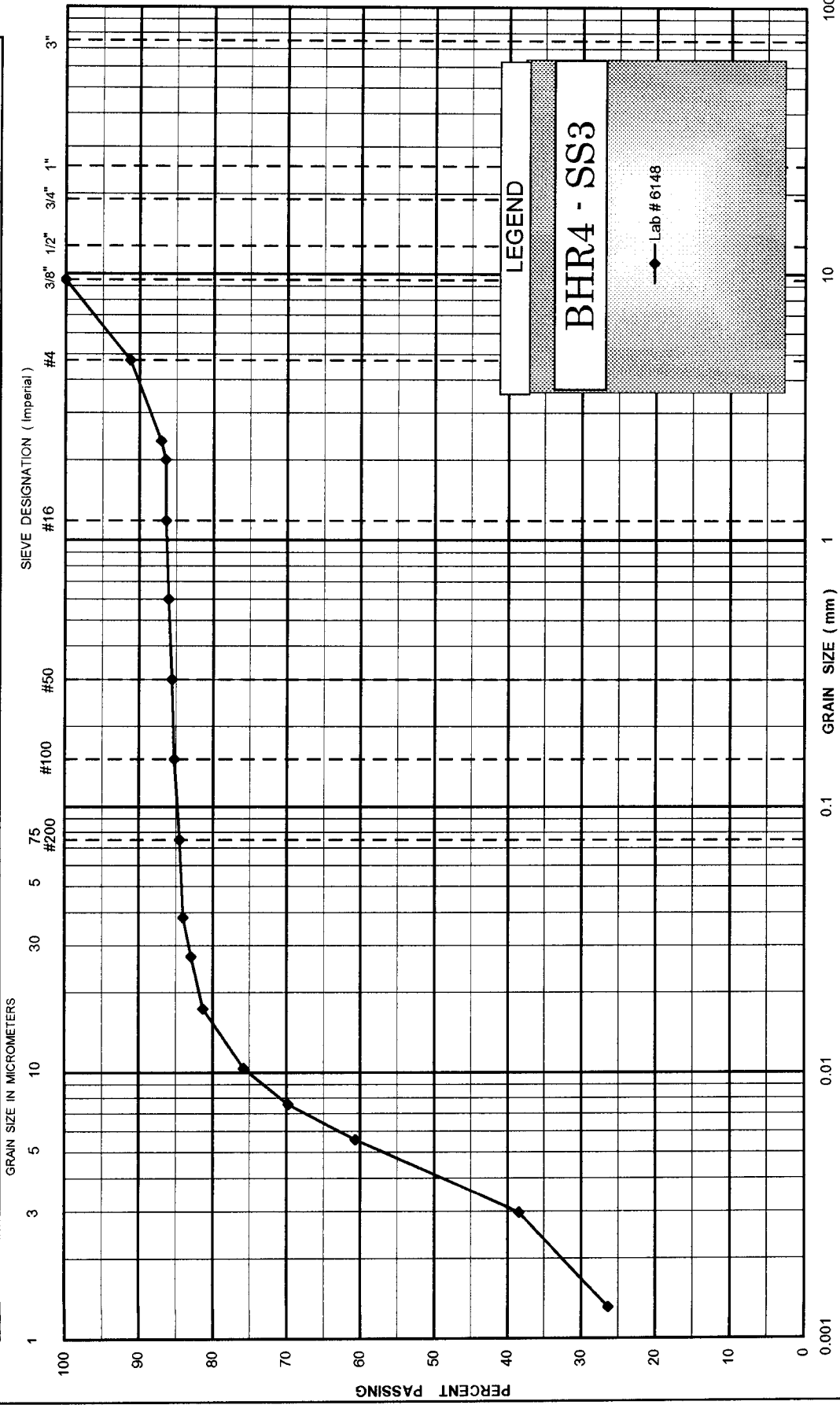


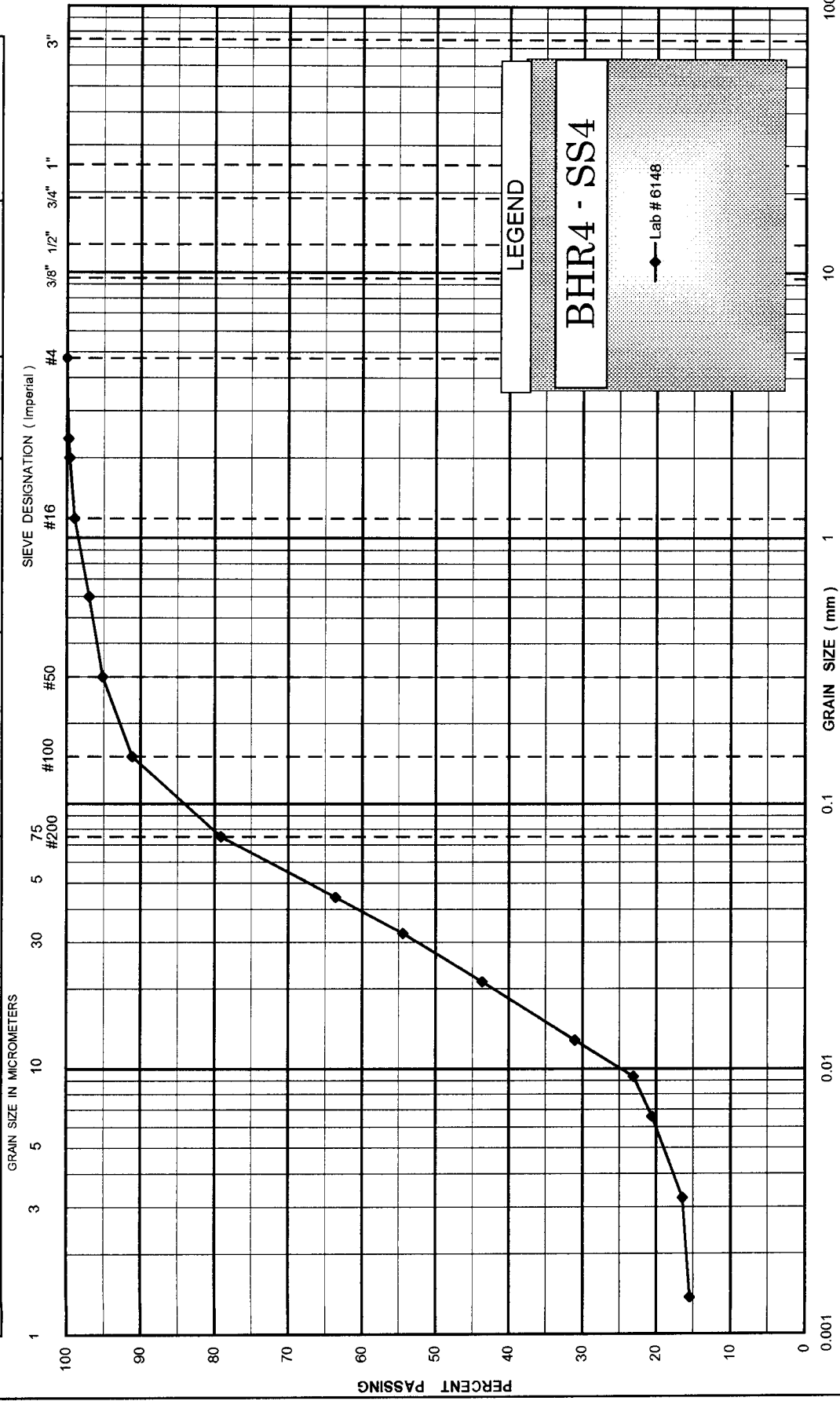
FIGURE No.: C-7  
PROJECT No: SPT - 1151G  
Date: April 10, 2006

