

**FOUNDATION INVESTIGATION REPORT  
PRELIMINARY FIELD INVESTIGATION  
FOR RE-ALIGNMENT OF  
HIGHWAY 11 AT THREE LOCATIONS  
BETWEEN HWY 64 AND TOWN OF LATCHFORD  
AGREEMENT NO. 5004-E-0058  
(ASSIGNMENT #3)**

**Prepared For:**

**MINISTRY OF TRANSPORTATION  
NORTHEASTERN REGION GEOTECHNICAL SECTION**

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PRELIMINARY FIELD INVESTIGATION FOR RE-ALIGNMENT OF  
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AGREEMENT NO. 5004-E-0058 (ASSIGNMENT #3)**

## **1. INTRODUCTION**

Shaheen and Peaker (S&P) Limited, under Consultant Assignment No. 5004-E-0058, was retained by MTO Northeastern Region to conduct a preliminary foundation investigation for the re-alignment of Highway 11 at three locations between Highway 64 and the Town of Latchford, in the Township of Olive of Nipissing District and Townships of Best and Gillies Limit of Timiskaming District, Ontario.

The purpose of the investigation was to obtain information on the subsurface conditions by means of boreholes.

The findings of the investigation are presented in this report.

## **2. SITE DESCRIPTION AND PHYSIOGRAPHY**

This project involves three re-alignment areas along Highway 11 between Highway 64 and Town of Latchford. The locations of these areas are as follows:

Site No.	Description	Distance North of Hwy 64	Township	Stations
1	Robin Creek Re-alignment	9.9 km	Olive	15+100 to 15+400
2	Granite Lake Bridge Re-alignment	51.5 km	Best	11+100 to 12+200
3	'S' Curve and Pond	63.2 km	Gillies Limit	19+600 to 22+500

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. Tall grass and cattails are prominent in the swamps. 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 during the period of November 1 to 3, 2005 and consisted of the following:

- Site 1 – 2 boreholes (Boreholes R1 and R2);
- Site 2 – 10 boreholes (Boreholes G1 through G10);
- Site 3 – 9 boreholes (Boreholes S1 through S9);

The depths of the boreholes ranged from 0 to 6.6 m. The zero depth occurred in Boreholes G4 and G10 which were located on top of bedrock outcrops. 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.

The majority of the boreholes were advanced using a track mounted drill rig owned and operated by Landcore Drilling Limited. In the bedrock outcrop areas and at locations where difficult access was encountered by the drill rig, the boreholes were advanced using a light portable power auger and hand-drilling equipment.

From the bottom of the borehole, Dynamic Cone Penetration tests (DCPT) were performed in Borehole S8 to refusal depth of 9.6 m below the ground surface. In DCPT, a 51 mm diameter, 60-degree apex cone, screw attached to the tip of an A-size rod, is driven into the ground, using the same driving energy as the SPT method. By recording the number of blows of the hammer to drive the cone/rod assembly into the soil every 0.3 m, a qualitative record of soil compactness condition is obtained, while the test also provides some limited information on the consistency of cohesive (clay) soils.

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 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. Road centerline elevations for Boreholes S5 through S9 in Site No. 3 are not available, and therefore, borehole elevations at these locations were reference to a highway centerline datum of 100.0 m. We understand that MTO will revise these elevations once data become available.

The results of drilling, in-situ testing and water level measurements are summarized on the Record of Borehole Sheets in Appendices B1 through B3 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 Appendices C1 through C3.

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

##### **4.1 SITE 1 (STA. 15+100 TO 15+400): ROBIN CREEK RE-ALIGNMENT**

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. Standing water is prominent in the swamp area, especially near the water course. 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.

Two boreholes (Boreholes R1 and R2) were put down for this investigation at this stage. Three more boreholes are also proposed in this section, but will be postponed to winter season (on a separate contract), due to the deep water and difficult access. The two boreholes drilled were extended to depths of 2.1 and 6.1 m below the ground surface. These boreholes indicate, in general, below some granular fill in the ditch area or peat deposit which extends to depths of about 0.3 to 2.9 m below the existing grade, the presence of silt deposits. In Borehole R1, the silt deposit was probably underlain by bedrock as inferred from the auger refusal at a depth of 2.1 m, while in Borehole R2, a clayey silt deposit was contacted below the silt at a depth of 5.2 m.

The location plan of the boreholes is presented on Drawing No. 1. Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A1. The individual strata encountered in Boreholes R1 and R2 put down for this investigation are briefly described in the following paragraphs.

#### 4.1.1 FILL

Borehole R1 was drilled in the ditch area of the existing embankment and the borehole contacted a granular fill material consisting of sand and gravel mixed with topsoil, extending to a depth of 0.3 m below the ground surface. The measured moisture content of this deposit is about 16%.

It should be pointed out that in our experience at many sites the thickness of topsoil and fill materials can frequently vary in between and beyond borehole locations, and therefore, allowance should be made when estimating quantities.

#### 4.1.2 PEAT

Borehole R2, located about 14 m off the road centerline, contacted a peat deposit extending to a depth of 2.9 m below the ground surface. The peat deposit was found to contain some organic silt/clayey silt pockets and zones, and has a black to dark brown appearance. The measured natural moisture contents of the samples retrieved from the peat deposit range from 62 to 130%, indicating a wet condition.

Based on the Standard Penetration test results of 0 (i.e. sampler sank under static weight of the sampler and the rods) to 3 blows/0.3 m, the consistency of these deposits is described as very soft to soft but generally very soft. Owing to their organic nature, these soils can be expected to be highly compressible.

#### 4.1.3 SILT

Underlying the granular fill material in Borehole R1 and the peat deposit in Borehole R2, both boreholes encountered a silt deposit at depths of 0.3 m in Borehole R1 and of 2.9 m in Borehole R2. In Borehole R1, this deposit was found to extend probably to bedrock as indicated by the auger refusal at 2.1 m below the ground surface. In Borehole R2, the silt deposit was found underlain by a clayey silt deposit at a depth of 5.2 m below the ground surface.

In Borehole R2, the silt deposit was found to contain some organics in the upper portion and some silty clay to clay seams. The results of a grain-size analysis performed on one selected sample are presented in Figure C1-1 in Appendix C1. These indicate the following particle size distribution:

Gravel:	0%
Sand:	1%
Silt:	87%
Clay:	12%

Atterberg limits test carried out in the laboratory on one sample from this deposit yielded the following index values:

Liquid Limit:	22%
Plastic Limit:	24%
Plasticity Index:	2%

As presented in Figure C1-2 in Appendix C1, these values are characteristic of silt deposit. The measured natural moisture contents of the silt deposit range from 15 to 35%, indicating a moist to wet condition.

In Borehole R1, based on the measured N-values which ranged from 16 to 26 blows/0.3 m, the silt deposit can be described as possessing a very stiff consistency. In Borehole R2, the Standard Penetration tests results yielded N-values of 2 and 3 blows/0.3 m above a depth of 4.4 m and 13 blows/0.3 m below 4.4 m. A field vane test yielded undrained in-situ shear strength value of 20 kPa at a depth of 3.7 m. Based on these values the consistency of the silt deposit in Borehole R2 can be described as soft above a depth of 4.4 m and stiff below.

#### 4.1.4 CLAYEY SILT

In Borehole R2, a clayey silt deposit was contacted below the silt deposit at a depth of 5.2 m. This clayey silt deposit was found to extend to the remaining depth of the exploration (6.0 m), and probably deeper.

Atterberg limits test carried out in the laboratory on one sample from this deposit yielded the following index values.

Liquid Limit:	19%
Plastic Limit:	25%
Plasticity Index:	6%

As presented in Figure C1-3 in Appendix C1, these values indicate a clayey soil of low plasticity. The clayey silt deposit is considered wet as indicated by a measured natural moisture content test of about 47% from a retrieved sample.

This deposit was found to possess a stiff consistency condition as indicated by the measured 'N' value of 9 blows/0.3 m.

#### 4.1.5 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 B1.

Upon completion, no free water was observed in the boreholes. However, this was not believed to represent the stabilized groundwater condition. Based on measured moisture contents, the permanent groundwater table at the site can be expected to be near or at the ground surface beside the roadway embankment. It should be pointed out that the groundwater table is subject to seasonal fluctuations and in response to major weather events.

#### 4.2 SITE 2 (STA. 11+000 TO 12+200): GRANITE LAKE BRIDGE RE-ALIGNMENT

In order to reduce the curvature of the highway, a re-alignment towards the east and then to the west are proposed at this section. The site is located immediately south of Granite Lake Bridge, and is characterized by intermittent rock outcrops in the middle and north portions of the site. The south portion of the site is covered by dense wooded areas, and the road embankment is about 2 m in height. In the north portion, however, swampy area is prevalent west of the highway and the height of the embankment reaches more than 3 m.

A total of ten boreholes were put down to depths ranging from 0 to 6.0 m below the ground surface. Among them, one borehole (Borehole G1) was drilled on top of the embankment and nine were put down off the road near or at the proposed re-alignment. The zero penetration was encountered in Boreholes G4 and G10 which were located on top of bedrock outcrops. The boreholes drilled beyond the bedrock outcrop areas show, in general, below some topsoil/peat or the embankment fill which extend to depths of about 0.5 to 1.8 m below the existing grade, the presence of generally loose to compact granular deposits (silt and sand) and silty sand till.

The borehole location plans are presented on Drawing Nos. 2-1 and 2-2. Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix B2. The individual strata are briefly described in the following paragraphs.

#### 4.2.1 FILL

##### 4.2.1.1 EMBANKMENT FILL

Borehole G1 was put down on the right shoulder of the existing road. This borehole contacted a 0.6 m thick sand and gravel granular pavement fill at the ground surface. This pavement fill is underlain by an embankment fill which consists of sand with traces to some gravel as well as some silty clay pockets. The sand sill was found to extend to a depth of 1.8 m below the ground surface. The moisture content tests performed on samples from the embankment fills yielded the measured moisture contents of 8 and 14%.

##### 4.2.1.2 BACKFILL

In Borehole G6, a backfill material consisting of silty sand with traces of gravel and organics was encountered below the thin topsoil veneer. The silty sand fill was found to be about 0.75 m thick and extended to 0.9 m below the ground surface. The silty sand fill is in a wet condition as indicated by the measured moisture content of 21%.

#### 4.2.2 TOPSOIL

Boreholes G5, G6 and G9, drilled off the road, contacted a 0.15 to 0.3 m thick topsoil layer at the ground surface.

It should be pointed out that in our experience at many sites the thickness of the topsoil and fill materials can frequently vary in between and beyond borehole locations, and therefore, allowance should be made when estimating quantities.

#### 4.2.3 PEAT/ORGANIC SILT

Boreholes G2, G3, G7 and G8 contacted a peat deposit which extends from the ground surface to depths ranging between 0.15 to 0.9 m below the ground surface. In Borehole G2, a 0.35 m thick organic silt deposit was encountered underlying the peat deposit at the surface. One moisture content test performed on a sample from the organic silt deposit yielded a measured moisture content of 23%, while the measure moisture contents of the peat deposit ranged from 28 to in excess of 400%. The low moisture content on some of the peat deposit is due to the presence of large quantities of sand and gravel inside the peat matrix at some locations.

N-values of between 0 and 8 blows/0.3 m penetration were recorded in these deposits indicating a very soft to firm consistency. Owing to their organic nature, these soils can be expected to be highly compressible.

#### 4.2.4 SILT

Underlying the peat/organic silt deposits, Boreholes G2, G3 and G7 encountered a silt deposit at depths ranging from 0.5 m in Boreholes G2 to 0.9 m in Borehole G7. In Borehole G2, this silt deposit was found to extend to the remaining depth of the boreholes at 3.5 m below the ground surface. In Boreholes G3 and G7, the silt deposit was underlain by silty sand to sand deposits at depths of 3.7 and 2.1 m below the ground surface, respectively.

The silt deposit was found to contain traces to some sand/sand seams and traces of clay. The results of grain-size analyses performed on three selected samples are presented in Figure C2-1 in Appendix C2. These indicate the following particle size distribution:

Gravel:	0%
Sand:	8 – 15%
Silt:	76 – 86%
Clay:	9 – 11%

The measured natural moisture contents of the silt deposit ranged from 16 to 22%. Standard Penetration tests performed in this deposit gave N-values ranging from 6 to 16 blows for 0.3 m penetration. Based on these, the relative density of the silt deposit can be described as loose to compact.

#### 4.2.5 SAND/SILTY SAND/GRAVELLY SAND

Boreholes drilled at the south portion of the site encountered a sand deposit below the embankment fill deposit at a depth of 1.8 m in Borehole G1 and below the silt deposit at a depth of 3.7 m in Borehole G3. Towards the north, in Borehole G7, a silty sand deposit was contacted underlying the silt deposit at a depth of 2.1 m. Borehole G7 was terminated in this deposit at a depth of 6.0 m below the ground surface. Further north in Borehole G8, a gravelly sand deposit was found to be about 2.2 m thick and interbedded with the silty sand till deposit at a depth 2.1 m.

In Boreholes G1 and G3, the sand deposit was found to contain traces of silt. The results of grain-size analyses performed on two selected samples are presented in Figure C2-2 in Appendix C2. These indicate the following particle size distribution:

Gravel:	0%
Sand:	92 – 93%
Silt & Clay:	7 – 8%

The silty sand deposit in Borehole G7 was found to contain some gravel. The results of a grain-size analysis performed on one sample are presented in Figure C2-3 in Appendix C2. These indicate the following particle size distribution:

Gravel:	11%
Sand:	70%
Silt & Clay:	19%

The results of a grain-size analysis performed on one sample from the gravelly sand deposit in Borehole G8 are presented in Figure C2-4 in Appendix C2. These indicate the following particle size distribution:

Gravel:	29%
Sand:	67%
Silt & Clay:	4%

The measured natural moisture contents of these sandy deposits ranged from 8 to 23%, indicating a wet condition. Standard Penetration tests performed in these sandy deposits gave N-values widely ranging from 6 to 57 blows for 0.3 m penetration but typically between 15 and 42. Based on these, the relative density of these sand/silty sand/gravelly sand deposits can be generally described as compact to dense.

#### 4.2.6 SILTY SAND TILL

Underlying the backfill material in Borehole G6 and the peat deposit in Borehole G8, silty sand till deposit was contacted at a depth of about 0.9 m and extended to the remaining depths of the exploration (3.0 m in Borehole G6 and 5.3 m in Borehole G8). In Borehole G8, a gravelly sand deposit was found interbedded in the glacial till deposit from 2.1 to 4.3 m depths below the ground surface.

This silty sand till consists of a heterogeneous mixture of silt and sand with traces of gravel and clay. The presence of cobbles and boulders can always be expected in the glacial till deposits, owing to their mode of deposition. The results of grain-size analyses performed on two selected samples from this glacial till are presented in Figure C2-5 in Appendix C2. These indicate the following particle size distribution:

Gravel:	15 – 20 %
Sand:	48 – 49%
Silt:	25 – 29%
Clay:	7%



The measured natural moisture contents of the silty sand till deposit ranged from 11 to 14%, indicating a wet condition. Based on the measured 'N' values of 11 and 41 blows/0.3 m, this deposit is considered compact to dense.

#### 4.2.7 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 B2.

The observations show that at the time of our investigation, except for the bedrock outcrop areas, the groundwater table was at or near the ground surface level. It should be pointed out that the groundwater table is subject to seasonal fluctuations and in response to major weather events.

#### 4.3 SITE 3 (STA. 19+600 TO 22+500): 'S' CURVE AND POND

At this site, the existing highway is characterized by an 'S' shaped curve which is proposed to be re-aligned to lessen the curvature. The site is located about 63 km north of Highway 64 and approximately 10 km south of the Town of Latchford. Bedrock outcrops are prominent along both sides of the highway within the site limits. Between the rock outcrops, waterlogged swampy grounds prevail. At both ends of this section the embankment is usually less than 1 m high, while in the swamp areas of this section, the existing road embankment reaches up to about 5 m in height.

A total of nine boreholes were put down to depths ranging from 0.2 to 6.6 m below the ground surface. Among them, three boreholes were drilled on top of the embankment and six were put down off the road near or at the proposed re-alignment. In the bedrock outcrop areas, auger refusal at shallow depths was recorded after the penetration of the thin topsoil veneer or the embankment fill. The boreholes drilled beyond the bedrock outcrop areas show, in general, below some topsoil/peat which extends to depths of about 0.05 to 6 m below the existing grade, the presence of basal granular deposits of sand and silt. In two of the boreholes, silty sand till was also encountered during our exploration.

The borehole location plans are presented on Drawing Nos. 3-1 through 3-4. Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix B3. The individual strata are briefly described in the following paragraphs.

##### 4.3.1 FILL

Boreholes S1, S2 and S3 were put down on the right shoulder of the existing road near the south limit of this section. From the ground surface, these boreholes contacted a sand and

gravel granular pavement fill which extends to depths ranging from 0.3 to 1.4 m. In Borehole S1, auger refusal was encountered at 1.4 m below the ground surface, probably on bedrock. In Boreholes S2 and S3, pavement fill is underlain by an embankment fill which consists of sand with traces to some gravel. In Borehole S2, the sand fill was found to extend to a depth of 1.3 m overlying a silty sand till deposit, while in Borehole S3, the thickness of the sand fill is about 0.7 m extending to probably to bedrock, as indicated by the auger refusal at a depth of 1.2 m below the ground surface. Based on the measured moisture contents of the fill materials which ranged from 5 to 7%, the granular fills encountered in Boreholes S1, S2 and S3 are considered in a moist condition.

#### 4.3.2 TOPSOIL

Boreholes S4, S7 and S9, drilled off the road, contacted a 0.05 to 0.3 m thick topsoil layer at the ground surface.

#### 4.3.3 PEAT

Boreholes S6 and S8 contacted a peat deposit which extends from the ground surface to depths of 0.9 m and 6.0 m, respectively.

The measure natural moisture contents of the peat deposit ranges from 135 to in excess of 500%. N-values of 0 and 2 blows/0.3 m penetration were recorded in these deposits indicating a very soft consistency. Owing to their organic nature, these soils can be expected to be highly compressible.

#### 4.3.4 BOULDERS AND COBBLES

At the ground surface, Borehole S5 contacted a layer of boulders and cobbles extending to a depth of about 0.6 m below the ground surface.

#### 4.3.5 SILTY SAND TILL

In Borehole S2, silty sand till deposit was contacted below the fill materials at a depth of 1.3 m and extended probably to bedrock, as indicated by the auger refusal at a depth of 1.7 m below the ground surface. Towards the north, in Borehole S6, a 0.6 m thick silty sand till layer was contacted below the silt deposit at a depth of 1.5 m below the ground surface.

This silty sand till consists of a heterogeneous mixture of silty sand with gravel and traces of clay. The presence of cobbles and boulders can always be expected in the glacial till deposits, owing to their mode of deposition. The results of grain-size analyses performed on two selected samples from this glacial till are presented in Figure C3-1 in Appendix C3. These indicate the following particle size distribution:

Gravel:	29 – 50 %
Sand:	30 – 44%
Silt:	17 – 20%
Clay:	3 – 7%

The measured natural moisture contents of this sandy till deposit are about 10%. Based on the recorded N-values of 22 and in excess of 50 blows/0.3 m penetration, the relative density of this glacial till deposit can be described as compact to very dense.

#### 4.3.6 SILT

In Borehole S6, underlying the peat a silt deposit was contacted at a depth of 0.9 m and extended to 1.5 m overlying the silty sand till deposit.

The measured natural moisture content of the silt deposit is about 19%. Standard Penetration test performed in this deposit gave an N-value of 20 blows for 0.3 m penetration indicating a compact condition.

#### 4.3.7 SAND/GRAVELLY SAND

Boreholes S5, S6, S8 and S9 encountered sand/gravelly sand deposits below the boulders/cobbles, clayey silt till or peat/topsoil deposits at depths ranging from 0.05 m in Borehole S9 to 6.0 m in Borehole S8. In Boreholes S5, S6 and S9, these sandy deposits were found to extend probably to bedrock at depths ranging from 1.1 to 3.7 m as indicated by the auger refusal. In Borehole S8, the sand deposit was found to extend at least to 6.6 m (end of the borehole) below the ground surface, and probably to 9.6 m as indicated by the refusal depth of the DCPT.

In Boreholes S6, S8 and S9, the sand deposit was found to contain traces of silt and gravel. The results of grain-size analyses performed on two selected samples are presented in Figure C3-2 in Appendix C2. These indicate the following particle size distribution.

Gravel:	1 – 2%
Sand:	91 – 93%
Silt & Clay:	5 – 8%

The gravelly sand deposit in Borehole S5 was found to contain some silt. The results of a grain-size analysis performed on one sample are presented in Figure C3-3 in Appendix C2. These indicate the following particle size distribution.

Gravel:	33%
Sand:	50%
Silt & Clay:	17%

The measured natural moisture contents of these sandy deposits ranged from 7 to 21%, indicating a wet condition. Standard Penetration tests performed in the sand deposit gave N-values ranging from 4 to in excess of 50 blows for 0.3 m penetration. Based on these, the relative density of this sandy deposit can be described as loose to very dense.

#### 4.3.8 CLAYEY SILT

In Borehole S9, underlying the surficial sand deposit a clayey silt deposit was contacted at a depth of 0.7 m and extended probably to bedrock at a depth of 1.1 m as indicated by the auger refusal.

Atterberg limits test carried out in the laboratory on one sample from this deposit yielded the following index values.

Liquid Limit:	14%
Plastic Limit:	26%
Plasticity Index:	12%

As presented in Figure C3-4 in Appendix C1, these values indicate a clayey soil of low plasticity. The measured natural moisture content of this cohesive deposit is about 18%, indicating a moist to wet condition.

Standard Penetration test performed in this deposit gave an N-value in excess of 50 blows for 0.3 m penetration indicating a hard condition.

#### 4.3.9 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 B3.

The observations show that at the time of our investigation, except for the bedrock outcrop areas, the groundwater table was at or near the ground surface level. It should be pointed out that the groundwater table is subject to seasonal fluctuations and in response to major weather events.

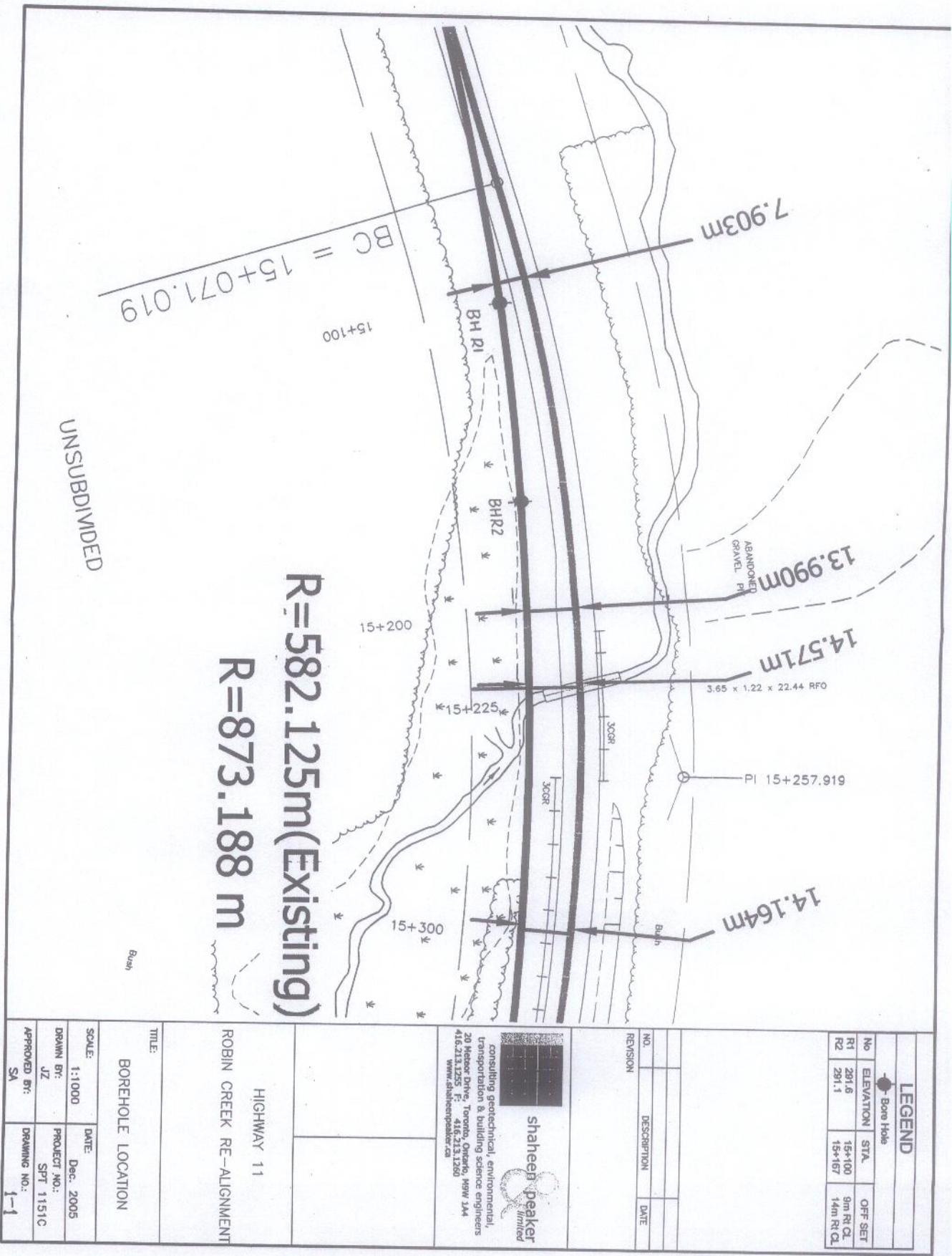
### **SHAHEEN & PEAKER LIMITED**

Yuxin Lang, P.Eng.