GRAIN SIZE DISTRIBUTION  
Clayey Silt trace sand and gravel

SHAHEEN & PEAKER LIMITED

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



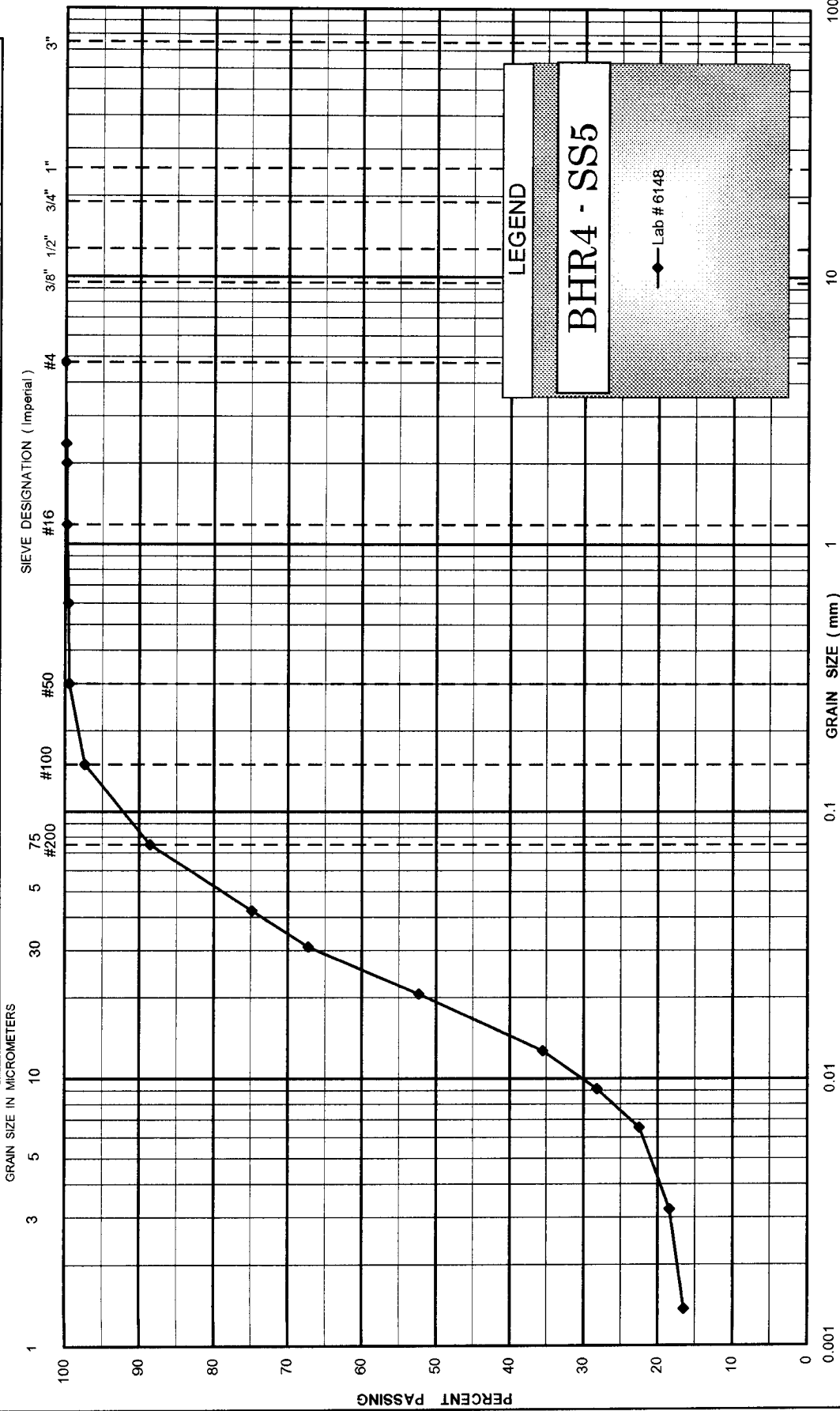
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION  
Sandy Silt some clay

FIGURE No.: C-8  
PROJECT No: SPT - 1151G  
Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