R. Miranda, P.Eng.



# Drawings



LEGEND			
No	ELEVATION	STA	OFF SET
R1	291.6	15+100	9m R/C
R2	291.1	15+167	14m R/C

NO.	DESCRIPTION	DATE

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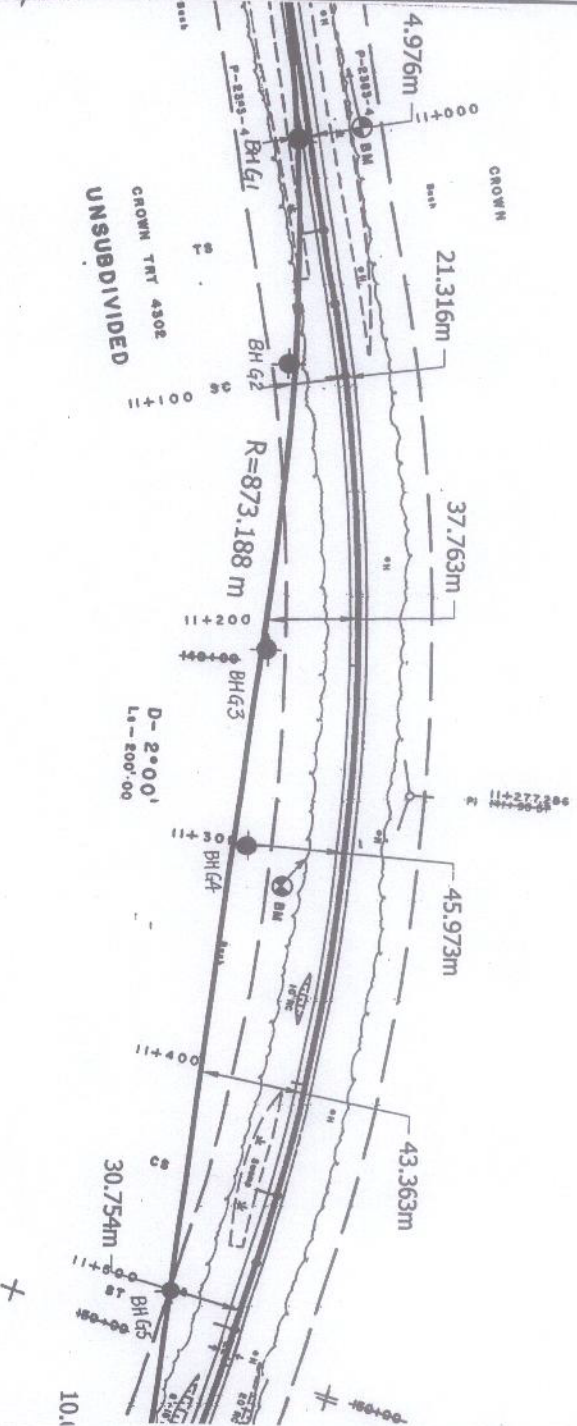
TITLE:		BOREHOLE LOCATION	
SCALE:		DATE:	
1:1000		Dec. 2005	
DRAWN BY:		PROJECT NO.:	
JZ		SPT 1151C	
APPROVED BY:		DRAWING NO.:	
SA		1-1	



# LEGEND

Bore Hole

No.	ELEVATION	STA.	OFF SET
G1	302.8	11+000	5m RI CL
G2	303.2	11+090	21m RI CL
G3	304.1	11+210	38m RI CL
G4	316.0	11+300	40m RI CL
G5	309.9	11+500	31m RI CL
G6	309.5	11+600	11m LI CL
G7	308.9	11+700	14m RI CL
G8	309.1	11+800	16m LI CL
G9	312.9	11+895	27m LI CL
G10	313.0	12+000	28m LI CL



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HIGHWAY 11  
GRANITE LAKE BRIDGE  
RE-ALIGNMENT

TITLE:

BOREHOLE LOCATION

SCALE:	DATE:
1:2000	Dec. 2005
DRAWN BY:	PROJECT NO.:
JZ	SPT 1151C
APPROVED BY:	DRAWING NO.:
SA	2-1





# LEGEND

● Bore Hole

No	ELEVATION	STA	OFF SET
S1	364.6	19+600	5.5m RI CL
S2	364.3	19+700	6m RI CL
S3	363.4	19+800	6m RI CL
S4	364.0	20+000	27m RI CL
S5	36.8	20+090	36m RI CL
S6	95.1	20+180	36m RI CL
S7	94.7	20+275	28m RI CL
S8	95.8	20+750	16m LI CL
S9	99.2	22+400	12m RI CL

NO.	DESCRIPTION	DATE
-----	-------------	------

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HIGHWAY 11

'S' CURVE AND POND  
RE-ALIGNMENT

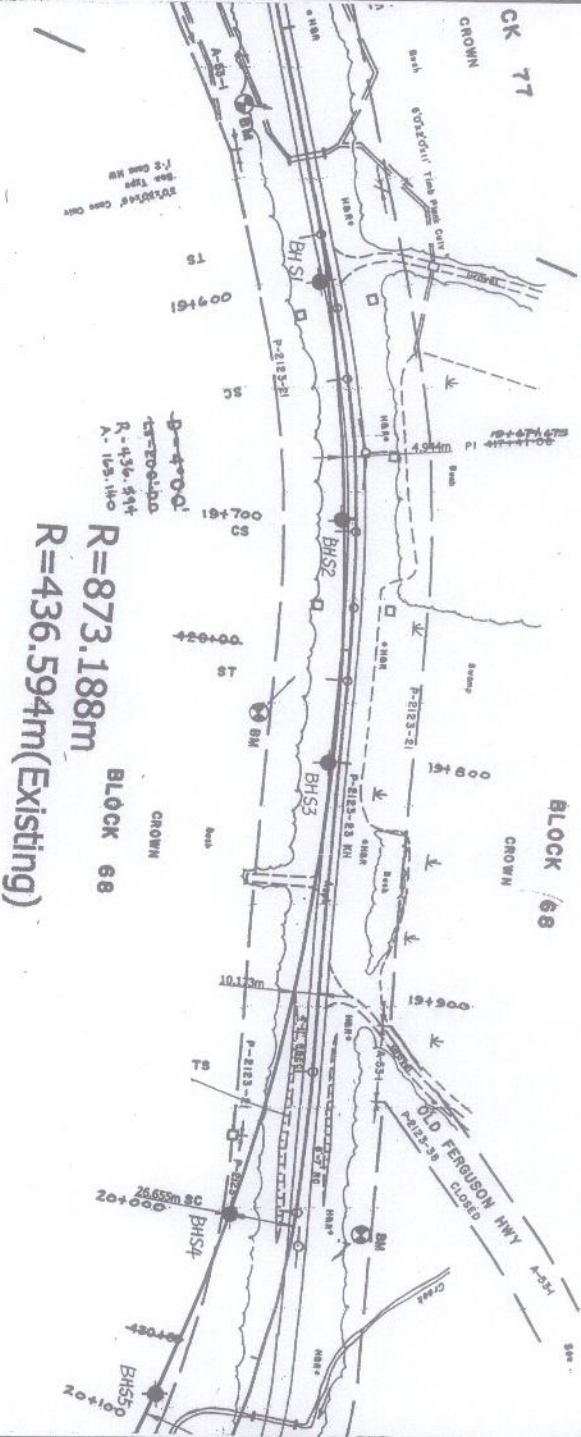
TITLE:

BOREHOLE LOCATION

SCALE:	DATE:
1:2000	Dec. 2005

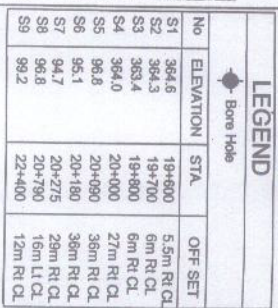
DRAWN BY:	PROJECT NO.:
JZ	SPT 1151C

APPROVED BY:	DRAWING NO.:
SA	3-1




Gillies Limit Twp





REVISION		
NO.	DESCRIPTION	DATE

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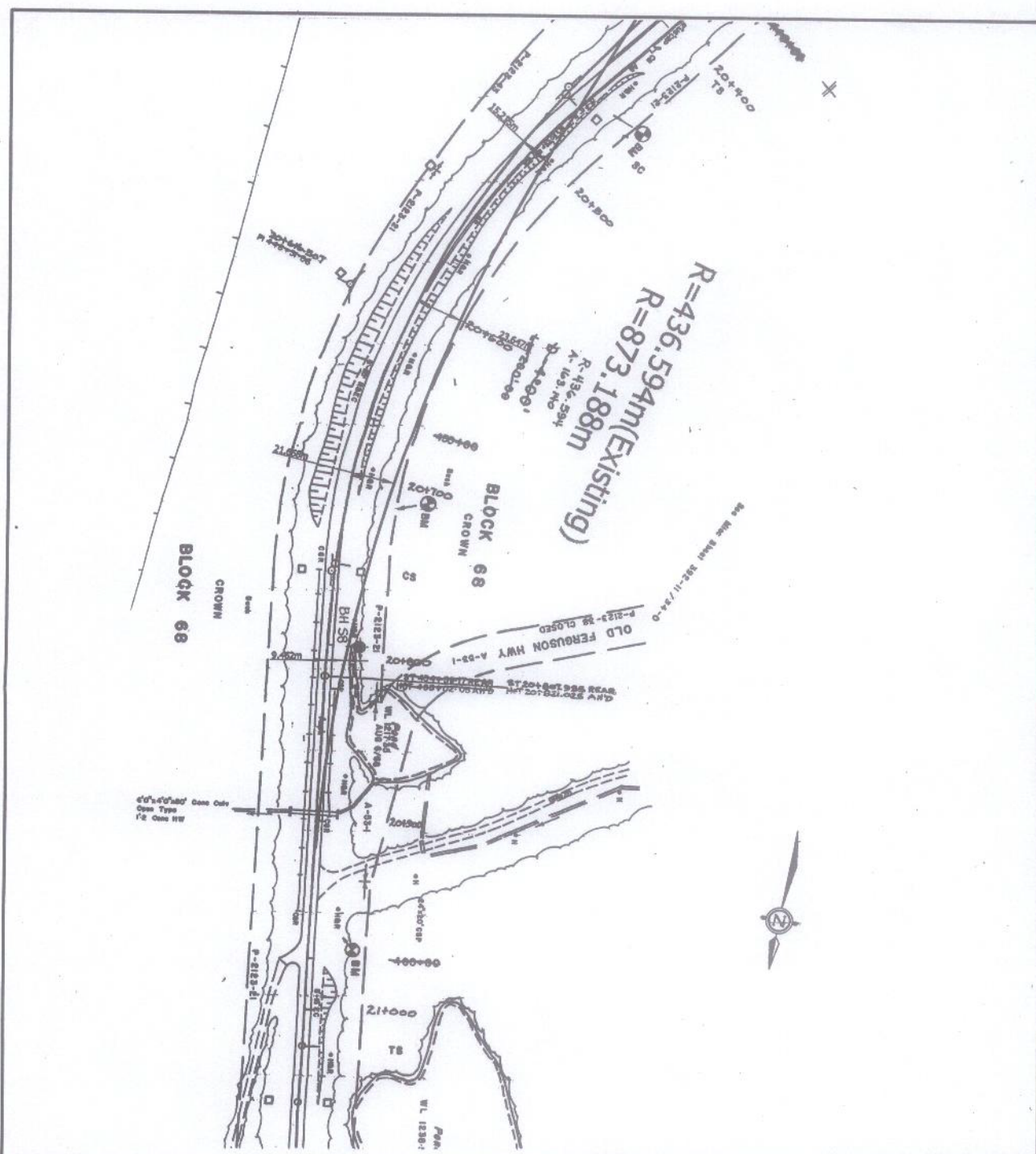
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transportation & building science engineers