## GRAIN SIZE DISTRIBUTION

Silt some clay trace sand

SHAHEEN & PEAKER LIMITED

FIGURE No.: C-9

PROJECT No: SPT - 1151G

Date: April 10, 2006

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	

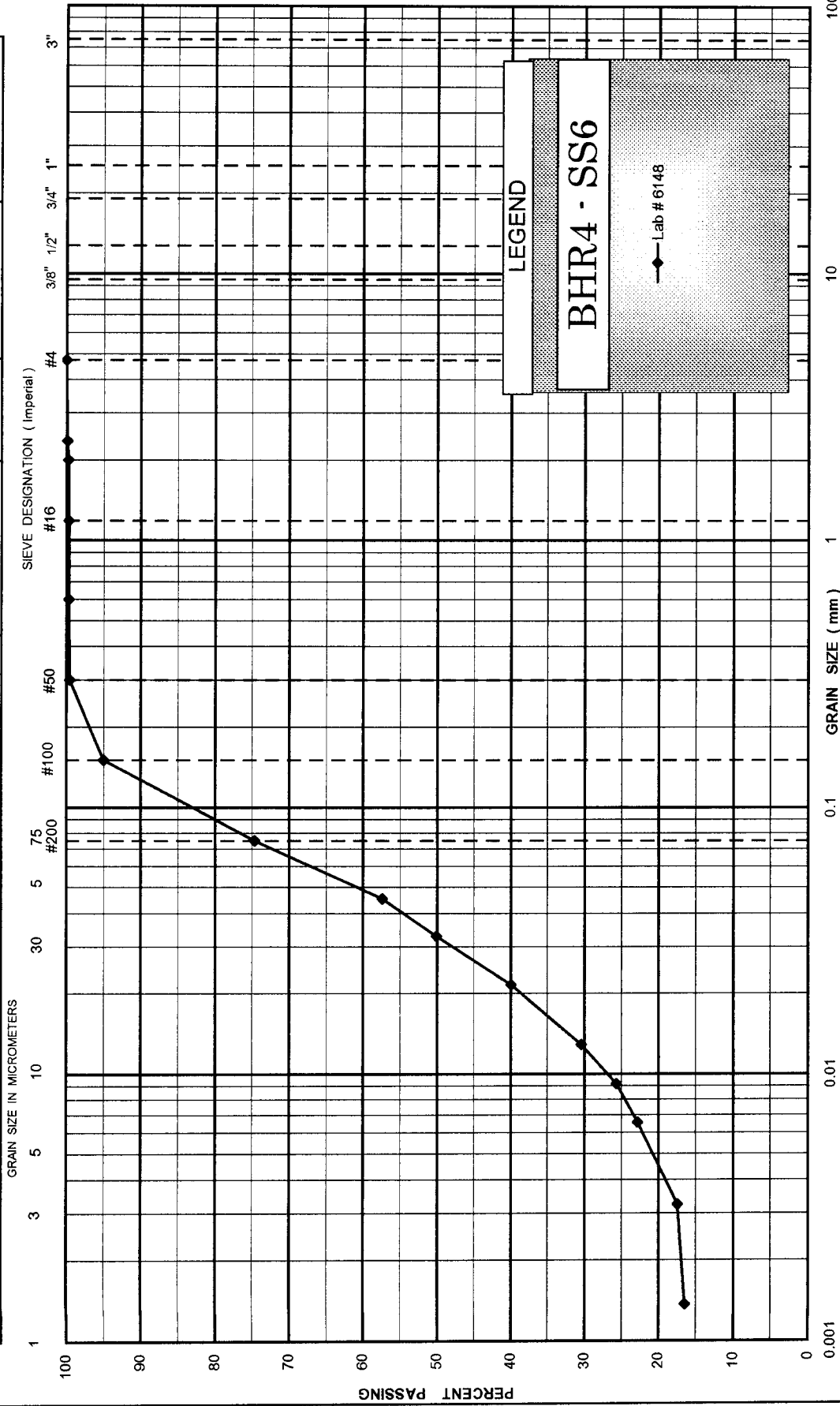
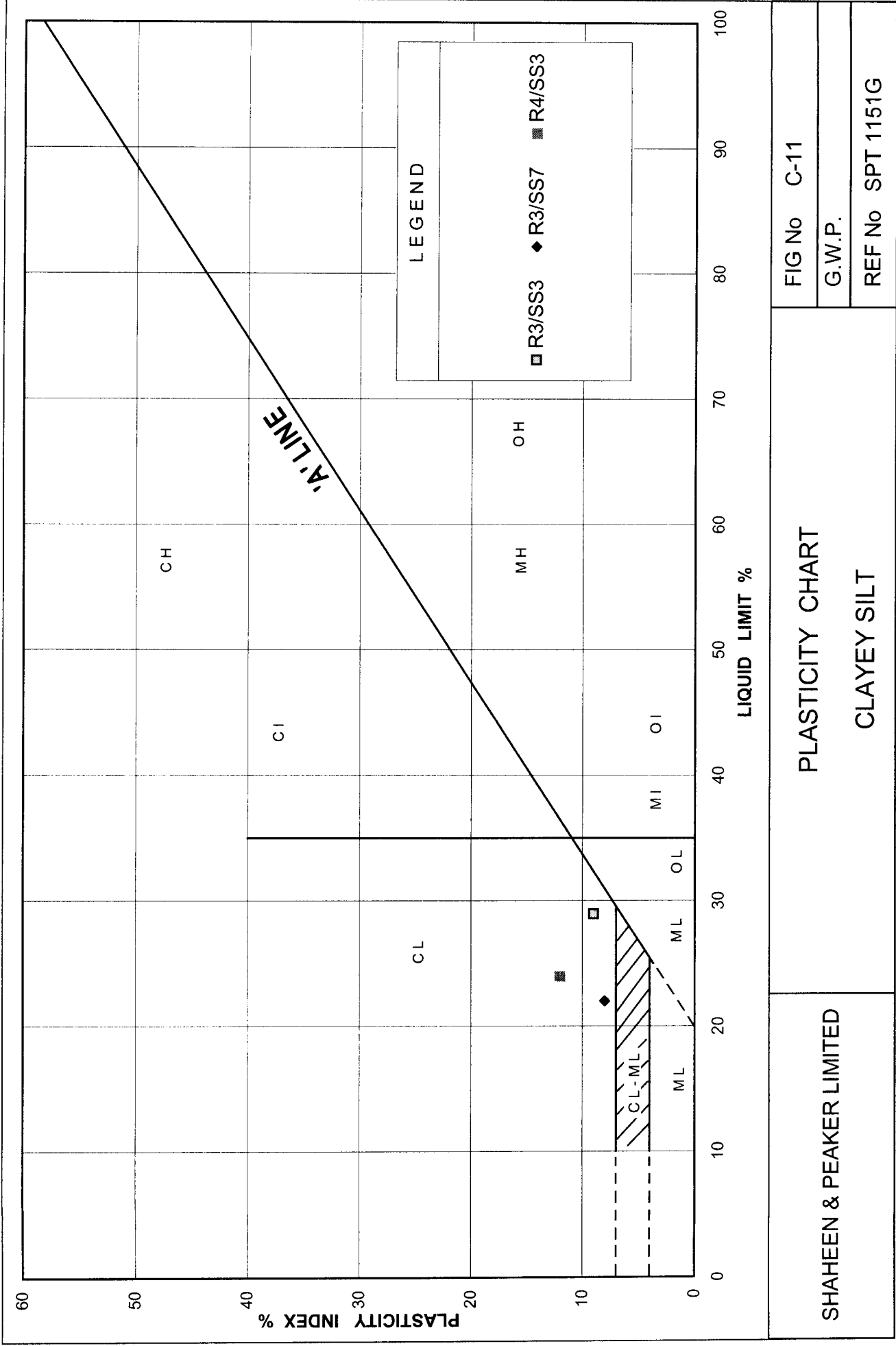
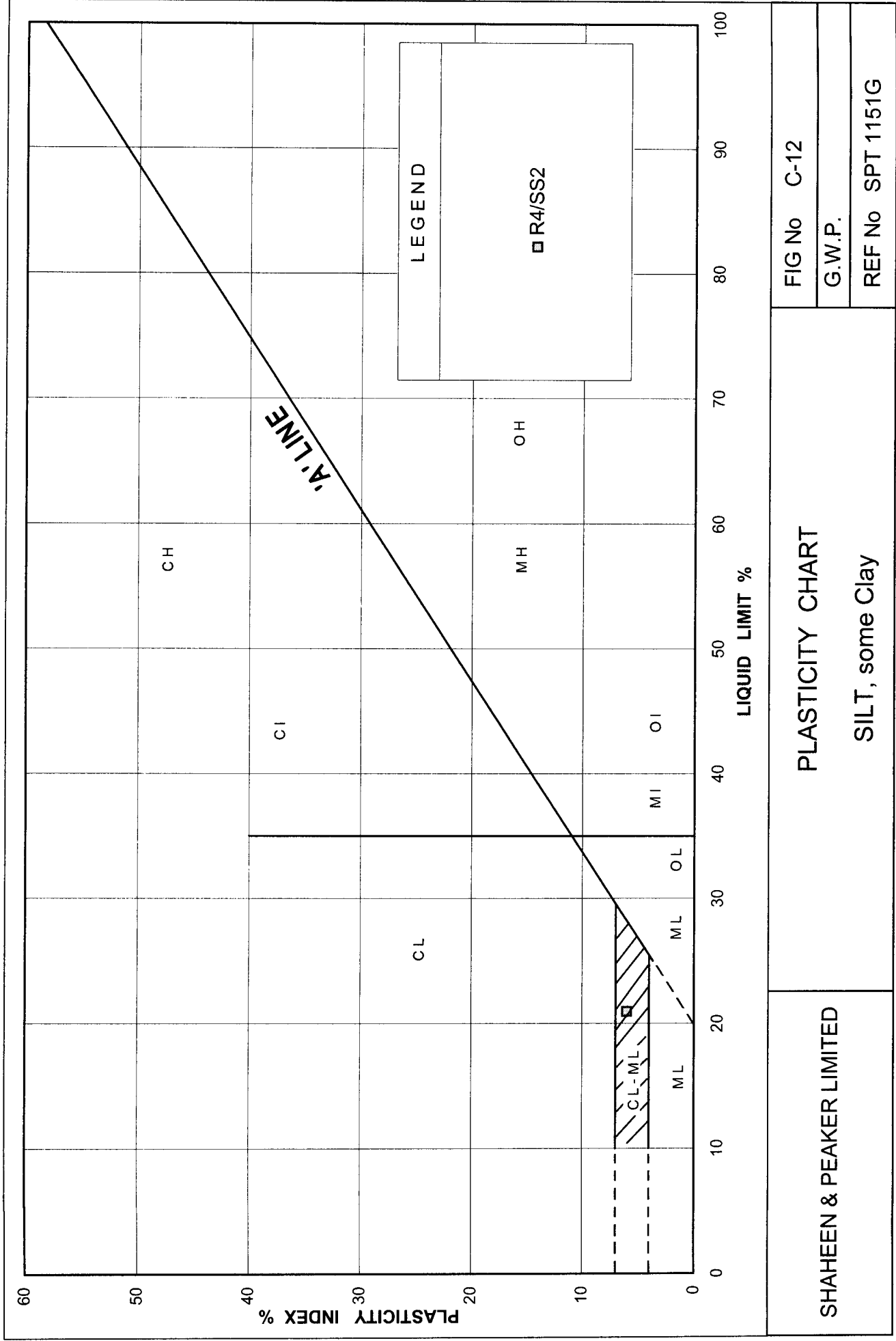


FIGURE No.: C-10  
PROJECT No: SPT - 1151G  
Date: April 10, 2006

**GRAIN SIZE DISTRIBUTION**  
Sandy Silt some clay

SHAHEEN & PEAKER LIMITED





## 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 COMPOSITION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

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

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

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

**JOINT AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICALL PROPERTIES OF SOIL

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

## PHYSICAL PROPERTIES OF SOIL

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