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HIGHWAY 11  
'S' CURVE AND POND  
RE-ALIGNMENT

TITLE:	BOREHOLE LOCATION

SCALE:	DATE:
1:2000	Dec. 2005
DRAWN BY:	PROJECT NO.:
JZ	SPT 1151C
APPROVED BY:	DRAWING NO.:
SA	3-2



**LEGEND**

◆ Bore Hole

No	ELEVATION	STA.	OFF SET
S1	364.6	19+600	5.5m RI CL
S2	364.3	19+700	6m RI CL
S3	363.4	19+800	6m RI CL
S4	364.0	20+000	27m RI CL
S5	365.8	20+090	36m RI CL
S6	365.1	20+180	36m RI CL
S7	364.7	20+275	29m RI CL
S8	364.8	20+790	16m LI CL
S9	369.2	22+400	12m RI CL

NO.	DESCRIPTION	DATE
REVISION		

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**TITLE:**

**BOREHOLE LOCATION**

**SCALE:** 1:2000      **DATE:** Dec. 2005

**DRAWN BY:** JZ      **PROJECT NO.:** SPT 1151C

**APPROVED BY:** SA      **DRAWING NO.:** 3-3



# LEGEND

● Bore Hole

No	ELEVATION	STA.	OFF SET
S1	364.6	19+600	5.5m RI CL
S2	364.3	19+700	6m RI CL
S3	363.4	19+800	6m RI CL
S4	364.0	20+000	27m RI CL
S5	368.8	20+090	36m RI CL
S6	95.1	20+180	36m RI CL
S7	94.7	20+275	29m RI CL
S8	96.8	20+790	16m LI CL
S9	99.2	22+400	12m RI CL

NO.	DESCRIPTION	DATE



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HIGHWAY 11

'S' CURVE AND POND  
RE-ALIGNMENT

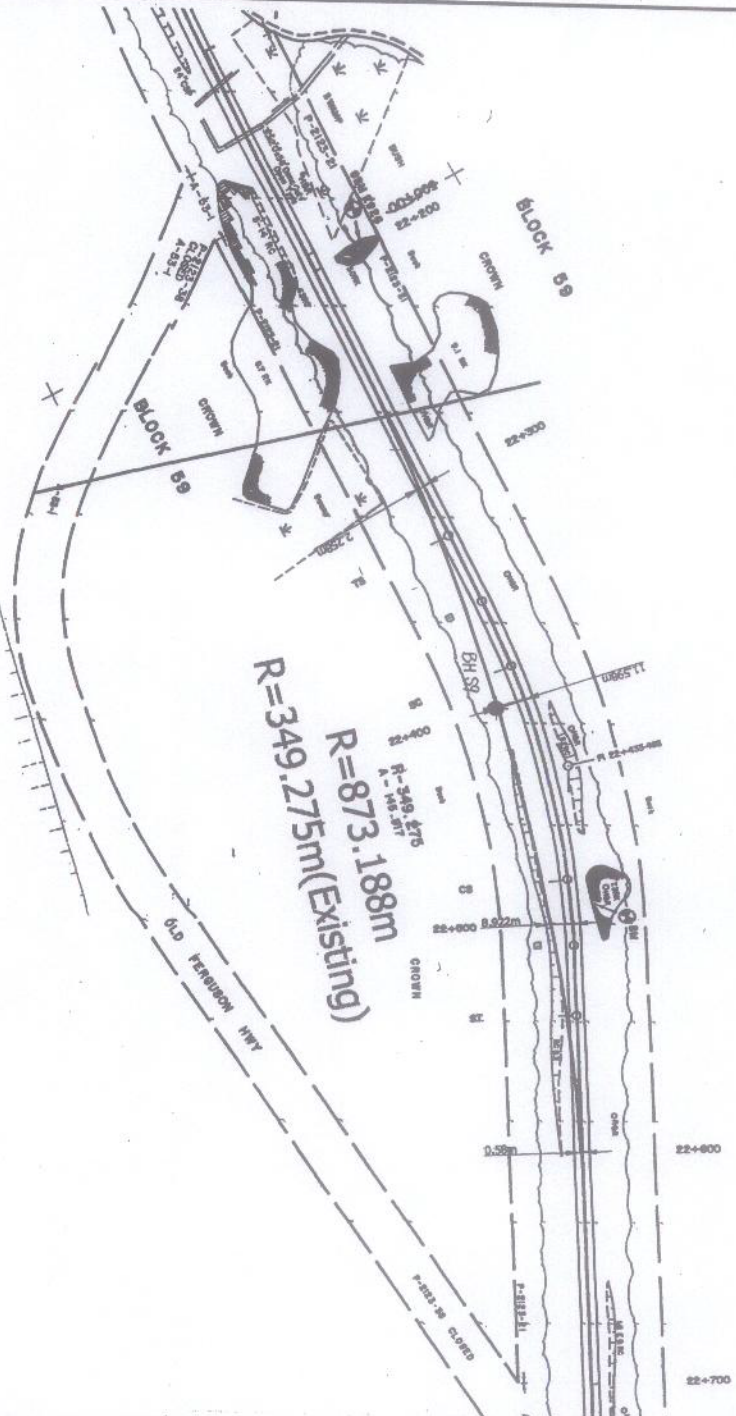
TITLE:

BOREHOLE LOCATION

SCALE: 1:2000 DATE: Dec. 2005

DRAWN BY: JZ PROJECT NO.: SPT 1151C

APPROVED BY: SA DRAWING NO.: 3-4



# Appendix A

## Site Photographs



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





Photograph A-2: Site #2 - Sta. 11+000 Looking Northeast



Photograph A-3: Site #2 - Sta. 11+600 Looking North





Photograph A-4: Site #3 - Sta. 20+175 Looking East



Photograph A-5: Site #3 - Sta. 20+800 Looking Northwest

## Appendix B1

### Records of Boreholes for Site 1 (Boreholes R1 and R2)


SPT1151C

# RECORD OF BOREHOLE No R1

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Robin Creek Re-alignment, Station 15+100; 9m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY YL  
 DATUM Local DATE 11/1/2005 CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
291.6	Ground Surface					*											
0.0																	
291.3	<b>FILL: SAND &amp; GRAVEL</b> with topsoil		1	SS	17												
0.3	trace clay, moist some gravel, wet																
	<b>SILT</b> trace sand, brown to greyish brown, very stiff		2	SS	15												
			2	SS	26												
289.5																	
2.1	End of Borehole. Auger refusal at 2.1 m, probably on bedrock. Moved to Sta. 15+099; 9m Rt, auger refusal at 1.2 m.  * No free water was observed (not stabilized) and hole opened to the full depth on completion.																

SPT1151C

# RECORD OF BOREHOLE No R2

1 OF 1

**METRIC**

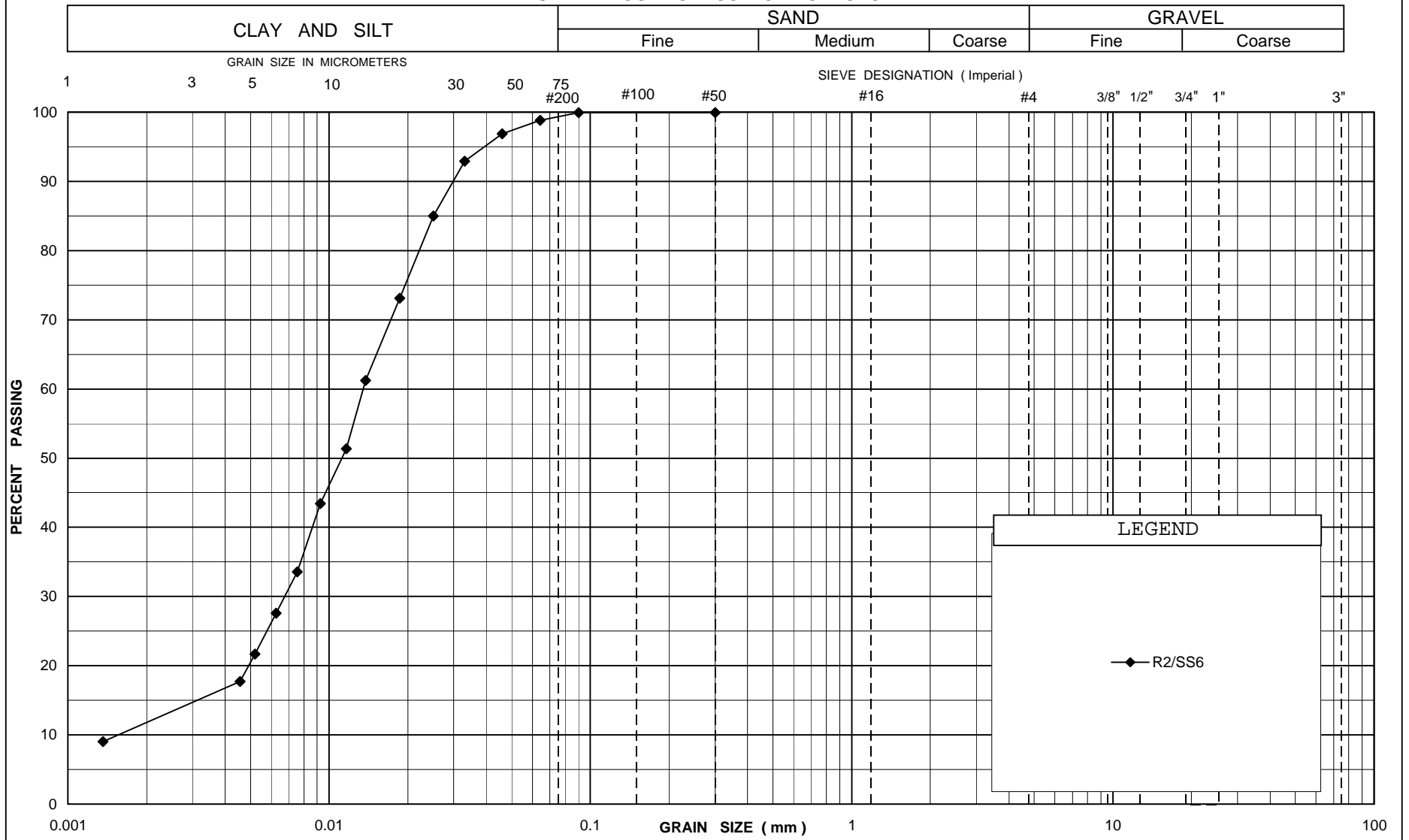
GWP \_\_\_\_\_ LOCATION Robin Creek Re-alignment, Station 15+167; 14m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY YL  
 DATUM Local DATE 11/1/2005 CHECKED BY RM

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		
291.1	Ground Surface													
0.0			1	SS	3		291							
			2	SS	1		290							
	<b>PEAT</b> some organic silt/clayey silt pockets, black to dark brown, wet, very soft		3	SS	0**		289							
			4	SS	1		288							
288.2			5	SS	2		287							
2.9	some organics ----- <b>SILT</b> grey, wet trace to some silty clay/clay seams, soft ----- occasional sand seams, stiff		6	SS	3		286							
			7	SS	13									
285.9			8	SS	9									
5.2	<b>CLAYEY SILT</b> grey, wet, stiff													
285.1														
6.0	End of Borehole.  * No free water was observed (not stabilized) and hole opened to the full depth on completion.  ** Sampler sunk under the weight of hammer and rods													

## Appendix C1

# Laboratory Test Results for Site 1 (Boreholes R1 and R2)

# UNIFIED SOIL CLASSIFICATION SYSTEM



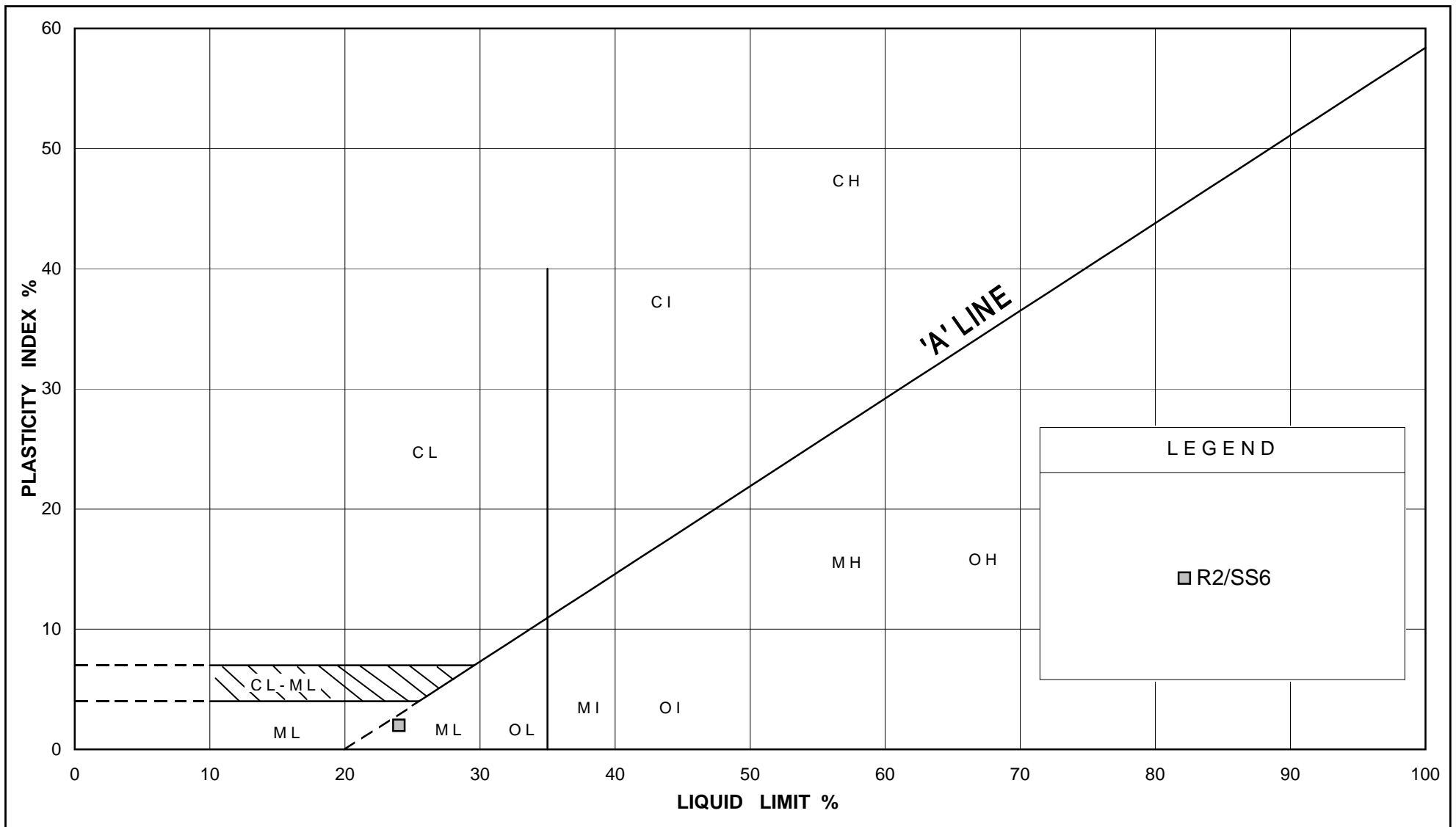
SHAHEEN & PEAKER LIMITED

**GRAIN SIZE DISTRIBUTION**  
SILT, some clay

FIGURE No. C1-1

REF. No. SPT 1151C

DATE NOVEMBER , 2005



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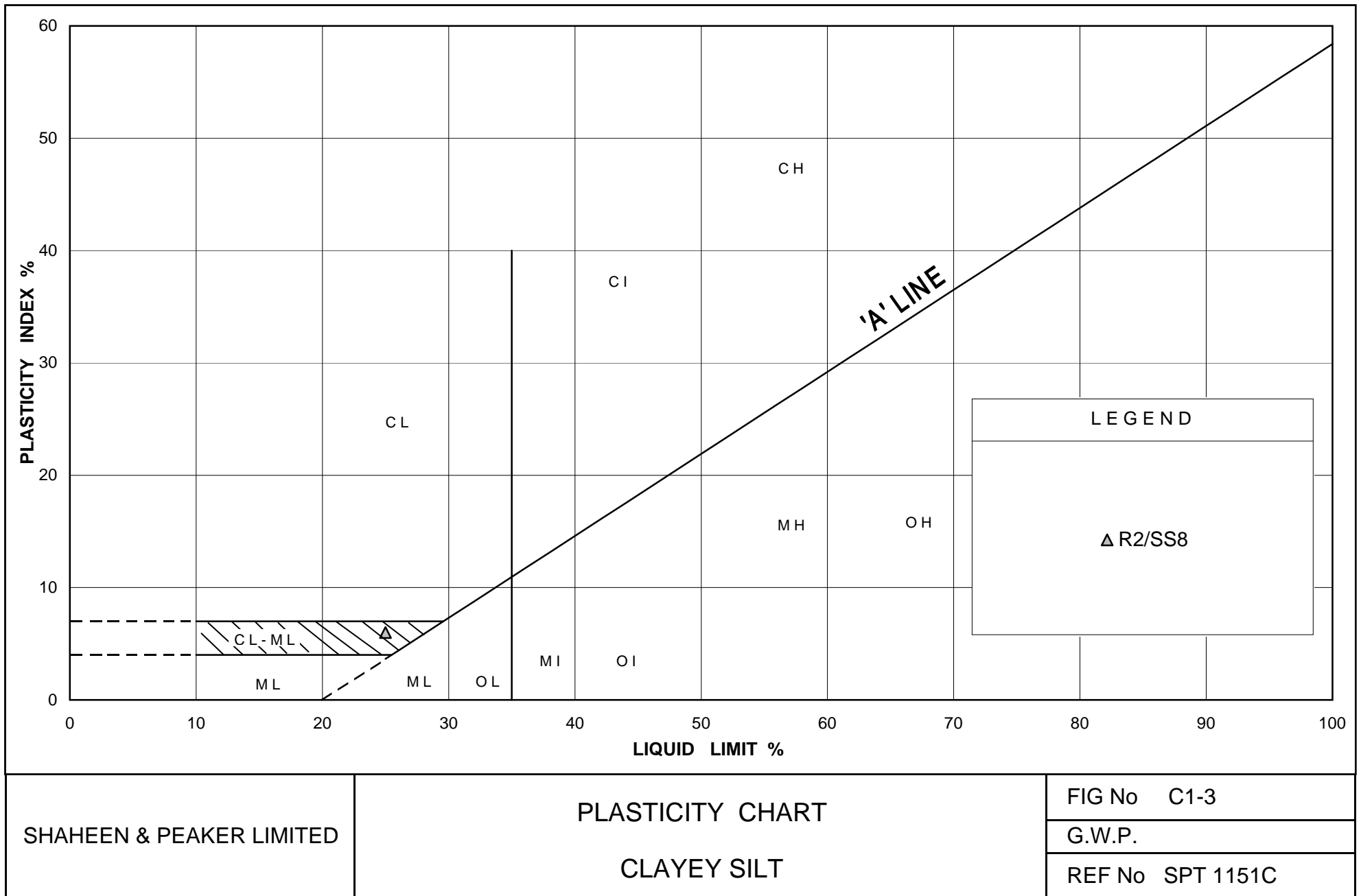
PLASTICITY CHART

SILT, some clay

FIG No C1-2

G.W.P.

REF No SPT 1151C





## Appendix B2

### Records of Boreholes for Site 2 (Boreholes G1 through G10)




SPT1151C

# RECORD OF BOREHOLE No G1

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+000; 5m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ \_\_\_\_\_  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL \_\_\_\_\_  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ 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									WATER CONTENT (%)	
302.8	Ground Surface																	
0.0	Top 0.3 m with Asphalt Fragments		1	SS	6													
302.2	<b>FILL: Sand and Gravel</b> dark brown to brown, damp to moist																	
0.6			2	SS	10													
	<b>FILL: Sand</b> trace to some gravel, some silty clay pockets/zones, brown, moist																	
301.0		3	SS	30														
1.8																		
	<b>SAND</b> trace silt, grey, wet,		4	SS	42													
			5	SS	19													
299.3																		
3.5	End of Borehole.																	
	* Water level at 1.8 m (not stabilized) and hole opened to 2.4 m on completion.																	

SPT1151C

# RECORD OF BOREHOLE No G2

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+090; 21m Rt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY YL  
 DATUM Local DATE 11/3/2005 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							
303.2	Ground Surface														
0.0	Top 0.15 m Peat		1	SS	7	303									0 8 82 10
302.7	ORGANIC SILT black to dark brown, wet, firm														
0.5			2	SS	14	302									
	SILT occasional sand seams, brownish grey to grey, wet, dilatant														
	compact		3	SS	15	301									
	loose														
			4	SS	9	300									
	some sand														
299.7			5	SS	6	300									
3.5	End of Borehole.  * Borehole wet-caved at 2.4 m (not stabilized) on completion.														



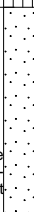
SPT1151C

# RECORD OF BOREHOLE No G3

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+210; 38m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ 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 (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								○ UNCONFINED      + FIELD VANE ● POCKET PENETR.    × LAB VANE				
304.1	Ground Surface						20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT		
0.0	<b>PEAT</b> black, wet, very soft		1	SS	0**						405	
303.5												
0.6	<b>SILT</b> trace clay, grey, wet, dilatant		2	SS	12							
			3	SS	12							0 8 81 11
		compact	4	SS	10							
		loose										
			5	SS	7							
300.4												
3.7	<b>SAND</b> trace silt, grey, wet		6	SS	6							
			7	SS	8							0 82 (8)
		loose										
		compact										
298.1			8	SS	23							
6.0	End of Borehole.											
	* Water level at 2.4 m (not stabilized) and hole opened to 3.7 m on completion.											
	** Sampler sunk under the weight of hammer and rods											

SPT1151C

## 1 OF 1

METRIC

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

SPT1151C

1 OF 1

METRIC

[illegible]

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

SPT1151C

# RECORD OF BOREHOLE No G6

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+600; 11m Lt C/L \_\_\_\_\_ ORIGINATED BY JZ \_\_\_\_\_  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL \_\_\_\_\_  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ CHECKED BY RM \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			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				WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>				
309.5 0.0	Ground Surface															
	Top 0.15 m Topsoil FILL: Silty Sand trace organic/topsoil pockets, trace gravel, brown to grey, wet		1	SS	7											
308.6 0.9			2	SS	21											
	SILTY SAND TILL brownish grey to grey, wet, compact		3	SS	24											
306.5 3.0			4	SS	30											
	End of Borehole.  * Water level at 1.5 m (not stabilized) and hole opened to the full depth on completion.															

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# RECORD OF BOREHOLE No G7

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+700; 14m Lt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			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			WATER CONTENT (%)						
								○ UNCONFINED      + FIELD VANE	● POCKET PENETR.      × LAB VANE								
308.9	Ground Surface							20   40   60   80   100									
0.0	PEAT with sand and gravel layer, black, wet		1	SS	8										0   15   76   9		
308.0																	
0.9																	
306.8	SILT some sand, trace clay, grey, wet, dilatant, compact to loose		2	SS	16												
			3	SS	9												
2.1	SILTY SAND some gravel, grey, wet		4	SS	23												
			5	SS	17												
			6	SS	34												
			7	SS	37												
			8	SS	57												
302.9																	
6.0	End of Borehole.																
	* Water level at 1.1 m (not stabilized) and hole opened to 1.8 m on completion.																



SPT1151C

## 1 OF 1

METRIC

[illegible]


SPT1151C

# RECORD OF BOREHOLE No G9

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION Granite Lake Bridge Re-alignment, Station 11+895; 27m Lt C/L ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 BOREHOLE TYPE Hand Auger COMPILED BY YL  
 DATUM Local DATE 11/3/2005 CHECKED BY RM

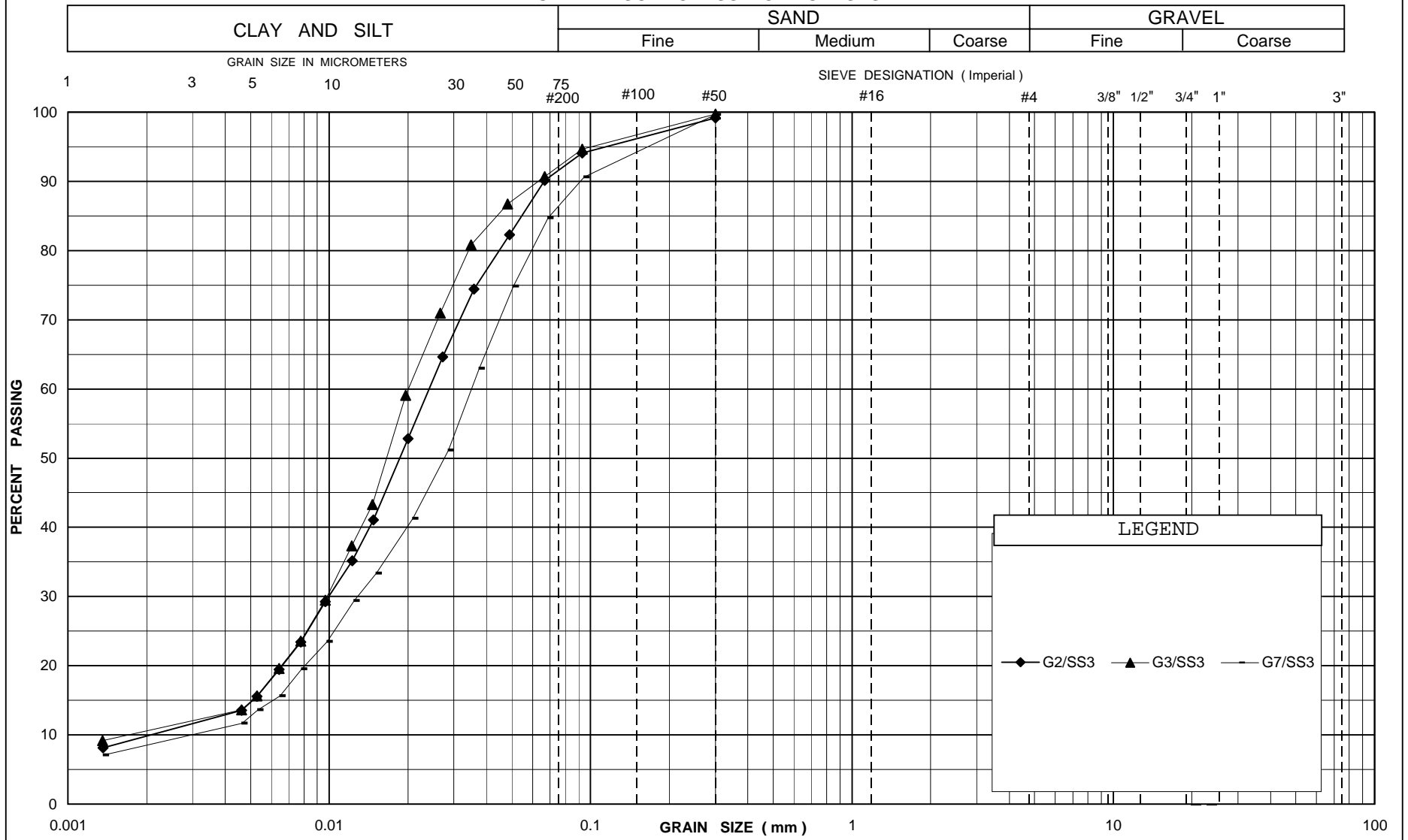
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
312.9	Ground Surface																
312.9	<b>TOPSOIL</b>																
0.2	End of Borehole. Auger refusal on bedrock.						312										

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

## Appendix C2

### Laboratory Test Results for Site 2 (Boreholes G1 through G10)

# UNIFIED SOIL CLASSIFICATION SYSTEM



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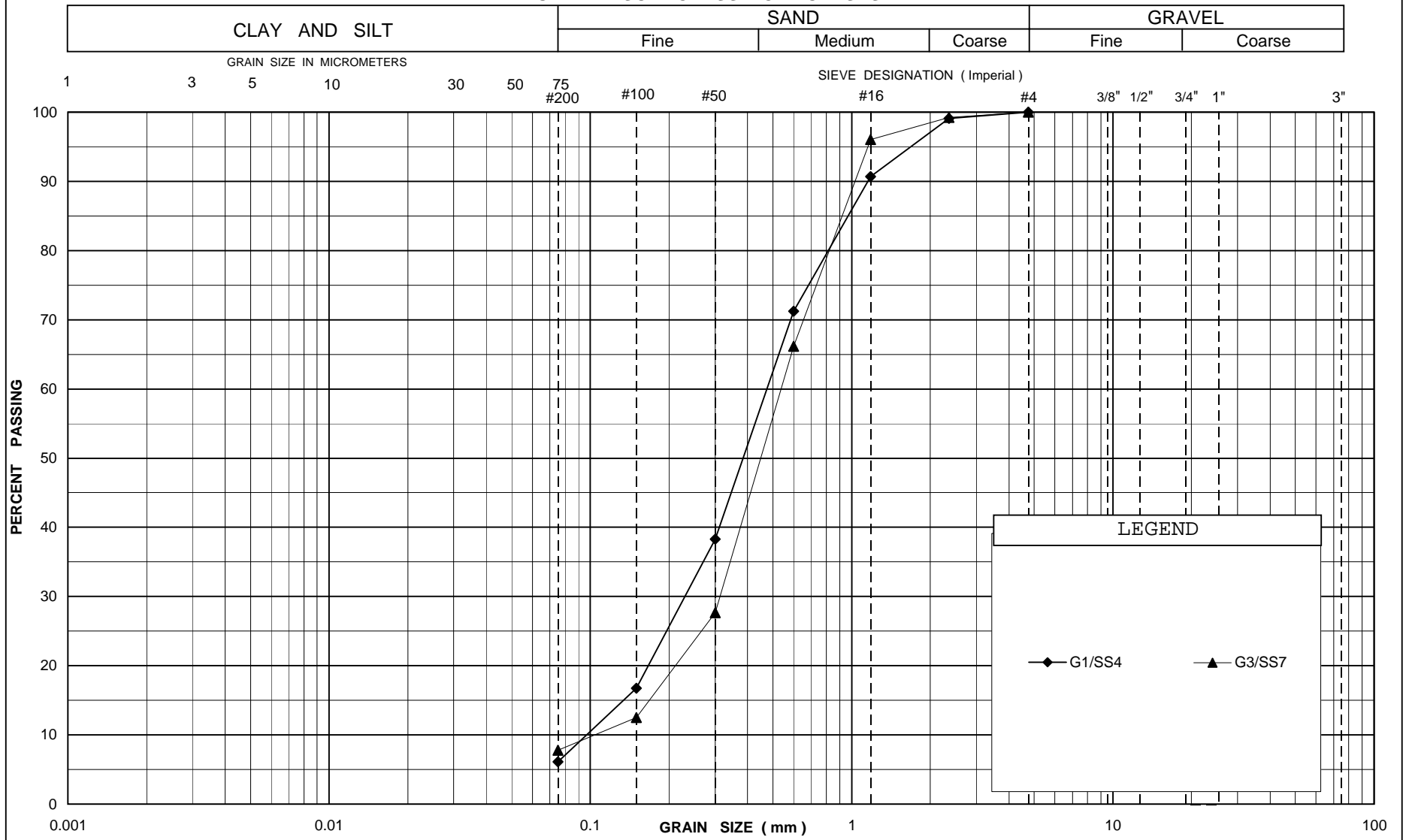
**GRAIN SIZE DISTRIBUTION**  
SILT, trace to some sand, trace clay

FIGURE No. C2-1

REF. No. SPT 1151C

DATE NOVEMBER , 2005

# UNIFIED SOIL CLASSIFICATION SYSTEM



SHAHEEN & PEAKER LIMITED

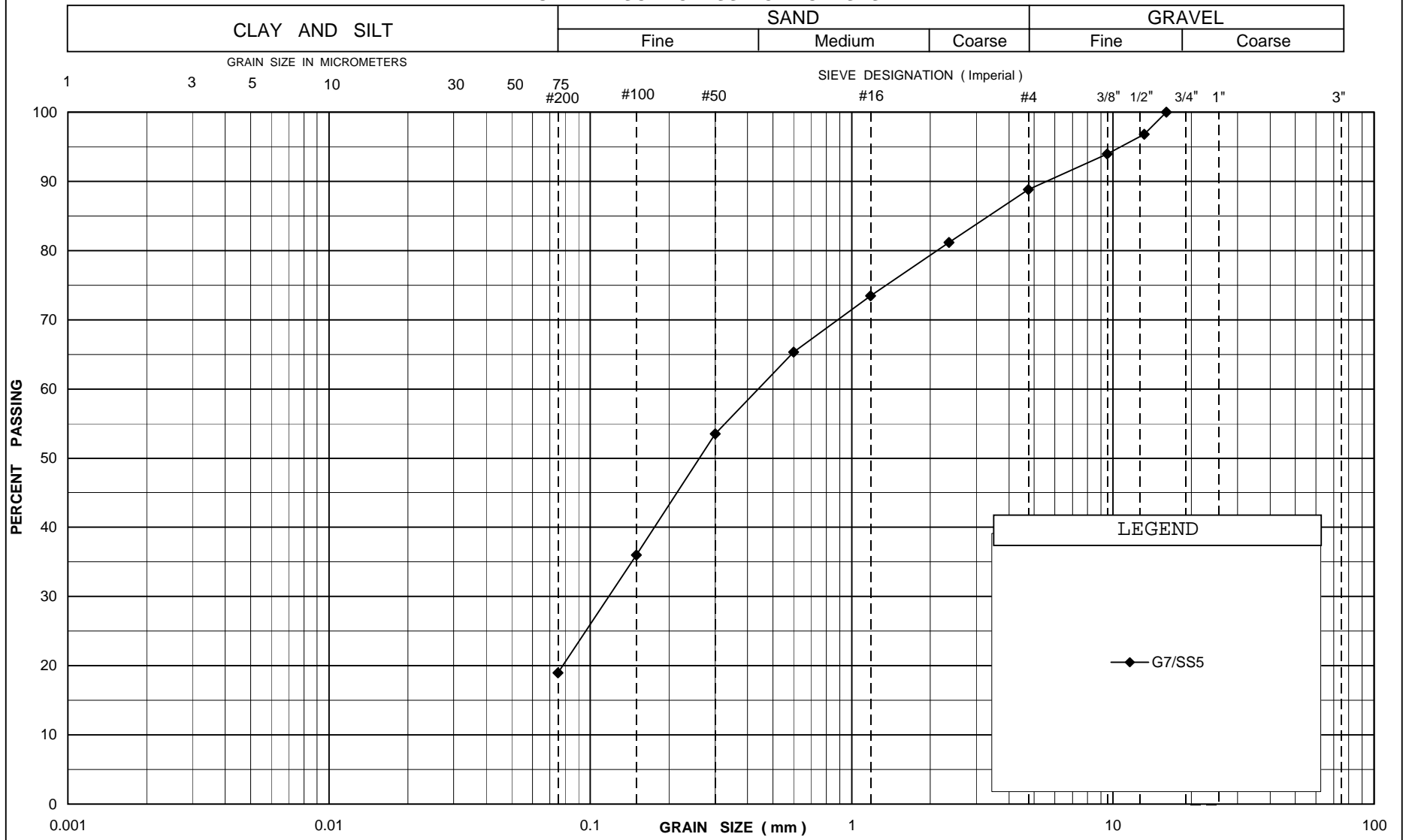
GRAIN SIZE DISTRIBUTION  
SAND, trace silt

FIGURE No. C2-2

REF. No. SPT 1151C

DATE NOVEMBER , 2005

# UNIFIED SOIL CLASSIFICATION SYSTEM



SHAHEEN & PEAKER LIMITED

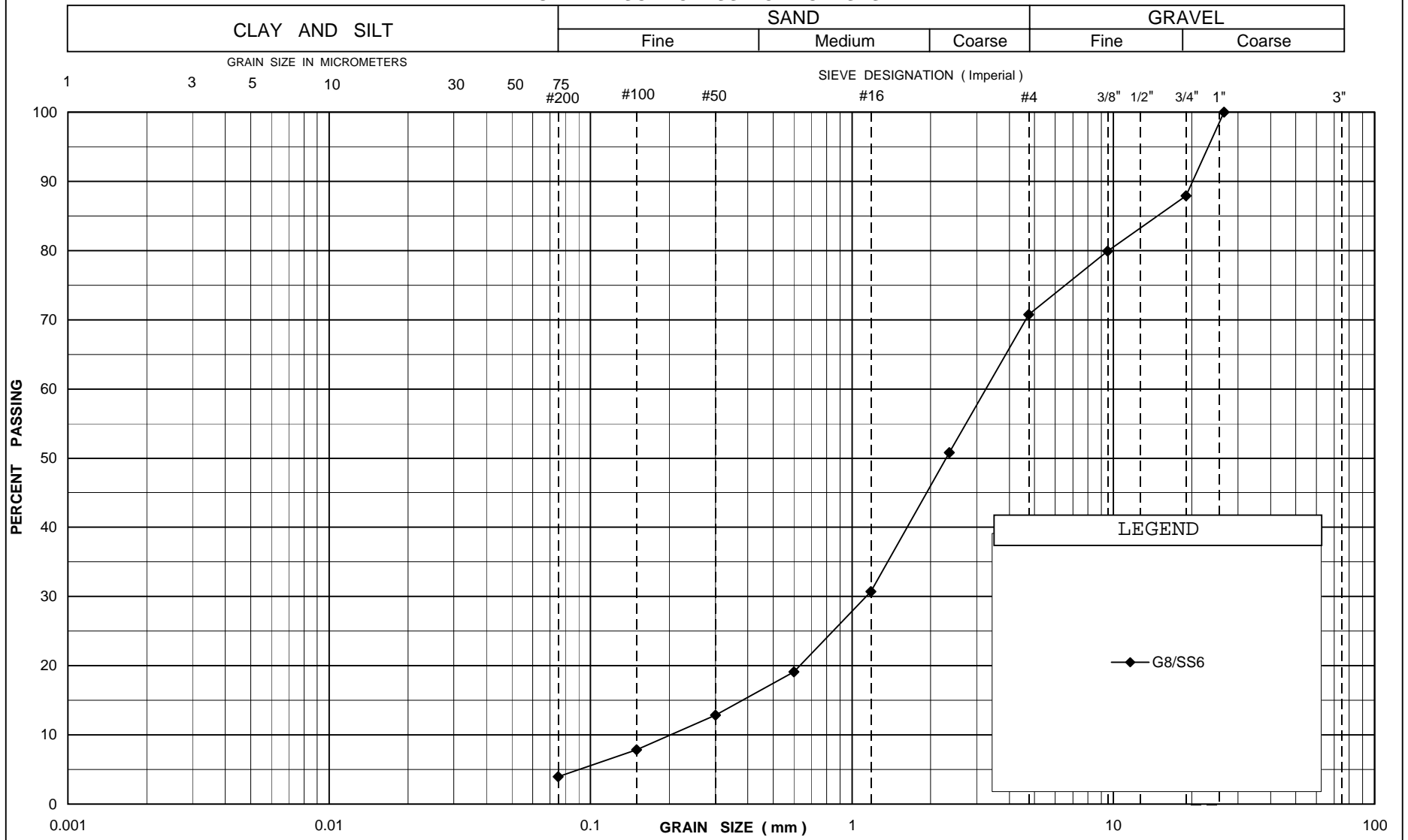
**GRAIN SIZE DISTRIBUTION**  
SILTYSAND, some gravel

FIGURE No. C2-3

REF. No. SPT 1151C

DATE NOVEMBER , 2005

# UNIFIED SOIL CLASSIFICATION SYSTEM



SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION  
GRAVELLY SAND

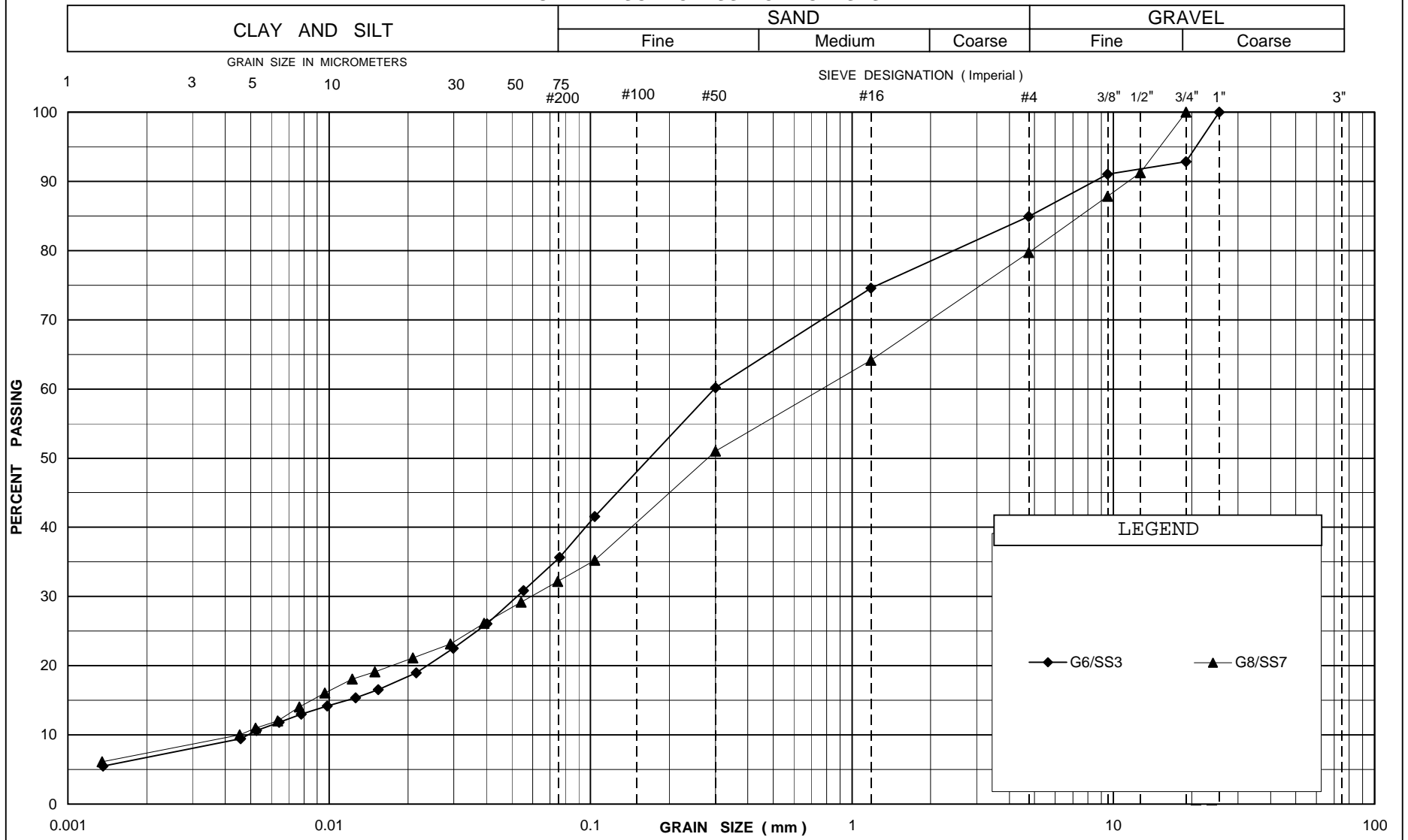
FIGURE No. C2-4

REF. No. SPT 1151C

DATE NOVEMBER , 2005



# UNIFIED SOIL CLASSIFICATION SYSTEM



SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION  
SILTY SAND TILL

FIGURE No. C2-5

REF. No. SPT 1151C

DATE NOVEMBER , 2005

## Appendix B3

### Records of Boreholes for Site 3 (Boreholes S1 through S9)

SPT1151C

# RECORD OF BOREHOLE No S1

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 19+600; 5.5m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
364.6	Ground Surface		1	SS	14												
0.0																	
	<b>FILL: Sand and Gravel</b> brown, moist, compact		2	SS	17												
363.2																	
1.4	End of Borehole.  Auger refusal at 1.4 m, probably on bedrock.  * No free water was observed (not stabilized) and hole opened to the full depth on completion.																




SPT1151C

# RECORD OF BOREHOLE No S2

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 19+700; 6m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Solid Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ 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			SHEAR STRENGTH kPa									WATER CONTENT (%)
364.3	Ground Surface					*		20	40	60	80	100					GR SA SI CL
0.0	Top 0.3 m Crushed Sand and Gravel FILL: Sand some gravel, brown, moist, compact		1	SS	12		364							o			
363.0			2	SS	13									o			
1.3	SILTY SAND TILL						363										
362.6	with gravel, brown, moist to wet, compact		3	SS	20/2									o			50 30 17 3
1.7	End of Borehole.  Auger refusal at 1.7 m, probably on bedrock.  * No free water was observed (not stabilized) and hole opened to the full depth on completion.																




SPT1151C

# RECORD OF BOREHOLE No S3

1 OF 1

**METRIC**

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 19+800; 6m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Solid Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ 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									WATER CONTENT (%)	
363.4	Ground Surface		1	SS	22	*	363							○				
0.0	<b>FILL: Sand and Gravel</b> brown, moist																	
362.9																		
0.5	<b>FILL: Sand</b> trace gravel, brown, moist, compact		2	SS	50/13									○				
362.2																		
1.2	End of Borehole.  Auger refusal at 1.2 m, probably on bedrock.  * No free water was observed (not stabilized) and hole opened to the full depth on completion.																	


SPT1151C

# RECORD OF BOREHOLE No S4

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 20+000; 27m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hand Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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. × LAB VANE					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
364.0	Ground Surface						364										
363.8	TOPSOIL																
0.2	End of Borehole.  Auger refusal on bedrock. Moved to Sta. 20+001; 27m Rt, auger refusal at 0.25 m.																

SPT1151C

# RECORD OF BOREHOLE No S5

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 20+090; 36m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Solid Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
96.8	Ground Surface					*											
0.0	<b>BOULDERS and COBBLES</b>	0.0															
96.2		0.6															
0.6	<b>GRAVELLY SAND</b> some silt, brown, wet, compact to very dense	0.6	1	SS	20							o				33 50 (17)	
			2	SS	90/20							o					
94.8		1.0															
2.0	End of Borehole.  Auger refusal at 2.0 m, probably on bedrock.  * Water level at 0.2 m (not stabilized) and hole opened to 0.3 m on completion.	2.0															

SPT1151C

# RECORD OF BOREHOLE No S6

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 20+180; 36m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ CHECKED BY RM \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)							
								○ UNCONFINED      + FIELD VANE	w <sub>p</sub> w      w <sub>L</sub>								
						● POCKET PENETR.      × LAB VANE											
						20   40   60   80   100								GR   SA   SI   CL			
95.1	Ground Surface					▼ *	95								395 ○	29   44   20   7	
0.0	<b>PEAT</b> black, wet, very soft		1	SS	2												
94.2																	
0.9	<b>SILT</b> grey, moist to wet, compact		2	SS	20												
93.6																	
1.5	<b>SILTY SAND TILL</b> with gravel, trace clay, grey, wet, very stiff		3	SS	22		93										
93.0																	
2.1	<b>SAND</b> trace silt, grey, wet		4	SS	25		92										
	compact																
	----- dense to v. dense		5	SS	50/5												
91.4																	
3.7	End of Borehole.																
	Auger refusal at 3.7 m, probably on bedrock.																
	* Water level at 1.1 m (not stabilized) and hole opened to 1.5 m on completion.																




SPT1151C

# RECORD OF BOREHOLE No 57

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 20+275; 29m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hand Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/2/2005 \_\_\_\_\_ 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					
94.7	Ground Surface																
0.0																	
94.4	TOPSOIL																
0.3	End of Borehole.																
	Auger refusal on bedrock. Moved to Sta. 20+274; 29 m Rt, auger refusal at 0.3 m.						94										

SPT1151C

# RECORD OF BOREHOLE No S8

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 20+790; 16m Lt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Hollow Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ CHECKED BY RM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● POCKET PENETR.      × LAB VANE							
96.8 0.0	Ground Surface		1	SS	0**								GR   SA   SI   CL		
			2	SS	0**										
			3	SS	0**										
			4	SS	0**										
			5	SS	0**										
			6	SS	0**										
			7	SS	0**										
90.8 6.0			8	SS	0**										
90.2 6.6			9	SS	6										

SPT1151C

# RECORD OF BOREHOLE No S9

1 OF 1

METRIC

GWP \_\_\_\_\_ LOCATION 'S' Curve and Pond, Station 22+400; 12m Rt C/L \_\_\_\_\_ ORIGINATED BY JZ  
 DIST \_\_\_\_\_ HWY 11 \_\_\_\_\_ BOREHOLE TYPE Solid Stem Auger \_\_\_\_\_ COMPILED BY YL  
 DATUM Local \_\_\_\_\_ DATE 11/3/2005 \_\_\_\_\_ 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					
99.2	Ground Surface																
0.0	Top 0.05 m Topsoil	0.0	1	SS	4		99										
98.5	SAND some gravel, brown, wet, loose to compact	0.0															
0.7	CLAYEY SILT																
98.1	trace to some sand, trace gravel, brown, moist		2	SS	57/18												
1.1	to wet, hard																
	End of Borehole.																
	Auger refusal at 1.4 m, probably on bedrock. Moved to Sta. 22+401; 12 m Rt, auger refusal at 1.1 m.																
	* No free water was observed (not stabilized) and hole opened to the full depth on completion.																

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

20  
15  
10  
5  
(%) STRAIN AT FAILURE

## Appendix C3

### Laboratory Test Results for Site 3 (Boreholes S1 through S9)

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	

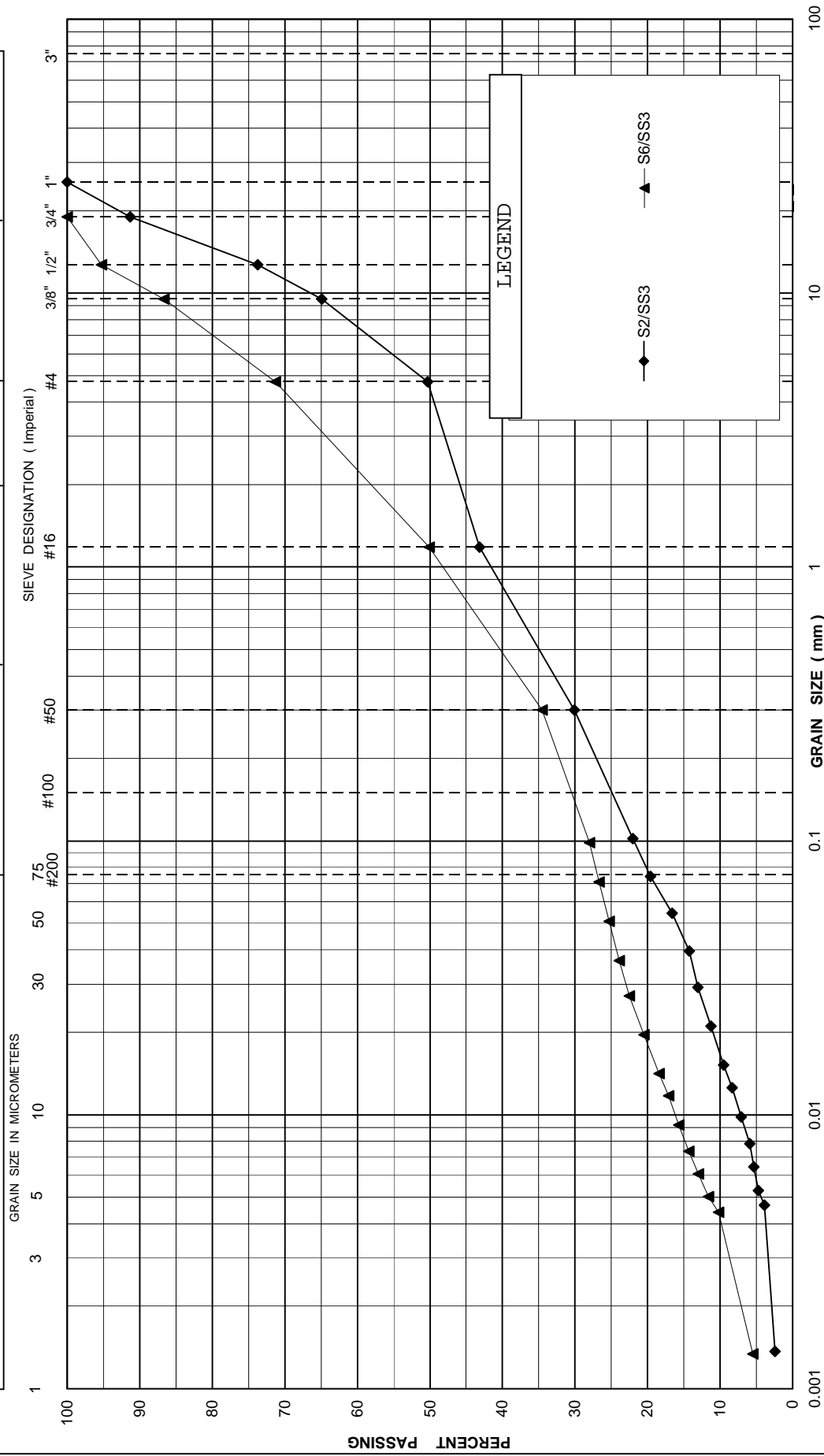


FIGURE No. C3-1

REF. No. SPT 1151C

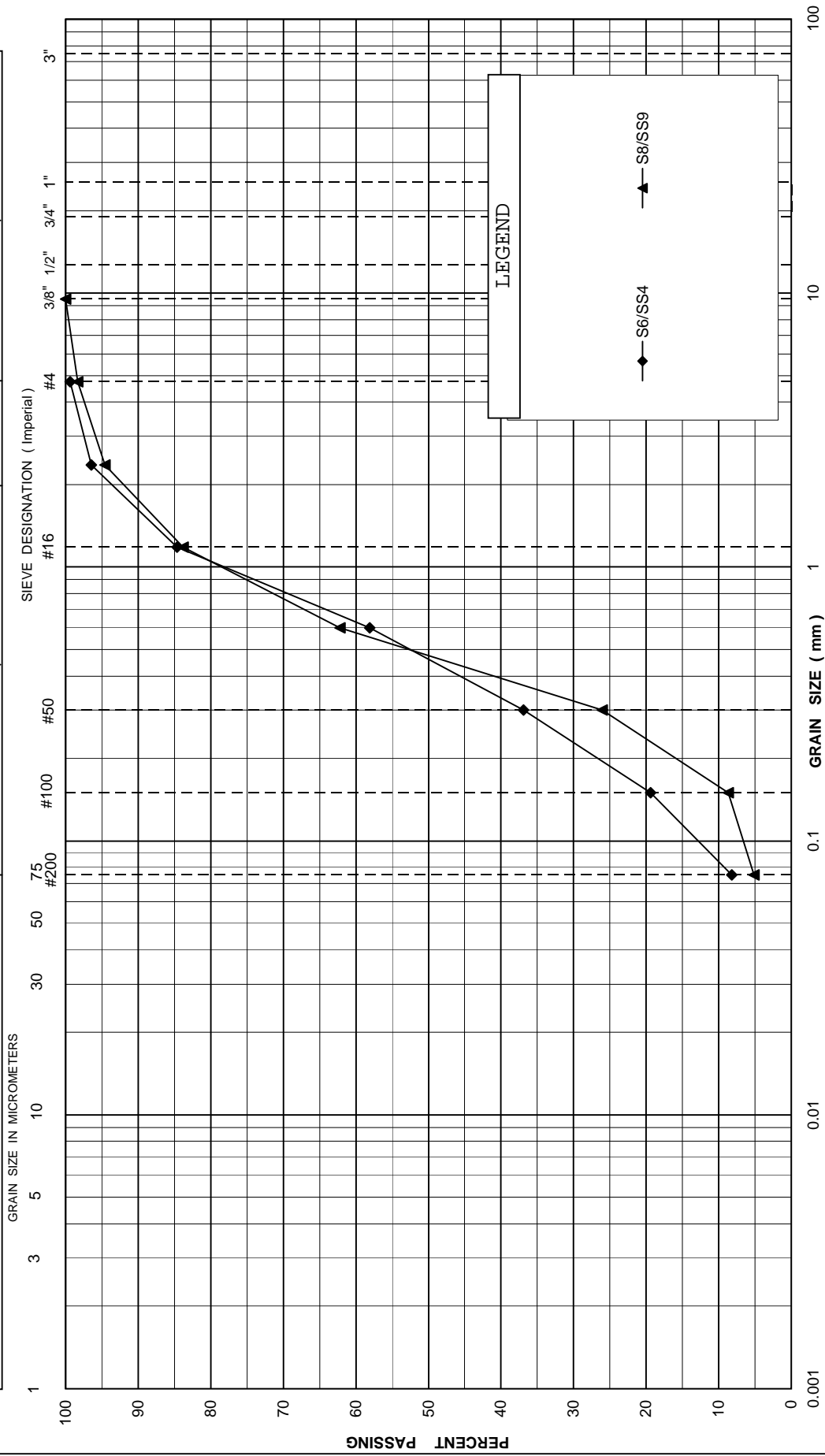
DATE NOVEMBER, 2005

**GRAIN SIZE DISTRIBUTION**  
SILTY SAND TILL, with gravel

SHAHEEN & PEAKER LIMITED

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	



## GRAIN SIZE DISTRIBUTION SAND, trace silt

SHAHEEN & PEAKER LIMITED

FIGURE No. C3-2

REF. No. SPT 1151C

DATE NOVEMBER, 2005

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT

SAND

GRAVEL

Fine

Medium

Coarse

Fine

Coarse

GRAIN SIZE IN MICROMETERS

1

3

5

10

30

50

#200

#100

#50

SIEVE DESIGNATION (Imperial)

#16

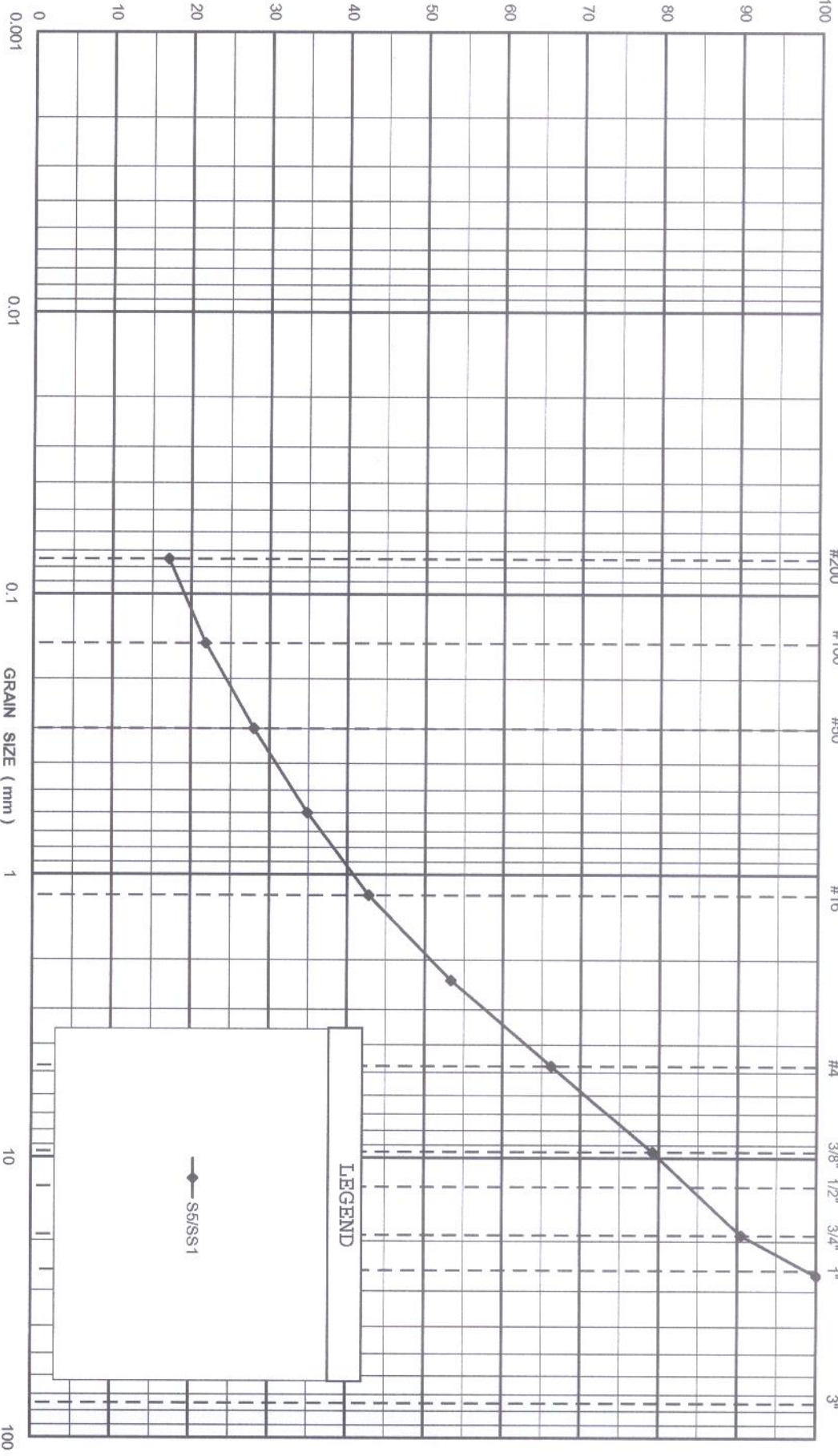
#4

3/8" 1/2"

3/4" 1"

3"

PERCENT PASSING



LEGEND

—●— S6/SS1

SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION  
GRAVELLY SAND, some Silt

FIGURE No. C3-3

REF. No. SPT 1151C

DATE NOVEMBER, 2005



SHAHEEN & PEAKER LIMITED

PLASTICITY CHART  
CLAYEY SILT

FIG No C3-4

G.W.P.

REF No SPT 1151C



## 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 64.5kg, 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 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

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$c_c$	1	COMPRESSION INDEX
$c_e$	1	SWELLING INDEX
$c_a$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	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

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